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NOV 21 1978

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Docket Nos: 50-275
and 50-323

MEMORANDUM FOR: John F. Stolz, Chief, Light Water Reactors Branch No. 1, Division of Project Management

FROM: Dennis P. Allison, Project Manager, Light Water Reactors Branch No. 1, Division of Project Management

SUBJECT: DIABLO CANYON INFORMAL INFORMATION

The enclosed information which is listed in Enclosure No. 1 and included in Enclosure No. 2, was recently provided informally by PG&E. It is detailed information related to the seismic design audits and the fire protection review. The purpose of this memorandum is to place the material in the files and the public document rooms and to inform the parties.

/s/

Dennis P. Allison, Project Manager
Light Water Reactors Branch No. 1
Division of Project Management

Enclosures:
1. List of Informal Information
2. Informal Information Listed in Enclosure No. 1

FOR ENCLOSURES SEE RRt FILE UNDER MEMO ATTACHMENTS ccp

cc:
See next page

ccp MEMO4

7811290400

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DATE➤	11/21/78	11/21/78				

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ENCLOSURE NO. 1 (ALL ENCLOSURES IN REPORT FILE)

LIST OF INFORMAL INFORMATION

1. Supplementary Information for Fire Protection Review, Revised 11/13/78
2. A package beginning "Q.5 Substantiate the fire reisitance . . . ."
3. Color coded drawing 57579, marked question 26.
4. Diablo Canyon Intake Structure Factor of Safety Against Sliding - 11/10/78
5. Hosgri ReEvaluation of Diablo Canyon Containment base Mat (A-7) 11/09/78
6. Outdoor Water Storage Tanks - Dynamic Seismic Analysis for 7.5 M Hosgri Criteria November 1978 - URS/Blume
7. Intake Structure Crane - Blume report 10/12/78 revised 11/02/78 - Final
8. Portions of Draft Amendment 70 - Hosgri
   a. Monitoring of Circuit Breker Contacts 10-44 e and f
   b. Cranes - Section 4A
9. Electrical EquipmentFunctionality (3.10.6)
   a. Battery Charger
   b. 125VDC Distribution Panelboard
   c. Figure on Turbine Lube Oil Starter -

IN FOLDER #1

---

10. Electrical Equipment Functionality Rewrite dated October 20, 1978
11. Scott Co Drawings (5) of Auxiliary Salt Water Piping.
12. Color Coded Figure 9.2-2 - Arrangement of Intake Structure
13. Change to 4KV Switchgear Drawings: Attachments C, D and E
14. New materials on relay boards, Section 10.3.21.6
15. Civil Drawings regarding intake structure.
16. Intake Structure A-5 (Supplement)

IN FOLDER #2

---

17. "Seismic Testing of one 14-inch motor operated Valve . . ."

#3

18. "Qualification of NAMCO Controls . . ."

19. Visacorder reading of the 4KV Swtichgear

20. Additional material in response to SER Supplement 7 item 3.8.5.4.4 - Intake Structure - Packway to ASW Pumps.

21. Discussion of Time history analysis sensitivity to variation of input assumptions. This item responds to SER item 3.9.3.9 (2)

22. Additional material in response to SER Supplement 7 item 3.8.5.4.1 (2) Containment Base Mat A-7

23. Additional material in response to SER Supplement 7 item 3.8.5.4.7 Storage Tanks Items A-2 and A-3

24. Additional Draft Material on Electrical Functionality

    a. Instrument Power AC Panelboards

    b. Battery Charger Diagram

    c. Diesel Generator Excitation Cubicle

25. "Diablo Canyon Units 1 and 2 Intake Structure . . ."

26. Two sets of color coded drawings, layouts

27. Schematic Diagram of battery charger

#3

ENCLOUSURE NO. 2

INFORMAL INFORMATION LISTED IN ENCLOSURE NO. 1

Monitoring Electrical Functionality

50-275/323
Memo 11-21-78
7811290400
To Stolz frm Allison
Diablo Canyon Informal Information.
ENCL #1

TABLE II - CONTENTS

Test Response Spectra

4 KV Switchgear

4160/120V Potential Transformers

Safeguard Relay Boards

Emergency Lighting Units

Ventilation Control Logic

Ventilation Control Relay Panel

Main Annunciator Components

125 VDC Distribution Panelboard

Battery Charger

125/250 VDC Motor Control Center

Station Battery and Racks

Vital Load Center

Local Starters

INTRODUCTION

The safety related electrical equipment for Diablo Canyon Units 1 and 2 was originally seismically qualified in accordance with IEEE Std. 344-1971. Recently the Diablo Canyon equipment was re-evaluated to newly established criteria based on response spectra derived from the postulated 7.5M Hosgri event. In the process of this re-evaluation, PG&E committed to perform any additional testing on certain plant equipment to the spectra derived from the postulated 7.5M Hosgri event and according to the methods for seismic qualification of electrical equipment contained in IEEE Std. 344-1975 and NRC Regulatory Guide 1.100. This additional testing has been completed, and the results have been presented to the NRC Staff in several licensing review meetings. At the most recent such meeting PG&E was requested by the NRC Staff technical reviewers to provide summary information on the results of these tests to facilitate the Staff's review. The attached material is provided in response to that request. For each type of equipment tested, the following information is presented:

1. Name of Equipment
2. Description of Equipment
3. Safety Function
4. Test Criteria and Plan
5. Test Procedure and Setup
6. Test Results
7. Conclusions

The equipment was tested in seven groups, with one seismic required response spectra per group. The required response spectra is given in attached Figures 1 through 7 of Wyle Test Report 3642. Complete test results are given in Wyle Reports 58255 and 58255-1.

Table 1 lists the balance of plant equipment tested to the Hosgri seismic spectra and to IEEE 344-1975.

Table I

GROUP I	4160 Volt Metalclad Switchgear
	4160 Volt Potential Transformer
	Vital Relay Board
	Emergency Light Units
GROUP II	Diesel Generator Excitation Cubicle
	Diesel Generator Control Panel Door
	Diesel Generator Control Cabinet Sub-Panel with the following items mounted on the panel:
	1. Differential Pressure Switch (two)
	2. Contactor (one)
	3. Switching Tachometer (one)
	4. Time Delay Relays (two)
	5. Relays (four)
	6. Industrial Control Relays (four)
GROUP III	Ventilation System Printed Circuit Board and Power Supply
	Ventilation System Relay Sub-Panel
	Annunciator Components consisting of:
	Power Transfer Panel
	Printed Circuit Boards (four)
	Printed Circuit Board Rack
	Constant Voltage Transformer
	Power Transformer
	Logic Power Supply
	Auxiliary Logic Power Supply
	Relays (four: two dc and two ac)

Table I

(Continued)

GROUP III	DC to DC Converter
(Cont'd.)	DC to AC Inverter
	Typewriter
GROUP IV	DC Distribution Panel
	Battery Charger
	Turbine Lube Oil Starter
	Fire Pump Controller
	Local Starter (LPF 37)
	Battery Cells (two)
GROUP V	Vital Load Center (480v)
	Local Starter (LPG66)
	Circuit Breakers 100 Amp (two)
	Motor Starters (seven)
	Auxiliary Relay Panel (480v Bus 2H)
	Auxiliary Relay Panel (Bus G)
GROUP VI	Local Starter (LPF 36)
GROUP VII	Switches (six)
	Ammeter

FIGURE 1

REVISION A

GROUP I - VITAL RELAY BOARD AND 4160 SWITCHBOARD
Turbine Building 119 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE - 3% Damping
OBE = 60% SSE

A

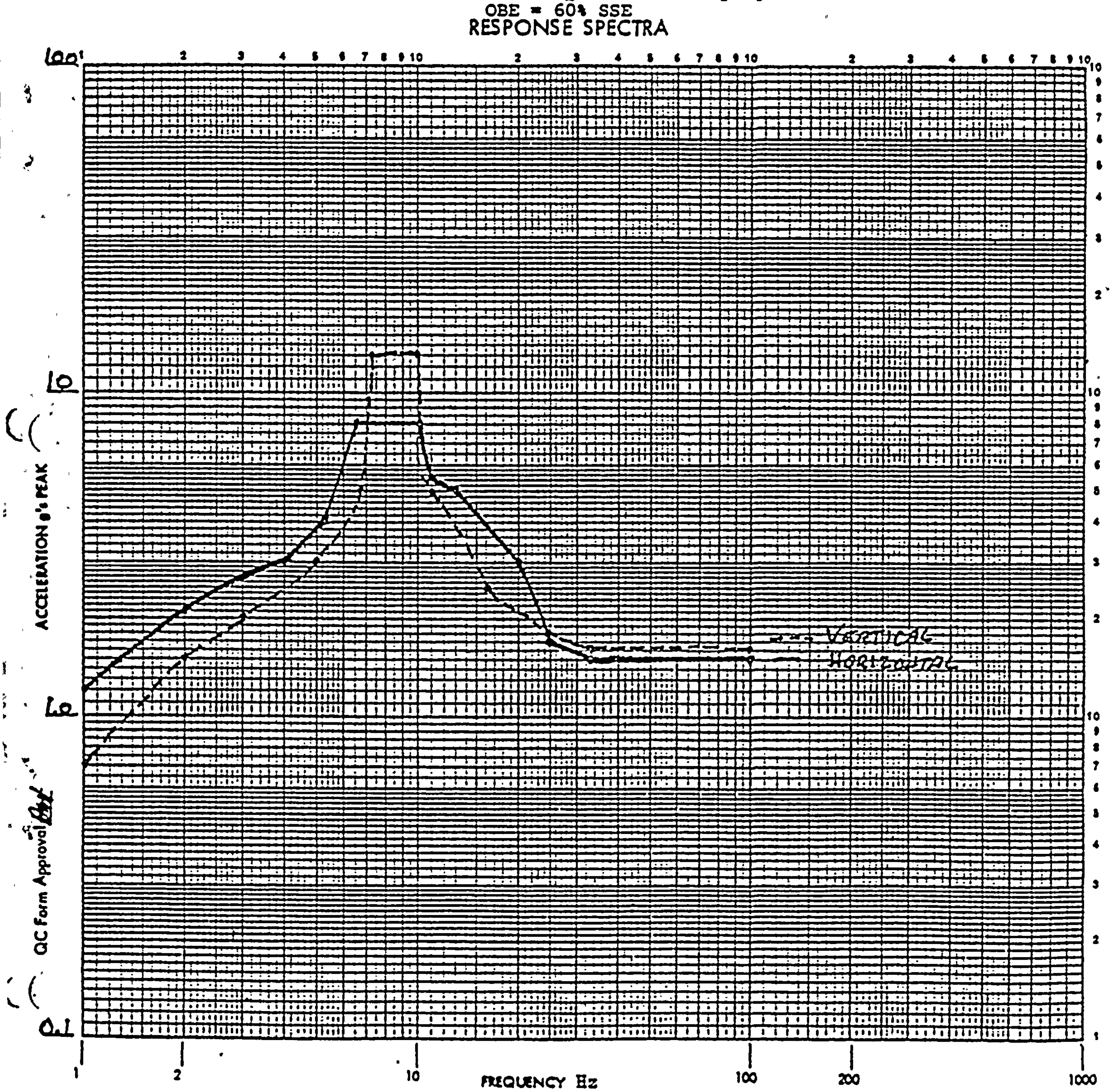
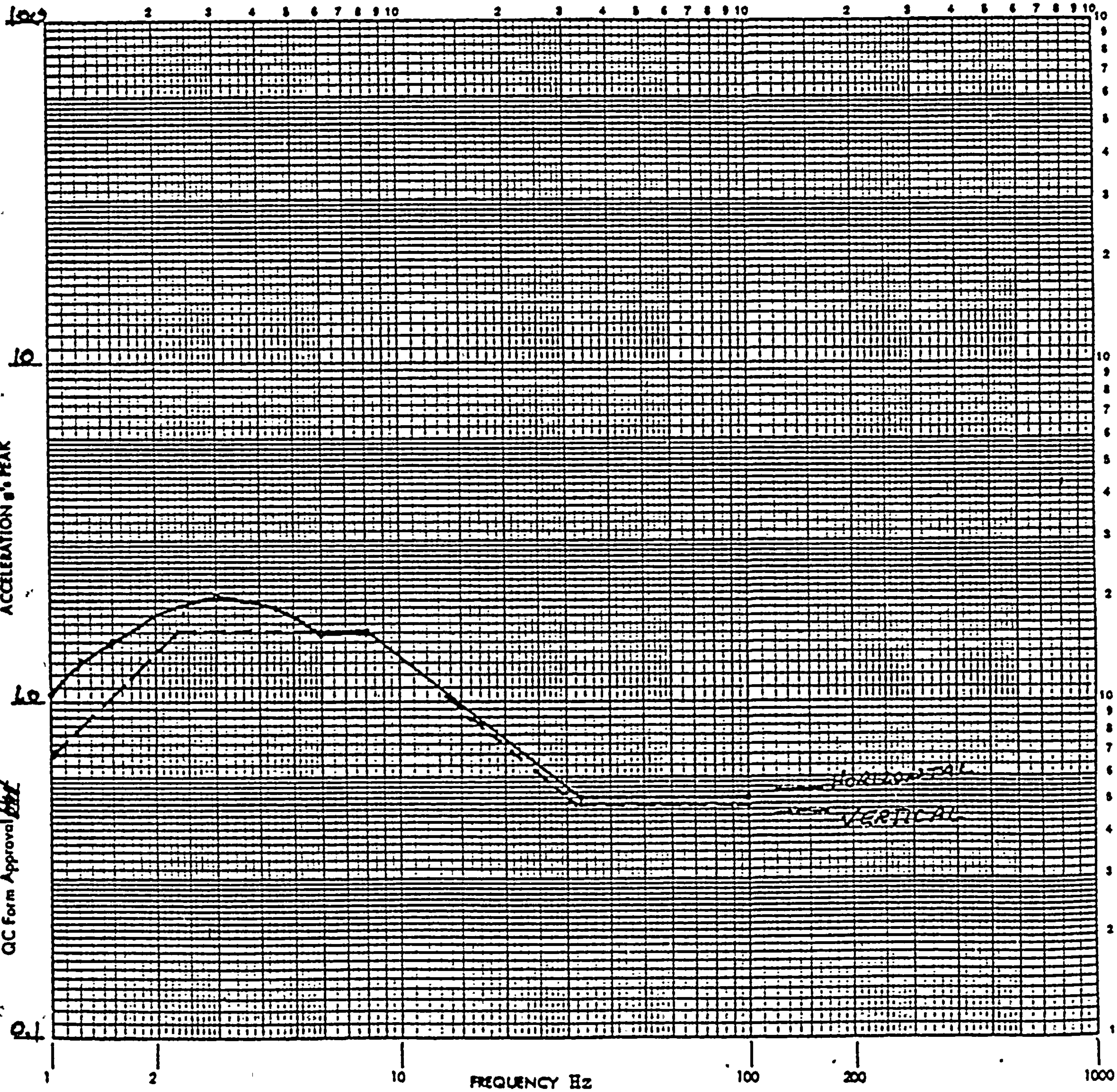


FIGURE 2

GROUP II - DIESEL GENERATOR CONTROL CABINET
AND DIESEL GENERATOR EXCITATION CUBICLE
Turbine Building 85 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE
3% Damping
OBE = 60% SSE

A

RESPONSE SPECTRA



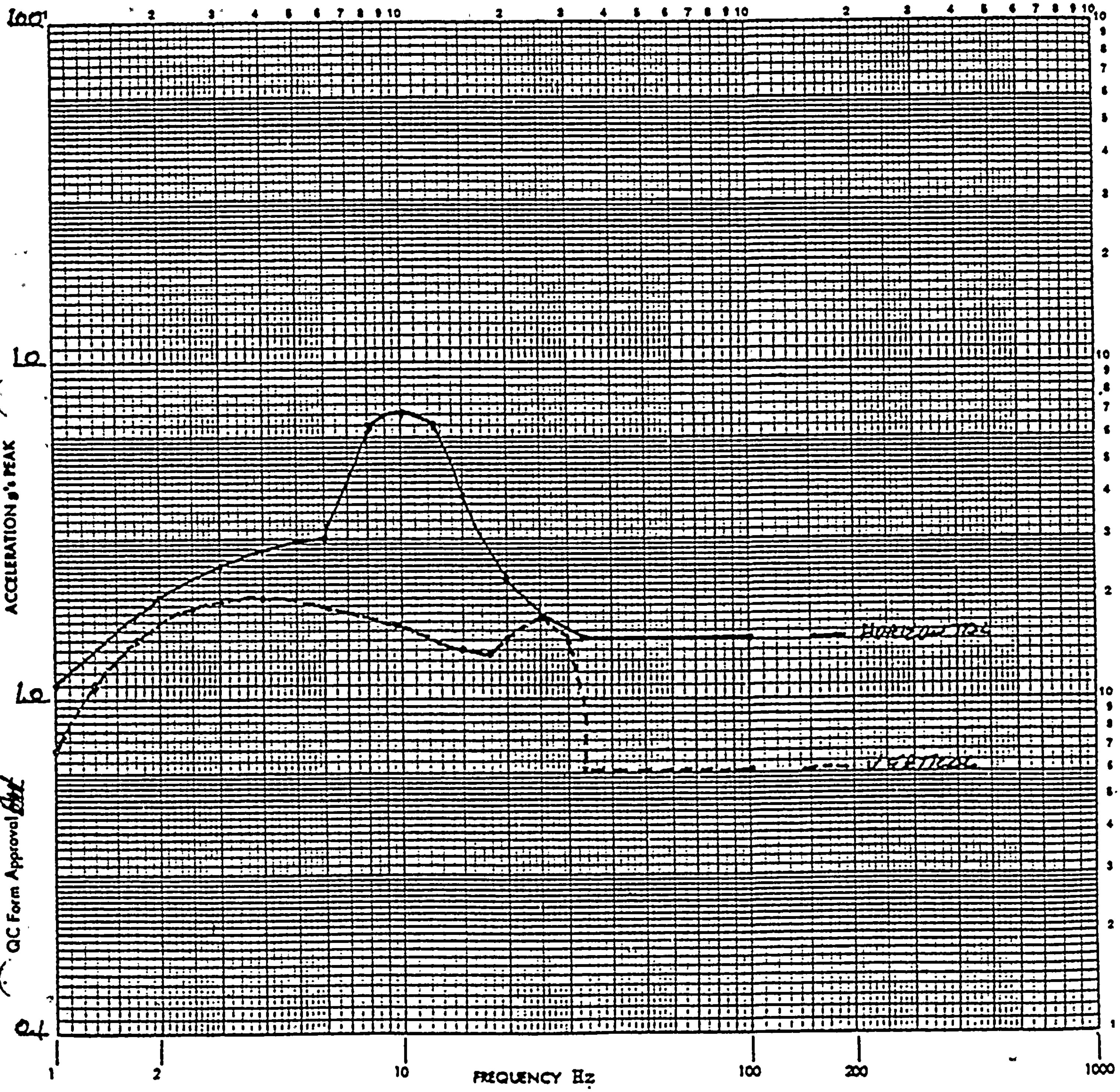
QC Form Approval

FIGURE 3

GROUP III - VENTILATION SYSTEM RELAY PANEL, VENTILATION SYSTEM LOGIC PANEL AND MAIN ANNUNCIATOR
Auxiliary Building 140 and 128 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE - 3% Damping
OBE = 60% SSE

A

RESPONSE SPECTRA



QC Form Approval

REVISION A

FIGURE 4

GROUP IV - LOCAL STARTER LPF37, FIRE PUMP CONTROLLER, 125-250vdc M.C.C., DC SWITCHGEAR, AND BATTERY CHARGER
Auxiliary Building 115 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE - 3% Damping
OBE = 60% SSE

A

RESPONSE SPECTRA

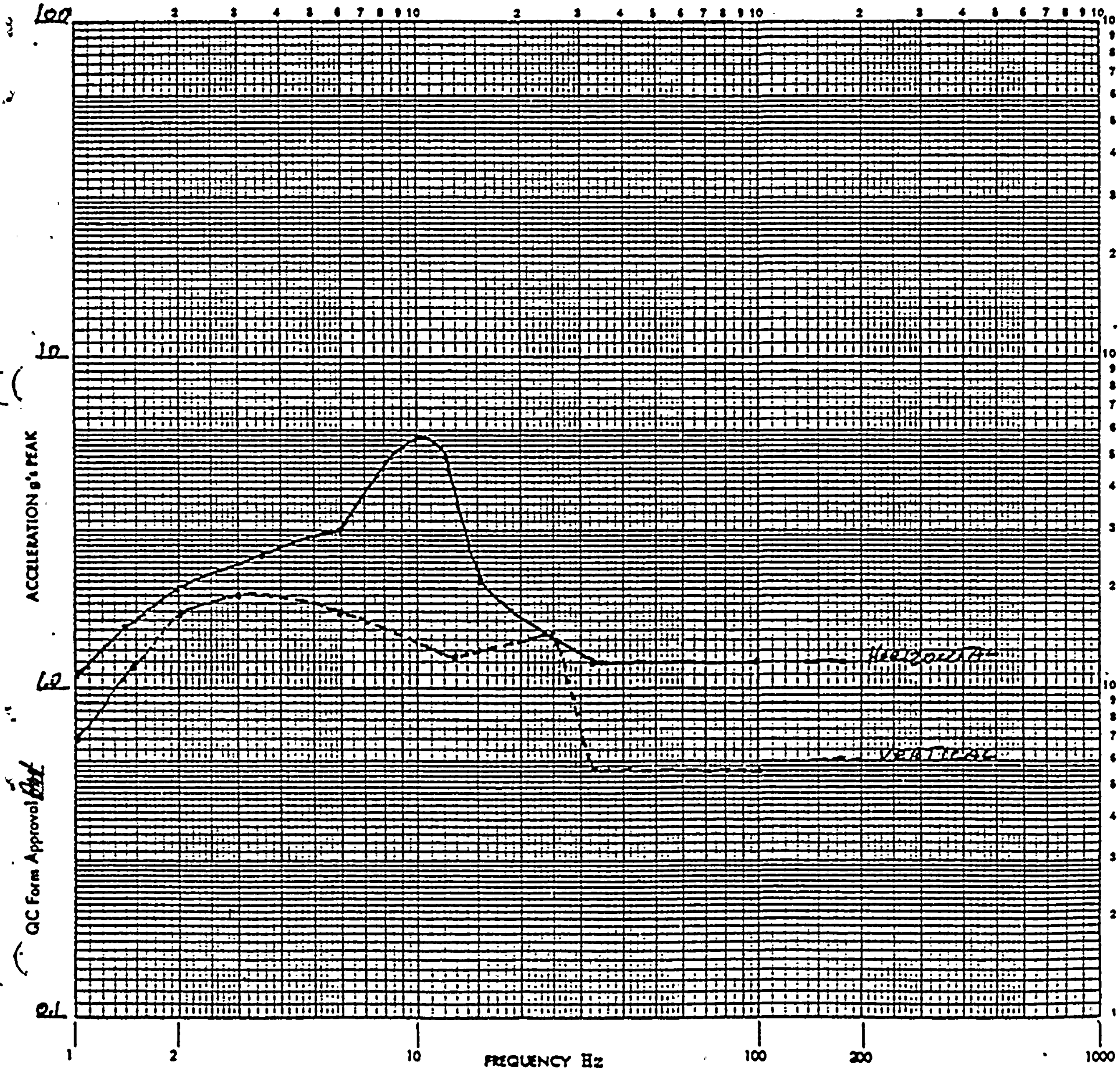


FIGURE 5

GROUP V - FISHER CONTROLLER, LOCAL STARTER LPG66, VITAL LOAD CENTER

Auxiliary Building - 100 feet B

HORIZONTAL AND VERTICAL SSE - CRITERIA HOSGRI EARTHQUAKE A

3% Damping

OBE = 60% SSE

RESPONSE SPECTRA

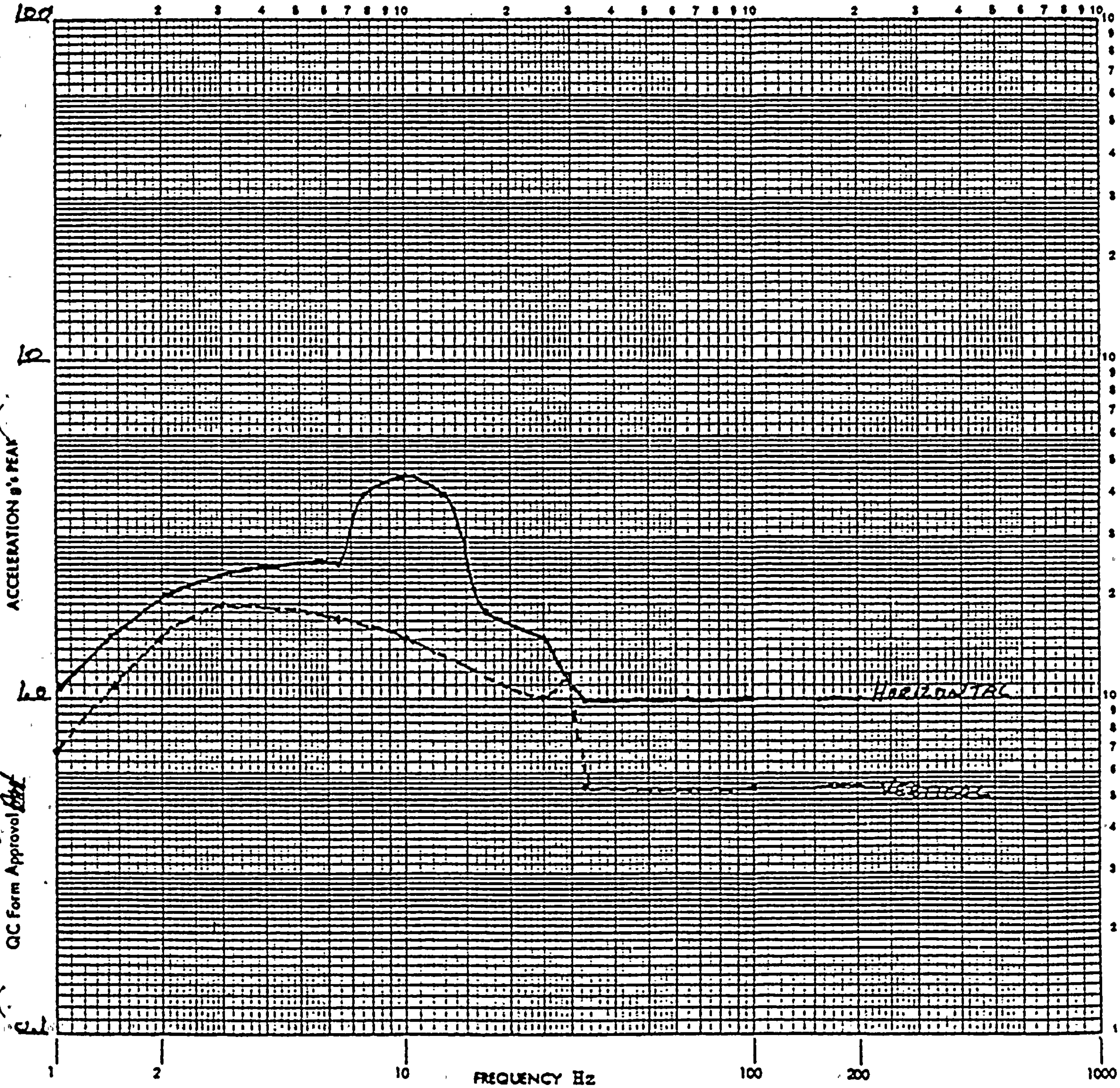
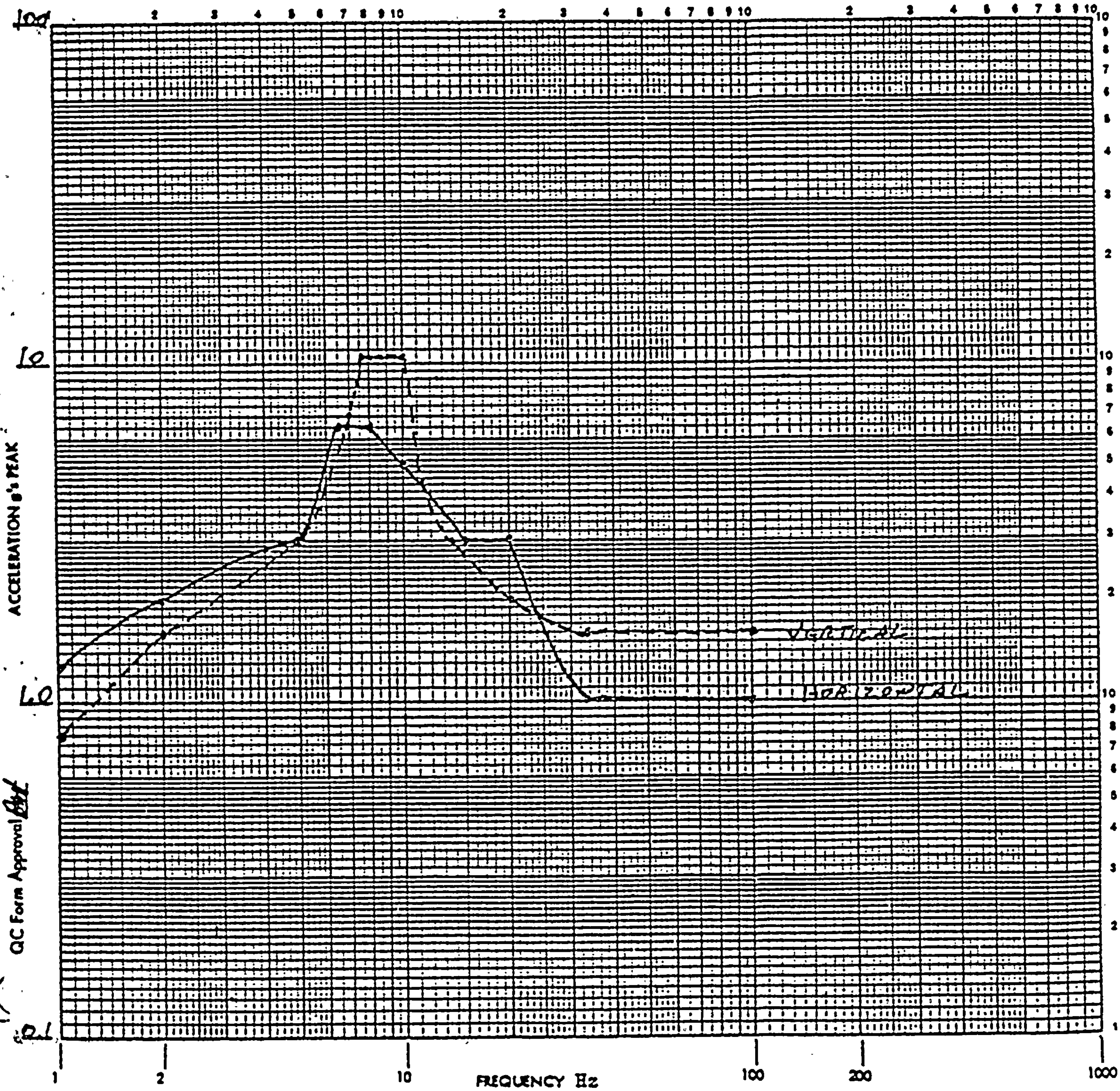


FIGURE 6

GROUP VI - LOCAL STARTER LPF36 AND LIMIT SWITCHES
Auxiliary and Turbine Building - 110 feet B
HORIZONTAL AND VERTICAL SSE - CRITERIA HOSGRI EARTHQUAKE
3% Damping A
OBE = 60% SSE

RESPONSE SPECTRA

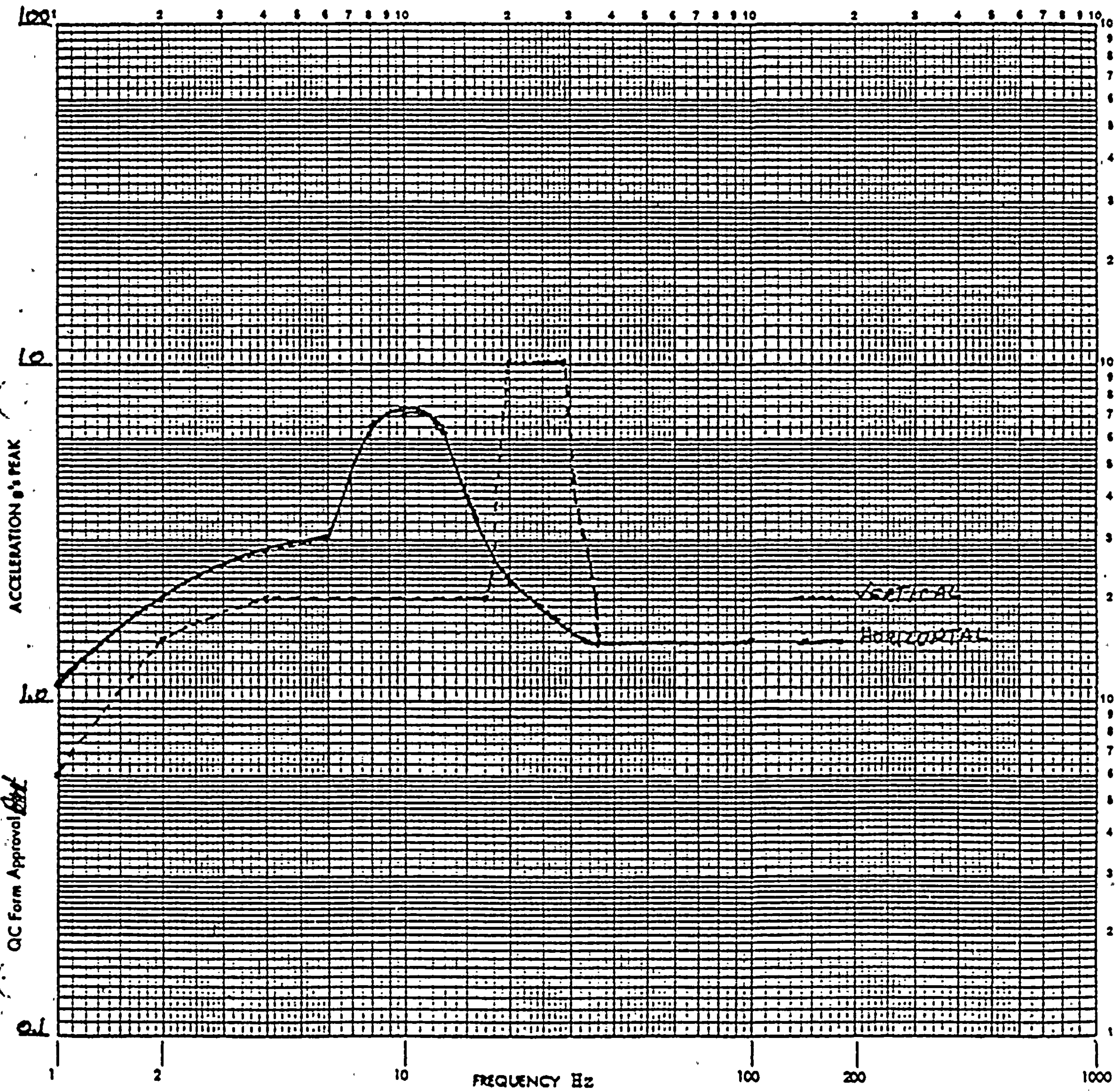


B

FIGURE 7

GROUP VII - SWITCHES AND AMMETER
AUXILIARY BUILDING MAIN CONTROL ROOM - 140 Feet
HORIZONTAL AND VERTICAL SSE - CRITERIA HOSGRI EARTHQUAKE
3% Damping
OBE = 60% SSE

RESPONSE SPECTRA



10.3.26.1 Name of Equipment

4160V Class IE Switchgear

10.3.26.2 Description of Equipment

The 4160V switchgear consists of three bus sections (F, G and H) for each of the two Diablo Canyon units. The switchgear is metalclad, rated 250 MVA interrupting capacity and 80,000A momentary. The circuit breakers are in individual cells and separated from each other by a metal barrier. Doors in the front provide access to the individual breakers and control wiring. Doors in the back provide access to the 4.16 kV power connections. Protective relays, meters, control switches, indicating lights, auxiliary relays and voltage relays are mounted on the upper portion of the front doors. Potential transformers for sensing bus or feeder voltages are mounted in back on top of cells F7, G5, H7, F12, G12 and H12, and in front and top of cells 13 and 14 of each of the bus sections F, G, and H. All circuit breakers are rated 1200A continuous with the exception of G15 which is rated 2000A.

The bus sections F, G and H are interconnected by overhead bus ducts. The bus ducts do not have a Class IE function. However, their rigid tie to the switchgear would have an effect on the switchgear qualification. For that reason it has been decided to dynamically decouple the two by inserting an earthquake joint at the point of entry of the bus duct into the switchgear. The required amount of deflection the joint must provide will be determined by the measuring the amount of horizontal and vertical deflection on top of the test specimen during the seismic test.

10.3.26.3 Safety Function

The 4160 VAC bus sections F, G, and H control and distribute electric power to the engineered safeguard load.

The safety functions of the individual devices are as follows:

a) Power circuit breakers switch 4160V power on or off; either incoming power from one of three sources, the station auxiliary transformer, the stand-by start-up transformer and if necessary the diesel generator or outgoing power for the engineered safeguard loads. The breakers must operate during a seismic event if required to do so and must not change state inadvertently at any time.

b) Overcurrent relays, designated "51" with additional bus and cell designation, must not cause the circuit breaker to trip inadvertently at any time.

c) Potential transformers must stay operative at all times and provide a signal for control and instrumentation which is proportional to the level of the high voltage bus or feeder to which they are connected. While the transformer itself has no moving parts which could compromise this safety feature the contact fingers connecting the transformer windings to the high voltage and low voltage terminals must stay closed at all times.

d) Voltage relays must sense the signal voltage of the potential transformers to which they are connected. Their contacts must open or close as required at any time. Contact chatter must not prevent downstream devices from operating and conversely must not operate downstream devices inadvertently.

e) The 2HH9 timing relay closes the breaker after time delay on a safety injection signal. It must operate during or after a seismic event.

10.3.26.4 Test Criteria and Plan

The test criteria and plan are detailed in the Test Plan for the Seismic Qualification of the Switchgear, Revision 2, dated July 27, 1978. The

test plan is now part of WYLE's Test Procedure No. 3642, Addendum 1 and is contained at the end of WYLE's Test Report No. 58255-1, dated August 22, 1978. The following is an abstract of this test plan emphasizing the electrical criteria.

The object of the seismic qualification test is to demonstrate that the Class IE switchgear retains it normal function, during and after the seismic event. In addition, any non-class IE equipment must not fail in a manner to jeopardize the Class IE function. To demonstrate normal function of the switchgear all control circuits must be energized to duplicate exactly during the test their normal state, and power must be applied to the trip coils and operating mechanisms of the circuit breakers. During the seismic event circuit breakers are tested in the open, closed and in the actual tripping and closing operation to demonstrate the Class IE function. As a backup, the state of selected relay contacts is recorded for monitoring purposes and also sometimes for chatter duration. However, by itself chatter duration does not conclusively demonstrate normal function or lack of normal function. If a relay contact is an input to a Class IE device not located on the switchgear then the relay contact must be monitored and the chatter or change of state record analyzed to demonstrate Class IE function.

10.3.26.5 Test Procedure and Set-Up

The test procedure and set-up are also detailed in the before mentioned Test Plan, Revision 2, dated July 27, 1978.

Selected for the test were Cells H7, H8 and H9 of Unit 2 with front doors from Cells H12 and H13 mounted on Cells H8 and H9 respectively. This arrangement represented all the relay types installed in the Diablo Canyon Units 1 and 2 Class 1E 4160V switchgear. The devices on the doors were wired to the cells to such an extent that all Class IE circuits were complete and their function could be demonstrated.

Early in the test it was decided to remove potential transformer roll out units from top of Cells H8 and H9 since their mass and motion appeared to

induce chatter of the switchgear relays. These potential transformers are normally located on top of Cells H13 and H14. They will be permanently removed from this location and are qualified separately.

The test specimen was 78 inches wide (3 cells each 26 inches), 90 inches high and 75 inches deep.

The three cell test specimen was welded to a special base with the same amount and type of welding as is done at the Diablo site. The base with the test specimen than was welded to the test machine.

The seismic test sequence is shown in Attachment "A".

The switchgear and its devices were wired per attached wiring instructions contained in Attachment "B".

Following are illustrations which expand on the test set-up wiring beyond the termination points.

a. 125 VDC was applied to the switchgear DC bus energizing the control and overcurrent protection circuits of all three cells.

b. 3 phase current and 3 phase 120 VAC restraining potential were applied to the three 51 overcurrent relays of Cell H7. Single phase current was applied to the 51 overcurrent relays of Cells H8 and H9. This simulated the actual operating conditions of these relays by normal 4160V power flow. See Attachment "F" and "G".

c. The same 120 VAC from "b" above also provided potential to the following relays:

59HHG1, 59HHG2	Diesel Generator Voltage Relays
27HHB1	4160V Bus Undervoltage Auto Transfer Relay

27HHB2	4160V Bus Undervoltage Diesel Start Relay
27HHT1, 27HHT2	4160 Bus Undervoltage

See Attachment "G".

d. The same 120 VAC energized the potential transformer on top of Cell 7 and subsequently energized the whole high voltage portion of the test specimen with 4160V providing the breaker of Cell 7 was closed. See Attachment "G".

e. All output contacts of the relays listed under "c" above were connected to secondary devices to demonstrate or simulate their safety functions. Contacts of the secondary devices were than connected to direct readout recorder to monitor change of state and chatter. Some of these secondary or auxiliary relays were part of the Safeguard Relay Board. The relay board was standing at the side off of the shake table. See Attachment "G".

f. The coil of the 2HH9 Containment Spray Signal Timing Relay was connected to a 120 VAC supply via a switch "H". A normally closed contact was connected to the direct readout recorder to monitor its operation and contact chatter. See Attachment "H".

g. Two linear variable displacement transducers were installed near the top of the switchgear to measure the maximum vertical and horizontal displacement of the switchgear structure. This measurement was taken as an input to the design of the earthquake joints of the bus ducts.

10.3.26.6 Test Results

The 4160V switchgear and the associated relays met the test criteria specified in section 10.3.26.4 above during and after the seismic testing while being operated per the test procedure described in section 10.3.26.5

above. It is worthy of note that the equipment was subjected to more than the minimum number of test runs for qualification, demonstrating margin in the equipment's resistance to seismic damage.

No physical damage to the switchgear structure or the associated devices was observed.

Maximum horizontal displacement of the structure was measured to be .55 inches; maximum vertical displacement was .2 inches.

As a result of this test the following actions will be taken:

a) Potential transformers on top of Cells 13 and 14 of all 4160V Class IE switchgear sections will be removed and relocated to a separate stand next to the respective switchgear. Electrically they will be wired to the switchgear as they were connected before.

b) Bus duct earthquake joints will be installed in all joints at the top of the Class IE switchgear sections. The test measurement will be used in the design criteria.

10.3.26.7 Conclusion

A representative sample of the 4160V Class IE Switchgear of Diablo Canyon Unit 2 was seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report Number 58255-1 dated August 22, 1978, pp. 139-323. Thus qualification of this sample will apply to all Diablo Canyon 4160V Class IE Switchgear.

The test results presented in section 10.3.26.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 4160V Class IE Switchgear are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

TABLE IV. SEISMIC TEST SEQUENCE DIABLO CANYON UNITS 1 AND 2 4.16 KV SWITCHGEAR

Condition	Axes	Horizontal RM ZPA g	Horizontal RM Figure No.	Vertical RM or RM + SB ZPA g	Vertical RM or RM + SB Figure No.	Sine Beat Freq. Hz.	Bkr. Pos.	Remarks
1	SS	.2	-	-	-	-	C	1-33 Hz-Sweep
2	SS	.2	-	-	-		↓	33-1 " "
3	V	-	-	.2	-	↓	↓	1-33 " "
4	V	-	-	.2	-	↓	↓	33-1 " "
5	SS-V	.75	50%-1	.8	50%-2			1 OBE
6							0	2
7		↓	↓	↓	↓		CO	3 ↓
8	↓						OC	4
9	↓						COC	5
10	↓	1.5	1	1.6	2	7.1	C	1 SSE
11						8	0	2
12		↓	↓	↓	↓	9	CO	3 ↓
13						10	OC	4
		Rotate Sample 90°						
14	FB	.2	-	-	-	-	C	1-33 Sweep
15	FB	.2	-	-	-		C	33-1 "
16	FB-V	.75	50%-1	.8	50%-2	↓	C	1 OBE
17							0	2
18		↓	↓	↓	↓		CO	3 ↓
19	↓						OC	4
20	↓						COC	5
21	↓	1.5	1	1.6	2	7.1	C	1 SSE
22						8	0	2
23		↓	↓	↓	↓	9	CO	3 ↓
24						10	OC	4

Legend

RM - Random Motion
RM & SB - Random Motion with Sine Beat
ZPA - Zero Period Acceleration
SS - Side to Side
V - Vertical
FB - Front to Back
Bkr.Pos. - Breaker Movable Contact Position

Notes

The circuit breaker should be lowered and re-raised after selected tests at the direction of the General Electric Company Representative. At such times, the PTRO's will also be opened and inspected.

ATTACHMENT "A"

July 12, 1978

WIRING INSTRUCTIONS

DIABLO CANYON SWITCHGEAR TEST SAMPLE
4.16 KV-1200-250 MVA

A. Diagrams

Cell	Skematics	Connection Diagrams
7	441356	441589
8	Marked copy 441302	HH53078
9	Marked copy 441307	HH53178

B. Control Power Connections

<u>Cell 7</u> (441589)

a) 2W-DC-125V-20A Supply, (+) to DC3, (-) DC1

b) 3W-AC-120V-3Ø-60 Hz Supply, Leg A to X5, Leg B to X7, Leg C to X6
4W-AC-5A-3Ø-60 Hz Supply, Leg A to CG4, Leg B to CG5, Leg C to CG6, Neutral to CG1

Both supplies needed for IJCV Relays. Leg A, Leg B and Leg C for voltage and current sources are related to Wyle's Ø1, Ø2 and 0/3 respectively.

<u>IMPORTANT</u> The 3Ø 120 volt circuit should not be energized when primary compartment covers or panels are removed so that primary conductors are exposed. If interaction effects between primary conductors and Wyle instrumentation can not be readily resolved, the PTRO primary fuses will be removed to de-energize the primary conductors.

c) Wyle is to provide a remote 3Ø switch to disconnect power to the 59HHG 1 & 2(SV relay) coils. This switch will be open for the majority of tests to simulate the Diesel Generators not being energized.

d) Connect NO "Close" Push Button to B5 and B6.
Connect NO "Trip" Push Button to DD7 and DD8.

e) Remove and tape ground leads from ground bus in rear of cell

<u>Cell 8</u> with Cell 12 door (53078)

a) 2W AC 1Ø 5A 60 Hz supply, Leg 1 to C18, Leg 2 to CD4 (IAC66 source)

b) 3W AC 3Ø 120V 60 Hz supply, Leg A to AK8, Leg B to AK9, Leg C to AK10(RA\
Jumper AK8 to AH15 and AK9 to AH16 (IAV)

c). Connect NO "Close" Push Button in series with a NC 43 X HH12 contact to DD4 and BB9. PG&E to provide connection details.
Connect NO "Trip" Push Button to DD4 and DD7. Jumper DD9 to EE1

d) Remove and tape ground leads from ground bus in rear of cell.

Rev 1 7/27/78
EWS.

B. Control Power Connections (Cont'd.)

Cell 9 with Cell 13 door (53178)

a) 2W AC1Ø 5A 60 Hz., Leg 1 to C18, Leg 2 to CD4 (IAC53)

b) 2W AC1Ø 120 60 Hz.,Leg A to AF15, Leg B to AF16 (Øs A & B to IAV)

c) 2W AC1Ø 120 60 Hz.,Leg A to AG9, Leg B to AG8 (Øs B & C to SV)
d) PG&E to provide details for 120V AC energization of Agastat Relay.

e) Connect "Close" Push Button to DD9 and BB6
Connect "Trip Push Button to DD9 and BB9

f) Remove and tape ground leads from ground bus in rear of cell.

C. Electrical Monitoring

Cell 7 (441589)

52HH7 Aux. Sw.	A contact	GG5 & GG6
3HH1 lockout NO contact from Safe Guard Panel PG&E to furnish connection details for 3HH1 relay to be energized by the 59HHG 1 & 2 SV relay contacts.		G6 C17

Cell 8 with Cell 12 door (53078)

52HH8 Aux. Sw.	A contact	FF11 & FF12
27ZHHB2 W SG contact on Safeguard Panel PG&E to furnish connection details for 27ZHHB2 to be energized from IAV relay		AA8 AA12
4HH14 W SG contact on Safe Guard Panel PG&E to furnish connection details for 4HH14 to be energized by the RAV relay.		C6 C4

Cell 9 with Cell 13 door (53108)

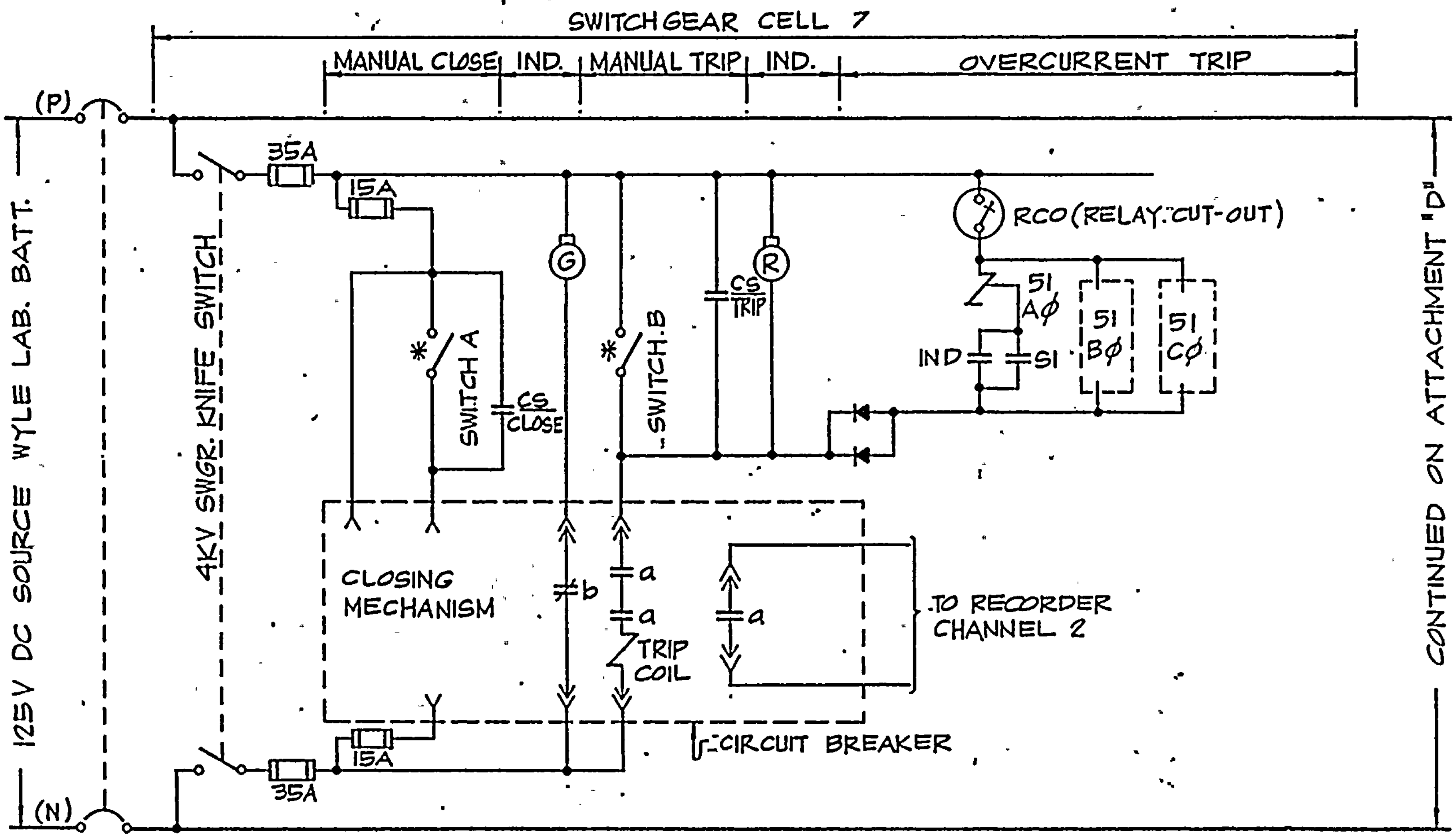
52HH9 Aux. Sw.	B contact	FF9 & FF10
52HH9 CI	NO breaker raised	HH1 & HH2
52HH9 CI	NC breaker raised	HH3 & HH4
2HH9 AGA	NO	DE2 & DE6
2HH9 AGA	NC	DE2 & DE4

D. Non Electrical Monitoring

PG&E to provide connection details to energize blue lights from 51X HH7, HH8 and HH9. HFA relays. Not class 1E.

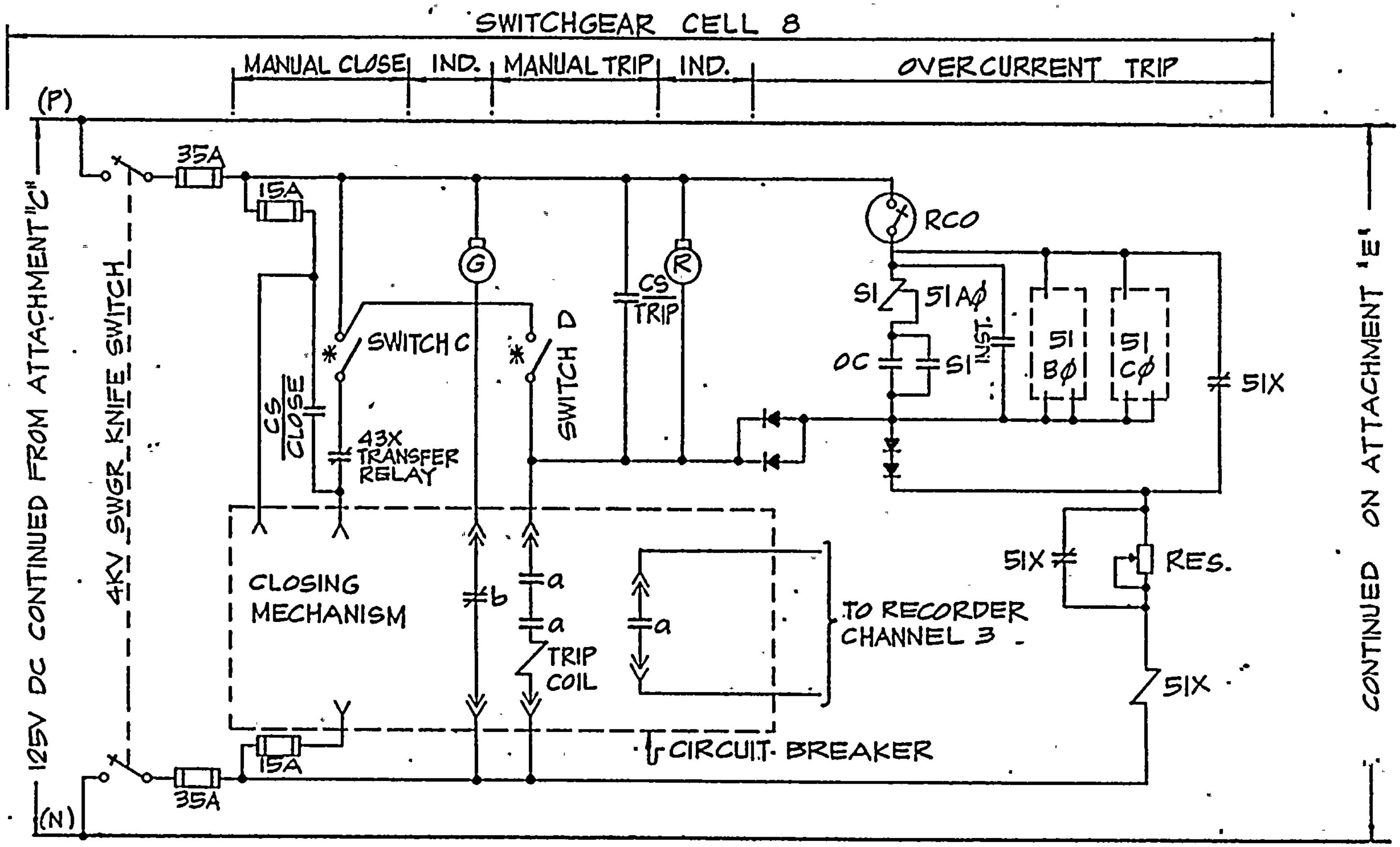
E M Fitzgerald
July 14, 1978
Rev 1 7/27/78 EMF

ATTACHMENT "B" SH.2



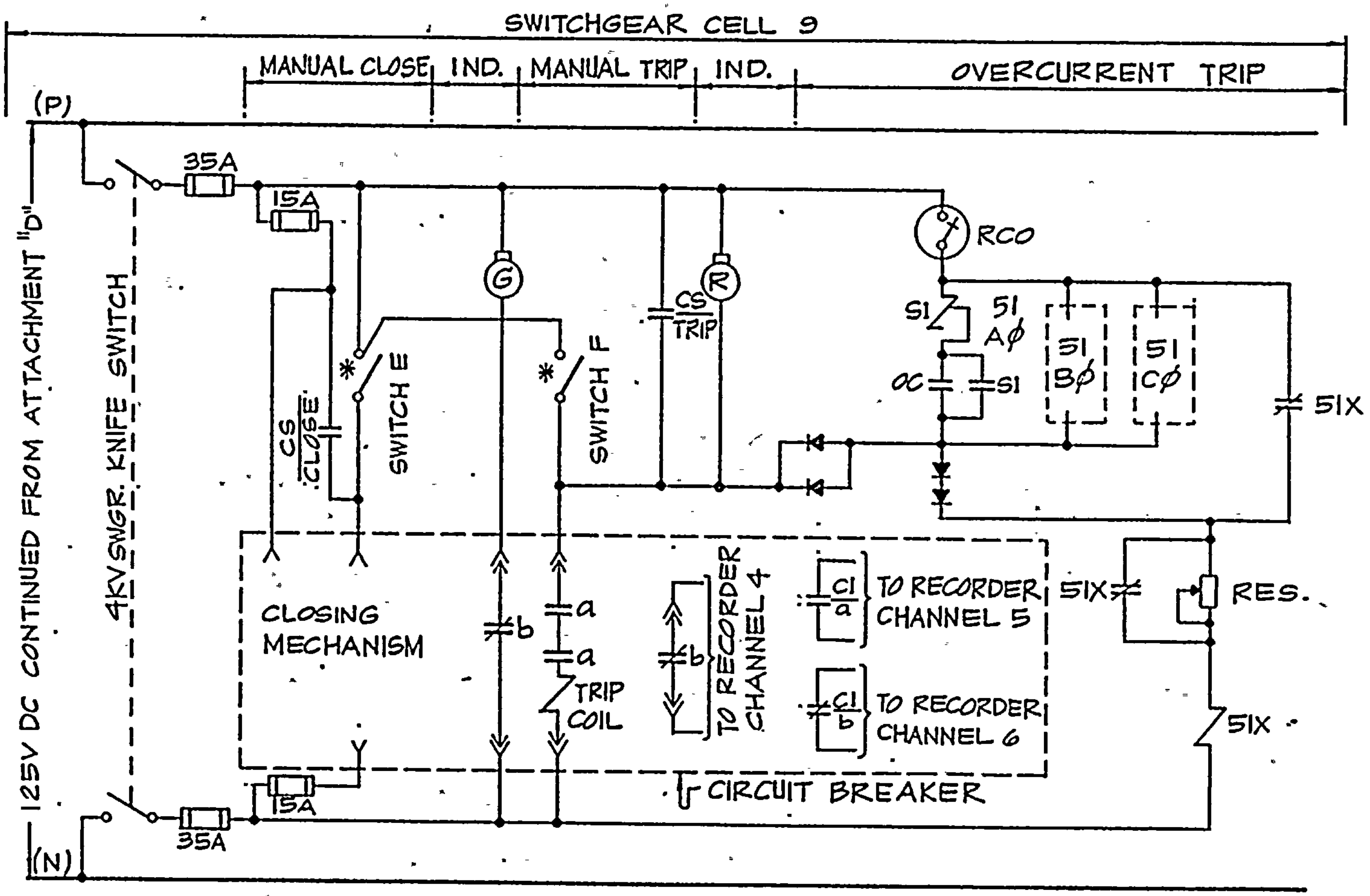
* LOCATED AT TEST BENCH

ATTACHMENT "C"



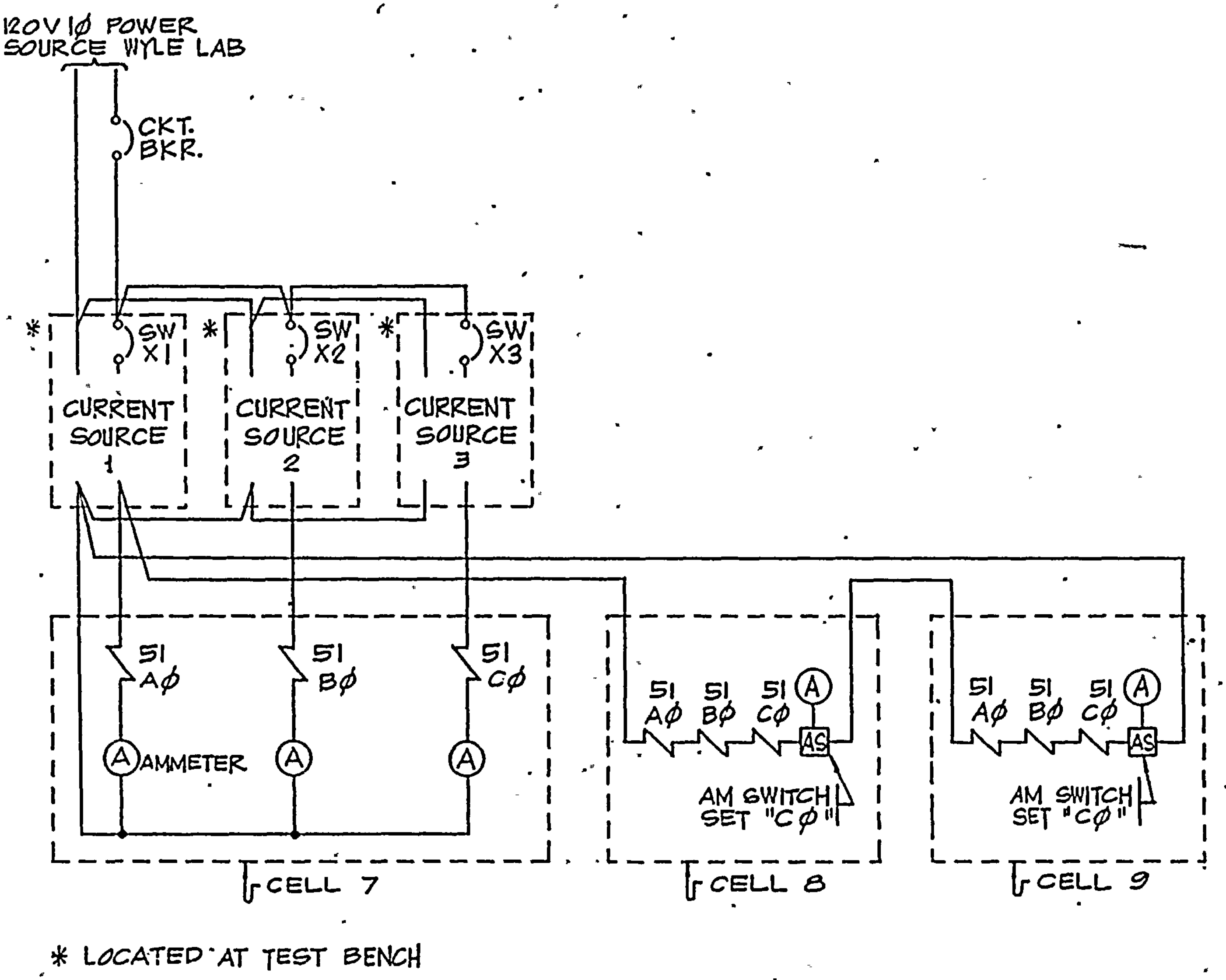
✱ LOCATED AT TEST BENCH

ATTACHMENT "D"



* LOCATED AT TEST BENCH

ATTACHMENT "E"



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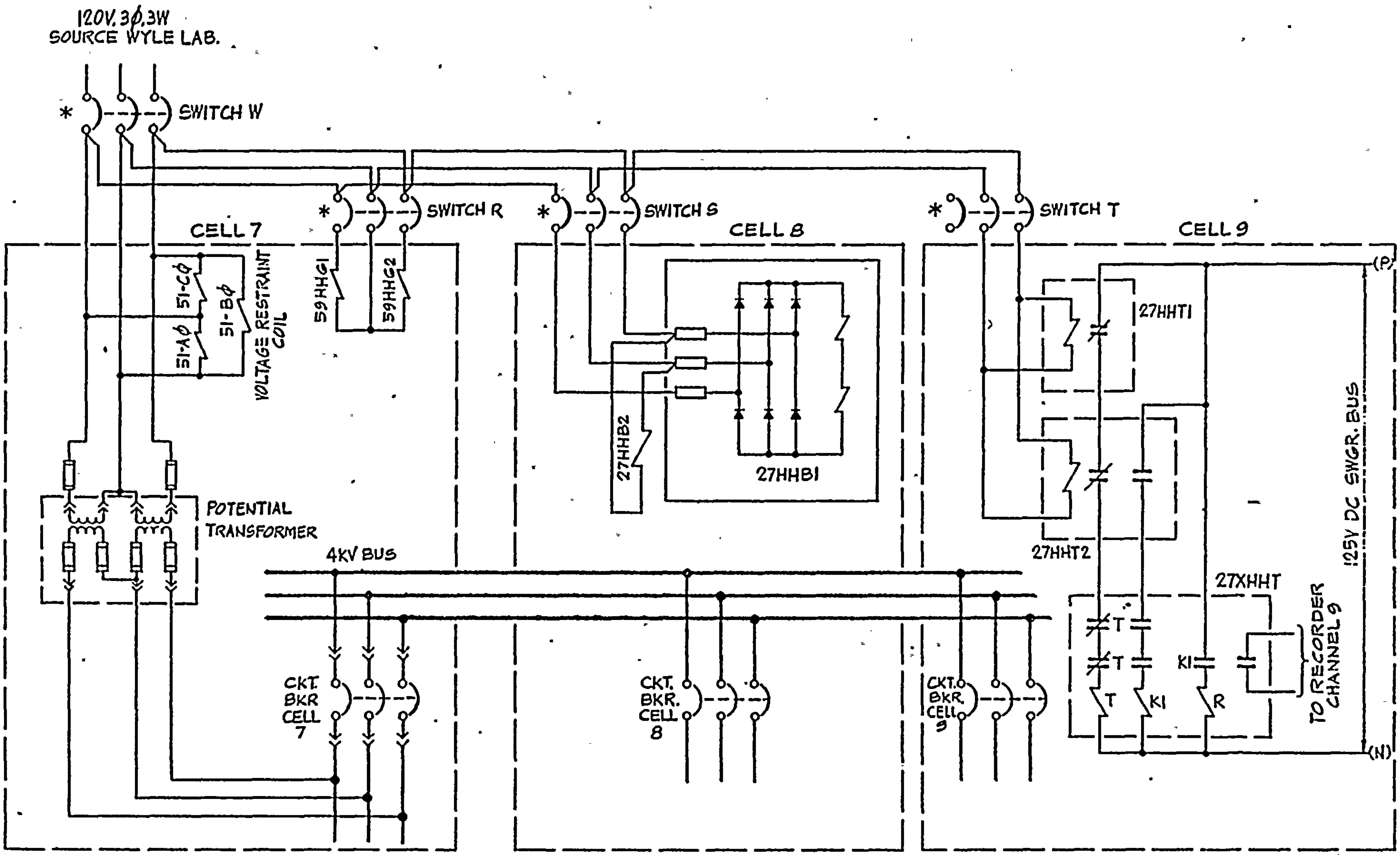
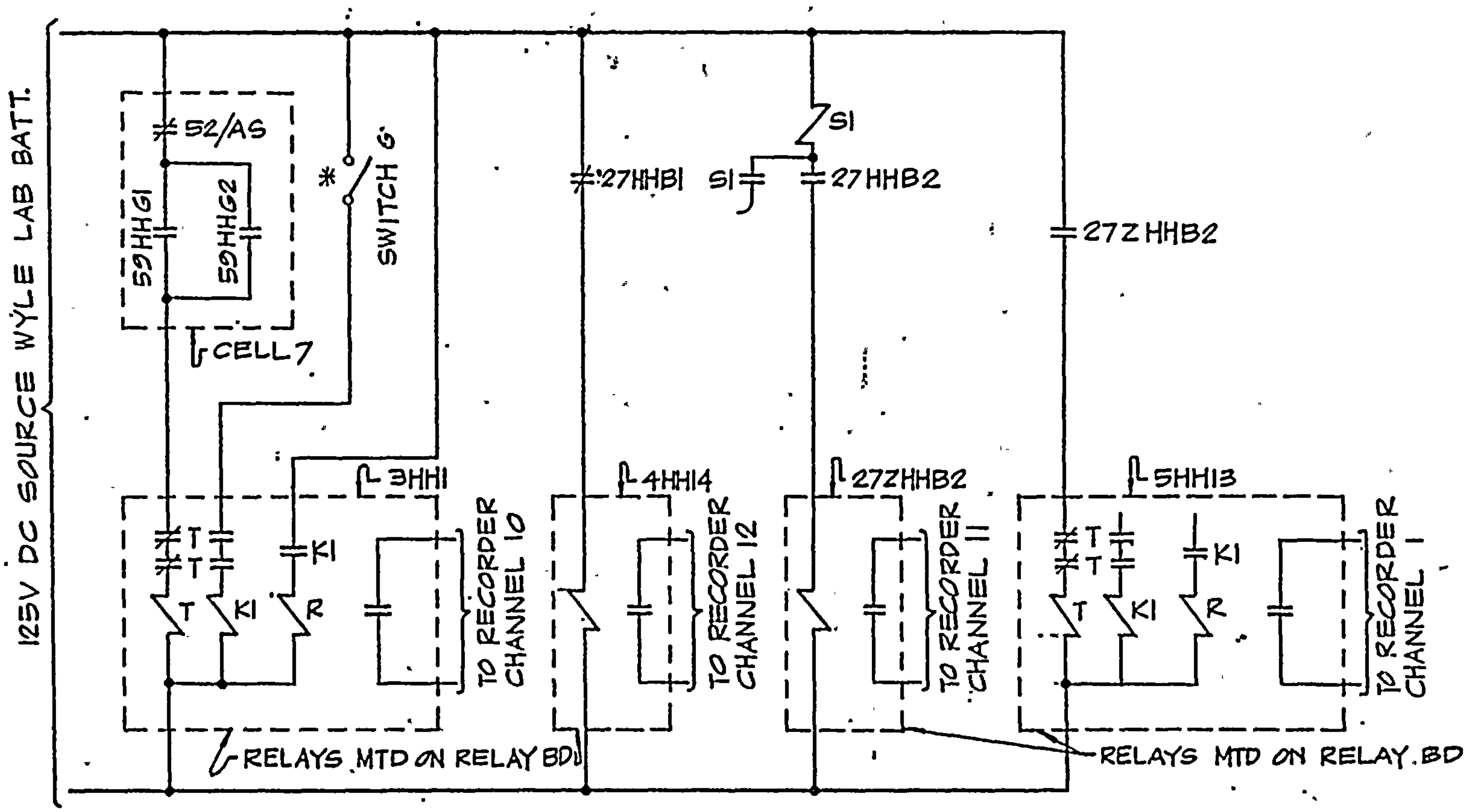


* LOCATED AT TEST BENCH

ATTACHMENT 'G1'



* LOCATED AT TEST BENCH

ATTACHMENT "G2"

GENERAL ELECTRIC 0156C1250

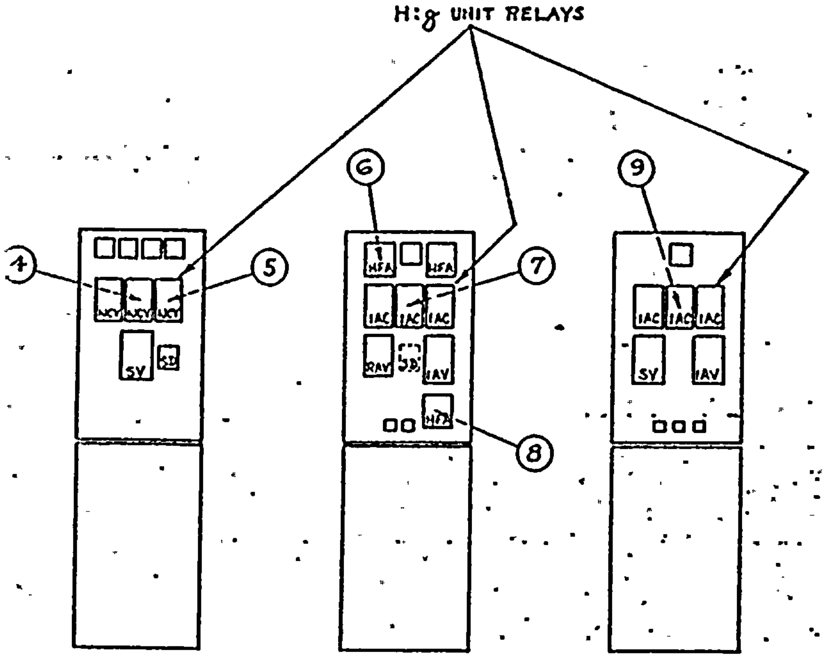
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES ✓ | TOLERANCES ± ± ±

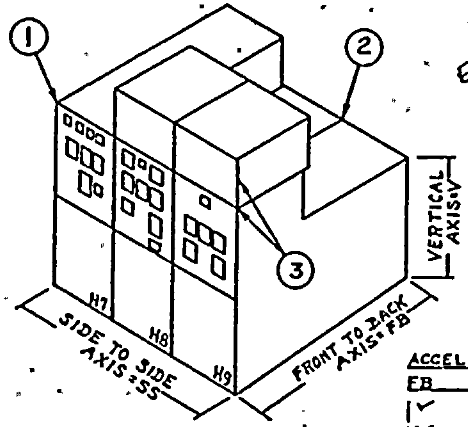
ACCELEROMETER LOCATIONS

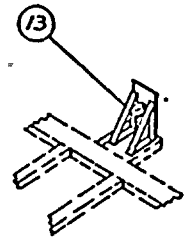
FIRST MADE FOR 250MVA 4.16 KV SWITCHGEAR

PG&E DIABLO CANYON

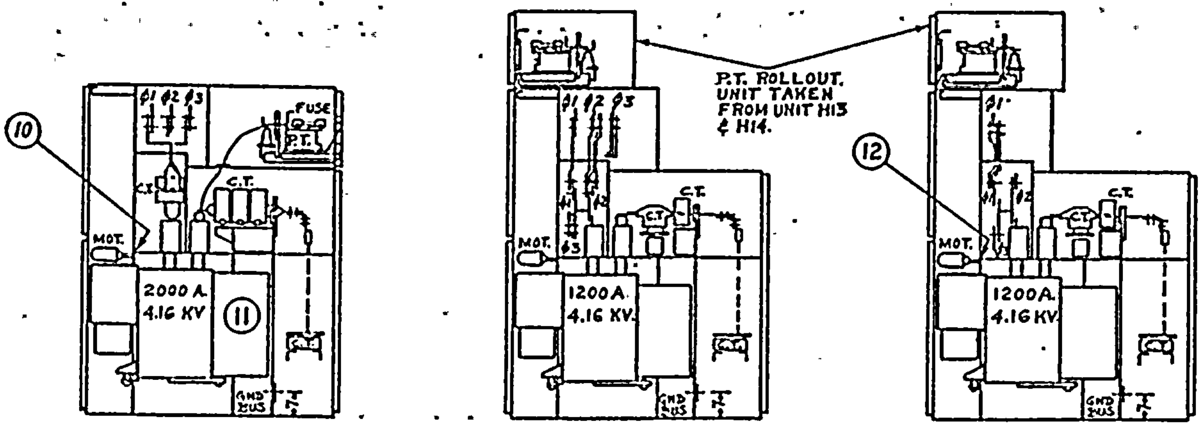
G.E. REQ'N 474-68849







ACCELEROMETER AXIS FB	SS	V	POSITION NO.	LOCATION
✓	✓		1	TOP FRONT LEFT CORNER H7
✓	✓	✓	2	TOP REAR JUNCTION OF H8 & H9, MOTION AT EARTHQUAKE JOINT
✓	✓	✓	3	P.T. ROLLOUT TRAY
✓	✓	✓	4	BACK OF MIDDLE IJCV RLY H7
✓	✓	✓	5	BACK OF RIGHT IJCV (H:g UNIT) RELAY H7
✓	✓	✓	6	BACK OF TOP LEFT HFA RELAY H8 (H12 DOOR)
✓	✓	✓	7	BACK OF MIDDLE IAC RELAY H8 (H12 DOOR)
✓	✓	✓	8	BACK OF LOWER HFA RELAY H8 (H12 DOOR)
✓	✓	✓	9	BACK OF MIDDLE IAC RELAY H9 (H13 DOOR)
✓	✓	✓	10	INSIDE FRAME RIGHT SIDE 44 INCH LEVEL H7
✓	✓	✓	11	ARC CHUTE 2000 A BRKR H7
✓	✓		12	INSIDE FRAME RIGHT SIDE 44 INCH LEVEL H9
✓	✓	✓	13	RIGID RELAY MOUNTING LOCATION.



REVISIONS: 1 — ADDED POS #13 7-19-78

PRINTS TO

6-2-70 — SWGR PHILA. — 0156C1250

10.3.30.1 Name of Equipment

Potential Transformers 4160/120V.

10.3.30.2 Description of Equipment

The potential transformers are housed in a metal cabinet 26 inches wide, 22 inches high and 33.5 inches deep. The butyl molded transformer is fastened to a roll-out slide which can be pulled forward with the cabinet front. Contact fingers mounted to the stationary housing provide the electrical connections to the primary and secondary windings of the slide mounted transformers. The potential transformers are usually mounted on top of the switchgear of which they are an electrical accessory. The potential transformers discussed here were removed from the top of the switchgear and will be mounted on a rigid stand and fastened to the floor near the 4160V Class 1E switchgear.

10.3.30.3 Safety Function

The safety function of the potential transformer is to provide a signal, for control and instrumentation, which is proportional to the level of high voltage of the bus or feeder to which it is connected.

10.3.30.4 Test Criteria and Plan

The potential transformer must provide the signal, proportional to the level of high voltage it monitors, without interruption at all times. X

The transformer itself has no moving parts which could compromise its safety function. However, the primary and secondary contact fingers could cause an interruption of the voltage signal.

The plan is to test the integrity of the contact fingers while subjecting the potential transformer assembly to simulated seismic events in accordance with IEEE Standard 355-1975.

10.3.30.5 Test Procedure and Setup

One potential transformer cabinet was rigidly bolted to a steel plate which in turn was welded to the shake table thus simulating its future installation at the plant. Two primary and two secondary contact finger assemblies were connected in series and wired to direct readout recorder for monitoring. See Attachment "A".

The seismic test sequence was the same as for the safeguard relay board see 10.3.21.5. "Test Procedure and Setup" for the safeguard relay board. The potential transformer was tested alongside the safeguard relay board.

10.3.30.6 Test Results

At no time during the seismic test sequences did any chatter of the contact finger occur.

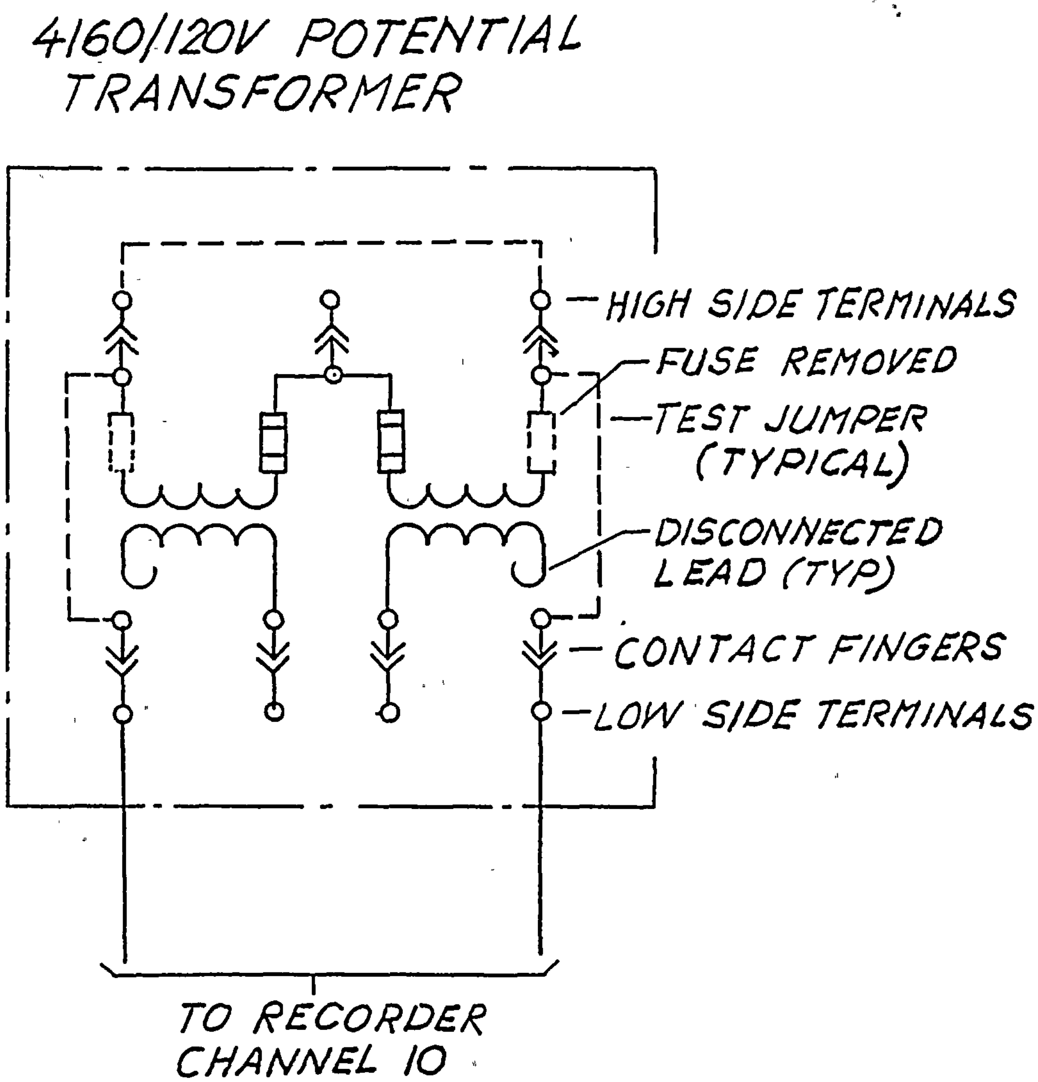
No physical damage to the equipment was observed.

10.3.30.7 Conclusion

A typical Potential Transformer Cabinet with its contents was seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report No. 58255-1, dated August 22, 1978.

The test results presented in section 10.3.30.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 4160/120V Potential Transformers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.



ATTACHMENT "A"

10.3.21.1 Name of Equipment

Safeguard Relay Boards.

10.3.21.2 Description of Equipment

The safeguard relay boards are steel cabinets 7'-10" high 3'-7" wide and 2'-0" deep. Mounted semi flush on their front are an array of electrical relays, switches and lights. Doors in the back provide access to the wiring and secondary devices such as fuses, test and cut-out switches, and a timing relay.

Of the six boards installed in the Diablo Canyon Power Plant, five boards are identical to each other. These are Safeguard Relay Boards F, G and H of Unit 1 and G and H of Unit 2. Safeguard Relay Board F of Unit 2 has the same physical outline but does not contain the diesel generator protective relays contained in the other five boards since there are only five diesel generators at Diablo Canyon.

Safeguard Relay Board H of Diablo Canyon Unit 2 was chosen to be tested to qualify all Safeguard Relay Boards. Relays of Board H, Unit 2 are listed in Attachment A, "Device Table". The "Device Number" is PGandE's designation of the relay. "Type" is the manufacturers designation. "Use" indicates the application of the device in the plants electrical system. "Schematic Diagram" is PGandE's drawing number where the device appears. "Affect on a Class IE function" is shown with yes or no and explanatory remarks.

10.3.21.3 Safety Functions

The Devices on the safeguard relay boards perform the following safety functions:

a. Initiate start of diesel generators in case of loss of the off-site stand-by power source and loss of 4.16 kV bus voltage.

b. On loss of 4160 volt bus voltage, initiate transfer of the 4160V bus from the station auxiliary transformer to the stand-by start-up transformer, and if necessary to the diesel generators.

c. Stop the diesel generator and trip its output breaker on sensing differential phase current.

d. Initiate start of the component cooling water pump on cooling water low pressure.

The test acceptance criteria specified in section 10.3.21.4 below have been established based on these safety questions.

10.3.21.4 Test Criteria in Plan

The test criteria are based on the evaluation of all devices on the safeguard relay board as shown on the attached device table. The devices shall not inadvertently operate or its contacts chatter during a seismic event. If contact chatter occurs during the seismic testing, it shall be evaluated to demonstrate that the equipment safety function is not comprised. Devices which can have an adverse affect on Class IE function if they malfunction during or after a seismic event, are discussed below.

a. Device 87HHG, Diesel Generator Differential Relay: Must trip diesel generator and open 4.16 kV diesel generator breaker on diesel generator differential current flow. Must not operate inadvertently.

b. Devices 32XHH7, 32YHH7, 87XHHG, 87YHHG, 40XHH7 and 40YHH7, Auxiliary Relays normally open contacts must not close (chatter) during a seismic event. Such a contact closure could seal in the respective auxiliary relay, and cause the diesel generator breaker to open and in the case of the 87XHHG and 87YHHG relay could cause the diesel generator itself to trip. The 87X and Y relays must also operate during and after a seismic event.

c. Devices 4HH, 3HH1 and 5HH13 Transfer-, Interlocking-, and Trip Relays: Must operate during and after a seismic event. They must not change state inadvertently at any time.

d. 27ZHHB2 4.16 kV Switchgear Bus Undervoltage Auxiliary Relay: Must operate during and after a seismic event on contact closure of the 27HHB2 bus undervoltage relay.

e. 62HH2 Diesel Auto Transfer Timer shall operate on demand during a seismic event.

The following test procedure tests all the above requirements during and after a simulated earthquake as required to qualify the equipment to IEEE Standard 344-1975 and USNRC R.G. 1.100.

10.3.21.5 Test Procedure and Setup

The relay board was bolted to the seismic test machine to simulate its rigid floor mounting at elevation 119' in the turbine building. Attachment "B" describes the test mounting.

Two strain gages were installed on structural members inside the relay board to monitor structural performance during the test as shown in Attachment "C". The seismic test sequence shown in Attachment "D" was modeled after the one for the 4.16 kV switchgear as described in Addendum 1 of WYLE's Test Report No. 58255-1, August 22, 1978.

The devices on the relay board were wired per attached wiring instructions. See Attachment "E".

Following are illustrations which show the test setup wiring beyond the termination points.

a. 125 VDC energizes the diesel generator protective circuitry (see Attachment "F") and the automatic transfer circuitry (see Attachment "J").

b. 3 phase current was applied to the circuitry of the 46HH7, negative sequence. See Attachment "H".

c. Single phase current was applied to the 87HHG Differential Relay via a switch to demonstrate the diesel generator differential relay operation. See Attachment "H".

d. One normally open contact each of relays 87XHH7, 40XHH7 and 32XHH7 were wired to trip a 4.16 kV switchgear breaker to demonstrate their function as outlined in the test criteria above. In addition a second contact of each relay was wired to a direct readout recorder to monitor chatter. See Attachment "F".

e. Relays 4HH and 3HH1 were wired to trip and reset via separate switches. Relay 5HH13 was wired such that the operation of relay 3HH1 conversely tripped and reset 5HH13 which simulated the interaction of these relays in the plant. In addition one normally open and one normally closed contact of the 3HH1 relay were wired to the direct readout recorder to monitor chatter and indicate change of state when operated. See Attachment "J".

f. 120 VAC, single phase, was connected to relay 27HHB2, which was mounted rigidly to the shake table by means of a stand. The output contact was connected to the 27ZHHB2 relay in such a manner that deenergization of 27HHB2 would pick-up 27ZHHB2, energization would drop out 27ZHHB2. One normally open contact of 27ZHHB2 was connected to the direct reading recorder to monitor chatter and indicate change of state when operated. See Attachment "K".

g. 125 VDC was connected to the 62HH2 Diesel Auto Transfer Timing Relay via a switch to demonstrate its timing function and that it permits the 4HH7, Diesel Auto Transfer Close Relay, to be energized which in turn initiates the closure of the diesel generator breaker. A second contact of above switch was directly connected to the direct reading recorder to indicate the start of timing. Relay 4HH7 was connected to a normally open contact of 62HH2. A normally open contact of 4HH7 than was monitored on the direct reading recorder to demonstrate the end of timing. See Attachment "L".

10.3.21.6 Test Results

With the exception of anomalies discussed below for relays 27ZHHB2, 32XHH7, and 40XHH7, all relays met the test criteria specified in section 10.3.21.4 above during and after the seismic testing while being operated per the test procedure described in section 10.3.21.5 above. It is worthy of note that the equipment was subjected to more than the minimum number of test runs for qualification, demonstrating margin in the equipment's resistance to seismic damage.

During the testing, pulsation of the 27ZHHB2 relay, caused by chatter of the deenergized 27HHB2 relay was observed. Testing performed on the 4.16 kV switchgear (see section 10.3.26 below) has demonstrated that pulsations of the 27ZHHB2 relay will not prevent the pickup of the 5HH13 relay, and thus will not compromise the safety function of power transfer of the 4160V bus from the station auxiliary transformer to the stand-by start-up transformer, and if necessary to the diesel generators.

Momentary change of state of the contacts of the 32YHH7 and 40YHH7 auxiliary relays was observed during a portion of the testing. This was demonstrated to be pulsation of these relays due to chatter of the prime relays 32HH7 (Reverse Power Relay) and 40HH7 (Loss of Field Relay) since the anomaly did not occur when the cut out switches for the prime relays had been opened. This anomaly would not occur in the event of a seismic event during plant operation, since these relays are normally cut out.

The evaluation of the strain gage traces showed that the structural members of the relay board were exposed to stresses well within their design limits.

No physical damage to the relay board or its devices was observed.

10.3.21.7. Conclusion

Safeguard Relay Board H of Diablo Canyon Unit 2 was seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report Number 58255-1, dated August 22, 1978, pp. 92-138. This board contains devices representative of the contents of all Diablo Canyon Unit 1 and 2 Safeguard Relay Boards. Thus qualification of this board will apply to all Diablo Canyon Safeguard Relay Boards.

The test results presented in section 10.3.21.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 Safeguard Relay Boards are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

DEVICE TABLE

SAFEGUARD RELAY BOARD "H"

Device	Type	Use	Affect Class 1E Function	Remarks	Schematic Diagram No.
25HH	IJS	Synchronism Check	no	Used during tests only	441341
32HH7	CRN-1	Reverse Power	no	Used during test only	441356
46HH7	COQ	Negative Sequence	no	Alarm only	441355
59HHU	SV	Start-up Voltage	no	Chatter will not produce abnormal operation	441354
27HHU	CV-2	Start-up Under Voltage	no	Chatter could start diesel. This is failsafe	441354
62HH1	TD-5	Start-up Auto Transf. Timer	no	Chatter will not produce abnormal operation	441354
87HHG	SA-1	Diesel Gen. Differential	yes	Monitor Aux. Relays	441356
40HH7	KLF	Loss of Field	no	Used during tests only	441356
32XHH7	AR	Rev. Pwr. Auxiliary	yes	Monitor NO contact	441356
32YHH7	AR	Rev. Pwr. Auxiliary	yes	of 32YHH7	441356
87XHHG	AR	Diesel Gen. Diff.	yes	Monitor NO contact	441356
87YHHG	AR	Auxiliary Relays	yes	of 87YHHG	441356
40XHH7	AR	Loss of Field	yes	Monitor NO contact	441356
40YHH7	AR	Auxiliary Relays	yes	of 40YHH7	441356
4HH	LORE	Diesel Gen. Auto Transf. Control Relay	yes	See 3HH1	441354
3HH1	LORE	Diesel Gen Auto Transf. Interlocking Relay	yes	Monitor 1NO & 1NC cont. (typ. for 4HH & 5HH13)	441354
5HH13	LORE	St-up Auto Transf. Trip Relay	yes	See 3HH1	441354
PS190XH	SG	Comp. Cool Wtr. Low	no	Chatter would start	441311
PS191XH	SG	Press. Aux. Relay		Comp. Cool. Wtr. Pp. This is failsafe	441311
27XHHB2	SG	Bus UV Aux. Relay (st.-up & 4kV Bus)	no	Chatter would start diesel. This is failsafe	441354
25XHH	SG	Synch. Check Aux. Rel.	no	Used during test only	441340

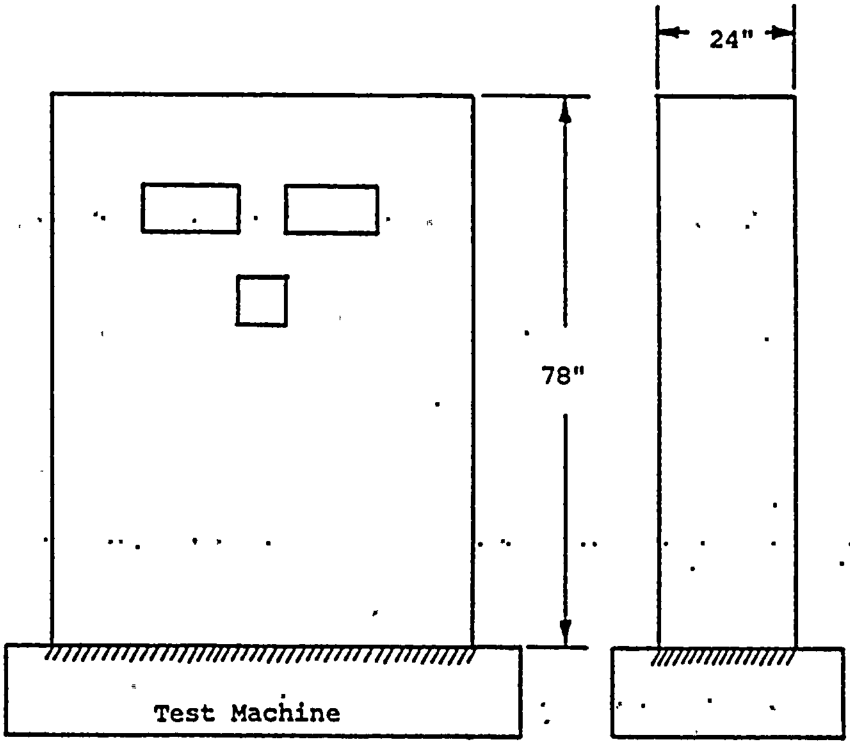
DEVICE TABLE

SAFEGUARD RELAY BOARD "H"

Device	Type	Use	Affect Class 1E Function	Remarks	Schematic Diagram No.
4HH7	SG	Diesel Gen. Auto Transf. Close Relay	no	Chatter will not produce abnormal operation	441354
27HHDC	SG	DC Contr. Bus UV Rel.	no	Alarm only	441354
27GHDC	SG	DC Contr. Bus UV Rel.	no	Alarm only	441356
27ZHHB2	SG	4kV Bus UV Aux. Rel.	yes	Connect NO Cont. to 5HH13 and monitor trip	441354
27YHHB2	SG	Same as 27XHHB2	no	Same as 27XHHB2	441354
4HH14X	SG	Start-up Auto Transfer	no	Chatter will nor produce	441354
4HH14	SG	Close Aux. Relays	no	abnormal operation	
62HH2	AGASTAT	Diesel Auto Transfer Timer	no	Chatter will not produce abnormal operation	441354

FIGURE 8 B

SAFEGUARD RELAY BOARD C
GROUP I B

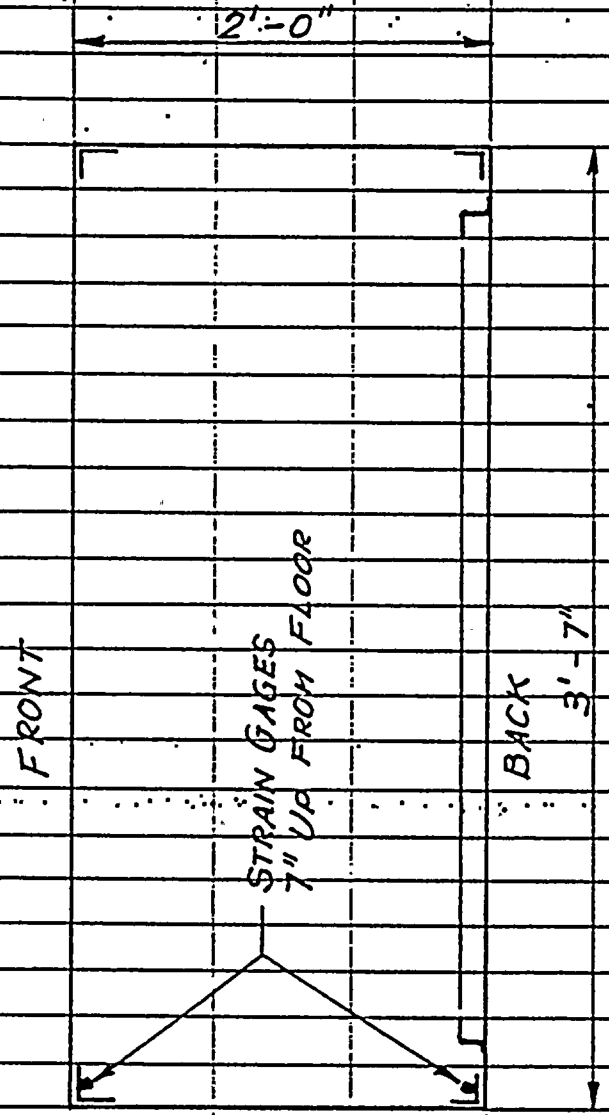


Bolt to the seismic test machine with eight 1/2 x 13 bolts. C

PG&E
62-3408 (5/77)

~~Test Procedure No. 3642~~
~~ADDENDUM 1~~
~~Page No. A1-9~~

STRAIN GAGE LOCATION
SAFEGUARD RELAY BOARD "H"



HORIZ. SECTION THROUGH
RELAY BOARD
LOOKING DOWN.

J. E. HERBST
8/7/78

ATTACHMENT "C"

SEISMIC TEST SEQUENCE
FOR SAFEGUARD RELAY BOARD "H"

CONDITION	AXES	HORIZONTAL ZPA g	HORIZONTAL RM FIG. NO.	VERTICAL ZPA g	VERTICAL RM or RM + SB FIG. NO.	SB Hz	REMARKS
1	FB	.2	-	-	-	-	1-33 Hz Sweep
2	V	-	-	.2	-	-	1-33 Hz Sweep
3	FB+V	.75	50% - 1	.8	50% - 2	-	1 OBE
4							2
5							3
6							4
7							5
8		1.5	1	1.6	2	7.1	1 SSE
9						8	2
10						9	3
11						10	4
ROTATE RELAY BOARD 90°							
12	SS	.2	-	-	-	-	1-33 Hz Sweep
13	SS-V	.75	50% - 1	.8	50% - 2	-	1 OBE
14							2
15							3
16							4
17							5
18		1.5	1	1.6	2	7.1	1 SSE
19						8	2
20						9	3
21						10	4

LEGEND:

RM	Random Motion
RM+SB	Random Motion plus Sine Beat
ZPA	Zero Period Acceleration
FB	Front to Back
SS	Side to Side
V	Vertical
FB+V	Front to Back and Vertical (Biaxial)
SS+V	Side to Side and Vertical (Biaxial)

ATTACHMENT "D"

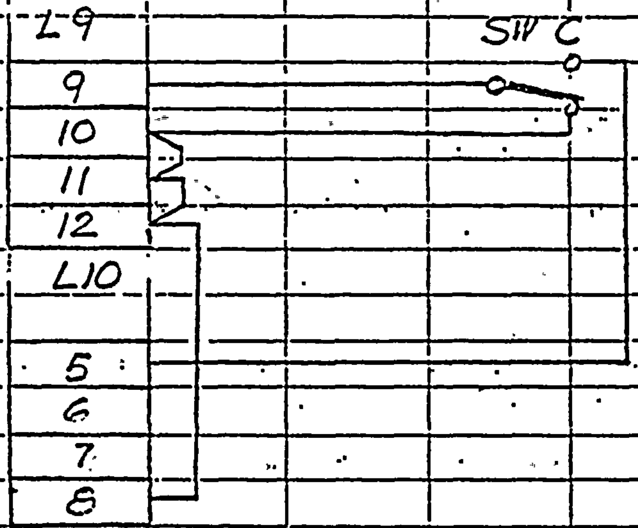
~~Test Procedure No. 3642~~
~~ADDENDUM~~
~~Page No. A1-10~~

WIRING INSTRUCTIONS
FOR SEISMIC TEST OF
SAFEGUARD RELAY BOARD "H"
POTENTIAL TRANSFORMER COMPARTMENT
EMERGENCY LIGHT UNIT
RELAYS DEVICE NO 59HHG1, 59HHG2 AND 27HHB2

SW. NO								
A	125V DC	TERM. TBA-1 POS	(W. IND. LT. ON)					
		TBA-2 NEG						
B	5A, 3Ø, 4 WIRE	CURRENT	RELS 46HH7					
			40HH7					
		TERM L10-1 AØ	32HH7					
		L10-2 BØ						
		L10-3 CØ						
		L10-4 GND						

JUMPER AS FOLLOWS:

C



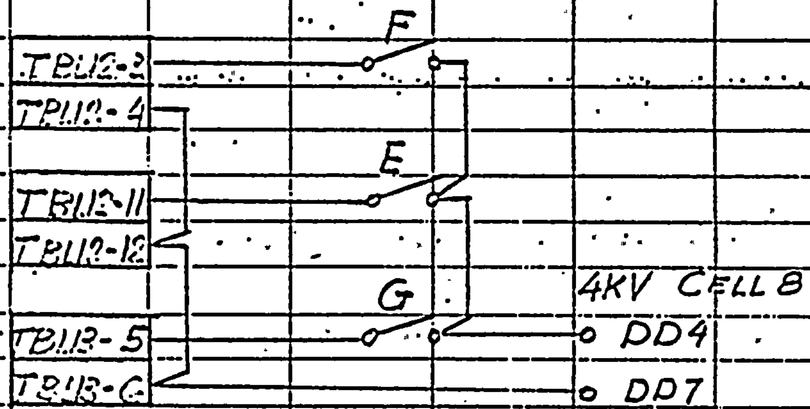
OPERATION OF SW D WILL CAUSE 87HHG (DIFF. REL) TO OPERATE.

D	120V AC, 3Ø	TERM. L8-10	AØ	POT FOR:	
		L8-11	BØ	40HH7	
		L8-12	CØ	32HH7	

ATTACHMENT "E" SH.1

* IND. CHANGE FROM PRELIM.

SW. NO		
	87XHH7	TO TRIP 4KV BKR. 8
E		TERM: TBL12-11 VIA CUT-OUT
		TBL12-12 TO PREVENT BKR TRIP
	40XHH7	TO TRIP 4KV BKR 8
F		TERM: TBL12-3 VIA CUT-OUT
		TBL12-4 TO PREVENT BKR TRIP
	32XHH7	TO TRIP 4KV BKR 8
G		TERM: TBL13-5 VIA CUT-OUT
		TBL13-6 TO PREVENT BKR TRIP



*

87XHH7	MONITOR	TBL15-1 AND TBL15-2
40XHH7	"	TBL14-11 AND TBL14-12
32XHH7	"	TBL15-3 AND TBL15-4
		LIFT POSSIBLE JUMPER AT TBL15-1, -3, -11

SW. NO.

H	4HH	(TRIP)	125V DC POS. TO TERM TBR10-2 VIA SW. "H"
I	3HHI	(TRIP	" " " " TERM TBR5-11 VIA SW. "I"
			RESET IS ONLY MANUAL AND NEED NOT BE TESTED DURING SHAKE
	5HH13	(TRIP)	125V DC P JUMPER TBR10-4 TO TBR7-3 NO SWITCH OPERATION. 3HHI WILL CONVERSELY TRIP AND RESET 5HH13
J	4HH 3HH1	(RESET)	125V DC POS TO TERM TBR5-3 VIA SW. "J"
	3HH1		MONITOR TBR1-7 AND TBR1-8 NC; TBR1-9 " TBR1-10 NO. THIS IS TYP. MONITORING FOR LORE RELAYS 3HH1, 4HH, AND 5HH13
	27ZHHB2		CONNECT TERM 12 OF 27HHB2 (IAC) TO TBR9-3. CONNECT TERM 1 OF 27HHB2 (IAC) TO 125V DC POS. (NO SW. REQ'D)
			MONITOR 27ZHHB2 TERM 3 AND 7

* INDICATES CHANGE FROM PREL.

SW. NO.

K 120V AC 3ϕ TO 59HH1 & 2 TERM. 2 (Aϕ 4)
" 8 (Cϕ 8)
" 3 + 9 (Bϕ 9)

1ϕ TO 27HHB2 " 15 Aϕ *
" 16 Bϕ *

59HH1 & 2 MONITOR TERM'S 1-5 AND 7-10

27HHB2 CONNECT 125V DC TO TERM. 1 *
" TERM. 12 TO TBR9-3

P.T. COMPARTMENT *

CONNECT SECONDARY - PRIMARY - SECONDARY
DISCONNECT SWITCHES IN SERIES AND
MONITOR CONTINUITY.

EMERGENCY LIGHT UNIT *

L CONNECT 120V AC TO JUNCTION BOX
VIA DISCONNECT SWITCH "L"

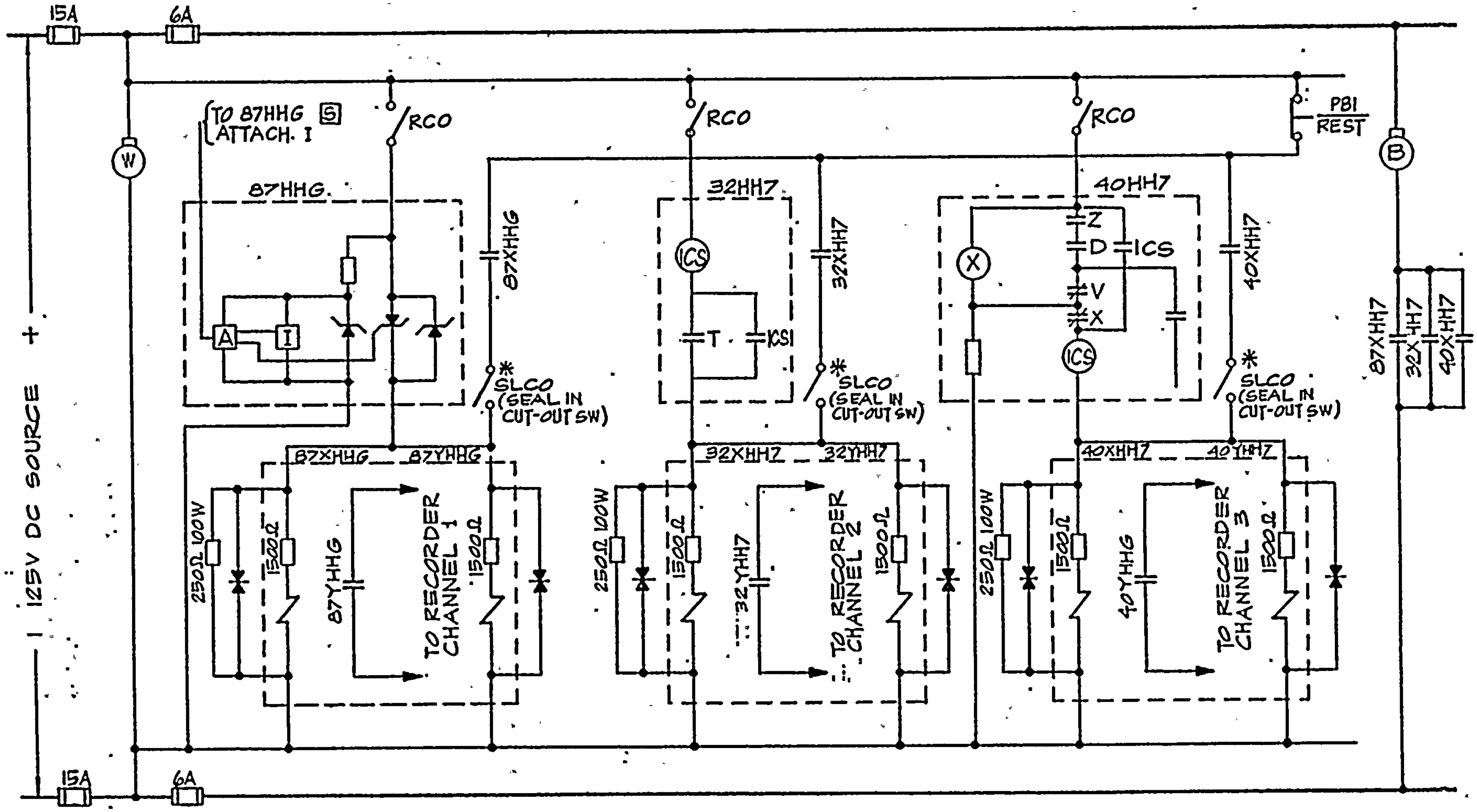
A 125V DC TO 4.16kV SWITCHGEAR DC BUS

M MAN. CLOSE SWGR DD4 - CONTROL SW - BB9 *

N MAN. OPEN SWGR DD4 - CONTROL SW - DD7 *

P 62HH2 125V DC POS TO TERM. TBR5-10 *
VIA DOUBLE POLE SW. P
MONITOR 1 POLE OF SW P

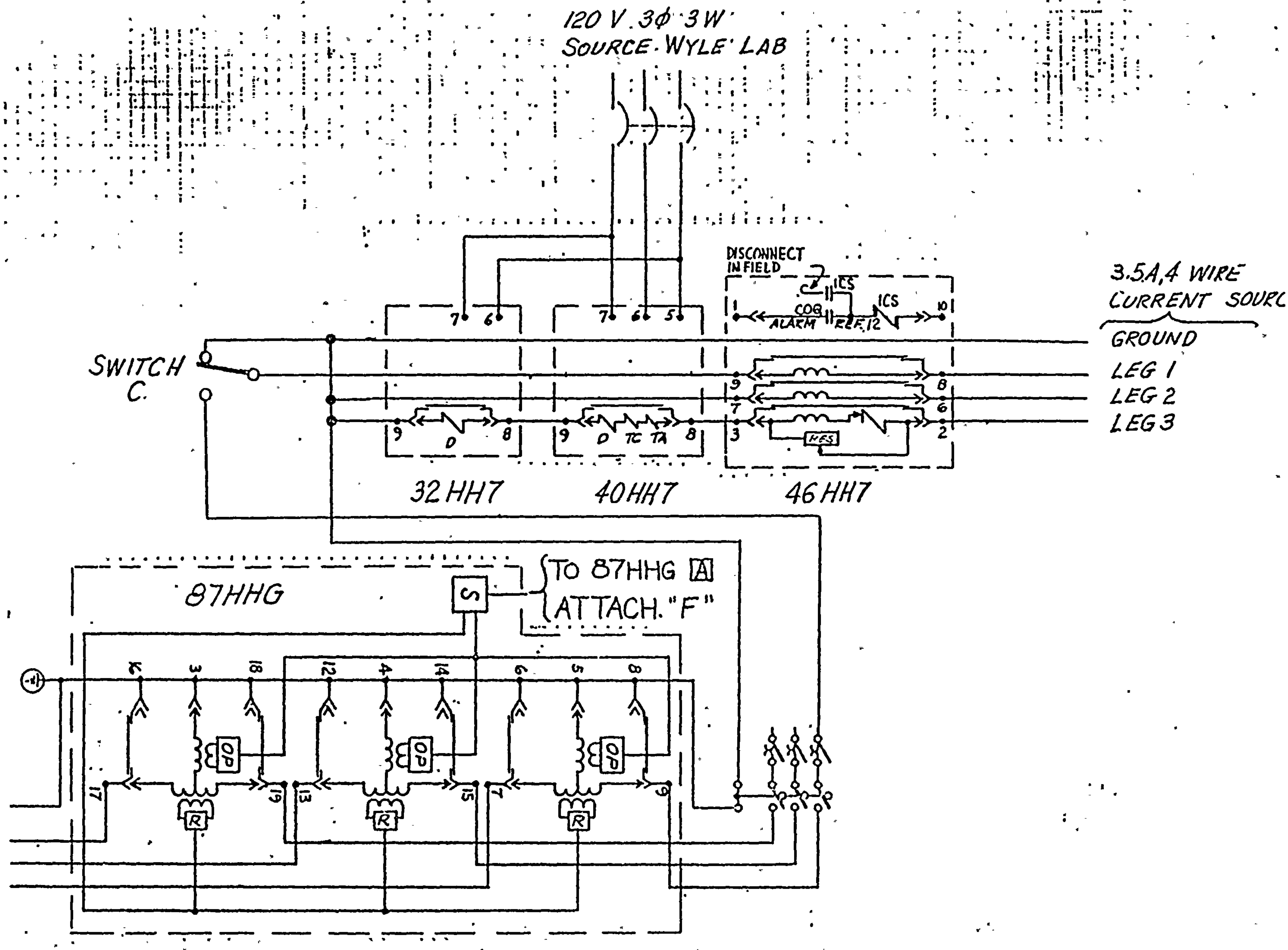
4HH7 JUMPER TBR5-5 TO TBR7-11 (POS) *
MONITOR TBR3-7 AND TBR3-8



125 V.D.C. CONTROL SCHEMATIC DIAGRAM
DIESEL GENERATOR Nº 22 PROTECTIVE
RELAYING-SEISMIC TEST CONNECTIONS-

* SLCO SWITCHES WERE CLOSED DURING TESTS

ATTACHMENT "F"



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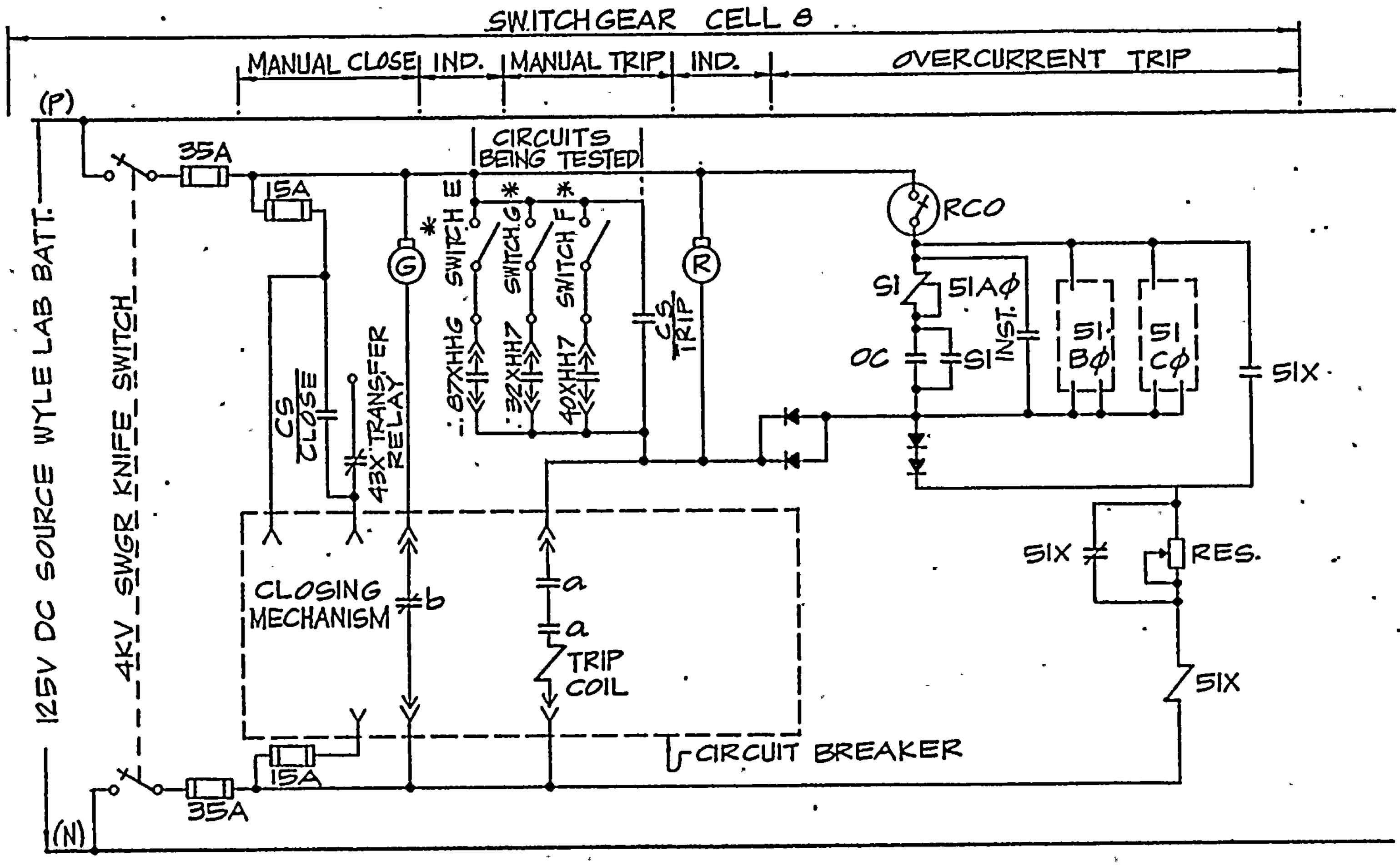
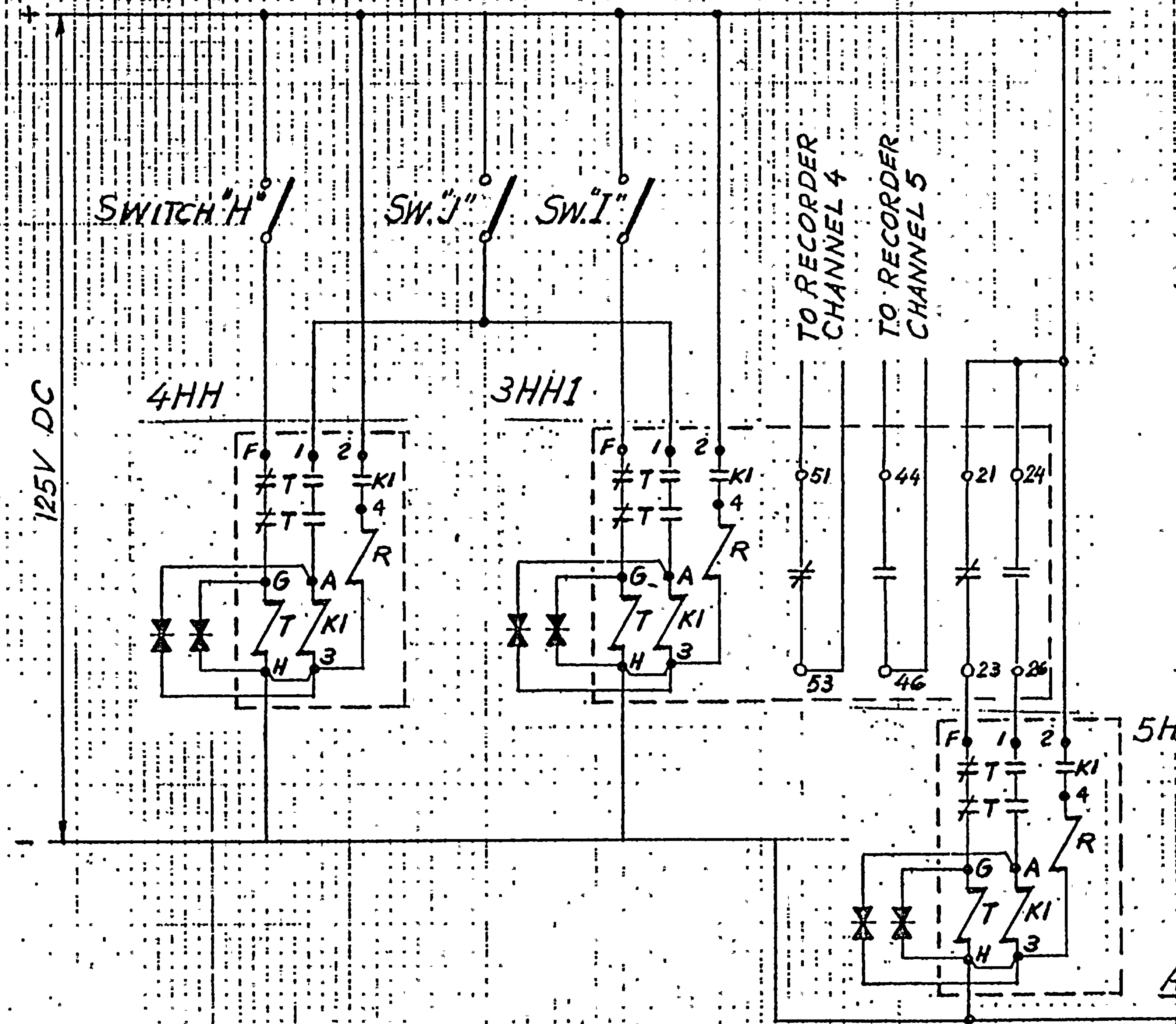
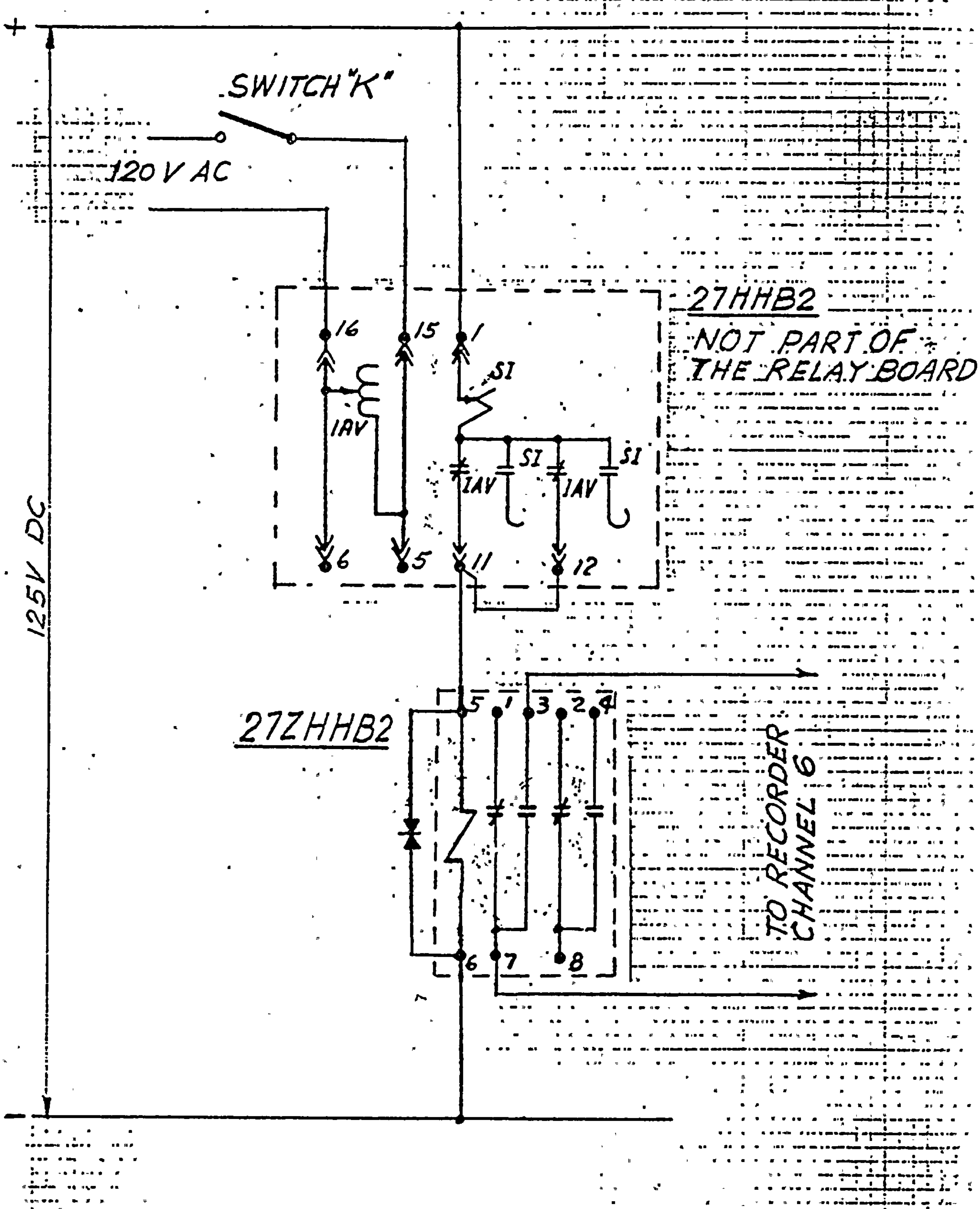


* LOCATED AT TEST BENCH

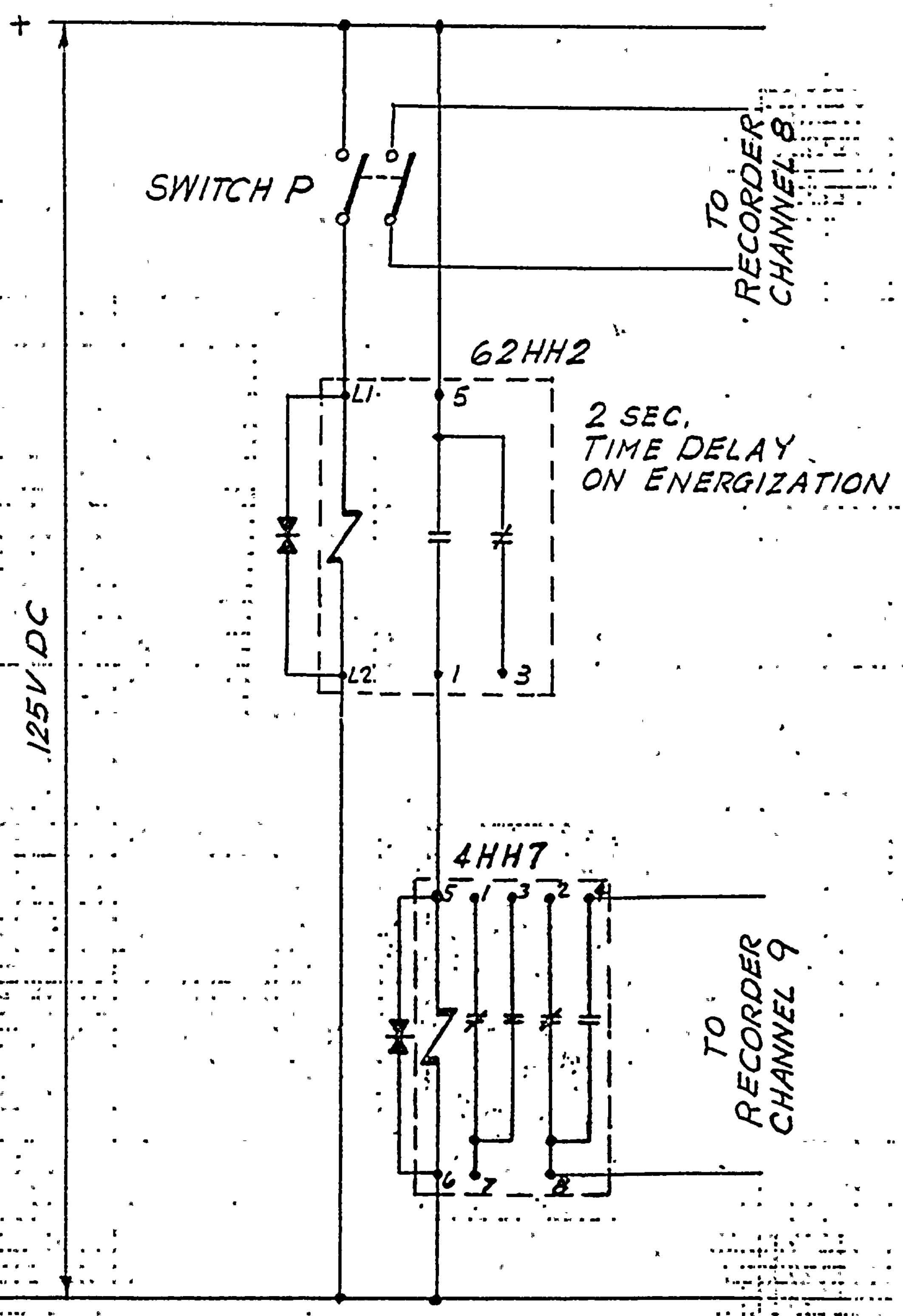
ATTACHMENT "I"



ATTACHMENT "J"



ATTACHMENT "K"



ATTACHMENT "L"

1. Name of Equipment Tested

Teledyne Big Beam 2S6N70-80 8 hour rated Emergency Light Battery Pack.

2. Description of Equipment

The Emergency Light Battery Pack is a metal chassis 8 hour rated nickel-cadmuim battery with a battery charger and two 6 VDC sealed beam lights.

3. Safety Function

The safety function of the Emergency Light Battery Pack is to provide 8 hours of lighting if the (3) redundant normal AC, Emergency AC, and 125 VDC lights are lost due to seismic or fire in designated class IE operating areas.

4. Test Criteria and Plan

The test criteria for this unit is that it perform its safety function during, and after a seismic event. The unit shall demonstrate this as follows:

a) On loss of emergency AC power the unit will automatically revert to the battery and light the sealed beam lights.

b) On return of AC power the unit lights will turn off and its charter will recharge the battery at the high charge rate, equalizing change rate or the trickle charge rate.

c) After testing the unit powered the sealed beam lights for 8 hours.

d) The battery charger recharged the battery in 12 hours.

5. Test Procedure and Set-Up

See the attached Procedure for Testing one Teledyne Big Beam 8 hour rated Battery Back Emergency Lights Unit for Hosgri 7.5M. Before testing, (2) 1/8 x 1 inch steel straps were placed across the top of the battery and bolted to the mounting shelf using 1/4 inch threaded rod with standard nuts and washers. This modification was done before the seismic test to assure a successful test.

6. Test Results

This unit was run thru 10 OBE's and 13 SSE's and demonstrated that:

a) On loss of AC input the sealed beam units energized.
b) On return of AC power the sealed beam lights go off.
c) The unit operated the sealed beam lights for 8 hours.
d) After discharge in (c) above the charger recharged the battery in 12 hours.
e) Attached find Test Run Data Sheet on the testing.

7. Conclusions

Based on the above test and functional qualification this Emergency Light Battery Pack is qualified as an emergency light battery pack with an 8 hour rating, and rechargeable in 12 hours.

The same modifications are being done to the battery packs being put into the plant as were done on this unit before seismic testing.

1.0 Procedure for Testing one Teledyne Big Beam 8 Hour rated Battery Pack Emergency Lights Unit for Hosgri 7.5M

1.1 Model No. 2S6N70-80

1.2 Before seismic testing hook-up the 120 VAC power circuit to the junction box for conduit connection.

1.3 On first energizing with 120 VAC input observe which of the following lights come on:

1.3.1 Red light only, indicating a high rate charge (low charge on battery)

1.3.2 Red and Green light indicating an equalizing charge rate

1.3.3 Green light indicating a trickle charge rate (fully charged battery).

1.4 Depress the momentary test switch for 90 seconds simulating power failure. Verify that:

1.4.1 The amber indicating light goes off.

1.4.2 The emergency light comes on.

1.4.3 Read voltmeter under load and record the value.

1.5 Check the electrolyte level. Electrolyte level should be between the top maximum "full" line, and the lower "add" line. If not, record the level and adjust the electrolyte level.

1.6 Test Reference:

1.6.1 This equipment shall be tested to either the requirements specified in the contract for seismic testing of the:

1.6.1.1 4 kV switchgear

1.6.1.2 or the safeguards relay board

1.7 Mount the Battery Pack Emergency D.C. Light by its seismic type mounting including the securement type mounting shelf to the seismic table fixture simulating wall mounting of the unit. Mounting to approved by P.G.& E. before testing.

1.7.1 Connect 120 VAC power to the unit with external to the table means for deenergizing.

1.8 Perform seismic testing as specified in paragraph 1.6.1 or

1.8.1 Perform 5 OBE's and 1 SSE in the North-South direction to envelope the RRS as developed for 119' El. Area A, Turbine Bldg. for Hosgri 7.5M.

1.8.2 Perform 5 OBE's and 1 SSE in the East-West direction to envelope the PSS as developed for 119' El. Area A, Turbine Bldg. for Hosgri 7.5M.

1.9 During one OBE and one SSE in each direction perform the following:

1.9.1 Deenergize the 120 VAC power input.

1.9.1.1 Observe and record the initation of the sealed beam lights.

1.9.1.2 Observe the seal beamed lights for continuous output.

1.9.1.3 Observe and record if the amber lights goes off.

1.9.1.4 Take voltmeter readings if possible.

1.9.2 Reenergize the 120 VAC power to the Unit.

1.9.2.1 Observe and record the turn-off of the sealed beam units.

1.9.2.2 Note and record if the amber, red, red and green, or green lights come on.

1.9.3 Record any of the following during the test.

1.9.3.1 Leakage of electrolyte

1.9.3.2 Excessive deformation of Unit of its parts.

1.9.3.3 Recommendations for additional structural supports.

1.10 During the remaining four OBE's

1.10.1 Have the Unit energized by 120 VAC for 2 OBE test.

1.10.2 Have the Unit deenergized with the Seal Beam Units on for 2 OBE tests.

1.11 After the seismic test and upon removal of the Unit from the shake table deenergized the 120 VAC and run 8 hour emergency light duration test.

1.12 After the 8 hour emergency light duration test reenergized the 120 VAC and recharge the Unit up with the 12 hour recharge cycle.

1.12.1 Observe and record times when the indicating light are red, red and green, and green only.

1.13 The following conditions must be satisifed for the Unit to be qualified.

1.13.1 The Unit shall exhibit no observable damage, structural or otherwise.

1.13.2 There shall be no electrolyte leakage indicated by external moisture or change in level.

1.13. Upon deenergization of the 120 VAC the unit shall meet the requirements of paragraphs 1.9.1.1, 1.9.1.2, 1.9.1.3

1.13. Upon reenergization of the 120 VAC to the unit the Sealed Beam units shall go off, the amber light shall come on, and the red, red and green, or green light shall come on indicating that the charger is operating.

1.13. Unit shall meet the requirements of paragraphs 1.11 and 1.12.

TEST RUN
DATA SHEET

RUN NO.	OBE or SSE	AXIS	SEALED BEAM LIGHTS	AMBER	RED	GREEN	VDC
5	OBE	F.B.-V	OFF	125 VAC-ON	OFF	OFF	6.5
6	OBE	F.B.-V	6 VDC-ON	125 VAC-OFF	OFF	OFF	6.5
7	OBE	F.B.-V	6 VDC-ON	125 VAC-OFF	OFF	OFF	6
8	OBE	F.B.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
9	SSE	F.B.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
10	SSE	F.B.-V	OFF	125 VAC-ON	OFF	TRICKLE CHGE. ON	7
11	SSE	F.B.-V	OFF TO 6 VDC ON	OFF	OFF	OFF	6
12	SSE	F.B.-V	6 VDC ON TO OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
13	SSE	F.B.-V	OFF TO 6 VDC ON	OFF	OFF	OFF	7
14	SSE	F.B.-V	6 VDC ON-OFF - 6 VDC ON-OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
15	SSE	F.B.-V	6 VDC ON-OFF - 6 VDC ON-OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
16		S.S.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	8
17	OBE	S.S.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
18	OBE	S.S.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
19	OBE	S.S.-V	OFF-6 VDC ON	OFF	OFF	OFF	6
20	OBE	S.S.-V	OFF-6 VDC ON	125 VAC ON-OFF	HIGH CHGE. ON-OFF	OFF	6
21	OBE	S.S.-V	6 VDC ON	OFF	OFF	OFF	6
22	OBE	S.S.-V	6 VDC ON-OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
23	SSE	S.S.-V	OFF	125 VAC ON	HIGH CHGE. ON	OFF	7
24	SSE	S.S.V	OFF	125 VAC ON	HIGH CHGE. ON	OFF	7.5
25	SSE	S.S.V	OFF-6 VDC ON	125 VAC ON-OFF	HIGH CHGE. ON-OFF	OFF	7
26	SSE	S.S.-V	6 VDC ON-OFF	125 VAC OFF-ON	HIGH CHGE. OFF-ON	OFF	7
27	SSE	S.S.-V	6 VDC ON	OFF	OFF	OFF	7

10.3.23.1 - Name of Equipment

Ventilation Control Logic

10.3.23.2 - Description of Equipment

The Ventilation Control Logic consists of a rigid steel cabinet housing 2 hinged card racks each containing approximately 80 printed circuit cards. The system utilizes solid state components to perform logic functions and operate output relays and solenoid valves. There is also a power supply with multiple outputs for each rack.

The logic system receives input information in the form of contact closures from air flow switches and limit switches and actuates from motor controllers and solenoid valves which control air to position air flow dampers.

During normal plant operation some fans are running and a normal air flow path is established. If ESF equipment should be called upon to operate, the logic system will adjust the air flow as necessary to provide adequate ventilation.

10.3.23.3 - Safety Function

The ventilation control logic must control ventilation fans and dampers to maintain acceptable ventilation to Engineered Safety Feature equipment and to direct air flow through charcoal filters on demand in order to reduce plant emissions.

Momentary delays in signaled changes in the logic output during seismic testing are acceptable, however the equipment must not be damaged by the seismic event, and must assume the proper operating mode following the seismic event.

10.3.23.4 - Test Plan and Criteria

The following test criteria have been established to demonstrate that the ventilation control logic will perform its safety function during and after a seismic event:

1. The logic shall not be damaged by the seismic testing and shall be capable of normal operation following the seismic testing.

2. The logic shall be tested energized with inputs simulated and outputs monitored. The outputs shall not inadvertently change state as a result of the seismic testing.

3. Multi-axis, multi-frequency seismic tests shall be conducted per the RRS contained in Wyle Report No. 58255, pp. 182-197.

10.3.23.5 - Test Procedure and Set-Up

1. Mount the hinged panel housing the printed circuit cards, and the power supply rigidly in a manner equivalent to plant mounting. See Wyle Report No. 58255, for details of equipment mounting for test.

2. Apply 120 Volts AC to the power supply.

3. Apply 125 Volt DC to typical input converters and monitor output signals on a strip chart recorder.

4. Conduct five OBE tests and two SSE tests.

5. Rotate the equipment 90 degrees, and repeat test with five OBE's and two SSE's.

6. Test the equipment completely after the completion of seismic testing to verify normal functional capability.

10.3.23.6 - Test Results

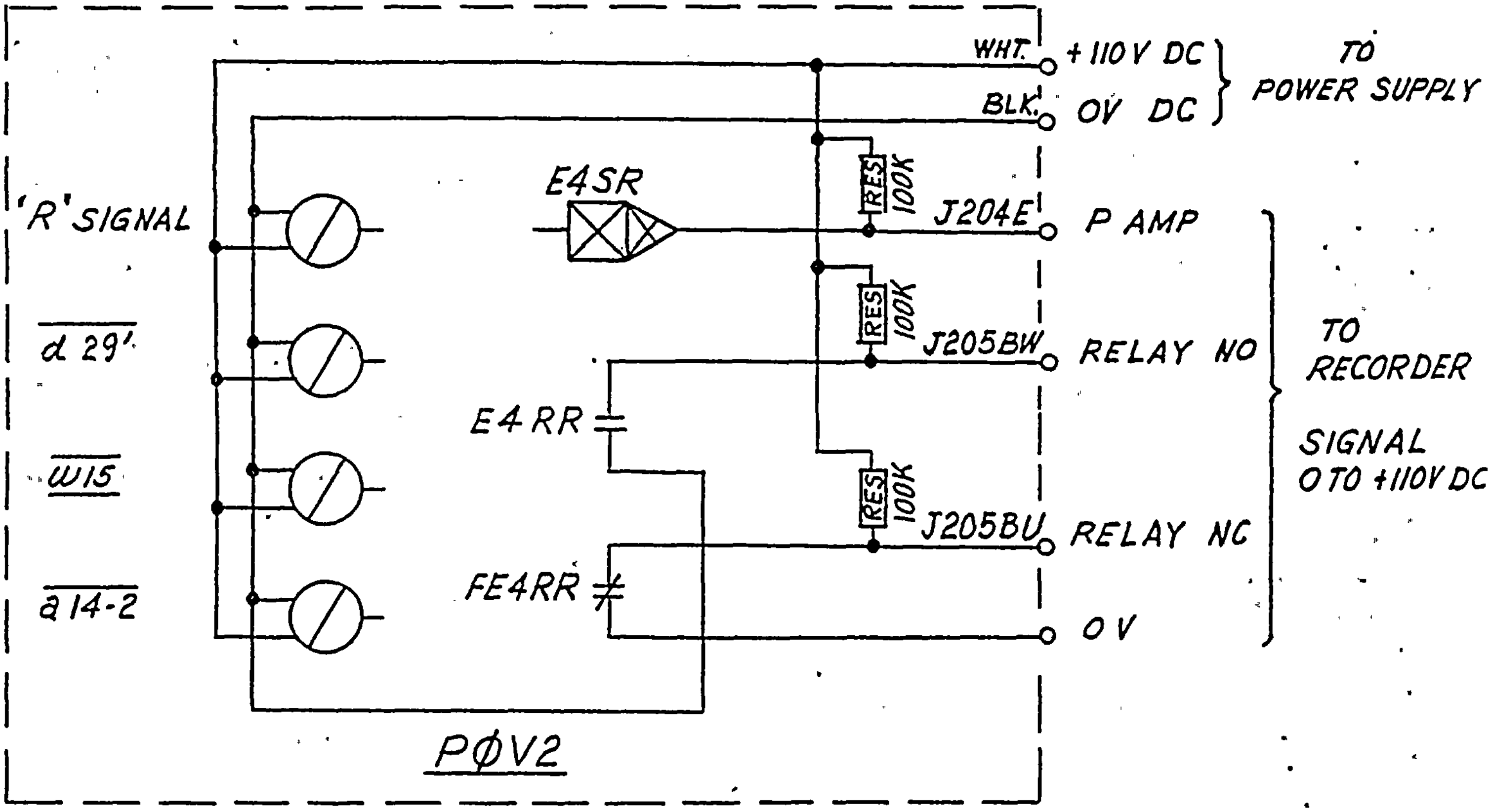
The ventilation control logic was undamaged by the seismic testing, as verified by functional testing after completion of the seismic shaking. The typical outputs monitored maintained the proper relationship to the logic input during and after the tests.

10.3.23.7 - Conclusions

The Ventilation Control Logic cabinet from Diablo Canyon Unit 2 was tested by a multi-axis, multi-frequency seismic simulation described in Wyle Report No. 58255, pp. 182-197. This Ventilation Control Logic Cabinet is identical to that installed in Diablo Canyon Unit 1.

The test results in section 10.3.23.6 demonstrate that the test criteria specified in section 10.3.23.4 are met and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 Ventilation Control Logic Cabinets are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and NRC RG 1.100.



WIRING LIST

INPUTS:

SIGNAL	CARD	+	−
"R" SIGNAL	D 12 6	J202 CC	J200 L
$\overline{a}$ 14-2	D 13 4	J202 CJ	J200 P
$\overline{d}$ 29'	D 13 10	J202 CM	J200 P
$\overline{w}$ 15	C 7 4	J201 CB	J200 U

OUTPUTS:

E4SR	A 2 3	J204 E	J204 BF
FE4RR	A 8 3	J205 BU	J205 BV
E4RR	A 11 6	J205 BW	J205 BX

SEISMIC TEST MONITORING

VENTILATION CONTROL LOGIC

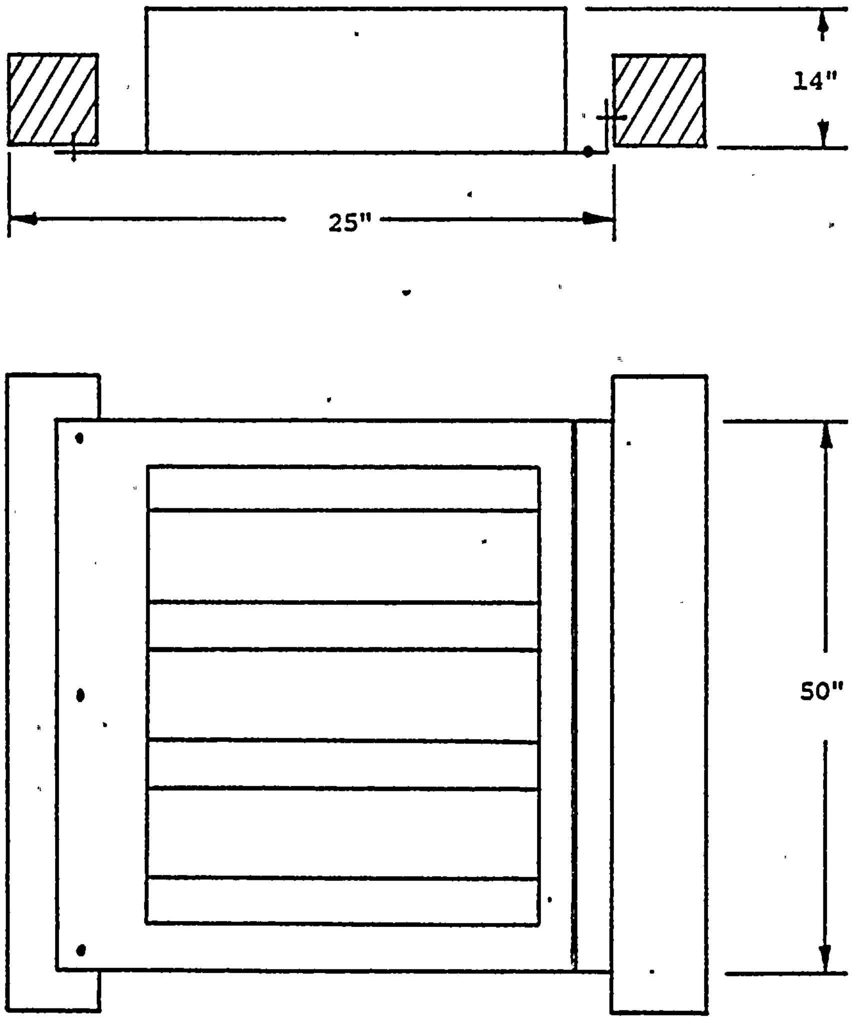
DIABLO CANYON UNITS 1 & 2.

9/18/78

ATTACHMENT

VENTILATION SYSTEM P. C. BOARD AND
POWER SUPPLY
GROUP III

B



Test fixture welded to test machine and test specimens bolted to fixture.

B

Ventilation Control Relay Panel

Description

The Ventilation Control Relay Panel consists of rigid steel electrical enclosure containing relays which provide interface between the Ventilation Control Logic described in Section 10.3.2.3 and the 480 Volt Vital Load Center described in Section 10.3.2.5. The panel is located in the Auxiliary Building on elevation 128'. Analysis and in-situ testing has determined that the cabinet is rigid.

Safety Function

Relays with a safety function are activiated by the Ventilation Control Logic system and in turn provide 'start' signals for ventilation fans. The fans are not required to started or operated during the short period of the seismic event. Therefore, if the equipment is capable of responding properly and starting the required fans after the seismic event it will have met its safety function. Other relays in this cabinet have no safety function to perform. They provide undervoltage alarms only and momentary misoperation has not effect on safety.

Test Criteria and Plan

The purpose of the seismic that is to verify that the equipment is capable of performing its safety function during and after a seismic event.

The plan was to test a relay cabinet subpanel containing representative relays of the type used for control of the ventilation system. Relay contacts were to be monitored for contact chatter in both the energized and deenergized state.

Five Operating Base Earthquakes (OBE) and two Safe Shutdown Earthquakes (SSE) were to be applied to the equipment in each axis. Required Response Spectra (RRS) developed for the plant location where the relay cabinet is mounted were used. Random bi-axial motion was to be applied to the equipment supports.

All testing was to be conducted in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100.

Test Procedure and Set-Up

A relay cabinet subpanel was removed from the plant and mounted to the shake table in the same manner as it is mounted in the field.

Fan control relays E1SR and S1SR are typical for safety related relays and were monitored for contact chatter. Each relay had one normally open (N.O.) and one normally closed (N.C.) contact connected to the chatter detector set at 2 milliseconds. Undervoltage relay 27-11UV also had one N.O. and one N.C. contact monitored for chattered.

The Test Response Spectrum (TRS) was developed which enveloped the RRS (see Wyle Report 58255, pages 150-156 and 162-168). Fine OBE and three SSE test runs were then conducted. During two OBEs and one SSE the relays were energized. The subpanel was then rotated 90 degrees and the test runs repeated.

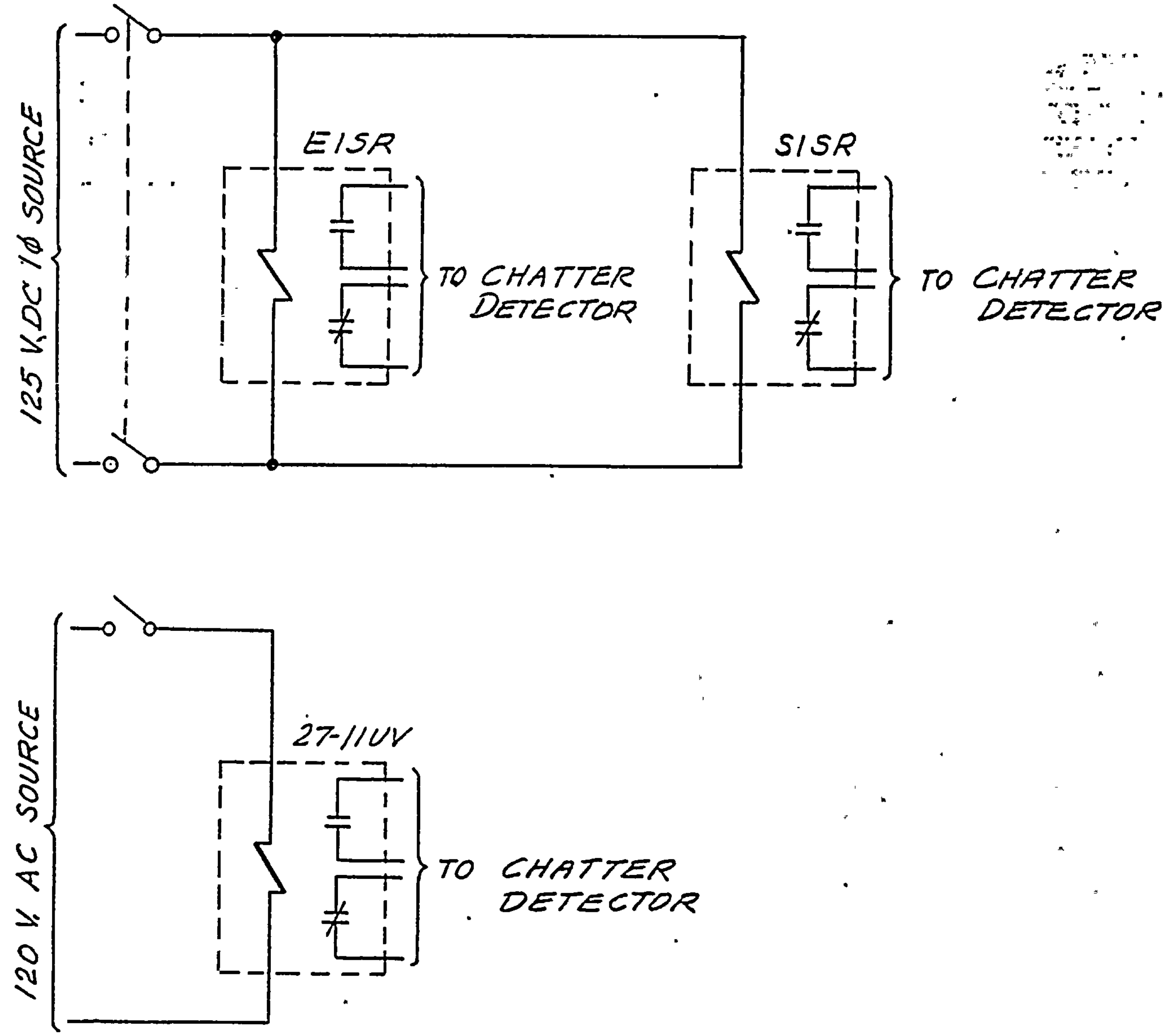
All relays were tested for satisfactory operation after the testing was completed.

Test Results

No physical damage was observed or detected and no relay contact chatter was detected in either the energized or deenergized state.

Conclusions

As a result of the above described testing which demonstrated satisfactory operation of the relay subpanel and the relays it can be concluded that the Ventilation Control Relay Cabinet is qualified to perform its safety function during and after a Hosgri fault seismic event.

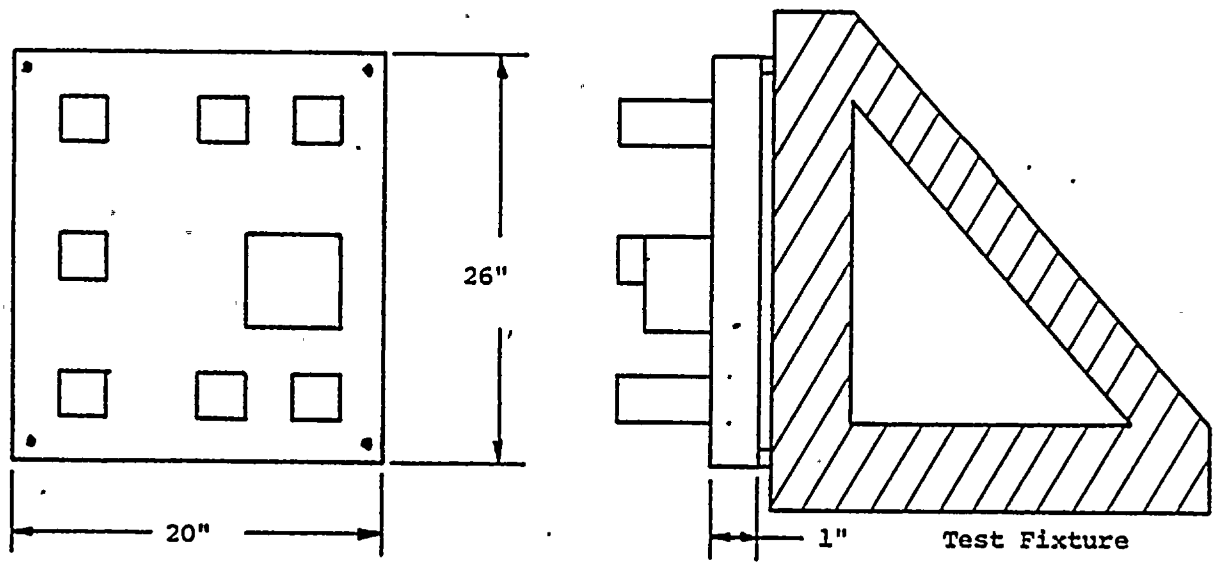


TEST SETUP
VENTILATION CONTROL RELAY PANEL

ATTACHMENT

VENTILATION SYSTEM RELAY SUB-PANEL
GROUP III

B



Four mounting bolts

Fixture support at mounting bolts only.

10.3.1.1 Main Annunciator Components Tested

The following Main Annunciator Components were tested on a biaxial seismic test table.

1.	Constant Voltage Transformer	- Sola #20-22-159 480 VAC/120 VAC
2.	Power Transfer Panel	- RIS-RA-189 117 VAC/125 VDC in 117 VAC OUT.
3.	50 R02-SCO-K1	- Sigma Relay, 115 VAC 115 VAC inputs pick-up the relay.
4.	50 R02-SCO-K2	- Sigma Relay, 115 VAC 115 VAC inputs pick-up the relay.
5.	Power Transformer	- Signal Transformer Co. #120-20 120 VAC input 120 VAC output.
6.	Logic Power Supply	- RIS RA-875A 117 VAC in.
7.	Aux. Logic Power Supply	- RIS RA-897A 117 VAC in.
8.	DC to DC Converter	- RIS-UNK AN 159 125 VDC input +12, -28, +125 VDC output.
9.	DC to AC Inverter	- Lorain WBA 102 H1 125 VDC in, 117 VAC out.
10.	Typewriter	- IBM 735 Selectric Ser. #926026740.
11.	Printed Circuit Bd	- RIS 139B-Reflasher Module.
12.	Printed Circuit Bd	- RIS RA847-Input Module 10 N.O. contacts.

13.	Printed Circuit Bd	- RIS RA848A-Input Module 10 N.C. contacts.
14.	Printed Circuit Bd	- RIS RA849-Input Buffer Module.
15.	Printed Circuit Bd	- RIS RA851-Status Memory Module.
16.	Printed Circuit Bd	- RIS RA852-Sequential Memory Module.
17.	Printed Circuit Bd	- RIS RA853-Oscillator and Interface Module.
18.	Printed Circuit Board Card Tray Rack	- RIS 1009-273.
19.	62R2-24 VDC	- Sigma Relay-24 VDC To Monitor Annun. Power.
20.	62R2-110 VDC	- Sigma Relay 110 VDC' To Monitor Annun. Power.

The above components were judged to be the most limiting components in the Main Annunciator from a seismic standpoint based on in-situ inspection and testing at the site.

The solid state RIS RA-800L system was added to this annunciator in event of drum failure. Alarm No's are available on loss of Drum and English Print-Out.

The Main Annunciator is located at elevation 128'0", area H, of the Auxiliary Bldg.

10.3.1.3 - Safety Function

The Main Annunciator functions to provide alarms to the plant operator on plant conditions. While the Main Annunciator has no direct safety function, it has been designed and qualified as Seismic Class I equipment to minimize the potential for confusion of the plant operators during and after a seismic event. The information necessary for the operator to diagnose plant conditions and take any manual action required is provided via position lights, status lights, monitor lights and gages displaying the key plant process variables; thus the Main Annunciator is not required even for operator information.

Nevertheless it is desirable to have accurate alarm information conveyed to the operator via the Main Annunciator during a seismic event, and to have the Main Annunciator functioning normally after a seismic event, such that any spurious alarms generated during the seismic event can be easily cleared and the remaining alarms and their sensors evaluated.

10.3.1.3 Test Criteria and Plan

The test criteria and plan for the individual components tested are as follows:

1. The Constant Voltage Transformer mounting shall be tested during the seismic shaking.
2. The Power Transfer Panel shall be operated in both the By-pass mode with 117 VAC in and 117 VAC out, and also in the Auto Position for input power (117 VAC in shall be removed, the 125 VDC inverter shall automatically supply 117 VAC out). The unit shall be

switched to auto position during the 4th and 5th OBE and the 1st SEE. The unit shall be demonstrated to perform the above functionally during and after the seismic test.

3. The Sigma Relay, 50 RO2-SCO-K1 shall be cycled before, during energized test, and after seismic testing. The relay contacts shall be monitored for contact chatter.

4. The Sigma Relay, 50 RO2-SCO-K2 shall be tested the same as item 3 above.

5. The Power Transformer shall be energized during the seismic testing. The output shall be monitored before and after the seismic test. Any change in output shall be recorded.

6. The Logic Power Supply, RIS RA-875A shall have 117 VAC input. The input power shall be turned on and off twice during the deenergized tests (1st, 2nd, 3rd OBE, and the 2nd SSE) and the output voltages observed. During energized tests with 117 VAC input (4th, 5th OBE, and 1st SSE) the output voltage shall be monitored.

7. The Auxiliary Logic Power Supply, RIS-RA 897A shall be tested the same way as item 6.

8. The DC to DC Converter RIS-UNK AN 159 shall have 125 VDC input and its outputs shall be +12, -28, and +125 VDC. During 1st, 2nd, 3rd OBE and 2nd SSE unit to be deenergized. During the 4th and 5th OBE, and 1st SSE unit to be energized, and the -28 VDC outputs monitored for voltage. Before and after seismic tests the Unit shall be functionally tested.

9. DC-AC Inverter, Lorain WBA 102 H1 shall be mounted as in the actual equipment. 125 VDC in shall be applied and the output monitored for continuous 122 VAC output. The unit functions continuously, and shall be energized continuously before, during, and after the seismic testing.

10. Typewriter - IBM 735 Selectric shall be mounted on the seismic table to simulate on site mounting. Four mounting screws shall be used to attach the typewriter to its mounting platform. The mounting platform shall be rigidly attach to roll out side rails. The side rails shall be rigidly locked and attached to the structural steel mounting rails on the seismic table to simulate the cabinet mounting at the site.

    An IBM, On Line Selectric Analyzer, OLSA, shall operate the typewriter before the tests. During the seismic shake on the table the typewriter shall be powered. Between shakes the typewriter shall be actuated manually by its keys. After the shake the typewriter shall again be operated by the IBM, OLSA.

11. Printed Circuit Board, RIS 139B-Reflasher Module shall be inserted in the Printed Circuit Board Card Tray Rack, RIS 1009-273. Common voltage inputs shall be supplied by the logic power supply and the board shall be energized during energized test run. The printed circuit boards shall be returned to Diablo Canyon and tested and operated as before being shipped to Wyle Laboratories.

12. Printed Circuit Board, RIS RA 847 Input Module for 10 remote N.O. circuits shall be tested the same as item 11.

13. Printed Circuit Board, RIS-RA84A, Input Module with 10 N.C. contacts shall be tested the same as item 11.

14. Printed Circuit Board, RIS-RA849, Input Buffer Module shall be tested the same as item 11.
15. Printed Circuit Board, RIS-RA851 Status Memory Module shall be tested the same as item 11.
16. Printed Circuit Board, RIS-RA852 Sequential Memory Module shall be tested the same as item 11.
17. Printed Circuit Board, RIS-RA853 Oscillator and Interface Module shall be tested the same as item 11.
18. Printed Circuit Board Card Tray Rack RIS-1009-273 shall be mounted the same as in the Main Annunciator on the shake table. The Printed circuit boards listed on items 11 thru 18 shall be inserted in the card tray during the seismic tests and energized as stated above.
19. Sigma relay 62R2-24 VDC shall be monitored for contact chatter, unenergized during 1st, 2nd, 3rd OBE and 2nd SSE, and energized during the 4th and 5th OBE and the 1st SSE.
20. Sigma relay 62R2 110 VDC shall be tested the same as Item 19.

Test Procedure and Set-Up

1. Mount the Annunciator tested components in the same configuration and orientation as in the Diablo Canyon plant, (See Wyle Report No. 58255, April 19, 1978, Test Procedure No. 3642, dated November 30, 1977, pp. 29-37.)
2. Supply the required inputs and monitor the outputs or contact chatter as required per the test criteria.

(

Component	Input	Output or Chatter
Constant Voltage Transformer	480 VAC in	120 VAC out
Power Transfer Panel	117 VAC/	117 VAC out
	125 VDC in	117 VAC out
50 R02-SCO-K1	115 VAC in	Contact Chatter
50 R02-SCO-K2	115 VAC in	Contact Chatter
Power Transformer	120 VAC in	120 VAC out
Logic Power Supply	117 VAC in	Monitor on Direct Rendant Recorder
Aux Logic Power Supply	117 VAC in	
DC to DC Converter	125 VDC in	-28 VDC out
DC to DC Inverter	125 VDC in	117 VAC out
Typewriter	125 VAC in	Manual typing
Printed Circuit Bds		
RIS 139B	24 VDC in	Various
RA 847	24 VDC in	outputs
RA 848A	24 VDC in	tested on
RA 849	24 VDC in	return to
RA 851	24 VDC in	plant
RA 852	24 VDC in	
RA 853	24 VDC in	
62 R2-24 VDC	24 VDC in	Contact Chatter
62 R2-110 VDC	110 VDC in	Contact Chatter

3. Visually monitor the input and output on meters or record on direct readout recorder.

6. Results of Tests

The tested components on the Annunciator were run through the series of OBE's and SSE's and the results are as follows:

1. The mounting of the Constant Voltage transformer was adequate for the seismic tests.
2. The Power Transfer Panel operated as required in the By-Pass and Automatic modes during and after the seismic testing.
3. The Sigma Relay 50R02-SCO-K1 did not chatter when cycled during and after the seismic testing.
4. The Sigma Relay 50R02-SCO-K2 did not chatter when cycled during and after the seismic testing.
5. The Power Transformer did not have a loss of output during or after the seismic testing.
6. The Logic Power Supply, RIS-RA 875A did not show any loss of output on the direct readout recorder.
7. The Auxiliary Logic Power Supply, RIS RA-897A did not show any loss of output in the direct readout recorder.
8. The DC to DC converter, RIS-UNK AN159 had a continuous -28 VDC output during and after the seismic test.
9. The DC-AC Inverter, Lorain WBA 1021-1 had a malfunction on the 1st series of test. After repair at suppliers facility and at Wyle Laboratories the Inverter operated continuously at 122 VAC out during and after the seismic tests.
10. The typewriter - IBM 735 Selectric operated manually between seismic tests and after the testing by the On Line Selectric Analyzer.

11.-17. The Printed Circuit Boards item 11 through 17 were not damaged during the seismic tests when energized with common voltage inputs from the logic power supply.

18. The Printed Circuit card tray rack, RIS-1009-273 with all the above card inserted retained the cards without damage during the seismic tests.

19. The Sigma relay 62R2-24 VDC contacts did not chatter during the seismic testing.

20. The Sigma relay 62R2-110 VDC did not chatter during the seismic testing.

The above components performed their functional requirements before, during, and after the seismic testing.

7. Conclusions

1. The Main Annunciator components were tested by a multi-axis multi-frequency seismic simulation described in Wyle Report Number 58255, April 19, 1978, pp. 143-213. The test results described in section 6 above demonstrate that the test criteria of section 4 are met, and thus the tested components operability has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. On this basis the Diablo Canyon Unit 1 and 2 Main Annunciators tested components are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Std. 344-1975 and USNRC Regulatory Guide 1.100. The Main Annunciator rigid cabinet qualification for the postulated 7.5M Hosgri event in accordance with IEEE Std. 344-1975 and USNRC Regulatory Guide 1.100 is documented in paragraph 10.3.1 Main Annunciator, page 10-10a - 10-10b of Volume III of the Seismic Evaluation of the 7.5M Hosgri Earthquake.

2. All the equipment listed under items 1 through 20 above have been returned to Diablo Canyon and retested at the site. No malfunction was detected in the equipment. Equipment has been placed back in service on the Unit 2, Main Annunciator or placed in spare stores.

3. The DC-AC Inverter, Lorain WBA 102H1 (3) identical units, 2 in Unit 1 Main Annunciator, and the second one in Unit 2, Main Annunciator have been checked for proper mounting of the SCR mounting panel and proper clamping by the mounting screws.

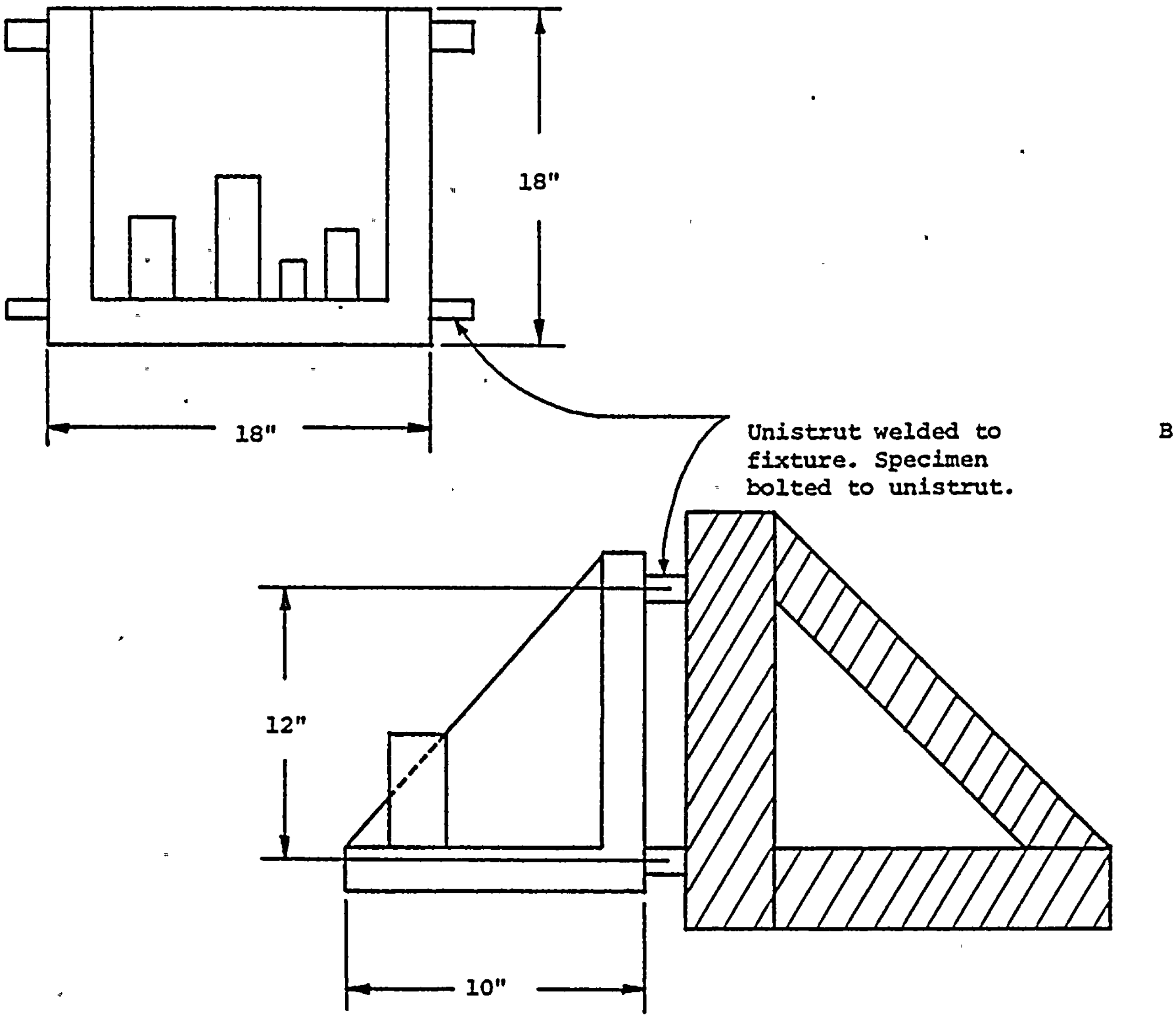
4. The typewriter mounting at the plant has been modified to match the mounting on the seismic test table.

5. The printed circuits boards have been retested at Diablo Canyon. No malfunction was detected. The boards have been returned to service in spare stores.

6. The Printed Circuit card tray rack has been returned to service on Unit 2, Diablo Canyon.

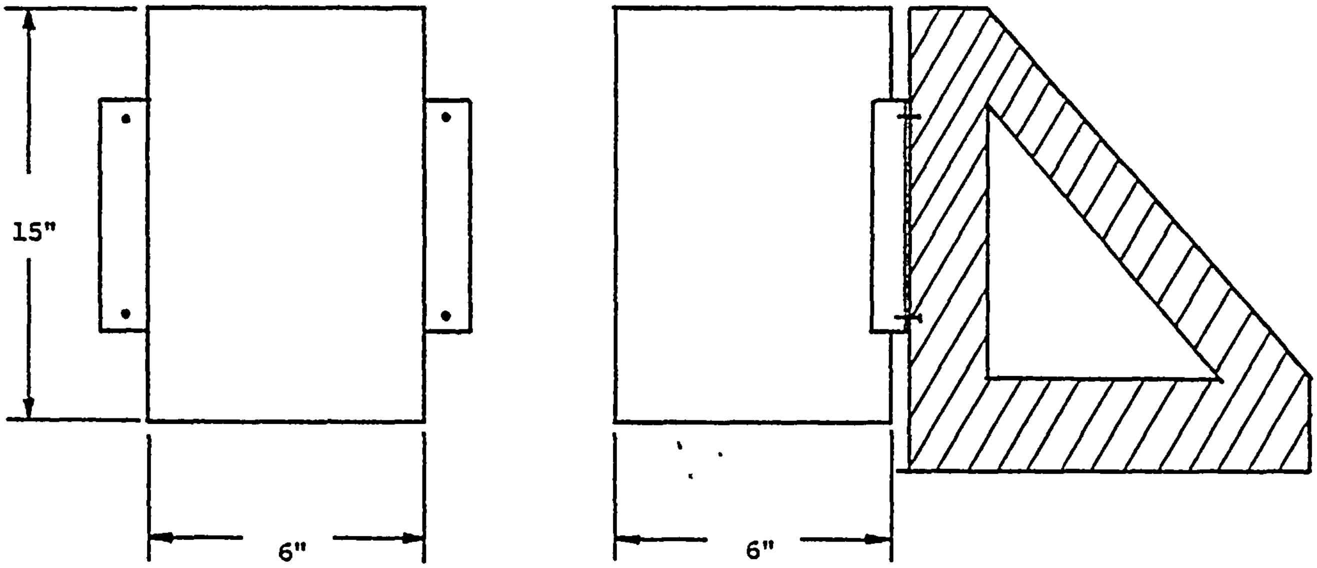
POWER SUPPLY
GROUP III

B

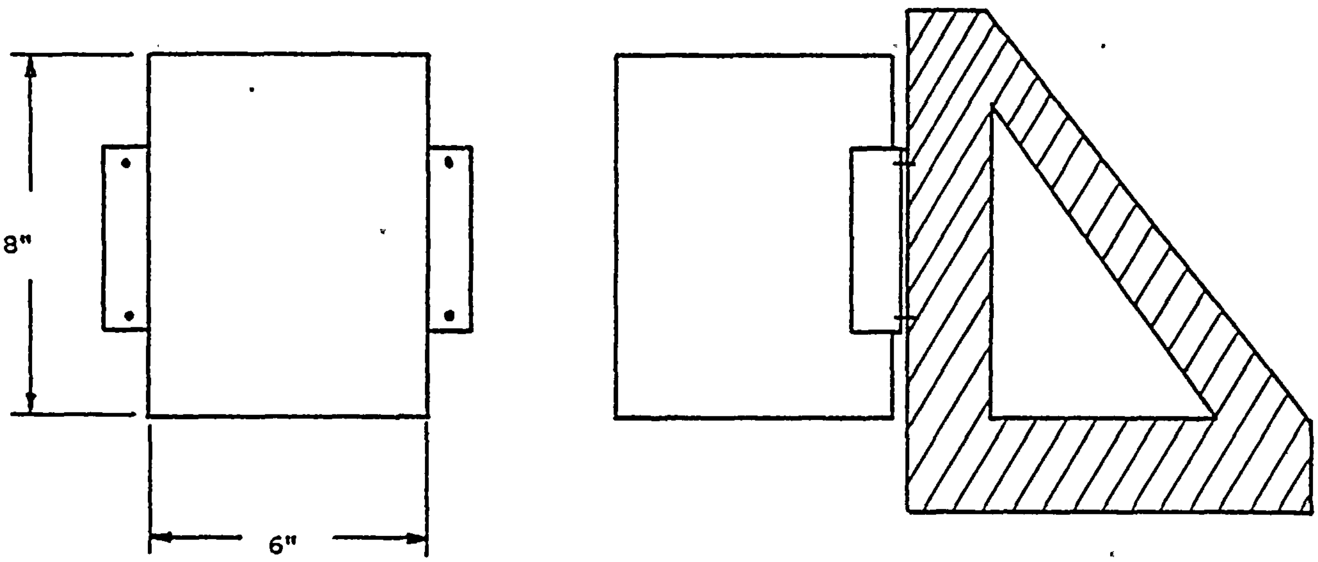


MAIN ANNUNCIATOR
TWO TRANSFORMERS
GROUP III

B



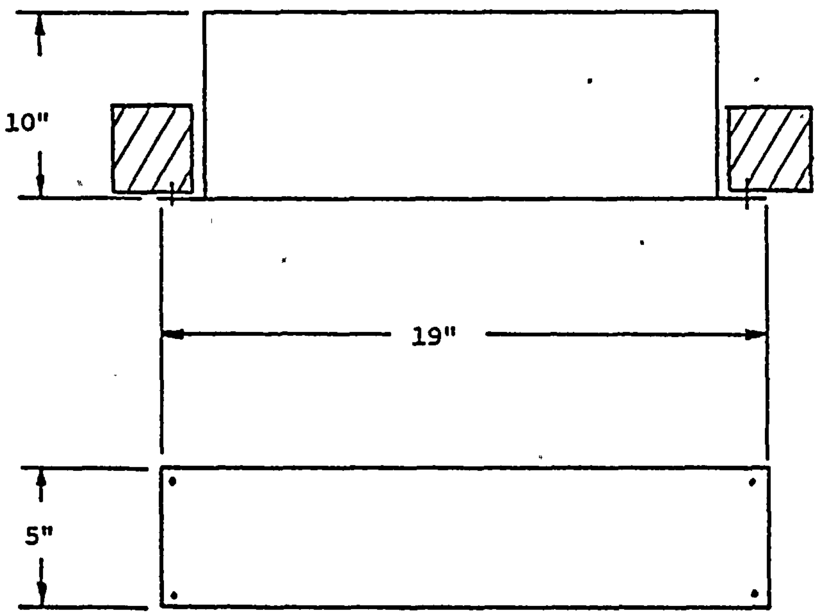
Four 5/16" bolts



Four 1/4" bolts

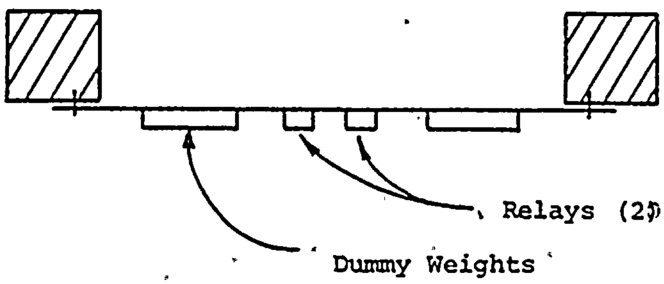
MAIN ANNUNCIATOR
POWER TRANSFER UNIT
GROUP III

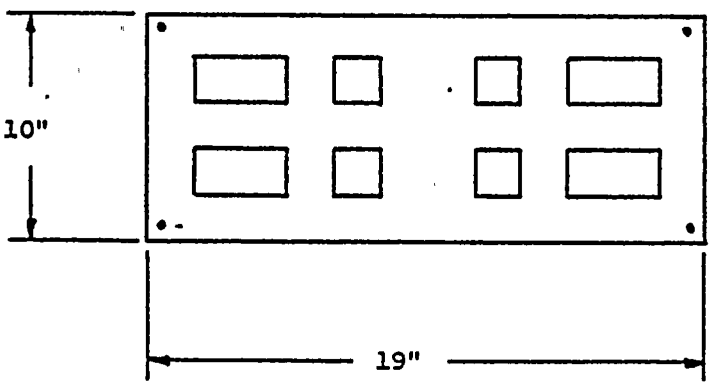
B



Test specimen bolted to fixture B

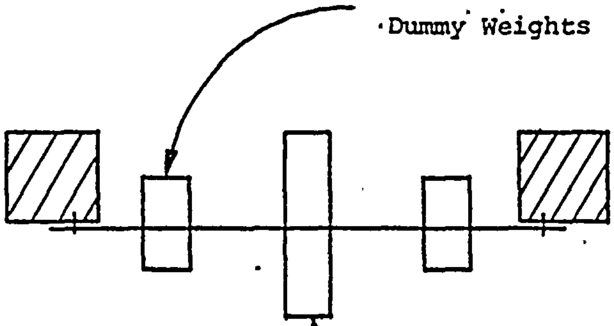
GROUP III
MAIN ANNUNCIATOR
SIGMA RELAYS AND SOCKETS B

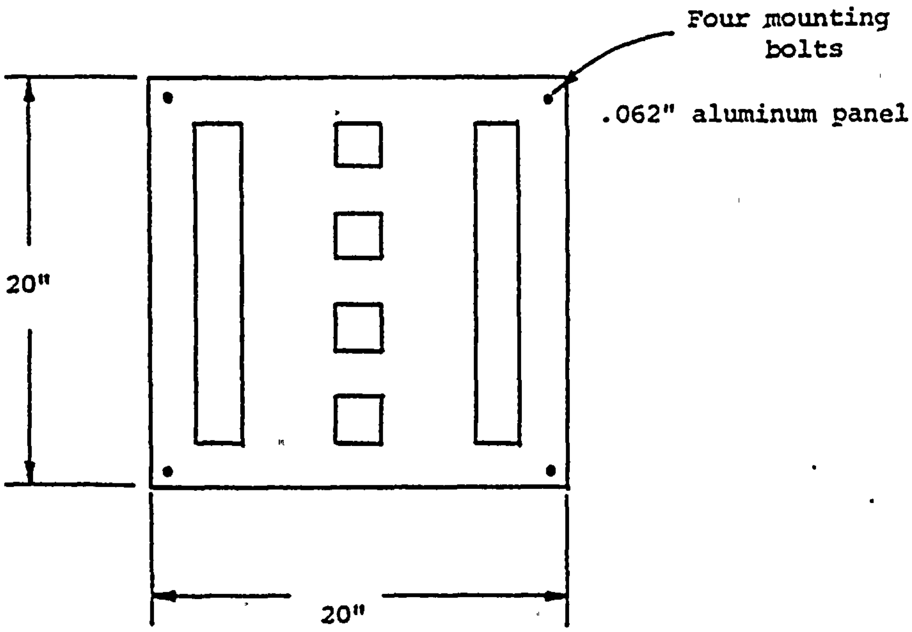




Panel bolted to fixture; test specimen bolted to panel. B

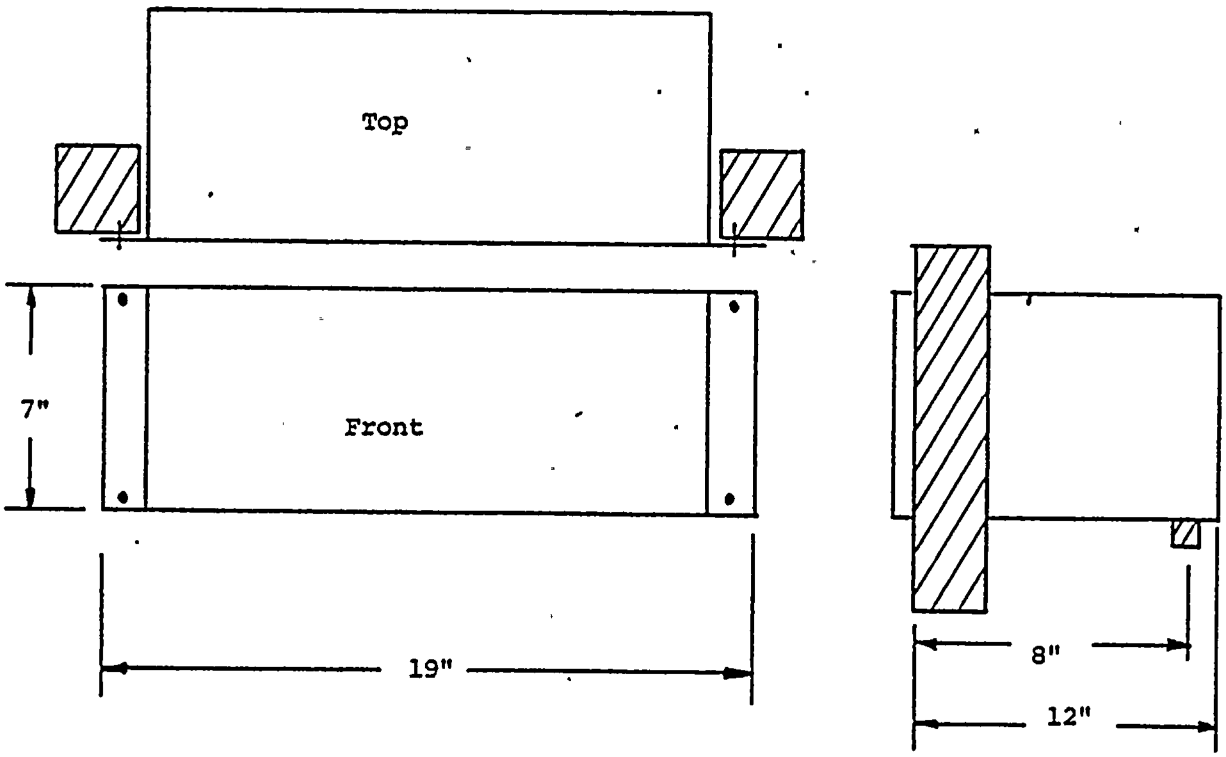
MAIN ANNUNC...
AC INPUT RELAYS AND SOCKETS
GROUP III B





Panel bolted to fixture; test specimens bolted to panel. B

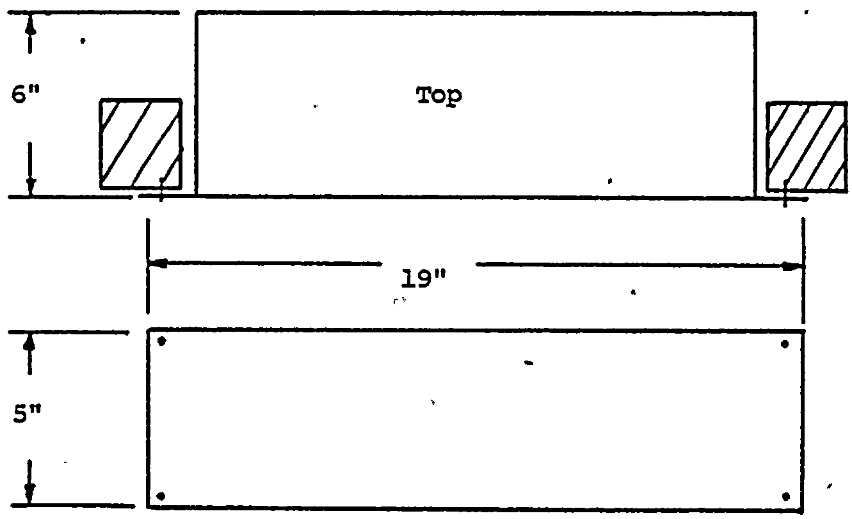
MAIN ANNUNCIATOR
LOGIC POWER SUPPLY
GROUP III B



Test specimen bolted to fixture B

MAIN ANNUNCIATOR
AUXILIARY LOGIC POWER SUPPLY
GROUP III

B

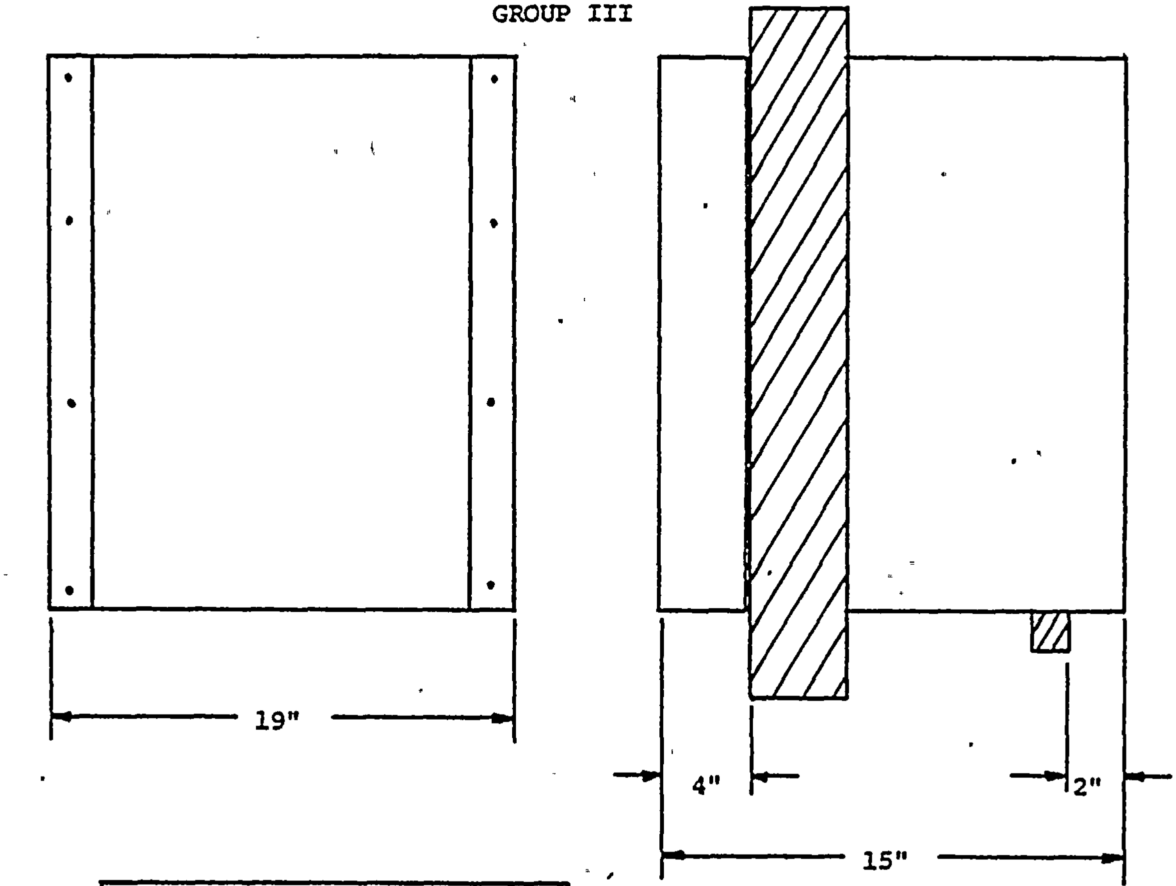


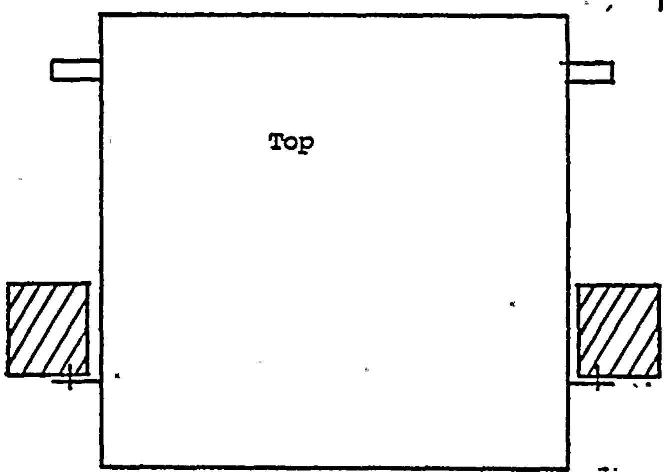
Test specimen bolted to fixture

B

MAIN ANNUNCIATOR
INVERTER
GROUP III

B





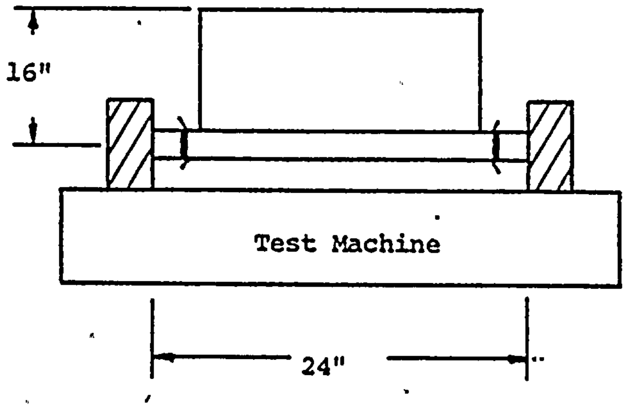
Test specimen bolted to fixture

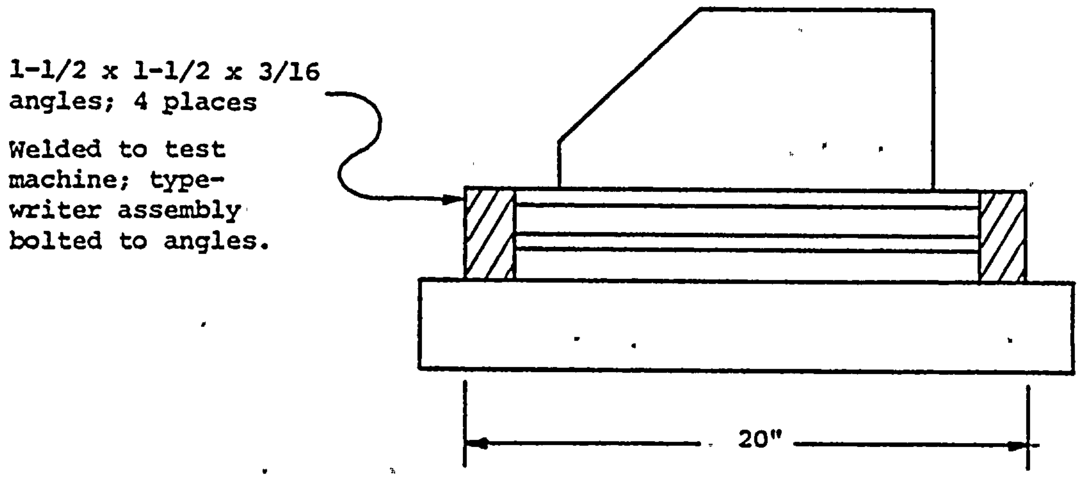
B

B

B

GROUP III
MAIN ANNUNCIATOR
TYPEWRITER ASSEMBLY



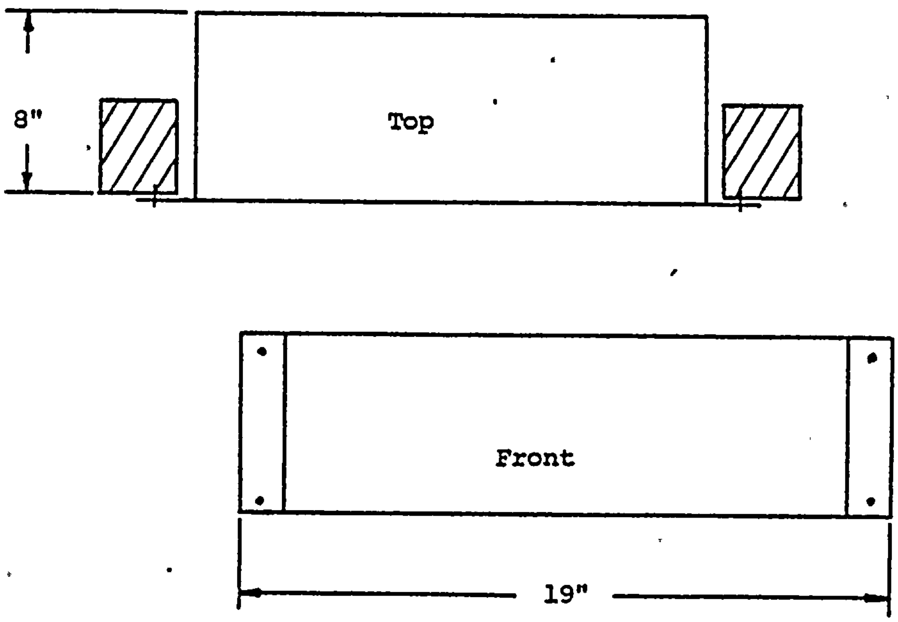


B

Fixture four corners only

PRINTED CIRCUIT BOARD RACK

GROUP III B



Test specimen bolted to fixture. B

10.3.5.2.1 - Name of Equipment

125 VDC Distribution Panelboard, (ITE DC SWITCHGEAR)

10.3.5.2.2 - Description of Equipment

This electrical switchgear consists of a three section, welded frame construction cabinet with a 125 VDC bus arrangement, 3000 ampere input fuse from the battery, and two 600 ampere molded case input breakers for primary and backup battery chargers. A 600 ampere draw-out breaker from the main bus supplies the circuit breaker panelboards. The circuit breaker panelboard consists of molded case breakers rated for 20 to 150 amperes. This equipment is located on El 115'0", area H of the Auxiliary Building.

10.3.5.2.3 - Safety Function

The 125 VDC Distribution Panelboard is required to continuously distribute 125 VDC power to plant DC loads (power, control protection, instrumentation, and monitoring) during and after a seismic event.

10.3.5.2.4 - Test Plan and Criteria

In order to assure the performance of the safety function specified in 10.3.5.2.4 above, the following specific test criteria shall be met:

1. Circuit breakers shall maintain their position during and after the seismic event; no circuit breakers are required to operate during the seismic event.

2. The following components and positions shall be monitored:

   a. Breaker 72-2100 (I.T.E. KM 2B600); monitor the following auxiliary switch contacts (see figures 10.3.5.2-1 and 10.3.5.2-2) to ensure the breaker maintains its closed position:

      (1) Terminals 17 and 18: Closed

(2) Terminals 19 and 20: Open

(3) Terminals 21 and 22: Closed

b. Breaker 72-2102 (I.T.E. K600); monitor the following auxiliary switch contacts (see figures 10.3.5.2-1 and 10.3.5.2-2) to ensure the breaker maintains its closed position.

(1) Terminals 9 and 10: Open

(2) Terminals 15 and 16: Closed

(3) Terminals 5 and 6: Open (no overcurrent alarm)

c. Undervoltage Relay 27DBG21 Westinghouse SV type 125 VDC. Monitor the following contacts to verify that bus voltage is maintained during and after the test:

Contact Terminal 2 and 3: Open

d. HE2-B070 I.T.E. Molded Case Circuit Breaker. Visually monitor the status of this breaker to verify the breaker remained closed.

e. HE2-B020 I.T.E. Molded Case Circuit Breaker. Visually monitor the status of this breaker to verify the breaker remained closed.

f. Verify that the 0-150 VDC voltmeter indicates that the bus was continuously energized during and after the tests.

g. Verify that the white indicating light stays on, indicating that the bus was continuously energized during and after the test.

10.3.5.2.5 - Test Procedure and Set-Up

1. Mount the 125 VDC Distribution Panelboard, SD-21 on the seismic test table in the same configuration as in the power plant as shown in Wyle Report No. 58255, Appendix I, Test Procedure 3642, dated November 30, 1977, pp. 41.

2. Supply 125 VDC power to the 72-2100 input breaker to bus No. 21 by the PGandE 125 VDC Battery Charger, ED-21.

3. Supply 125 VDC battery power (Wyle 125 VDC battery) to the bus on the supply side of the 3000 ampere bus fuse.

4. Connect the 70A and 20A output breakers in panel SD-21 to the PGandE resistor load bank with approximately 16 amperes at 125 VDC on the 20A breaker and 34 amperes at 125 VDC on the 70A breaker.

5. Close breakers 72-2100, 72-2102, and the 70A and 20A load breakers. Energize Battery Charger, ED-21.

6. Perform multi-axis, multi-frequency, seismic testing per the RRS in Wyle Report No. 58255 dated April 19, 1978, pp. 255-280.

7. See figures 10.3.5.2-1 and 10.3.5.2-2 for testing set-up.

10.3.5.2.6 - Test Results

The equipment was energized during all the seismic tests, 5 OBE's and 2 SSE's in the Z-Y and X-Y axis. The components listed on Table 10.3.5.2-1 were either monitored during and after the seismic tests. No malfunction of any of the components occurred during the tests. All contacts of auxiliary switches and relays remained in the equipment energized position during all tests. All breakers remained in the proper positions during the testing. Indicating meters and lights on the front of the panelboard indicated that the bus remained energized during, and after the test.

Following the seismic tests, the SD-21 Distribution Panelboard was shipped back to Diablo Canyon Unit 2, its functional performance was tested and verified, and it was placed back in service in the plant.

10.3.5.2.7 - Conclusions

A 125 VDC Distribution Panelboard (SD-21) from Diablo Canyon Unit 2 was tested by a multi-axis, multi-frequency seismic simulation described in Wyle Report No. 58255, April 19, 1978, pp. 255-280. This panelboard is identical to the other five 125 VDC Distribution Panelboards installed in Diablo Canyon Units 1 and 2. The test results described in 10.3.5.2.6 above demonstrate that the test criteria specified in section 10.3.5.2.4 are met, and thus that the equipments' safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event.

Thus it is concluded that the Diablo Canyon Unit 1 and 2 125 VDC Distribution Panelboards are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Std 344-1975 and NRC Regulatory Guide 1.100.

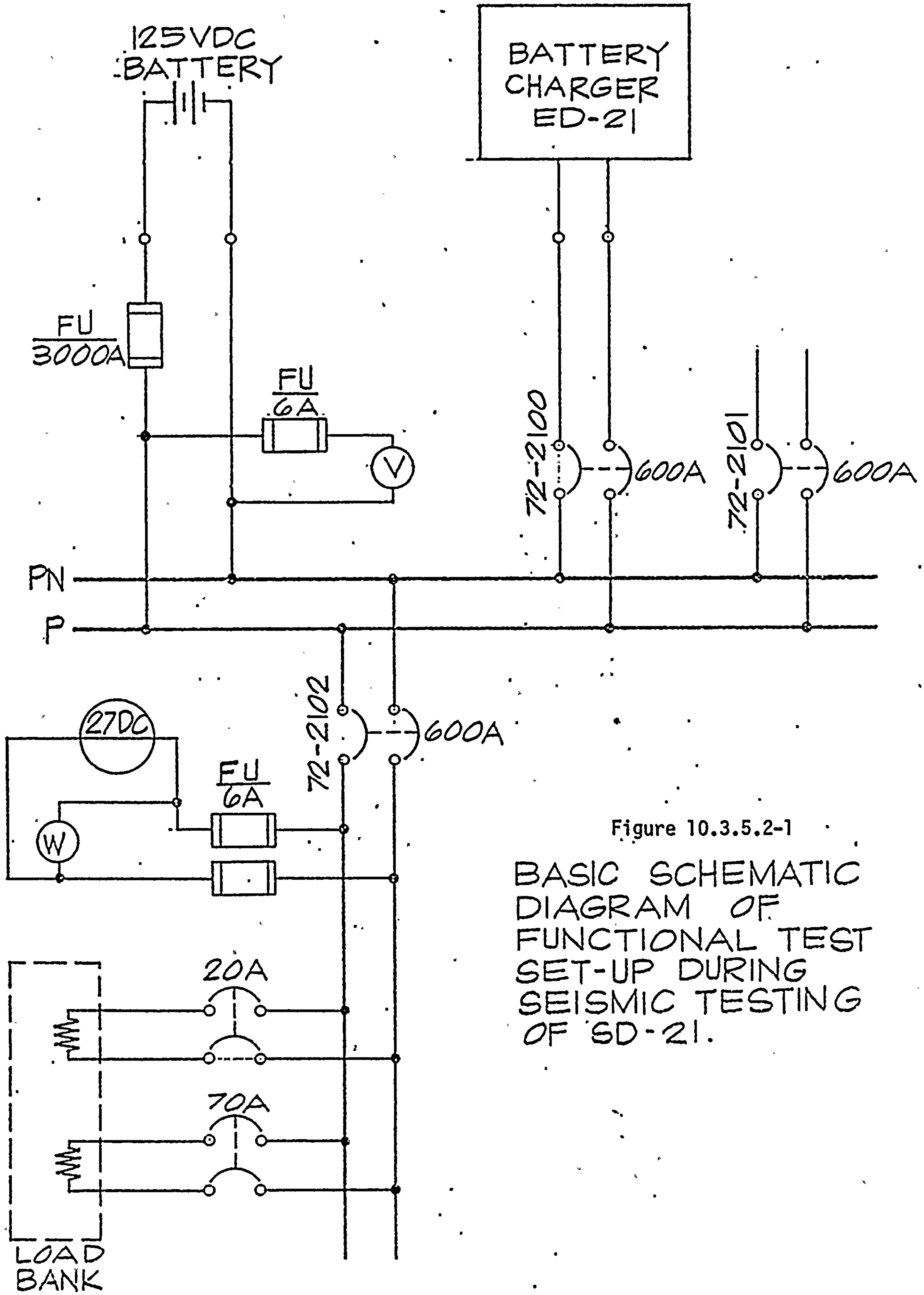


Figure 10.3.5.2-1

BASIC SCHEMATIC DIAGRAM OF FUNCTIONAL TEST SET-UP DURING SEISMIC TESTING OF SD-21.

		SWITCH, RELAY POSITION, OR CONTACT O=OPEN C=CLOSED															
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE			
DEVICE	SW. NO.	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y		
72-2100, I.T.E. KM 2B600 BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
AUX. SW. TERMINALS	17 & 18	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
AUX. SW. TERMINALS FOR ALARM	19 & 20	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
AUX. SW. TERMINALS	21 & 22	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
27DGB21 UV RELAY W SV	2 & 3	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
72-2102 I.T.E. K600 BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
AUX. SW. OVERCURRENT ALM. TERMINALS	5 & 6	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
AUX. SW. TERMINALS	9 & 10	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
AUX. SW. TERMINALS	15 & 16	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
HE 2B070 I.T.E. CIRCUIT BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
HE 2B020 I.T.E. CIRCUIT BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
VOLTMETER 0-150 VDC	VDC	125	125	125	125	125	125	125	125	125	125	125	125	125	125		
125 VDC BUS INDICATING LT.	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON		

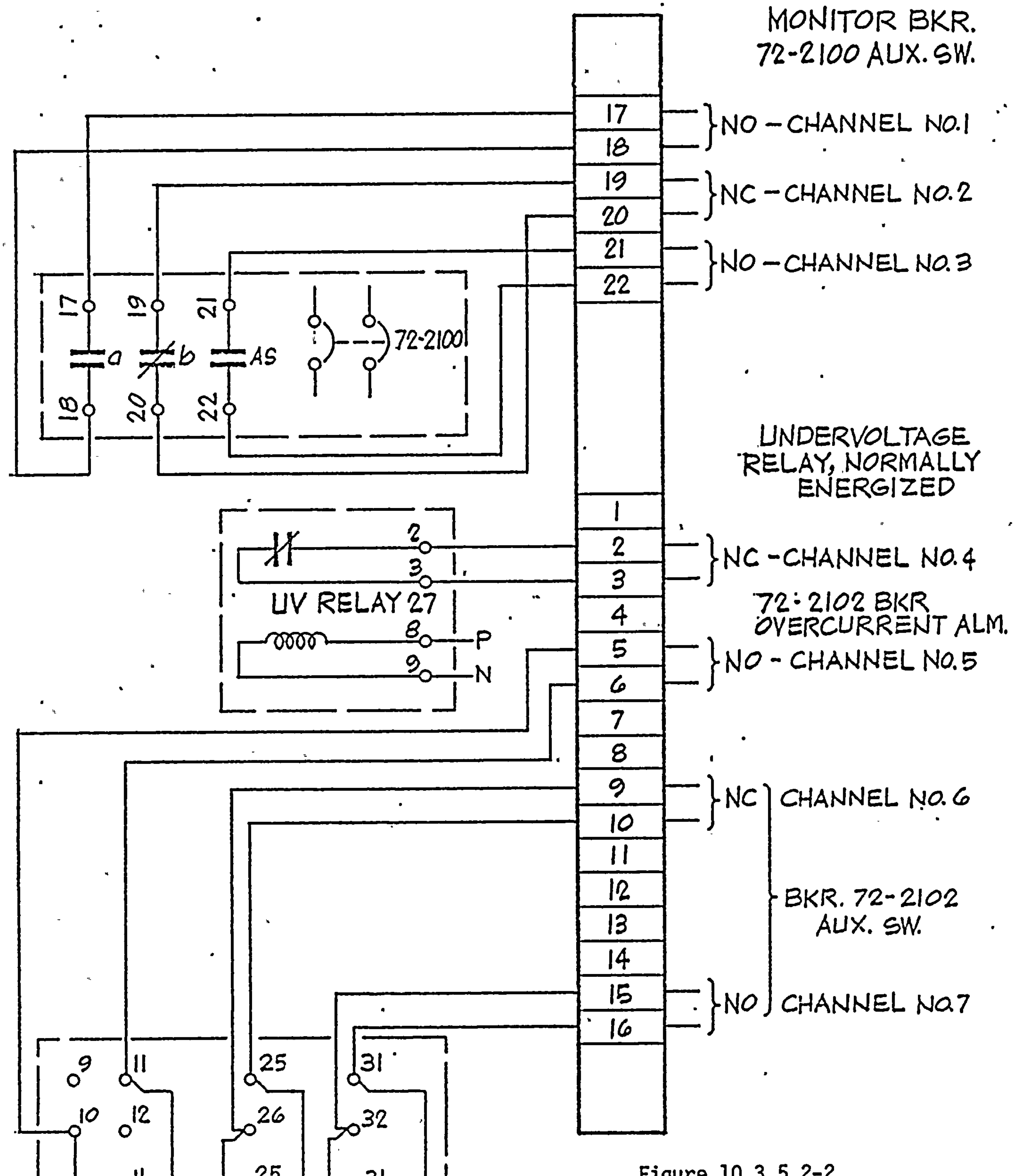
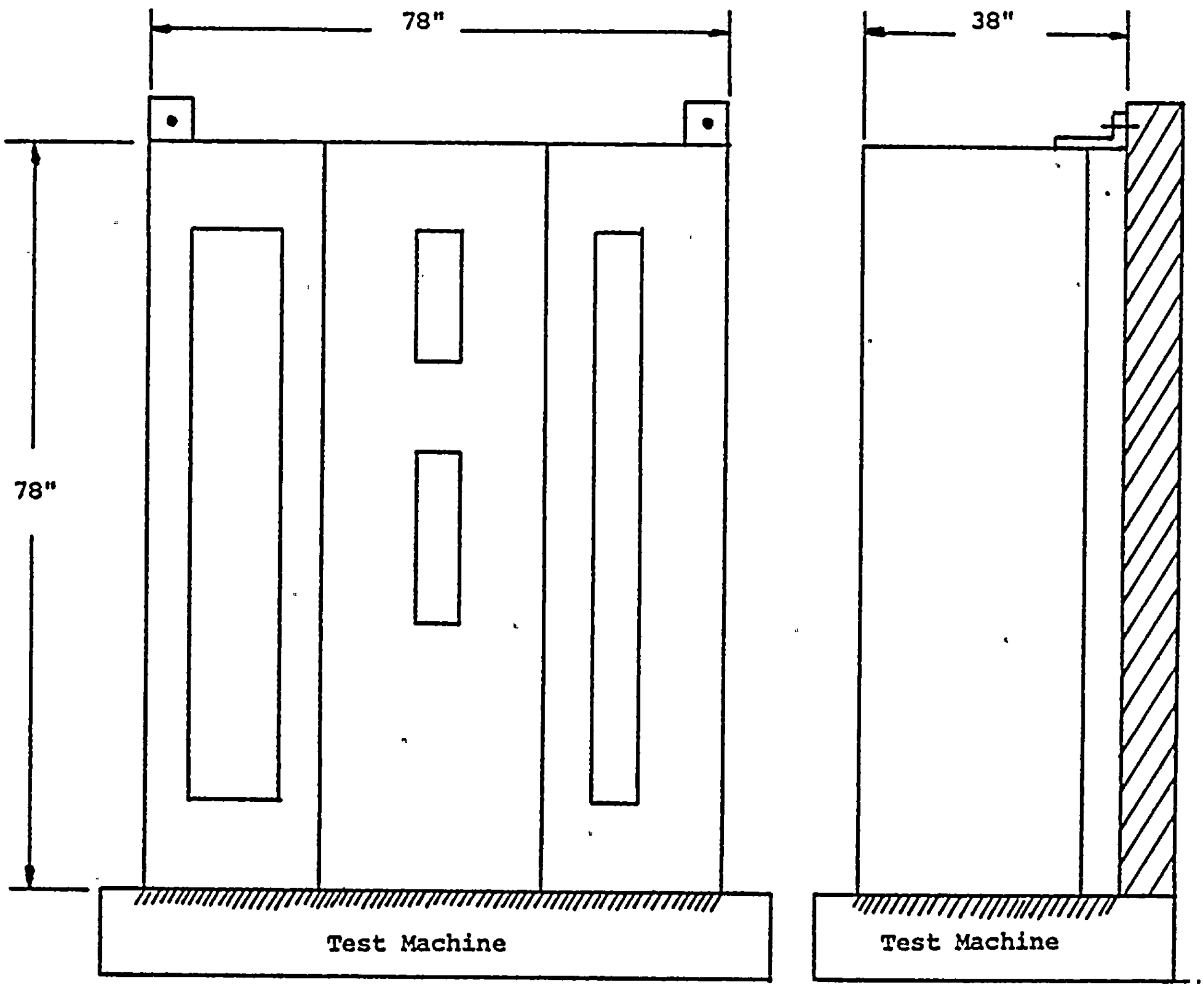


Figure 10.3.5.2-2

MONITORING WIRING DIAGRAM
125VDC DISTRIBUTION PANELBOARD
SD-21

GROUP IV
DC SWITCHGEAR CABINET



Test specimen will be welded to the test machine with supports bolted at the top.

B

10.3.3.1 Name of Equipment Tested

Battery Charger, ED-21 (Exide UPC 130-3-400, 400 amp.) of Unit 2 Diablo Canyon was tested on January 31, 1978.

10.3.3.2 Description of Equipment

The battery charger is a welded frame construction 2 section cabinet with solid-state components. The charger provides rated direct current continuously at a voltage smoothly adjustable from 125 to 140 volts. The charger has a locally mounted voltmeter, ammeter, d-c undervoltage and overvoltage relays for alarm, adjustable controls for both normal and equalizing charge settings, and an equalize timer manually adjustable from 0 to 24 hours.

10.3.3.3 Safety Function

The safety function of the battery charger is to provide 125 VDC power to the 125 VDC bus, and to provide 125 VDC charging current to the bus battery during any condition of plant operation.

10.3.3.4 Test Criteria and Plan

The test criteria for this battery charger is that it perform its safety function during, and after a seismic event. The charger shall demonstrate this as follows:

1. The charger shall provide continuous power to the 125 VDC bus 21.

2. Monitoring of the following devices shall be performed to verify proper, continuous operation of the battery charger:

   a. Monitor Power Input 480 VAC circuit breaker 52.21 in the closed position to verify that breaker remained closed during and after seismic testing.

b. Monitor Power Output, 125 VDC circuit breaker 72-21, in the closed position to verify the breakers remained closed during and after the seismic testing.

c. Verify that the A.C. failure relay, PLR-1, contacts did not change state when the charger was energized.

d. Verify that the A.C. fuse failure relay, PLR-2, contacts did not change state when the relay was in the normal deenergized condition.

e. Verify that the 125 VAC Manual Control Relay, Normally Open contacts did not change state during the seismic shaking and switch Battery Charger Control to manual.

f. Verify that the 125 VDC low voltage relay contacts did not change state indicating a loss of 125 VDC output.

3. The seismic test spectra (RRS) are contained in Wyle Report 58255, April 19, 1978, pp. 288-293.

10.3.3.5 <u>Test Procedure and Setup</u>

1. Mount the 125 VDC Battery Charger ED-21 on the seismic test table in the same configuration as in the auxiliary building 115' elevation plant location. See attached photographs on pages 16, 17 and 18.

2. Supply 480 VAC power to the input side of the 52-21 input breaker.

3. Connect the 125 VDC output breaker, 72-21 to the 125 VDC load bank.

4. Connect the Wyle Laboratory 125 VDC battery to the output terminals of the battery charger.

5. Connect a Normally Closed contact of the A.C. Failure relay, PLR-1, to the chatter detector.

6. Connect a normally open contacts of the A.C. Failure relay, PLR-1, to the chatter detector.

7. Connect a normally closed contact of the A.C. fuse failure relay, PLR-2, to the chatter detector.

8. Connect a normally open contact of the A.C. fuse failure relay, PLR-2 to the chatter detector.

9. Connect a Normally Closed, and a a normally open contact of the manually control relay, MCR to the chatter detector.

10. Connect a normally closed contact of the Low Voltage Relay, LVRA, to the chatter detector.

11. Close breakers on the battery charger in the following sequence.

    a) Close the 125 VDC output breaker 72-21 first
    b) Then close the 480 VAC input breaker 52-21.

12. Close resistor bank toggle switches until the charger is loaded with 60 ampere load.

13. After energizing the battery charger and loading the charger deenergize the charger.

14. Perform the seismic tests with the battery charger deenergized during 1st and 3rd OBE and with the charger energized during the 4th and 5th OBE and the 1st and 2nd SSE.

15. After the seismic tests deenergize, energize, and again deenergize the battery charger to verify the charger functional manually after the seismic testing.

10.3.3.6 Test Results

The battery charger was run through the test series with the following results:

1. The input 480 VAC breaker 52-21 remained closed during and after the seismic testing.

2. The output 125 VDC breaker, 72-21 remained closed during and after the seismic testing.

3. The 125 VAC failure relay PLR-1, was seismically tested with the charger energized, and the normally closed contact picked up in its normal operating position of normally open. The seismic tests did not cause this contact to chatter shut to give false indication of a loss of A.C. power.

4. During the seismic testing the 125 VAC Manual Control Relay did not chatter, and thus did not cause the battery charger to switch from automatic to manual control.

5. The 125 VDC low voltage relay, LVRA, did not change state to indicate a loss of 125 VDC output.

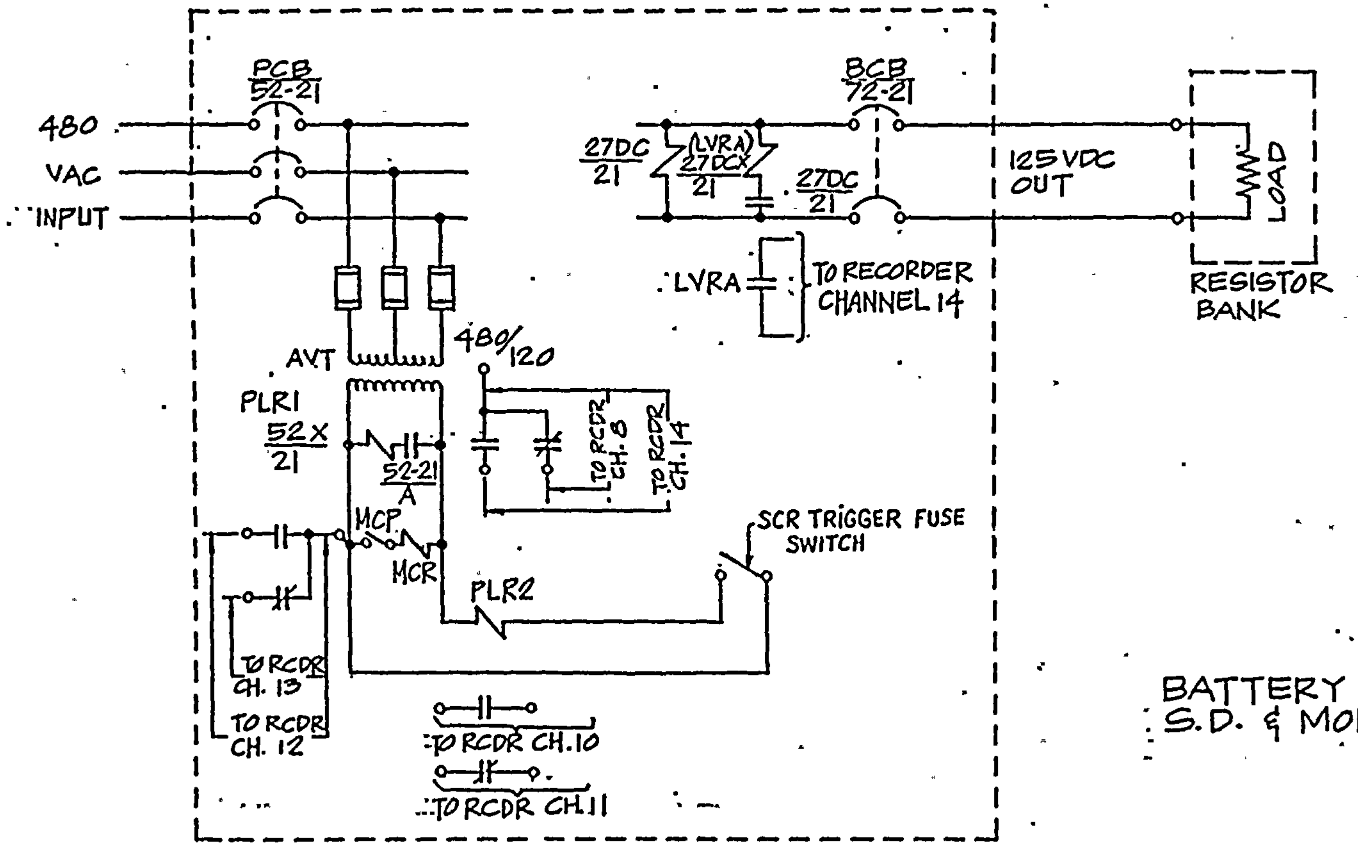
   Table 10.3.3-1 shows the functional performance of these devices during seismic testing.

10.3.3.7 Conclusions

Battery charger ED-21 from Diablo Canyon Unit 2 was tested by a multi-axis multi-frequency seismic simulation described in Wyle Report Number 58255, April 19, 1978, pp. 288-293. This battery charger is identical to the other nine battery chargers installed in Diablo Canyon Units 1 and 2. The test results described in section 10.3.3.6 above demonstrate that the test criteria of section 10.3.3.4 are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. On this basis the Diablo Canyon Units 1 and 2 battery chargers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100.

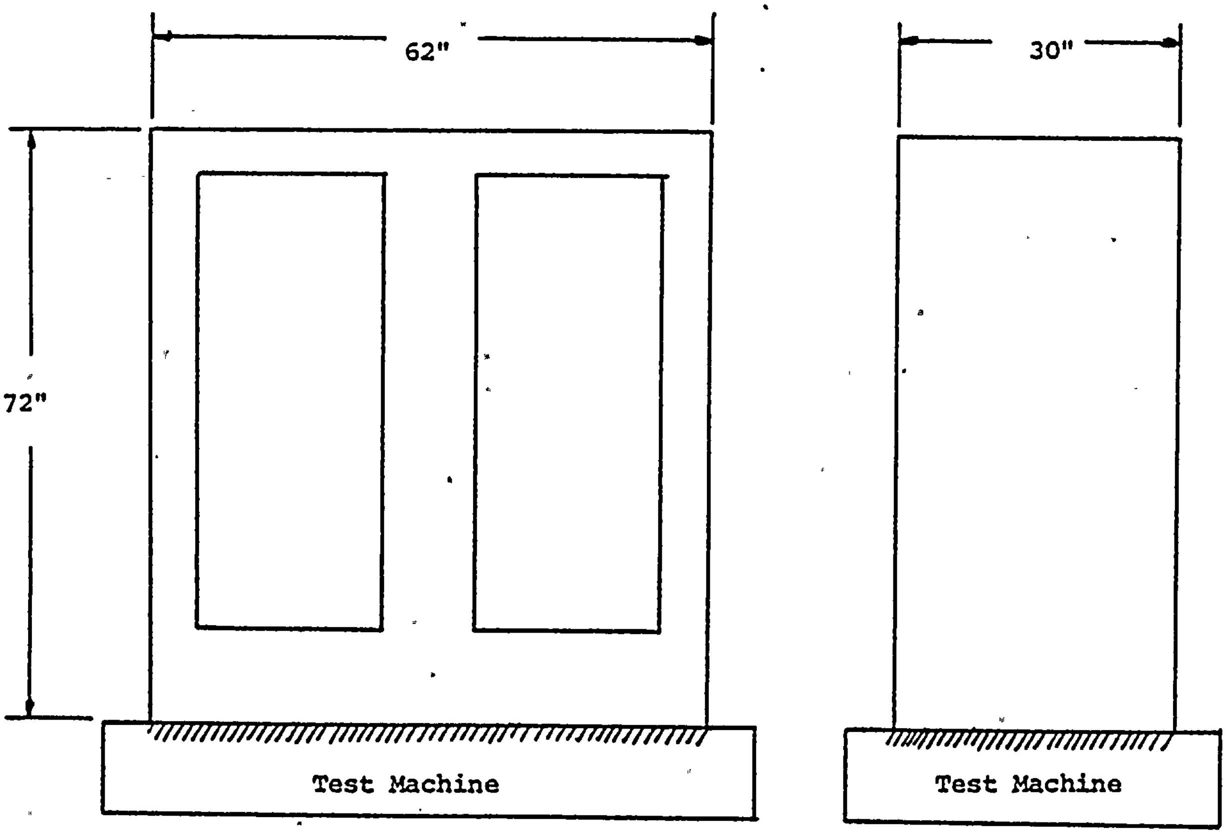
BATTERY CHARGER - TABLE 10.3.3-1

		SWITCH, RELAY POSITION OR CONTACT 0=OPEN C=CLOSED															
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE		3RD SSE	
DEVICE	SW. NO.	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y
52-21 I.T.E. FJ3-B175	BKR	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
72-21 I.T.E. KM-2-B500	BKR	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
DLR-1 125 VAC FAILURE RELAY	N.C.	C	C	C	C	C	C	0	0	0	0	0	0	0	0	C	C
	N.O.	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
DLR-2 125 VAC FUSE FAIL. RELAY	N.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N.C.	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
MCR, ROWAN TYPE E 125 VAC	N.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N.C.	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
27-DC 21 LVRA	N.O.	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0



BATTERY CHARGER ED-21
S.D. & MONITORED CHANNELS

GROUP IV
BATTERY CHARGER CABINET



Test specimen will be bolted to the test machine. B

10.3.5.1.1 - Name of Equipment

125/250 VDC Motor Control Center

Description of Equipment

The 250 VDC Turbine Lube Oil Pump motor starter is mounted in the 250 VDC Motor Control Center. The Motor Control Center is a four section welded construction control cabinet; it is welded to floor plates at elevation 115 ft. in the auxiliary building. The Motor Control Center also contains three other, 250 VDC motor starters similar to the Turbine Lube Oil Pump motor starter.

The starter consists of a vertical panel, on which are mounted the following components:

a. Input power breaker 72-2008; Westinghouse adjustable magnetic only HLA 2700 TM breaker.

b. Four contactors that apply progressively lower starting resistance:

   1. Contactor 42-2008; 3 pole, 250 VDC contactor ITE Type A103G12.
   2. Contactors 18A2008, 18B2008, and 18C2008; (2 pole, 250 VDC contactors) ITE Type P102F11.

c. Time delay relays that time out to energize both the contactor to shunt out a portion of the starting resistance and the next time delay relay, 2A 2008, 2B 2008, and 2C 2008; Agastat Type 2412 PN.

The input power breaker is normally closed. When the Turbine Lube Oil Pump is signaled to start either by low lube oil pressure or by a manual start, contactor 42-2008 closes, applying voltage to the motor armature through the full series starting resistance, and time delay relay 2A 2008 is energized. When relay 2A 2008 has timed out, it energizes contactor 18A 2008 to shunt out a portion of the starting resistance and energizes

the next time delay relay, 2B 2008. This sequence is continued until all the starting resistance in series with the motor armature has been shunted out. The operation of the starter is shown schematically in Figure 10.3.5.1-1.

Safety Function

This equipment has no direct safety function. However, during a seismic event the starters must not apply full voltage to the D.C. motor before it has had time to accelerate. Otherwise, a current surge could result in damage to the motor and voltage dip on the D.C. bus.

Test Criteria and Plan

The functional test criteria for this motor starter are as follows:

1. The contactors shall not close during the seismic test except when required.

2. The timers shall not initiate and time out except when required to do so during the seismic test.

3. The contactors shall drop out, and motor starter shall trip out when signaled to stop.

4. The motor starter functions described above shall be demonstrated during, and after the seismic test.

The test plan is to monitor, visually or electrically the following during, and after seismic testing to simulate 5 OBE's and an SSE with the multi-axis, multi-frequency inputs applied to envelope the required response spectra described in Wyle test report 58255, April 19, 1978, pp. 214-239.

a) 42-2008 Contactor stays open during shaking, closes when energized, stays closed when energized, and trips off when deenergized.

b) 18A 2008, 18B 2008, and 18C 2008 shall be monitored the same as item (a).

c) 2A 2008, 2B 2008, 2C 2008 shall be monitored the same as item (a).

Testing Procedure and Set-Up

1. Mount the Motor Starter in the same configuration and orientation as in the Diablo Canyon plant, (See Wyle Report No. 58255, April 19, 1978 pp. 570-571 for test mounting).

2. Supply 125 VDC to the input terminals of the input breaker 72-2008.

3. Provide a 125 VDC rated switch for energizing or deenergizing the 42-2008 contactor coil to simulate starting and stopping signals.

4. Visually monitor during seismic testing the proper sequence and timing for closure of the motor starter contactors and timers.

Test Results[1]

After mounting on the seismic test table, the starter was functionally tested by applying 125 VDC control power to the input of the starter breaker 72-2008, then manually closing this breaker. The manual switch on the test set-up was closed to provide a signal to start the motor. Contactor 42 energized, starting the time delay relay sequences. Upon completion of all contactors closing, the manual switch was returned to open and the motor starter returned to its motor tripped state.

During the 1st, 2nd, 3rd, and 4th OBE and the SSE in the X-Y (east-west and vertical plant orientation) the starter was observed in its motor-tripped state. The timers, relays and contactors did not close or chatter to inadvertently start the motor starter sequences during the seismic test. The starter did not operate in its deactivated state during the 1st, 2nd, 3rd, and 5th OBE, and the 1st SSE in the Z-Y direction.

During the 5th OBE and the 2nd SSE in the X-Y direction, and the 4th, 5th, OBE's and 2nd SSE in the Z-Y direction, the manual switch was closed energizing contactor 42 and started the time delay relay contactor sequence. Upon completion of the sequence, the stop switch was opened releasing all the contactors. The entire sequence was completed before the end of each 30 second test.

Upon completion of the last SSE, the manual switch was again closed and the starter run through its sequence and again, deenergized.

The above seismic and functional testing verifies that this representative direct current motor starter was not inadvertently activated by the seismic shaking. Functionally, during a seismic event, the starter would remain off, would start the motor if switched on in the automatic position or manually, and would trip off if switched automatically or manually.

Table 10.3.5.1-1 shows a list of components contained in this starter and summarizes their functional performance during the seismic testing.

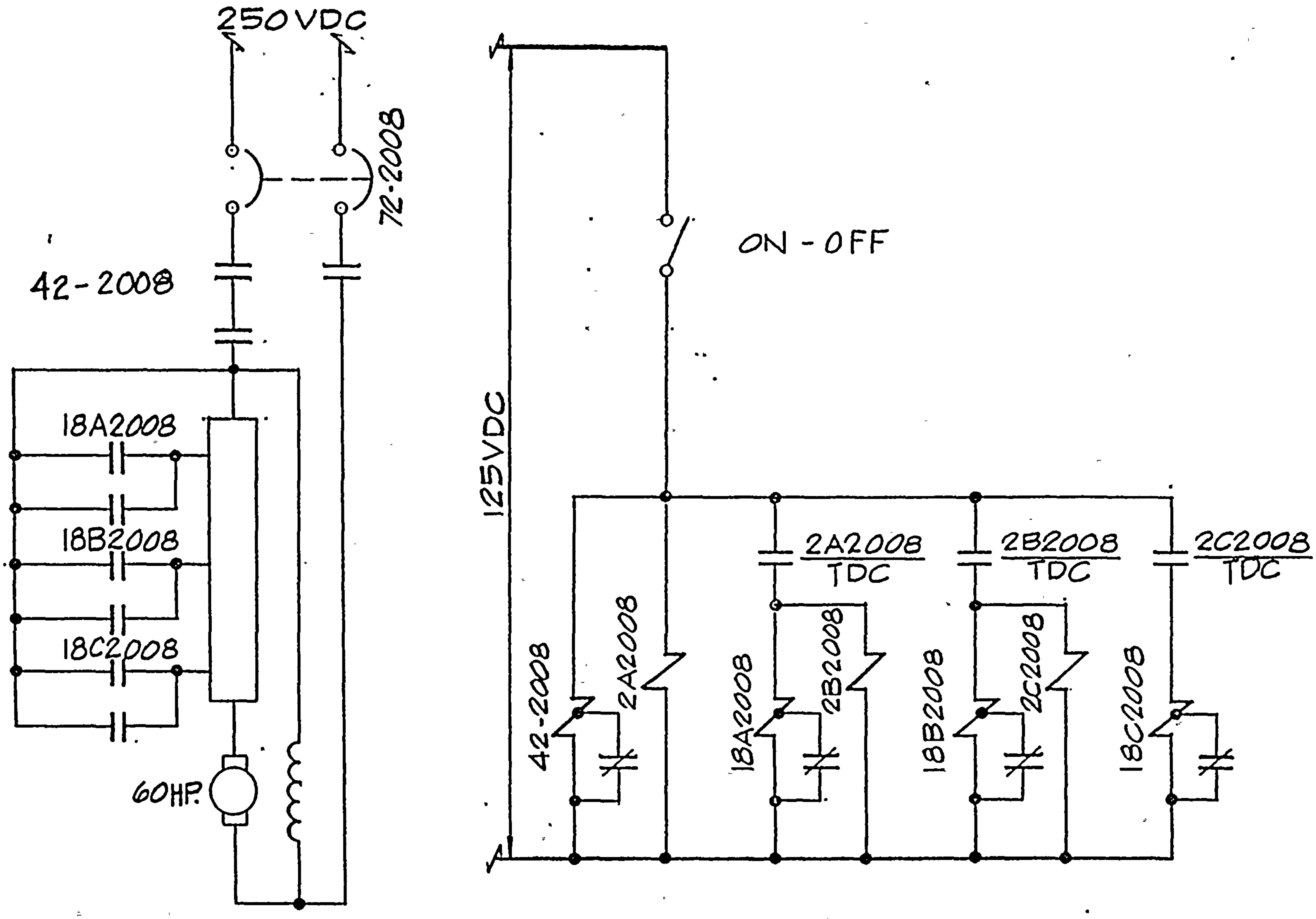
---

1. Detailed test results are contained in Wyle test report 58255, April 19, 1978, pp. 214-239.

Conclusions

The results of the tests of the 250 VDC Turbine Lube Oil Pump motor starter subjected to a multi-axis, multi-frequency seismic simulation bounding the 7.5M Hosgri event have demonstrated that the test criteria specified above have been met.

Thus it is concluded that the 250 VDC Turbine Lube Oil motor starter is qualified for service in the Diablo Canyon plant for the 7.5M Hosgri event in accordance with IEEE-344-1975 and USNRC Regulatory Guide 1.100.

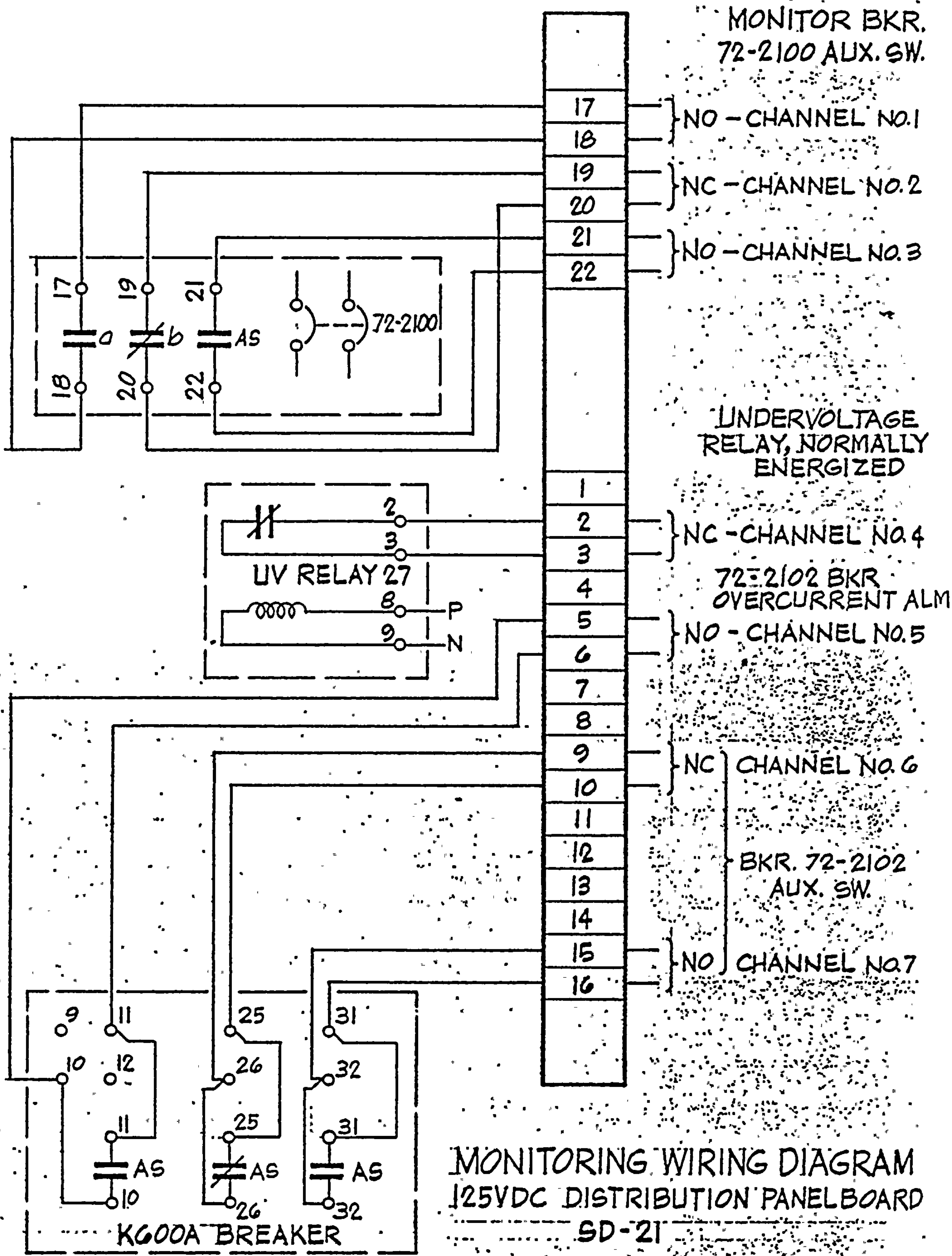


S.D. TURBINE GEN. EMERGENCY BEARING OIL PUMP № 21
TEST-SET-UP AT WYLE

Figure 10.3.5.1-1

TABLE 10.3.5.1-1

		SWITCH, RELAY POSITION, OR CONTACT O=OPEN C=CLOSED													
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE	
DEVICE	SW. NO.	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y
72-2008 W ADJ. MAG. ONLY BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C
42-2008 I.T.E. A103G12 CONTACTOR	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
2A2008 AGASTAT 2412PN T.D. RELAY	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
18A2008 I.T.E. CONTACTOR P102F11	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
2B2008 AGASTAT 2412PN T.D. RELAY	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
18B2008 I.T.E. CONTACTOR P102F11	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
2C2008 AGASTAT 2412PN T.D. RELAY	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
18C2008 I.T.E. CONTACTOR P102F11	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C

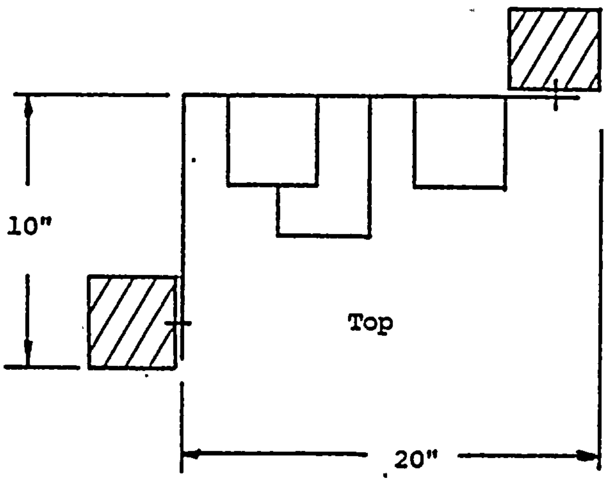


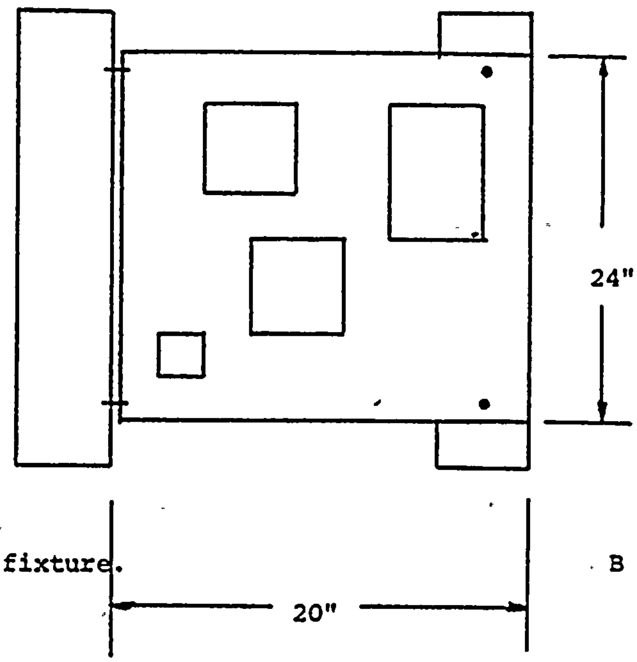
MONITORING WIRING DIAGRAM

125VDC DISTRIBUTION PANELBOARD

SD-21

GROUP IV
125-250vdc M.C.C.
TURBINE LUBE OIL STARTER





Test specimen bolted to fixture.

Fixture 4" tubing .

10.3.4.1 - Name of Equipment

Station Battery and Racks.

10.3.4.2 - Description of Equipment

Diablo Canyon Units 1 and 2 each have three identical batteries each made up of 60 C&D Inc. LCU-27 cells installed in battery racks at the 115' elevation in the Auxiliary Building.

The battery racks have been braced such that there are no natural frequencies below 35 hz, and such that they are structurally capable of withstanding 3.0g Horizontal and 0.65g Vertical accelerations.

The average operating current on a typical Diablo Canyon Battery bus is about 100 amperes. In actual operation this current is supplied by the battery charger and the battery is floating on the charger and connected to the bus. If the battery charger should trip the battery would supply the 100 amperes.

10.3.4.3 - Safety Function

The Station Batteries must provide nominal 125 vdc power to supply the station dc loads in the event that the ac source to one or more battery charger becomes unavailable.

10.3.4.4 - Test Criteria and Plan

The following test criteria have been established to demonstrate that the station battery will perform its safety function during and after a seismic event.

1. The cells shall provide continuous nominal power output during and after the seismic test.

2. Battery cells shall not be damaged by the seismic testing.

3. Two battery cells shall be tested. The battery cells shall have an average operating current load on them during the seismic testing. A 1 ohm load shall be used on the two cells in series, or an approximate current of 3.4 amperes shall be established.

4. The battery shall be able to accept charging current after the seismic tests.

5. The battery shall meet its discharge requirement per IEEE-Std-450 after seismic testing.

<u>10.3.4.5 - Test Procedure and Setup</u>

1. The two battery cells to be tested shall be mounted in a rigid test fixture to simulate their service mounting. The test fixture to be used is the same test fixture used in the earlier test at Wyle Laboratories (.4g SSE test) on June 18, 1978, except it was modified to satisfy the postulated 7.5M Hosgri Earthquake requirements, and also to simulate as closely as possible the existing battery racks at Diablo Canyon Units 1 and 2. Side diagonal braces and side rail shims were added to the test fixture. The test mounting for the cells is illustrated in Wyle Report No. 58255, dated April 19, 1978, pp. 577 and 578.

2. Testing shall be performed using the multi-axis, multi-frequency test inputs described in Wyle Report Number 58255, dated April 19, 1978, pp. 240-254.

3. The two batteries shall be connected in series to a 1 ohm load. Use the standard battery straps and bolts and nuts provided with the 60 cell battery.

4. Monitor the current and voltage of the two cells before, during, and after the seismic tests.

10.3.4.6 - Test Results

The two battery cells functioned as required during, and after the seismic testing. The batteries provided a continuous current flow at 3.4 amperes through the 1 ohm resistor. The starting two cell battery voltage was 3.79 vdc and ending two cell battery voltage was 3.75 vdc. Before test and before application of the 1 ohm load the two cell battery voltage was 4.12 vdc. After the test and after disconnecting the load the battery volts was 4.07 vdc.

The cells tested exhibited no damage and they have been returned to the Diablo Canyon Unit 2 Battery 21. A discharge test of Battery 21 will be performed with these two cells included to verify that the cells will meet their discharge and charging requirements after the tests.

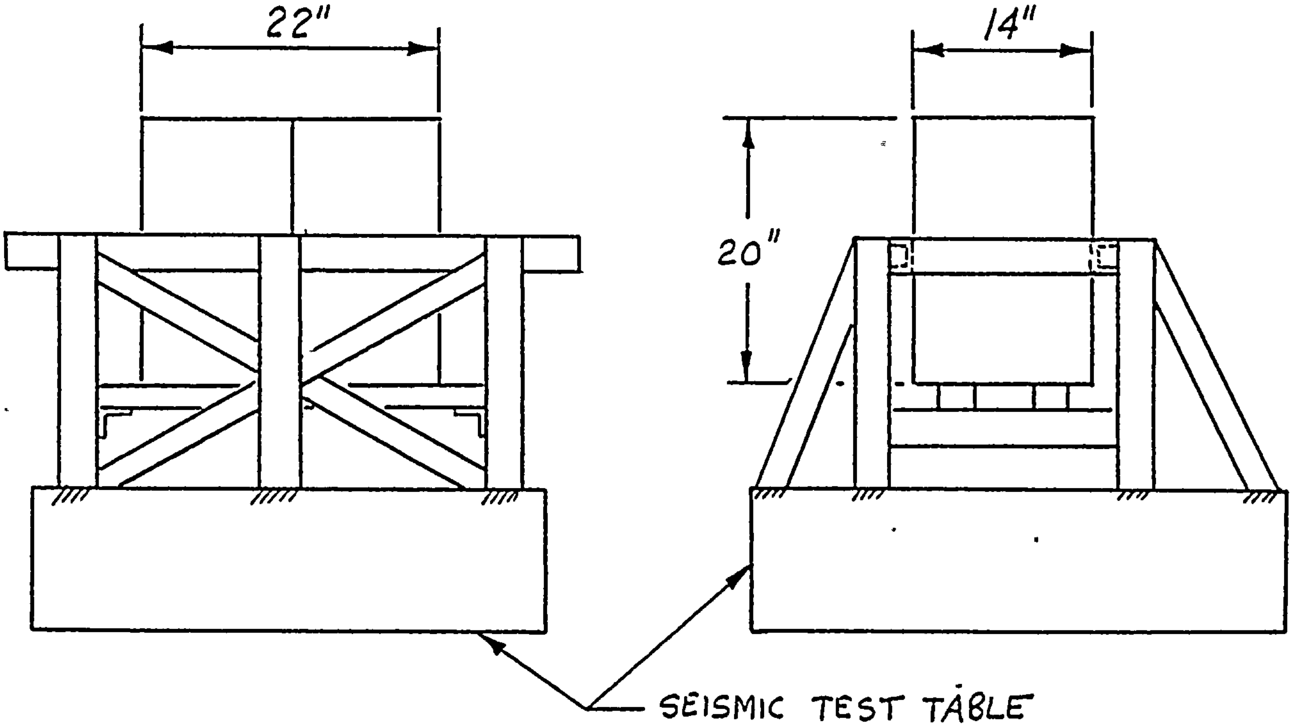
Following the previous test of two identical cells to qualify the station batteries to the 0.4g DDE (See Wyle Report No. 43255-1, 6-18-76) the test cells passed an eight hr. rated capacity discharge test and were then recharged to their original capacity.

10.3.4.7 - Conclusions

Two C&D, Inc. LCU-27 station battery cells have been tested by multi-axis, multi-frequency seismic simulation as described in Wyle Report No. 58255, 4-19-78, pp. 240-254. These cells are identical to the other cells contained in the 6-60 cell station batteries in Diablo Canyon Units 1 and 2. The test results show that the test cells continued to supply dc power at the

average load during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. The cells were not damaged by the test. Discharge testing following this seismic test will be completed at the Diablo Canyon Site by October 15, 1978; however discharge and charging capability following a seismic event has previously been demonstrated on two identical LCU-27 cells tested earlier (see Wyle Report No. VL-762-02, August 4, 1976.

On this basis it is concluded that the six Diablo Canyon station batteries are qualified for the postulated 7.5M Hosgri event in accordance with IEEE-Std 344-1975 and USNRC RG 1.100.



BATTERY SEISMIC TEST RACK

To: [illegible]
[illegible] 1805

Work Request No. ____
Laboratory Test No. VL-762-02
B. E. No. ____
R. M. A. No. ____

LABORATORY REPORT

BATTERY SECTION

QUALIFICATION TEST
TYPE LCU-27

Prepared for: Pacific Gas & Electric Co.
77 Beale Street
San Francisco, CA 94106

P.G.&E. Purchase Order No. T4R-93205
P.G.&E. Specification 0132
P.G.&E. File No. 128.061
P.G.&E. Record No. 663343-4

C&D BATTERIES
DIVISION OF ELTRA CORPORATION

Distribution:
(10) Pacific Gas & Electric Co.
(1) L. K. Isbill, P.G.&E. Inspector
(1) H. J. Schaetzle, C&D
(1) F. Wagner, C&D
(1) File

Prepared Graham Walker [signature]
Date Prepared 4 Aug 76
Approved H.J.Schaetzle [signature]
Date Approved 4 Aug 76

FORWARD

Two cells, C&D type LCU-27, identical to the Diablo Canyon Unit 1 and 2 battery were tested as follows:

1. After filling, forming and conditioning the specimen cells, an 8 hour capacity discharge test was conducted in accordance with IEEE 450-1975 directives. This is shown as discharge number 4.

2. Seismic testing was performed per Wyle Laboratories' Seismic Test Plan 541/4024/ES, dated 16 June 76, Rev. A. Seismic Test results are provided in Wyle Report No. 43255-1.

3. Upon return of the specimen cells from Wyle Laboratories, boost charging followed by an 8 hour capacity discharge test was conducted in accordance with IEEE 450-1975. This is shown as discharge number 5.

INSTANT CURRENT, RESISTANT

8 HR. RATE

3.75 AMPS. TO

.75 FINAL VOLTS

an **Eltra** company

BATTERY LABORATORY

DISCHARGE RECORD

TYPE LCU-27

DATE 4-19-76

DIS. NO. 4

CIRCUIT NO. 27

CELL NO.-	1	2
OAT @ 100 MA	2.240	2.270
TEMP / Sp. GR.	71° 1.220	1.220
TIME STARTED 8:40		
8:50	1.987	1.985
9:40	1.982	1.980
10:40	1.971	1.968
11:45	1.956	1.954
12:25	1.938	1.936
13:45	1.908	1.905
14:40	1.872	1.871
15:40	1.818	1.824
15:55	1.795	1.805
16:22	1.75	1.761
16:28		1.75
@ FV	74° 1.090	74° 1.087
TOTAL HRS. TO FV	7.70	7.80
PERCENT RATED CAPACITY @ TIME		

$$\text{PERCENT CAPACITY @ } 77°F = \frac{T_A}{T_S K_1} \times 100$$

WHERE T_A = ACTUAL TIME

T_S = RATED TIME

K_1 = TEMP. FACTOR

$$\% \text{ CAPACITY} = \frac{7.75}{8 \times .978} \times 100$$

$$= 99.05\%$$

AVER. TEMP. 72.[illegible]

FACTOR .97[illegible]

TESTED BY: CA[illegible]

C&D BATTERIES

an Eltra company

BATTERY. LABORATORY

DISCHARGE RECORD

TEST NO. VL-762-0

TYPE LCU-27

DATE 4-19-76

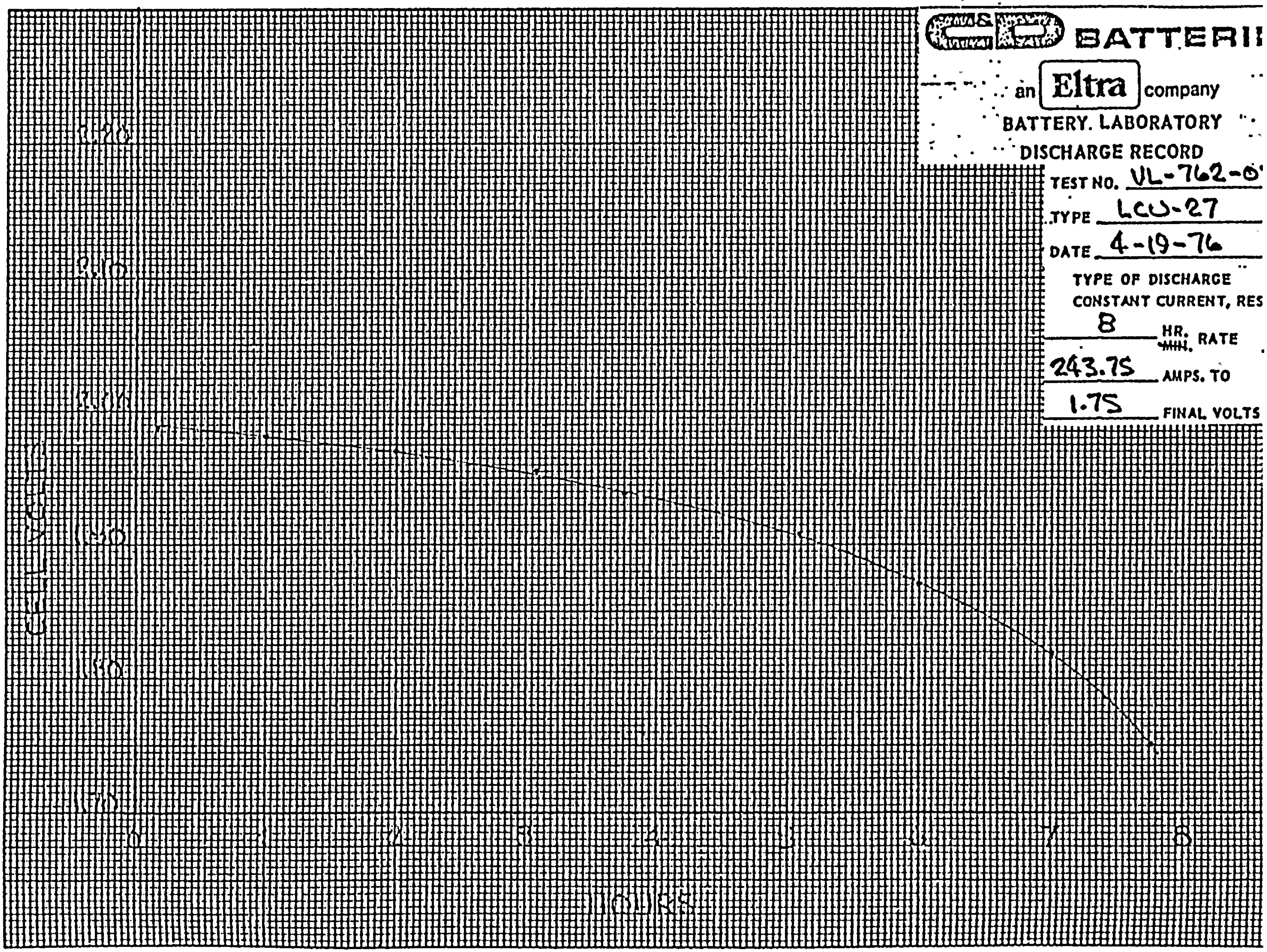
TYPE OF DISCHARGE

CONSTANT CURRENT, RES

8 HR. ~~MIN.~~ RATE

243.75 AMPS. TO

1.75 FINAL VOLTS



an Eltra company

BATTERY LABORATORY

DISCHARGE RECORD

3 HR. RATE

3.75 AMPS. TO

75 FINAL VOLTS

TYPE [illegible]

DATE 7-23-76

DIS. NO. 5

CIRCUIT NO. 1 & 2

CELL NO.–	1	2
AT @123MA	2.235	2.238
TEMP. / Sp. GR.	76° / 1.216	1.216
ME STARTED 8:35		
8:45	1.983	1.982
9:35	1.982	1.982
10:35	1.969	1.969
11:25	1.955	1.955
12:30	1.935	1.936
13:35	1.908	1.909
14:50	1.872	1.873
15:40	1.829	1.832
16:15	1.787	1.793
16:28	1.750	1.761
16:30		1.750
. @ FY / R. @ FY	76° / 1.080	76° / 1.078
JAL HRS. TO FY	7.88	7.92
CENT RATED		

PERCENT CAPACITY @ 77°F =

$$\frac{T_A}{T_3 K_1} \times 100$$

WHERE T_A = ACTUAL DURATION

T_3 = RATED TIME

K_1 = TEMP. FACTOR

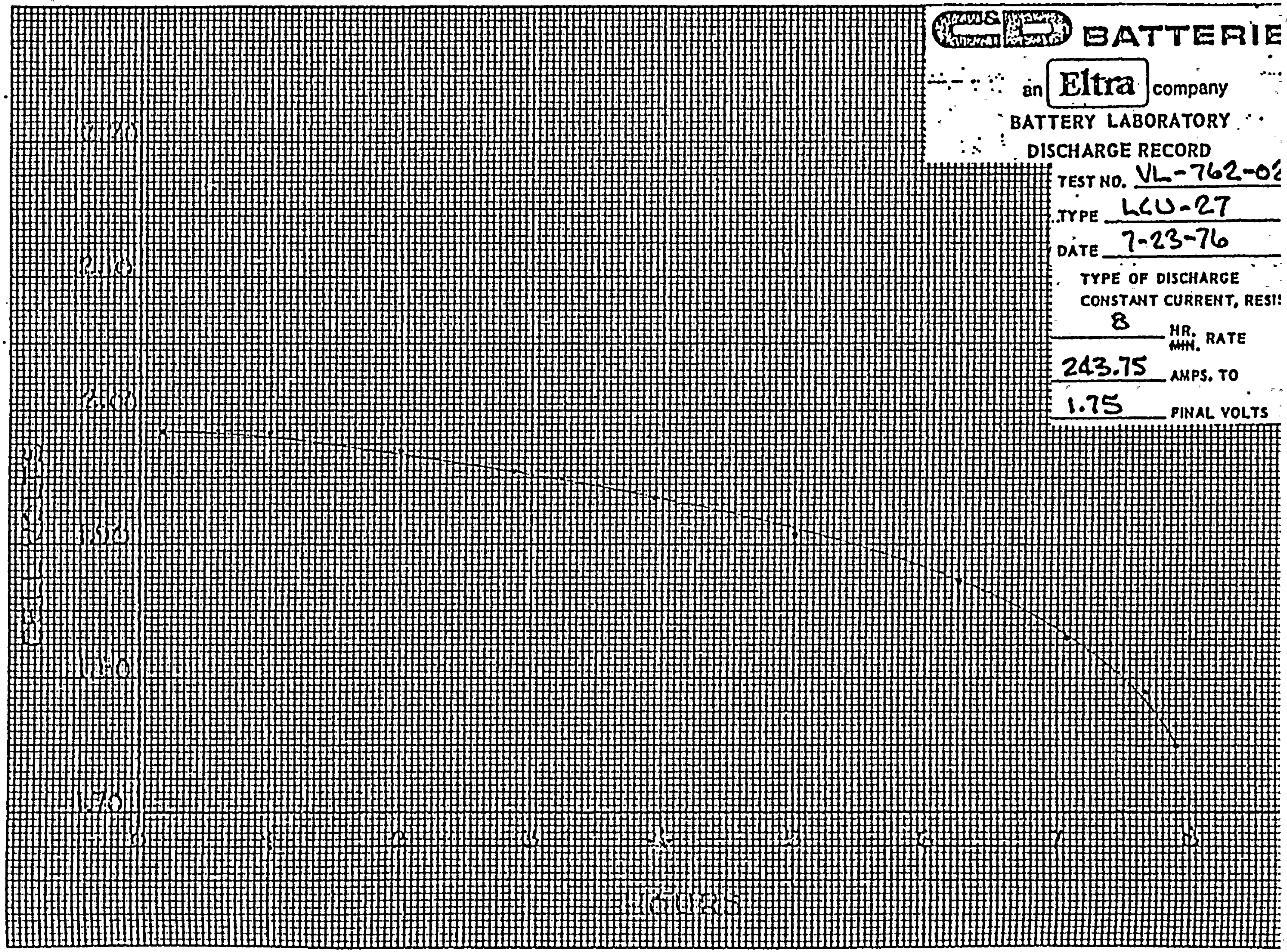
$$\% \text{ CAPACITY} = \frac{7.90}{8.0 \times .996} \times 100$$

$$= 99.15\%$$

AVER. TEMP. 76°

FACTOR .99

TESTED BY: [illegible]


C&D BATTERIE
an Eltra company
BATTERY LABORATORY
DISCHARGE RECORD
TEST NO. VL-762-0
TYPE LCU-27
DATE 7-23-76
TYPE OF DISCHARGE
CONSTANT CURRENT, RESI
8 HR. MIN. RATE
243.75 AMPS. TO
1.75 FINAL VOLTS

CONCLUSION

It is demonstrated that the specimen cells suffered no reduction of capacity as a result of the prescribed simulated seismic environment for the Diablo Nuclear Power Plant, Unit 1 and 2.

10.3.25.1 - Name of Equipment

Vital Load Center

10.3.25.2 - Description of Equipment

The Vital Load Center (480 volt MCC, bus, F, G and H) consists of draw-out modules containing combination motor controllers or feeder breakers. These modules are arranged in vertical stacks which are bolted together to make a line-up. Electrical bussing is provided both horizontally between stacks and vertically between modules. Each combination motor controller consists of a molded case magnetic-only circuit breaker, magnetic contactor and overload unit. Feeder breakers are manually operated molded case thermal-magnetic circuit breakers. The Vital Load Centers are located at elevation 100' in the auxiliary building.

10.3.25.3 - Safety Function

The Vital Load Center must provide power on demand for Engineered Safety Features Equipment. The major loads are electric motor operated valves and ventilation fans. In orderly accomplish this basic function, feeder breakers must not chatter or change state, contactors must close on demand and remain closed, and overload relays must not spuriously operate to interrupt power inadvertently.

10.3.25.4 - Test Plan and Criteria

One vertical section from a Vital Load Center was removed from Diablo Canyon Unit 2 for seismic testing. Each NEMA size controller and representative feeder breakers will be placed in the vertical section and seismically tested.

The specific test criteria to be met in order to demonstrate that the equipment safety function is assured during and after a seismic event are the following:

a. Feeder breakers must not change state during the seismic testing.

b. Controllers must close on demand, and only on demand, and remain closed during and after the seismic testing.

c. Overload relays (except for those bypassed per NRC Regulatory Guide 1.106) must not inadvertently interrupt power to the load.

<u>10.3.25.5</u> - <u>Test Procedure and Set-Up</u>

1. Mount the Vital Load Center vertical section to the test table to simulate field mounting by welding at base and rigidly supporting at top. (see attached Figures 10.3.25-3, and 10.3.25-4)

2. Mount three Size 1 reversing controllers in the vertical section; fill the remainder of the section with dummy typical equipment that will not be monitored during the tests.

3. Connect and monitor each controller as shown in Figure 10.3.25-1.

4. Perform multi-frequency, multi-axis seismic testing to the RRS shown in the Attachments.

   a. Run three OBE tests with the equipment deenergized.

   b. Run one OBE test, energizing all "forward" contactors.

   c. Run one OBE test, energizing all "reverse" contactors.

   d. Run one SSE test, energizing the "reverse" contactors.

e. Run one SSE test with the equipment deenergized.

f. Run one SSE test, energizing the "forward" and "reverse" contactors 3 times each.

5. Mount NEMA Size 2 reversing and non-reversing controllers, NEMA Size 3, 4, and 5 controllers, and two 100 amp feeder breakers in the vertical section.

6. Connect and monitor each device as shown in Figure 10.3.25-2.

7. Perform seismic testing with inputs as described in 4 above:

   a. Run three OBE tests with the equipment deenergized.

   b. Run two OBE tests with the equipment energized.

   c. Run one SSE test with the equipment energized.

   d. Run one SSE test with the equipment deenergized.

   e. Run one SSE test and switch size 3, 4 & 5 controllers on-off 4 times.

   f. Rotate equipment 90 degrees and repeat a through e.

8. Check normal functional operation of each controller and feeder breaker on completion of the seismic testing.

<u>10.3.25.6</u> - <u>Test Results</u>

With the exception of the anomalies discussed below, all Vital Load Center equipment met the test criteria specified in section 10.3.25.4 during and after the seismic testing while being operated per the test procedure described in 10.3.25.5 above.

During the initial tests it was determined that the draw-out modules required additional hold down brackets to maintain structural integrity during the seismic testing. Additional hold down brackets were fabricated and utilized throughout the following test sequences.

During one SSE one N.O. and one N.C. auxiliary contact on the size 4 controllers chattered. These auxiliary contacts are used only for indication and could at most result in momentary actuation of indicating lights. Momentary actuation of indicating lights during seismic shaking, with the contacts and indicating lights returning to proper status on cessation of the seismic motion has no unacceptable impact on plant safety.

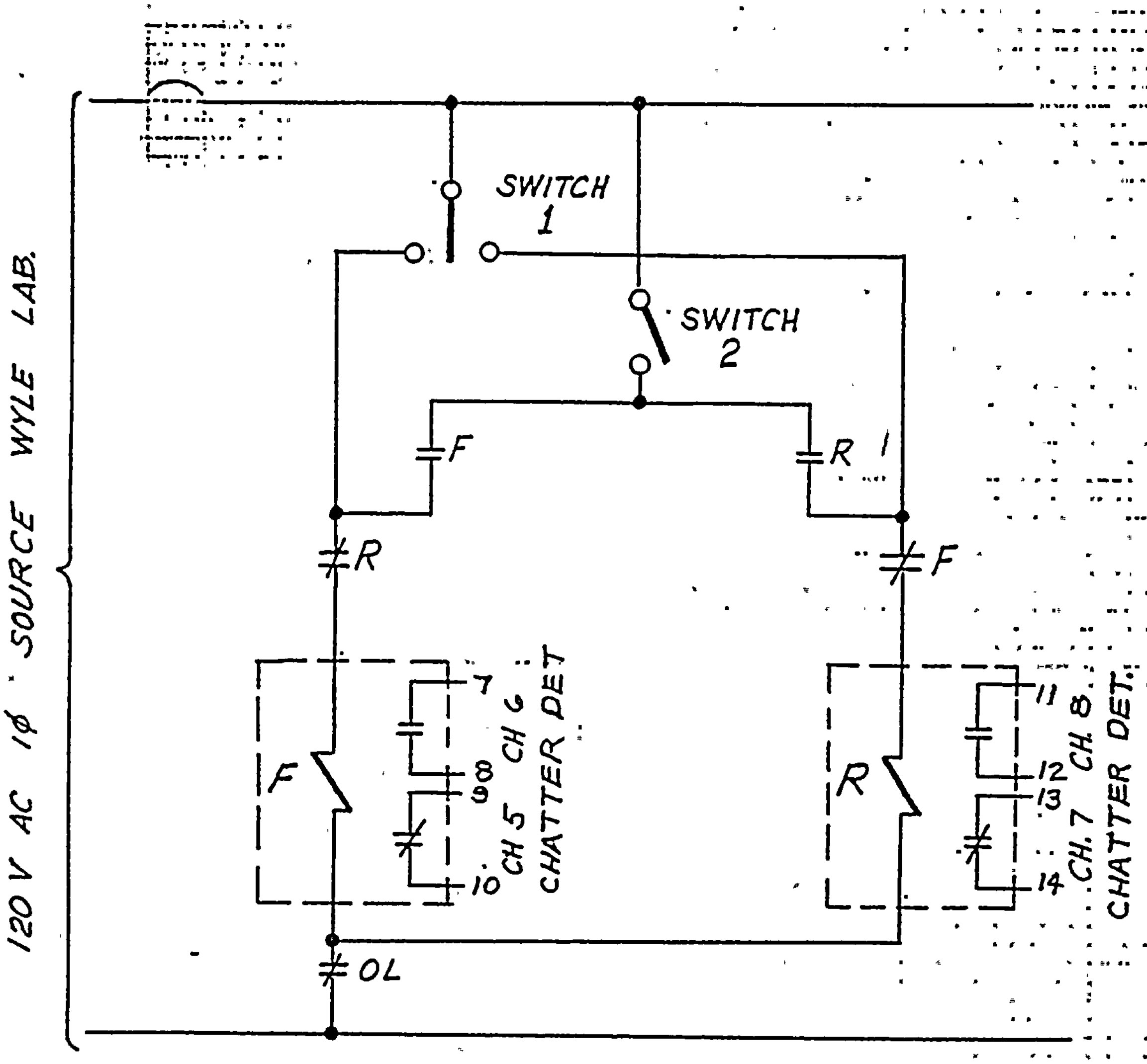
Also, one N.C. contact chattered with the size 2 reversing controller deenergized. This effect has been analyzed and found to have no degradation of any safety function. Because all safeguards initiation signals are sealed-in until manually reset, the N.C. chatter may momentarily cause a motor operated valve to stop for a fraction of a second, but it would immediately resume travel as directed by the safeguards initiation signal.

10.3.25.7 - Conclusions

A vertical section of the Vital Load Center with each NEMA size controller and representative circuit breakers installed was tested by a multi-axis, multi-frequency seismic simulation. Based on the components tested and the test procedure employed, these qualification tests will bound the seismic requirements for all Vital Load Center equipment.

The test results described in 10.3.25.6 above rely upon additional hold-down brackets to maintain the structural integrity of the draw-out module stacks. These additional hold-down brackets have been provided in Diablo Canyon Units 1 and 2 Vital Load Centers to ensure that the test results are applicable.

The test results described in section 10.3.25.6 above demonstrate that the test criteria of section 10.3.25.4 are met, and the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. Thus it is concluded that the Diablo Canyon Unit 1 and 2 Vital Load Centers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.



SIZE 2R CONTACTOR

FIG. 10.3.25-1

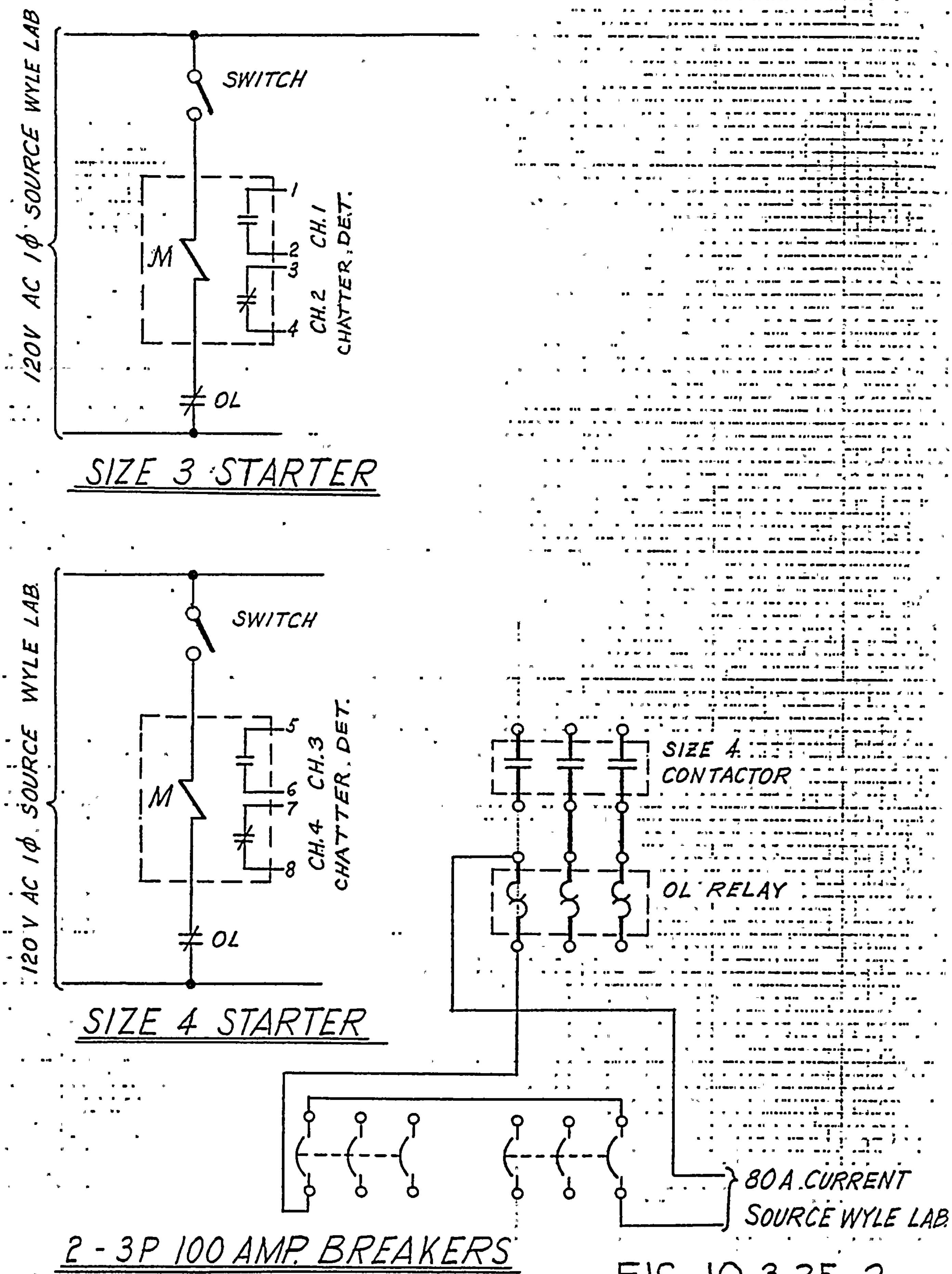
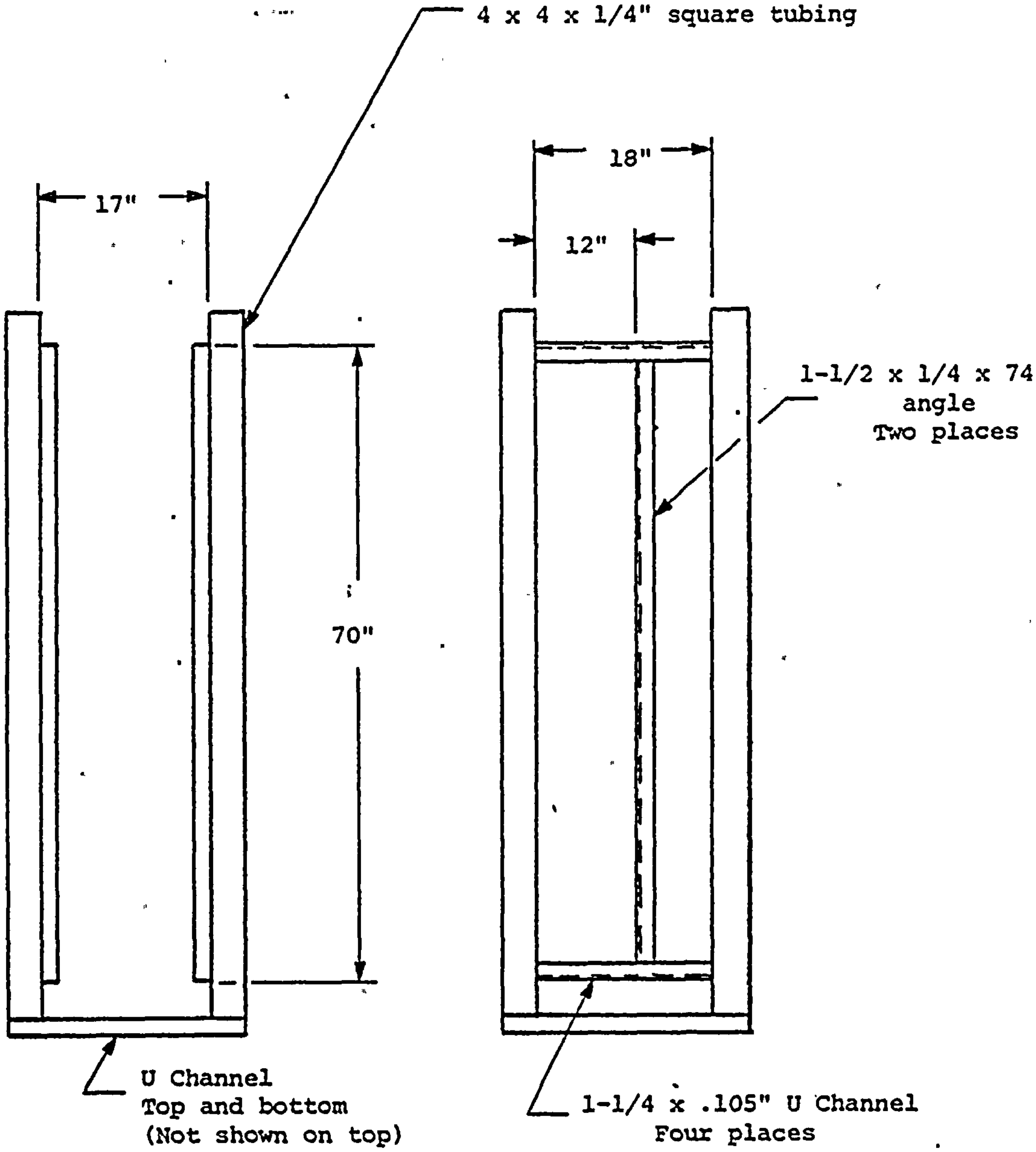

120V AC 1φ SOURCE WYLE LAB
SWITCH
M
1
2
3
4
CH.1
CH.2
CHATTER, DET.
OL
SIZE 3 STARTER
120 V AC 1φ SOURCE WYLE LAB
SWITCH
M
5
6
7
8
CH.3
CH.4
CHATTER, DET.
OL
SIZE 4 STARTER
SIZE 4 CONTACTOR
OL RELAY
80 A CURRENT SOURCE WYLE LAB
2 - 3P 100 AMP. BREAKERS

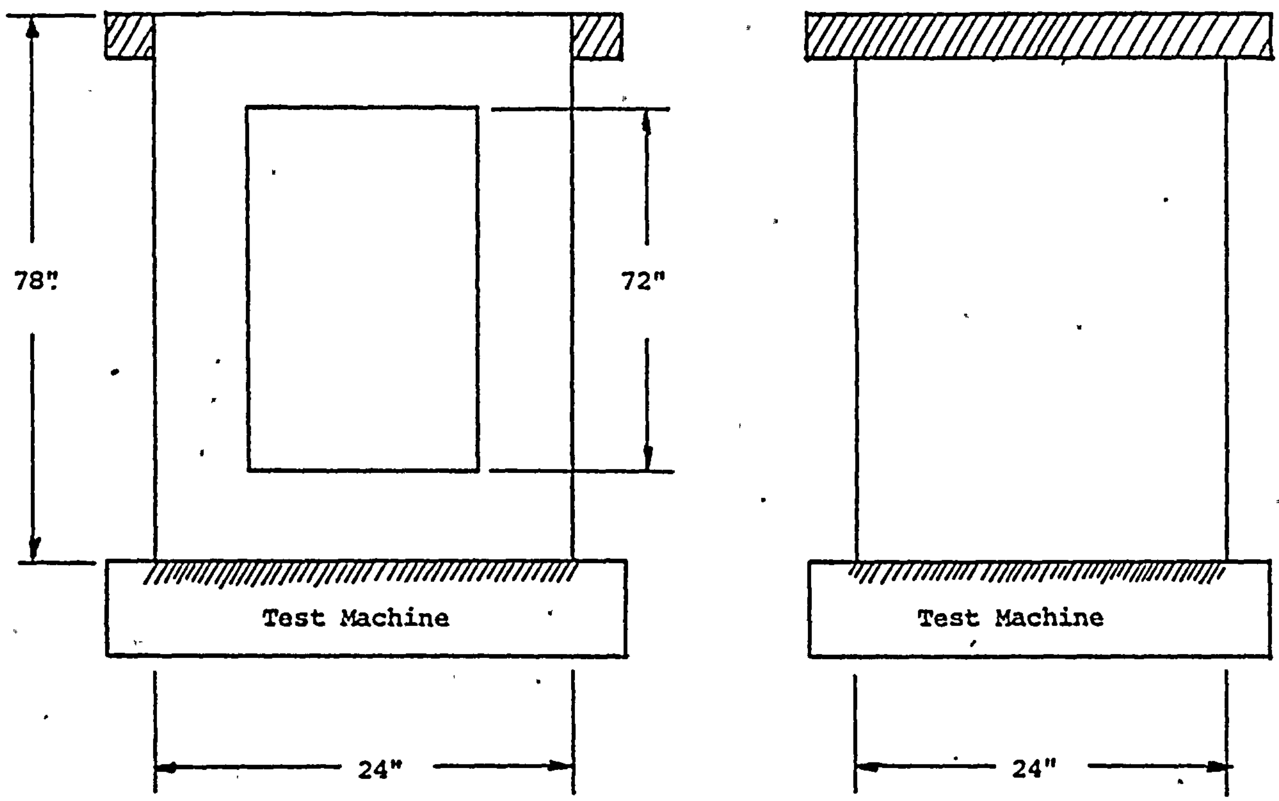
FIG 10.3.25-2

GROUP V
VITAL LOAD CENTER
FAN COOLER STARTER - UNIT NO. 1



NOTE: Fan cooler starter from Unit 2 will be mounted on 1-1/8 x 3-3/8 x .105" angle and supported in the same fixture at top, bottom, and middle.

GROUP V
VITAL LOAD CENTER
SINGLE CELL CABINET



Test specimen will be bolted to the test machine with supports bolted at the top.

B

10.3.14 Local Starters

10.3.14.1 Description:

Local starters are non-fused, disconnect type combination motor controllers housed in small sheet metal enclosures. Local starters are mounted in the area of the motors they control and are fed power from the Vital 480V Load Center.

Each local starter consists of disconnect switch and motor controller. Four units control tank heaters and do not have overcurrent relays. There are a total of 18 local starters fed from the vital busses.

10.3.14.2 Safety Function:

The local starters are used to control electric power for the following functions: ventilation fans for electrical equipment, auxiliary salt water gates operators, tank heaters, lube oil pumps for component cooling water and charging pumps, and spent fuel pool pumps. None of these are required to perform any active function during any seismic event. Their safety function is, therefore, to be able to perform their design function after the seismic event.

10.3.14.3 Test Criteria and Plan:

The criteria was that the equipment should maintain its state during the seismic testing and that the equipment be capable of operation after the seismic event.

The testing was to be conducted in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100 with support accelerations greater than the RRS developed for the location of the equipment.

10.3.14.4 Test Procedure and Setup:

Representative starters were removed from the plant and sent to Wyle Laboratories for seismic testing.

Test Setup:

1. Mount starter to rigid support on table according to the applicable mounting shown in the attached Wyle Test Procedure 3642, Figs. 23, 30 and 33. This mounting simulates field mounting.

2. Connect starter auxiliary contacts, one normally open and one normally closed and also a relay contact (N.C.) to a chatter detector.

3. Connect 480 volts through disconnect switch and motor controller power contacts to 480V-6V transformer. Connect transformer output to strip chart recorder. Refer to the diagrams given in the Attachment.

Procedure:

1. Run three OBE tests with controller coils de-energized.

2. Run two OBE tests with controller coils energized.

3. Run one SSE test with controller coil de-energized.

4. Run one SSE test with controller coil energized. Repeat test for both high and low speeds on two speed starters.

5. Rotate equipment 90 degrees on table.

6. Repeat steps 1, 2, 3, and 4.

7. Verify equipment operability prior to placing in service.

10.3.14.5 Test Results:

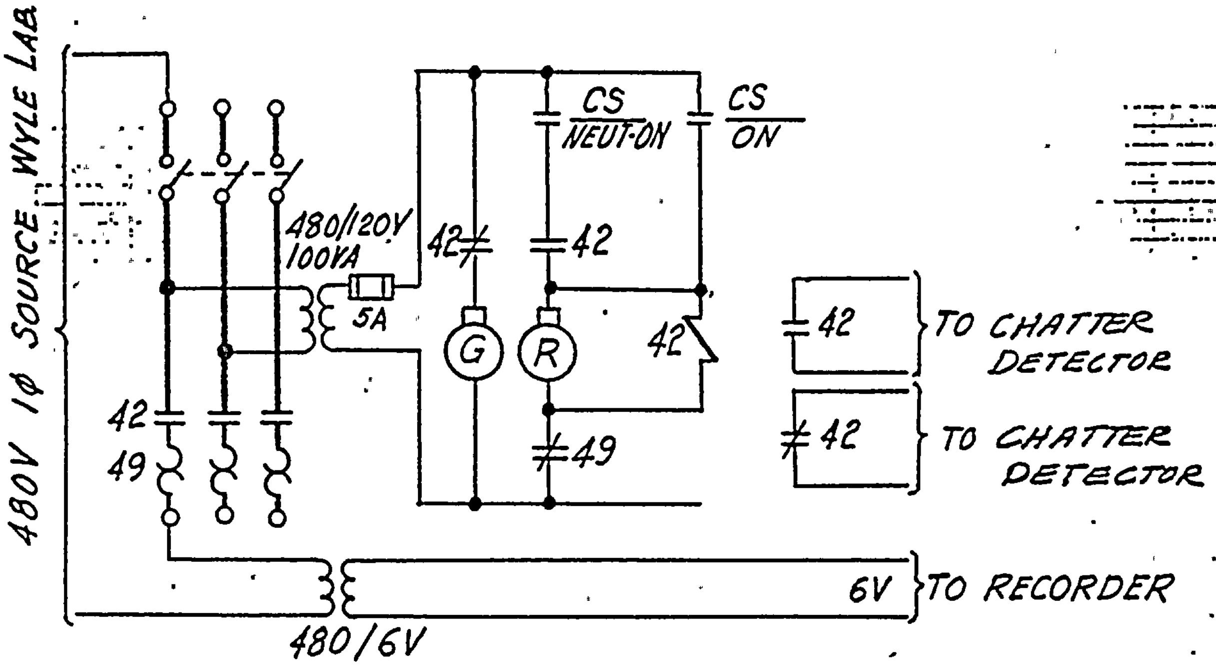
All local starters met the test criteria specified in section 10.3.14.3. No contact chatter or interruption was detected. All Test Response Spectra enveloped Required Response Spectra.

10.3.14.6 Conclusion:

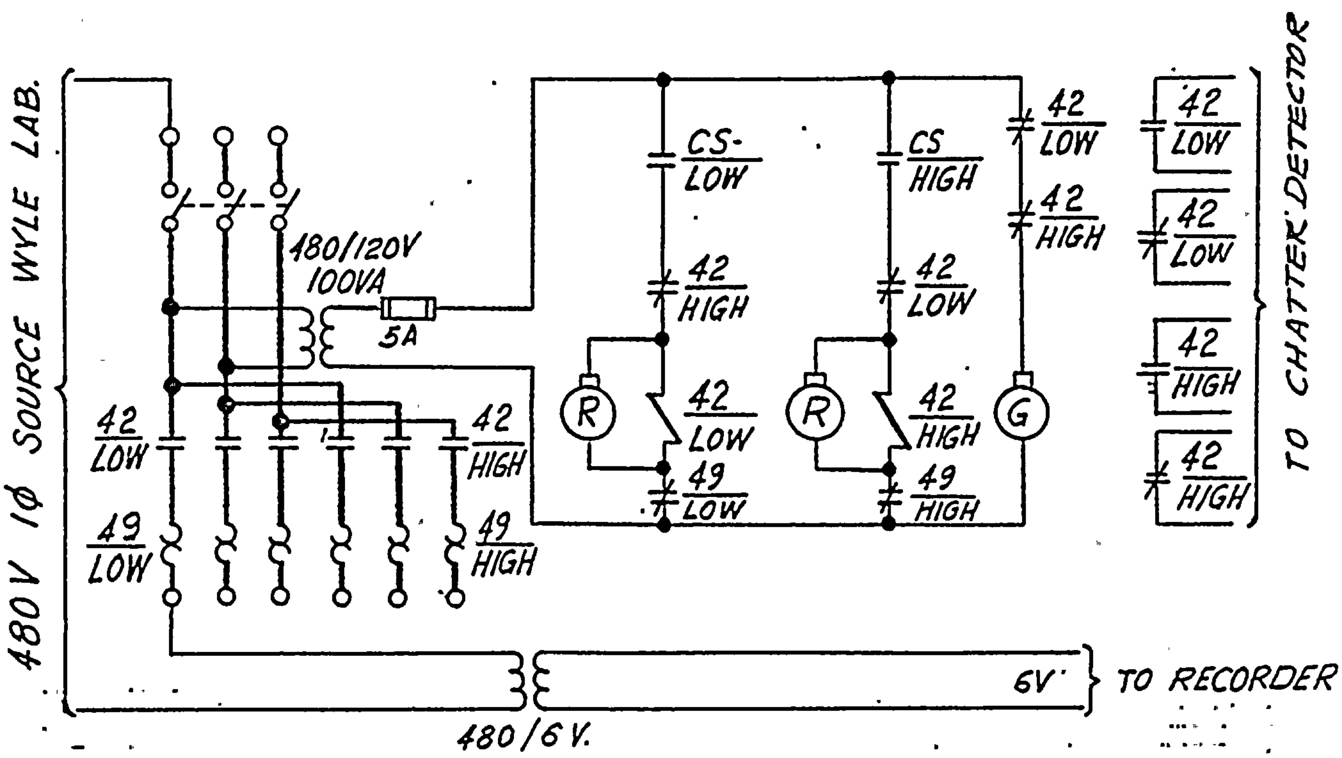
Representative local starters were tested by a multi-axis multi-frequency seismic simulation described in Wyle Report 58255.

Based on the equipment tested and the test procedure employed, these qualification tests bound the seismic requirements for all local starters.

The test results described above show that the test criteria and the equipment's safety function have been demonstrated during and after seismic testing to the RRS based on the postulated 7.4M Hosgri event. Thus it is concluded that the Diablo Canyon Unit 1 and 2 Vital Load Centers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.



FULL VOLTAGE NON REVERSING STARTER

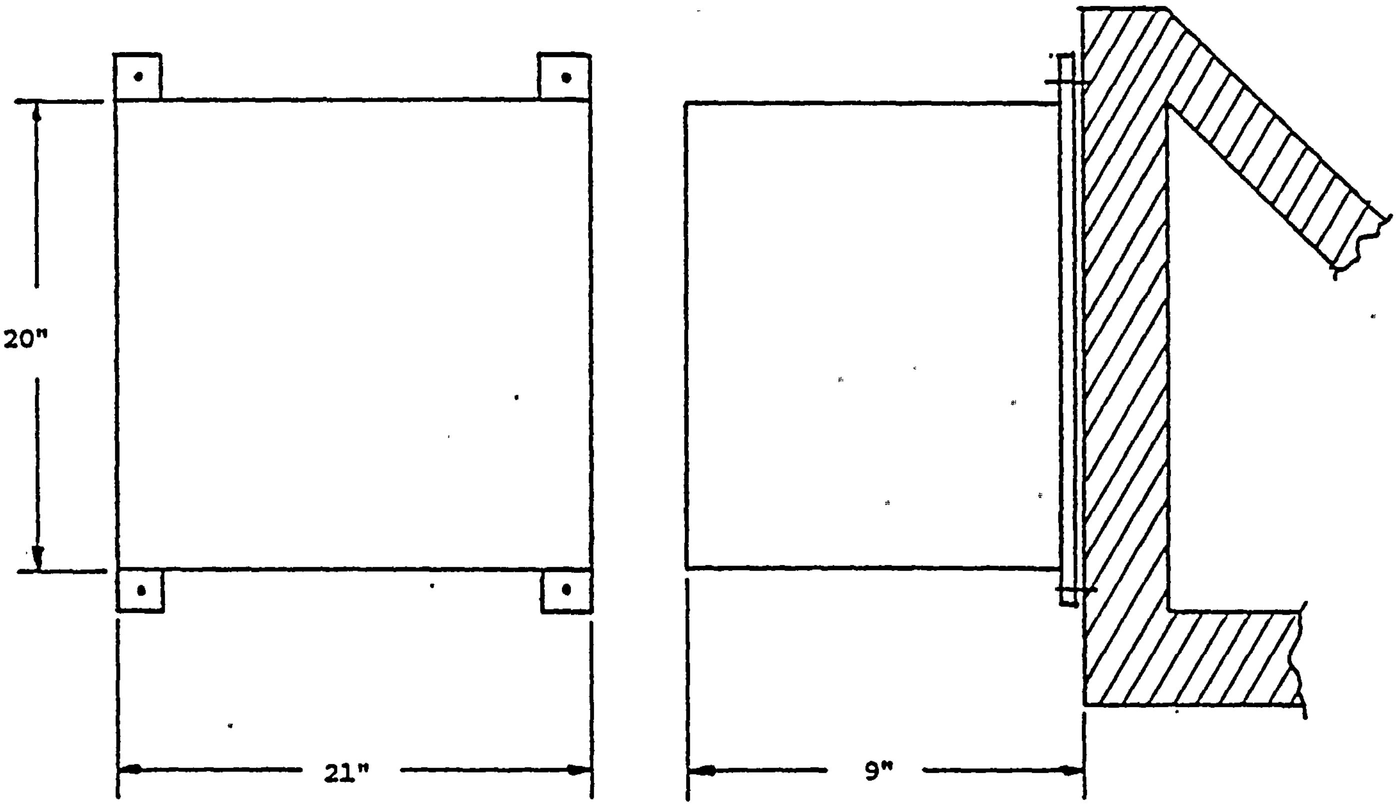


TWO SPEED STARTER

ATTACHMENT

FIGURE 23 B

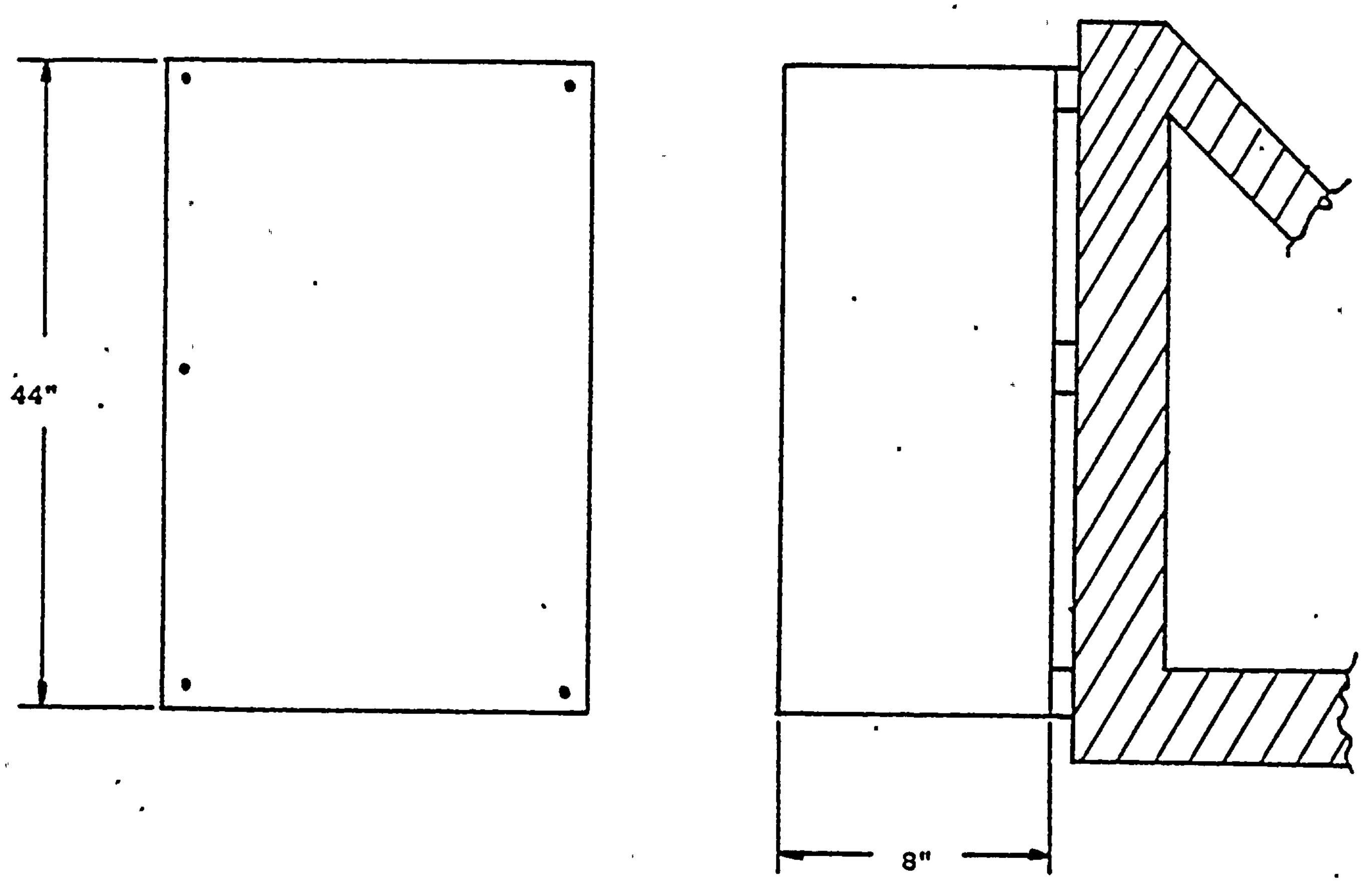
GROUP IV
LOCAL STARTER LPF37



Test specimen bolted to fixture B

FIGURE 30 B

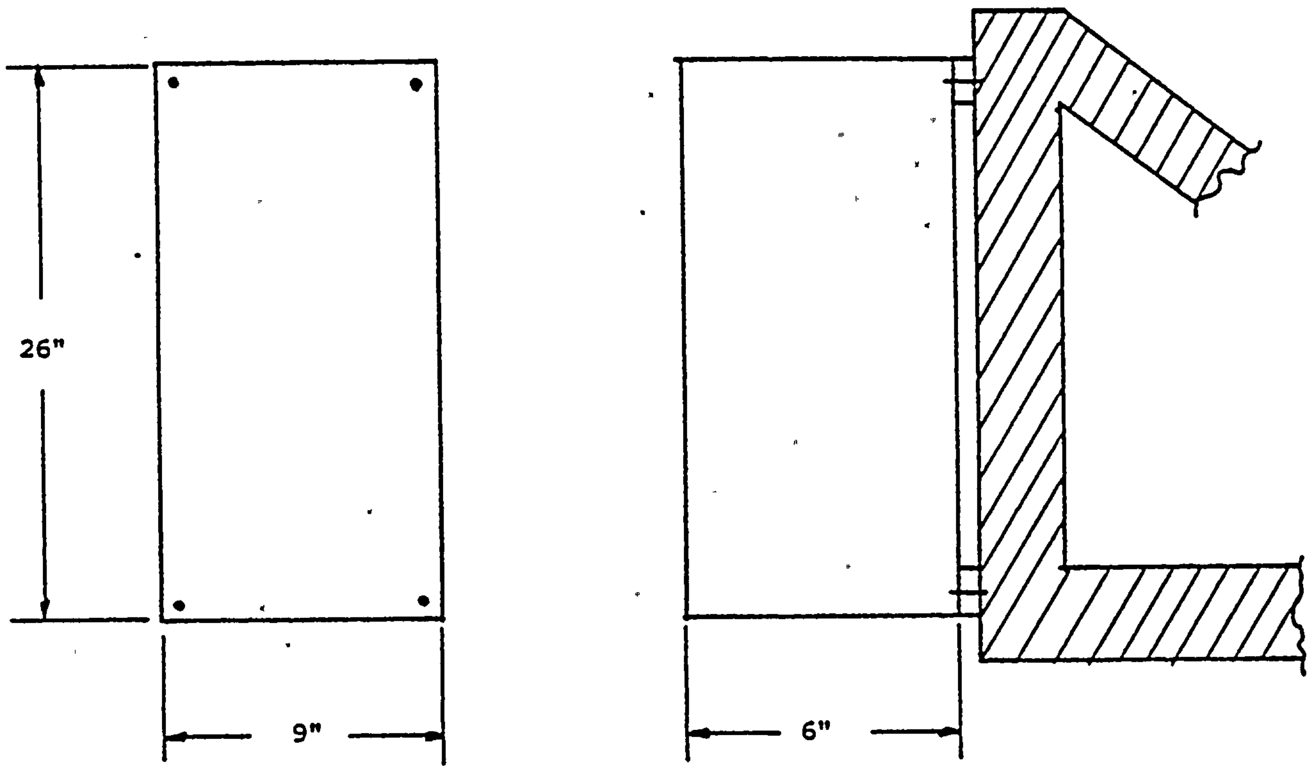
GROUP V
LOCAL STARTER LPG66



Five mounting bolts
Test specimen will be bolted to fixture. B

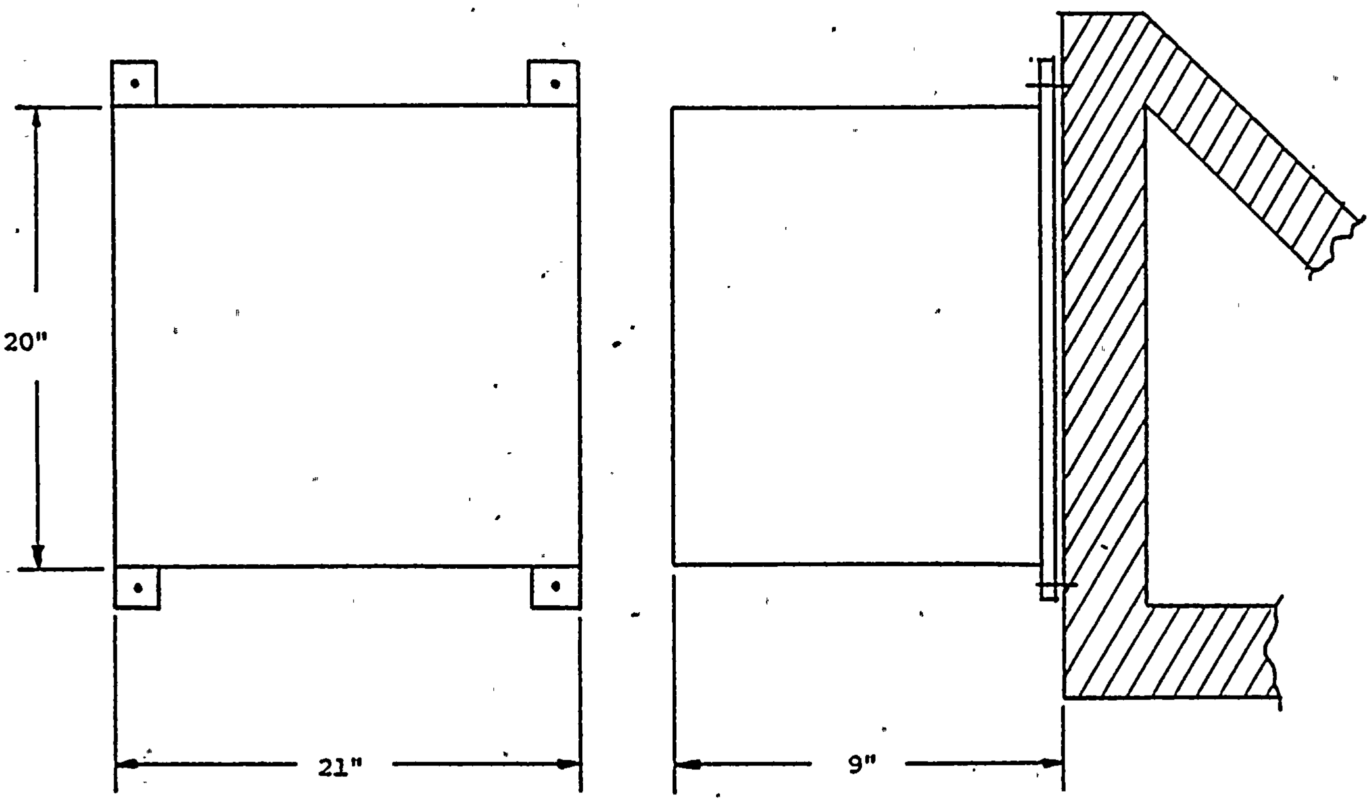
FIGURE 33 B

GROUP VI
LOCAL STARTER LPF36



Four mounting bolts
Fixture support only
near bolts.

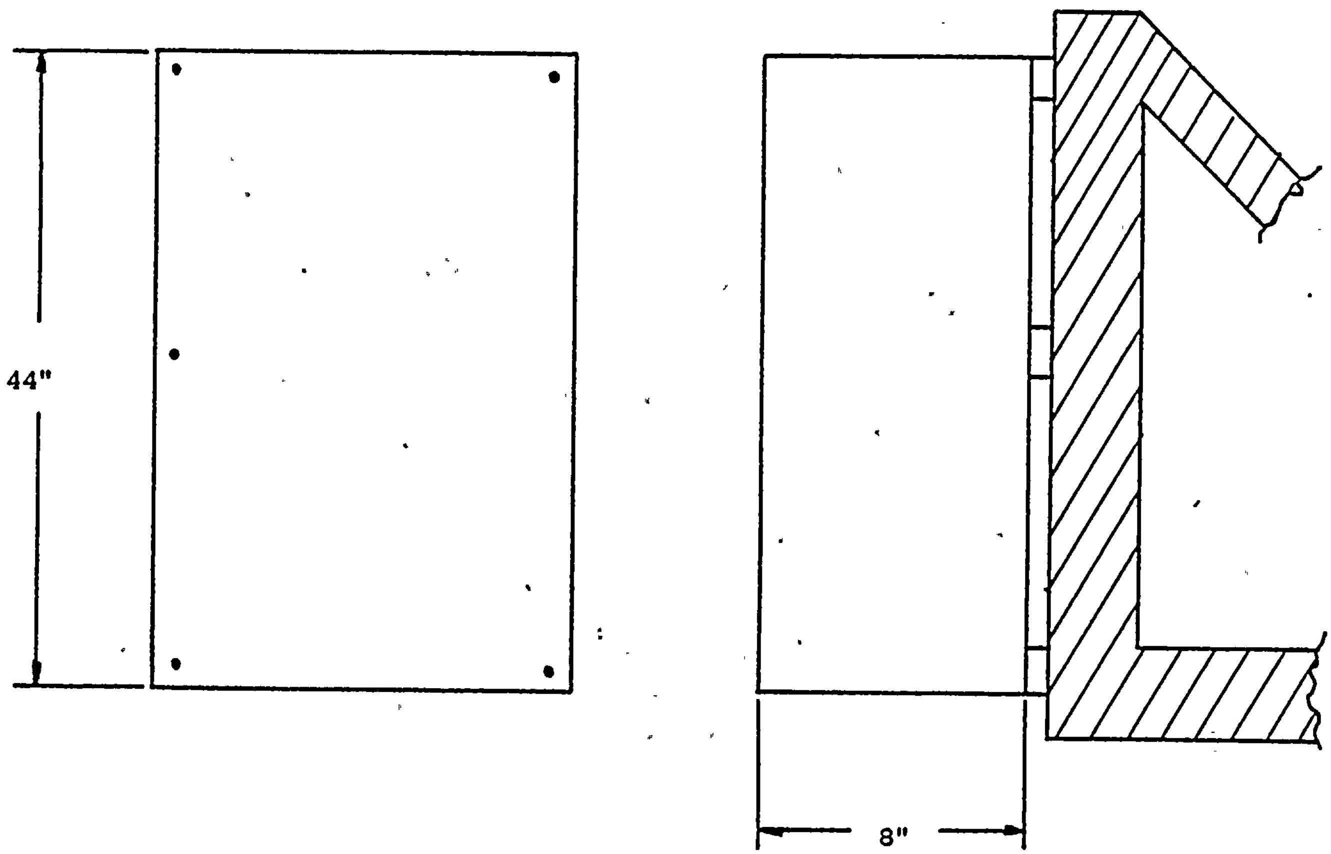
GROUP IV
LOCAL STARTER LPF37



Test specimen bolted to fixture

B

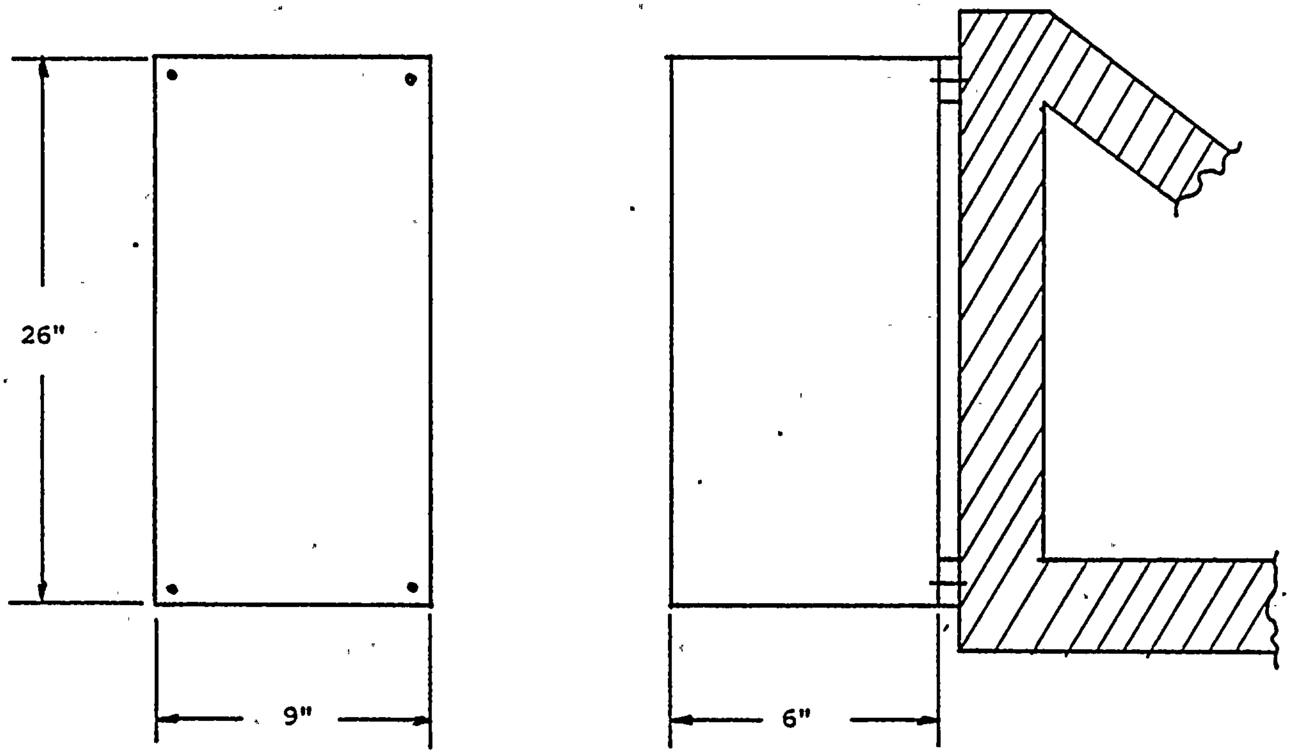
GROUP V
LOCAL STARTER LPG66



Five mounting bolts
Test specimen will be bolted to fixture.

B

GROUP VI
LOCAL STARTER LPF36



Four mounting bolts
Fixture support only
near bolts.

50-275/323
Memo 11-21-78
7811290400
To Stolz frm Allison
Diablo Canyon Informal Information
Encl 2

Two Copies Given CSB 11/8/78 Steam Line Break

November 8, 1978

DR. DONALD F. KNUTH
President

Mr. D.V. Kelly
Chief Nuclear & Mechanical Engineer
Pacific Gas & Electric Company
77 Beale Street
San Francisco, Cal. 94106

Dear Mr. Kelly:

In accordance with a request of PG&E, I have reviewed the environmental temperature conditions that identified instruments and equipment would be subjected to in the event of a steam break within containment. Since the Westinghouse calculations for the containment bulk environmental temperature and saturation conditions are incomplete, calculations made by the NRC for a typical containment were used as a basis for calculating temperatures. As indicated in the attached memorandum report the calculated instrument and equipment temperatures are less than what would be expected from a design basis loss-of-coolant accident; hence, I believe your qualification program provides adequate margin for steam line break accidents.

Sincerely,

Donald F. Knuth

Donald F. Knuth

encl.

RETURN TO REACTOR DOCKET FILES

KMC, Inc. 1747 PENNSYLVANIA AVENUE, N.W. WASHINGTON, D.C. 20006 202/223-3163

MEMORANDUM

TO: Pacific Gas & Electric DATE: November 7, 1978

FROM: Donald F. Knuth DFK

SUBJECT: Environmental Temperature Qualifications for Containment Instrumentation

In accordance with a request of PG&E I have reviewed the environmental conditions (mainly temperature) that identified instruments and equipment would be subject to in the event of a steam line break accident at Diablo Canyon. The instruments and equipment were identified in a letter from P.A. Crane, Jr. to John Stolz dated May 3, 1978. In addition, a visit was made to the Diablo Canyon site and the identified instruments and equipment as then installed within the containment were examined. As discussed with PG&E personnel (as well as NRC personnel), the protection that the instrument transmitters are afforded at the Diablo Canyon Units are quite unique, being greater than provided at most other reactor installations as a consequence of the protective cabinets in the design. Although the instrument cabinets were provided for other purposes, they do afford insulation from the general containment environment in the event of a super-heated steam environment.

As indicated in discussions with PG&E and NRC personnel, the design pressure, temperature conditions for a steam line break accident have not been completed as yet for the Diablo Canyon Units. Hence, for purposes of calculating the environmental temperatures of the instrument transmitters and equipment, parameters were taken from a typical NRC staff calculated containment atmosphere. The staff's calculational results were obtained from an internal memorandum dated February 24, 1978, "Containment Environmental Qualification Best Estimates Evaluation for Main Steam Line Break Analysis." The basic parameters as used are contained in a figure attached to this memorandum. The assumptions and a sample calculation are shown in a second attachment.

Using conservative heat transfer assumptions, I calculate that the peak surface temperature of the instrument transmitters would be less than the saturation temperatures resulting from a design basis LOCA; the peak temperature calculated was about 252°F. Using more realistic, best estimates, heat transfer coefficients would result in a peak temperature of about 230°F which is less than the saturation temperature of the steam environment. With regard to equipment in the containment the peak temperatures were calculated to be 262°F. We, therefore, believe that your qualification program for a design basis LOCA environment provides adequate margin for a steam line break temperature excursion.

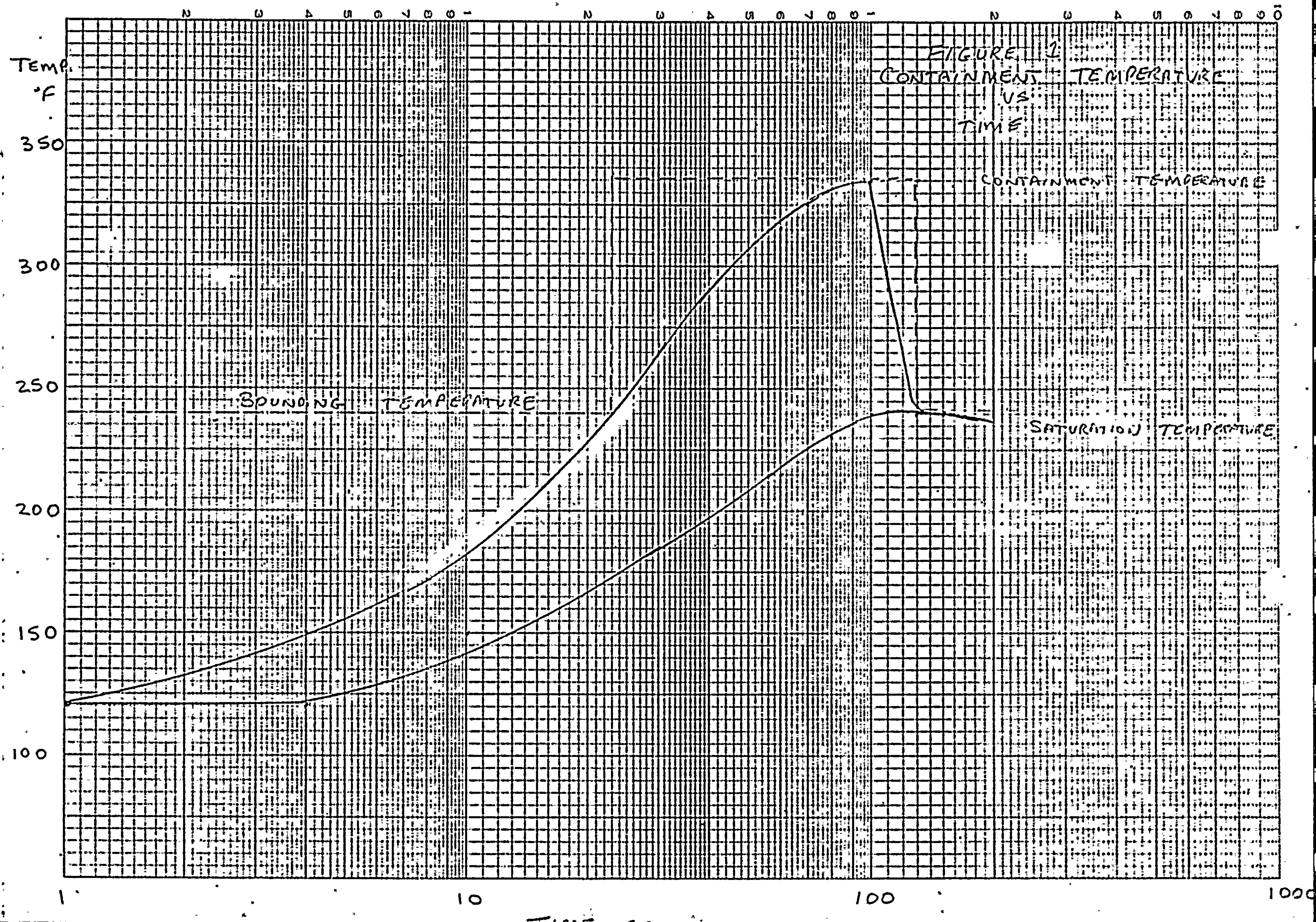


FIGURE 1
CONTAINMENT TEMPERATURE
VS
TIME
TEMP. °F
350
300
250
200
150
100
CONTAINMENT TEMPERATURE
BOUNDING TEMPERATURE
SATURATION TEMPERATURE
1
10
100
1000

Sample Temperature Calculations

Assumptions

1. Material is steel flat plate geometry
2. Use infinite thermal conductivity -- no insulation effect of paint
3. Instrument wall thickness of ¼ inch

Heat Balance

$$WC_p \frac{dT}{d\theta} = hA(T_C - T)$$

Where:

W = weight of instrument
C_p = specific heat
T = temperature
θ = time
h = convection heat transfer coefficient
A = heat transfer area

Subscripts:

C = temperature of containment atmosphere
sat = saturation temperature of steam
in = initial wall temperature

Referring to temperature response figure, it is assumed that the heat transfer process is in two distinct parts; that of steam condensing for the first 23 seconds followed by a heat up due to superheated steam in the second time period. In the first time period a high condensing heat transfer coefficient of 400 BTU/hr ft^2OF was assumed and in the second time period a high steam heat transfer coefficient of 5 BTU/hr ft^2OF was chosen

Performing calculation for 1 ft^2 area for first 23 seconds:

W = 10.4
C_p = 0.11
h = 400
T_{sat} = 240
T_{in} = 120

$$T_{23} = T_{sat} - (T_{sat} - T_{in})\, e^{-\frac{hA}{WC_p}\Theta}$$

$T_{23} = 227$

Or for ease of calculation it was assumed that at 23 seconds
$T_{23} = 240$

Calculating second time period to 130 seconds:

$h = 5$
$T_{in} = 240$
$T_c = 335$
and $T_{130} = 252$

Encl 3 50-275/323
7811290400
Memo to Stolz frm Allison
Memo dtd 11-21-78

DRAFT

RETURN TO REACTOR DOCKET FILES

Mr. John F. Stolz, Chief
Light Water Reactors Branch No. 1
Division of Project Management
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Re: Docket No. 50-275-OL
Docket No. 50-323-OL
Diablo Canyon Units 1 & 2

Dear Mr. Stolz:

Please refer to our letter of February 10, 1977 followed by our FSAR submittal dated July 5, 1977 relative to the subject of reactor vessel overpressure at low temperature. As mentioned therein, Pacific Gas and Electric Company participated in Westinghouse Electric Corporation's evaluation of this issue; the results of this analysis have previously been submitted on Docket 50-266. Based on this analysis, as a permanent solution, we propose to install a secondary setpoint into the power operated relief valve control system as described in Attachment I. As described in Attachment II, a secondary setpoint of 450 psi will be used for both units. While somewhat over conservative for Unit 2, the single setpoint based on the limiting Appendix G curve for Unit 1 (see Figure 6, Attachment II) is proposed at this time. Should this prove to be a significant burden to plant operation, Pacific Gas and Electric Company may subsequently request modification to this setpoint in the form of a Technical Specification Change.

Very truly yours,

Philip A. Crane, Jr.

JBHoch/PCA:TC

Attachments
cc w/attachment: Service List
bcc w/attachment: Diablo Distribution

DESCRIPTION OF WATER SOLID OVERPRESSURE PROTECTION SYSTEM

The Water Solid Overpressure Protection System consists of 2 mutually redundant control systems. Each system receives a reactor coolant pressure signal and a pressurizer level signal. When a water solid pressure excursion occurs, it opens a power operated relief valve until the pressure returns to within limits.

The following discussion applies to one system which controls one valve, PCV 456. The redundant system, which controls PCY 455C, is identical. The device cross reference table is given in Figure 1 on Sheet 2 of 2.

During normal operation, the system is off. Whenever the pressurizer level (LC 461C) exceeds 99% (actually the highest trippable level), it is assumed that there is no steam bubble in the pressurizer. Whenever this is the case, the operator enables the system by operating the enable switch (PCV 456/ES). If the pressurizer level does exceed 99% and the enable switch is not in the enable mode, an alarm will sound on the main annunciator. The auxiliary relay contacts for the pressurizer level (LC 461CX) are also installed in the trip circuit. This allows the operator to enable the circuit before the water solid condition is reached, when reactor coolant system pressure is still high. After the steam bubble collapses, the LC 461CX contacts will close and the system will be ready to trip without further operator action.

During startup, as soon as the steam bubble is formed, the trip circuit will be defeated by the LC 461CX contacts, and the operator can disable the system at a less hectic part of the start up sequence.

Whenever the system is enabled and pressurizer level exceeds 99%, a high pressure signal (above 450 psig) to PC 403C will trip it and the auxiliary relay PC 403CAX which will energize the solenoid valve SV 276. This will open the power operated relief valve (PORV) PCV 456 until the pressure drops below reset.

Other features of the system include:

1) An annunciator alarm from PC 403CAX when the system trips.

2) A blue light on the enable switch module which lights when the system trips.

3) A white light on the enable switch module which lights when the system is enabled.

4) An annunciator alarm when the isolation valve for the PORV is closed and the system is enabled.

5) A test provision which enables the entire system except that the actual final solenoid valve signal is defeated. This allows testing without fear of tripping the valve.

The system meets the following NRC staff criteria:

Criterion:

Operator Action: No credit can be taken for operator action for 10 minutes after the operator is aware of a transient.

Response:

Once the system is enabled, it will automatically trip if the system is water solid.

Criterion:

Single Failure: The system must be designed to relieve the pressure transient given a single failure in addition to the failure that initiated the pressure transient.

Response:

Two totally independent mutually redundant systems are provided.

Criterion:

Testability: The system must be testable on a periodic basis consistent with the system's employment.

Response:

Each system is fully testable. The entire system can be tested either on or off line.

Criterion:

Seismic and IEEE 279 Criteria: Ideally, the system should meet seismic Category I and IEEE 279 criteria. The basic objective is that the system should not be vulnerable to a common failure that would both initiate a pressure transient and disable the overpressure mitigating system. Such events as loss of instrument air and loss of offsite power must be considered.

Response:

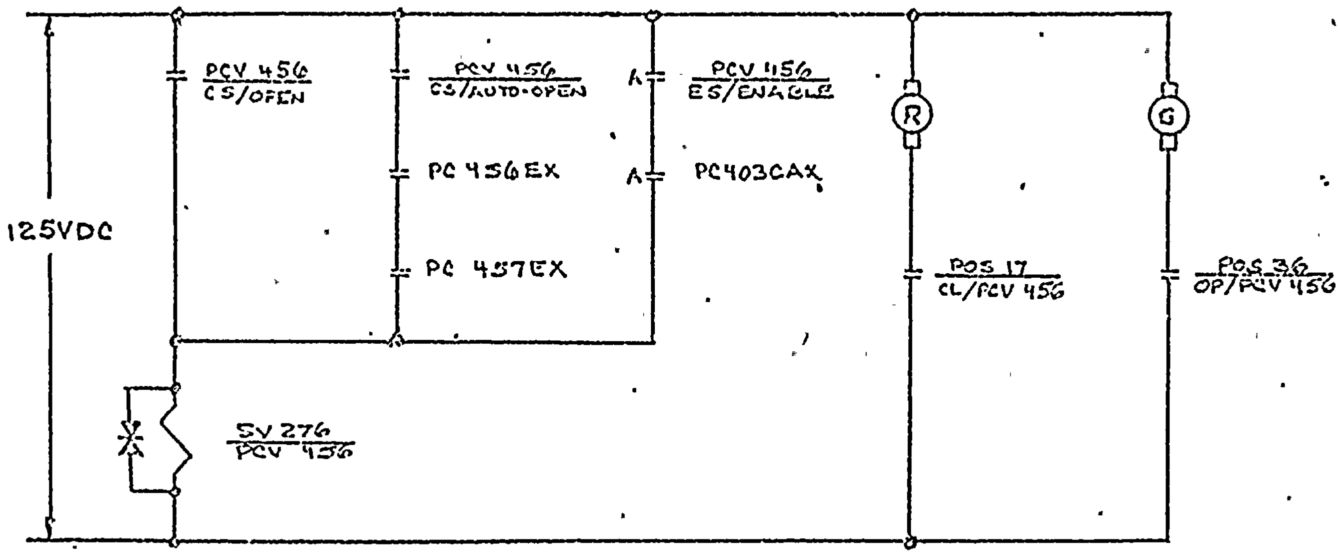
The systems are IEEE Class IE and are seismically qualified as part of the safeguards systems. Each system will be operated from a separate vital bus. Each system will have air accumulators isolated from the air header. These accumulators will have sufficient capacity to operate the valves if the air supply is lost.

Criterion:

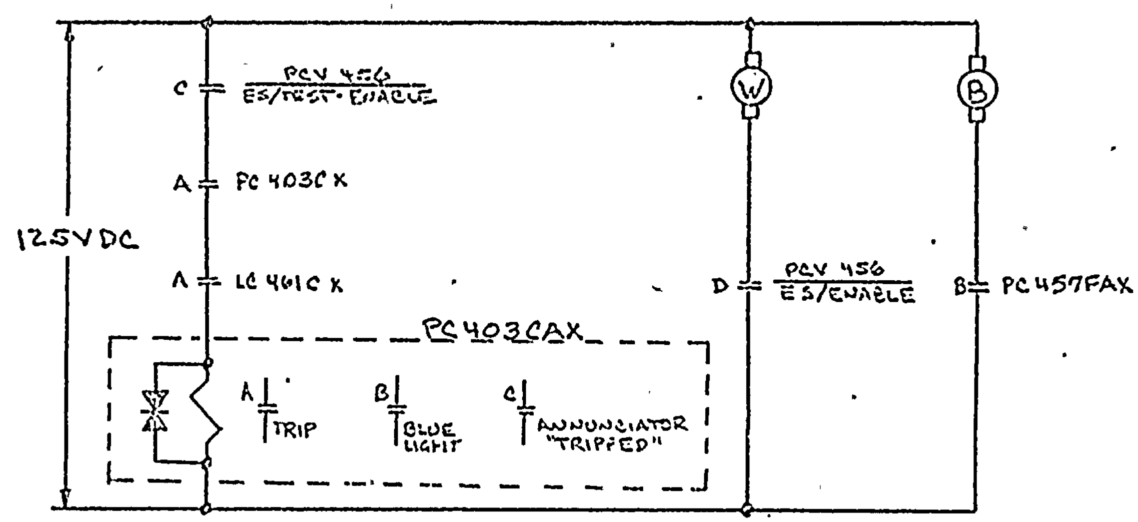
An alarm must be provided to monitor the position of the pressurizer relief valve isolation valves, along with the low set point enabling switch, to assure that the overpressure mitigating system is properly aligned for shutdown conditions.

Response:

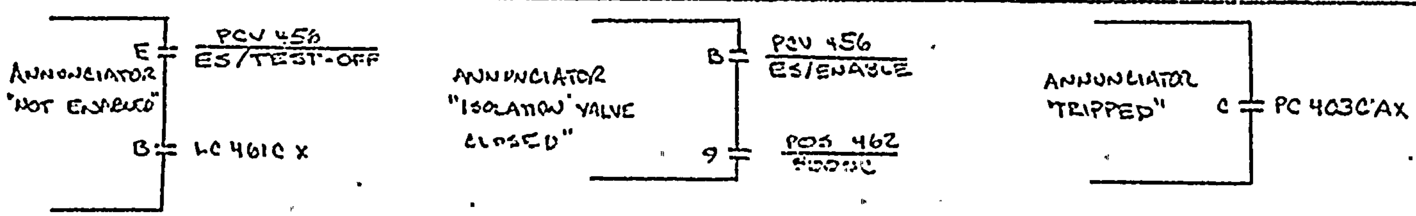
An alarm will be provided for each isolation valve. The alarm will sound when a system is enabled and its isolation valve is not fully open.



CONTROL CIRCUIT - PCV 456



WATER SOLID TRIP CIRCUIT - PCV 456

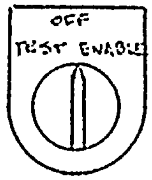


ANNUNCIATOR INPUTS

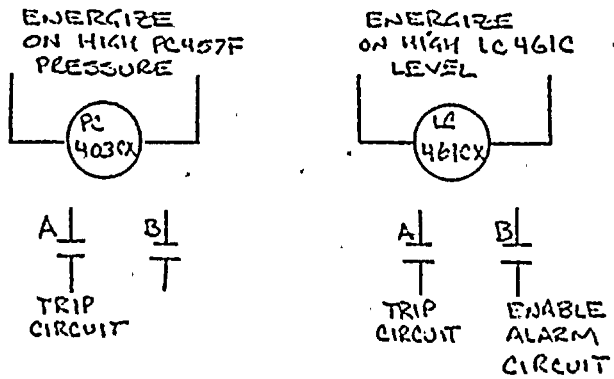
FIGURE 1 PCV 456 OVERPRESSURE PROTECTION SYSTEM CONTROL SCHEMATICS

(PCV 455C SIMILAR EXCEPT AS SHOWN IN TABLE ON SHT 2)

CONTACTS	POSITION TEST	OFF	ENABLE
A			X
B			X
C	X		X
D			X
E	X	X	



ENABLE SWITCH PCV 455C ES PCV 456 ES
NO SPRING RETURN



AUXILIARY RELAYS

CROSS REFERENCE TABLE

Power Operated Relief Valve	PCV 456	PCV 455C
Pressurizer Level Comparator	LC 461C	LC 459G
Pressurizer Level Auxiliary Relay	LC 461CX	LC 459GX
Enable Switch	PCV 456 ES	PCV 455C ES
Reactor Coolant Pressure Comparator	PC 403C	PC 405C
Reactor Coolant Pressure Auxiliary Relay	PC 403CX	PC 405CX
Trip Relay	PC 403CAX	PC 405CAX
Solenoid Valve	SV 276	SV 455C
Isolation Valve	8000C	8000A
Isolation Valve Position Switch	POS 462	POS 445
Valve Open Position Switch	POS 36	POS 35
Valve Closed Position Switch	POS 17	POS 16
Normal Trip Auxiliary Relay	PC 456EX	PC 455EX
Normal Interlock Auxiliary Relay	PC 457EX	PC 474EX

FIGURE 1 PCV 456 OVER PRESSURE PROTECTION SYSTEM CONTROL SCHEMATICS (PCV 455C SIMILAR EXCEPT AS SHOWN IN TABLE)

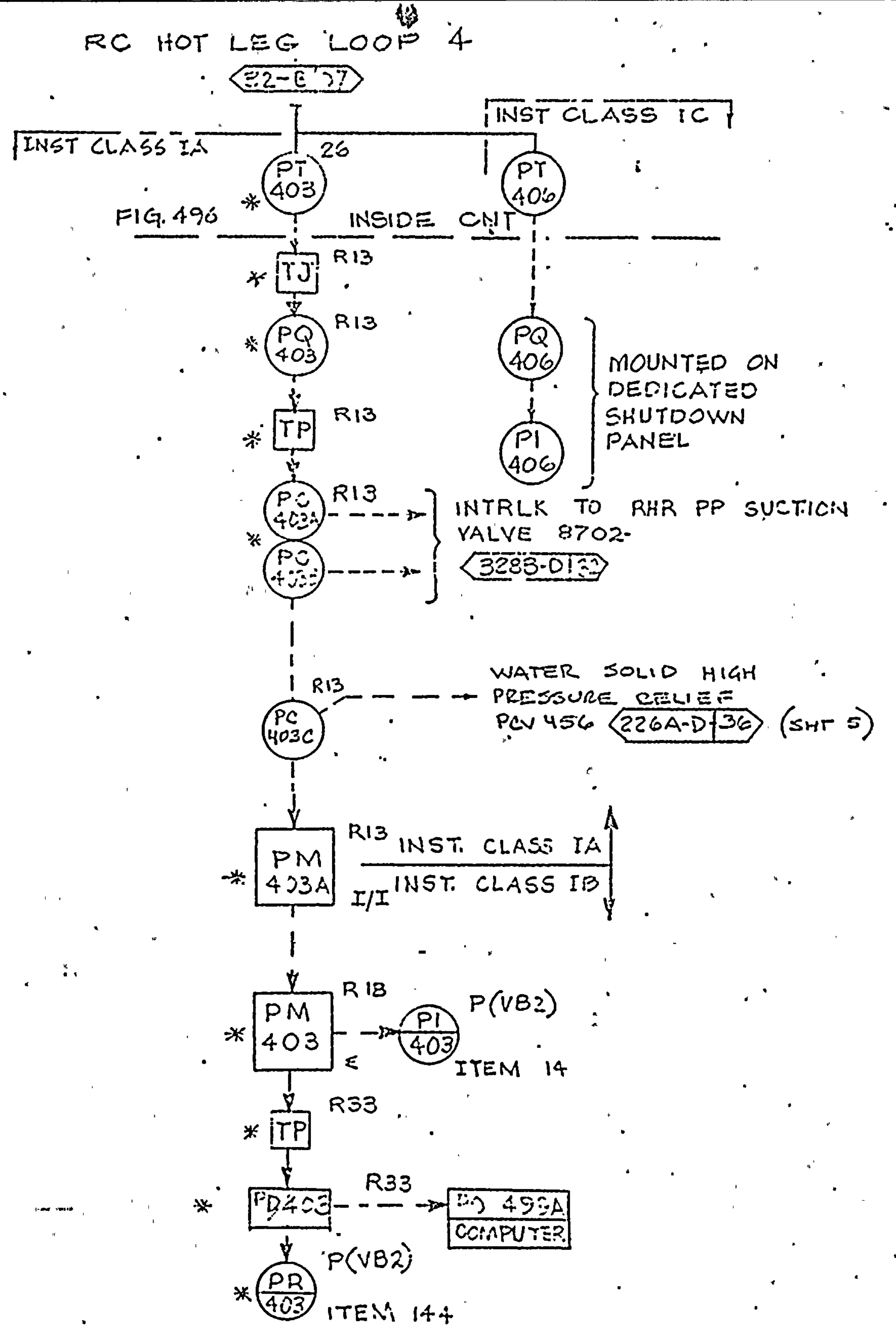


FIGURE 2 LOOP BLOCK DIAGRAMS
OVERPRESSURE PROTECTION SYSTEM

SHEET 1 OF 6
(CONTROL TO PCV 456)

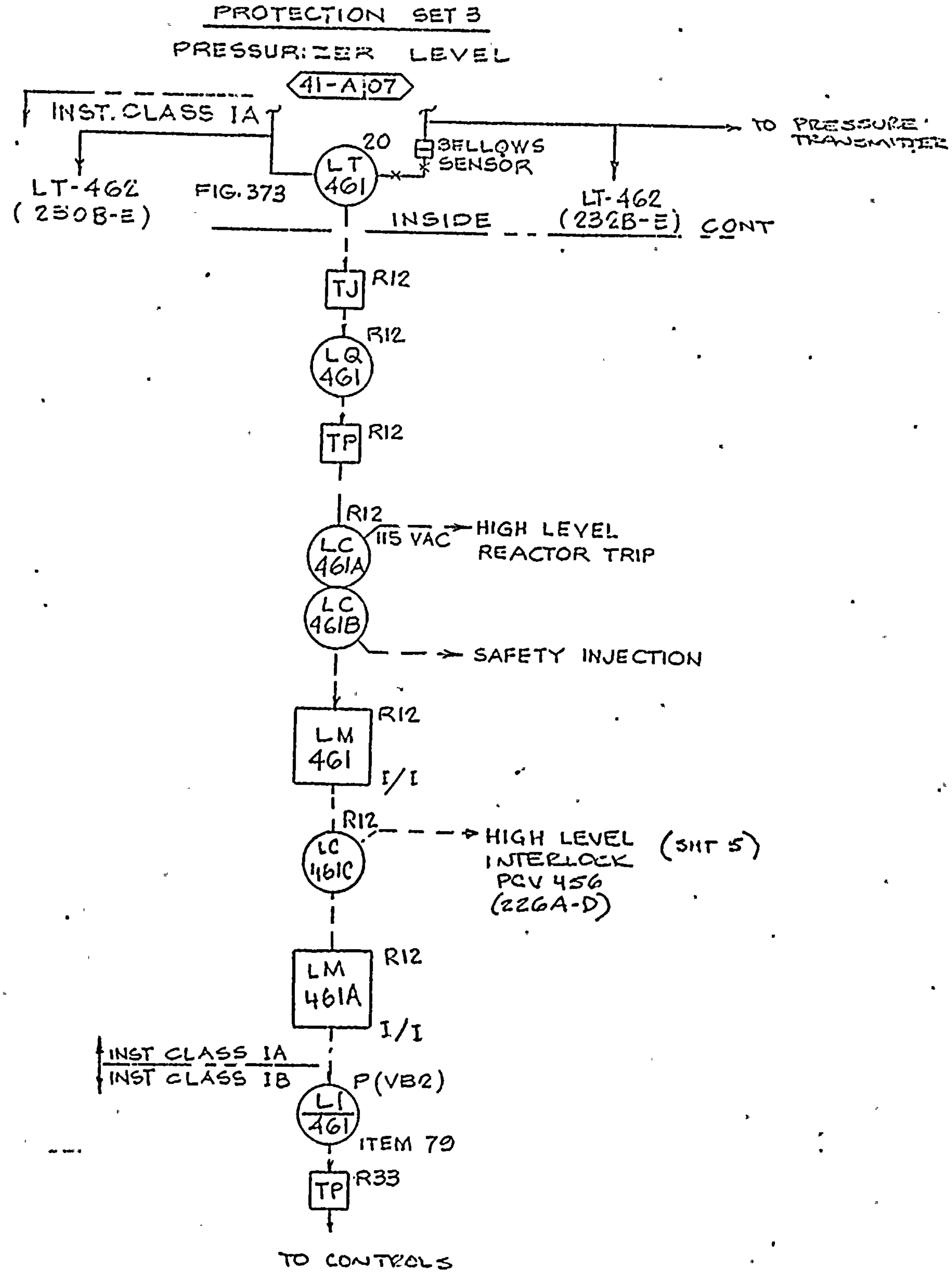


FIGURE 2 LOOP BLOCK DIAGRAMS
OVERPRESSURE PROTECTION SYSTEM

SHEET 2 OF 6
(CONTROL TO PCV 456)

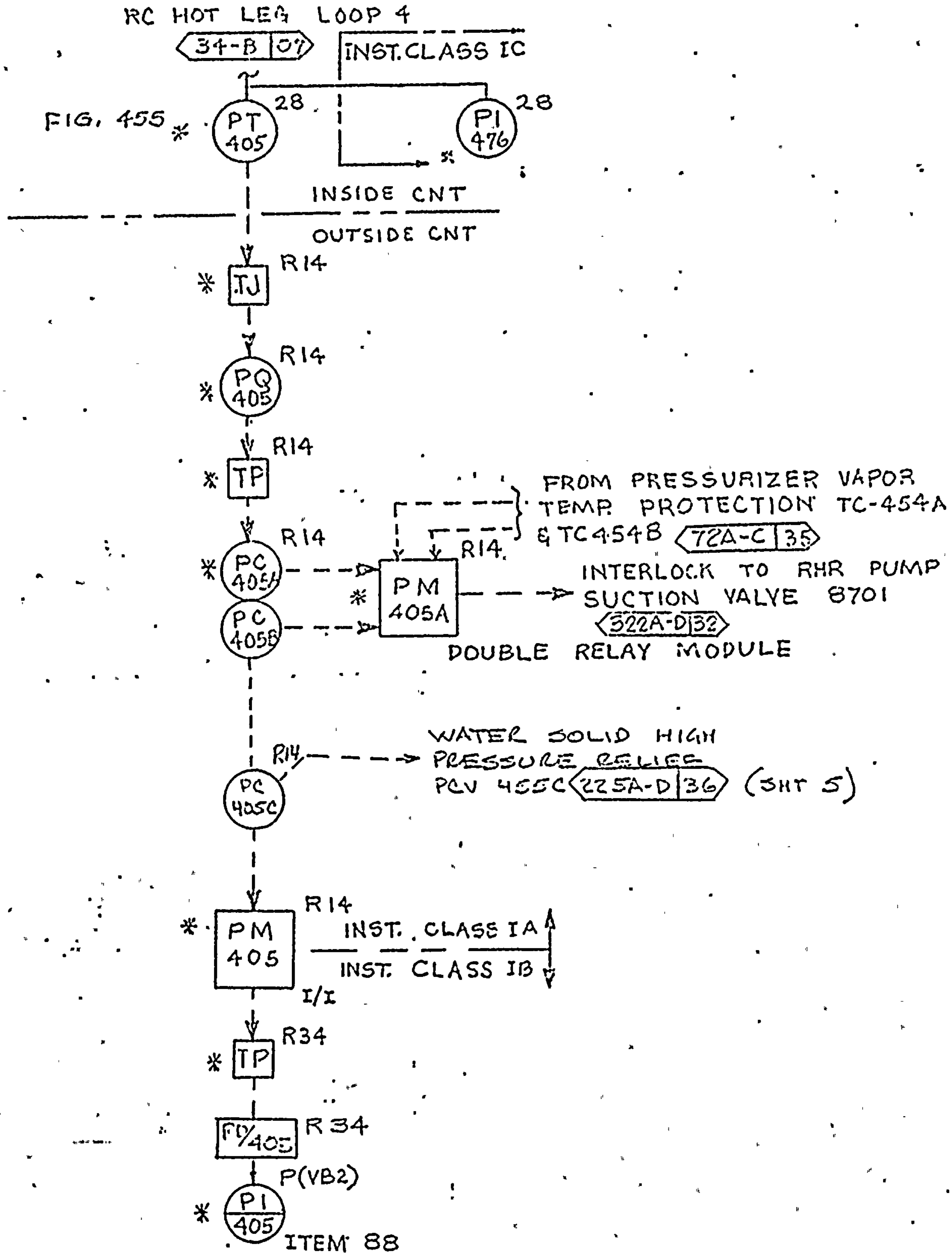


FIGURE 2 LOOP BLOCK DIAGRAMS
OVERPRESSURE PROTECTION SYSTEM

SHEET 3 OF 6
(CONTROL TO PCV455C)

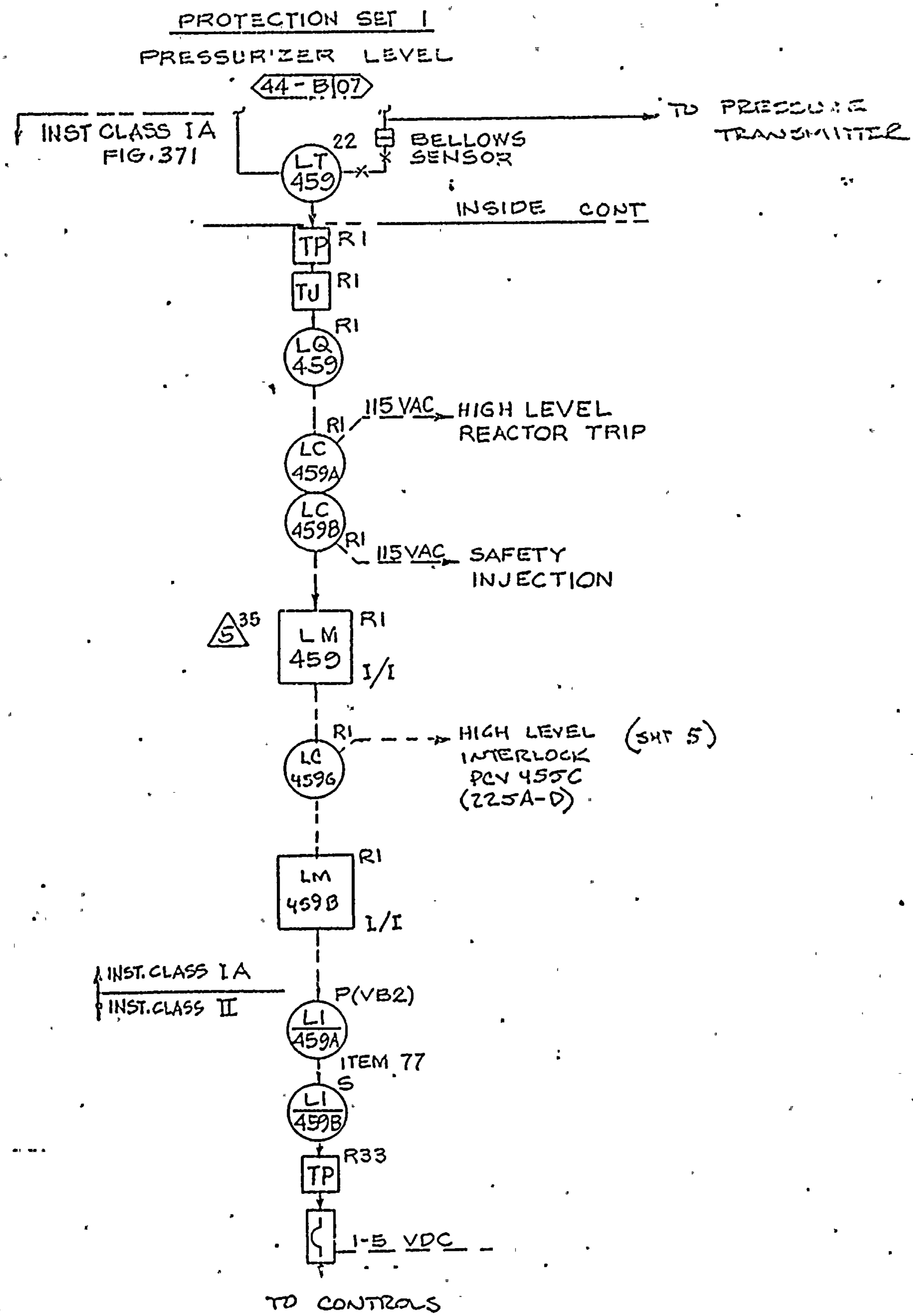
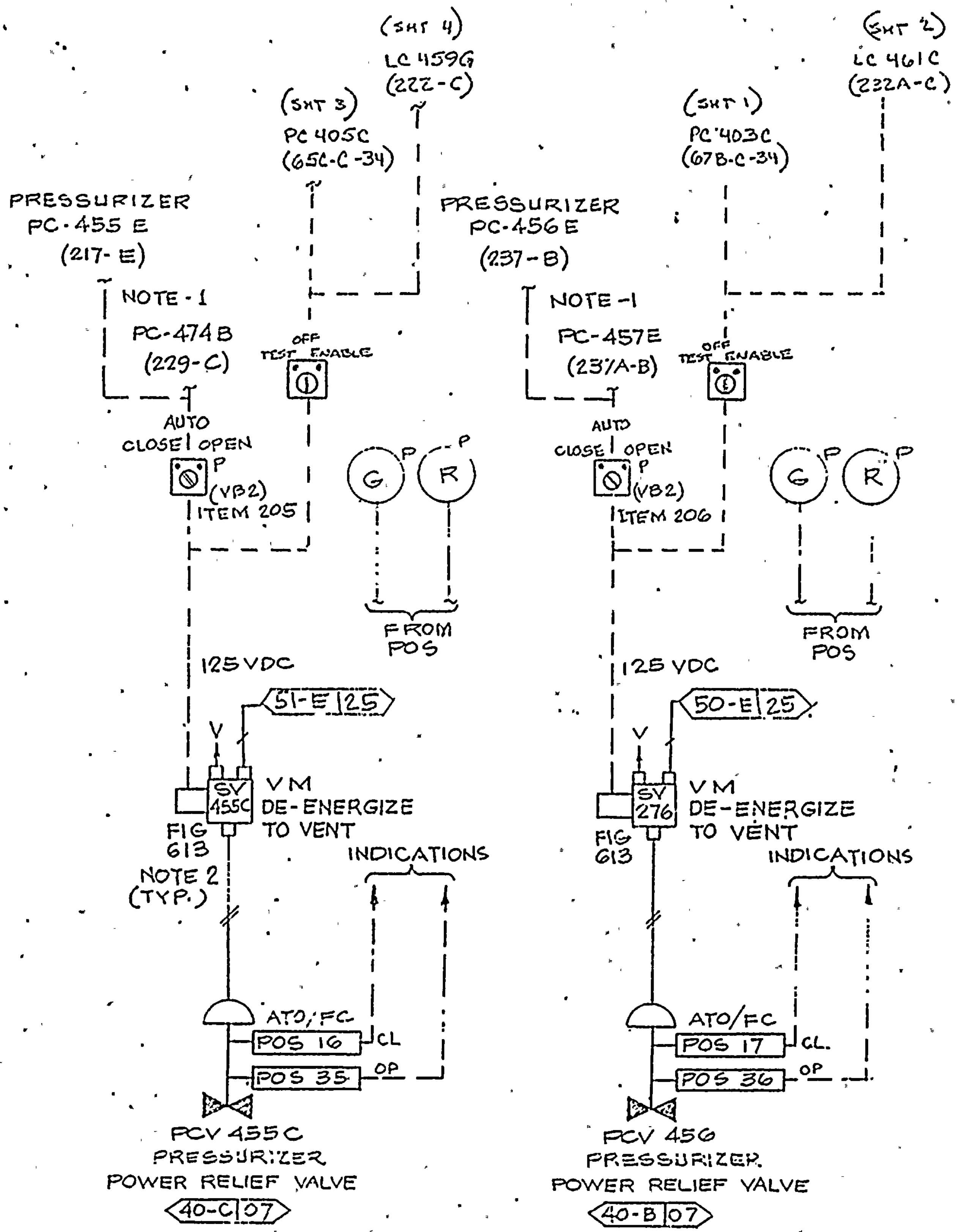


FIGURE 2 LOOP BLOCK DIAGRAMS
OVERPRESSURE PROTECTION SYSTEM

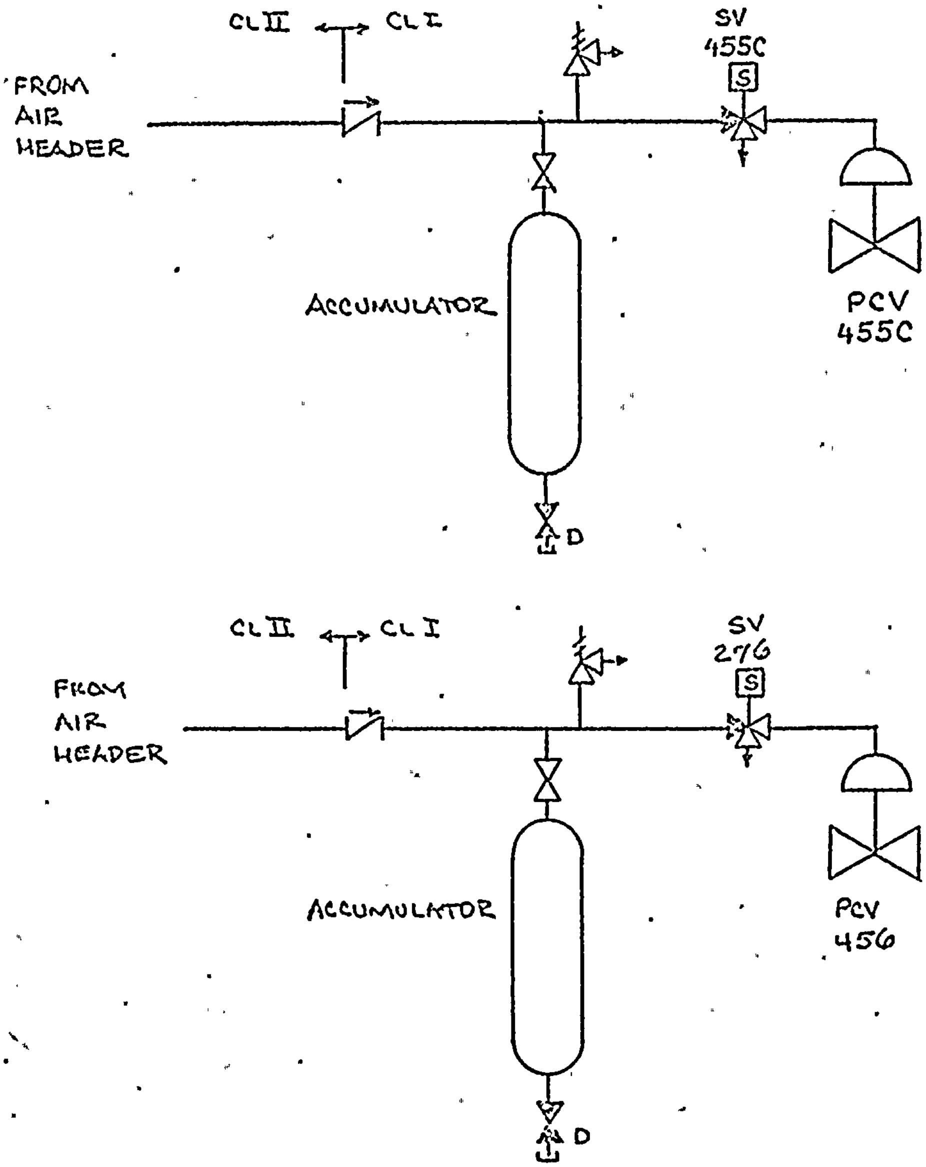
SHEET 4 OF 6
(CONTROL TO PCV 455C)



NOTES:

1- PRESSURIZER PC CONTACTS ARE IN SERIES THROUGH AUX. RELAY RACK.
2- SEE INSTRUMENT AIR PIPING REQUIREMENTS DWG # 049096, (SPECIAL AIR REQ'T) (SHEET 6)

FIGURE 2 LOOP BLOCK DIAGRAMS
OVERPRESSURE PROTECTION SYSTEM



AIR SUPPLY TO PORV'S

FIGURE 2 LOOP BLOCK DIAGRAMS
OVERPRESSURE PROTECTION SYSTEM

SHT 6 OF 6

ATTACHMENT II

DETERMINATION OF OVERPRESSURE PROTECTION SETPOINT

The following analysis is the plant specific calculations for Units I & II Diablo Canyon Site performed in accordance with Reference 1. This analysis follows the procedure set out in Reference 1.

The mass input model is controlled by the safety injection pump startup case over the reactor coolant pressure range of 400 to 600 psig.

Using an assumed setpoint of 450 psig and using the data obtained in Figures 2-5, the mass point overshoot is as follows:

$$\Delta P = \Delta P_{ret} \times F_u \times F_x \times F_2 = 108 \times 0.518 \times 1.20 \times .60 \doteq 39.2 \text{ psi}$$

Since the Appendix G limit for Unit 1 is 500 psig (see Figure 6) the appropriate lower setpoint of the pressurizer power operated relief valves on Unit 1 is 450 psig.

Also using the alogrithms of Reference 1, calculations for the Heat Input Case were made. At 100^{o}F, the transient associated with a 50^{o}F ΔT temperature mismatch is on 24 psi compared with 40 psi calculated for the Mass Input Case, therefore, the 450 psi setpoint is appropriate.

Reference 1:

Pressure Mitigating Systems Transient Analysis Results Prepared By Westinghouse Electric Corporation for the Westinghouse Owners' Group originally submitted on Docket 50-266.

PACIFIC GAS AND ELECTRIC COMPANY

Figure 1

GENERAL COMPUTATION SHEET

JOB / FILE NO. 450 ...

LOCATION

SUBJECT Figure 4.2.1 from Reference I reproduced

MADE BY | DATE | CHECKED BY | APPROVED BY

Fig I

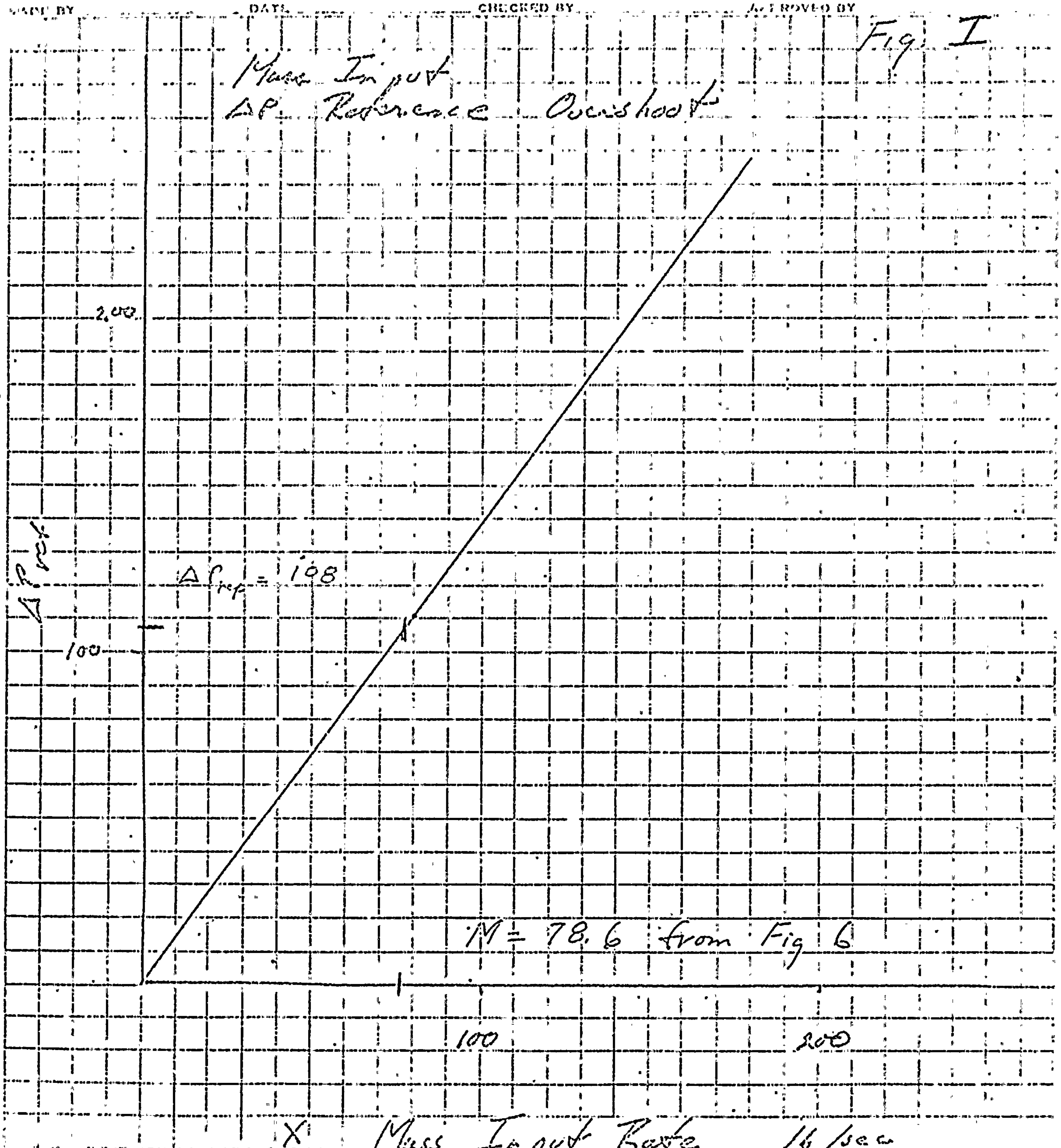
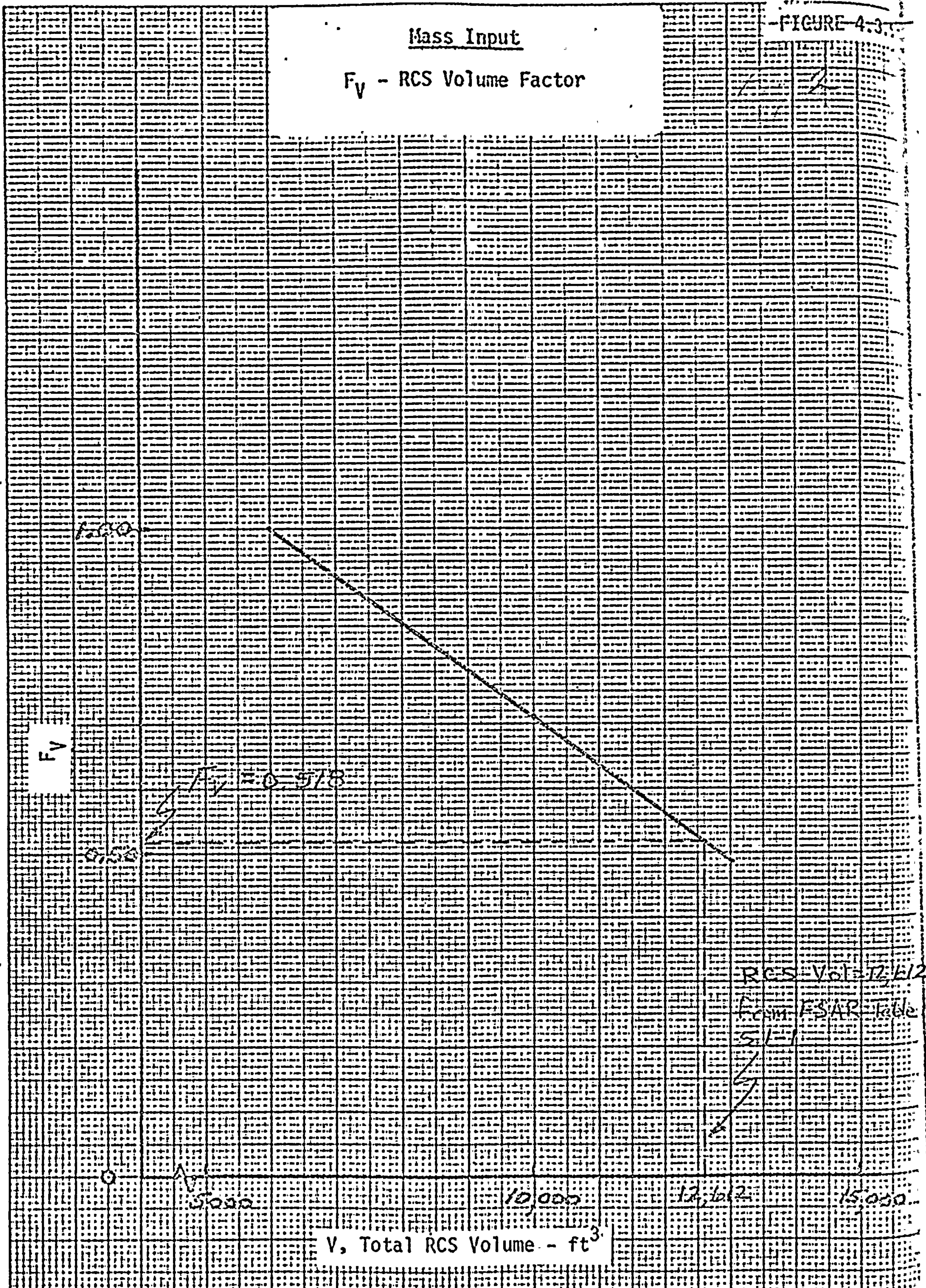


Figure 2

FIGURE 4.3



46 1320

K&E 10 X 10 TO 1/2 INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 3

FIGURE 4.3.7

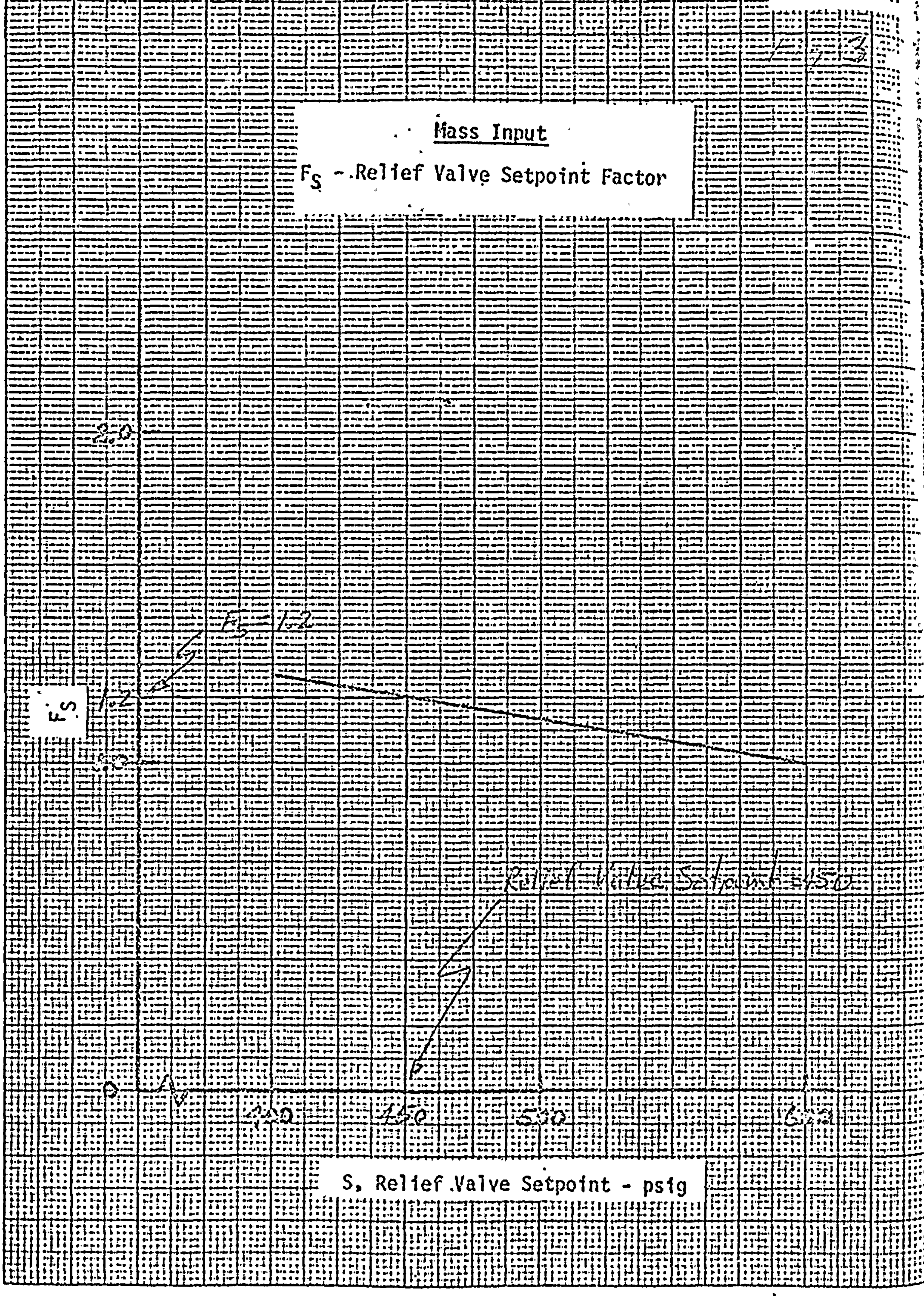


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Figure 4

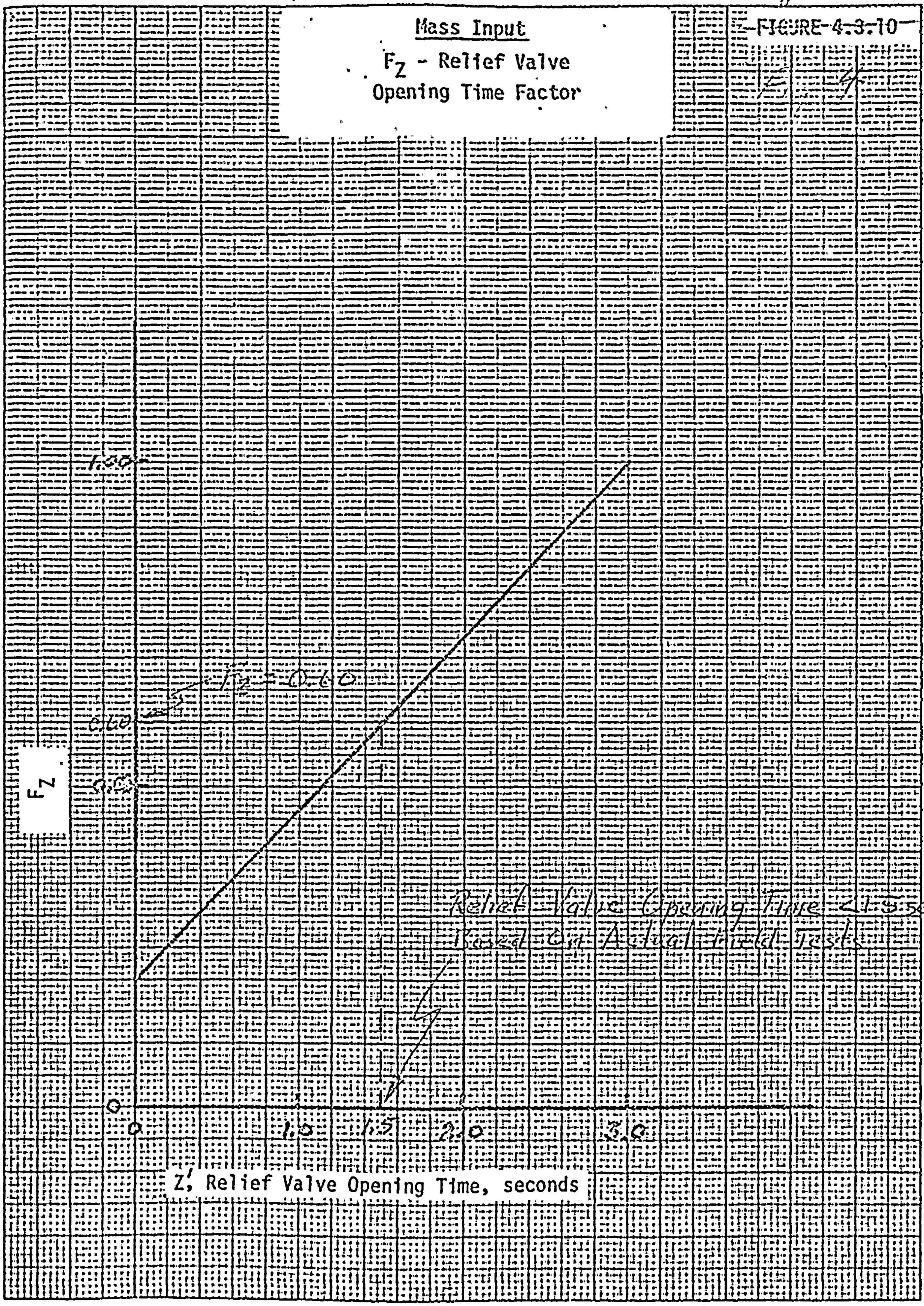
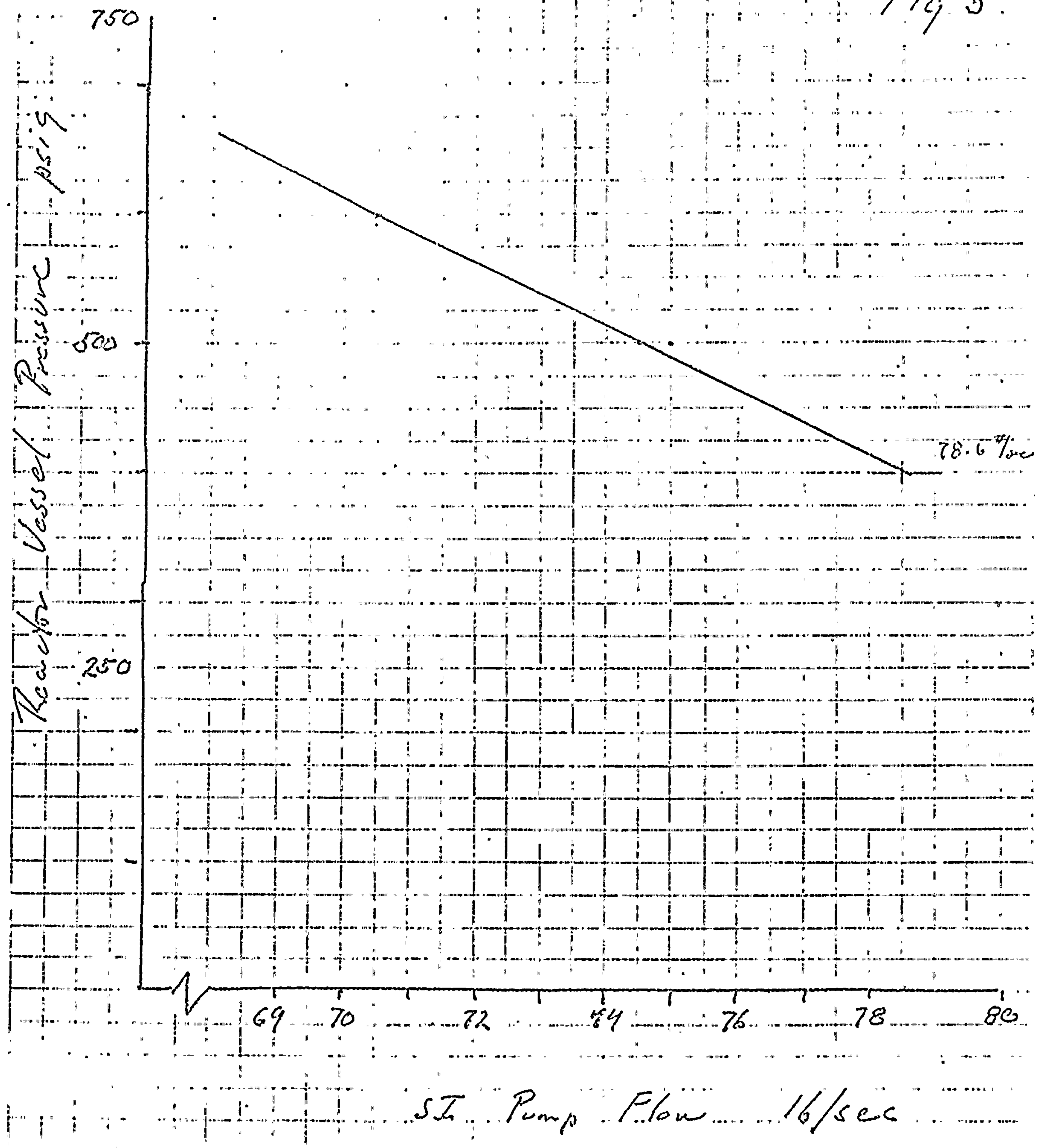


Figure 5

GENERAL COMPUTATION SHEET

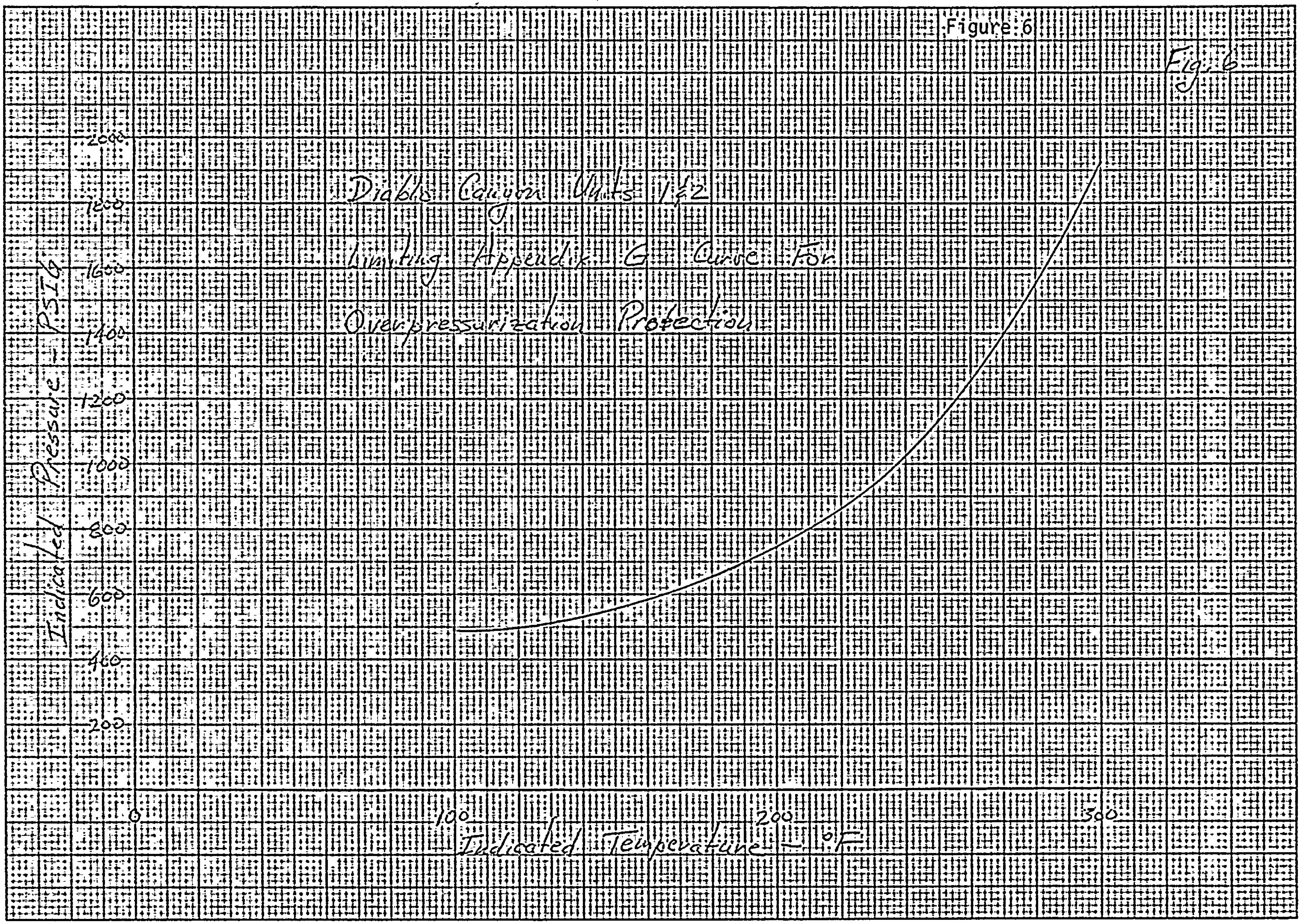
S.I. Pump Flow vers System Pressure in the range of interest

Fig 5.



K&E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320

Figure 6



CALCULATION OF HEAT INPUT TRANSIENT ΔP_{RCS} FOR DIABLO CANYON UNITS FOR AN RCS PUMP STARTUP

Table 1

	100°F	140°F	180°F	250°
ΔP6K from Figure 7 (psi)	31	62	98	156
ΔP13K from Figure 7 (psi)	27	49	68	118
UA6K from Figure 8	0.082	0.10	0.114	0.138
UA13K from Figure 9	0.130	0.16	0.19	0.226
UA'6K = UA6K x 51,000 ft.²/58,000 ft.²	0.072	0.098	0.10	0.121
UA'13K = UA13K x 51,000 ft.²/58,000 ft.²	0.114	0.141	0.167	0.199
ΔP'6K from Figure 10 (psi)	26	54	85	136
ΔP'13K from Figure 11 (psi)	24	44	62	105
ΔP'12.6K*	24.1	44.6	63.3	108.3

$$* \quad \Delta P'_{VRCS} = \Delta P'6K \quad \frac{VRCS - 6000}{7000} \quad (\Delta P'6K - \Delta P'13K)$$

Where V_{RCS} = 12,612 from Figure 2

$$\Delta P'12.6K = \Delta P'6K \quad \left(\frac{12,612-6000}{7000}\right) \quad (\Delta P'6K - \Delta P'13K))$$

FIGURE 4.2.9

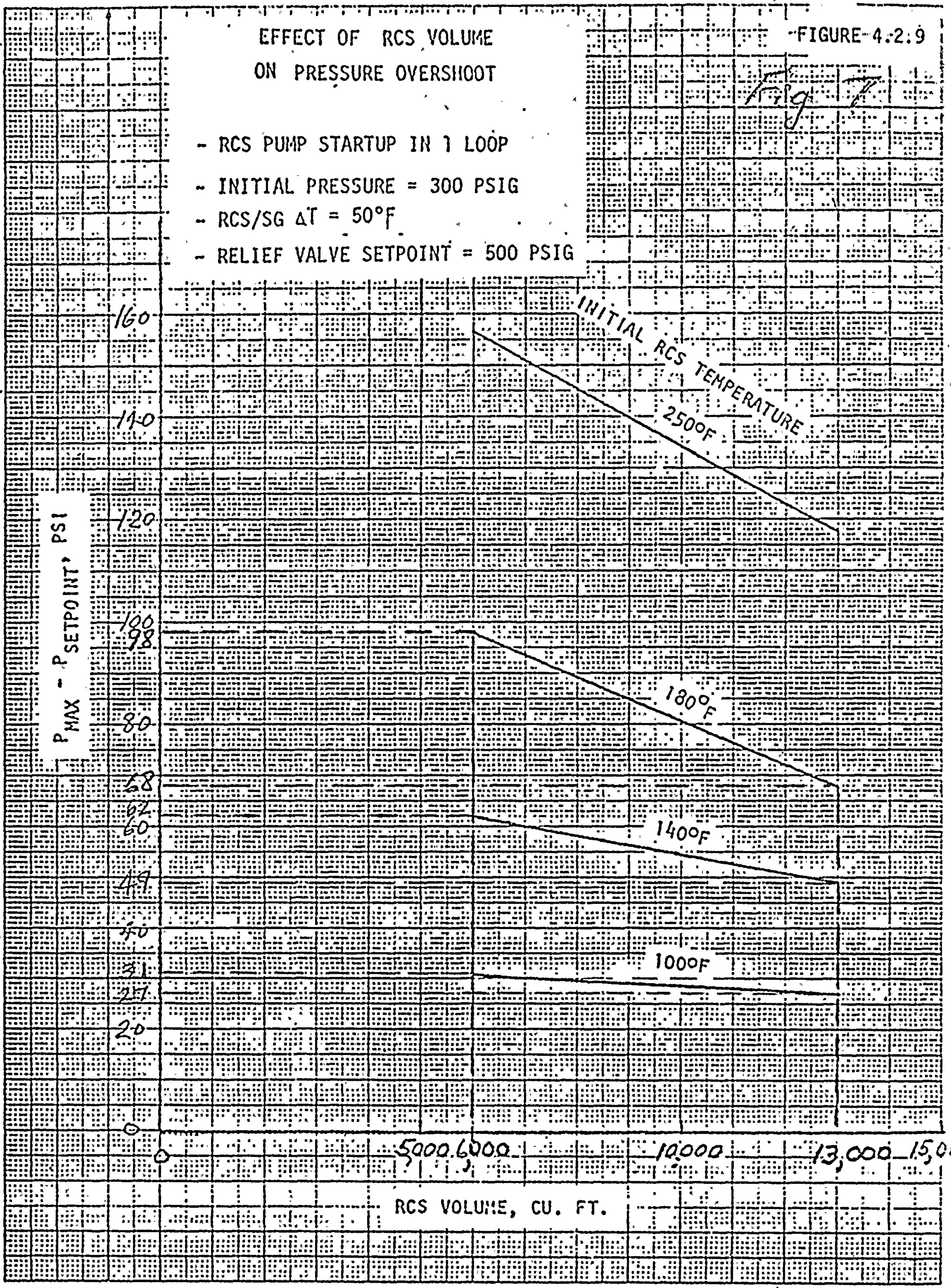

EFFECT OF RCS VOLUME
ON PRESSURE OVERSHOOT
- RCS PUMP STARTUP IN 1 LOOP
- INITIAL PRESSURE = 300 PSIG
- RCS/SG ΔT = 50°F
- RELIEF VALVE SETPOINT = 500 PSIG
Fig 7
INITIAL RCS TEMPERATURE
250°F
180°F
140°F
100°F
P MAX - P SETPOINT, PSI
160
140
120
100
98
80
68
62
60
49
40
31
27
20
0
0
5000
6000
10,000
13,000
15,000
RCS VOLUME, CU. FT.

Figure 8

~~FIGURE 4.2.7~~

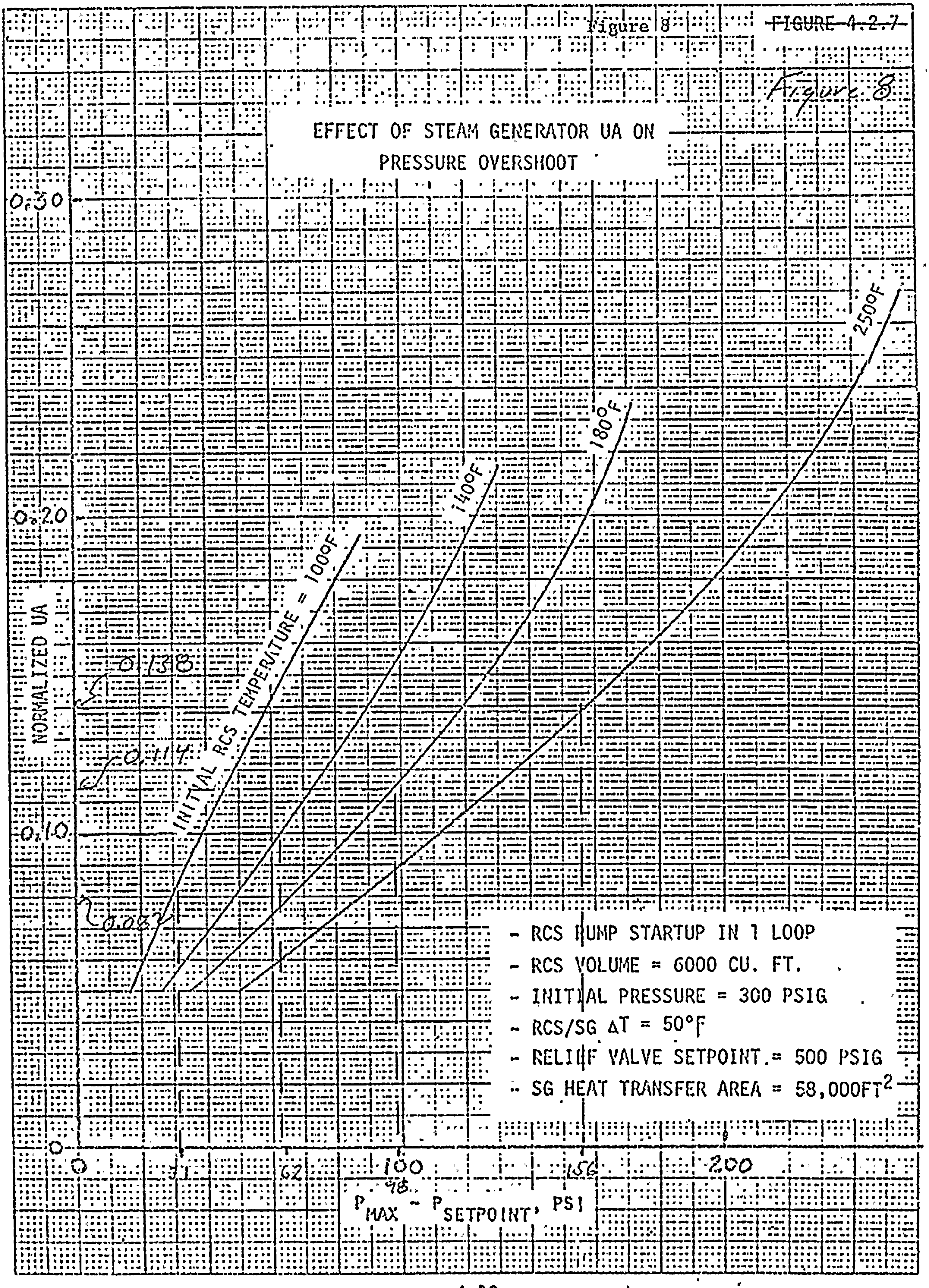
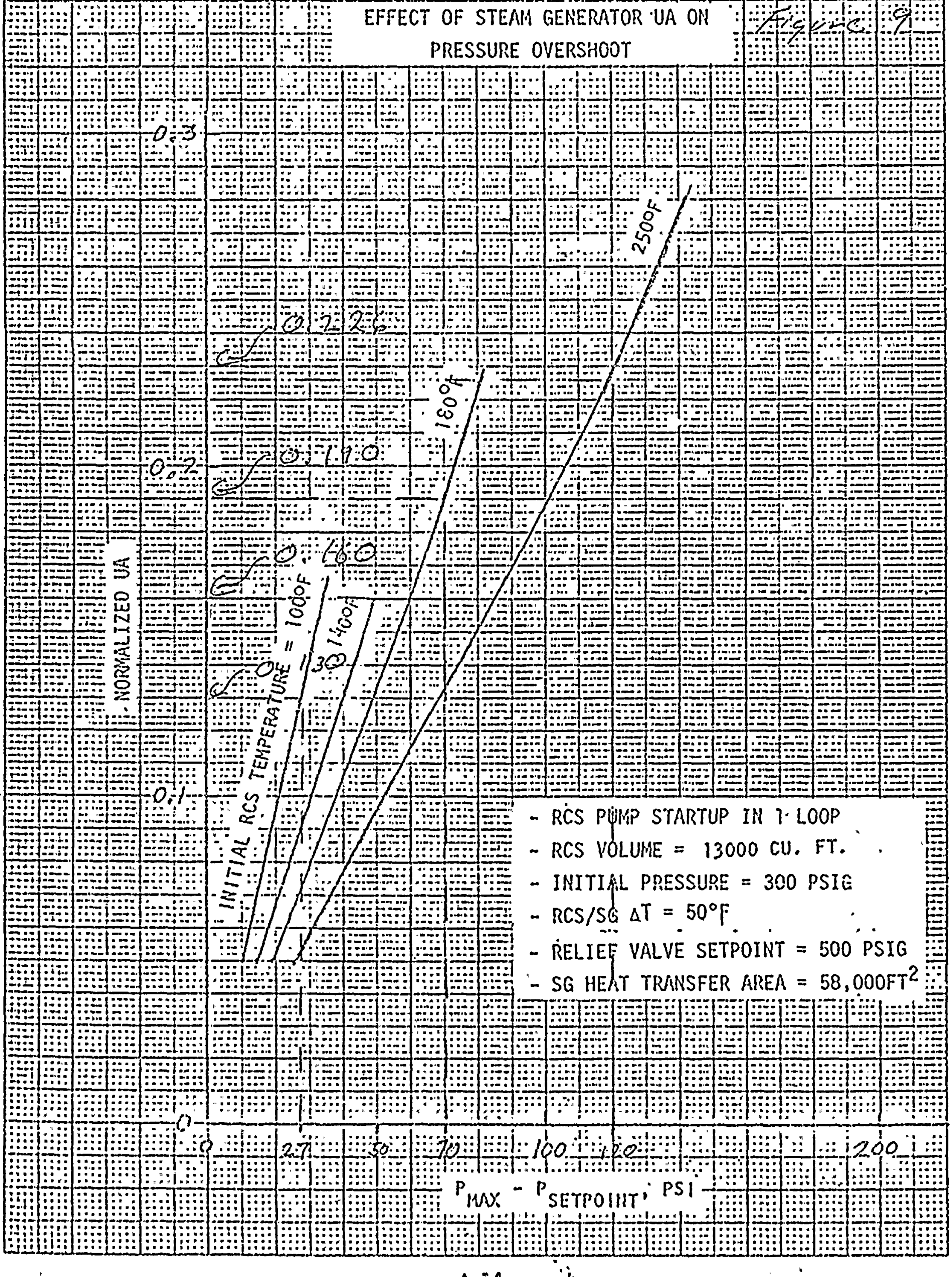


Figure 9 ~~FIGURE 4.2.8~~

Figure 9



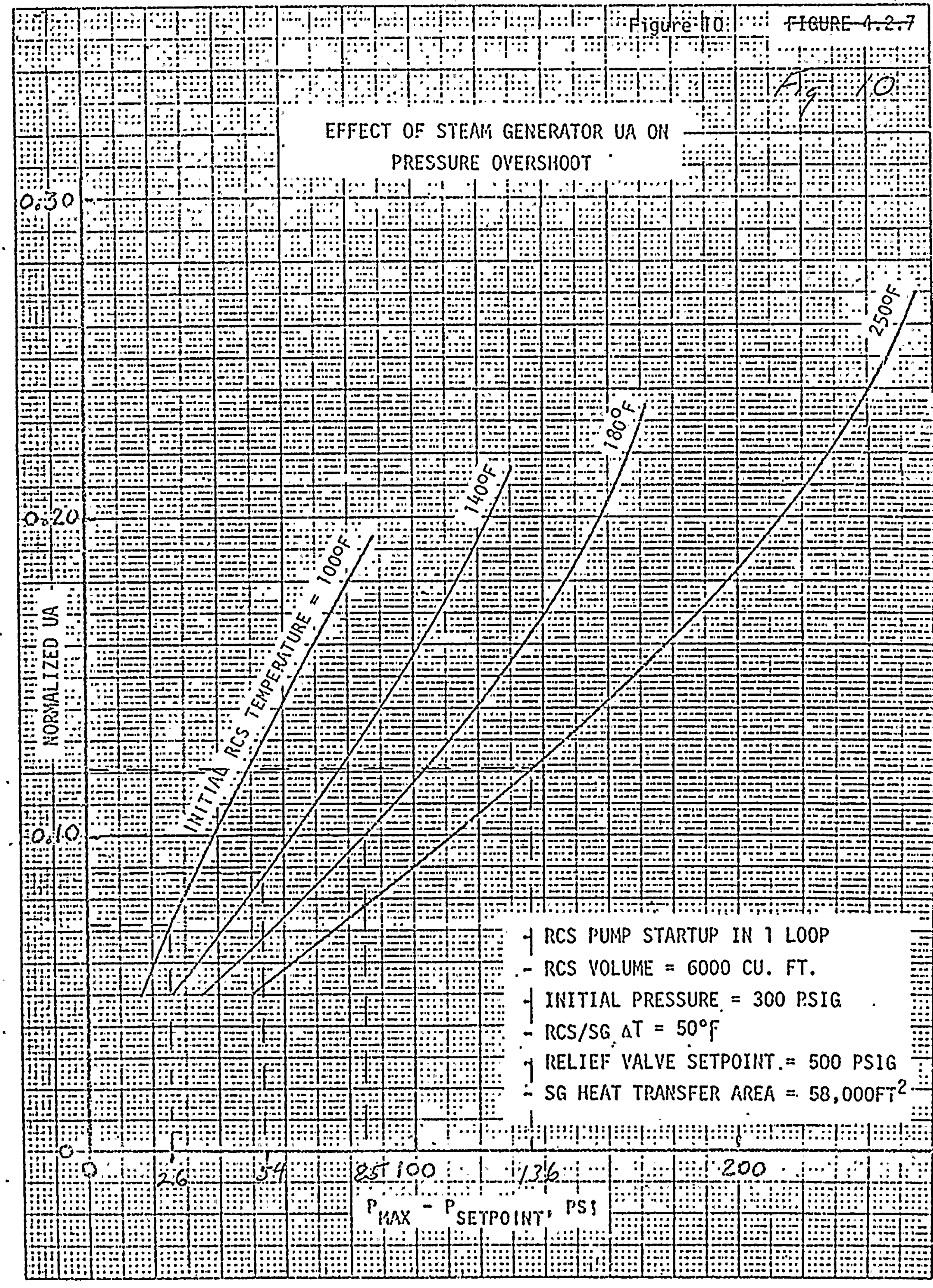


Figure 10
~~FIGURE 4.2.7~~
Fig 10
EFFECT OF STEAM GENERATOR UA ON PRESSURE OVERSHOOT
0.30
0.20
0.10
0
NORMALIZED UA
INITIAL RCS TEMPERATURE = 100°F
140°F
180°F
250°F
RCS PUMP STARTUP IN 1 LOOP
RCS VOLUME = 6000 CU. FT.
INITIAL PRESSURE = 300 PSIG
RCS/SG ΔT = 50°F
RELIEF VALVE SETPOINT = 500 PSIG
SG HEAT TRANSFER AREA = 58,000FT²
0
26
34
85
100
136
200
P MAX - P SETPOINT, PSI

FIGURE 4.2.8

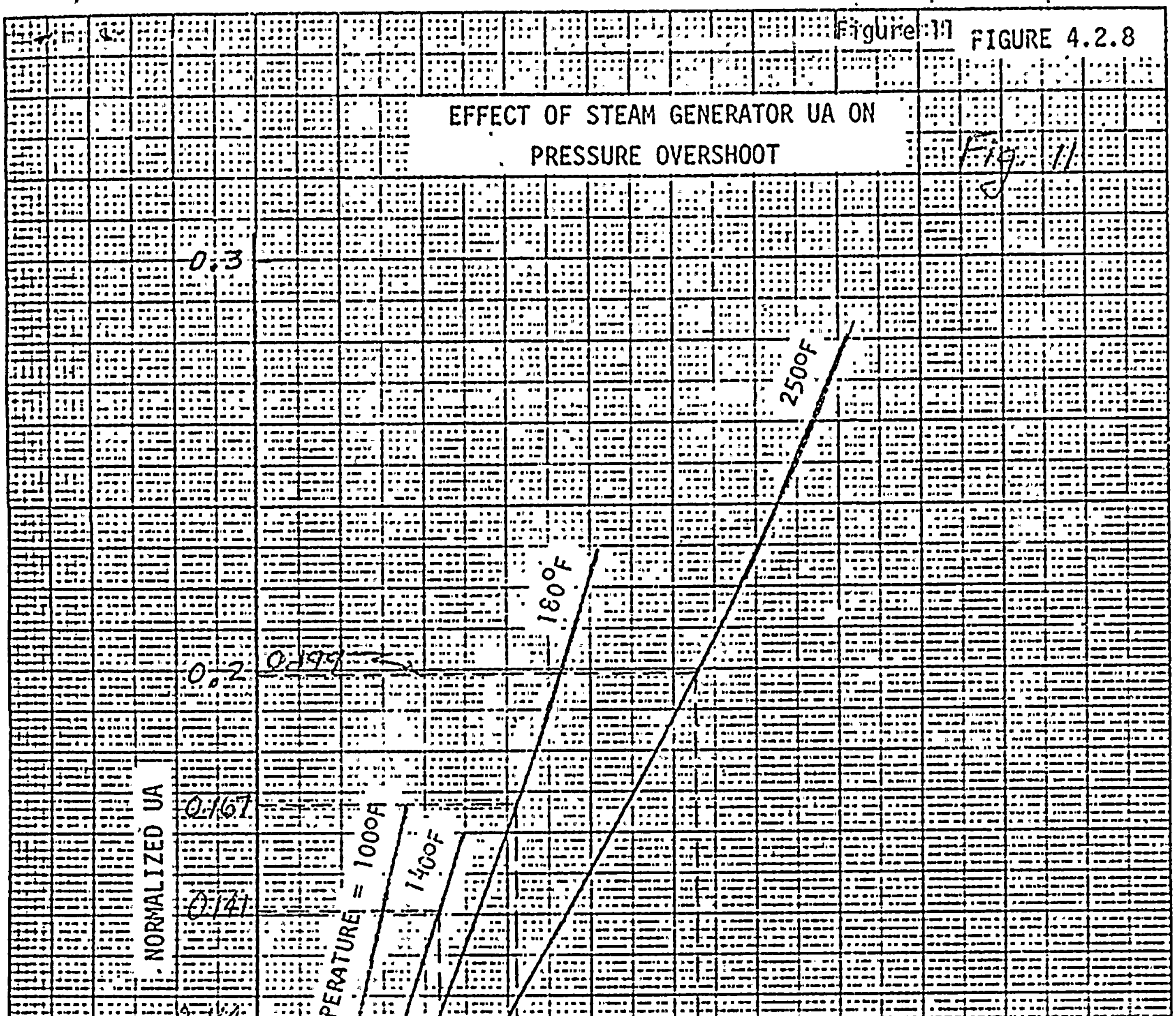


Figure 11
EFFECT OF STEAM GENERATOR UA ON
PRESSURE OVERSHOOT
Fig. 11
NORMALIZED UA
0.3
0.2
0.199
0.167
0.141
0.114
0.1
0
INITIAL RCS TEMPERATURE = 100°F
140°F
180°F
250°F
- RCS PUMP STARTUP IN 1 LOOP
- RCS VOLUME = 13000 CU. FT.
- INITIAL PRESSURE = 300 PSIG
- RCS/SG ΔT = 50°F
- RELIEF VALVE SETPOINT = 500 PSIG
- SG HEAT TRANSFER AREA = 58,000FT²
0
24
44
62
100
105
200
P MAX - P SETPOINT, PSI

#2

Q.5 Substantiate the fire resistance capability of the following items by verifying that their construction is in accordance with a particular design that has been fire tested.

a. Rated fire barriers, including hatch covers and fire doors.
b. Fire barrier penetration seals, including containment penetrations.
c. Fire stops in cable trays.
d. Ventilation fire dampers. Provide a typical drawing showing how they are installed in the ventilation ducts that penetrate rated fire barriers of safety related areas.

Also identify the design and the test method used and acceptance criteria. The design as tested should be representative of field installation.

Revised Response

a. Concrete walls

Concrete walls, floors, ceilings, and hatches, consisting of Portland cement, sand, and aggregate, are heavily reinforced and minimum thickness is one foot. As specified in the 1976 edition of the Uniform Building Code, Section 43, Table No. 43-B, Item No. 34, a wall one foot thick would have a four hour fire rating.

Concrete block walls

Concrete block walls, consisting of expanded slag aggregate, are a minimum of 7 5/8" thick and are filled with grout and reinforced with No. 4 bars at 16" on center. As specified in the 1976 edition of the Uniform Building Code, Section 43, Table 43-B, Items Nos. 30-33, a concrete block wall 7 5/8" thick would have a four hour fire rating. Construction is similar to "UL design No. U901, assembly rating - 4 hours, bearing or non-bearing."

Gypsum wallboard partition

These walls consist of metal studs with two layers of 5/8" fire code Gypsum wallboard on one side and one layer of 1" Gypsum wallboard on the other side. This assembly is rated for 2 hours based on tests performed by the University of California on March 4, 1975. This type of fire barrier was used to upgrade the exterior walls in the 4KV electrical area of the turbine building.

Metal lath and plaster

All walls consist of 16 gauge metal studs at 16" on center with 3/4" Bypsum plaster on 3.4# diamond mesh on both sides. As specified in the Gypsum Association Fire Resistance Design Manual, 1978 Edition, this assembly (GA file No. WP 1725) is rated for two hours based on Underwriter Lab's fire test UL R4024-9, 10, January 1967. This assembly is similar to Item No. 64 in Table 43-B of the Uniform Building Code, 1976 edition (two-hour rating).

Response to Q.5 - Continuation

Two-hour rated metal lath and plaster fire barriers are used in the following areas at Diablo Canyon.

1. To separate the 4KV cable spreading rooms from the corridor to the west (turbine building, elevation 104').

2. To separate the lab area (zone 4-A) from the access control area (zone 4-B), auxiliarly building, elevation 85'.

3. To separate the computer rooms (zones 8-A and 8-D) form the control room (zone 8-C).

Pyrocrete 102 partitions and fireproofing of structural steel

Wall and deck fireproof design of 2" thickness qualifies for three hour fire rating based on the interpolation from small scale thermal transmission testing done at an independent testing laboratory. A copy of the test report is attached. Applications in which Pyrocrete is used within the plant are:

1. The three hour fire barriers that separate the component cooling water heat exchangers from the rest of the plant.

2. As a portion of the barriers that separate the component cooling water pumps from each other.

3. As a portion of the barriers that separates the turbine driven auxiliary feedwater pump from the motor driven auxiliary feedwater pumps.

4. As barriers to isolate banks of safe shutdown conduits from their environs (for example, in the 12kV switchgear room, fire zone 10).

5. To upgrade certain corner seals in walls that are part of fire barriers.

Structural steel fireproof design meets U.L. design No. X716 (installed thickness of 7/8", qualifies steel for three hour fire rating). Structural steel in the 4kV switchgear rooms is fireproofed with Pyrocrete.

Metal lath and plaster fireproofing of structural steel (superstructure protection)

1 3/4" Gypsum-Perlite plaster over 3.4# metal lath. This assembly is rated for three hours per U.L. fire test R3187-4,5,7, design 6-3 or X402, July 30, 1952.

Response to Q.5 - Continuation

Ventilation duct fireproofing

Metal lath and plaster ventilation duct fireproofing consist of 3/4" Gypsum plaster over 3.4# diamond mesh. As specified in the Gypsum Association Fire Resistance Design Manual, 1978 Edition, this assembly (GA file No. CM-1300) is rated for one hour based on test 92/40 performed by Building Material and Structures, National Bureau of Standards, October 1942. This assembly is similar to Item No. 17 in Table 43-A of the Uniform Building Code, 1976 Edition (three-hour rating for one-inch Gypsum plaster over metal lath).

In those safety-related areas where the ventilation ducting has been fireproofed, the duct supports will also be fireproofed. The duct supports will have the same fire rating as the ducts themselves (except that the rating will be for fireproofing structural steel, not ducting).

Hatch covers

Hatch covers are either one foot thick concrete (rated at four hours) or one inch thick steel (no fire rating). The steel hatch covers provide adequate fire resistance in the areas in which they are located.

Fire doors

The ratings of all doors that are part of fire barriers defining fire zones are shown on the attached fire zone drawings. In some situations, specialized requirements for doors preclude the doors from being U.L. labeled. These situations are summarized below:

1. Certain exterior steel rolling doors are unlabeled due to their size, but were manufactured to "A" label specifications.

2. Some exterior steel rolling doors cannot be labeled due to a personnel access door built into the rolling door. Safe shutdown equipment is not located close to any of these doors and the exterior fire hazard in the vicinity of these doors is negligible.

3, The auxiliary saltwater pump room doors are required to withstand the effects of a tsunami and be water tight. This type of door construction has not been fire tested. The doors are satisfactory for the low fuel loading in the area, especially considering that each auxiliary saltwater pump is in its own compartment.

4. A door that also acts as a missile barrier separates the diesel generators from the turbine bay. The door is of heavier construction than an "A" labeled door, but is unlabeled.

Response to Q.5 - Continuation

5. The doors and associated panels between the turbine building and the penetration area act as blow out panels for main steam line break pressure relief in the penetration area. The doors and panel are of three hour construction but "A" labeled latching mechanisms would interfere with their blow out function. The doors and panels do have closure devices that keep them normally closed.

6. In some areas monorails for equipment removal penetrate the fire doors (for example, the RHR pump room doors are built to "A" label specs., but are unlabeled due to the penetration). It is felt that the sealed monorail penetration does not significantly degrade the effectiveness of the fire door. None of these doors are located in areas with any significant fuel loading.

7. Certain ventilation fan room doors have sliding plexiglass pressure relief windows built into them to enable the door to be opened when the ventilation equipment is operating. As such, these doors do not have a fire rating. However, without the sliding window these doors would be equivalent to "B" labeled doors. The minimal fire hazard in the vicinity of these doors does not warrant a door with a fire rating. Locations where these doors are used in fire barriers are:

   a. The door to the Unit 1 auxiliary building supply fan room (zone 8-B-1) from stairwell fire zone S-2.

   b. The doors to the corridors adjacent to the auxiliary building and fuel handling building exhaust fan rooms (zones 3-P-3, 3-P-4, 3-P-5, 3-P-6, 3-P-7). These doors are not part of fan room fire barriers.

   c. The door from zone 3-P-2 (area outside of fan rooms containing ventilation ducting) to zone 31 (fuel handling building corridor).

8. In some areas, doors are unlabeled because their fire rating at the time of purchase was not felt to be relevant due to the low fuel loading environment in which they are located. However, many of these doors are equivalent to "B" labeled doors and are so designated on the attached drawings. PGandE has on record certification from the manufacturer that these doors are built to the specification of a labeled door.

9. Doors leading to the stairwells in all cases are either "B" labeled doors or are equivalent to "B" labeled doors (for the reasons explained in No. 8 above). This door rating is in accordance with NFPA Standards for stairwells.

Response to Q. 5 - Continuation

10. Some of the doors in the auxiliary building mechanical equipment areas and the 4kV electrical equipment area in the turbine building are either "B" labeled or equivalent to "B" labeled doors. The 4kV electrical equipment area is separated from the rest of turbine building by a three hour barrier with "A" labeled doors. The low fuel loading within these areas does not warrant replacement of these doors to attain an "A" rating.

11. Certain fire zones have access openings which also serve as ventilation flow paths. In these situations, it is not possible to install fire doors in the access openings. Areas in which this occurs are the: (a) component cooling water pump rooms; (b) one of two RHR heat exchanger compartments; (c) the reciprocating charging pump room (all areas are at elevation 73 ft. in the auxiliary building); and (d) the spent fuel pool heat exchanger, pump, and filter area (fuel handling building, elevation 100 ft.). Automatic sprinkler protection and smoke detectors will be provided for the component cooling water pump rooms and the charging pump rooms (the RHR heat exchanger room adjoins the centrifugal charging pump room). The spent fuel pool equipment is not required for safe shutdown. The opening to this room leads to an open cooridor in which automatic sprinkler protection will be provided and smoke detectors will be provided for the spent fuel pool equipment room.

12. The openings between fire zones 1-A and 1-B within the containment do not have doors but do have shielding barriers. No credible fire could propagate from fire zone 1-A into fire zone 1-B. Within fire zone 1-B, a reactor coolant pump oil fire would not spread to fire zone 1-A because the RCP oil collection and drainage shield will contain the oil (along with preventing oil spillage onto hot piping). There is no other credible fire within fire zone 1-B that could propagate to fire zone 1-A.

As a result of PGandE's review of its fire protection program, in excess of 80 doors have been replaced at Diablo Canyon to attain labeled fire doors in fire zone boundaries. Those remaining doors that are unlabeled have been evaluated and are felt to provide adequate fire protection for the hazards in question.

Response to Q.5 - Continuation

b. Pipe penetration seals

As discussed in our response to Question 18, three hour rated penetration seals will be provided for the containment pipe penetration.

Pipe penetrations through fire barriers are sealed with materials subjected to a three hour fire test in accordance with ASTM E-119-1973. Test reports are provided in our response to Question 33.

Electrical penetration seals

Containment electrical penetrations consist of 12" or 24" diameter schedule 40 pipe sleeves five feet long through the concrete containment. Electrical conductors run inside the sleeves. At each end of the five foot long sleeve the electrical conductors pass through steel header plates and are completely encased in self-extinguishing epoxy. The assembly of steel and epoxy is approximately four inches thick. The epoxy has been tested in accordance with Method 2021, Federal Test Method Standard No. 406 (identical to ASTM-D 635 test for flammability of rigid plastics). The space within the sleeve between the two seals is pressurized with dry nitrogen. The cabling is enclosed in steel junction boxes at end of the penetration sleeves and is run in steel conduit from there. For a fire to propagate through the containment, it would have to breach the junction box, progress through the steel header plate, burn along five feet of electrical conductor in an oxygen free atmosphere, progress through the other steel header plate and the other junction box. While not having a specific fire rating, these containment penetrations are felt to be adequate fire barriers.

Electrical penetrations through fire barriers (other than containment) are either sealed with grout or silicone foam. The silicone foam has been subjected to a three-hour fire test in accordance with ASTM-E-119-1973. The grout used is a fine aggregate concrete and as such has the same fire rating as concrete. The grout is injected to completely fill the void in the fire barrier between the electrical conduits and the poured concrete walls. The configuration of the grout and/or silicone foam is such that the electrical penetration seals have three-hour ratings.

c. Fire stops in cable trays

All safety related electrical cabling is run in conduits except in those fire zones that contain only one redundant electrical division (specifically, the 4.16kV cable spreading rooms, the D.C. switchgear and inverter rooms, and the 480V vital switchgear rooms). In all other areas of the plant, cable trays contain only non-safety related cabling. Cable tray fire stops are installed at intervals of 4 feet on vertical trays, 10 feet on horizontal trays, and within 5 feet of cable tray crossings. All cable entrances to the cable spreading room, control room areas, and inter-connecting cable entrances between these two rooms are sealed.

Response to Q.5 - Continuation

Cable tray fire stops are made of Dow Corning Q3-6548 silicone foam (refer to our response to Question 33 for test reports). For vertical cable trays, Marinite boards surround the silicone foam to prevent ignition of the cabling above the fire stop. The Marinite boards extend out eight inches in all directions from the cable tray.

Fire tests of cable tray fire stops in horizontal and vertical orientations were conducted by PGandE's Department of Engineering Research in 1975. A 300,000 BTU/hr. flame was applied to ignite the cable insulation on one side of the fire stop. The test was terminated once the cable insulation on one side of the fire stop was completely burned (approximately 20 minutes). The fire stops prevented the spread of fire to the other side of the fire stop for both the horizontal and vertical cable trays.

d. Ventilation fire dampers

Ventilation fire dampers are U.L. listed with a fire rating of 1½ hours (the maximum U.L. listing for fire dampers). Procurement specifications for the ventilation system called for fire dampers and not fire doors, therefore, the U.L. label is for 1½ hours. The manufacturer of the fire dampers has indicated that none of their product line had been tested in excess of 1½ hours. However, he felt the fire dampers would pass a fire test in excess of 1½ hours.

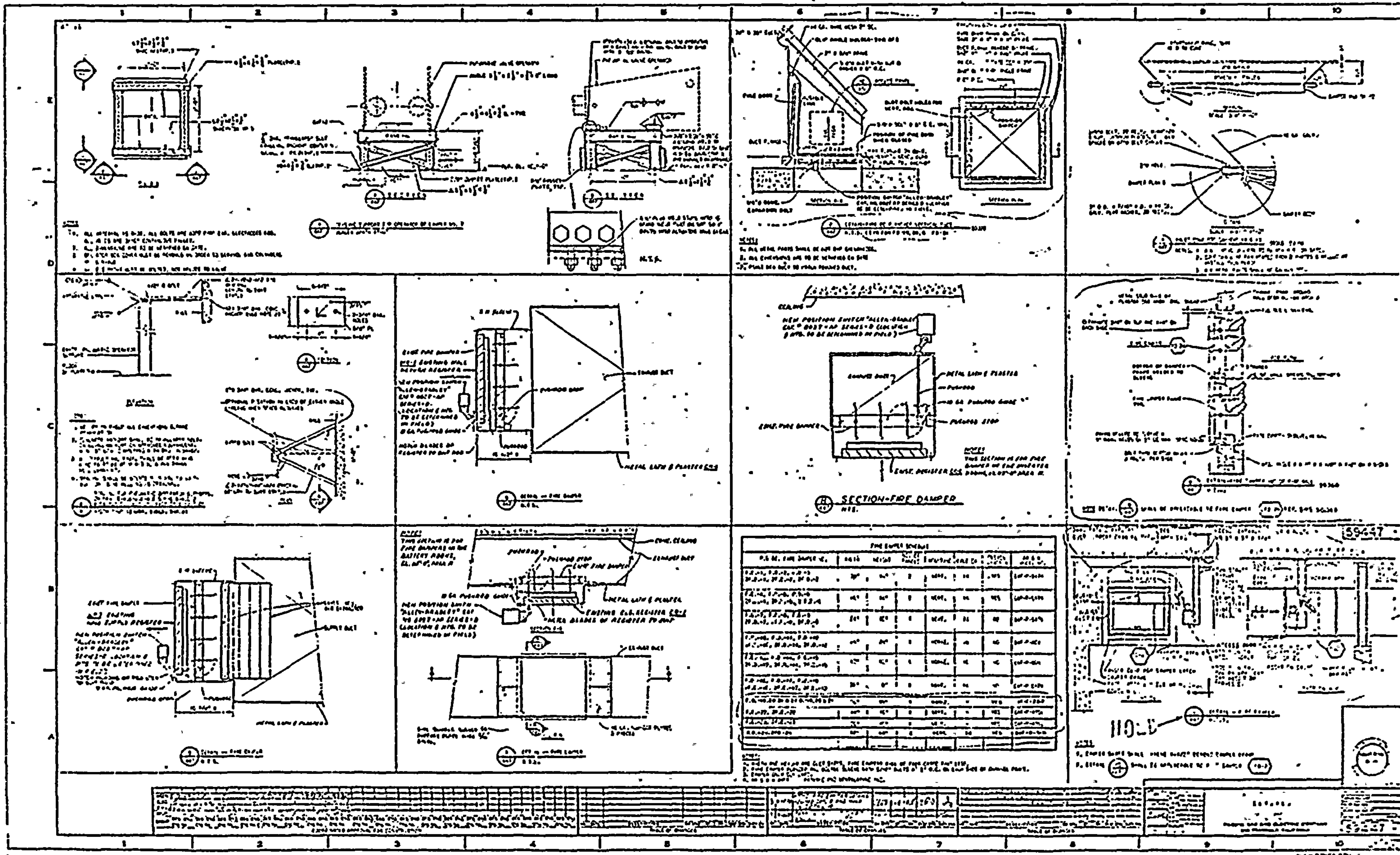
The areas in which fire dampers are used as part of fire zone boundaries are predominantly electrical equipment areas. The 1½ hour rating for the fire dampers is felt to be sufficient; three hour fire doors are not warranted for these low fuel loading areas.

Attached is a drawing showing typical fire dampers.

It is believed that the field installation of all the above items does not deviate significantly from the test installations. Manufacturer's instructions and guidance, when provided, were followed to the extent practicable.

If any additional fire testing of materials is to be done by PGandE for Diablo Canyon, NRC will be allowed to review the test procedures and witness the testing.

Question 5



from "Fire Resistance Design Manual, 1978 edition" – Gypsum Assoc.

WALLS AND INTERIOR PARTITIONS, NONCOMBUSTIBLE

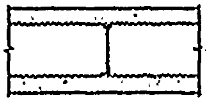
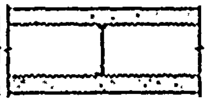
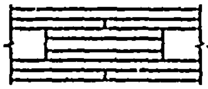
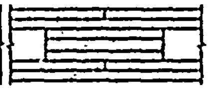
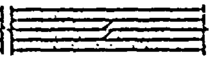
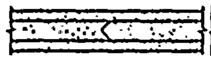
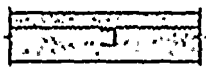
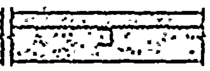
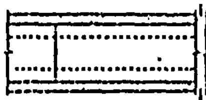
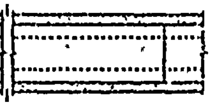
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
	40 to 44	WP 1725	Construction Type: Gypsum Plaster, Metal Lath, Metal Studs ¾" 1:1, 1:1 fibered gypsum sand plaster applied over 3.4 lb. metal lath wire tied at right angles to each side of 2½" open web metal studs 16" o.c. (NLB)	 Thickness: 4¼" Limiting Height: 11′ 2″ Approx. Weight: 16 psf Fire Test: UL R4024-9, 10, 1-5-67	
		WP 1830	Construction Type: Semi-Solid Gypsum Wallboard Base layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 1⅝" x 6" type X gypsum board studs 24" o.c. with laminating compound combed over entire surface of gypsum studs and 2" type G drywall screws at 24" o.c. to studs. Face layer ½" type X gypsum wallboard or veneer base applied parallel to studs on each side with laminating compound combed over entire contact surface and 2" type G drywall screws spaced 24" o.c. into gypsum studs. Edges secured to top and bottom channels with 1½" type S drywall screws 24" o.c. Stagger joints 24" o.c. for each layer and side. (NLB)	 Thickness: 3⅝" Limiting Height: 14′ 0″ Approx. Weight: 10 psf Fire Test: UC, 2-8-62	
2 HR	35 to 39	WP 1840	Construction Type: Solid Gypsum Wallboard One layer ½" regular gypsum wallboard or veneer base applied with laminating compound over entire surface to each side of 1" laminated, interlocking, gypsum coreboard. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 2" Limiting Height: 11′ 0″ Approx. Weight: 9 psf Fire Test: UL R3564 Design U508, 3-24-53 Sound Test: See WP 1310	
		WP 1850	Construction Type: Solid Gypsum Wallboard One layer ½" type X gypsum wallboard or veneer base applied parallel to each side of 1" tongue and groove gypsum coreboard with laminating compound combed over entire surface. Stagger joints 24" o.c. each layer and side. (NLB)	 Thickness: 2" Limiting Height: 11′ 0″ Approx. Weight: 9 psf Fire Test: OSU T-1339, 4-8-60 Sound Test: See WP 1310	
	30 to 34	WP 1930	Construction Type: Gypsum Plaster, Solid Metal Channel, Metal Lath 2½" solid 1:2-1:2 gypsum-perlite plaster applied over each side of 3.4 lb. metal lath wire tied to one side of ¾" cold rolled channels 16" o.c. embedded in plaster. (NLB)	 Thickness: 2½" Limiting Height: 12′ 0″ Approx. Weight: 12 psf Fire Test: UL R3453, 2-13-52	
3 HR	35 to 39	WP 2450	Construction Type: Gypsum Block, Gypsum Plaster ½" 1:3 gypsum-sand plaster applied over both sides of 3" thick hollow gypsum block. (NLB)	 Thickness: 4" Approx. Weight: 21 psf Fire Test: OSU T-118-27, 28, 7-18-50	

TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[1]—Continued

MATERIAL	ITEM NUMBER	CONSTRUCTION[2]	MINIMUM FINISHED THICKNESS FACE-TO-FACE[3] (In Inches) 4 Hr.	3 Hr.	2 Hr.	1 Hr.
Solid Perlite and Portland Cement	54	Perlite mixed in the ratio of 3 cubic feet to 100 pounds of portland cement and machine applied to stud side of 1½" mesh by No. 17 gauge paper-backed woven wire fabric lath wire-tied to 4" deep steel trussed wire[4] studs 16" on center. Wire ties of 18 gauge galvanized steel wire 6" on center vertically			3⅛[4]	
Solid Neat Wood Fibered Gypsum Plaster	55	¾" by No. 16 gauge cold-rolled channels, 12" on center with 2.5-pound flat metal lath applied to one face and tied with No. 18 gauge wire at 6" spacing. Neat gypsum plaster applied each side			2[4]	
Solid Gypsum Wallboard Partition	56	One full-length layer ½" Type "X" gypsum wallboard laminated to each side of 1" full length V-edge gypsum coreboard with approved laminating compound. Vertical joints of face layer and coreboard staggered at least 3"			2[4]	
Hollow (Studless) Gypsum Wallboard Partition	57	One full-length layer of ⅝" Type "X" gypsum wallboard attached to both sides of wood or metal top and bottom runners laminated to each side of 1"x6" full-length gypsum coreboard ribs spaced 24" on center with approved laminating compound. Ribs centered at vertical joints of face plies and joints staggered 24" in opposing faces. Ribs may be recessed 6" from the top and bottom				2¼[4]
	58	1" regular gypsum "V" edge full-length backing board attached to both sides of wood or metal top and bottom runners with nails or 1⅝" drywall screws at 24" on center. Minimum width of runners 1⅝". Face layer of ½" regular full-length gypsum wallboard laminated to outer faces of backing board with approved laminating compound			4⅝[4]	
Noncombustible Studs—Interior Partition with Plaster Each Side	59	3¼" by No. 18 gauge steel studs spaced 24" on center. ⅝" gypsum plaster on metal lath each side mixed 1:2 by-weight, gypsum to sand aggregate				4¾[4]
	60	3⅝" No. 16 gauge approved nailable[4] studs spaced 24" on center. ⅝" neat gypsum wood fibered plaster each side over ⅜" rib metal lath nailed to studs with 6d common nails, 8" on center. Nails driven 1¼" and bent over			5⅝	
	61	2½" steel studs 16" on center formed with No. 16 gauge angle flanges and No. 7 gauge wire diagonals. ⅜" perforated gypsum lath attached to the studs each side with No. 12 gauge wire clips at horizontal and vertical joints. ½" gypsum plaster applied each side mixed 1:2 by weight, gypsum to sand aggregate				4¼[4]
	62	2½" steel studs 16" on center formed with No. 16 gauge angle flanges and No. 7 gauge wire diagonals. ⅜" perforated gypsum lath attached to the studs each side with No. 12 gauge approved steel wire clips. End joints of lath held by approved end joint clips. ¾" perlite or vermiculite gypsum plaster applied each side			4¾[4]	
	63	4" No. 18 gauge channel-shaped steel studs at 16" on center. On each side approved resilient clips pressed onto stud flange at 16" vertical spacing, ¼" pencil rods snapped into or wire-tied onto outer loop of clips, metal lath wire-tied to pencil rods at 6" intervals, 1" perlite gypsum plaster, each side		7⅝[4]		
	64	2½" No. 18 gauge steel studs spaced 16" on center. Wood fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied on 3.4 pound metal lath wire tied to studs, each side. ¾" plaster applied over each face, including finish coat			4½[4]	

(Continued)

from "Fire Resistance Design Manual, 1978 edition" – Gypsum Assoc.

COLUMNS

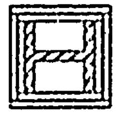
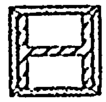
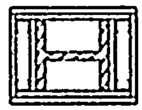
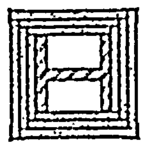
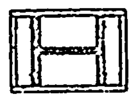
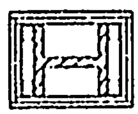
Fire Rating		GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA
1 HR		CM 1100	**Construction Type: Gypsum Wallboard** Base layer ½″ regular gypsum wallboard or veneer base tied to column with 18 gage wire 15″ o.c. Face layer ½″ regular gypsum wallboard or veneer base applied with laminating compound over entire contact surface.	 Fire Test: NBS 303, 7-3-52
		CM 1300	**Construction Type: Metal Lath, Gypsum Plaster** ⅝″ 1:3 gypsum-sand plaster applied to 3.4 lb. metal lath wrapped and wire tied to column with 18 gage wire 6″ o.c.	 Fire Test: BMS 92/40, 10-7-42
2 HR		CM 2010	**Construction Type: Gypsum Wallboard** Base layer ½″ type X gypsum wallboard or veneer base against flanges and across web openings fastened to 1⅝″ metal studs with 1″ type S drywall screws 24″ o.c. at corners. Face layers ½″ type X gypsum wallboard or veneer base and screw-attached to studs with 1″ type S drywall screws 12″ o.c. to provide a cavity between boards on the flange. Face layers across the web opening laid flat across the base layer and screw attached with 1⅝″ type S drywall screws 12″ o.c. Metal corner beads nailed to outer layer with 4d nails 1⅜″ long, 0.067″ shank, 13/64″ heads, 12″ o.c.	 Fire Test: UL R1319-80 Design X518, 5-27-65
		CM 2020	**Construction Type: Gypsum Wallboard** Three layers of ⅝″ type X gypsum wallboard or veneer base around column with first and second layers nailed with 1⅜″ long ring shank nails as required for support. ½″ x 0.015″ metal strapping 30″ o.c. around second layer beginning 18″ from each end of column. Face layer attached to 1¼″ x 1¼″ 25 gage steel angles held on corners by metal strapping. Drywall corner bead applied each corner with 1″ type S drywall screws spaced 12″ o.c. at each corner.	 Fire Test: UL R1319-33 Design X516, 11-3-60
		CM 2110	**Construction Type: Metal Studs, Gypsum Wallboard** One layer ½″ type X gypsum wallboard or veneer base attached to 1⅝″ steel studs with 1″ type S drywall screws 12″ o.c. Studs located at each corner of heavy steel column. 1¼″ metal corner bead crimp attached at 6″ intervals.	 Fire Test: UL R3501-58 Design X520, 10-10-67
		CM 2120	**Construction Type: Metal Studs, Gypsum Wallboard** Two layers of ⅝″ type X gypsum wallboard or veneer base, screw attached to 1⅝″ metal studs located at each corner of columns with 1″ type S screws 24″ o.c. for base layer and 1⅝″ type S drywall screws 12″ o.c. for face layer. 1¼″ metal beads at corners attached with 6d coated nails 1¾″ long, 0.0915″ shank, ¼″ heads, 12″ o.c.	 Fire Test: UL R2717-34 Design X517, 5-15-64

TABLE NO. 43-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (In Inches)			
			4 Hr.	3 Hr.	3 Hr.	1 Hr.
Steel Columns and All Members of Primary Trusses	1	Grade A concrete, members 6"x6" or greater (not including sandstone, granite and siliceous gravel)[1]	2½	2	1½	1
	2	Grade A concrete, members 8"x8" or greater (not including	2	1½	1	1
	3	Grade A concrete, members 12"x12" or greater (not including sandstone, granite and siliceous gravel)[1]	1½	1	1	1
	4	Grade B concrete and Grade A concrete excluded above, members 6"x6" or greater[1]	3	2	1½	1
	5	Grade B concrete and Grade A concrete excluded above, members 8"x8" or greater[1]	2½	2	1	1
	6	Grade B concrete and Grade A concrete excluded above, members 12"x12" or greater[1]	2	1	1	1
	7	Clay or shale brick with brick and mortar fill[1]	3¾			2¼
	8	4" Hollow clay tile in two 2" layers; ½" mortar between tile and column; ⅜" metal mesh (wire diameter = .046") in horizontal joints; tile fill[1]	4			
	9	2" Hollow clay tile; ¾" mortar between tile and column; ⅜" metal mesh (.046" wire diameter) in horizontal joints; Grade A concrete fill[1]; plastered with ¾" gypsum plaster	3			
	10	2" Hollow clay tile with outside wire ties (.08" diameter) at each course of tile or ⅜" metal mesh (.046" diameter wire) in horizontal joints; Grade A concrete fill[1] extending 1" outside column on all sides			3	
Steel Columns and All Members of Primary Trusses (Cont'd.)	11	2" Hollow clay tile with outside wire ties (.08" diameter) at each course of tile with or without Grade A concrete fill; ¾" mortar between tile and column				2
	12	Solid gypsum blocks with woven wire mesh[2] in horizontal joints, laid with 1" mortar on flanges[1] and plastered with ½" gypsum plaster	2½	2½		
	13	Hollow gypsum blocks with ¾" wide No. 12 gauge metal cramps and woven wire mesh[2] in horizontal joints. PL denotes ½" gypsum plaster	3½ PL	3½ PL	3	3
	14	Portland cement plaster over metal lath wire tied to ¾" cold-rolled vertical channels with No. 18 gauge wire ties spaced 3" to 6" on center. Plaster mixed 1:2½ by volume, cement to sand			2½[3]	⅞
	15	Vermiculite concrete, 1:4 mix by volume over paperbacked wire fabric lath wrapped directly around column with additional 2"x2" No. 16/16 gauge wire fabric placed ¾" from outer concrete surface. Wire fabric tied with No. 18 gauge wire spaced 6" on center for inner layer and 2" on center for outer layer	2			
	16	Perlite or vermiculite gypsum plaster over metal lath wrapped around column and furred 1¼" from column flanges. Sheets lapped at ends and tied at 6" intervals with No. 18 gauge tie wire. Plaster pushed through to flanges.	1½	1		
	17	Perlite or vermiculite gypsum plaster over self-furring metal lath wrapped directly around column, lapped 1" and tied at 6" intervals with No. 18 gauge wire	1¾	1⅜	1	

(Continued)

Q.8 (RSP) The majority of the fire protection valves are either sealed open with a metal tape and lead sealed or are supervised by administrative controls. It is our position that you should implement one of the following in accordance with NFPA 13, Section 3-13.

a. All fire protection valves controlling the water supply to the fixed water extinguishing systems should be provided with electrical supervisory switches arranged to give visual valve position indication in the control room in the event the valve is closed or partially closed.

b. All the fire protection valves controlling the water supply to the fixed water extinguishing should be locked open with a strict administrative key control procedure. The valve position should be verified periodically.

Revised Response

NFPA 13, Section 3-13 permits other alternatives to those listed in the question. It continues to be our position that compliance with Section 3-13.2.3 (d), which allows sealing valves in the proper position with breakable seals and carrying out weekly documented surveillance, provides adequate assurance against misoperation of fire protection system valves. Accordingly, there is no plan to install electrical supervisory switches with control room position indicators or to lock fire protection system valves.

PGandE strongly believes that an administrative control procedure involving sealing valves is preferable to one using locks. In emergency situations, the operator may not have the necessary key readily available to unlock and operate a valve. Being unable to quickly open or close a locked valve could create hazardous situations.

The use of administrative controls of this nature is well established within PGandE. Such controls have a demonstrated successful history, which has been observed by NRC Inspection and Enforcement personnel during the 15 year operating history of our Humboldt Bay Power Plant, Unit No. 3.

These administrative controls have included:

1. The PGandE System-wide use of tags (called "man-on-line" tags) for operating and maintenance clearances (instead of locking valves, electrical controls, etc.) to prevent hazards to personnel. All PGandE operating and maintenance personnel are aware that violation of a clearance tag is grounds for serious disciplinary action.

Revised Response (Continued)

2. The use of an administratively controlled sealed valve check list at our Humboldt Bay Power Plant Unit No. 3 for the control of all safety-related valves associated with the Unit. These include a number of fire protection system valves since this system provides a backup emergency core cooling function.

Finally, it should be noted that security requirements under 10CFR73.55 preclude unescorted access to the security protected area of the plant for other than trained plant personnel or other specially designated individuals. This provides added assurance that valves will not be intentionally or inadvertently operated without the knowledge of plant operating personnel.

Q.9 (RSP) (4-2) In the containment cable penetration zone (fire zone 1-A), it is our position that automatic sprinklers be installed in areas where two or more divisions of safety systems cables could be affected by a transient fire.

Revised Response

For the purposes of this discussion, the postulated fire within fire zone 1-A will be assumed to affect equipment within a 20 foot diameter. This assumption is felt to be extremely conservative considering the nature and quantity of the fuel loading in the area; the in-depth detection (14 smoke detectors in zone 1-A) and manual fire suppression capability in the area; and that a significant portion of this fire zone will be designated as a "No Storage" area. Specifically, 300° of the annular zone at elevation 91 feet will be posted as a "No Storage" area. (The 60° sector of this zone in the vicinity of the fuel transfer tube assembly does not contain any safe shutdown components.) This area was designated as a "No Storage" area because safe shutdown instrumentation circuitry runs in that annular region approximately 20 feet above the 95 foot elevation. These conduits run below the open floor grating at elevation 117 feet with cable trays above the conduits and piping below. The piping does not contain flammable liquids, gases, or oxygen. Therefore, with the "No Storage" provision, a fire due to fixed combustibles in this are would not be capable of affecting redundant safe shutdown instrumentation conduits. However, the circuit routing for the safe shutdown instrumentation is described below to verify that proper separation does exist between redundant components.

Steam generator pressure transmitter circuitry emanates from mechanical panels at elevation 117 feet mounted on the missile barrier wall adjacent to the four steam generators. The conduits run beneath the open floor grating at elevation 117 feet and leave containment through containment electrical penetrations 8E, 14E, 24E, and 31E at elevation 120 feet six inches. The separation distances between the penetrations are 12 feet, 20 feet, and 9 feet, respectively. No single fire would be capable of affecting the circuitry associated with all four steam generators. In the worst case, the postulated fire could result in level transmitters available for only two steam generators. However, only one steam generator is required for safe shutdown.

Mechanical panels for reactor coolant system pressure transmitters and pressurizer pressure transmitters are located 180° apart at elevation 95 feet in fire zone 1-A; from there the circuits run below the open floor grating at elevation 117 feet to the containment penetrations. Containment penetrations for the electrical circuits from these transmitters are the same as specified for the steam generator level transmitters. Therefore, the postulated fire could not damage all pressure transmitters circuitry (a minimum of two pressure indications would be available after the postulated fire).

Revised Response to Q.9 - Continued

Pressurizer level transmitter circuitry for LT-459, LT-460, and LT-461 runs from the mechanical panels at elevation 95 feet in the vicinity of the pressurizer (but outside the missile barrier) to the penetration area along the same routing as specified above. Pressurizer level signals leave containment through penetrations 14E, 24E, and 31E. In addition, the pressurizer level transmitter (LT-406) for the dedicated safe shutdown instrument panel will be located at least 20 feet from the other pressurizer level transmitters. Circuit routing from LT-406 to penetration 13E will be in the opposite direction as the other pressurizer level transmitter circuits. Thus, any 20 foot diameter postulated fire in fire zone 1-A could not affect all pressurizer level transmitter circuits.

Reactor coolant system temperature element circuitry emanates from fire zone 1-B and runs to electrical penetrations 16E and 33E at elevation 134 feet 8 inches. The four RCS temperature element circuits for loops 1 and 2 pass through penetration 33E while loops 3 and 4 pass through 16E. The penetrations are separated by 32 feet. That penetration separation distance is the closest distance the two sets of temperature circuitry run to each other. Thus, the postulated fire could affect, at most, four of eight RCS temperature elements within fire zone 1-A. Within fire zone 1-B, the two groups of RCS temperature element circuits are completely isolated from another. A fire in zone 1-B could not affect more than four of the eight temperature element circuits.

The remaining safe shutdown components and circuits within fire zone 1-A are described in the June 6, 1978 report "Supplementary Information for Fire Protection Review."

Q.21 (4-32) Battery Room is located in Fire Zone 6-A. Provide drawings showing the ventilation systems of the three battery rooms, and the construction of the walls separating the three battery rooms from each other and from the rest of Fire Area 6-A is 3-hour rated. Drawings should show all fire doors and fire dampers as well as their fire rating. Rubber ventilation seals at corners of walls are not an acceptable arrangement.

Revised Response

As shown on the revised fire zone drawings, fire zone 6-A has been subdivided into five fire zones. Each of the battery rooms and associated battery charger and inverter rooms have been designated as fire zones. All doors and associated panels in these fire zone boundaries will be replaced with "A" labeled assemblies. The corner seals in the walls will be upgraded to a three-hour rated barrier. Within each of these fire zones, the batteries are separated from the other electrical equipment by three-hour barriers (except for the doors built to "B" label specifications). Battery room ventilation is provided by a supply fan and an exhaust fan located in compartments separated by 25 feet. Either fan provides adequate flow to limit hydrogen concentration well below the explosion concentration. Redundant Class 1E air flow switches in the supply ducting will be installed to provide control room annunciation for loss of battery room ventilation. Additional control room annunciation is provided for excessive hydrogen generation due to overcharge and battery room ventilation damper closure. Ventilation supply and exhaust ducting within the battery rooms has been fireproofed to provide a one-hour rating. Battery room ventilation duct supports will also be fireproofed wherever the ducting has been fireproofed. Electrically supervised, one and one-half hour rated fire dampers have been installed in the ventilation supply and exhaust openings, such that heat and smoke from a fire in one battery room will be confined to that room while normal ventilation is maintained to the other rooms. Air discharged from the battery rooms is mixed with air flows from adjoining rooms and exhausted directly outside.

Ventilation for the battery charger and inverter rooms is provided by two 100% supply fans (these fans also supply ventilation for the 480V switchgear and are unrelated to the battery room ventilation). Electrically supervised, one and one-half hour rated fire dampers have been provided in the supply and exhaust ducting to each room, such that heat and smoke from a fire in one room will be confined to that room while normal ventilation flow is maintained to the other rooms. Ventilation ducting inside these rooms has been fireproofed to provide a one-hour rating. Duct supports and ducting outside these rooms in fire zone 6-A-5 will also be fireproofed to provide a one-hour rating. One of two redundant supply fans and motors will be encased within a one-hour barrier to preclude

Q.21 (4-32) Battery Room is located in Fire Zone 6-A. Provide drawings showing the ventilation systems of the three battery rooms, and the construction of the walls separating the three battery rooms from each other and from the rest of Fire Area 6-A is 3-hour rated. Drawings should show all fire doors and fire dampers as well as their fire rating. Rubber ventilation seals at corners of walls are not an acceptable arrangement.

Revised Response

As shown on the revised fire zone drawings, fire zone 6-A has been subdivided into five fire zones. Each of the battery rooms and associated battery charger and inverter rooms have been designated as fire zones. All doors and associated panels in these fire zone boundaries will be replaced with "A" labeled assemblies. The corner seals in the walls will be upgraded to a three-hour rated barrier. Within each of these fire zones, the batteries are separated from the other electrical equipment by three-hour barriers (except for the doors built to "B" label specifications). Battery room ventilation is provided by a supply fan and an exhaust fan located in compartments separated by 25 feet. Either fan provides adequate flow to limit hydrogen concentration well below the explosion concentration. Redundant Class 1E air flow switches in the supply ducting will be installed to provide control room annunciation for loss of battery room ventilation. Additional control room annunciation is provided for excessive hydrogen generation due to overcharge and battery room ventilation damper closure. Ventilation supply and exhaust ducting within the battery rooms has been fireproofed to provide a one-hour rating. Battery room ventilation duct supports will also be fireproofed wherever the ducting has been fireproofed. Electrically supervised, one and one-half hour rated fire dampers have been installed in the ventilation supply and exhaust openings, such that heat and smoke from a fire in one battery room will be confined to that room while normal ventilation is maintained to the other rooms. Air discharged from the battery rooms is mixed with air flows from adjoining rooms and exhausted directly outside.

Ventilation for the battery charger and inverter rooms is provided by two 100% supply fans (these fans also supply ventilation for the 480V switch-gear and are unrelated to the battery room ventilation). Electrically supervised, one and one-half hour rated fire dampers have been provided in the supply and exhaust ducting to each room, such that heat and smoke from a fire in one room will be confined to that room while normal ventilation flow is maintained to the other rooms. Ventilation ducting inside these rooms has been fireproofed to provide a one-hour rating. Duct supports and ducting outside these rooms in fire zone 6-A-5 will also be fireproofed to provide a one-hour rating. One of two redundant supply fans and motors will be encased within a one-hour barrier to preclude

Revised Response Q.21 - Continued

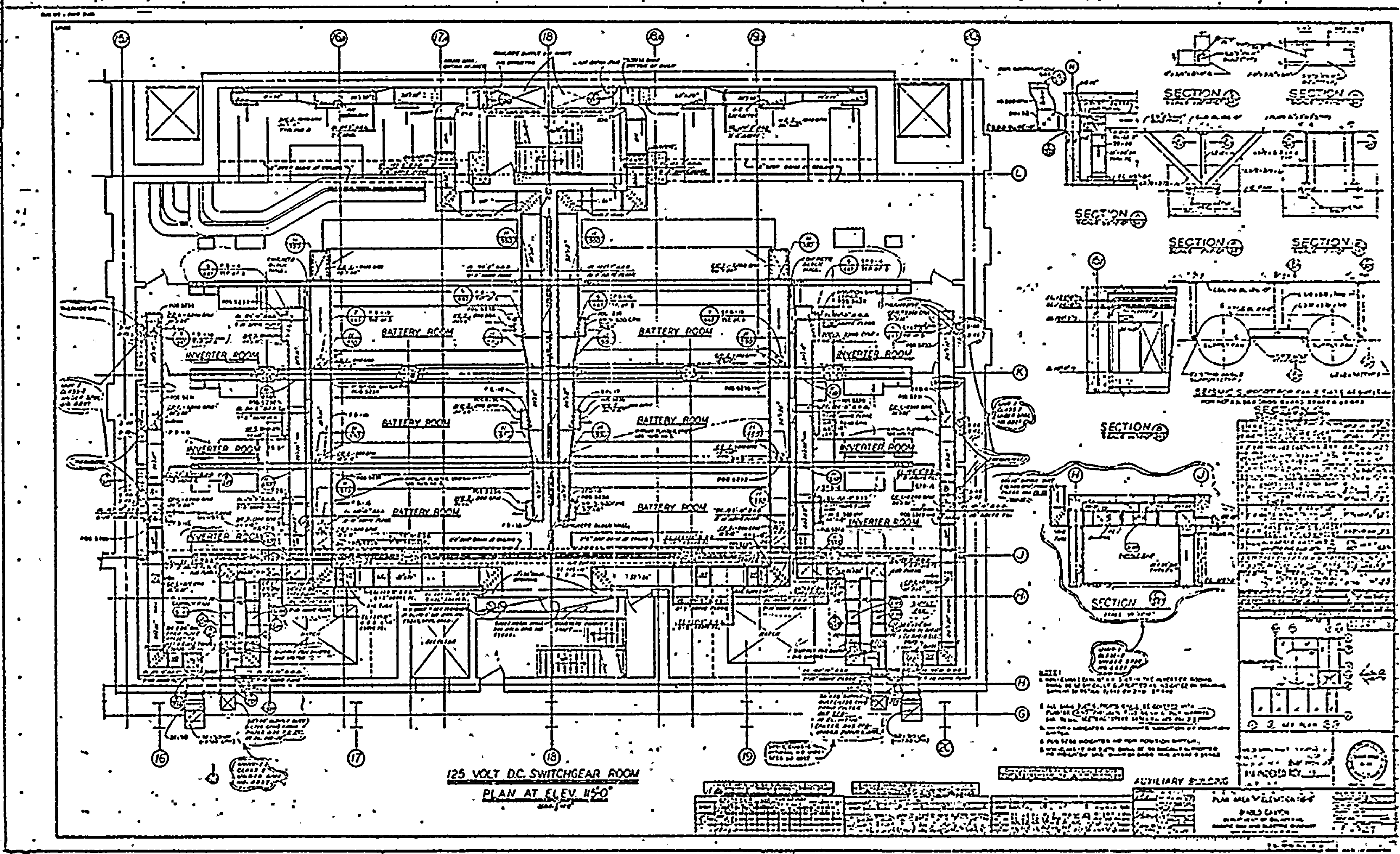
an exposure fire in fire zone 6-A-5 from affecting both fans. Furthermore, this fire zone will be designated as a "No Storage" area to prevent an exposure fire from breaching the equipment hatch above and possibly affecting components in the cable spreading room.

Smoke detectors are provided throughout these fire zones; in-depth fire suppression capability is provided by CO_2 hose reels, a firewater hose reel, and portable extinguishers.

A fire in either a battery room and/or its associated battery charger and inverter room will not adversely affect safe shutdown capability. Safe shutdown components that could be affected as a result of this fire are tabulated and assessed in Section 5 of the June 6, 1978 submittal entitled "Supplementary Information for Fire Protection Review."

The consequences of a fire in the areas adjoining the battery rooms (fire zones 6-A-4 and 6-A-5) were also assessed in that report. Safe shutdown capability cannot be affected as a result of fire in fire zone 6-A-5 due to planned fire protection modifications to the ventilation system in fire zone 6-A-5 and the designation of this zone as a "No Storage" area. The only safety related components located in fire zone 6-A-4 are the reactor trip switchgear and the rod drive motor generator set controllers. The reactor trip switchgear contains two circuit breakers in series to interrupt power to the control rod drives. The probable result, if any, of a fire in zone 6-A-4 would be for the reactor to trip. A fire in this zone could not prevent a reactor trip. Manual reactor trip from the control room would be possible by tripping the switchgear or by de-energizing the motor generator sets irrespective of the fire in zone 6-A-4. Early warning of a fire is provided by seven smoke detectors installed in fire zone 6-A-4.

Question 21


BATTERY ROOM
BATTERY ROOM
BATTERY ROOM
BATTERY ROOM
BATTERY ROOM
BATTERY ROOM
INVERTER ROOM
INVERTER ROOM
INVERTER ROOM
INVERTER ROOM
INVERTER ROOM
INVERTER ROOM
SECTION
SECTION
SECTION
SECTION
SECTION
SECTION
125 VOLT D.C. SWITCHGEAR ROOM
PLAN AT ELEV. 115'-0"
AUXILIARY BUILDING

Q.23 (RSP) (4-36) Control Room Complex is located in Fire Zone 8.

A. Unit 1 Computer Room is also located in Fire Zone 8-A. The computer room is cut-off from the control room by a 1-hour protection; however, the openings are unprotected. It is our position that 3-hour fire doors and fire dampers be provided for the protection of openings that penetrate the wall separating the computer room from the control room. It is also our position that you provide automatic protection for the computer room or show that a fire in the computer room will not affect the safe cold shutdown of the plant.

B. Control Room ventilation equipment is located in Fire Zone 8-B. Verify that the ventilation ducts that penetrate the floor of this room have 3-hour fire dampers installed at all floor penetrations. Also verify that fire hose reels can reach all areas of the room and are readily available.

C. Control Room is located in Fire Zone 8-C. Verify that fire hose stations in the area can cover all portions of the control room complex.

Identify those safety-related control room cabinets that contain cables from both divisions. Provide an analysis of the consequences of a fire in each cabinet. The analyses should take into account the damage to wiring and instrumentation in adjoining safety-related cabinets due to heat and corrosive vapors. In order to meet the guidelines of D.2 of Appendix A, it is our position that you provide smoke and heat detectors in the control room cabinets.

Verify that all door and ventilation openings in the control room walls and ceiling are protected by 3-hour rated fire doors. It is our position that you provide smoke detectors throughout the room at the ceiling level.

D. Office and Record Storage and Instrumentation Repair Areas are located in Fire Area 8-E and 8-F. Provide 3-hour fire rated construction including the protection of all ventilation and door openings.

Revised Response

A. The existing barrier between the computer room and the control room is consistent with the low fuel load within the computer room. It will be upgraded to a one hour barrier by extending the wall from the suspended ceiling to the concrete ceiling above. Providing a three hour door in a one hour rated barrier is unnecessary and will not be done.

In the event of a fire in the control room complex, the ventilation system mode of operation is changed to 100% outside air make-up and exhaust to provide smoke venting. Installation of fire dampers in the computer room ventilation penetrations would prevent proper smoke venting and might degrade the habitability of the control room complex. Fire dampers will not be installed in the ventilation ducting.

The plant computer is not required for safe shutdown nor would a fire in the plant computer room affect control room safe shutdown capability. A fire in the computer room would be suppressed using portable extinguishers and, if necessary, firewater hose reels located adjacent to the control room complex. Automatic fire protection will not be provided for this area. However, smoke detectors will be installed in the computer room and the exhaust air duct from the computer room.

B. Units 1 and 2 auxiliary building supply fan rooms are located at elevation 140 ft. in fire zones 8-B-1 and 8-B-2, respectively (refer to revised fire zone drawing figure 3-10). Fire zones 8-B-1 and 8-B-2 are separated from the control room complex by three hour rated barriers. The floor penetrations in the supply air plenum rooms communicate with the auxiliary building mechanical equipment areas below. Fire dampers in the floor penetrations are not necessary to protect the control room complex from a fire in zone 8-B-1 or 8-B-2 and could degrade the reliability of the auxiliary building ventilation system. Therefore, fire dampers will not be installed in the floor penetrations. However, the auxiliary building supply fan rooms will be protected by smoke detectors and an automatic sprinkler system. A firewater hose reel located outside the fan rooms provides satisfactory backup manual fire suppression capability.

The Units 1 and 2 control room ventilation equipment rooms are located at elevation 154 ft. 6 in. in fire zones 8-B-3 and 8-B-4 respectively (refer to revised fire zone drawing figure 3-11). Control room supply and exhaust ducts penetrate the wall at column line "L". Installation of fire dampers in these penetrations would require extensive modifications, including relocation of major ventilation equipment. Since smoke detectors, automatic sprinkler protection, and a firewater hose reel will be provided for the control room ventilation equipment rooms, fire dampers are not felt to be necessary for these penetrations.

C. Existing firewater hose stations provide proper coverage of all portions of the control room complex.

The only cabinets in the control room which contain cables from both divisions are the operator's control console and the main control board. Many precautions have been taken to minimize fire hazard in these boards. All wiring is routed internally in metal wireways. All switching components are contained in individual housings (modules) which have an electrical insulating and fire retardant material on both sides. Wiring to the devices is separated by several inches of air. Wire insulation was specifically selected for flame retardancy to prohibit release of corrosive gases.

As described in our revised response to Question 51, safe (cold) shutdown can be accomplished outside the control room assuming a loss of the main control board. However, early detection and suppression capability should minimize the damage caused by any postulated fire in the main control board, and complete loss of the main control board is felt to be an extremely unlikely occurrence.

Response to Q.23 - Continued

Thirteen ionization type smoke detectors will be installed in the main control board and three ionization type smoke detectors will be installed in the operators control console. Smoke detectors will be installed in other control room cabinets also. The smoke detectors mounted in these cabinets will have seismically qualified mounts.

The doors leading to the control room complex (consisting of fire zones 8-A, C, D, E, F, G, and H as shown on the revised fire zone drawing figure 3-10) all are three-hour rated "A" labeled doors. With the exception of the ventilation penetrations into the control room complex (described in 23.B above), the control room complex is isolated from the rest of the plant by minimum three-hour rated fire barriers. As described in the revised response to Question 24, the safeguards rooms (fire zones 8-G and 8-H) will be separated from the rest of the control room complex by three-hour rated fire barriers. The computer rooms (fire zones 8-A and 8-D) are described in 23.A above and the remainder of the control room complex, fire zones 8-E and 8-F, are described in 23.D below.

Because the control room is continuously occupied, smoke detectors are not necessary in the ceiling of the control room and will not be provided.

D. Fire zone 8-E, consisting of an office and a records storage room, is separated from the turbine building by a three-hour rated fire barrier. The wall separating zone 8-E from the control room (zone 8-C) is a three-hour rated concrete wall. Fire dampers have not been provided in the ventilation ducting to fire zone 8-E. This was done to ensure proper smoke venting so that the control room complex would remain habitable if a fire were to occur in this area. Smoke detectors and automatic sprinkler protection have been provided within this fire zone.

Fire zone 8-F, previously an instrument repair room, is now designated as the security central alarm station. This room is separated from the turbine building by a three-hour fire barrier and the wall separating zone 8-F from 8-C is a three-hour rated concrete wall with "C" labeled doors.

Q.24 Safeguards Room is located in Fire Zone 8-G and 8-H. Provide the results of an analysis showing an exposure fire in the Safeguards Room will not prevent safe cold shutdown of the reactor. If the results of an analysis shows safe shutdown of the reactor will be jeopardized by the exposure fire, provide additional measures including upgrading barriers to 3 hours to ensure safe shutdown.

Revised Response

The Unit 1 Safeguards Room is located in fire zone 8-G. The equipment in this room consists of the two redundant safeguards trains within cabinets separated by about five feet. They are safety-related and a fire in the room could conceivably cause undersirable spurious actions.

The north and west walls of fire zone 8-G are three hour rated fire barriers. The remaining walls that define this fire zone will be upgraded to three hour rated fire barriers. The floor and ceiling are three hour barriers. Three hour rated fire dampers will be provided in the ventilation ducting to contain the total flooding fire suppression agent (described below).

Strict administrative controls for this fire zone will greatly minimize the possibility of an exposure fire from occurring. For example, smoking will be prohibited in this area (to minimize fire hazard as well as prevent false alarms of the smoke detectors). Combustible liquids will not be authorized in this area and paper will be kept to a minimum.

In-depth fire protection will be provided for this area. Four cross-zoned smoke detectors installed in the ceiling of the room will be positioned to provide early detection of a fire in any of the safeguards cabinets or the room itself. A total flooding automatic/manual actuated Halon 1301 system will be provided with a reserve supply of Halon 1301 for subsequent manual discharge if required. Halon 1301 design concentration will be specified to be 5% minimum, 7% maximum. The supplier furnishing the Halon system will be required to verify the proper Halon concentration within the room as well as within the safeguards cabinets by test discharge. Two dry chemical and two CO_2 portable extinguishers are located close by in the control room as well as firewater hose reel immediately outside of the control room.

Any postulated fire in this zone would be immediately detected by smoke detectors and control room personnel response would be in a matter of seconds. With the proposed administrative controls and in-depth fire detection and suppression capability, an exposure fire in the safeguards area would not affect safe shutdown. If the fire were a deep-seated electrical fire within a safeguards cabinet, the plant would be shut down and the safeguards train could be de-energized. The automatic discharge Halon could then be assured to completely suppress the fire and additional levels of manual suppression capability are available as back-up protection. Safe shutdown capability is assured since such a postulated fire would not affect the redundant safeguards train.

Revised Response to Q.24 - Continued

The Unit 2 Safeguards Room is located in fire zone 8-H. All fire protection commitments made for the Unit 1 Safeguards Room apply to the Unit 2 Safeguards Room.

Q.26 Provide the following information for all three diesel generators:

a. Verification that the fire hose can reach all areas of each diesel room.

b. The results of an analysis of a fire in a diesel generator room caused by a break or leak in the day tank under the diesel engine. Verify that the fire will not spread to all three diesel generator rooms through the floor drains.

c. The CO_2 system should only be locked out when personnel egress in the room would take a longer time that the delay provided for system discharge.

Revised Response

a. A fire hose reel station for each unit will be added that can reach all areas of each diesel generator room. Location of hose reel stations is shown on the drawings provided for Question 38.

b. As discussed in Section 4.1.11 of the Diablo Canyon Fire Protection Review (Amendment 51), a postulated fire within a diesel generator room would not affect safe shutdown. As described in our response to Question 57, the diesel generators are properly protected from each other and from other hazards in the area. Curbs will be added to the doorways to the diesel generator rooms to contain any oil spillage. The diesel generator room floor drainage system will drain postulated day tank fuel oil spillage to the turbine building sump. Numerous four-inch floor drains are provided in the diesel generator rooms, in particular, floor drains are located directly beneath the day tanks. Each floor drain is covered by a circular grating and a supporting steel catch basin in the throat of the drain. This prevents debris from entering the drain system. A common four-inch header connects the drains from the individual compartments with the turbine building sump. This drain header is a minimum of 3½ ft. below the floor drain openings. Drainage of an oil spill in a compartment would not result in a flame pathway down the drain line since flame passage would be inhibited by the floor drain covers, oxygen depletion in the drain line, and the considerable distance downward and laterally that the flame would have to traverse to propagate to an adjacent compartment. If the interconnecting header is postulated to be blocked between the diesel generator compartments and the turbine building sump and a large oil spill from one compartment occurs, the fuel oil in the drain provides flame trap protection since the system would be solid-filled and flame cannot migrate from the burning surface of the fuel oil in the affected compartment to the unaffected compartments.

Complete combustion of a 550 gallon diesel generator day tank would generate about 77 x 10^6 Btu of heat (approximately 100,000 Btu/ft^2). However, the diesel generator rooms are routinely inspected at least once per eight hour shift and drainage is provided in each room. Therefore, diesel fuel leakage would not accumulate in the compartment. If a fire were to start in a diesel generator room, the automatic total flooding CO_2 system would quickly extinguish it. Therefore, it is felt that a fire of this magnitude would not occur in a diesel generator room. Even if it did, the fire should not breach the barrier between the diesel generator room. In the unlikely event that such a fire occurred, it would not affect safe shutdown capability because it would be confined to a single diesel generator.

c. The CO_2 system in the diesel generator rooms will be operable at all times when equipment in the area is required to be operable, except when personnel are working in a diesel generator room. When an operator makes a routine inspection of the equipment in a diesel generator room, he would not ordinarily lock out the CO_2 system. If maintenance work is being done on a diesel generator, the normally closed three hour rated equivalent rolling fire doors for the other diesel generator rooms would protect those diesel generators.

If a CO_2 system is locked out, that information is alarmed in the control room. While the system is locked out, personnel working in the area provide continuous surveillance. In the event that the CO_2 system is inadvertently left locked out after the maintenance work is done, the control room operators would be alerted to that fact by the CO_2 system status board.

Additional Information

Diesel generator backup control circuitry is fed off of a different electrical division than the normal control circuitry. Thus, a fire in certain areas (4.16KV cable spreading room, 480V switchgear room, and inverter room) could, for example, affect the "F" bus diesel generator circuitry and the "F" bus backup control circuitry for the "G" bus diesel generator. A fire in one of these areas could render the "F" bus diesel generator inoperative, but the "G" bus diesel generator would still be operative using the normal "G" bus control circuitry. As described in FSAR Section 8.3.2, the manual transfer switches to transfer the diesel generator control circuitry from normal to backup are located within each diesel generator compartment. There is no automatic transfer scheme and the manual transfer switch is maintained in the normal position. As shown in FSAR Figure 8.3-12 (schematic diagram - 4KV diesel generator controls), damage to the backup control circuitry cannot affect diesel generator operation using normal control circuitry. Thus, a single fire can affect, at most, one diesel generator.

Backup power for the diesel fuel transfer pumps comes from Unit 2. The backup power circuits for the two transfer pumps run from the Unit 2 480V switchgear rooms to the Unit 1 480V switchgear rooms. In running from the Unit 2 to the Unit 1 switchgear rooms, the redundant backup circuits run in the same fire zone. However, the transfer switches to transfer power for the pumps from Unit 1 to Unit 2 are located in the Unit 1 switchgear rooms. Thus, damage to the backup power circuits could not affect fuel transfer pump operation from Unit 1 power. This is shown on the fuel transfer pump electrical schematic, drawing 437657.

As identified in the June 6, 1978, submittal, "Supplementary Information for Fire Protection Review," diesel fuel transfer pumps power circuits are separated by approximately 15 ft. in the auxiliary building, elevation 73 ft., fire zones 3-J-1 and 3-C (ref: drawing 57691). Since fire zone 3-J-1 will have automatic sprinkler protection, the area has low fuel loading and both fire zones have smoke detectors, it is felt that the 15 ft. separation for these redundant circuits is adequate. However, two-hour protection of the conduits will be provided.

These same circuits run through an office area containing a whole body counter in fire zone 4-B at elevation 85 ft. In running up the wall of this office, the conduits maintain their 15 ft. separation and are each enclosed behind two-hour rated metal lathe and plaster walls that isolate the conduits from the office and each other. One conduit runs above the suspended ceiling in the south end of the office while the redundant conduit runs above the suspended ceiling in the counting room to the north (fire zone 4-A). This office area has been designated as a "No Storage" area and automatic sprinkler protection is provided for the space.

As identified in the June 6, 1978 report "Supplementary Information for Fire Protection Review," a fire in a diesel generator compartment could adversely affect operation of both diesel fuel transfer pumps.
For example, a fire in diesel generator 1-1 compartment could conceivably (1) start the fuel transfer pump(s) and supply fuel to the diesel generator 1-1 day tank, or (2) prevent fuel transfer pumps from starting when required to replenish other diesel generator day tanks. Revision 6 of drawing 437657 (fuel transfer pump electrical schematic) shows the circuit modification that will be made to correct this potential problem. Relays located in fire zone 11-D controlled by control switches in the diesel generator compartments will cause the fuel transfer pump(s) to start. If a fire in the diesel generator compartment causes an open circuit in the control circuit, neither pump will start and fuel will not be supplied to the affected diesel generator. However, the pumps can still start to provide fuel for the other diesel generators. If the fire causes a short to ground in the control circuit, a fuse would blow and again fuel would not be provided to the affected diesel generator, but could be supplied to the

other two diesel generators. Protection of the circuit susceptible to fire requires two fuses in series; the fuses will be coordinated to ensure proper operation. Testing will be conducted to verify this coordination results in proper system response. If the fire causes a short in the control circuit, the transfer pump will start and try to supply fuel to the affected diesel generator. However, to prevent that from occurring, fusible plugs will be installed in the air lines to the day tank level control valves (the valves fail closed on loss of air). Since the fire would melt the fusible plugs prior to affecting the control circuit, no additional fuel would be introduced into the diesel generator compartment.

The new relays located in fire zone 11-D will be mounted above the one hour suspended ceiling. These relays are located in junction boxes BTA211 and BTA208 separated by approximately 15 ft. as shown on Revision 18 of drawing 57579. There is no fuel load above the suspended ceiling and automatic sprinklers will be installed in the ceiling. This circuit modification will ensure proper fuel transfer pump operation during normal plant operation as well as during and after a diesel generator fire.

Q.27 (4-45) In Unit 1, 4.16 KV cable spreading rooms separate each division with 3-hour fire rated barrier.

Revised Response

The walls that separate the three-4.16KV cable spreading rooms will be upgraded to two-hour rated barriers. This will be accomplished by fireproofing the exposed steel beams in the walls and ceiling of the 4.16KV cable spreading room and fireproofing the one-inch gaps between the concrete block walls and the poured concrete walls. The fireproofing of the structural steel will be in accordance with a rated U.L. design. Outside walls on the north and east are already two-hour rated barriers. The doors separating these rooms are "B" labeled and are felt to provide adequate fire protection for the small quantity of combustible materials in the area. It is not considered necessary or cost effective to replace these doors and frames to obtain "A" labels. Two-hour rated fire barriers will be constructed in the corridors west of the 4KV cable spreading rooms to separate redundant safe shutdown electrical circuits in these areas. These compartmentalized corridors will be included within the fire zone boundaries of the respective 4KV cable spreading rooms as shown on the revised fire zone drawing 3-2. This modification will result in each redundant 4KV division at elevation 104 ft. in the turbine building being enclosed within a minimum two-hour fire barrier. Ventilation air supply ducting to each 4KV cable spreading room at elevation 104 ft. is contained within its respective division's fire zone. Ventilation air exhausts from each cable spreading room to each respective 4KV switchgear room above.

In-depth fire protection in this area is provided by smoke detectors, CO_2 hose reels, a firewater hose reel, and portable extinguishers. All comments and commitments made regarding fire area 12 in Unit 1 apply equally to fire area 23 in Unit 2.

Circuitry from one electrical division may be located within the 4.16KV cable spreading room of a redundant division in certain instances. For example, in the "G" bus cable spreading room, conduit K2669 contains "F" bus control circuitry for an auxiliary saltwater pump. That circuit is an automatic start circuit for the "G" bus auxiliary saltwater pump due to under voltage of the "F" bus. Damage to that control circuit as a result of a "G" bus cable spreading room fire would not prevent operation of the auxiliary saltwater pump powered off of the "F" bus. This is shown on Revision 10 of drawing 437594, Schematic Diagram - Auxiliary Saltwater Pumps. Other instances where circuitry from one division is located in the cable spreading room of a redundant division have been reviewed and in none of the instances are the circuits in question required for safe shutdown, nor would damage to the circuits adversely affect safe shutdown capability.

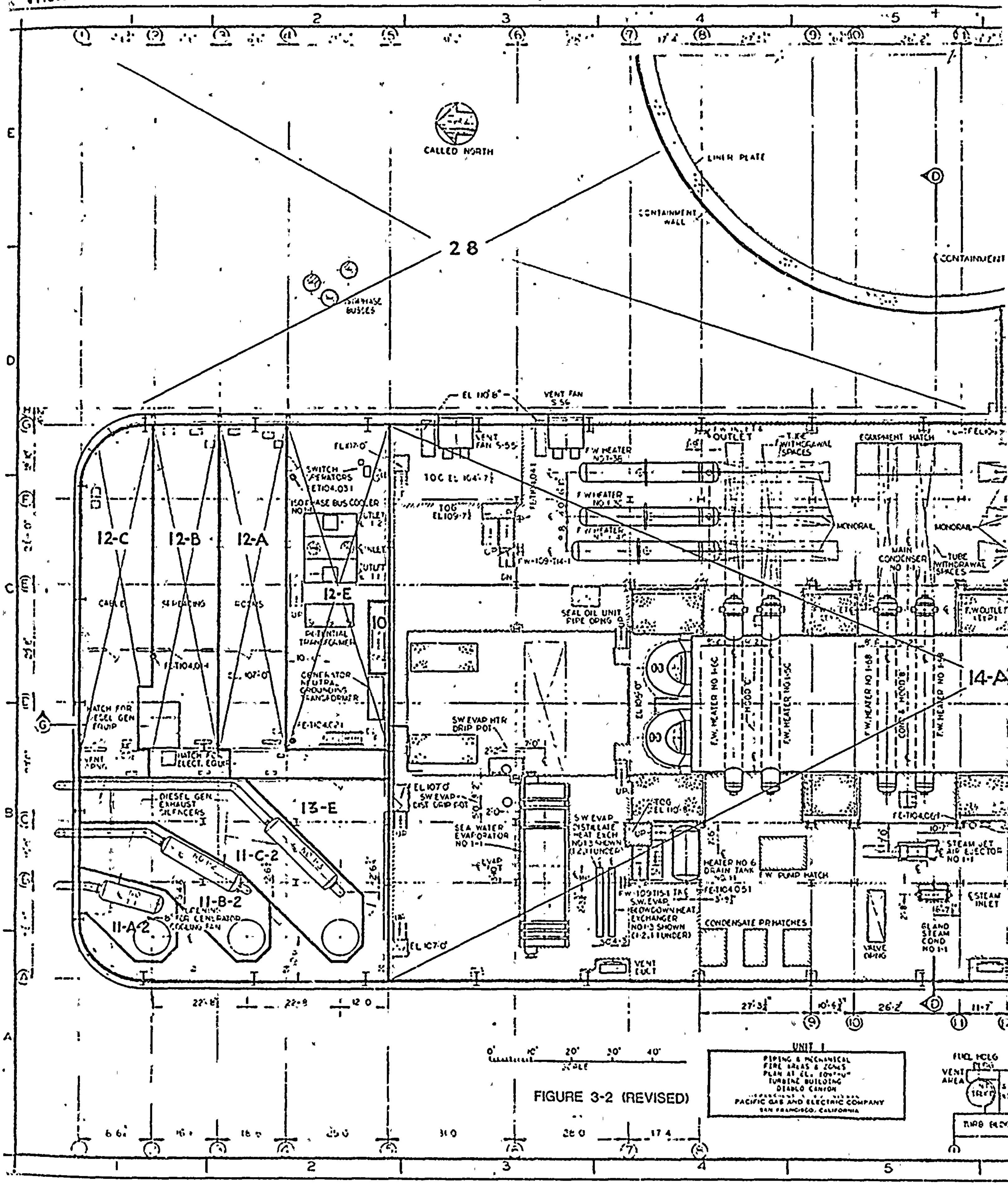


FIGURE 3-2 (REVISED)

Q.28 All three divisions are located at the ceiling in the corridor adjacent to 4.16KV cable spreading room and the turbine building at elevation 104'. Provide automatic sprinklers at the ceiling throughout the corridor in accordance with Section D.3 of Appendix A.

Revised Response

The three divisions of 4.16KV cables located at the ceiling of the corridor adjacent to the 4.16KV cable spreading rooms are in conduits and are well separated. The fuel load in this corridor is negligible and barriers separate this corridor from the other low fuel load compartments adjacent to it. Because this corridor will be within a security area allowing only limited access to the area, it would not be a normal area for storage. Therefore, it is unlikely transient combustibles would be present in this area. (Fire zone 13-F at elevation 119 ft. is a designated storage area for the turbine building. The area contains no safety related equipment or circuitry and is properly isolated from the rest of the turbine by three-hour fire barriers.)

As described in the revised response to Question 27, redundant safe shutdown electrical circuits will be separated from each other by two-hour rated fire barriers. As a result of these barriers, automatic sprinkler protection will not be provided since a fire in this area could affect at most one electrical division. This would not affect safe shutdown capability.

Circuitry in fire zones 12-D and 12-F required for safe shutdown has been identified and tabulated in Section 5 of the June 6, 1978, report entitled "Supplementary Information for Fire Protection Review." Control circuits for the auxiliary feedwater pumps in conduits K2665 and K2666 in fire zone 12-F were previously identified as being required for safe shutdown. These circuits are from the feedwater pumps and are part of the automatic start circuitry for the auxiliary feedwater pumps. As such, they are not required for safe shutdown and damage to the circuits would not affect safe shutdown capability.

Q.29 (4-46) The fire hazard analysis for 4.16 the KV switchgear rooms is not acceptable. Provide 3-hour fire barriers which separate all three divisions from each other and from other areas of the plant as recommended in Section D.5 of Appendix A.

<u>Revised Response</u>

The walls that separate and enclose the three 4.16KV switchgear rooms will be upgraded to two hour rated barriers. This will be accomplished by fireproofing the exposed steel beams in the walls and ceiling of the 4.16KV switchgear rooms and fireproofing the one-inch gaps between the concrete block walls and the poured concrete walls. The fireproofing of the structural steel will be in accordance with a rated U.L. design. Outside walls on the north and east are already two hour rated barriers. The doors to these rooms are "B" labeled and are felt to provide adequate fire protection for the small quantity of combustible materials in the area. It is not considered necessary or cost effective to replace these doors and frames to obtain "A" labels.

Ventilation air for the 4KV switchgear rooms is supplied by fans located in fire zone 13-E via ducting running through fire zone 13-D. Smoke detectors and automatic sprinkler protection will be provided for the 4KV switchgear ventilation fans in fire zone 13-E. The ventilation ducting to each switchgear room in fire zone 13-D will be fireproofed to provide one hour rated protection and one and one-half hour rated fire dampers will be provided in the ventilation ducting where it passes from fire zone 13-D into the switchgear rooms. Three hour rated fire dampers will be installed in the ventilation exhaust ducting in the ceiling of the 4.16KV switchgear rooms. This will isolate the 4.16KV switchgear rooms from the turbine building operating deck (el. 140 ft.).

In-depth fire protection in these areas is provided by smoke detectors, CO_2 hose reels, a firewater hose reel, and portable extinguishers.

Q.45 Demonstrate that the Diablo Canyon can be safely shutdown assuming that a fire is induced by a safe shutdown earthquake. Describe portions of the fire protection system that are designed for a seismic event.

Revised Response

Fire suppression capability after a safe shutdown earthquake will consist of manual hose reels and portable extinguishers. Hose reels have been provided throughout the plant so that all areas of the plant are accessible by at least one hose stream. Portions of the firewater system will be seismically qualified so that all hose reels in safety related areas of the plant will be available following a safe shutdown earthquake. The qualified system will consist of the 300,000 gallon firewater tank, the two motor-driven fire pumps, and the fire mains and piping required to provide water to the hose reel stations in safety related areas of the plant. Cross-ties between the auxiliary building and the turbine building will be provided so that the fire pumps can supply water to any fire system component within the plant without the use of the yard loop. Check valves will be installed in the six yard loop feeder lines into the plant. This will prevent water loss out of the yard loop (which could conceivably be damaged as a result of an earthquake). The check valves will have normally closed, manual by-passes to ensure availability of a backup water supply for the transformer deluge systems. The attached figure shows what portion of the firewater system will be seismically qualified.

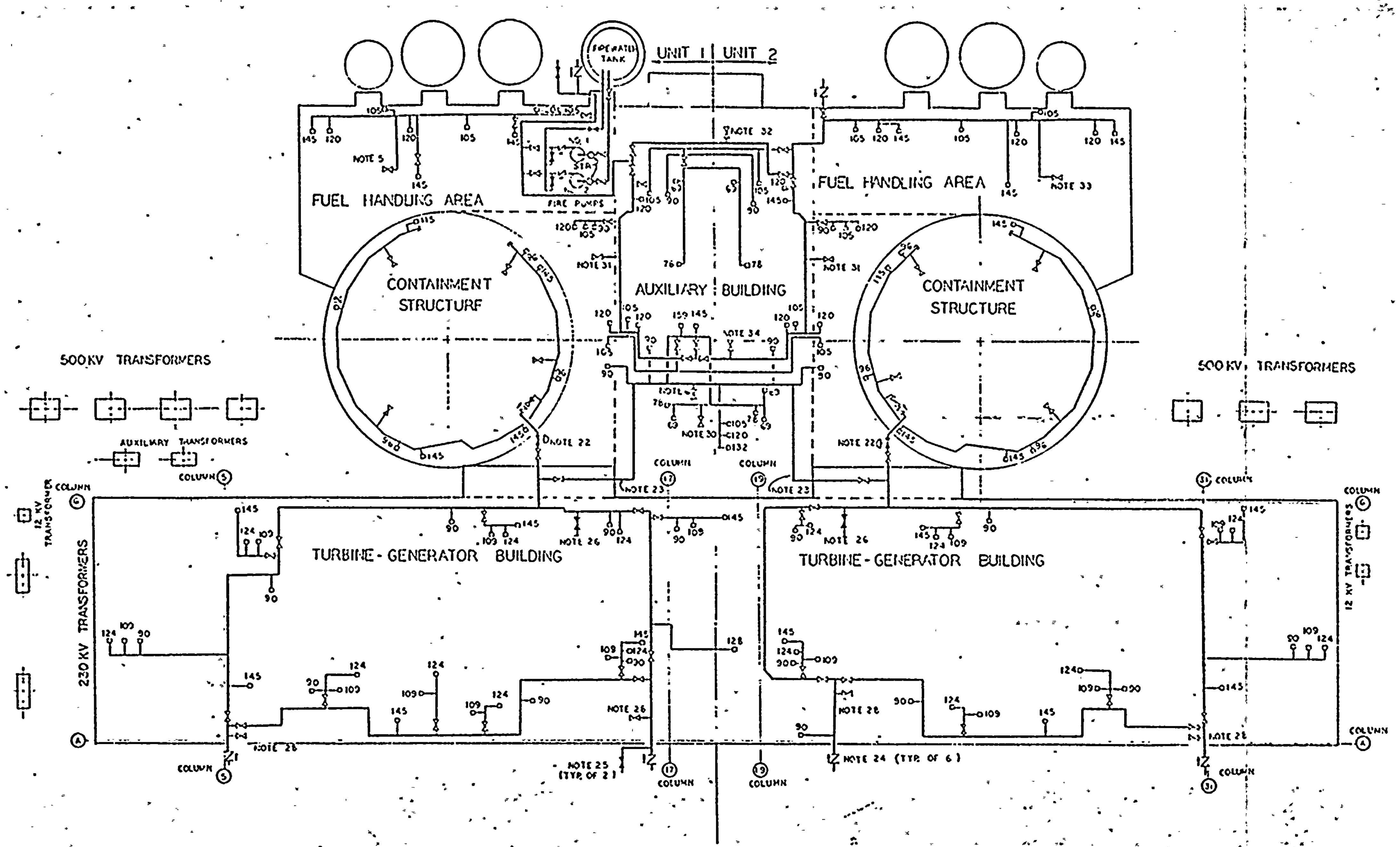
The seismically qualified portion of the fire system can be readily isolated from the rest of the fire system. The existing turbine building sprinkler systems and new sprinkler systems to be provided in the turbine building can be isolated from the rest of the system by closing two valves per unit. Reactor coolant pump sprinklers can be isolated from the seismically qualified portion of the fire system by closing valves in the lines to the sprinkler systems or by closing the containment fire system isolation valves inside or outside of containment. The existing auxiliary building sprinklers can be isolated by closing one valve. Additional auxiliary building automatic sprinklers to be installed will be readily isolatable by closing five valves (total for both units). All sprinkler systems have flow alarms to provide control room annunciation of system actuation and/or leakage. Sufficient firewater would be available for multiple hose streams even considering the water that could be lost from breaks in non-qualified sprinkler piping prior to plant operators isolating the leaks. Backup fire protection capability will be provided by three-250 gpm portable engine-driven fire pumps. Connections will be installed from the auxiliary saltwater system (at the component cooling water heat exchanger) to provide suction to the portable pumps. The pump discharge can be tied into a fire main to resupply the firewater tank or to pressurize the fire system for long-term fire fighting. The portable pumps will be stored in a suitable area to ensure that they will not be affected by a seismic event.

Revised Response to Q.45 - Continued

All buildings in which the qualified fire system piping is run have been re-evaluated for the Hosgri earthquake and, where necessary, are being strengthened as a result of the analysis. The qualified fire system piping runs in the vicinity of some non-Class I equipment in the turbine building; however, as a part of the Hosgri re-evaluation, supports for major non-Class I equipment are being reanalyzed and modified where necessary. Areas in which the seismically qualified portions of the fire system are run will be reassessed to ensure damage to non-Class I equipment or piping will not render the fire system inoperative.

Fire protection system modifications will be evaluated to ensure that in the event of a seismic disturbance, the new fire protection systems will not adversely affect safety related equipment. This will be accomplished by supporting fire system components such that the components will not endanger safety related equipment in the area. This evaluation will be done in particular for any additional fire system/sprinkler system piping, smoke detectors within safety related cabinets and the Safeguards Room Halon 1301 system.

Plant operating procedures specify that after a seismic event, a thorough inspection of all plant areas be conducted to assess, and if possible, remedy any damage that might have occurred to plant components as a result of the seismic event. Any earthquake induced fire or potential fire hazard created by the earthquake would be identified during this inspection and, if necessary, the plant fire brigade would be dispatched to the fire. This inspection of all plant areas would be completed within two hours after a seismic event.



LEGEND

- ⋈ CONTROL VALVE
- CHECK VALVE
- HOSE SHELTER
- FIRE WATER HOSEREEL STATION
- AUTOMATIC SPRINKLER SYSTEM OR DELUGE SYSTEM
- 95 INDICATES ELEVATION IN FEET

NOTES

5. AUXILIARY BOILER ROOM SPRINKLER VALVE.
6. LABORATORY, ACCESS CONTROL, LAUNDRY ROOM, LOCKER ROOM, ETC SPRINKLER VALVE.

22. FCV FOR CONTAINMENT FIRE SYSTEM NORMALLY CLOSED.
23. PIPING CROSSTIE ADDED TO ALLOW FIRE PUMPS TO PROVIDE FLOW TO ALL PORTIONS OF THE FIRE SYSTEM WITHIN THE PLANT WITHOUT THE USE OF THE YARD LOOP.
24. CHECK VALVES IN YARD LOOP FEEDER LINE TO ISOLATE SEISMICALLY QUALIFIED PORTIONS OF FIRE SYSTEM FROM THE NON QUALIFIED YARD LOOP. VALVES LOCATED INSIDE PLANT BUILDING.

NOTES (CONT'D)

25. NORMALLY CLOSED GATE VALVES ARE BY PASSES AROUND CHECK VALVES IN YARD LOOP FEEDER LINES SO THAT SECONDARY FIRE WATER SUPPLY (FIRE WATER TANK) CAN BE MADE AVAILABLE FOR TRANSFORMER DELUGE SYSTEMS, INTAKE STRUCTURE HOSE REELS, ETC.
26. CONNECTIONS FOR 250 GPM ENGINE DRIVEN PORTABLE PUMPS WATER SUPPLY IS SEAWATER FROM AUXILIARY SALTWATER SYSTEM.
28. TURBINE BUILDING SPRINKLER SYSTEM VALVES.(4 TOTAL).
30. CHARGING PUMP AND COMPONENT COOLING WATER PUMP SPRINKLER VALVE.
31. PENETRATION AREA SPRINKLER VALVE.
32. AUXILIARY FEEDWATER PUMP, FUEL HANDLING BUILDING CORRIDOR, BORIC ACID TRANSFER PUMP SPRINKLER VALVE.
33. SECURITY SYSTEM DIESEL GENERATOR SPRINKLER VALVE.
34. AUXILIARY BUILDING SUPPLY FAN CONTROL ROOM VENTILATION ROOM SPRINKLER VALVE.
36. FOR COMPLETE DRAWING OF FIRE PROTECTION SYSTEM, REFER TO FIGURE 5-1A

UNITS 1 AND 2
DIABLO CANYON SITE

FIGURE 5-1B

SEISMICALLY QUALIFIED PORTION OF FIRE WATER SYSTEM

Q.46 Describe the procedure employed for heat and smoke removal using fixed or portable equipment in areas that house safety related systems or components. Describe how these areas can be ventilated for manual fire fighting purposes. Include a discussion regarding control accesses to the equipment as well as the ability to handle high temperature gases and particulates.

Revised Response

The ventilation systems either supply fresh outside air to rooms or exhaust air from rooms into a closed duct system (or both for some rooms). Ventilation exhaust capability, either manual or automatic, exists in all plant areas.

Situations where rated fire dampers have been provided include: a) rooms that have total flooding CO_2 protection, b) where heat (and smoke) transmission through a fire barrier might result in a fire propagating to an adjacent room, and c) where it is desirable to reduce air flow to confine the fire. Ventilation for manual fire fighting in areas with normal ventilation flow cut-off can be accomplished with portable blower-exhaust fans and by opening doors. Four portable fans, each rated at 750 cfm, are available. These fans could exhaust to the outside or to nearby operating ventilation exhaust ducts. Self contained breathing apparatus is available as described in our response to Question 40. Fire dampers would not normally be opened until after the fire was extinguished. If the normal ventilation system is used for heat and smoke venting, system design is such that the heat and smoke would be discharged outside, and not to other rooms. Distances between air intakes and exhausts are specified in Section 5.4.4.2 of the Fire Protection Review (Amendment 51). These distances are adequate to ensure against contamination of intake air.

Additional Information

The June 6, 1978 submittal "Supplementary Information for Fire Protection Review" identified the ventilation system components required for safe shutdown equipment and tabulated the fire zones in which ventilation components/circuitry are located. As shown on the attached table, redundant ventilation system components/circuitry are located in the same fire zone in certain instances. This table also specifies the fire protection modifications to be made in these fire zones. As a result of these planned modifications, it is extremely unlikely that a fire would adversely affect redundant ventilation system components.

However, if such a fire were to affect redundant ventilation system components, numerous actions could be taken to prevent this fire from affecting safe shutdown capability. Some of these actions are described below:

a) If a cable spreading room or control room fire affects the auxiliary building or fuel handling building ventilation fans, the equipment can be controlled at the motor control centers.

b) Operation of redundant pumps could be staggered to prevent motor overheating. A temperature monitoring system has been provided for the vital equipment rooms and pump bearing temperature and motor bearing and stator temperature indication is available in the control room.

c) The unit can be kept at hot standby until the necessary ventilation is lined up. Hot standby can be adequately maintained with only the turbine driven auxiliary feedwater pump. This component does not require ventilation to operate.

d) Portable ventilation fans can be used and doors can be opened to provide air circulation. Four portable fans (total for the two units), each rated at 750 cfm, are available.

The fans run off of 115 volt ac power. Suitable electrical outlets are located throughout the plant to power these fans. If loss of off-site power occurs, the fans could be readily plugged into the receptacles for the emergency ac lighting. The emergency ac lighting circuits can carry the additional load from these fractional horsepower fans as well as the emergency lights themselves.

e) The ventilation system has been conservatively designed to provide adequate cooling for all equipment under all operating modes. Even with portions of the ventilation system inoperative, equipment room temperatures, while higher than normal, would not be so high as to cause equipment failure. Equipment life may be shortened but would certainly be available for the duration of the safe shutdown process.

f) Auxiliary building ventilation is provided by Unit 1 and Unit 2 supply and exhaust fans. No single fire can affect both Unit 1 and Unit 2 auxiliary building ventilation. There is free communication between the Unit 1 and Unit 2 portions of the auxiliary building. If one unit lost all or a portion of its ventilation, the second unit's ventilation system could pick up much of the load. Opening doors and rigging portable fans would be especially effective in the auxiliary building.

In conclusion, due to the planned fire protection modifications, it is felt that redundant ventilation components will not be affected by a fire. Even if they were, enough mitigating actions can be taken to prevent such a fire from affecting safe shutdown capability.

DIABLO CANYON UNITS 1 AND 2
FIRE ZONES IN WHICH REDUNDANT VENTILATION FOR
SAFE SHUTDOWN EQUIPMENT COULD BE AFFECTED

Fire Zones	Auxiliary Building* Supply	Auxiliary Building* Exhaust	Fuel Handling Bldg.** Supply	Fuel Handling Bldg.** Exhaust	Auxiliary Saltwater Pumps	480V Swgr. & Inverter	4KV Swgr.
3-L (Aux. Bldg. el. 85')	4,6	4,6	4,6	4,6	--	--	--
3-P-1 (Fuel hdl. bldg. supply fan room)	--	--	3,4	--	--	--	--
3-P-4 (Aux. bldg. exh. fan E-1 room)	--	3,4	--	--	--	--	--
3-Q-1 (Aux. feedwater pump room)	--	1,3	1,3	--	--	--	--
3-X (Aux. bldg. el. 100')	4	1,3	1,3	4	--	--	--
3-AA (Aux. bldg. el. 115')	4	--	--	4	--	--	--
4-A (Lab area)	2,3	2,3	2,3	2,3	2,3	--	2,3
6-A-5 (Space west of batteries, el. 115')	--	--	--	--	--	2,3,4	--
7-A (Cable spreading room)	3,5	3,5	3,5	3,5	--	--	--
8-B-1 (Aux. bldg. supply fan room)	1,3	--	--	--	--	--	--
8-C (Control room)	3	3	3	3	--	--	--
10 (12KV swgr. room)	--	--	--	--	2	--	2
12-D, 12-F (Corridors 4KV area)	--	--	--	--	--	--	1
13-E (4KV swgr. vent. room)	--	--	--	--	--	--	1,3
31 (Fuel hdl. bldg. corridor)	--	1	1	--	--	--	--

Notes

* Required for component cooling water pumps, charging pumps, and RHR pumps.
**Required for auxiliary feedwater pumps.

Notes (Continued)

-- = Ventilation components not located in this fire zone.

1 = Automatic sprinkler protection in the fire zone.

2 = Fireproofing of circuitry to ventilation components.

3 = Smoke detectors in the fire zone.

4 = Posted "No Storage" area.

5 = Total flooding CO_2 system.

6 = Exposure of these components is limited to electrical circuits in juction boxes and one foot of conduit high on the west wall of zone 3-L near the ceiling.

Q.49 Hydrogen lines are presently located near safety-related equipment and cables throughout your plant. It is our position that hydrogen lines whose explosion could affect safety equipment be relocated prior to fuel loading. Modify you design to meet this position. Provide the location in which all such situations exist.

Revised Response

Excess flow automatic shutoff valves have been provided for the hydrogen system which will shut off hydrogen supply if system demand exceeds 50 cfm. If a shutoff valve trips closed, an alarm will annunciate in the control room. These trip valves are located outside of the plant in the hydrogen bottle storage vault. The valves are inherently reliable, passive elements, and the light weight internals and housings would not be vulnerable to damage from a seismic event since the valves are rigidly supported in place. These valves would provide protection against and indication of a significant hydrogen leak.

To further minimize hazards from a hydrogen explosion, hydrogen lines will be rerouted out of certain areas containing safety-related equipment and will be enclosed within a guard pipe where it runs in any areas containing safety-related equipment. The guard pipe will be vented to the outdoors and will be pressure tested to verify that it is leak tight. The guard pipe will be constructed of carbon steel piping and fittings. Hydrogen leakage in safety-related areas would require failure of both the hydrogen piping and the guard piping. This could be postulated to occur only in the event of complete collapse of the piping system. If this were to occur, hydrogen flow would be sufficient to trip the excess flow valves. A small hydrogen leak (insufficient to close the trip valves) is unlikely to occur in safety-related areas and, as described below, would not create a hazard.

Fire zones containing safety-related equipment in which the hydrogen piping (within guard pipe) will run are:

1. Fire pump room (fire zone 3-R) elevation 115'. This area is ventilated by the fuel handling building supply and exhaust fans. Ventilation air to this room is provided by supply ducts over the fire pumps; the air exhausts through floor-to-ceiling access openings to a ventilation corridor to the north. There are no pockets near the ceiling of this room where hydrogen could accumulate.

2. Penetration areas (fire zones 3-BB and 3-CC), elevation 115' and 100'. In the penetration areas, elevations 100' and 115' communicate, the volume of these fire zones are 400,000 ft^3 each and ventilation air from these areas exhaust to the outdoors through openings in the ceiling (including an 8" gap between the containment structure and the ceiling)

Revised Response to Q.49 - Continued

There are no pockets in the ceilings of the elevation 100' and 115' areas; any hydrogen leakage in these areas would migrate to the ceiling of the elevation 115' area and would be purged to the outdoors.

3. Auxiliary building, elevation 100' (fire zone 3-X). Hydrogen piping in fire zone 3-X is confined to just the volume control tank compartment and the adjacent compartment. The volume control tank is not required for safe shutdown. These areas are ventilated by the auxiliary building supply and exhaust fans. Supply air to these compartments is provided via the access ways to the compartments and each compartment is provided with an exhaust register. The exhaust air is ducted to the auxiliary building exhaust fans. The exhaust ducting will be modified to ensure air at the top of the compartments is exhausted from the compartment. With this modification, no pockets will exist in the compartments where hydrogen could accumulate.

In summary, large hydrogen leaks in safety-related areas are unlikely, and if such a lea occurred, the excess flow trip valves would prevent hydrogen build up. Small hydrogen leaks in safety-related areas cannot be reasonably expected to occur and even if such a lea were to occur, an explosive concentration of hydrogen could not build up since these areas are properly ventilated to purge any hydrogen leakage.

Installation of portable hydrogen bottles for the chemical and volume control system in the volume control tank compartment was evaluated and found to be unsatisfactory for the following reasons:

1. The hydrogen bottles would have to be transported through areas containing safety-related equipment. The potential hazard of a handling accident creating a hydrogen bottle missile is felt to be much more serious than retaining hydrogen piping enclosed within a guard pipe.

2. OSHA requirement for storage of hydrogen bottles in an occupied building may create conflicts with existing PGandE safety and operations standards for nuclear plants.

3. The volume control tank compartment is a high radiation area. Additional personnel exposure and possible contamination of the hydrogen bottles would result from storage of the bottles in that area.

It is felt that the reroute and installation of guard piping for the hydrogen system will minimize the potential of a hydrogen explosion affecting safe shutdown equipment.

Q.50 Supplement the information which has been provided to include a listing of all systems and components such as instruments and controls which are essential to achieve and/or maintain cold shutdown (safe shutdown). Also, identify any of these systems and/or components whose associated electrical circuitry and/or cables are not redundant.

Revised Response

The systems, components and instruments which are required to achieve and/or maintain a safe cold shutdown condition are listed in the attached table. The redundancy of the components and instruments is also included. This information is an excerpt from Section 2 of PGandE's June 6, 1978, submittal entitled "Supplementary Information for Fire Protection Review".

DIABLO CANYON UNITS 1 AND 2
FIRE PROTECTION REVIEW OF
EQUIPMENT REQUIRED FOR SAFE SHUTDOWN

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
1. Emergency Power Supply	
A. Diesel Generator	2 of 3 required
B. Diesel fuel oil transfer pumps and day tank level control valves	1 of 2 pumps required, 1 of 2 LCV's per day tank required
C. 125v DC batteries	2 of 3 required
D. Battery chargers	2 of 5 required
E. Inverters	2 of 4 required
F. 4KV power supplies to 480v load centers and load center transformers	2 of 3 required
G. 125v DC supplies to 4KV switchgear	2 of 3 required
H. 125v DC power supplies to main control board	2 of 3 required
I. Instrument AC power	2 of 4 channels required
2. Auxiliary Feedwater System	
A. Auxiliary feedwater pumps (turbine driven auxiliary feedwater pump 1-1 and electric motor driven auxiliary feedwater pumps 1-2 and 1-3).	1 of 3 pumps required
B. Associated steam supply valves for pump 1-1:	Applicable only to pump 1-1
FCV-95, FCV-15, FCV-152	Required for pump 1-1
FCV-37, FCV-38	1 of 2 valves required for pump 1-1
C. Associated level control valves:	
Pump 1-1: LCV-106, LCV-107, LCV-108 LCV-109	1 of 4 valves required for pump 1-1
Pump 1-2: LCV-110, LCV-111	1 of 2 valves required for pump 1-2
Pump 1-3: LCV-113, LCV-115	1 of 2 valves required for pump 1-3
D. Water supply and associated valves:	1 of 2 water supplies required
(1) Condensate storage tank	No valves required
or (2) Raw water reservoir, FCV-436, FCV-437	1 of 2 valves required for raw water reservoir

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
3. Residual Heat Removal System	
A. Residual heat removal pump	1 of 2 pumps required
B. Residual heat removal heat exchanger	1 of 2 HX required
C. Residual heat removal valves:	
8701, 8702 (hot leg RHR suction)	Both valves required
HCV-637, HCV-638 (RHR flow path)	1 of 2 valves required
8809-A, 8809-B (RHR flow path)	1 of 2 valves required
D. RHR heat sink:	
Component cooling water system	See Item 5
Auxiliary saltwater system	See Item 6
4. Charging and Boration	
A. Charging pumps (2 centrifugal and 1 reciprocating pump)	1 of 3 pumps required
B. Charging pump cooling:	
Component cooling water system	see Item 5
Auxiliary saltwater system	see Item 6
C. Centrifugal charging pump auxiliary lube oil pumps	Only utilized to start pumps. Can be by-passed.
D. Charging and boration flow path	1 flow path required
(1) Using boric acid tanks:	
Boric acid tanks	1 of 2 tanks required
Boric acid tank heaters*	1 of 2 heaters per tank required
Boric acid tank temperature controllers*	1 of 2 TIC's required
Boric acid transfer pumps	1 of 2 pumps required
Boric acid filter	Only flow path required
Valves 8104, FCV-110A	1 of 2 valves required
Heat tracing for boric acid lines in flow path*	1 of 2 heat traces required
Charging pumps	1 of 3 pumps required
Valve FCV-128	Required for centrifugal charging pumps. Two manual by-pass flow paths.
and a. Charging through reactor coolant pump seals via RCP seal injection	No additional components required
or b. Charging through regenerative HX and valves HCV-142, 8108, 8107 and:	Flow path through HX required and all valves required for this flow path.
1. Valve 8145, charging to auxiliary pressurizer spray	Valve required for pressurizer spray.
or 2. Valve 8146, charging to loop 3 cold leg	Valve required
or 3. Valve 8147, charging to loop 4 cold leg	Valve required

*Components are not required for safe shutdown but have been tabulated to assess in what areas a fire could damage these components.

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
or (2) Using boron injection tanks:	
Refueling water storage tank	Required for this flow path
Valves 8805A, 8805B	1 of 2 valves required
Charging pumps	1 of 3 pumps required
Valve FCV-128	Required for reciprocating charging pump
Valves 8803A, 8803B	1 of 2 valves required
Boron injection tank (BIT)	Required
BIT heater*	1 of 2 heaters required
BIT temperature controller*	Required
Valves 8801A, 8801B	1 of 2 valves required
Heat tracing for boric acid lines in flow path*	1 of 2 heat traces required
5. Component Cooling Water System	
A. Component cooling water pump	1 of 3 pumps required
B. Component cooling water heat exchanger	1 of 2 HX required
C. Component cooling water valves:	
FCV-430, FCV-431 (CCW vital service headers)	1 of 2 valves required
FCV-355 (CCW miscellaneous service header)	Required for charging pump 1-3 cooling
FCV-364, FCV-365 (CCW to RHRHX)	1 of 2 valves required for RHR system cooling
D. CCW pump auxiliary lube oil pump	Only required to start CCW pump
E. CCW heat sink: Auxiliary saltwater system	See Item 6
6. Auxiliary Saltwater System	
A. Auxiliary saltwater pump	1 of 2 pumps required
B. Auxiliary saltwater valves: FCV-602, FCV-603 (ASW to CCWHX)	1 of 2 valves required
7. Main Steam System	
A. Main steam isolation valves: FCV-41, FCV-42, FCV-43, FCV-44	Required to close only for a main steam line break
B. 10% power relief valves: PCV-19, PCV-20, PCV-21, PCV-22	1 of 4 valves required. Backup to 10% power relief valves provided by 35% power relief system and 40% steam dump valves.
C. Steam generator safety valves	Five per loop, 20 total. Required to lift if only 1 of 4 10% power relief valves is available.
D. Steam generator blowdown isolation valves: FCV-760, FCV-761, FCV-762, FCV-763	Required to close to maintain water inventory for safe shutdown

*Components are not required for safe shutdown but have been tabulated to assess in what areas a fire could damage these components.

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
8. Instrumentation	
A. Steam Generator level SG 1-1: LT-517, LT-518, LT-519 SG 1-2: LT-527, LT-528, LT-529 SG 1-3: LT-537, LT-538, LT-539 SG 1-4: LT-547, LT-548, LT-549	1 steam generator required for cooldown, 1 of 3 LT's required for that SG.
B. Steam generator pressure Loop 1: PT-514, PT-515, PT-516 Loop 2: PT-524, PT-525, PT-526 Loop 3: PT-534, PT-535, PT-536 Loop 4: PT-544, PT-545, PT-546	1 steam generator required for cooldown 1 of 3 PT's required for that loop
C. Reactor coolant system temperature Loop 1: TE-413A, TE-413B Loop 2: TE-423A, TE-423B Loop 3: TE-433A, TE-433B Loop 4: TE-443A, TE-443B	1 of 2 required per loop, 1 loop required for cooldown
D. Reactor coolant system or pressurizer pressure PT-403, PT-405, PT-455, PT-456	1 of 4 required
E. Pressurizer level LT-459, LT-460, LT-461, LT-406	1 of 4 required
F. Boric acid tank level LT-102, LT-106	1 of 2 required
9. Ventilation for Safe Shutdown Equipment	
A. Control room supply fans S-35, S-36	1 of 2 fans required. Unit 2 ventilation also available for shared control room.
B. Auxiliary building supply and exhaust fans S-31, S-32 E-1, E-2	 1 of 2 required 1 of 2 required
C. 480 volt switchgear room and inverter room supply fans S-43, S-44	1 of 2 required
D. 4.16KV switchgear room supply fans S-67, S-68, S-69	2 of 3 required
E. Auxiliary saltwater pump room exhaust fans E-101, E-103	1 of 2 required
F. Fuel handling building supply and exhaust fans S-1, S-2 E-5, E-6	 1 of 2 required 1 of 2 required

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
10. Fire System	1 of 2 water supplies required in the event of a fire
A. Primary water supply: Raw water reservoir	
B. Secondary water supply: Fire water storage tank, Fire pumps 0-1, 0-2	1 of 2 pumps required for this water supply
11. Pressurizer Spray**	
A. Water supply to charging pumps	1 of 2 supplies required
(1) Boric acid tanks	1 of 2 tanks required
Boric acid tank heaters*	1 of 2 heaters per tank required
Boric acid tank temperature controllers*	1 of 2 TIC's required
Boric acid transfer pumps	1 of 2 pumps required
Boric acid filter	Only flow path required
Valves 8104, FCV-110A	1 of 2 valves required
Heat tracing for boric acid lines in flow path*	1 of 2 heat traces required
or (2) Refueling water storage tank	Required for this flow path
Valves 8805A, 8805B	1 of 2 valves required
B. Charging pumps	1 of 3 pumps required
C. Charging flow path	
Valves HCV-142, 8108, 8107	Valves required
Regenerative HX	Flow path required
Valve 8145, auxiliary pressurizer spray	Manual by-pass around valve 8145

* Components are not required for safe shutdown but have been tabulated to assess in what areas a fire could damage these components.

**All components required for Pressurizer Spray have been tabulated for Charging and Boration. Alternative pressurizer spray methods available provided reactor coolant pumps and PCV-455A and PCV-455B operable (valves require instrument air). Backup pressure relief capability provided by pressurizer power relief valves (PCV-455C, PCV-456, PCV-474).

Q.51 Assuming that an emergency alternate method is employed, outside of the control room, to achieve and/or maintain a safe cold shutdown, provide responses to items below:

1. Provide a list of essential safe shutdown equipment with a description of how remote instrumentation and control would be accomplished. Identify each safe shutdown equipment and/or its associated instrumentation and control equipment for which electrical energy is essential for its proper operation.

2. Provide supporting information which may be used to conclude that (if a fire occurs in the main control room or cable spreading room) electrical power, instrumentation, or control required for safe shutdown equipment will not be lost, assuming that the offsite power grid is not available.

3. Confirm that the associated electrical design or corresponding remote shutdown instrumentation and control panels is the same for the two units.

4. Identify and describe any changes in the original electrical design as a result of the incorporation of this emergency alternate method for achieving and/or maintaining a safe shutdown.

Revised Response

Control of Equipment at the Hot Shutdown Remote Control Panel

In the event that the control room is uninhabitable or portions of it are non-functional as a result of a fire in either the cable spreading room or the control room, safe (cold) shutdown would be carried out at the hot shutdown remote control panel located at elevation 100 feet in the auxiliary building (west end of fire zone 5-A-4). For a tabulation of how safe shutdown components would be controlled outside of the control room, refer to the attached table, "Status of Safe Shutdown Equipment Assuming Loss of Cable Spreading Room/Control Room." To operate equipment from the hot shutdown panel, the door panels would be opened, a transfer switch (one for each component) would be thrown from "control room" to "local", and the control switch could then operate the component in question. All of these actions are annunciated or indicated in the control room. Once the transfer switch is thrown to the local position, control circuitry running in the cable spreading room and control room is isolated from the rest of the circuit. None of the circuitry associated with the hot shutdown panel controls runs in the cable spreading room or control room, nor do any power circuits for safe shutdown components run in the cable spreading room or control room. Thus, any fire damage as a result of a cable spreading room or control room fire cannot affect control of safe shutdown equipment from the hot shutdown panel. The electrical and instrument schematics for the following safe shutdown equipment with control at the hot shutdown panel verify the above statements:

Revised Response to Q.51 (Continued)

Drawing	Component
437583	Motor-driven auziliary feedwater pumps
437584	FCV-95; steam supply valve for turbine-driven auxiliary feedwater pump
437507	LCV-106, 107, 108, 109; level control valves for turbine-driven auxiliary feedwater pump
102036 Sh. 8,8A	LCV-110, 111, 113, 115; level control valves for motor-driven auxiliary feedwater pumps
437595	Centrifugal charging pumps
437597	Boric acid transfer pumps
437607	Valve 8104, emergency borate valve
102032 Sh. 26	HCV-142; charging pump discharge to regenerative HX valve
102036 Sh. 30A	FCV-128; charging pump discharge header valve
437593	Component cooling water pumps
437594	Auxiliary saltwater pumps
102036 Sh. 16,16A	10% power relief valves

Local Control of Safe Shutdown Equipment

Some safe shutdown equipment might have to be operated locally at the switchgear, or in the case of certain motor operated valves, manually. For example, the diesel generators and the fire pumps are controllable locally, the RHR pumps and the reciprocating charging pump can be started at the 4KV switchgear, and the auxiliary building and/or fuel handling building ventilation can be started at their 480V motor control centers if necessary. The electrical schematics for these safe shutdown components with local controls verify the above statement:

Drawing	Component
437625	"F" Bus Diesel Generator automatic starting and loading ("G" and "H" bus similar)
437591	RHR pumps
437595	Reciprocating charging pump
445643	Auxiliary building and fuel handling building ventilation fans
437630	Fire pumps

A cable spreading room or control room fire would not prevent operation of these components either locally or at the switchgear. In situations where it might be necessary to manually open or close a motor operated valve, the motor operator for the valve would be de-energized at the motor control center to prevent a subsequent fault in the circuitry from causing spurious valve movement. This de-energizing requirement will be incorporated into the emergency operating procedures. All safe shutdown air operated valves fail to their desired position if the air supply is removed.

Revised Response to Q. 51 (Continued)

Instrumentation Required for Safe Shutdown

Existing safe shutdown instrumentation with readouts in the control room or at the hot shutdown panel could be affected by a cable spreading room fire. To prevent loss of vital instrumentation due to cable spreading room fire, dedicated safe shutdown instrumentation will be provided that is not vulnerable to a cable spreading room (or control room) fire. The parameters to be monitored will be pressurizer pressure and level, reactor coolant system temperature, and steam generator level and pressure. These parameters, along with reactor coolant system boron concentration (determined from the reactor coolant system sampling system or change in boric acid tank level), are sufficient to take the plant to a safe (cold) shutdown condition. The dedicated safe shutdown instrumentation will be separate from the protection system instrumentation.

Steam generator pressure will be provided by pressure indicators on the main steam lines outside containment (fire zone 3-BB). Two reactor coolant system temperature elements will be located in fire zone 1-B; pressurizer pressure and level and steam generator level transmitters (one per SG) will be located in fire zone 1-A. The circuits from these transmitters will pass through the containment and terminate at the dedicated safe shutdown instrument panel in fire zone 3-BB at elevation 100 feet. The power supply for the instrumentation will be vital Instrument AC power, Channel IV. Circuit routing for the Instrument AC power will be confined to the "H" bus electrical rooms and fire zone 3-BB. Since none of the circuitry associated with the dedicated safe shutdown instrumentation or its power supply passes through the cable spreading room or the control room, a fire in either of these areas cannot affect this instrumentation. Electrical design of the hot shutdown panel and associated local panels is the same for the two units. All electrical modifications (including dedicated safe shutdown instrumentation) will be done for both units.

Consequences of a Fire at the Hot Shutdown Panel

A fire in the west end of fire zone 5-A-4 could affect the hot shutdown panel or the circuitry to the hot shutdown panel. This area has a minimal fuel loading, smoke detectors have been provided in the area, and the area has been designated as a "No Storage" area. Thus, it is felt that a significant fire would not occur in this area. However, the consequences of such a fire are described below.

There are three considerations in assessing the consequences of a hot shutdown panel fire:

1. damage to circuitry running to the hot shutdown panel,

2. a fire that affects the transfer switches within the hot shutdown panel, and

3. components affected in the control room due to the hot shutdown panel fire.

Revised Response to Q.51 (Continued)

Control circuit routing for all the pumps and motor operated valves with controls at both the hot shutdown panel and the control room is such that damage to the circuits to the hot shutdown panel will not affect control room circuitry and vice versa. This is demonstrated on the electrical schematics listed above for the pumps and motor-operated valves that have controls at the hot shutdown panel. During normal operation, the hot shutdown panel control circuitry is isolated from the rest of the circuit by open contacts located in the 480V or 4KV motor control centers. Any damage to this isolated circuitry running between the motor control room center and the hot shutdown panel cannot in any way affect control room operation of this component. This is true for all 480V pumps and motor operated valves with controls at the hot shutdown panel.

A fire affecting the transfer switches in the hot shutdown panel could conceivably cause control of components to be taken away from the control room and transferred to the hot shutdown panel. Switches within the motor control centers will be provided to restore control back to the control room (as shown on the electrical schematics). Once this switch is thrown, operation of the equipment from the control room cannot be affected by a hot shutdown panel fire.

Circuitry for the electrohydraulic auxiliary feedwater level control valves (LCV-110, 111, 113, 115), if damaged by a fire in or near the hot shutdown panel, could prevent control room operation of these valves. However, these valves would still be manually operable and, as stated above, the motor-operated auxiliary feedwater level control valves would still be operable from the control room.

Valves FCV-128 (charging pumps discharge header) and HCV-142 (charging pump discharge to regenerative heat exchanger) have pneumatic controls at the hot shutdown panel. Damage to the pneumatic controller or tubing as a result of a hot shutdown panel fire could prevent control room operation of these valves. However, FCV-128 is normally open and fails open on loss of air. Furthermore, the reciprocating charging pump does not require this valve for operation. HCV-142 is not required for charging via the reactor coolant pump seal flow path; furthermore, a manual by-pass around HCV-142 could be opened if necessary.

The 10% power relief valves (PCV-19, 20, 21, 22) have pneumatic controls of the hot shutdown panel also. However, a backup pneumatic air supply (air bottles) independent of the hot shutdown panel would allow valve operation from the control room in the event of a fire at the hot shutdown panel.

Revised Response to Q.51 (Continued)

A hot shutdown panel fire that affects instrumentation with readouts at the hot shutdown panel would affect control room readout of that same instrumentation. However, sufficient redundancy in instrumentation is provided in the control room such that loss of that instrumentation with readouts at the hot shutdown panel would not affect safe shutdown capability from the control room. None of the hot shutdown panel instrumentation is associated with the protection system.

The components described above are all of the safe shutdown components with controls/readouts at the hot shutdown panel. In summary, safe shutdown capability from the control room is not adversely affected by a hot shutdown panel fire.

DIABLO CANYON UNITS 1 AND 2
STATUS OF SAFE SHUTDOWN EQUIPMENT ASSUMING
LOSS OF CABLE SPREADING ROOM/CONTROL ROOM

SYSTEM AND COMPONENTS	COMMENT
Emergency Power Supply	
Diesel generators	Local controls in DG rooms
Diesel fuel transfer pumps	Unaffected by CSR/CR fire
Auxiliary Feedwater System	
Motor driven auxiliary feedwater pumps	Control at HSD panel
Turbine driven auxiliary feedwater pump	Control at HSD panel
Auxiliary feedwater level control valves	Control at HSD panel
Residual Heat Removal System	
RHR pumps	Control at 4KV switchgear
RHR valves	Open 8701, 8702 manually; HCV-637, HCV-638 fail open; 8809A, 8809B normally open, fail as is
Charging and Boration	
Boric acid transfer pumps	Control at HSD panel
Valve 8104	Control at HSD panel
Centrifugal charging pumps	Control at HSD panel
FCV-128	Control at HSD panel
1) Reactor coolant pump seal flow path	Available
or 2) HCV-142	Control at HSD panel
Valves 8107, 8108	Normally open, fail as is
a) Valves 8146, 8147	Fail open on loss of air
or b) Valve 8145 (pressurizer spray)	Open manual by-pass
Component Cooling Water System	
Component cooling water pumps	Control at HSD panel
CCW vital service header valves	1 of 2 valves open, fail as is
CCW to RHR HX valves	Fail open on loss of air
Auxiliary Saltwater System	
Auxiliary saltwater pumps	Control at HSD panel
ASW valves	Fail open on loss of air

#4

November 10, 1978

DIABLO CANYON INTAKE STRUCTURE FACTOR OF SAFETY AGAINST SLIDING

The factor of safety against sliding for a structure represents a ratio between the calculated forces resisting sliding to the calculated forces causing sliding. A lower limit of 1.5 is commonly used in conventional structural design with normal loadings. The enclosed pages contain the calculations made to determine the factor of safety against sliding for the Intake Structure.

The forces attempting to slide the structure include the seismic response of the structure itself, and the static and dynamic soil pressures acting on the east or back wall of the structure. The dynamic forces, which include the structure response and the dynamic soil pressure, have been combined on the SRSS basis in order to properly consider the respective frequencies of oscillation. The result is combined with the static soil pressure on an absolute sum basis.

The resisting forces include the friction force resulting from the net weight of the structure, the shear strength of the rock below the structure, and the friction forces resulting from the backfill forces on the north and south ends of the structure.

The calculated factor of safety of 2.27, while well above the normally accepted limit of 1.5, does not represent the total resisting forces acting on the structure. The passive pressure acting on the front or west wall of the structure was not included, nor was the effect of the upward sloping grade at the front of the structure. The friction force due to the weight of the structure resulted from a combination of the maximum vertical uplift response with the maximum horizontal response, whereas a more realistic approach would be to use 40% of the maximum uplift combined with the maximum horizontal response. The restraining effect of the large concrete intake conduits at the back of the structure was also not included.

An additional element of conservatism is the dynamic earth pressure forces. The calculated dynamic pressure increment according to the Mononobe-Okabe

method was increased by a factor of 3 to account for the increased amplification resulting from the rigidity of the structure.

This analysis demonstrates the ability of the Intake Structure to safely resist, with a comfortable margin, the forces attempting to cause sliding.

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902.26	JOB DIABLO CANYON	BY DAL	DATE 5/10/7
CLIENT P.G.&E.	SUBJECT INTAKE STRUCTURE	CHK'D	DATE

SHEET NO.

FACTOR OF SAFETY AGAINST SLIDING

SLIDING FORCES

1) STRUCTURE RESPONSE			
a) UPPER WALLS	6820^k		
b) PEDESTAL	23536^k	(SRSS) →	36958^k
2) DYNAMIC SOIL PRESSURE	27666^k		
3) STATIC SOIL PRESSURE	9907^k	→	9907^k
		TOTAL =	46865^k

RESISTING FORCES

1) FRICTION FORCE	22199^k
2) SHEAR FRACTURE	77031^k
3) SKIN FRICTION ON ENDS	7290^k
TOTAL =	106520^k

$$\text{FACTOR OF SAFETY AGAINST SLIDING} = \frac{106520^k}{46865^k} = 2.27$$

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0302.26	JOB DIABLO CANYON	BY DAL	DATE 11/5/78
CLIENT P.G.&E.	SUBJECT INTAKE STRUCTURE	CHK'D	DATE

SHEET NO.

FACTOR OF SAFETY AGAINST SLIDING

BASE SHEAR FROM EARTHQUAKE

WALLS : TOTAL SUMMATION OF SHEAR FORCES FROM THE DYNAMIC COMPUTER ANALYSIS OF THE STRUCTURE. (REF. "INTAKE STRUCTURE - CALCULATIONS FOR 7.5M HOSGRI SEISMIC ANALYSIS", VOL 1 OF 1, EAST-WEST ANALYSIS)

TOTAL BASE SHEAR: 6820^{k}

PEDESTAL : THE PUMPDECK PEDESTAL, NOT INCLUDED IN THE DYNAMIC COMPUTER ANALYSIS BECAUSE OF ITS EXTREME RIGIDITY, IS INCLUDED BY APPLYING THE PEAK GROUND ACCELERATION (0.67g FOR BLUME 7.5M HOSGRI) TO THE MASS OF THE PEDESTAL. TOTAL WEIGHT OF PEDESTAL IS 35128^{k} (REF "INTAKE STRUCTURE - CALCULATIONS FOR 7.5M HOSGRI SEISMIC ANALYSIS," VOL 1 OF 1, EAST-WEST ANALYSIS)

$$35128^{k} \times 0.67 = 23536^{k}$$

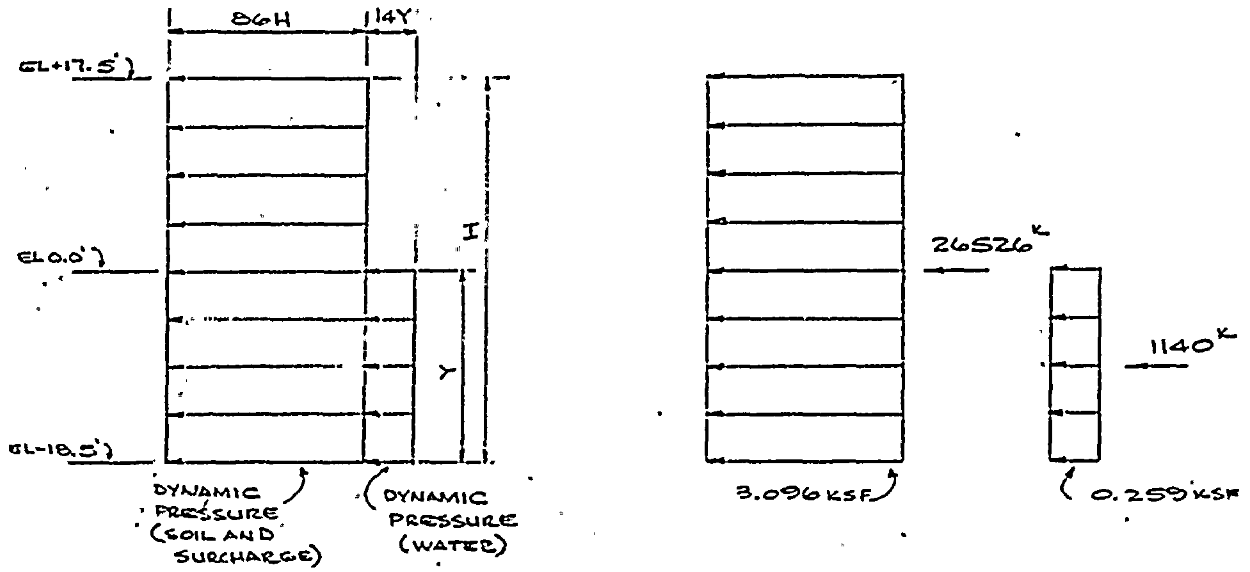
URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO.

JOB NO. 0902.26 JOB DIABLO CANYON BY DAL DATE 11/9/78
CLIENT P.G.&E. SUBJECT INTAKE STRUCTURE CHK'D DATE

FACTOR OF SAFETY AGAINST SLIDING

DYNAMIC SOIL PRESSURE



THE DYNAMIC PRESSURES HAVE BEEN SUPPLIED BY HARDING-LAWSON ASSOCIATES. THE DYNAMIC PRESSURE DUE TO SOIL AND SURCHARGE HAVE BEEN INCREASED BY A FACTOR OF 3 TO ACCOUNT FOR THE RIGIDITY OF THE STRUCTURE.

SOIL AND SURCHARGE: 0.086 KCF × 36' = 3.096 KSF
3.096 × 36' × 238' = 26526^k

WATER: 0.014 KCF × 18.5' = 0.259 KSF
0.259 × 18.5' × 238' = 1140^k

TOTAL: 26526^k + 1140^k = 27666^k

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

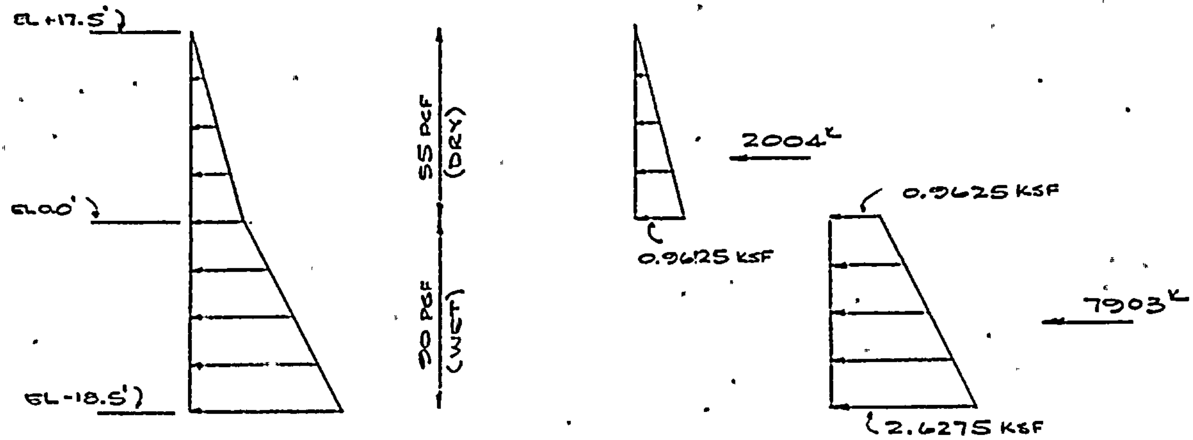
SHEET NO.

JOB NO. 0902.26 JOB DIABLO CANYON BY DAL DATE 11/9/78

CLIENT P.G. & E. SUBJECT INTAKE STRUCTURE CHK'D DATE

FACTOR OF SAFETY AGAINST SLIDING

STATIC SOIL PRESSURE



EQUIVALENT FLUID PRESSURES OF 55 PCF DRY AND 90 PCF WET FOR BACKFILL WAS SUPPLIED BY HARDING-LAWSON ASSOCIATES

DRY : $0.055 \text{ kcf} \times 17.5' = 0.9625 \text{ ksf}$

$0.9625 \times 17.5' \times 238' \times 1/2 = 2004^k$

WET : $0.090 \text{ kcf} \times 18.5' + 0.9625 \text{ ksf} = 2.6275 \text{ ksf}$

$(0.9625 + 2.6275) \times 18.5' \times 238' \times 1/2 = 7903^k$

TOTAL $= 9907^k \longleftarrow$

FACTOR OF SAFETY AGAINST SLIDING

FRICTION FORCE

TOTAL WEIGHT OF STRUCTURE (IN AIR) = 112,000^{k}

BUOYANT FORCE: 562,543 FT × 0.0624 KCF = −35,103^{k}

NET WEIGHT OF STRUCTURE = 76897^{k}

LESS VERTICAL ACCELERATION OF 0.5g UPWARD = −38448^{k}

REDUCED WEIGHT OF STRUCTURE = 38449^{k}

USE 38450^{k}

ANGLE OF INTERNAL FRICTION, SUPPLIED BY HARDING-LAWSON ASSOCIATES, IS $\phi = 30°$.

FRICTION FORCE: 38450 tan 30° = 22199^{k}

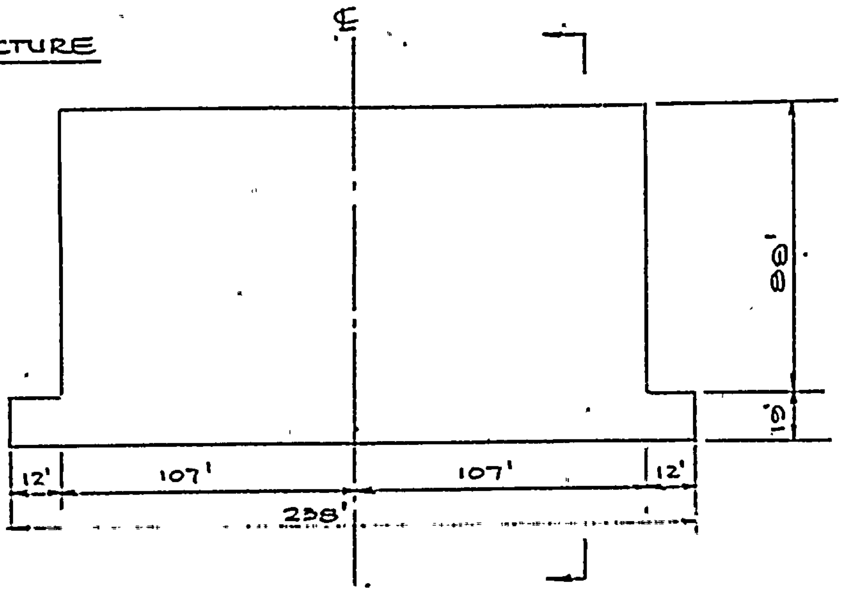
URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-26	JOB DIABLO CANYON	BY DAL	DATE 11/6/78
CLIENT P.G.&E.	SUBJECT INTAKE STRUCTURE	CHK'D	DATE

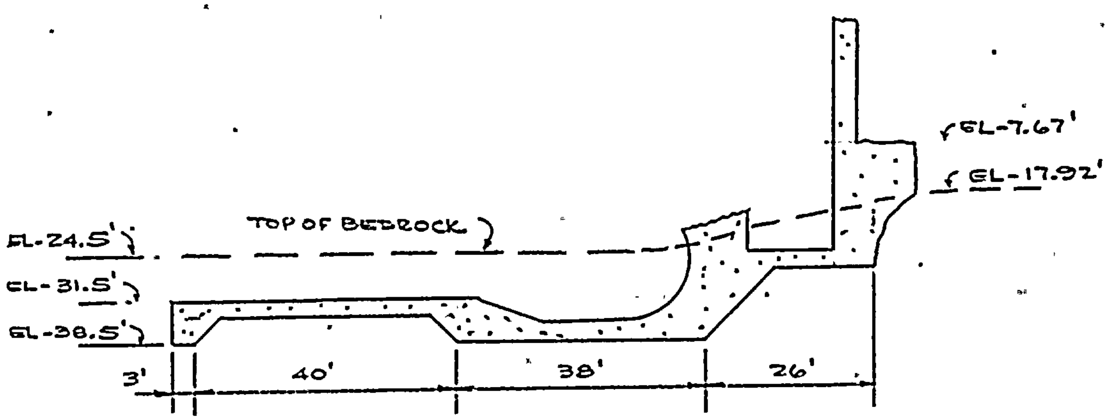
SHEET NO.

FACTOR OF SAFETY AGAINST SLIDING

SHEAR FRACTURE



PLAN



SECTION

FACTOR OF SAFETY AGAINST SLIDING

SHEAR FRACTURE

WHEN CONCRETE IS POURED DIRECTLY AGAINST ROCK, THERE EXISTS A VERY HIGH DEGREE OF COHESION BETWEEN THE TWO MATERIALS. A VALUE OF 500 PSI HAS BEEN USED IN THE ANALYSIS OF THE AUBURN DAM (REF. "DESIGN AND ANALYSIS OF AUBURN DAM," U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, VOL. 4, 1978. THIS COHESIVE EFFECT CAUSES THE FAILURE PLANE TO MOVE FROM THE CONCRETE-ROCK INTERFACE TO THE ROCK ITSELF. THE SHEAR STRENGTH OF THE ROCK, 3000 PSF OR 20.8 PSI, WAS SUPPLIED BY HARDING-LAWSON ASSOCIATES AS A RESULT OF TESTS OF THE ROCK MATERIAL.

IN ADDITION TO THE ENTIRE LOWER SURFACE OF THE SURFACE, APPROXIMATELY 14' OF THE END WALLS OF THE STRUCTURE HAVE ALSO BEEN POURED AGAINST THE ROCK.

BOTTOM: $2 \times 119' \times 19' = 4522\ FT^2$
$2 \times 88' \times 107' = 18832\ FT^2$
TOTAL $= 23354\ FT^2$

ENDS: $2 \times 107' \times 14' = 2996\ FT^2$
DEDUCT $2 \times 36' \times 4' = 288\ FT^2$
DEDUCT $2 \times 35/2 \times 11' = 385\ FT^2$
TOTAL $= 2323\ FT^2$

SHEAR FRACTURE FORCE:

$$(23354 + 2323)\ 3\ KSF = 77031^{K}$$

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

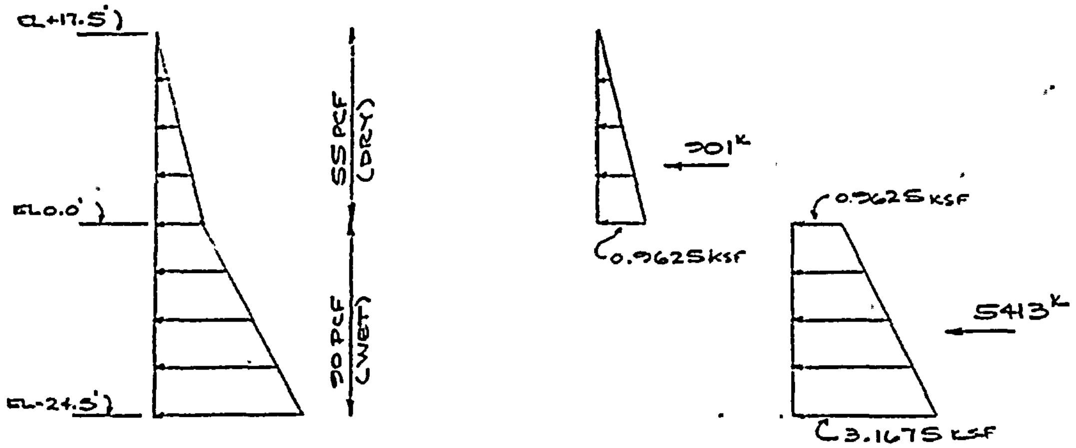
SHEET NO.

JOB NO. 0902-26 JOB DIABLO CANYON BY DAL DATE 11/2/78

CLIENT P.G & E. SUBJECT INTAKE STRUCTURE CHK'D DATE

FACTOR OF SAFETY AGAINST SLIDING

SKIN FRICTION ON ENDS



EQUIVALENT FLUID PRESSURES OF 55 PCF DRY AND 90 PCF WET FOR BACKFILL WAS SUPPLIED BY HARDING-LAWSON ASSOCIATES.

DRY : 0.055 KCF × 17.5' = 0.9625 KSF

0.9625 × 17.5' × 107' × 1/2 = 901k (NORMAL FORCE)

2 × 901k × tan 30° = 1040k (FRICTION FORCE)

WET : 0.090 KCF × 24.5' + 0.9625 KSF = 3.1675 KSF

(3.1675 + 0.9625) × 24.5' × 107' × 1/2 = 5413k (NORMAL FORCE)

2 × 5413k × tan 30° = 6250k (FRICTION FORCE)

TOTAL FRICTION FORCE = 7290k

Docket # 50-275/323
Control # 7811290460
Memo Date 11-21-78 of Document
REGULATORY DOCKET FILE
Memo 11-21-78 to Stolz from Allison

HOSGRI RE-EVALUATION OF DIABLO CANYON CONTAINMENT BASE MAT (ITEM A7)

General Description.

Containment base mat is a 14'-6" thick circular reinforced concrete slab. The center portion around the reactor pit has a depth of 36'-0". Reinforcing has been placed in two perpendicular directions (E-W, N-S) and arranged such that the walls of the reactor pit form a grid of four main girders. The base mat and reinforcing steel is shown in Figures 1 and 2.

Hosgri Analysis

A detailed analysis of the containment base mat has been performed using the SAP IV program, considering the Hosgri loads in combination with other applicable loads. The load combinations analyzed were:

a) Dead load + LOCA + Horizontal seismic + Vertical seismic up
This combination produces the maximum positive moments.

b) Dead load + Horizontal seismic + Vertical seismic down
This condition produces the maximum negative moments.

Analytical Model

The analytical model consists of a grid of orthogonal beams as shown in Figure 3, each representing a corresponding strip of slab and reinforcing identified on construction drawings. (See Figure 3). The containment shell and crane wall are represented as beams with increased bending stiffness to model the effect of wall depth.

The foundation is represented by compressive spring elements (no tensile stiffness). Each spring stiffness is based on tributary area of foundation it represents. This model represents a refinement of the simplified model used in a previous submittal dated September 29, 1978 which gave the results for load combination b).

Results

1) Maximum positive moments are due to load combination a). These moments are given in Table 1. All moments are within the acceptance limits in Chapter 4 of the Hosgri Seismic Evaluation Report. Figures 4-6 show moment diagrams for load combination a).

2) Load combination b) controls negative moments. The maximum negative moments and the concurrent positive moments are given in Table 2 and shown graphically on Figure 7.

TABLE I

CONTAINMENT BASE MAT - MAX. POSITIVE MOMENTS AT CRITICAL SECTIONS

LOCATION	MAX. BENDING MOMENT ~ 10^5 K-FT	ALLOWABLE MOMENT - 10^5 K-FT
STRIP X1 (1)	4.11	4.15
STRIP X2 (2)	1.19	1.27
STRIP X3 (3)	.75	.83
STRIP Y2 (4)	2.71	3.10
STRIP Y3 (5)	1.39	1.58
STRIP Y4 (6)	1.52	1.65
STRIP Y5 (7)	4.00	4.52
STRIP Y6 (2)	2.12	2.20

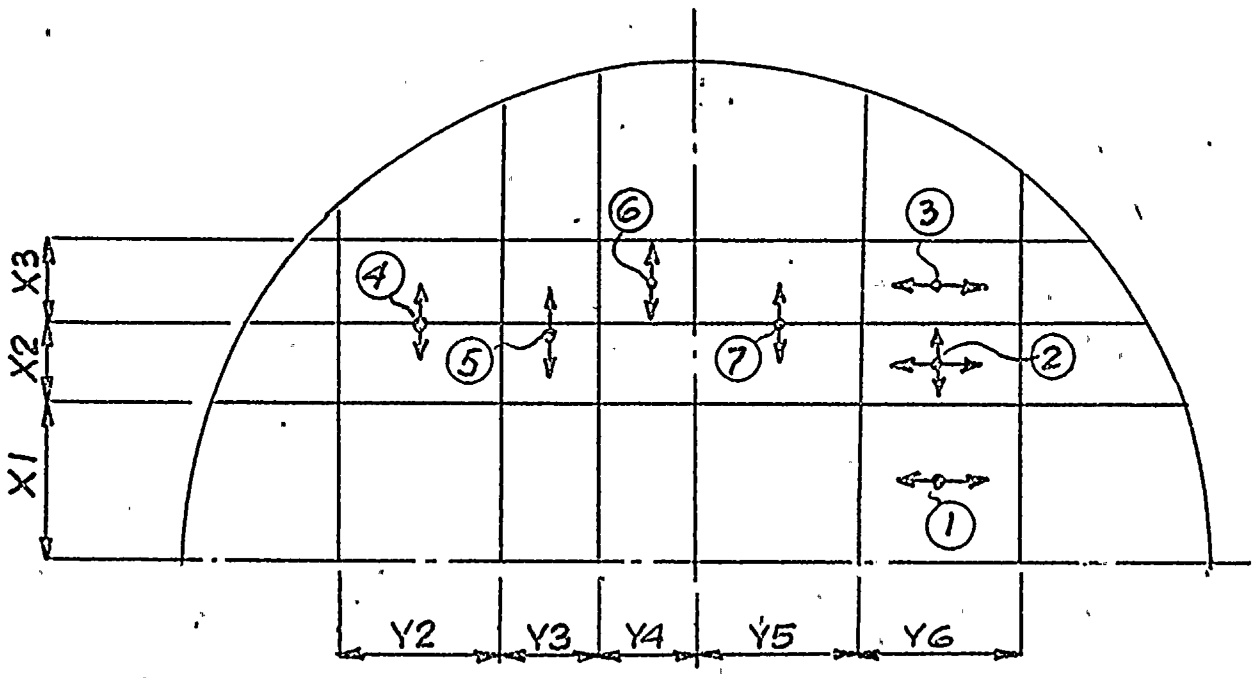
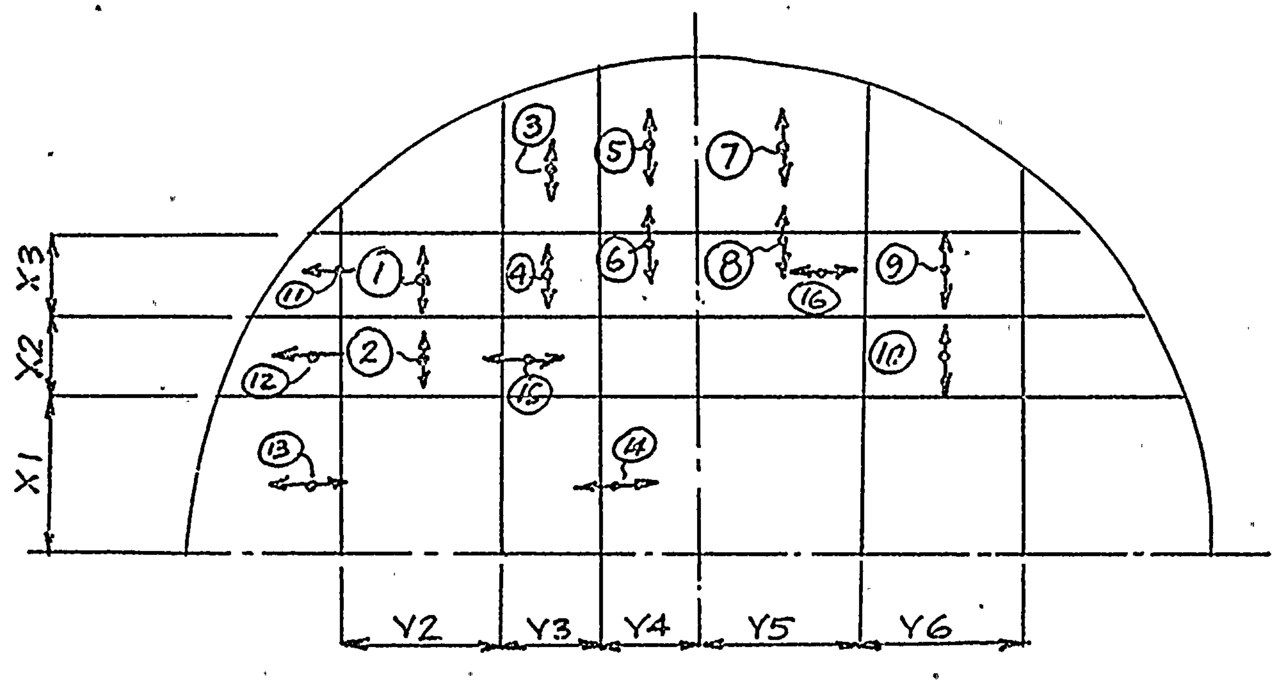


TABLE 2

CONTAINMENT BASE MAT - MAX. MOMENTS LOAD COMBINATION b
(CASE #5)

LOCATION		MAX. BENDING MOMENT	ALLOWABLE MOMENT	
			NEGATIVE	POSITIVE
STRIP X1	(13) (14)	-.23×10^5 KFT = -920 KF/FT .30×10^5 KFT = 1200 KF/FT	-1,480 KFT/FT	4.15×10^5 KFT
STRIP X2	(12) (15)	-.12×10^5 KFT = -1040 KF/FT .04×10^5 KFT = 320 KF/FT	-"-	1.27×10^5 KFT
STRIP X3	(11) (16)	-.12×10^5 KFT = -960 KF/FT .07×10^5 KFT = 560 KF/FT	-"-	.83×10^5 KFT
STRIP Y2	(1) (2)	-.29×10^5 KFT = -1161 KF/FT +.56×10^5 KFT = +2240 KFT/FT	-"-	3.10×10^5 KFT
STRIP Y3	(3) (4)	-.22×10^5 KFT = -1439 KFT/FT +.30×10^5 KFT = +2000 KFT/FT	-"-	1.58×10^5 KFT
STRIP Y4	(5) (6)	-.21×10^5 KFT = -1412 KFT/FT +.36×10^5 KFT = +2400 KF/FT	-"-	1.65×10^5 KFT
STRIP Y5	(7) (8)	-.28×10^5 KFT = -1115 KFT/FT +.69×10^5 KFT = +2760 KFT/FT	-"-	4.52×10^5 KFT
STRIP Y6	(9) (10)	-.23×10^5 KFT = -941 KFT/FT +.40×10^5 KFT = 1600 KFT/FT	-"-	2.20×10^5 KFT



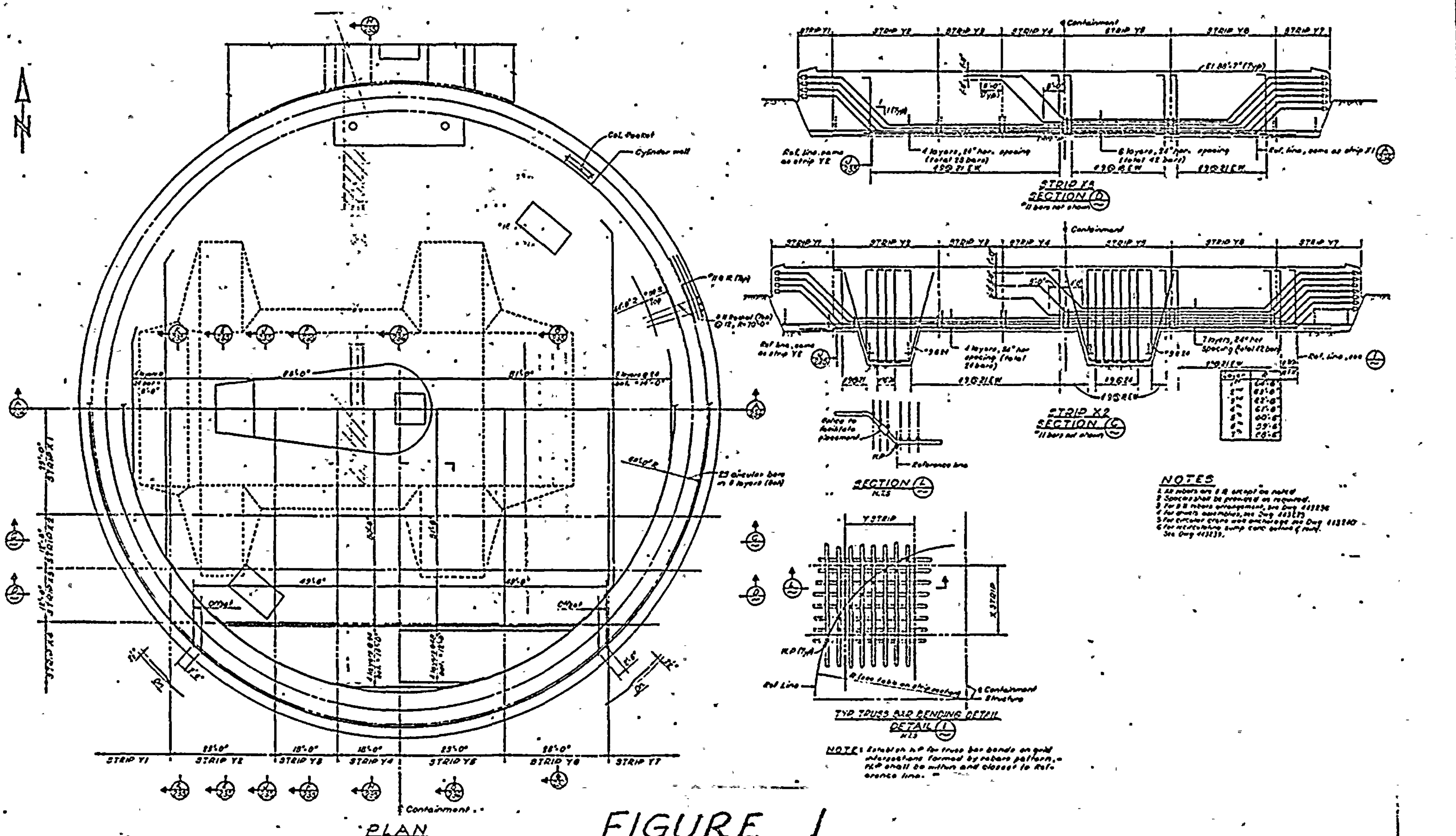

PLAN
STRIP Y1
STRIP Y2
STRIP Y3
STRIP Y4
STRIP Y5
STRIP Y6
STRIP Y7
Containment
Col. Pocket
Cylinder wall
STRIP X2 SECTION
SECTION
TYP TRUSS BAR BENDING DETAIL
NOTES
Reference line
X STRIP
Y STRIP

FIGURE 1

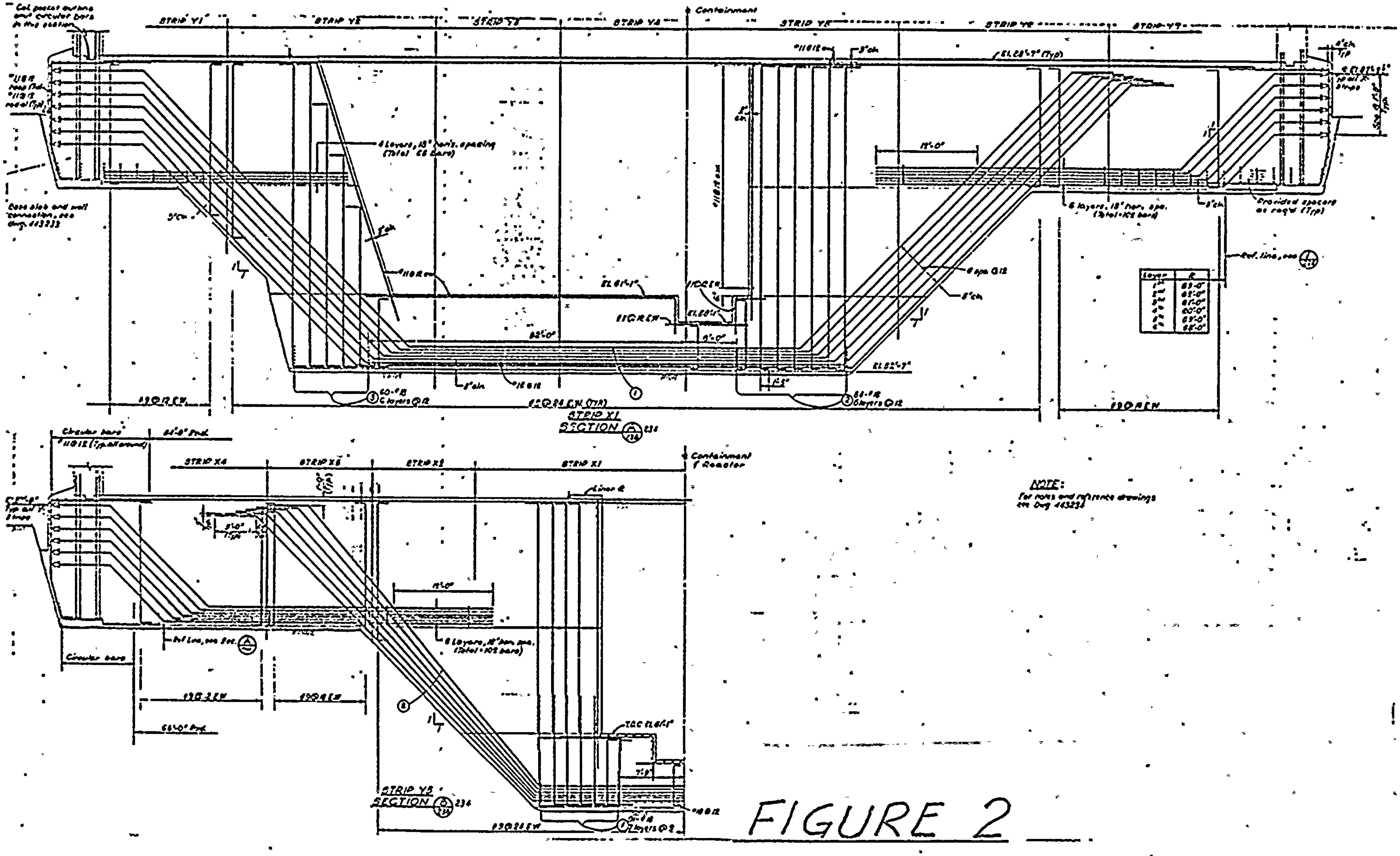
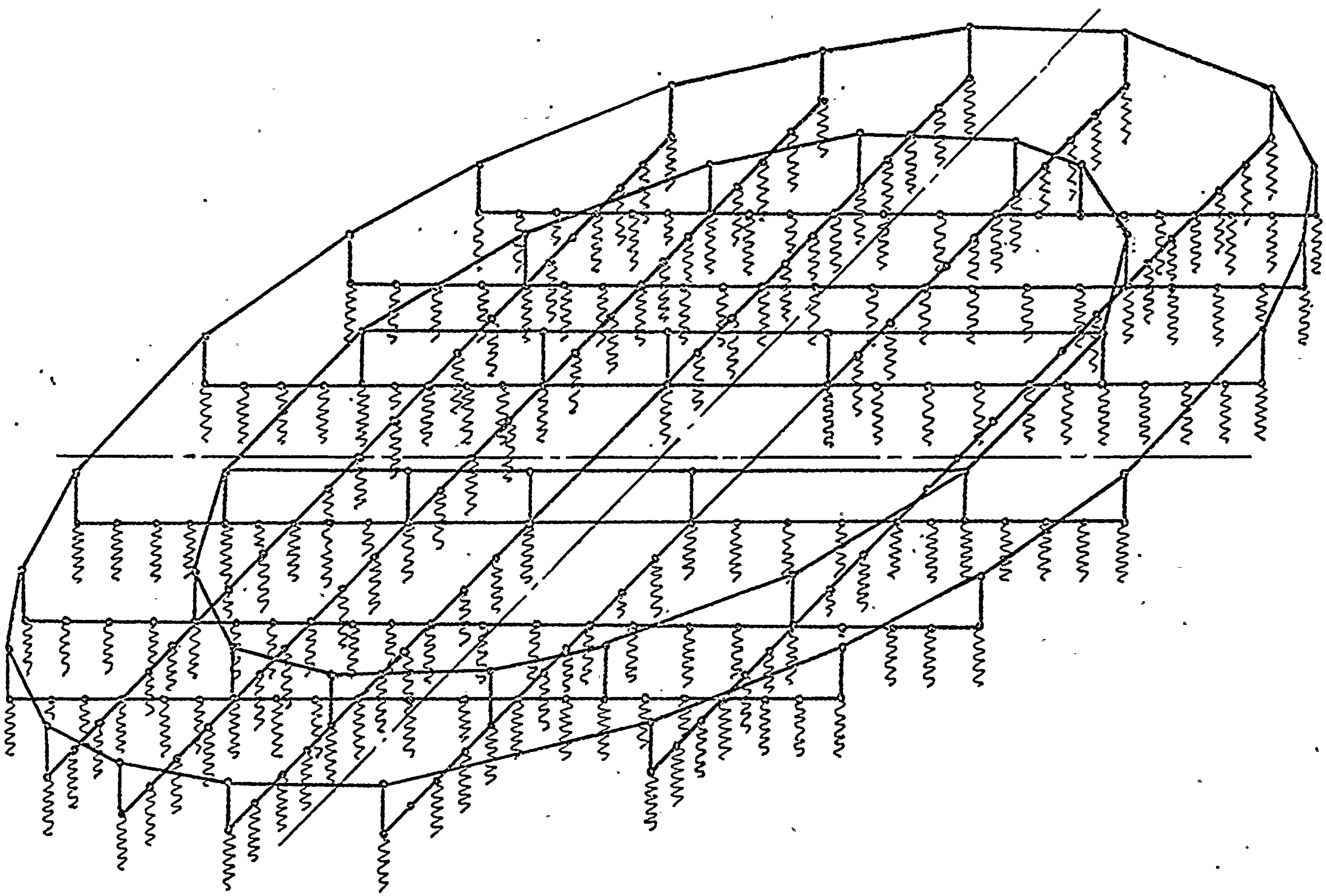


FIGURE 2



CONTAINMENT BASE MAT - ANALYTICAL MODEL

FIGURE 3

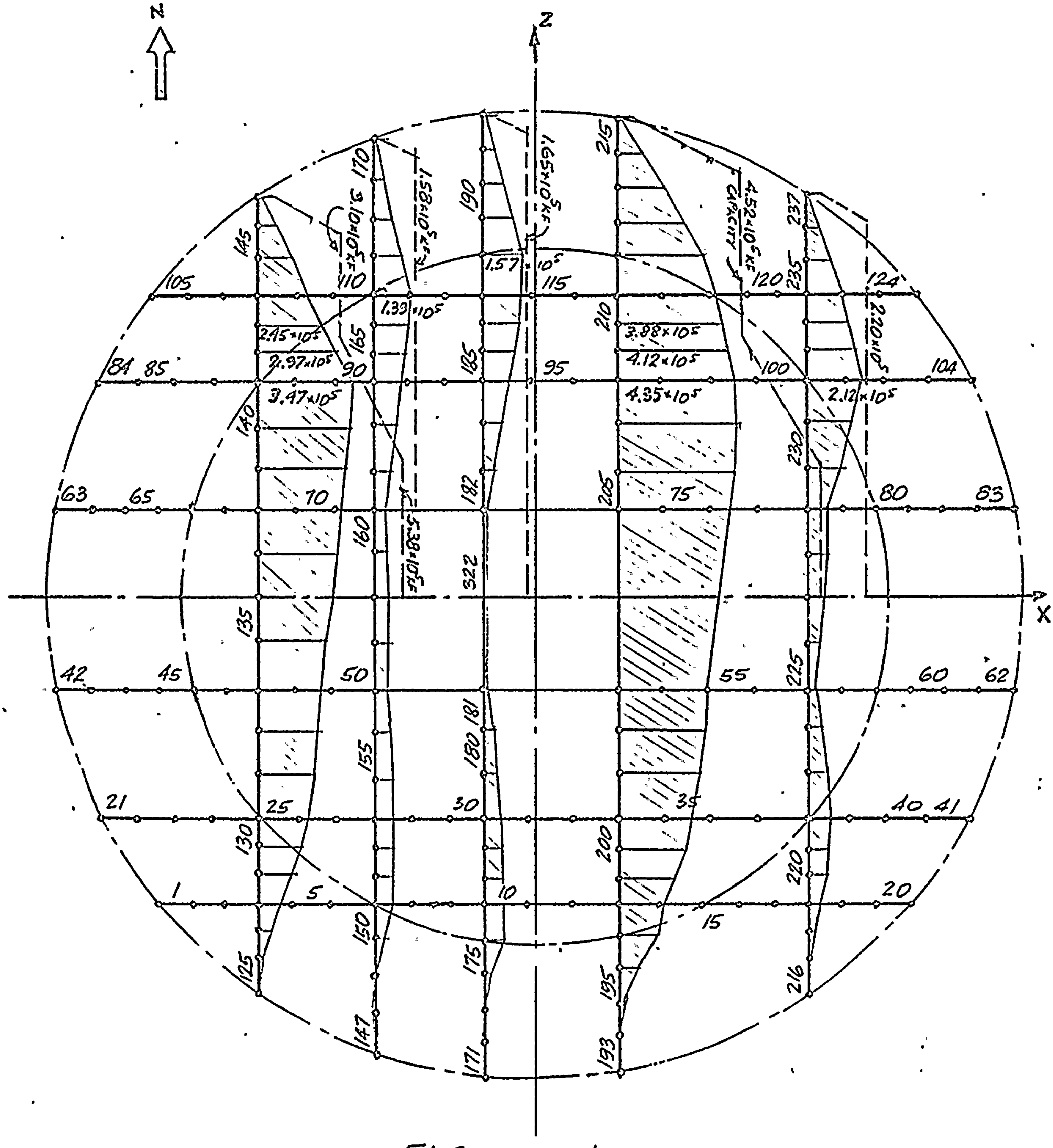


FIGURE 4

LOAD COMBINATION a) (CASE #1) MOMENTS

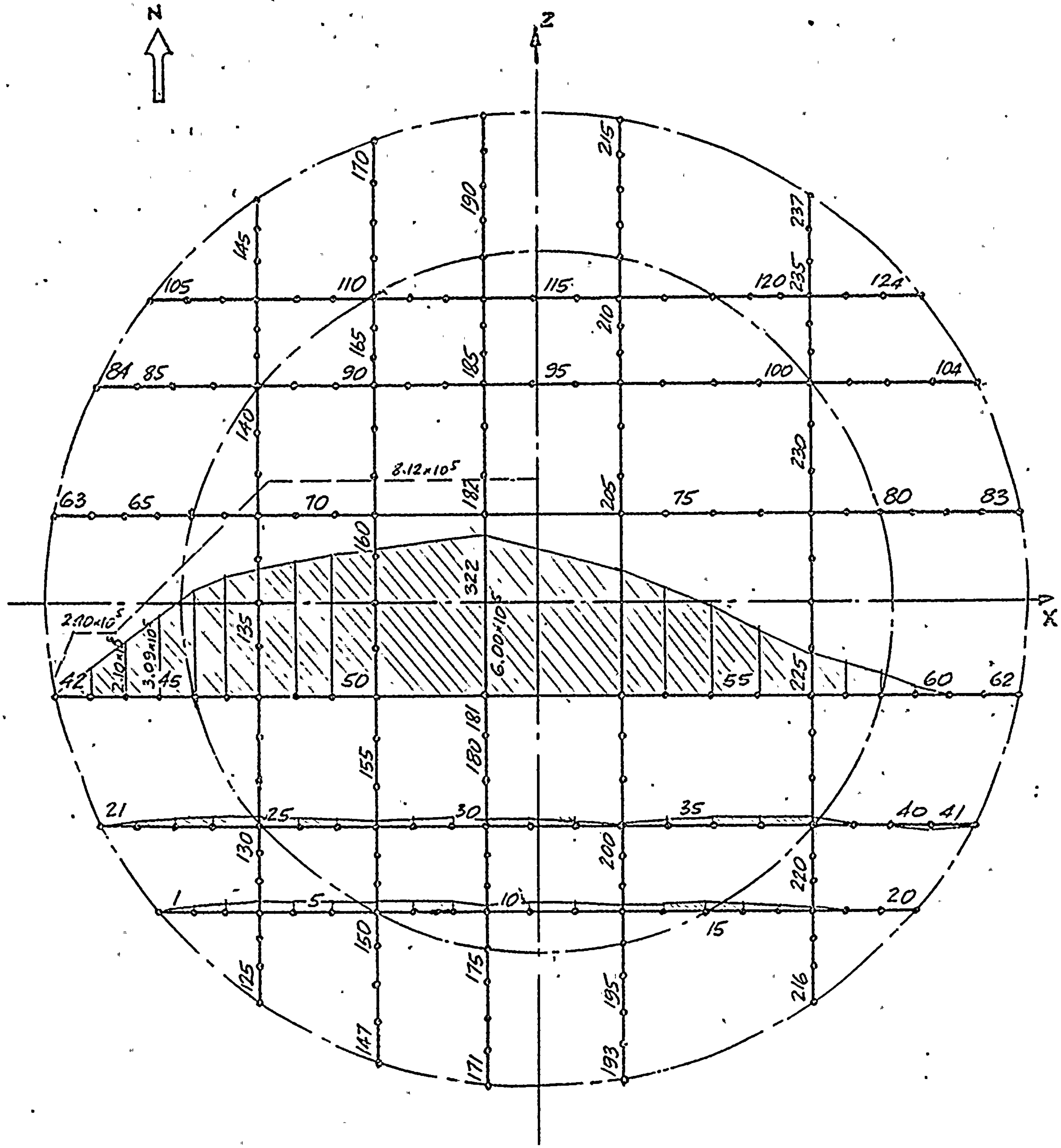


FIGURE 5

LOAD COMBINATION a) (CASE #2) MOMENTS

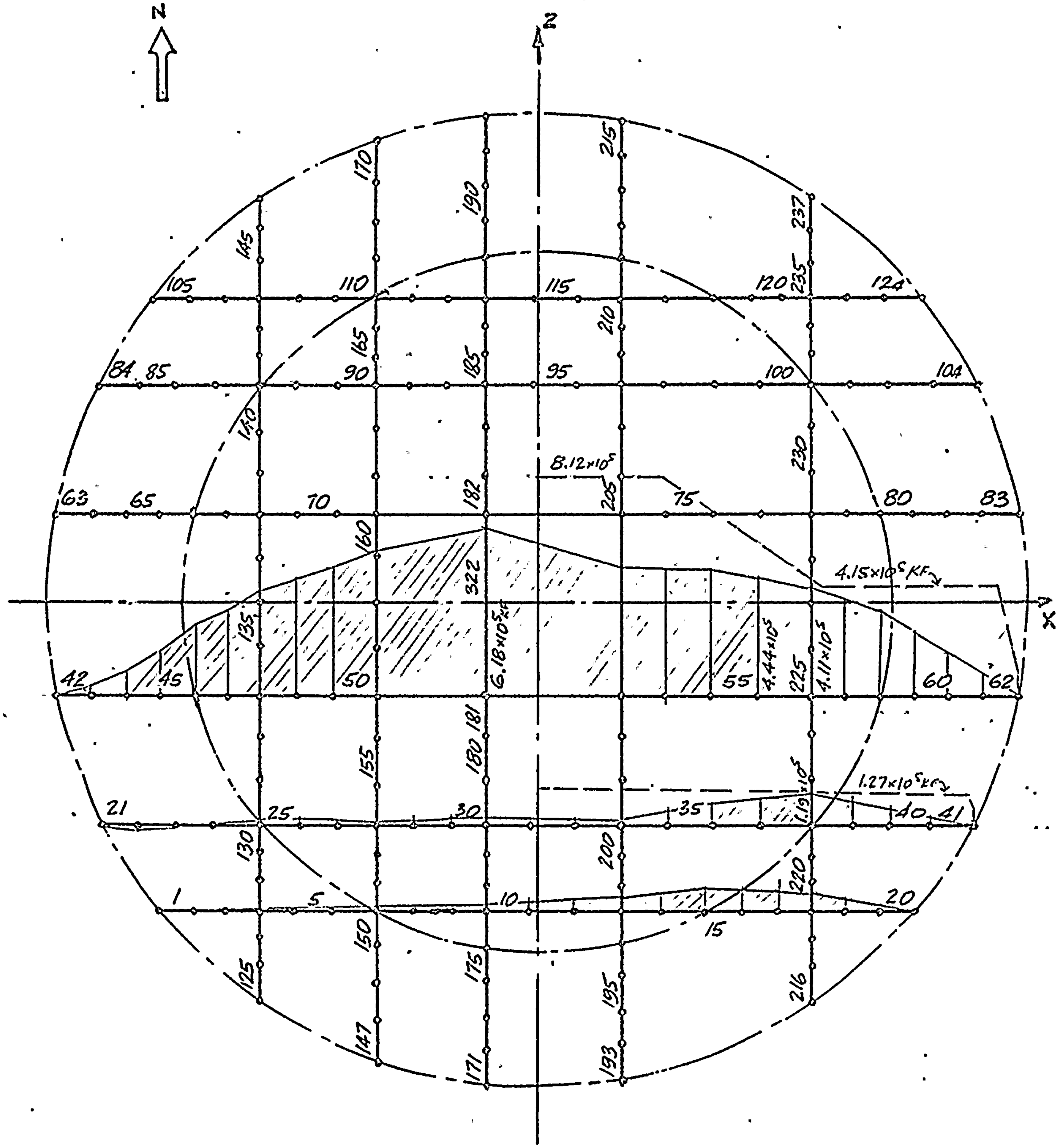


FIGURE 6

LOAD COMBINATION a) (CASE #3) MOMENTS

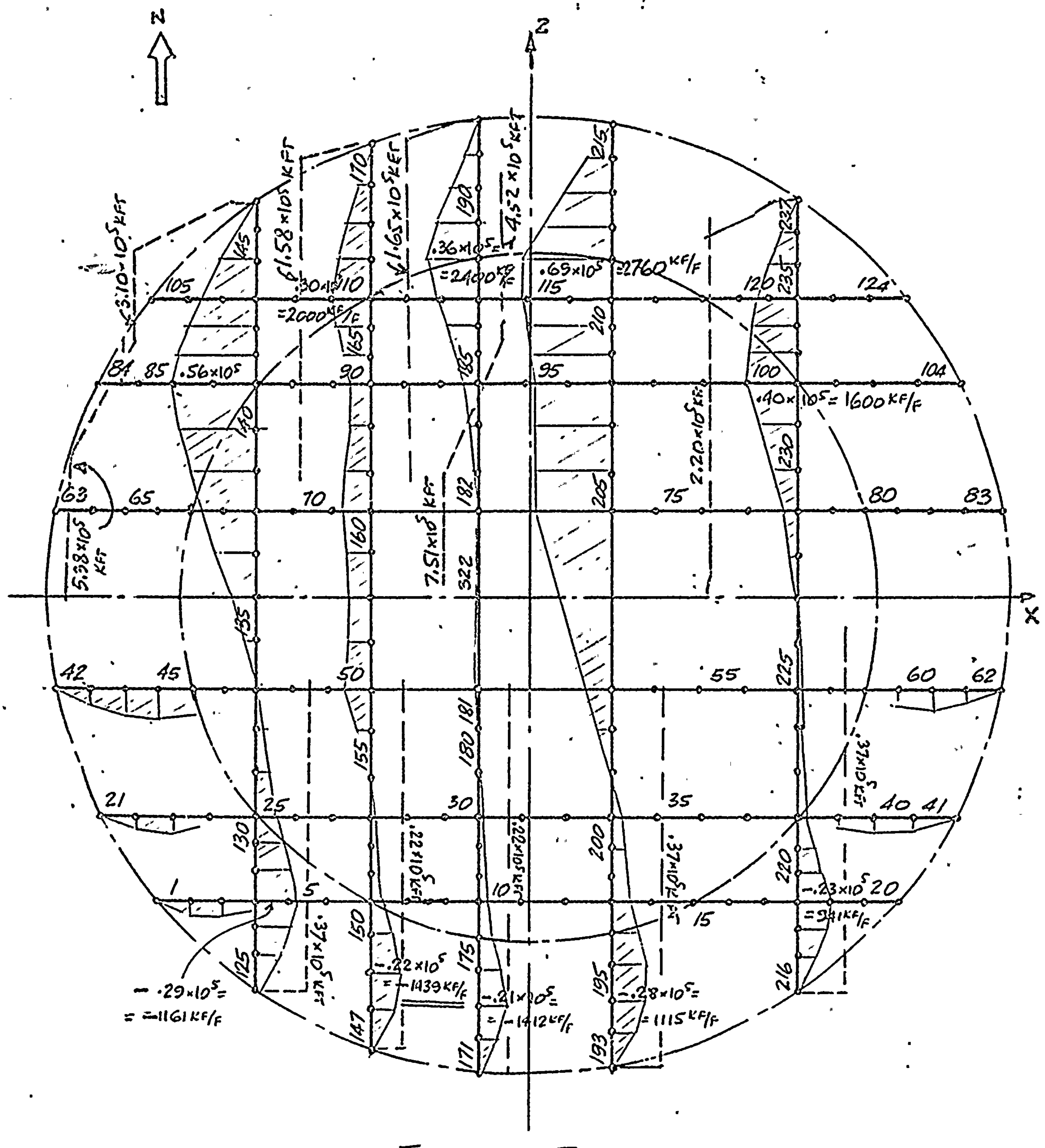


FIGURE 7

LOAD COMBINATION b) (CASE #5) MOMENTS

PACIFIC GAS AND ELECTRIC COMPANY
DIABLO CANYON UNITS 1 AND 2
DOCKET NOS. 50-275, 50-323

SUPPLEMENTARY INFORMATION FOR
FIRE PROTECTION REVIEW

June 6, 1978
REVISED November 13, 1978

TABLE OF CONTENTS

UNITS 1 and 2 - DIABLO CANYON SITE
SUPPLEMENTARY INFORMATION FOR
FIRE PROTECTION REVIEW

INTRODUCTION

The attached information is submitted as a collective response to NRC fire protection review question 48 (dated December 9, 1977) and questions 50, 51, and 53 (dated December 27, 1977). This information supersedes the February 6, 1978 PGandE response to those questions.

Question 50 requested a listing of systems, components, and instrumentation required to reach safe shutdown and identification of components that do not have redundancy. This information is tabulated in "Fire Protection Review of Equipment Required for Safe Shutdown". All required safe shutdown equipment is tabulated, the redundancy of the equipment is described, and where appropriate, supporting or backup equipment is also listed. Throughout this submittal, "safe shutdown" is construed to mean cold shutdown.

Question 48 requested an identification of the electrical system required for safe shutdown and a demonstration of the capability of the system to withstand a single fire without loss of function. The main components of the emergency power system have been tabulated in "Fire Protection Review of Equipment Required for Safe Shutdown". A single fire in certain locations could cause loss of one of three vital electrical divisions. The "Evaluation of Safe Shutdown Capability Assuming Loss of One Electrical Division" assesses what equipment is still available after this postulated fire individually affects each vital electrical division. It is assumed for this analysis (and throughout this submittal) that off site power has been lost. In each case, sufficient equipment is still available to attain safe shutdown.

Question 53 requested cable routing drawings showing the routing of all required circuitry for safe shutdown equipment. Rather than try to provide all this information on drawings that would be difficult to review due to their complexity, the following information has been provided:

1. Required circuitry for all safe shutdown components is listed in "Tabulation of Safe Shutdown Electrical Cable Routing by Safe Shutdown System". Electric schematics for each component were reviewed and the essential circuits were identified. Circuit routings were determined and then tabulated by fire zone. The above mentioned tabulation lists the components, the essential circuits for those components, and the routing (by fire zone) of each circuit. This information provided the basis for item 2 described below.

2. The "Tabulation of Safe Shutdown Equipment and Electrical Cabling within each Fire Zone" is an inventory of what safe shutdown equipment and/or electrical circuitry could be damaged as a result of a fire in each fire zone. The ramifications of each fire are assessed, and where necessary, commitments for fire protection modifications have been made. The conclusion reached for each fire zone was, with existing fire protection and/or proposed modifications, a single fire in any fire zone will not adversely affect safe shutdown capability.

3. Proposed modifications as a result of this analysis are listed in "Summary of Modifications within Fire Zones to Protect Safe Shutdown Equipment and Electrical Cabling".

4. In certain cases, circuitry was color coded on electrical conduit routing drawings to supplement the descriptions elsewhere. The description of the information shown on the drawings is summarized in "Summary of Information Shown on Electrical Cable Routing Drawings". These drawings will have limited distribution due to the time and effort required to color code each drawing by hand.

It is felt this method of analyzing safe shutdown circuit routing is the most accurate and complete and is easiest to review.

The fire zone drawings contained in the Fire Protection Review (Amendment 51), Figures 3-1 through 3-20, have been revised and are included as a part of this submittal. The drawings were revised to include some areas not previously specified as fire zones, to sub divide some fire zones, and to correct minor boundary errors. The barriers that define each fire zone are (or will be) appropriate for the hazards in question. The assumption has been made that any fire stays confined to its fire zone; that is felt to be a proper assumption for the redefined fire zones.

This analysis has been done for Unit #1 (including those circuits in Unit #2 that could affect Unit #1 systems). The Unit #2 electrical design is essentially identical. All modifications committed to for Unit #1 are implied to be committed to Unit #2 also and will be so carried out. A review of the Unit #2 electrical design will be undertaken and differences of substance, if any, will be evaluated and appropriate fire protection modifications will be undertaken, if necessary.

UNITS 1 AND 2 - DIABLO CANYON
FIRE PROTECTION REVIEW OF
EQUIPMENT REQUIRED FOR SAFE SHUTDOWN

This tabulation specifies the systems, components, and instrumentation required to attain safe shutdown. Redundancy of equipment is also specified for each component. In some cases supporting or back up equipment is also listed. Each of these safe shutdown systems is briefly discussed below.

Emergency Power Supply

Required emergency power supply for safe shutdown equipment and instrumentation has been tabulated assuming loss of off site power. Two of the three emergency power supply buses are adequate for safe shutdown. This is borne out in "Evaluation of Safe Shutdown Capability Assuming Loss of One Electrical Division".

Auxiliary Feedwater System

One of three auxiliary feedwater pumps and associated level control valves are required for safe shutdown. These components are controllable from the hot shutdown panel if required.

The normal auxiliary feedwater system supply is the condensate storage tank with a back up provided by the raw water reservoir. The condensate storage tank provides adequate water for safe shutdown, however, to provide operational flexibility, the raw water reservoir has been designated as a back up. Therefore, the raw water reservoir isolation valves (FCV-436, FCV-437) are not required for safe shutdown, but have been tabulated in this analysis for completeness.

Residual Heat Removal System

One of two residual heat removal flow paths is required to reach cold shutdown. This requires an RHR pump, heat exchanger, and valves in the flow path to be available. If the control room is uninhabitable, the required RHR pump and valves can be operated at the switchgear or locally when necessary.

Charging and Boration

One of three charging pumps is required for safe shutdown; two of these pumps (and the boric acid transfer pumps and necessary valves) are controllable from the hot shutdown panel.

Numerous charging and boration flow paths have been identified, any one of which is adequate for safe shutdown. Two sources of boron are available (boric acid tanks, boron injection tank), either of which is adequate to reach cold shutdown. Boric acid tank heaters, temperature controllers, and heat tracing (for lines containing a concentrated boric acid solution) have been tabulated in this analysis. However, these components are not required for safe shutdown. If a fire were to damage one of these components (and its redundant counterpart), boration could be initiated at that time and sufficient boron for cold shutdown could be introduced into the primary system before solidification occurred.

Cable routings for these components have been determined by fire zone and tabulated along with the equipment required for safe shutdown. This was done to determine in what fire zones these components could be affected. If a fire were to occur in one of those areas and there was some liklihood of these components being affected, boration would be initiated at that time. Otherwise, there would be no need to borate until normal operational conditions so dictated.

Component Cooling Water System

The component cooling water system is required to provide cooling for the RHR system and the charging pumps. One of three CCW pumps and one of two CCW heat exchangers is required for safe shutdown; the CCW pumps are controllable from the hot shutdown panel.

Auxiliary Saltwater System

The auxiliary saltwater system is the ultimate heat sink for the component cooling water system. One of two auxiliary saltwater pumps (controllable at hot shutdown panel) is required for safe shutdown.

Main Steam System

Components associated with the main steam system required for safe shutdown function to maintain water inventory and provide steam generator pressure relief and heat removal. Maintenance of water inventory is accomplished with the steam generator blowdown isolation valves and main steam isolation valves. However, the main steam isolation valves are required to close only if a steam line break occurs. No fire is postulated that could cause a steam line break. If a seismic event were to cause a steam line break and a subsequent fire, the main steam isolation valves would close prior to a fire affecting the MSIV'S or their electrical circuitry. Steam generator pressure relief and heat removal is accomplished with the 10% power relief valves or the steam generator safety valves.

Instrumentation

Instrumentation required for safe shutdown consists of indication for steam generator level and pressure, reactor coolant system pressure and temperature, pressurizer level, and boric acid tank level. Cooldown can be accomplished using a single reactor coolant loop and steam generator; instrumentation would be required for that loop and steam generator. Boric acid tank level indication is required only if the boric acid tanks are used as the boration source. Four instrument AC channels provide power for the instrumentation. Channels I and II are powered from the F and G buses respectively and channels III and IV are powered from the H bus. Sufficient instrumentaion is available assuming two of three vital buses are available.

Ventilation for Safe Shutdown Equipment

Areas requiring ventilation for safe shutdown equipment consist of the control room, auxiliary building, fuel handling building, 480V switchgear and inverter rooms, 4.16KV switchgear room, and auxiliary saltwater pump rooms.

Two 100% ventilation systems are provided for both the Unit 1 and Unit 2 control room. However, being a shared control room, any one of the four ventilation systems would be adequate for safe shutdown.

Auxiliary building ventilation is provided by two 100% supply fans and two 100% exhaust fans per unit (one supply fan and one exhaust fan per unit is normally required for safe shutdown). However, much of the Unit 1 and Unit 2 auxiliary building is common. Therefore, loss of both supply fans or both exhaust fans for one unit would be tolerable provided the other unit maintained its proper ventilation flow. Adequate ventilation to vital compartments under these circumstances would be accomplished by opening doors, isolating flow to or from non-vital areas, and if necessary, rigging portable fans.

Fuel handling building ventilation is required only for the auxiliary feedwater pumps and fire pumps. Again, ventilation is provided by two 100% supply fans and two 100% exhaust fans per unit (one supply fan and one exhaust fan is normally required for safe shutdown). However, a single supply fan or a single exhaust fan would provide adequate ventilation. Under these circumstances, air flow to or from non-vital areas could be reduced, doors to the vital pump rooms could be opened, and if necessary, portable fans could be rigged.

Fire System

The fire pumps have been tabulated as being required for safe shutdown. However, the raw water reservoir is the primary fire water source and is a gravity feed system. The fire pumps are a back up to the raw water reservoir.

Pressurizer Spray

The pressurizer spray function utilizes some of the same components identified as required for charging and boration. This flow path has redundant parallel components up to valves HCV-142, 8108, 8107 and 8145. HCV-142 is air operated and is pneumatically controllable at the hot shutdown panel. Valves 8108 and 8107 are normally open motor-operated valves. Valve 8145 is an air-operated valve that fails closed. However, a manual by-pass will be provided around valve 8145 to ensure the pressurizer spray flow path will remain functional.

DIABLO CANYON UNITS 1 AND 2
FIRE PROTECTION REVIEW OF
EQUIPMENT REQUIRED FOR SAFE SHUTDOWN

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
1. Emergency Power Supply	
A. Diesel Generator	2 of 3 required
B. Diesel fuel oil transfer pumps and day tank level control valves	1 of 2 pumps required, 1 of 2 LCV's per day tank required
C. 125v DC batteries	2 of 3 required
D. Battery chargers	2 of 5 required
E. Inverters	2 of 4 required
F. 4KV power supplies to 480v load centers and load center transformers	2 of 3 required
G. 125v DC supplies to 4KV switchgear	2 of 3 required
H. 125v DC power supplies to main control board	2 of 3 required
I. Instrument AC power	2 of 4 channels required
2. Auxiliary Feedwater System	
A. Auxiliary feedwater pumps (turbine driven auxiliary feedwater pump 1-1 and electric motor driven auxiliary feedwater pumps 1-2 and 1-3).	1 of 3 pumps required
B. Associated steam supply valves for pump 1-1:	Applicable only to pump 1-1
FCV-95, FCV-15, FCV-152	Required for pump 1-1
FCV-37, FCV-38	1 of 2 valves required for pump 1-1
C. Associated level control valves:	
Pump 1-1: LCV-106, LCV-107, LCV-108 LCV-109	1 of 4 valves required for pump 1-1
Pump 1-2: LCV-110, LCV-111	1 of 2 valves required for pump 1-2
Pump 1-3: LCV-113, LCV-115	1 of 2 valves required for pump 1-3
D. Water supply and associated valves:	1 of 2 water supplies required
(1) Condensate storage tank	No valves required
or (2) Raw water reservoir, FCV-436, FCV-437	1 of 2 valves required for raw water reservoir

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
3. Residual Heat Removal System	
A. Residual heat removal pump	1 of 2 pumps required
B. Residual heat removal heat exchanger	1 of 2 HX required
C. Residual heat removal valves:	
8701, 8702 (hot leg RHR suction)	Both valves required
HCV-637, HCV-638 (RHR flow path)	1 of 2 valves required
8809-A, 8809-B (RHR flow path)	1 of 2 valves required
D. RHR heat sink:	
Component cooling water system	See Item 5
Auxiliary saltwater system	See Item 6
4. Charging and Boration	
A. Charging pumps (2 centrifugal and 1 reciprocating pump)	1 of 3 pumps required
B. Charging pump cooling:	
Component cooling water system	see Item 5
Auxiliary saltwater system	see Item 6
C. Centrifugal charging pump auxiliary lube oil pumps	Only utilized to start pumps. Can be by-passed.
D. Charging and boration flow path	1 flow path required
(1) Using boric acid tanks:	
Boric acid tanks	1 of 2 tanks required
Boric acid tank heaters*	1 of 2 heaters per tank required
Boric acid tank temperature controllers*	1 of 2 TIC's required
Boric acid transfer pumps	1 of 2 pumps required
Boric acid filter	Only flow path required
Valves 8104, FCV-110A	1 of 2 valves required
Heat tracing for boric acid lines in flow path*	1 of 2 heat traces required
Charging pumps	1 of 3 pumps required
Valve FCV-128	Required for centrifugal charging pumps. Two manual by-pass flow paths.
and a. Charging through reactor coolant pump seals via RCP seal injection	No additional components required
or b. Charging through regenerative HX and valves HCV-142, 8108, 8107 and:	Flow path through HX required and all valves required for this flow path.
1. Valve 8145, charging to auxiliary pressurizer spray	Valve required for pressurizer spray.
or 2. Valve 8146, charging to loop 3 cold leg	Valve required
or 3. Valve 8147, charging to loop 4 cold leg	Valve required

*Components are not required for safe shutdown but have been tabulated to assess in what areas a fire could damage these components.

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
or (2) Using boron injection tanks:	
Refueling water storage tank	Required for this flow path
Valves 8805A, 8805B	1 of 2 valves required
Charging pumps	1 of 3 pumps required
Valve FCV-128	Required for reciprocating charging pump
Valves 8803A, 8803B	1 of 2 valves required
Boron injection tank (BIT)	Required
BIT heater*	1 of 2 heaters required
BIT temperature controller*	Required
Valves 8801A, 8801B	1 of 2 valves required
Heat tracing for boric acid lines in flow path*	1 of 2 heat traces required
5. Component Cooling Water System	
A. Component cooling water pump	1 of 3 pumps required
B. Component cooling water heat exchanger	1 of 2 HX required
C. Component cooling water valves:	
FCV-430, FCV-431 (CCW vital service headers)	1 of 2 valves required
FCV-355 (CCW miscellaneous service header)	Required for charging pump 1-3 cooling
FCV-364, FCV-365 (CCW to RHRHX)	1 of 2 valves required for RHR system cooling
D. CCW pump auxiliary lube oil pump	Only required to start CCW pump
E. CCW heat sink: Auxiliary saltwater system	See Item 6
6. Auxiliary Saltwater System	
A. Auxiliary saltwater pump	1 of 2 pumps required
B. Auxiliary saltwater valves: FCV-602, FCV-603 (ASW to CCWHX)	1 of 2 valves required
7. Main Steam System	
A. Main steam isolation valves: FCV-41, FCV-42, FCV-43, FCV-44	Required to close only for a main steam line break
B. 10% power relief valves: PCV-19, PCV-20, PCV-21, PCV-22	1 of 4 valves required. Backup to 10% power relief valves provided by 35% power relief system and 40% steam dump valves.
C. Steam generator safety valves	Five per loop, 20 total. Required to lift if only 1 of 4 10% power relief valves is available.
D. Steam generator blowdown isolation valves: FCV-760, FCV-761, FCV-762, FCV-763	Required to close to maintain water inventory for safe shutdown

*Components are not required for safe shutdown but have been tabulated to assess in what areas a fire could damage these components.

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
8. Instrumentation	
A. Steam Generator level SG 1-1: LT-517, LT-518, LT-519 SG 1-2: LT-527, LT-528, LT-529 SG 1-3: LT-537, LT-538, LT-539 SG 1-4: LT-547, LT-548, LT-549	1 steam generator required for cooldown, 1 of 3 LT's required for that SG.
B. Steam generator pressure Loop 1: PT-514, PT-515, PT-516 Loop 2: PT-524, PT-525, PT-526 Loop 3: PT-534, PT-535, PT-536 Loop 4: PT-544, PT-545, PT-546	1 steam generator required for cooldown 1 of 3 PT's required for that loop
C. Reactor coolant system temperature Loop 1: TE-413A, TE-413B Loop 2: TE-423A, TE-423B Loop 3: TE-433A, TE-433B Loop 4: TE-443A, TE-443B	1 of 2 required per loop, 1 loop required for cooldown
D. Reactor coolant system or pressurizer pressure PT-403, PT-405, PT-455, PT-456	1 of 4 required
E. Pressurizer level LT-459, LT-460, LT-461, LT-406	1 of 4 required
F. Boric acid tank level LT-102, LT-106	1 of 2 required
9. Ventilation for Safe Shutdown Equipment	
A. Control room supply fans S-35, S-36	1 of 2 fans required. Unit 2 ventilation also available for shared control room.
B. Auxiliary building supply and exhaust fans S-31, S-32 E-1, E-2	 1 of 2 required 1 of 2 required
C. 480 volt switchgear room and inverter room supply fans S-43, S-44	1 of 2 required
D. 4.16KV switchgear room supply fans S-67, S-68, S-69	2 of 3 required
E. Auxiliary saltwater pump room exhaust fans E-101, E-103	1 of 2 required
F. Fuel handling building supply and exhaust fans S-1, S-2 E-5, E-6	 1 of 2 required 1 of 2 required

SYSTEM AND COMPONENTS	REDUNDANCY AND/OR COMMENTS
10. Fire System	1 of 2 water supplies required in the event of a fire
A. Primary water supply: Raw water reservoir	
B. Secondary water supply: Fire water storage tank, Fire pumps 0-1, 0-2	1 of 2 pumps required for this water supply
11. Pressurizer Spray**	
A. Water supply to charging pumps	1 of 2 supplies required
(1) Boric acid tanks	1 of 2 tanks required
Boric acid tank heaters*	1 of 2 heaters per tank required
Boric acid tank temperature controllers*	1 of 2 TIC's required
Boric acid transfer pumps	1 of 2 pumps required
Boric acid filter	Only flow path required
Valves 8104, FCV-110A	1 of 2 valves required
Heat tracing for boric acid lines in flow path*	1 of 2 heat traces required
or (2) Refueling water storage tank	Required for this flow path
Valves 8805A, 8805B	1 of 2 valves required
B. Charging pumps	1 of 3 pumps required
C. Charging flow path	
Valves HCV-142, 8108, 8107	Valves required
Regenerative HX	Flow path required
Valve 8145, auxiliary pressurizer spray	Manual by-pass around valve 8145

* Components are not required for safe shutdown but have been tabulated to assess in what areas a fire could damage these components.

**All components required for Pressurizer Spray have been tabulated for Charging and Boration. Alternative pressurizer spray methods available provided reactor coolant pumps and PCV-455A and PCV-455B operable (valves require instrument air). Backup pressure relief capability provided by pressurizer power relief valves (PCV-455C, PCV-456, PCV-474).

DIABLO CANYON UNITS 1 AND 2
EVALUATION OF SAFE SHUTDOWN CAPABILITY
ASSUMING LOSS OF ONE ELECTRICAL DIVISION

Minimum Equipment Required For Safe Shutdown	Equipment Available Assuming Loss Of Bus F	Equipment Available Assuming Loss of Bus G	Equipment Available Assuming Loss of Bus H
Emergency Power Supply			
Diesel fuel transfer pump. (1 required)	2 pumps available	1 pump available	1 pump available
Auxiliary Feedwater System			
A. Auxiliary feedwater pump and its associated LCV's (1 pump and 1 assoc. LCV required).	Auxiliary feedwater pumps 1-1 and 1-2 and their associated LCV's available.	Auxiliary feedwater pumps 1-2 and 1-3 and their associated LCV's available.	Auxiliary feedwater pumps 1-1 and 1-3 and their associated LCV's available.
B. Raw water supply to auxiliary feedwater pumps.	Available to pump 1-1.	Available to pumps 1-2, 1-3.	Available to all 3 pumps.
Residual Heat Removal System			
A. Series valves 8701 and 8702.	Both valves available.	8702 available. Open 8701 manually.	8701 available. Open 8702 manually.
B. RHR flow path (pump, HX, 2 valves per flow path).	Both flow paths available.	RHR pump 1-2 flow path available.	RHR pump 1-1 flow path available.
C. Component cooling water for RHR HX and pump.	Cooling for either RHR HX and pump available.	Cooling for either RHR HX and pump available.	Cooling for either RHR HX and pump available.
D. Auxiliary saltwater for CCW HX.	Available	Available	Available
Charging and Boration			
A. Charging pump (1 required).	2 charging pumps available.	1 charging pump available.	3 charging pumps available.
B. Boric acid tank flow path or boron injection tank flow path.	Both flow paths available.	Both flow paths available.	Both flow paths available.

Minimum Equipment Required For Safe Shutdown	Equipment Available Assuming Loss of Bus F	Equipment Available Assuming Loss of Bus G	Equipment Available Assuming Loss of Bus H
Charging and Boration (Cont'd)			
C. Component Cooling water for charging pumps.	Available for all 3 charging pumps.	Available for all 3 charging pumps.	Available for all 3 charging pumps.
D. Auxiliary saltwater for CCW HX.	Available	Available	Available
Pressurizer Spray (Requires charging pump and appropriate flow path through valve 8145).	Available	Manual bypass around valve 8145 available.	Available
Component Cooling Water System (1 pump and HX required for RHR and charging pump cooling).	2 CCW pumps and HX 1-2 available.	2 CCW pumps and HX 1-1 available.	2 CCW pumps and either HX available.
Auxiliary Saltwater System (Required as CCW heat sink).	Pump 1-2 flow path available.	Pump 1-1 flow path available.	Both pumps available.
Main Steam System			
A. Main steam isolation valves (4 valves).	Available with normal or backup power.	Available with normal or backup power.	Available with normal or backup power.
B. One 10% power relief valve.	2 valves available with pneumatic control of other 2 valves at HSD panel.	2 valves available with pneumatic control of other 2 valves at HSD panel.	4 valves available.
C. SG blowdown isolation valves (4 valves).	Valves fail safe.	Valves fail safe.	All valves available.
Instrumentation			
A. SG level (1 per SG required).	Available	Available	Available
B. SG pressure (1 per SG required).	Available	Available	Available

Minimum Equipment Required For Safe Shutdown	Equipment Available Assuming Loss of Bus F	Equipment Available Assuming Loss of Bus G	Equipment Available Assuming Loss of Bus H
Instrumentation (Cont'd)			
C. RCS temperature (1 per loop required).	Available	Available	Available
D. RCS or PZR pressure (1 required).	Available	Available	Available
E. PZR level (1 required).	Available	Available	Available
Ventilation for Safe Shutdown Equipment			
A. Control room ventilation.	Available	Available	Available
B. Auxiliary building ventilation (1 supply fan and 1 exhaust fan).	Available	Available	Available
C. 480v switchgear, inverter room ventilation.	Available	Available	Available
D. 4KV switchgear ventilation.	Available to G, H buses.	Available to F, H buses.	Available to F, G buses.
E. ASW pump room ventilation.	Available for ASW pump 1-2.	Available to ASW pump 1-1.	Available to both pumps.
F. Fuel handling building ventilation (1 supply fan and 1 exhaust fan).	Available	Available	Available

DIABLO CANYON POWER PLANT

TABULATION OF SAFE SHUTDOWN ELECTRICAL CABLE ROUTING BY SAFE SHUTDOWN SYSTEM

1. EMERGENCY POWER SUPPLY

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
EP-1	Diesel Generator 1-1 (Bus H)	11-A-1	H	Power	11-A-1 embedded to 10, 12-C, 13-C
				Control to CB	11-A-1, 11-D, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3, CSR, MCB
				Control to swgr	11-A-1, 11-D, 12-C, 13-C
				125V DC power	11-A-1, 11-D, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3
			G	Backup control to CB	11-A-1, 11-D, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB
				125V DC power (backup)	11-A-1, 11-D, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2
EP-2	Diesel Generator 1-2 (Bus G)	11-B-1	G	Power	11-B-1 embedded to 10, 12-B, 13-B
				Control to CB	11-B-1, 11-D, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB
				Control to swgr	11-B-1, 11-D, 12-B, 13-B
				125V DC power	11-B-1, 11-D, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2
			F	Backup control to CB	11-B-1, 11-D, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1, CSR, MCB
				125V DC power (backup)	11-B-1, 11-D, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1
EP-3	Diesel Generator 1-3 (Bus F)	11-C-1	F	Power	11-C-1 embedded to 10, 12-A, 13-A
				Power to Unit 2	13-A, 12-A, 10, embedded to 20, 23-D, 23-A, 24-A
				Control to CB	11-C-1, 11-D, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1, CSR, MCB
				Control to swgr	11-C-1, 11-D, 12-A, 13-A
				125V DC power	11-C-1, 11-D, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1
			H	Backup control to CB	11-C-1, 11-D, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3, CSR, MCB
				125V DC power (backup)	11-C-1, 11-D, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3
EP-4	Fuel Transfer Pump 0-1	Buried west of Turbine Bldg.	H	Power	5-A-3, 4-A, 4-B, 3-C(57691), embedded to transfer pump 0-1
				Control	5-A-3, 4-A, embedded to 10, 12-C, 11-D
				Control from Diesel 1-1	11-A-1, 11-D
				Control from Diesel 1-2	11-B-1, 11-D
				Control from Diesel 1-3	11-C-1, 11-D
				Power (backup from U#2)	5-B-3, 5-B-4, 5-A-4, 5-A-3
EP-5	Fuel Transfer Pump 0-2	Buried west of Turbine Bldg.	G	Power	5-A-2, 4-A, 4-B, 3-J-1(57691), embedded to transfer pump 0-2
				Control	5-A-2, 4-A, embedded to 10, 12-B, 11-D
				Control from Diesel 1-1	11-A-1, 11-D
				Control from Diesel 1-2	11-B-1, 11-D
				Control from Diesel 1-3	11-C-1, 11-D
				Power (backup from U#2)	5-B-2, 5-B-4, 5-A-4, 5-A-2
EP-6	4kV Supply to Load Center 1F	-	F	Power	13-A, 12-A, 10, embedded to 4-A, 5-A-1
				Control	13-A, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1, CSR, MCB
EP-7	4kV Supply to Load Center 1G	-	G	Power	13-B, 12-B, 10, embedded to 4-A, 5-A-2
				Control	13-B, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB
EP-8	4kV Supply to Load Center 1H	-	H	Power	13-C, 12-C, 10, embedded to 4-A, 5-A-3
				Control	13-C, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3, CSR, MCB
EP-9	125V DC Supply to main control board (Bus F)	-	F	Power	6-A-1, CSR, MCB
EP-10	125V DC Supply to main control board (Bus G)	-	G	Power	6-A-2, CSR, MCB

1. EMERGENCY POWER SUPPLY (Cont'd)

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
EP-11	125V DC Supply to main control board (Bus H)	-	H	Power	6A-3, CSR, MCB
EP-12	125V DC Supply to main control board (non-vital)	-	Non-vital portion of G	Power	6-A-2, 6-A-1, 6-A-5, CSR, MCB
EP-13	125V DC Supply for 4kV swgr (Bus F)	-	F	Power	6-A-1, 5-A-1, 4-A, embedded to 10, 12-A, 13-A
EP-14	125V DC Supply for 4kV swgr (Bus G)	-	G	Power	6-A-2, 5-A-2, 4-A, embedded to 10, 12-B, 13-B
EP-15	125V DC Supply for 4kV swgr (Bus H)	-	H	Power	6-A-3, 5-A-3, 4-A, embedded to 10, 12-C, 13-C

2. AUXILIARY FEEDWATER SYSTEM

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
AF-1	FCV-95, Steam Supply to AFWP turbine 1-1	3-BB el. 115'	G	Power and control	5-A-2, 4-A, embedded to 3-X, 3-Q-1, 3-Q-2, 3-R, 3-BB el. 115' (existing routing), 5-A-2, 4-A, 3-BB el. 85' (501450), 3-BB el. 100' (502078), 3-BB el. 115' (502079) (re-route)
				Control to MCB	5-A-2, 6-A-2, CSR, MCB
				Control to HSD panel	5-A-2, embedded to 5-A-4 (HSD panel)
AF-2	LCV-106, LCV-107; AFW Supply from AFWP 1-1	28	G	Power	5-A-2, 3-BB el. 100' (502078), 3-BB el. 85' (501450), 28
				Control to MCB	5-A-2, 6-A-2, CSR, MCB
				Control to HSD panel	5-A-2, embedded to 5-A-4 (HSD panel)
AF-3	LCV-108, LCV-109; AFW Supply from AFWP 1-1	3-BB	G	Power	5-A-2, 3-BB el. 100' (502078), 3-BB el. 115' (502079)
				Control to MCB	5-A-2, 6-A-2, CSR, MCB
				Control to HSD panel	5-A-2, embedded to 5-A-4 (HSD panel)
AF-4	AFWP 1-2	3-Q-2	H	Power	13-C, 12-C, 10, embedded to 3-L (57616), 3-P-3, S-3, 3-Q-2
				Control to MCB	13-C, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3, CSR, MCB
				Control to HSD panel	13-C, 12-C, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel)
AF-5	LCV-110 and LCV-111, AFW Supply from AFWP 1-2	28	H	Power	5-A-3, 3-BB el. 100' (502078), 3-BB el. 85' (501450), 28
				120 V power to HSD panel	6-A-3, 5-A-3, embedded to 5-A-4 (HSD panel)
				Control for LCV-110, 111	5-A-4, 14-A and 14-E (57566), 3-BB el. 100' (502078), 3-BB el. 85' (501450), 28
				Control to MCB	5-A-4, 6-A-5, CSR, MCB
AF-6	AFWP 1-3	3-Q-2	F	Power	13-A, 12-A, 10, embedded to 3-L (57616), 3-P-3, S-3, 3-Q-2
				Control to MCB	13-A, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1, CSR, MCB
				Control to HSD panel	13-A, 12-A, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel)
AF-7	LCV-113 and LCV-115, AFW Supply from AFWP 1-3	3-BB el. 115'	F	Power	5-A-1, 3-BB el. 100' (502078), 3-BB el. 115' (502079)
				120 V power to HSD panel	6-A-1, 5-A-1, embedded to 5-A-4 (HSD panel)
				Control to LCV-113, 115	5-A-4, 14-A (57566), 3-BB el. 100' (502078), 3-BB el. 115' (502079)
				Control to MCB	5-A-4, 6-A-5, CSR, MCB
AF-8	FCV-436. Raw water supply to AFWP 1-1	3-Q-1	G	Power and control	5-A-2, 4-A, 3-L, embedded to 3-X, 3-Q-1
				Control	5-A-2, 6-A-2, CSR, MCB
				Control	3-Q-1, 3-X, 3-L, embedded to CSR, MCB
AF-9	FCV-437. Raw water supply to AFWP 1-2, 1-3	3-Q-1	F	Power and control	5-A-1, 4-A, 3-L, embedded to 3-X, 3-Q-1
				Control	5-A-1, 6-A-1, CSR, MCB
				Control	3-Q-1, 3-X, 3-L, embedded to CSR, MCB
AF-10	FCV-37, SG 1-2 supply to AFWP turbine	28	H	Power	5-A-3, 3-BB el. 115', 28
				Control	5-A-3, 6-A-3, CSR, MCB
				Control	28, 3-BB el. 115', embedded to CSR, MCB
AF-11	FCV-38, SG 1-3 supply to AFWP turbine	3-BB el. 115'	F	Power	5-A-1, 3-BB el. 100', 3-BB el. 115'
				Control	5-A-1, 6-A-1, CSR, MCB
				Control	3-BB el. 115', embedded to CSR, MCB
AF-12	FCV-15, FCV-152; AFWP turbine steam supply valves	3-Q-1	-		No electrical circuits associated with these valves.

3. RESIDUAL HEAT REMOVAL SYSTEM

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
RHR-1	RHR pump 1-1	3-B-1	G	Power Control to MCB	13-B, 12-B, 10, embedded to 3-B-1 13-B, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB
RHR-2	RHR pump 1-2	3-B-2	H	Power Control to MCB	13-C, 12-C, 10, embedded to 3-B-2 13-C, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3, CSR, MCB
RHR-3	Valve 8701, RHR suction from hot leg	1-A	G	Power Control to MCB Control to MCB	1-A, 3-BB, 5-A-2 1-A, 3-BB, 5-A-2, 6-A-2, CSR, MCB 1-A, 3-BB, embedded to CSR, MCB
RHR-4	Valve 8702, RHR suction from hot leg	1-B	H	Power Control to MCB	1-B, 1-A, 3-BB, 5-A-3 1-B, 1-A, 3-BB, 5-A-3, 6-A-3, CSR, MCB
RHR-5	HCV-637, HCV-638; parallel valves in flowpath	3-BB el. 100'	Inst. AC Ch. IV, III	Control	3-BB, CSR, MCB
RHR-6	Valve 8809A, valve in 1-1 flowpath	3-BB el. 100'	G	Power Control to MCB	5-A-2, 3-BB el. 100' 3-BB, 5-A-2, 6-A-2, CSR, MCB
RHR-7	Valve 8809B, valve in 1-2 flowpath	3-BB el. 100'	H	Power Control to MCB	5-A-3, 3-BB el. 100' 3-BB, 5-A-3, 6-A-3, CSR, MCB

4. CHARGING & BORATION SYSTEM
Sheet No. 1 of 3

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
C-1	Charging Pump No. 1-1 and Aux. L.O. pump 1-1	3-H-1	F	Power Control to MCB Control HSD panel Power L.O. pump Control L.O. pump	13-A, 12-A, 10, embedded to 3-H-1 13-A, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1, CSR, MCB 13-A, 12-A, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel) 5-A-1, 4-A, 3-J-2, 3-J-3, 3-H-1 13-A, 12-A, 10, embedded to 3-J-2, 3-J-3, 3-H-1
C-2	Charging Pump No. 1-2 and Aux. L.O. pump 1-2	3-H-1	G	Power Control to MCB Control to HSD panel Power L.O. pump Control L.O. pump	13-B, 12-B, 10, embedded to 3-H-1 13-B, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB 13-B, 12-B, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel) 5-A-2, 4-A, 3-J-2, 3-J-3, 3-H-1 13-B, 12-B, 10, embedded to 3-J-2, 3-J-3, 3-H-1
C-3	Charging Pump No. 1-3	3-H-2	G	Power Control to MCB Control to PS 292	13-B, 12-B, 10, embedded to 3-H-2 13-B, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB 13-B, 12-B, 10, embedded to 3-J-2, 3-J-3, 3-H-1, 3-H-2, 3-F, 3-H-2
C-4	FCV-128, charging pumps discharge header	3-H-1	-		No electrical circuits identified. Pneumatic control for valve locally and at HSD panel.
Boric Acid Tank Flowpath:					
C-5	Boric Acid Trans. pump 1-1	3-X	F	Power Control to MCB Control to HSD	5-A-1, 4-A, 3-L, embedded to 3-X 5-A-1, 6-A-1, CSR, MCB 5-A-1, embedded to 5-A-4 (HSD panel)
C-6	Boric Acid Trans. pump 1-2	3-X	G	Power Control to MCB Control to HSD	5-A-2, 4-A, 3-L, embedded to 3-X 5-A-2, 6-A-2, CSR, MCB 5-A-2, embedded to 5-A-4 (HSD panel)
C-7	FCV-110A, transfer pumps to charging pumps	3-X	Non-vital portion of G	Control	MCB, CSR, 3-AA, 3-BB, el. 115', 3-BB el. 100', 3-X
C-8	Valve 8104, transfer pumps to charging pumps	3-X	G	Power & Control Control to MCB Control to HSD	5-A-2, 4-A, 3-L, 3-X, 3-AA, 3-BB el. 115', 3-BB el. 100', 3-X 5-A-2, 6-A-2, CSR, MCB 5-A-2, embedded to 5-A-4 (HSD panel)
C-9	HCV-142, charging pumps discharge to regen. HX	3-BB el. 85'	-		No electrical circuits identified. Pneumatic control for valve locally and at HSD panel.
C-10	Valve 8107, charging flow path	3-BB el. 100'	F	Power & Control Control to MCB	5-A-1, 3-BB el. 100' 5-A-1, 6-A-1, CSR, MCB
C-11	Valve 8108, charging flow path	3-BB el. 85'	G	Power & Control Control to MCB	5-A-2, 3-BB el. 100', 3-BB el. 85' 5-A-2, 6-A-2, CSR, MCB
C-12	Valve 8145, Chg. to Press. Aux. Spry	1-A	Non-vital portion of G	Power & Control	1-A, 3-BB el. 100', 3-BB el. 115', CSR, MCB
C-13	Valve 8146, Chrg. to Loop 4 Cold Leg.	1-A	Non-vital portion of G	Power & Control	1-A, 3-BB el. 100', 3-BB el. 115', CSR, MCB

4. CHARGING & BORATION SYSTEM (Continued)
Sheet No. 2 of 3

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
C-14	Valve 8147 Chrg. to Loop 3 Cold Leg.	1-A	Non-vital Portion of G	Power & Control	1A, 3-BB el. 100', 3-BB el. 115', CSR, MCB
C-15*	Boric Acid Tanks 1-1, 1-2 heaters "A"	3-AA	G	Power Control	5-A-2, 4-A, 3-L, 3-X, 3-AA 3-AA
C-16*	Boric Acid Tanks 1-1, 1-2 heaters "B"	3-AA	H	Power Control	5-A-3, 4-A, 3-L, 3-X, 3-AA 3-AA
C-17*	TIC-103, B/A TK 1-1 Temp. Cont.	3-AA	H	Power	6-A-3, CSR, embedded to 3-AA
C-18*	TIC-107, B/A TK 1-2 Temp. Cont.	3-AA	G	Power	6-A-2, CSR, embedded to 3-AA
C-19*	Heat trace "A" for boric acid flowpath (THIA)	3-X 3-X 3-H-1	F	Power to HT transformer Power to HT controller Power to HT controller	5-A-1, 4-A, 3-L, 3-X 3-X 3-X, 3-L, 3-H-1
C-20*	Heat trace "B" for boric acid flowpath (THIB)	3-X 3-X 3-H-1	H	Power to HT transformer Power to HT controller Power to HT controller	5-A-3, 4-A, 3-L, 3-X 3-X 3-X, 3-L, 3-H-1
Boron Injection Tank Flowpath:					
C-21	Valve, 8805A, refueling water supply to chg. pumps	3-BB el. 85'	F	Power & Control Control to MCB	5-A-1, 4-A, 3-L, 3-BB el. 85' 5-A-1, 6-A-1, CSR, MCB
C-22	Valve 8805B, refueling water supply to chg. pumps	3-BB e. 85'	G	Power & Control Control MCB	5-A-2, 4-A, 3-L, 3-BB el. 85' 5-A-2, 6-A-2, CSR, MCB
C-23	Valve 8803A, chg. pumps to BIT	3-B-3	F	Power and Control Control to MCB	5-A-1, 4-A, 3-J-2, 3-J-3, 3-H-1, 3-B-3 5-A-1, 6-A-1, CSR, MCB
C-24	Valve 8803B, chg. pump to BIT	3-B-3	G	Power and Control Control to MCB	5-A-2, 4-A, 3-J-2, 3-J-3, 3-H-1, 3-B-3 5-A-2, 6-A-2, CSR, MCB
C-25	Valve 8801A, BIT outlet	3-BB el. 100'	F	Power and Control Power and Control	5-A-1, 3-BB el. 100' 5-A-1, 6-A-1, CSR, MCB
C-26	Valve 8801B, BIT outlet	3-BB el. 100'	G	Power and Control Power and Control	5-A-2, 3-BB el. 100' 5-A-2, 6-A-2, CSR, MCB
C-27*	Boron injection tank heater	3-B-3	F	Power Control	5-A-1, 4-A, 3-J-2, 3-J-3, 3-H-1, 3-B-3 3-B-3
C-28*	Boron injection tank backup heater	3-B-3	H	Power Control	5-A-3, 4-A, 3-L, 3-H-1, 3-B-2, 3-B-3 3-B-3
C-29*	TIC-945, BIT temp. controller	3-B-3	H	Power	6-A-3, 3-BB el. 115', 3-BB el. 100", 3-BB el. 85', 3-M, 3-L, 3-M, 3-BB el. 85', 3-F, 3-B-3

4. CHARGING & BORATION SYSTEM (Continued)
Sheet No. 3 of 3

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
C-30*	Heat trace "A" for BIT flowpath (TH2A)	3-L 3-B-3 3-BB el. 100'	G	Power to HT transformer Power to HT controller Power to HT controller	5-A-2, 4-A, 3-L, 3-H-1, 3-B-3 3-B-3 3-B-3, 3-BB el. 85', 3-BB el. 100'
C-31*	Heat trace "A" for BIT flowpath (TH1A)	3-X 3-BB el. 100'	F	Power to HT transformer Power to HT controller	5-A-1, 4-A, 3-L, 3-X 3-X, 3-BB el. 100'
C-32*	Heat trace "B" for BIT flowpath (TH2B)	3-L 3-B-3 3-BB el. 100'	H	Power to HT transformer Power to HT controller Power to HT controller	5-A-3, 4-A, 3-L, 3-H-1, 3-B-3 3-B-3 3-B-3, 3-BB el. 85', 3-BB el. 100'
C-33*	Heat trace "B" for BIT flowpath (TH1B)	3-X 3-BB el. 100'	H	Power to HT transformer Power to HT controller	5-A-3, 4-A, 3-L, 3-X 3-X, 3-BB el. 100'

* Components are not required for safe shutdown but have been tabulated to assess in what areas a fire could damage these components.

5. COMPONENT COOLING WATER SYSTEM

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
CCW-1	CCW Pump 1-1 and Aux. L.O. Pump 1-1	3-J-1	F	Power Control to MCB Control HSD panel Power to Aux. L.O. pump Control for Aux L.O. pump	13-A, 12-A, 10, embedded to 3-J-1. 13-A, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1, CSR, MCB 13-A, 12-A, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel) 5-A-1, 4-A, 3-J-2, 3-J-1 13-A, 12-A, 10, embedded to 3-J-2, 3-J-1
CCW-2	CCW Pump 1-2 and Aux. L.O. Pump 1-2	3-J-2	G	Power Control to MCB Control to HSD panel Power to Aux. L.O. pump Control for Aux. L.O. pump	13-B, 12-B, 10, embedded to 3-J-2 13-B, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB 13-B, 12-B, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel) 5-A-2, 4-A, 3-J-2 13-B, 12-B, 10, embedded to 3-J-2
CCW-3	CCW Pump 1-3 and Aux. L.O. Pump 1-3	3-J-3	H	Power Control to MCB Control to HSD panel Power to Aux. L.O. pump Control for Aux. L.O. pump	13-C, 12-C, 10, embedded to 3-J-3 13-C, 12-C, 10, embedded to 4-A, 5-A-3, 6-A-3, CSR, MCB 13-C, 12-C, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel) 5-A-3, 4-A, 3-J-3 13-C, 12-C, 10, embedded to 3-J-3
CCW-4	FCV-430, CCW HX 1-1 isolation	14-E	F	Power & Control Control to MCB	5-A-1, 4-A, 14-A, 14-E 5-A-1, 6-A-1, CSR, MCB
CCW-5	FCV-431, CCW HX 1-2 isolation	14-E	G	Power & Control Control to MCB	5-A-2, 4-A, 14-A, 14-E 5-A-2, 6-A-2, CSR, MCB
CCW-6	FCV-355, CCW Supply Header C	14-E	H	Power & Control Control to MCB	5-A-3, 4-A, 14-A, 14-E 5-A-3, 6-A-3, CSR, MCB
CCW-7	FCV-364 and 365, CCW Supply to RHR HX	3-BB el. 85'	Non-vital portion of G	Control to SV's	3-BB, 3-L, 3-X, 3-AA, CSR, MCB

6. AUXILIARY SALT WATER SYSTEM

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
ASW-1	ASW pump 1-1	30-A-1	F	Power Control to MCB Control to HSD panel	13-A, 12-A, 10, embedded to 30-A-1 13-A, 12-A, 10, embedded to 4-A, 5-A-1, 6-A-1, CSR, MCB 13-A, 12-A, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel)
ASW-2	ASW pump 1-2	30-A-2	G	Power Control to MCB Control to HSD panel	13-B, 12-B, 10, embedded to 30-A-2 13-B, 12-B, 10, embedded to 4-A, 5-A-2, 6-A-2, CSR, MCB 13-B, 12-B, 10, embedded to 4-A, embedded to 5-A-4 (HSD panel)
ASW-3	FCV-602, ASW to CCW HX 1-1	14-E	F	Control to SV	14-E, 14-A, 4-A, 5-A-4, 6-A-5, CSR, MCB
ASW-4	FCV-603, ASW to CCW HX 1-2	14-E	G	Control to SV	14-E, 14-A, 4-A, 5-A-4, 6-A-5, CSR, MCB

7. MAIN STEAM SYSTEM

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
MS-1	FCV-41, FCV-42; MSIV, Leads 1 and 2	28	G	SV control to MCB	28, 3-BB el. 85', 3-BB el. 100', 5-A-2, 6-A-2, CSR, MCB
MS-2	FCV-43, FCV-44; MSIV, Leads 3 and 4	3-BB el. 115'	H	SV control to MCB	3-BB el. 100', 3-BB el. 115', embedded to CSR, MCB
MS-3	FCV-760, FCV-761; SG Blowdown Isolation valves	1-B	G	Control Control	1-B, 1-A, 3-BB el. 100', 3-BB el. 115', embedded to CSR, MCB 1-B, 1-A, 3-BB el. 100', 3-BB el. 115', 5-A-2, 6-A-2, CSR, MCB
MS-4	FCV-762, FCV-763; SG Blowdown Isolation valves	1-B	H	Control Control	1-B, 1-A, 3-BB el. 100', 3-BB el. 115', embedded to CSR, MCB 1-B, 1-A, 3-BB el. 100', 3-BB el. 115', 5-A-3, 6-A-3, CSR, MCB
MS-5	PCV-19, PCV-20; 10% power relief valves	28	F	Control to MCB	28, 3-BB el. 100', 3-BB el. 115', 5-A-1, 6-A-1, CSR, MCB (tentative routing)
MS-6	PCV-21, PCV-22; 10% power relief valves	3-BB	G	Control to MCB	3-BB el. 100', 3-BB el. 115', 5-A-2, 6-A-2, CSR, MCB (tentative routing)

8. INSTRUMENTATION

Ref. No.	Component and Function	Fire Zone	Bus/Channel	Circuit Function	Fire Zone and Conduit Layout Drawing
I-1	Instr. AC Ch. I	6-A-1	F	Power	6-A-1, CSR
I-2	Instr. AC Ch. II	6-A-2	G	Power	6-A-2, CSR
I-3	Instr. AC Ch. III	6-A-3	H	Power	6-A-3, CSR
I-4	Instr. AC Ch. IV	6-A-3	H	Power	6-A-3, CSR
I-5	PT-514, PT-524; SG pressure, Channel I	28	I	Input signal Indication to MCB Indication to HSD	28, 3-BB el. 100', 3-BB el. 115' (502079), CSR CSR, MCB CSR, 6-A-1, 5-A-1, embedded to 5-A-4 (HSD panel)
I-6	PT-534, PT-544; SG pressure, Channel I	3-BB el 115'	I	Input signal Indication to MCB Indication to HSD	3-BB el. 115' (502079), CSR CSR, MCB CSR, 6-A-1, 5-A-1, embedded to 5-A-4 (HSD panel)
I-7	PT-515, PT-525; SG pressure, Channel II	28	II	Input signal Indication	28, 3-BB el. 100', 3-BB el. 115' (502079), CSR CSR, MCB
I-8	PT-535, PT-545; SG pressure, Channel II	3-BB el. 115'	II	Input signal Indication	3-BB el. 115' (502079), CSR CSR, MCB
I-9	PT-516, PT-546; SG pressure, Channel IV	3-BB el. 115' 28 (PT-516)	IV	Input Signal Indication	28 (PT-516 only), 3-BB el. 115' (502079), CSR CSR, MCB
I-10	PT-526, PT-536; SG pressure, Channel III	3-BB el. 115' 28 (PT-526)	III	Input Signal Indication	28 (PT-526 only), 3-BB el. 115' (502079), CSR CSR, MCB
I-11	LT-517, 527, 537 & 547; SG level, Channel IV	1-A	IV	Input Signal Indication	1-A, embedded in 3-BB el. 115' (57608), CSR CSR to MCB
I-12	LT-518, 528, 538 & 548; SG level, Channel III	1-A	III	Input Signal Indication	1-A, embedded in 3-BB el. 115' (57608), CSR CSR to MCB
I-13	LT-519 & LT-549; SG level, Channel II	1-A	II	Input Signal Indication	1-A, embedded in 3-BB el. 115' (57608), CSR CSR to MCB
I-14	LT-529 & LT-539; SG level, Channel I	1-A	I	Input Signal Indication	1-A, embedded in 3-BB el. 115' (57608), CSR CSR to MCB
I-15	TE-413A, B, 423A, B, 433A, B, 443A, B RCS temperature	1-B	Non-vital Portion of I & II	Input Signal Indication	1-B, 1-A, embedded in 3-BB el. 115' (57608), CSR CSR, MCB
I-16	PT-403 RCS Pressure Ch. III	1-A	III I	Input Signal Indication	1-A, embedded in 3-BB el. 115' (57608), CSR CSR, MCB
I-17	PT-405 RCS Pressure Ch. IV	1-A	IV	Input Signal Indication	1-A, embedded in 3-BB el. 115' (57608), CSR CSR, MCB

8. INSTRUMENTATION (Continued)

Ref. No.	Component and Function	Fire Zone	Bus/Channel	Circuit Function	Fire Zone and Conduit Layout Drawing
I-18	LT-459 Pressurizer Level Ch. I	1-A	I	Input Signal Indication MCB Indication HSD	1-A, embedded in 3-BB el. 115' (57608), CSR CSR, MCB CSR, 6-A-1, 5-A-1, embedded to 5-A-4 (HSD panel)
I-19	LT-460 Pressurizer Level Ch. II	1-A	II	Input Signal Indication MCB Indication HSD	1-A, embedded in 3-BB el. 115' (57608), CSR CSR, MCB CSR, 6-A-2, 5-A-2 (57606), embedded to 5-A-4 (HSD panel)
I-20	LT-461 Pressurizer Level Ch. III	1-A	III	Input Signal Indication	1-A, embedded in 3-BB el. 115' (57608), CSR CSR, MCB
I-21	LT-106 B/A Tank 1-1 Level	3-AA	I	Input Signal Indication	3-AA, CSR CSR, MCB
I-22	LT-102 B/A Tank 1-2 Level	3-AA	III	Input Signal Indication	3-AA, CSR CSR, MCB
I-23	LT-406 Pressurizer Level	1-A	IV	Input Signal Indication DSSIP*	1-A, 3-BB el. 100' 3-BB el. 100'
I-24	PT-455 Pressurizer pressure	1-A	I	Input Signal Indication MCB Indication HSD	1-A, embedded in 3-BB el. 115', CSR CSR, MCB CSR, 6-A-1, 5-A-1, embedded to 5-A-4 (HSD panel)
I-25	PT-456 Pressurizer pressure	1-A	II	Input Signal Indication MCB	1-A, embedded in 3-BB el. 115', CSR CSR, MCB

* DSSIP= Dedicated safe shutdown instrument panel

9. VENTILATION FOR SAFE SHUTDOWN EQUIPMENT

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
V-1	S-35, Control room supply fan and air cond. system	8-B-3	H	Power Control	5-A-3, 4-A, 3-L and 3-X and 3-AA (57693), 8-B-1, 8-B-3 8-B-3 embedded to CSR, MCB
V-2	S-36, Control room supply fan and air cond. system	8-B-3	F	Power Control	5-A-1, 4-A, 3-L and 3-X and 3-AA (57693), 8-B-1, 8-B-3 8-B-3 embedded to CSR, MCB
V-3	S-31, Aux. bldg. supply fan	8-B-1	G	Power Control	5-A-2, 4-A, 3-L and 3-X and 3-AA (57693), 8-B-1 5-A-2, 6-A-2, CSR, MCB
V-4	S-32, Aux. bldg. supply fan	8-B-1	H	Power Control	5-A-3, 4-A, 3-L and 3-X and 3-AA (57693), 8-B-1 5-A-3, 6-A-3, CSR, MCB
V-5	E-1, Aux. bldg. exhaust fan	3-P-4	F	Power Control	5-A-1, 4-A, 3-L (57693), embedded to 3-X (57615), 3-Q-1 and 31 (57611), embedded to 3-P-4 5-A-1, 6-A-1, CSR, MCB
V-6	E-2, Aux. bldg. exhaust fan	3-P-3	H	Power Control	5-A-3, 4-A, 3-L (57693), embedded to 3-X (57615), 3-Q-1 and 31 (57611), embedded to 3-P-4, 3-P-3 5-A-3, 6-A-3, CSR, MCB
V-7	S-43, 480 V Swgr and inverter rooms supply fan	6-A-5	F	Power Control	5-A-1, 6-A-1, 6-A-5 6-A-5, 6-A-1, 6-A-2, 6-A-3
V-8	S-44, 480 V Swgr and inverter rooms supply fan	6-A-5	H	Power Control	5-A-3, 6-A-3, 6-A-2, 6-A-1, 6-A-5 (existing routing) 5-A-3, 5-A-4, 6-A-5 (proposed reroute) 6-A-5, 6-A-1, 6-A-2, 6-A-3
V-9	S-67, 4 kV Swgr bus H supply fan	13-E	H	Power Control	5-A-3, 4-A, embedded to 10, 12-C, 13-E 13-E, 12-F and 12-D (57563), 12-C, 13-C
V-10	S-68, 4 kV Swgr bus G supply fan	13-E	G	Power Control	5-A-2, 4-A, embedded to 10, 12-B, 13-E 13-E, 12-F and 12-D (57563), 12-B, 13-B
V-11	S-69, 4 kV Swgr bus F supply fan	13-E	F	Power Control	5-A-1, 4-A, embedded to 10, 12-A, 13-E 13-E, 12-F and 12-D (57563), 12-A, 13-A
V-12	E-101, ASW pump room 1-2 exh. fan	30-A-2	G	Power Control Control	5-A-2, 4-A, 3-J-1, embedded to 30-A-2 13-B, 12-B, 10, embedded to 4-A, 5-A-2 13-B, 12-B, 10, embedded to 4-A, embedded to 5-A-4, embedded to 5-A-2
V-13	E-103, ASW pump room 1-1 exh. fan	30-A-1	F	Power and control Control	5-A-1, 4-A, embedded to 10, 12-A, 10, embedded to 30-A-1 13-A, 12-A, 10, 12-A, 10, embedded to 4-A, 5-A-1

9. VENTILATION FOR SAFE SHUTDOWN EQUIPMENT (Continued)

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
V-14	S-1, Fuel handling bldg. supply fan	3-P-1	G	Power Control	5-A-2, 4-A, 3-L (57693), embedded to 3-X (57615), 3-Q-1 and 3L (57611), 3-P-1 5-A-2, 6-A-2, CSR, MCB
V-15	S-2, Fuel handling bldg. supply fan	3-P-1	H	Power Control	5-A-3, 4-A, 3-L (57693), embedded to 3-X (57615), 3-Q-1 and 3L (57611), 3-P-1 5-A-3, 6-A-3, CSR, MCB
V-16	E-5, Fuel handling bldg. exhaust fan	3-P-7	F	Power Control	5-A-1, 4-A, 3-L and 3-X and 3-AA (57693), embedded to 3-P-7 5-A-1, 6-A-1, CSR, MCB
V-17	E-6, Fuel handling bldg. exhaust fan	3-P-8	H	Power Control	5-A-3, 4-A, 3-L and 3-X and 3-AA (57693), embedded to 3-P-8 5-A-3, 6-A-3, CSR, MCB

10. FIRE SYSTEM

Ref. No.	Component and Function	Fire Zone	Bus	Circuit Function	Fire Zone and Conduit Layout Drawing
F-1	Fire Pump 0-1	3-R	F	Power	5-A-1, 4-A, 3-L, embedded to 3-X, 3-Q-1, 3-Q-2, 3-R
				Control	CR, CSR, 3-AA, 3-X, 3-L, embedded to 3-X, 3-Q-1, 3-Q-2, 3-R
F-2	Fire Pump 0-2	3-R	H	Power	5-A-3, 4-A, 3-L, embedded to 3-X, 3-Q-1, 3-Q-2, 3-R
				Control	CR, CSR, embedded to 3-X, 3-Q-1, 3-Q-2, 3-R

DIABLO CANYON POWER PLANT

TABULATION OF SAFE SHUTDOWN EQUIPMENT
AND ELECTRICAL CABLING WITHIN EACH FIRE ZONE

All equipment and electrical cabling required for safe shutdown has been tabulated by fire zone for each Unit 1 fire zone. Those fire zones not containing safe shutdown equipment or electrical cabling have not been included. An assessment of the consequences of a fire damaging each component within a fire zone was made and a conclusion concerning how this fire affects safe shutdown capability was reached. Fire zones in which a postulated fire could conceivably affect safe shutdown will be modified so that safe shutdown can be assured. Modifications to be made include additional fire suppression and detection capability, conduit protection and/or relocation, and new administrative controls and procedures. These modifications are summarized in "Summary of Modifications Within Fire Zones to Protect Safe Shutdown Equipment and Electrical Cabling".

The components and associated electrical cabling located within each fire zone were determined by sorting the information contained in "Tabulation of Safe Shutdown Electrical Cable Routing by Safe Shutdown System". Reference numbers have been provided for each safe shutdown component to allow cross-referencing between the two tabulations.

FIRE ZONE 1-A (CONTAINMENT PENETRATION AREA)

Ref. No.	System and Components Affected	Comments
	Residual Heat Removal System	
RHR-3,4	Valves 8701, 8702; RHR suction from hot leg	Motor operated, normally closed series valves. If fire prevents operation of valves, open manually. Several hours would be available before valves must be opened to line up RHR system to reach cold shut down.
	Charging and Boration Boric Acid Tank Flowpath:	
C-12,13,14	Valves 8145, 8146, 8147	Parallel, air operated valves. 8146 normally open; 8146, 8147 fail open of loss of air, open or short circuit. Alternate charging and boration flow paths provided by reactor coolant pump seal flow or boron injection tank flow path.
	Main Steam System	
MS-3,4	SG blowdown isolation valves, (FCV-760, 761, 762, 763)	Loss of air, open or short circuit cause desired valve closure. If hot short prevents valve closure, manual or air operated isolation valves outside of containment can be closed.
	Instrumentation	
I-11,12,13,14 I-15 I-16,17 I-18,19,20	All SG LT's All RCS TE's All RCS PT's All Pressurizer LT's	Cabling located in an area of low fuel loading, no combustible gases or liquids are in the area, and minimal transient combustibles will be inside containment during plant operation. Area where these cables run will be labeled as a "No Storage" area. Smoke detectors to be provided in penetration area.
I-23	Pressurizer LT-406	LT-406 is separated by 20 ft. from other pressurizer LT's and circuitry is routed to containment penetration in opposite direction from other LT circuitry. A 20 ft. diameter fire within zone 1-A would not affect all pressurizer level transmitters. This is shown on drawings 57596, 57685, 57686, 57687.
I-24,25	Pressurizer PT-455,456	PT-455 and PT-456 are located 180° away from RCS PT's in zone 1A. As such, a 20 ft. diameter fire in zone 1-A would not affect all PT's or associate circuitry. This is shown on drawings 57596, 57685, 57686, 57687.

FIRE ZONE 1-B (REACTOR COOLANT SYSTEM AREA)

Ref. No.	System and Components Affected	Comments
	Residual Heat Removal	
RHR-4	Valve 8702, RHR suction hot leg	Motor operated, normally closed valve. If fire prevents operation of valve, open manually. Several hours would be available before valve must be opened to line up RHR system to reach cold shutdown.
	Main Steam System	
MS-3,4	FCV-760, 761, 762, 763; SG blowdown isolation valves	Air operated valves will fail closed upon loss of air, open or short circuit. If hot short prevents valve closure, manual or air operated valves outside of containment can be closed.
	Instrumentation	
I-15	Reactor coolant system temperature elements; TE-413A and B, 423A and B, 433A and B, 443A and B	Reactor coolant pump fire could affect at most 4 of 8 temperature elements (for example, a RCP 1-1 fire could affect TE's for RCP 1-1 and 1-2). Smoke detectors and automatic sprinklers are provided for the reactor coolant pumps. Outside of RCP area, separation fro TE cabling is such that at most 4 of 8 TE's could be affected by a single fire.

FIRE ZONE 3-B-1 (RESIDUAL HEAT REMOVAL HEAT EXCHANGER AND PUMP 1-1 ROOM)

Ref. No.	System and Components Affected	Comments
	Residual Heat Removed System	
RHR-1	RHR pump 1-1	Power cabling is embedded to the pump. RHR pump 1-2 not affected by fire in Zone 3-B-1. Smoke detector to be provided in this fire zone.

FIRE-ZONE 3-B-2 (RESIDUAL HEAT REMOVAL HEAT EXCHANGER AND PUMP 1-2 ROOM)

Ref. No.	System and Components Affected	Comments
	Residual Heat Removal System	
RHR-2	RHR pump 1-2	Power cabling is embedded to the pump. RHR pump 1-1 not affected by fire in Zone 3-B-2. Smoke detector to be provided in this fire zone.
	Charging and Boration	
	Boron injection tank flowpath:	
C-28	Boron injection tank backup heater	Boron injection tank heater not affected by a fire in this zone.

FIRE ZONE 3-B-3 (BORON INJECTION TANK AREA)

Ref. No.	System and Components Affected	Comments
	Charging and Boration Boron injection tank flow path:	Charging and boration flow path using boric acid tanks unaffected by a fire in this zone.
C-23,24	Valves 8803A, 8803B; boron injection tank supply valves	
C-27,28	Boron injection tank heater and backup heater	
C-30,32	Heat trace for boron injection tank flow path	
C-29	TIC-945, boron injection tank temperature controller	

FIRE ZONE 3-C (GAS DECAY TANK AND LIQUID RECEIVER TANK AREA)

Ref. No.	System and Componets Affected	Comments
	Emergency Power Supply	
EP-4	Fuel transfer pump 0-1	Conduit for power supply to pump runs up the wall in northwest corner of this zone at elevation 73'. Power supply conduit for fuel transfer pump 0-2 located 15 feet away in fire zone 3-J-1 (component cooling water pump 1-1 room). Smoke detectors to be provided in zones 3-C and 3-J-1 and automatic sprinklers to be provided in fire zone 3-J-1. These circuits have been identified on drawing 57691. Two-hour protection of this conduit in fire zone 3-C will be provided.

FIRE ZONE 3-F (CONTAINMENT SPRAY PUMPS AREA)

Ref. No.	System and Componenst Affected	Comments
C-3	Charging and Boration Charging pump 1-3	A two foot section of conduit for a control circuit for charging pump 1-3 (as described in fire zone 3-H-1) passes in zone 3-F. Conduit is separated from equpment in zone 3-F by concrete shielding barrier. Charging pumps 1-1 and 1-2 not affected by a fire in this zone.
C-29	Boron Injection Tank flowpath: TIC-945, BIT temp. controller	Boric acid tank flow path not affected by a fire in this zone.

FIRE ZONE 3-H-1 (CENTRIFUGAL CHARGING PUMPS ROOM)

Ref. No.	System and Components Affected	Comments
	Charging and Boration	
C-1,2	Charging pumpl 1-1, 1-2	Smoke detectors and automatic sprinkler protection to be provided for this zone. Fire zone 3-H-1 to be separated from zone 3-H-2 (reciprocating charging pump room) by a three hour fire barrier.
C-3	Charging pump 1-3	Control circuit to reciprocating charging pump runs through this zone. Damage to this circuit could cause pump to trip due to erroneous low lube oil pressure signal. If this happens, circuit could be bypassed at switchgear. Instructions will be posted inside the switchgear to enable the operator to jumper this circuit in the event of a fire in zones 3-F, 3-J-2, 3-J-3, or 3-H-1
	Boric acid tank flow path:	
C-19,20	Heat trace for boric acid tank flow path	Automatic sprinkler protection for this area. If fire damages redundant heat trace for boric acid tank flow path and also damages boron injection tank flow path components, borate before solidification occurs.
	Boron injection tank flow path:	
C-23,24	Valves 8803A, 8803B; boron injection tank supply valves.	Use boric acid tank flow path if fire affects these components. See comment above.
C-27,28	Boron injection tank heater and backup heater	
C-30,32	Heat trace for boron injection tank flow path	

FIRE ZONE 3-H-2 (RECIPROCATING CHARGING PUMP ROOM)

Ref. No.	System and Components Affected	Comments
	Charging and Boration	
C-3	Charging pump 1-3	Charging pumps 1-1 and 1-2 not affected by fire in this zone. Smoke detector to be provided in this fire zone.

FIRE ZONE 3-J-1 (COMPONENT COOLING WATER PUMP 1-1 ROOM)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-5	Fuel transfer pump 0-2	Conduit for power supply to pump runs up the west wall of this zone. Power supply conduit for fuel transfer pump 0-1 located 15 feet away in fire zone 3-C. Smoke detector and automatic sprinklers to be provided in fire zone 3-J-1. Entranceway to fire zone 3-J-1 to be curbed to prevent liquid spillage in zone 3-J-1 from spreading to fire zone 3-C. These circuits have been identified on drawing 57691. Two-hour protection of this conduit in fire zone 3-J-1 will be provided.
	Component Cooling Water System	
CCW-1	Component cooling water pump 1-1	Component cooling water pumps 1-2 and 1-3 not affected by fire zone 3-J-1 (one of three pumps required for safe shutdown). Non-combustible barriers extending from the existing 5 foot high barriers to the ceiling will be provided to separate the three component cooling water pump rooms from each other.
	Ventilation for Safe Shutdown Equipment	
V-12	E-101, auxiliary saltwater pump room 1-2 exhaust fan	Ventilation for auxiliary saltwater pump 1-1 not affected by a fire in this zone.

Ref. No.	System and Components Affected	Comments
	Component Cooling Water System	
CCW-2	Component cooling water pump 1-2	Component cooling water pump 1-3 not affected by fire in zone 3-J-2. See comments for fire zone 3-J-1 concerning fire protection modifications to be made in this fire zone (smoke detectors, sprinklers, curbs, barriers).
CCW-1	Component cooling water pump 1-1	Power and control circuit for CCW auxiliary lube oil pump pass through this zone. Damage to this circuit would not affect continued operation of pump but could prevent pump from being started. Circuit can be bypassed at the switchgear and the pump could then be started. Shaft driven pump provides satisfactory pump lubrication. Instructions will be posted inside the switchgear to enable the operator to jumper this circuit in the event of fire in this zone.
	Charging and Boration	
C-1,2	Charging pump 1-1, 1-2	Power and control circuitry to the centrifugal charging pump auxiliary lube oil pumps pass through this fire zone. A fire in this zone could prevent the charging pumps from starting. If a fire in zone 3-J-2 were to damage the circuitry associated with the charging pump auxiliary lube oil pumps, the pressure switch that prevents the charging pump from starting could be bypassed at the switchgear and the charging pump could then be started. The shaft-driven lube oil pump would provide satisfactory pump lubrication. Instructions will be posted inside the switchgear to enable the operator to jumper this circuit in the event of fire in this zone.
C-3	Charging pump 1-3	A control circuit to a pressure switch for the reciprocating charging pump passes through zone 3-J-2. Damage to this circuit could cause pump to trip due to the erroneous low lube oil pressure signal. The pressure switch could be bypassed at the switchgear and the pump could then be started. Instructions will be posted inside the switchgear to enable the operator to jumper this circuit in the event of fire in this zone.

Ref. No.	System and Components Affected	Comments
C-23,24	Boron Injection Tank flowpath: Valves 8803A, 8803B; charging pumps to BIT	Boric acid tank flow path not affected by a fire in this zone.
C-27	Boron injection tank heater	

FIRE ZONE 3-J-3 (COMPONENT COOLING WATER PUMP 1-3 ROOM)

Ref. No.	System and Components Affected	Comments
	Component Cooling Water System	
CCW-3	Component cooling water 1-3	Component cooling water pumps 1-1 and 1-2 not affected by fire in zone 3-J-1. See comments for fire zone 3-J-1 concerning fire protection modifications to be made in this fire zone (smoke detectors, sprinklers, curbs, barriers).
	Charging and Boration	
C-1,2,3	Charging pumps 1-1, 1-2, 1-3	See fire zone 3-J-2 comments concerning these components. Boric acid tank flow path not affected by a fire in this zone.
	Boron injection tank flow path:	
C-23,24	Valves 8803A, 8803B; charging pumps to BIT	
C-27	Boron injection tank heater	

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-4,6	Auxiliary Feedwater pumps 1-2, 1-3	Conduits containing power circuits for motor driven auxiliary feedwater pumps pass along the ceiling in the northeast corner of fire zone 3-L above the auxiliary building control panel. To reduce dependence on the turbine driven auxiliary feedwater pump, these conduits will be encased in zone 3-L with a two hour rated fire barrier. These conduits have been identified on Drawing 57616.
AF-8,9	FCV-436, FCV-437; raw water reservoir supply valves to auxiliary feedwater pumps	Raw water reservoir is backup to condensate storage tank. If and when raw water reservoir supply is required, FCV-436 and FCV-437 can be opened manually.
	Charging and Boration Boric acid tank flow path:	
C-5,6	Boric acid transfer pumps 1-1, 1-2	Power conduits for transfer pumps penetrate high in the west wall of zone 3-L and immediately leave zone 3-L through the ceiling. Exposure of the components in this zone is limited to circuits in junction boxes and approximately one foot of conduit. This area will be designated as a "No Storage" area.
C-8	Valve 8104, boric acid tank to charging pumps	Parallel valve FCV-110A unaffected by fire in this zone.
C-15,16	Boric acid tank heaters, A and B	Circuits are located in the northwest end of zone 3-L in an area of low fuel loading. If an exposure fire in this part of zone 3-L were to damage redundant circuitry associated with the boric acid tank heaters or heat tracing, operators would initiate plant shut-down and boration. Several hours after loss of heat tracing or tank heaters are available to borate before solidification occurs.
C-19,20	Heat trace for boric acid tank flow path	
	Boron injection tank flow path:	
C-21,22	Valves 8805A, 8805B; refueling water supply	Valve(s) can be opened manually if this flow path is to be used for charging and boration.
C-28	Boron injection tank backup heater	BIT normal heater not affected by a fire in this zone.

Ref. No.	System and Components Affected	Comments
	Boron injection tank flow path:	Circuits are located in the northwest end of zone 3-L in an area of low fuel loading. If an exposure fire in this part of zone 3-L were to damage the temperature controller circuitry or redundant heat trace circuitry, operators would initiate plant shutdown and boration. Several hours are available to borate before solidification occurs.
C-30,31,32,33	Heat trace for boron injection tank flow path	
C-29	TIC-945, boron injection tank temperature controller	
	Component Cooling Water System	
CCW-7	FCV-364, FCV-365; component cooling water supply to RHR HX's	Air operated valves fail open upon loss of air, open or short circuit. If hot short causes valve closure, valve can be open manually when necessary to line up RHR system.
	Ventilation for Safe Shutdown Equipment	Comment applies to all components: Conduits penetrate high in the west wall of zone 3-L from zone 4-A and immediately leave zone 3-L through the ceiling. Exposure of these components in this zone is limited to power circuits in junction boxes and approximately one foot of conduit. These circuits have been identified on Drawing 57693.
V-1,2	S-35, S-36; control room supply fans	
V-3,4	S-31, S-32; auxiliary building supply fans	
V-5,6	E-1, E-2; auxiliary building exhaust fans	
V-14,15	S-1, S-2; fuel handling building supply fans	
V-16,17	E-5, E-6; fuel handling building exhaust fans	
	Fire System	
F-1,2	Fire pumps 0-1, 0-2	Fire pump power circuits have the same routing in zone 3-L as was described for the ventilation system components.

FIRE ZONE 3-M (SAFETY INJECTION PUMP ROOM)

Ref. No.	System and Components Affected	Comments
	Charging and Boration Boron Injection Tank flowpath:	
C-29	TIC-945, BIT temp. controller	Boric acid tank flow path not affected by a fire in this zone.

FIRE ZONE 3-P-1 (FUEL HANDLING BUILDING SUPPLY FAN ROOM)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-14,15	S-1, S-2, fuel handling building supply fans	Fuel handling building ventilation required for auxiliary feedwater pumps and fire pumps. If fire affects S-1 and S-2, fuel handling building exhaust fans available and auxiliary building ventilation provides supply air to auxiliary feedwater pumps and fire pumps if doors are opened. Fire detection device to be provided for this zone. Fuel load in this zone is exceedingly low and transient combustibles will not be stored in this area. The area will be designated as a "No Storage" area.

FIRE ZONE 3-P-3 (FUEL HANDLING BUILDING EXHAUST FAN E-2 ROOM)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-6	E-2, auxiliary building exhaust fan	E-1 not affected by fire in this zone.
	Auxiliary Feedwater System	
AF-4,6	Auxiliary feedwater pumps 1-2, 1-3	Power circuits for these pumps run from zone 3-L, into the southern end of a concrete exhaust air duct (part of zone 3-P-3), into an area adjoining a stairwell (zone S-3), and up to the auxiliary feedwater pump room. No combustible materials are located within this concrete air duct nor could any transient combustibles be reasonably expected to appear in this area.

FIRE ZONE 3-P-4 (AUXILIARY BUILDING EXHAUST FAN E-1 ROOM)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-5,6	E-1, E-2; auxiliary building exhaust fans	Conduit containing power supply to fan E-2 passes through the E-1 fan room. Fire detection device to be located in this zone. Fuel load in vicinity of fan E-1 (and E-2 power conduit) is exceedingly low and transient combustibles will not be stored in this area. The area will be designated as a "No Storage" area.

FIRE ZONE 3-P-7 (FUEL HANDLING BUILDING EXHAUST FAN E-5 ROOM)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-16	E-5, fuel handling building	E-6 not affected by a fire in this zone.

FIRE ZONE 3-P-8 (FUEL HANDLING BUILDING EXHAUST FAN E-6 ROOM)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-17	E-6, fuel handling building exhaust fan	E-5 not affected by a fire in this zone.

FIRE ZONE 3-Q-1 (TURBINE DRIVEN AUXILIARY FEEDWATER PUMP AREA)

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
-	Auxiliary feedwater pump 1-1 and valves FCV-15, FCV-152	Auxiliary feedwater pumps 1-2 and 1-3 not affected by fire in this zone.
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1	Conduit to be relocated out of this zone (to eliminate it from running in zone 3-Q-2).
AF-8,9	FCV-436, FCV-437; raw water supply to auxiliary feedwater pumps	Condensate storage tank available. If water from raw water reservoir required, extinguish fire in zone 3-Q-1 and open valves manually.
	Ventilation for Safe Shutdown Equipment	
V-5,6	E-1, E-2; auxiliary building exhaust fans	Smoke detector and automatic sprinklers to be provided in this zone. Conduits for these fans have been identified of Drawing 57611.
V-14,15	S-1, S-2; fuel handling building supply fans	
	Fire System	
F-1,2	Fire pumps 0-1, 0-2	Fire pumps and fire water tank are back-up fire water supply to raw water reservoir.

FIRE ZONE 3-Q-2 (MOTOR DRIVEN AUXILIARY FEEDWATER PUMP ROOM)

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine	Circuit to be relocated out of this fire zone.
AF-4,6	Auxiliary feedwater pumps 1-2, 1-3	Turbine driven auxiliary feedwater pump not affected by fire in this zone (after FCV-95 circuit relocated). Smoke detector and automatic sprinkler protection to be provided for this zone.
	Fire System	
F-1,2	Fire pumps 0-1, 0-2	Fire pumps and fire water tank are back-up fire water supply to raw water reservoir.

FIRE ZONE 3-R (FUEL HANDLING BUILDING)

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine	Circuit to be relocated out of this fire zone (to remove it from zone 3-Q-2).
	Fire System	
F-1,2	Fire pumps 0-1, 0-2	Exposure fire in vicinity of fire pumps or fire pump controllers could affect both pumps; however, raw water reservoir is primary fire water supply and does not utilize fire pumps. Smoke detector to be provided in the vicinity of the fire pumps.

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine	Circuit will be rerouted out of this zone (to remove it from zone 3-Q-2).
AF-8,9	FCV-436, FCV-437; raw water supply to auxiliary feedwater pumps	Raw water reservoir is backup to condensate storage. If and when raw water reservoir supply is required, FCV-436, FCV-437 can be opened manually. Conduits for FCV-436, FCV-437 are located along east wall of zone 3-X (automatic sprinkler protection to be provided in this area).
	Charging and Boration Boric acid tank flow path:	
C-5,6	Boric acid transfer pumps 1-1, 1-2	Smoke detectors and automatic sprinkler protection to be provided in vicinity of boric acid transfer pumps.
C-7,8	Valves 8104, FCV-110A; boric acid tank to charging pumps	FCV-110A air operated valve, fails open on loss of air, short or open circuit. Open either valve manually if required.
C-15,16	Boric acid tank heaters A and B	Automatic sprinkler protection to be provided in area within 3-X where redundant tank heaters could be affected by a single fire (in vicinity of columns line T and 16.8).
C-19,20	Heat trace for boric acid tank	Circuits are located in the west end of zone 3-X in an area of low fuel loading. If an exposure fire were to damage redundant heat trace circuitry, operators would initiate plant shutdown and boration. Several hours are available to borate after loss of heat trace before solidification occurs.
	Boron injection tank flow path:	
C-31,33	Heat trace for boron injection tank flow path	Same as above
	Component Cooling Water System	
CCW-7	FCV-364, 365; component cooling water supply to RHR HX	Air operated valves, fail open upon loss of air, short or open circuit. If hot short causes valve closure, remove air supply to open valve when required for RHR cooling.

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-1,2	S-35, S-36; control room supply fans	Conduits run up along west wall of zone 3-X in a compartment containing a negligible fuel load. This area will be designated as a "No Storage" area. Conduits have been identified on Drawing 57693.
V-3,4	S-31, S-32; auxiliary building supply fans	Same as S-35, S-36
V-5,6	E-1, E-2; auxiliary building exhaust fans	Conduits run east-west embedded in the floor between zone 3-L and 3-X and are exposed in the east end of zone 3-X. These conduits have been identified on Drawing 57615. Automatic sprinkler protection to be provided in this area of zone 3-X.
V-14,15	S-1, S-2; fuel handling building supply fans	Same as E-1, E-2
V-16,17	E-5, E-6; fuel handling building exhaust fans	Same as S-35, S-36
	Fire System	
F-1,2	Fire pumps 0-1, 0-2	Fire pump power circuits run at east end of zone 3-X, control circuits run up west end of zone 3-X. East end of zone 3-X to have automatic sprinkler protection, west end of zone 3-X to be designated as a "No Storage" area.

FIRE ZONE 3-AA (BORIC ACID TANK AREA)

Ref. No.	System and Components Affected	Comments
	Charging and Boration Boric acid tank flow path:	Boron injection tank flow path unaffected by a fire in this zone.
C-7,8	Valves 8104, FCV-110A; valves between transfer pumps and charging pumps	FCV-110A air operated valve, fails open on loss of air, short or open circuit. If hot short causes valve closure, open either valve manually.
C-15,16	Boric acid tank heaters, A and B	Smoke detectors to be provided in vicinity of boric acid tanks. Conduits for redundant tank heaters are separated from each other by the boric acid tanks. Single fire would not affect both heaters to each tank.
C-17,18	TIC-103, TIC-107; boric acid tank temperature controllers	Temperature controllers for the two boric acid tanks are located on the northwest side of tank 1-1 and the southeast side between 1-1 and tank 1-2. A single fire in zone 3-AA would not affect both temperature controllers and associated circuitry.
	Component Cooling Water System	
CCW-7	FCV-364, FCV-365; component cooling water supply to RHR HX	Air operated valves, fail open up loss of air, short or open circuit. If hot short causes valve closure, remove air supply to open valve when required for RHR cooling.
	Instrumentation	
I-21,22	LT-102, LT-106; boric acid tank level transmitters	Boron injection tank flow path does not require these level transmitters and is not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-1,2	S-35, S-36; control room supply	Conduits run up along west wall of zone 3-AA in a compartment containing a negligible fuel load. This area will be designated as a "No Storage" area. Conduits have been identified on Drawing 57693.
V-3,4	S-31, S-32; auxiliary building supply fans	Same as above
V-16,17	E-5, E-6; fuel handling building exhaust fans	Same as above
	Fire System	
F-1	Fire pump 0-1	Fire pump 0-2 not affected by a fire in this zone.

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine	Conduit for FCV-95 will run along south wall of zone 3-BB to the east end of zone 3-BB at el. 85 feet. Conduit will not pass within 30 feet of conduit for LCV-110, LCV-111. Therefore, fire affecting FCV-95 conduit in zone 3-BB at el. 85 feet would not affect auxiliary feedwater pumps 1-2 and 1-3 and their associated level control valves.
AF-2	LCV-106, LCV-107; auxiliary feedwater supply to SG 1-1, 1-2 from pump 1-1	Conduits for LCV-106, 107, 110, and 111 located in west end of zone 3-BB at el. 85 feet. If fire affects these conduits, provide feedwater flow to SG 1-3 or 1-4 via auxiliary feedwater pump 1-1 and LCV-108; LCV-109 or auxiliary feedwater pump 1-3 and LCV-113, LCV-115. Conduits for FCV-95, LCV-106, 107, 110, 111 have been shown on drawing 501450.
AF-5	LCV-110, LCV-111; auxiliary feedwater supply to SG 1-1, 1-2 from pump 1-2	
	Charging and Boration	
	Boric acid tank flow path:	
C-11	Valve 8108, charging flow path	Normally open, motor operated valve. If hot short in control circuitry causes valve closure, de-energize motor operator at switchgear and open manually. Charging via RCP seal flowpath not affected by a fire in this zone.
	Boron injection tank flow path:	
C-21,22	Valves 8805A, 8805B; refueling water supply to charging pumps	Valves are located in small vestibule south of main portion of zone 3-BB (in vicinity of column lines N and 15.7). If fire affects valves or circuitry to valves, the valves can be opened manually. Charging via boric acid tank flow path can be done if fire causes valves to be inoperable.
C-29	TIC-945, BIT temp. controller	Boric acid tank flow path not affected by a fire in this zone.
C-30,32	Heat trace for BIT flowpath	Boric acid tank flow path not affected by a fire in this zone.
	Component Cooling Water System	
CCW-7	FCV-364, FCV-365; CCW supply to RHR HX	Air operated valves, fail open on loss of air, short or open circuit. If hot short causes valve closure, remove air supply to open valves when required for RHR cooling.

Ref. No.	System and Components Affected	Comments
	Main Steam System	
MS-1	FCV-41, FCV-42; main steam isolation valves, loops 1 and 2	If fire affects circuitry to main steam isolation valves, valves can be closed manually if necessary.

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine	FCV-95 conduit will run vertically along east wall of zone 3-BB at a minimum distance of 25 feet from any conduits for LCV's associated with the motor driven auxiliary feedwater pumps. Therefore, fire affecting FCV-95 conduit in zone 3-BB, el. 100 feet, would not affect auxiliary feedwater pumps 1-2, 1-3 and their associated LCV's.
AF-2,3	LCV-106, 107, 108, 109; auxiliary feedwater supply from pump 1-1	Conduits for LCV-110, 111, 113, and 115 will have two hour protection in zone 3-BB, el. 100 feet in areas where these redundant conduits pass within 15 feet of each other. With these conduits protected as indicated, an exposure fire in zone 3-BB, el. 100 feet could affect (depending upon location of fire within zone): (1) LCV-110, LCV-111 in northwest corner of 3-BB, or (2) LCV-106, 107,108, and 109 in southwest corner of zone 3-BB, or (3) LCV-108, 109, 113, and 115 in mid-section of zone 3-BB. Sufficient feedwater flow capability still exists after any of the postulated exposure fires. Automatic sprinkler protection to be provided in this zone at elevation 100 feet. Conduits for FCV-95 and the LCV's have been shown on drawing 502078 with protected conduits identified.
AF-5	LCV-110, LCV-111; auxiliary feedwater supply from pump 1-2	
AF-7	LCV-113, LCV-115; auxiliary feedwater supply from pump 1-3	
AF-11	FCV-38, SG 1-3 steam supply to pump 1-1 turbine	Normally open, motor operated valve. If hot short in control circuitry causes valve closure, and auxiliary feedwater pump 1-1 is to be used, use FCV-37 and/or open FCV-38 manually.
	Residual Heat Removal System	
RHR-3,4	Valves 8701, 8702; residual heat removal suction from hot leg	Open valves manually if fire damages circuits to these valves.
RHR-5	HCV-637, HCV-638; residual heat removal valves in flow path	Air operated valves, fail open. Fire in zone 3-BB affecting current loop circuitry to valve would cause valve to open.
RHR-6,7	Valves 8809A, 8809B, residual heat removal valves in flow path	Normally open, motor operated valves. If hot short in control circuitry causes valve closure, open manually.

Ref. No.	System and Components Affected	Comments
	Charging and Boration Boric acid tank flow path:	
C-7,8	Valves 8104, FCV-110A; charging flow path	FCV-110A is air opened valve that fails open upon loss of air, short or open circuit. Valve 8104 is normally closed, motor operated valve. If fire damages 8104 circuitry and creates hot short to close FCV-110A, open either valve manually.
C-10,11	Valves 8107, 8108; charging flow path	Normally open, motor operated valves. If hot short in control circuitry causes valve closure, de-energize motor operator at switchgear and open valve(s) manually.
C-12,13,14	Valves 8145, 8146, 8147; charging flow path	Air operated valves, 8146 normally open, 8146 and 8147 fail open upon loss of air, short or open circuit. If hot short causes valve closure, open manually by removing air supply.
	Boron injection tank flow path:	
C-25,26	Valves 8801A, 8801B; BIT outlet	Normally closed, parallel motor operated valves. If fire affects circuitry to both valves, open a valve manually or use boric acid tank flow path.
C-29	TIC 945, BIT temperature controller	Damage to circuitry in zone 3-BB will turn on heaters.
C-30,31,32,33	Heat trace for BIT flow path	Heat trace for boric acid tank flow path not affected by a fire in this zone.
	Main Steam System	
MS-1,2	FCV-41,42,43,44; main steam isolation valves	If fire affects circuitry to main steam isolation valves, valves can be closed manually if necessary.
MS-3,4	FCV-760, 761, 762, 763; SG blowdown isolation valves	Air operated valves, fail closed. Short or open circuit would cause desired valve closure. Manual or air operated valves outside of containment can be closed if necessary.
MS-5,6	PCV-19, 20, 21, 22; 10% power relief valves	If fire damages circuitry to 10% power relief valves, they can be operated manually at the valves or with pneumatic controls at hot shutdown panel.
	Instrumentation	
1-5	PT-514, PT-524; SG pressure, loops 1 and 2	Fire in zone 3-BB, el. 100 feet could affect at most 2 of 3 SG pressure indication for loops 1 and 2. (1 of 3 SG pressure indications required for each SG used for cooldown).
1-7	PT-515, PT-525; SG pressure, loops 1 and 2	
I-23	LT-406, pressurizer level	Pressurizer LT-459, 460, 461 circuitry not routed in this fire zone.

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine	Valve and conduits to valve located in east end of zone 3-BB at El. 115 feet at a minimum distance of 25 feet from LCV-113, LCV-115 conduits. Therefore, fire affecting FCV-95 in zone 3-BB, el. 115 feet would not affect auxiliary feedwater pumps 1-2, 1-3 and their associated LCV's.
AF-3	LCV-108, LCV-109; auxiliary feedwater supply to SG 1-3, 1-4 from pump 1-1	If fire affects LCV-108, 109, 113, and 115, provide feedwater flow to SG 1-1, 1-2 via auxiliary feedwater pump 1-1 and LCV-106, LCV-107, or auxiliary feedwater pump 1-2 and LCV-110, LCV-111.
AF-7	LCV-113, LCV-115; auxiliary feedwater supply to SG 1-3, 1-4 from pump 1-3	Conduits for FCV-95, LCV-108, 109, 113, and 115 have been identified on drawing 502079.
AF-10,11	FCV-37, FCV-38; SG 1-2, 1-3 steam supply to pump 1-1 turbine	Normally open, motor operated valves. Hot short in control circuitry could cause valve closure. It is unlikely this would occur to both valves. If it does, motor operators could be de-energized at switchgear and valves opened manually. Auxiliary feedwater pump 1-2 and its LCV's would be unaffected by a fire in zone 3-BB at el. 115 feet.
	Residual Heat Removal System	
RHR-3,4	Valve 8701, residual heat removal suction from hot leg	Open valve manually if fire damages circuits to the valve. Conduit for valve 8701 is exposed in 3-BB el-115' only at the penetration area (automatic sprinklers to be provided in this area).
RHR-5	HCV-637, HCV-638; residual heat removal valves in flow path	Air operated valves, fail open. Fire in zone 3-BB affecting current loop circuitry to valve would cause valves to open.
	Charging, Boration, and Pressurizer Spray	
C-12,13,14	Valves 8145, 8146, 8147 charging flow path	Air operated valves, 8146 normally open, 8146 and 8147 fail open upon loss of air, short or open circuit. If hot short causes valve closure, open manually by removing air supply.

Ref. No.	System and Components Affected	Comments
	Charging and Boration Boric acid tank flow path:	
C-7,8	Valves 8104, FCV-110A; charging flow path	FCV-110A is air operated valve that fails open upon loss of air, short or open circuit. Valve 8104 is normally closed, motor operated valve. If fire damages 8104 circuitry and creates hot short to close FCV-110A, open either valve manually.
	Boron injection tank flow path:	
C-29	TIC-945, BIT temperature controller	Damage to circuitry in zone 3-BB will turn on heaters.
	Main Steam System	
MS-2	FCV-43, FCV-44; main steam isolation valves	If fire affects circuitry to main steam isolation valves, valves can be closed manually if necessary.
MS-3,4	FCV-760, 761, 762, 763; SG blowdown isolation valves	Conduits run from containment penetrations directly through floor to zone 3-BB elevation 100 feet. Air operated valves, fail closed. Short or open circuit would cause desired valve closure. Manual or air operated valves outside of containment can be closed if necessary.
MS-5,6	PCV-19, 20, 21, 22; 10% power relief valves	If fire damages circuitry to 10% power relief valves, they can be operated manually at the valves or with pneumatic controls at hot shutdown panel.
	Instrumentation	
I-5,6,7,8 9,10	All SG pressure indications	Pressure transmitters and circuitry located in west end of zone 3-BB elevation 115 feet. Automatic sprinkler protection to be provided for this area. Conduits for these components have been identified on Drawing 502079.
I-11,12,13,14	All SG level indications	Circuits run from containment penetrations directly to floor and are embedded to cable spreading room. Automatic sprinkler protection to be provided in penetration area in zone 3-BB elevation 115 feet. Conduits for these components have been identified on Drawing 57608.

Ref. No.	System and Components Affected	Comments
	Instrumentation	
I-15	All RCS temperature indications	Same as I-11, 12, 13, 14
I-16,17,24,25	All RCS and PZR pressure indications	Same as above
I-18,19,20	All pressurizer level indications (except LT-406)	Same as above

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-1,2,3	Diesel generator 1-1, 1-2; 1-3	Conduits are located in two raceways at north end of laboratory as well as in the ceiling of the lab area above the suspended ceiling and automatic sprinklers. Electrical raceways are to be subdivided such that redundant divisions are separated from each other by two hour rated barriers. Existing ceiling to be replaced with a one hour rated ceiling and automatic sprinklers to be retained. Smoke detectors to be provided in the ceiling of the laboratory area.
EP-4,5	Fuel transfer pumps 0-1, 0-2	
EP-6,7,8	4KV supplies to 480 load centers	
EP-13,14,15	125V DC supply for 4KV switchgear	
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to pump 1-1 turbine	
AF-4,6	Auxiliary feedwater pumps 1-2, 1-3	
AF-8,9	FCV-436, FCV-437; raw water supply to auxiliary feedwater pumps	
	Residual Heat Removal System	
RHR-1,2	Residual heat removal pumps 1-1, 1-2	
	Charging and Boration	
C-1,2,3	Charging pumps 1-1, 1-2, 1-3	
	Boron acid tank flow path	
C-5,6	Boric acid transfer pumps 1-1, 1-2	
C-8	Valve 8104	
C-15,16	Boric acid tank heaters, A and B	
C-19,20	Heat trace for boric acid tank flow path.	
	Boron injection tank flow path:	
C-21,22	Valves 8805A, B; refueling water supply to charging pumps	
C-23,24	Valves 8803A, B; charging pumps to BIT	
C-27,28	BIT heater, backup heater	
C-30,31,32,33	Heat trace for boron injection tank flowpath.	

Ref. No.	System and Components	Comments
	Component Cooling Water System	
CCW-1,2,3	Component cooling water pumps 1-1, 1-2, 1-3	
CCW-4,5,6	Valves FCV-430, FCV-431, FCV-355	
	Auxiliary Saltwater System	
ASW-1,2	Auxiliary saltwater pumps 1-1, 1-2	
ASW-3,4	Valves FCV-602, FCV-603	
	Ventilation for Safe Shutdown Equipment	
V-1,2	S-35, S-36; control room ventilation equipment	
V-3,4	S-31, S-32; auxiliary building supply fans	
V-5,6	E-1, E-2; auxiliary building exhaust fans	
V-9,10,11	S-67, S-68, S-69; 4KV switchgear room fans	
V-12,13	E-101, E-103; auxiliary saltwater pump room exhaust fans	
V-14,15	S-1, S-2; fuel handling building supply fans	
V-17,18	E-5, E-6 fuel handling building exhaust fans	
	Fire System	
F-1,2	Fire pumps 0-1, 0-2	

FIRE ZONE 4-B (ACCESS CONTROL AREA)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-4,5	Fuel transfer pumps 0-1, 0-2	Power circuits for fuel transfer pumps run through an office area containing a whole body counter in fire zone 4-B at elevation 85 ft. In running up the wall of this office, the conduits maintain 15 ft. separation and are each enclosed behind two-hour rated metal lathe and plaster walls that isolate the conduits from the office and each other. One conduit runs above the suspended ceiling in the south end of the office while the redundant conduit runs above the suspended ceiling in the counting room to the north (fire zone 4-A). This office area has been designated as a "No Storage" area and automatic sprinkler protection is provided for the space.

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-3	Diesel generator 1-3	Diesel generators 1-1 and 1-2 not affected by fire in these zones.
EP-6	4KV supply to load center 1F	Power supplies to G and H load centers not affected by a fire in these zones.
EP-9,12	125V DC supply to main control board, F bus and nonvital bus (zone 6-A-1 only)	Nonvital loads powered by G bus and pass through this zone. G and H power supplies not affected by a fire in this zone.
EP-13	125V DC supply to 4KV switchgear, F bus	DC power supplies to G and H 4KV switchgear not affected by a fire in these zones.
EP-2	Diesel generator 1-2	Only the backup control circuitry for diesel generator 1-2 affected. Fire in these zones will not prevent diesel generator 1-2 operation using normal (G bus) control circuitry.
	Auxiliary Feedwater System	
AF-6,7	Auxiliary feedwater pump 1-3 and associated valves, LCV-113, LCV-115	Auxiliary feedwater pump 1-1 and 1-2 and associated LCV's not affected by fire in these zones.
AF-9	FCV-437; raw water reservoir supply to auxiliary feedwater pumps 1-2, 1-3	Condensate storage tank available and raw water to auxiliary feed-water pump 1-1 via FCV-436 available.
AF-11	FCV-38, steam supply valve to auxiliary feedwater pump turbine 1-1	Normally open motor operated valve. Alternate steam supply for auxiliary feedwater turbine via FCV-37.
	Charging and Boration	
C-1	Charging pump 1-1	Charging pumps 1-2 and 1-3 not affected by a fire in this zone
	Boric acid tank flow path:	
C-5	Boric acid transfer pump 1-1	Transfer pump 1-2 not affected by a fire in these zones
C-10	Valve 8107, charging flow path	If fire in these zones causes valve closure due to hot short, valve can be opened manually. Charging flow path via RCP seals not affected by a fire in this zone.
C-19	Heat trace 1A (zone 5-A-1 only)	Redundant heat trace 1B not affected by a fire in this zone.
	Boron injection tank flow path:	
C-21	Valve 8805A, refueling water storage tank isolation valves	Parallel valve 8805B not affected by a fire in these zones.

Ref. No.	System and Components Affected	Comments
	Boron injection tank flow path:	
C-23	Valve 8803A, charging pumps to BIT	Parallel valve 8803B not affected by a fire in these zones.
C-25	Valve 8801A, BIT discharge	Parallel valve 8801B not affected by a fire in these zones.
C-27	Boron injection tank heater (zone 5-A-1 only)	BIT backup heater not affected by a fire in these zones.
C-31	Heat trace 1A (zone 5-A-1 only)	Redundant heat trace 1B not affected by a fire in this zone.
	Component Cooling Water System	
CCW-1	Component cooling water pump 1-1	Component cooling water pump 1-2 or 1-3 available.
CCW-4	FCV-430, component cooling water HX 1-1 isolation valve	Component cooling water heat exchanger 1-2 available. Open FCV-430 manually, if necessary.
	Auxiliary Saltwater System	
ASW-1	Auxiliary saltwater pump 1-1	Auxiliary saltwater pump 1-2 not affected by a fire in these zones.
	Main Steam System	
MS-5	PCV-19, PCV-20; 10% power relief valves	Pneumatic controls for these valves at hot shutdown panel are not affected by a fire in these zones.
	Instrumentation	
I-1	Instrument AC power, channel I (zone 6-A-1 only)	Power failure of instrument AC, channel I, will initiate trip signal to solid state protection system. Redundant channels II, III, and IV unaffected by a fire in this zone.
I-5,6	Steam generator PT's, channel I; PT-514, 524, 534, 544	Channel II, III, and IV steam generator pressure transmitters available (2 PT's for each SG).
I-18,24	Pressurizer LT-459 and PT-455	Two redundant pressurizer level transmitters and three redundant RCS/PZR pressure transmitters not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-2	S-36, control room supply fan (zone 5-A-1 only)	Control room supply fan S-35 not affected by a fire in this zone.
V-5	E-1, auxiliary building exhaust fan	Auxiliary building exhaust fan E-2 not affected by a fire in these zones.

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-7,8	S-43, S-44; 480V switchgear and inverter rooms supply fans	S-43 powered by F bus; S-44 power circuit runs through this zone, it will be rerouted out of this zone. Control circuitry for both fans are located in zone 6-A-1 (as well as 6-A-2 and 6-A-3). Fire in 6-A-1 (high temperature) would cause fans to start or switch to high speed. Fusible link fire dampers would isolate zone 6-A-1 while maintaining ventilation flow to 6-A-2 and 6-A-3. Fan(s) would continue to operate properly as long as control circuitry in zone 6-A-2 or 6-A-3 was functional.
V-11	S-69, 4KV switchgear room supply fan, bus F (zone 5-A-1 only)	Ventilation to G and H bus 4KV switchgear rooms not affected by a fire in this zone.
V-13	E-103, auxiliary saltwater pump room 1-1 exhaust fan (zone 5-A-1 only)	Ventilation to auxiliary saltwater pump room 1-2 not affected by a fire in this zone.
V-16	E-5, fuel handling building exhaust fan	Fuel handling building exhaust fan E-6 not affected by a fire in this zone.
	Fire System	
F-1	Fire pump 0-1 (zone 5-A-1 only)	Fire pump 0-2 not affected by a fire in this zone.

FIRE ZONES 5-A-2 and 6-A-2 (480V SWITCHGEAR ROOM, INVERTER ROOM, BATTERY ROOM, BUS G)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-2	Diesel generator 1-2	Diesel generator 1-1 and 1-3 not affected by a fire in these zones.
EP-5	Fuel transfer pump 0-2 (zone 5-A-2 only)	Fuel transfer pump 0-1 not affected by a fire in zone 5-A-2.
EP7	4KV supply to load center 1G	Power supplies to F and H load centers not affected by a fire in this zone.
EP-10,12	125V DC supply to main control board, G bus and nonvital bus (zone 6-A-2 only)	Nonvital loads powered off of G bus. F and H DC power supplies not affected by a fire in zone 6-A-2.
EP-14	125V DC supply for 4KV switch-gear, G bus	DC power supplies to F and H 4KV switchgear not affected by a fire in this zone.
EP-1	Diesel generator 1-1	Only the backup control circuitry for diesel generator 1-1 affected. Fire in these zones will not prevent diesel generator 1-1 operation using normal (H bus) control circuitry.
	Auxiliary Feedwater System	
AF-1	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine	Auxiliary feedwater pumps 1-2 and 1-3 not affected by a fire in these zones.
AF-2,3	LCV-106, 107, 108, 109; auxiliary feedwater supply from auxiliary feedwater pump 1-1	Auxiliary feedwater pumps 1-2 and 1-3 LCV's not affected by a fire in these zones.
AF-8	FCV-436, raw water supply to auxiliary feedwater pump 1-1	FCV-437, raw water supply to auxiliary feedwater pumps 1-2 and 1-3 not affected by a fire in these zones.
	Residual Heat Removal System	
RHR-1	Residual heat removal pump 1-1	Residual heat removal pump 1-2 not affected by a fire in this zone.
RHR-3	Valve 8701, residual heat removal suction form hot leg	Open valve manually if fire in these zones prevents control room operation of valve.
RHR-6	Valve 8809A, valve in flow path	Parallel valve 8809B (in residual heat removal pump 1-2 flow path) not affected by a fire in this zone.

Ref. No.	System and Components Affected	Comments
	Charging and Boration	
C-2,3	Charging pumps 1-2, 1-3	Charging pump 1-1 not affected by a fire in this zone.
	Boric acid tank flow path:	
C-6	Boric acid transfer pump 1-2	Transfer pump 1-1 not affected by a fire in these zones.
C-8	Valve 8104, transfer pumps to charging pumps	Parallel valve FCV-110A not affected by a fire in these zones.
C-11	Valve 8108, charging flow path	If fire in these zones cuases valve closure due to hot short, valve can be opened manually. Charging flow path via RCP seals not affected by a fire in these zones.
C-15	Boric acid tanks 1-1 and 1-2 heater A (zone 5-A-2 only)	Tank heaters B not affected by a fire in this zone.
C-18	TIC-107, boric acid tank 1-2 temperature controller (zone 6-A-2 only)	TIC-103 not affected by a fire in this zone.
	Boron injection tank flow path:	
C-22	Valve 8805B, refueling water storage tank isolation valve	Parallel valve 8805A not affected by a fire in these zones.
C-24	Valve 8803B, charging pumps to BIT	Parallel valve 8803A not affected by a fire in these zones.
C-26	Valve 8801B, BIT discharge	Parallel valve 8801A not affected by a fire in these zones.
C-30	Heat trace 2A (zone 5-A-2 only)	Redundant heat trace 2B not affected by a fire in this zone.
	Component Cooling Water System	
CCW-2	Component cooling water pump 1-2	Component cooling water 1-1 or 1-3 not affected by a fire in these zones
CCW-5	FCV-431, component cooling water HX 1-2 isolation	Component cooling water heat exchanger 1-1 isolation valve (FCV-430) not affected by a fire in these zones. Open FCV-431 manually, if necessary.
	Auxiliary Saltwater System	
ASW-2	Auxiliary saltwater pump 1-2	Auxiliary saltwater pump 1-1 not affected by a fire in these zones.

Ref. No.	System and Components Affected	Comments
	Main Steam System	
MS-1	FCV-41, FCV-42; main steam isolation valves, leads 1 and 2	If fire in these zones affect circuitry to main steam isolation valves, they can be closed manually if required.
MS-3	FCV-760, FCV-761; SG blowdown isolation valves	Air operated valves, fail closed on loss of air, short or open circuit. If hot short keeps valve(s) open, manual or air operated valves outside of containment can be closed.
MS-6	PCV-21, PCV-22; 10% power relief valves	Pneumatic controls for these valves at hot shutdown panel are not affected by a fire in these zones.
	Instrumentation	
I-2	Instrument AC power, channel II (zone 6-A-2 only)	Power failure of instrument AC, channel II, will initiate trip signal to solid state protection system. Redundant channels I, III, and IV unaffected by a fire in this zone.
I-19	LT-460, pressurizer level	Two redundant pressurizer LT's not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-3	S-31, auxiliary building supply fan	Auxiliary building supply fan S-32 not affected by a fire in this zone.
V-7,8	S-43, S-44; 480V switchgear and inverter rooms supply fans (zone 6-A-2 only)	S-44 power circuit runs through this zone, it will be rerouted out of this zone. Control circuitry for both fans are located in zone 6-A-2 (as well as 6-A-1 and 6-A-3). Fire in 6-A-2 (high temperature) would cause fans to start or switch to high speed. Fusible link fire dampers would isolate zone 6-A-2 while maintaining ventilation flow to 6-A-1 and 6-A-3. Fan(s) would continue to operate properly as long as control circuitry in zone 6-A-1 or 6-A-3 was functional.
V-10	S-68, 4KV switchgear, bus G, supply fan (zone 5-A-2 only)	Ventilation to F and H bus 4KV switchgear rooms not affected by a fire in this zone.
V-12	E-101, auxiliary saltwater pump 1-2 room exhaust fan (zone 5-A-2 only)	Ventilation to auxiliary saltwater pump 1-1 room not affected by a fire in this zone.
V-14	S-1, fuel handling building supply fan	Fuel handling building fan S-2 not affected by a fire in this zone.

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-1	Diesel generator 1-1	Diesel generators 1-2 and 1-3 not affected by a fire in these zones.
EP-4	Fuel transfer pump 0-1 (zone 5-A-3 only)	Fuel transfer pump 0-2 not affected by a fire in these zones.
EP-8	4KV supply to load center 1H	Power supplies to F and G load centers not affected by a fire in these zones.
EP-11	125V DC supply to main control board, H bus (zone 6-A-3 only)	F and G DC power supplies not affected by a fire in this zone.
EP-15	125V DC supply for 4KV switchgear, H bus	Power supplies to F and G 4KV switchgear not affected by a fire in these zones.
EP-3	Diesel generator 1-3	Only the backup control circuitry for diesel generator 1-3 affected. Fire in these zones will not prevent diesel generator 1-3 operation using normal (F bus) control circuitry.
	Auxiliary Feedwater System	
AF-4	Auxiliary feedwater pump 1-2	Auxiliary feedwater pumps 1-1 and 1-3 not affected by a fire in these zones.
AF-5	LCV-110, LCV-111; auxiliary feedwater supply from auxiliary feedwater pump 1-2	Auxiliary feedwater pumps 1-1 and 1-3 LCV's not affected by a fire in these zones.
AF-10	FCV-37, SG 1-2 supply to auxiliary feedwater pump turbine	Normally open, motor operated valve. Alternate steam supply for auxiliary feedwater turbine via FCV-38.
	Residual Heat Removal System	
RHR-2	Residual heat removal pump 1-2	Residual heat removal pump 1-1 not affected by a fire in these zones.
RHR-4	Valve 8702, residual heat removal suction from hot leg	Open valve manually if fire in these zones prevents control room operation of valve.
RHR-7	Valve 8809B, valve in flow path	Parallel valve 8809A (in residual heat removal pump 1-1 flow path) not affected by a fire in this zone.

Ref. No.	System and Components Affected	Comments
	Charging and Boration	
	Boric acid tank flow path:	
C-16	Boric acid tanks 1-1, 1-2 heater B (zone 5-A-3 only)	Tank heaters A not affected by a fire in this zone.
C-17	TIC-103, boric acid tank 1-1 temperature controller (zone 6-A-3 only)	TIC-107 not affected by a fire in this zone.
C-20	Heat trace 1B (zone 5-A-3 only)	Redundant Heat trace 1A not affected by a fire in this zone.
	Boron injection tank flow path:	
C-28	Boron injection tank backup heater (zone 5-A-3 only)	BIT heater not affected by a fire in this zone.
C-29	TIC-945, BIT temperature controller (zone 6-A-3 only)	If fire in this zone damages TIC-945 circuitry, heaters can be controlled manually.
C-33	Heat trace 1B (zone 5-A-3 only)	Redundant heat trace 1A not affected by a fire in this zone.
C-32	Heat trace 2B (zone 5-A-3 only)	Redundant heat trace 2A not affected by a fire in this zone.
	Component Cooling Water System	
CCW-3	Component cooling water pump 1-3	Component cooling water pump 1-1 or 1-2 not affected by a fire in these zones.
CCW-6	FCV-355, component cooling water header C supply	Normally open, motor operated valve. If hot short in control circuitry causes valve closure, open manually (required only for charging pump 1-3 cooling).
	Main Steam System	
MS-4	FCV-762, FCV-763; SG blowdown isolation valves	Air operated valves, fail closed on loss of air, short or open circuit. If hot short keeps valve(s) open, manual or air operated valves outside of containment can be closed.
	Instrumentation	
I-3,4	Instrument AC power, channels III and IV (zone 6-A-3 only)	Power failure of instrument AC, channels III or IV, will initiate trip signal to solid state protection system. Redundant channels I and II unaffected by a fire in this zone.

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-1	S-35, control room supply fan (zone 5-A-3 only)	Control room supply fan S-36 not affected by a fire in this zone.
V-4	S-32, auxiliary building supply fan	Auxiliary building supply fan S-31 not affected by a fire in these zones.
V-6	E-2, auxiliary building exhaust fan	Auxiliary building exhaust fan E-1 not affected by a fire in these zones
V-7,8	S-43, S-44, 480V switchgear and inverter rooms supply fans	S-44 powered by H bus. Control circuitry for both fans in 6-A-3 (high temperature) would cause fans to start or switch to high speed. Fusible link fire dampers would isolate zone 6-A-3 while maintaining ventilation flow to 6-A-1 and 6-A-2. Fan(s) would continue to operate properly as long as control circuitry in zone 6-A-1 or 6-A-2 was functional.
V-9	S-67, 4KV switchgear, bus H, supply fan (zone 5-A-3 only)	Ventilation to F and G bus 4KV switchgear rooms not affected by a fire in this zone.
V-15	S-2, fuel handling building supply fan	Fuel handling building supply fan S-1 not affected by a fire in these zones.
V-17	E-6, fuel handling building exhaust fan	Fuel handling building exhaust fan E-5 not affected by a fire in these zones.
	Fire System	
F-2	Fire pump 0-2 (zone 5-A-3 only)	Fire pump 0-1 not affected by a fire in this zone.

FIRE ZONES 5-B-2, 5-B-3, 5-B-4 (UNIT 2 480V SWITCHGEAR ROOMS)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-4,5	Fuel transfer pumps 0-1, 0-2	Unit 2 backup power circuit to pumps 0-1 and 0-2 could be affected by a Unit 2 fire in these zones. Pumps would still be operable using normal (Unit 1) power supply

FIRE ZONE 5-A-4 (AREA OUTSIDE 480V SWITCHGEAR ROOMS)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-4,5	Fuel transfer pumps 0-1, 0-2	Back-up power circuits for fuel transfer pumps pass through this zone from Unit 2 to Unit 1 480 volt switchgear rooms. Normal (Unit 1) power supply for the transfer pumps is not affected by a fire in this zone.
	Auxiliary Feedwater System	
AF-1,2,3	FCV-95, steam supply to auxiliary feedwater pump 1-1 turbine and associated level control valves LCV-106, 107 108, 109	Control circuits to hot shutdown panel are embedded from the switchgear to the immediate proximity of the hot shutdown panel. The only location where a fire could affect these circuits would be right at the hot shutdown panel. Damage to these circuits would not affect control of this equipment from control room.
AF-4,6	Auxiliary feedwater pump 1-2, 1-3	However, fire affecting transfer switches in the hot shutdown panel could transfer control away from control room to hot shutdown panel. Procedure to be established to jumper out hot shutdown panel control circuitry in the event of such a fire. Instructions to be posted in the switchgear or motor control centers. This will allow operators to transfer control of equipment back to control room if fire at hot shutdown panel transfers control. Smoke detector located in vicinity of hot shutdown panel and west end of zone 5-A-4 (hot shutdown panel area) to be designated as a "No Storage" area.
AF-5,7	LCV-110, 111, 113, 115, auxiliary feedwater supply from pumps 1-2, 1-3	Electro-hydraulic LCV's would fail as is (open) if fire in hot shutdown panel affects circuitry or controller in hot shutdown panel. Valves can be operated manually if required and pump 1-1 LCV's would be operable from control room (as described above).
	Charging and Boration	Comments made for auxiliary feedwater pumps also apply to these components.
C-1,2	Charging pumps 1-1, 1-2	
	Boric acid tank flow path:	
C-5,6	Boric acid transfer pumps 1-1, 1-2	
C-8	Valve 8104	

Ref. No.	System and Components Affected	Comments
	Component Cooling Water System	
CCW-1,2,3	Component cooling water pumps 1-1, 1-2, 1-3	Comments made for auxiliary feedwater pumps also apply to the component cooling water pumps.
	Auxiliary Saltwater System	
ASW-1,2	Auxiliary saltwater pumps 1-1, 1-2	Comments made for auxiliary feedwater pumps also apply to the auxiliary saltwater pumps.
ASW-3,4	FCV-602, FCV-603; auxiliary saltwater to component cooling water HX	Circuits for these valves run vertically along west wall through zone 5-A-4 (near hot shutdown panel). Valves fail open on loss of air, short or open circuit. If hot short causes valve closure, valves can be opened manually by removing air supply.
	Instrumentation	Circuitry for these instruments is embedded from the 480 volt switchgear to the immediate proximity of the hot shutdown panel. A fire at the hot shutdown panel could affect control room readout of these instruments. However, redundant instrumentation in control room not affected by a fire in this zone (LT-461, LT-462 for pressurizer level, channels II, III, and IV SG pressure (two additional PT's per SG), and PT-403, PT-405, PT-456 for RCS/PZR pressure).
I-18,19	LT-459, LT-460, pressurizer level	
I-5,6	PT-514, 524, 534, 544; SG pressure, channel I	
I-24	PT-455, pressurizer pressure	
	Ventilation for Safe Shutdown Equipment	
V-12	E-101, auxiliary saltwater pump room 1-2 exhaust fan	Circuit passes in vicinity of hot shutdown panel. Auxiliary saltwater pump room 1-1 exhaust fan E-103 not affected by a fire in this zone.
V-8	S-44, 480V switchgear and inverter rooms supply fan	Power circuit for S-44 to be rerouted through zone 5-A-4 to eliminate it from running in same area as fan S-43. Redundant fan, S-43, not affected by a fire in this zone.

FIRE ZONE 6-A-5 (SPACE WEST OF BATTERY ROOMS, EL. 115')

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-12	125V DC supply to main control board, non-vital bus	All components powered by non-vital 125V DC power fail to safe position upon loss of power.
	Auxiliary Feedwater System	
AF-5,7	LCV-110, 111, 113, 115; AFW supply from pumps 1-2, 1-3	Auxiliary feedwater pump 1-1 and its associated LCV's not affected by a fire in this zone. If fire damages circuitry for these LCV's, valves can be operated manually.
	Auxiliary Saltwater System	
ASW-3,4	FCV-602, FCV-603; auxiliary saltwater to component cooling water HX	Short or open circuit causes valves to fail open. If hot short causes valve closure, valve could be opened manually at component cooling water HX by removing air supply to solenoid valve.
	Ventilation for Safe Shutdown Equipment	
V-7,8	S-43, S-44; 480V switchgear and inverter rooms supply fans	Fans and duct work in this zone to be fireproofed with one hour rated protection. Power circuit for S-44 to be relocated so that fan motor starters are separated by minimum of 15 feet. Smoke detector to be provided in this zone.

Ref. No.	System and Components Affected	COMMENTS
	Emergency Power Supply	
EP-1,2,3	Diesel generator 1-1, 1-2, 1-3	Fire could affect automatic start or control room manual start capability. In the event of a cable spreading room or control room fire, throwing transfer switch in each diesel generator room restores automatic start capability as well as manual start capability at the diesel generator.
EP-6,7,8	4KV supplies to 480V load centers	Automatic power transfer scheme could be affected. However, diesel generators can be manually loaded to 4KV supplies at the 4KV switchgear, if necessary.
EP-9,10,11,12	125V DC supplies to main control board	All components requiring 125V DC power fail to safe position loss of power (except for main steam isolation valves - see discussion below).
	Auxiliary Feedwater System	
AF-1	FCV-95 steam supply to auxiliary feedwater pump 1-1 turbine	Control of FCV-95 at hot shutdown panel not affected by cable spreading room fire
AF-2,3	LCV-106, 107, 108, 109; AFW supply from AFW pump 1-1	Control of pump 1-1 LCV's at hot shutdown panel not affected by cable spreading room or control room fire.
AF-4,6	Auxiliary feedwater pump 1-2, 1-3	Control of pumps at hot shutdown panel not affected by cable spreading room or control room fire.
AF-5,7	LCV-110, 111, 113, 115; AFW supply from AFW pumps 1-2, 1-3	If cable spreading room or control room fire affects circuitry for these LCV's, valves can be operated manually.
AF-8,9	FCV-436 and FCV-437, raw water reservoir supply to auxiliary feedwater pumps	If cable spreading room or control room fire affects operability of valves, they can be opened manually if and when raw water reservoir supply required.
AF-10,11	FCV-37, FCV-38, SG 1-2 and SG 1-3 supply to auxiliary feedwater pump 1-1 turbine	Normally open, motor operated valves, fail as is. If hot short causes valve closure, it can be opened manually.
	Residual Heat Removal System	
RHR-1,2	RHR pumps 1-1, 1-2	Pumps can be started at 4KV switchgear when required.
RHR-3,4	8701, 8702; RHR suction hot leg	If inoperable from control room, open valves manually when required.

Ref. No.	System and Components Affected	COMMENTS
	Residual Heat Removal System	
RHR-5	HCV-637, HCV-638, valves in RHR flow path	Valves fail open upon loss of air, short or open circuit. If hot short causes valve closure, open manually when required.
RHR-6,7	Valves 8809A and B, valves in RHR flow path	Normally open, motor operated valves, fail as is. If hot short causes valve closure, open manually when required.
	Charging and Boration	
CC-1,2	Centrifugal charging pumps 1-1, 1-2	Control of pumps at hot shutdown panel not affected by cable spreading room or control room fire.
	Reciprocating charging pump 1-3	Pump can be started at 4KV switchgear if required.
	Boric acid tank flow path:	
C-5,6	Boric acid transfer pumps 1-1, 1-2	Control of pumps at hot shutdown panel not affected by cable spreading room fire.
C-7,8	Valves 8104 and FCV-110A; charging flowpath	FCV-110A fails open upon loss of air, open or short circuit. If hot short causes valve closure, open either valve manually.
C-10,11	Valves 8107, 8108; charging flow	Normally open, motor operated valves, fail as is. If hot short causes valve closure, open manually. Alternate charging via RCP seal flow path (independent of these valves).
C-12,13,14	Valves 8145, 8146, 8147; charging flow path	Valves 8146 and 8147 fail open upon loss of air, open or short circuit. Alternate charging via RCP seal flowpath (independent of these valves).
C-17,18	TIC-103, TIC-107; Boric acid tank temperature controller	Boric acid tank heaters can be turned on manually at the tanks.
	Boron injection tank flow path:	
C-21,22	Valves 8805A, B; refueling water supply valves	All valves are normally closed motor operated valves. Valves could be opened manually, if required. However, charging via boric acid tank flow path and reactor coolant pump seals is a more viable flowpath and is controllable from the hot shutdown panel irrespective of a fire in the cable spreading room or control room.
C-23,24	Valves 8803A, B; charging pumps to BIT	
C-25,26	Valves 8801A, B; BIT outlet	

Ref. No.	System and Components Affected	COMMENTS
	Component Cooling Water System	
CCW-1,2,3	Component cooling water pumps 1-1, 1-2, 1-3	Control of component cooling water pumps at hot shutdown panel not affected by cable spreading room fire.
CCW-4,5	FCV-430, 431; component cooling water HX isolation valves	Motor operated valves, fail as is. One valve normally open. If hot short causes valve closure, open manually.
CCW-6	FCV-355; component cooling water supply header "C"	Normally open, motor operated valve, fails as is. Required to be open only for charging pump 1-3 cooling.
CCW-7	FCV-364, 365; component cooling water supply to RHR HX	Valves fail open upon loss of air, short to ground, or open circuit. If hot short causes valve closure, open manually.
	Auxiliary Saltwater System	
ASW-1,2	Auxiliary saltwater pumps 1-1, 1-2	Control of pumps from hot shutdown panel not affected by cable spreading room fire.
ASW-3,4	FCV-602, 603; auxiliary salt-water to component cooling water HX	Valves fail open upon loss of air, short or open circuit. If hot short causes valve closure, open manually.
	Main Steam System	
MS-1,2	FCV-41, 42, 43, 44; main steam isolation valves	Fire in cable spreading room could prevent valve closure. Main steam isolation valves required to close only for a steam line break. If seismic event causes main steam line break and subsequent cable spreading room fire, main steam isolation valve would close prior to fire damaging main steam isolation valve circuitry in cable spreading room. Valves can be closed manually if required.
MS-3,4	FCV-760, 761, 762, 763; SG blowdown isolation valves	Valves fail closed upon loss of air, open or short circuit. If hot short keeps a valve open, manual or air operated valves outside of containment can be closed.
MS-5,6	PCV-19, 20, 21, 22; 10% power relief valve	Pneumatic controls at hot shutdown panel for these valves.

Ref. No.	System and Components Affected	Comments
	Instrumentation	
I-1,2,3,4	Instrument AC Power (cable spreading room only)	Instrument panel to be provided in penetration area (zone 3-BB) with necessary safe shutdown instrument readouts. Instrumentation signals to this panel and instrument power supply will not be vulnerable to a cable spreading room or control room fire.
I,6,7,8,9,10	All SG PT's	
I-11,12,13,14	All SG LT's	
I-15	All RCS TE's	
I-16,17,24,25	All RCS PT's and PZR PT's	
I-18,19,20	All PZR LT's	
I-21,22	All BA LT's	
	Ventilation for Safe Shutdown Equipment	
V-1,2	S-35, S-36; control room supply fans	Fan can be started by adding jumper in local starter (located in ventilation room elevation 156'-4"). Procedure for starting fan at local starter will be posted at starter.
V-3,4	S-31, S-32; auxiliary building supply fans	Fan can be started by adding jumper in 480V motor control center. Once starter at motor control center, the fan would not be vulnerable to cable spreading room fire. Procedure for starting fans at motor control center will be posted in MCC cabinets.
V-5,6	E-1, E-2; auxiliary building exhaust fans	Same as above
V-14,15	S-1, S-2; fuel handling building supply fans	Same as above
V-16,17	E-5, E-6; fuel handling building exhaust fans	Same as above
	Fire System	
0-1,2	Fire pump 0-1, 0-2	If required, pumps can be started locally.

FIRE ZONE 8-B-1 (AUXILIARY BUILDING SUPPLY FAN ROOM)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-1,2	S-35, S-36; control room supply fans (and air conditioning)	Power supplies to control room ventilation equipment run in conduits in the supply air plenum room of this fire zone. There is no combustible fuel load in this plenum.
V-3,4	S-31, S-32; auxiliary building supply fans	Automatic sprinkler protection and smoke detectors to be provided for supply fans S-31 and S-32.

FIRE ZONE 8-B-3 (CONTROL ROOM VENTILATION EQUIPMENT)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-1,2	S-35, S-36; control room supply fans and other control room ventilation equipment	Automatic sprinkler protection and smoke detectors to be provided for this zone. If a fire were to damage S-35 and S-36, adequate ventilation for the shared control room could be maintained by Unit 2 control room ventilation equipment (S-37 and S-38 and associated equipment). A fire affecting Unit 1 control room ventilation equipment could not affect Unit 2 control room ventilation equipment.

FIRE ZONE 10 (12KV SWITCHGEAR ROOM)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-1,2,3	Diesel generator 1-1, 1-2, 1-3	Conduits run in banks vertically along east and west walls of 12KV switchgear room and down to cable spreading room at elevation 76 feet. Redundant divisions are separated by minimum of 10 feet. Banks of safe shutdown conduits will be boxed in to give two hour rated protection for conduits. East wall to be upgraded to minimum two hour barrier, west wall is existing three hour barrier. In cable spreading room below, all conduits (except a portion of H bus components) are enclosed within five concrete compartments separated from the cable spreading room by two-inch thick non-combustible transite barriers.
EP-4,5	Fuel transfer pumpl 0-1, 0-2	
EP-6,7,8	4KV supplies to 480 load centers	
EP-13,14.15	125V DC supply for 4KV switchgear	
	Auxiliary Feedwater System	
AF-4,6	Auxiliary feedwater pumps 1-2, 1-3	
	Residual Heat Removal System	
RHR-1,2	Residual heat removal pumps 1-1, 1-2	
	Charging and Boration	
C-1,2,3	Charging pumps 1-1, 1-2, 1-3	
	Component Cooling Water System	
CCW-1,2,3	Component cooling water pumps 1-1, 1-2, 1-3	
	Auxiliary Saltwater System	
ASW-1,2	Auxiliary saltwater pumps 1-1, 1-2	
	Ventilation for Safe Shutdown Equipment	
V-9,10,11	S-67, S-68, S-69; 4KV switchgear room fans	
V-12,13	E-101, E-103; auxiliary saltwater pump room exhaust fans	

FIRE ZONE 11-A-1 (DIESEL GENERATOR 1-1 ROOM)

Ref. No.	System and Component Affected	Comments
	Emergency Power Supply	Similar comments apply to fire zones 11-B-1 and 11-C-1 (diesel generators 1-2 and 1-3 rooms).
EP-1	Diesel generator 1-1	Diesel generators 1-2 and 1-3 unaffected by a fire in this zone.
EP-4,5	Fuel transfer pumps 0-1, 0-2	Fire in diesel generator 1-1 compartment could conceivably (1) start fuel transfer pump(s) and supply diesel fuel to diesel generator 1-1 day tank, or (2) prevent fuel transfer pumps from starting when required to replenish other diesel generator day tanks. Fuel transfer pump circuit modification and protection of conduits within the diesel generator compartments will prevent this from occurring. Total flooding CO2 protection provided for each diesel generator room.

FIRE ZONE 11-D (CORRIDOR OUTSIDE DIESEL GENERATOR ROOMS)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	Comment applies to all components: Control circuitry runs along the west wall of this corridor above the normally closed rolling fire doors. These circuits are separated from the diesel generator rooms, the turbine building, and the 12KV switchgear room by three hour fire barriers. To protect against an exposure fire within zone 11-D, a one hour rated ceiling will be constructed approximately seven feet below the existing concrete ceiling to separate the conduits from the area below. Automatic sprinkler protection to be provided in the suspended ceiling.
EP-1,2,3	Diesel generators 1-1, 1-2, 1-3	
EP-4,5	Fuel transfer pumps 0-1, 0-2	

FIRE ZONE 12-A and 13-A (4KV CABLE SPREADING ROOM AND SWITCHGEAR ROOM, BUS F)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-3	Diesel generator 1-3	Diesel generators 1-1 and 1-2 and G and H buses not affected by a fire in this zone.
EP-6	4KV supply to load center 1F	See description of emergency power supply for a compilation of safe shutdown components lost due to loss of a 4KV power supply to a 480V load center.
EP-13	125V DC supply to 4KV switchgear, F bus	
EP-2	Diesel generator 1-2 (12-A only)	Only the backup control circuitry for diesel generator 1-2 affected. Fire in this zone will not prevent diesel generator 1-2 operation using normal (G bus) control circuitry.
	Auxiliary Feedwater System	
AF-6	Auxiliary feedwater pump 1-3	Auxiliary feedwater pumps 1-1 and 1-2 not affected by a fire in this zone.
	Charging and Boration	
C-1	Charging pump 1-1	Charging pumps 1-2 and 1-3 not affected by a fire in this zone.
	Component Cooling Water System	
CCW-1	Component cooling water pump 1-1	Component cooling water pumps 1-2 and 1-3 not affected by a fire in this zone.
	Auxiliary Saltwater System	
ASW-1	Auxiliary saltwater pump 1-1	Auxiliary saltwater pump 1-2 not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-11	S-69, 4KV switchgear bus F supply fan	Supply fans to the other switchgear and cable spreading rooms not affected by a fire in this zone.
V-13	E-103, ASW pump 1-1 room exh. fan	Ventilation to ASW pump 1-2 (E-101) not affected by a fire in this zone.

FIRE ZONE 12-B and 13-B (4KV CABLE SPREADING ROOM AND SWITCHGEAR ROOM, BUS G)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-2	Diesel generator 1-2	Diesel generator 1-1 and 1-3 and F and H buses not affected by a fire in this zone.
EP-7 EP-14	4KV supply to load center 1G 125V DC supply to 4KV switchgear, G bus	See description of emergency power supply for a compilation of safe shutdown components lost due to loss of a 4KV power supply to a 480V load center.
EP-1	Diesel generator 1-1 (12-B only)	Only the backup control circuitry for diesel generator 1-1 affected. Fire in this zone will not prevent diesel generator 1-1 operation using normal (H bus) control circuitry.
EP-5	Fuel transfer pump 0-2 (12-B only)	Fuel transfer pump 0-1 not affected by a fire in this zone.
	Residual Heat Removal System	
RHR-1	Residual heat removal pump 1-1	Residual heat removal pump 1-2 not affected by a fire in this zone.
	Charging and Boration	
C-2,3	Charging pumps 1-2, 1-3	Charging pump 1-1 not affected by a fire in this zone.
	Component Cooling Water System	
CCW-2	Component cooling water pump 1-2	Component cooling water pumps 1-1 and 1-3 not affected by a fire in this zone.
	Auxiliary Saltwater System	
ASW-2	Auxiliary saltwater pump 1-2	Auxiliary saltwater pump 1-1 not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-10	S-68, 4KV switchgear bus G supply fan	Supply fans to the other switchgear and cable spreading rooms not affected by a fire in this zone.
V-12	E-101, ASW pump 1-2 room exh. fan	Ventilation to ASW pump 1-1 (fan E-103) not affected by a fire in this zone.

FIRE ZONE 12-C and 13-C (4KV CABLE SPREADING ROOM AND SWITCHGEAR ROOM, BUS H)

Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-1	Diesel generator 1-1	Diesel generators 1-2 and 1-3 and F and G buses not affected by a fire in this zone.
EP-8	4KV supply to load center 1H	See description of emergency power supply for a compilation of safe shutdown components lost due to loss of a 4KV power supply to a 480V load center.
EP-15	125V DC supply to 4KV switch-gear, H bus	
EP-3	Diesel generator 1-3 (12-C only)	Fire in this zone will not prevent diesel generator 1-3 operation using normal (F bus) control circuitry.
EP-4	Fuel transfer pump 0-1 (12-C only)	Fuel transfer pump 0-2 not affected by a fire in this zone.
	Auxiliary Feedwater System	
AF-4	Auxiliary feedwater pump 1-2	Auxiliary feedwater pumps 1-1 and 1-3 not affected by a fire in this zone.
	Residual Heat Removal System	
RHR-2	Residual heat removal pump 1-2	Residual heat removal pump 1-1 not affected by a fire in this zone.
	Component Cooling Water System	
CCW-3	Component cooling water pump 1-3	Component cooling water pumps 1-1 and 1-2 not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-9	S-67, 4KV switchgear bus H supply fan	Supply fans to the other switchgear and cable spreading rooms not affected by a fire in this zone.

FIRE ZONES 12-D AND 12-F (CORRIDORS OUTSIDE 4KV CABLE SPREADING ROOM)

THESE FIRE ZONES HAVE BEEN INCORPORATED AS PART OF FIRE ZONES 12-A, 12-B, 12-C. SEE FIGURE 3-2

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Ref. No.	System and Components Affected	Comments
	Emergency Power Supply	
EP-1,2,3	Diesel generators 1-1, 1-2, 1-3	Power circuits from diesel generators could be affected by a fire in zone 12-D or 12-F. Redundant conduits to be separated from each other by two hour rated fire barriers. Conduits have been identified on Drawing 57563.
EP-4,5	Fuel transfer pumps 0-1, 0-2	Control circuits for fuel transfer pumps could be affected by a fire in zone 12-D or 12-F. These conduits will be protected in the same manner as the diesel generator circuits. Circuits have been identified on Drawing 57563.
	Auxiliary Saltwater System	
ASW-1,2	Auxiliary saltwater pumps 1-1, 1-2 (fire zone 12-D only)	Power circuits for auxiliary saltwater pumps could be affected by a fire in zone 12-D. These conduits will be protected in the same manner as the diesel generator circuits. Circuits have been identified on Drawing 57563.
	Ventilation for Safe Shutdown Equipment	
V-13	E-103, auxiliary saltwater pump room 1-1 exhaust fan (fire zone 12-D only)	Auxiliary saltwater pump room 1-2 exhaust fan unaffected by a fire in this zone (fire in zone 12-D that affects auxiliary saltwater pump room 1-1 fan could affect auxiliary saltwater pump 1-1, but would not affect auxiliary saltwater pump 1-2).
V-9,10,11	S-67, S-68, S-69; 4KV switchgear supply fans	Conduits for each fan to be separated from each other by two hour rated fire barriers. Conduits have been identified on Drawing 57563.

FIRE ZONE 13-E (4KV SWITCHGEAR VENTILATION FANS)

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-9,10,11	S-67, S-68, S-69; 4KV switchgear supply fans	Smoke detectors and automatic sprinkler protection to be provided in this zone.

FIRE ZONE 14-A (TURBINE BUILDING)

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-5,7	LCV-110, 111, 113, 115; auxiliary feedwater supply from motor driven auxiliary feedwater pumps 1-2, 1-3	Automatic sprinkler protection provided throughout zone 14-A. Conduits are located on the southeast wall of the turbine building between elevation 104 ft. and 119 ft. Turbine driven auxiliary feedwater pump and its level control valves are unaffected by a fire in this zone. To reduce dependence upon turbine driven auxiliary feedwater pump, conduits for these LCV's will be encased within a two hour rated fire barrier. Conduits have been identified on Drawing 57566.

FIRE ZONE 14-E (COMPONENT COOLING WATER HEAT EXCHANGER AREA)

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-5	LCV-110, LCV-111; auxiliary feedwater supply from auxiliary feedwater pump 1-2	Auxiliary feedwater pumps 1-1 and 1-3 and their associated LCV's are unaffected by a fire in this zone. Conduits have been identified on Drawing 57566.
	Component Cooling Water System	
CCW-4,5	FCV-430, FCV-431, CCW HX isolated valves	Motor operated valves, one normally open. If fire damages circuitry of closed valve and hot short in control circuitry of open valve causes valve closure, the valve(s) can be opened manually. Component cooling water heat exchanger area to be separated from rest of turbine building by a three hour barrier.
CCW-6	FCV-355, CCW supply header "C" isolation valve	Normally open, motor operated valve. If hot short in control circuitry causes valve closure, valve can be opened manually. The reciprocating charging pump 1-3 is the only component that requires cooling from header "C".
	Auxiliary Saltwater System	
ASW-3,4	FCV-602, FCV-603; ASW to CCW HX	Air operated valves, fail open upon loss of air, short or open circuit. If hot short causes valve closure, valve can be opened manually by removing air supply.

FIRE ZONES 20, 23-D, 23-A, 24-A (UNIT 2 4KV SWITCHGEAR AND ADJOINING AREAS)

Ref. No.	System and Component Affected	Comments
	Emergency Power Supply	
EP-3	Diesel generator 1-3	Diesel generator 1-3 is shared by Units 1 and 2. Unit 2 fire in these zones could affect diesel generator 1-3, but would not affect the use of diesel generator 1-3 for Unit 1.

FIRE ZONE 28 (MAIN TRANSFORMER AREA)

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-2	LCV-106, LCV-107; auxiliary feedwater supply to SG 1-1, 1-2 from pump 1-1	Auxiliary feedwater to SG 1-3, 1-4 from pump 1-1 not affected by a fire in this zone (1 of 4 SG's required for cooldown).
AF-5	LCV-110, LCV-111; auxiliary feedwater supply to SG 1-1, 1-2 from pump 1-2	Auxiliary feedwater to SG 1-3, 1-4 from pump 1-3 not affected by a fire in this zone (1 of 4 SG's required for cooldown).
AF-10	FCV-37; SG 1-2 supply to pump 1-1 turbine	Steam supply to turbine driven auxiliary feedwater pump still available from SG 1-3 via FCV-38.
	Main Steam System	
MS-1	FCV-41, FCV-42; main steam isolation valves, loops 1 and 2	Fire at main steam isolation valves could prevent valve closure. Main steam isolation valves required to close only for a steam line break. Fusible link in air lines to main steam isolation valves will be provided to allow valve closure if main transformer fire encroaches upon main steam lines. Valves can be closed manually in the event of a small fire.
MS-5	PCV-19, PCV-20; 10% power relief valves, loops 1 and 2	PCV-21 and PCV-22 not affected by a fire in this area. PCV-19 and PCV-20 may be operable with pneumatic controls at hot shutdown panel.
	Instrumentation	
I-5,7	SG pressure transmitters for loops 1 and 2	SG pressure transmitters for loops 3 and 4 not affected by a fire in this zone.

FIRE ZONE 30-A-1 (AUXILIARY SALTWATER PUMP 1-1 ROOM)

Ref. No.	System and Components Affected	Comments
	Auxiliary Saltwater System	
ASW-1	Auxiliary Saltwater pump 1-1	Auxiliary saltwater pump 1-2 not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-13	E-103, auxiliary saltwater pump room 1-1 exhaust fan	Ventilation for auxiliary saltwater 1-2 (E-101) not affected by a fire in this zone.

FIRE ZONE 30-A-2 (AUXILIARY SALTWATER PUMP 1-2 ROOM)

Ref. No.	System and Components Affected	Comments
	Auxiliary Saltwater System	
ASW-2	Auxiliary saltwater pump 1-2	Auxiliary saltwater pump 1-1 not affected by a fire in this zone.
	Ventilation for Safe Shutdown Equipment	
V-12	E-101, auxiliary saltwater pump room 1-2 exhaust fan	Ventilation for auxiliary saltwater pump room 1-1 (E-103) not affected by a fire in this zone.

FIRE ZONE 31 (FUEL HANDLING BUILDING CORRIDOR, EL. 100')

Ref. No.	System and Components Affected	Comments
	Ventilation for Safe Shutdown Equipment	
V-5,6	E-1, E-2; auxiliary building exhaust fans	Conduits fun the length of this corridor. Fuel loading in corridor is extremely low. Automatic sprinkler protection to be provided for the corridor. These conduits have been identified on Drawing 57611.
V-14,15	S-1, S-2; fuel handling building supply fans	Same as above.

FIRE ZONE S-3 (AUXILIARY BUILDING STAIRWELL, NORTHEAST CORNER)

Ref. No.	System and Components Affected	Comments
	Auxiliary Feedwater System	
AF-4,6	Auxiliary feedwater pumps 1-2, 1-3	Turbine driven auxiliary feedwater pump 1-1 not affected by a fire in this zone. This hallway presently contains no combustible materials and will be designated as a "No Storage" area.

DIABLO CANYON UNITS 1 AND 2
SUMMARY OF MODIFICATIONS WITHIN FIRE ZONES TO PROTECT
SAFE SHUTDOWN EQUIPMENT AND ELECTRICAL CABLING

This summary of modifications tabulates, by fire zone, modifications required to protect safe shutdown components or electrical cabling in those fire zones. With these modifications and administrative controls as proposed, a credible fire in any zone containing safe shutdown equipment or electrical cabling will not adversely affect safe shutdown capability.

Locations and boundaries of areas designated as "No Storage" will be clearly defined with signs and administratively controlled. In some areas, limited storage of certain specific non-combustible items will be authorized. For example, metal ladders and metal scaffolding will be authorized within containment in the area that is designated as "No Storage". Storage of non-combustibles in other "No Storage" areas will be reviewed and, when allowable, authorized on a case-by-case basis.

This summary does not include all the modifications to upgrade barriers that define fire zones, nor does it include any fire protection modifications in fire zones that do not contain safe shutdown equipment or electrical cabling. These modifications have been described in the Fire Protection Review (Amendment 51) and PGandE's February 6, 1978, response to 58 NRC questions concerning fire protection.

Modifications have been specified only for Unit 1. The Unit 2 electrical design and layout is essentially identical, thus, these modifications will also be undertaken for Unit 2.

DIABLO CANYON POWER PLANT
SUMMARY OF MODIFICATIONS TO PROTECT SAFE SHUTDOWN EQUIPMENT AND ELECTRICAL CABLING

Fire Zone	Modifications
1-A (Containment penetration area)	The area below redundant safe shutdown cabling in the containment penetration area will be designated as a "No Storage" area. This area consists of approximately 300° of the annular zone 1-A at elevation 91 ft. (excluded from being a "No Storage" area is the 60° sector in the vicinity of the fuel transfer tube assembly). Smoke detectors for containment penetration area.
3-B-1 (RHR HX and pump 1-1 room)	Smoke detector for RHR pump room.
3-B-2 (RHR HX and pump 1-2 room)	Smoke detector for RHR pump room.
3-H-1 (Centrifugal charging pump room)	Smoke detectors, automatic sprinkler protection for this zone. Procedure to be established to jumper out control circuit for charging pump 1-3 in the event of fire in zone 3-H-1.
3-H-2 (Reciprocating charging pump room)	Smoke detector.
3-J-1 (CCW pump 1-1 room)	Smoke detector, automatic sprinkler protection, curb to contain oil spillage. Barrier to separate CCW pump rooms.
3-J-2 (CCW pump 1-2 room)	Same as 3-J-1 plus procedure to jumper out control circuit for CCW pump 1-1, charging pumps 1-1, 1-2, 1-3 in event of fire in zone 3-J-2.
3-J-3 (CCW pump 1-3 room)	Same as 3-J-1 plus procedure to jumper out control circuit for charging pumps 1-1, 1-2, 1-3 in event of fire in zone 3-J-3.
3-L (Boric acid evaporator area)	Motor driven auxiliary feedwater pump power circuits to be encased in a two-hour rated fire barrier in zone 3-L. West end of zone 3-L behind sample panel to be designated as a "No Storage" area.
3-P-1 (Fuel handling building supply fan room)	Smoke detector; fan room to be designated as a "No Storage" area.
3-P-4 (Auxiliary building exhaust fan E-1 room)	Smoke detector; fan room to be designated as a "No Storage" area.
3-Q-1, 3-Q-2 (Auxiliary feedwater pump room)	Smoke detectors, automatic sprinkler protection, curbs to contain oil spillage. Barrier to be constructed to separate turbine driven auxiliary feedwater pump from motor driven auxiliary feedwater pumps. Circuit for FCV-95 to be relocated out of these zones.

Fire Zone	Modifications
3-R (Fuel handling building)	Smoke detector to be provided in vicinity of fire pumps.
3-X (Boric acid transfer pumps, CVCS demineralizers)	Smoke detectors to be provided in vicinity of boric acid transfer pumps. Automatic sprinkler protection to be provided for east end of zone 3-X. Compartments in west end of zone 3-X to be designated as "No Storage" areas.
3-AA (Boric acid tank area)	Smoke detectors to be provided in vicinity of boric acid tanks. Compartments in west end of zone 3-AA to be designated as "No Storage" areas.
3-BB el. 100' (Penetration area)	Automatic sprinkler protection for this zone at el. 100'. Conduits for LCV-110, 111, 113, 115 (auxiliary feedwater system) to be encased in two-hour fire barriers in areas where these redundant conduits pass within 15 ft. of each other.
3-BB el. 115' (Penetration area)	Automatic sprinkler protection for this zone at el. 115'.
4-A (Laboratory area)	Suspended ceiling to be replaced with a one-hour rated ceiling. Automatic sprinklers in ceiling to be retained. Smoke detectors to be provided. Electrical raceway at north end of lab area to be subdivided with two-hour fire barrier to separate F and G bus conduits.
5-A-4 (Area outside 480V switchgear rooms)	Procedure to be established to jumper out hot shutdown panel control circuitry in the event fire at HSD panel transfers control to HSD panel.
6-A-1 (Inverter room, bus F)	Ventilation fan S-44 power circuit to be rerouted out of this zone.
6-A-2 (Inverter room, bus G)	Same as 6-A-1.
6-A-5 (Space west of battery rooms)	Ventilation fans S-43 and S-44 and associated duct work to be protected with a one-hour rated fire barrier. Power circuit for S-44 to be relocated so that fan motor starters are separated by 15 ft.
7-A (Cable spreading room)	Instrument panel to be provided in zone 3-BB el. 100' with necessary safe shutdown instrument readouts. Instrumentation signals to panel will not be vulnerable to cable spreading room or control room fire.
8-C (Control room)	Smoke detectors to be provided in safety related control cabinets.
8-B-1 (Auxiliary building supply fan room)	Automatic sprinkler protection to be provided in supply fan room.
8-B-3 (Control room ventilation equipment)	Automatic sprinkler protection to be provided in this zone.

Fire Zone	Modifications
10 (12KV switchgear room)	Banks of safe shutdown conduits to be boxed in with two-hour rated fire barriers.
11-A-1 (Diesel generator 1-1)	Circuit modification to fuel transfer pump control circuit.
11-B-1 (Diesel generator 1-2)	Same as 11-A-1.
11-C-1 (Diesel generator 1-3)	Same as 11-B-1
11-D (Corridor outside diesel generator rooms)	One-hour rated suspended ceiling to be constructed in this corridor. Automatic sprinkler protection to be provided in ceiling.
12-D, 12-F (Corridors outside 4KV CSR)	Two-hour rated fire barriers to be constructed to separate redundant safe shutdown circuits in corridors outside 4KV cable spreading rooms. Fire zones 12-D, 12-F deleted and fire zones 12-A, 12-B, 12-C expanded to include the compartmentalized corridors
13-E (4KV switchgear ventilation fans)	Smoke detectors and automatic sprinkler protection for this zone.
14-A (Turbine building)	Conduits for auxiliary feedwater system LCV's (LCV-110, 111, 113, 115) to be encased in two-hour rated fire barrier in southeast corner of turbine building between el. 104' and 119'.
14-E (CCW heat exchanger)	CCW heat exchanger area to be separated from rest of turbine building by three-hour fire barrier.
28 (Main transformer area)	Fusible link in air lines to MSIV's to be provided to allow valve closure if transformer fire encroaches upon main steam lines.
30-A-1 (Auxiliary saltwater pump 1-1 room)	Smoke detector to be provided outside auxiliary saltwater pump room door.
30-A-2 (Auxiliary saltwater pump 1-2 room)	Same as 30-A-1.
31 (Fuel handling building corridor)	Automatic sprinkler protection for this zone.
S-3 (Auxiliary building stairwell, northeast corner)	Hallway at el. 85' to be designated as "No Storage" area.
3-C, 3-J-1 (CCW pump 1-1 room and adjacent corridor)	Two-hour fireproofing of power circuits for diesel fuel transfer pumps in these zones.

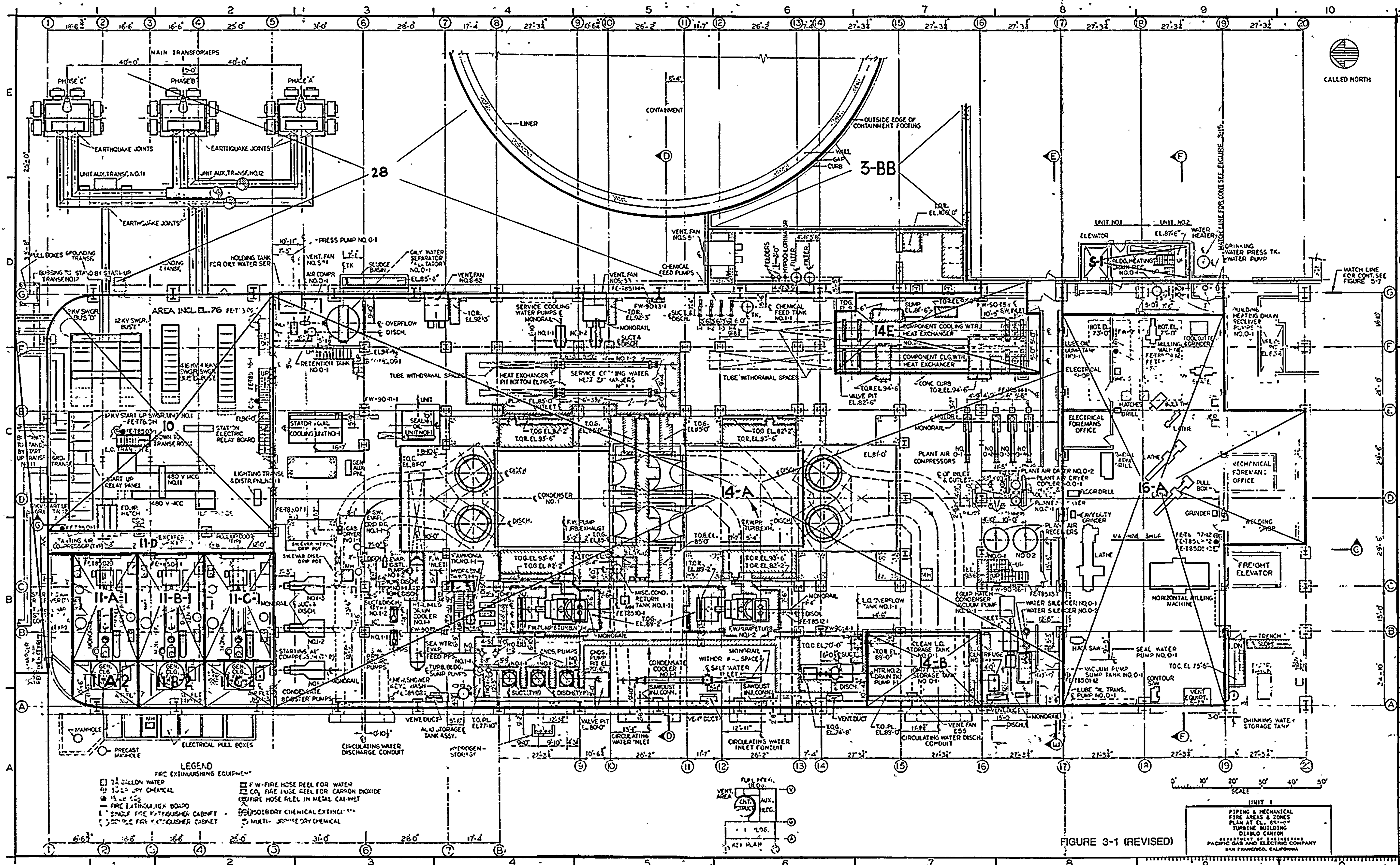


FIGURE 3-1 (REVISED)

UNIT 1
PIPING & MECHANICAL
FIRE AREAS & ZONES
PLAN AT EL. 85'-0"
TURBINE BUILDING
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

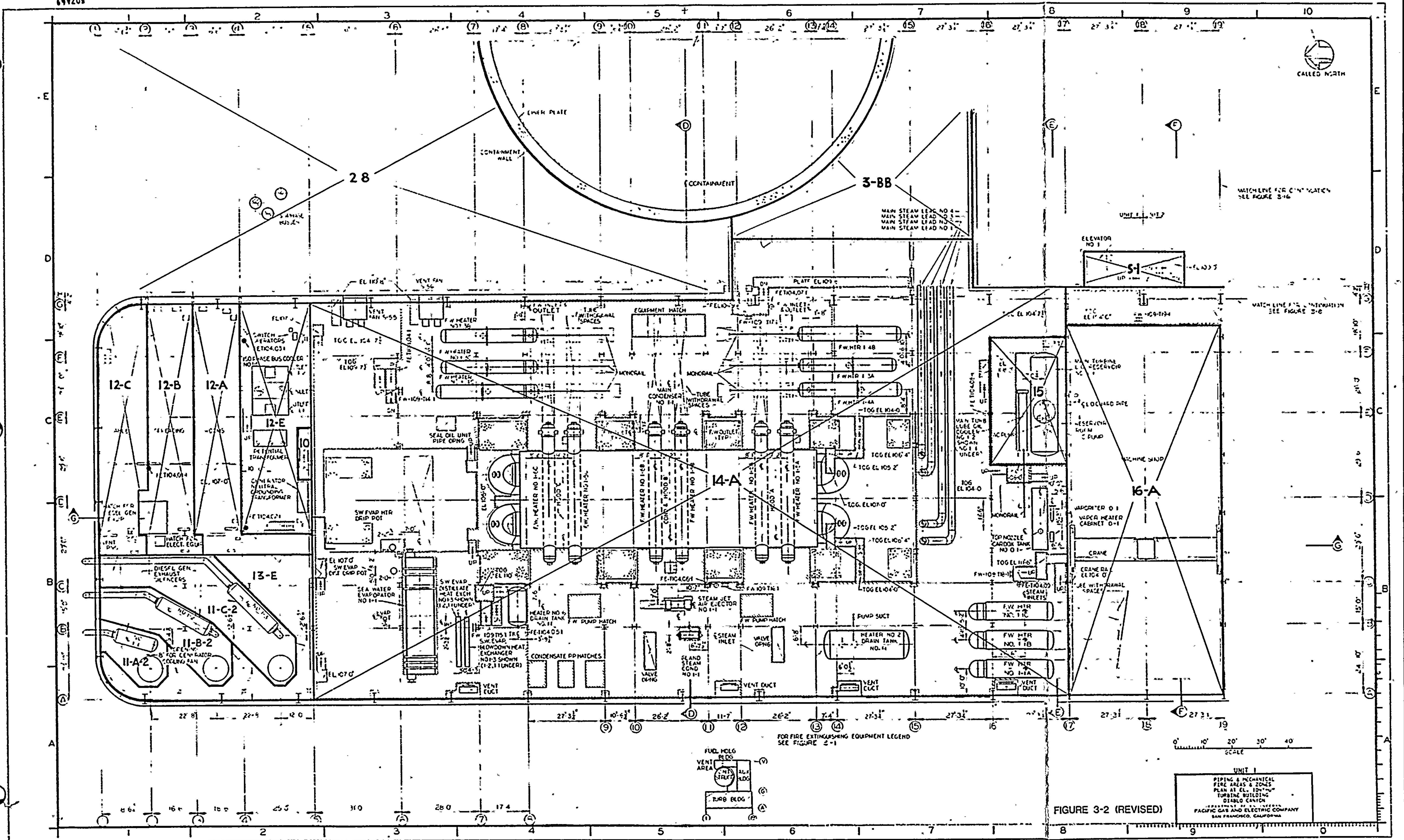


FIGURE 3-2 (REVISED)

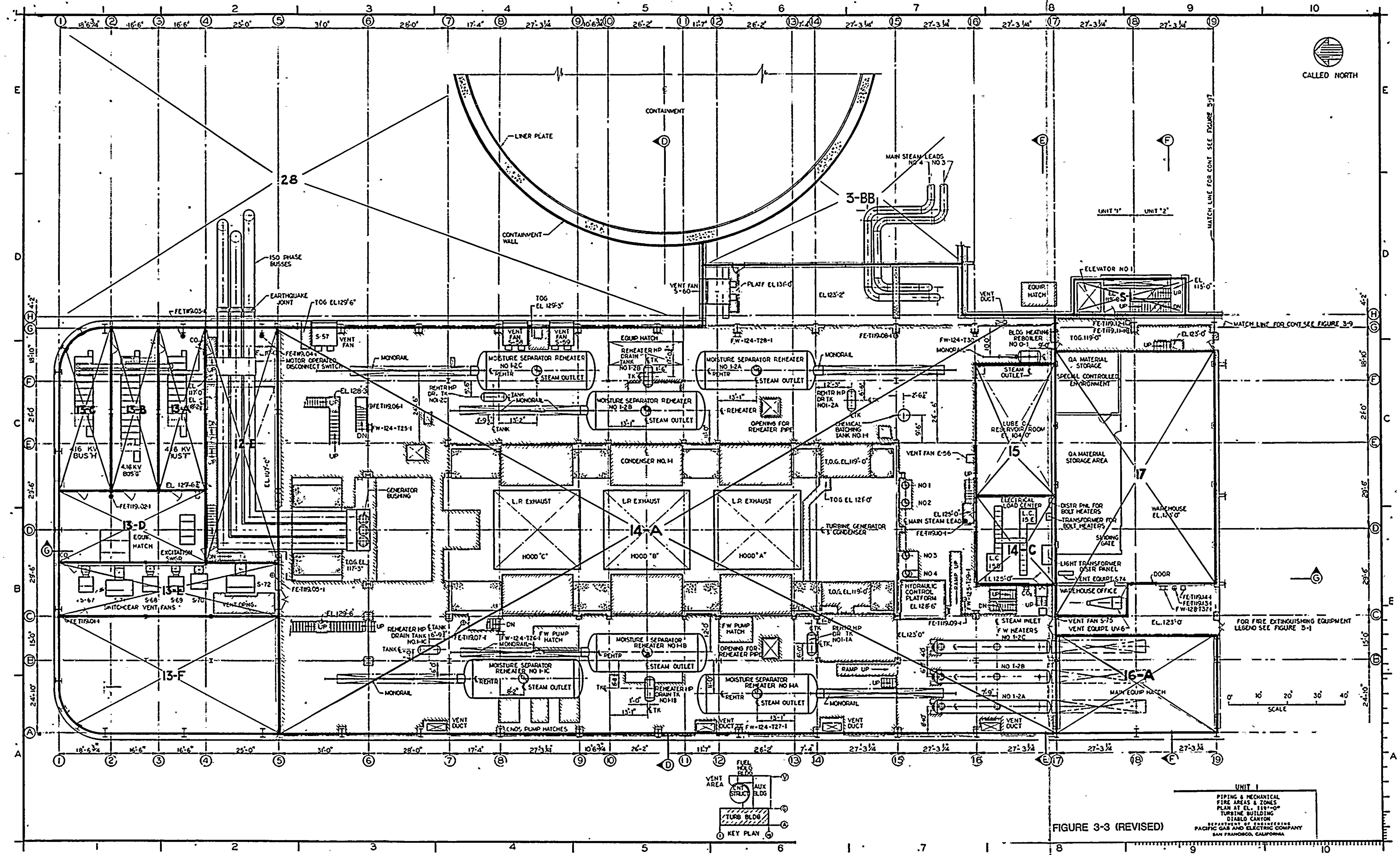


FIGURE 3-3 (REVISED)

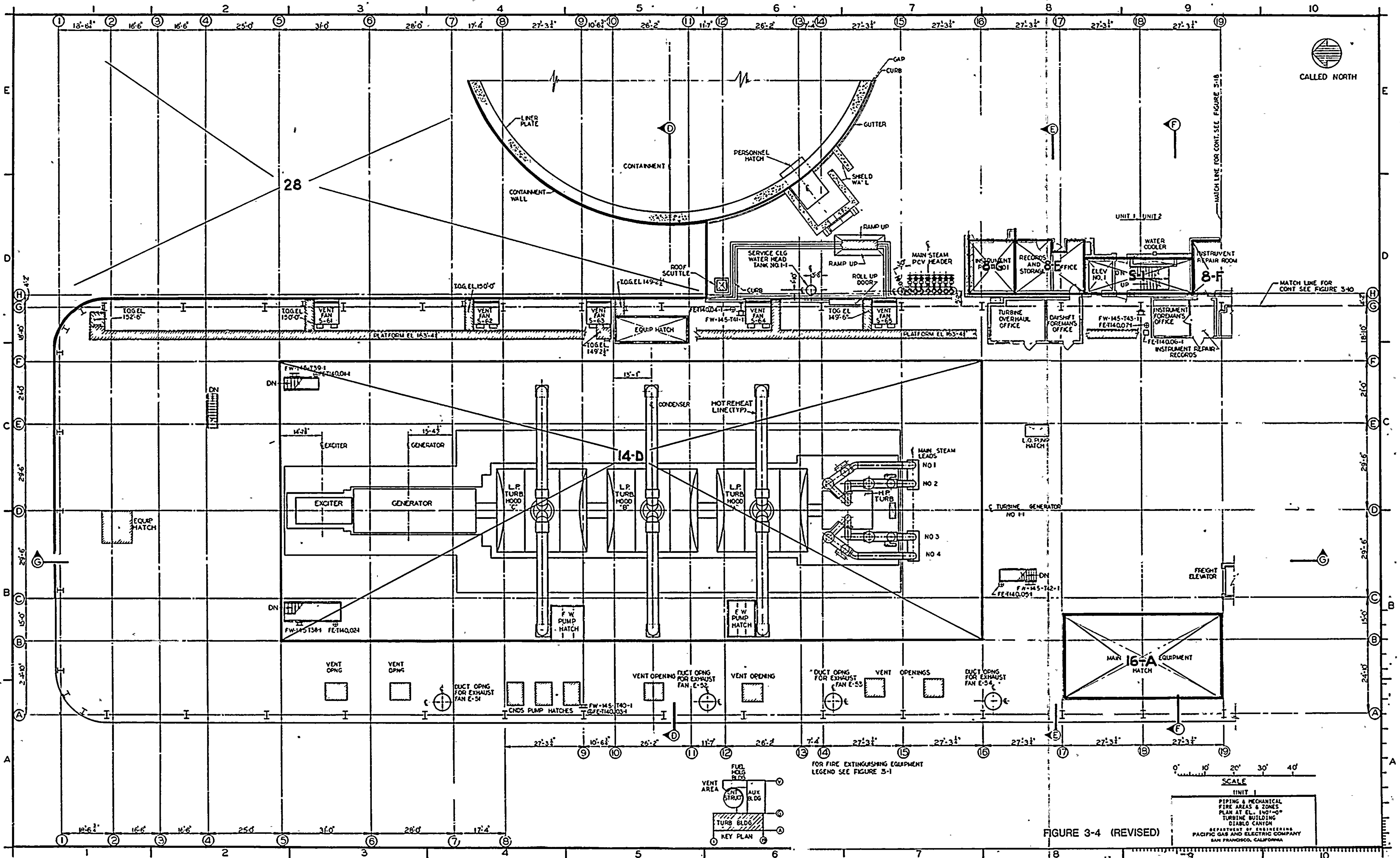


FIGURE 3-4 (REVISED)

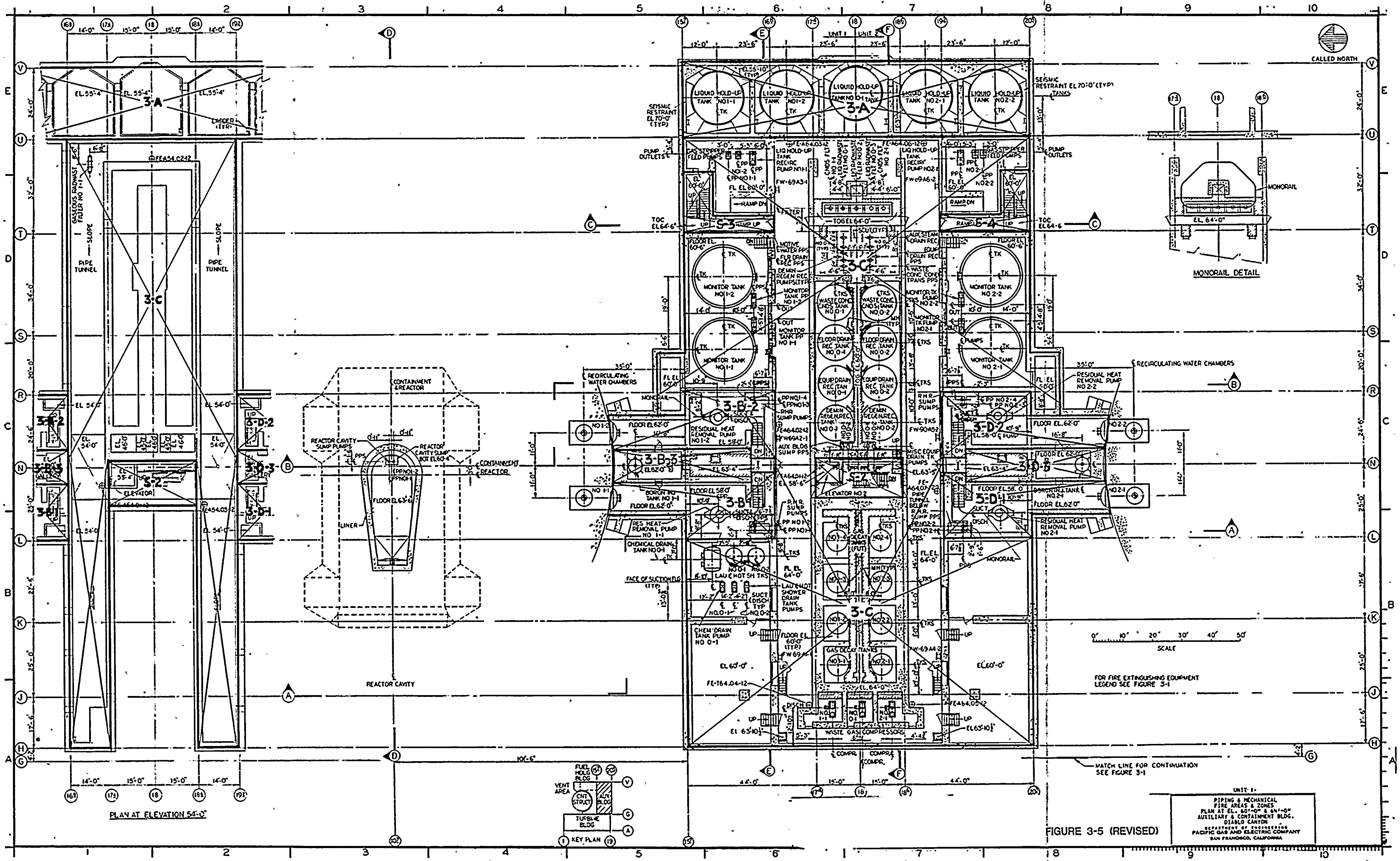
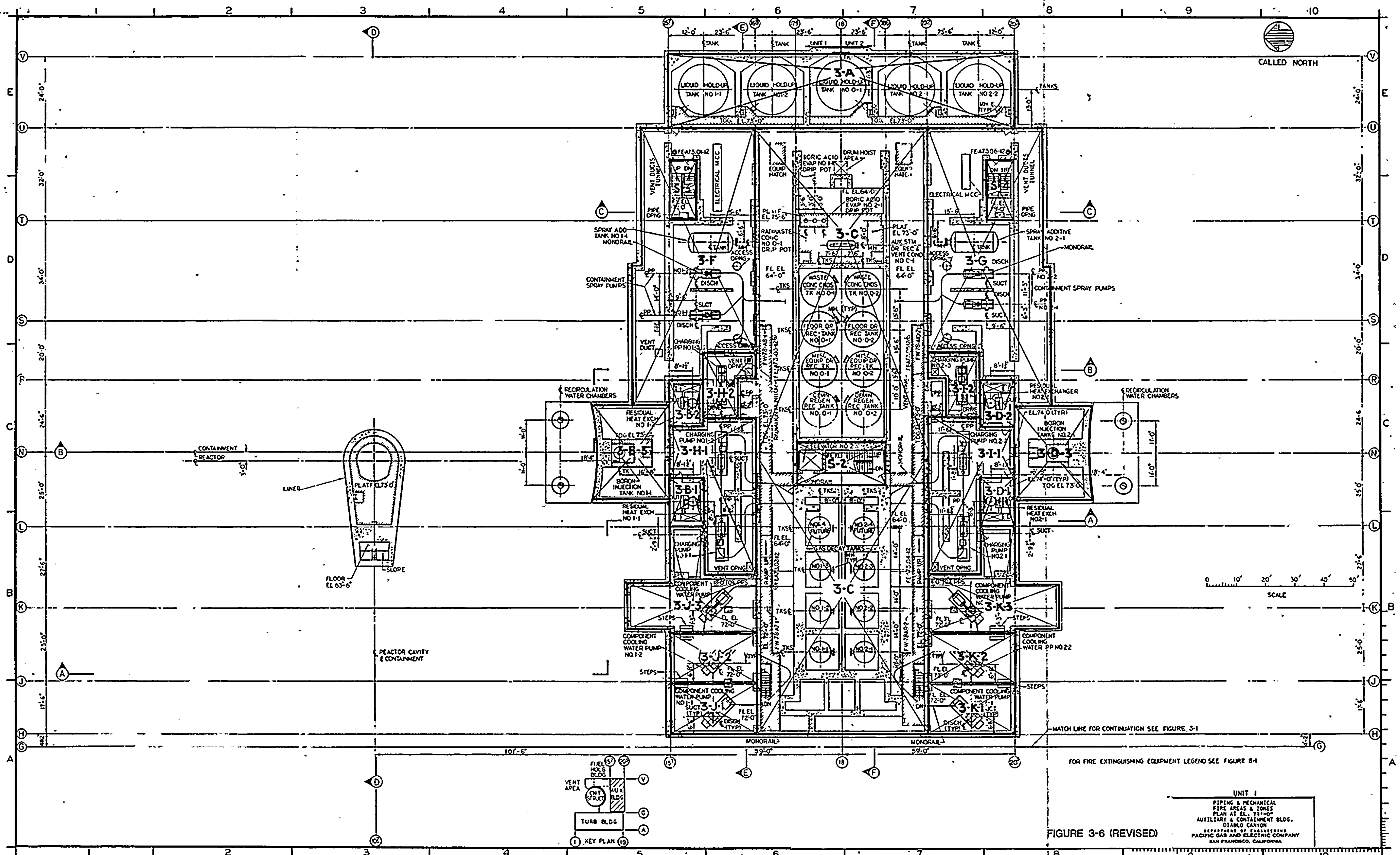


FIGURE 3-5 (REVISED)



FOR FIRE EXTINGUISHING EQUIPMENT LEGEND SEE FIGURE 3-1

UNIT 1

PIPING & MECHANICAL
FIRE AREAS & ZONES
PLAN AT EL. 73'-0"
AUXILIARY & CONTAINMENT BLDG.
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 3-6 (REVISED)

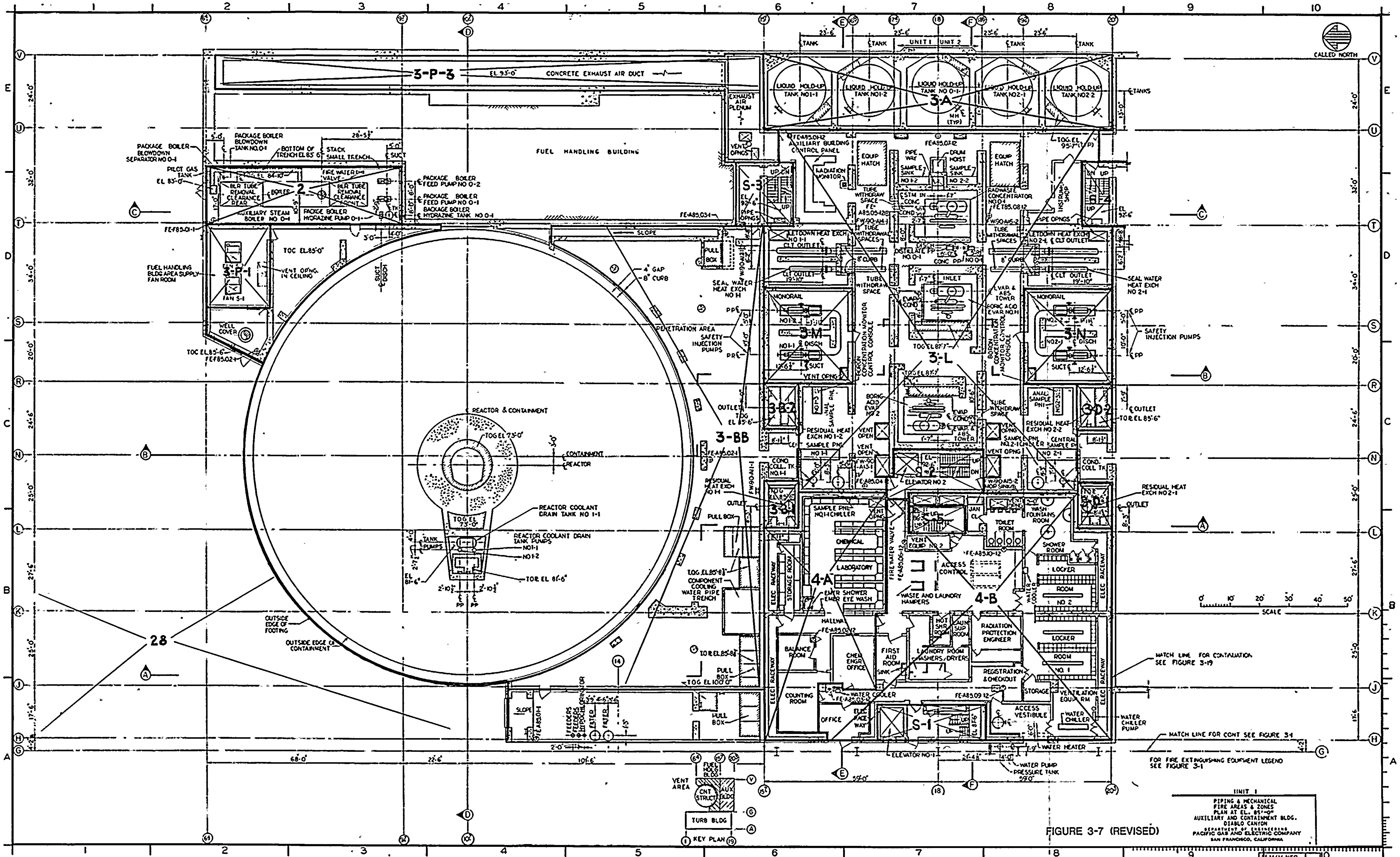


FIGURE 3-7 (REVISED)

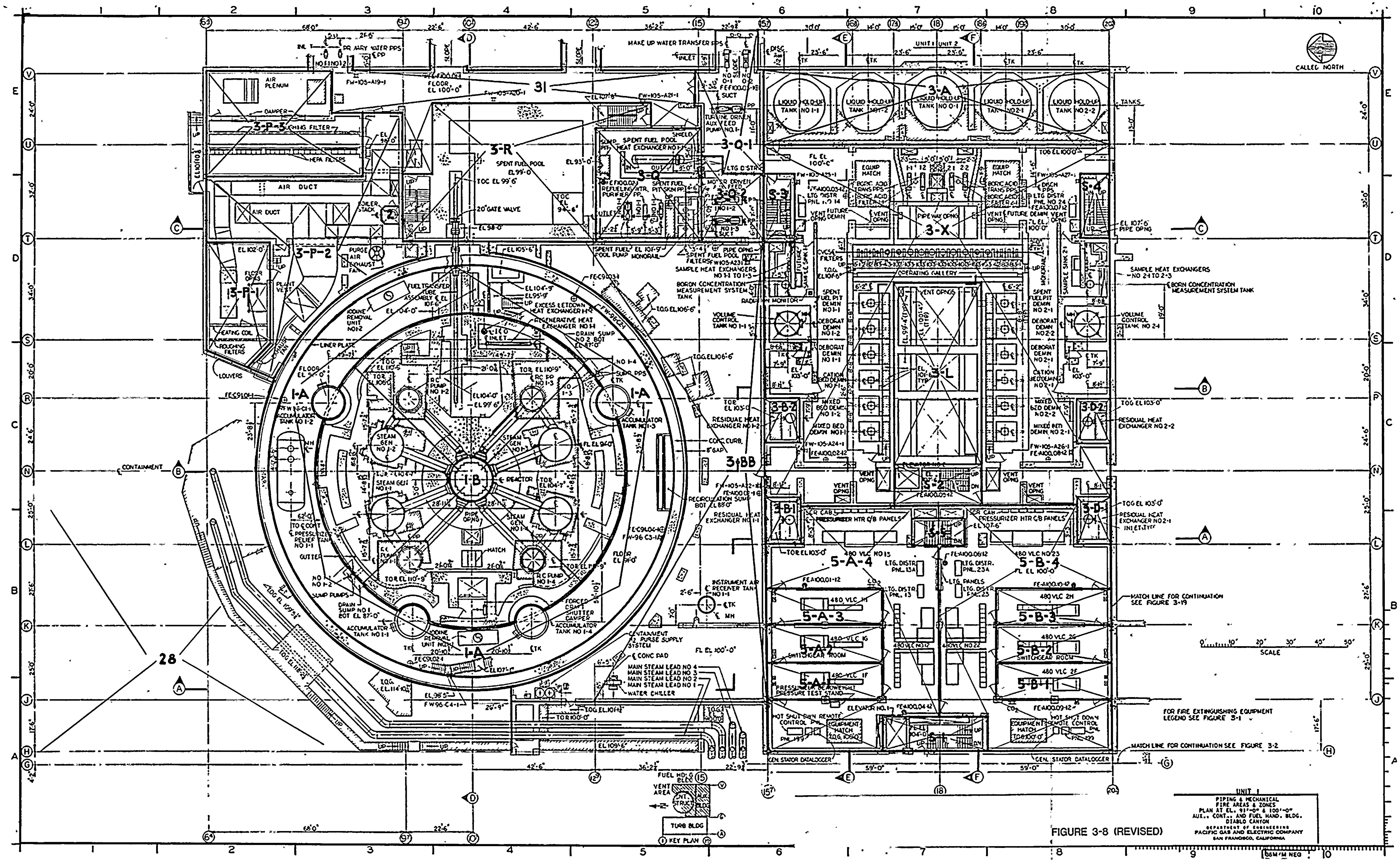


FIGURE 3-8 (REVISED)

UNIT 1
PIPING & MECHANICAL
FIRE AREAS & ZONES
PLAN AT EL. 91'-0" & 100'-0"
AUX., CONT., AND FUEL HAND. BLDG.
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

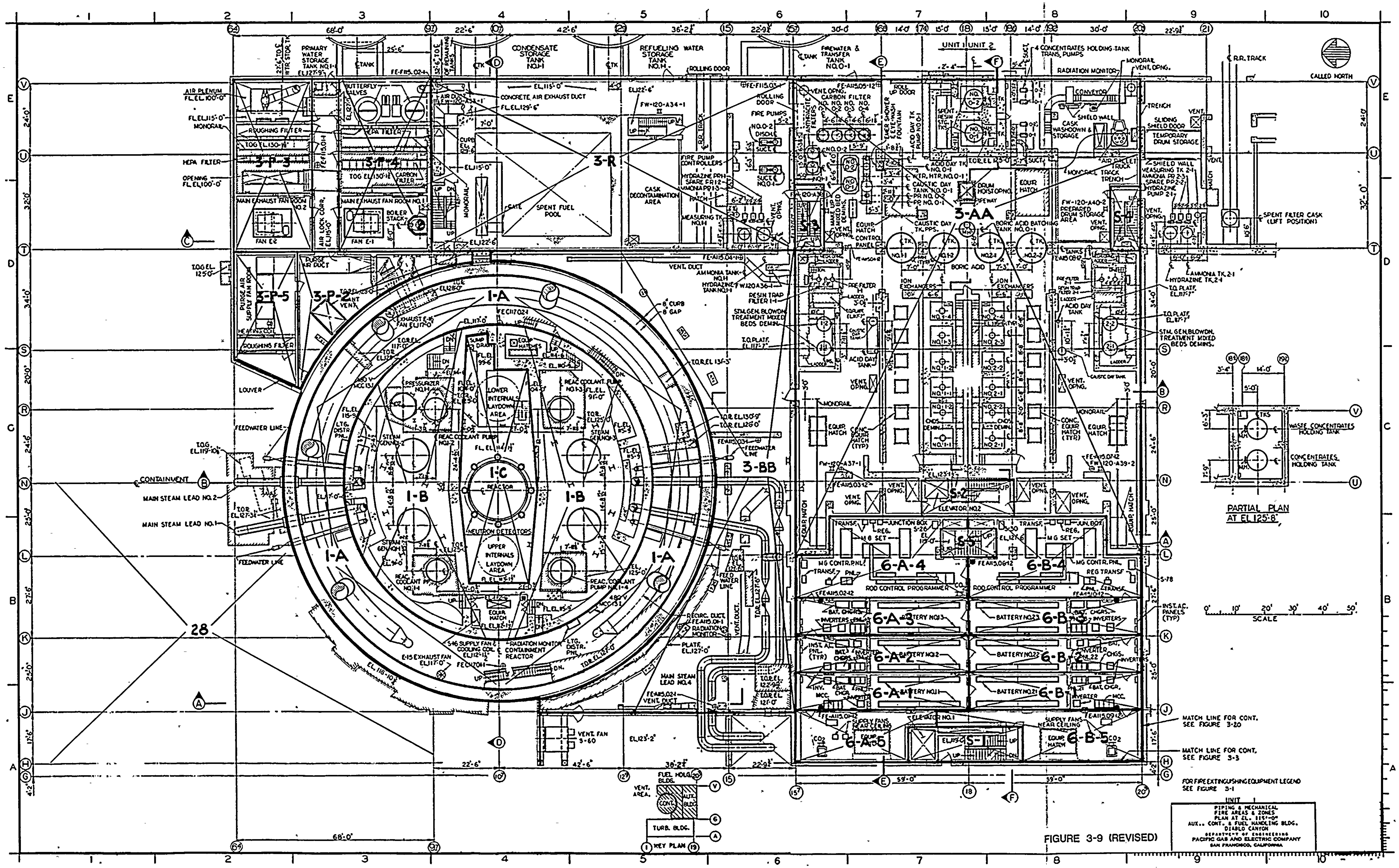


FIGURE 3-9 (REVISED)

224205

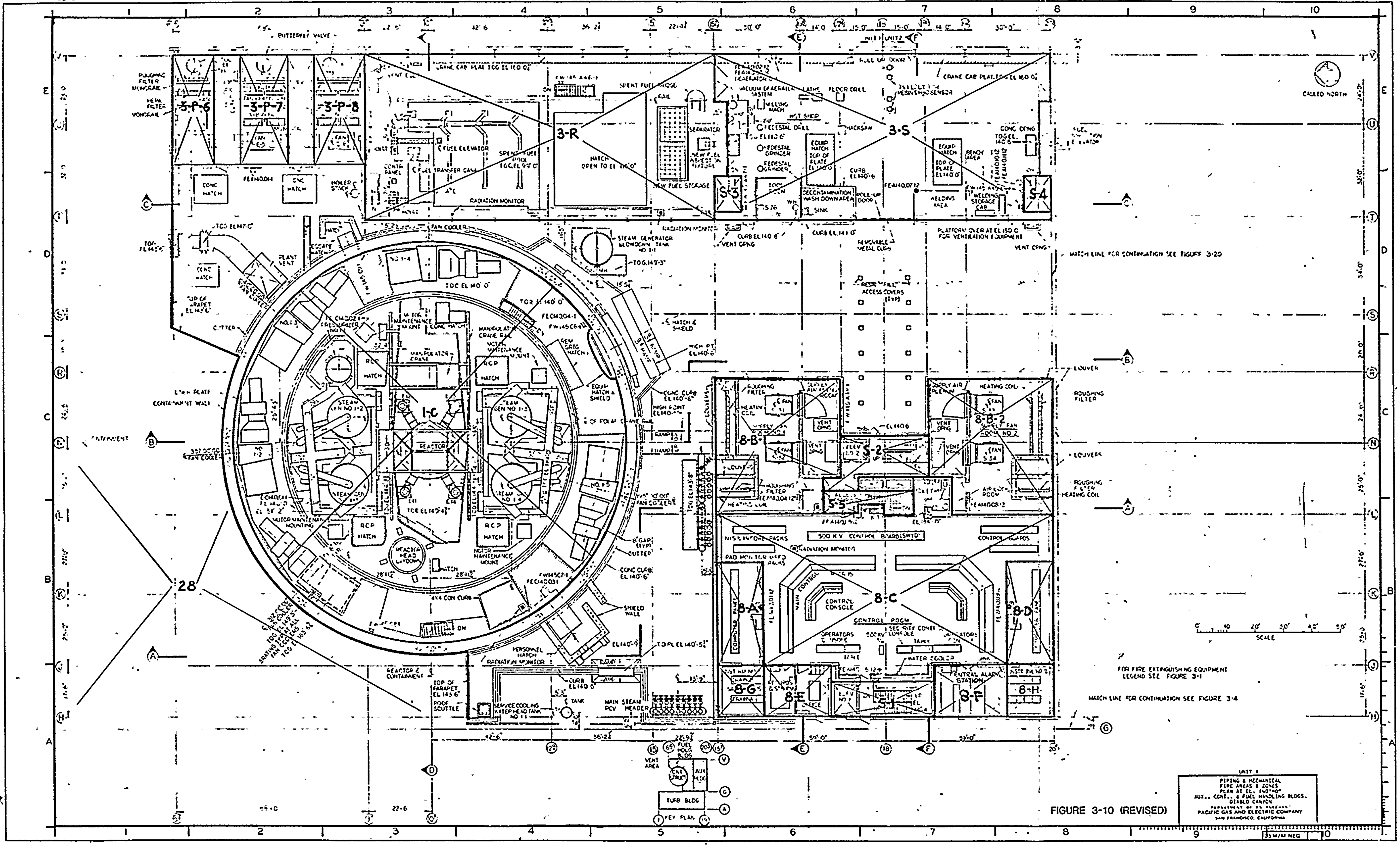


FIGURE 3-10 (REVISED)

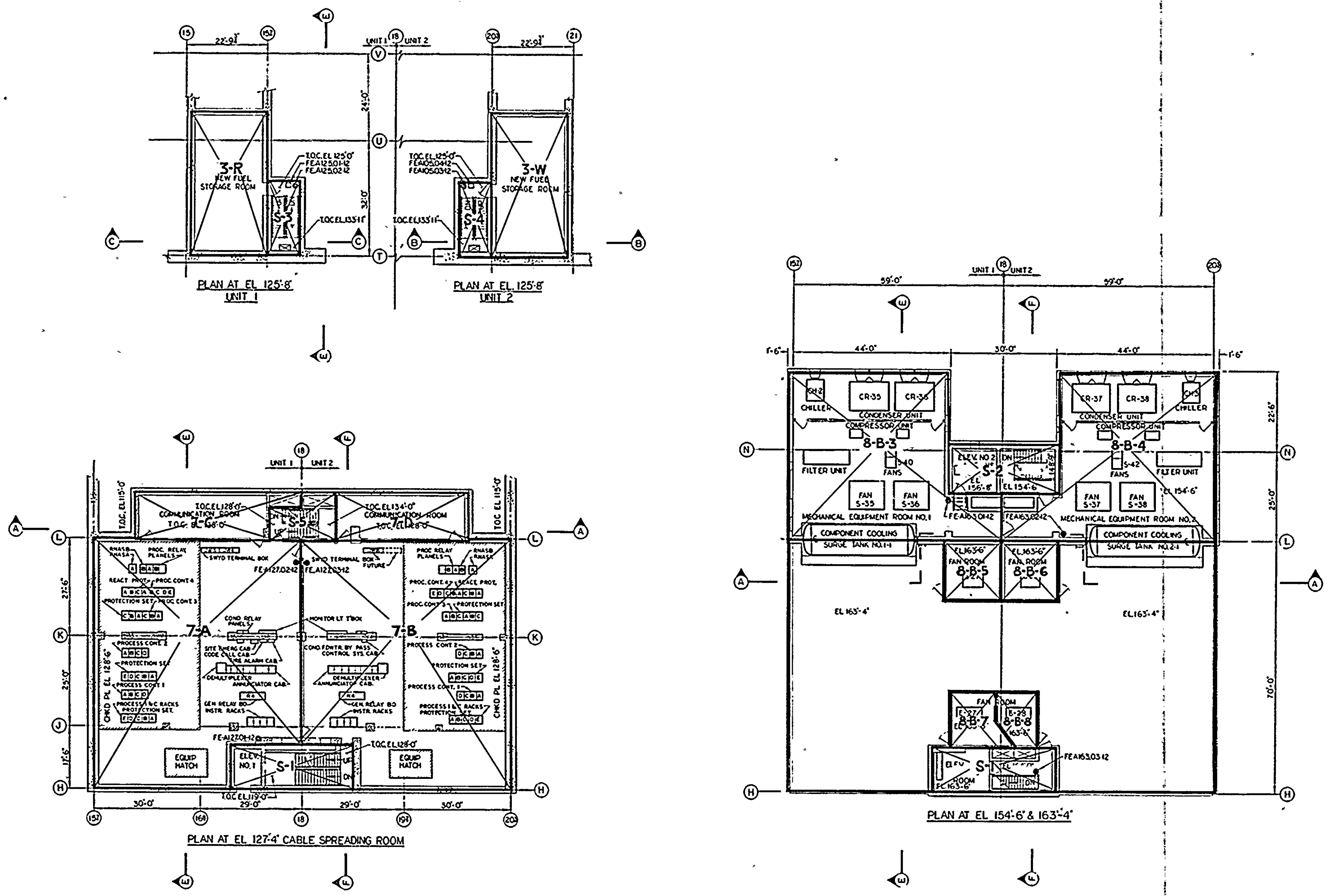
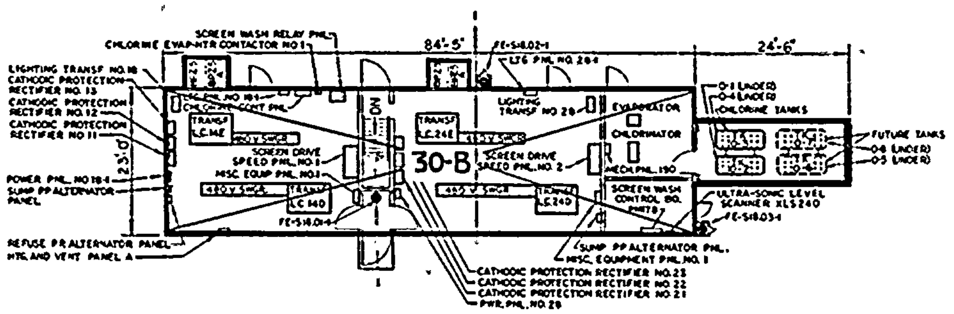


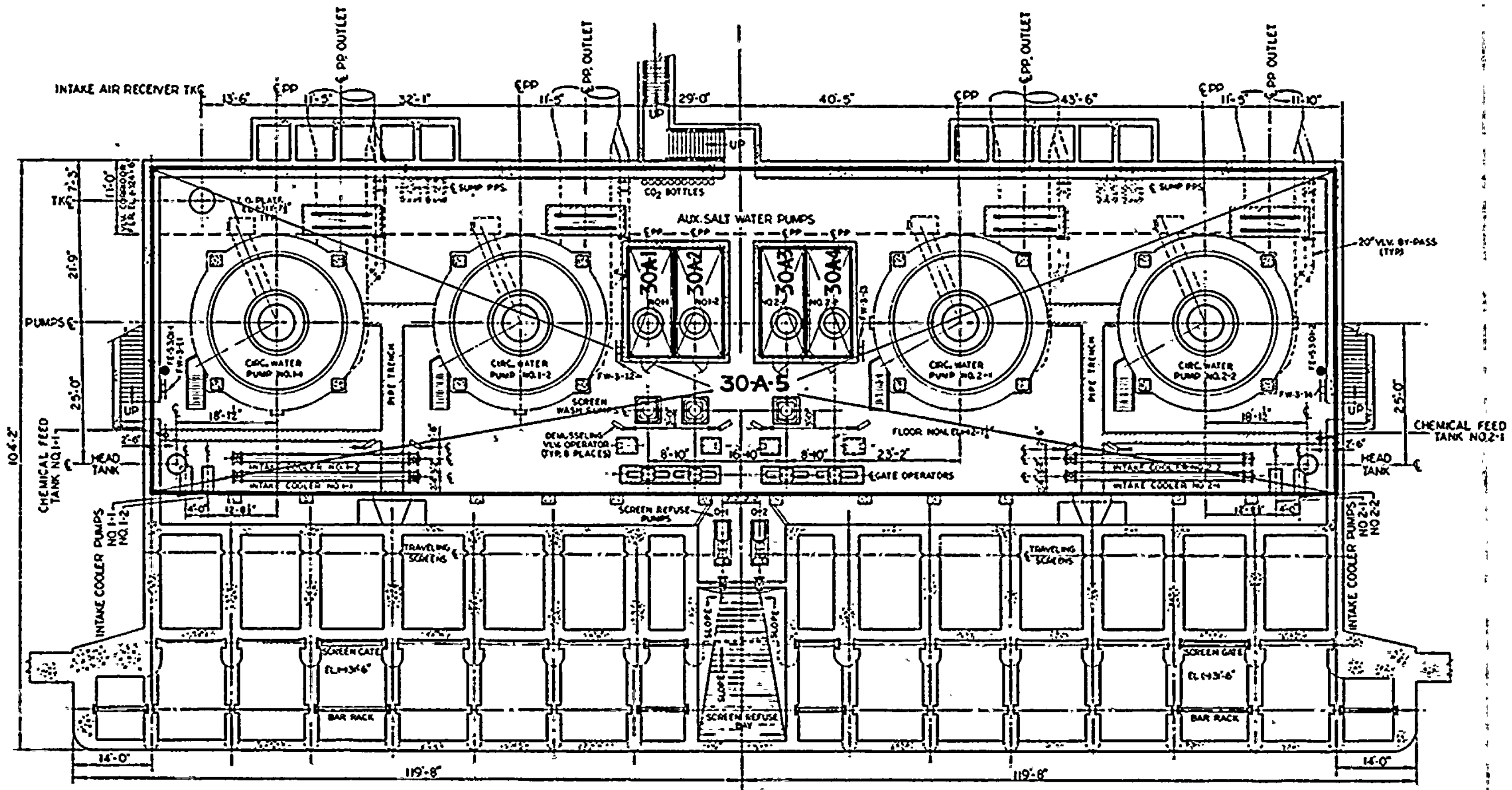
FIGURE 3-11 (REVISED)

UNITS 1 & 2
PIPING & MECHANICAL
FIRE AREAS & ZONES
MISCELLANEOUS PLAN
AUXILIARY BUILDING
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

CALLED NORTH



CONTROL ROOM FLOOR PLAN
AT EL. 18'-0



INTAKE STRUCTURE PLAN
AT EL. (-)2'-1½"

EQUIPMENT	ELEV
STRUCTURE SUMP PUMPS DISCH. ℄	[illegible]
INTAKE COOLERS ℄	[illegible]
INTAKE COOLERS PUMPS INLET ℄	[illegible]
COOLING WTR HEAD TANK OUTLET	[illegible]
SCREEN REFUSE PUMPS INLET ℄	[illegible]
CIRC. WATER PUMPS DISCH. ℄	[illegible]
CHEMICAL FEED TANKS	[illegible]
AUX. SALT WTR PUMPS DISCH. ℄	[illegible]
SCREEN WASH PUMPS DISCH ℄	[illegible]

COORDINATED APPROVAL FOR CONSTRUCTION

TABLE OF CHANGES

FIGURE 3-12 (REVISED)

UNITS 1 & 2
PIPING & MECHANICAL
FIRE AREAS & ZONES
PLANS AT INTAKE STRUCTURE
AND CONTROL ROOM
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

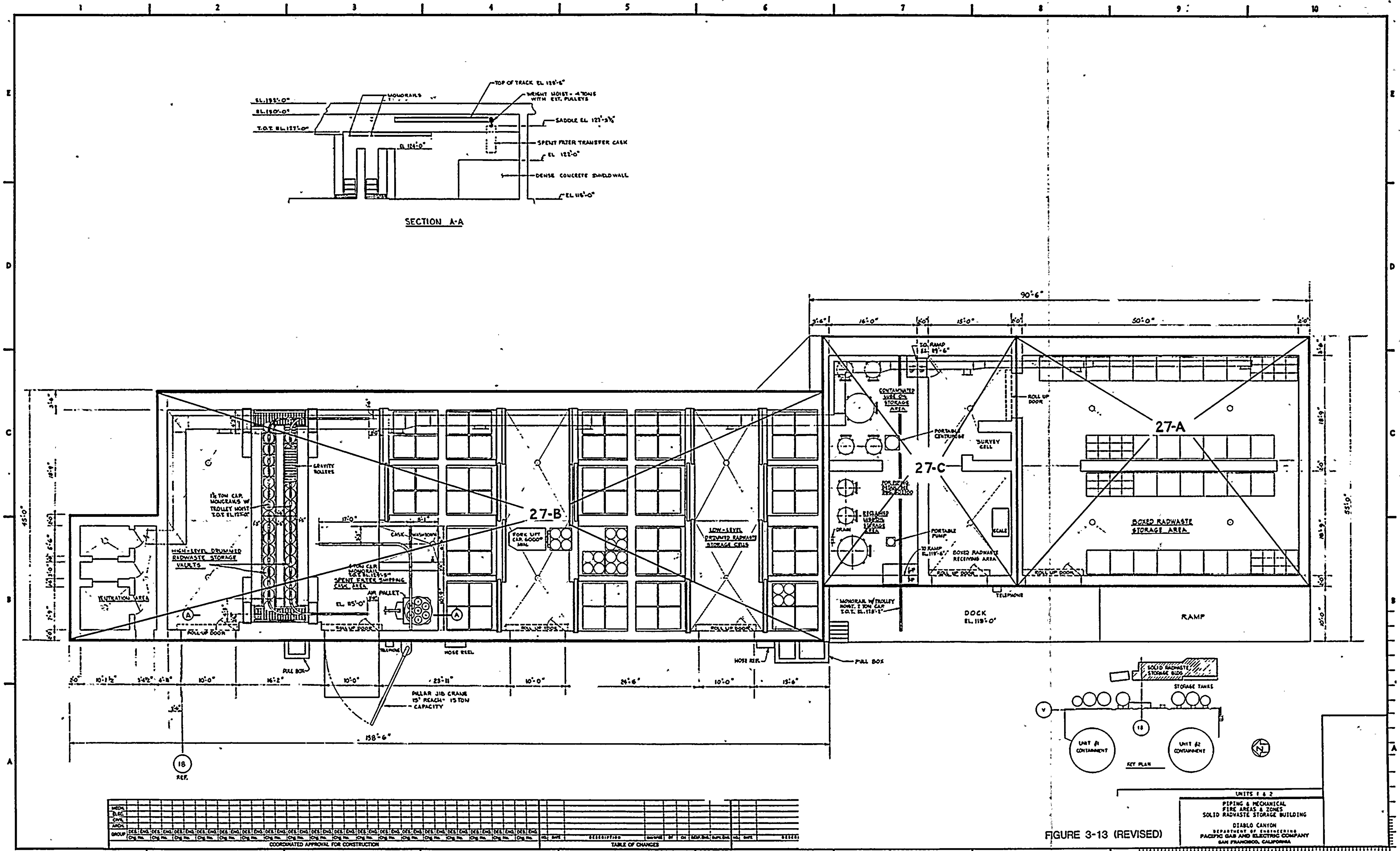


FIGURE 3-13 (REVISED)

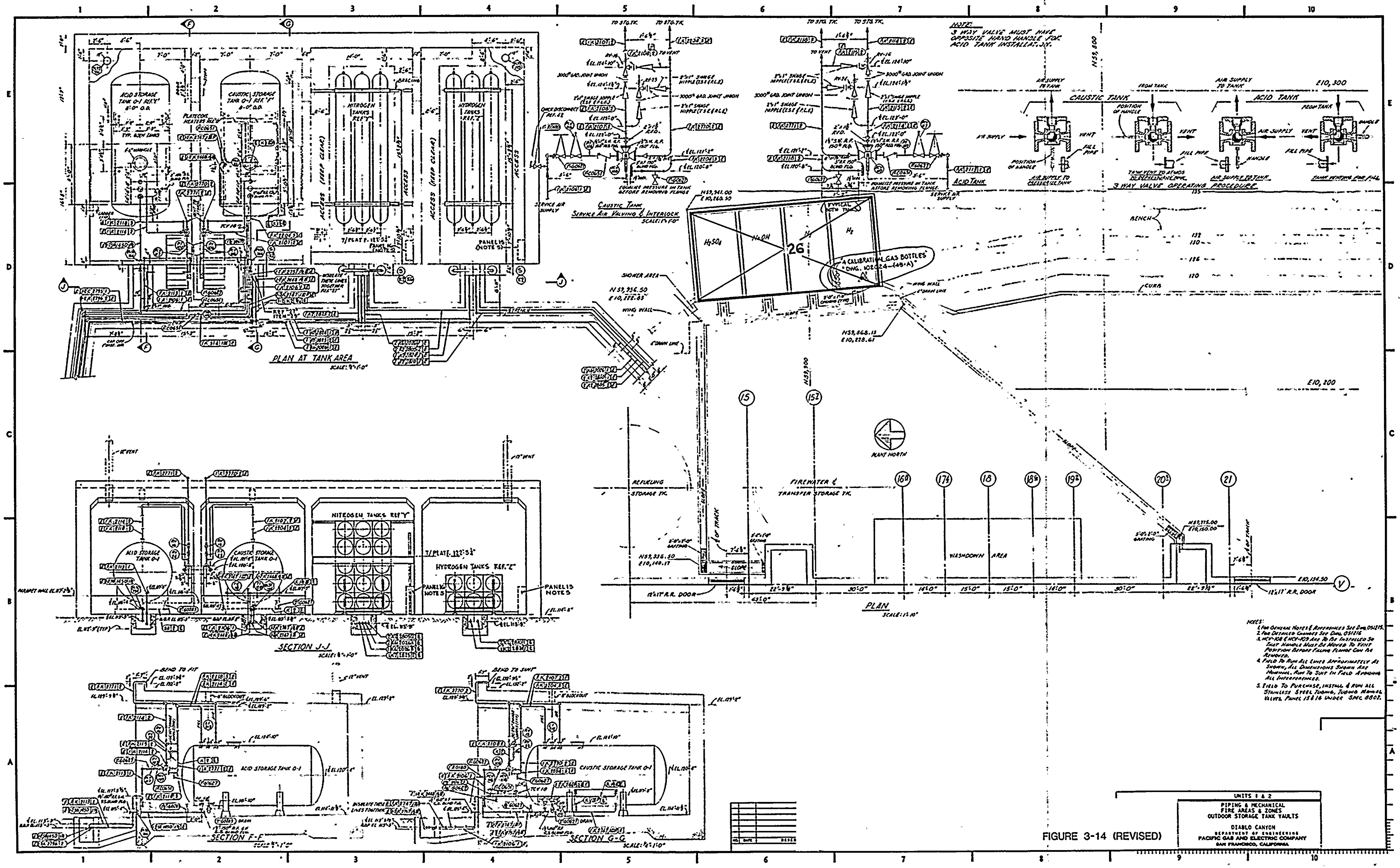
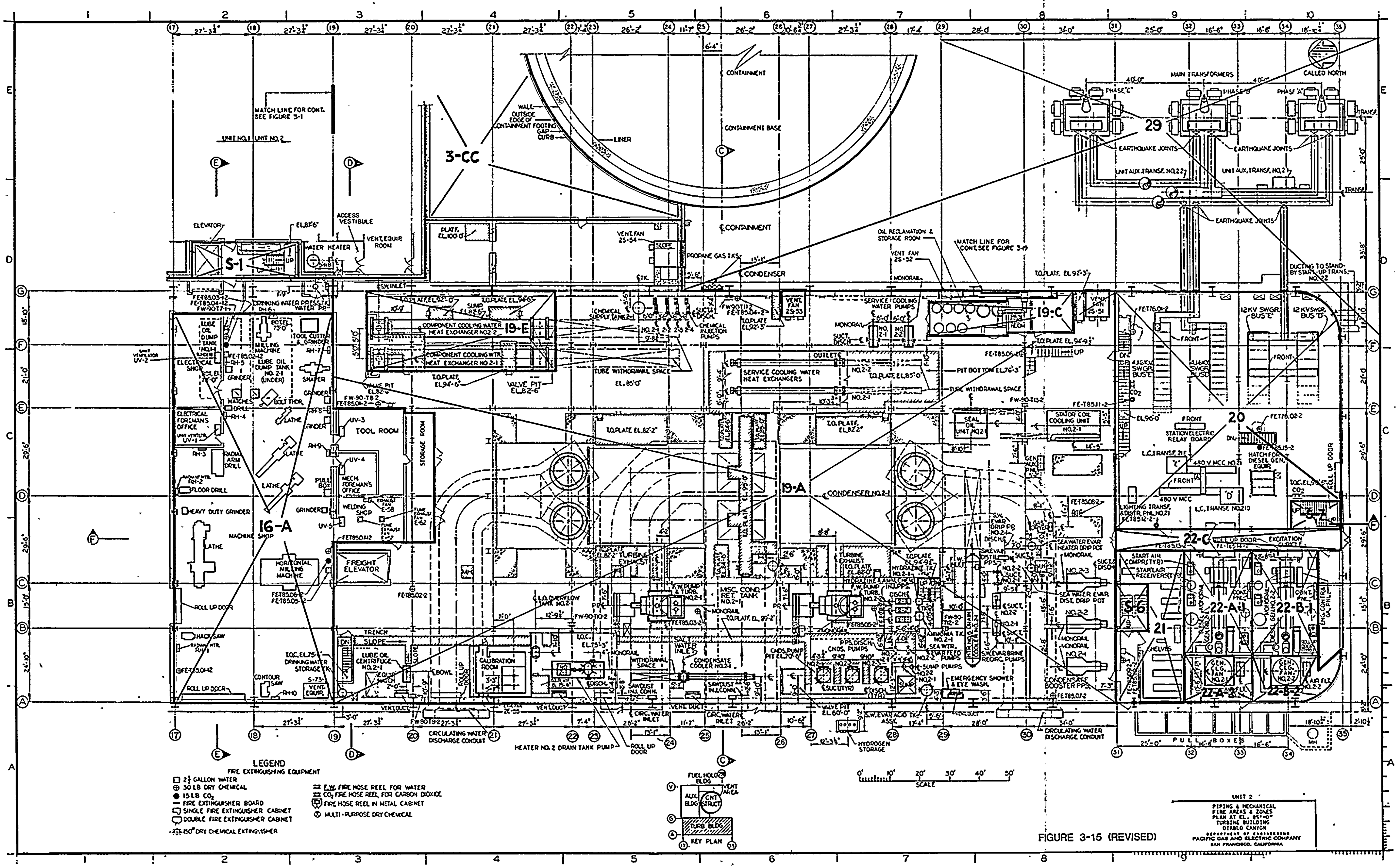
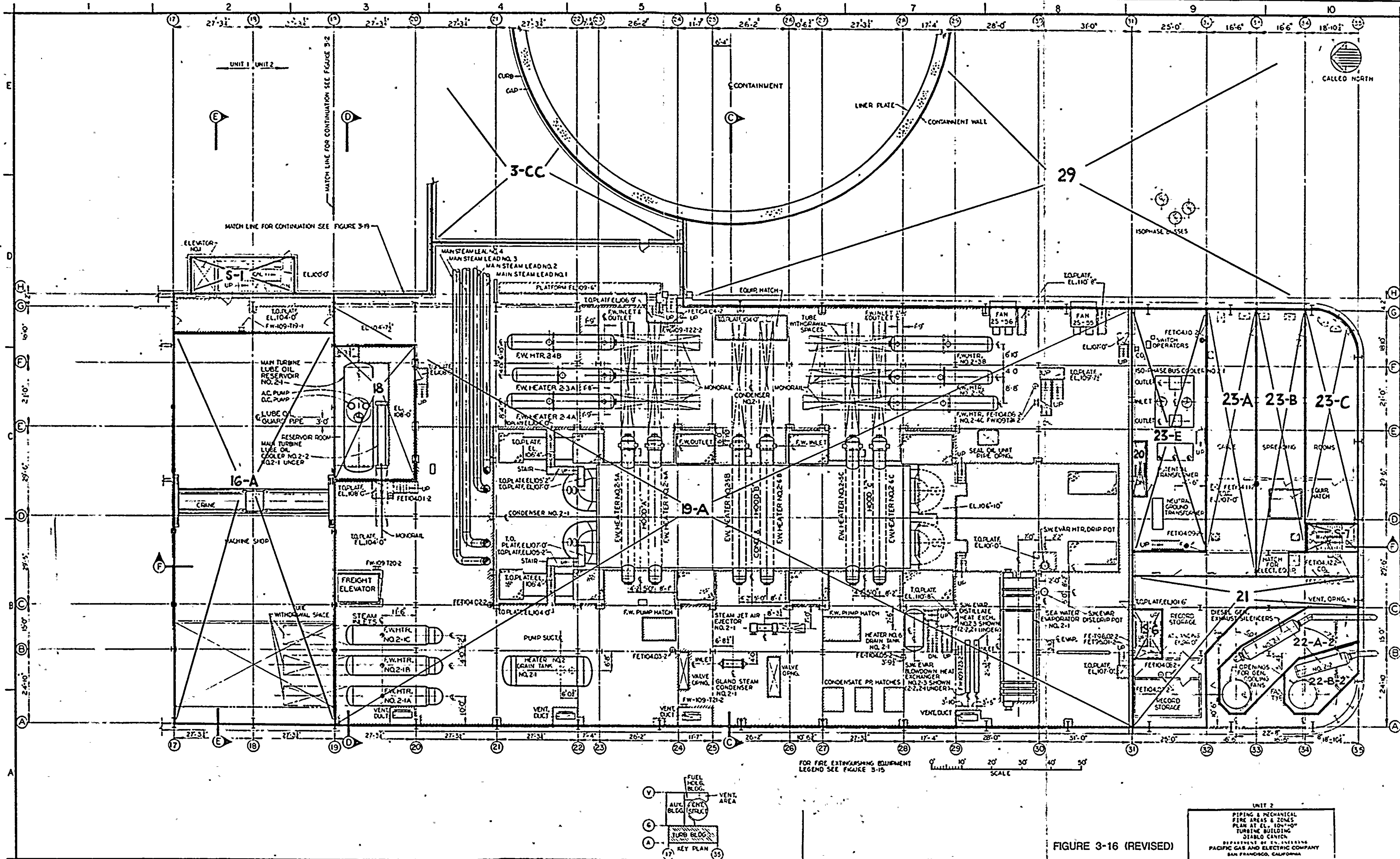


FIGURE 3-14 (REVISED)



UNIT 2
PIPING & MECHANICAL
FIRE AREAS & ZONES
PLAN AT EL. 85'-0"
TURBINE BUILDING
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 3-15 (REVISED)



UNIT 2

PIPING & MECHANICAL
FIRE AREAS & ZONES
PLAN AT EL. 104'-0"
TURBINE BUILDING
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 3-16 (REVISED)

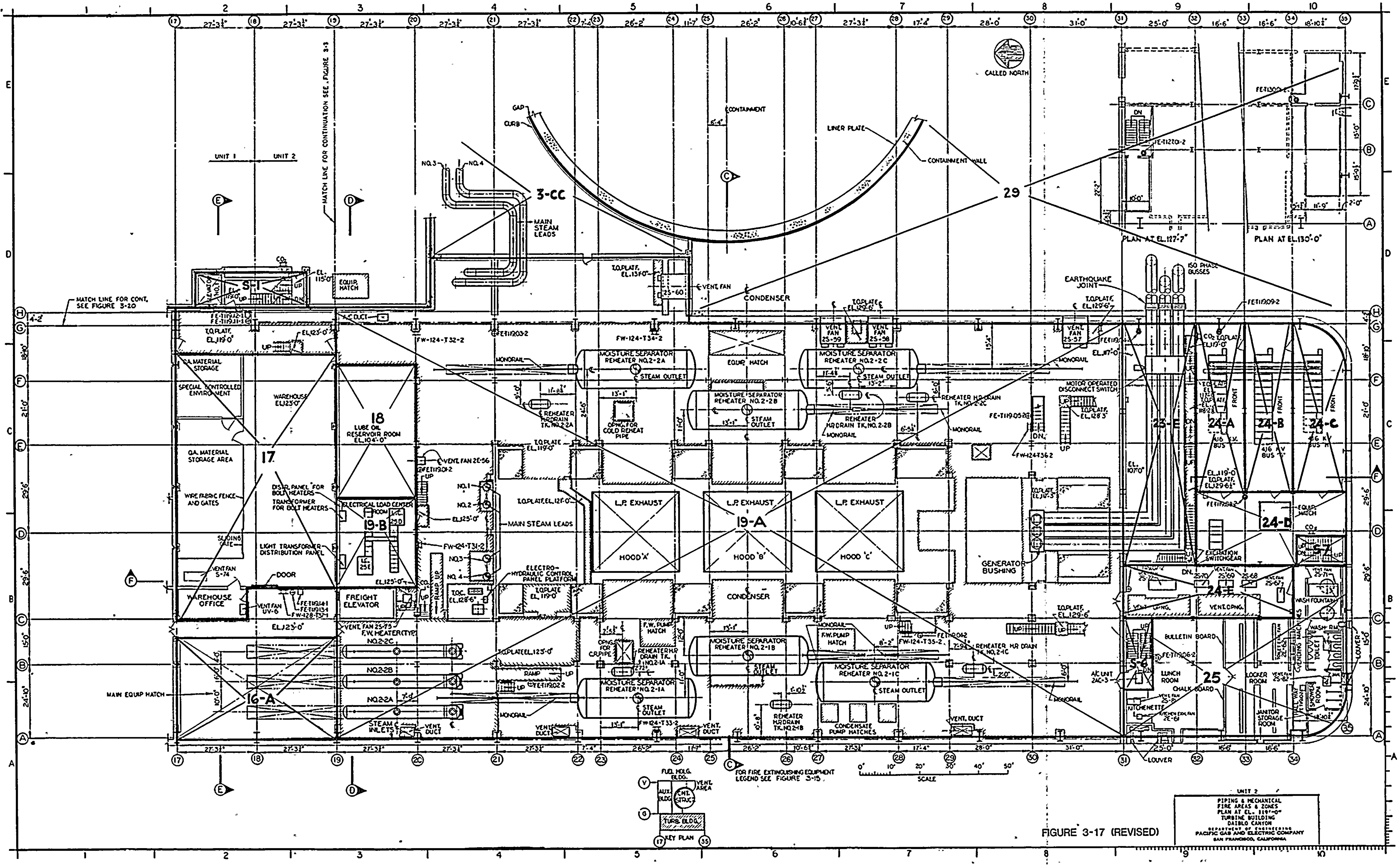


FIGURE 3-17 (REVISED)

UNIT 2
PIPING & MECHANICAL
FIRE AREAS & ZONES
PLAN AT EL. 119'-0"
TURBINE BUILDING
DAIBLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

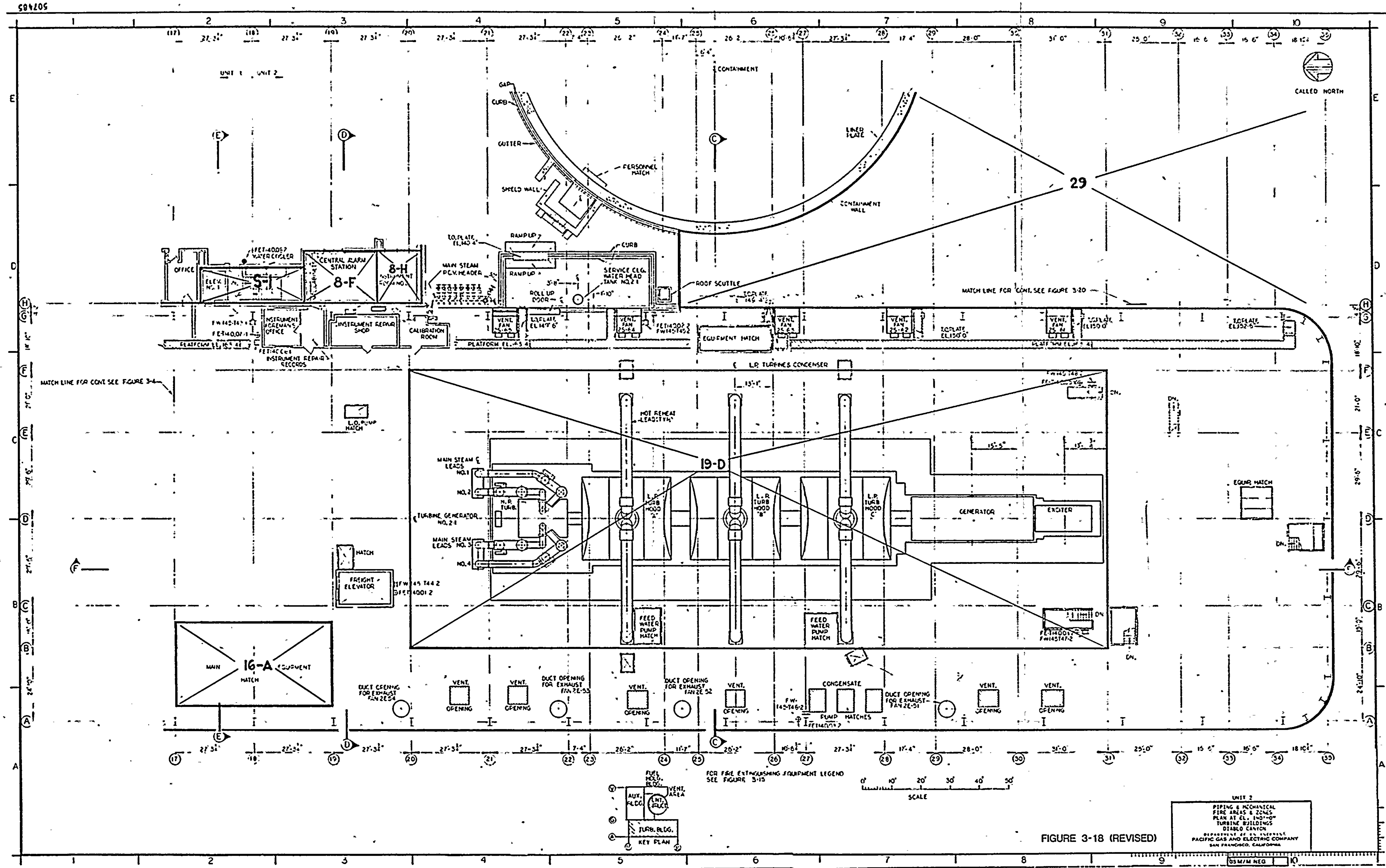
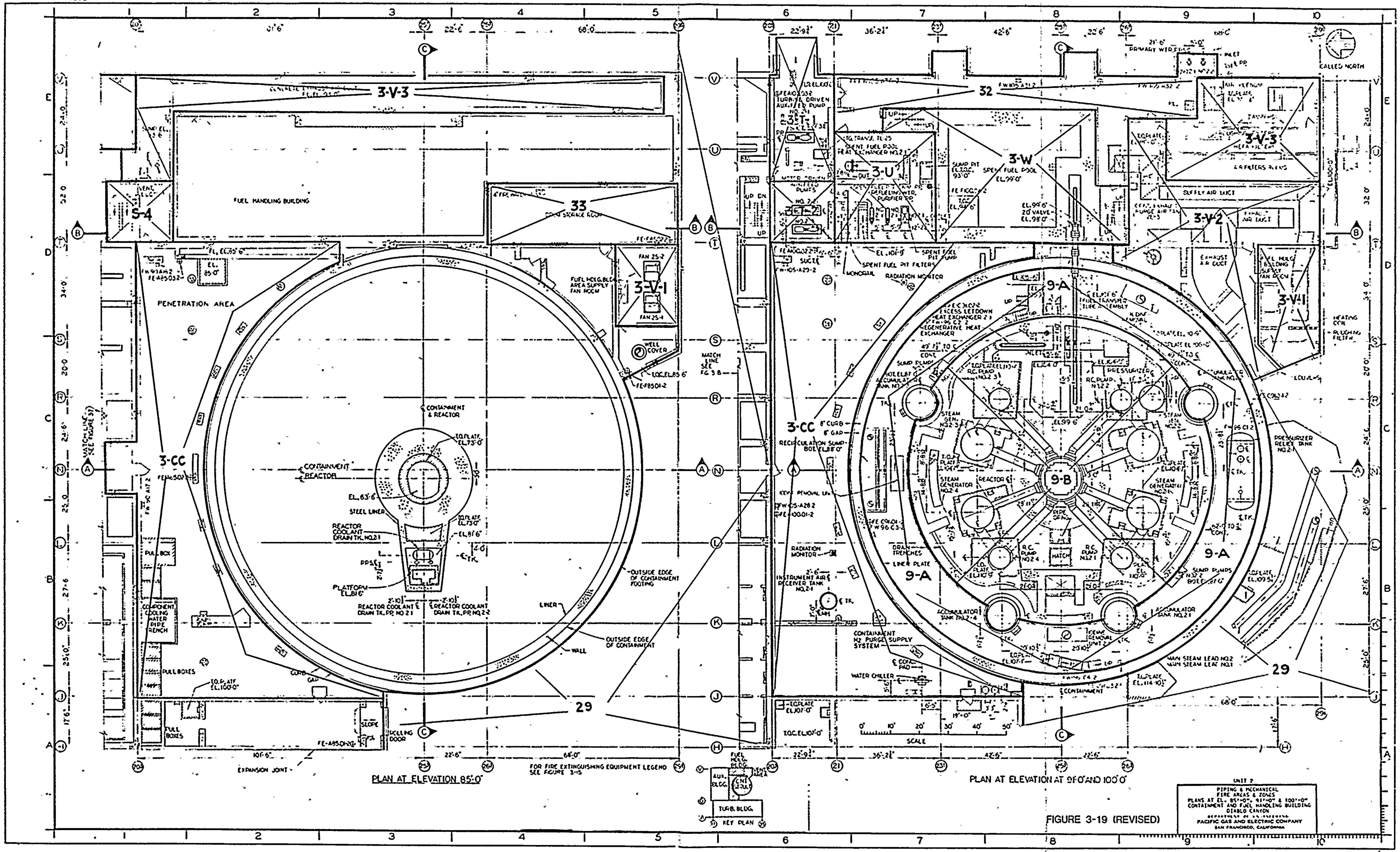


FIGURE 3-18 (REVISED)



UNIT 2
PIPING & MECHANICAL
FIRE AREAS & ZONES
PLANS AT EL. 85'-0", 91'-0" & 100'-0"
CONTAINMENT AND FUEL HANDLING BUILDING
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 3-19 (REVISED)

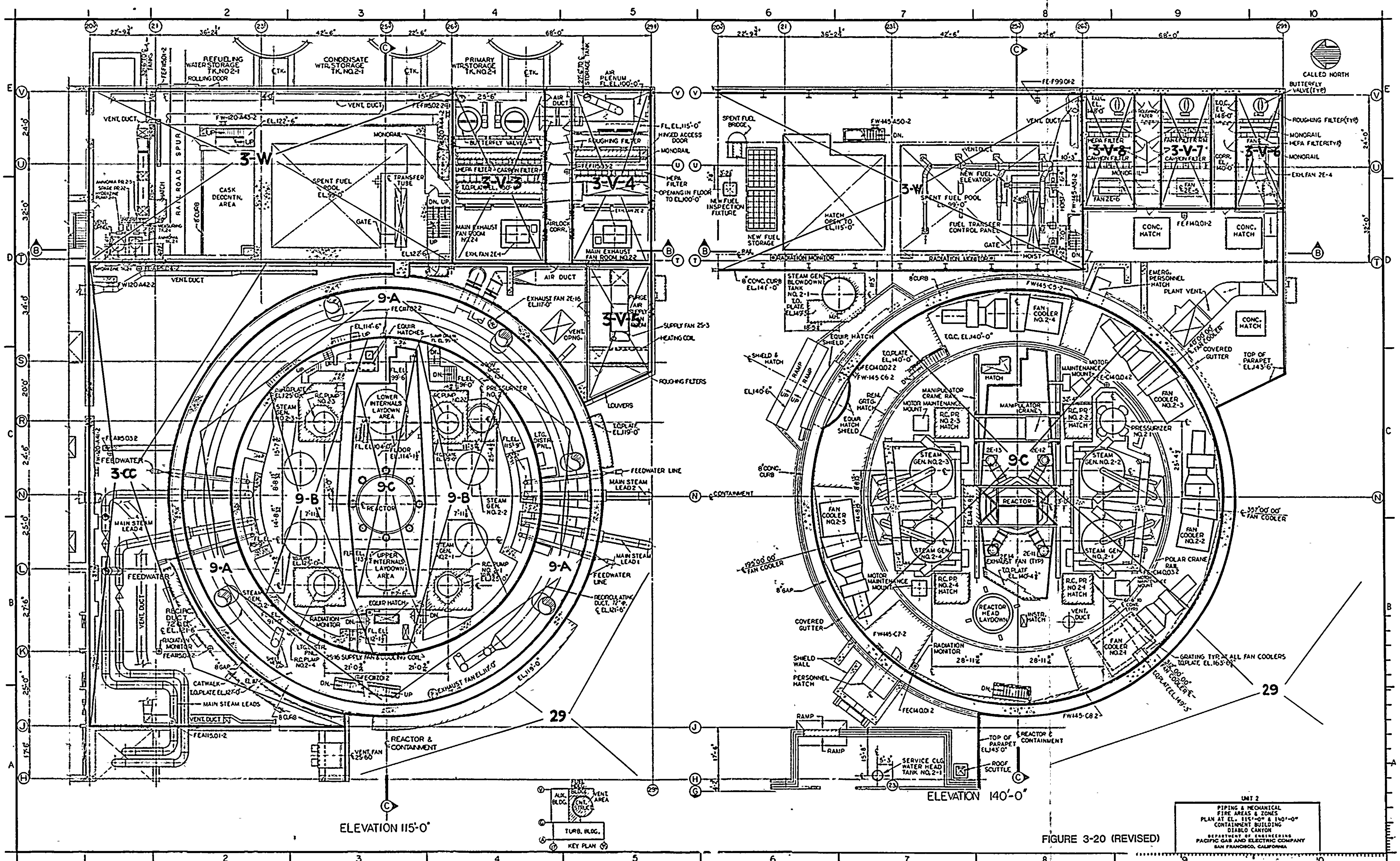


FIGURE 3-20 (REVISED)

UNIT 2
PIPING & MECHANICAL
FIRE AREAS & ZONES
PLAN AT EL. 115'-0" & 140'-0"
CONTAINMENT BUILDING
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DIABLO CANYON POWER PLANT
SUMMARY OF INFORMATION SHOWN ON
ELECTRICAL CONDUIT ROUTING DRAWINGS

Drawing	Fire Zones	Components	Comments
57563	12-D, 12-F FIRE ZONES DELETED AND INCORPORATED INTO ZONES 12A, 12-B, 12-C	Diesel generators Diesel fuel transfer pumps Auxiliary saltwater pumps Ventilation fans: S-67, S-68, S-69	Two 2-hour rated fire barriers to be constructed in zones 12-D and 12-F to separate redundant components (proposed locations of barriers shown in by dashed yellow line).
57566	14-A	LCV's for motor driven auxiliary feedwater pumps	These conduits are to be encased in a two hour rated fire barrier in zone 14-A.
57608	3-BB (section)	Instrumentation: SG LT's, RCS TE's, RCS PT's, PZR Lt's	Section drawing shows separation of redundant instrumentation conduits. Automatic sprinkler protection to be provided in this area.
57611	3-Q-1, 3-Q-2, 31	Ventilation fans: E-1, E-2; S-1, S-2	Drawing shows routing of power supplies for ventilation equipment. Automatic sprinkler protection to be provided in these zones.
57615	3-X	Ventilation fans: E-1, E-2; S-1, S-2	Same as above
57616	3-L	Motor driven auxiliary feedwater pumps	These conduits are to be encased in two-hour rated fire barriers in zone 3-L.
57691	3-C, 3-J-1	Diesel fuel transfer pumps	Drawing shows separation of power conduits for redundant fuel transfer pumps.
57693	3-L, 3-X, 3-AA (Section)	Ventilation fans: S-35, S-36; S-31, S-32; E-1, E-2; S-1, S-2; E-5, E-6	Section E-E of this drawing shows routing of power conduits for redundant ventilation fans. These areas are to be designated as "No Storage" areas. Section GG of this drawing shows the same information as drawing 57615.
501450	3-BB el. 85'	Auxiliary feedwater pump turbine FCV; auxiliary feedwater system LCV's for SG loops 1 and 2	Drawing shows conduit separation between components associated with auxiliary feedwater system that are located at el. 85' in zone 3-BB.

Drawing	Fire Zones	Components	Comments
502078	3-BB el. 100'	Auxiliary feedwater pump turbine FCV; all auxiliary feedwater system LCV's	Drawing shows conduit separation between FCV-95 and LCV's for motor driven auxiliary feedwater pumps. Conduits for LCV's associated with motor driven auxiliary feedwater pumps will be encased in two-hour fire barriers in areas where these redundant conduits pass within 15' of each other. Automatic sprinkler protection to be provided in this zone.
502079	3-BB el. 115'	Auxiliary feedwater pump turbine FCV; auxiliary feedwater system LCV's for SG loops 3 and 4; and SG PT's	Drawing shows conduit separation between components associated with auxiliary feedwater system that are located at el. 115' in zone 3-BB. Drawings show routing of SG pressure transmitter cabling. Automatic sprinkler protection to be provided in this zone.

SYSTEM AND COMPONENTS	COMMENT
Main Steam System	
10% power relief valves	Control at HSD panel
Steam generator blowdown isolation valves	Fail closed on loss of air
Instrumentation	
Steam generator level	Indication at DSSIP*
Steam generator pressure	Local indication
Reactor coolant system temperature	Indication at DSSIP
Pressurizer pressure	Indication at DSSIP
Pressurizer level	Indication at DSSIP
Boric acid tank level	Local indication
Ventilation for Safe Shutdown Equipment	
Auxiliary building ventilation	Start at motor control center
Fuel handling building ventilation	Start at motor control center
480V switchgear and inverter room ventilation	Not affected by CSR/CR fire
4KV switchgear room ventilation	Not affected by CSR/CR fire
Auxiliary saltwater pump ventilation	Not affected by CSR/CR fire
Fire System	
Fire pumps	Local controls at fire pumps

*DSSIP = Dedicated safe shutdown instrument panel

URS

DIABLO CANYON NUCLEAR POWER PLANT UNITS 1 & 2

OUTDOOR WATER STORAGE TANKS DYNAMIC SEISMIC ANALYSES FOR THE 7.5M HOSGRI CRITERIA

November 1978

prepared for
Pacific Gas & Electric Co.

prepared by
URS/John A. Blume & Associates, Engineers
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

CONTENTS

APPENDICES

CONTENTS (Continued)

Page

TABLES

FIGURES

1. INTRODUCTION

This report summarizes the dynamic seismic analyses of the Category I outdoor water storage tanks of Units 1 and 2 of the Diablo Canyon Nuclear Power Plant for a postulated 7.5 magnitude (M) earthquake on the Hosgri fault. The plant is located in San Luis Obispo County, California, on the coast near Diablo Creek. A site plan is shown in Figure 1. The tanks were originally investigated by Pacific Gas & Electric Co. (PG&E) for the 0.40g Double Design Earthquake (DDE). It was necessary to reevaluate the plant for the postulated 7.5M Hosgri event.

The outdoor water storage tanks that are considered Category I structures are the refueling water storage tanks, the firewater and transfer tank, and the condensate tanks. Each tank consists of a steel liner and a proposed concrete cover. The firewater and transfer tank has an inner steel tank as well.

The reevaluation of the tanks was accomplished according to the February 8, 1977, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake.*[1] Maximum shears, overturning moments, and shell forces were calculated at specific nodal-point elevations of the mathematical models of the tanks. On the basis of the results of this investigation, stresses in the existing steel liner were checked, and the steel reinforcement required for the concrete cover was determined.

The investigation reported here consisted of two sets of analyses. First, an axisymmetric model, which ignored all non-axisymmetric features of the tank, was developed for analysis with the AXIDYN[2] computer program. The AXIDYN dynamic-analysis run to determine effects of the horizontal components of the earthquake considered fluid-structure interaction approximately. Next, to assess the effects of the non-axisymmetric vault opening, a three-dimensional model of the tank was developed for analysis with computer program SAP IV.[3] In this analysis, the effects of horizontal earthquake motion were represented by static loads based on the total acceleration response obtained from the AXIDYN analysis.

The tanks were analyzed for effects of gravity loading, hydrostatic pressure, and the two horizontal components and the vertical component of the 7.5M Hosgri ground motion. The different loading conditions, particularly the effects of horizontal ground motion, are discussed in subsequent sections. The finite-element models used and the results of each analysis are discussed in Sections 4, 5.2, and 5.4 of this report. Modeling, loading, and stress calculations are provided in Appendices A, B, C, and D.

Results of the analyses presented here were used by PG&E to design the foundation for the tanks. Soil properties used were based on the findings presented in Reference 4.

2. DESCRIPTION OF TANKS

The Category I outdoor water storage tanks are located just outside the fuel handling building. They were designed for the DDE simply as steel tanks (that is, without concrete cover). The present plan is to provide a concrete cover that varies in thickness from 3 ft at the base to 12 in. at mid-height, then to 8 in. at the dome. The existing steel tanks are anchored to the foundation base slab. In addition, studs will be provided to tie the steel liner and the concrete cover together.

There are two refueling water storage tanks, one to service each unit of the plant. Each refueling water storage tank is 40 ft in diameter and is intended to store water up to a depth of 51.75 ft. Overall height is approximately 58 ft. The thickness of the steel liner varies from 0.578 in. at the base to 0.25 in. at the dome.

The firewater and transfer tank, intended to service both Units 1 and 2 of the plant, is made up of two concentric cylindrical steel tanks connected by a common dome roof. There is a concrete cover on the outer tank. The inner cylindrical tank, called the firewater tank, is 32.67 ft in diameter and is made of steel plates that vary in thickness from 0.802 in. at the base to 0.375 in. at the top. The outer tank, called the transfer tank, is 40 ft in diameter and is made of steel plates that vary in thickness from 0.627 in. at the base to 0.25 in. at the top.

The structure configuration of the condensate tank is similar to that of the refueling water storage tank. Each of the two condensate tanks is 40 ft in diameter and is intended to store water up to a depth of 46.5 ft. The thickness of the cylindrical steel liner varies from 0.60 in. at the base to 0.25 in. at the top. The dome is made of plates that are 0.263 in. thick.

Typical sections of the refueling water storage tank, firewater and transfer tank, and condensate tank are shown in Figures 2a, 2c, and 2d, respectively. Thicknesses of the steel liner plates are indicated on the figures. Figure 2b shows the 14-ft x 14-ft vault opening in the concrete shell of the refuel-

ing water storage tank. The vault openings in the other tanks are slightly smaller.

The steel plates in the refueling water storage tanks are made of SA-240 Type 304L plates, whereas the steel plates in both the firewater and transfer tank and the condensate tank are made of SA-516-55 to SA-300 plates.[5] The concrete cover will have a minimum compressive strength of 4,000 psi at 28 days. The concrete fill under the existing base slab will have a minimum compressive strength of 3,000 psi at 28 days.

3. ANALYSIS CRITERIA

3.1 Seismic Input

Two different postulated 7.5M Hosgri free-field, smooth ground-response spectra have been developed for the Diablo Canyon Nuclear Power Plant site: one by URS/John A. Blume & Associates, Engineers (URS/Blume), and another, developed independently for the staff of the U.S. Nuclear Regulatory Commission (NRC), by Nathan M. Newmark Consulting Engineering Services. Figures 3 and 4 illustrate the Blume and Newmark 0.75g free-field horizontal spectra for 7% and 5% damping, respectively. Also shown in the figures is the 5%-damped, 0.4g DDE free-field spectrum. The vertical input to the outdoor water storage tanks was taken as two-thirds of the 0.75g horizontal free-field ground spectrum. Comparison of the Blume and Newmark spectra in Figures 3 and 4 shows that the Newmark spectrum is generally higher than the Blume spectrum. Thus, for the outdoor water storage tanks, only one set of analyses, using the Newmark spectrum, was performed. Major resistance is provided by the concrete liner, and a 7% damping value was assumed.

3.2 Dynamic Effects of Horizontal Earthquake Components

Analysis of the behavior of liquid-filled, ground-supported tanks subjected to horizontal seismic excitation is a complex problem. G. W. Housner[6] presents an approximate method to determine the hydrodynamic pressures that develop when a rigid cylindrical tank is subjected to seismic motion. A. S. Veletsos and J. Y. Yang[7] offer modifications to Housner's approach that consider the effects of tank flexibility. They analyze a tank-fluid system as a single-degree-of-freedom system by assuming that the system vibrates in a fixed configuration along its height. The investigation reported here was based on that approach; a half-sine vibration configuration, the most conservative of the three configurations suggested in Reference 7, was used in the analysis.

Horizontal earthquake motion generates three types of dynamic load in a tank-fluid system:

- structure inertial forces, associated with the mass of the structure;
- impulsive pressure, exerted on the tank by the fluid; and
- convective pressure, also exerted on the tank by the fluid.

Impulsive pressure represents the effects of the portion of the liquid that moves in unison with the tank; convective pressure represents the effects of the sloshing action of the liquid. Both structure inertial forces and impulsive pressures are dependent on the vibration configuration of the structure and on the accelerations produced on the walls of the tank during the earthquake. Impulsive pressure, including the derivation of the equivalent fluid impulsive mass, m_{eff}, is discussed further in Section 3.2.1. Convective pressure is discussed in Section 3.2.2.

3.2.1 Impulsive Pressure

Reference 7 calculates hydrodynamic loads consisting of impulsive and convective pressures caused by the horizontal components of earthquakes and investigates the effects of horizontal components of ground motion on circular cylindrical tanks that are fixed at the base, have a radius a and a height H_s, and are filled to a height H with a liquid of density ρ. The surface of the liquid is considered to be free. The fluid is considered to be incompressible and inviscid, and only linear effects are investigated. Distortion of the tank cross section is not considered.

Reference 7 gives the following equation for the impulsive component, p_o, of the hydrodynamic pressure exerted on the tank wall:

$$p_o(z,\theta,t) \;=\; C\, b_o(z)\, \rho\, H\, A_o(t) \cos\theta \tag{1}$$

in which C is a dimensionless coefficient, $b_o(z)$ is also a dimensionless function and defines the pressure distribution along the height of the tank, and $A_o(t)$ represents the pseudo-acceleration corresponding to the natural frequency of the tank-fluid system for the assumed mode of vibration.

Reference 7 plots the pressure distribution function, b_o, for tanks with values of H/a of 0.5 and 3. The b_o values used in the present investigation were interpolated from those plots.

The factor C in Equation (1) is defined by the following equation:

$$C = \frac{m_x}{m_w} = \frac{m_{x,s} + m_{x,l}}{m_{w,s} + m_{w,l}} \tag{2}$$

The symbol m_x in this equation represents the effective mass of the structure-fluid system for a rigid body motion of the tank, and $m_{x,s}$ and $m_{x,l}$ represent the components contributed by the structural mass and the liquid mass, respectively. In an analogous manner, m_w represents the effective mass of the system when it is vibrating in a deflection configuration specified by the function $\psi(z)$, and $m_{w,s}$ and $m_{w,l}$ are the components contributed by the structural mass and the liquid mass. These quantities are defined by the equations

$$m_{x,s} = \int_0^{H_s} \mu_s(z)\ \psi(z)\ dz + m_r\ \psi(H_s) \tag{3}$$

$$m_{w,s} = \int_0^{H_s} \mu_s(z)\ \psi^2(z)\ dz + m_r\ \psi^2(H_s) \tag{4}$$

in which $\mu_x(z)$ is the mass per unit of height of the structure without the liquid, and m_r is the mass of any concentrated roof loading that may be present at $z = H_s$.

Assuming that the tank-fluid system vibrates in a half-sine curve configuration along its height, values for $m_{x,s}$ and $m_{w,s}$ were calculated from Equations (3) and (4), respectively. Values of $m_{x,l}$ and $m_{w,l}$ were determined from the $m_{x,l}$ and $m_{w,l}$ plots of Reference 7 for tanks with different H/a values. With values of C and b_o known, the impulsive pressures were then calculated.

3.2.2 Convective Pressure

Reference 7 also gives the following equation for the convective pressure, p_k, exerted on the tank wall by the sloshing motion of the liquid:

$$p_k\ (z,\theta,t) = \sum_{k=1}^{\infty} c_k(z)\ A_k(t)\ \rho\ H \cos\theta \tag{5}$$

where

$$c_k(z) = \frac{2}{\lambda_k^2 - 1}\ \frac{a}{h}\ \frac{\cosh(\lambda_k\ z/a)}{\cosh(\lambda_k\ H/a)} \tag{6}$$

and λ_k represents the zero values of the first derivative of the Bessel function of the first kind and first order. $A_k(t)$ is the spectral acceleration that correcponds to the natural frequency of the liquid in sloshing motion.

The individual terms of the series in Equation (5) represent the modal contribution of the portion of the liquid in sloshing motion. Reference 7 shows that effects for larger values of H/a, particularly of the component associated with the second sloshing mode, are concentrated near the free surface and that the values of $c_2(z)$ are substantially smaller than those for $c_1(z)$. Consequently, for the analysis reported here, only effects of the first sloshing mode were considered, and convective pressures were analyzed as static loads.

3.3 Gravity Load and Hydrostatic Pressure

Gravity load refers to the self-weight of the tank, whereas the hydrostatic pressure at a point is equal to the product of the liquid density, ρ, and the height, h, of the liquid. Both gravity load and hydrostatic pressure are static loads and are constant around the circumference of the tank. The values for net in-plane shear and torsion due to these loads are both zero. The hydrostatic pressures that were input to the computer program are calculated on Sheet A-9 (Appendix A, Calculation Sheet 9).

3.4 Vertical Earthquake Component

It was found that the fundamental period of the empty refueling water storage tank is 0.033 sec in the vertical direction. Thus, it was assumed initially that the tank and the fluid act as a rigid mass during vertical motion, and effects of the vertical earthquake component were obtained by scaling the stresses caused by gravity load and hydrostatic pressure by 0.5 (2/3 of the maximum horizontal ground acceleration; i.e., 2/3 x 0.75g = 0.50g). This assumption was used in the axisymmetric phase of the investigation.

At the present time, there is no accepted procedure for analyzing the fluid motion in a tank that results from the vertical earthquake component. To consider the possibility that the fluid may not act as a rigid mass during vertical motion, an amplification factor of 2 (i.e., the acceleration at zero period of 0.5g is amplified to a value of 1.0g) was used in the non-axisymmetric phase of the investigation. Effects of the vertical component were then obtained by scaling the sum of the dead load and hydrostatic pressure stresses by 1.0.

3.5 Load Combination

Responses due to the two horizontal components and the vertical component of the 7.5M Hosgri ground motion were combined by the square-root-of-sum-of-squares (SRSS) method. That is:

$$EQ = \sqrt{(HE_1)^2 + (HE_2)^2 + (VE)^2} \qquad (7)$$

where

EQ = total earthquake response

HE_1, HE_2 = the responses due to the two horizontal components of the ground motion, respectively

VE = response due to the vertical component of the ground motion

Each of the responses HE_1 and HE_2 is obtained by taking the absolute sum of the responses due to structure inertial forces, impulsive pressure, and convective pressure.

The total load used to calculate stresses is obtained as follows:

$$TL = DL + HS + EQ \quad (8)$$

where

TL = total load

DL = dead load

HS = hydrostatic pressure

EQ = earthquake response, as defined by Equation (7).

3.6 Allowable Stresses

3.6.1 Reinforced Concrete

The capacities of reinforced concrete structural members were determined in accordance with "Structural Analysis and Proportioning of Members - Ultimate Strength Design," given in ACI 318-71,[8] except that unit load factors were used for combining loads.

3.6.2 Structural Steel

The capacities of structural steel members other than plates were based on the seventh edition of the AISC *Manual of Steel Construction*.[9] The capacities of structural steel plates were based on *ASME Boiler and Pressure Vessel Code, Section VIII, Division 2*,[5] and API Standard 620,[10] with the exception that the capacities of the plates for the load combination $DL + HS + EQ$ were taken to be 1.5 times the load combination $DL + HS$. (These codes give factors of 1.2 or 1.25 for EQ, which are interpreted as applying to the operating-basis earthquake.)

4. AXISYMMETRIC ANALYSIS

4.1 Refueling Water Storage Tank

4.1.1 Axisymmetric Computer Model

The basic axisymmetric finite-element model used in the analysis of the refueling water storage tank is shown in Figure 5. The tank was assumed fixed at the base. The model consisted of 30 nodes, 29 steel shell elements, and 29 concrete shell elements. The steel shell liner and the concrete cover were modeled as axisymmetric shell elements parallel to each other. The global coordinates (R,Z) of the nodal points are given on Sheet A-1. Material properties for steel and concrete are given on Sheet A-2. The model was used to analyze for the following effects:

- gravity loading
- hydrostatic pressure
- structure inertial forces
- hydrodynamic loads consisting of impulsive and convective pressures caused by the horizontal components of earthquake motion

AXIDYN,[2] a computer program for the static and dynamic analysis of axisymmetric structures by the finite-element method, was used in all the analysis runs.

4.1.2 Analysis Approach

Horizontal ground motion generates structure inertial forces and hydrodynamic pressures (impulsive pressure and convective pressure acting on the tank wall). For the analysis reported here, the combined dynamic effects of structure inertial forces and impulsive pressures were determined in one computer run. Effects of convective pressures were determined in a separate run. This two-step procedure was used because the frequency differences between the tank motion and the liquid sloshing motion were expected to be large; thus, coupling between the two motions would be negligible. The total effect of the horizontal earthquake components was obtained by taking the absolute sum of the results of the two runs.

To determine in one computer run the combined dynamic effects of both structure inertial forces and impulsive pressures, the method adopted here entails first determining an equivalent effective fluid (impulsive) mass, m_{eff}, then adding it to the structure mass, and finally subjecting the tank with the combined mass to the horizontal earthquake motion. The resulting stresses thus include effects of both inertial forces and impulsive pressures.

The impulsive pressures, calculated from Equation (1), act normal to the tank wall, and the magnitude varies over the circumference as a cosine function of the angle θ from the direction of the applied ground motion. The impulsive pressure (p_o) variation around the circumference is shown in Figure 6. Initially, the procedure adopted in the dynamic analysis of the refueling water storage tank for impulsive pressures was to simulate the computed impulsive pressure in terms of an equivalent shell with mass density ρ_e, thickness t, and radius a, but with no stiffness.

From Equation (1), the effective fluid mass, m_{eff}, causing an impulsive pressure, p_o, can be expressed as follows:

$$m_{eff} = \frac{p_o}{A_o} = C\, b_o(z)\, \rho H \cos\theta \tag{9}$$

By definition, the mass of a shell per foot of circumference per foot of height is:

$$m_{eff} = \rho_e t \tag{10}$$

Therefore:

$$\rho_e\, t = \frac{p_o}{A_o} \tag{11}$$

and

$$\rho_e = \frac{C\, b_o(z)\ \rho H \cos\theta}{t} = \frac{\tilde{p}_o}{t} \tag{12}$$

where $\tilde{p}_o$ is pressure for A_o equal to a unit acceleration.

The above equation for equivalent fluid density, ρ_e, was used in the calculations shown on Sheet A-7 assuming a shell thickness of 0.25 ft. In the final computer run, however, the fluid inertial force (mass) was assumed to be attached to the concrete shell elements. The equivalent fluid inertial force (mass) previously calculated was therefore modified so that the fluid density is based on a thickness equal to the corresponding concrete element thickness:

$$\rho_{e_{\text{mod}}} = \rho_e \frac{t}{t_c} \tag{13}$$

where t_c is the thickness of the concrete element. The concrete-plus-fluid-element mass density was obtained by adding the concrete density, ρ_e, and the fluid density, $\rho_{e_{\text{mod}}}$.

According to Equation (9), m_{eff} varies as cosine θ over the circumference. However, the computer program AXIDYN assumes an axisymmetric structure and thus requires a constant value of m_{eff} over the circumference.

The constant equivalent mass, m^k_{eff}, is defined as follows:

$$m^k_{\text{eff}} = \frac{m_{\text{eff}}}{\cos\theta} = C\, b_o(z)\ \rho H \tag{14}$$

The horizontal pressure, p_h, exerted on the tank wall by an m^k_{eff} as a result of horizontal acceleration is given by:

$$p_h = m^k_{\text{eff}}\, A \tag{15}$$

and is shown in Figure 7a as a constant pressure over the circumference. AXIDYN analyses p_h as the sum of two components: (1) a radial component, p_r (see Figure 7b), which varies over the circumference as the cosine function of the angle θ, and (2) a tangential component, p_t (see Figure 7c), which varies as the sine function of θ. Figure 7d shows the resultant pressure, p_h, and its components, p_r and p_t. From Figure 7d and from Equations (14) and (15), it follows that:

$$p_r = p_h \cos\theta = m^k_{\text{eff}} A \cos\theta = C\, b_o(z)\, \rho HA \cos\theta \qquad (16)$$

and

$$p_t = p_h \sin\theta = m^k_{\text{eff}} A \sin\theta = C\, b_o(z)\, \rho HA \sin\theta \qquad (17)$$

Note that the impulsive pressure defined in Equation (1) and shown in Figure 6 is equal to the radial pressure defined in Equation (17) and shown in Figure 7b. The tangential pressure, p_t, shown in Figure 7c is an additional loading being considered here. Thus, because of the use of a (heavier) constant mass m^k_{eff} instead of an m_{eff} that varies with cosine θ and because of the additional effects of the tangential pressure shown in Figure 7c, the procedure adopted here gives conservative results.

The impulsive pressure determined from Equation (1) represents only the contribution of the mode being considered, with $A_o(t)$ representing the spectral acceleration corresponding to the assumed mode of vibration. It was therefore necessary to determine and consider contributions of all other significant modes of vibration. Calculations for the impulsive pressure defined by Equation (1) are shown on Sheets A-3 to A-7. A value of C equal to 1.37 was determined. Calculations for the fluid density, $\rho_{e_{\text{mod}}}$, are shown on Sheet A-8.

With the combined structure mass and equivalent effective fluid mass as input, a dynamic analysis of the tank for effects of structure inertial forces and impulsive pressure was performed using the computer program AXIDYN. The response-spectrum, modal-superposition approach was used with a cut-off period of 0.30 sec. The periods of vibration and the percentage

modal participation factors obtained are summarized on Sheet A-17. A damping ratio of 7% was used for all of the seven significant modes.

Studies in the literature indicate that consideration of the foundation and soil flexibility would lengthen the periods of vibration, mainly that of the fundamental mode. To take this into account, peak ground spectral acceleration was used as the spectral acceleration corresponding to the fundamental mode of vibration, regardless of the value of the fundamental period.

Only the combined loading from structure inertial forces and impulsive pressure caused by horizontal earthquake motion was analyzed dynamically. Gravity, hydrostatic pressure, and convective pressure loads were analyzed statically. Effects of the vertical earthquake component were obtained by scaling the results of the analysis for gravity loading and hydrostatic pressure by 0.5.

The calculations for convective pressures, based on Equation (5), are shown on Sheets A-10 to A-13. The fundamental period of the sloshing motion of the liquid was calculated to be 3.65 sec (see Sheet A-12); for 1% damping, the corresponding spectral acceleration is 0.171g, or 5.51 ft/sec^2. Note that the fundamental mode of the tank motion has a period of 0.132 sec (see Sheet A-17). As expected, the frequency difference of the tank motion and the sloshing motion of the liquid is large, which justifies the assumption that coupling between the two motions is negligible.

4.1.3 Discussion of Results

The longitudinal forces and moments, circumferential forces and moments, and in-plane shears at critical points in the steel liner and concrete cover that were obtained from the analysis runs are summarized on Sheets A-18 to A-21. The summaries indicate that impulsive pressure loading and, to a lesser degree, hydrostatic pressure loading contribute most to the total forces and moments. Increases in stresses that might occur because of a partial restraining effect of the dome on the sloshing motion of the liquid are disregarded because convective pressures themselves are very small in comparison with impulsive pressure loading. Moments in the steel liner are negligible. Longitudinal and circumferential forces and moments due to impulsive pressure loading are plotted on Sheets A-22 to A-25.

Preliminary design of the concrete cover and checking of stresses in the steel liner were carried out using the results of the axisymmetric analysis. The stress intensities in the steel elements are presented in Table 1.

4.2 Firewater and Transfer Tank

The firewater and transfer tank model, shown on Figure 8, is analyzed for effects of gravity loading, hydrostatic pressure, and horizontal and vertical earthquake components. The analytical procedures used in the analysis of the refueling water storage tank were used in this analysis, also, and thus are not discussed here.

Modeling and analysis of the firewater and transfer tank were based on the preliminary sizing of the thickness of the concrete cover. The original thickness of concrete cover was 12 in. up to about 8 ft above the base and 8 in. for the remainder. Results of the refueling water storage tank analysis indicate that the concrete cover should have a 12-in. thickness up to the mid-height of the tank, which is about 25 ft above the base.

Modeling, loading, and stress calculations are provided in Appendix B. The basic axisymmetric finite-element model used to analyze the firewater and transfer tank is shown on Sheet B-1. The steel sections and the concrete cover were modeled as axisymmetric shell elements. The model consisted of 46 nodes, 27 concrete shell elements, and 45 steel shell elements. The exterior tank was assumed to be fixed at the base, whereas the inner steel tank was considered to be pinned at the base.

Two loading conditions were considered:

- Case 1, in which both inner and outer cylindrical tanks are filled with water up to design level
- Case 2, in which the inner tank is filled to design level and the outer tank is empty

A third case, in which the inner tank is empty and the outer tank filled to design level, was not considered because buckling of the inner tank will not affect the structural integrity of the outer (transfer) tank or the safety requirements of the system. A set of analyses for effects of hydrostatic

pressure and the horizontal and vertical earthquake components was performed for the two cases considered. For the first case, it was assumed that the fluid exerts hydrostatic, impulsive, and convective pressures on the outer tank only. For the second case, the fluid was assumed to exert these pressures on the inner tank only.

Because fluid impulsive pressure is essentially exerted only on the exterior concrete tank and because large inertial forces are generated on the concrete shell, damping of 7%, which is the damping specified for concrete structures by NRC *Regulatory Guide 1.61*,[11] was used in the dynamic analysis of the combined effects of structure inertial forces and impulsive pressure for Case 1.

In the analysis for Case 2, however, while large inertial forces are generated on the concrete shell, impulsive forces, also, act on the interior steel tank. Thus, a modified damping value was calculated to consider the lower (4%) damping value specified for steel structures by NRC *Regulatory Guide 1.61*.

The modified damping value was calculated from the first mode, using the following:

$$\lambda = \frac{\sum m_c \phi^2{}_c \lambda_c + \sum m_s \phi^2{}_s \lambda_s}{\sum m_c \phi^2{}_c + \sum m_s \phi^2{}_s} \qquad (18)$$

where

λ = the modified damping value

m_c, m_s = mass of the concrete and steel shell elements, respectively

λ_c, λ_s = damping specified by NRC *Regulatory Guide 1.61* for concrete and steel, respectively.

The calculations on Sheets B-26 to B-29 give a modified damping value of 6.3%. Because there is no spectrum specified for 6.3% damping, the more conservative 5%-damped Newmark spectrum shown on Figure 4 was used in the analysis for Case 2.

Longitudinal forces and moments, circumferential forces and moments, and in-plane shears at critical points in the two steel tanks and concrete cover

for Case 1 and Case 2 are summarized on Sheets B-31 to B-35. The more critical value from the two sets of total forces and moments was used to check critical sections in the tank. As in the case of the refueling water storage tank, the summaries indicate that the impulsive pressure loading and the hydrostatic pressure loading contribute the most to the total forces and moments and that moments in the steel sections are negligible. The maximum stress intensity in each steel liner section was determined and is compared in Tables 2 and 3 with the allowable stress intensity in the liner section. The steel plate will be reinforced to reduce stresses to be within allowable intensity.

A comparison of the design forces and moments in the concrete elements of the transfer tank and refueling water storage tank at corresponding levels is presented in Table 4. The comparison indicates that the values for the former tank are less than for the latter tank at corresponding concrete elements. Therefore, the type of steel reinforcement that is provided for the concrete cover of the refueling water storage tank will be adequate for the transfer tank as well.

4.3 Condensate Tank

The structure configuration of the condensate tank is very similar to that of the refueling water storage tank. The tanks have the same inside diameter. The height of the condensate tank and its design liquid depth are both 5.25 ft less than the height and liquid depth of the refueling water storage tank. Because of the similarity between the two tanks, it is felt that results of the analysis of the refueling water tank apply also to the condensate tank. The steel plates specified for the condensate tank are slightly thicker and are made of stronger material than those for the refueling water storage tank and should therefore be adequate. Conservatively assuming that the same forces occur in the refueling water storage tank and the condensate tank, revised stresses in the steel shell elements of the condensate tank are calculated from actual thicknesses (see Sheets C-1 to C-4). Maximum stress intensity at each steel liner section is presented in Table 5. The steel plate will be reinforced to reduce stresses to be within allowable intensity. A concrete cover with steel reinforcement that is the same as that specified for the refueling water storage tank is adequate for the condensate tank as well.

5. NON-AXISYMMETRIC ANALYSIS OF THE REFUELING WATER STORAGE TANK

5.1 Purpose

In the earlier dynamic analysis, the refueling water storage tank was assumed to be an axisymmetric shell structure and was analyzed using the AXIDYN[2] program. That analysis, however, did not take into account a 14-ft x 14-ft vault opening in the concrete shell. To get a clearer understanding of the stress distribution in the concrete and steel shell elements in and around the opening area, a more comprehensive, three-dimensional model was made. Thin shell elements and the concrete shell opening were included in the model, and it was analyzed using the computer program SAP IV.[3] Loads were applied statically.

Two distinct features of the SAP IV static analyses of the tank were (1) the consideration of the 14-ft x 14-ft opening in the concrete shell and (2) the application of horizontal earthquake loads as equivalent static lateral loads based on the SRSS accelerations computed from the AXIDYN (dynamic) analysis. The equivalent static lateral loads included the impulsive pressures.

5.2 Non-Axisymmetric Half-Tank Computer Model

Because the tank is symmetrical about the centerline through the opening, only one-half of the tank was modeled. Quadrilateral shell elements were used to model all steel and concrete members except for the concrete framing around the opening. Beam elements were used to model the heavy concrete framing. The three-dimensional half-tank model is shown in Figure 9. It consists of 408 nodes, 360 steel shell elements, 348 concrete shell elements, and 13 concrete beam elements. The tank was fixed at the base against all six degrees of freedom. Because of computer program limitations, and for modeling convenience, a 1-ft-diameter opening was left at the crown of the dome. The nodes, steel shell elements, concrete shell elements, and concrete beam elements are shown in Figures 10 to 13.

Appropriate boundary conditions at the plane of symmetry of the tank structure, i.e., at nodes located on the z-y plane (see Figure 10), were determined by the nature (symmetric or anti-symmetric) of the loading considered. Dead load and the load from the horizontal earthquake component along the z-z axis are symmetric with respect to the z-y plane. On the other hand, horizontal earthquake load along the x-x axis is anti-symmetric with respect to the z-y plane.

For symmetric loading, joints on planes of symmetry are restrained in such a way that they displace only in those planes. Thus, for dead load and horizontal earthquake load along the z-z axis, joints of the y-z plane, for example, were allowed to displace only in the y and z directions and to rotate only about the x axis. For anti-symmetric loading, joints on planes of symmetry were compelled to displace in an anti-symmetric manner. Thus, for the case where the horizontal earthquake component is acting along the x axis, joints located on the y-z plane were restrained against translational motion in the plane of anti-symmetry and rotation normal to the plane. This modeling technique is discussed further elsewhere.[12]

5.3 Analysis Approach

Using the SAP IV three-dimensional model, a new set of static analysis runs was performed to determine the effects of gravity loading and hydrostatic pressure. Calculations for the hydrostatic pressure input to the program are given on Sheet D-3.

Effects of convective pressure caused by horizontal ground motion were observed to be small in the AXIDYN analysis and thus were not considered significant enough to require further analysis with the SAP IV model. Thus the seismic forces that result from horizontal ground motion principally consist of: (1) the lateral forces contributed by the impulsive pressures imposed on the tank by the contained liquid and (2) the lateral forces contributed by inertial forces of the tanks themselves.

The SAP IV model was analyzed for two cases of the effects of horizontal ground motion: first, when it acts along the x-x axis and, second, when it acts along the z-z axis. Calculations for the effects of structure inertial

forces and impulsive pressures were simplified by using the accelerations obtained from the earlier axisymmetric analysis. Loads from structure inertial forces were calculated by multiplying the mass of an element by the corresponding acceleration obtained from the AXIDYN analysis, and the results were then applied statically to the SAP IV model. Calculation of impulsive pressures is explained in the following paragraphs.

In the earlier axisymmetric analysis, impulsive pressure was input into the AXIDYN program in terms of an equivalent impulsive mass density. This method did not allow for a cosine θ variation along the circumference of the tank. For the SAP IV analysis, the cosine θ variation in the fluid impulsive pressure is taken into account.

A plot of the variation of impulsive mass density along the height of the tank structure is shown on the left-hand side of Sheet D-5. The impulsive mass density plotted is for θ equal to zero and is based on a unit acceleration. On the right-hand side of Sheet D-5 is a plot of the SRSS values of radial accelerations obtained from the earlier AXIDYN analysis. Corresponding SAP IV nodes and AXIDYN nodes are also indicated along the vertical axis of the plot.

From Equation (11), the radial impulsive pressure acting on an element can be expressed as follows:

$$p_o = \rho_e t A_o \tag{19}$$

where

ρ_e = equivalent fluid density as defined in Equation (12), varying as a cosine function along the circumference

t = assumed fluid thickness

A_o = acceleration of the element based on AXIDYN results

The calculations for the impulsive pressures acting on the steel and concrete shell elements are given on Sheets D-8 to D-11. These impulsive pressure loads were then applied statically to the model shown in Figure 9 and were analyzed using SAP IV.

5.4 Discussion of Results

Direct stresses and moments, obtained from the SAP IV analysis runs for dead load, hydrostatic pressure, and horizontal earthquake motion along the x-x and z-z axes, at critical points in the steel liner and concrete cover are given on Sheets D-12 to D-25. The values used for responses to vertical earthquake motion correspond to an amplification of 2 (that is, from zero period acceleration of 0.5g to a value of 1.0g) and thus are equal to the sum of the results of the dead load and hydrostatic pressure analyses.

Stresses in critical steel sections are presented on Sheets D-32 to D-33. Table 6 gives the stress intensity values at critical points in the steel liner section. The allowable stress intensity is exceeded at two sections in the concrete shell opening area. The steel plate will be reinforced to reduce stresses to be within allowable intensity.

The concrete cover, including the concrete framing around the vault opening, was designed for whichever value from the two analyses (axisymmetric and non-axisymmetric) was the more critical. Design calculations are given on Sheets D-36 to D-47. Comparison of design strength and required strength of concrete liner sections considering the steel reinforcement provided is given in Table 7. A typical section of concrete cover, showing the required steel reinforcement, is shown in Figure 14. Steel reinforcement details for the concrete framing are shown in Figure 15.

The assumption that the axisymmetric analysis would yield relatively more conservative results than those from the non-axisymmetric analysis is generally established in the comparisons presented on Sheet D-30 and Sheet D-31. Where such conservatism was not reflected, the magnitudes of forces and moments from the two analyses may be attributed to one or more of the following reasons:

- A uniform acceleration of 0.75g was considered up to a height of 14 ft above the base in the non-axisymmetric analysis. In the axisymmetric analysis, however, the radial accelerations vary from zero value at the base to 0.75g at a height of 14 ft. Above 14 ft, the analyses considered the same accelerations.

- The nature of applied loading is different for the two analyses. The axisymmetric model was analyzed for a dynamic loading, whereas the non-axisymmetric model was analyzed for an equivalent static loading.
- There are basic differences between the two models. The axisymmetric model has only steel and concrete shell elements, whereas the non-axisymmetric model includes a heavy concrete frame with beam elements and has a 14-ft x 14-ft opening in the concrete shell.

A comparison of base shears and overturning moments obtained from the axisymmetric and non-axisymmetric analyses is presented on Sheet D-30. The longitudinal, circumferential, and shear forces obtained from the two analyses at four corresponding locations are compared on Sheet D-31.

Results of the axisymmetric analyses are summarized on Sheets A-18 to A-21 and on Sheets A-26 to A-29. Axisymmetric analysis results consist of:

- a dynamic analysis, with the combined structure mass and equivalent fluid mass as input, to obtain the effects of structure inertial forces and uniform impulsive pressure (as described in Section 4.1.2)
- an approximate static analysis, using only the first-mode accelerations (obtained from the above-mentioned dynamic analysis), to obtain the effects of the tangential pressure load

Non-axisymmetric analysis considered both the vault opening in the concrete shell and the cosine variation of the impulsive pressure. Thus the resulting output values for horizontal earthquake motion in either direction (seismic force in x-x direction was considered for comparison on Sheet D-30) represent the actual state of the stresses in the structure that would result in the event of lateral seismic motion.

6. SUMMARY AND CONCLUSIONS

The Category I outdoor water storage tanks of Units 1 and 2 of the Diablo Canyon Nuclear Power Plant were analyzed for the postulated 7.5M Hosgri earthquake. The tanks considered to be Category I are the refueling water storage tanks, the firewater and transfer tank, and the condensate tank.

Axisymmetric analyses were made for the refueling water storage tank and the double-walled firewater and transfer tank. The forces and moments resulting from the analyses were used to check critical sections of the steel liners and concrete cover of each tank. The results from analysis of the refueling water storage tank were used to check the smaller condensate tank.

Because of the large openings in each of the concrete shells, a non-axisymmetric analysis of the refueling water storage tank was made. This finite-element analysis was made to properly consider the distribution of stress in the tank. The results of this analysis were again used to check the critical steel and concrete sections of the tank. The results from the non-axisymmetric analysis of the refueling water storage tank were used to check the other two tanks. The non-axisymmetric distribution of stresses necessitated reinforcement of the steel liner in the vault opening areas of the tanks.

The extensive analyses carried out demonstrate the ability of the Category I outdoor water storage tanks with the proposed modifications to safely withstand the Hosgri 7.5M earthquake motions.

7. REFERENCES

1. URS/John A. Blume & Associates, Engineers, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake* (Preliminary), revised February 8, 1977.

2. Ghosh, S., and E. Wilson, *Dynamic Stress Analysis of Axisymmetric Structures Under Arbitrary Loading*, EERC 69-10, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, June 1973.

3. Bathe, K-J., E. L. Wilson, and F. E. Peterson, *SAP IV, A Structural Analysis Program for Static and Dynamic Response of Linear Systems*, EERC 73-11, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, June 1973.

4. Harding-Lawson Associates, *Geotechnical Studies - Intake Structure, Water Storage Tanks, Diesel Fuel Oil Storage Tanks - Diablo Canyon Nuclear Power Plant, San Luis Obispo County, California*, April 1978.

5. American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Alternative Rules for Pressure Vessels*, New York, 1974.

6. U.S. Atomic Energy Commission, *Nuclear Reactors and Earthquakes*, TID 7024, Washington, D.C., August 1963.

7. Veletsos, A. S., and J. Y. Yang, *Dynamics of Fixed-Base Liquid Storage Tanks*, Proceedings of U.S. - Japan Seminar on Earthquake Engineering Research with Emphasis on Lifeline Systems, Tokyo, November 1976.

8. American Concrete Institute, *Building Code Requirements for Reinforced Concrete*, ACI 318-71, Detroit, 1971.

9. American Institute of Steel Construction, *Manual of Steel Construction*, 7th edition, New York, February 1969.

10. American Petroleum Institute, *API Standard 620, Recommended Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, 5th edition, Washington, D.C., July 1973.

11. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61, *Damping Values for Seismic Design of Nuclear Power Plants*, Washington, D.C., October 1973.

12. Weaver, William, Jr., *Computer Programs for Structural Analysis*, Van Nostrand, Princeton, 1967.

TABLE 1

DIABLO CANYON UNITS 1 AND 2

REFUELING WATER STORAGE TANK:

MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

(AXIDYN ANALYSIS, AXISYMMETRIC MODEL)

Nodal Points	Plate Thickness, in.	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
		DL + HS	DL + HS + HE + VE	DL + HS	DL + HS + HE + VE
1 - 6	0.578	3.58	18.40*	16.7	25.05
6 - 9	0.490	4.52	19.63*	16.7	25.05
9 - 12	0.356	4.59	13.33	16.7	25.05
12 - 15	0.275	3.64	17.25	16.7	25.05
15 - 30	0.250	2.17	12.12	16.7	25.05

NOTE: DL = dead load

HS = hydrostatic pressure

HE = horizontal earthquake component

VE = vertical earthquake component

*On the basis of analysis of a non-axisymmetric model of the refueling tank using the SAP IV computer program, the plate will be reinforced to reduce stresses to be within allowable stress intensity (see Table 6).

TABLE 2
DIABLO CANYON UNITS 1 AND 2
FIREWATER TANK:
MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS
(AXIDYN ANALYSIS, AXISYMMETRIC MODEL)

Nodal Points	Plate Thickness, in.	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
		DL + HS	DL + HS + HE + VE	DL + HS	DL + HS + HE + VE
46 - 43	0.813	8.20	21.38	18.3	27.45
43 - 40	0.688	5.59	20.87	18.3	27.45
40 - 37	0.625	5.20	19.77	18.3	27.45
37 - 34	0.531	4.59	18.48	18.3	27.45
34 - 28	0.438	3.89	17.04	18.3	27.45
28 - 22	0.375	3.17	24.93	18.3	27.45

NOTE: DL = dead load
HS = hydrostatic pressure
HE = horizontal earthquake component
VE = vertical earthquake component

TABLE 3

DIABLO CANYON UNITS 1 AND 2

TRANSFER TANK:

MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

(AXIDYN ANALYSIS, AXISYMMETRIC MODEL)

Nodal Points	Plate Thickness, in.	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
		DL + HS	DL + HS + HE + VE	DL + HE	DL + HS + HE + VE
1 - 6	0.627	3.63	15.36*	18.3	27.45
6 - 9	0.522	3.55	16.06*	18.3	27.45
9 - 12	0.417	3.39	14.46	18.3	27.45
12 - 15	0.313	2.70	11.92	18.3	27.45
15 - 33	0.250	1.60	9.39	18.3	27.45

NOTE: DL = dead load; HS = hydrostatic pressure; HE = horizontal earthquake component; VE = vertical earthquake component

*On the basis of analysis of a non-axisymmetric model of the refueling tank using the SAP IV computer program, the plate will be reinforced to reduce stresses to be within allowable stress intensity (see Table 6).

TABLE 4

DIABLO CANYON UNITS 1 AND 2

REFUELING WATER STORAGE TANK AND TRANSFER TANK:

COMPARISON OF FORCES AND MOMENTS IN CONCRETE ELEMENTS

(AXIDYN ANALYSES, AXISYMMETRIC MODELS)

Nodal Point	Force, kip			Moment, kip/ft	
	Longitudinal	Circumferential	Shear	Longitudinal	Circumferential
Refueling Water Storage Tank					
1	206.6	46.1	102.9	83.9	16.7
2	168.8	40.8	95.4	37.5	7.6
4	139.3	63.1	89.9	5.1	1.1
6	125.6	57.0	90.8	4.2	1.0
22	3.6	41.9	4.6	1.7	0.5
Firewater and Transfer Tank					
1	157.3	31.5	87.3	72.5	14.5
2	160.4	46.8	82.9	25.0	6.9
4	103.1	68.6	74.7	5.0	1.1
6	86.2	56.6	74.6	2.2	0.6
18	8.4	36.6	34.6	3.0	0.7

TABLE 5

DIABLO CANYON UNITS 1 AND 2

CONDENSATE TANK:

MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

(AXIDYN ANALYSIS, AXISYMMETRIC MODEL)

Plate Thickness, in.	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
	DL + HS	DL + HS + HE + VE	DL + HS	DL + HS + HE + VE
0.600	3.84	18.13*	18.3	27.45
0.500	5.07	20.80*	18.3	27.45
0.398	4.87	18.83	18.3	27.45
0.297	4.26	17.29	18.3	27.45
0.250	2.89	13.24	18.3	27.45

NOTE: DL = dead load

HS = hydrostatic pressure

HE = horizontal earthquake component

VE = vertical earthquake component

*On the basis of analysis of a non-axisymmetric model of the refueling tank using the SAP IV computer program, the plate will be reinforced to reduce stresses to be within allowable stress intensity (see Table 6).

TABLE 6

DIABLO CANYON UNITS 1 AND 2

REFUELING WATER STORAGE TANK:

MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

(SAP IV ANALYSIS, NON-AXISYMMETRIC MODEL)

Element Number	Plate Thickness, in.	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
		DL + HS	DL + HS + HE + VE	DL + HS	DL + HS + HE + VE
49	0.578	11.12	23.86*	16.7	25.05
65	0.490	12.22	26.56*	16.7	25.05
156	0.356	2.59	10.50	16.7	25.05
196	0.275	2.82	11.90	16.7	25.05
231	0.250	2.05	8.62	16.7	25.05

NOTE: DL = dead load; HS = hydrostatic pressure; HE = horizontal earthquake component; VE = vertical earthquake component

*The plate will be reinforced to reduce stresses to be within allowable stress intensity.

TABLE 7

DIABLO CANYON UNITS 1 AND 2
REFUELING WATER STORAGE TANK:
STRENGTH COMPARISON OF CONCRETE ELEMENTS
(SAP IV ANALYSIS, NON-AXISYMMETRIC MODEL)

Element Number	Moment, kip/kip-ft				Force, kip/ft				Shear, kip/ft	
	Longitudinal		Circumferential		Longitudinal		Circumferential			
	Required Strength	Design Strength	Required Strength	Design Strength	Required Strength	Design Strength	Required Strength	Design Strength	Required Strength	Design Strength
534	0.97	19.72	0.80	19.72	35.78	238.57	56.01	238.57	50.22	92.18
463	0.86	97.30	1.15	35.56	68.30	492.24	72.42	329.96	60.88	156.41
386	0.76	71.78	3.84	35.56	102.10	400.96	41.79	329.96	65.16	156.41
375	4.08	71.78	20.21	35.56	107.15	400.96	25.23	329.96	60.46	156.41

NOTE: Calculations based on 1-ft-width beam.

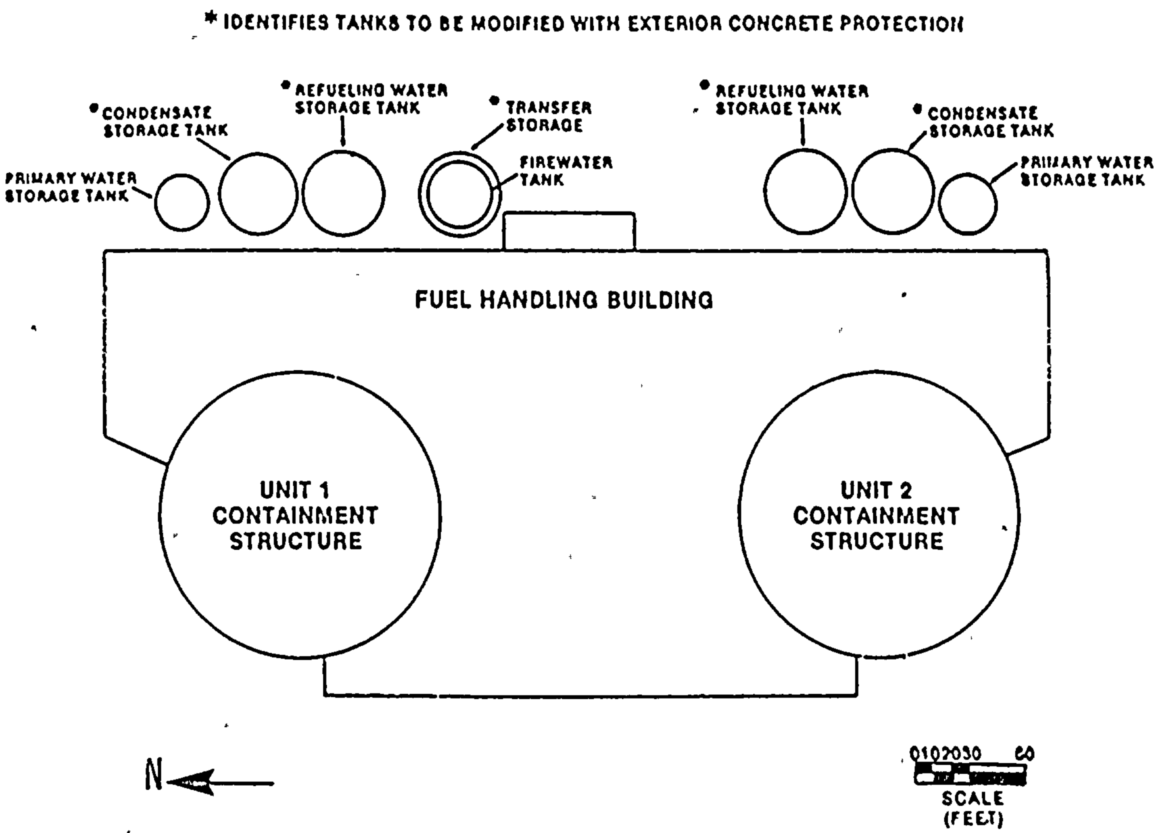
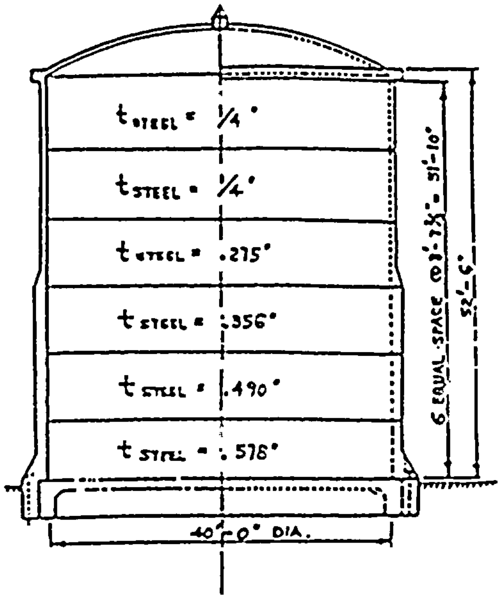
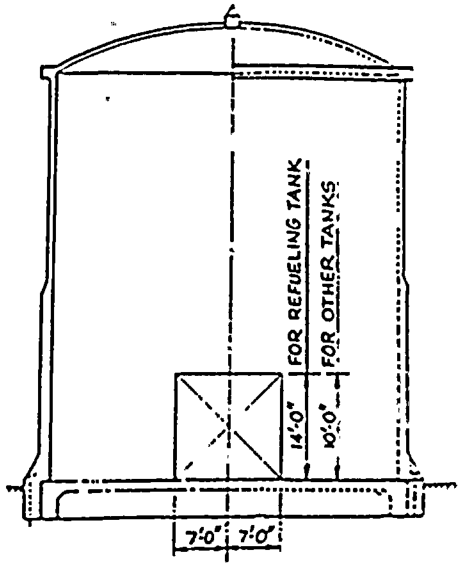


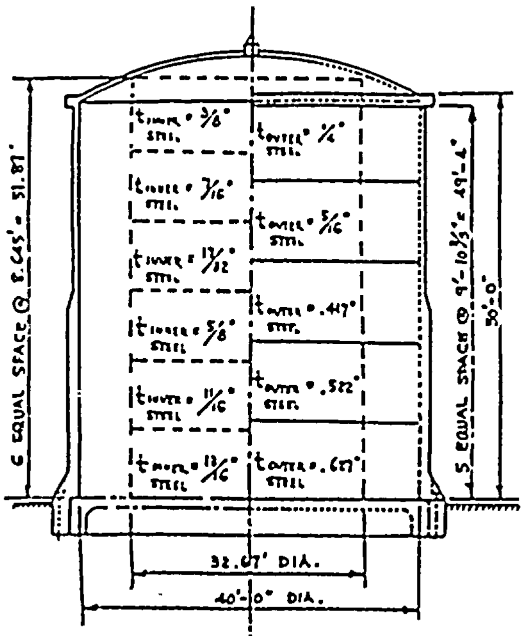
FIGURE 1 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: SITE PLAN



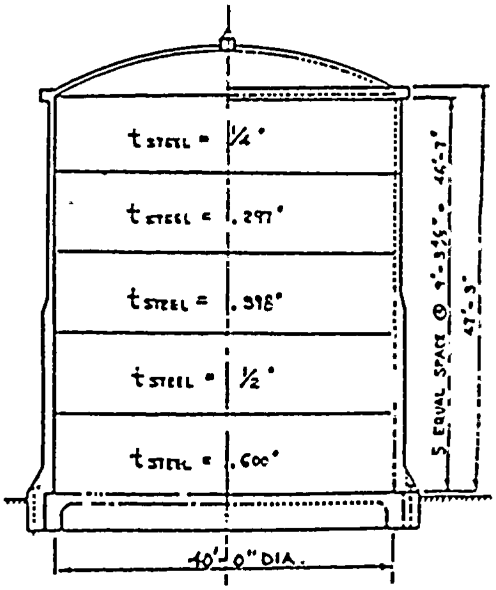
2a. Refueling Water Storage Tank



2b. Typical Vault Opening in Concrete Shell of Storage Tanks



2c. Firewater and Transfer Tank



2d. Condensate Tank

FIGURE 2 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER
WATER STORAGE TANKS: SECTIONS OF TANKS

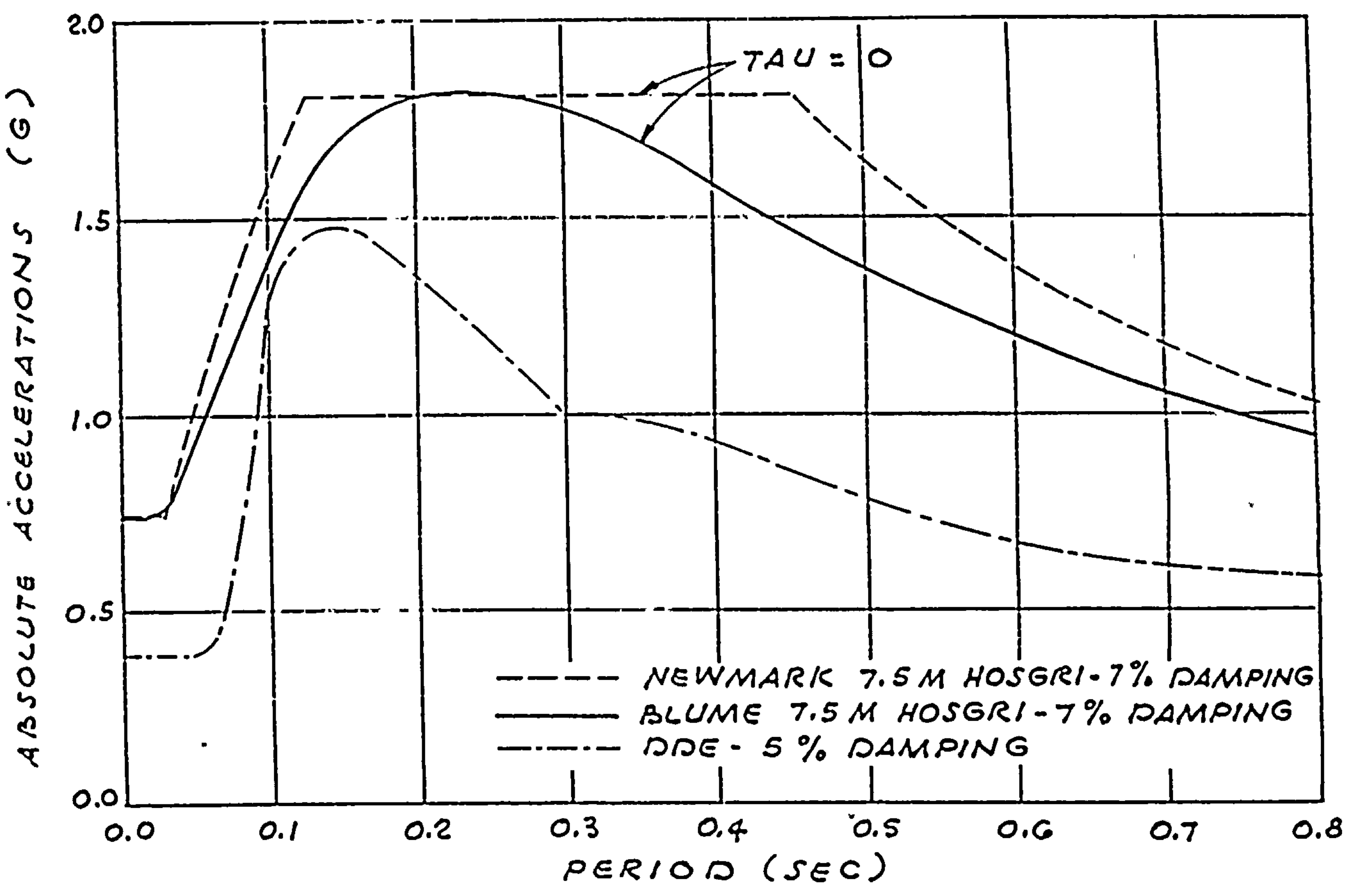


FIGURE 3 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: BLUME AND NEWMARK 7.5M HOSGRI SPECTRA, 7% DAMPING

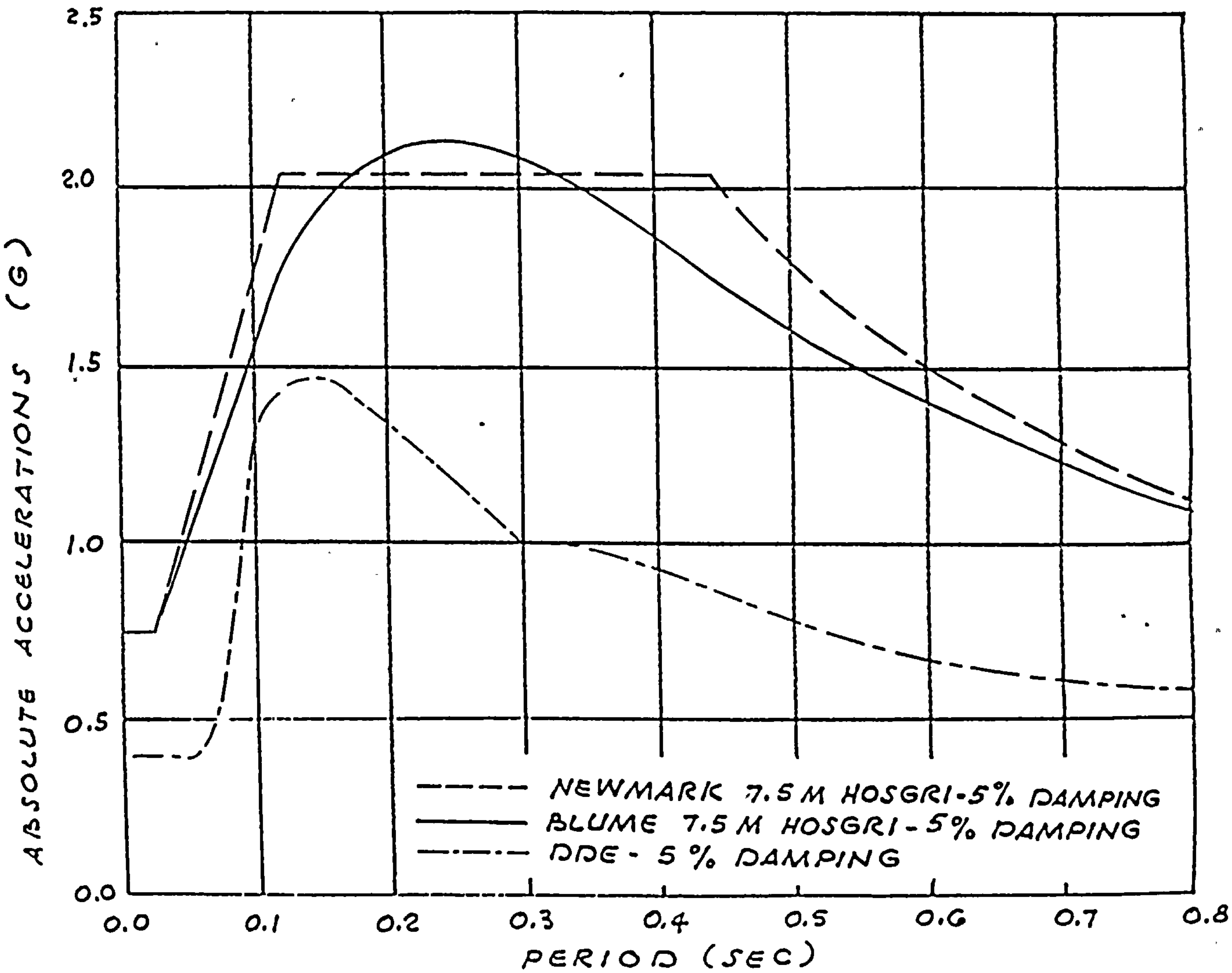


FIGURE 4 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: BLUME AND NEWMARK 7.5M HOSGRI SPECTRA, 5% DAMPING

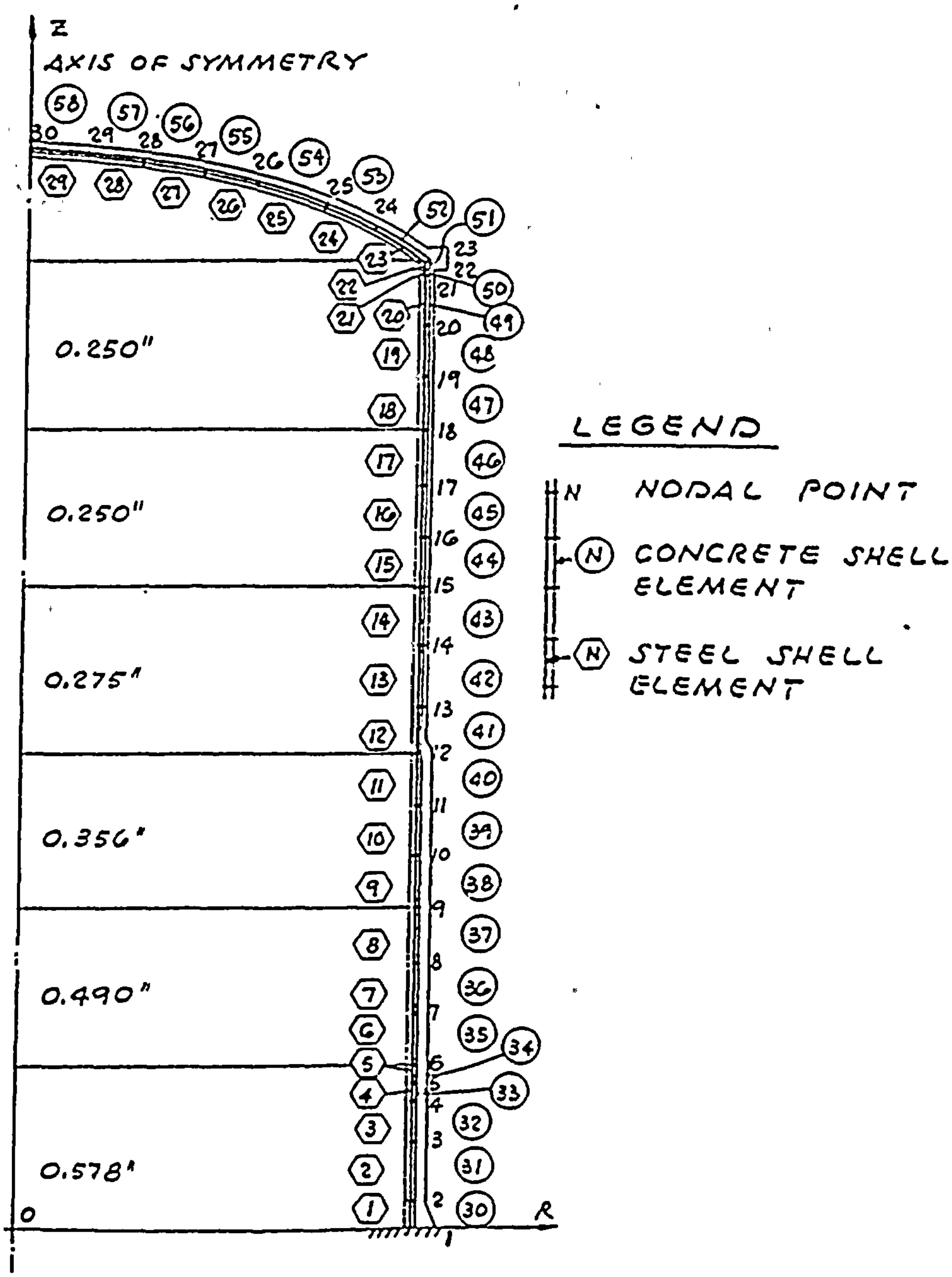
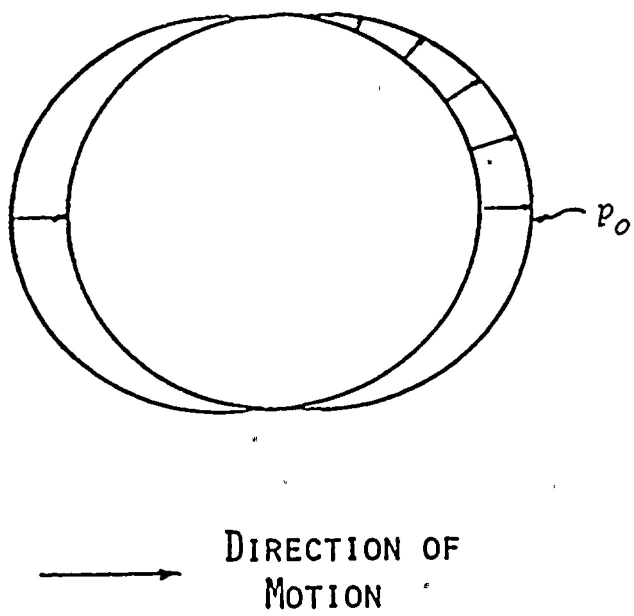


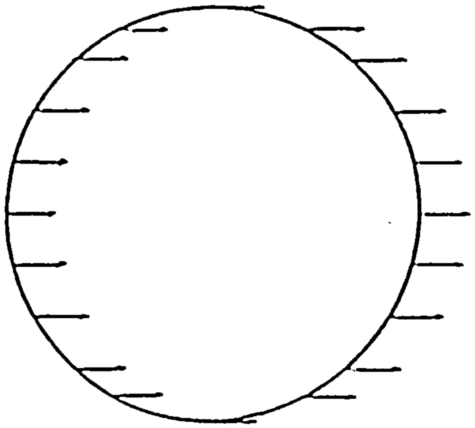
FIGURE 5 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: REFUELING WATER TANK, AXISYMMETRIC MODEL



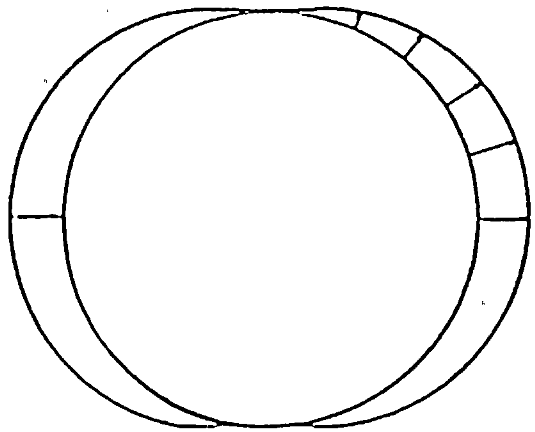
$$p_o(z,\theta,t) = C\, b_o(z)\, \rho H\, A_o(t) \cos\theta$$

Variation of Impulsive Pressure, p_o, Over the Circumference

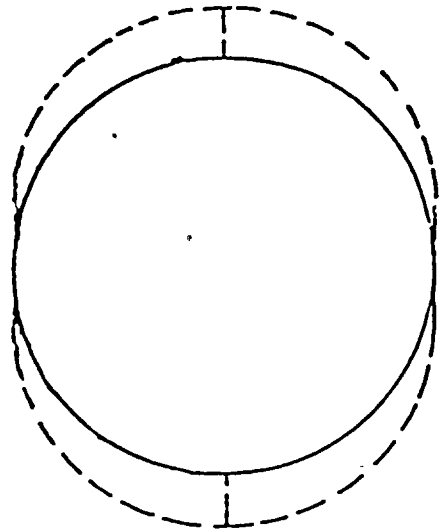
FIGURE 6 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: VARIATION OF IMPULSIVE PRESSURE



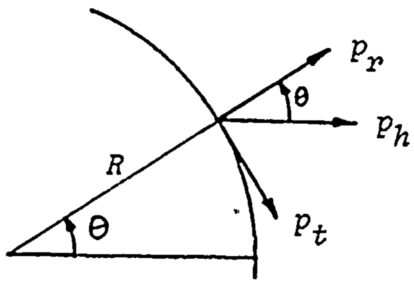
7a. Horizontal Pressure, p_h



7b. Radial Pressure, p_r



7c. Tangential Pressure, p_t



7d. Resolution of Forces

$$p_h = m\,A_o(t) = C\,b_o(\dot{z})\;\rho H\,A_o(t)$$

$$p_r = p_h \cos\theta = C\,b_o(z)\;\rho H\,A_o(t)\cos\theta$$

$$p_t = p_h \sin\theta$$

FIGURE 7 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: COMPONENTS OF HORIZONTAL PRESSURE

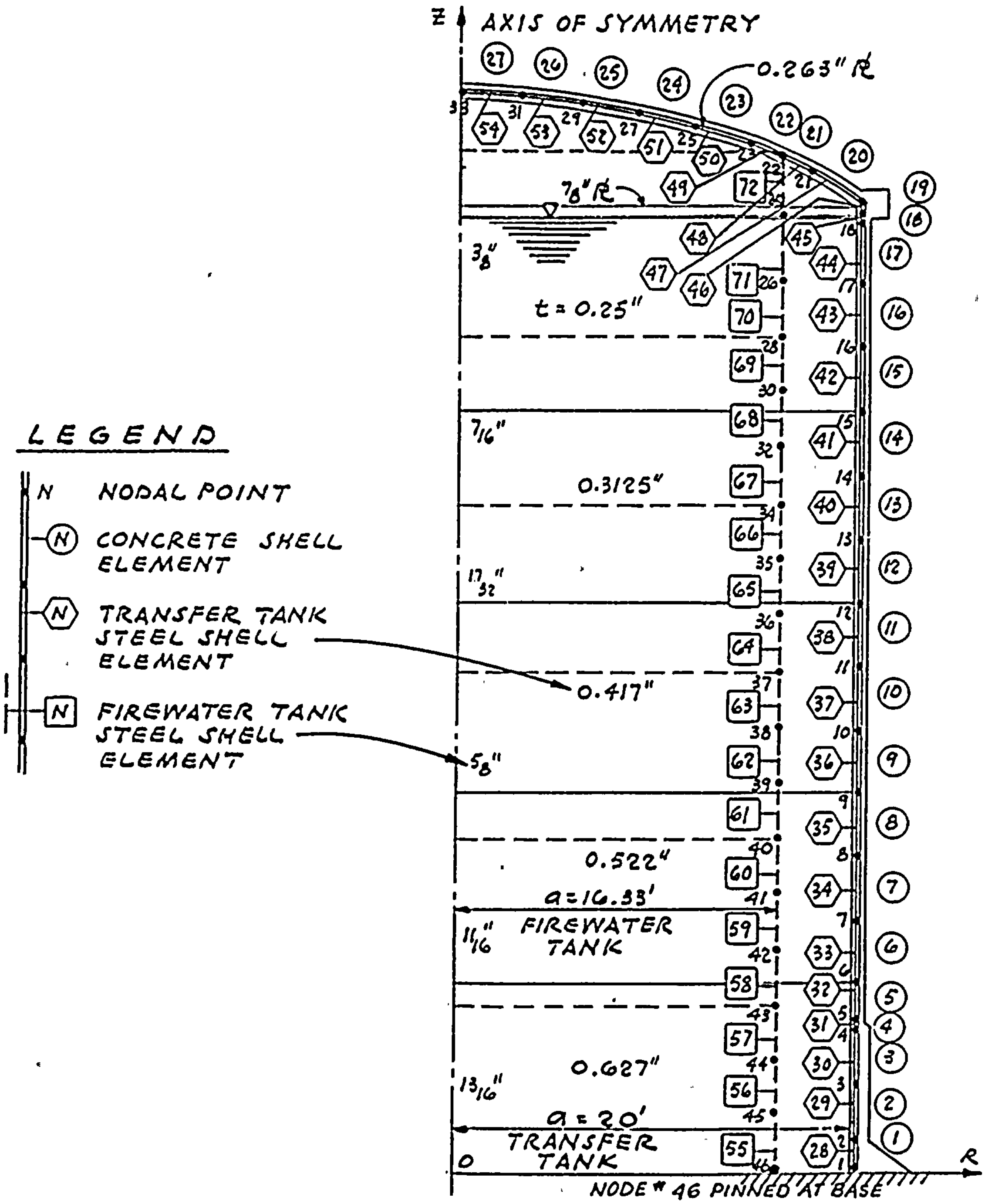


FIGURE 8 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: FIREWATER AND TRANSFER TANK

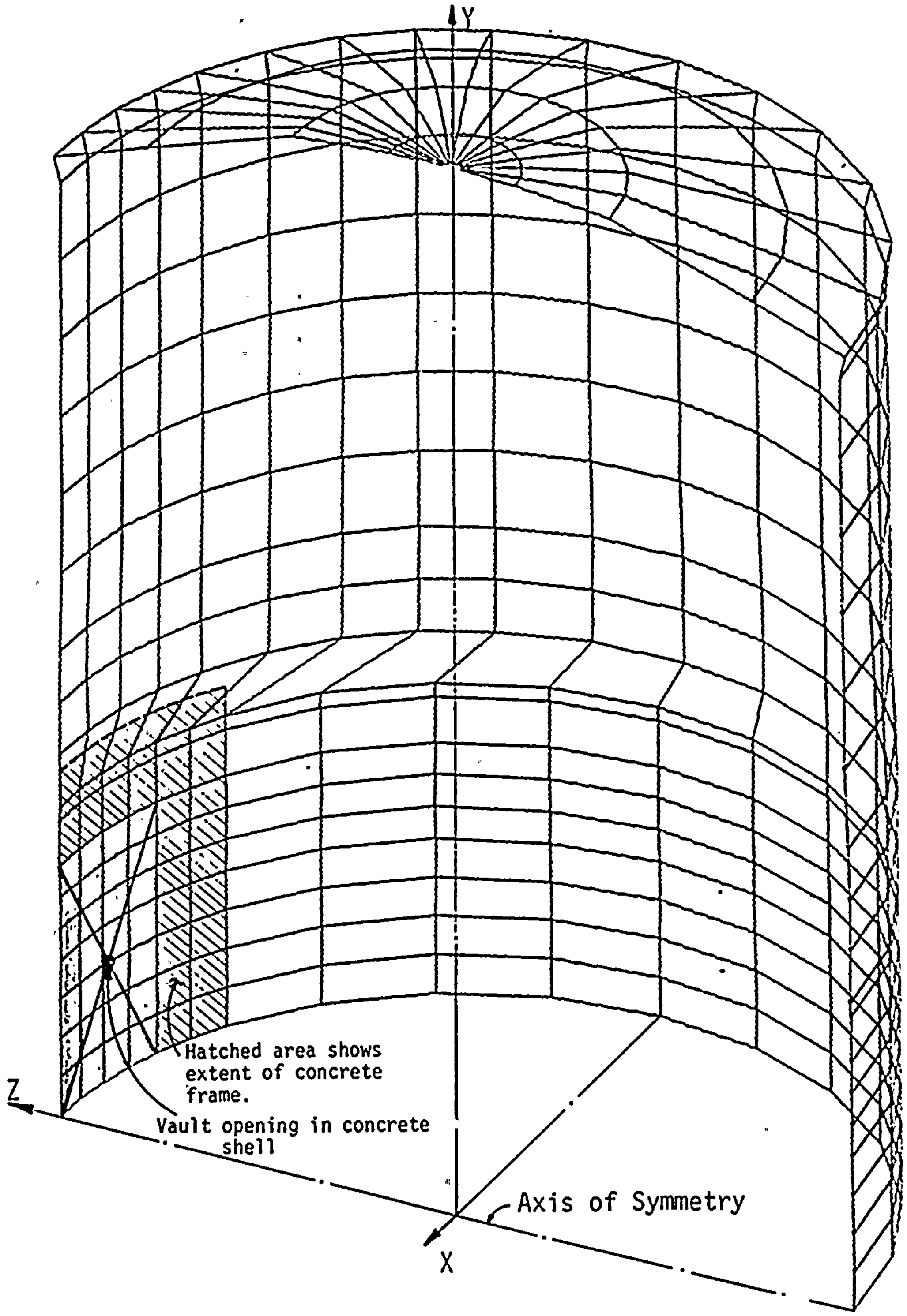


FIGURE 9 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: REFUELING WATER TANK, PERSPECTIVE VIEW OF HALF-TANK MODEL

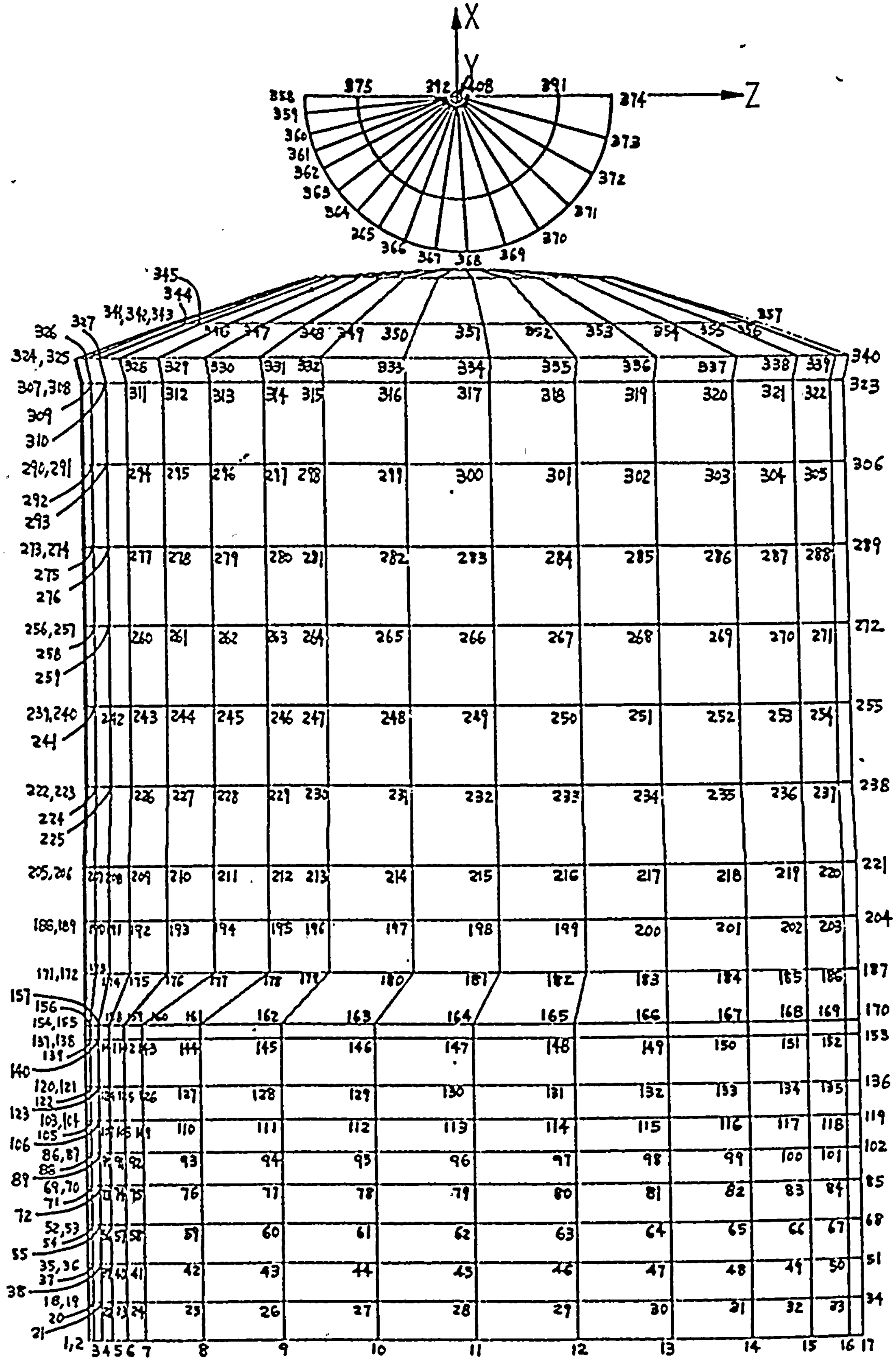


FIGURE 10 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: REFUELING WATER TANK, NODE NUMBERS

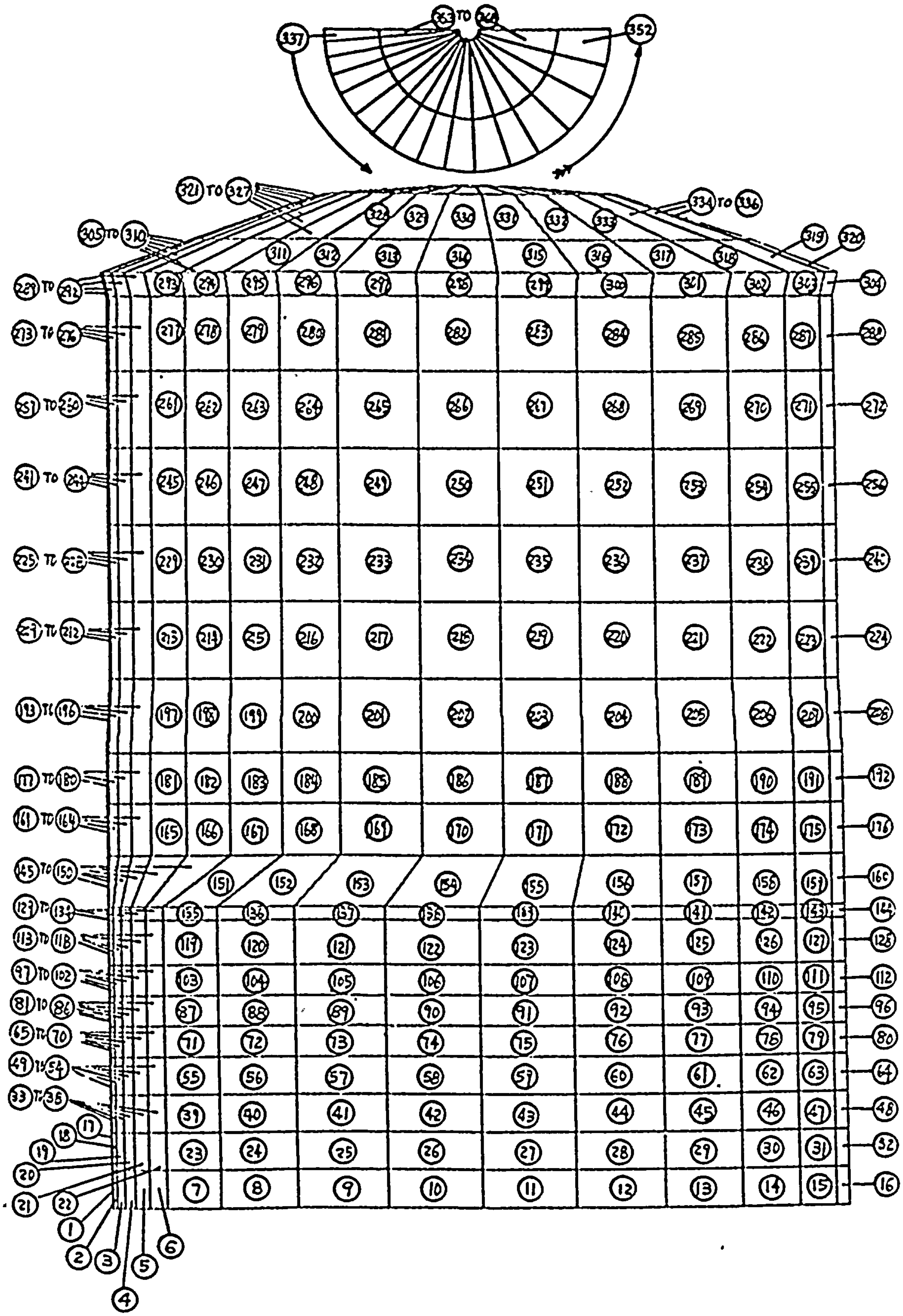
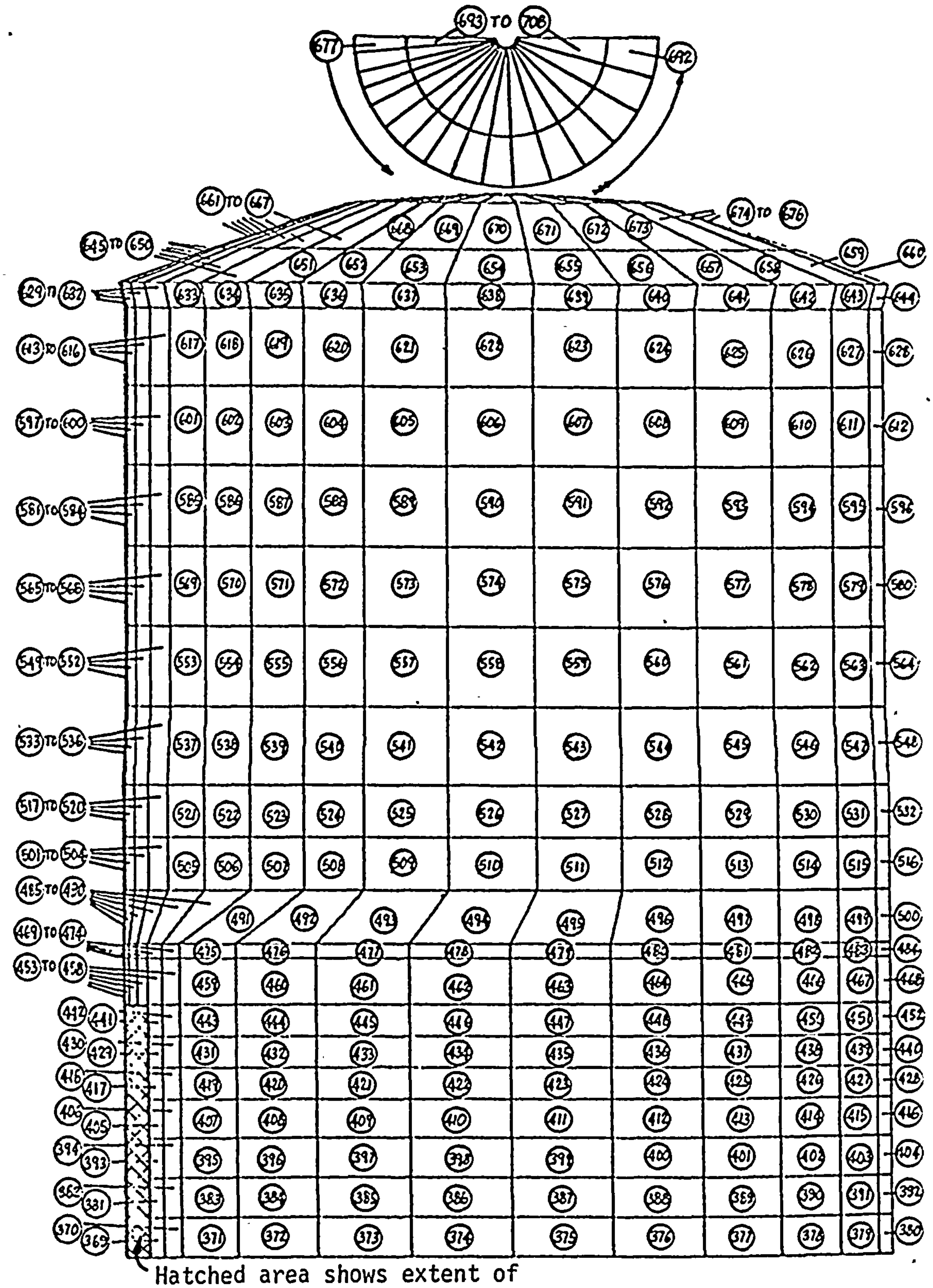


FIGURE 11 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: REFUELING WATER TANK, STEEL SHELL ELEMENTS



Hatched area shows extent of
vault opening in concrete shell.

FIGURE 12 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: REFUELING WATER TANK, CONCRETE SHELL ELEMENTS

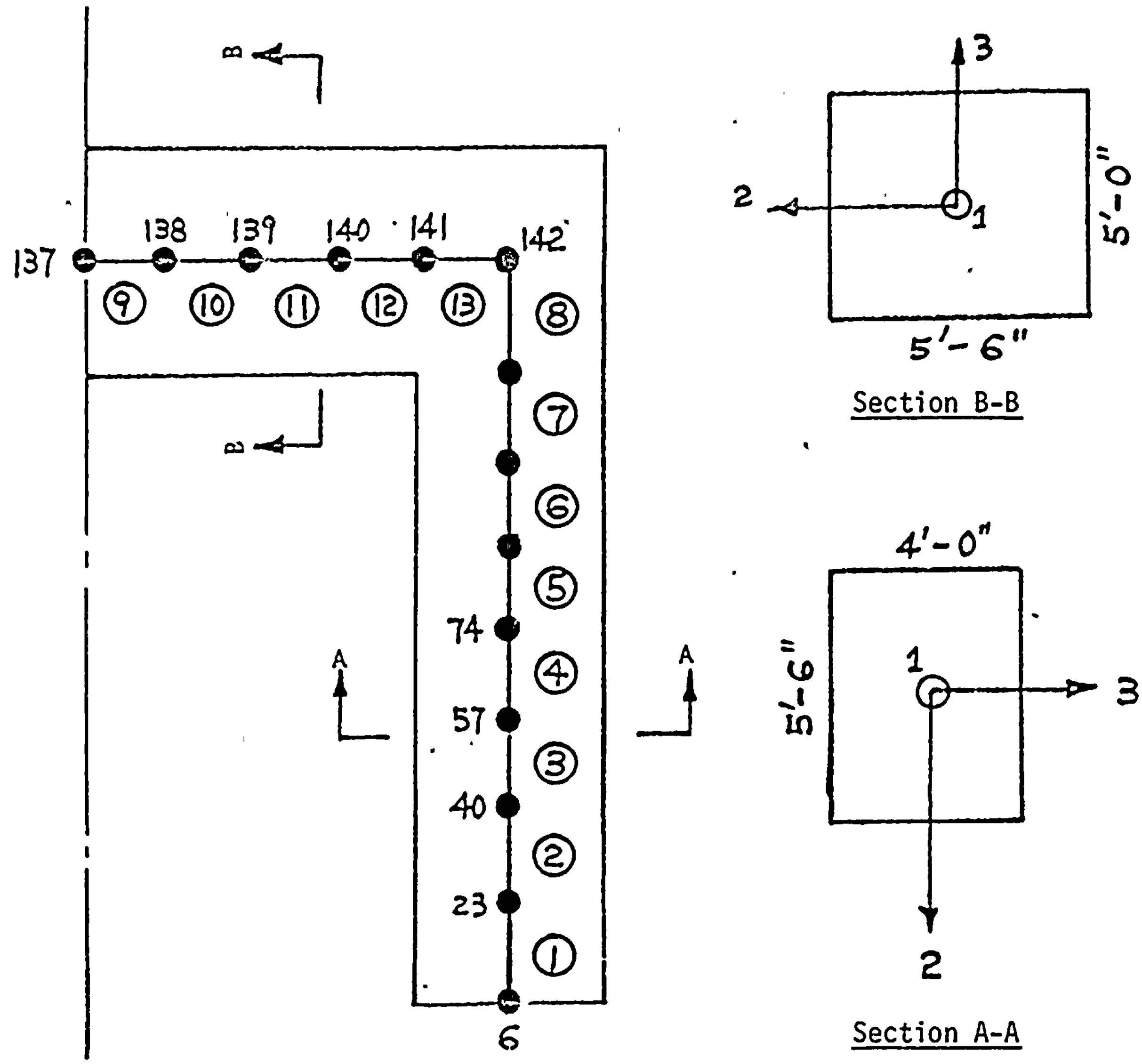


FIGURE 13 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: REFUELING WATER TANK, BEAM ELEMENTS IN CONCRETE FRAME

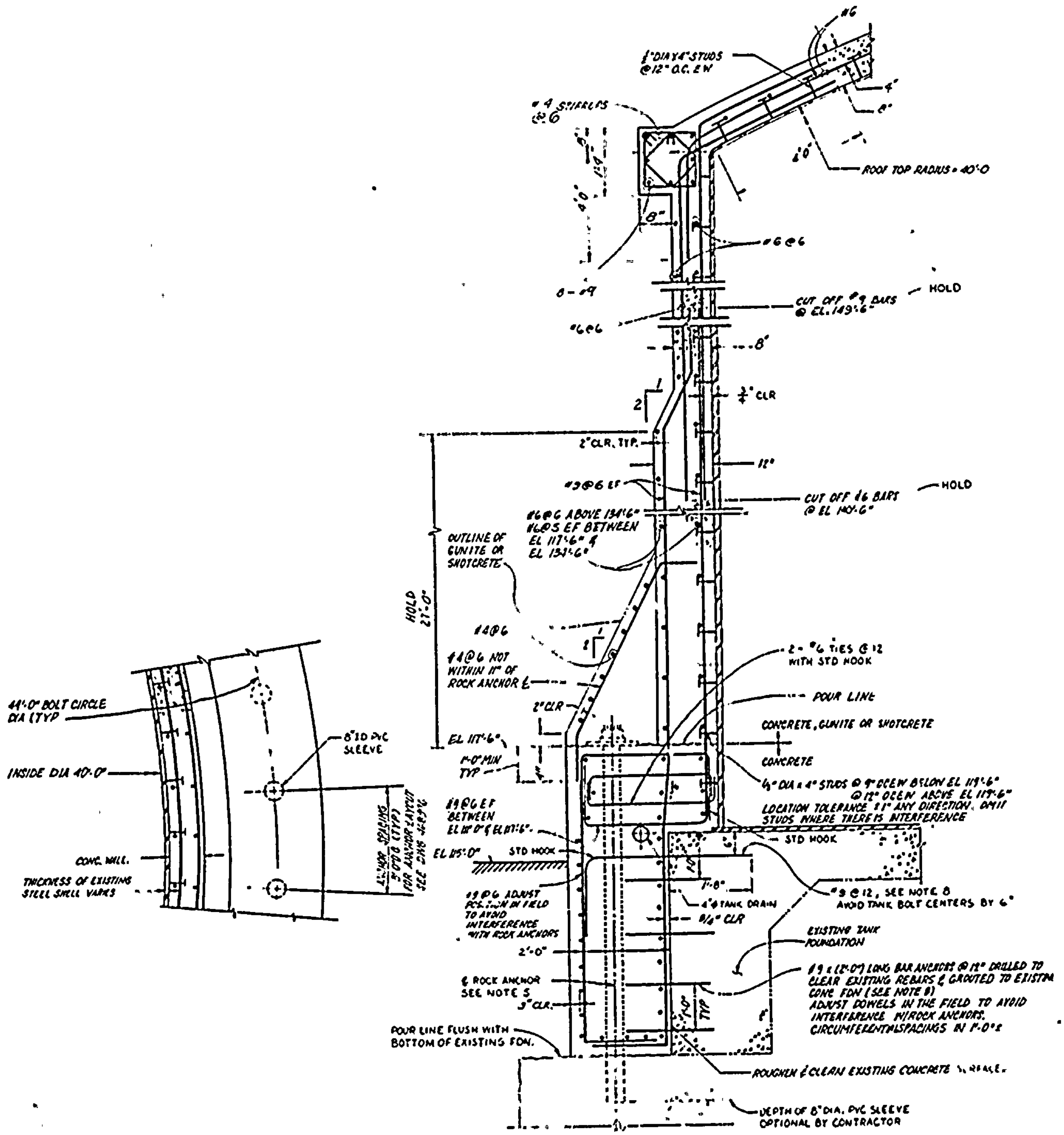


FIGURE 14 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: TYPICAL REINFORCEMENT DETAILS IN CONCRETE SHELL

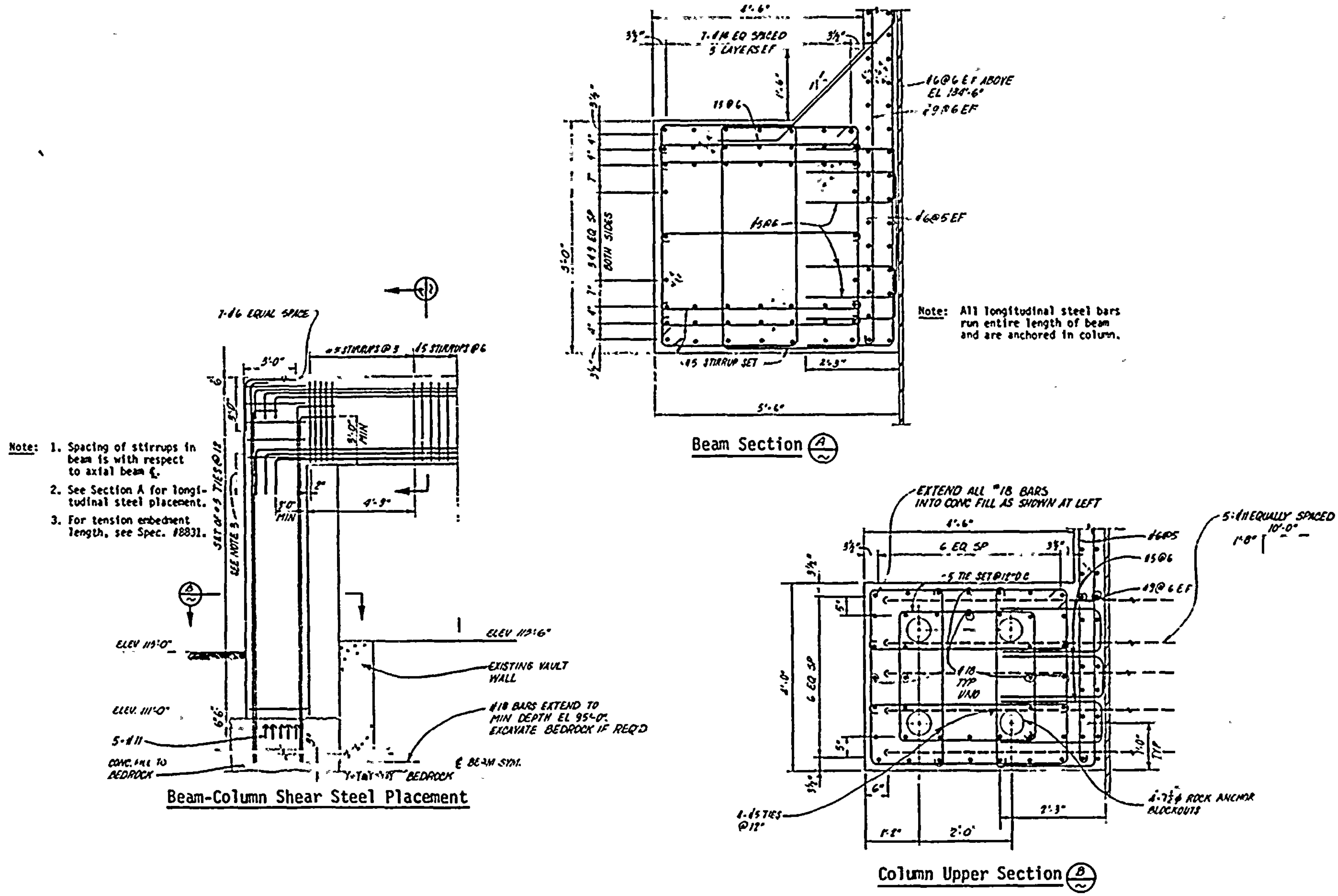


FIGURE 15 DIABLO CANYON UNITS 1 AND 2, OUTDOOR WATER STORAGE TANKS: TYPICAL REINFORCEMENT DETAILS IN CONCRETE FRAME

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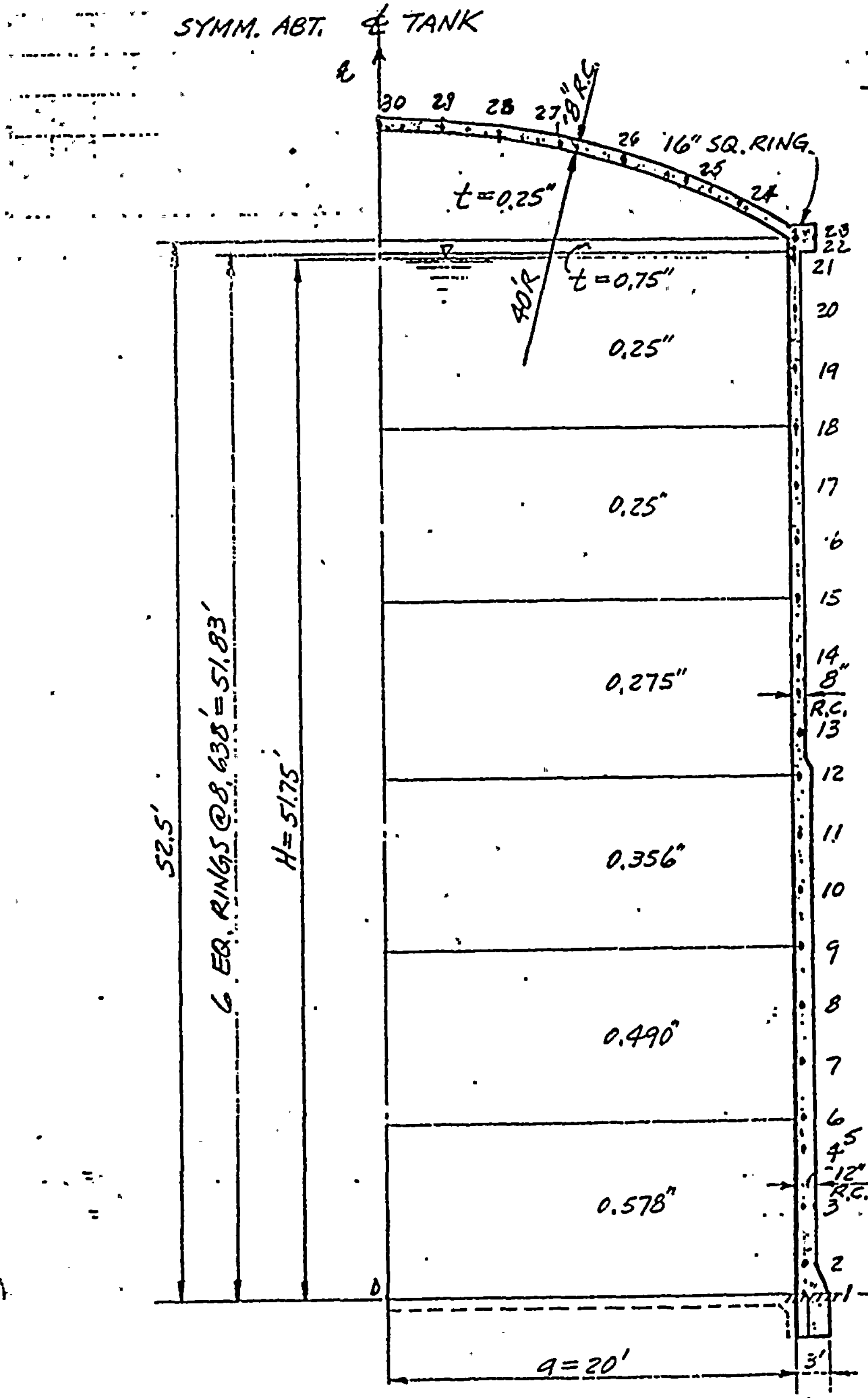
San Francisco, California 94105

SHEET NO. A-1

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 2-21-78

CLIENT PG&E SUBJECT REFUELING WATER TANK PERIOD CALCULATION CHK'D RRV DATE 2-23-78



N.P.	Z ft	ΔZ ft	*R ft
1	0	1.500	20.333
2	1.500	3.000	
3	4.500	3.000	
4	7.500	0.192	
5	7.692	0.946	
6	8.638	2.879	
7	11.517		
8	14.396		
9	17.277		
10	20.156		
11	23.035		
12	25.915		
13	28.794		
14	31.673		
15	34.553		
16	37.432		
17	40.311		
18	43.191		
19	46.070	2.879	
20	48.949	2.801	
21	51.750	0.080	20.333
22	51.830	0.670	20.333
23	52.500	1.416	20.333
24	53.910	1.206	17.500
25	55.116	0.996	14.735
26	56.112	0.781	11.888
27	56.893	0.561	8.975
28	57.454	0.337	6.011
29	57.791	0.113	3.014
30	57.904		0

* Radius to the mid-point of concrete shell.

AXI-SYMMETRIC MODEL.

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-2

JOB NO. 020249 JOB Diablo Refueling Water Storage Tank BY RRW DATE 2/23/78
CLIENT PG&E SUBJECT Material Properties CHK'D CSC DATE 2/25/78

1. Steel Shell —

mass density = 0.490 k/cu.ft. $\times \frac{1}{32.2}$ = 15.217 $\times 10^{-3}$ kip-sec²/ft⁴

poisson's ratio = 0.30

E = 29,000 ksi × 144 = 4.176 × 10⁶ ksf

2. concrete shell

mass density = 0.150 k/cu.ft. $\times \frac{1}{32.2}$ = 4.658 $\times 10^{-3}$ k-sec²/ft⁴

Poisson's ratio = 0.20

E = $\frac{29,000}{9^*}$ × 144 = 464,000. ksf.

* ACI n value for concrete with $f_c' = 3000$ psi

Notes on the Axi-symmetric Model:

1. Concrete elements are modeled as axisymmetric shell elements.
2. Steel (liner) elements are also modeled as axisymmetric shell elements in parallel to the concrete elements.
3. Dynamic analysis for impulsive pressures were made by calculating equivalent fluid inertia attached to the concrete elements.
4. The effect of vertical earthquake is considered by scaling the dead load and hydrostatic results.
5. Dead load, hydrostatic, and convective pressure loads were taken as static loads.

I. REFUELING WATER STORAGE TANK (continued)

The effective mass of the structure for a rigid body motion of the tank, $m_{x,s}$:

RING	z_i ft.	z_j ft.	t_s in.	(1) μ_s lbs-sec²/in²	(2) A $\cos\frac{\pi}{2}\left(\frac{z_j}{H}\right)$	(2) B $\cos\frac{\pi}{2}\left(\frac{z_i}{H}\right)$	(2) A − B	$-\frac{2H\times12}{\pi}\mu_s(A-B)$ lbs-sec²/in.
6	43.19	51.83	0.25	3.04	−0.0024	0.2569	−0.2593	311.64
5	34.55	43.19	0.25	3.04	0.2569	0.4987	−0.2418	290.60
4	25.91	34.55	0.275	3.06	0.4987	0.7064	−0.2077	251.26
3	17.28	25.91	0.356	3.15	0.7064	0.8656	−0.1592	198.26
2	8.64	17.28	0.490	3.30	0.8656	0.9658	−0.1002	130.72
1	0	8.64	0.578	1.42 + 3.40 = 4.82	0.9658	1.0000	−0.0342	$\frac{4.82}{3.40}$ 45.97 = 65.17
Σ						$\int_0^{H_s}\mu_s(z)\psi(z)\,dz =$		~~1228.15~~ 1247.65
ROOF	$z = 52.54' + \frac{1}{3}5.26'$ $= 56.07' = H_s$		$m_r\,\psi(H_s) = \frac{264.8^k \times 1000}{32.2\times12}\times 1$				=	685.30
TOTAL						$m_{x,s} = \int_0^{H_s}\mu_s(z)\psi(z)\,dz + m_r\psi(H_s) =$		~~1913.75~~ 1932.95

(1) $\mu_s = \frac{\pi D \rho t}{g} = \frac{\pi}{32.2}\left[40(0.284)t_s + 40.67(0.057)8''\right] = 1.108\,t_s + 2.76$, lbs-sec²/in² ($\rho_{st.}$, $\rho_{conc.}$; 41'(0.087)12'', 1.18, — t = 12'', 3.32)

(2) $\int_i^j \psi(z)\,dz = \int_i^j \sin\frac{\pi}{2}\frac{z}{H}\,dz = -\frac{2H}{\pi}\left|\cos\frac{\pi}{2}\frac{z}{H}\right|_{z_i}^{z_j}$, $H = 51.75'$

I. REFUELING WATER STORAGE TANK (continued)

The effective mass of the structure vibrating with deflection $\psi(z)$, $m_{\omega,s}$:

RING	μ_s lbs-sec²/in²	z_i ft.	z_j ft.	A: $12(z_j - z_i)$ in.	B: (1) $\sin \frac{\pi}{H} z_j$	C: (1) $\sin \frac{\pi}{H} z_i$	D: $\frac{12H}{\pi}(B-C)$	E: $A-D$	$\frac{\mu_s}{2} E$ lbs-sec²/in.
6	3.04	43.19	51.83	103.68	-0.0049	0.4966	-99.13	202.81	308.27
5	3.04	34.55	43.19	103.68	0.4966	0.8645	-72.72	176.40	268.13
4	3.06	25.91	34.55	103.68	0.8645	1.0000	-26.78	130.46	199.60
3	3.15	17.28	25.91	103.68	1.0000	0.8669	+26.31	77.31	121.76
2	3.30	8.64	17.28	103.68	0.8669	0.5008	+72.37	31.31	51.66
1	1.42 +3.40 = 4.82	0	8.64	103.68	0.5008	0	+98.99	4.69	$\frac{4.82}{3.40}$ 7.97 = 11.30
Σ	$\int_0^{H_s} \mu_s(z)\psi^2(z)dz =$								~~944.16~~ 960.72
ROOF	$z = 56.07' = H_s$			$m_r \psi^2(H_s) = 685.3 \times 1^2 =$					685.30
TOTAL	$m_{\omega,s} = \int_0^{H_s} \mu_s(z)\psi^2(z)dz + m_r\psi^2(H_s) =$								~~1,634.72~~ 1,646.02

$$(1)\quad \int_i^j \mu_s(z)\psi^2(z)dz = \mu_s \int_i^j \sin^2 \frac{\pi}{2}\frac{z}{H}\, dz$$

$$= \frac{\mu_s}{2}\int_i^j \left(1 - \cos \pi \frac{z}{H}\right) dz$$

$$= \frac{\mu_s}{2}\left| z - \frac{H}{\pi} \sin \pi \frac{z}{H} \right|_{z_i}^{z_j}$$

$$= \frac{\mu_s}{2}\left[12(z_j - z_i) - \frac{12H}{\pi}\left(\sin \frac{\pi}{H} z_j - \sin \frac{\pi}{H} z_i\right)\right], \quad \text{lbs-sec}^2/\text{in.}$$

From previous calculation:

Total mass of the liquid content of the tank:

$m = \rho \pi a^2 H = 10501.9$ lb-sec²/in.

$\frac{H}{a} = \frac{51.75}{20} = \sim 2.6$

From Fig. 9 of "DYNAMICS OF FIXED-BASE LIQUID-STORAGE TANKS" by A.S. Veletsos & J.Y. Yang:

$m_{x,l} = 4935.89$ lbs-sec²/in.

$m_{w,l} = 3,360.61$ lbs-sec²/in.

$\frac{m_{x,l}}{m} = 0.47 \quad \frac{m_{w,l}}{m} = 0.32$

$$C = \frac{m_x}{m_w} = \frac{m_{x,s} + m_{x,l}}{m_{w,s} + m_{w,l}}$$

$$= \frac{1932.95 + 4935.89}{1646.02 + 3360.61} = 1.37$$

No change from the previous calculation.

The impulsive component, p_o, of the hydrodynamic pressure exerted on the tank wall:

$$p_o(z, \theta, t) = C\, b_o(z)\, \rho H A_o(t) \cos\theta$$

where:

$\rho = \frac{62.4}{32.2} = 1.94$ lbs-sec²/ft⁴

$A_o(t) = 1$ ft/sec² (Assumed pseudo-acceleration)

$\theta = 0°, \quad \cos\theta = 1$ (Parallel to the direction of excitation)

$b_o(z)$ — interpolated from Fig. 7 of "DYNAMIC OF FIXED-BASE LIQUID-STORAGE TANKS" by A.S. Veletsos & J.Y. Yang

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SHEET NO. A-6

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 2-21-78

CLIENT PG&E SUBJECT REFUELING WATER TANK PERIOD CALCULATION CHK'D RAV DATE 2-23-78

Interpolating the values of $b_0(z)$:

NODAL POINT	z ft.	H/a → z/H ↓	0.5	3.0	INTERPOLATED 2.6
21	51.750	1.0	0	0	0
20	48.949	0.95	0.105	0.100	$0.10 + \frac{3-2.6}{3-0.5}(0.105-0.1) = 0.101$
19	46.070	0.89	0.200	0.153	$0.153 + \frac{0.4}{2.5}(0.2-0.153) = 0.161$
18	43.191	0.83	0.255	0.190	$0.190 + \frac{0.4}{2.5}(0.255-0.19) = 0.20$
17	40.311	0.78	0.290	0.215	$0.215 + \frac{0.4}{2.5}(0.29-0.215) = 0.227$
16	37.432	0.72	0.325	0.225	$0.225 + \frac{0.4}{2.5}(0.325-0.225) = 0.241$
15	34.553	0.67	0.345	0.225	$0.225 + \frac{0.4}{2.5}(0.345-0.225) = 0.244$
14	31.673	0.61	0.360	0.222	$0.222 + \frac{0.4}{2.5}(0.36-0.222) = 0.244$
13	28.794	0.56	0.370	0.220	$0.220 + \frac{0.4}{2.5}(0.37-0.22) = 0.244$
12	25.915	0.50	0.380	0.212	$0.212 + \frac{0.4}{2.5}(0.38-0.212) = 0.239$
11	23.035	0.45	0.385	0.200	$0.20 + \frac{0.4}{2.5}(0.385-0.2) = 0.230$
10	20.156	0.39	0.370	0.180	$0.180 + \frac{0.4}{2.5}(0.37-0.180) = 0.210$
9	17.277	0.33	0.365	0.160	$0.160 + \frac{0.4}{2.5}(0.365-0.16) = 0.193$
8	14.396	0.28	0.360	0.145	$0.145 + \frac{0.4}{2.5}(0.36-0.145) = 0.179$
7	11.517	0.22	0.345	0.125	$0.125 + \frac{0.4}{2.5}(0.345-0.125) = 0.160$
6	8.638	0.17	0.335	0.115	$0.115 + \frac{0.4}{2.5}(0.335-0.115) = 0.150$
5	7.692	0.15	0.330	0.105	$0.105 + \frac{0.4}{2.5}(0.33-0.105) = 0.141$
4	7.500	0.14	0.328	0.100	$0.100 + \frac{0.4}{2.5}(0.328-0.1) = 0.136$
3	4.500	0.09	0.325	0.088	$0.088 + \frac{0.4}{2.5}(0.325-0.088) = 0.126$
2	1.500	0.03	0.322	0.078	$0.078 + \frac{0.4}{2.5}(0.322-0.078) = 0.117$
1	0	0	0.320	0.075	$0.075 + \frac{0.4}{2.5}(0.32-0.075) = 0.114$

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SHEET NO. A-7

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 2-22-78

CLIENT PG&E SUBJECT REFUELING WATER TANK PERIOD CALCULATION CHK'D RRV DATE 2-25-78

FLUID INERTIA FORCE : $P_o = C\, b_o(z)\, \rho H A_o(t) \cos\theta$

P for $A_o = 1$ ft/sec²

* Tangential Acceleration & Pressure

NODAL POINT	$b_o(z)$	$C b_o(z)$	P_o lbs/ft²	ρ_{ave} k-sec²/ft⁴	A_o ft/sec² *	P_o lbs/ft² *
21	0	0	0	.0277	78.12	0
20	0.101	0.138	13.85	.0721	75.07	1,039.7
19	0.161	0.221	22.19	.0995	71.72	1,591.5
18	0.200	0.274	27.51	.1175	68.04	1,871.8
17	0.227	0.311	31.22	.1288	63.99	1,997.8
16	0.241	0.330	33.13	.1335	59.56	1,973.2
15	0.244	0.334	33.53	.1343	54.77	1,836.4
14	0.244	0.334	33.53	.1343	49.71	1,666.8
13	0.244	0.334	33.53	.1328	44.41	1,489.1
12	0.239	0.327	32.83	.1290	38.92	1,277.7
11	0.230	0.315	31.62	.1210	33.53	1,060.2
10	0.210	0.288	28.91	.1108	28.10	812.4
9	0.193	0.264	26.50	.1022	22.73	602.3
8	0.179	0.245	24.60	.0932	17.80	437.9
7	0.1[illegible]	0.219	21.99	.0853	13.04	286.7
6	0.150	0.206	20.68	.0802	8.50	175.5
5	0.141	0.193	19.38	.0762	7.13	138.2
4	0.136	0.186	18.67	.0721	6.89	128.6
3	0.126	0.173	17.37	.0670	3.63	63.1
2	0.117	0.160	16.06	.0636	0.75	12.0
1	0.114	0.156	15.66		0	0

$P_{ii} = \int p_o \cos^2\theta\, a\, d\theta = \pi a\, p_o$

effective fluid mass density $\rho_e = \dfrac{P_o}{1000\, t}$ kip-sec²/ft⁴

say fluid thickness $t = 3'' = 0.25$

$$\rho_e = \frac{P_o}{1000\,(0.25)} = \frac{P_o}{250} \text{ kip-sec}^2/\text{ft}^4$$

$$\rho_{ave} = \frac{\rho_i + \rho_j}{2} = \frac{P_{oi} + P_{oj}}{500}$$

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-8

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSL DATE 2-24-78

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D RFV DATE 4-10-78

$$\rho' = \rho_1 + \rho_2 \, t_2/t_1$$

$t_1 = t_{concrete}$
$t_2 = t_{fluid}$

$\rho_1 = \rho_{concrete}$

$\rho_2 = \rho_{fluid}$

MATERIAL NO.	$\rho_{concrete}$ ρ_1	ρ_{fluid} ρ_2	t_2	$t_{concrete}$ t_1	$\rho_2 \frac{t_2}{t_1}$	ρ' K-sec²/ft.⁴
22	4.658×10^{-3}	0.0277	0.25'	0.6667	10.387×10^{-3}	0.015045
21	↓	0.0721	↓	↓	27.036×10^{-3}	0.031694
20		0.0995			37.311×10^{-3}	0.041969
19		0.1175			44.060×10^{-3}	0.048718
18		0.1288			48.298×10^{-3}	0.052956
17		0.1335			50.060×10^{-3}	0.054718
16		0.1343			50.360×10^{-3}	0.055018
15		0.1343			50.360×10^{-3}	0.055018
14		0.1328			49.798×10^{-3}	0.054456
13		0.1290		0.6667	48.373×10^{-3}	0.053031
12		0.1210		1.0000	30.250×10^{-3}	0.034908
11		0.1108		↓	27.700×10^{-3}	0.032358
10		0.1022			25.550×10^{-3}	0.030208
9		0.0932			23.300×10^{-3}	0.027958
8		0.0853			21.325×10^{-3}	0.025983
7		0.0802			20.050×10^{-3}	0.024708
6		0.0762			19.050×10^{-3}	0.023708
5		0.0721		1.0000	18.025×10^{-3}	0.022683
4	↓	0.0670	↓	1.0000	16.750×10^{-3}	0.021408
3	4.658×10^{-3}	0.0636	0.25'	2.0000	7.950×10^{-3}	0.012608

URS/BLUME

130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-9

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 2-2?-75

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D RCV DATE 2-25-75

HYDROSTATIC PRESSURE : $p_s = wh = 62.4(51.75' - z')$, lbs/ft²

NODAL POINT	z ft	H-z ft	p_s lbs/ft²	TOTAL HYDROSTATIC FORCE $P_s = \frac{p_s(H-z)}{2 \times 1000}$ K
21	51.750	0	0	0
20	48.949	2.801	174.8	0.24
19	46.070	5.680	354.4	1.01
18	43.191	8.559	534.1	2.29
17	40.311	11.439	713.8	4.08
16	37.432	14.318	893.4	6.40
15	34.553	17.197	1,073.1	9.23
14	31.673	20.077	1,252.8	12.58
13	28.794	22.956	1,432.5	16.44
12	25.915	25.835	1,612.1	20.82
11	23.035	28.715	1,791.8	25.73
10	20.156	31.594	1,971.5	31.14
9	17.277	34.473	2,151.1	37.08
8	14.396	37.354	2,330.9	43.53
7	11.517	40.233	2,510.5	50.50
6	8.638	43.112	2,690.2	57.99
5	7.692	44.058	2,749.2	60.56
4	7.500	44.250	2,761.2	61.09
3	4.500	47.250	2,948.4	69.66
2	1.500	50.250	3,135.6	78.78
1	0	51.750	3,229.2	83.56

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-10

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 2-23-78

CLIENT PG&E SUBJECT REFUELING WATER TANK PERIOD CALCULATION CHK'D RRY DATE 2-23-78

CONVECTIVE PRESSURE

... By Veletsos approach :

... The convective pressure $p_w = \sum_{k=1}^{\infty} C_K(z) A_K(t) \rho H \cos\theta$

$$\text{where } C_K(z) = \frac{2}{\lambda_K^2 - 1} \frac{a}{H} \frac{\cosh(\lambda_K \frac{z}{a})}{\cosh(\lambda_K \frac{H}{a})}$$

Let $\lambda_K = \lambda_1 = 1.8412$

$$\text{Then } C_1(z) = \frac{2}{(1.8412)^2 - 1} \frac{20}{51.75} \frac{\cosh(1.8412 \frac{z}{20})}{\cosh(1.8412 \frac{51.75}{20})}$$

$$= 0.0055 \cosh(0.09206 z)^{55.62}$$

$\rho = 62.4/32.2 = 1.94$ lbs-sec²/ft⁴

$H = 51.75$ ft.

$A_K(t) = \omega S_v = 0.1g = 3.22$ ft./sec/sec.

$\cos\theta = 1$

$\therefore \quad p_w = C_1(z) A_1(t) \rho H \cos\theta$

$= 0.0055 \cosh(0.09206 z)(3.22)1.94(51.75)1$

$= \underline{1.778 \cosh(0.09206 z)}$

The convective pressure at each Nodal Point is calculated accordingly as follows:

NODAL PT.	p_w lbs/ft²	NODAL PT.	p_w lbs/ft²	NODAL PT.	p_w lbs/ft²
1	1.778	9	4.535	17	36.313
2	1.795	10	5.815	18	47.319
3	1.938	11	7.504	19	61.598
4	2.223	12	9.727	20	80.288
5	2.241	13	12.643	21	103.922
6	2.365	14	16.431	22	104.739
7	2.863	15	21.392	23	111.336
8	3.574	16	27.865	* z_{max}	123.037

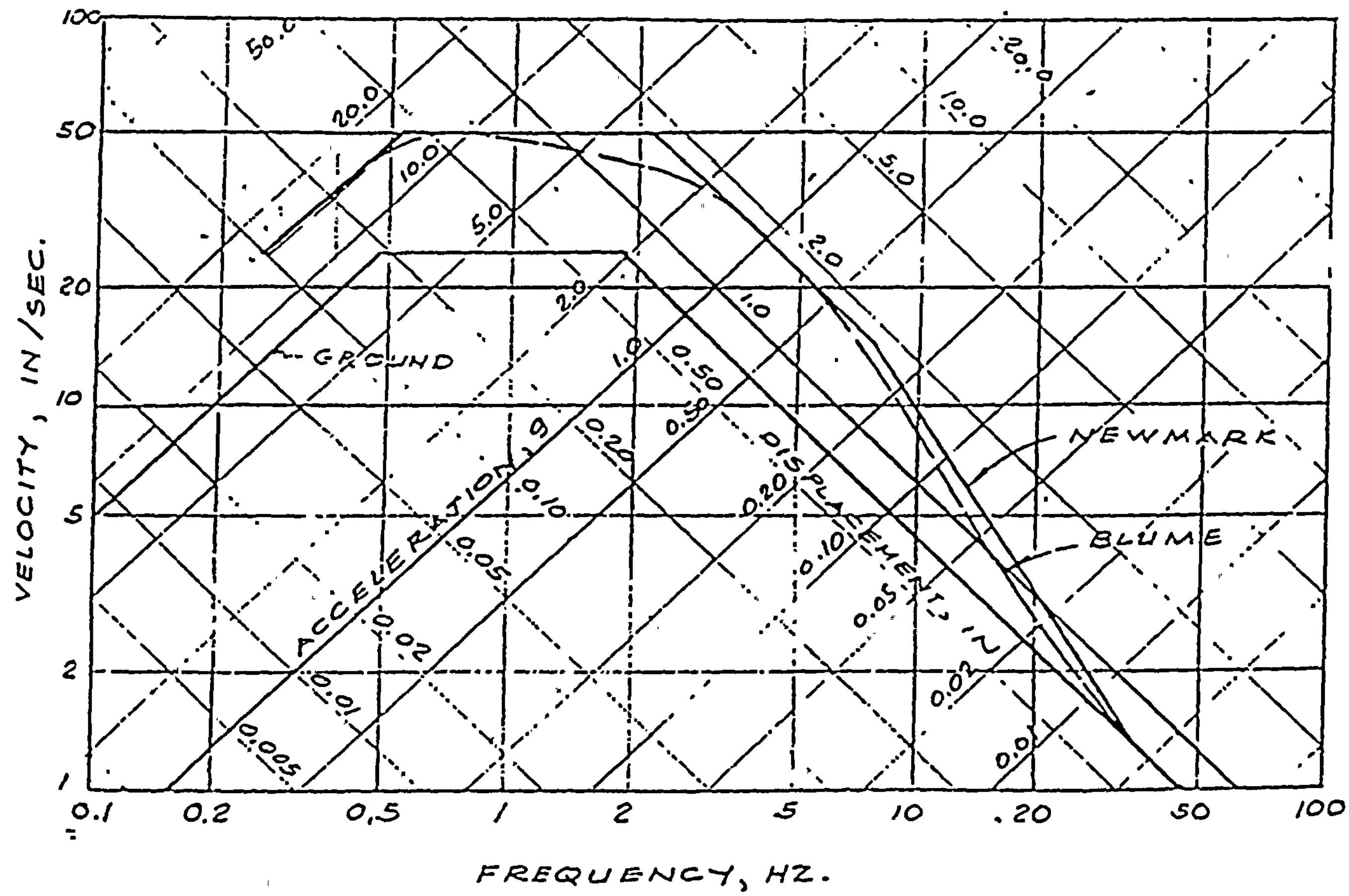
* $z_{max} = 53.59$ ft.

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-11

JOB NO. 0902-19 JOB DIABLO REVIEW BY BNS DATE 8/2/77

CLIENT PG&E SUBJECT SPECTRA CHK'D RRV DATE



DIABLO UNITS 1 & 2

7.5M HOSGRI EARTHQUAKE SPECTRA

$\tau = 0$ 7% DAMPING

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-12

JOB NO. 0902-19 JOB DIABLO REVIEW BY [illegible] DATE
CLIENT PG&E SUBJECT Refueling Water Storage Tank CHK'D PMN DATE

Convective Pressure —

Fundamental Period of Vibration.
Reference: Housner's approach, Eqn. F.91, TID 7024

$$\omega^2 = \frac{g}{R}\sqrt{\frac{27}{8}}\tanh\sqrt{\frac{27}{8}}\frac{h}{R}$$

$$= \frac{g}{R} \times 1.84 \tanh\left(1.84\frac{h}{R}\right)$$

$$= \frac{32.2}{20}(1.84)\tanh\left(1.84 \times \frac{51.75}{20}\right)$$

$$\omega^2 = 2.9624 \tanh(4.761) = 2.9620$$

$$\omega = 1.721 \text{ rad./sec.}$$

$$f = \frac{1.721}{2\pi} = 0.2740 \text{ cycles/sec.}$$

$$T = \frac{1}{f} = 3.65 \text{ seconds}$$

From 7.5 M Hosgri spec., $\tau = 0$, 7% damping 42.F-11

At $T = 3.65$ sec. → $S_a = 0.1g = 3.22$ ft/sec^2

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-13

JOB NO. 0902-17 JOB DIABLO REVIEW BY RRV DATE 5/6/78

CLIENT PG&E SUBJECT Refueling Water Storage Tank CHK'D PMN DATE

From Digitized Newmark 7.5 M H05 gui Spectra, T = 0 :

Period	1%	2%	7%
3.333	0.200	0.178	0.138
4.000	0.139	0.124	0.096

(SA – g)

Convective Pressure T_1 = 3.65 seconds

At T_1 = 3.65 seconds:

1) For 1% damping

$$SA = 0.20 - \frac{(3.65 - 3.333)}{4.00 - 3.333}(0.200 - 0.139) =$$

$$= 0.171 g$$

2) For 2% damping

$$SA = 0.178 - \frac{(3.650 - 3.333)}{4.000 - 3.333}(0.178 - 0.124) =$$

$$= 0.1523 g$$

3) For 7% damping

$$SA = 0.138 - \frac{(3.650 - 3.333)}{4.000 - 3.333}(0.138 - 0.096) =$$

$$= 0.1180 g$$

Use 1% damping : SA = 0.171 g

DESIGN HORIZONTAL SPECTRA TAU=0,000 NEWMARK 9/76

SHEET A-14

COLUMN 1 = PERIODS (SEC)
2 = FREQUENCIES
3 = 0,005 DAMPING
4 = 0,010 DAMPING
5 = 0,020 DAMPING
6 = 0,030 DAMPING
7 = 0,050 DAMPING
8 = 0,070 DAMPING

****

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
-1-	,029	34,000	,750	,750	,750	,750	,750	,750
-2-	,032	31,000	,806	,800	,794	,790	,784	,779
-3-	,036	28,000	,906	,890	,872	,860	,842	,830
-4-	,040	25,000	1,032	1,002	,967	,944	,912	,890
-5-	,045	22,000	1,195	1,145	1,087	1,050	,997	,963
-6-	,050	20,000	1,334	1,264	1,186	1,136	1,067	1,022
-7-	,056	18,000	1,506	1,411	1,306	1,240	1,149	1,091
-8-	,059	17,000	1,608	1,497	1,377	1,300	1,196	1,130
-9-	,063	16,000	1,724	1,595	1,455	1,367	1,248	1,173
-10-	,067	15,000	1,857	1,706	1,544	1,443	1,306	1,221
-11-	,069	14,500	1,931	1,767	1,592	1,484	1,337	1,246
-12-	,071	14,000	2,010	1,833	1,644	1,528	1,371	1,274
-13-	,074	13,500	2,095	1,904	1,700	1,574	1,406	1,303
-14-	,075	13,250	2,141	1,941	1,730	1,599	1,425	1,318
-15-	,077	13,000	2,189	1,980	1,760	1,624	1,444	1,334
-16-	,078	12,750	2,238	2,021	1,791	1,651	1,464	1,350
-17-	,080	12,500	2,290	2,063	1,824	1,678	1,485	1,366
-18-	,082	12,250	2,344	2,107	1,858	1,706	1,506	1,383
-19-	,083	12,000	2,400	2,153	1,894	1,736	1,528	1,401
-20-	,085	11,750	2,459	2,201	1,931	1,767	1,551	1,419
-21-	,087	11,500	2,520	2,250	1,969	1,798	1,574	1,438
-22-	,089	11,250	2,585	2,302	2,009	1,831	1,599	1,458
-23-	,091	11,000	2,652	2,357	2,051	1,866	1,624	1,478
-24-	,093	10,750	2,723	2,414	2,094	1,902	1,651	1,500
-25-	,095	10,500	2,798	2,474	2,140	1,939	1,678	1,522
-26-	,098	10,250	2,877	2,537	2,188	1,978	1,707	1,544
-27-	,100	10,000	2,960	2,603	2,238	2,019	1,737	1,568
-28-	,103	9,750	3,047	2,673	2,290	2,062	1,768	1,593
-29-	,105	9,500	3,139	2,746	2,345	2,107	1,801	1,619
-30-	,108	9,250	3,237	2,824	2,403	2,154	1,835	1,646
-31-	,111	9,000	3,341	2,906	2,464	2,204	1,870	1,674
-32-	,114	8,750	3,451	2,992	2,529	2,256	1,908	1,703
-33-	,118	8,500	3,567	3,084	2,597	2,311	1,947	1,734
-34-	,121	8,250	3,692	3,181	2,669	2,369	1,989	1,766
-35-	,125	8,000	3,825	3,285	2,745	2,430	2,032	1,800
-36-	,127	7,850	3,825	3,285	2,745	2,430	2,032	1,800
-37-	,129	7,750	3,825	3,285	2,745	2,430	2,032	1,800
-38-	,131	7,630	3,825	3,285	2,745	2,430	2,032	1,800
-39-	,133	7,500	3,825	3,285	2,745	2,430	2,032	1,800
-40-	,136	7,370	3,825	3,285	2,745	2,430	2,032	1,800
-41-	,138	7,250	3,825	3,285	2,745	2,430	2,032	1,800
-42-	,140	7,120	3,825	3,285	2,745	2,430	2,032	1,800
-43-	,143	7,000	3,825	3,285	2,745	2,430	2,032	1,800
-44-	,146	6,870	3,825	3,285	2,745	2,430	2,032	1,800
-45-	,148	6,750	3,825	3,285	2,745	2,430	2,032	1,800
-46-	,151	6,630	3,825	3,285	2,745	2,430	2,032	1,800
-47-	,154	6,500	3,825	3,285	2,745	2,430	2,032	1,800
-48-	,157	6,370	3,825	3,285	2,745	2,430	2,032	1,800
-49-	,160	6,250	3,825	3,285	2,745	2,430	2,032	1,800
-50-	,163	6,130	3,825	3,285	2,745	2,430	2,032	1,800
-51-	,167	6,000	3,825	3,285	2,745	2,430	2,032	1,800
-52-	,170	5,870	3,825	3,285	2,745	2,430	2,032	1,800

[illegible] RW
checked [illegible]

SHEET · A-15

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
-54-	,178	5,630	3,825	3,285	2,745	2,430	2,032	1,800
-55-	,182	5,500	3,825	3,285	2,745	2,430	2,032	1,800
-56-	,186	5,370	3,825	3,285	2,745	2,430	2,032	1,800
-57-	,190	5,250	3,825	3,285	2,745	2,430	2,032	1,800
-58-	,195	5,130	3,825	3,285	2,745	2,430	2,032	1,800
-59-	,200	5,000	3,825	3,285	2,745	2,430	2,032	1,800
-60-	,204	4,900	3,825	3,285	2,745	2,430	2,032	1,800
-61-	,208	4,800	3,825	3,285	2,745	2,430	2,032	1,800
-62-	,213	4,700	3,825	3,285	2,745	2,430	2,032	1,800
-63-	,217	4,600	3,825	3,285	2,745	2,430	2,032	1,800
-64-	,222	4,500	3,825	3,285	2,745	2,430	2,032	1,800
-65-	,227	4,400	3,825	3,285	2,745	2,430	2,032	1,800
-66-	,233	4,300	3,825	3,285	2,745	2,430	2,032	1,800
-67-	,238	4,200	3,825	3,285	2,745	2,430	2,032	1,800
-68-	,244	4,100	3,825	3,285	2,745	2,430	2,032	1,800
-69-	,250	4,000	3,825	3,285	2,745	2,430	2,032	1,800
-70-	,256	3,900	3,825	3,285	2,745	2,430	2,032	1,800
-71-	,263	3,800	3,825	3,285	2,745	2,430	2,032	1,800
-72-	,270	3,700	3,825	3,285	2,745	2,430	2,032	1,800
-73-	,278	3,600	3,825	3,285	2,745	2,430	2,032	1,800
-74-	,290	3,450	3,825	3,285	2,745	2,430	2,032	1,800
-75-	,303	3,300	3,825	3,285	2,745	2,430	2,032	1,800
-76-	,317	3,150	3,825	3,285	2,745	2,430	2,032	1,800
-77-	,333	3,000	3,825	3,285	2,745	2,430	2,032	1,800
-78-	,345	2,900	3,825	3,285	2,745	2,430	2,032	1,800
-79-	,357	2,800	3,825	3,285	2,745	2,430	2,032	1,800
-80-	,370	2,700	3,825	3,285	2,745	2,430	2,032	1,800
-81-	,385	2,600	3,825	3,285	2,745	2,430	2,032	1,800
-82-	,400	2,500	3,748	3,285	2,745	2,430	2,032	1,800* 3.84[illegible]
-83-	,417	2,400	3,598	3,165	2,736	2,430	2,032	1,800
-84-	,435	2,300	3,448	3,033	2,622	2,371	2,032	1,800 → 4.013
-85-	,455	2,200	3,298	2,901	2,508	2,268	1,975	1,789
-86-	,476	2,100	3,148	2,769	2,394	2,165	1,885	1,707
-87-	,500	2,000	2,999	2,638	2,280	2,062	1,795	1,626
-88-	,526	1,900	2,849	2,506	2,166	1,959	1,705	1,545
-89-	,556	1,800	2,699	2,374	2,052	1,856	1,616	1,464
-90-	,588	1,700	2,549	2,242	1,938	1,753	1,526	1,382
-91-	,625	1,600	2,399	2,110	1,824	1,650	1,436	1,301
-92-	,667	1,500	2,249	1,978	1,710	1,546	1,346	1,220
-93-	,714	1,400	2,099	1,846	1,596	1,443	1,257	1,138
-94-	,769	1,300	1,949	1,714	1,482	1,340	1,167	1,057
-95-	,833	1,200	1,799	1,583	1,368	1,237	1,077	,976
-96-	,909	1,100	1,649	1,451	1,254	1,134	,987	,894
-97-	1,000	1,000	1,499	1,319	1,140	1,031	,898	,813
-98-	1,111	,900	1,349	1,187	1,026	,928	,808	,732
-99-	1,250	,800	1,199	1,055	,912	,825	,718	,650
-100-	1,429	,700	1,050	,923	,798	,722	,628	,569
-101-	1,538	,650	,974	,857	,741	,670	,583	,529
-102-	1,667	,600	,894	,791	,684	,619	,539	,488
-103-	2,000	,500	,821	,557	,495	,457	,411	,383
-104-	2,500	,400	,397	,356	,317	,293	,263	,245
-105-	3,333	,300	,223	,200	,178	,165	,148	,138
-106-	4,000	,250	,155	,139	,124	,114	,103	,096

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
-107-	5,000	,200	,099	,089	,079	,073	,066	,061
-108-	10,000	,100	,025	,022	,020	,018	,016	,015

SHEET .A-16

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. A-17

JOB NO. 0902-19 JOB DIABLO REVIEW BY RRV DATE 4/10/78

CLIENT PG&E SUBJECT Refueling Water Storage Tank CHK'D CSC DATE 4/10/78

SUMMARY OF DYNAMIC ANALYSIS RESULTS — PERIODS & PARTICIPATION FACTORS

Mode No.	Period, sec.	Spectral Velocity, ft/sec.	Modal Participation Factor, %	Damping ζ
1	0.132	1.218	50.7	0.07
2	0.052	0.285	22.6	0.07
3	0.040	0.182	1.5	0.07
4	0.037	0.164	9.3	0.07
5	0.034	0.142	5.0	0.07
6	0.032	0.127	6.0	0.07
7	0.028	0.111	4.9	0.07

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SHEET NO. A-18

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-12-78

CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS
IN CONCRETE ELEMENTS
(FROM 2-SHELL MODEL AXIDYN OUTPUT)

NOTE: NUMBERS IN PARENTHESES CORRESPOND TO 1% DAMPING

NODAL POINT	FORCE / MOMENT K / K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
1	LONG. MOMENT	36.5	(0.7) 0.4	0.7	25.2	13.0	75.8
	CIRC. MOMENT	7.3	(0.2) 0.1	0.1	5.0	2.6	15.1
	LONG. FORCE	188.2	(3.4) 2.0	6.2	0.4	3.3	200.1
	CIRC. FORCE	37.6	(0.7) 0.4	1.2	3.3	2.3	44.8
	SHEAR	86.5	(1.5) 0.9	0	0	0	87.4
2	LONG. MOMENT	15.4	(0.3) 0.2	0.3	10.1	5.2	31.2
	CIRC. MOMENT	3.1	—	0.1	2.0	1.1	6.3
	LONG. FORCE	150.5	(2.7) 1.6	5.0	2.2	3.6	162.9
	CIRC. FORCE	35.9	(0.7) 0.4	0.9	1.2	1.1	39.5
	SHEAR	82.4	(1.5) 0.9	0	0	0	83.3
4	LONG. MOMENT	0.8	—	—	2.9	1.5	5.2
	CIRC. MOMENT	0.1	—	—	0.6	0.3	1.0
	LONG. FORCE	137.3	(2.2) 1.3	4.2	1.5	2.9	147.2
	CIRC. FORCE	31.6	(0.2) 0.1	0.2	37.5	18.9	88.3
	SHEAR	94.3	(1.4) 0.8	0	0	0	95.1
6	LONG. MOMENT	4.1	—	—	2.4	1.2	7.7
	CIRC. MOMENT	0.9	—	—	0.5	0.3	1.7
	LONG. FORCE	135.4	(2.1) 1.2	3.9	1.2	2.6	144.3
	CIRC. FORCE	16.7	(0.2) 0.1	0.1	33.3	16.7	66.9
	SHEAR	103.9	(1.4) 0.8	0	0	0	104.7
8	LONG. MOMENT	0.5	—	—	0.1	0.1	0.7
	CIRC. MOMENT	0.2	—	—	—	—	0.2
	LONG. FORCE	106.1	(1.7) 1.0	3.4	1.0	2.2	113.7
	CIRC. FORCE	17.5	(0.2) 0.1	0.2	30.8	15.5	64.1
	SHEAR	99.2	(1.4) 0.8	0	0	0	100.0

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SHEET NO. A-19
JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-12-78
CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS IN CONCRETE ELEMENTS
(FROM 2-SHELL MODEL AXIDYN OUTPUT)

NOTE: NUMBERS IN PARENTHESES CORRESPOND TO 1% DAMPING

NODAL POINT	FORCE / MOMENT K / K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
10	LONG. MOMENT	2.1	—	—	0.1	0.1	2.3
	CIRC. MOMENT	0.3	—	—	—	—	0.3
	LONG. FORCE	87.2	(1.7) 1.0	3.6	1.0	2.3	95.1
	CIRC. FORCE	24.8	(0.2) 0.1	0.1	28.1	14.1	67.2
	SHEAR	96.6	(1.4) 0.8	0	0	0	97.4
12	LONG. MOMENT	3.9	—	—	0.1	0.1	4.1
	CIRC. MOMENT	0.9	—	—	—	—	0.9
	LONG. FORCE	57.8	(1.4) 0.8	3.1	1.0	2.1	64.8
	CIRC. FORCE	32.8	(0.3) 0.2	0.1	24.0	12.1	69.2
	SHEAR	76.5	(1.4) 0.8	0	0	0	77.3
13	LONG. MOMENT	2.7	—	—	—	—	2.7
	CIRC. MOMENT	0.5	—	—	—	—	0.5
	LONG. FORCE	47.8	(1.2) 0.7	3.1	0.8	2.0	54.4
	CIRC. FORCE	27.6	(0.3) 0.2	—	21.9	11.0	60.7
	SHEAR	70.2	(1.4) 0.8	0	0	0	71.0
17	LONG. MOMENT	0.8	—	—	0.1	0.1	1.0
	CIRC. MOMENT	0.2	—	—	—	—	0.2
	LONG. FORCE	14.1	(0.5) 0.3	2.2	0.6	1.4	18.6
	CIRC. FORCE	39.4	(1.0) 0.6	—	11.2	5.6	56.8
	SHEAR	32.7	(1.2) 0.7	0	0	0	33.4
22	LONG. MOMENT	0.5	(0.2) 0.1	0.7	0.1	0.4	1.8
	CIRC. MOMENT	0.3	—	0.1	—	0.1	0.5
	LONG. FORCE	2.0	—	1.1	—	0.6	3.7
	CIRC. FORCE	38.1	(1.2) 0.7	3.4	0.8	2.1	45.1
	SHEAR	4.5	(0.2) 0.1	0	0	0	4.6

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SHEET NO. A-20

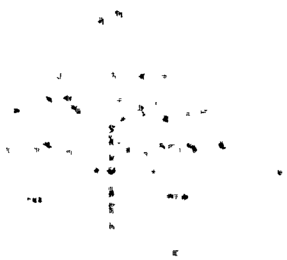
JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-13-78

CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS IN STEEL ELEMENTS (FROM 2-SHELL MODEL AXIDYN OUTPUT)

NOTE: NUMBERS IN PARENTHESES CORRESPOND TO 1% DAMPING

NODAL POINT	FORCE / MOMENT K/K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
3	LONG. MOMENT	—	—	—	—	—	—
	CIRC. MOMENT	—	—	—	—	—	—
	LONG. FORCE	68.0	(1.2) 0.7	0.2	0.2	0.2	69.3
	CIRC. FORCE	34.9	(0.3) 0.2	0.4	10.3	5.4	51.2
	SHEAR	37.7	(0.5) 0.3	0	0	0	38.0
5	LONG. MOMENT	—	—	—	—	—	—
	CIRC. MOMENT	—	—	—	—	—	—
	LONG. FORCE	62.3	(1.4) 0.8	2.5	1.5	2.0	69.1
	CIRC. FORCE	19.3	(0.2) 0.1	0.2	20.6	10.4	50.6
	SHEAR	38.4	(0.9) 0.5	0	0	0	38.9
6	LONG. MOMENT	—	—	—	—	—	—
	CIRC. MOMENT	—	—	—	—	—	—
	LONG. FORCE	52.1	(1.2) 0.7	2.5	1.6	2.1	59.0
	CIRC. FORCE	11.8	—	0.2	22.3	11.3	45.6
	SHEAR	35.2	(0.7) 0.4	0	0	0	35.6
7	LONG. MOMENT	—	—	—	—	—	—
	CIRC. MOMENT	—	—	—	—	—	—
	LONG. FORCE	45.3	(1.2) 0.7	0.2	1.5	0.9	48.6
	CIRC. FORCE	26.2	—	0.1	18.9	9.5	54.7
	SHEAR	34.7	(0.7) 0.4	0	0	0	35.1
9	LONG. MOMENT	—	—	—	—	—	—
	CIRC. MOMENT	—	—	—	—	—	—
	LONG. FORCE	27.1	(1.0) 0.6	1.9	1.0	1.5	32.1
	CIRC. FORCE	3.1	—	0.1	16.6	8.4	28.2
	SHEAR	25.2	(0.5) 0.3	0	0	0	25.5



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SHEET NO. A-21

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-13-75

CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS IN STEEL ELEMENTS
(FROM 2-SHELL MODEL AXIDYN OUTPUT)

NOTE: NUMBERS IN PARENTHESES CORRESPOND TO 1% DAMPING

NODAL POINT	FORCE / MOMENT K / K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
12	LONG. MOMENT	—	—	—	—	—	—
	CIRC. MOMENT	—	—	—	—	—	—
	LONG. FORCE	17.5	(0.5) 0.3	1.3	0.7	1.0	20.8
	CIRC. FORCE	8.8	—	0.1	9.9	5.0	23.8
	SHEAR	21.9	(0.5) 0.3	0	0	0	22.2
15	LONG. MOMENT	—	—	—	—	—	—
	CIRC. MOMENT	—	—	—	—	—	—
	LONG. FORCE	7.6	(0.2) 0.1	0.8	0.3	0.6	9.4
	CIRC. FORCE	9.6	(0.2) 0.1	0.1	5.3	2.7	17.8
	SHEAR	14.0	(0.3) 0.2	0	0	0	14.2
	LONG. MOMENT						
	CIRC. MOMENT						
	LONG. FORCE						
	CIRC. FORCE						
	SHEAR						
	LONG. MOMENT						
	CIRC. MOMENT						
	LONG. FORCE						
	CIRC. FORCE						
	SHEAR						
	LONG. MOMENT						
	CIRC. MOMENT						
	LONG. FORCE						
	CIRC. FORCE						
	SHEAR						

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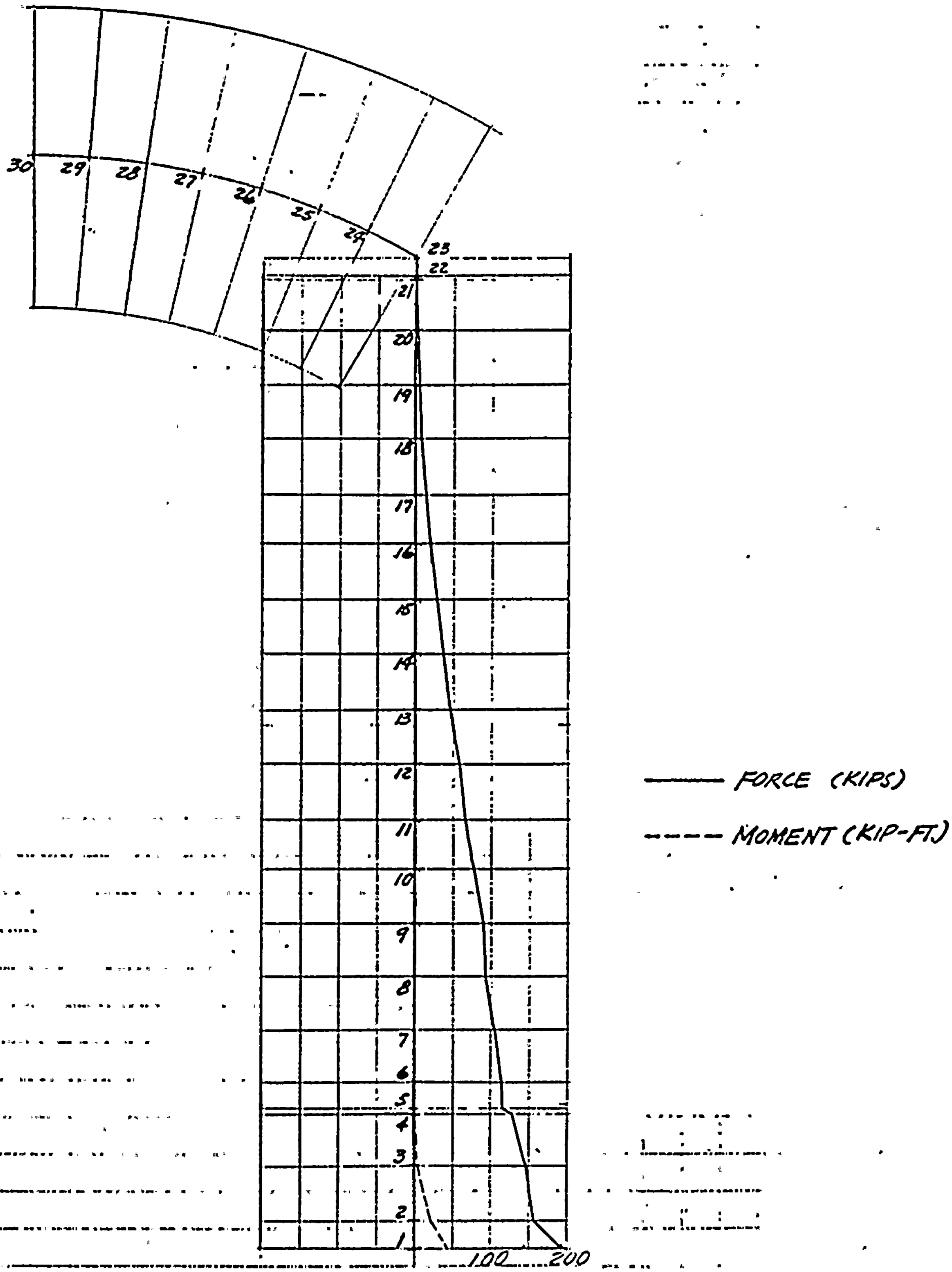
SHEET NO. A-22

JOB NO. 0902-19 JOB DIABLO - REFUELING WATER STORAGE TANK BY CSC DATE 4-10-78

CLIENT PG&E SUBJECT DYNAMIC ANALYSIS - IMPULSIVE PRESSURE CHK'D RRI DATE 4-10-78



LONGITUDINAL FORCES AND MOMENTS
IN CONCRETE ELEMENTS

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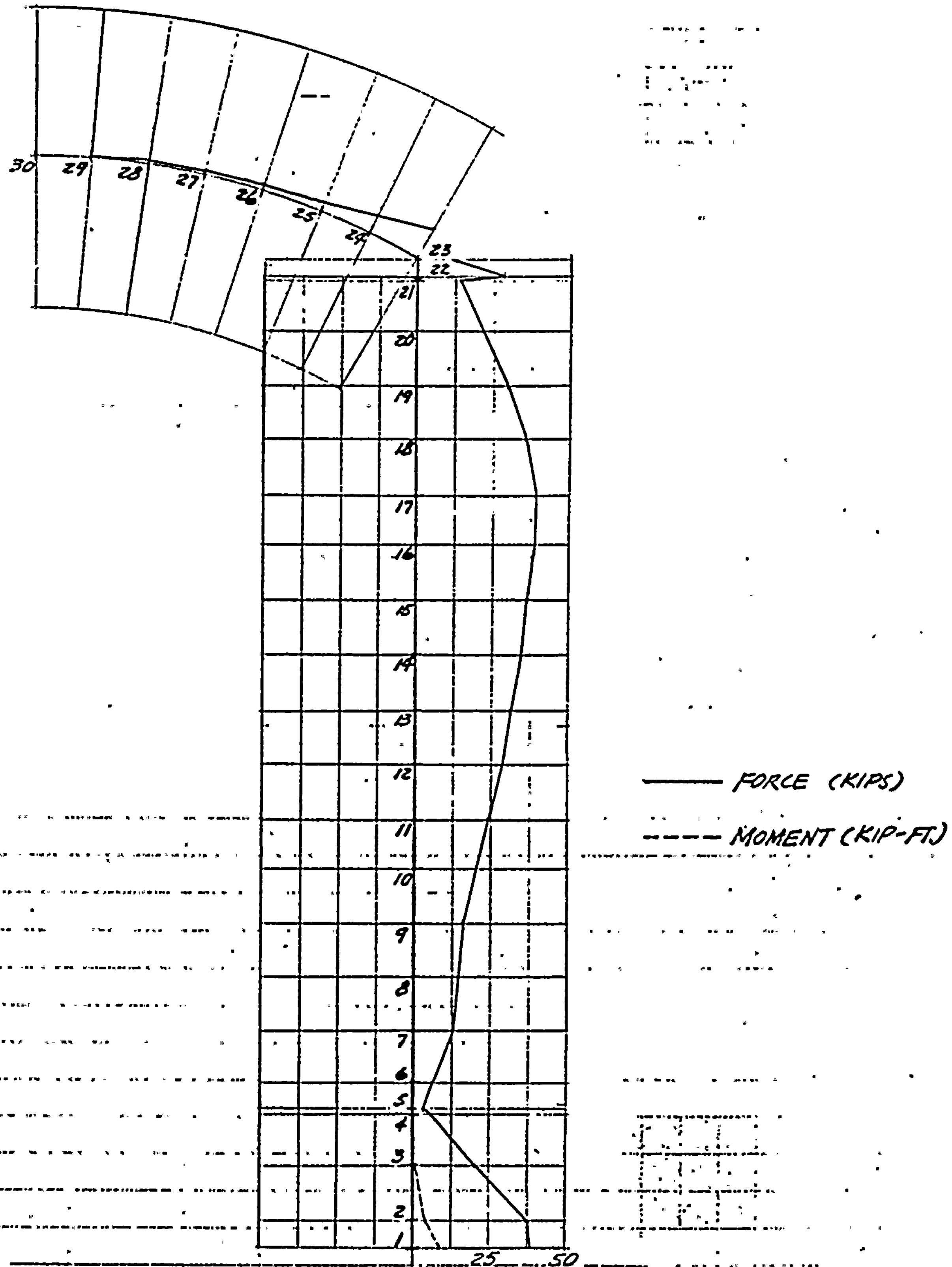
SHEET NO. A-23

JOB NO. 0902-19 JOB DIABLO - REFUELING WATER STORAGE TANK BY CJC DATE 4-10-78

CLIENT PG&E SUBJECT DYNAMIC ANALYSIS — IMPULSIVE PRESSURE CHK'D RJV DATE 4-10-78



CIRCUMFERENTIAL FORCES AND MOMENTS IN CONCRETE ELEMENTS

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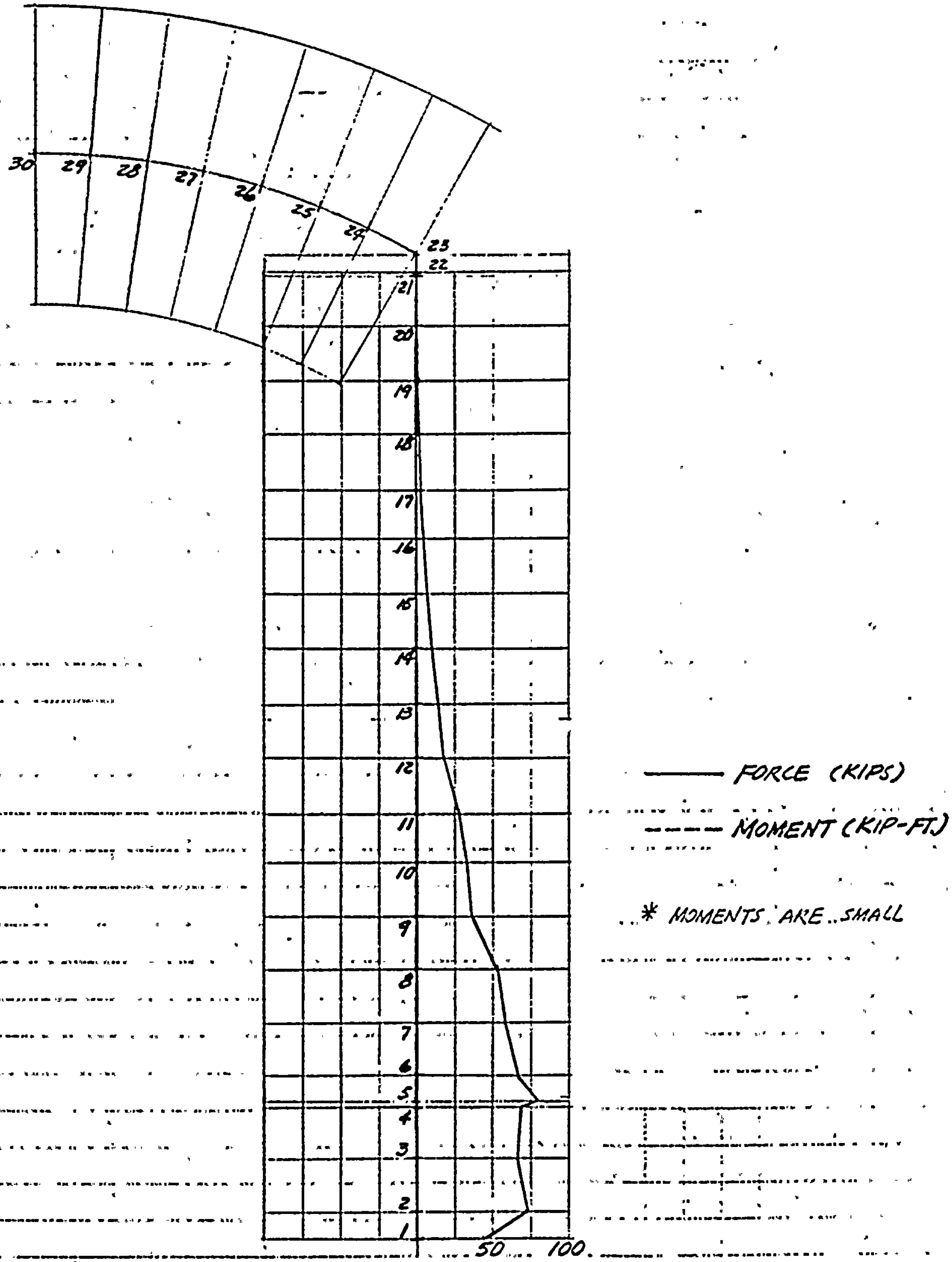
SHEET NO. A-24

JOB NO. 0902-19 JOB DIABLO - REFUELING WATER STORAGE TANK BY CSC DATE 4-10-78

CLIENT PG&E SUBJECT DYNAMIC ANALYSIS — IMPULSIVE PRESSURE CHK'D RRV DATE 4-18-78



LONGITUDINAL FORCES AND MOMENTS*
IN STEEL ELEMENTS

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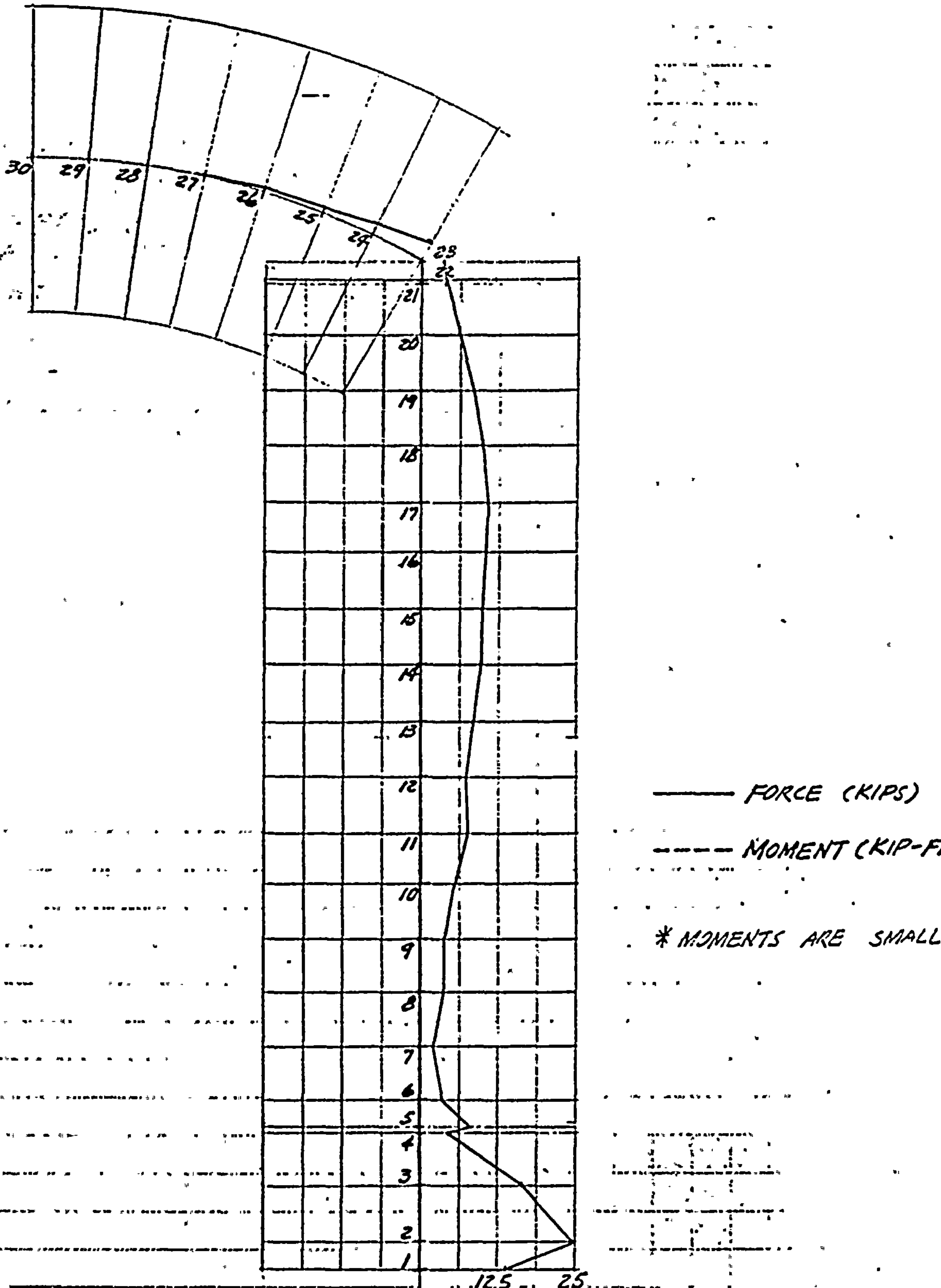
SHEET NO. A-25

JOB NO. 0902-19 JOB DIABLO-REFUELING WATER STORAGE TANK BY CSC DATE 4-10-78

CLIENT PG&E SUBJECT DYNAMIC ANALYSIS—IMPULSIVE PRESSURE CHK'D RRV DATE 4-10-78



CIRCUMFERENTIAL FORCES AND MOMENTS*
IN STEEL ELEMENTS

URS/BLUME
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SHEET NO. A-26

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-13-78

CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS
IN CONCRETE ELEMENTS
(FROM 2-SHELL MODEL AXIDYN OUTPUT)
TANGENTIAL FORCE

NODAL POINT	FORCE K / MOMENT K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
1	LONG. MOMENT	+13.9					
	CIRC. MOMENT	+ 2.7					
	LONG. FORCE	-64.2					
	CIRC. FORCE	-12.8					
	SHEAR	-33.8					
2	LONG. MOMENT	- 4.6					
	CIRC. MOMENT	- 0.9					
	LONG. FORCE	-50.9					
	CIRC. FORCE	-12.5					
	SHEAR	-31.9					
4	LONG. MOMENT	-0.3					
	CIRC. MOMENT	—					
	LONG. FORCE	-45.6					
	CIRC. FORCE	-11.7					
	SHEAR	-33.4					
6	LONG. MOMENT	-1.3					
	CIRC. MOMENT	-0.3					
	LONG. FORCE	-44.2					
	CIRC. FORCE	-6.7					
	SHEAR	-35.9					
8	LONG. MOMENT	-0.2					
	CIRC. MOMENT	—					
	LONG. FORCE	-33.3					
	CIRC. FORCE	+2.5					
	SHEAR	-36.7					

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SHEET NO. A-27

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-13-78

CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS
IN CONCRETE ELEMENTS
(FROM 2-SHELL MODEL AXIDYN OUTPUT)
TANGENTIAL

NODAL POINT	FORCE / MOMENT K / K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
10	LONG. MOMENT	+0.4					
	CIRC. MOMENT	—					
	LONG. FORCE	-25.7					
	CIRC. FORCE	+1.5					
	SHEAR	-36.8					
12	LONG. MOMENT	-0.9					
	CIRC. MOMENT	-0.2					
	LONG. FORCE	-15.6					
	CIRC. FORCE	+2.6					
	SHEAR	-29.7					
13	LONG. MOMENT	+0.7					
	CIRC. MOMENT	+0.1					
	LONG. FORCE	-12.1					
	CIRC. FORCE	-0.9					
	SHEAR	-26.8					
17	LONG. MOMENT	-0.1					
	CIRC. MOMENT	-0.3					
	LONG. FORCE	-2.0					
	CIRC. FORCE	+0.1					
	SHEAR	-10.4					
22	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	—					
	CIRC. FORCE	—					
	SHEAR	—					

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SHEET NO. A-28

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-13-75
CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS
IN STEEL ELEMENTS
(FROM 2-SHELL MODEL AXIDYN OUTPUT)
TANGENTIAL FORCE

NODAL POINT	FORCE / MOMENT K / K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
3	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	-24.8					
	CIRC. FORCE	-12.7					
	SHEAR	-11.9					
5	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	-20.8					
	CIRC. FORCE	- 7.0					
	SHEAR	-14.4					
6	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	-17.1					
	CIRC. FORCE	- 4.3					
	SHEAR	-13.4					
7	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	-16.3					
	CIRC. FORCE	- 1.8					
	SHEAR	-12.6					
9	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	-8.4					
	CIRC. FORCE	-0.4					
	SHEAR	-9.6					

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SHEET NO. A-29

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 7-13-7?

CLIENT PG&E SUBJECT REFUELING WATER STORAGE TANK CHK'D PMN DATE

SUMMARY OF FORCES & MOMENTS
IN STEEL ELEMENTS
(FROM 2-SHELL MODEL AXIDYN OUTPUT)
TANGENTIAL FORCE

NODAL POINT	FORCE / MOMENT K / K-F	IMPULSIVE PRESSURE	CONVECTIVE PRESSURE	DEAD LOAD	HYDRO-STATIC PRESSURE	VERTICAL EQ.	TOTAL
12	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	-4.9					
	CIRC. FORCE	+0.3					
	SHEAR	-8.5					
15	LONG. MOMENT	—					
	CIRC. MOMENT	—					
	LONG. FORCE	-1.8					
	CIRC. FORCE	-0.1					
	SHEAR	-5.0					
	LONG. MOMENT						
	CIRC. MOMENT						
	LONG. FORCE						
	CIRC. FORCE						
	SHEAR						
	LONG. MOMENT						
	CIRC. MOMENT						
	LONG. FORCE						
	CIRC. FORCE						
	SHEAR						
	LONG. MOMENT						
	CIRC. MOMENT						
	LONG. FORCE						
	CIRC. FORCE						
	SHEAR						

NET BASE SHEAR & OVERTURNING MOMENT

BASED ON THE DYNAMIC ANALYSIS WITH UNIFORM IMPULSIVE PRESSURE AND A STATIC ANALYSIS (WITH ONLY FIRST MODE ACCELERATIONS FROM DYNAMIC ANALYSIS) TO OBTAIN THE EFFECTS OF TANGENTIAL PRESSURE LOAD, THE NET BASE SHEAR AND OVERTURNING MOMENT ARE CALCULATED AS BELOW FOR THE AXI-SYMMETRIC MODEL.

BASE SHEAR: @ NODE # 1 (SHEAR. FORCE)

ELEMENTS	IMPULSIVE* (RMS VALUES)	TANGENTIAL**
CONCRETE	86.47	33.80
STEEL	17.31	6.76
	103.78 K/ft	40.56 K/ft

NET BASE SHEAR INTENSITY = 103.78 − 40.56 = 63.22 K/ft

∴ TOTAL BASE SHEAR = $\pi R f_s$
$= \pi \times 21.0 \times 63.22 = 4164$ KIPS

OVERTURNING MOMENT: @ NODE # 1 (LONGL. FORCE)

ELEMENTS	IMPULSIVE* (RMS VALUES)	TANGENTIAL**
CONCRETE	188.20	64.18
STEEL	43.03	14.68
	231.23 K/FT	78.86 K/ft

NET LONG^L MOMENT INTENSITY = 231.23 − 78.86 = 152.37 K/ft

∴ TOTAL OVERTURNING MOMENT = $\pi R^2 f_s$
$= \pi \times (21.0)^2 \times 152.37 = 211{,}100$ K-FT

NOTE: THE ABOVE VALUES DO NOT INCLUDE THE EFFECTS OF LONGITUDINAL MOMENT CONTRIBUTION FOR THESE DETAILS REFER Sh. D-30.

* SEE SH. A-18 TO A-21 FOR SUMMARY OF FORCES

** SEE SH. A-26 TO A-29 FOR SUMMARY OF FORCES

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SHEET NO A-31
JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE AUG 24,78
CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 11/[illegible]

CHECK FOR STRESSES IN STEEL SHELL

AS PER ASME PRESSURE VESSELS CODE SECTION VIII, DIVISION 2,
FOR SA-240, TP 304L $S_y = 25$ KSI
TABLE AHA-1 $S_m = 16.7$ KSI at 100°F

1) GENERAL PRIMARY MEMBRANE STRESS INTENSITY (P_L)

LOAD COMBINATION	ALLOWABLE STRESS
i) DL + HS	$k\,S_m = 1.0 \times 16.7 = 16.7$ KSI
ii) $DL + HS + \sqrt{EQ_{YY}^2 + EQ_{XX}^2 + EQ_{ZZ}^2}$	$k\,S_m = 1.5 \times 16.7 = 25.05$ KSI

2) PRIMARY MEMBRANE STRESS + BENDING

This case not critical for Refueling water tank because bending moments in steel shell elements are negligible. Hence check for stresses made as per criterion (1).

* DUE TO THE USE OF CARBON STEEL AFFECTED BY CORROSSION, SHELL THICKNESS REDUCED BY 1/16"

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JOB NO 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT REFUELING TANK (AXIDYN MODEL)
SHEET NO A-32
BY LC DATE 11/2/78
CHK'D PMN DATE

CHECK FOR STRESSES IN STEEL SHELL

ELEMENT NO. (NODAL PTS)	t** (in) ① *	Fx (K/FT) ② *	Fy (K/FT) ③ *	Fxy (K/FT) ④ *	σ_{xx} (KSI) ②/(12×①)	σ_{yy} (KSI) ③/(12×①)	σ_{xy} (KSI) ④/(12×①)	CHECK FOR STRESSES (DL + HS + HE + VE)
1-5 (1-6)	0.516	85.1	37.6	50.5	13.74	6.87	8.16	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{13.74-(-6.87)}{2}\right)^2 + (8.16)^2}$ $= 13.14$; $.7(2\tau_{max}) = 18.40 < 25.05$
6-8 (6-9)	0.428	73	37.5	46.2	14.21	7.30	9.00	$\tau_{max} = \sqrt{\left(\frac{14.21-(-7.30)}{2}\right)^2 + (9.00)^2}$ $= 14.02$; $.7(2\tau_{max}) = 19.63 < 25.05$
9-11 (9-12)	0.294	41.8	29.0	33.7	8.14	5.65	6.56	$\tau_{max} = \sqrt{\left(\frac{8.14-(-5.65)}{2}\right)^2 + (6.56)^2}$ $= 9.52$; $.7(2\tau_{max}) = 13.33 < 25.05$
12-14 (12-15)	0.213	21.4	22.3	22.7	8.37	8.72	8.88	$\tau_{max} = \sqrt{\left(\frac{8.37-(-8.72)}{2}\right)^2 + (8.88)^2}$ $= 12.32$; $.7(2\tau_{max}) = 17.25 < 25.05$

* FROM CALCULATIONS BY RRV DATED 6/6/78
** $t = t_{pl.} - 1/16$ (corrosion allowable)

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JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT REFUELING TANK (AXIDYN MODEL)
BY LC DATE 11/2/78
CHK'D ____ DATE ____
SHEET NO. A-33

CHECK FOR STRESSES IN STEEL SHELL

ELEMENT NO. (NODAL PTS)	t (in) ① *	Fx (K/FT) ② *	Fy (K/FT) ③ *	Fxy (K/FT) ④ *	σ_{xx} (KSI) ②/(12×①)	σ_{yy} (KSI) ③/(12×①)	σ_{xy} (KSI) ④/(12×①)	CHECK FOR STRESSES (DL + HS + HE + VE)
15-29 (15-30)	0.188	9.2	18.0	14.0	4.08	7.98	6.21	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{4.08 - (-7.98)}{2}\right)^2 + (6.21)^2}$ $= 8.66$ $\therefore (2\tau_{max}) = 12.12 < 25.05$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$

* FROM CALCULATIONS BY RRV DATED 6/6/78
** t = t PL. − 1/16 (corrosion allowable)

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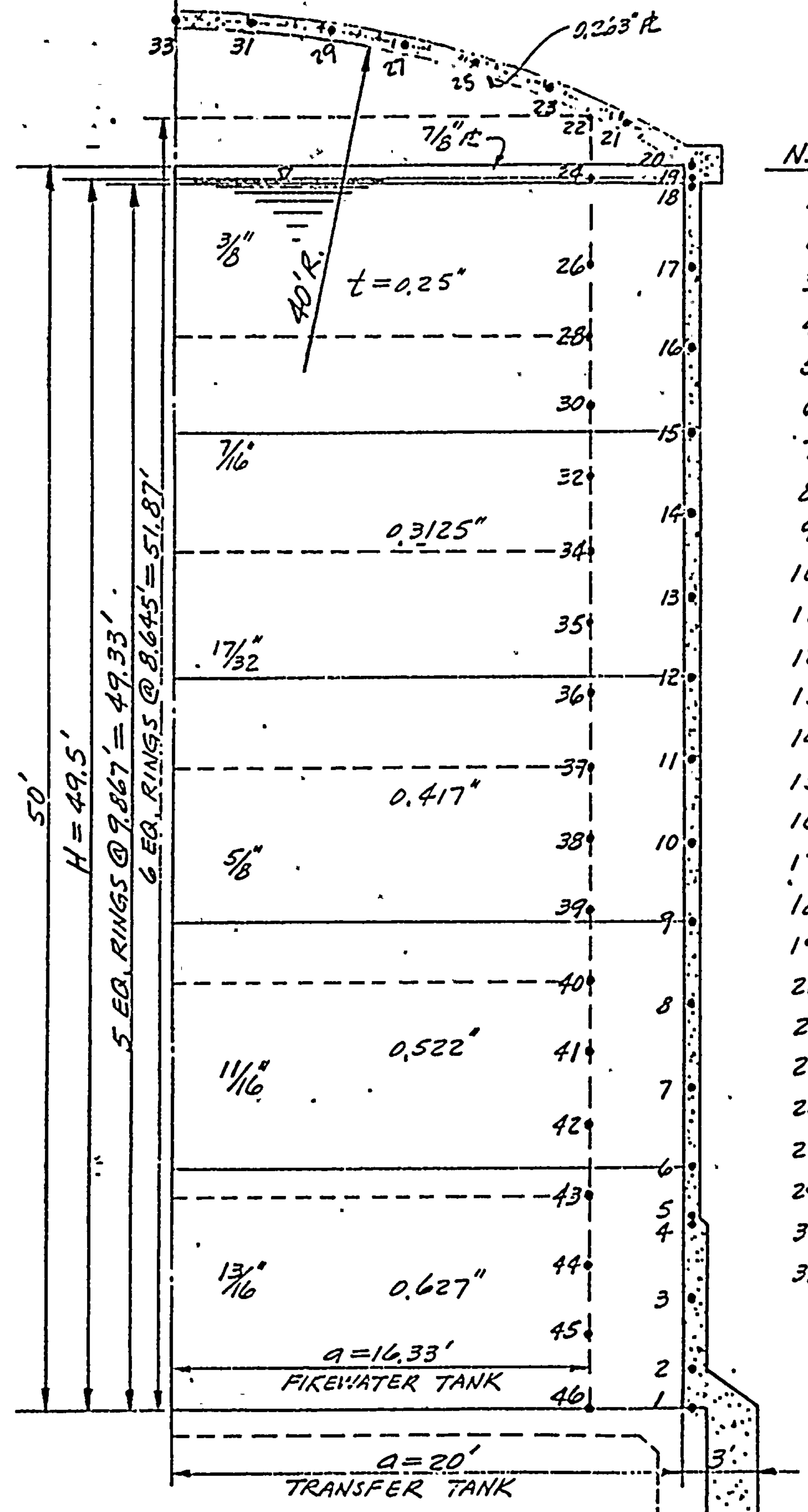
SHEET NO. B-1

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-8-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS CHK'D RRV DATE 4-4-78

SYMM. ABT. ℄ TANKS



N. P.	Z ft.	ΔZ ft.	R ft.
1	0	1.500	20.333
2	1.500	3.000	↓
3	4.500	3.000	
4	7.500	0.192	
5	7.692	2.175	
6	9.867	3.289	
7	13.156	↓	
8	16.445		
9	19.734		
10	23.023		
11	26.312		
12	29.601		
13	32.890		
14	36.179		
15	39.468		
16	42.757	3.289	
17	46.046	3.287	
18	49.333	0.167	
19	49.500	0.500	↓
20	50.000	1.410	20.333
21	51.410	1.206	17.500
23	52.616	0.996	14.735
25	53.612	0.781	11.383
27	54.393	0.561	8.975
29	54.954	0.337	6.011
31	55.291	0.113	3.014
33	55.404		0

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SHEET NO. B-2

JOB NO. 0902-19 JOB DIABLO REVIEW BY RLV DATE
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS CHK'D PMN DATE 9/16/78

Two cases of loading conditions will be considered:

1. Case where both inner (Firewater) and outer (Transfer). cylindrical tanks are filled with water up to design level.
2. Case where inner tank is filled to design level while the outer tank is empty.

The effective mass of the structure for a rigid body motion of Transfer Tank, $m_{x,s}$:

RING	z_i ft	z_j ft	t_s in	(1) μ_s lbs-sec²/in²	(2) A $\cos\frac{\pi}{2}\left(\frac{z_j}{H}\right)$	(2) B $\cos\frac{\pi}{2}\left(\frac{z_i}{H}\right)$	(2) A−B	$-\frac{2H\times12}{\pi}\mu_s(A-B)$ lbs-sec²/in
5	39.47	49.33	0.25	3.04	0.0054	0.3129	−0.3075	353.50
4	29.60	39.47	0.3125	3.11	0.3129	0.5903	−0.2774	326.24
3	19.73	29.60	0.417	3.22	0.5903	0.8103	−0.2200	267.88
2	9.87	19.73	0.522	3.34	0.8103	0.9514	−0.1411	178.21
1	0	9.87	0.627	4.87	0.9514	1.0000	−0.0486	89.50
Σ					$\int_0^{H_s}\mu_s(z)\psi(z)\,dz =$			1,215.33
ROOF	$z = 50' + \frac{2}{3}(5.36') = 53.57'$				$m_r\psi(H_s) = \frac{^{(3)}198.3^k\times1000}{32.2\times12}\times1 =$			513.20
TOTAL					$m_{x,s} = \int_0^{H_s}\mu_s(z)\psi(z)\,dz + m_r\psi(H_s) =$			1,728.53

(1) $\mu_s = \frac{\pi D\rho t}{g} = \frac{\pi}{32.2}\left[40(0.284)t_s + 40.67(0.087)8''\right] = 1.108t_s + 2.76$, lbs-sec²/in² ($\rho_{STL}$, ρ_{conc})

$41.0'(0.087)12'' = 1.108t_s + 4.18 \quad (t_c = 12'')$

(2) $\int_i^j \psi(z)\,dz = \int_i^j \sin\frac{\pi}{2}\frac{z}{H}\,dz = -\frac{2H}{\pi}\left|\cos\frac{\pi}{2}\frac{z}{H}\right|_{z_i}^{z_j}$, $H = 49.5'$

(3) WEIGHT OF ROOF:

STEEL ROOF: $\frac{0.263''}{0.25''}14.1^k$(P.G.&E Calc.) $+ \pi\,40'(51.87'-49.33')\frac{0.375''}{12}\times0.49^k/ft^3 = 19.7^k$

CONC. RING & COVER: $0.15^k/ft^3\,\pi[41.33'(1.33')^2 + 2(40.33')(5.69')(\frac{8''}{12})] = 178.6^k$

TOTAL WEIGHT 198.3^k

TRANSFER TANK

The effective mass of Transfer tank vibrating with deflection $\psi(z)$, $m_{w,s}$:

RING	μ_s lbs-sec²/in²	z_i ft.	z_j ft.	A: $12(z_j - z_i)$ in.	B: (1) $\sin \frac{\pi}{H} z_j$	C: (1) $\sin \frac{\pi}{H} z_i$	D: $\frac{12H}{\pi}(B-C)$	E: A−D	$\frac{\mu_s}{2} E$ lbs-sec²/in.
5	3.04	39.47	49.33	118.39	0.0108	0.5944	−110.34	228.73	347.67
4	3.11	29.60	39.47	118.39	0.5944	0.9530	−67.80	186.19	289.53
3	3.22	19.73	29.60	118.39	0.9530	0.9497	+ 0.62	117.77	189.61
2	3.34	9.87	19.73	118.39	0.9497	0.5862	+ 68.73	49.66	82.93
1	4.87	0	9.87	118.39	0.5862	0	+ 110.84	7.55	18.38
Σ	$\int_0^{H_s} \mu_s(z)\psi^2(z)dz =$								928.12
ROOF	$z = 53.57' = H_s$			$m_r\psi^2(H_s) = 513.2 \times 1^2 =$					513.20
TOTAL	$m_{w,s} = \int_0^{H_s} \mu_s(z)\psi^2(z)dz + m_r\psi^2(H_s) =$								1441.32

(1) $$\int_i^j \mu_s(z)\psi^2(z)dz = \mu_s \int_i^j \sin^2 \frac{\pi}{2}\frac{z}{H}\,dz$$

$$= \frac{\mu_s}{2}\int_i^j \left(1 - \cos \pi \frac{z}{H}\right)dz$$

$$= \frac{\mu_s}{2}\left| z - \frac{H}{\pi}\sin \pi \frac{z}{H} \right|_{z_i}^{z_j}$$

$$= \frac{\mu_s}{2}\left[12(z_j - z_i) - \frac{12H}{\pi}\left(\sin\frac{\pi}{H}z_j - \sin\frac{\pi}{H}z_i\right)\right], \quad \text{lbs-sec}^2/\text{in.}$$

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JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS
SHEET NO. B-5
BY CSC DATE 3-10-78
CHK'D RCY DATE 4-4-78

The effective mass of the structure for a rigid body motion of Firewater Tank, $m_{x,s}$:

FIREWATER TANK (INTERIOR TANK)

RING	z_i ft.	z_j ft.	t_s in.	(1) μ_s lbs-sec²/in.	(2) A $\cos\frac{\pi}{2}\left(\frac{z_j}{H}\right)$	(2) B $\cos\frac{\pi}{2}\left(\frac{z_i}{H}\right)$	(2) A−B	$-\frac{2H\times12}{\pi}\mu_s(A-B)$ lbs-sec²/in.
6	43.23	51.87	0.375	0.42	−0.0751	0.1977	−0.2728	43.33
5	34.58	43.23	0.4375	0.48	0.1977	0.4560	−0.2583	46.88
4	25.94	34.58	0.5313	0.59	0.4560	0.6799	−0.2239	49.95
3	17.29	25.94	0.625	0.69	0.6799	0.8532	−0.1733	45.22
2	8.65	17.29	0.6875	0.76	0.8532	0.9626	−0.1094	31.44
1	0	8.65	0.8125	0.90	0.9626	1.0000	−0.0374	12.73
Σ	$\int_0^{H_s}\mu_s(z)\psi(z)dz =$							229.55
ROOF	INCLUDED IN THE CALCULATION FOR TRANSFER TANK							—
TOTAL	$m_{x,s} = \int_0^{H_s}\mu_s(z)\psi(z)dz =$							229.55

(1) $\mu_s = \frac{\pi D \rho t}{g} = \frac{\pi}{32.2}\left[40(0.284)t_s\right] = 1.108\, t_s$, lbs-sec²/in.² (0.284: STL.)

(2) $\int_i^j \psi(z)\,dz = \int_i^j \sin\frac{\pi}{2}\frac{z}{H}\,dz = -\frac{2H}{\pi}\left|\cos\frac{\pi}{2}\frac{z}{H}\right|_{z_i}^{z_j}$, $H = 49.5'$

FIREWATER TANK

The effective mass of Firewater tank vibrating with deflection $\psi(z)$, $m_{w,s}$:

RING	μ_s lbs-sec²/in.²	z_i ft.	z_j ft.	A: $12(z_j - z_i)_{in}$	B: $\sin\frac{\pi}{H}z_j$ (1)	C: $\sin\frac{\pi}{H}z_i$ (1)	D: $\frac{12H}{\pi}(B-C)$	E: $A-D$	$\frac{\mu_s}{2}E$ lbs-sec²/in.
6	0.42	43.23	51.87	103.74	-0.1498	0.3875	-101.59	205.33	43.12
5	0.48	34.58	43.23	103.74	0.3875	0.8116	-80.19	183.93	44.14
4	0.59	25.94	34.58	103.74	0.8116	0.9971	-35.07	138.81	40.95
3	0.69	17.29	25.94	103.74	0.9971	0.8900	+20.25	83.49	28.80
2	0.76	8.65	17.29	103.74	0.8900	0.5218	+69.62	34.12	12.97
1	0.90	0	8.65	103.74	0.5218	0	+98.66	5.08	2.29
Σ	$\int_0^{H_s} \mu_s(z)\psi^2(z)\,dz =$								172.27
ROOF	INCLUDED IN THE CALCULATION FOR TRANSFER TANK								—
TOTAL	$m_{w,s} = \int_0^{H_s} \mu_s(z)\psi^2(z)\,dz =$								172.27

(1) $\int_i^j \mu_s(z)\psi^2(z)\,dz = \mu_s \int_i^j \sin^2\frac{\pi}{2}\frac{z}{H}\,dz$

$$= \frac{\mu_s}{2}\int_i^j \left(1 - \cos\pi\frac{z}{H}\right)dz$$

$$= \frac{\mu_s}{2}\left| z - \frac{H}{\pi}\sin\pi\frac{z}{H}\right|_{z_i}^{z_j}$$

$$= \frac{\mu_s}{2}\left[12(z_j - z_i) - \frac{12H}{\pi}\left(\sin\frac{\pi}{H}z_j - \sin\frac{\pi}{H}z_i\right)\right],\ \text{lbs-sec}^2/\text{in.}$$

* Case 1. BOTH FIREWATER & TRANSFER TANKS FILLED WITH WATER

The total mass of the liquid content ~~of Transfer Tank~~:

$$m = \rho \pi a^2 H = \frac{62.4 \pi (20)^2 49.5}{32.2 \times 12} = 10{,}045.3 \text{ lb-sec}^2/\text{in.}$$

$$\frac{H}{a} = \frac{49.5}{20} = \sim 2.5$$

From Fig. 9 of "DYNAMICS OF FIXED-BASE LIQUID-STORAGE TANKS" by A.S. Veletsos & J.Y. Yang :

Find the effective mass of the liquid for a rigid body motion of the tank, $m_{x,l}$:

$$\frac{m_{x,l}}{m} = 0.46, \quad m_{x,l} = 0.46(10{,}045.3) = 4{,}620.84 \text{ lbs-sec}^2/\text{in.}$$

Find the effective mass of the liquid vibrating with deflection $\psi(z)$, $m_{w,l}$:

$$\frac{m_{w,l}}{m} = 0.316, \quad m_{w,l} = 0.316(10{,}045.3) = 3{,}174.31 \text{ lbs-sec}^2/\text{in.}$$

$$C = \frac{m_x}{m_w} = \frac{m_{x,s} + m_{x,l}}{m_{w,s} + m_{w,l}}$$

$$C = \frac{1{,}728.53 + 4{,}620.84}{1{,}441.32 + 3{,}174.31} = 1.38$$ (considering exterior tank only)

or

$$\frac{(1728.53 + 229.55) + 4620.84}{(1441.32 + 172.27) + 3174.31} = 1.37$$ (considering both tanks)

* The impulsive component, p_o, of the hydrodynamic pressure exerted on the exterior tank wall:

$$p_o(z, \theta, t) = C\, b_o(z)\, \rho H A_o(t) \cos\theta$$

Use $C = 1.38$

$$\rho = \frac{62.4}{32.2} = 1.94 \text{ lbs-sec}^2/\text{ft.}^4$$

$A_o(t) = 1 \text{ ft/sec}^2$ (Assumed pseudo-acceleration)

$\theta = 0°$, $\cos\theta = 1$ (Parallel to the direction of excitation)

$b_o(z)$ — interpolated from Fig. 7 of "DYNAMIC OF FIXED-BASE LIQUID-STORAGE TANKS" by A.S. Veletsos & J.Y. Yang

* Calculate impulsive pressure p_o on exterior tank wall assuming there is no inner tank (also, p_o on interior tank is zero)

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SHEET NO. B-8

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-8-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS CHK'D RRV DATE 4-4-78

Interpolating the values of $b_o(z)$:

NODAL POINT	Z ft.	Z/H \ H/a	0.5	3.0	INTERPOLATED 2.5
19	49.500	1.0	0	0	0
18	49.333	0.997	0.010	0.030	$0.01 + \frac{3-2.5}{3-0.5}(0.010-0.030) = 0.014$
17	46.046	0.93	0.150	0.145	0.145 + 0.2(0.150 − 0.145) = 0.146
16	42.757	0.86	0.230	0.170	0.17 + 0.2(0.23 − 0.17) = 0.182
15	39.468	0.80	0.280	0.208	0.208 + 0.2(0.28 − 0.208) = 0.222
14	36.179	0.73	0.330	0.223	0.223 + 0.2(0.33 − 0.223) = 0.224
13	32.890	0.66	0.360	0.230	0.230 + 0.2(0.36 − 0.23) = 0.236
12	29.601	0.60	0.370	0.226	0.226 + 0.2(0.37 − 0.226) = 0.255
11	26.312	0.53	0.380	0.220	0.22 + 0.2(0.38 − 0.22) = 0.252
10	23.023	0.47	0.380	0.205	0.205 + 0.2(0.38 − 0.205) = 0.240
9	19.734	0.40	0.375	0.185	0.185 + 0.2(0.375 − 0.185) = 0.223
8	16.445	0.33	0.350	0.162	0.162 + 0.2(0.35 − 0.162) = 0.200
7	13.156	0.27	0.360	0.140	0.14 + 0.2(0.36 − 0.14) = 0.184
6	9.867	0.20	0.345	0.118	0.118 + 0.2(0.345 − 0.118) = 0.163
5	7.692	0.16	0.335	0.106	0.106 + 0.2(0.335 − 0.106) = 0.152
4	7.500	0.15	0.330	0.103	0.103 + 0.2(0.33 − 0.103) = 0.148
3	4.500	0.09	0.325	0.086	0.086 + 0.2(0.325 − 0.086) = 0.134
2	1.500	0.03	0.320	0.078	0.078 + 0.2(0.32 − 0.078) = 0.126
1	0	0	0.315	0.073	0.073 + 0.2(0.315 − 0.073) = 0.121

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SHEET NO. B-9

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-9-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS CHK'D KRV DATE 4-4-78

EXTERIOR TANK

FLUID INERTIA FORCE : $p_0 = C b_0(z) \rho H A_0(t) \cos\theta$

* Error would lead to conservative results. o.k. KRV

NODAL POINT	$b_0(z)$	$Cb_0(z)$	p_0 lbs/ft²	$p_u = \pi a p_0$ lbs/ft	ΔZ ft.	$P_T = \frac{P_u}{1000} \times \Delta Z$ K	ρ_{ave} K-sec²/ft⁴
19	0.814	.0	0	0	0.167	0	0.0117
18	0.044	0.061	5.86	368.19	3.287	0.06	0.0503
17	0.146	0.201	19.30	1212.65	3.289	3.99	0.0868
16	0.182	0.251	24.10	1514.25	↓	4.98	0.1070
15	0.222	0.306	29.39	1,846.63	↓	6.07	0.1181
14	0.224	0.309	29.67	1,864.22	↓	6.13	0.1220
13	0.236	0.326	31.31	1,967.27	↓	6.47	0.1302
12	0.255	0.352	33.80	2,123.72	↓	6.98	0.1344
11	0.252	0.348	33.42	2,099.84	↓	6.91	0.1304
10	0.240	0.331	31.79	1,997.42	↓	6.57	0.1227
9	0.223	0.308	29.58	1,858.57	↓	6.11	0.1122
8	0.200	0.276	26.50	1,665.04	↓	5.48	0.1018
7	0.184	0.254	24.39	1,532.47	3.289	5.04	0.0920
6	0.163	0.225	21.61	1,357.80	2.175	4.47	0.0836
5	0.152	0.210	20.17	1,267.32	0.192	2.76	0.0795
4	0.148	0.204	19.59	1,230.88	3.000	0.24	0.0747
3	0.134	0.185	17.77	1,116.52	3.000	3.35	0.0690
2	0.126	0.174	16.71	1,049.92	1.500	3.15	0.0655
1	0.121	0.167	16.04	1,007.82		3.02	

$p_u = \int p_0 \cos^2\theta \, a \, d\theta = \pi a p_0$

Effective fluid mass density $\rho = \frac{p_0}{1000\, t}$, K-sec²/ft⁴

Say fluid thickness $t = 3'' = 0.25'$

Then $\rho = \frac{p_0}{1000\,(0.25)} = \frac{p_0}{250}$, K-sec²/ft⁴

$\rho_{ave} = \frac{\rho_i + \rho_j}{2} = \frac{p_{0i} + p_{0j}}{500}$, K-sec²/ft⁴

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SHEET NO. B-10

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-17-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS CHK'D RRV DATE 4-4-78

EXTERIOR TANK

Impulsive Pressure

$$\rho' = \rho_1 + \rho_2 \frac{t_2}{t_1}, \quad \text{k-sec}^2/\text{ft}^4$$

where: $\rho_1 = \rho_{concrete}$, k-sec²/ft⁴

$\rho_2 = \rho_{fluid}$, k-sec²/ft⁴

$t_1 = t_{concrete}$, ft.

$t_2 = t_{fluid}$, ft.

MATERIAL No.	ρ_1	ρ_2	t_2	t_1	$\rho_2 \frac{t_2}{t_1}$	ρ'
20	4.658×10^{-3}	0.0117	0.25	0.6667	4.387×10^{-3}	0.009045
19	↓	0.0503	↓	↓	18.862×10^{-3}	0.023520
18		0.0868			32.548×10^{-3}	0.037206
17		0.1070			40.123×10^{-3}	0.044781
16		0.1181			44.285×10^{-3}	0.048943
15		0.1220			45.748×10^{-3}	0.050406
14		0.1302			48.823×10^{-3}	0.053481
13		0.1344			50.397×10^{-3}	0.055055
12		0.1304			48.898×10^{-3}	0.053556
11		0.1227			46.010×10^{-3}	0.050668
10		0.1122			42.073×10^{-3}	0.046731
9		0.1018			38.173×10^{-3}	0.042831
8		0.0920		↓	34.498×10^{-3}	0.039156
7		0.0836		0.6667	31.348×10^{-3}	0.036006
6		0.0795		0.8333	23.851×10^{-3}	0.028509
5		0.0747		1.0000	18.675×10^{-3}	0.023333
4	↓	0.0690	↓	1.0000	17.250×10^{-3}	0.021908
3	4.658×10^{-3}	0.0655	0.25	2.0000	8.188×10^{-3}	0.012846

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CASE 2.

When Transfer Tank is empty and only the Firewater Tank is filled, then

$$m = \rho \pi a^2 H = \frac{62.4\pi(16.33)^2 49.5}{32.2 \times 12} = 6{,}696.9 \text{ lb-sec}^2/\text{in.}$$

$$\frac{H}{a} = \frac{49.5}{16.33} = \sim 3$$

From Fig. 9 of "DYNAMICS OF FIXED-BASE LIQUID-STORAGE TANKS" by A.S. Veletsos & J.Y. Yang

Find the effective mass of the liquid for a rigid body motion of the tank, $m_{x,\ell}$:

$$\frac{m_{x,\ell}}{m} = 0.487, \quad m_{x,\ell} = 0.487(6{,}696.9) = 3{,}261.39 \text{ lbs-sec}^2/\text{in.}$$

Find the effective mass of the liquid vibrating with deflection $\psi(z)$, $m_{w,\ell}$:

$$\frac{m_{w,\ell}}{m} = 0.34; \quad m_{w,\ell} = 0.34(6696.9) = 2{,}276.95 \text{ lbs-sec}^2/\text{in}$$

$$C = \frac{m_x}{m_w} = \frac{m_{x,s} + m_{x,\ell}}{m_{w,s} + m_{w,\ell}}$$

$$= \frac{(1{,}728.53 + 229.55) + 3{,}261.39}{(1{,}441.32 + 172.27) + 2{,}276.95} = 1.34$$

The impulsive component, p_o, of the hydrodynamic pressure exerted on the Firewater Tank wall:

$$p_o(z,\theta,t) = C b_o(z) \rho H A_o(t) \cos\theta$$

where: $\rho = \frac{62.4}{32.2} = 1.94 \text{ lbs-sec}^2/\text{ft}^4$

$A_o(t) = 1 \text{ ft/sec}^2$ (Assumed pseudo-acceleration)

$\theta = 0°$, $\cos\theta = 1$ (Parallel to the direction of excitation)

$b_o(z)$ — interpolated from Fig. 7 of "DYNAMIC OF FIXED-BASE LIQUID-STORAGE TANKS" by A.S. Veletsos & J.Y. Yang

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SHEET NO. B-12

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-18-78

CLIENT PG & E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS CHK'D RRV DATE 4-4-78

INTERIOR TANK

Interpolating the values of $b_o(z)$:

NODAL POINT	z ft.	z/H	$b_o(z)$ AT $\frac{H}{a} = 3.0$
24	49.500	1.00	0
26	46.107	0.93	0.145
28	43.225	0.87	0.175
30	40.343	0.82	0.200
32	37.462	0.76	0.220
34	34.580	0.70	0.225
35	31.698	0.64	0.225
36	28.817	0.58	0.220
37	25.935	0.52	0.215
38	23.053	0.47	0.205
39	20.172	0.41	0.185
40	17.290	0.35	0.170
41	14.408	0.29	0.150
42	11.527	0.23	0.120
43	8.645	0.17	0.110
44	5.763	0.12	0.095
45	2.882	0.06	0.085
46	0	0	0.075

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SHEET NO. B-13

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-21-78
CLIENT PG & E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS CHK'D RRV DATE 4-4-78

INTERIOR TANK

FLUID INERTIA FORCE : $p_o = C b_o(z) \rho H A_o(t) \cos\theta$

$$p_u = \int p_o \cos^2\theta \, d\theta = \pi a p_o$$

Effective fluid mass density $\rho = \dfrac{p_o}{1{,}000\,t}$, $k\text{-}sec^2/ft^4$

For Steel Shell Thickness : t_s in ft.

$$\rho = \frac{p_o}{1000\, t_s} \qquad k\text{-}sec^2/ft^4$$

$$\rho_{ave} = \frac{\rho_i + \rho_j}{2} = \frac{p_{oi} + p_{oj}}{2000\, t_s} , \qquad k\text{-}sec^2/ft^4$$

t_s	NODAL POINT	$b_o(z)$	$C b_o(z)$	p_o lbs/ft²	$p_u = \pi a \frac{p_o}{a}$ lbs/ft.	ΔZ ft.	$P_T = \frac{P_u \Delta Z}{1000}$ K	ρ_{ave} k-sec²/ft⁴	* ρ' k-sec²/ft⁴
$t_s = 3/8"$	24	0	0	0	0	3.393	0	0.29808	0.31329
	26	0.145	0.194	18.63	955.76	2.882	3.24	0.65920	0.67441
	28	0.175	0.235	22.57	1,157.89	2.882	3.34	0.662537	0.67775
$t_s = 7/16"$	30	0.200	0.268	25.74	1,320.52	2.881	3.81	0.741531	0.75674
	32	0.220	0.295	28.33	1,453.39	2.882	4.19	0.786240	0.80145
	34	0.225	0.302	29.00	1,487.76	2.882	4.29	0.655059	0.67027
$t_s = 17/32"$	35	0.225	0.302	29.00	1,487.76	2.881	4.29	0.647492	0.66270
	36	0.220	0.295	28.33	1,453.39	2.882	4.19	0.632358	0.64757
	37	0.215	0.288	27.66	1,419.02	2.882	4.09	0.519072	0.53428
$t_s = 5/8"$	38	0.205	0.275	26.41	1,354.89	2.881	3.90	0.482208	0.49742
	39	0.185	0.248	23.82	1,222.02	2.882	3.52	0.438816	0.45403
	40	0.170	0.228	21.89	1,123.01	2.882	3.24	0.359476	0.37469
$t_s = 11/16"$	41	0.150	0.201	19.30	990.13	2.881	2.85	0.303360	0.31857
	42	0.120	0.161	15.46	793.13	2.882	2.29	0.258153	0.27337
	43	0.110	0.147	14.12	724.39	2.882	2.09	0.192886	0.20810
$t_s = 13/16"$	44	0.095	0.127	12.20	625.89	2.881	1.80	0.170954	0.18617
	45	0.085	0.114	10.95	561.76	2.882	1.62	0.152492	0.16770
	46	0.075	0.101	9.70	497.63		1.43		

* $\rho' = \rho_{steel} + \rho_{fluid}$
$= 0.015217 + \rho_{ave}$, $k\text{-}sec^2/ft^4$

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SHEET NO. B-14

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-16-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS STRESS ANALYSIS CHK'D RLV DATE 4-4-78

EXTERIOR TANK

HYDROSTATIC PRESSURE : $p_s = wh = 62.4(49.5' - Z)$, lbs/ft²

NODAL POINT	Z ft.	H − Z ft.	p_s lbs/ft²	TOTAL HYDROSTATIC FORCE $P_s = \frac{p_s(H-Z)}{2\times1000}$ K
19	49.500	0	0	0
18	49.333	0.167	10.4	—
17	46.046	3.454	215.5	0.37
16	42.757	6.743	420.8	1.42
15	39.468	10.032	626.0	3.14
14	36.179	13.321	831.2	5.54
13	32.890	16.610	1036.5	8.61
12	29.601	19.899	1,241.7	12.35
11	26.312	23.188	1,446.9	16.78
10	23.023	26.477	1,652.2	21.87
9	19.734	29.766	1,857.4	27.64
8	16.445	33.055	2062.6	34.09
7	13.156	36.344	2,267.9	41.21
6	9.867	39.633	2,473.1	49.01
5	7.692	41.808	2,608.8	54.53
4	7.500	42.000	2620.8	55.04
3	4.500	45.000	2,808.0	63.18
2	1.500	48.000	2995.2	71.88
1	0	49.500	3,088.8	76.45

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SHEET NO. B-15

JOB NO. 0932-1308 DIABLO CANYON — BY RCV DATE 3/15/78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS — CHK'D CSC DATE 4-4-78

INTERIOR TANK

CASE 2

HYDROSTATIC PRESSURE : $p_s = wh = 62.4(49.5 - z)$, lbs/ft²

NP	R, ft.	z, ft.	p_s lbs/ft²
22	16.33	51.870	0
24	↓	48.988	32.0
26		46.106	211.8
28		43.224	391.6
30		40.342	571.5
32		37.460	751.3
34		34.578	931.1
35		31.696	1,111.0
36		28.814	1290.8
37		25.932	1,470.6
38		23.050	1,650.5
39		20.168	1,830.3
40		17.286	2,010.2
41		14.404	2,190.0
42		11.522	2,369.8
43		8.640	2,549.7
44		5.758	2,729.5
45		2.876	2,909.3
46	↓	0	3,088.8

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SHEET NO. B-16

JOB NO. 0202-17 JOB DIABLO REVIEW BY R.R.V DATE 6/12/78

CLIENT PG&E SUBJECT Fire Water & Transfer Tank CHK'D CSC DATE 6-21-78

Convective Pressure

Fundamental Period of Vibration

- Ref. Housner's approach, Eqn. F.91, TID 7024

$$\omega^2 = \frac{g}{R}\sqrt{\frac{27}{8}}\ \tanh\sqrt{\frac{27}{8}}\ \frac{h}{R}$$

$$= 1.84\ \frac{g}{R}\ \tanh\left(1.84\ \frac{h}{R}\right)$$

Case 1 - Inner and Outer Tanks Full of Water

$$\frac{h}{R} = \frac{49.5}{20} = 2.475$$

$$\omega^2 = 1.84\left(\frac{32.2}{20}\right)\tanh\left(1.84 \times \frac{49.5}{20}\right)$$

$$\omega^2 = 2.9624\ \tanh(4.554)$$

.999775

$$\omega^2 = 2.962$$

$$\omega = 1.721\ \text{rad./sec.}$$

$$f = \frac{1.721}{2\pi} = 0.2740\ \text{cycles/sec.}$$

$T = 3.65$ sec. / same as Refueling Wtr. Tank

From Figure

7% damp. at $T = 3.65$ sec., $\rightarrow S_a = 0.1g = 3.22\ ft/sec^2$

For 1% damping, $S_A = 0.171g$.

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SHEET NO. B-17

JOB NO. 0705-17 JOB DIABLO REVIEW BY RRV DATE 4/18/78

CLIENT PG&E SUBJECT Firewater & Transfer Tanks, CHK'D CSC DATE 6-21-78

Convective Pressure

Case 2 - Inner Tank Full, Outer Tank Empty

$$w^2 = 1.84 \left(\frac{32.2}{16.33}\right) \tanh \left(1.84 \times \frac{49.5}{16.33}\right)$$

$$w^2 = 3.6282 \tanh (5.5775)$$

.99997

$$w^2 = 3.6282$$

$$w = 1.905 \text{ rad/sec.}$$

$$f = 0.3033 \text{ cycles/sec}$$

$$T = 3.297 \text{ seconds.}$$

From Figure
7% damp. at T = 3.297 seconds, Sa ≈ 0.1 g = 3.22 ft/sec²

From Digitized Newmark 7.5 M Hosgri Spectra, T=0

Period	Sa - g 1%	2%	7%
2.500	0.356	0.317	0.245
3.333	0.200	0.178	0.138

For 1% damping: at T = 3.297 sec.

$$S_a = 0.356 - \frac{(3.297 - 2.500)^{0.797}}{3.333 - 2.500_{0.833}} (0.356 - 0.200)^{0.156} =$$

$$= 0.207 \text{ g.}$$

CASE I EXTERIOR TANK

CONVECTIVE PRESSURE

By Veletsos approach:

The convective pressure $p_w = \sum_{K=1}^{\infty} C_K(z) A_K(t) \rho H \cos\theta$

where $C_K(z) = \frac{2}{\lambda_K^2 - 1} \frac{a}{H} \frac{\cosh(\lambda_K \frac{z}{a})}{\cosh(\lambda_K \frac{H}{a})}$

Let $\lambda_K = \lambda_1 = 1.8412$

Then $C_1(z) = \frac{2}{(1.8412)^2 - 1} \frac{20}{49.5} \frac{\cosh(1.8412 \frac{z}{20})}{\cosh(1.8412 \frac{49.5}{20})}$

$= 0.0071 \cosh(0.09206 z)$

$\rho = 62.4/32.2 = 1.94 \text{ lbs-sec}^2/ft^4$

$H = 49.5$ ft.

$A_1(t) = \omega S_v = 0.1g = 3.22$ ft./sec/sec

$\cos\theta = 1$

$\therefore p_w = C_1(z) A_1(t) \rho H \cos\theta$

$= 0.0071 \cosh(0.09206 z)(3.22) 1.94 (49.5) 1$

$= \underline{\underline{2.195 \cosh(0.09206 z)}}$

Find the max. vertical displacement of fluid surface, d_{max}:

By Housner's approach:

$$d_{max} = \frac{0.408 R}{\left(\frac{g}{\omega^2 \theta_h R} - 1\right) \tanh 1.84 \frac{h}{R}} \quad (F.115)$$

where $\omega^2 = \frac{g}{R} \sqrt{\frac{27}{8}} \tanh \sqrt{\frac{27}{8}} \frac{h}{R}$ (F.91)

$= \frac{32.2}{20}(1.84) \tanh(1.84 \times \frac{49.5}{20})$

$= 2.962$, $\omega = 1.721$ rad./sec.

$\theta_h = \frac{A_1}{0.653 R} \tanh \sqrt{\frac{27}{8}} \frac{h}{R}$, $Y_{max} = A_1 = \frac{S_v}{\omega} = \frac{2.17}{1.721} = 1.26$

$= \frac{1.26}{0.653(20)}(0.99978) = 0.09646$ radians

CASE I EXTERIOR TANK

CONVECTIVE PRESSURE (continued)

$$\therefore \; d_{max} = \frac{0.408(20)}{\left(\frac{32.2}{2.962 \times 0.09646 \times 20}\right)(0.99978)}$$

$$= 1.448 \text{ ft.}$$

$$z_{max} = H + d_{max} = 49.5 + 1.448 = 50.948 \text{ ft.}$$

NODAL POINT	z ft.	$p_w = 2.195 \cosh(0.09206\, z)$ lbs/ft.²
1	0	2.195
2	1.500	2.216
3	4.500	2.386
4	7.500	2.739
5	7.692	2.769
6	9.867	3.165
7	13.156	4.012
8	16.445	5.229
9	19.734	6.930
10	23.023	9.271
11	26.312	12.468
12	29.601	16.817
13	32.890	22.720
14	36.179	(31.608) 30.721 say ok.
15	39.468	41.561
16	42.757	56.240
17	46.046	76.114
18	49.333	103.002
19	49.500	104.597
20	50.000	109.512 } use 119.509 at NP 20
z_{max}	50.948	119.509

CASE 2 INTERIOR TANK

CONVECTIVE PRESSURE

By Veletsos' approach:

The convective pressure $p_w = \sum_{k=1}^{\infty} C_k(z) A_k(t) \rho H \cos\theta$

where $C_k(z) = \frac{2}{\lambda_k^2 - 1} \frac{a}{H} \frac{\cosh(\lambda_k \frac{z}{a})}{\cosh(\lambda_k \frac{H}{a})}$

Let $\lambda_k = \lambda_1 = 1.8412$

Then $C_1(z) = \frac{2}{(1.8412)^2 - 1} \frac{16.33}{49.5} \frac{\cosh(1.8412 \frac{z}{16.33})}{\cosh(1.8412 \frac{49.5}{16.33})}$

$= 0.0021 \cosh(0.11275 z)$

$\rho = 62.4/32.2 = 1.94$ lbs-sec²/ft⁴

$H = 49.5$ ft.

$A_1(t) = \omega S_v = 0.1g = 3.22$ ft./sec/sec

$\cos\theta = 1$

$\therefore p_w = C_1(z) A_1(t) \rho H \cos\theta$

$= 0.0021 \cosh(0.11275 z)(3.22)(1.94) 49.5 (1)$

$= \underline{0.649 \cosh(0.11275 z)}$

Find the max. vertical displacement of fluid surface, d_{max}:

By Housner's approach:

$$d_{max} = \frac{0.408 R}{\left(\frac{g}{\omega^2 \theta_h R} - 1\right) \tanh 1.84 \frac{h}{R}}$$

where $\omega^2 = \frac{g}{R}\sqrt{\frac{27}{8}} \tanh\sqrt{\frac{27}{8}} \frac{h}{R}$

$= \frac{32.2}{16.33}(1.84) \tanh(1.84 \times \frac{49.5}{16.33})$

$= 3.627, \quad \omega = 1.904$ rad./sec.

$\theta_h = \frac{A_1}{0.653 R} \tanh\sqrt{\frac{27}{8}} \frac{h}{R}, \quad Y_{max} = A_1 = \frac{S_v}{\omega} = \frac{2.17}{1.904} = 1.14$

$= \frac{1.14}{0.653(16.33)}(0.9997) = 0.10687$ radians

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SHEET NO. B-21

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 3-21-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK STRESS ANALYSIS CHK'D RRV DATE 4-4-78

CASE 2 Interior Tank

CONVECTIVE PRESSURE (continued)

$$\therefore \quad d_{max} = \frac{0.408(16.33)}{\left(\frac{32.2}{3.627 \times 0.10687 \times 16.33} - 1\right) 0.9997}$$

$$= 1.631 \text{ ft.}$$

$$z_{max} = H + d_{max} = 49.5 + 1.631 = 51.131 \text{ ft.}$$

NODAL POINT	z ft.	$p_w = 0.649 \cosh(0.11275 z)$ lbs/ft.^{2}
46	0	0.649
45	2.882	0.684
44	5.763	0.791
43	8.645	0.983
42	11.527	1.279
41	14.408	1.711
40	17.290	2.326
39	20.172	3.188
38	23.053	4.390
37	25.935	6.059
36	28.817	8.374
35	31.698	11.580
34	34.580	16.020
32	37.462	22.167
30	40.343	30.671
28	43.225	42.445
26	46.107	58.741
24	49.500	86.114
z_{max}	51.131	103.499

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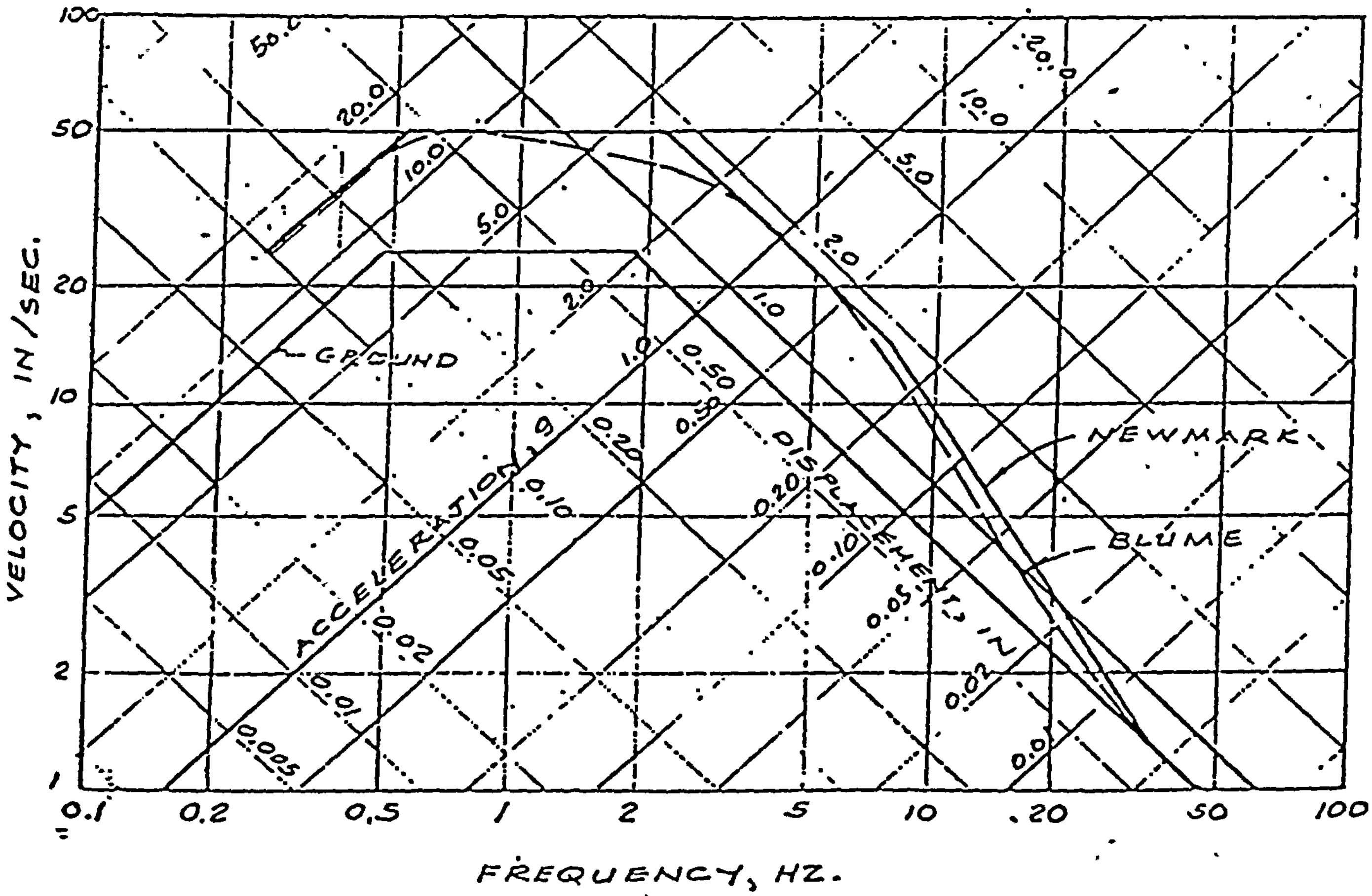
SHEET NO. B-22

JOB NO. 0902-19 JOB DIABLO REVIEW BY BNS DATE 8/2/77

CLIENT PG&E SUBJECT SPECTRA CHK'D RRV DATE



DIABLO UNITS 1 & 2

7.5M HOSGRI EARTHQUAKE SPECTRA

$\tau = 0$ 7% DAMPING

DESIGN HORIZONTAL SPECTRA

SHEET NO. B-23

COLUMN 1 - PERIODS (SEC)
2 - FREQUENCIES
3 - 0.005 DAMPING
4 - 0.010 DAMPING
5 - 0.020 DAMPING
6 - 0.030 DAMPING
7 - 0.050 DAMPING
8 - 0.070 DAMPING

$SV = \frac{SA \times 32.2}{2\pi f}$

****

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	SV	
									0.038	→ f = 10
-1-	.029	34.000	.750	.750	.750	.750	.750	.750	0.113	0.113
-2-	.032	31.000	.806	.800	.794	.790	.784	.779	0.129	0.131
-3-	.036	28.000	.906	.890	.872	.860	.842	.830	0.152	0.160
-4-	.040	25.000	1.032	1.002	.967	.944	.912	.890	0.182	0.193
-5-	.045	22.000	1.195	1.145	1.087	1.050	.997	.963	0.224	0.253
-6-	.050	20.000	1.334	1.264	1.186	1.136	1.067	1.022	0.262	0.304
-7-	.056	18.000	1.506	1.411	1.306	1.240	1.149	1.091	0.311	0.372
-8-	.059	17.000	1.608	1.497	1.377	1.300	1.196	1.130	0.341	0.399
-9-	.063	16.000	1.724	1.595	1.455	1.367	1.248	1.173	0.376	0.46?
-10-	.067	15.000	1.857	1.706	1.544	1.443	1.306	1.221	0.417	0.523
-11-	.069	14.500	1.931	1.767	1.592	1.484	1.337	1.246	0.441	0.563
-12-	.071	14.000	2.010	1.833	1.644	1.528	1.371	1.274	0.467	0.602
-13-	.074	13.500	2.095	1.904	1.700	1.574	1.406	1.303	0.495	0.645
-14-	.075	13.250	2.141	1.941	1.730	1.599	1.425	1.318	0.506	0.669
-15-	.077	13.000	2.189	1.980	1.760	1.624	1.444	1.334	0.526	0.694
-16-	.078	12.750	2.238	2.021	1.791	1.651	1.464	1.350	0.543	0.720
-17-	.080	12.500	2.290	2.063	1.824	1.678	1.485	1.366	0.560	0.748
-18-	.082	12.250	2.344	2.107	1.858	1.706	1.506	1.383	0.579	0.777
-19-	.083	12.000	2.400	2.153	1.894	1.736	1.528	1.401	0.599	0.809
-20-	.085	11.750	2.459	2.201	1.931	1.767	1.551	1.419	0.619	0.842
-21-	.087	11.500	2.520	2.250	1.969	1.798	1.574	1.438	0.641	0.877
-22-	.089	11.250	2.585	2.302	2.009	1.831	1.599	1.458	0.664	0.915
-23-	.091	11.000	2.652	2.357	2.051	1.866	1.624	1.478	0.689	0.956
-24-	.093	10.750	2.723	2.414	2.094	1.902	1.651	1.500	0.715	0.998
-25-	.095	10.500	2.798	2.474	2.140	1.939	1.678	1.522	0.743	1.0??
-26-	.098	10.250	2.877	2.537	2.188	1.978	1.707	1.544	0.772	1.09?
-27-	.100	10.000	2.960	2.603	2.238	2.019	1.737	1.568	0.804	1.147
-28-	.103	9.750	3.047	2.673	2.290	2.062	1.768	1.593	0.838	1.204
-29-	.105	9.500	3.139	2.746	2.345	2.107	1.801	1.619	0.874	1.265
-30-	.108	9.250	3.237	2.824	2.403	2.154	1.835	1.646	0.912	1.331
-31-	.111	9.000	3.341	2.906	2.464	2.204	1.870	1.674	0.953	1.403
-32-	.114	8.750	3.451	2.992	2.529	2.256	1.908	1.703	0.998	1.481
-33-	.118	8.500	3.567	3.084	2.597	2.311	1.947	1.734	1.046	1.566
-34-	.121	8.250	3.692	3.181	2.669	2.369	1.989	1.766	1.097	1.655
-35-	.125	8.000	3.825	3.285	2.745	2.430	2.032	1.800 *	1.154	1.758
-36-	.127	7.850	3.825	3.285	2.745	2.430	2.032	1.800	1.176	1.792
-37-	.129	7.750	3.825	3.285	2.745	2.430	2.032	1.800	1.191	1.815
-38-	.131	7.630	3.825	3.285	2.745	2.430	2.032	1.800	1.210	1.844
-39-	.133	7.500	3.825	3.285	2.745	2.430	2.032	1.800	1.230	
-40-	.136	7.370	3.825	3.285	2.745	2.430	2.032	1.800	1.252	
-41-	.138	7.250	3.825	3.285	2.745	2.430	2.032	1.800		
-42-	.140	7.120	3.825	3.285	2.745	2.430	2.032	1.800		
-43-	.143	7.000	3.825	3.285	2.745	2.430	2.032	1.800		
-44-	.146	6.870	3.825	3.285	2.745	2.430	2.032	1.800		
-45-	.148	6.750	3.825	3.285	2.745	2.430	2.032	1.800		
-46-	.151	6.630	3.825	3.285	2.745	2.430	2.032	1.800		
-47-	.154	6.500	3.825	3.285	2.745	2.430	2.032	1.800		
-48-	.157	6.370	3.825	3.285	2.745	2.430	2.032	1.800		
-49-	.160	6.250	3.825	3.285	2.745	2.430	2.032	1.800		
-50-	.163	6.130	3.825	3.285	2.745	2.430	2.032	1.800	1.506	
-51-	.167	6.000	3.825	3.285	2.745	2.430	2.032	1.800	1.538	
-52-	.170	5.870	3.825	3.285	2.745	2.430	2.032	1.800	1.572	

SHEET NO. B-24

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
-54-	,178	5,630	3,825	3,285	2,745	2,430	2,032	1,800
-55-	,182	5,500	3,825	3,285	2,745	2,430	2,032	1,800
-56-	,186	5,370	3,825	3,285	2,745	2,430	2,032	1,800
-57-	,190	5,250	3,825	3,285	2,745	2,430	2,032	1,800
-58-	,195	5,130	3,825	3,285	2,745	2,430	2,032	1,800
-59-	,200	5,000	3,825	3,285	2,745	2,430	2,032	1,800
-60-	,204	4,900	3,825	3,285	2,745	2,430	2,032	1,800
-61-	,208	4,800	3,825	3,285	2,745	2,430	2,032	1,800
-62-	,213	4,700	3,825	3,285	2,745	2,430	2,032	1,800
-63-	,217	4,600	3,825	3,285	2,745	2,430	2,032	1,800 -
-64-	,222	4,500	3,825	3,285	2,745	2,430	2,032	1,800
-65-	,227	4,400	3,825	3,285	2,745	2,430	2,032	1,800
-66-	,233	4,300	3,825	3,285	2,745	2,430	2,032	1,800
-67-	,238	4,200	3,825	3,285	2,745	2,430	2,032	1,800
-68-	,244	4,100	3,825	3,285	2,745	2,430	2,032	1,800
-69-	,250	4,000	3,825	3,285	2,745	2,430	2,032	1,800
-70-	,256	3,900	3,825	3,285	2,745	2,430	2,032	1,800
-71-	,263	3,800	3,825	3,285	2,745	2,430	2,032	1,800
-72-	,270	3,700	3,825	3,285	2,745	2,430	2,032	1,800
-73-	,278	3,600	3,825	3,285	2,745	2,430	2,032	1,800
-74-	,290	3,450	3,825	3,285	2,745	2,430	2,032	1,800
-75-	,303	3,300	3,825	3,285	2,745	2,430	2,032	1,800
-76-	,317	3,150	3,825	3,285	2,745	2,430	2,032	1,800
-77-	,333	3,000	3,825	3,285	2,745	2,430	2,032	1,800
-78-	,345	2,900	3,825	3,285	2,745	2,430	2,032	1,800
-79-	,357	2,800	3,825	3,285	2,745	2,430	2,032	1,800
-80-	,370	2,700	3,825	3,285	2,745	2,430	2,032	1,800
-81-	,385	2,600	3,825	3,285	2,745	2,430	2,032	1,800
-82-	,400	2,500	3,748	3,285	2,745	2,430	2,032	1,800* 3.844
-83-	,417	2,400	3,598	3,165	2,736	2,430	2,032	1,800
-84-	,435	2,300	3,448	3,033	2,622	2,371	2,032	1,800 → 4.013
-85-	,455	2,200	3,298	2,901	2,508	2,268	1,975	1,789
-86-	,476	2,100	3,148	2,769	2,394	2,165	1,885	1,707
-87-	,500	2,000	2,999	2,638	2,280	2,062	1,795	1,626
-88-	,526	1,900	2,849	2,506	2,166	1,959	1,705	1,545
-89-	,556	1,800	2,699	2,374	2,052	1,856	1,616	1,464
-90-	,588	1,700	2,549	2,242	1,938	1,753	1,526	1,382
-91-	,625	1,600	2,399	2,110	1,824	1,650	1,436	1,301
-92-	,667	1,500	2,249	1,978	1,710	1,546	1,346	1,220
-93-	,714	1,400	2,099	1,846	1,596	1,443	1,257	1,138
-94-	,769	1,300	1,949	1,714	1,482	1,340	1,167	1,057
-95-	,833	1,200	1,799	1,583	1,368	1,237	1,077	,976
-96-	,909	1,100	1,649	1,451	1,254	1,134	,987	,894
-97-	1,000	1,000	1,499	1,319	1,140	1,031	,898	,813
-98-	1,111	,900	1,349	1,187	1,026	,928	,808	,732
-99-	1,250	,800	1,199	1,055	,912	,825	,718	,650
-100-	1,429	,700	1,050	,923	,798	,722	,628	,569
-101-	1,538	,650	,974	,857	,741	,670	,583	,529
-102-	1,667	,600	,894	,791	,684	,619	,539	,488
-103-	2,000	,500	,621	,557	,495	,457	,411	,383
-104-	2,500	,400	,397	,356	,317	,293	,263	,245
-105-	3,333	,300	,223	,200	,178	,165	,148	,138
-106-	4,000	,250	,155	,139	,124	,114	,103	,096

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
-107-	5,000	,200	,099	,089	,079	,073	,066	,061
-108-	10,000	,100	,025	,022	,020	,018	,016	,015

SHEET NO.
B-25

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 6-20-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER WATER TANKS CHK'D GB DATE 6-20-78

CASE WHEN INTERIOR (FIREWATER) TANK ONLY IS FULL

N.P.	l_1 / l_2 FT.	t FT.	$\overline{W}$ lbs/L.F.	m lbs-sec²/in.	ϕ	λ	$m\phi^2$	$m\phi^2\lambda$
1	0 / 0.75	2.00	0 / 225	0 / 0.583	0	0.07	0	0
2	0.75 / 1.50	2.00 / 1.00	450	1.166	0.0004		—	—
3	1.50 / 1.50	1.00 / 1.00	450	1.166	0.0063		0.046×10^{-3}	0.003×10^{-3}
4	1.50 / 0.10	1.00 / 0.83	237	0.615	0.0146		0.131×10^{-3}	0.009×10^{-3}
5	0.10 / 1.09	0.83 / 0.67	121	0.315	0.0152		0.073×10^{-3}	0.005×10^{-3}
6	1.09 / 1.64	0.67	274	0.711	0.0206		0.302×10^{-3}	0.021×10^{-3}
7	1.64 / 1.64	0.67	330.5	0.856	0.0280		0.671×10^{-3}	0.047×10^{-3}
8					0.0356		1.085×10^{-3}	0.084×10^{-3}
9					0.0441		1.665×10^{-3}	0.117×10^{-3}
10					0.0534		2.441×10^{-3}	0.171×10^{-3}
11					0.0631		3.408×10^{-3}	0.239×10^{-3}
12					0.0734		4.612×10^{-3}	0.323×10^{-3}
13					0.0843		6.083×10^{-3}	0.426×10^{-3}
14					0.0954		7.791×10^{-3}	0.545×10^{-3}
15	1.64 / 1.64	0.67	330.5	0.856	0.1067		9.745×10^{-3}	~~0.751~~ 0.682 $\times 10^{-3}$

(to be continued)

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-27

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 6-20-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER WATER TANKS CHK'D GB DATE 6-20-78

CASE WHEN INTERIOR (FIREWATER) TANK ONLY IS FULL

N.P.	l_1 - l_2 FT.	t FT.	W lbs/L.F.	m lbs-sec²/in.	ϕ	λ	$m\phi^2$	$m\phi^2\lambda$
16	1.64 1.64	0.67	330.5	0.856	0.1182	0.07	11.959×10^{-3}	0.837×10^{-3}
17	1.64 1.64	0.67	330.5	0.856	0.1310		14.690×10^{-3}	1.028×10^{-3}
18	1.64 0.08	0.67 1.33	180.8	0.468	0.1478		10.223×10^{-3}	0.716×10^{-3}
19	0.08 0.25	1.33	65.8	0.171	0.1487		3.781×10^{-3}	0.265×10^{-3}
20	0.25 1.50 ~~2.72~~	1.33 0.67	200.6 ~~323.9~~	0.520 ~~0.837~~	0.1515		11.735 ~~19.211~~ $\times10^{-3}$	0.835 ~~1.345~~ $\times10^{-3}$
21	1.50 ~~2.72~~ 1.50 ~~2.72~~	0.67	301.5 ~~546.7~~	0.781 ~~1.416~~	0.1583		19.571 ~~35.483~~ $\times10^{-3}$	1.370 ~~2.484~~ $\times10^{-3}$
23					0.1608		20.174 ~~36.613~~ $\times10^{-3}$	1.414 ~~2.563~~ $\times10^{-3}$
25					0.1611		20.264 ~~36.751~~ $\times10^{-3}$	1.419 ~~2.572~~ $\times10^{-3}$
27					0.1619		20.471 ~~37.116~~ $\times10^{-3}$	1.433 ~~2.598~~ $\times10^{-3}$
29					0.1628		20.700 ~~37.529~~ $\times10^{-3}$	1.445 ~~2.627~~ $\times10^{-3}$
31					0.1636		20.903 ~~37.899~~ $\times10^{-3}$	0.735 ~~2.653~~ $\times10^{-3}$
33	1.50 ~~2.72~~ ~~2.72~~ 0	0.67	150.8 ~~546.7~~	0.391 ~~1.416~~	0.1639		10.504 ~~38.039~~ $\times10^{-3}$	0.735 ~~2.663~~ $\times10^{-3}$
Σ							223.253 ~~357.345~~ $\times10^{-3}$	15.632 ~~25.971~~ $\times10^{-3}$

(to be continued)

CASE WHEN INTERIOR (FIREWATER) TANK ONLY IS FULL

N.P.	l_1 - l_2 FT.	t FT.	W lbs/L.F.	m lbs-sec²/in.	φ	λ	$m\phi^2$	$m\phi\lambda$
46	0 1.441	0.068	48.014	0.124	0	0.04	0	0
45	1.441 1.441	0.068	96.028	0.249	0.2576 E-1		1.652 E-4	6.608 E-6
44	1.441 1.441	0.068	96.028	0.249	0.3958 E-1		3.90 E-4	1.560 E-6
43	1.041 1.441	0.068 0.057	48.014 40.247	0.124 0.104	0.5555 E-1		3.826 E-4 3.209 E-4	1.530 E-6 1.284 E-6
42	1.441 1.441	0.057	80.494	0.209	0.7465 E-1		11.646 E-4	46.50 E-6
41	1.441 1.441	0.057	80.494	0.209	0.9363 E-1		18.321 E-4	73.20 E-6
40	1.441 1.441	0.057 0.052	40.247 36.717	0.104 0.095	0.1132 E+0		13.326 E-4 12.173 E-4	53.30 E-6 48.60 E-6
39	1.441 1.441	0.052	73.433	0.190	0.1338 E+0		34.014 E-4	1.36 E-4
38	1.441 1.441	0.052	73.433	0.190	0.1528 E+0		44.36 E-4	1.774 E-4
37	1.441 1.441	0.052 0.044	36.717 31.068	0.095 0.080	0.1711 E+0		27.811 E-4 23.420 E-4	1.112 E-4 0.936 E-4
36	1.441 1.441	0.044	62.136	0.161	0.1889 E+0		57.449 E-4	2.297 E-4
35	1.441 1.441	0.044	62.136	0.161	0.2018 E+0		65.564 E-4	2.622 E-4
34	1.441 1.441	0.044 0.036	31.068 25.419	0.081 0.066	0.2131 E+0		36.783 E-4 29.971 E-4	1.471 E-4 1.198 E-4
32	1.441 1.441	0.036	50.838	0.132	0.2197 E+0		63.713 E-4	2.548 E-4
30	1.441 1.441	0.036	50.838	0.132	0.2175 E+0		62.444 E-4	2.497 E-4

(to be continued)

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-29

JOB NO. 0902-19 JOB DIABLO REVIEW BY GD DATE 6/20/78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER WATER TANKS CHK'D CSC DATE 6-20-78

CASE WHEN INTERIOR (FIREWATER) TANK ONLY IS FULL

N.P.	l_1 - l_2 FT.	t FT.	W lbs/L.F.	m lbs-sec²/in.	ϕ	λ	$m\phi^2$	$m\phi^2\lambda$
28	1.441 1.441	0.036 0.031	25.419 21.889	0.066 0.057	0.2126 E+0	0.04	29.831 E-4 25.763 E-4	1.193 E-4 1.030 E-4
26	1.441 1.697	0.031	47.666	0.123	0.1947 E+0	↓	46.626 E-4	1.865 E-4
24	1.697 1.185	0.031	43.778	0.113	0.1714 E+0	↓	33.197 E-4	1.327 E-4
22	1.185 0	0.031	18.000	0.047	0.1598 E+0	↓	12.001 E-4	0.480 E-4
Σ							6.610E-2	26.036 E-4

$$\lambda = \frac{\Sigma m\phi^2\lambda}{\Sigma m\phi^2} = \frac{\Sigma m\phi^2\lambda_{conc.} + \Sigma m\phi^2\lambda_{st.}}{\Sigma m\phi^2}$$

$$= \frac{(15.632 + 2.604)\,10^{-3}}{(223.253 + 66.1)\,10^{-3}}$$

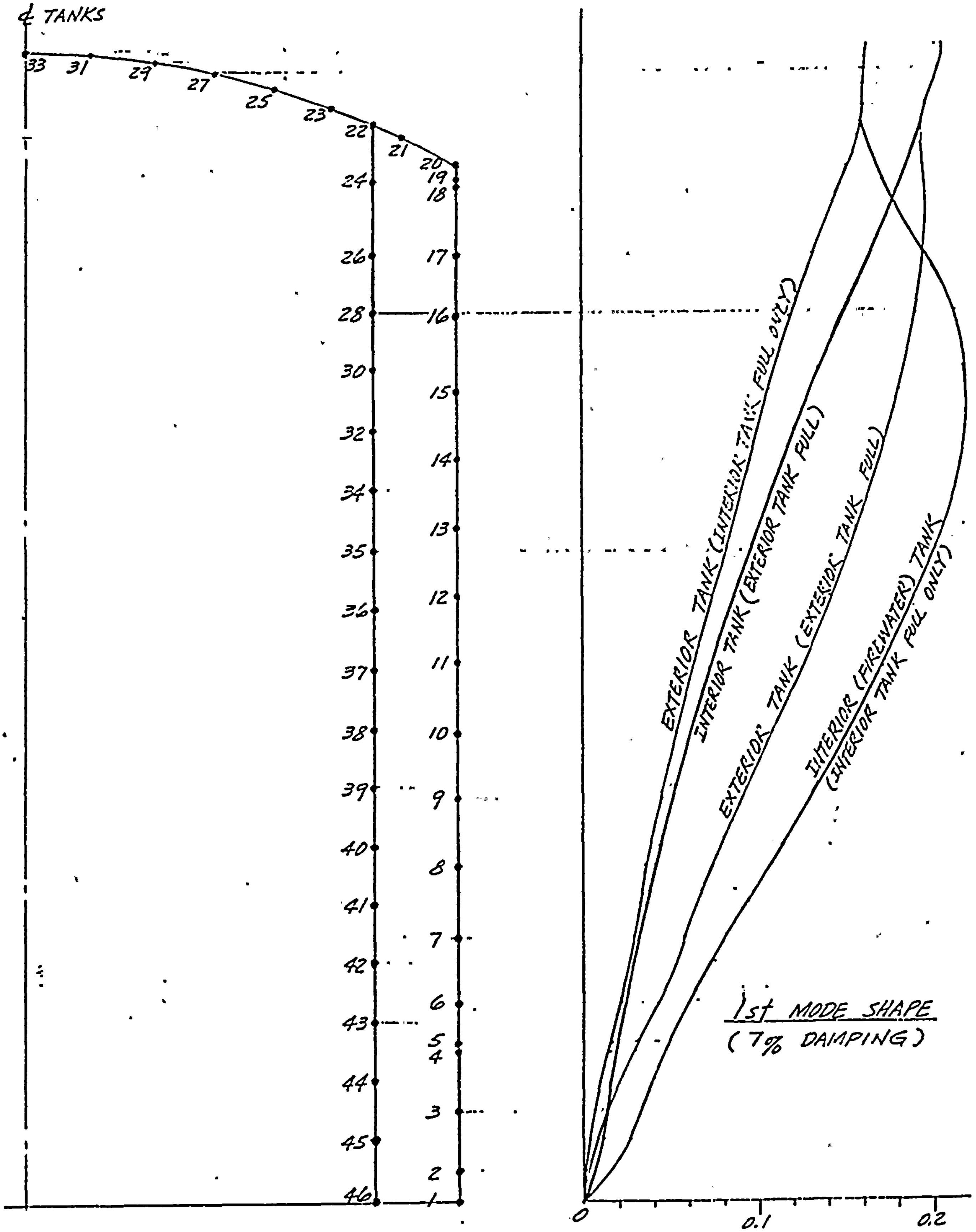
$$= 0.063 \text{ or } 6.3\%$$

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-30

JOB NO. 7952-19 JOB DIABLO REVIEW BY CSC DATE 6-30-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER WATER TANKS CHK'D PMN DATE



URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-31

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 10/3/78
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK CHK'D PMN DATE

VERSION C

FORCES & MOMENT IN
STEEL ELEMENTS
INTERIOR TANK

NODAL POINT	FORCE/MOMENT K/K-FT	Exterior Tank ① IMPULSIVE PRESSURE	② CONVECTIVE PRESSURE	③ HYDROSTATIC PRESSURE	④ DEAD LOAD	INTERIOR TANK ⑤ IMPULSIVE PRESSURE	⑥ CONVECTIVE PRESSURE	⑦ HYDROSTATIC PRESSURE	⑧ VERT. EQ. 0.5(3+4)	⑨ VERT. EQ. 0.5(4+7)	⑩ 1+2+3+4+8	⑪ 4+5+6+7+9
46 t=13/16"	LONG. FORCE	69.0	0.8	−0.9	−2.2	105.4	.0.7	12.2	1.6	7.2	74.5	127.7
	CIRC. FORCE	20.7	0.2	−0.3	−0.7	22.6	0.2	58.7	0.5	29.7	22.4	111.9
	LONG. MOM.	0.1	—	—	—	0.2	—	0.6	—	0.3	0.1	1.1
	CIRC. MOM.	—	—	—	—	—	—	0.2	—	0.1	—	0.3
	SHEAR	23.7	0.2	—	—	86.6	0.4	—	—	—	23.9	87.0
43 t=11/16"	LONG. FORCE	52.5	0.6	−0.9	−1.8	74.8	0.5	1.6	1.4	1.7	57.2	80.4
	CIRC. FORCE	0.4	0.1	—	—	15.8	—	38.5	—	19.3	0.5	73.6
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	23.2	0.2	—	—	80.7	0.4	—	—	—	23.4	81.1
42 t=11/16"	LONG. FORCE	48.4	0.6	−0.8	1.8	63.3	0.5	2.5	1.3	2.2	52.9	70.3
	CIRC. FORCE	1.0	—	—	—	21.7	—	38.9	—	19.5	1.0	80.1
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	8.7
	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	23.0	0.2	—	—	77.1	0.4	—	—	—	23.2	77.5
40 t=5/8"	LONG. FORCE	41.0	0.5	−0.9	1.6	38.9	0.3	2.0	1.3	1.8	45.3	44.6
	CIRC. FORCE	—	—	—	—	35.9	—	31.5	—	15.8	0.4	83.3
	LONG. MOM	0.4	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	22.6	0.2	—	—	70.3	0.4	—	—	—	22.8	70.7
37 t=17/32"	LONG. FORCE	29.9	0.4	−0.9	1.3	17.6	0.1	2.0	1.1	1.7	33.6	22.7
	CIRC. FORCE	0.4	—	—	—	54.1	0.1	22.5	—	11.3	0.4	88.0
	LONG. MOM	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	21.8	0.2	—	—	49.2	0.3	—	—	—	22.0	49.5

✱ TRANSFER FROM RRV CALCULATION VERSION B DATED 3/31/78

* COL ⑤ FROM AXIDYN RUN ON FIREWATER & TRANSFER TANK DATED 6/13/78

SHEET NO. B-31

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-32

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 10/3/78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK CHK'D PMN DATE

VERSION 9

FORCES & MOMENT IN
STEEL ELEMENTS
INTERIOR TANK

NODAL POINT	FORCE/MOMENT K/K-FT	Exterior Tank ① IMPULSIVE PRESSURE	Exterior Tank ② CONVECTIVE PRESSURE	Exterior Tank ③ HYDROSTATIC PRESSURE	④ DEAD LOAD	INTERIOR TANK ⑤ IMPULSIVE PRESSURE	INTERIOR TANK ⑥ CONVECTIVE PRESSURE	INTERIOR TANK ⑦ HYDROSTATIC PRESSURE	⑧ VERT. EQ. 0.5(3+4)	⑨ VERT. EQ. 0.5(4+7)	⑩ 1+2+3+4+8	⑪ 4+5+6+7+9
34	LONG. FORCE	18.9	0.25	-0.9	1.2	28.5	0.1	2.1	1.1	1.7	22.4	33.9
	CIRC. FORCE	0.6	—	—	—	53.3	0.2	14.2		7.1	0.6	74.8
t=7/16"	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	20.9	0.2	—	—	16.4	0.2	—	—	—	21.1	16.6
28	LONG. FORCE	8.2	0.1	-0.9	1.0	23.5	—	2.3	1.0	1.7	11.2	29.0
	CIRC. FORCE	1.0	—	—		47.7	0.6	6.2		3.1	1.0	57.6
t=3/8"	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	20.0	0.2	—	—	30.8	—	—	—	—	20.2	31.3
45	LONG. FORCE	62.7	-0.7	-0.8	2.0	97.9	0.7	12.2	1.4	7.1	67.6	119.9
	CIRC. FORCE	0.5	—	—	—	6.4	—	58.7	—	29.4	0.5	94.5
t=13/16"	LONG. MOM.	—	—	—	—	—	—	0.5	—	0.3	—	0.8
	CIRC. MOM.	—	—	—	—	—	—	0.2	—	0.1	—	0.3
	SHEAR	19.4	-0.2	—	—	85.6	0.4	—	—	—	19.6	86.0
EXT. TANK 1	LONG. FORCE	38.2	0.4	0.1	1.3	24.9	0.2	0.3	0.7	0.8	40.7	27.5
	CIRC. FORCE	11.5	0.1	—	0.4	7.5	0.1	0.1	0.2	0.3	12.2	8.40
t=0.487	LONG. MOM	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	21.1	0.2	—	—	8.8	0.1	—	—	—	21.3	8.9
	LONG. FORCE											
	CIRC. FORCE											
	LONG. MOM											
	CIRC. MOM											
	SHEAR											

* TRANSFER FROM RRV CALCULATION VERSION B DATED 3/31/78

** COL. ⑤ FROM AXIDYN RUN ON FIREWATER & TRANSFER TANK DATED 6/13/78

SHEET NO. B-32

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW SHEET NO. B-33
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK BY LC DATE 10/3/78
CHK'D PMN DATE

VERSION C

FORCES & MOMENT IN
STEEL ELEMENTS
EXTERIOR TANK

NODAL POINT	FORCE/MOMENT K/K-FT	Exterior Tank ① * IMPULSIVE PRESSURE	Exterior Tank ② * CONVECTIVE PRESSURE	Exterior Tank ③ * HYDROSTATIC PRESSURE	④ * DEAD LOAD	INTERIOR TANK ⑤ ** IMPULSIVE PRESSURE	INTERIOR TANK ⑥ * CONVECTIVE PRESSURE	INTERIOR TANK ⑦ * HYDROSTATIC PRESSURE	⑧ * VERT. EQ. 0.5(3+4)	⑨ * VERT. EQ. 0.5(4+7)	⑩ * 1+2+3+4+8	⑪ 4+5+6+7+9
5	LONG. FORCE	65.5	0.6	1.7	1.7	44.7	0.4	-0.7	2.0	1.5	72.0	49.5
	CIRC. FORCE	6.1	0.5	20.5	20.5	40.7	—	-0.1	10.4	0.2	37.2	41.4
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
t=0.627"	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	50.0	0.4	—	—	22.2	0.2	—	—	—	50.4	22.4
6	LONG. FORCE	52.8	0.5	1.7	1.9	44.2	0.4	-0.6	1.8	1.3	58.7	48.9
	CIRC. FORCE	3.7	—	18.9	0.1	2.3	—	-0.4	9.5	0.1	32.2	2.9
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
t=0.552"	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	43.6	0.4	—	—	20.4	0.2	—	—	—	44.0	20.6
8	LONG. FORCE	39.9	0.4	1.5	1.7	33.8	0.3	0.6	1.6	1.2	45.1	31.0
	CIRC. FORCE	11.3	—	15.9	0.1	2.1	—	—	8.0	0.1	35.3	1.3
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
t=0.532"	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	38.8	0.4	—	—	19.5	0.2	—	—	—	39.2	17.7
9	LONG. FORCE	28.8	0.3	1.2	1.2	23.5	0.2	0.6	1.2	0.9	32.7	26.4
	CIRC. FORCE	12.1	—	11.9	0.1	1.6	—	—	6.0	0.1	30.1	1.8
	LONG. MOM	—	—	—	—	—	—	—	—	—	—	—
t=0.417"	CIRC. MOM	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	30.4	0.3	—	—	16.5	0.2	—	—	—	30.7	16.7
	LONG. FORCE	23.0	0.2	1.1	1.1	17.9	0.2	-0.5	1.1	0.8	26.5	20.5
	CIRC. FORCE	16.4	0.1	9.7	0.1	0.9	—	—	4.9	0.1	31.2	1.1
	LONG. MOM	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	25.5	0.3	—	—	15.9	0.1	—	—	—	25.8	16.0

* TRANSFER FROM RRV CALCULATION VERSION B DATED 3/31/78

** COL. ⑤ FROM AXIDYN RUN ON FIRE WATER & TRANSFER TANK DATED 6/13/78

SHEET NO. B-33

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-34

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 10/3/78
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK CHK'D PMN DATE

VERSION C

FORCES & MOMENT IN
STEEL ELEMENTS
EXTERIOR TANK

NODAL POINT	FORCE/MOMENT K/K-FT	Exterior Tank ① IMPULSIVE PRESSURE	Exterior Tank ② CONVECTIVE PRESSURE	Exterior Tank ③ HYDROSTATIC PRESSURE	④ DEAD LOAD	INTERIOR TANK ⑤ IMPULSIVE PRESSURE	INTERIOR TANK ⑥ CONVECTIVE PRESSURE	INTERIOR TANK ⑦ HYDROSTATIC PRESSURE	⑧ VERT. EQ. 0.5(3+4)	⑨ VERT. EQ. 0.5(4+7)	⑩ 1+2+3+4+8	⑪ 4+5+6+7+9
12 t=.3125"	LONG. FORCE	10.7	0.1	0.8	0.7	17.9	0.1	-0.4	0.8	0.6	13.1	19.7
	CIRC. FORCE	14.8	0.1	6.5	0.1	0.9	—	—	3.3	0.1	24.8	1.2
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	16.9	0.2	—	—	14.8	0.1	—	—	—	17.1	14.9
14 t=.3125"	LONG. FORCE	7.0	0.1	0.7	0.6	10.4	0.1	-0.4	0.7	0.5	9.1	12.0
	CIRC. FORCE	13.7	0.2	4.6	0.1	0.6	—	—	2.4	0.1	21.0	0.8
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	13.4	0.2	—	—	11.9	0.1	—	—	—	13.6	12.0
15 t=0.25"	LONG. FORCE	1.5	—	0.5	0.3	8.3	0.1	-0.4	0.4	0.4	2.7	9.5
	CIRC. FORCE	12.6	0.2	2.8	—	0.6	0.1	1.1	1.4	0.6	17.0	2.4
	LONG. MOM.	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM.	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	5.6	0.1	—	—	11.41	0.1	—	—	—	5.7	11.42
18 t=7/8"	LONG. FORCE	1.0	0.1	0.2	0.1	1.0	—	-0.6	0.2	0.2	1.6	1.9
	CIRC. FORCE	14.7	0.5	0.9	-1.6	19.6	0.3	4.2	1.3	2.9	19.0	28.6
	LONG. MOM	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	3.2	—	—	—	13.0	0.1	—	—	—	3.2	13.1
19 t=7/8"	LONG. FORCE	1.2	0.1	0.2	0.1	0.3	—	-0.3	0.2	0.2	1.8	0.9
	CIRC. FORCE	13.8	0.5	1.0	-1.6	20.7	0.3	4.0	1.3	2.8	18.2	29.4
	LONG. MOM	—	—	—	—	—	—	—	—	—	—	—
	CIRC. MOM	—	—	—	—	—	—	—	—	—	—	—
	SHEAR	3.3	0.1	—	—	13.0	0.1	—	—	—	3.4	13.1

* TRANSFER FROM RRV. CALCULATION VERSION B, DATED 3/31/78

** COL. ⑤ FROM AXIDYN RUN ON FIREWATER & TRANSFER TANK DATED 6/13/78

SHEET NO. B-34

[VERSION C]

URS/BLUME
100 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW SHEET NO. B-35
BY LC DATE 10-9-78
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK CHKD PMN DATE

FORCES & MOMENT IN CONCRETE ELEMENTS

NODAL POINT	FORCE/MOMENT K/K-FT	Exterior Tank				INTERIOR TANK						
		① IMPULSIVE PRESSURE	② CONVECTIVE PRESSURE	③ HYDROSTATIC PRESSURE	④ DEAD LOAD	⑤ IMPULSIVE PRESSURE	⑥ CONVECTIVE PRESSURE	⑦ HYDROSTATIC PRESSURE	⑧ VERT. EQ. 0.5(3+4)	⑨ VERT. EQ. 0.5(4+7)	⑩ 1+2+3+4+8	⑪ 4+5+6+7+9
1	LONG. FORCE	147.2	1.5	0.3	-5.4	100.6	1.0	1.3	2.8	3.4	157.3	111.7
	CIRC. FORCE	29.4	0.3	0.1	1.1	20.1	0.2	0.3	0.6	0.7	31.5	22.4
	LONG. MOM.	35.8	0.4	23.6	-0.6	20.8	0.2	0.2	12.1	0.4	72.5	22.2
	CIRC. MOM.	7.2	0.1	4.7	0.1	4.2	–	–	2.4	0.1	14.5	4.4
	SHEAR	86.5	0.8	–	–	40.3	0.4	–	–	–	87.3	40.7
2	LONG. FORCE	149.4	1.2	3.1	4.2	101.5	1.0	-1.2	3.2	3.3	160.4	111.2
	CIRC. FORCE	40.2	0.3	1.2	0.8	24.6	0.2	-0.2	2.1	0.6	46.8	26.4
	LONG. MOM.	18.9	0.2	9.0	0.2	10.6	0.1	–	4.7	0.2	25.0	11.1
	CIRC. MOM.	4.0	–	1.8	–	2.2	–	–	1.0	0.1	6.9	2.3
	SHEAR	82.2	0.7	–	–	37.4	0.3	–	–	–	82.9	37.7
4	LONG. FORCE	94.3	1.0	1.4	3.8	74.5	0.7	-1.0	2.6	2.4	103.1	82.4
	CIRC. FORCE	5.8	0.1	41.6	-0.2	4.3	–	0.1	20.9	0.2	68.6	4.8
	LONG. MOM.	0.7	0.1	-2.8	–	0.6	–	–	1.4	–	5.0	0.6
	CIRC. MOM.	0.2	–	0.6	–	0.2	–	–	0.3	–	1.1	0.2
	SHEAR	74.0	0.7	–	–	35.5	0.3	–	–	–	74.7	35.8
6	LONG. FORCE	79.5	0.8	3.1	3.1	61.3	0.6	0.9	2.0	2.0	86.2	67.9
	CIRC. FORCE	9.4	0.1	-0.2	-0.2	3.4	–	–	15.7	0.1	56.6	3.7
	LONG. MOM	0.2	–	–	–	0.2	–	–	0.7	–	2.2	0.2
	CIRC. MOM	0.1	–	–	–	0.1	–	–	0.2	–	0.6	0.1
	SHEAR	73.9	0.7	–	–	36.9	0.3	–	–	–	74.6	37.2
18	LONG. FORCE	1.1	–	0.5	0.5	5.6	0.1	-1.3	0.5	0.9	2.6	8.4
	CIRC. FORCE	23.3	1.1	1.9	-3.1	18.7	0.6	8.3	2.5	5.7	31.9	36.6
	LONG. MOM	1.3	–	0.6	0.1	0.9	–	-1.3	0.4	0.7	2.4	3.0
	CIRC. MOM	0.4	–	0.1	–	0.2	–	-0.3	0.1	0.2	0.6	0.7
	SHEAR	5.7	0.1	–	–	[illegible]	0.4	[illegible]	–	–	5.8	34.6

* Values in the table are from Version A calculation by RRV 3/21/78 except Col ⑤ from AXIDYN RUN ON FIREWATER & TRANSFER TANK DATED 6/13/78

SHEET NO. B-35

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

CHECK FOR STRESSES IN STEEL SHELL

PER ASME PRESSURE VESSELS CODE SECTION VIII, DIV. 2, FOR SA 516-55 TO SA 300 PL's, FROM TABLE ACS-1,

$S_Y = 30$ ksi

$S_m = 18.3$ ksi @ 100°F

1) GENERAL PRIMARY MEMBRANE STRESS INTENSITY

LOAD COMBINATION	ALLOWABLE STRESS
i) DL + HS	$kS_m = 1.0 \times 18.3 = 18.3$ ksi
ii) $DL + HS + \sqrt{EQ_{yy}^2 + EQ_{xx}^2 + EQ_{zz}^2}$	$kS_m = 1.5 \times 18.3 = 27.45$ ksi

2) PRIMARY MEMBRANE STRESS + BENDING

THIS CASE WITH HIGHER ALLOWABLE STRESSES WAS NOT CONSIDERED CRITICAL SINCE BENDING MOMENTS IN STEEL SHELL ELEMENTS ARE FOUND TO BE NEGLIGIBLE.

HENCE, CHECK FOR STRESSES WAS MADE AS PER CRITERION (1).

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT FIREWATER TANK.
BY LC DATE 11/2/7[illegible] SHEET NO B-37
CHK'D PMN DATE

CHECK FOR STRESSES IN STEEL SHELL

ELEMENT NO. (NODAL PTS)	t** (in) ①*	F_x (K/FT) ②*	F_y (K/FT) ③*	F_{xy} (K/FT) ④*	σ_{xx} (KSI) ②/(12×①)	σ_{yy} (KSI) ③/(12×①)	σ_{xy} (KSI) ④/(12×①)	CHECK FOR STRESSES (DL + HS + HE + VE)
55-57 (46-43)	0.75	119.9	94.5	86.0	13.32	10.50	9.56	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{13.32 - (-10.50)}{2}\right)^2 + (9.56)^2}$ $= 15.27$ $.7(2\tau_{max}) = 21.38 < 27.45$
58-60 (43-40)	0.625	80.4	73.6	81.1	10.72	9.81	10.81	$\tau_{max} = \sqrt{\left(\frac{10.72 - (-9.81)}{2}\right)^2 + (10.81)^2}$ $= 14.91$ $.7(2\tau_{max}) = 20.87 < 27.45$
61-63 (40-37)	0.5625	44.6	83.3	70.7	6.61	12.34	10.47	$\tau_{max} = \sqrt{\left(\frac{6.61 - (-12.34)}{2}\right)^2 + (10.47)^2}$ $= 14.12$ $.7(2\tau_{max}) = 19.77 < 27.45$
64-66 (37-34)	0.46875	22.7	88.0	49.5	4.04	15.64	8.80	$\tau_{max} = \sqrt{\left(\frac{4.04 - (-15.64)}{2}\right)^2 + (8.80)^2}$ $= 13.20$ $.7(2\tau_{max}) = 18.48 < 27.45$

* FROM CALCULATIONS BY CSC DATED 6/7/78

** $t = t_{PL} - 1/16$ (corrosion allowable).

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT FIREWATER TANK
SHEET NO B-38
BY LC DATE 11/2/78
CHK'D PMN DATE

CHECK FOR STRESSES IN STEEL SHELL

ELEMENT NO. (NODAL PTS)	t (in) ① *	F_x (K/FT) ② *	F_y (K/FT) ③ *	F_{xy} (K/FT) ④ *	σ_{xx} (KSI) ②/(12×①)	σ_{yy} (KSI) ③/(12×①)	σ_{xy} (KSI) ④/(12×①)	CHECK FOR STRESSES (DL + HS + HE + VE)
67-69 (34-28)	0.375	33.9	74.8	6.6	7.54	16.62	1.47	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{7.54-(-16.62)}{2}\right)^2 + (1.47)^2}$ $= 12.17$ $(2\tau_{max}) = 17.04 < 27.45$
70-72 (28-22)	0.25	29.0	57.6	31.3	9.67	19.20	10.43	$\tau_{max} = \sqrt{\left(\frac{9.67-(-19.20)}{2}\right)^2 + (10.43)^2}$ $= 17.81$ $.7(2\tau_{max}) = 24.93 < 27.45$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ = $2\tau_{max}$ =
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ = $2\tau_{max}$ =

* FROM CALCULATIONS BY CSC DATED 6/7/78
** $t = t_{ft.} - 1/16$ (corrosion allowable)

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT TRANSFER TANK
BY LC DATE 11/2/78
CHK'D PMN DATE
SHEET NO. B-39

CHECK FOR STRESSES IN STEEL SHELL

ELEMENT NO. (NODAL PTS)	t** (in) ① *	Fx (K/FT) ② *	Fy (K/FT) ③ *	Fxy (K/FT) ④ *	σ_{xx} (KSI) ②/(12x①)	σ_{yy} (KSI) ③/(12x①)	σ_{xy} (KSI) ④/(12x①)	CHECK FOR STRESSES (DL+HS+HE+VE)
28-32 (1-6)	0.5645	72	37.2	50.4	10.63	5.49	7.44	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{10.63-(-5.49)}{2}\right)^2+(7.44)^2}$ $= 10.97$ $.7(2\tau_{max}) = 15.36 < 27.45$
33-35 (6-9)	0.4595	58.7	32.2	44	10.65	5.84	7.98	$\tau_{max} = \sqrt{\left(\frac{10.65-(-5.84)}{2}\right)^2+(7.98)^2}$ $= 11.47$ $.7(2\tau_{max}) = 16.06 < 27.45$
36-38 (9-12)	0.3545	32.7	30.1	30.7	7.69	7.08	7.22	$\tau_{max} = \sqrt{\left(\frac{7.69-(-7.08)}{2}\right)^2+(7.22)^2}$ $= 10.33$ $.7(2\tau_{max}) = 14.46 < 27.45$
39-41 (12-15)	0.25	13.1	24.8	17.1	4.37	8.27	5.70	$\tau_{max} = \sqrt{\left(\frac{4.37-(-8.27)}{2}\right)^2+(5.70)^2}$ $= 8.51$ $.7(2\tau_{max}) = 11.92 < 27.45$

* FROM CALCULATIONS BY CSC DATED 6/7/78
** t = t_{pl} - 1/16 (corrosion allowable)

CHECK FOR STRESSES IN STEEL SHELL

ELEMENT NO. (NODAL PTS)	t^{**} (in) ①*	F_x (K/FT) ②*	F_y (K/FT) ③*	F_{xy} (K/FT) ④*	σ_{xx} (KSI) ②/(12×①)	σ_{yy} (KSI) ③/(12×①)	σ_{xy} (KSI) ④/(12×①)	CHECK FOR STRESSES (DL + HS + HE + VE)
42-44 (15-33)	0.1875	2.7	17	11.42	1.2	7.56	5.08	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{1.2 - (-7.56)}{2}\right)^2 + (5.08)^2}$ $= 6.71$ $7(2\tau_{max}) = 9.39 < 27.45$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$

* FROM CALCULATIONS BY CSC DATED 6/7/78
** $t = t_{pl} - 1/16$ (corrosion allowable)

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-4 i

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE 10-3-78
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK CHK'D LC DATE 11-4-78

ELEMENTS 55-57 (NODES 46-43); 67-69 (NODES 34-28); AND 70-72 (@ NODES 28-22) WILL BE RECHECKED BY CALCULATIN THE SRSS VALUE OF THE EARTHQUAKE COMPONENTS. THE FORCE FROM THE 1st MODE ONLY WILL BE CONSIDERED FOR THIS PURPOSE, 1st MODE BEING THE MOST PREDOMINANT.

ELEMENTS 55-57 (NODES 46-43)

$F_x = 94.0$ k/ft ; $F_y = 4.8$ k/ft $F_{xy} = 78.8$ k/ft { 1st MODE FORCES FROM LC RUN DATED 10-2-78.

$$F_{x\ modified} = \sqrt{(97.9-94.0)^2 + (9.4)^2} = 94.1 \text{ k/ft}$$

$$F_{y\ mod.} = \sqrt{(6.4-4.8)^2 + (4.8)^2} = 5.1 \text{ k/ft}$$

$$F_{xy\ mod} = \sqrt{(85.6-78.8)^2 + (78.8)^2} = 79.1 \text{ k/ft}$$

{ REFER SHEETS B-31 & B-32 FOR OTHER VALUES }

∴ SRSS VALUES ARE GIVEN BY

$$F_{x\ SRSS} = \sqrt{(94.1+0.7)^2 + (7.1)^2} = 95.1 \text{ k/ft}$$

$$F_{y\ SRSS} = \sqrt{(5.1+0)^2 + (29.4)^2} = 29.8 \text{ k/ft}$$

$$F_{xy\ SRSS} = \sqrt{(79.1+0.4)^2 + (0)^2} = 79.5 \text{ k/ft}$$

$$\therefore \sigma_x = \frac{2.0+12.2+95.1}{12(0.75)} = 12.14 \text{ KSI}$$

$$\sigma_Y = \frac{0+58.7+29.8}{12(0.75)} = 9.83 \text{ ksi}$$

$$\sigma_{xy} = \frac{0+0+79.5}{12(0.75)} = 8.83 \text{ ksi}$$

$$\therefore \tau_{max} = \sqrt{\left[\frac{12.14-(-9.83)}{2}\right]^2 + (8.83)^2} = 14.09 \text{ ksi}$$

$$0.7(2\tau_{max}) = 0.7 \times 2 \times 14.09 = 19.73 \text{ ksi} < 27.45 \text{ ksi}$$

↑ FACTOR OF 0.7 TAKEN TO ACCOUNT FOR THE REDUCTION DUE TO TANGENTIAL EFFECTS BASED ON NON-AXISYM. ANALYSIS OF REFUELING TANK.

CALCULATIONS FOR MODIFIED F_x, F_y, F_{xy} ; $F_{xSRSS}, F_{ySRSS}, F_{xySRSS}$ AND MAX SHEAR STRESS τ_{max} DONE SIMILAR TO THOSE SHOWN ON SHEET B-42.

ELE. NOS. (NODE NOS. & PL THICKNESS ⊕)	FORCE K/FT OR STRESS KSI DESIGNATION	MODE I FORCES FROM LC RUN 10/2/78	IMPULS. PRESS. <COL 5>*	MODIFIED VALUES	CONVEC. PRESS. <COL 6>*	VERT EQ <COL 9>*	SRSS VALUES	STRESSES {SRSS + <COL 4>* + <COL 7>*} ÷ 12×t	τ_{max}	0.7 × $2\tau_{max}$
67-69 (34-28) (0.375")	LONG FORCE/STRESS	23.5	28.5	24.0	0.1	1.7	24.2	$\frac{24.2+1.2+2.1}{12t}$ = 6.11	8.56	11.98
	CIRCUM FORCE/STRESS	43.2	53.3	44.4	0.2	7.1	45.1	10.02		
	SHEAR FORCE/STRESS	11.8	16.4	12.7	0.2	—	12.9	2.87		
70-72 (28-22) (0.25")	LONG FORCE/STRESS	21.1	23.5	21.2	—	1.7	21.3	$\frac{21.3+1.0+2.3}{12t}$ = 8.20	15.56	21.78
	CIRCUM FORCE/STRESS	35.3	47.7	37.4	0.6	3.1	38.1	$\frac{38.1+0+6.2}{12t}$ = 14.77		
	SHEAR FORCE/STRESS	37.3	30.8	31.5	—	—	31.5	10.49		

⊕ PL THICKNESSES ARE REDUCED BY 1/16" FOR COROSSION PROTECTION

* THESE VALUES OBTAINED FROM SHEETS B-31 & B-32

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK

SHEET NO. B-42

BY PMN DATE 10-3-78

CH'K'D LC DATE 11-4-78

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-43

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 10/2/78
CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK CHK'D PMN DATE 10/5/78

EXTERIOR

Tangential Presure

* 1st MODE

NODAL POINT	P_o lb/ft²	$A_o'T$ * FT/sec²	$P_T = P_o A_o'T$
19	0.	74.84	0.
18	5.86	74.70	437.74
17	19.30	71.93	1388.25
16	24.10	68.64	1654.22
15	29.39	64.70	1901.53
14	29.67	60.15	1784.65
13	31.31	54.97	1721.11
12	33.80	49.21	1663.30
11	33.42	43.24	1445.08
10	31.79	36.92	1173.69
9	29.58	30.39	898.94
8	26.50	24.12	639.18
7	24.39	17.92	437.07
6	21.61	11.89	256.94
5	20.17	8.28	167.01
4	19.59	8.00	156.72
3	17.77	4.25	75.52
2	16.71	0.89	14.89
1	16.04	0.	0.

Interior

Tangential Pressure

* 1st MODE

NODAL POINT	P_o lbs/ft^2	A'_{oT} * ft/sec^2	$P_T = P_o A'_{oT}$
24	0	63.9	0.
26	18.63	69.8	1300.37
28	22.57	73.6	1661.15
30	25.74	75.3	1938.22
32	28.33	75.4	2136.08
34	29.00	73.6	2134.40
35	29.00	70.4	2041.60
36	28.33	65.8	1864.11
37	27.66	59.9	1656.83
38	26.41	53.7	1418.22
39	23.82	46.8	1114.78
40	21.89	39.3	860.28
41	19.30	32.1	619.53
42	15.46	24.8	383.41
43	14.12	17.5	247.10
44	12.20	11.3	137.86
45	10.95	5.5	60.23
46	9.70	0.5	4.85

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-45

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 10/4/78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANK CHK'D PMN DATE

Node 46	Exterior	Interior
Long. Force	74.5 − 21.6 = 52.9	127.7 − 33.9 = 93.8
Circ. Force	22.4 − 4.6 = 17.8	111.9 − 7.2 = 104.7
Long. Mom.	0.1 − 0 = 0.1	1.1 − 0.1 = 1.0
Circ. Mom.	0.0 − 0 = 0.0	0.3 − 0. = 0.3
Shear	23.9 − 0 = 23.9	87.0 − 30.0 = 57.0

Node 1	Exterior	Interior
Long. Force	40.7 − 12.6 = 28.1	27.5 − 7.4 = 20.1
Circ. Force	12.2 − 3.7 = 8.5	8.4 − 2.2 = 6.2
Long. Mom.	0.0 − 0. = 0.	0. − 0. = 0.
Circ. Mom.	0.0 − 0. = 0.	0. − 0. = 0.
Shear	21.3 − 0. = 21.3	8.9 − 2.4 = 6.5

NOTE: FORCES & MOMENTS GIVEN ABOVE ARE IN EXTERIOR & INTERIOR STEEL SHELLS AND CORRESPOND TO THE SUMMARY FOR "VERSION C".

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. B-46

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 4-25-78

CLIENT PG&E SUBJECT FIREWATER & TRANSFER TANKS CHK'D PMN DATE

COMPARISON OF FORCES & MOMENTS
IN CONCRETE ELEMENTS
BETWEEN REFUELING WATER STORAGE TANK
AND FIREWATER & TRANSFER TANKS

NODAL POINT	FORCE / MOMENT K/ K-F	REFUEL WATER STORAGE TANK	FIREWATER & TRANSFER TANKS
1	LONG. FORCE	206.6	157.3
	CIRC. FORCE	46.1	31.5
	LONG. MOM.	83.9	72.5
	CIRC. MOM.	16.7	14.5
	SHEAR	102.9	87.3
2	LONG. FORCE	168.8	160.4
	CIRC. FORCE	40.8	46.8
	LONG. MOM.	37.5	25.0
	CIRC. MOM.	7.6	6.9
	SHEAR	95.4	82.9
4	LONG. FORCE	139.3	103.1
	CIRC. FORCE	63.1	68.6
	LONG. MOM.	5.1	5.0
	CIRC. MOM.	1.1	1.1
	SHEAR	89.9	74.7
6	LONG. FORCE	125.6	86.2
	CIRC. FORCE	57.0	56.6
	LONG. MOM.	4.2	2.2
	CIRC. MOM.	1.0	0.6
	SHEAR	90.8	74.6
22 (18 For F.&T. Tanks)	LONG. FORCE	3.6	8.4
	CIRC. FORCE	41.9	36.6
	LONG. MOM.	1.7	3.0
	CIRC. MOM.	0.5	0.7
	SHEAR	4.6	34.4

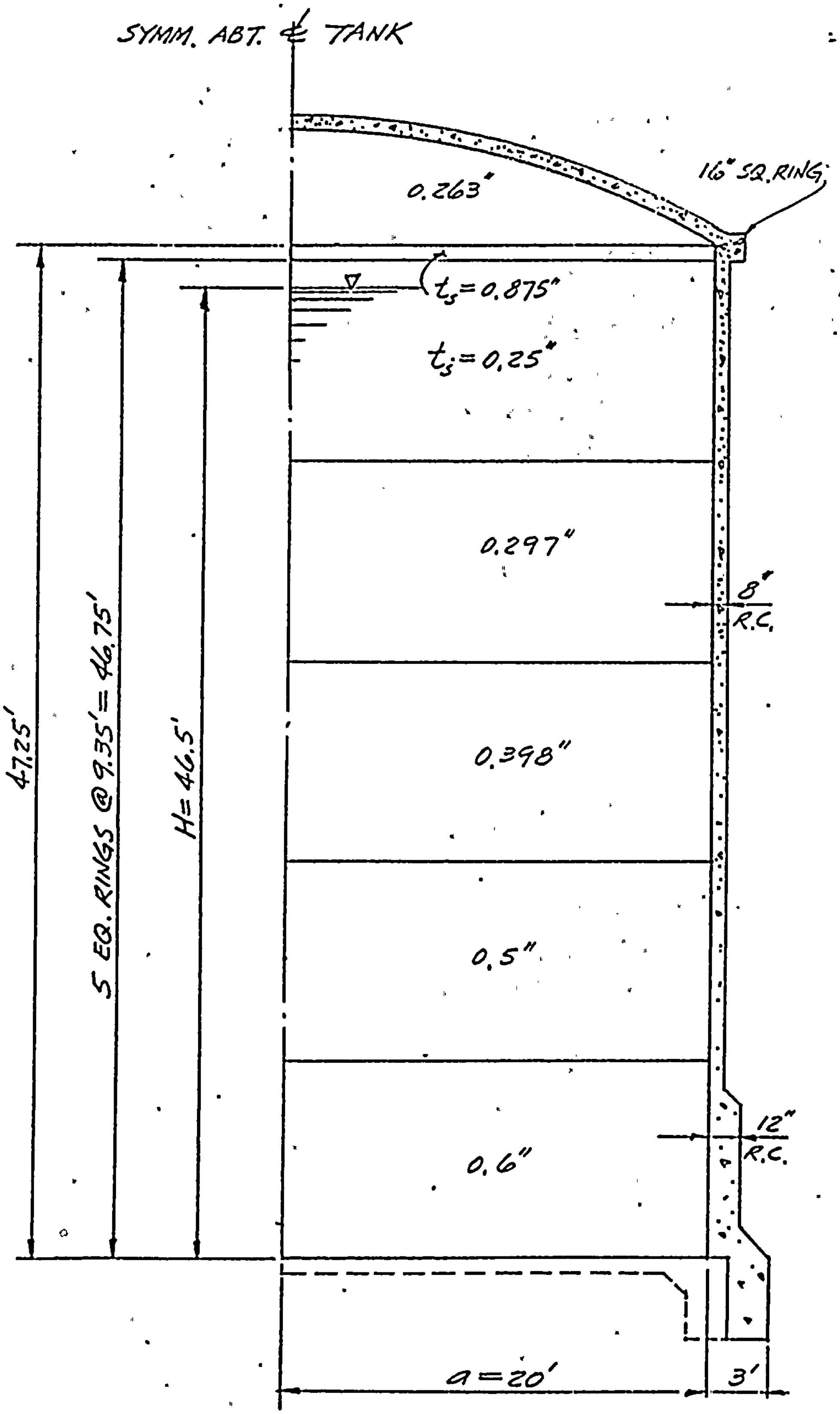
As all the tanks are of same diameter with concrete shells of same thickness, however, the Firewater & Transfer Tanks are subject to smaller forces and moments, ∴ USE SAME R-C DESIGN OF REFUELING WATER TANK FOR FIREWATER & TRANSFER TANKS [illegible]

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. C-1

JOB NO. 0902-19 JOB DIABLO REVIEW BY CSC DATE 4-25-78

CLIENT PG&E SUBJECT CONDENSATE TANK CHK'D PMN DATE 10-9-78



CHECK FOR STRESSES IN STEEL SHELL

BOTH THE HEIGHT AND DESIGN LIQUID DEPTH OF CONDENSATE TANK ARE LESSER THAN THOSE OF THE REFUELING TANK. FOR THIS REASON, NO SEPARATE ANALYSIS FOR THE CONDENSATE TANK WAS MADE. HOWEVER, SINCE THE STEEL LINER THICKNESSES OF THE TWO TANKS ARE DIFFERENT, (THE FORCES OBTAINED FROM THE AXISYMMETRIC ANALYSIS OF THE REFUELING TANK WERE CONSERVATIVELY ASSUMED TO OCCUR IN THE CONDENSATE TANK) THE STRESSES ARE PROPORTIONED IN THE RATIO OF THE THICKNESSES OF STEEL LINER SECTIONS AT CORRESPONDING HEIGHTS IN BOTH THE TANKS.

AS PER ASME PRESSURE VESSELS CODE SECTION VIII DIVISION 2,

FOR SA 516-55 TO SA-300 R^s,
$S_y = 30$ ksi
$S_m = 18.3$ ksi @ 100°F

1) GENERAL PRIMARY MEMBRANE STRESS INTENSITY

LOAD COMBINATION	ALLOWABLE STRESS
i) DL+HS	$kS_m = 1.0 \times 18.3 = 18.3$ ksi
ii) $DL+HS+\sqrt{EQ_{yy}^2+EQ_{xx}^2+EQ_{zz}^2}$	$kS_m = 1.5 \times 18.3 = 27.45$ ksi

2) PRIMARY MEMBRANE STRESS + BENDING

THIS CASE WITH HIGHER ALLOWABLE STRESSES WAS NOT CONSIDERED SINCE BENDING MOMENTS IN STEEL SHELL ELEMENTS ARE VERY SMALL.

HENCE, CHECK FOR STRESSES WAS MADE AS PER CRITERION (1).

URS/BLUME
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San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT CONDENSATE TANK
SHEET NO. C-3
BY LC DATE 11/2/78
CHK'D PMN DATE

CHECK FOR STRESSES IN STEEL SHELL

PLATE THICKNESS (IN)	t** (in) ①*	F_x (K/FT) ②*	F_y (K/FT) ③*	F_{xy} (K/FT) ④***	σ_{xx} (KSI) ②/(12x①)	σ_{yy} (KSI) ③/(12x①)	σ_{xy} (KSI) ④/(12x①)	CHECK FOR STRESSES (DL+HS+HE+VE)
0.600	0.538	77.26	56.0	50.5	11.97	8.67	7.82	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{11.97-(-8.67)}{2}\right)^2 + (7.82)^2}$ $= 12.95$ $.7(2\tau_{max}) = 18.13 < 27.45$
0.500	0.438	78.64	47.30	46.2	14.96	9.00	8.79	$\tau_{max} = \sqrt{\left(\frac{14.96-(-9.00)}{2}\right)^2 + (8.79)^2}$ $= 14.86$ $.7(2\tau_{max}) = 20.80 < 27.45$
0.398	0.336	46.74	38.26	33.7	11.59	9.49	8.36	$\tau_{max} = \sqrt{\left(\frac{11.59-(-9.49)}{2}\right)^2 + (8.36)^2}$ $= 13.45$ $.7(2\tau_{max}) = 18.83 < 27.45$
0.297	0.235	25.14	27.70	22.7	8.91	9.82	8.05	$\tau_{max} = \sqrt{\left(\frac{8.91-(-9.82)}{2}\right)^2 + (8.05)^2}$ $= 12.35$ $.7(2\tau_{max}) = 17.29 < 27.45$

*** FROM CALCULATIONS OF REFUELING TANK BY RRV DATED 5/5/78
* FROM CALCULATIONS BY RRV DATED 6/6/78
** $t = t_{PL} - 1/16$ (corrosion allowable)

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT CONDENSATE TANK
BY LC DATE 11/2/78
CHK'D PMN DATE
SHEET NO C-4

CHECK FOR STRESSES IN STEEL SHELL

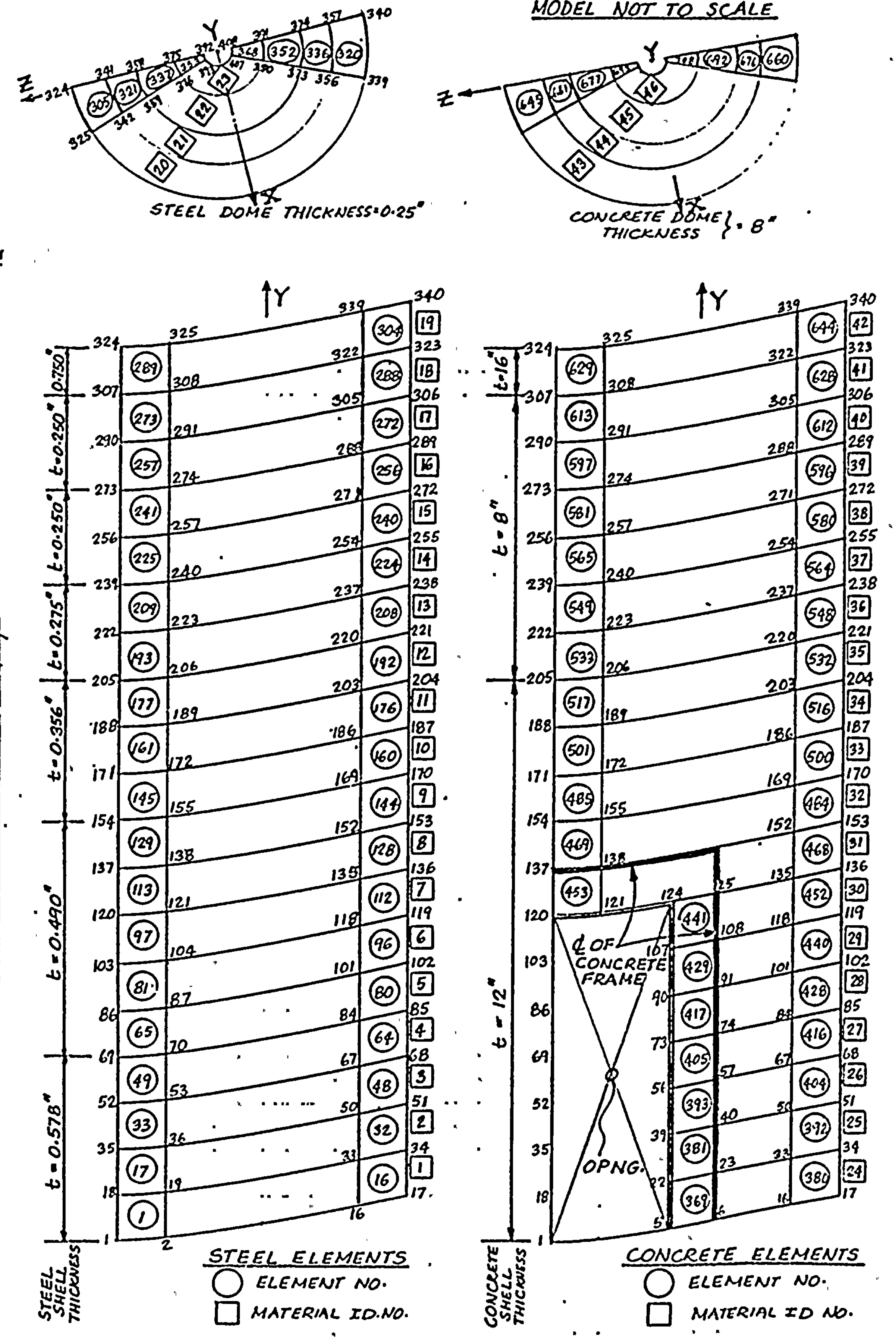
PLATE THICKNESS (in)	t ** (in) ① *	Fx (K/FT) ② *	Fy (K/FT) ③ *	Fxy (K/FT) ④ ***	σ_{xx} (KSI) ②/(12×①)	σ_{yy} (KSI) ③/(12×①)	σ_{xy} (KSI) ④/(12×①)	CHECK FOR STRESSES (DL + HS + HE + VE)
0.250	0.188	12.16	20.03	14.0	5.39	8.88	6.21	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$ $= \sqrt{\left(\frac{5.39 - 8.88}{2}\right)^2 + (6.21)^2}$ $= 9.46$ $.7(2\tau_{max}) = 13.24 < 27.45$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$
								$\tau_{max} = \sqrt{\left(\frac{\quad - \quad}{2}\right)^2 + (\quad)^2}$ $=$ $2\tau_{max} =$

*** FROM CALCULATIONS OF REFUELING TANK BY RRV DATED 5/5/78
* FROM CALCULATIONS BY RRV DATED 6/6/78
** t = t pl. − 1/16 (corrosion allowable)

SHEET NO. D-1

NO OF NODES = 408
NO OF ELEMENTS = 708
NO OF MATERIALS = 46

COMPUTER MODEL FOR REFUELING WATER TANK
{only half-tank about axis of Symmetry thro' Concrete shell opng considered}
MODEL NOT TO SCALE



URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG & E SUBJECT REFUELING WATER TANK
SHEET NO. D-1
BY PMN DATE 7-12-78
CH'K'D RRV DATE 8/18/78

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-2

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE 7-14-78

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9-18-78

COMPUTATION OF ELASTIC CONSTANTS FOR COMPUTER INPUT DATA :-

$$\begin{Bmatrix} \sigma_{xx} \\ \sigma_{YY} \\ \tau_{xY} \end{Bmatrix} = \begin{bmatrix} C_{xx} & C_{xY} & C_{xs} \\ C_{xY} & C_{YY} & C_{Ys} \\ C_{xs} & C_{Ys} & G_{xY} \end{bmatrix} \begin{Bmatrix} \epsilon_{xx} \\ \epsilon_{YY} \\ \gamma_{xY} \end{Bmatrix}$$

i.e.

$$\begin{Bmatrix} \sigma_{xx} \\ \sigma_{YY} \\ \tau_{xy} \end{Bmatrix} = \begin{bmatrix} \frac{E}{1-\nu^2} & \frac{E\nu}{1-\nu^2} & 0 \\ \frac{E\nu}{1-\nu^2} & \frac{E}{1-\nu^2} & 0 \\ 0 & 0 & \frac{E}{2(1+\nu)} \end{bmatrix} \begin{Bmatrix} \epsilon_{xx} \\ \epsilon_{YY} \\ \gamma_{xY} \end{Bmatrix}$$

$E_{steel} = 29000$ ksi $\qquad \nu_s = 0.3$

$E_{concrete} = 29000/9^*$ $\qquad$ *ACI value for $f_c' = 3000$ psi

≈ 3222.2 ksi $\qquad \nu_c = 0.2$

MATERIAL	$E/(1-\nu^2)$	$E\nu/(1-\nu^2)$	$E/[2(1+\nu)]$
STEEL	31,868.1	9560.5	11,153.9
CONCRETE	3,356.5	671.3	1,342.6
	C_{xx}	C_{xY}	G_{xY}

MASS DENSITIES:

STEEL : $\frac{0.490}{32.2} \times \frac{1}{(12)^4} = 7.3386 \times 10^{-7}$ k-sec²/in⁴

CONCRETE : $\frac{0.150}{32.2} \times \frac{1}{(12)^4} = 2.2465 \times 10^{-7}$ k-sec²/in⁴

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO D-3

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE 7-18-78
CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9-13-78

COMPUTATION OF HYDROSTATIC PRESSURES
(APPLIED TO STEEL SHELL ELEMENTS)

NODE NO^S IN SAP MODEL	STEEL ELEMENT NO^S	MATERIAL I.D. NO.	DISTANCE FROM TOP TO CG. OF ELEM. in.	DENSITY OF WATER k/in³	NORMAL PRESSURE ON ELEMENTS ksi
1-17	1-16	1	609.04	3.6111×10^{-5}	21.99×10^{-3}
18-34	17-32	2	583.12	↓	21.06
35-51	33-48	3	557.20		20.12
52-68	49-64	4	531.28		19.19
69-85	65-80	5	507.61		18.33
86-102	81-96	6	486.17		17.56
103-119	97-112	7	464.72		16.78
120-136	113-128	8	446.17		16.11
137-153	129-144	9	426.50		15.40
154-170	145-160	10	397.39		14.35
171-187	161-176	11	362.84		13.10
188-204	177-192	12	328.28		11.85
205-221	193-208	13	285.08		10.29
222-238	209-224	14	233.25		8.42
239-255	225-240	15	181.41		6.55
256-272	241-256	16	129.58		4.68
273-289	257-272	17	77.74	↓	2.81 ↓
290-306	273-288	18	25.91	3.6111×10^{-5}	0.94×10^{-3}
307-323					

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-4

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE AUG 18,78
CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9/14/78

CALCULATION OF DEAD WEIGHT OF TANK & CONTENTS

WEIGHT OF ANY ANULAR RING = $2\pi\rho \times r t h$ where ρ = density of material

I) WEIGHT OF CONCRETE SHELL W/FRAME & OPENING ($\rho = 0.150\ k/ft^3$)

i) TAPERED BOTTOM PORTION OF TANK

$= 2\pi\rho \times 22 \times 2 \times 1.5$ $= 62.20$

ii) WEIGHT TILL HALF HEIGHT OF TANK

= WEIGHT OF ANULAR RING − WT OF OPNG + WT OF FRAME

$= 2\pi\rho \times 20.5 \times 1 \times 24.41$ $= 471.62$

$- 14.60 \times 1 \times 14 \times \rho$ (arc length, op. height) $= -30.66$

$+ 2 \times 4.5 \times 4 \times 14 \times \rho + 4.5 \times 5 \times 14.6 \times \rho$ (2 COLUMNS; 1 BEAM, arc length — FRAME ADDITIONAL WT) $= 124.88$

iii) TOP HALF OF TANK EXCLUDING DOME

$= 2\pi\rho \times 20.33 \times 0.67 \times 25.91$ $= 332.62$

iv) DOMED ROOF OF TANK

$= 2\pi\rho \times 40.0 \times 0.67 \times 5.41$ $= 136.64$

v) WEIGHT OF RING BEAM BELOW DOME

$= 2\pi\rho \times 20.67 \times 1.33 \times 1.33$ $= 34.63$

TOTAL WEIGHT OF CONCRETE SHELL $= 1131.93^k$

II) WEIGHT OF STEEL SHELL ($\rho = 0.490\ k/ft^3$)

i) WEIGHT OF CYLINDRICAL PORTION OF TANK

$$= 2\pi\rho \left[20.5 \left(\frac{0.578 + 0.490 + 0.356}{12} \right) \times 8.638 + 20.33 \left(\frac{0.275 + 0.250 + 0.250}{12} \right) \times 8.638 \right] = 99.62$$

ii) WEIGHT OF RING BEAM

$= 2\pi\rho \times 20.67 \times \frac{0.75}{12} \times 1.33$ $= 5.29$

iii) WEIGHT OF DOMED ROOF

$= 2\pi\rho \times 40.0 \times \frac{0.25}{12} \times 5.41$ $= 13.88$

TOTAL WEIGHT OF STEEL SHELL $= 118.79^k$

III) WEIGHT OF WATER WHEN TANK FULL

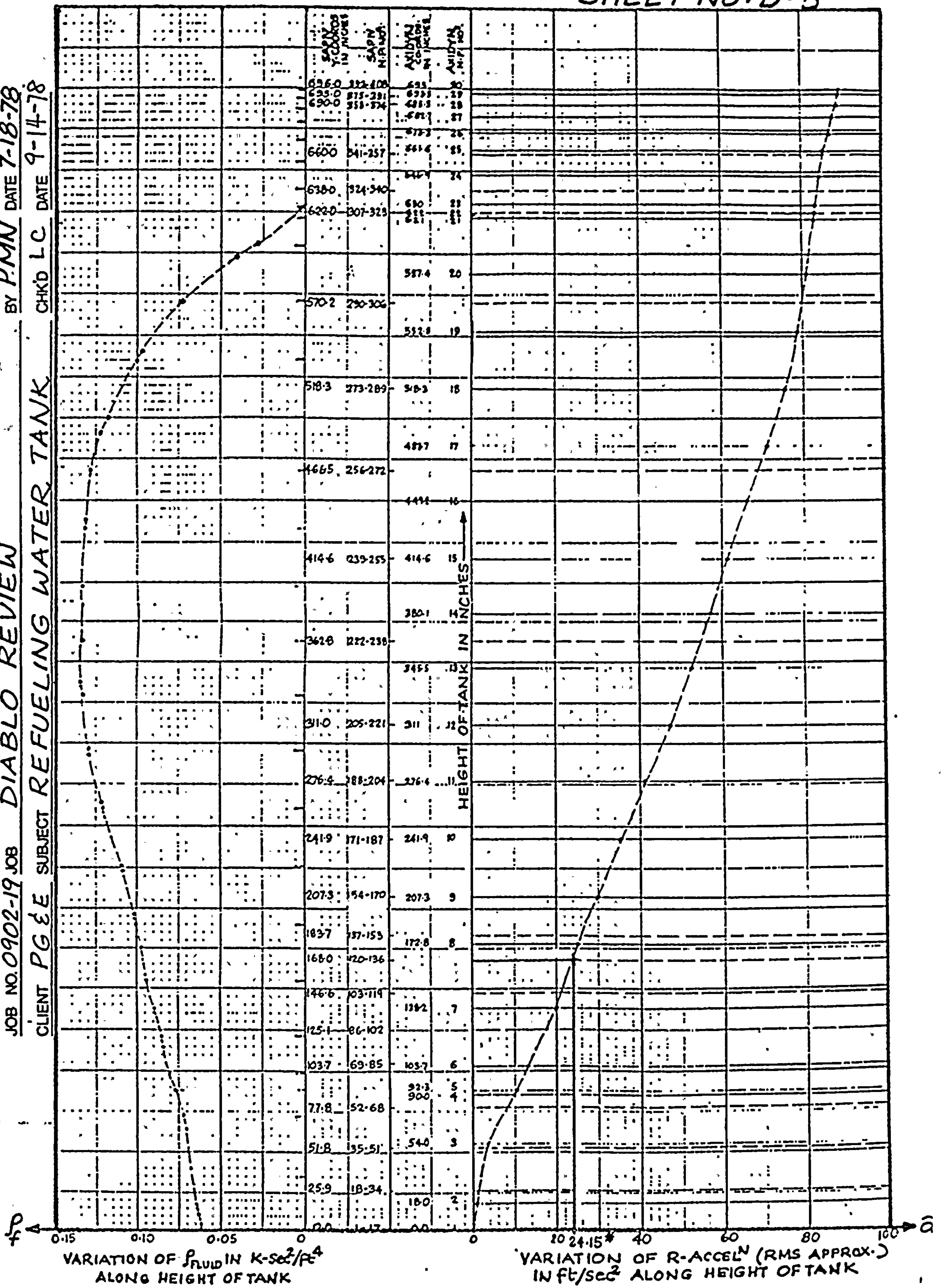
$= \pi r^2 h \times \rho = \pi \times (20)^2 \times 51.75 \times \frac{62.5}{1000} = 4064.44^k$

∴ TOTAL DEAD WEIGHT AT BASE $= 1131.93 + 118.79 + 4064.44 \approx 5317^k$

SHEET NO. D-5

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT REFUELING WATER TANK
SHEET NO. D-5 BY P.MN DATE 7-18-78
CHK'D LC DATE 9-14-78



URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT REFUELING WATER TANK
SHEET NO. D-6
BY PMN DATE 7-18-78
CHK'D LC DATE 9-11-78

R-ACCELERATIONS (RMS APPROX.) AND ρ_{FLUID} VALUES INTERPOLATED FROM · AXIDYN ANALYSIS

(Refer Sh. No. D-5)

NODE NOS. IN SAP MODEL	a RMS ACCEL^N INTERPOLATED FROM AXIDYN ft/sec²	a' in/sec²	STEEL ELEMENT NOS. IN SAP MODEL	a'' RMS ACCEL^N @CG. OF ELEMENT in/sec²	ρ_{FLUID} VALUES INTERPOLATED FROM PREVIOUS CALCS. K-sec²/ft⁴	ρ'_{FLUID} X10^{-7} k-sec²/in4
1 - 17	0	0	1-16 (t_s = 0.578")	290*	0.065	31.3465
18 - 34	1	12	17-32	290*	0.067	32.3110
35 - 51	3.5	42	33-48	290*	0.070	33.7577
52 - 68	8.5	102	49-64	290*	0.078	37.6157
69 - 85	13.5	162	65-80 (0.490")	290*	0.085	40.9915
86 - 102	17.5	210	81-96	290*	0.090	43.4028
103 - 119	21.0	252	97-112	290*	0.095	45.8140
120 - 136	24.0	288	113-128	301	0.0975	47.0197
137 - 153	26.0	312	129-144	336	0.1025	49.4309
154 - 170	30.0	360	145-160 (0.356")	393	0.1075	51.8422
171 - 187	35.5	426	161-176	459	0.120	57.8704
188 - 204	41.0	492	177-192	531	0.1255	60.5228
205 - 221	47.5	570	193-208 (0.275")	615	0.1345	64.8630
222 - 238	55.0	660	209-224	699	0.1345	64.8630
239 - 255	61.5	738	225-240 (0.250")	783	0.1325	63.8985
256 - 272	69.0	828	241-256	863	0.1225	59.0760
273 - 289	75.5	906	257-272	933	0.0975	47.0197
290 - 306	80.0	960	273-288	981	0.040	19.2901
307 - 323	83.5	1002	289-304 (0.750")	1005	0	0
324 - 340	84.0	1008	305-320 (0.250")	1017	↓	↓
341 - 357	85.5	1026	321-336	1041	↓	↓
358 - 374	88.0	1056	337-352	1062	↓	↓
375 - 391	89.0	1068	353-368	1071	0	0
392 - 408	89.5	1074				

t_{fluid} = 3" (as used in AXIDYN)

* minimum ground acceln of 0.75g considered

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-7
JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE JULY 20
CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9-15-78

MODIFIED MASS DENSITIES FOR LATERAL LOAD ANALYSES

$a_o(y)$ = R-Accelerations (RMS) interpolated from AXIDYN output @ c.g.'s of element
ρ_s = Mass density of steel
$\rho_{s(mod)}$ = Modified mass density of steel, $\{\rho_s \times a_o(y)\}$
t_s, t_f, t_c = thicknesses of steel, fluid and concrete shells
ρ_f = Mass density of fluid with $t_f = 3"$ {see sh. No. D-6}
ρ_c = Mass density of concrete
$\rho_{c(mod.)}$ = Modified Mass density of concrete $\{\rho_c \times a_o(y)\}$

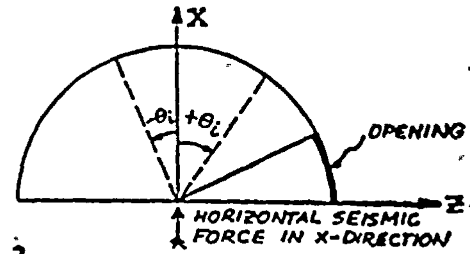
NODE NUMBERS IN SAP MODEL	$a_o(y)$ in/sec²	STEEL ELEMENTS				CONCRETE ELEMENTS				
		ELEMENT NUMBERS IN SAP MODEL	MATL. ID. NO.	ρ_s $\times 10^{-7}$ k-sec²/in⁴	$\rho_{s(mod.)}$ $\times 10^{-4}$ k-sec²/in⁴	ELEMENT NUMBERS IN SAP MODEL	MATL. ID. NO.	t_c inches	ρ_c $\times 10^{-7}$ k-sec²/in⁴	$\rho_{c(mod.)}$ $\times 10^{-4}$ k-sec²/in⁴
1-17	290*	1-16	1	7.34	2.13	369-380	24	12	2.25	0.65
18-34	290*	17-32	2		2.13	381-392	25	12		0.65
35-51	290*	33-48	3		2.13	393-404	26	12		0.65
52-68	290*	49-64	4		2.13	405-416	27	12		0.65
69-85	290*	65-80	5		2.13	417-428	28	12		0.65
86-102	290*	81-96	6		2.13	429-440	29	12		0.65
103-119	290*	97-112	7		2.13	441-452	30	12		0.65
120-136	301	113-128	8		2.21	453-468	31	12		0.68
137-153	336	129-144	9		2.47	475-484	32	12		0.75
154-170	393	145-160	10		2.88	491-500	33	12		0.88
171-187	459	161-176	11		3.37	501-516	34	12		1.03
188-204	531	177-192	12		3.90	517-532	35	12		1.19
205-221	615	193-208	13		4.51	533-548	36	8		1.38
222-238	699	209-224	14		5.13	549-564	37	8		1.57
239-255	783	225-240	15		5.75	565-580	38	8		1.76
256-272	863	241-256	16		6.33	581-596	39	8		1.94
273-289	933	257-272	17		6.85	597-612	40	8		2.10
290-306	981	273-288	18		7.20	613-628	41	8		2.20
307-323	1005	289-304	19		7.38	629-644	42	16		2.26
324-340	1017	305-320	20		7.46	645-660	43	8		2.29
341-357	1041	321-336	21		7.64	661-676	44	8		2.34
358-374	1062	337-352	22	↓	7.79	677-692	45	8	↓	2.39
375-391	1071	353-368	23	7.34	7.86	693-708	46	8	2.25	2.41
392-408										

* MIN. GROUND ACCELERATION OF 0.75g CONSIDERED

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-8

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE JULY 24
CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9/16/78



HYDRODYNAMIC PRESSURES ON STEEL SHELL ELEMENTS DUE TO IMPULSIVE PRESSURE

ρ_f = mass density of fluid w/ t_f = 3"
$a_o(y)$ = R-accelerations @ C.G.'s of Elements } SEE SH. NO. D-6

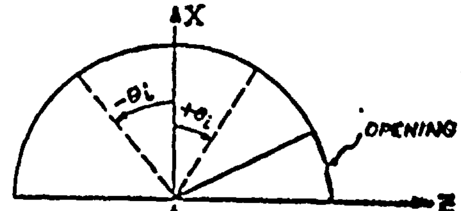
ELEMENT NUMBERS IN SAP MODEL	ρ_f ×10⁻⁷ K-sec²/in⁴	$a_o(y)$ in/sec²	$p_o = \rho_f \cdot t_f \cdot a_o(y) \cdot \cos\theta_i$ (×10⁻³ ksi)															
			θ_1=87.45	θ_2=82.35	θ_3=77.25	θ_4=72.15	θ_5=67.05	θ_6=60.5	θ_7=50.75	θ_8=37.5	θ_9=22.5	θ_{10}=7.5	θ_{11}=−7.5	θ_{12}=−22.5	θ_{13}=−37.5	θ_{14}=−52.5	θ_{15}=−67.5	θ_{16}=−82.5
			$\cos\theta_1$= 0.044	$\cos\theta_2$= 0.133	$\cos\theta_3$= 0.221	$\cos\theta_4$= 0.307	$\cos\theta_5$= 0.390	$\cos\theta_6$= 0.492	$\cos\theta_7$= 0.633	$\cos\theta_8$= 0.793	$\cos\theta_9$= 0.924	$\cos\theta_{10}$= 0.991	$\cos\theta_{11}$= 0.991	$\cos\theta_{12}$= 0.924	$\cos\theta_{13}$= 0.793	$\cos\theta_{14}$= 0.609	$\cos\theta_{15}$= 0.383	$\cos\theta_{16}$= 0.131
1 - 16	31.35	290	0.1	0.4	0.6	0.8	1.0	1.3	1.7	2.1	2.5	2.7	2.7	2.5	2.1	1.6	1.0	0.4
17 - 32	32.31	290	0.1	0.4	0.6	0.9	1.1	1.4	1.8	2.2	2.6	2.8	2.8	2.6	2.2	1.7	1.1	0.4
33 - 48	33.76	290	0.1	0.4	0.7	0.9	1.2	1.5	1.9	2.4	2.8	3.0	3.0	2.8	2.4	1.9	1.2	0.4
49 - 64	37.62	290	0.1	0.4	0.7	1.0	1.3	1.7	2.1	2.7	3.1	3.3	3.3	3.1	2.7	2.0	1.3	0.4
65 - 80	40.99	290	0.2	0.5	0.8	1.1	1.4	1.7	2.2	2.8	3.3	3.5	3.5	3.3	2.8	2.1	1.3	0.5
81 - 96	43.40	290	0.2	0.5	0.8	1.1	1.5	1.8	2.3	2.9	3.4	3.7	3.7	3.4	2.9	2.3	1.4	0.5
97 - 112	45.81	290	0.2	0.5	0.9	1.2	1.5	1.9	2.5	3.1	3.6	3.9	3.9	3.6	3.1	2.4	1.5	0.5
113 - 128	47.02	301	0.2	0.6	0.9	1.3	1.7	2.1	2.7	3.4	4.0	4.2	4.2	4.0	3.4	2.6	1.6	0.6
129 - 144	49.43	336	0.2	0.7	1.1	1.6	2.0	2.5	3.2	4.0	4.7	5.0	5.0	4.7	4.0	3.1	1.9	0.7

URS/BLUME
100 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-9

JOB NO. 0902-19 JOB DIABLO REVIEW — BY PMN DATE JULY 24

CLIENT PG & E SUBJECT REFUELING WATER TANK — CHKD LC DATE 9/16/78



HORIZONTAL SEISMIC FORCE IN X-DIRECTION

HYDRODYNAMIC PRESSURES ON STEEL SHELL ELEMENTS DUE TO IMPULSIVE PRESSURE

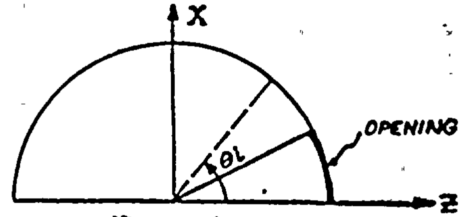
ρ_f = mass density of fluid w/ $t_f = 3"$; $a_o(y)$ = R-accelerations @ C.G.s of Elements } SEE SH. NO. D-6

ELEMENT NUMBERS IN SAP MODEL	ρ_f x 10^{-7} K-sec²/in⁴	$a_o(y)$ in/sec²	$p_o = \rho_f \cdot t_f \cdot a_o(y) \cdot \cos\theta_i$ (x 10^{-3} KSI)															
			$\theta_1 = 86.5$	$\theta_2 = 79.5$	$\theta_3 = 72.5$	$\theta_4 = 65.5$	$\theta_5 = 57$	$\theta_6 = 47$	$\theta_7 = 37$	$\theta_8 = 27$	$\theta_9 = 15.5$	$\theta_{10} = 2.5$	$\theta_{11} = -10.5$	$\theta_{12} = -23.5$	$\theta_{13} = -37.5$	$\theta_{14} = -52.5$	$\theta_{15} = -67.5$	$\theta_{16} = -82.5$
			$\cos\theta_1 = 0.061$	$\cos\theta_2 = 0.182$	$\cos\theta_3 = 0.301$	$\cos\theta_4 = 0.415$	$\cos\theta_5 = 0.545$	$\cos\theta_6 = 0.682$	$\cos\theta_7 = 0.799$	$\cos\theta_8 = 0.891$	$\cos\theta_9 = 0.961$	$\cos\theta_{10} = 0.999$	$\cos\theta_{11} = 0.983$	$\cos\theta_{12} = 0.917$	$\cos\theta_{13} = 0.793$	$\cos\theta_{14} = 0.609$	$\cos\theta_{15} = 0.383$	$\cos\theta_{16} = 0.131$
145-160	51.84	393	0.4	1.2	1.9	2.6	3.5	4.3	5.1	5.7	6.1	6.4	6.3	5.8	5.1	3.9	2.4	0.8
161-176	57.87	459	0.5	1.5	2.5	3.4	4.4	5.6	6.5	7.3	7.8	8.1	8.0	7.5	6.5	5.0	3.1	1.1
177-192	60.52	531	0.6	1.8	3.0	4.2	5.5	6.9	8.0	9.0	9.7	10.0	9.9	9.2	8.0	6.1	3.9	1.3
193-208	64.86	615	0.7	2.2	3.6	5.0	6.5	8.2	9.6	10.7	11.5	11.9	11.8	11.0	9.5	7.3	4.6	1.6
209-224	64.86	699	0.8	2.5	4.1	5.7	7.4	9.3	10.9	12.1	13.1	13.6	13.4	12.5	10.8	8.3	5.2	1.8
225-240	63.90	783	0.9	2.8	4.6	6.3	8.3	10.4	12.2	13.6	14.6	15.2	15.0	13.9	12.1	9.3	5.8	2.0
241-256	59.08	863	0.9	2.8	4.6	6.3	8.2	10.3	12.0	13.5	14.5	15.0	14.9	13.9	12.0	9.2	5.8	2.0
257-272	47.02	933	0.8	2.3	3.9	5.3	7.0	8.8	10.3	11.4	12.3	12.8	12.6	11.8	10.2	7.8	4.9	1.7
273-288	19.29	981	0.4	1.0	1.7	2.4	3.1	3.9	4.5	5.1	5.5	5.7	5.6	5.2	4.5	3.5	2.2	0.7

SHEET NO. D-9

URS/BLUME
100 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW SHEET NO. D-10
CLIENT PG & E SUBJECT REFUELING WATER TANK BY PMN DATE JULY 24
CHKD L.C. DATE 9/16/78



HORIZONTAL SEISMIC FORCE IN Z-DIRECTION

HYDRODYNAMIC PRESSURES ON STEEL SHELL ELEMENTS DUE TO IMPULSIVE PRESSURE

ρ_f = mass density of fluid w/ t_f = 3"
$a_o(y)$ = R-accelerations @ C.G.^{s} of Elements
} SEE SH. NO. D-6

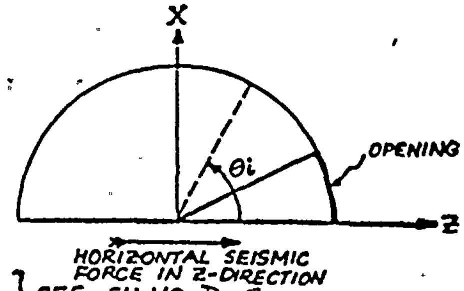
ELEMENT NUMBERS IN SAP MODEL	ρ_f $\times 10^{-7}$ K-sec²/in⁴	$a_o(y)$ in/sec²	$p_o = \rho_f . t_f . a_o(y) . \cos\theta_i$ ($\times 10^{-3}$ ksi)															
			θ_1 = 2.55	θ_2 = 7.65	θ_3 = 12.75	θ_4 = 17.85	θ_5 = 22.85	θ_6 = 29.5	θ_7 = 39.25	θ_8 = 52.5	θ_9 = 67.5	θ_{10} = 82.5	θ_{11} = 97.5	θ_{12} = 112.5	θ_{13} = 127.5	θ_{14} = 142.5	θ_{15} = 157.5	θ_{16} = 172.5
			$\cos\theta_1$ = 0.999	$\cos\theta_2$ = 0.991	$\cos\theta_3$ = 0.975	$\cos\theta_4$ = 0.952	$\cos\theta_5$ = 0.922	$\cos\theta_6$ = 0.870	$\cos\theta_7$ = 0.774	$\cos\theta_8$ = 0.609	$\cos\theta_9$ = 0.383	$\cos\theta_{10}$ = 0.131	$\cos\theta_{11}$ = -0.131	$\cos\theta_{12}$ = -0.383	$\cos\theta_{13}$ = -0.609	$\cos\theta_{14}$ = -0.793	$\cos\theta_{15}$ = -0.924	$\cos\theta_{16}$ = -0.991
1 - 16	31.35	290	2.7	2.6	2.6	2.5	2.5	2.3	2.1	1.6	1.0	0.3	-0.3	-1.0	-1.6	-2.1	-2.5	-2.6
17 - 32	32.31	290	2.8	2.8	2.8	2.7	2.6	2.5	2.2	1.7	1.1	0.4	-0.4	-1.1	-1.7	-2.2	-2.6	-2.8
33 - 48	33.76	290	3.1	3.0	3.0	2.9	2.8	2.7	2.4	1.9	1.2	0.4	-0.4	-1.2	-1.9	-2.4	-2.8	-3.0
49 - 64	37.62	290	3.4	3.3	3.3	3.2	3.1	2.9	2.6	2.0	1.3	0.4	-0.4	-1.3	-2.0	-2.7	-3.1	-3.3
65 - 80	40.99	290	3.5	3.5	3.4	3.4	3.2	3.1	2.7	2.1	1.3	0.5	-0.5	-1.3	-2.1	-2.8	-3.3	-3.5
81 - 96	43.40	290	3.7	3.7	3.6	3.5	3.4	3.2	2.9	2.3	1.4	0.5	-0.5	-1.4	-2.3	-2.9	-3.4	-3.7
97 - 112	45.81	290	3.9	3.9	3.8	3.8	3.6	3.4	3.1	2.4	1.5	0.5	-0.5	-1.5	-2.4	-3.1	-3.6	-3.9
113 - 128	47.02	301	4.3	4.2	4.2	4.1	3.9	3.7	3.3	2.6	1.6	0.6	-0.6	-1.6	-2.6	-3.4	-3.9	-4.2
129 - 144	49.43	336	5.0	5.0	4.9	4.8	4.7	4.4	3.9	3.1	1.9	0.7	-0.7	-1.9	-3.1	-4.0	-4.7	-5.0

SHEET NO. D-10

URS/BLUME
100 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-11

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE JULY 24
CLIENT PG&E SUBJECT REFUELING WATER TANK CHKD LC DATE 9/16/78



HYDRODYNAMIC PRESSURES ON STEEL SHELL ELEMENTS DUE TO IMPULSIVE PRESSURE

ρ_f = mass density of fluid w/ t_f = 3"
$a_o(y)$ = R-accelerations @ C.G.s of Elements
} SEE SH. NO. D-6

ELEMENT NUMBERS IN SAP MODEL	ρ_f $\times 10^{-7}$ K-sec²/in⁴	$a_o(y)$ in/sec²	$p_o = \rho_f . t_f . a_o(y) . \cos\theta_i$ ($\times 10^{-3}$ ksi)															
			θ_1 = 3.5	θ_2 = 10.5	θ_3 = 17.5	θ_4 = 24.5	θ_5 = 33	θ_6 = 43	θ_7 = 53	θ_8 = 63	θ_9 = 74.5	θ_{10} = 87.5	θ_{11} = 100.5	θ_{12} = 113.5	θ_{13} = 127.5	θ_{14} = 142.5	θ_{15} = 157.5	θ_{16} = 172.5
			$\cos\theta_1$ = 0.998	$\cos\theta_2$ = 0.983	$\cos\theta_3$ = 0.954	$\cos\theta_4$ = 0.910	$\cos\theta_5$ = 0.839	$\cos\theta_6$ = 0.731	$\cos\theta_7$ = 0.602	$\cos\theta_8$ = 0.454	$\cos\theta_9$ = 0.267	$\cos\theta_{10}$ = 0.044	$\cos\theta_{11}$ = -0.182	$\cos\theta_{12}$ = -0.399	$\cos\theta_{13}$ = -0.609	$\cos\theta_{14}$ = -0.793	$\cos\theta_{15}$ = -0.924	$\cos\theta_{16}$ = -0.991
145 - 160	51.84	393	6.4	6.3	6.1	5.8	5.3	4.7	3.8	2.9	1.7	0.3	-1.2	-2.5	-3.9	-5.1	-5.9	-6.3
161 - 176	57.87	459	8.1	8.0	7.8	7.4	6.8	6.0	4.9	3.7	2.2	0.4	-1.5	-3.2	-5.0	-6.5	-7.5	-8.1
177 - 192	60.52	531	10.0	9.9	9.6	9.2	8.4	7.4	6.1	4.6	2.7	0.5	-1.8	-4.0	-6.1	-8.0	-9.3	-10.0
193 - 208	64.86	615	12.0	11.8	11.4	10.9	10.0	8.8	7.2	5.4	3.2	0.5	-2.2	-4.8	-7.3	-9.5	-11.1	-11.9
209 - 224	64.86	699	13.6	13.4	13.0	12.4	11.4	10.0	8.2	6.2	3.6	0.6	-2.5	-5.4	-8.3	-10.8	-12.6	-13.5
225 - 240	63.90	783	15.2	15.0	14.5	13.8	12.8	11.1	9.2	6.9	4.1	0.7	-2.8	-6.1	-9.3	-12.1	-14.1	-15.1
241 - 256	59.08	863	15.1	14.9	14.4	13.8	12.7	11.0	9.1	6.9	4.0	0.7	-2.8	-6.0	-9.2	-12.0	-14.0	-15.0
257 - 272	47.02	933	12.8	12.6	12.2	11.7	10.8	9.4	7.7	5.8	3.4	0.6	-2.3	-5.1	-7.8	-10.2	-11.9	-12.7
273 - 288	19.29	981	5.7	5.6	5.4	5.2	4.8	4.2	3.4	2.6	1.5	0.3	-1.0	-2.8	-3.5	-4.5	-5.3	-5.6

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-12

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 9-27-78

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D PMN DATE

SUMMARY OF STRESSES AND MOMENTS <STEEL SHELL>

ELEMENT NUMBER	THICKNESS inches	LENGTH & HEIGHT inches	LOAD CASE	ELEMENT STRESSES & MOMENTS FROM SAP RUNS					
				S_{XX} (HOOP) KSI	S_{YY} (LONG'L) KSI	S_{XY} (SHEAR) KSI	M_{XX} (LONG'L) k-in/in	M_{YY} (CIRCUMF) k-in/in	M_{XY} (TORSION) k-in/in
1	0.578	21.90 25.92	DL	-0.036	-0.268	0.010	—	—	—
			HS	5.120	1.507	-0.018	-0.027	-0.058	-0.010
			EQ Y-Y	5.084	1.238	-0.008	-0.027	-0.058	-0.010
			EQ X-X	0.009	0.099	6.620	-0.006	-0.007	-0.007
			EQ Z-Z	-0.104	-5.276	-0.040	-0.012	-0.022	-0.006
4	0.578	21.90 25.92	DL	-0.053	-0.246	-0.012	-0.001	-0.001	0.002
			HS	4.097	1.206	-2.177	-0.051	-0.039	0.126
			EQ Y-Y	4.044	0.960	-2.189	-0.052	-0.040	0.128
			EQ X-X	-0.290	2.047	4.056	-0.021	-0.022	0.052
			EQ Z-Z	-0.453	-4.992	-1.539	-0.021	-0.019	0.047
9 (373)	0.578	64.40 25.92	DL	-0.095	-0.354	-0.002	—	—	—
			HS	0.353	0.010	0.082	-0.002	-0.008	—
			EQ Y-Y	0.258	-0.344	0.080	-0.002	0.008	—
			EQ X-X	-1.907	-6.368	1.523	-0.004	-0.012	—
			EQ Z-Z	-0.721	-2.346	-3.077	-0.002	-0.005	—
49	0.578	21.90 25.92	DL	0.004	-0.310	0.009	-0.001	—	—
			HS	8.402	1.829	0.023	-0.034	-0.003	-0.003
			EQ Y-Y	8.407	1.519	0.033	-0.036	-0.004	-0.004
			EQ X-X	0.088	0.187	5.957	-0.003	0.002	-0.004
			EQ Z-Z	1.577	-4.963	—	-0.028	-0.008	0.001
58	0.578	64.40 25.92	DL	-0.023	-0.318	0.003	—	—	—
			HS	2.494	0.217	0.014	0.001	0.002	—
			EQ Y-Y	2.470	-0.101	0.017	—	0.002	—
			EQ X-X	0.030	-5.217	0.477	—	0.001	—
			EQ Z-Z	0.027	-0.559	-3.536	—	—	—
			DL						
			HS						
			EQ Y-Y						
			EQ X-X						
			EQ Z-Z						

( ) NUMBERS IN PARENTHESES INDICATE CORRESPONDING STEEL OR CONCRETE ELEMENTS WHERE APPLICABLE

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-13

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 9-27-78

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D PMN DATE

SUMMARY OF STRESSES AND MOMENTS < STEEL SHEEL >

ELEMENT NUMBER	THICKNESS inches	LENGTH & HEIGHT inches	LOAD CASE	ELEMENT STRESSES & MOMENTS FROM SAP RUNS					
				S_{XX} (HOOP) KSI	S_{YY} (LONG'L) KSI	S_{XY} (SHEAR) KSI	M_{XX} (LONG'L) k-in/in	M_{YY} (CIRCUMF.) k-in/in	M_{XY} (TORSION) k-in/in
97	0.490	21.90 21.44	DL	-0.0263	-0.417	0.011	—	—	—
			HS	5.028	1.717	0.055	-0.015	-0.038	0.005
			EQ Y-Y	5.002	1.300	0.065	-0.015	-0.038	0.005
			EQ X-X	-0.215	-0.279	6.520	-0.002	-0.007	0.016
			EQ Z-Z	0.468	-5.959	0.005	-0.007	-0.013	0.004
107 (447)	0.490	64.40 21.44	DL	-0.023	-0.296	0.003	—	—	—
			HS	2.372	0.206	0.008	—	—	—
			EQ Y-Y	2.349	-0.092	0.011	—	—	—
			EQ X-X	0.361	-4.354	-0.489	—	—	—
			EQ Z-Z	-0.031	0.645	-3.542	—	—	—
128 (468)	0.490	64.40 15.67	DL	0.022	-0.293	—	—	—	—
			HS	2.234	0.177	—	—	—	—
			EQ Y-Y	2.212	-0.116	—	—	—	—
			EQ X-X	0.062	-0.528	-3.565	—	—	—
			EQ Z-Z	-0.497	3.801	-0.453	—	—	—
65	0.490	21.90 21.44	DL	-0.003	-0.384	0.011	-0.001	—	—
			HS	9.028	2.030	0.072	-0.024	-0.020	0.004
			EQ Y-Y	9.025	1.647	0.083	-0.025	-0.020	0.004
			EQ X-X	0.110	0.119	6.824	—	—	0.001
			EQ Z-Z	1.757	-5.887	0.010	-0.018	-0.014	0.002
81	0.490	21.90 21.44	DL	0.003	-0.400	0.010	—	—	—
			HS	9.101	1.868	0.051	0.003	0.050	0.004
			EQ Y-Y	9.104	1.468	0.061	0.003	0.050	0.004
			EQ X-X	0.111	-0.068	6.580	0.002	0.007	0.002
			EQ Z-Z	2.058	-5.923	-0.010	-0.003	0.018	0.003
120 (460)	0.490	64.40 15.67	DL	-0.025	-0.256	-0.013	—	—	—
			HS	2.208	0.169	-0.065	—	—	—
			EQ Y-Y	2.183	-0.087	-0.078	—	—	—
			EQ X-X	0.219	-2.606	2.298	0.001	0.001	—
			EQ Z-Z	0.171	-1.982	-2.858	—	—	—

( ) NUMBERS IN PARENTHESES INDICATE CORRESPONDING STEEL OR CONCRETE ELEMENTS WHERE APPLICABLE

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-14

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 9/27/78

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D PMN DATE

SUMMARY OF STRESSES AND MOMENTS <STEEL SHELL>

ELEMENT NUMBER	THICKNESS inches	LENGTH & HEIGHT inches	LOAD CASE	ELEMENT STRESSES & MOMENTS FROM SAP RUNS					
				S_{XX} (HOOP) KSI	S_{YY} (LONG'L) KSI	S_{XY} (SHEAR) KSI	M_{XX} (LONG'L) k-in/in	M_{YY} (CIRCUMF) k-in/in	M_{XY} (TORSION) k-in/in
156 (496)	0.356	55.36 34.56	DL	-0.023	-0.277	0.001	—	—	—
			HS	2.071	0.185	0.005	—	—	—
			EQ Y-Y	2.048	-0.0926	0.006	—	—	—
			EQ X-X	0.686	-3.265	-1.378	0.012	0.009	-0.001
			EQ Z-Z	-0.229	1.387	-3.194	0.0411	0.033	-0.003
161 (501)	0.356	29.81 34.56	DL	-0.029	-0.208	0.013	—	—	—
			HS	1.619	0.226	0.024	—	—	—
			EQ Y-Y	1.590	0.019	0.037	—	—	—
			EQ X-X	0.105	-0.449	3.973	—	—	—
			EQ Z-Z	0.666	-2.236	-0.024	—	—	—
164 (504)	0.356	29.81 34.56	DL	0.009	-0.319	0.023	—	—	—
			HS	1.860	0.078	0.039	—	—	—
			EQ Y-Y	1.869	-0.241	0.062	—	—	—
			EQ X-X	0.675	-2.262	2.960	—	—	—
			EQ Z-Z	1.199	-3.693	-1.088	—	—	—
172 (512)	0.356	55.36 34.56	DL	-0.009	-0.252	0.001	—	—	—
			HS	1.972	0.184	0.005	—	—	—
			EQ Y-Y	1.963	-0.068	0.006	—	—	—
			EQ X-X	1.151	-2.785	-1.396	—	—	—
			EQ Z-Z	-0.431	1.253	-3.109	—	—	—
			DL						
			HS						
			EQ Y-Y						
			EQ X-X						
			EQ Z-Z						
			DL						
			HS						
			EQ Y-Y						
			EQ X-X						
			EQ Z-Z						

( ) NUMBERS IN PARENTHESES INDICATE CORRESPONDING STEEL OR CONCRETE ELEMENTS WHERE APPLICABLE

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-15

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 9-27-78

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D PMN DATE

SUMMARY OF STRESSES AND MOMENTS <STEEL TANK>

ELEMENT NUMBER	THICKNESS inches	LENGTH & HEIGHT inches	LOAD CASE	ELEMENT STRESSES & MOMENTS FROM SAP RUNS					
				S_{XX} (HOOP) KSI	S_{YY} (LONG'L) KSI	S_{XY} (SHEAR) KSI	M_{XX} (LONG'L) k-in/in	M_{YY} (CIRCUMF.) k-in/in	M_{XY} (TORSION) k-in/in
193 (533)	0.275	29.81 51.83	DL	-0.043	-0.293	0.005	—	—	—
			HS	2.036	0.198	0.009	—	—	—
			EQ_{Y-Y}	1.994	-0.095	0.014	—	—	—
			EQ_{X-X}	0.177	-0.372	4.435	—	—	—
			EQ_{Z-Z}	2.276	-2.482	-0.167	—	—	—
196 (536)	0.275	29.81 51.83	DL	-0.026	-0.330	0.004	—	—	—
			HS	2.039	0.159	0.002	—	—	—
			EQ_{Y-Y}	2.013	-0.171	0.007	—	—	—
			EQ_{X-X}	1.095	-1.866	3.636	—	—	—
			EQ_{Z-Z}	2.288	-2.865	-1.625	—	—	—
203 (543)	0.275	55.36 51.83	DL	-0.033	-0.295	0.002	—	—	—
			HS	1.973	0.191	0.005	—	—	—
			EQ_{Y-Y}	1.940	-0.104	0.008	—	—	—
			EQ_{X-X}	2.288	-2.713	-0.746	—	—	—
			EQ_{Z-Z}	-4.182	0.668	-3.991	—	—	—
231 (571)	0.250	42.59 51.83	DL	-0.024	-0.238	-0.007	—	—	—
			HS	1.438	0.109	-0.003	—	—	—
			EQ_{Y-Y}	1.414	-0.129	-0.010	—	—	—
			EQ_{X-X}	2.723	-0.837	1.616	—	—	—
			EQ_{Z-Z}	2.030	-0.721	-2.416	—	—	—
			DL						
			HS						
			EQ_{Y-Y}						
			EQ_{X-X}						
			EQ_{Z-Z}						
			DL						
			HS						
			EQ_{Y-Y}						
			EQ_{X-X}						
			EQ_{Z-Z}						

( ) NUMBERS IN PARENTHESES INDICATE CORRESPONDING STEEL OR CONCRETE ELEMENTS WHERE APPLICABLE

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-16

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE AUG 24,78

CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9/16/78

CHECK FOR STRESSES IN STEEL SHELL

AS PER ASME PRESSURE VESSELS CODE SECTION VIII, DIVISION 2,

FOR SA-240, TP 304L $S_y = 25\,KSI$

TABLE AHA-1 $S_m = 16.7\,KSI$ at $100°F$

1) GENERAL PRIMARY MEMBRANE STRESS INTENSITY (P_L)

LOAD COMBINATION	ALLOWABLE STRESS
i) $DL + HS$	$k\,S_m = 1.0 \times 16.7 = 16.7\,KSI$
ii) $DL + HS + \sqrt{EQ_{YY}^2 + EQ_{XX}^2 + EQ_{ZZ}^2}$	$k\,S_m = 1.5 \times 16.7 = 25.05\,KSI$

2) PRIMARY MEMBRANE STRESS + BENDING

This case not critical for Refueling water tank because bending moments in steel shell elements are negligible. Hence check for stresses made as per criterion (1).

* DUE TO THE USE OF CARBON STEEL AFFECTED BY CORROSSION, SHELL THICKNESS REDUCED BY 1/16"

URS/BLUME
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San Francisco, California 94105

SHEET NO. D-17

JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 11-1-78
CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D PMN DATE

CHECK FOR STRESSES IN STEEL SHELL ($EQ_{YY} = DL + HS$)

SEE SHEET NOS. D-12 TO D-15

* NOTE: FOR COMPUTATION OF STRESSES, SHELL THICKNESS REDUCED BY 1/16" DUE TO CORROSION SENSITIVITY OF CARBON STEEL

ELEMENT NO.	LOAD CASE	S_{XX} KSI	S_{YY} KSI	S_{XY} KSI	CHECK FOR STRESSES* (DL + HS + EQ)
4 (0.578")	DL	-0.053	-0.246	-0.012	$\tau_{max} = \sqrt{\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)^2 + \sigma_{xy}^2}$
	HS	4.097	1.206	-2.177	$= \sqrt{\left(\frac{8.124-(5.48+0.96)}{2}\right)^2 + (7.048)^2}$
	DL+HS	4.044	0.960	-2.189	$= 9.47$
	EQ_{Y-Y}	4.044	0.960	-2.189	$2\tau_{max} = 18.94 < 25.05$
	EQ_{X-X}	-0.290	2.047	4.056	
	EQ_{Z-Z}	-0.453	-4.992	-1.539	
	EQ_{SRSS}	4.080	5.480	4.859	
	DL+HS+EQ	8.124	6.440	7.048	
49 (0.578")	DL	0.004	-.310	0.009	$\tau_{max} = \sqrt{\left(\frac{16.961-(-5.19+1.52)}{2}\right)^2 + (5.99)^2}$
	HS	8.402	1.829	0.023	$= 11.93$
	DL+HS	8.407	1.519	-0.033	$2\tau_{max} = 23.86 < 25.05$
	EQ_{Y-Y}	8.407	1.519	-0.033	
	EQ_{X-X}	0.088	0.187	5.957	
	EQ_{Z-Z}	1.577	-4.963	0.	
	EQ_{SRSS}	8.554	5.194	5.957	
	DL+HS+EQ	16.961	6.713	5.990	
65 (0.490")	DL	-0.003	-0.384	1.123	$\tau_{max} = \sqrt{\left(\frac{18.22-(-6.11+1.65)}{2}\right)^2 + (6.908)^2}$
	HS	9.028	2.030	0.072	$= 13.28$
	DL+HS	9.025	1.647	0.083	$2\tau_{max} = 26.56 > 25.05$
	EQ_{Y-Y}	9.025	1.647	0.083	
	EQ_{X-X}	0.110	0.119	6.824	
	EQ_{Z-Z}	1.757	-5.887	0.010	
	EQ_{SRSS}	9.195	6.114	6.825	
	DL+HS+EQ	18.220	7.761	6.908	
156 (0.356")	DL	-0.023	-0.277	0.001	$\tau_{max} = \sqrt{\left(\frac{4.219-(3.55-0.092)}{2}\right)^2 + (3.485)^2}$
	HS	2.071	0.185	0.005	$= 5.25$
	DL+HS	2.048	-0.092	0.006	$2\tau_{max} = 10.50 < 25.05$
	EQ_{Y-Y}	2.048	-0.092	0.006	
	EQ_{X-X}	0.686	-3.265	-1.378	
	EQ_{Z-Z}	-0.229	1.387	-3.194	
	EQ_{SRSS}	2.171	3.549	3.479	
	DL+HS+EQ	4.219	3.641	3.485	

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SHEET NO D-18
JOB NO. 0902-19 JOB DIABLO REVIEW BY LC DATE 11-1-78
CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D PMN DATE

CHECK FOR STRESSES IN STEEL SHELL (EQ_{YY} = DL + HS)

SEE SHEET NOS. D-12 TO D-15

* NOTE: FOR COMPUTATION OF STRESSES, SHELL THICKNESS REDUCED BY 1/16" DUE TO CORROSION SENSITIVITY OF CARBON STEEL

ELEMENT NO.	LOAD CASE	S_{XX} KSI	S_{YY} KSI	S_{XY} KSI
196 (0.275")	DL	-0.026	-0.330	0.004
	HS	2.039	0.159	0.002
	DL+HS	2.013	-0.171	0.007
	EQ_{Y-Y}	2.013	-0.171	0.007
	EQ_{X-X}	1.095	-1.866	3.636
	EQ_{Z-Z}	2.288	-2.865	-1.625
	EQ_{SRSS}	3.238	3.423	3.983
	DL+HS+EQ	5.251	3.594	3.990
231 (0.250")	DL	-0.024	-0.238	-0.007
	HS	1.438	0.109	-0.003
	DL+HS	1.414	-0.129	-0.010
	EQ_{Y-Y}	1.414	-0.129	-0.010
	EQ_{X-X}	2.723	-0.837	1.616
	EQ_{Z-Z}	2.030	-0.721	-2.416
	EQ_{SRSS}	3.679	1.114	2.907
	DL+HS+EQ	5.093	1.243	2.917
	DL			
	HS			
	DL+HS			
	EQ_{Y-Y}			
	EQ_{X-X}			
	EQ_{Z-Z}			
	EQ_{SRSS}			
	DL+HS+EQ			
	DL			
	HS			
	DL+HS			
	EQ_{Y-Y}			
	EQ_{X-X}			
	EQ_{Z-Z}			
	EQ_{SRSS}			
	DL+HS+EQ			

CHECK FOR STRESSES* (DL + HS + EQ)

Element 196:

$$\tau_{max} = \sqrt{\left(\frac{\sigma_{XX} - \sigma_{YY}}{2}\right)^2 + \sigma_{XY}^2}$$

$$= \sqrt{\left(\frac{5.251 - (3.42 - .17)}{2}\right)^2 + (3.99)^2} = 5.95$$

$$2\tau_{max} = 11.90 < 25.05$$

Element 231:

$$\tau_{max} = \sqrt{\left(\frac{5.093 - (1.114 - .129)}{2}\right)^2 + (2.917)^2}$$

$$= 4.31$$

$$2\tau_{max} = 8.62 < 25.05$$

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-19

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE 9-16-78

CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 11-3-78

SUMMARY OF STRESSES AND MOMENTS (CONCRETE SHELL)

ELEMENT NUMBER	THICKNESS inches	LENGTH & HEIGHT inches	LOAD CASE	ELEMENT STRESSES & MOMENTS FROM SAP RUNS					
				S_{XX} (HOOP) KSI	S_{YY} (LONG'L) KSI	S_{XY} (SHEAR) KSI	M_{XX} (LONG'L) k-in/in	M_{YY} (CIRCUMF) k-in/in	M_{XY} (TORSION) k-in/in
375 (11)	12	64·40 25·92	DL	-0·007	-0·040	—	-0·042	-0·211	-0·001
			HS	0·040	—	—	-1·399	-6·954	0·022
			EQ Y-Y	0·034	-0·041	—	-1·441	-7·166	0·021
			EQ X-X	-0·136	-0·696	-0·057	-2·201	-10·830	0·088
			EQ Z-Z	0·017	0·091	-0·416	0·236	1·248	0·212
380 (16)	12	64·40 25·92	DL	-0·007	-0·042	—	0·044	-0·221	—
			HS	0·041	-0·001	—	-1·382	-6·909	—
			EQ Y-Y	0·033	-0·043	—	-1·426	-7·131	—
			EQ X-X	-0·018	-0·092	-0·420	-0·288	-1·435	0·175
			EQ Z-Z	0·131	0·675	-0·055	2·134	10·600	0·015
386	12	64·40 25·92	DL	-0·003	-0·038	—	0·010	0·471	-0·004
			HS	0·137	-0·004	0·018	0·325	1·752	0·112
			EQ Y-Y	0·133	-0·042	0·020	0·335	1·799	0·109
			EQ X-X	-0·083	-0·661	0·059	-0·232	-0·894	0·290
			EQ Z-Z	-0·012	-0·079	-0·428	-0·107	-0·350	0·507
392	12	64·40 25·92	DL	-0·004	-0·040	—	0·011	0·055	—
			HS	0·138	-0·004	—	0·363	1·810	—
			EQ Y-Y	0·134	-0·044	—	0·374	1·865	-0·001
			EQ X-X	-0·010	-0·087	-0·437	-0·014	-0·099	0·308
			EQ Z-Z	0·076	0·633	-0·057	0·132	0·677	0·023
463	12	64·40 30·00	DL	—	-0·030	—	0·002	-0·014	0·009
			HS	0·242	-0·004	0·001	-0·073	-0·118	0·006
			EQ Y-Y	0·242	-0·034	0·002	-0·071	-0·132	0·015
			EQ X-X	0·097	-0·434	-0·056	-0·688	-0·988	0·209
			EQ Z-Z	-0·011	0·066	-0·417	-0·383	-0·200	0·103
468	12	64·40 30·00	DL	—	-0·032	—	—	-0·010	—
			HS	0·241	-0·007	—	-0·014	-0·115	-0·002
			EQ Y-Y	0·242	-0·038	—	-0·013	-0·125	-0·003
			EQ X-X	0·013	-0·058	-0·422	0·037	-0·083	0·041
			EQ Z-Z	-0·098	0·419	-0·055	0·126	0·672	-0·015

( ) NUMBERS IN PARENTHESES INDICATE CORRESPONDING STEEL OR CONCRETE ELEMENTS WHERE APPLICABLE

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-20

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE 9-16-78
CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 11-3-78

SUMMARY OF STRESSES AND MOMENTS <CONCRETE SHELL>

ELEMENT NUMBER	THICKNESS inches	LENGTH & HEIGHT inches	LOAD CASE	ELEMENT STRESSES & MOMENTS FROM SAP RUNS					
				S_{XX} (HOOP) KSI	S_{YY} (LONG'L) KSI	S_{XY} (SHEAR) KSI	M_{XX} (LONG'L) k-in/in	M_{YY} (CIRCUMF) k-in/in	M_{XY} (TORSION) k-in/in
533 (193)	8	29.81 51.83	DL	-0.001	-0.031	—	0.047	0.034	0.001
			HS	0.219	-0.002	0.001	0.206	0.245	-0.010
			EQ Y-Y	0.218	-0.033	0.002	0.253	0.279	-0.087
			EQ X-X	0.024	-0.043	0.534	-0.228	-0.096	0.316
			EQ Z-Z	0.276	-0.296	-0.020	0.872	0.577	0.009
534 (194)	8	29.81 51.83	DL	—	-0.033	0.002	0.025	0.025	0.003
			HS	0.220	-0.004	0.002	0.144	0.219	-0.028
			EQ Y-Y	0.220	-0.037	0.004	0.169	0.243	-0.025
			EQ X-X	0.069	-0.121	0.515	-0.606	-0.252	0.241
			EQ Z-Z	0.281	-0.311	-0.065	0.498	0.430	0.020
542 (202)	8	55.36 51.83	DL	—	-0.031	—	0.007	0.018	0.002
			HS	0.212	-0.002	—	0.061	0.118	-0.008
			EQ Y-Y	0.212	-0.034	—	0.068	0.135	-0.006
			EQ X-X	0.287	-0.310	0.025	-0.067	0.124	0.053
			EQ Z-Z	0.009	0.001	-0.488	0.136	0.047	-0.085
543 (203)	8	55.36 51.83	DL	—	-0.032	—	0.003	0.016	0.001
			HS	0.212	-0.002	—	0.033	0.113	-0.001
			EQ Y-Y	0.212	-0.034	0.001	0.036	0.129	—
			EQ X-X	0.280	-0.322	-0.090	-0.149	0.075	0.039
			EQ Z-Z	-0.053	0.078	-0.480	-0.057	-0.044	0.004
547 (207)	8	63.88 51.83	DL	—	-0.033	—	0.003	0.017	—
			HS	0.212	-0.006	—	0.021	0.103	-0.001
			EQ Y-Y	0.211	-0.039	—	0.024	0.120	-0.001
			EQ X-X	0.106	-0.131	-0.457	0.110	0.070	-0.043
			EQ Z-Z	-0.258	0.292	-0.185	-0.058	-0.130	-0.019
548 (208)	8	63.88 51.83	DL	—	-0.033	—	0.005	0.017	—
			HS	0.212	-0.006	—	0.027	0.105	—
			EQ Y-Y	0.211	-0.039	—	0.032	0.122	—
			EQ X-X	0.036	-0.044	-0.491	0.045	0.027	-0.032
			EQ Z-Z	-0.277	0.314	-0.063	-0.048	-0.127	-0.004

( ) NUMBERS IN PARENTHESES INDICATE CORRESPONDING STEEL OR CONCRETE ELEMENTS WHERE APPLICABLE

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-21

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE 9-26-7[illegible]

CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D LC DATE 11-3-78

SEE SHEET NOS. D-19 & D-20

DESIGN FORCES & MOMENTS IN CONCRETE SHELL ELEMENTS

ELEMENT NO.	THICKNESS (t) in	LENGTH & HEIGHT in	LOAD CASE	FORCES KIPS/ft CIRCUMF. $S_{xx} \times 12t$	LONGL. $S_{yy} \times 12t$	SHEAR $S_{xy} \times 12t$	MOMENTS K-IN/ft LONGL. $M_{xx} \times 12$	CIRCUMF. $M_{yy} \times 12$	TORSION $M_{xy} \times t$
375	12	64.40 25.92	DL						
			HS						
			DL+HS	4.90	-5.90	—	-17.29	-85.99	0.25
			EQ_{Y-Y}						
			EQ_{X-X}						
			EQ_{Z-Z}						
			EQ_{SRSS}	20.33	101.25	60.46	31.70	156.55	2.77
			DL+HS+EQ	25.23	107.15	60.46	48.99	242.54	3.02
386	12	64.40 25.92	DL						
			HS						
			DL+HS	19.15	-6.05	2.88	4.02	21.59	1.31
			EQ_{Y-Y}						
			EQ_{X-X}						
			EQ_{Z-Z}						
			EQ_{SRSS}	22.64	96.05	62.28	5.06	24.47	7.13
			DL+HS+EQ	41.79	102.10	65.16	9.08	46.06	8.44
463	12	6440 25.92	DL						
			HS						
			DL+HS	34.85	-4.90	0.29	-0.85	-1.58	0.18
			EQ_{Y-Y}						
			EQ_{X-X}						
			EQ_{Z-Z}						
			EQ_{SRSS}	37.58	63.40	60.59	9.49	12.20	2.80
			DL+HS+EQ	72.42	68.30	60.88	10.34	13.78	2.98
534	8	29.81 51.83	DL						
			HS						
			DL+HS	21.12	3.55	0.38	2.03	2.92	0.30
			EQ_{Y-Y}						
			EQ_{X-X}						
			EQ_{Z-Z}						
			EQ_{SRSS}	34.89	32.23	49.84	9.63	6.65	2.92
			DL+HS+EQ	56.01	35.78	50.22	11.66	9.57	3.22

SUMMARY OF FORCES & MOMENTS IN CONCRETE FRAME

BEAM/ COLUMN	ELEMENT NO.	FORCES IN KIPS			MOMENTS IN KIP-INCHES			REMARKS
		AXIAL FORCE P	R_2 SHEAR	R_3 SHEAR	TORSIONAL MOMENT	M_{2-2} MOMENT	M_{3-3} MOMENT	
COL.	1	151	58	63	322	-1882 250	-4225 2722	
COL.	2	176	45	28	252	-250 -481	-2603 1445	
COL.	3	187	29	—	107	482 -480	-1402 651	
COL.	4	187	19	14	46	480 -107	-625 149	
COL.	5	178	12	21	156	107 350	-126 -122	
COL.	6	161	6	22	213	-350 830	140 -277	
COL.	7	136	—	13	205	-830 1117	289 -285	
COL.	8	105	6	28	164	-1118 289	268 -78	
BEAM	9	189	1	1	11	539 -509	-223 193	
BEAM	10	191	4	3	38	511 -451	-192 102	
BEAM	11	193	7	4	69	455 -377	-104 -42	
BEAM	12	188	7	7	81	383 -223	30 -191	
BEAM	13	168	1	22	67	229 295	177 -199	

LOAD CASE: DL + HS

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT REFUELING WATER TANK
LOAD CASE: HORIZ EQ IN X-X DIRECTION

SHEET NO. D-2[illegible]
BY PMN DATE 9-25-78
CHK'D LC DATE 11-3-7[illegible]

SUMMARY OF FORCES & MOMENTS IN CONCRETE FRAME

BEAM/ COLUMN	ELEMENT NO.	FORCES IN KIPS			MOMENTS IN KIP-INCHES			REMARKS
		AXIAL FORCE P	R_2 SHEAR	R_3 SHEAR	TORSIONAL MOMENT	M_{2-2} MOMENT	M_{3-3} MOMENT	
COL.	1	145	131	341	302	23,420 -14,580	-16,730 13,330	
COL.	2	179	136	233	364	14,580 -8,537	-13,100 9,580	
COL.	3	236	134	153	395	8,536 -4,564	-9,370 5,896	
COL.	4	299	130	122	339	4563 -1395	-5691 2331	
COL.	5	351	120	141	212	1394 1638	-2118 -454	
COL.	6	377	110	174	70	-1639 5362	673 -3034	
COL.	7	364	91	203	29	-5363 9713	3238 -5187	
COL.	8	354	63	226	110	-9715 16,490	5359 -7252	
BEAM	9	28	26	120	3330	150 2478	-16 58	
BEAM	10	79	17	135	3627	-2164 5127	-618 980	
BEAM	11	115	2	163	4225	-4773 8336	-1025 970	
BEAM	12	123	27	184	5114	-7,914 11,940	-1045 462	
BEAM	13	150	33	225	6334	-11,410 16,820	-467 -324	

LOAD CASE : X-X EARTHQUAKE

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG & E SUBJECT REFUELING WATER TANK
LOAD CASE : HORIZ EQ IN Z-Z DIRECTION
SHEET NO. D-24
BY PMN DATE 9-25-78
CHK'D LC DATE 11-2-7?

SUMMARY OF FORCES & MOMENTS IN CONCRETE FRAME

BEAM/ COLUMN	ELEMENT NO.	FORCES IN KIPS			MOMENTS IN KIP-INCHES			REMARKS
		AXIAL FORCE P	R_2 SHEAR	R_3 SHEAR	TORSIONAL MOMENT	M_{2-2} MOMENT	M_{3-3} MOMENT	
COL.	1	1157	129	167	116	-8761 4442	-18,870 15,520	
COL.	2	1130	121	97	23	-4442 1923	-15,280 12,150	
COL.	3	1079	104	39	172	-1923 908	-11,980 9286	
COL.	4	1009	89	3	389	-908 839	-9145 6839	
COL.	5	934	75	16	571	-839 1190	-6708 5098	
COL.	6	844	65	30	705	-1191 1829	-4962 3560	
COL.	7	729	55	35	785	-1829 2577	-3438 2249	
COL.	8	572	47	25	829	-2578 3334	-2150 731	
BEAM	9	0.5	8	4	178	2755 -2663	-2831 2662	
BEAM	10	7	23	15	510	2632 -2308	-2640 2142	
BEAM	11	22	37	33	776	2251 -1524	-2105 1298	
BEAM	12	48	47	60	929	1448 -1410	-1253 223	
BEAM	13	68	43	139	916	54 3292	-139 -88	

LOAD CASE : Z-Z EQ

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-25

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE 9-26-78
CLIENT PG&E SUBJECT REFUELING WATER TANK CHK'D LC DATE 11-3-78

SEE SHEET NOS. D-22 TO D-24

DESIGN FORCES & MOMENTS IN CONCRETE FRAME

COLUMN (ELEMENT #1 @ BASE OF COL)

LOAD CASE	P_u	R_3 SHEAR	TORSION	M_2	M_3	R_2 SHEAR
DL+HS	151	63	322	1822	4225	56
EQ Y-Y	76	32	161	911	2113	29
EQ Z-Z	1157	167	116	8761	18,870	129
EQ X-X	145	341	.302	23,420	16,730	131
EQ SRSS	1169	381	361	25,022	25,307	186
DL+HS+EQ	1320[K]	444[K]	683[K-IN]	26,844[K-IN]	29,532[K-IN]	244[K]

BEAM (ELEMENT #13 @ INTERSECTION OF BEAM & COL.)

LOAD CASE	P_U	R_3 SHEAR	TORSION	M_2	M_3
DL+HS	168	22	67	295	199
EQ Y-Y	84	11	34	148	100
EQ Z-Z	68	139	916	3292	88
EQ X-X	150	225	6334	16,820	324
EQ SRSS	185	265	6400	17,140	350
DL+HS+EQ	353[K]	287[K]	6467[K-IN]	17,435[K-IN]	550[K-IN]

COMPUTATION OF BASE SHEAR DUE TO EQ IN X-X DIRN.

TOTAL BASE SHEAR IS THE SUM OF ALL BASE REACTIONS IN X-DIRECTION AS OBTAINED FROM BOUNDARY ELEMENTS 1-17 CORRESPONDING TO NODE NOS 1-17

∴ BASE SHEAR FOR HALF-TANK
= 41.77 + 81.34 + 72.70 + 58.61 + 72.03 + 463.33 + 167.07
+ 238.00 + 172.58 + 90.85 + 58.75 + 83.62 + 154.21
+ 250.09 + 345.73 + 415.73 + 220.68
= 2987.09 KIPS

∴ TOTAL BASE SHEAR DUE TO X-X EQ = 2987.09 X 2 ≈ 5974^k

(SEE SH. NO. D-29) SHEAR @ C.G. OF ELEMENTS @ BASE ≈ $5974 - \frac{94.77}{2}$ ≈ 5927^k

COMPUTATION OF OVERTURNING MOMENT CONTRIBUTED BY LONGITUDINAL MOMENTS (M_{xx}) IN SHELL ELEMENTS

* only concrete shell elements have significant moment contributions and hence are considered.

ANGLE TO CG OF ELEMENT θ_i	$\cos\theta_i$	LENGTH OF ELEMENT (L) in	ELEMENT NO.*	M_{xx} k-in/in	O.T.M. COMPONENT ($M_{xx} \times L \times \cos\theta_i$)
67.05	0.390	21.9	369	-0.694	5.93
61.50	0.478	26.2	370	-0.600	7.51
51.75	0.620	57.5	371	-1.248	44.49
37.50	0.793	64.4	372	-1.847	94.32
22.50	0.924	↓	373	-2.257	134.30
7.50	0.991		374	-2.312	147.55
-7.50	0.991		375	-2.201	140.47
-22.50	0.924		376	-2.005	119.31
-37.50	0.793		377	-1.720	87.84
-52.50	0.609		378	-1.329	52.12
-67.50	0.383		379	-0.841	20.74
-82.50	0.131	64.4	380	-0.288	2.43

(FOR HALF TANK) ΣO.T.M. = 857.03^k-in

∴ O.T.M. CONTRIBUTION FROM FULL TANK DUE TO M_{xx} MOMENTS -

$= \frac{2 \times 857.03}{12} \approx 143^{k\text{-}ft}$

O.T.M. CONTRIBUTED BY SHEAR AT C.G. OF BASE ELEMENTS

$= 5927 \times \frac{12.96''}{12}$

$= 6401^{k\text{-}FT}$

O.T.M. CONTRIBUTED BY BASE MOMENTS AT THE COLUMNS

$= \frac{-16{,}730^{k\text{-}IN}}{12} \times \cos 74^\circ + \frac{23{,}420^{k\text{-}IN}}{12} \times \sin 74^\circ$

$= 1491.78^{k\text{-}FT}$

O.T.M. DUE TO SHEAR IN COL @ C.G. OF BASE ELEMENTS

$= (131 \times \cos 74^\circ - 302 \times \sin 74^\circ) \times 12.96''/12$

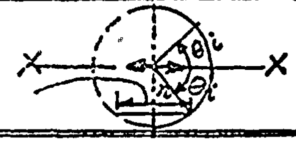
$= 274.53^{k\text{-}FT}$

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 0902-19 JOB DIABLO REVIEW
CLIENT PG&E SUBJECT REFUELING WATER TANK
BY PMN DATE AUG 25,78
CHK'D LC DATE 9/16/78
SHEET NO. D-27

COMPUTATION OF OVERTURNING MOMENT DUE TO EQ IN X-X DIR^N

LEVER ARM 'a' = 2r.COS θi



θi degrees	LEVER ARM (a) (2r COS θi) ft	STEEL ELEMENTS ELE. No.	Syy ksi	(L) ELE. LENGTH in.	(t) THICKNESS in	O.T.M ⟨Syy·L·t·a⟩ k-ft	CONCRETE ELEMENTS ELE. No.	Syy KSI	(L) ELE LENGTH in	(t) ELE. THICK. in	O.T.M. ⟨Syy·L·t·a⟩ k-ft
87.45	1.87	1	−0.099	21.9	0.578	−2.34					
82.35	5.59	2	−0.209	21.9	↓	−14.79					
77.25	9.27	3	0.212	21.9		24.88					
72.15	12.87	4	2.047	21.9		333.48					
67.05	16.38	5	1.568	21.9		325.11	369	0.171	21.9	12	736.10
61.50	20.04	6	−0.971	26.2		−294.68	370	−0.110	26.2	12	−693.06
51.75	26.00	7	−3.153	57.5		−2724.54	371	−0.335	57.5	12	−6009.90
37.50	33.32	8	−5.284	64.4		−6553.62	372	−0.557	64.4	↓	−14342.58
22.50	38.80	9	−6.368	↓		−9197.05	373	−0.671	↓		−20119.69
7.50	41.64	10	−6.719			−10414.28	374	−0.708			−22783.01
−7.50	41.64	11	−6.603			−10234.48	375	−0.696			−22396.86
−22.50	38.80	12	−6.111			−8825.87	376	−0.644			−19310.11
−37.50	33.32	13	−5.255			−6517.66	377	−0.554			−14265.33
−52.50	25.57	14	−4.052			−3856.68	378	−0.427			−8437.73
−67.50	16.07	15	−2.559			−1530.73	379	−0.270			−3353.10
−82.50	5.48	16	−0.876	64.4	0.578	−178.69	380	−0.092	64.4	12	−389.61

$\Sigma M_S = 59{,}661.94$ $\Sigma M_C = 131{,}364.89$

∴ TOTAL OVERTURNING MOMENT @ BASE

= {(59,662 + 131,365 + 6,401 + 275) + (143 + 1492)} ⟨SEE SH. D-26 FOR DETAILS⟩

= 197,703 + 1,635 = 199,338 ^k-FT

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-28

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE AUG 18, 78
CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9/17/78

LATERAL FORCE ON A RING OF ELEMENTS (height h) DUE TO IMPULSIVE PRESSURE CAUSED BY HORIZONTAL EARTHQUAKE

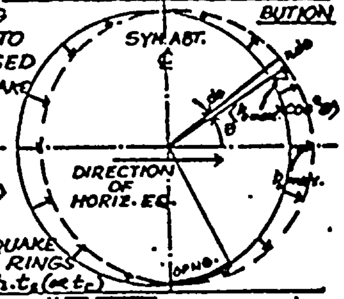
$$= 4\int_0^{\pi/2} p_{o\,max}.\cos^2\theta.\,r\,d\theta.h$$

i.e. $P_1 = \pi \cdot p_{o\,max} \cdot r\,h$

where $p_{o\,max} = \rho_f . t_f . a_o(y)$ $\langle t_f = 3" \rangle$

P_2, P_3 = INERTIAL FORCES DUE TO HORIZONTAL EARTHQUAKE IN STEEL & CONCRETE RINGS $= \rho_{s\,mod.}\,(\text{or}\ \rho_{c\,mod.}) \times 2\pi\,r.h.t_s\,(\text{or}\ t_c)$

IMPULSIVE PRESSURE DISTRIBUTION



CALCULATION OF LATERAL FORCES IN THE TANK

THESE CALCULATIONS ARE BEING MADE TO OBTAIN TOTAL BASE SHEAR AND OVERTURNING MOMENT DUE TO SEISMIC FORCES IN ANY GIVEN HORIZONTAL DIRN. FOR VALUES OF $a_o(y)$, ρ_f, $\rho_{s(mod)}$ and $\rho_{c(mod)}$ SEE SH NOS D-6,7. FINAL VALUES OF BASE SHEAR & O.T.M. (SEE SH. NO. D-29) WERE INDEPENDENTLY COMPARED AGAINST SHEAR & O.T.M. COMPUTED FROM S_{YY}, S_{XY} & M_{XX} RESULTS OF SAP IV OUTPUT AND WERE FOUND TO BE IN AGREEMENT.

RADIUS r in.	ACCEL.* $a_o(y)$ in/sec²	HEIGHT OF ELEMENTS h inches	LATERAL FORCE DUE TO IMPULSIVE PRESSURE: ELEMENT NOS. (SYM. ABT. ℄)	MASS DENSITY OF FLUID ρ_f (x10⁻⁷)	p_o max. (x10⁻³) KSI	P_1 KIPS	LATERAL FORCE DUE TO INERTIA IN STEEL: ELEMENT NOS. (SYM. ABT. ℄)	MOD. MASS DENSITY OF STEEL $\rho_{s(mod)}$ x10⁻⁴	STEEL SHELL THICKNESS t_s inches	P_2 KIPS	LATERAL FORCE DUE TO INERTIA IN CONCRETE: ELEMENT NOS. (SYM. ABT. ℄)	MOD. MASS DENSITY OF CONCRETE $\rho_{c(mod)}$ x10⁻⁴	CONCRETE SHELL THICKNESS t_c inches	P_3 KIPS
246	290	25.92	1 - 16	31.35	2.73	54.68	1 - 16	2.13	0.578	4.93	369 - 380	0.65	12, 66*	36.46
246	290	25.92	17 - 32	32.31	2.81	56.64	17 - 32	2.13	0.578	4.93	381 - 392	0.65	12, 66*	36.46
246	290	25.92	33 - 48	33.76	2.94	61.29	33 - 48	2.13	0.578	4.93	393 - 404	0.65	12, 66*	36.46
246	290	25.92	49 - 64	37.62	3.27	67.31	49 - 64	2.13	0.578	4.93	405 - 416	0.65	12, 66*	36.46
246	290	21.44	65 - 80	40.99	3.57	58.37	65 - 80	2.13	0.490	3.46	417 - 428	0.65	12, 66*	30.18
246	290	21.44	81 - 96	43.40	3.78	61.45	81 - 96	2.13	0.490	3.46	429 - 440	0.65	12, 66*	30.18
246	290	21.44	97 - 112	45.81	3.99	65.27	97 - 112	2.13	0.490	3.46	441 - 452	0.65	12, 66*	30.18
246	301	15.67	113 - 128	47.02	4.25	64.95	113 - 128	2.21	0.490	2.62	453 - 468	0.68	12, 66*	35.38
246	336	23.66	129 - 144	49.43	4.98	76.59	129 - 144	2.47	0.490	4.42	469 - 484	0.75	12, 66*	58.92
246	393	34.56	145 - 160	51.84	6.11	170.28	145 - 160	2.88	0.356	5.48	485 - 500	0.88	12, 66*	83.06
246	459	34.56	161 - 176	57.87	7.97	217.50	161 - 176	3.37	0.356	6.41	501 - 516	1.03	12	66.02
246	531	34.56	177 - 192	60.52	9.64	268.69	177 - 192	3.90	0.356	7.42	517 - 532	1.19	12	76.28
244	615	51.83	193 - 208	64.86	11.97	476.44	193 - 208	4.51	0.275	9.86	533 - 548	1.38	8	87.72
244	699	51.83	209 - 224	64.86	13.60	541.67	209 - 224	5.13	0.275	11.21	549 - 564	1.57	8	99.80
244	783	51.83	225 - 240	63.90	15.01	604.11	225 - 240	5.75	0.250	11.42	565 - 580	1.76	8	111.88
244	863	51.83	241 - 256	59.08	15.30	600.13	241 - 256	6.33	0.250	12.57	581 - 596	1.94	8	123.32
244	933	51.83	257 - 272	47.02	13.16	509.45	257 - 272	6.85	0.250	13.61	597 - 612	2.10	8	133.49
244	981	51.83	273 - 288	19.29	5.68	255.32	273 - 288	7.20	0.250	14.30	613 - 628	2.20	8	139.85
248	1005	16.00					289 - 304	7.38	0.750	13.82	629 - 644	2.26	16	90.15
484	1017	22.00					305 - 320	7.46	0.250	12.48	645 - 660	2.29	8	122.57
484	1041	30.00					321 - 336	7.64	0.250	17.43	661 - 676	2.34	8	170.79
484	1062	5.00					337 - 352	7.79	0.250	2.96	677 - 692	2.39	8	29.07
484	1071	1.00					353 - 368	7.86	0.250	0.60	693 - 708	2.41	8	5.86
					ΣP_1 =	4208.90			ΣP_2 =	176.62			ΣP_3 =	1670.54

* thickness of shell elements in concrete frame

SHEET NO. D-28

URS/BLUME
130 Jessie Street (at New Montgomery)
San Francisco, California 94105

SHEET NO. D-29

JOB NO. 0902-19 JOB DIABLO REVIEW BY PMN DATE AUG 18,78

CLIENT PG & E SUBJECT REFUELING WATER TANK CHK'D LC DATE 9/18/78

CALCULATION OF BASE SHEAR & OVERTURNING MOMENT

HEIGHT TO C.G. OF ELEMENTS FROM BASE inches	LATERAL FORCE (in KIPS) DUE TO				OVERTURNING MOMENT AT BASE DUE TO HORIZ. EQ. KIP-INCHES
	IMPULSIVE PRESSURE	INERTIA IN STEEL	INERTIA IN CONCRETE	TOTAL	
12.96	54.68	4.93	36.46	94.77	1228.22
38.88	56.64	4.93	36.46	98.03	3811.41
64.80	61.29	4.93	36.46	102.68	6653.66
90.72	67.31	4.93	36.46	108.70	9861.26
114.39	58.37	3.46	30.18	92.01	10525.02
135.83	61.45	3.46	30.18	95.09	12916.07
157.28	65.27	3.46	30.18	98.91	15556.56
175.83	64.95	2.62	35.38	102.62	18043.67
195.50	76.59	4.42	58.92	139.93	27356.32
224.61	170.28	5.48	83.06	258.82	58133.56
259.16	217.50	6.41	66.02	289.93	75138.26
293.72	268.69	7.42	76.28	352.39	103503.99
336.92	476.44	9.86	87.72	574.02	193398.82
388.75	541.67	11.21	99.80	652.68	253729.35
440.59	604.11	11.42	111.88	727.41	320489.57
492.42	600.13	12.57	123.32	736.02	362430.97
544.26	509.49	13.61	133.49	656.55	357333.90
596.06	255.32	14.30	139.85	409.47	244080.97
630.00		13.82	90.15	103.97	65501.10
649.00		12.48	122.57	135.05	87647.45
675.00		17.43	170.79	188.02	127048.50
692.50		2.96	29.07	32.03	22180.78
695.50		0.60	5.86	6.46	4492.93
Σ	4208.90	176.62	1670.54	6056.06	2,381,062.36

∴ TOTAL BASE SHEAR DUE TO HORIZONTAL SEISMIC FORCE WHEN TANK FULL = 6056 KIPS

TOTAL OVERTURNING MOMENT = 2,381,062 K-IN = 198,422 KIP-FEET

COMPARISON OF BASE SHEARS & OVERTURNING MOMENTS AS OBTAINED FROM AXIDYN OUTPUTS, SAPIV OUTPUT (For X-X Seismic load) AND DIRECT STATIC LOAD COMPUTATIONS

AXIDYN FORCES GIVEN BELOW ARE OBTAINED FROM COMBINING THE IMPULSIVE PRESSURE ANALYSIS WITH TANGENTIAL FORCE ANALYSIS. THERE IS NO OPENING IN THE MODEL AND NO FRAME.

SAPIV RESULTS CORRESPOND TO HORIZ SEISMIC FORCE IN X-X DIRECTION. THE MODEL HAS AN OPENING AND A SURROUNDING FRAME IN THE CONCRETE SHELL. IMPULSIVE PRESSURE VARIATION IS ACCOUNTED FOR (SEE (SEE SH NOS. D-26 & 27)

DIRECT STATIC LOAD COMPUTATIONS ARE BASED ON INPUT FORCES FOR SAP MODEL AND ARE THE SUMMATION OF LATERAL FORCES & OVERTURNING MOMENTS AT THE BASE DUE TO IMPULSIVE PRESSURE AND INERTIAL FORCES FOR AN EQUAKE IN X-X DIR^N (see Sh. NO. D-29)

FORCE/ MOMENT	DESCRIPTION	AXIDYN	SAP IV	DIRECT COMPUTATION FROM SAP INPUT FORCES
BASE SHEAR	IN-PLANE SHEAR LONG^L MOM. CONTRIBUTION TOTAL BASE SHEAR	4164^k 1421^k * 5585^k	5974^k	6056^k
OVERTURNING MOMENT	LONGL FORCE X LEVER ARM LONG^L MOM. CONTRIBUTION TOTAL OVERTURNING MOM.	211,100$^{k\text{-}ft}$ 1,521$^{k\text{-}ft}$ * 212,621$^{k\text{-}ft}$	199,338$^{k\text{-}ft}$	198,422$^{k\text{-}ft}$

* - AXIDYN LONG^L MOMENT CONTRIBUTION TO BASE SHEAR

$$= \left(\underset{\text{(impulsive)}}{\frac{36.36+12.70}{1.5}} - \underset{\text{(tangential)}}{\frac{13.42+3.75}{1.5}}\right) \times \pi \times 21' = 1421^k$$

Where 1.5' is the height of element & shear $\approx \Sigma M/1.5$

AXIDYN LONG^L MOMENT CONTRIBUTION TO O.T.M.

$$= (\underset{\text{(imp.)}}{36.36} - \underset{\text{(tang.)}}{13.42})\, \pi \times 21 = 1521^{k\text{-}ft}$$

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AXIDYN MODEL IS AXISYMMETRIC AND TWO ANALYSES WERE MADE TO SIMULATE THE ACTUAL VARIATION IN IMPULSIVE PRESSURE (SEE FIGURES 6 & 7). VALUES FROM BOTH THE ANALYSES TERMED HERE AS IMPULSIVE & TANGENTIAL ARE PRESENTED ALONG WITH NET FORCES FOR STEEL & CONCRETE ELEMENTS AND THE TOTAL FORCES.

SAP IV MODEL INCLUDES THE OPENING IN CONCRETE SHELL AND THE FRAME SURROUNDING THE OPENING. IMPULSIVE PRESSURE VARIATION IS INPUT IN ITS FINAL CONFIGURATION (SEE FIG. 6) AND SO NO MODIFICATION WAS NECESSARY. STRESS VALUES FROM OUTPUT ARE CONVERTED AS FORCE/FT TO COMPARE WITH AXIDYN RESULTS.

COMPARISON OF FORCES FROM AXIDYN & SAP IV ANALYSES

*NOTE: ALL FORCES BELOW ARE MAXIMA AT ANY GIVEN LEVEL BUT DO NOT NECESSARILY OCCUR AT THE SAME POINT

FORCE DESIGNATION	AXIDYN ANALYSES: NODE # & LOCATION	STEEL ELEMENTS: IMPULSIVE (I) KIPS/FT	STEEL ELEMENTS: TANGENTIAL (T) KIPS/FT	STEEL ELEMENTS: NET FORCE (I)-(T) KIPS/FT	CONCRETE ELEMENTS: IMPULSIVE (I) KIPS/FT	CONCRETE ELEMENTS: TANGENTIAL (T) KIPS/FT	CONCRETE ELEMENTS: NET FORCE (I)-(T) KIPS/FT	TOTAL FORCE KIPS/FT	SAP IV ANALYSIS (X-X EQ): ELEMENT NOS. AND LOCATION	STEEL ELEMENTS: STRESS KSI	STEEL ELEMENTS: FORCE = STRESS x 12t KIPS/FT	CONCRETE ELEMENTS: STRESS KSI	CONCRETE ELEMENTS: FORCE = STRESS x 12t KIPS/FT	TOTAL FORCE KIPS/FT
LONGL.	NODE # 2	69.08	23.39	45.69	150.50	50.9	99.60	145.29	#10 & 374	6.719	46.60	0.708	101.95	148.55
CIRCUMF.	@ 18" FROM BASE	23.24	8.02	15.22	35.86	12.48	23.38	38.60	@ 13" TO C.G. OF ELEMENTS	2.000	13.87	0.140	20.16	34.03
SHEAR		32.99	12.76	20.23	82.43	31.89	50.54	70.77	#16 & 380	3.490	24.21	0.420	60.48	84.69
LONGL.	NODE # 4	62.98	20.96	42.02	137.30	45.60	91.70	133.70	#58 & 410	5.217	36.19	0.568	81.79	117.98
CIRCUMF.	@ 90" FROM	20.69	7.41	13.28	31.61	11.71	19.90	33.20	@ 90.72" TO C.G. OF ELEMENTS	0.030	0.21	0.064	9.22	9.42
SHEAR	BASE	37.73	14.47	23.26	94.28	36.16	58.12	81.38	#64 & 416	3.621	25.12	0.436	62.78	87.90
LONGL.	MIDWAY BETWEEN	23.42 19.62	7.04 5.75	15.13	87.24 74.66	25.70 21.15	57.53	72.66	#170 & 510	2.898	12.38	0.330	47.52	59.90
CIRCUMF.	NODES* 10 & 11	4.74 8.29	0.33 0.16	6.27	24.77 37.03	1.53 2.82	28.73	35.00	@ 259.16" TO C.G. OF ELEMENTS	1.258	5.37	0.170	24.48	29.85
SHEAR	@ 259" FROM BASE	23.81 21.72	9.07 8.37	14.05	96.59 86.14	36.81 33.97	55.98	70.03	#176 & 516	3.414	14.58	0.411	59.18	73.77
LONGL.	MIDWAY BETWEEN	17.50 14.56	4.91 3.90	11.63	57.83 47.81	15.65 12.12	38.94	50.57	#202 & 542	2.598	8.57	0.310	29.76	38.33
CIRCUMF.	NODES # 12 & 13	8.80 7.63	0.29 0.69	7.73	32.81 27.60	2.58 0.87	27.98	35.71	@ 336.9" TO C.G. OF ELEMENTS	2.357	7.78	0.287	27.55	35.33
SHEAR	@ 337" FROM BASE	21.85 20.05	8.50 7.66	12.87	76.51 70.21	29.74 26.83	45.08	57.95	#208 & 548	4.080	13.46	0.491	47.14	60.60

* AT ANY GIVEN HEIGHT, IF LONGITUDINAL AND CIRCUMFERENTIAL FORCES ARE MAXIMUM AT ONE POINT, SHEAR FORCE WOULD BE MAXIMUM AT A POINT 90° AWAY FROM IT ON THE MODEL. IN OTHER WORDS, SHEAR WOULD BE MINIMUM WHERE LONG^L & CIRCUMF FORCES ARE MAXIMUM AND VICE-VERSA.

SHEET NO. D-31

STEEL SHELL MODIFICATIONS

For element 65

$\sigma_x + \sigma_y = 29.67^{ksi} \approx 30^{ksi}$

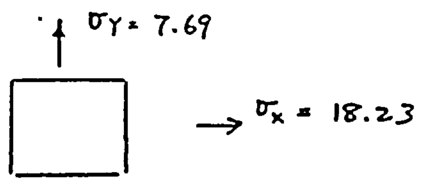
$0.490 \times \frac{30}{20} = 0.735''$ req'd

$0.735 - 0.490 = 0.245''$ reiforcement req'd

Use 1/4" ℄ $= 0.25'' > 0.245''$ O.K

Check minimum length req'd for 1/4" weld

size of the ℄ is 21.9" x 21.44"



For the height

$F = 7.69 \times 21.9 \times 0.49 = 82.52$

$l_{min} = \frac{82.52}{2 \times 0.707 (0.25)(18)} = 13.0'' < 21.44$

↑ E 60 electrode (assumed weld takes full load)

For the width

$F = 18.23 \times 21.44 \times 0.49 = 191.52$

$l_{min} = \frac{191.52}{2 \times 0.707 (0.25)(18)} = 30.1'' > 21.9$

↑ E 60 electrode (assumed

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For the height :

assume the existing PL will take up to the full yielding stress load, then the weld will carry only

$\frac{30}{20} - 1 = 0.5$ of the load

$$l_{min} = \frac{82.52 \times 0.5}{2 \times 0.707 \times (0.25)(18)} = 6.5'' < 21.44$$

For the width :

$$l_{min} = \frac{191.52 \times 0.5}{2 \times 0.707 \times (0.25)(18)} = 15.1'' < 21.9$$

Use 1/4" weld all way around

& 1/4" PL

For element 49

$\sigma_x + \sigma_y = 26.54^{ksi} \approx 27$

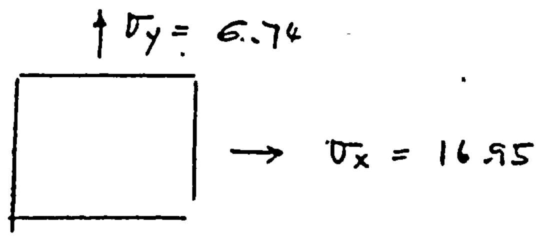
$0.578 \times \frac{27}{20} = 0.78''$ req'd

$0.78 - 0.578 = 0.21''$ additional ℞ thickness Req'd

use $\frac{1}{4}''$ ℞ $= 0.25'' > 0.21''$

Check min. length req'd for the weld

size of the ℞ 21.90×25.92



Assume the existing ℞ will take the load up to its yield capacity. Then the weld will carry $\frac{27}{20} - 1 = 0.35$ of the load

For the height

$F = 6.74 \times 21.90 \times 0.578 = 85.32$

$l_{min} = \frac{85.32\ (0.35)}{2 \times (0.707)(0.25)(18)} = 4.7 < 25.92$

For the width

$F = 16.95 \times 25.92 \times 0.578 = 254$

$l_{min} = \frac{254\ (0.35)}{\ldots} = 14.0 < 21.90$

Steel Shell

(A) Element #49:

Add 1/4" PL to 0.578" PL

$t_{total} = 0.25 + 0.578 = 0.828" - 1/16"$ corrosion $= 0.765"$

$\sigma_x + \sigma_y = \frac{0.516}{0.765} \times 26.51 = 17.88$ ksi < 20.04 ksi

(B) Element #65

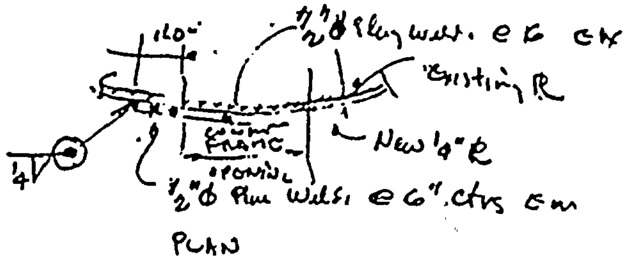
Add 1/4" PL to 0.490" PL

$t_{total} = 0.250 + 0.490 - 0.063 = 0.677$ in

$\sigma_x + \sigma_y = \frac{0.428}{0.677} \times 29.74$ ksi ~ 18.71 ksi < 20.04 ksi

(C) New 1/4" PL $f_y = 25$ ksi

P/1 = 25 ksi × 1/4" × 12" = 75 k/1



1/4 fillet welds (ultimate)

.707 × 25 ksi × 3 in² = 63 k/1 (one fillet weld cont)

4 × .707 × .79 in² × 25 ksi = 13 k/1 (2-3/4"Ø plug welds/ft)

76 k/1 > 75 k/1

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CONCRETE SHELL ELEMENTS

ELEMENT 534 (8" wall)

Long. & Circ. Mom. Capacity: (12" section)

For simplicity, only tension reinforcement is considered

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(2\times0.44)(60)}{0.85(4)(12)} = 1.29$$

$$\phi M_{n_{LONG}} = \phi A_s f_y (d - \frac{a}{2}) = 0.9(2\times0.44)(60)(6+\frac{0.75}{2}-\frac{1.29}{2})$$

$$= 236.65^{\text{"-k}} > 11.66^{\text{"-k}}$$

$$= 19.72^{\text{'-k}} > 1.6$$

$$\phi M_{n_{circ.}} = 236.65^{\text{'-k}} > 9.57^{\text{"-k}}$$

Long. & Circ. Force Capacity: (12" section)

$$\phi P_n = \phi\,(0.80\,(0.85 f'_c (A_g - A_{st}) + f_y A_{st})$$

$$P_{n_{LONG}} = 0.70\,(0.80\,(0.85(4)(12\times8-2\times2\times0.44)+60\,(2\times2\times0.44))$$

$$= 238.57 >$$

$$\phi P_{n_{circ}} = 238.57 > 56.01$$

Shear Capacity: (12" section)

$$\phi V_c = \phi 2\sqrt{f'_c}\, b d = 0.85(2)\sqrt{4000}\,(12)(6+\frac{0.75}{2})$$

$$= 7,257^{\text{lb}}$$

$$= 7.26^{\text{k}}$$ provided by concrete

$$\phi V_s = \phi \frac{A_v f_y d}{S} = 0.85 \frac{(0.44\times2\times2)(60)(6-\frac{0.75}{2})}{(6)}$$

$$= 84.92^{\text{k}}$$

$$\phi V_c + \phi V_s = 7.26 + 84.92 = 92.18^{\text{k}} > 50.22^{\text{k}}$$

ELEMENT 463 (12" wall)

For simplicity, all moment calculations consider tension reinforcement only.

Long. Mom. Capacity : (12" section)

$$a = \frac{(2 \times 0.44 + 2 \times 1.00)(60)}{0.85(4)(12)} = 4.24$$

$$\phi M_{n_{Long}} = 0.9\,(2 \times 0.44 + 2 \times 1.00)(60)\left(10 - \frac{0.75}{2} - \frac{4.24}{2}\right)$$

$$= 1167.54^{''-k} > 10.34^{''-k}$$

$$= 97.30^{'-k}$$

Circ. Mom. Capacity : (12" section)

$$a = \frac{(2 \times 0.44)(60)}{0.85(4)(12)} = 1.29$$

$$\phi M_{n_{circ.}} = 0.9\,(2 \times 0.44)(60)\left(10 - \frac{0.75}{2} - \frac{1.29}{2}\right)$$

$$= 426.73^{''-k} > 13.78^{''-k}$$

$$= 35.56^{'-k}$$

Long. Force Capacity : (12" section)

$$\phi P_{n\,Long} = 0.7\,(0.80\,(0.85\,(4)(12 \times 12 - 2 \times 0.44 - 6 \times 1.00) + 60\,(2 \times 0.44 + 6 \times 1.00))$$

$$= 492.24^{k} > 68.30^{k}$$

Circ. Force Capacity : (12" section)

$$\phi P_{n\,circ} = 0.7\,(0.80\,(0.85\,(4)(12 \times 12 - 2 \times 0.44 \times 2) + 60\,(2 \times 0.44 \times 2))$$

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ELEMENT 463 (continued)

Shear Capacity (12" section)

$$\phi V_c = \phi\, 2\sqrt{f'_c}\, bd = (0.85)(2)(4000)^{\frac{1}{2}}(12)(10 - \tfrac{0.75}{2})$$

$$= 12{,}418^{lb}$$

$$= 12.42^{k}$$

$$\phi V_s = 0.85\ \frac{(0.44 \times 2 \times 2)(60)(10 - \frac{0.75}{2})}{6}$$

$$= 143.99^{k}$$

$$\phi V_c + \phi V_s = 12.42 + 143.99 = 156.41^{k} > 60.88^{k}$$

ELEMENTS 386 & 375

Since the computer model uses 12" thickness, the following calculations are based on a 12" thickness section.

For simplicity, all moment calculations consider tension reinforcement only.

Long. Mom. Capacity: (12" section)

$$a = \frac{(2 \times 1.00)(60)}{0.85(4)(12)} = 2.92$$

$$\phi M_{n_{long}} = 0.9(2 \times 1.00)(60)\left(10 - \frac{1.128}{2} - \frac{2.92}{2}\right)$$

$$= 861.41^{\prime\prime-k} > 242.54$$

$$= 71.78^{\prime-k}$$

Circ. Mom. Capacity: (12" section)

$$a = \frac{(2 \times 0.44)(60)}{0.85(4)(12)} = 1.29$$

$$\phi M_{n_{circ}} = 0.9(2 \times 0.44)(60)\left(10 - \frac{0.75}{2} - \frac{1.29}{2}\right)$$

$$= 426.73^{\prime\prime-k} > 48.99$$

$$= 35.56^{\prime-k}$$

Long. Force Capacity: (12" section)

$$\phi P_{n_{long}} = 0.70(0.80(0.85(4)(12 \times 12 - 2 \times 2 \times 1.00) + 60(2 \times 2 \times 1.00))$$

$$= 400.96^{k} > 107.15$$

ELEMENTS 386 & 375 (CONTINUED)

Circ. Force Capacity : (12" section)

$\phi P_{n_{circ.}} = 0.7(0.80(0.85(4)(12\times12-2\times0.44\times2) + 60(2\times0.44\times2))$

$= 329.96^k > 41.79^k$

Shear Capacity : (12" section)

$\phi V_c + \phi V_s = 156.41^k$ (same as element 463, since we have identical circ. section)

$> 65.16^k$

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DESIGN STRENGTH OF CONCRETE SHELL ELEMENTS

ELEMENT NO.	LONG. MOM. K-FT/FT	CIRC. MOM. K-FT/FT	LONG. FORCE K/FT	CIRC. FORCE K/FT	SHEAR K/FT
534	19.72	19.72	238.57	238.57	92.18
463	97.30	35.56	492.24	329.96	156.41
386	71.78	35.56	400.96	329.96	156.41
375	71.78	35.56	400.96	329.96	156.41

* Calculations based on 1 ft section beam

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BY LC DATE 10-9-78 CHK'D PMW DATE
SHEET NO D-4

STRENGTH COMPARISON OF CONCRETE SHELL ELEMENTS

ELEMENT NO.	LONG. MOM. K-FT/FT		CIRC. MOM. K-FT/FT		LONG. FORCE K/FT		CIRC. FORCE K/FT		SHEAR K/FT	
	REQ'D STRENGTH	DESIGN STRENGTH*	REQ'D STRENGTH	DESIGN STRENGTH*	REQ'D STRENGTH	DESIGN STRENGTH*	REQ'D STRENGTH	DESIGN STRENGTH*	REQ'D STRENGTH	DESIGN STRENGTH*
534	0.97	19.72	0.80	19.72	35.78	238.57	56.01	238.57	50.22	92.18
463	0.86	97.30	1.15	35.56	68.30	492.24	72.42	329.96	60.88	156.41
386	0.76	71.78	3.84	35.56	102.10	400.96	41.79	329.96	65.16	156.41
375	4.08	71.78	20.21	35.56	107.15	400.96	25.23	329.96	60.46	156.41

* Calculations based on 1 ft width beam

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I. Concrete Frame Design

A. Column

$P = 1320^k$ (Axial Force)

1200^k (4-Rock Anchors Preloaded to 300^k each)

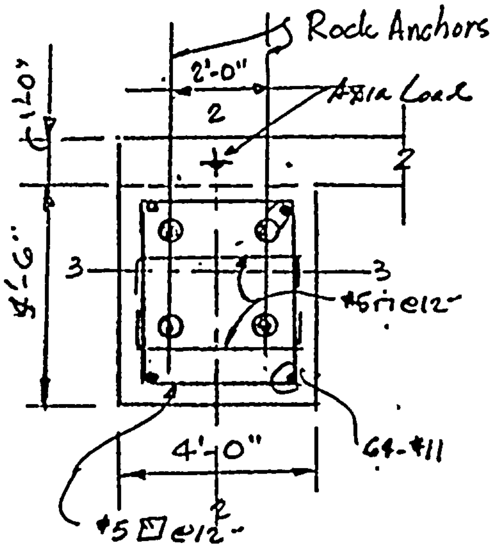
$P_u = 2520^k$

$M_{22_u} = 26,844''^k$

$M_{33} = 29,532''^k$

$43,560''^k$ ($1320^k \times 33''$)

M_{33_u} $73,092''^k$



Column Section

$\theta = \tan^{-1}\frac{M_{22}}{M_{33}} = \tan^{-1}\frac{26,844}{73,093} = 20.2°$

$M_u = \sqrt{(26,844)^2 + (73,092)^2} = 77,866''^k$

$K = \frac{P_u}{f'_c b t} = \frac{2520}{4 \times 48 \times 54} = 0.243$

$K\frac{e}{t} = \frac{P_u e}{f'_c b t^2} = \frac{77,866}{4 \times 48 \times 54^2} = 0.139$

$P_t m = 0.60$ (from ACI Biaxial Chart #15)

$P_t m = 0.44$ (fm. ACI Uniaxial Chart #63)

@ $\theta = 20.2°$

$P_t m = 0.44 + (0.60 - 0.44)\frac{20}{45} = 0.49$

$P_t = 0.49 \div \left(\frac{60}{0.85 \times 4}\right) = 0.0277$ (17.65)

$A_{st} = 0.0277 \times 48 \times 54 = 72.0\ in^2$

use: 72-#9s or 46-#11

Concrete Frame Design

A. Column

$P_{u_{min}} = (4169 \div \frac{151}{2} - 1200) = 107^k$ Compression

$M_u = 77,866^{'k}$

$K = \frac{107}{4 \times 48 \times 54} = 0.010$

$K \frac{e}{t} = 0.139$

$\theta = 45°$ $P_t m = 0.70$ (Biaxial Chart #15, ACI SP 17A)

$\theta = 0°$ or $90°$ $P_t m = 0.65$ (Uniaxial " #63, " " " ")

$\theta = 20.2°$: $P_t m = 0.65 + \frac{20.2}{45}(0.70 - 0.65) = 0.67$

$P_t = 0.67 \div 17.68 = 0.038$

$A_s = 0.038 \times 48 \times 54 = 98.5 \text{ in}^2 \sim 100 - \#9$ or 64-#11

$V_{22} = 244^k$

$v_{u_{22}} = 244 \div 0.85 \times 48'' \times 50'' = 120$ psi

$V_{33} = 444^k$

$v_{u_{33}} = 444,000 \div 0.85 \times 54 \times 44 = 220$ psi

$V_u = [(244)^2 + (444)^2]^{1/2} = 506.6^k$

$V_{all} = 44 \times 50 \times 0.85 \times \sqrt{4000} = 236^k$

$V_{steel} = 506.6 - 236 = 270.6^k$

$V_{22_{stl}} = 270.6 \times \frac{244}{506.6} = 130^k$ $v_u = 130 \div 0.85 \times 48 \times 50 = 63.7$ psi

$A_v = \frac{63.7 \times 48 \times 12}{60,000} = 0.61$

2-#5 @ 12"

$V_{33_{stl}} = 270.6 \times \frac{444}{506.6} = 237^k$

$v_{u_1} = 237,000 \div 0.85 \times 54 \times 44 = 117.4$ psi

$A_v = \frac{117.4 \times 54 \times 12}{60,000} = 1.26 \text{ in}^2$

4-#5 @ 12"

Concrete Frame Design

8. Beam

(1) Loads & Moments

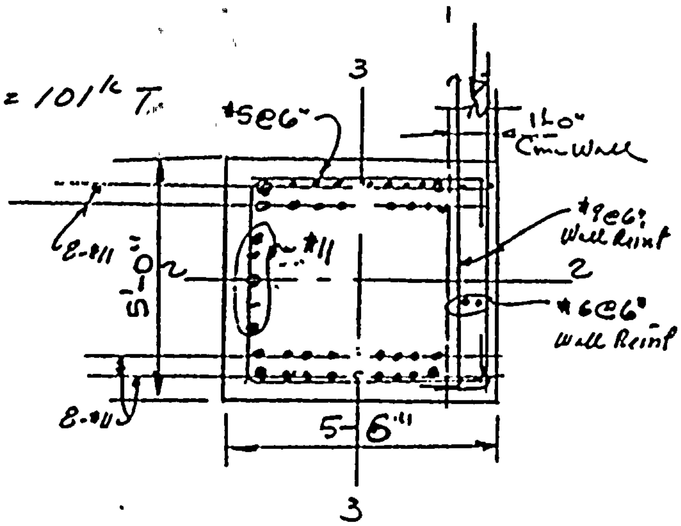
$P_u = 353^k C$ & $(185 - \frac{168}{2}) = 101^k T$

$V_u = 287^k$

$M_{22} = 17{,}435^{"k}$

$M_{33} = 550^{"k}$

$M_{Torsion} = 6467^{"k}$
$\quad 7749^{"k} (287^k \times 27")$
$\quad 14{,}216^{"k}$



Beam Section

(2) Bending Moment Reinforcement

$A_{s_{22}} = \frac{17{,}435^{"k}}{12 \times 4 \times 54"} = 18.3 in^2$

$A_{s_T} = \frac{101^k}{2} \div 0.9 \times 60 = \underline{1.0 in^2}$

$19.3 in^2$ use - 20-#9 T&B
13-#11 T&B

$A_{s_{33}} = 550 \div (12 \times 4 \times 60") = 0.2 in^2$

Shear & Torsion Reinforcement

$V = 287^k$, $v_u = 287{,}000 \div (0.85 \times 60 \times 54) = 104 psi < 2\sqrt{4000} = 126 psi$

$M_{Torsion} = 14{,}216^{"k}$

$v_{t_u} = \frac{3M_T}{\phi \Sigma x^2 y} = \frac{3 \times 14{,}216^{"k}}{0.85 \times 60^2 \times 66} = 211 psi > 1.5\sqrt{4000} = 95 psi$

$A_t = \frac{(v_{tu} - v_{tc}) s \Sigma x^2 y}{3 \alpha_1 x_1 y_1 f_y}$ $\quad \alpha_1 = [0.66 + (0.33 \times \frac{60"}{54"})] = 1.03$

$v_{tc} = \frac{2.4\sqrt{4000}}{\sqrt{1 + (1.2 \frac{v_u}{v_{tu}})^2}}$

$A_t = \frac{(211 - 130) 12" \times 60^2 \times 66}{3 \times 1.03 \times 54 \times 60 \times 60{,}000} = 0.39 in^2$ $\quad = \frac{2.4 \times \sqrt{4000}}{\sqrt{1 + (1.2 \times \frac{104}{211})^2}}$

#6@12" = 0.44 in²

#5@6" = 0.61 in² $\quad$ = 130 psi

Add'l Longitudinal Bars for Torsion

$A_l = 2A_t \frac{x_1 + y_1}{s} = 2 \times 0.39 \times (\frac{54 + 60}{12}) = 7.41 in^2$ (2-#9 ea face)

$A_l = \left[\frac{400 x s}{f_y}\left(\frac{v_{tu}}{v_{tu} + v_u}\right) - 2A_t\right]\left(\frac{x_1 + y_1}{s}\right)$

$= \left[\left(\frac{400 \times 54 \times 12}{60{,}000}\right)\left(\frac{211}{211 + 104}\right) - 2 \times 0.39\right] \frac{54 + 60}{12} = 20.16 in^2$ (5-#9 ea face)
3-#11 " "

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JOB NO. 0902-19 JOB DIABLO REVIEW BY RTY DATE 9/29/78

CLIENT PG&E SUBJECT REFUELING WATER TANKS CHK'D LC DATE 10/20/78

I Concrete Frame Design

B. Foundation @ Column

$M_{max_{33}} = 73{,}092''^{k}$

$A_{s_t} = 73{,}092 \div (12'' \times 4.3 \times 182'')$

$= 7.79 in^2$

USE: 8-#9 = 8.00 in²

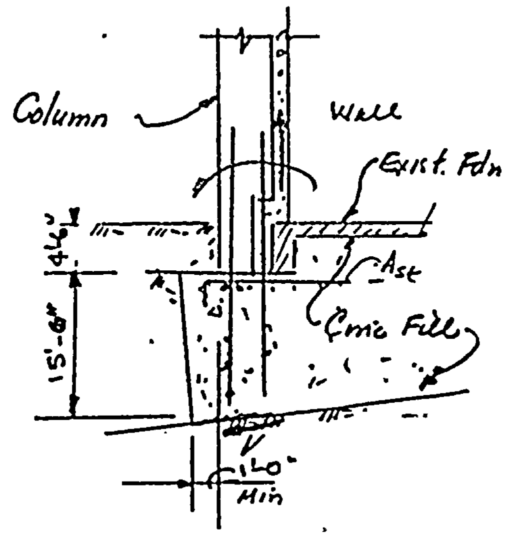
5-#11 = 7.80 in²

$M_{max_{22}} = 26{,}844''^{k} \div 176'' = 153^{k}$

$A_s = 153^{k} \div 0.9 \times 60ksi = 2.82 in^2$

3-#9 = 3.00 in²

(Ring Beam Reinf more than adequate)



II. Concrete Wall Design

A. 8" Conc Wall (#6 @ 6" EW EF)

(1) $V_{max} = 51.3^{k}/'$ (Element #533)

$v_u = 51{,}300 \div 12'' \times 8'' \times 0.85 = 629 psi < 10\sqrt{4000} = 632 psi$

$A_v = \frac{(v_u - v_c) b s}{f_y} = \frac{(629 - 126) 8'' \times 12''}{60{,}000} = 0.81 in^2/' < 1.76 in^2/'$

(2) $P_{max_y} = 35{,}780^{\#}/'$, $M_{xx} = 11.7^{k}/'$ (Longitudinal)

$A_{s_p} = 35{,}780^{\#}/' \div 0.9 \times 60{,}000 = 0.66 in^2/'$ } $0.71 in^2/' < 1.76 in^2$

$A_{s_M} = 11.7''^{k} \div (12 \times 4.0 \times 5'') = 0.05 in^2/'$

(3) $P_{max_x} = 56.01^{k}/'$, $M_{max_{yy}} = 9.6''^{k}/'$ (Element #534 - Hoop)

$A_{s_p} = 56.01^{k}/' \div 0.9 \times 60 = 1.04 in^2/'$ } $1.08 in^2/' < 1.76 in^2$

$A_{s_M} = 9.6 \div (12 \times 4.0 \times 5'') = 0.04 in^2/'$

(4) Hoop Force & Shear Force Combination (Element #534)

Steel Area required for Shear = 0.81 in²/'

" " " for Hoop Tension from EQ_{xx}, EQ_{yy} & EQ_{zz}

$96 (.220 + 0.281 + 0.069) = 54.7^{k}/' \div 0.9 \times 60ksi = 1.01 in^2/'$

Steel Area required for DL+HS = $21.12^{k} \div 0.9 \times 60ksi = 0.39 in^2/'$

$A = 0.39 in^2 + [(0.81)^2 + (1.01)^2]^{\frac{1}{2}} = 1.69 in^2/' < 1.76 in^2/'$

1.30 in²

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CLIENT SUBJECT REFUELING WATER TANKS CHK'D LC DATE 10/20/78

II Concrete Wall Design

B 12" Conc Wall (#9@6" EF Vert. & #6@6" EF Horizontal)

(1) $V = 65.16^k/_1$ (Element #386)

$v_u = 65,160 \div 0.85 \times 12" \times 12" = 532 psi < 10\sqrt{4000} = 632 psi$

$A_v \{(532-126)12" \times 12"\} \div 60,0000 = 0.97 in^2/_1 < 1.76 in^2/_1$

(2) $P_x = 72.42^k/_1$, $M_{yy} = 1.4'^k/_1$ (Element #463 - Hoop)

$As_p = 72.42^k \div 0.9 \times 60 ksi = 1.34 in^2/_1$

$As_M = 14^{"k}/_1 \div (12 \times 4 \times 8") = 0.04 in^2/_1$

$As_{TOTAL} = 1.38 in^2/_1 < 1.76 in^2/_1$

(3) $P_y = 107.15^k/_1$, $M_{xx} = 49"^k/_1$ (Element #463 - Longitudinal)

$As_p = 107.15 \div 0.9 \times 60 ksi = 1.98 in^2/_1$

$As_m = 49^{"k} \div (12"/_1 \times 4.0 \times 8") = 0.13 in^2/_1$

$As_{TOTAL} = 2.11 in^2/_1 < 4.0 in^2/_1$

(4) Hoop & Shear Combination (Element #463)

Steel Area require for shear =

$V = 60.59^k$, $v_u = 60,590 \div 0.85 \times 144 in^2 = 495 psi$

$A_v = (495-126)12 \times 12 \div 60,000 = 0.89 in^2$

Steel Area required for hoop forces from EQ_{xx}, EQ_{yy} & EQ_{zz}

$P = 144 in^2 \times (0.242 + 0.097 + 0.011) = 50.4^k/_1$

$As_p = 50.4^k/_1 \div 0.9 \times 60 ksi = 0.93 in^2$

Steel Area required for DL + HS

$P = 144 \times .242 = 34.85^k/_1$

$As = 34.85 \div 0.9 \times 60 ksi = 0.65 in^2/_1$

Total Area Required $= 0.65 + \sqrt{(0.89)^2 + (0.93)^2} = 1.94 in^2/_1 / 71.7\%$
1.28

USE: #6 @ 5" EF Horizontal = $2.11 in^2/_1 > 1.94 in^2$

#7

REVISED 11/2/78

DIABLO CANYON NUCLEAR POWER PLANT

INTAKE STRUCTURE CRANE EVALUATION FOR THE 7.5M HOSGRI EARTHQUAKE

October 12, 1978

prepared for
Pacific Gas & Electric Company

by

URS/John A. Blume & Associates, Engineers
130 Jessie Street
San Francisco, California

CONTENTS

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TABLES

FIGURES

1. INTRODUCTION

This report summarizes the seismic analysis and structural design evaluation used in reviewing the intake structure crane of the Diablo Canyon Nuclear Power Plant for response to the postulated 7.5M Hosgri earthquake. The 50 ton gantry crane travels on rails running north-south along the entire length of the top deck of the intake structure. The crane, designed for outdoor and marine environment service, is used for handling pumps, motors, traveling screens, gates and bar racks during routine equipment maintenance and overhaul. A trash rake, mounted on the ocean face of the gantry, is used for routine cleaning of the bar racks.

The Intake Structure, which serves both Units 1 and 2, is a Design Class II structure and was originally designed under seismic criteria which called for seismic forces to be determined on the basis of an equivalent static force coefficient of 0.20g with a one-third increase in allowable stresses. However, because it houses the four Design Class I auxiliary saltwater pumps, two for each unit, it was reviewed for the DDE and the postulated 7.5M Hosgri motions.

The objective of the analysis reported here is to demonstrate that the Design Class II intake crane, with full rated load, can satisfactorily resist the Hosgri earthquake or, for configurations where this is not demonstrable, that seismic induced failure cannot cause damage sufficient to result in loss of function of the auxiliary saltwater system.

The evaluation of the crane has been accomplished according to the February 8, 1977, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake.*[1] A modal superposition response-spectrum dynamic analysis was performed through the use of finite-element model representations of the structure.

This report contains a description of the salient structural features of the intake structure crane and a presentation of the analysis criteria, mathematical modeling and results.

2. DESCRIPTION OF CRANE STRUCTURE

The Intake Structure Crane is a bolted structural steel gantry crane with trolley. It is 40 ft tall and 100 ft long overall, spanning 88.9 ft between rails in the east-west direction with the upper girders cantilevered 11 ft beyond the legs. The trolley is supported on two 5 ft deep steel plate box girders at 14.5 ft centers which in turn are supported by tapered box section legs which are inclined to 26 ft centers at the lower end. Each lower end tie accommodates two trucks which together contain one driver wheel and three idlers.

The structure was designed in accordance with Standard No. 6 of the Association of Iron and Steel Engineers. Members not covered by that Standard were designed and fabricated in accordance with the current Specification for the Design, Fabrication and Erection of Structural Steel for Buildings by the American Institute of Steel Construction.

The gantry crane design load is 50 tons. Erection, startup, and initial operation of the crane were performed at the job site under the direction of a qualified engineer from the manufacturer. The crane was given an on-site load test at 1.25 design load. The hoist mechanism includes an 8-part tackle of 1 1/8"ϕ galvanized wire ropes.

3. ANALYSIS CRITERIA

General

The basic approach to the 7.5M Hosgri evaluation of the intake structure crane is outlined in the February 8, 1977 specification.[1] The evaluation for seismically-induced forces was performed with the crane in the parked and various operating positions, with and without the rated operating load.

Stress evaluation for noncontinuous members was undertaken according to AISC Specification,[2] Part 1 (Elastic design), with the following exceptions:

> Allowable bending stress, $F_b' = F_y = 36$ ksi
>
> Allowable uniaxial stress, $F_a' = 1.7\ F_a$ (F_a is the code computed value)
>
> Allowable shear stress, $F_v' = F_y/\sqrt{3}$

This is merely equivalent to determination of the elastic limit instead of a working stress approach, which is consistent with application of the postulated Hosgri 7.5M seismic event.

Strength determination for continuous members was undertaken according to AISC Code, Part 2 (Plastic design), with the yield strength of $F_y = 36$ ksi.

The structural stability criteria was that, in general, the seismic loading should not produce uplift or overturning.

Seismic Inputs

The horizontal base motion input applied to the intake structure crane at the crane rail was the 7 percent damped horizontal Blume ($\tau = .04$) and Newmark ($\tau = 0.04$) response spectra developed for the intake structure.

The vertical input was taken as two-thirds of the 0.75g, 7 percent damped horizontal Newmark free-field ground spectrum.

Although relatively insignificant for the intake structure crane, the effect of torsion was indirectly considered.

Modeling Parameters

Modal damping equal to 7 percent of critical was used in accordance with Regulatory Guide 1.61[3] recommendations and is further substantiated by conclusions of a URS/Blume study.[4]

The breaking strength for each wire rope was 48.5 tons. The elastic modulus was 1,200 ksi.

4. METHOD OF ANALYSIS

Linear three-dimensional finite element response spectrum analyses were undertaken using the SAP IV[5] structural analysis computer code. The model consisted entirely of beam elements and mass was applied at appropriate nodes (Figure 1).

The model was subjected to dead and seismic loading, with and without hook loads. Seismic loading in the horizontal direction corresponds to the Newmark (Figure 2) and Blume (Figure 3) elastic spectra for 7 percent damping and $\tau = 0.04$ in the east-west and north-south direction respectively. The elevation 17.5 ft modified response spectrum derived from the Blume spectrum in the north-south direction was virtually identical to the virgin spectrum. Crane inertial forces are limited in the north-south direction by sliding response with a coefficient of friction, $\mu = .25$, for each braked wheel (1 per side).

Seismic loading in the vertical direction corresponds to 2/3 of the Newmark free-field elastic spectrum for 7 percent damping (Figure 4) which was more severe than the equivalent Blume spectrum.

The resulting N/S and E/W responses and the vertical seismic results were combined on a SRSS basis. This total effect was in turn combined algebraically with dead load and hook load.

For the case with operating load, nonlinear response history analyses of the crane with the cable suspended hook load were undertaken for vertical motion using the DRAIN-2D[6] computer code. The model is shown in Figure 5. Structural damping of 4 percent in the first two modes was adopted for these analyses. Pendulum motion of the suspended load was also determined using DRAIN-2D and the response spectrum method. Resulting horizontal loads were insignificant.

5. DISCUSSION OF RESULTS

The natural periods of vibration and participation factors for the north-south, east-west, and the vertical response spectrum analyses of the unloaded and loaded crane are summarized in Tables 1 and 5 respectively. In accordance with the requirements of the NRC, only those modes with associated periods of vibration greater than or equal to 0.03 sec (33 Hz) are considered significant for response computations. The fundamental frequencies of the system in the north-south, east-west, and vertical directions are 1.1 Hz, 2.1 Hz, and 5.6 Hz, respectively for the unloaded system and 1.1 Hz, 2.1 Hz, and 3.6 Hz respectively for the loaded system.

The predicted seismic-induced displacements for the unloaded and loaded system are summarized in Tables 2 and 6. The element and node numbers shown in the tables correspond to the computer model shown in Figure 1. The maximum estimated displacements, relative to the base, are approximately 3 in. in the east-west and north-south directions.

Maximum bending moments and axial loads for the crane legs, girders, and end ties resulting from the SRSS combined effects of the separate response spectrum analyses added directly to the dead load effects for the unloaded and loaded case are shown in Tables 3 and 7 respectively. The ratios of the computed bending moment and axial stresses to allowable values are shown in Tables 4 and 8. For any member, the ratios are additive to obtain the combined stress effect. None of the combinations result in a ratio greater than 1. The ratios are sufficiently low that the stresses may be arbitrarily increased to account for any torsional response in lieu of undertaking a more refined torsional analysis.

Shear stresses were insignificant in all members.

When the crane is in an operating position, sliding of a few inches can be expected along the crane runway during the postulated earthquake. If the crane is parked at the end of the runway, and sliding is thus prevented,

stability analyses indicated that seismic overturning moments in the north-south direction may cause overstressing of the anchors. However, in this position, the unlikely event of the crane actually overturning would result in the crane falling off the north or south end of the intake structure; this does not pose a risk to the function of any safety related equipment.

Installation of a hold-down and lateral seismic restraint mechanism is required to transmit vertical uplift and horizontal forces directly from the trolley to the crane girder rails during the earthquake. This minor structural modification will be implemented.

6. SUMMARY

The results presented in this report are intended to provide information regarding the seismic adequacy of the intake structure crane under the postulated 7.5M Hosgri earthquake motions.

Results of the seismic analyses show that the intake crane is capable of carrying its maximum rated load of 50 ton without overstressing of structural members or the hoist cable.

During operation, sliding of the crane along the runway prevents the development of overturning moments of sufficient magnitude to cause instability problems. When the crane is parked, the unlikely event of overturning does not pose a risk to the function of any safety related equipment.

7. REFERENCES

1. URS/John A. Blume & Associates, Engineers, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake* (preliminary), revised February 8, 1977.

2. AISC Specification for the Design Fabrication and Erection of Structural Steel for Buildings, American Institute of Steel Construction, New York, 1969.

3. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61, *Damping Values for Seismic Design of Nuclear Power Plants*, October 1973.

4. Blume, J. A., and Kabir, A. F., *Data on Damping Ratios*, LL9.

5. Bathe, K. J., Wilson, E. L., and Peterson, F. E., "SAP IV: A Structural Analysis Program for Static and Dynamic Response of Linear Systems," Report No. EERC 73-11, Earthquake Engineering Research Center, University of California, Berkeley, June 1973.

6. Kanaan, A. E., and Powell, G. H., "General Purpose Computer Program for Inelastic Dynamic Response of Plane Structures," Report No. EERC 73-6, Earthquake Engineering Research Center, University of California, Berkeley, April 1973.

TABLE 1

INTAKE STRUCTURE CRANE

PERIODS OF VIBRATION AND PARTICIPATION FACTORS,

UNLOADED CASE

Mode	Participation Factor (%)			
	Period (sec)	North-South Direction	East-West Direction	Vertical Direction
1	0.924	39.3	0.3	0.4
2	0.481	0.3	72.2	0.7
3	0.349	1.2	5.7	2.7
4	0.304	17.4	-	0.2
5	0.181	0.9	-	19.2
6	0.177	0.4	0.3	25.4
7	0.155	3.0	0.1	0.6
8	0.148	13.1	0.1	0.4
9	0.097	0.2	1.7	1.1
10	0.070	4.2	-	2.0
11	0.066	1.9	0.2	0.3
12	0.057	2.4	1.8	5.1
13	0.055	1.4	4.8	10.1
14	0.051	4.0	0.2	0.8
15	0.050	3.1	0.1	0.1
16	0.048	0.8	4.1	4.1
17	0.040	0.6	0.8	6.1
18	0.039	0.1	0.1	2.0
19	0.037	0.8	0.1	7.6
20	0.035	1.7	1.6	8.8
21	0.032	1.9	0.6	0.7
22	0.032	0.6	3.4	0.5
23	0.031	0.6	1.5	1.1

TABLE 2

INTAKE STRUCTURE CRANE

MAXIMUM DISPLACEMENTS

UNLOADED CASE

Nodal Point	North-South Direction (in.)	East-West Direction (in.)	Vertical Direction (in.)
6	0.09	2.21	0.02
8	0.56	2.26	0.10
10	0.12	3.28	0.03
12	1.35	3.28	0.23
14	0.47	3.28	0.60
16	0.94	3.28	0.78
18	1.22	3.28	0.60
20	1.45	3.28	0.43

Notes:
1. All displacements are measured relative to the base of the crane.
2. All nodal points refer to Figure 1.

TABLE 3

INTAKE STRUCTURE CRANE

MAXIMUM MEMBER FORCES,

UNLOADED CASE

Element	Axial Load (kip)	Moment M_2 (kip-in.)	Moment M_3 (kip-in.)
1	-	6	463
2	-	6	2,223
4	79.8	13,187	444
6	98.9	13,302	2,223
8	75.8	25,507	991
10	91.7	25,003	940
11	-	991	2,493
13	-	25,179	2,536
15	-	15,035	1,712
17	-	14,647	1,712
19	-	26,032	2,153
21	-	2,053	3,946
22	-	-	3,951

Note: All element numbers refer to Figure 1.

TABLE 4

INTAKE STRUCTURE CRANE

MAXIMUM STRESS RATIOS,

UNLOADED CASE

Element	f_a/F_a	f_{b_2}/F_b	f_{b_3}/F_b	Total
1	-	-	0.04	0.04
2	-	-	0.21	0.21
4	0.04	0.39	0.02	0.45
6	0.06	0.39	0.05	0.50
8	0.04	0.52	0.04	0.60
10	0.04	0.51	-	0.55
11	-	0.01	0.09	0.10
13	-	0.37	0.09	0.46
15	-	0.22	0.06	0.28
17	-	0.21	0.06	0.27
19	-	0.38	0.08	0.46
21	-	0.03	0.14	0.17
22	-	-	0.14	0.14

Note: All element numbers refer to Figure 1.

Key

f_a - computed axial stress

f_{b_2} - computed bending stress about axis 2

f_{b_3} - computed bending stress about axis 3

F_a - axial stress permitted in absence of bending moment

F_b - bending stress permitted in absence of axial force

TABLE 5

INTAKE STRUCTURE CRANE

PERIODS OF VIBRATION AND PARTICIPATION FACTORS,

LOADED CASE

Mode	Period (sec)	Participation Factor (%)		
		North-South Direction	East-West Direction	Vertical Direction
1	0.929	36.3	0.3	0.3
2	0.481	0.3	71.6	0.9
3	0.351	1.0	5.8	7.6
4	0.304	15.5	-	0.8
5	0.276	4.4	0.2	26.9
6	0.274	5.0	0.3	24.3
7	0.155	3.2	0.1	0.2
8	0.149	11.8	0.1	0.3
9	0.097	0.3	1.6	1.0
10	0.070	3.9	-	1.5
11	0.066	1.7	0.3	0.3
12	0.057	2.3	2.3	4.6
13	0.056	1.0	4.5	7.0
14	0.051	3.7	0.2	0.7
15	0.050	2.9	-	0.1
16	0.048	0.7	4.1	3.0
17	0.041	0.4	1.1	3.6
18	0.039	-	0.1	1.4
19	0.038	0.5	-	3.5
20	0.035	1.3	1.4	8.3
21	0.033	1.5	3.1	2.3
22	0.032	0.9	1.7	0.8
23	0.031	1.2	1.0	0.5

TABLE 6

INTAKE STRUCTURE CRANE

MAXIMUM DISPLACEMENTS,

LOADED CASE

Nodal Point	North-South Direction (in.)	East-West Direction (in.)	Vertical Direction (in.)
6	0.12	2.31	0.03
8	1.10	2.36	0.19
10	0.17	3.29	0.05
12	2.65	3.29	0.45
14	0.92	3.30	1.36
16	1.74	3.30	2.03
18	2.31	3.30	1.40
20	2.85	3.29	0.73

Notes:
1. All displacements are measured relative to the base of the crane.
2. All nodal points refer to Figure 1.

TABLE 7

INTAKE STRUCTURE CRANE

MAXIMUM MEMBER FORCES,

LOADED CASE

Element	Axial Load (kips)	Moment M_2 (kip-in.)	Moment M_3 (kip-in.)
1	-	8	618
2	-	8	4,357
4	143.5	15,952	594
6	177.4	16,058	4,357
8	135.2	31,144	1,339
10	162.1	30,720	1,933
11	-	1,339	4,153
13	-	30,745	2,789
15	-	41,085	2,025
17	-	41,085	2,259
19	-	32,637	2,870
21	-	3,263	5,496
22	-	-	5,536

Note: All element numbers refer to Figure 1.

TABLE 8
INTAKE STRUCTURE CRANE
MAXIMUM STRESS RATIOS,
LOADED CASE

Element	f_a/F_a	f_{b_2}/F_b	f_{b_3}/F_b	Total
1	-	-	0.06	0.06
2	-	-	0.41	0.41
4	0.08	0.47	0.02	0.57
6	0.10	0.47	0.10	0.67
8	0.07	0.63	0.06	0.76
10	0.08	0.63	-	0.71
11	-	0.02	0.14	0.16
13	-	0.45	0.10	0.55
15	-	0.60	0.07	0.67
17	-	0.60	0.08	0.68
19	-	0.48	0.10	0.58
21	-	0.05	0.19	0.24
22	-	-	0.19	0.19

Note: All element numbers refer to Figure 1.

Key

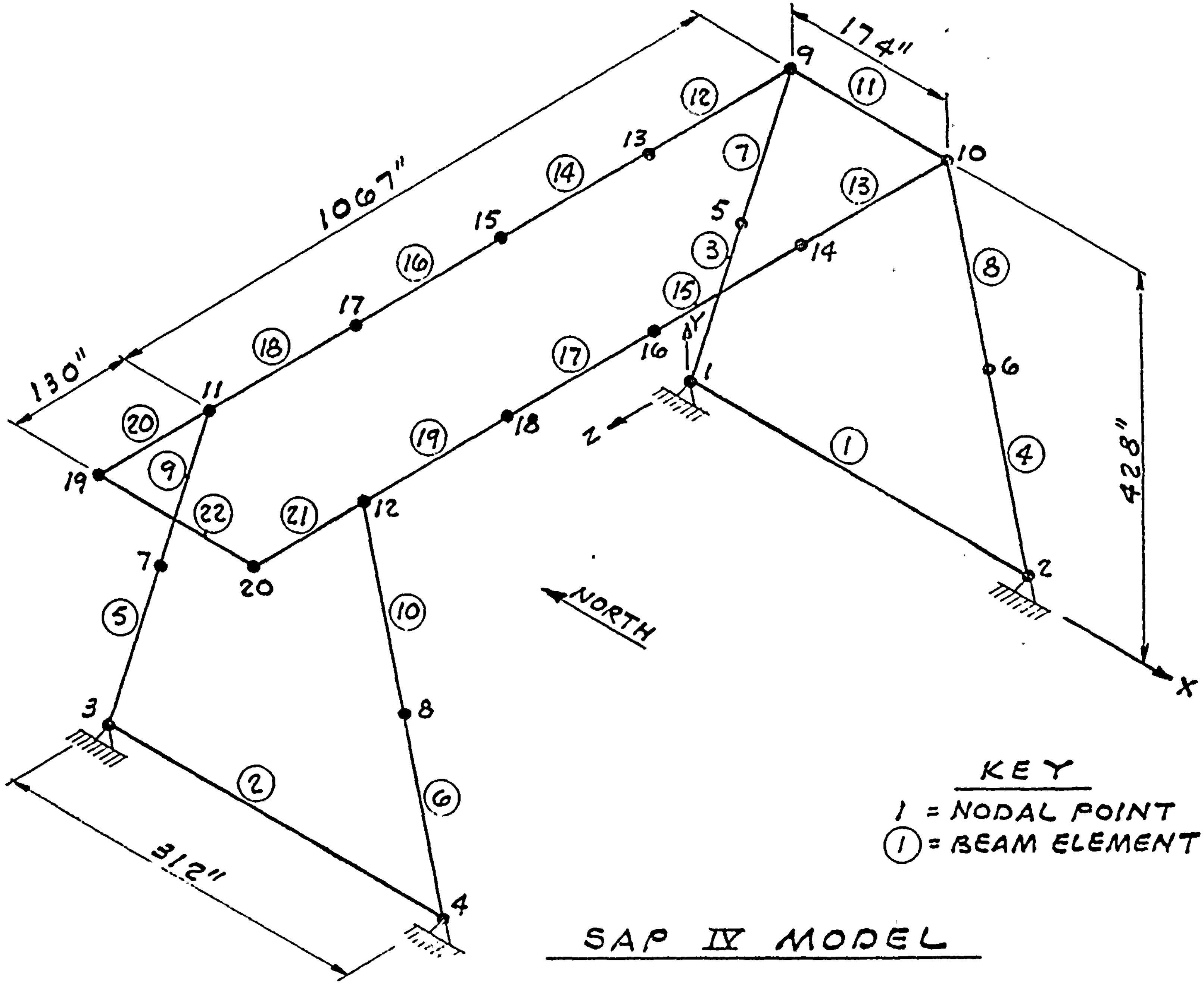
f_a - computed axial stress

f_{b_2} - computed bending stress about axis 2

f_{b_3} - computed bending stress about axis 3

F_a - axial stress permitted in absence of bending moment

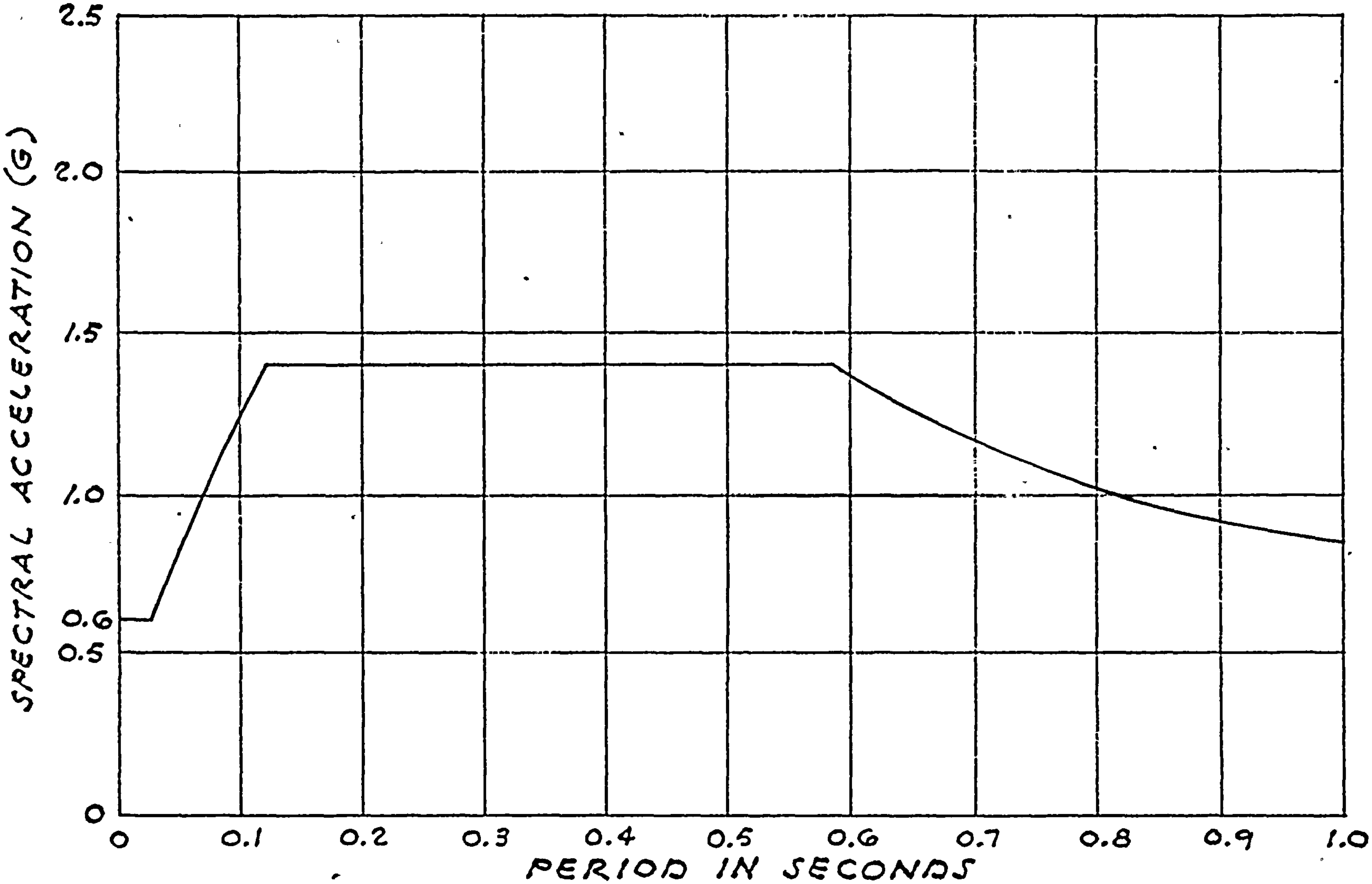
F_b - bending stress permitted in absence of axial force



SAP IV MODEL

DIABLO CANYON
INTAKE STRUCTURE CRANE

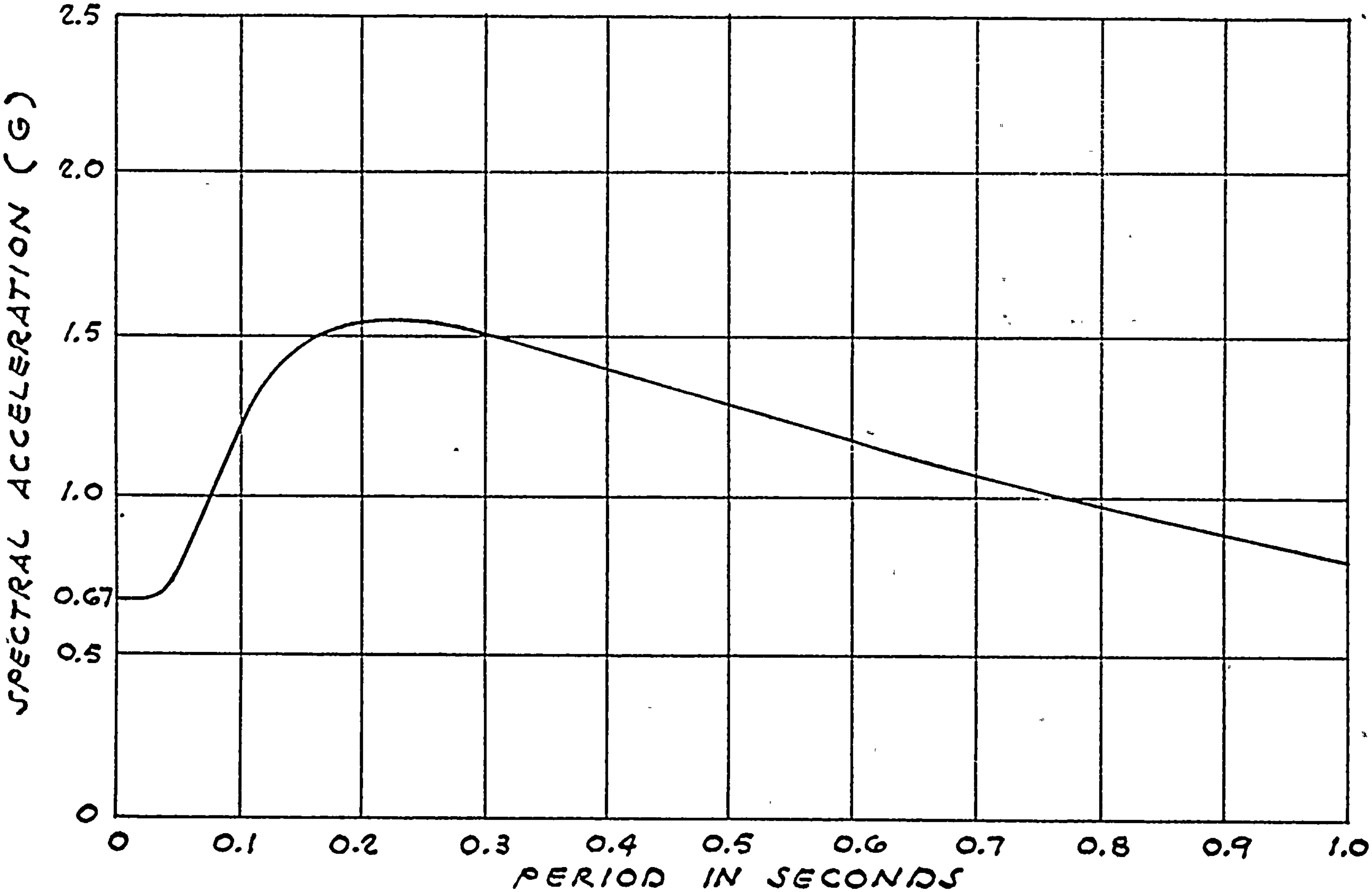
FIGURE 1



HORIZONTAL SPECTRUM - 7% DAMPING
NEWMARK 7.5M HOSGRI (TAU = 0.04)

DIABLO CANYON
INTAKE STRUCTURE CRANE

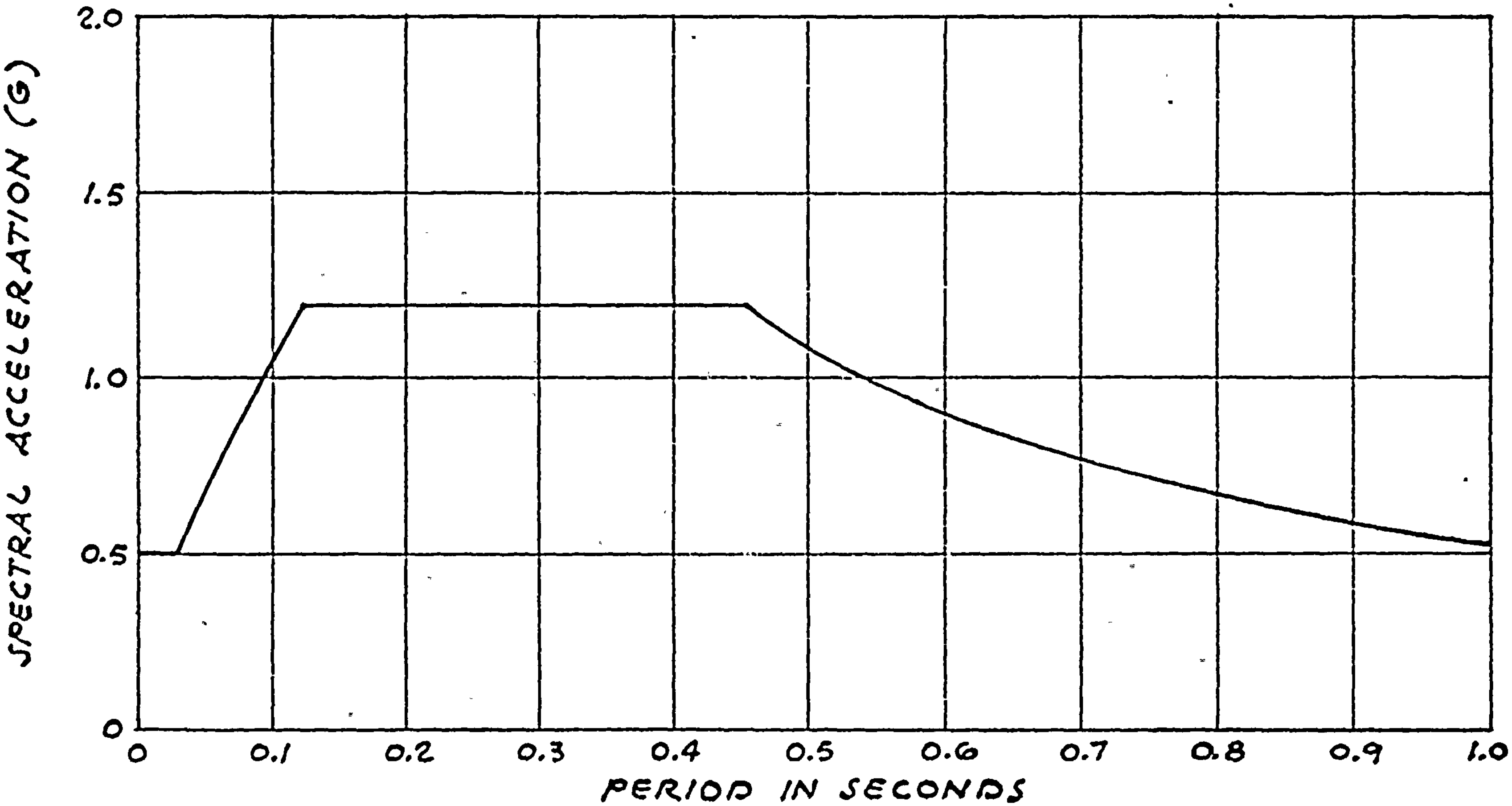
FIGURE 2



HORIZONTAL SPECTRUM - 7% DAMPING
BLUME 7.5 M HOSGRI (TAU = 0.04)

DIABLO CANYON
INTAKE STRUCTURE CRANE

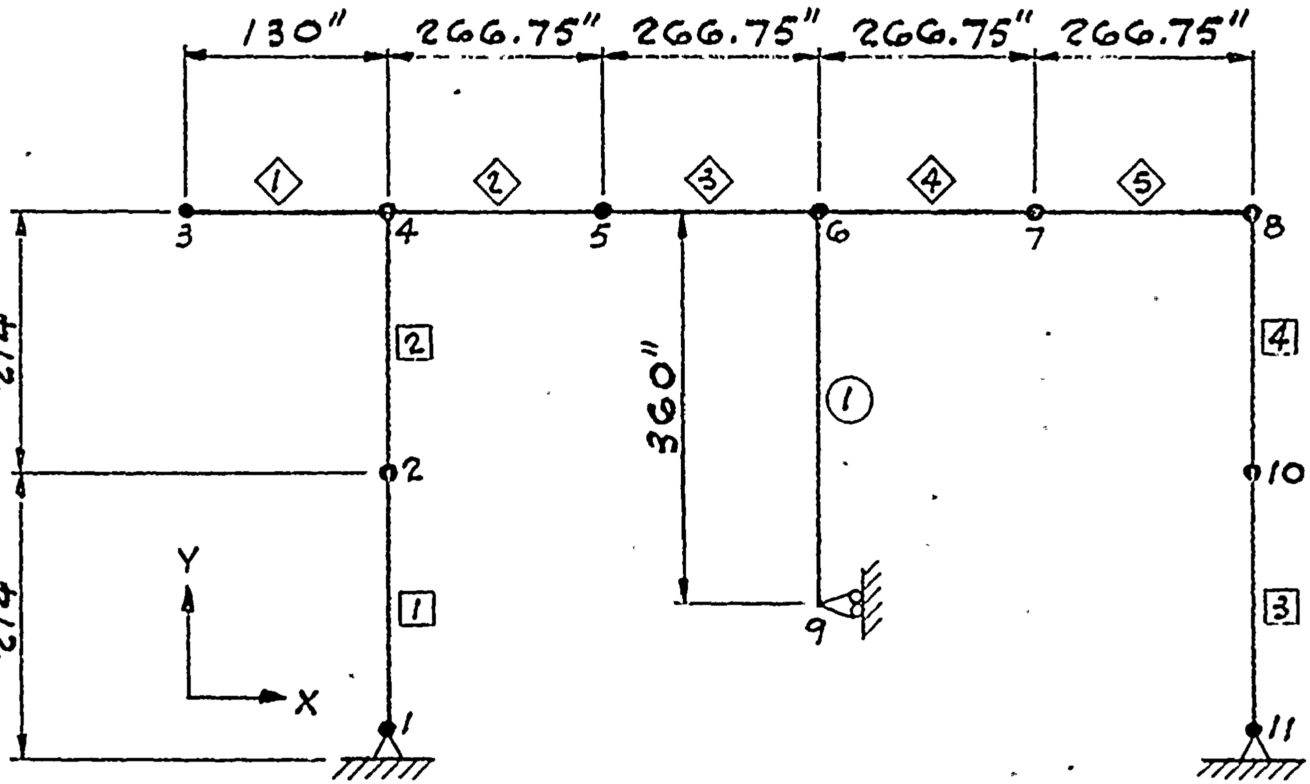
FIGURE 3



VERTICAL SPECTRUM - 7% DAMPING
NEWMARK 7.5M HOSGRI (TAU=0.00)

DIABLO CANYON
INTAKE STRUCTURE CRANE

FIGURE 4



DRAIN 2-D MODEL

KEY

1 = NODAL POINT

(1) = TRUSS ELEMENT

[1] = BEAM-COLUMN ELEMENT

◇1 = BEAM ELEMENT

DIABLO CANYON
INTAKE STRUCTURE CRANE

FIGURE 5

DRAFT #8

f. The coil of the 2HH9 Containment Spray Signal Timing Relay was connected to a 120 VAC supply via a switch "H". A normally closed contact was connected to the direct readout recorder to monitor its operation and contact chatter. See Figure 10-26G.

g. Two linear variable displacement transducers were installed near the top of the switchgear to measure the maximum vertical and horizontal displacement of the switchgear structure. This measurement was taken as an input to the design of the earthquake joints of the bus ducts.

The main contacts of the power circuit breakers needed not to be monitored since no chatter of any kind is possible.

K. M. Skreiner Ph.D prepared the statement below regarding monitoring of circuit breaker contacts.

Dr. Skreiner is the Manager of General Electrics Department of Applied Physics and Mechanical Engineering. He is also the Vice Chairman of the Working Group 2.5 (Seismic Qualification) of Subcommittee 2 (Equipment Qualification) of the Nuclear Power Engineering Committee which prepared IEEE Standard 344-1975, Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations.

Statement on Monitoring Circuit Breaker Contacts

Class IE circuit breakers are required to perform normally before, during and after the SSE event. This may require any or all of the functions of opening and closing on command or remaining open and closed to be demonstrated depending on the Class IE function of the circuit breakers. One method of evaluating the functional performance directly is to monitor the electrical continuity through the primary breaker contacts.

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However, it should be noted that industry standards for circuit breakers rated 1000 volts and above, specifically ANSI C37.04-4.5.2.4, require that circuit breakers must be able to close, latch closed, carry and interrupt high levels of short circuit currents. During the type tests to demonstrate this capability the magnetic forces which act on the primary contacts of circuit breakers far exceed the forces during an SSE event. Therefore it can be reasoned that it should not be necessary to monitor electrical continuity through the primary contacts during SSE testing.

A preferred method of evaluating the circuit breaker status is to monitor the contacts of the auxiliary switch which is operated by the circuit breaker mechanism. The contacts of the auxiliary switch are much more likely to experience chatter or changes of state. Monitoring the auxiliary switch has the advantage of demonstrating the status of both the circuit breaker primary contacts and the contacts of the auxiliary switch itself.

10.3.26.6 Test Results

The equipment was subjected to a total of 37 runs in both the side to side and front to back orientation. Table IV of the Test Plan (WYLE Test Report 58255-1, Test Procedures 3642, Addendum 1) shows that only 24 conditions needed to be met. And of these conditions 1, 2, 3, 4, 14 and 15 were low level sweeps.

The following table indicates the runs during which a given condition was met.

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ROUGH DRAFT
10-17-78
10-18-78 — Amend #2

DRAFT #9

10.3.5.2.1 - Name of Equipment

125 VDC Distribution Panelboard, (ITE DC SWITCHGEAR)

10.3.5.2.2 - Description of Equipment

This electrical switchgear consists of a three section, welded frame construction cabinet with a 125 VDC bus arrangement, 3000 ampere input fuse from the battery, and two 600 ampere molded case input breakers for primary and backup battery chargers. A 600 ampere draw-out breaker from the main bus supplies the circuit breaker panelboards. The circuit breaker panelboard consists of molded case breakers rated for 20 to 150 amperes. This equipment is located on El 115'0", area H of the Auxiliary Building. The center section of the SWGR has a SV-Undervoltage Relay which picks-up at 125 VDC as the bus voltage increases, (27DCB21). This relay would drop out at 90% or 112 VDC signaling bus undervoltage, alarm only. The center section also has a 0-150 VDC range voltmeter. This voltmeter and the battery charger voltmeter during this switchgear testing read the same voltage 132 VDC the Battery Charger output setting. At this same time the battery charger ammeter read 50 amperes output, before, during and after the seismic testing. The 125 VDC bus also has a white light to indicate bus voltage, a W minalite. 2

10.3.5.2.3 - Safety Function

The 125 VDC Distribution Panelboard is required to continuously distribute 125 VDC power to plant DC loads (power, control protection, instrumentation, and monitoring before, during and after a seismic event.

10.3.5.2.4 - Test Plan and Criteria

In order to assure the performance of the safety function specified in 10.3.5.2.3 above, the following specific test criteria shall be met:

1. Circuit breakers shall maintain their position before, during, and after the seismic event; no circuit breakers are required to operate during the seismic event.

2. The following components and positions shall be monitored:

a. Breaker 72-2100 (I.T.E. KM 2B600); 125 VDC Bus input breaker, fed from the Battery Charger, monitor the following auxiliary switch contacts (see figures 10.3.5.2-1 and 10.3.5.2-2) to ensure the breaker maintains its closed position: (50 amperes shall be flowing thru this breaker during energized tests) 2

(1) Terminals 17 and 18: Closed

(2) Terminals 19 and 20: Open

(3) Terminals 21 and 22: Closed

b. Breaker 72-2102 (I.T.E. K600); monitor the following auxiliary switch contacts (see figures 10.3.5.2-1 and 10.3.5.2-2) to ensure the breaker maintains its closed position. (50 amperes shall be flowing thru this breaker during test. Battery Charger Ammeter read 50 Amperes, Battery Charger Voltmeter 132 volts, and 125 VDC Swgr Voltmeter read 132 volts, observed visually.)

(1) Terminals 9 and 10: Open

(2) Terminals 15 and 16: Closed

(3) Terminals 5 and 6: Open (no overcurrent alarm)

c. Undervoltage Relay 27DBG21 Westinghouse SV type 125 VDC. Monitor the following contacts to verify that bus voltage is maintained during and after the test: (SV Relay should pick-up at 125 VDC with the voltage going up. Drops out at 112 VDC on undervoltage).

Contact Terminal 2 and 3: Open

d. HE2-B070 I.T.E. Molded Case Circuit Breaker. Visually monitor the status of this breaker to verify the breaker remained closed (Breaker had a load bank load on it equivalent to about 34 amps of the 50 amp charger output.)

e. HE2-B020 I.T.E. Molded Case Circuit Breaker. Visually monitor the status of this breaker to verify the breaker remained closed. (Breaker had a load bank load on it equivalent to about 16 amperes of the 50 ampere battery charger output.)

f. Verify that the 0-150 VDC voltmeter indicates that the bus was continuously energized during and after the tests. (Visually observed bus voltmeter at 132 VDC.)

g. Verify that the white indicating light stays on, indicating that the bus was continuously energized during and after the test. (White light stayed on all the time when 1st turned on the battery charger and hooked in the 125 VDC Wyle battery until the battery charger was tripped and the battery disconnected.) 2

10.3.5.2.5 - Test Procedure and Set-up

1. Mount the 125 VDC Distribution Panelboard, SD-21 on the seismic test table in the same configuration as in the power plant as shown in Wyle Report No. 58255, Appendix I, Test Procedure 3642, dated November 30, 1977, pp. 41.

2. Supply 125 VDC power to the 72-2100 input breaker to bus No. 21.by the P.G.& E. 125 VDC Battery Charger, ED-21. Supply 50 amperes by the Battery Charger (read battery charger Ammeter) to load bank Item 4 thru the Switchgear.

3. Supply 125 VDC battery power (Wyle 125 VDC battery) to the bus on the supply side of the 3000 ampere bus fuse.

4. Connect the 70A and 20A output breakers in panel SD-21 to the P.G.& E. resistor load bank with approximately 16 amperes at 125 VDC on the 20A breaker and 34 amperes at 125 VDC on the 70A breaker.

5. Close breakers 72-2100, 72-2102, and the 70A and 20A load breakers. Energize Battery Charger, ED-21. (Everything observed visually to read correctly before seismic shaking.)

6. Perform multi-axis, multi-frequency seismic testing per the RRS in Wyle Report No. 58255 dated April 19, 1978, pp. 255-280.

7. See figures 10.3.5.2-1 and 10.3.5.2-2 for testing set-up.

10.3.5.2.6 - Test Results

The equipment was energized during all the seismic tests, 5 OBE's and 2 SSE's in the Z-Y and X-Y axis. The components listed on Table 10.3.5.2-1 were ~~either~~ monitored before, during and after the seismic tests. No malfunction of any of the components occurred during the tests. All contacts of auxiliary switches and relays remained in the equipment energized position during all tests. All breakers remained in the proper positions during the testing. Indicating meters and lights on the front of the panelboard indicated that the bus remained energized during and after the test. (Also meters on battery charger indicated a load of 50 amperes was on the battery charger.) 2 / /

Results are listed per sub-paragraphs of 10.3.5.2.4 - Test Plan & Criteria:

1. No. breakers tripped open. 132 VDC output of the battery charger did not change. Battery charger ammeter continually read 50 amperes. If either breaker 72-2100 or 72-2102 had tripped the Battery Charger ammeter would go to zero with 72-2100 tripping (no load), or to nearly zero with 72-2102 tripping, (this would cut out the distribution panel load & the load bank & would only charge the Wyle Lab. Battery).

2a. (1) Closed auxiliary switch contacts remained closed. /

(2) Open auxiliary switch contacts remained open. (this contact is for alarm to ~~Annun)~~ Annunciator) 2

(3) Closed auxiliary switch contacts remained closed.

2b. Both Battery Charger Ammeter maintained 50 amperes & Battery Charger Voltmeter and the 125 VDC Swgr Bus Voltmeter maintained 132 VDC. Breaker did not trip to indicate loss of load.

2c. The SV relay picked-up as the battery charger energized the switchgear with breakers 72-2100 and 72-2102 closed. (125 VDC). At no time during the testing or after the testing did the SV contact pick up ~~pick-up~~ except when the breakers or the battery charger was tripped off. SV contacts did not pick-up during the energized time to indicate a drop in voltage below 112 VDC setting of the SV relay. The SV relay contact was monitored by channel No. 4 of the Chatter Detector as shown on FIG. 10.3.5.2-2 2

2d. If breaker had tripped off the battery charger output would have dropped by the amount of load bank resistance lost with open breaker.

2e. If breaker had tripped off the battery charger output would have dropped by the amount of load bank resistance lost with the open breaker.

2f. At no time by visual observation did the DC SWGR or the Battery Charger Voltmeter, reading drop, when the switchgear and Battery Charger were energized and the 125 VDC battery connected.

2g. White light stayed on indicating bus potential.

Following the seismic tests, the SD-21 Distribution Panelboard was shipped back to Diablo Canyon Unit 2, its functional performance was tested and verified, and it was placed back in service in the plant. 2

10.3.5.2.7 - Conclusions

A 125 VDC Distribution Panelboard (SD-21) from Diablo Canyon Unit 2 was tested by a multi-axis, multi-frequency seismic simulation described in Wyle Report No. 58255, April 19, 1978. pp. 255-280. This panelboard is identical to the other five 125 VDC Distribution Panelboards installed in Diablo Canyon Units 1 and 2. The test results described in 10.3.5.2.6 above demonstrate that the test criteria specified in section 10.3.5.2.4 are met, and thus that the equipments' safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event.

Thus it is concluded that the Diablo Canyon Unit 1 and 2 125 VDC Distribution Panelboards are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Std 344-1975 and NRC Regulatory Guide 1.100.

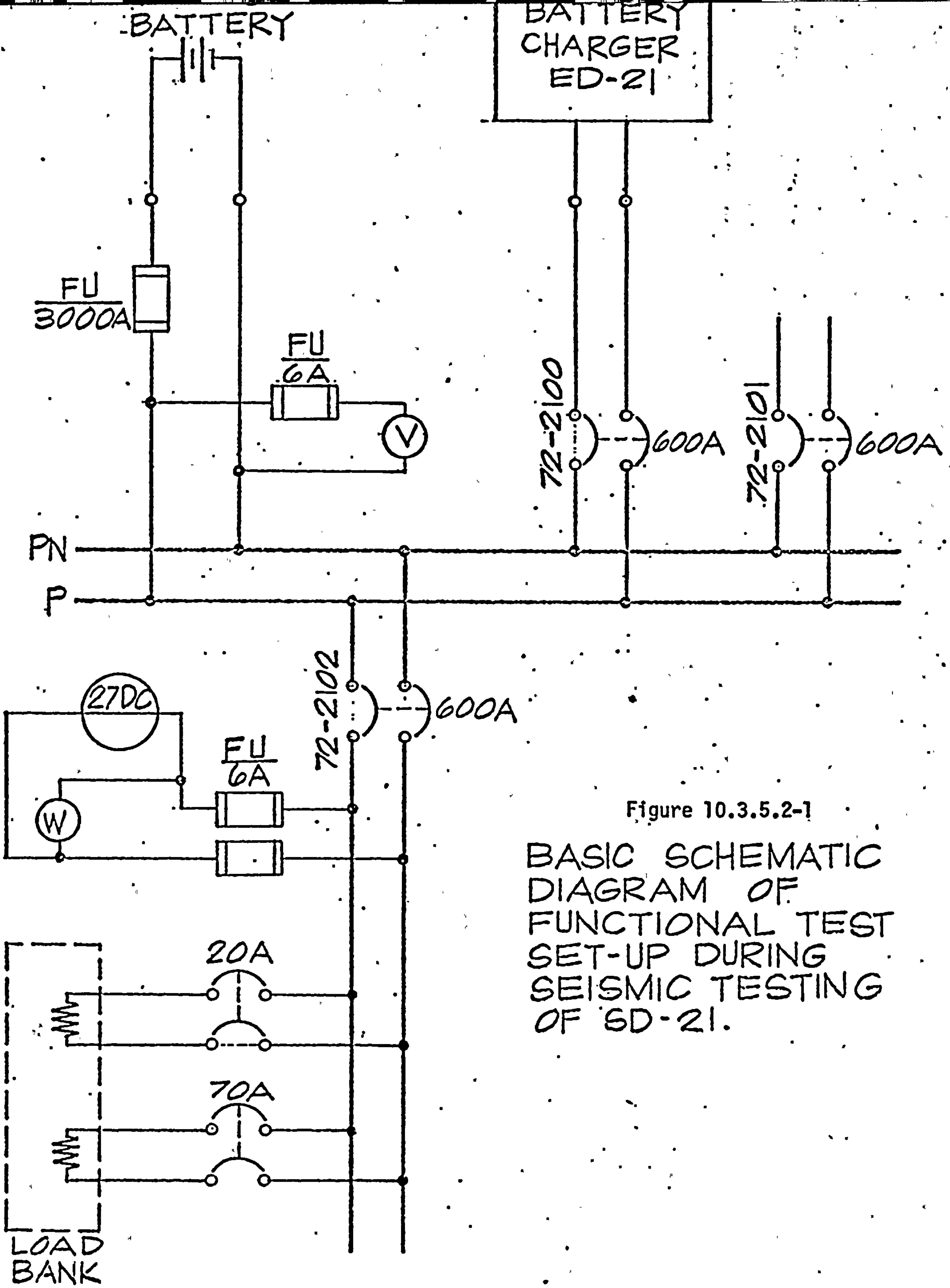


Figure 10.3.5.2-1

BASIC SCHEMATIC DIAGRAM OF FUNCTIONAL TEST SET-UP DURING SEISMIC TESTING OF SD-21.

Table 10.3.5.2-1

		SWITCH, RELAY POSITION, OR CONTACT O=OPEN C=CLOSED															
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE			
	SW. NO.	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y		
.T.E. BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
INALS	17 & 18	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
INALS ALARM	19 & 20	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
INALS	21 & 22	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
	2 & 3	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
T.E.	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
CURRENT TERMINALS	5 & 6	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
INALS	9 & 10	O	O	O	O	O	O	O	O	O	O	O	O	O	O		
INALS	15 & 16	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
T.E.	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
T.E.	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
	VDC	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~	132 ~~125~~		2
LT	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON		

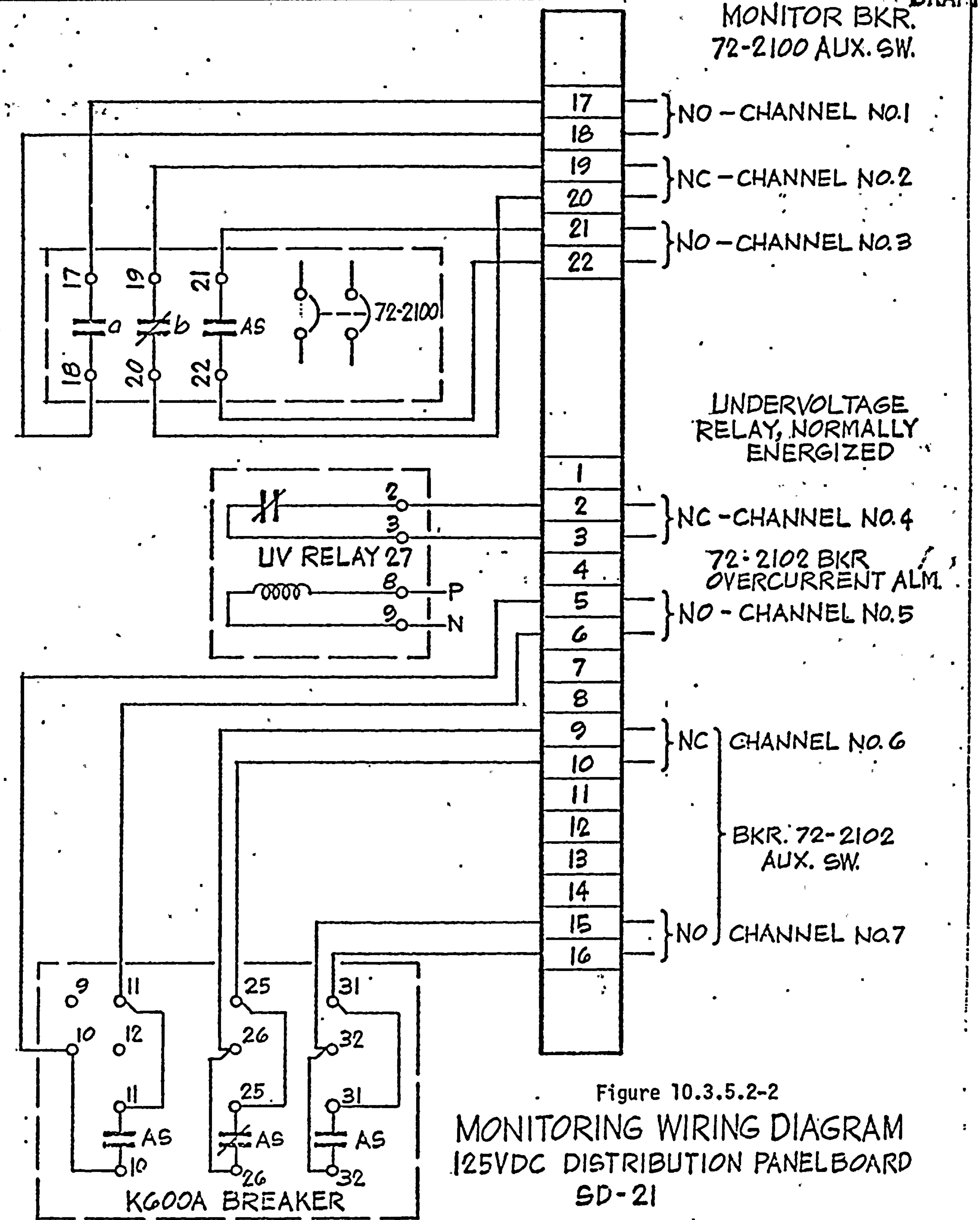


Figure 10.3.5.2-2

MONITORING WIRING DIAGRAM
125VDC DISTRIBUTION PANELBOARD
SD-21

Channels shown are chatter-detector channels.

(Battery Charger)

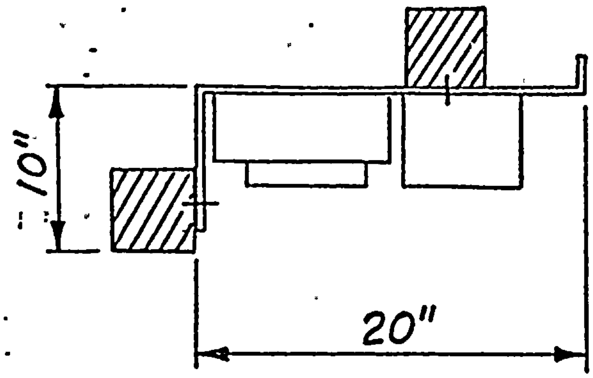
3. The 125 VAC failure relay PLR-1, was seismically tested with the charger nergized, and the normally closed contact picked up in its normal operating position of normally open. The seismic tests did not cause this contact to chatter shut to give false indication of a loss of A.C. power, nor did the contact close to indicate 480/120 VAC power failure.
4. During the seismic testing the 125 VAC Manual Control Relay did not chatter, and thus did not cause the battery charger to switch from automatic to manual control. The 125 VAC Manual Control Switch did not move from the Charger on Automatic Control position.
5. The 125 VDC low voltage relay, LVRA, did not change state to indicate a loss of 125 VDC output. N.O. contacts which are closed when the charger is operating, did not chatter nor did they open to indicate loss of 125 VDC output. Table 10.3.3-1 shows the functional performance of these devices during seismic testing.
6. All left front door indicating lights showed proper indication for all conditions. On when required to be on, and off when required to be off.
7. On all energized tests the charger ammeter showed a continuous output of 60 amperes.
8. On all energized tests the charger voltmeter read 132 volts continuously.
9. On all de-energized tests the charger voltmeter read 125 VDC, the Wyle Battery Voltage, and the charger ammeter read 0 amperes.

10.3.3.7 Conclusions

Battery charger ED-21 from Diablo Canyon Unit 2 was tested by a multi-axis multi-frequency seismic simulation described in Wyle Report Number 58255, April 19, 1978, pp. 288-293. This battery charger is identical to the other nine battery chargers installed in Diablo Canyon Units 1 and 2. The test results described in section 10.3.3.6 above demonstrate that the test criteria of section 10.3.3.4 are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. On this basis the Diablo Canyon Units 1 and 2 battery chargers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100.

BATTERY CHARGER - TABLE 10.3.3-1 *Amend. 2 10/26/78*

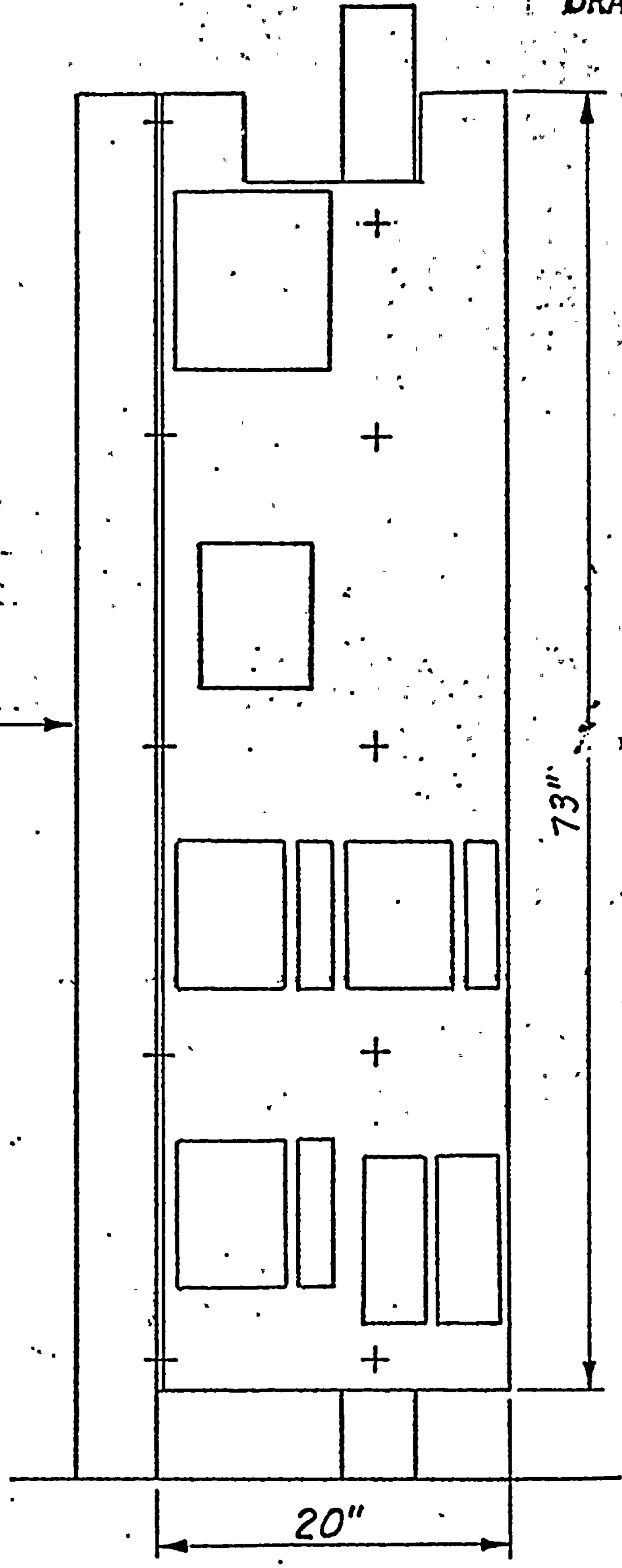
		SWITCH, RELAY POSITION OR CONTACT O=OPEN C=CLOSED															
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE		3RD SSE	
DEVICE	SW. NO.	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y
52-21 I.T.E. FJ3-B175	BKR	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
72-21 I.T.E. KM-2-B500	BKR	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
PLR-1 125 VAC FAILURE RELAY	N.C.	C	C	C	C	C	C	0	0	0	0	0	0	0	0	C	C
	N.O.	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
PLR-2 125 VAC FUSE FAIL. RELAY	N.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N.C.	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
MCR, ROWAN TYPE E 125 VAC	N.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N.C.	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
27-DC 21 LVRA	N.O.	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
BATTERY CHARGER AMMETER	MONITORED VISUALLY	0	0	0	0	0	0	60 Amps	60 Amps	60 Amps	60 Amps	60 Amps	60 Amps	60 Amps	60 Amps	0	0
BATTERY CHARGER VOLTMETER	MONITORED VISUALLY	125 VDC	125 VDC	125 VDC	125 VDC	125 VDC	125 VDC	132 VDC	132 VDC	132 VDC	132 VDC	132 VDC	132 VDC	132 VDC	132 VDC	125 VDC	125 VDC



TOP

TEST SPECIMEN BOLTED TO FIXTURE

FIXTURE 4" TUBING



GROUP IV
125-250VDC M.C.C.
TURBINE LUBE OIL STARTER

AMEND NO. 2

Intake Str. Item A3 (Supplement)
SER #7, 3.8.5.4.4 (2)
October 4, 1978

#25

Beraroya

Docket #50-275/323
Control #7811290460
Memo Date 11-22-78 of Document
REGULATORY DOCKET FILE
Memo to Stolz frm Allison

RETURN TO REACTOR DOCKET FILES

DIABLO CANYON UNITS 1 & 2
INTAKE STRUCTURE
PATHWAY TO ASW PUMPS

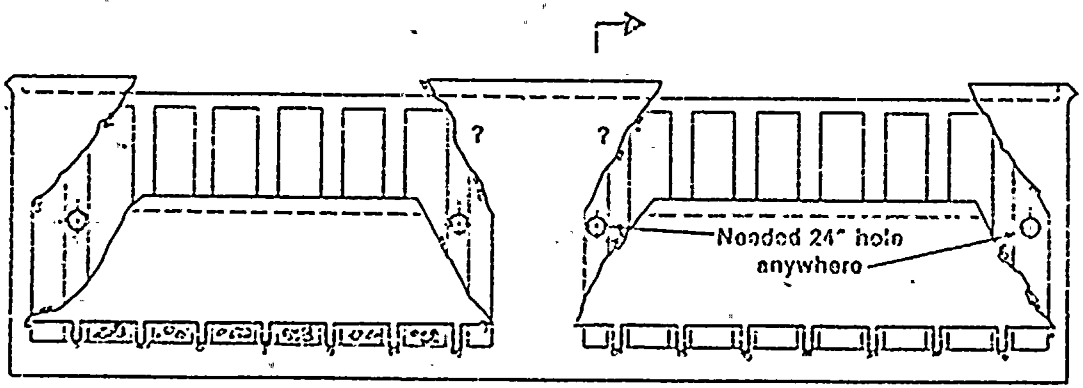
The auxiliary salt-water system is described in FSAR 9.2.1 and the intake is shown in Figure 9.2-2.

Piers supporting curtain wall are overstressed. The consequences of this are nil from several viewpoints. The attached sketch shows some possible modes of extreme collapses of wall. Our conclusion is that there is insufficient volume of concrete to plug all pathways to pumps. Some factors to support this conclusion are:

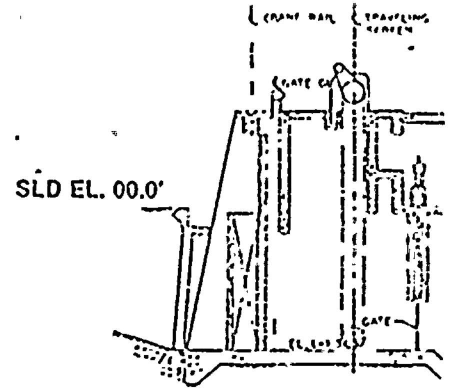
1. A Guillotine-type drop of the curtain wall would have to seal like a gate for the entire face of the intake (over 200 ft. in length). An equivalent area of a 24" pipe/unit in 6,000 ft.^{2} of face is all that is required. The back-flush effect of the water in the main cooling water lines above sea level (ten times the sea water volume in the intake) will clear face.

2. A Rubble-mound type plug would have to fill the entire auxiliary salt-water bay and have a porosity of less than coarse sand (0.4 - 3cm per second). This is not possible since there is insufficient volume of concrete involved.

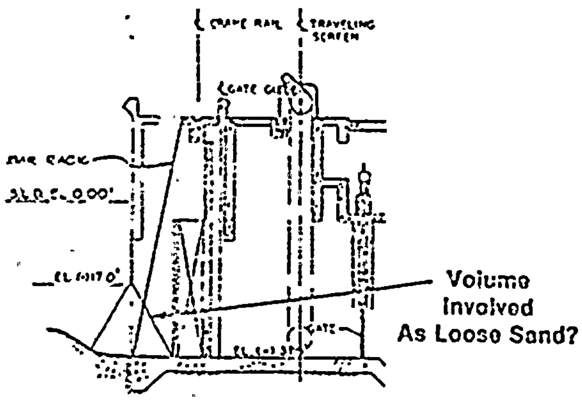
3. Domino effect of wall collapsing bar rack, which hits traveling water screens, will be retained or deflected by walls of gate well. While it is possible for debris to get into pump bay, the pump bell is 8.5 ft. above the bottom and near the back wall. Approach velocities are less than 1 ft/sec. Thus, turbulant suspension of debris large enough to damage empellor is not possible.



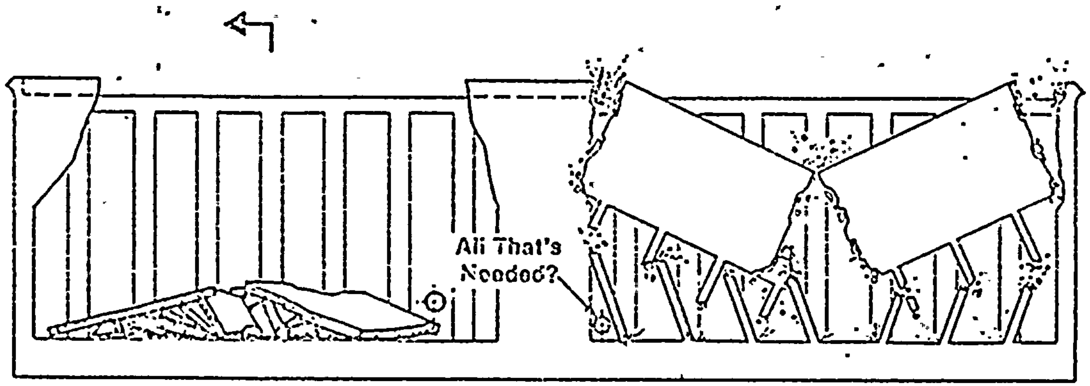
ELEVATION
FACE OF INTAKE



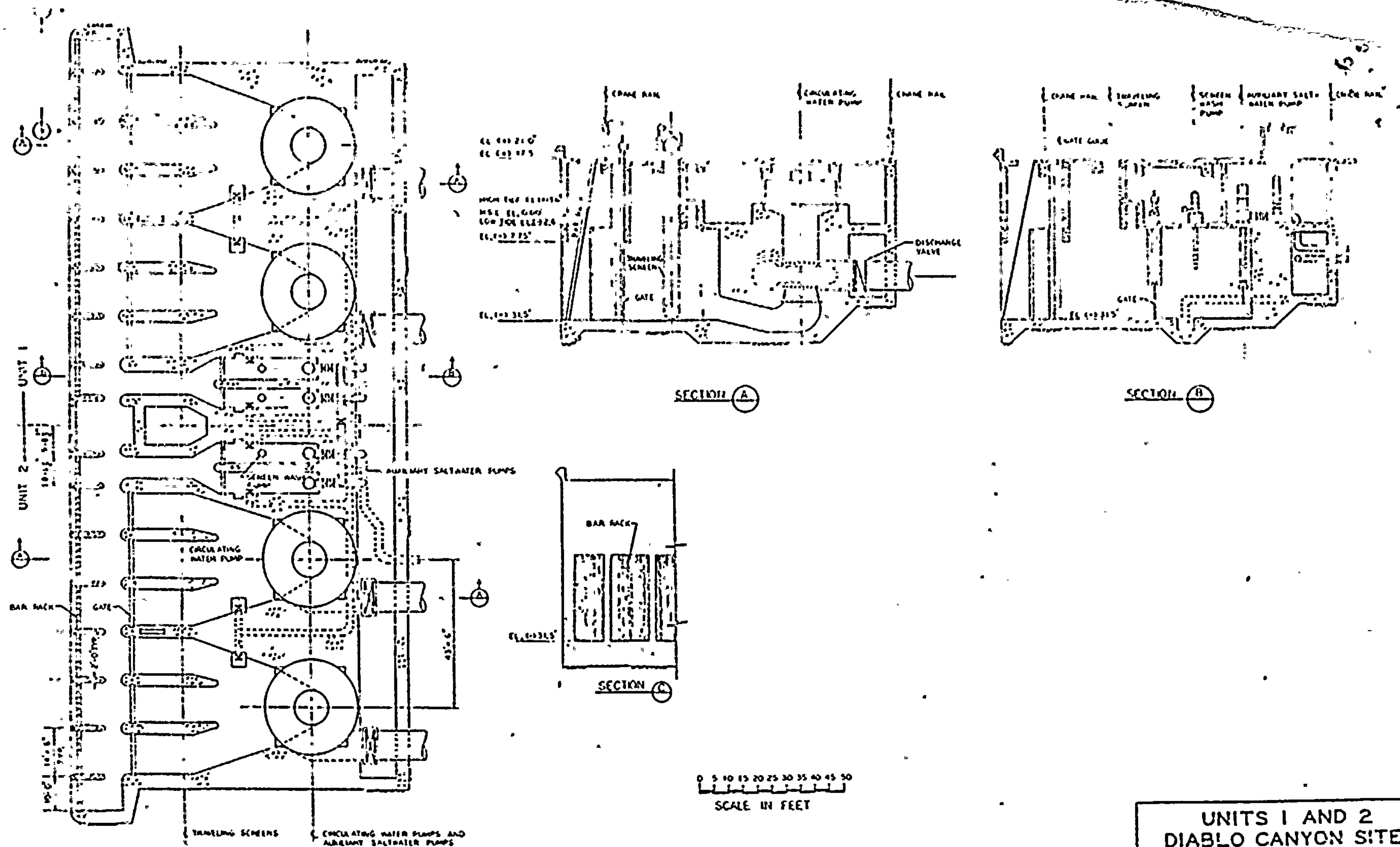
SECTION



SECTION

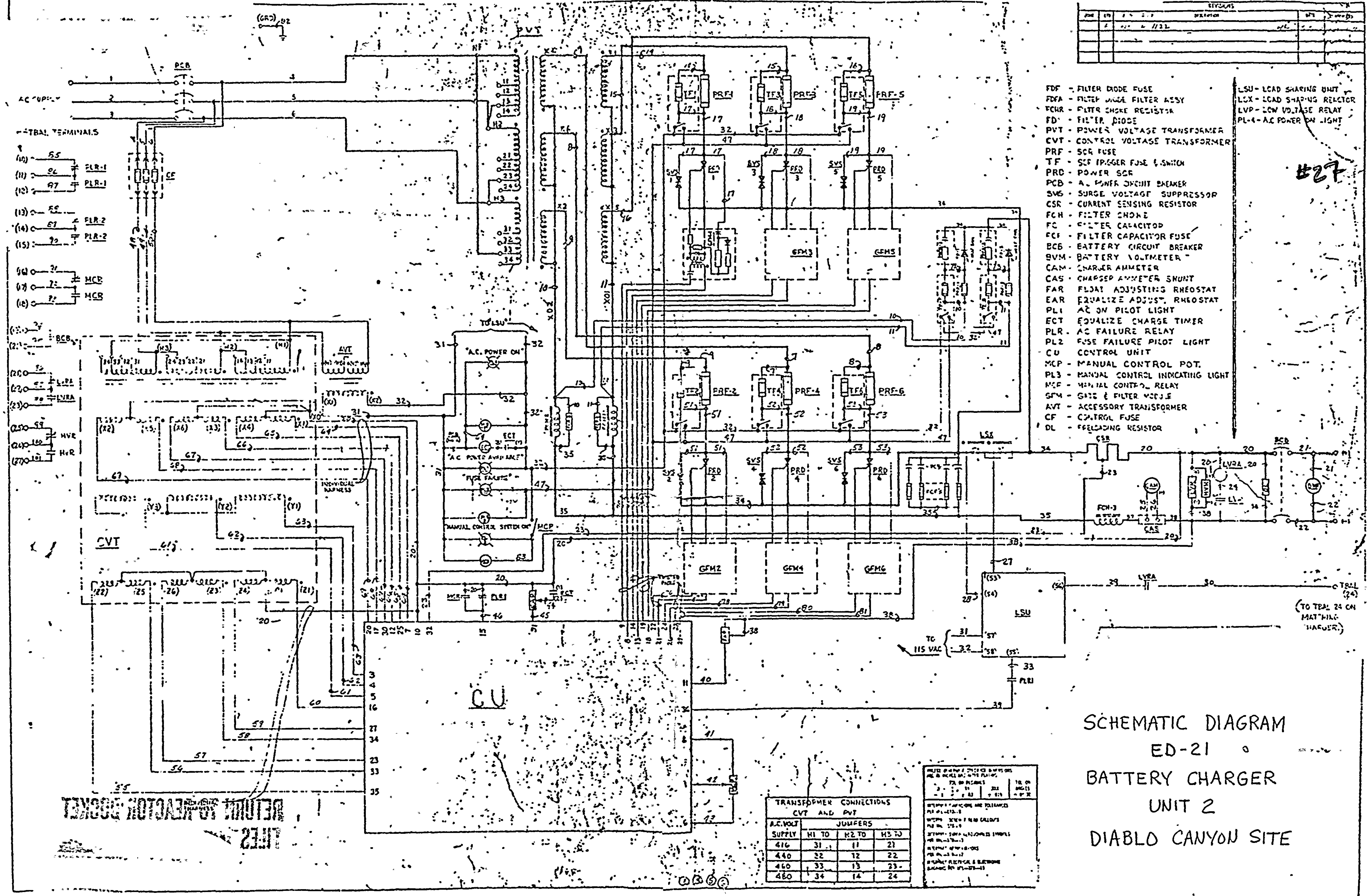


ELEVATION
FACE OF INTAKE



UNITS 1 AND 2
DIABLO CANYON SITE

FIGURE 9.2-2
ARRANGEMENT OF INTAKE STRUCTURE



FDF - FILTER DIODE FUSE
FDFA - FILTER DIODE FILTER ASSY
FCHR - FILTER CHOKE RESISTOR
FD - FILTER DIODE
PVT - POWER VOLTAGE TRANSFORMER
CVT - CONTROL VOLTAGE TRANSFORMER
PRF - SCR FUSE
TF - SCR TRIGGER FUSE & SWITCH
PRD - POWER SCR
PCB - AC POWER CIRCUIT BREAKER
SVS - SURGE VOLTAGE SUPPRESSOR
CSR - CURRENT SENSING RESISTOR
FCH - FILTER CHOKE
FC - FILTER CAPACITOR
FCF - FILTER CAPACITOR FUSE
BCB - BATTERY CIRCUIT BREAKER
BVM - BATTERY VOLTMETER
CAM - CHARGER AMMETER
CAS - CHARGER AMMETER SHUNT
FAR FLOAT ADJUSTING RHEOSTAT
EAR EQUALIZE ADJUST. RHEOSTAT
PL1 AC ON PILOT LIGHT
ECT EQUALIZE CHARGE TIMER
PLR - AC FAILURE RELAY
PL2 FUSE FAILURE PILOT LIGHT
CU CONTROL UNIT
MCP - MANUAL CONTROL POT.
PL3 - MANUAL CONTROL INDICATING LIGHT
MCR - MANUAL CONTROL RELAY
GFM - GATE & FILTER MODULE
AVT - ACCESSORY TRANSFORMER
CF - CONTROL FUSE
DL - FEELOADING RESISTOR

LSU - LOAD SHARING UNIT
LSX - LOAD SHARING REACTOR
LVP - LOW VOLTAGE RELAY
PL-4 - AC POWER ON LIGHT

TRANSFORMER CONNECTIONS
CVT AND PVT

A.C. VOLT SUPPLY	JUMPERS H1 TO	H2 TO	H3 TO
416	31	11	21
440	32	12	22
460	33	13	23
480	34	14	24

SCHEMATIC DIAGRAM
ED-21
BATTERY CHARGER
UNIT 2
DIABLO CANYON SITE

Memo to J F Stolz from DP Allison
Encl. #27

Devices from the subpanel were connected to appropriate power sources and monitored per attachment "G." The devices are listed in Attachment "H."

10.3.6.6 Test Results

The test specimens demonstrated their abilities to withstand without compromise of structure or safety functions the simulated seismic environment of seismic random biaxial motion performed to the required response spectra. The output field current was visually monitored and did not fluctuate during the test sequences.

10.3.6.7 Conclusion

One Diesel Generator Excitation Cubicle and pertinent parts of the Control Cabinet of Diablo Canyon Unit 2 were seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report Number 58255, dated April 19, 1978. The equipment contained devices representative of the contents of all Diablo Canyon Unit 1 and 2 Diesel Generator Control. Thus qualification will apply to all Diesel Generator Exitation Cubicles and Diesel Generator Control Cabinets.

The test results presented in section 10.3.6.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 Diesel Generator Exitation and Control Equipment are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

DRAFT

#24

ROUGH DRAFT
10-31-78 2:43 pm
P.S.T.

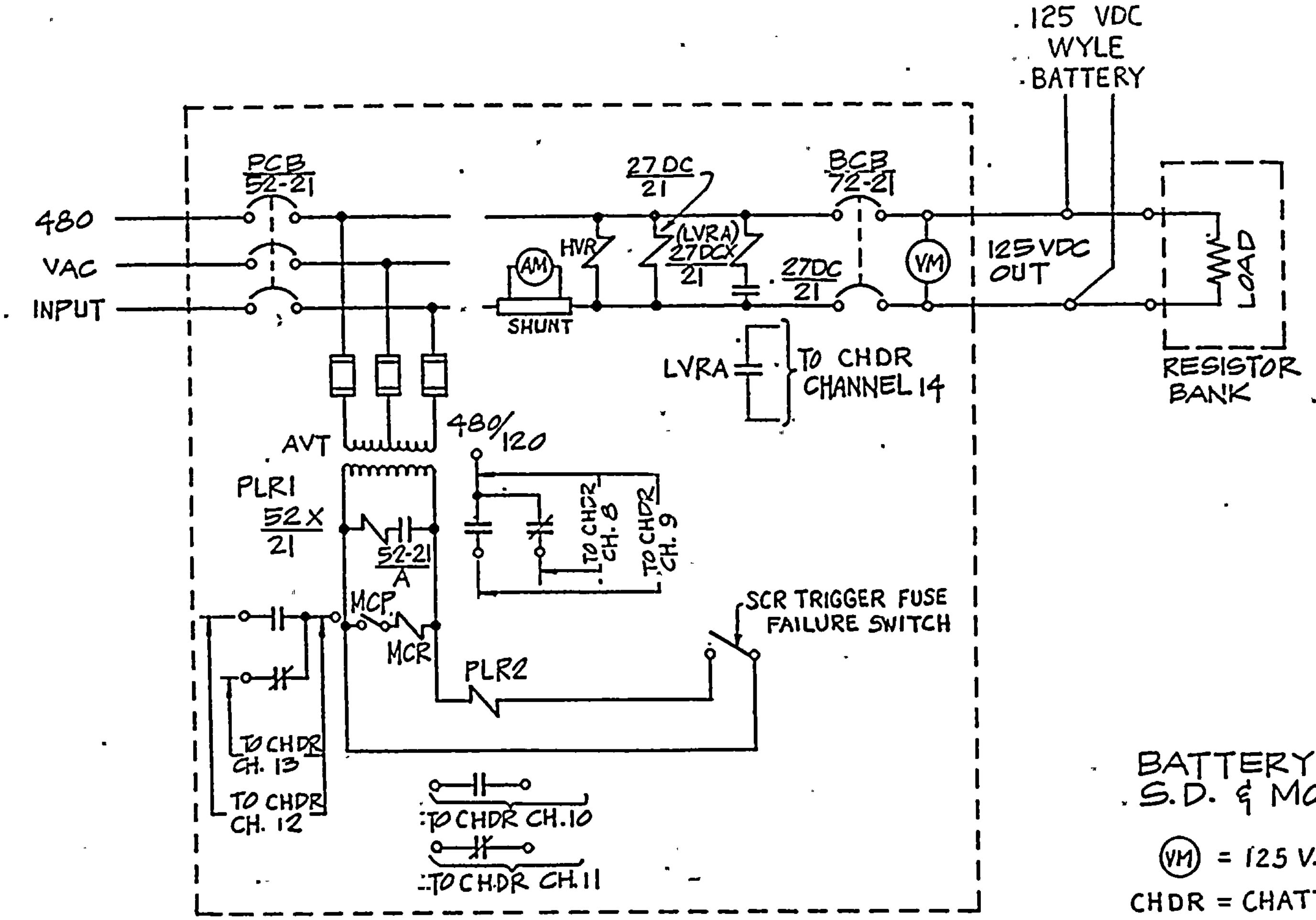
10.3.11 Instrument Power AC Panelboards

The instrumentation power panelboards (AC) are mounted on reinforced concrete walls five feet above the 115 ft. floor elevation of the Auxiliary Building. The panelboards were previously qualified for DDE accelerations (at the average elevation of 120 ft.) of 1.19g east-west, 1.41g north-south and 0.27g vertical. (The front-to-back direction is north-south.)

In March 1976, the P.G.& E. Department of Engineering Research, in situ tested one of the Instrument Power AC Panelboards, PY-22, (DER Report 7333.141-76), and determined that the panelboard (as a whole) and the panelback (as a component) have no natural frequency below 33Hz, and that the mounting plate (above the breaker assembly) has a resonance frequency of 30 Hz. This mounting plate has been modified on all panelboards with horizontal centerline supports to the back panel per the recommendations in the above report. The circuit breaker assembly has no resonance below 33 Hz. Therefore, the circuit breakers would be subjected to the unamplified accelerations of the wall on which the panelboard is mounted. The wall mounting can resist up to 18g acceleration in any direction.

For the Hosgri 7.5M event, at the Instrument AC Power Panels, the floor accelerations are: 0.92g Horizontal and 0.56 g Vertical. At a wall location 5 ft. above the floor at 115' Elevation these accelerations would be 1.00 g and 0.6 respectively.

In April 1975, Wyle Laboratories tested a single pole and a two-pole circuit breaker identical to those used in these Instrument AC Power Panels (Wyle Laboratory report No. 53744-2). ZPA of these tests were (on the average) 2.8g horizontal and 1.5g vertical, applied simultaneously. The circuit breakers were monitored electrically during the Wyle tests and did not chatter or malfunction. For these reasons it can be concluded, that the Instrument Power AC Panelboards are qualified for a postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.



2

DRAFT

BATTERY CHARGER ED-21
S.D. & MONITORED CHANNELS

(VM) = 125 V. DC VOLTMETER
CHDR = CHATTER DETECTOR
(AM) = DC AMMETER
HVR = HIGH VOLTAGE RELAY

2

AMENDMENT NO. 2

#21

SENSITIVITY OF THE NONLINEAR COMPONENT
TIME HISTORY ANLAYSIS TO THE
TIME HISTORY BASE INPUT

The time history used for the analysis of CRDM and fuel elements are based on building time history response from input applied at its base. The building motion is predominately controlled by its fundamental mode at 13.89 Hz (the interior concrete of the containment building). This falls within the important frequency range of the modes of these components (i.e., 2 to 20 Hz). The building actually filters and amplifies the base input motion over this frequency range. Since the building model is linear and the base input time history is random, its dynamic response is a function of the building dynamic characteristics. Consequently, in the frequency range of 2 to 20 Hz the building response motion should not be affected by different time history input which matches the Hosgri response spectra. Therefore, there should not be any significant effect to the component nonlinear time history analysis results if another time history input consistent with the Hosgri spectra at the base is used as input.

In addition, the Hosgri response spectra are smoothed, based on several actual earthquake records. There is extremely low probability that any future earthquakes affecting Diablo Canyon Plant would have response spectra reaching the Hosgri magnitude for all frequencies within the frequency range of interest (i.e., 2 to 20 Hz). The input time history at the base is generated to match the Hosgri response spectra with limited number of points falling slightly below the smoothed Hosgri spectra. Therefore, since the time history envelopes the Hosgri response spectra, any time history resulting from a potential earthquake with equal or less magnitude will have a response spectra that is enveloped by the Hosgri spectra. There is no need to further consider any input variations.

Finally, given the stress margins the components have maintained, and the large magnitude they have qualified for the DDE condition as discussed in Amendment 50 to the FSAR, the use of a different base time history input should not have any material effect on the conclusions reached for these components.

3.8.5.4.1(3)

Docket # 50-275/323
Control # 7811290460
Memo Date 11-21-78 of Document
REGULATORY DOCKET FILE
Memo to Stolz fm Allison

#22

HOSGRI RE-EVALUATION OF DIABLO CANYON
CONTAINMENT BASE MAT (ITEM A7)

General Description

Containment base mat is a 14'-6" thick circular reinforced concrete slab. The center portion around the reactor pit has a depth of 36'-0". Reinforcing has been placed in two perpendicular directions (E-W, N-S) and arranged such that the walls of the reactor pit form a grid of four main girders. The base mat and reinforcing steel is shown in Figures 1 and 2.

The base mat was originally evaluated for the Hosgri earthquake on a load comparison basis. The overall loading in the governing Hosgri and LOCA combination is only 2.6% greater than the loading used in the original DDE + LOCA analysis. Thus, on the load comparison basis, the 17% increase in allowable reinforcing stress resulting from the use of actual material strength is adequate to accomodate the 2.6% load increase due to the Hosgri earthquake.

Hosgri Analysis

A detailed analysis of the containment base mat has been performed using the SAP IV program, considering the Hosgri loads in combination with other applicable loads. The load combinations analyzed were:

a) Dead load + LOCA + Horizontal seismic + Vertical seismic up
This combination produces the maximum positive moments.

b) Dead load + Horizontal seismic + Vertical seismic down
This condition produces the maximum moments.

Analytical Model

The analytical model consists of a grid of orthgonal beams as shown in Figure 3, each representing a corresponding strip of slab and reinforcing identified on construction drawings. (See Figure 3). The containment shell and crane wall are represented as beams with increased bending stiffness to model the effect of wall depth.

The foundation is represented by compressive spring elements (no tensile stiffness). Each spring stiffness is based on tributary area of foundation it represents. This model represents a refinement of the simplified model used in a previous submittal dated September 29, 1978 which gave the results for load combination b).

Results

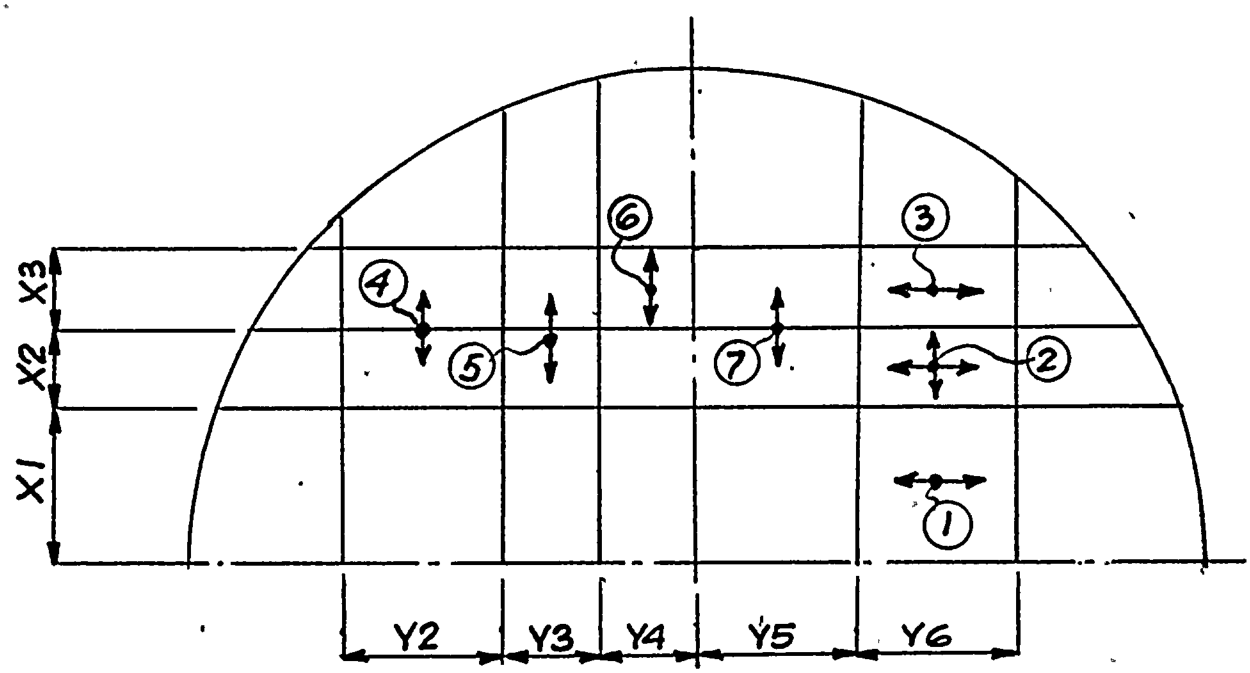
1) Maximum positive moments are due to load combination a). These moments are given in Table 1. All moments are within the acceptance limits in Chapter 4 of the Hosgri Seismic Evaluation Report.

2) Load combination c) controls negative moments. The refined model gives a 6% reduction of negative moments - from 1530 k-ft/ft to 1439 k-ft/ft - the latter value is 3% below the acceptance limit.

TABLE I

CONTAINMENT BASE MAT - MAX. POSITIVE MOMENTS AT CRITICAL SECTIONS

LOCATION	MAX. BENDING MOMENT - 10^5 K-FT	ALLOWABLE MOMENT - 10^5 K-FT
STRIP X1 ①	4.11	4.15
STRIP X2 ②	1.19	1.27
STRIP X3 ③	.75	.83
STRIP Y2 ④	2.71	3.10
STRIP Y3 ⑤	1.39	1.58
STRIP Y4 ⑥	1.57	1.65
STRIP Y5 ⑦	4.00	4.13
STRIP Y6 ②	2.12	2.20



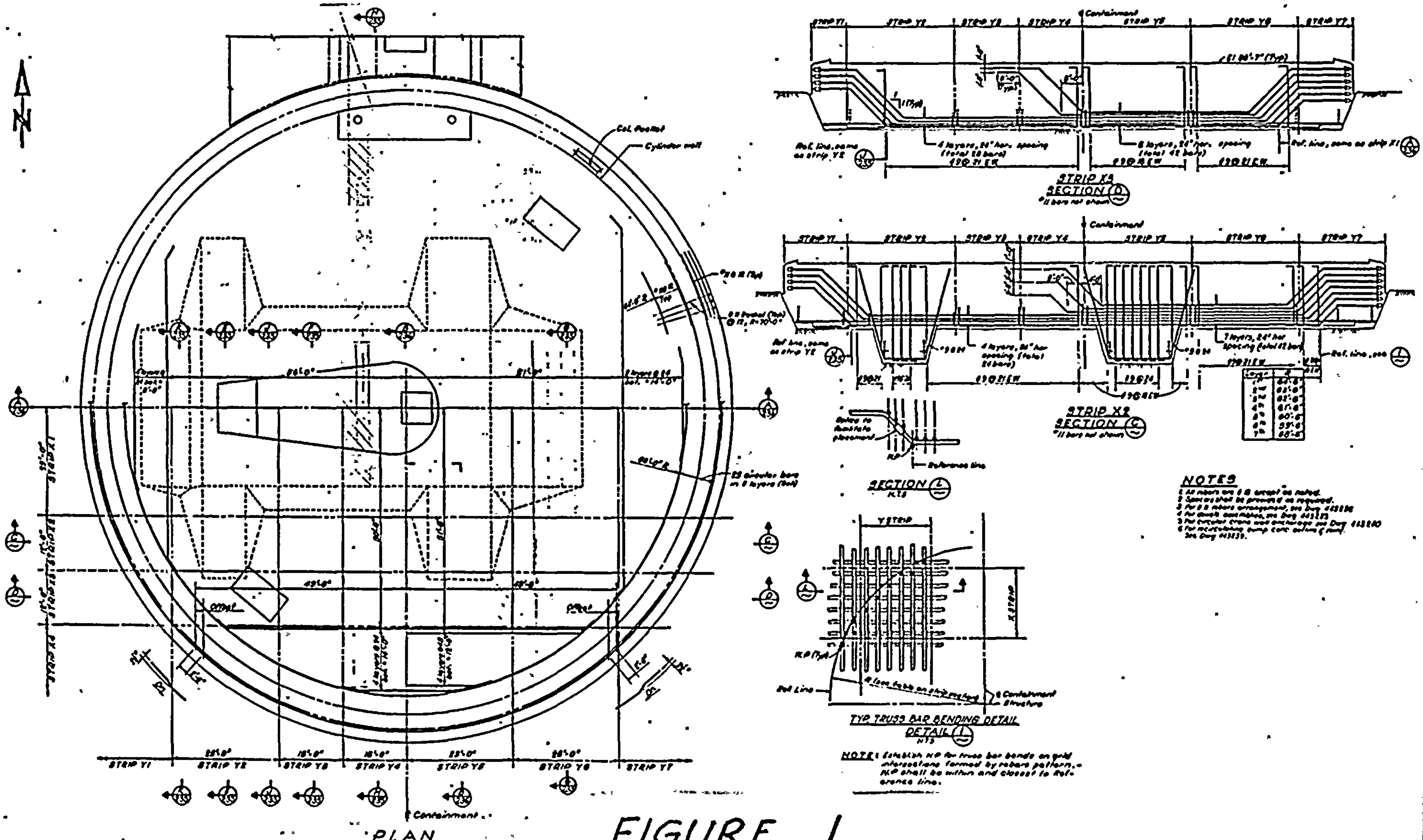

PLAN
STRIP X3
SECTION
STRIP X2
SECTION
NOTES
TYP TRUSS BAR BENDING DETAIL
DETAIL
STRIP Y1
STRIP Y2
STRIP Y3
STRIP Y4
STRIP Y5
STRIP Y6
STRIP Y7
Containment
Cylinder wall

FIGURE 1

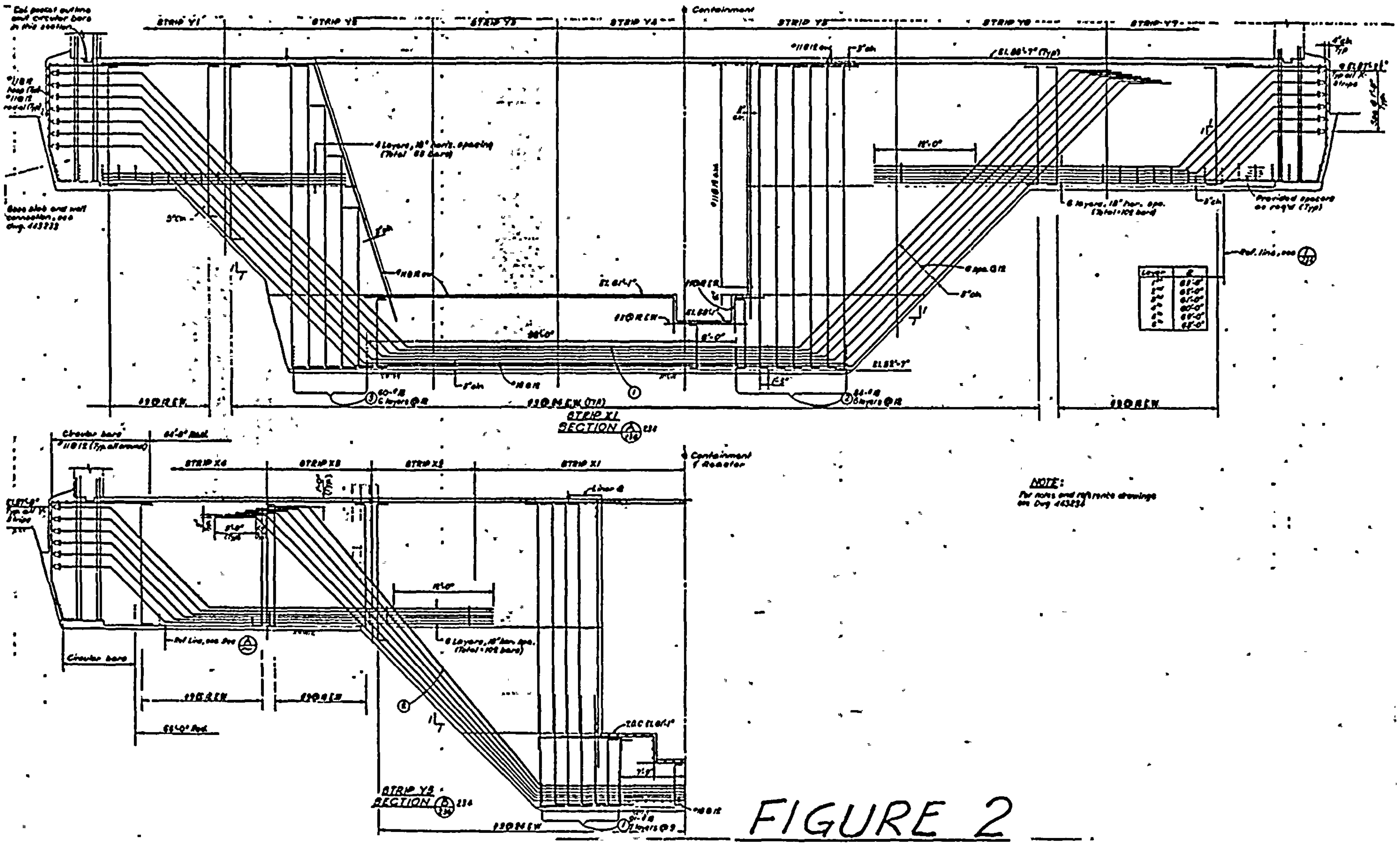
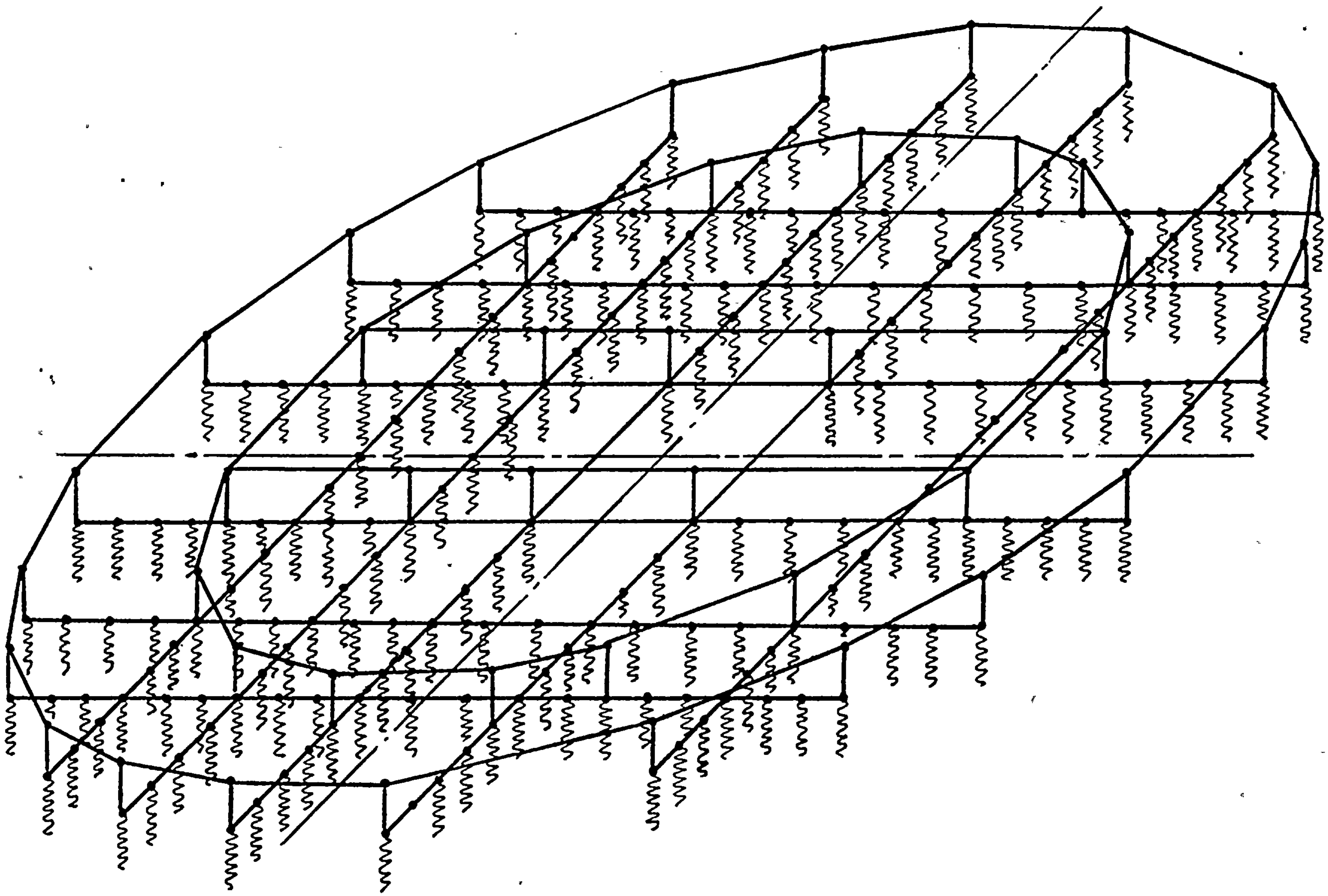


FIGURE 2



CONTAINMENT BASE MAT - ANALYTICAL MODEL

FIGURE 3

62-4713 3/65 3.8.5.4.7 A-22A-3

PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 1 OF ___ SHEETS
JOB FILE NO. ___
LOCATION #23

SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 7 SEPT 78 CHECKED BY JV APPROVED BY ___

DESIGN OF ANCHOR BOLTS

$$\text{FORCE IN BOLTS} = \frac{2\ (\text{OVERTURNING MOMENT})}{(\text{NO. OF BOLTS})\ (\text{TANK RADIUS @ BOLTS})}$$

USE VSL ER5-28 28 STRAND

$$\text{NO. OF BOLTS REQ} = \frac{2\ (198{,}122\ \text{K-FT})}{(693.8)\ \ 22^{FT}} = 26\ \text{BOLTS}$$

46 PROVIDED — OK

$$F.S. = \frac{46}{26} = 1.8$$

BOLT INFO:

WORKING FORCE = $0.6 f_s'$ = 693.8

MAX TEMP. FORCE = $0.8 f_s'$ = 925.1

f_s' = 1156 K ULT

f_y = 35.1 K (28) = 982.8 K

Memo to Stolz frm Allison

VERIFY FORMULA USED TO CHECK TENSION IN ANCHOR BOLTS

USED TO DETERMINE NO. OF ROCK ANCHORS

$$fb = \frac{2M}{NRAb}$$

where

M = Tank overturning moment

R = Tank radius

N = Number of bolts.

Ab = Bolt cross sectional area

f_b = Bolt tension stress

Axial Tension in tank shell due to M.

$$fs = \frac{M}{Z}$$

where

$Z = \pi R^2 t$ = shell section modulus

t = shell thickness then $f_s = \dfrac{M}{\pi R^2 t}$

The cross sectional area of all the bolts is equivalent to the shell cross sectional area or:

$$Asfs = NAbfb$$

but $As = 2\pi Rt$

therefore

$$fs = \frac{NAbfb}{2\pi Rt}$$

then

$$\frac{M}{\pi R^2 t} = \frac{NAbfb}{2\pi Rt}$$

therefore

$$fb = \frac{2M}{NRAb}$$

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PACIFIC GAS AND ELECTRIC COMPANY

SHEET NO. 1 OF ___ SHEETS

GENERAL COMPUTATION SHEET

JOB FILE NO. ___

LOCATION ___

SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 19 SEPT 78 CHECKED BY JL APPROVED BY ___

PRESTRESS ROCK ANCHORS

BASE SHEAR = 6662 K (F.S. = 1.1)

— DOWNHILL SLIDING IS WORST CONDITION —

ASSUMED AREA OF CONCRETE = $\pi(23')^2$ = 1662 FT^2

TANK SHELL WEIGHT = 154 K

CONC WEIGHT :

$40'\pi(25')\frac{2}{3}(0.15)$ = 314 K

$40'\pi(25')(0.15)$ = 471 K

$\pi(20')^2\frac{2}{3}(0.15)$ = 126 K

911 K

NO WATER (FOR WORST CONDITION)

TANK FDN & CONC. FILL

AVG. DEPTH ASSUMED @ EL 111'-0" (UNIT 2)

$\pi(23')^2 \cdot 4.5'(0.15)$ = 1122 K

TOTAL WEIGHT TO BEDROCK = 2187 K

w/ 0.5 g = 1094 K

ASSUME CONC - BEDROCK STATIC FRICTION = 1.0

AMOUNT OF BASE SHEAR TAKEN BY STRUCTURE WEIGHT:

$= 1.0 (1094^k) = 1094^k$

AMOUNT OF BASE SHEAR TAKEN BY ROCK ANCHOR LOAD:

$= 6662 - 1094^k = 5568^k$

REQUIRED PRELOAD PER ANCHOR:

USE ONLY 38 ROCK ANCHORS (NEGLECT COLS.)

LOAD PER ANCHOR $= \dfrac{5568^k}{38(\frac{1}{2})} \simeq$ **300 k/ROCK ANCHOR**

(WHERE ONLY ½ ARE ASSUMED IN COMP.)

CHECK ROCK SHEAR STRENGTH:

$S_u = 3\text{ ksf} + \dfrac{1094^k + 19(300^k)}{1662} \tan 30^\circ$

$= 5.36\text{ ksf}$

$V = 5.36 (1662\text{ ft}^2) = 8900^k > 6662$

∴ OK

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GENERAL COMPUTATION SHEET

SHEET NO. 3 OF ____ SHEETS

JOB FILE NO. ____

LOCATION ____

SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 19 SEPT 78 CHECKED BY [initials] APPROVED BY ____

ROCK ANCHORS MUST HAVE 300 K TENSION AT ALL TIMES.

IF WE ASSUME 20% PRESTRESS LOSS TO ALL SOURCES, ROCK ANCHORS MUST BE PRELOADED TO:

$300^{K}(1.20) \simeq 360^{K}$ / ANCHOR

CONSTRUCTION PROCEDURE:

1. LOAD EACH ANCHOR TO 360 K
2. COVER EACH ANCHORAGE HEAD W/ PVC CAP & ANTI-CORROSION GREASE.
3. IN 6 MONTHS, APPROX. 90% OF PRESTRESS LOSSES HAVE OCCURED. RELOAD AND SET AT MINIMUM OF 310 K
4. GROUT

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SHEET NO. 4 OF ____ SHEETS

GENERAL COMPUTATION SHEET

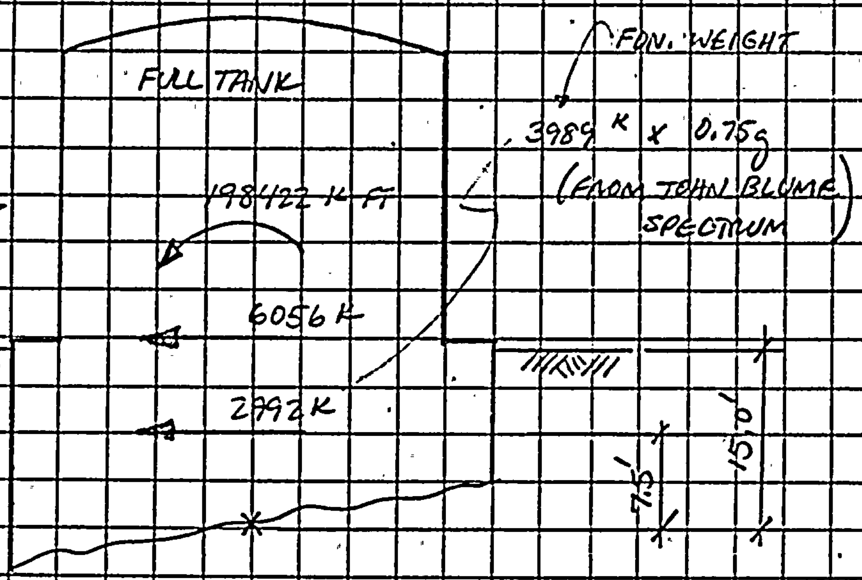
JOB/FILE NO. ____

LOCATION ____

SUBJECT: DIABLO CANYON STORAGE TANKS

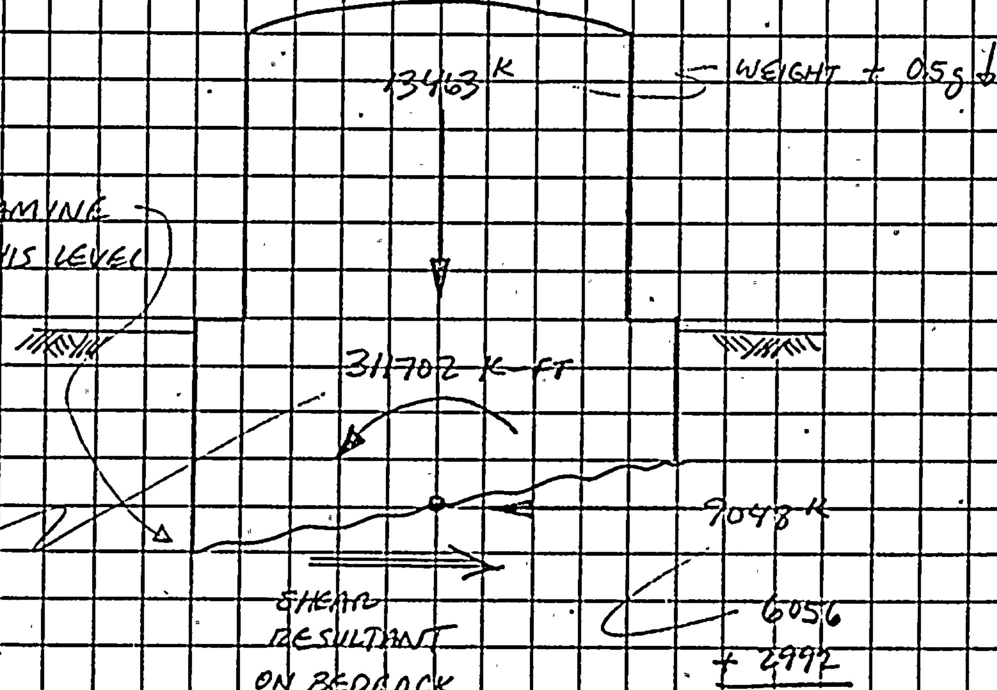
MADE BY: G. CARR DATE: 22 SEPT 78 CHECKED BY: J.L. APPROVED BY: ____

LOADS ON TANK & BASE



NO PASSIVE SOIL RESISTANCE IF SLIDING IS RESISTED BY SHEAR AT BEDROCK-CONC. INTERFACE

LOADS TRANSFERRED TO BEDROCK SURFACE



WE MUST EXAMINE STRESS AT THIS LEVEL

198422
+6056 x 15'
+2992 x 7.5'
311,702

6056
+2992
9048

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GENERAL COMPUTATION SHEET

SHEET NO. 5 OF ____ SHEETS
JOB FILE NO. ____
LOCATION ____

SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 22 SEPT 78 CHECKED BY Q.L. APPROVED BY ____

TANK SLIDING

WEIGHT OF TANK-BASE SYSTEM

STEEL TANK SHELL	= 154 K
CONC. " "	= 911 K
WATER = 50'(20')^2 π (0.0624)	= 3921 K
TANK FDN & CONC. FILL (UNIT 1). (23')^2 π (16') (0.150)	= 3989 K
TOTAL	= 8975 K
X 1.5g (FOR VERT. EQ. DOWN)	= 13463 K

WEIGHT W/OUT WATER = 5054 K

FIND ROCK ANCHOR PRELOAD TO RESIST SLIDING:

CONSIDER EARTHQUAKE UP & μ = 1.0 CONC. TO BEDROCK

WEIGHT REDUCED BY 0.5g ↑ = 4488 K

SLIDING RESISTANCE OF TANK WEIGHT = 1.0 (4488)
= 4488 K

BOLTS MUST PROVIDE 9048 - 4488 = 4560 K

REQ. FORCE / BOLT = $\frac{4560^K}{19 \text{ BOLTS}}$ = 240 K / BOLT

ACCOUNT FOR PRESTRESS LOSS: (20%)

PRELOAD = 1.2 (240) = 288 K / BOLT — USE THIS

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PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 6 OF ___ SHEETS

JOB FILE NO. ___

LOCATION ___

SUBJECT: DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 22 SEPT 78 CHECKED BY JL APPROVED BY ___

FIND STRESS IN CONC. & BEDROCK — (UNIT 1)

$$S_{CONC.FILL} = \pi \frac{R^3}{4} = \pi \frac{(23')^3}{4} = 9556\ FT^3$$

$$\sigma_b = \frac{M}{S} = \frac{311782\ K\text{-}FT}{9556\ FT^3} = 32.62\ KSF \quad (= 227\ PSI)$$

$$A_{BASE} = \pi (23')^2 = 1662\ FT^2$$

$$\sigma_{WEIGHT} = \frac{13463}{1662} = 8.10\ KSF \quad (= 56\ PSI)$$

$$\sigma_{BOLT} = \frac{4560^K}{1662\ FT^2} = 2.74\ KSF \quad (= 19\ PSI)$$

$\therefore$ MAX. STRESS = 227 + 56 + 19 = **302 PSI**

= (43.5 KSF)

BEDROCK CHARACTERISTICS:

WORKING LOAD = 33 KSF

FACTOR OF SAFETY = 3

HARDING LAWSON ASSOC.

$\therefore$ ULT. LOAD $\cong$ 100 KSF $>$ 43.5 KSF

$\therefore$ OK

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PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 7 OF ___ SHEETS

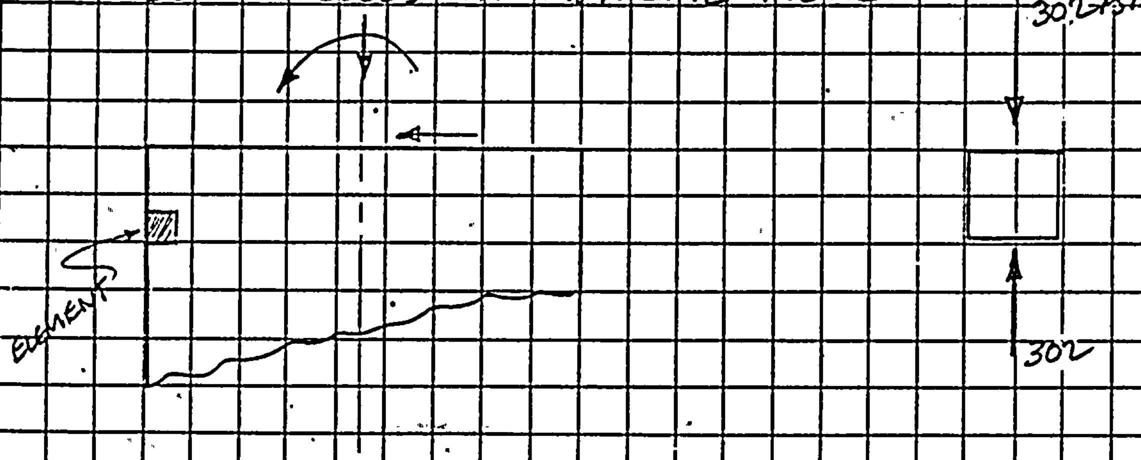
JOB / FILE NO. ___

LOCATION ___

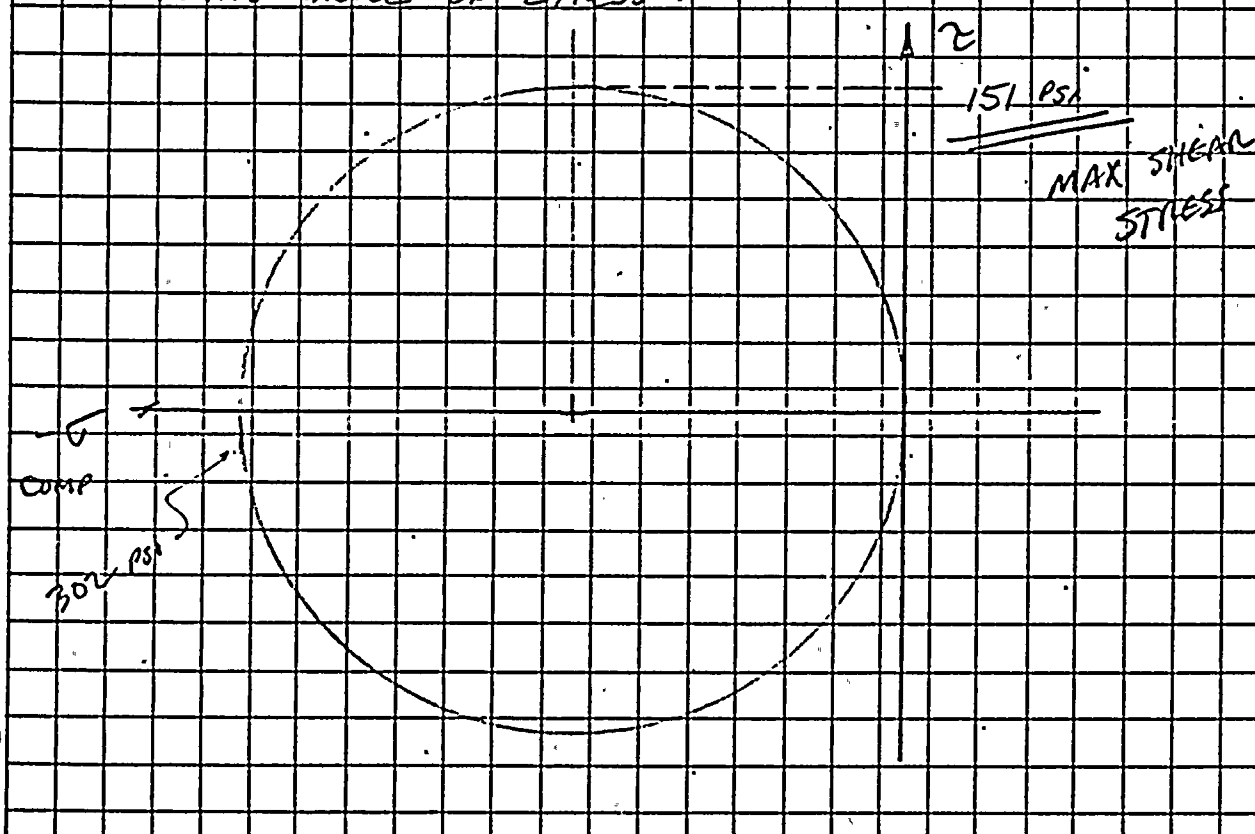
SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 22 SEPT 78 CHECKED BY [signature] APPROVED BY ___

CHECK STRESSES AT EXTREME FIBER:



MOHR'S CIRCLE OF STRESS:



SCALE: 1" = 100 PSI

USE 3000 PSI CONCRETE

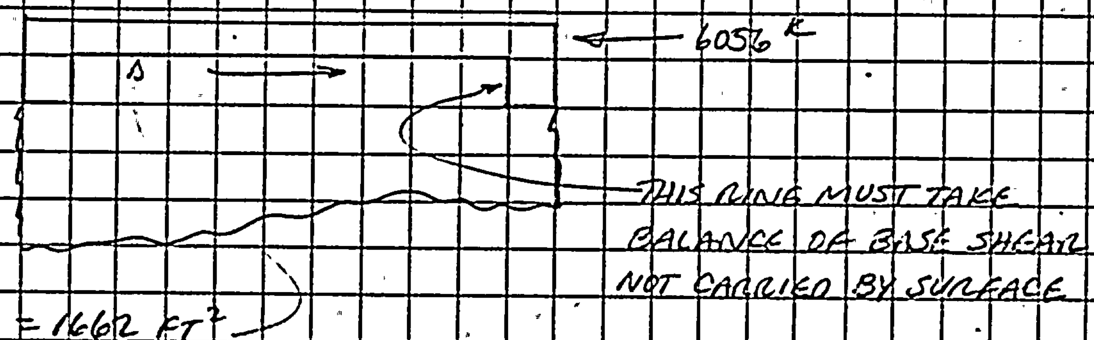
FACTOR OF SAFETY = 1.0

$v_c = 4\sqrt{f'_c} = 219 \text{ PSI} < 151 \text{ PSI}$ ∴ OK

(PUNCHING SHEAR VALUE)

SHEAR IN PLAIN CONCRETE: $= \dfrac{6056^k}{\pi (23')^2 144} = 25 \text{ PSI}$

CHECK SHEAR @ POUR INTERFACE TO OLD FDN:



WEIGHT ACTING DURING 0.5g $A = 0.5(8975) = 4487$ K

$\mu = 1.0$

BASE SHEAR CARRIED TO RING WALL = 6056 − 4487

= 1559 K

UNIFORM STRESS $= \dfrac{1559^k}{38' \times 3.5'} = 11.72$ KSF

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PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

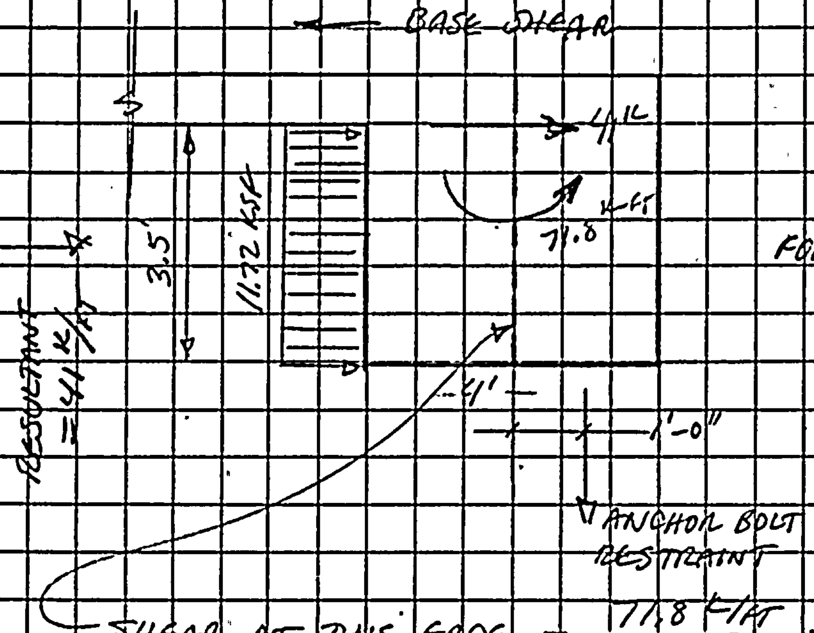
SHEET NO. 9 OF ____ SHEETS

JOB FILE NO. ____

LOCATION ____

SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 22 SEPT 78 CHECKED BY JL APPROVED BY ____



FORCES PER FOOT

FORCE/BOLT

= 71.8K x3 = 215.4 K

SHEAR AT THIS FACE = 71.8 K/FT / 4.5 FT = 16 K

BARS MUST DEVELOP 4.5 x 16 / 4 BOLT = 18 K #8 OK

GENERAL COMPUTATION SHEET

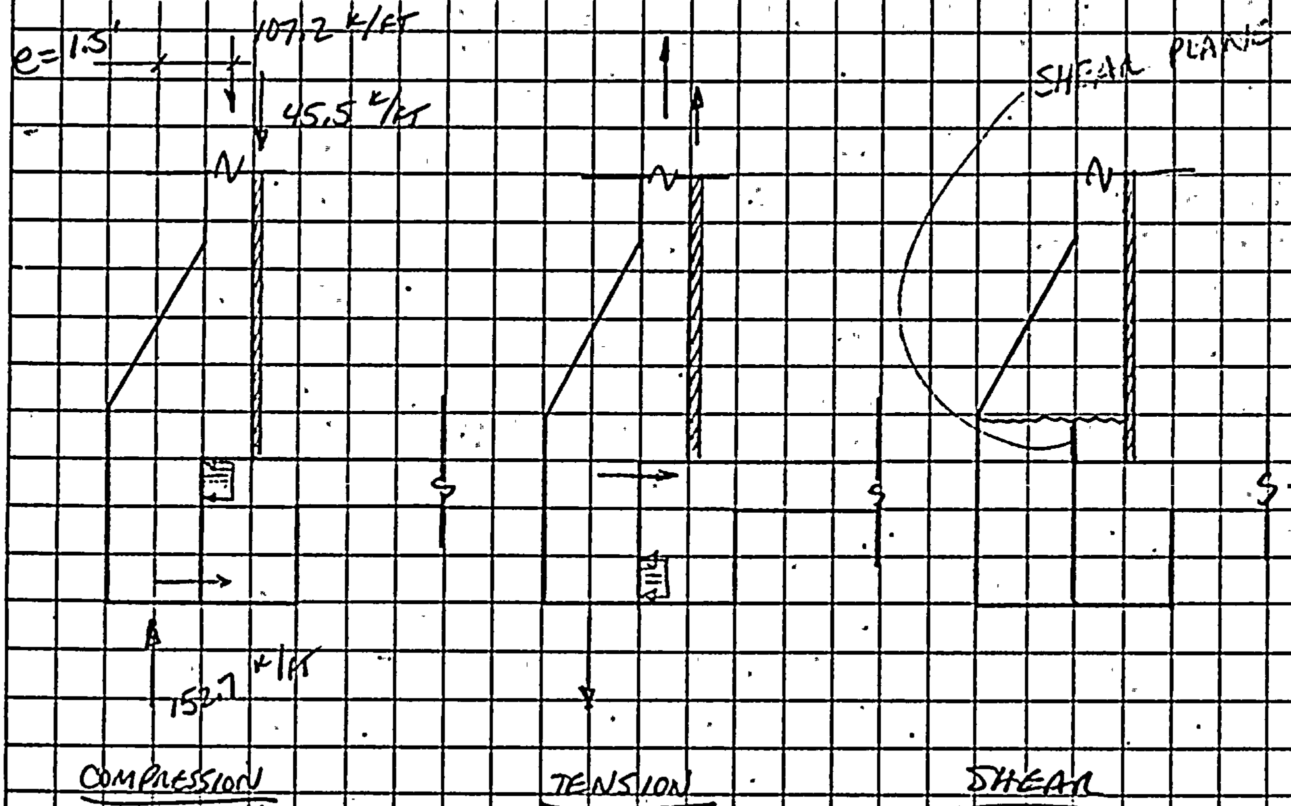
JOB/FILE NO. ______

LOCATION ______

SUBJECT DIABLO CANYON STORAGE TANK

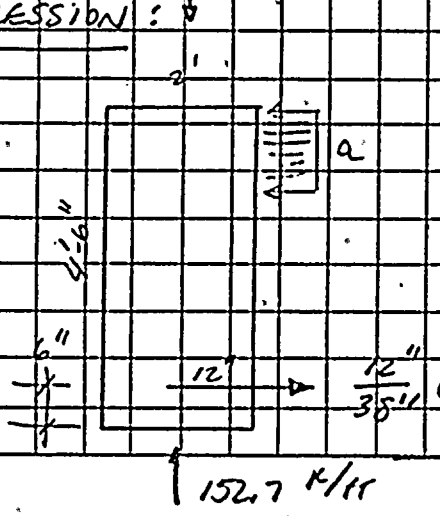
MADE BY G. CARR DATE 28 SEPT 78 CHECKED BY [initials] APPROVED BY ______

CHECK WALL – RING STRENGTH :



MOMENT = 1.5' (152.7 k/ft) = 229 k-ft/ft

COMPRESSION :



l_d (#9 in 4 ksi) = $\frac{0.04(1.0)\,60000}{\sqrt{4000}}$ = 38"

$f_{hook} = (540\sqrt{4000})\,1.3 = 44.5$ ksi

$\frac{12''}{38''}\,60\,k = 18.9$ k/ft

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PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 8 OF ____ SHEETS

JOB FILE NO. ____

LOCATION ____

SUBJECT: DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 28 SEPT. 78 CHECKED BY J.C. APPROVED BY ____

$T = 18.9 + 152.7\,(\mu = 1.0) = 172^{K}$

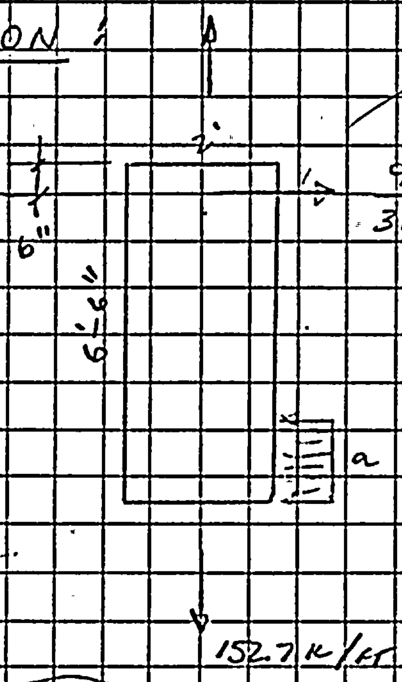
$C = 0.85\,(4\,KSI)\,12''\,a$

$a = \frac{172}{40.8} = 4.67''$

$\text{MOMENT CAPACITY} = \left[152.7\left(54'' - \frac{4.67}{2}\right) + 18.9\left(48'' - \frac{4.67}{2}\right)\right]\frac{0.9}{12}$

$= 656\ K\text{-}FT/FT > 229$ ∴ OK

TENSION:



$\frac{9''}{38''} \times 60\,KSI + 44.5\,KSI = 58.7\,KSI$

$\text{FORCE} = \frac{58.7}{60}\,120^{K} = 117.4^{K}$

$d \simeq 72''$

$T = 117.4\ K/FT$

$C = 0.85\,(4)\,12''\,a$

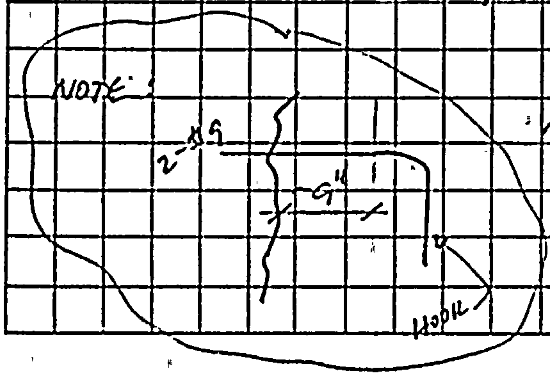
$a = 2.94''$

$\text{MOMENT CAPACITY} = 117.4^{K}\left(72'' - \frac{2.94''}{2}\right)\frac{0.9}{12}$

$= 705\ K\text{-}FT/FT > 229$

∴ OK

NOTE:



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PACIFIC GAS AND ELECTRIC COMPANY

SHEET NO. 9 OF ___ SHEETS

JOB / FILE NO. ___

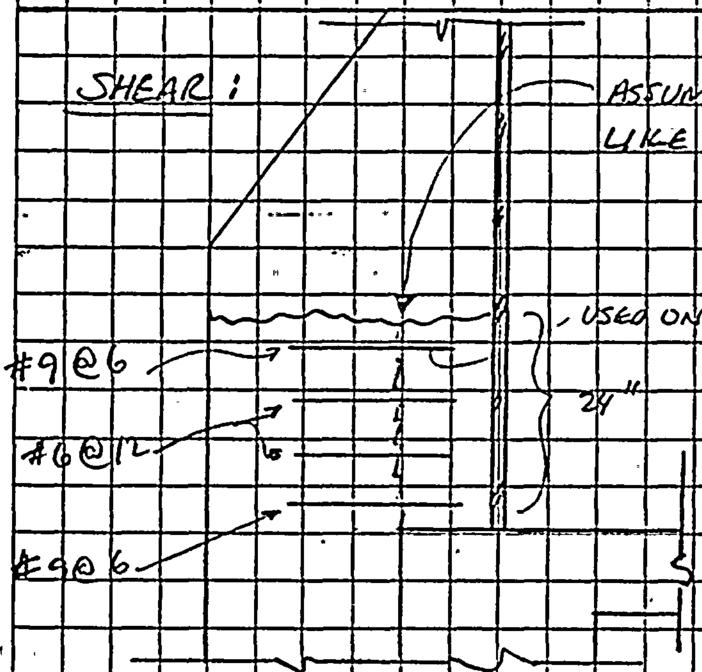
LOCATION ___

GENERAL COMPUTATION SHEET

SUBJECT: DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 29 SEPT 78 CHECKED BY gc. APPROVED BY ___

SHEAR:



SHEAR FORCE = 107.2 + 45.5 = 152.7 K/FT

$d \cong 21"$

AREA = 12" x 21" = 252 IN^2

$V_u = \frac{152.7}{252} = 606$ PSI

ALLOWABLE = $0.2 f_c'$ = 800 PSI ∴ OK

AVAILABLE STRENGTH:

2-#6 $V_u = A_{vf}\, \phi f_y \mu = 2(0.44)\, 0.85\, (60)\, 1.4 = 62.8$ K/FT

2-#9 $V_u = 2(1.00)\, 0.85\, (60)\, 1.4 = 142.8$ K/FT

TOTAL = 205.6 K/FT > 152.7

∴ OK

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PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 1 OF ___ SHEETS

JOB / FILE NO. ______

LOCATION ______

SUBJECT: DIABLO CANYON STORAGE TANKS

MADE BY: G. CARR DATE: 5 OCT 78 CHECKED BY: [initials] APPROVED BY: ______

FW & T STORAGE TANK TIE-DOWNS

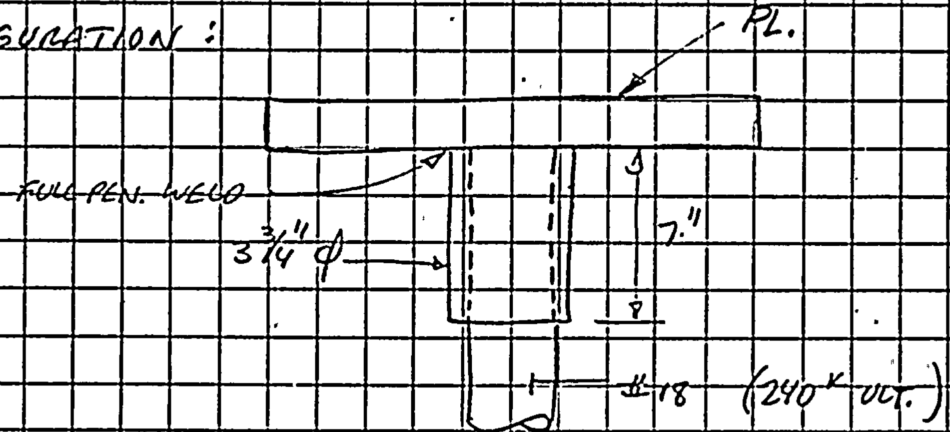
TIE-DOWNS MUST RESIST 93.8 K/FT ULT.

USE #18 TIE-DOWNS

$$\therefore \text{SPACING} = \frac{4.00 \text{ IN}^2}{\frac{93.8^K/FT}{60 \text{ KSI}}} \cong 2'-6''$$

USE CADWELD SERIES B SPLICE, ERICO CO.
CAT. NO. RBB-18101-JA

CONFIGURATION:



$$\#18 \text{ DEVELOPMENT LENGTH} = \frac{0.11 f_y}{\sqrt{f_c'}} = \frac{0.11(60000)}{\sqrt{3000}}$$

$$= 10'-0''$$

MAKE #18 12'-0" LG TO ACCOUNT FOR SLAB TOL.

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PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 2 OF ____ SHEETS

JOB / FILE NO. ____

LOCATION ____

SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 5 OCT 78 CHECKED BY [initials] APPROVED BY ____

USE $4\frac{1}{2}$" ϕ CLEARANCE HOLE THROUGH SLAB

DET. PL. TH. : (USE A36 PL.)

$$t = \frac{F_{ULT}}{0.4(36)\ \text{PERIMETER OF CADWELD}}$$

$$= \frac{240\ K}{0.4(36)\ 3.75''\pi} = 1.41''$$

BASED ON SHEAR STRENGTH → ∴ USE $1\frac{1}{2}$" PL

DET. PL. SIZE :

$$A = \frac{240\ K}{0.85\ (3\ KSI)} + \pi\left(2.25''\right)^2 = 110\ IN^2$$

∴ USE 12" SQ. PL. ← BASED ON ULT CONC. COMP.

CHECK MOMENT CAPACITY OF PL.

$$PL\ M_u = \sigma_{ALLOW\text{-}b}\ (S_{PL}/IN)$$

$$= 0.66(36)\left(\frac{1''(1.5'')^2}{6}\right) = 8.9\ ^{K\text{-}IN}/_{IN}$$

$$MAX\ M_u = 13.5\ ^{K\text{-}IN}/_{IN}$$

62-4713 3/65

PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 3 OF ___ SHEETS

JOB / FILE NO. ______

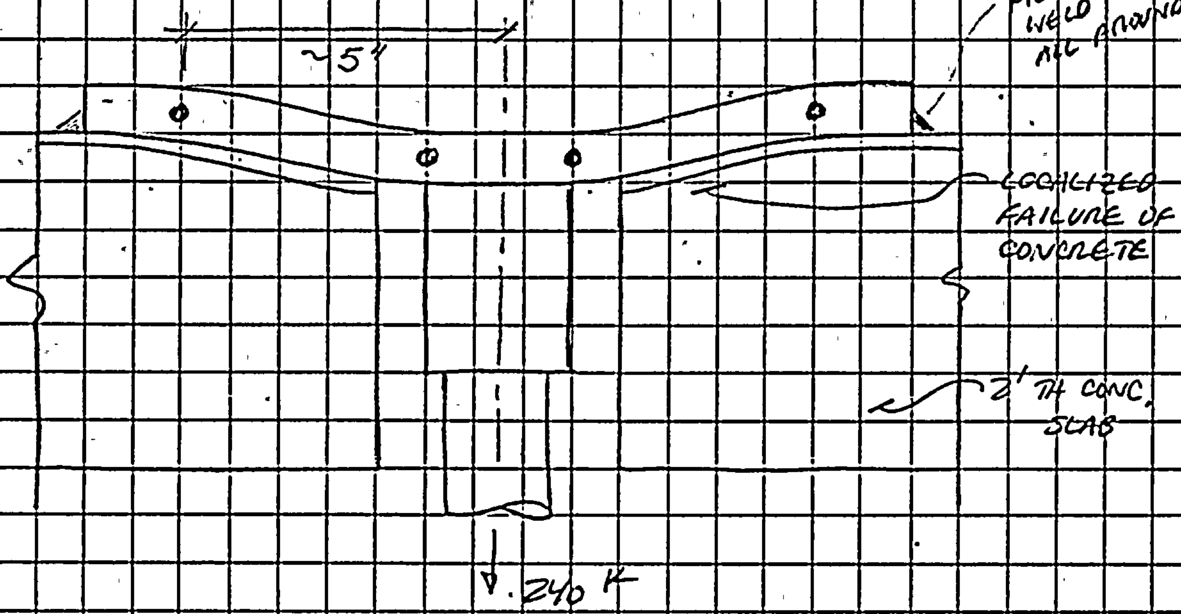
LOCATION ______

SUBJECT: DIABLO CANYON — STORAGE TANKS

MADE BY G. CARR DATE 5 OCT 78 CHECKED BY J.C. APPROVED BY ______

MAKE AN ASSUMPTION FOR YIELD-LINE ANALYSIS:

FAILURE WILL LOOK LIKE THIS:



ASSUME CIRCULAR YIELDING AT POINTS SHOWN ABOVE

$$E_x = 240\,K \times 1''$$

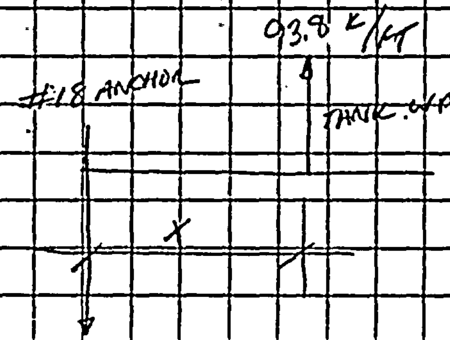
$$E_i = 2\left[\frac{\pi \cdot 10''}{4}\right] \times \frac{1''}{5 - 1.875''} \times m_u$$

EQUATE: $\Rightarrow$ REQ. $m_u = 11.9 \; K\text{-}in/in$

THIS IS $<$ $m_u = 13.5$ $\therefore$ OK

DETERMINE ALLOWABLE DISTANCE FROM TANK WALL:

2'-0" TH CONC SLAB STRENGTH $\cong$ 68 K-FT/FT

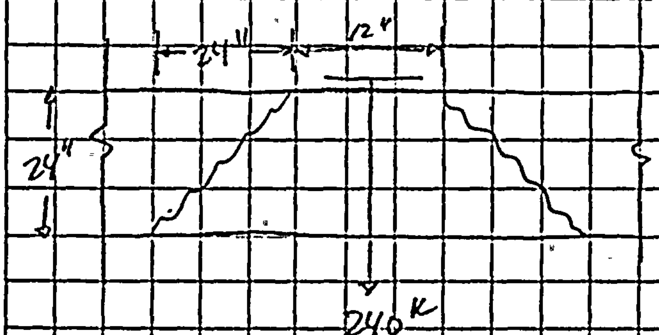


$$X \leq \frac{68 \text{ K-FT/FT}}{93.8 \text{ K/FT}} (12) = 8\tfrac{1}{2}''$$

∴ USE $8\frac{1}{2}''$ FROM TANK WALL

CHECK PUNCHING SHEAR IN SLAB:

NEGLECT TANK BOTTOM STEEL STRENGTH



$$A = 4\left[33'' \times 21''\sqrt{2}\right] = 3920 \text{ IN}^2$$

$$v_c = \frac{240}{3920}\left(\frac{1}{0.85}\right) = 72 \text{ psi}$$

$$v_{c\ \text{ALLOWABLE}} = 4\sqrt{f_c'} = 219 \text{ psi} \quad \therefore \text{OK}$$

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PACIFIC GAS AND ELECTRIC COMPANY

GENERAL COMPUTATION SHEET

SHEET NO. 5 OF ____ SHEETS

JOB FILE NO. ____

LOCATION ____

SUBJECT DIABLO CANYON STORAGE TANKS

MADE BY G. CARR DATE 5 OCT 78 CHECKED BY JC APPROVED BY ____

CHECK SHEAR ACROSS SLAB ;

$$v_u = \frac{93.8^k}{0.85\,(21'' \times 12'')} = 438 \text{ psi}$$

$$v_c = 2\sqrt{f_c'} = 110 \text{ psi}$$

$$\text{REQ. } v_s = 438 - 110 = \underline{\underline{328 \text{ psi}}}$$

ASSUME SHEAR FRICTION :

$$\text{REQ STEEL AREA} = \frac{328\,(21'' \times 12'')}{60000\,(1.4)}$$

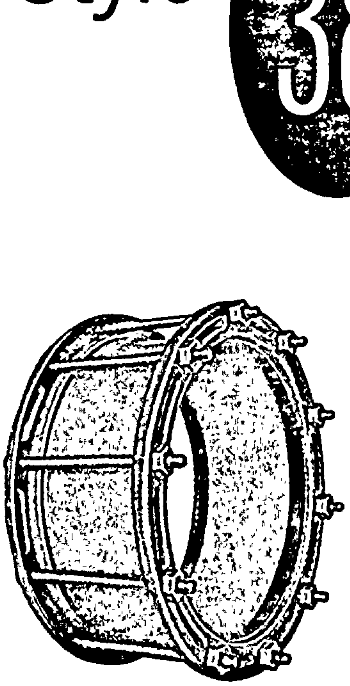
$$= 0.98 \text{ in}^2 \quad \therefore \#8 @ 12'' \text{ E.F.}$$

OK

(NEG STEEL)

+ SOME POS. STEEL.

Style 38 Couplings for Steel Pipe



Above. 16" OD Style 38, showing 10-bolt construction supplied also for the 18" OD size. All other sizes from 14" OD through 24" OD have the same design, the number of bolts increasing with size to assure adequate gasket compression.

Style 38 Steel Couplings for Steel Pipe 14" OD and Larger—Sizes, Specifications

PIPE (Steel)		MIDDLE RING[1] Thickness and Length (A & B)	BOLTS[2] Number, Diameter and Length (D & E)	WORKING PRESSURE[3] lbs.* per sq. in.	OVERALL DIMENSIONS			WEIGHT Approx. Shipping Each (Lbs.)	ITEM CODE[6] for Ordering
Nominal Size (ID)	Outside Diameter (OD)				Diam. (H)	Length (J)[4]	Length (L)[5]		
	14.000	¼ x 5	8–⅝ x 8½	510	18	11⅛	7⅛	51	0106
	14.000	¼ x 7	8–⅝ x 10½	510	18	13⅛	9⅛	60	0107
	14.000	5/16 x 5	8–⅝ x 8½	633	18⅛	10⅞	7⅜	62	0108
	14.000	5/16 x 7	8–⅝ x 10½	633	18⅛	12⅞	9⅜	71	0109
	16.000	¼ x 7	10–⅝ x 10½	449	20	13⅛	9⅛	70	0115
	16.000	5/16 x 7	10–⅝ x 10½	557	20⅛	12⅞	9⅜	80	0117
	16.000	⅜ x 7	10–⅝ x 10½	664	20 7/16	12¾	9⅝	98	0118
	18.000	¼ x 7	10–⅝ x 10½	401	22	13⅛	9⅛	75	0129
	18.000	5/16 x 7	10–⅝ x 10½	498	22⅛	12⅞	9⅜	91	0130
	18.000	⅜ x 7	10–⅝ x 10½	594	22 7/16	12¾	9⅝	111	0131
	20.000	¼ x 7	12–⅝ x 10½	362	24 1/16	13⅛	9⅛	86	0134
	20.000	5/16 x 7	12–⅝ x 10½	450	24 3/16	12⅞	9⅜	104	0135
	20.000	⅜ x 7	12–⅝ x 10½	537	24 9/16	12¾	9⅝	122	0136
	22.000	¼ x 7	14–⅝ x 10	330	26	12⅜	9⅛	98	0138
	22.000	⅜ x 7	14–⅝ x 10½	490	27	12¾	9⅝	141	0139
	24.000	¼ x 7	14–⅝ x 10	304	28	12⅜	9⅛	105	0141
	24.000	⅜ x 7	14–⅝ x 10½	451	29	12¾	9⅝	153	0142
30	30.500	¼ x 7	16–⅝ x 10	240	34½	12⅜	9⅛	133	0147
30	30.625	5/16 x 7	16–⅝ x 10	298	34⅝	12⅜	9⅛	145	0148
30	30.750	⅜ x 7	16–⅝ x 10½	354	35¼	12⅞	9½	190	0149
30	31.000	½ x 7	16–⅝ x 10½	465	36	12⅞	9½	226	0150
30	31.000	½ x 10	16–⅝ x 13½	465	36	15⅞	12⅜	258	0151
36	36.500	¼ x 7	18–⅝ x 10	201	40½	12⅜	9⅝	162	0155
36	36.625	5/16 x 7	18–⅝ x 10	250	40⅝	12⅜	9⅝	176	0156
36	36.750	⅜ x 7	18–⅝ x 10½	298	41¼	12⅞	9½	226	0157
36	37.000	½ x 7	18–⅝ x 10½	392	42	12⅞	9½	252	0158
36	37.000	½ x 10	18–⅝ x 13½	392	42	15⅞	12⅜	306	0159
42	42.750	⅜ x 10	20–⅝ x 14	257	47¼	16⅞	12⅞	313	0162
42	43.000	½ x 7	20–⅝ x 11	339	48	13⅞	10	287	0163
42	43.000	½ x 10	20–⅝ x 14	339	48	16⅞	12⅞	353	0164
48	48.750	⅜ x 10	22–⅝ x 14	226	53¼	16⅞	12⅞	354	0167
48	49.000	½ x 7	22–⅝ x 11	299	54	13⅞	10	326	0168
48	49.000	½ x 10	22–⅝ x 14	299	54	16⅞	12⅞	401	0169
54	54.750	⅜ x 10	24–⅝ x 14	217	59¼	16¾	13	401	0172
54	55,000	½ x 10	24–⅝ x 14	287	60	16¾	13	447	0173
60	61.000	½ x 10	26–⅝ x 14	241	66	16¾	13	494	0175
66	67.000	½ x 10	30–⅝ x 14	220	72	16¾	13	545	0179
72	73.000	½ x 10	32–⅝ x 14	202	78	16¾	13	598	0181

Full information on other sizes will be supplied upon request.
Dimensions are approximate, given in inches, and shown in section view on page 6

[1]MIDDLE RINGS thicker or longer than those listed can be supplied. Details and prices on request.

[2]BOLTS furnished as standard are shopcoated steel. Plated or coated bolts can be supplied if specified.

[3]WORKING PRESSURE. The working pressures shown were determined on the basis of Barlow's formula using a working stress equal to one half the minimum yield of the middle ring material. Couplings for higher pressures can be furnished. Where pipe movement out of coupling might occur, proper anchorage of the pipe must be provided.

[4]DIMENSION "J" (maximum) will be equal to Dimension "E" plus ½" (approximate bolt-head thickness) if all bolts are inserted from one side of Coupling.

[5]DIMENSION "L" (over-all length exclusive of bolts) is taken with bolts drawn up finger tight.

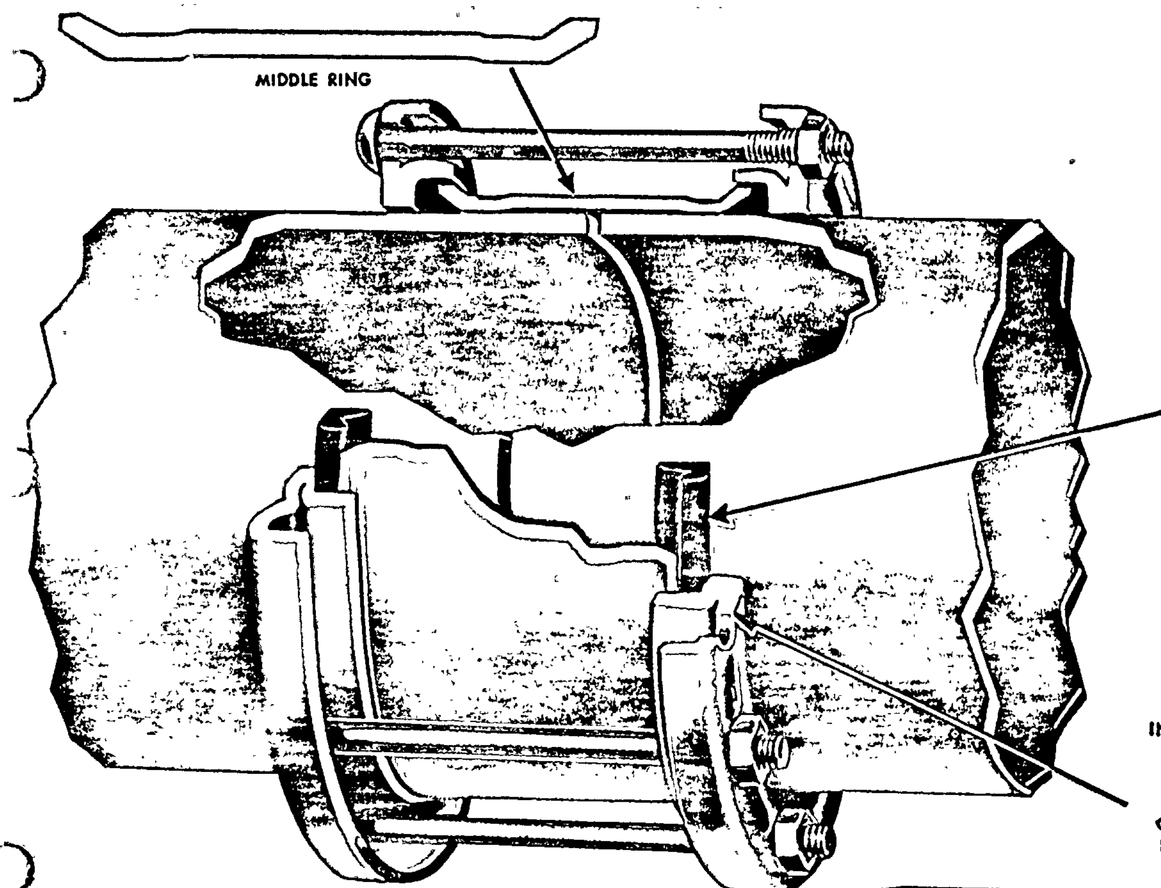
[6]CODE designates standard black couplings equipped with Plain Gaskets and shopcoated bolts. Dresser AL-CLAD coated couplings can be supplied if desired. Details on request.

NOTE: Specifications of all products shown in this catalog are subject to change without notice. PRICES will be supplied on request.

outer ends of the gaskets. Tightening the bolt draws the follower rings toward each other, compressing the gaskets in the spaces formed by follower rings, middle ring flares and pipe surface. This effects a flexible, leak-proof seal.

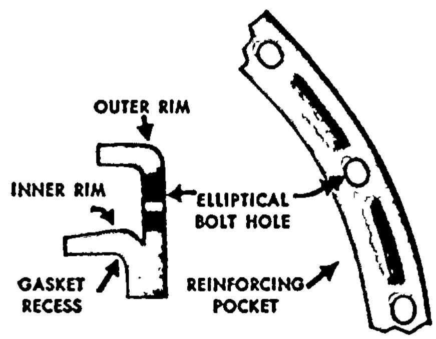
Dresser Couplings are carefully engineered at every point. Middle rings and followers have ample strength to maintain a constant, even pressure against the gaskets. The wide outer rim of the followers provides added rigidity. Gasket sections are made generous enough to furnish more than adequate sealing surface and "pack" between coupling pipe. Dresser bolts and nuts are of high grade, high strength steel.

COUPLINGS MAY BE FURNISHED DRESSER AL-CLAD™ FACTORY-COATED

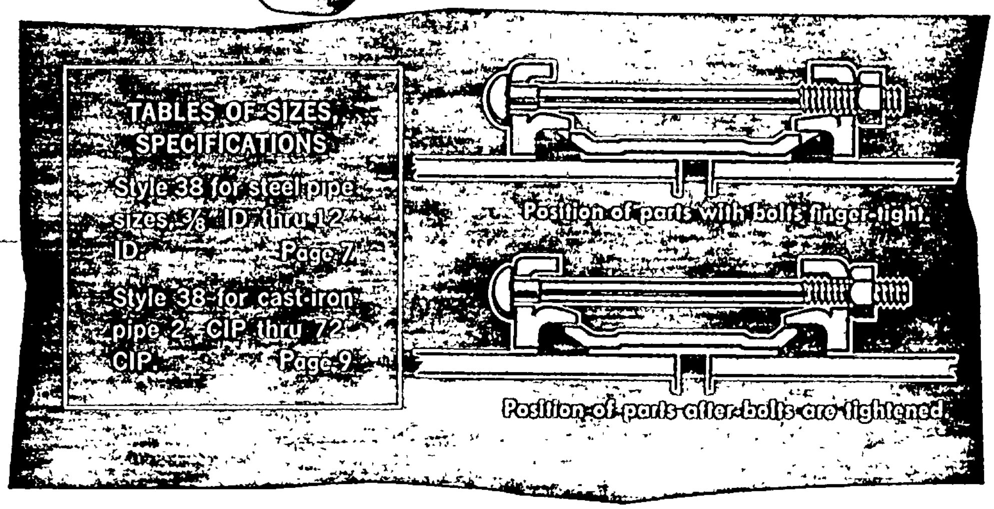


Style 38 and Style 40 Coupling Gasket cross section.

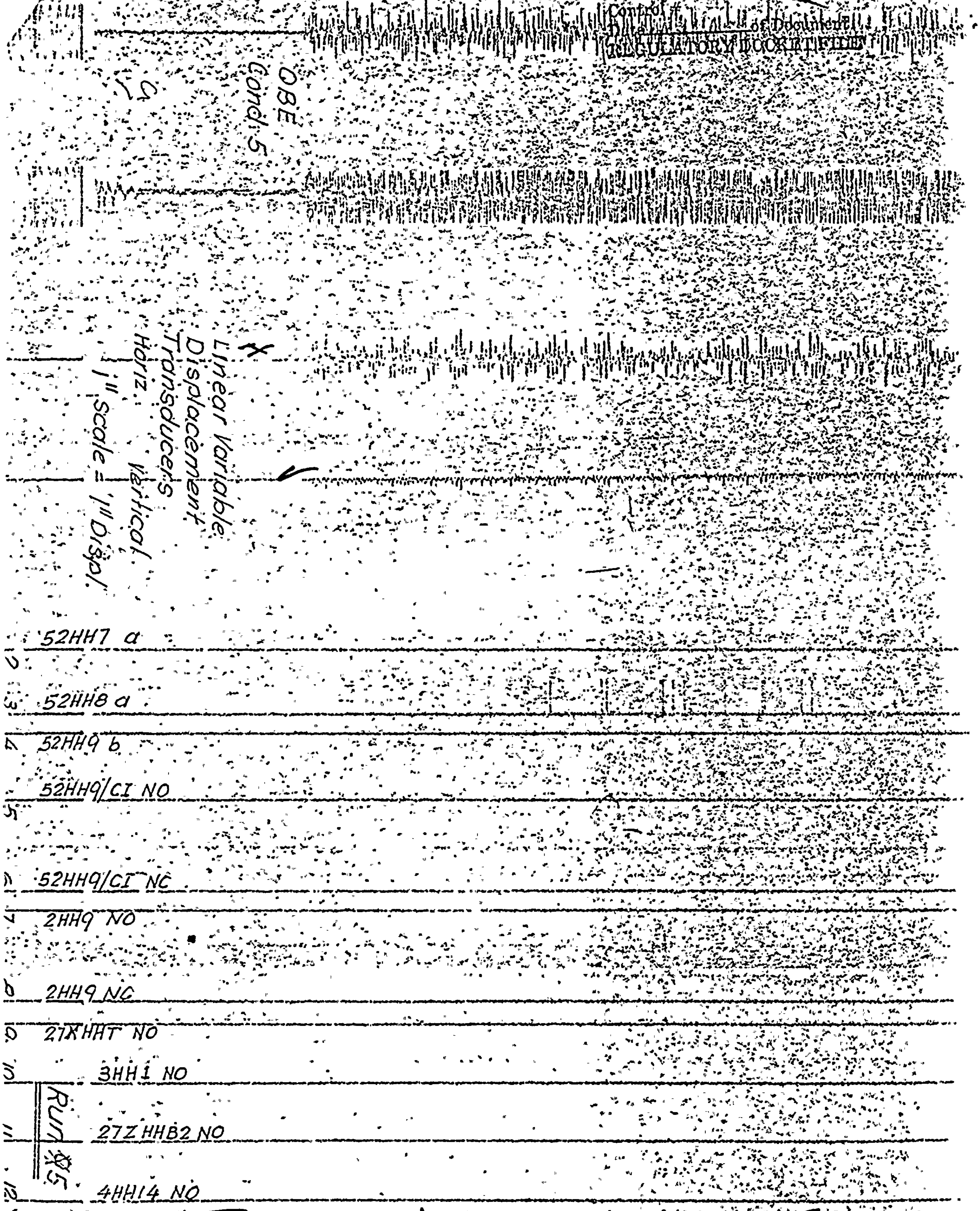
This section furnished for Stab-38 and Stab-39 Couplings.



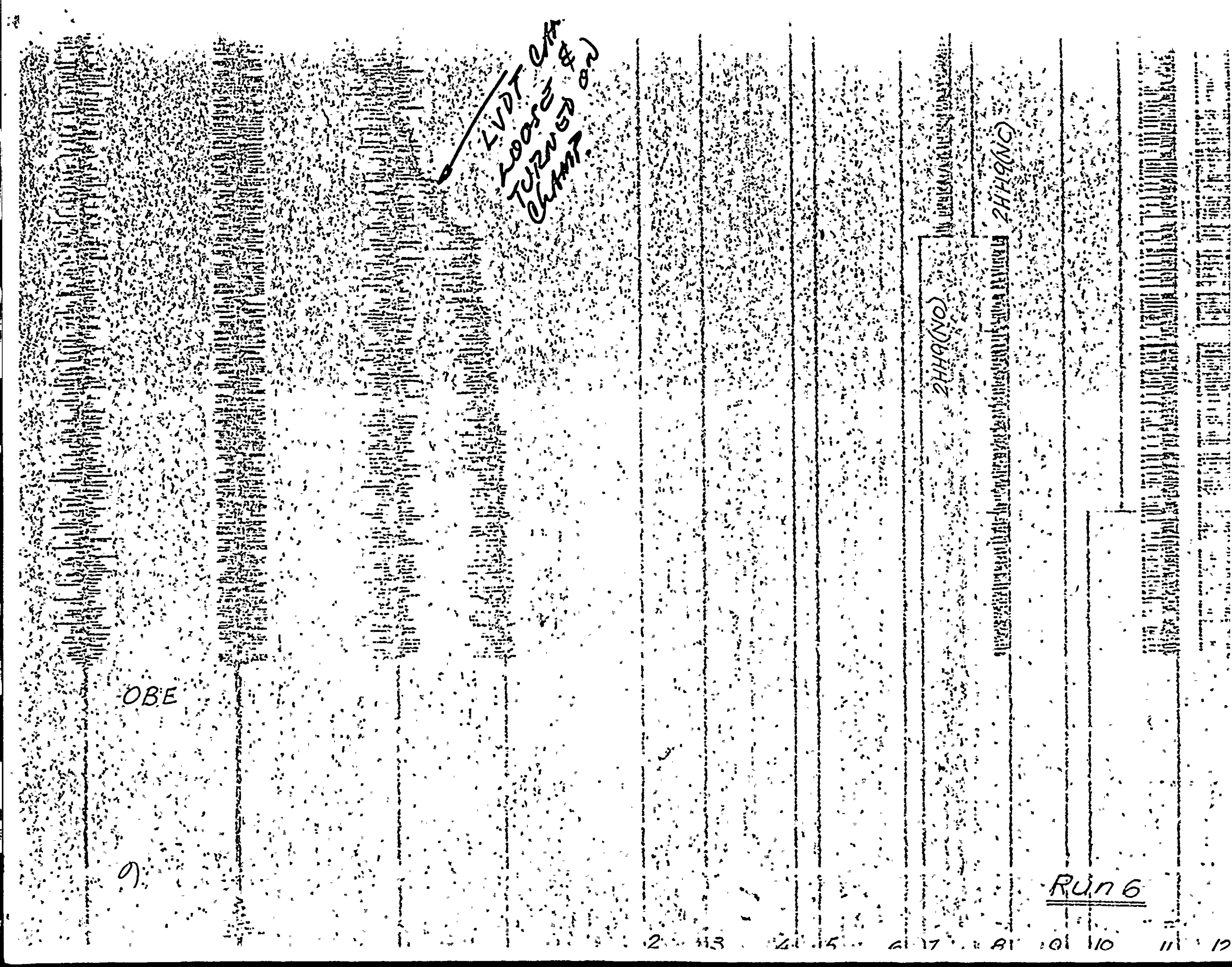
Cutaway view of Dresser Coupling, showing working principle and illustrating shape and relative position of component parts. Insets show details of parts.



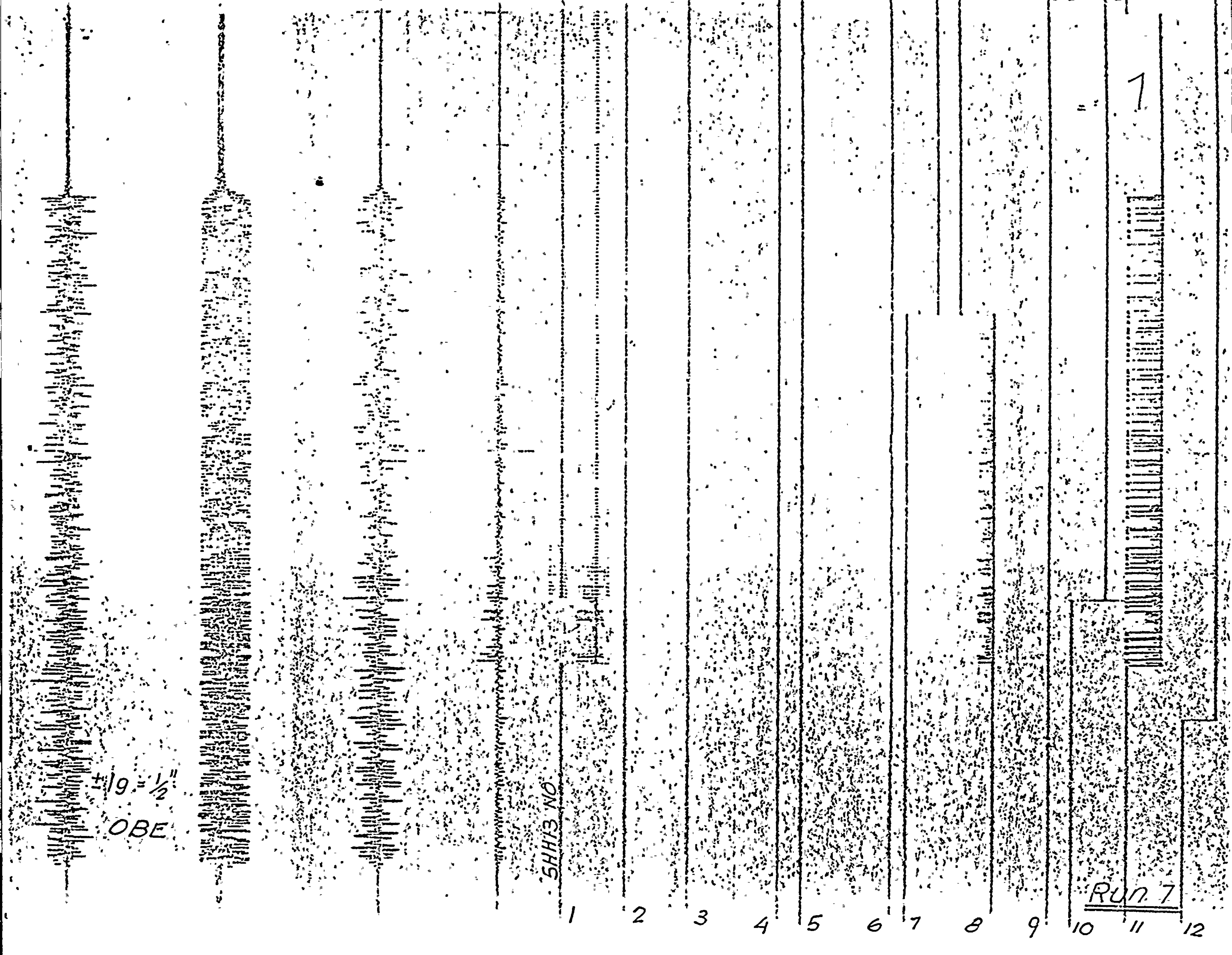
Note: Where pipe movement out of the coupling might occur, proper anchorage of the pipe must be provided.

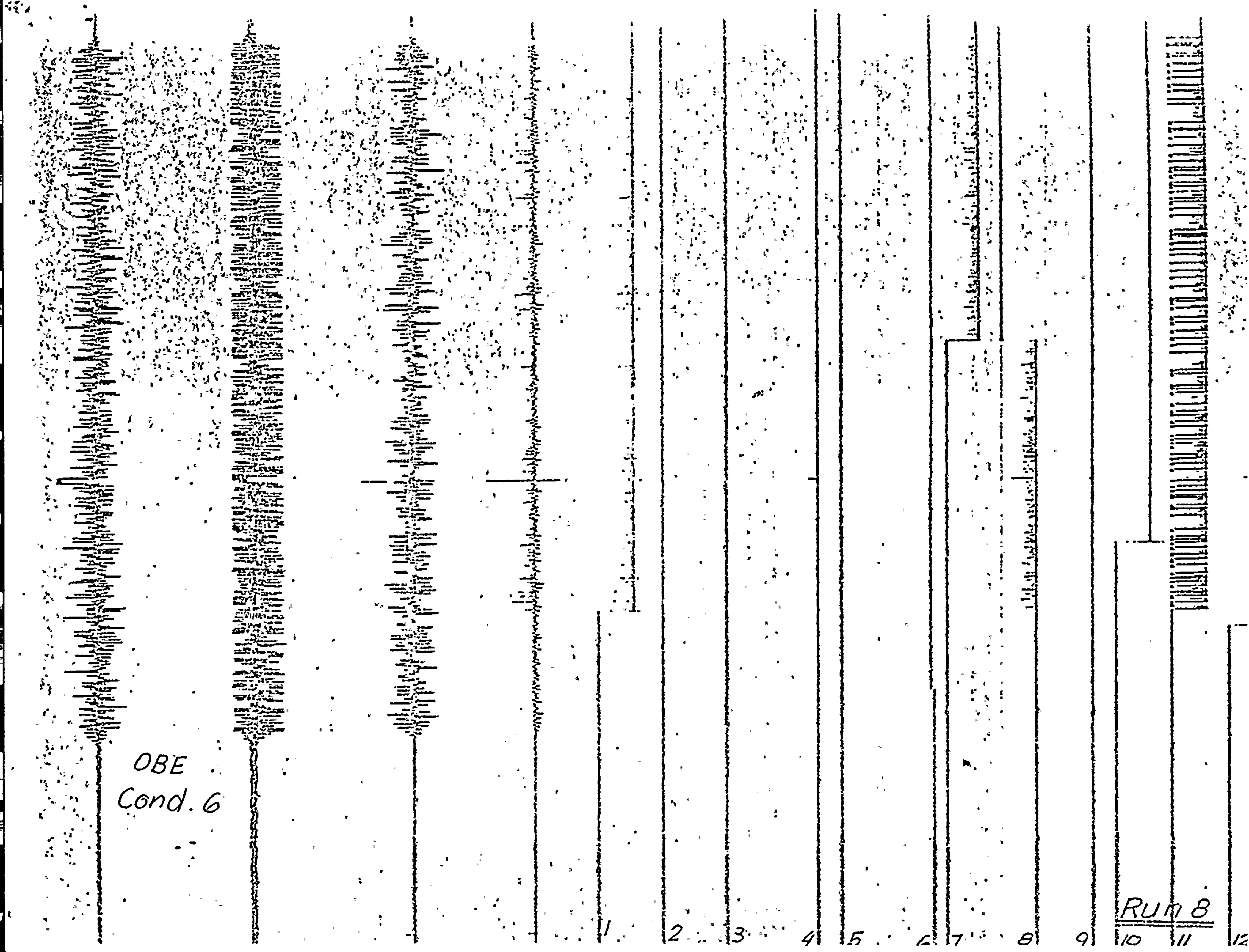


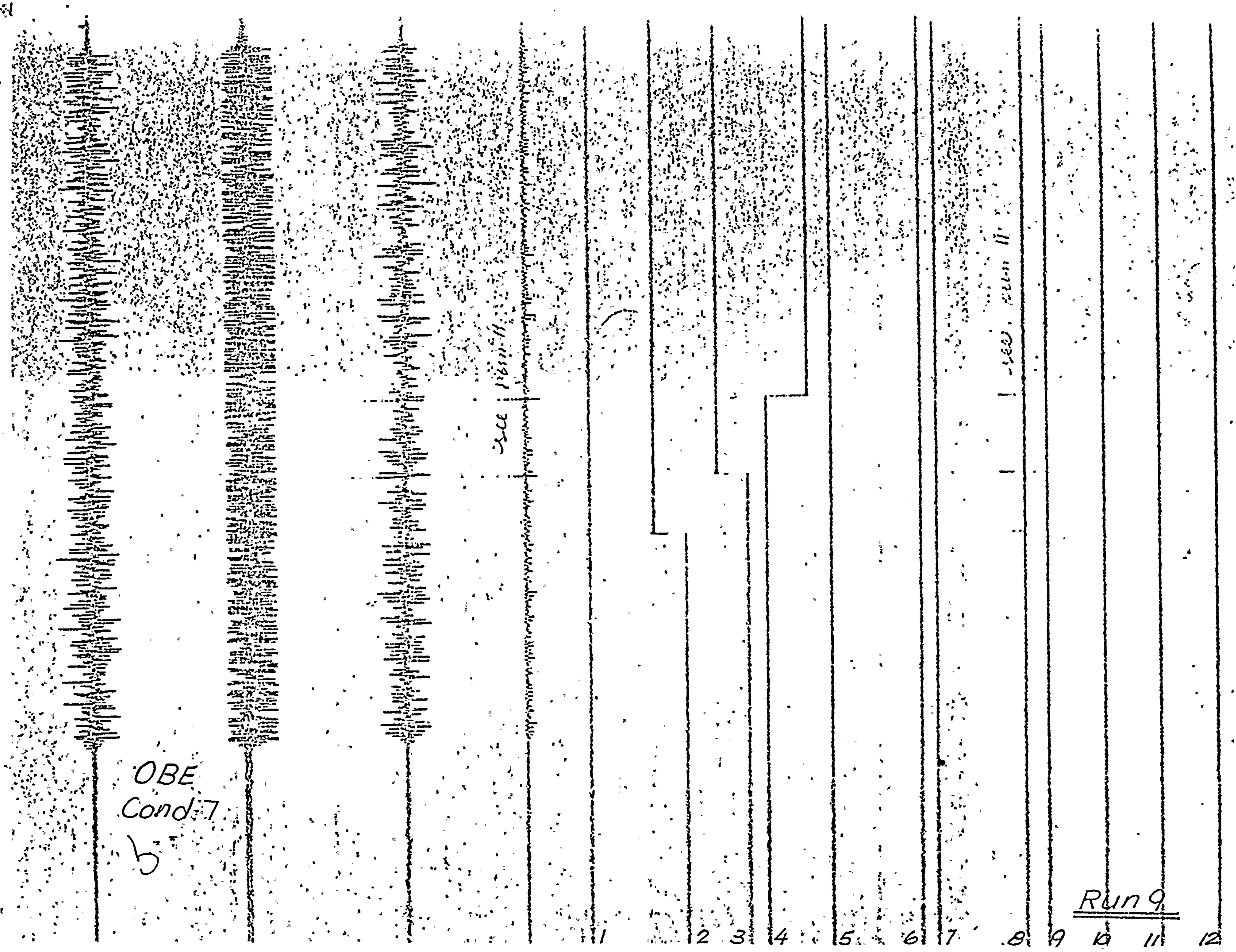
Memo to Stolz frm Allison: Memo dtd 11-21-78

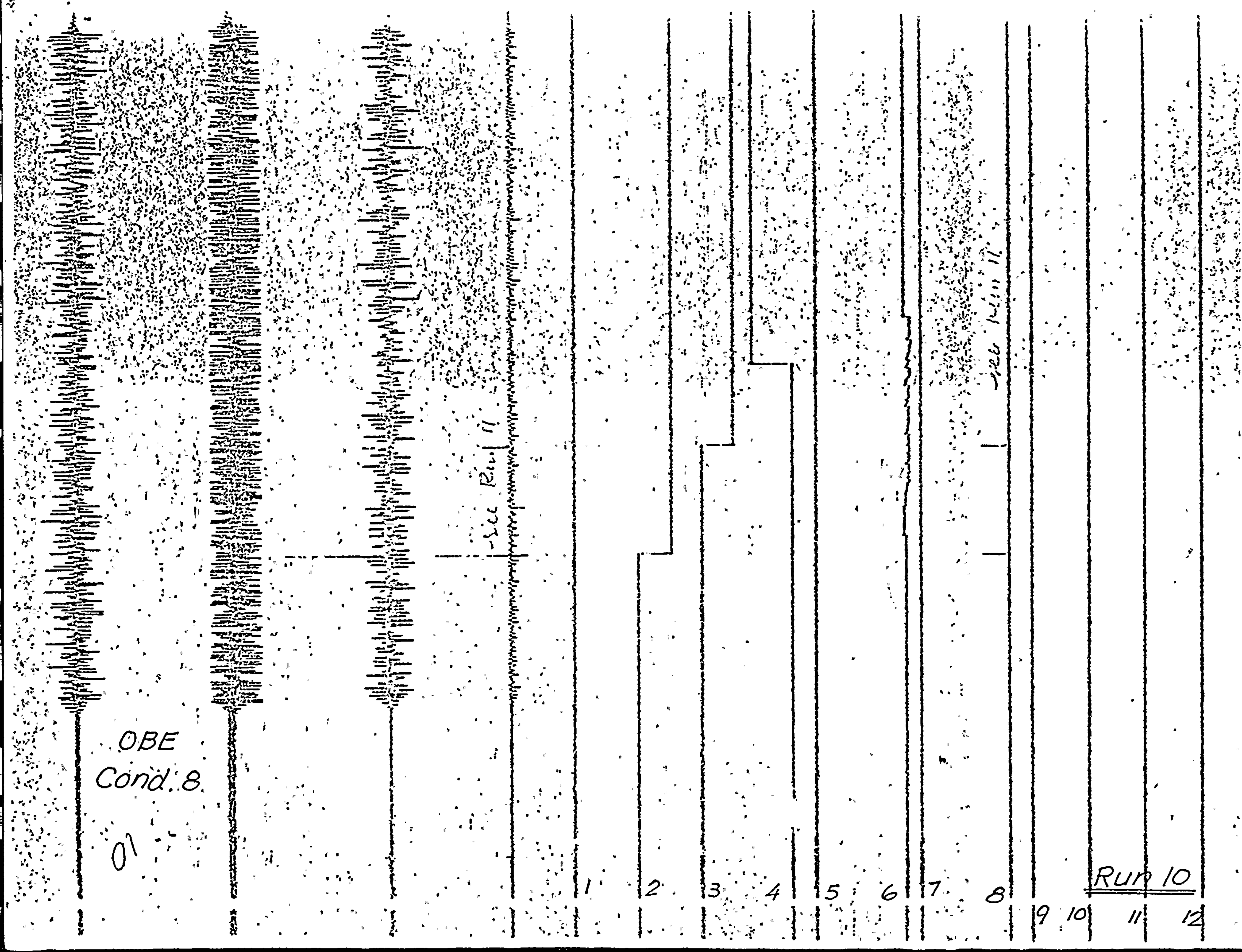


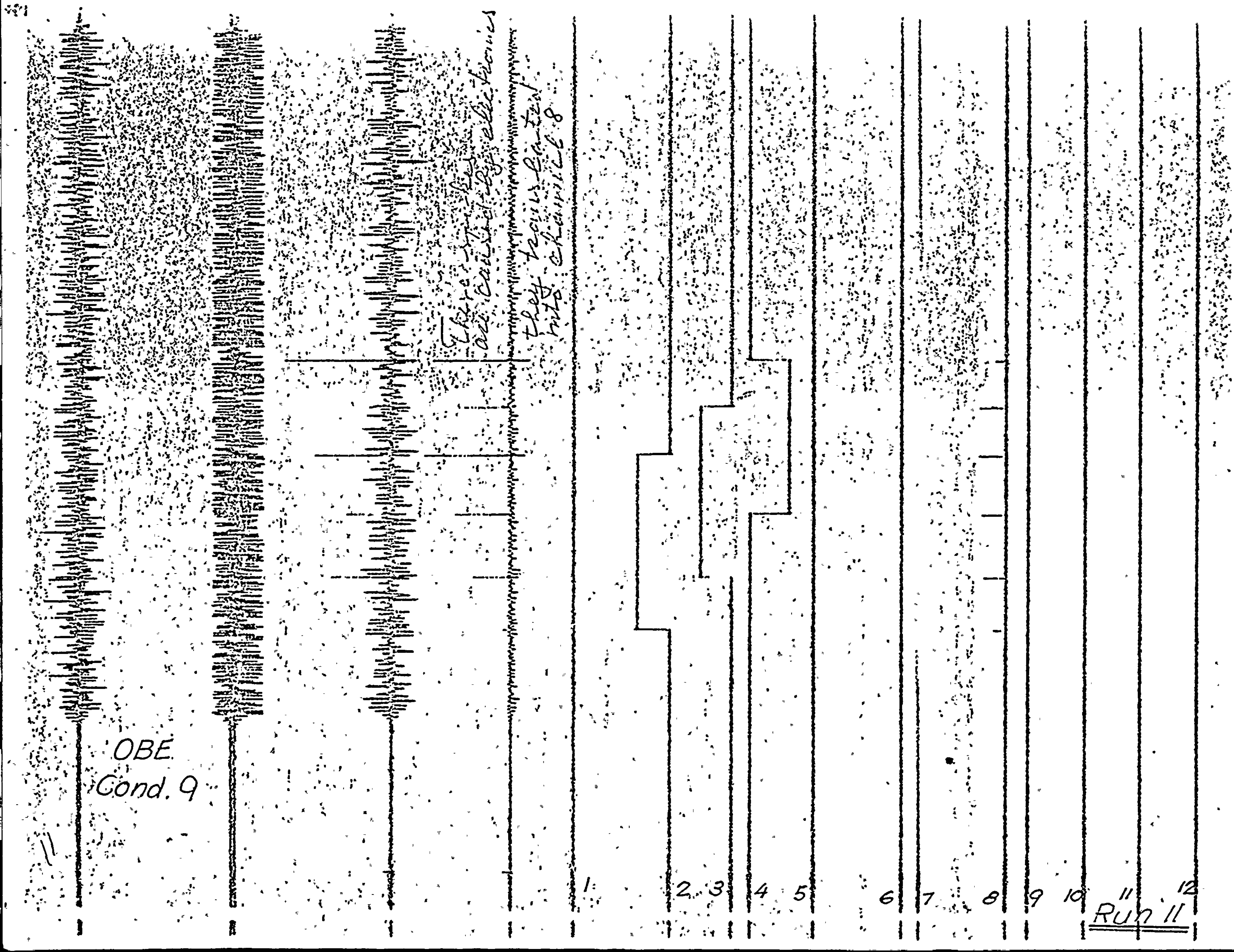
LVDT CH. LOOSE & TURNED ON CLAMP
2HH9(NO)
2HH9(NO)
OBE
Run 6
2
3
4
5
6
7
8
9
10
11
12

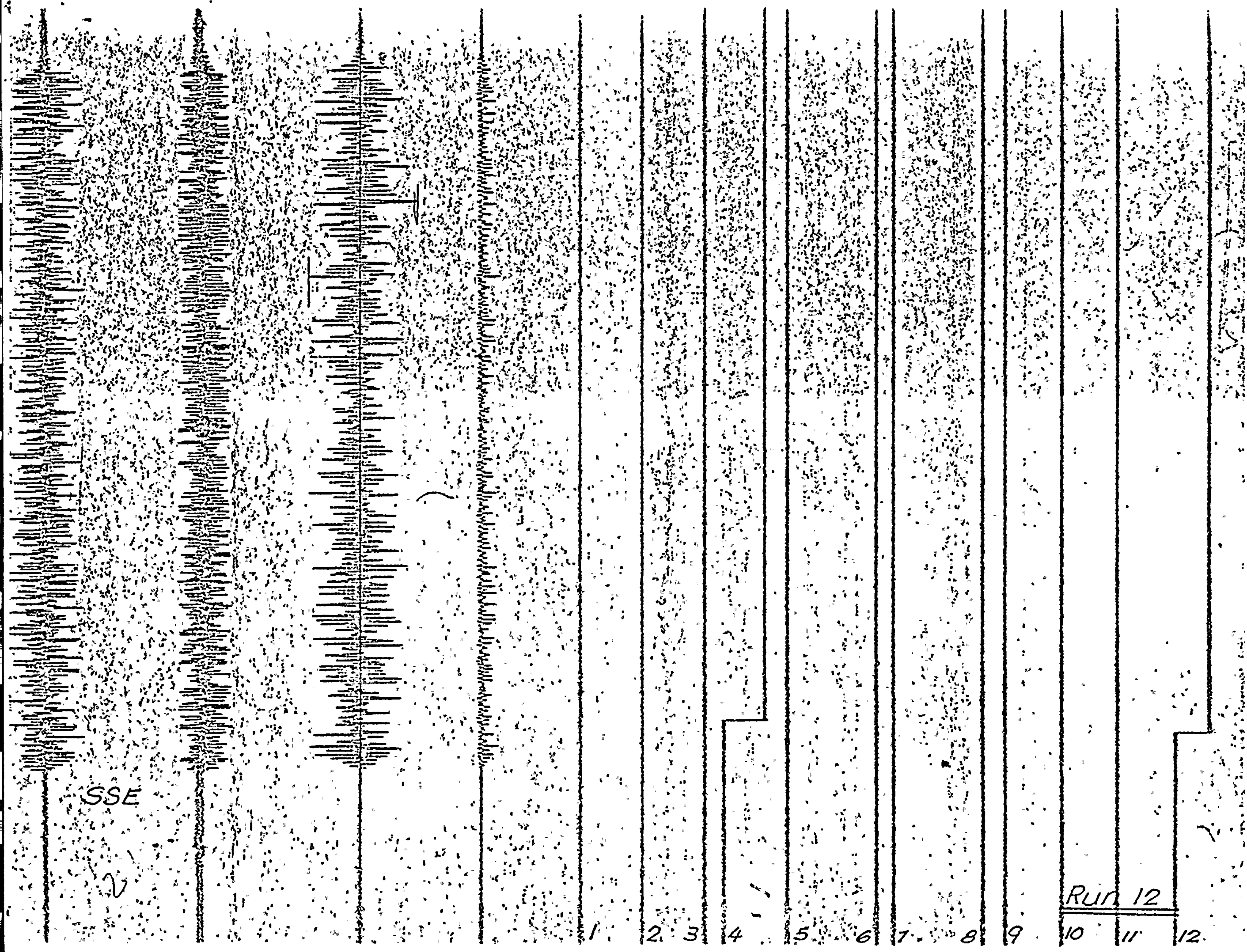

7
±19 = 1/2"
OBE
SHH13 NO
Run 7
1
2
3
4
5
6
7
8
9
10
11
12

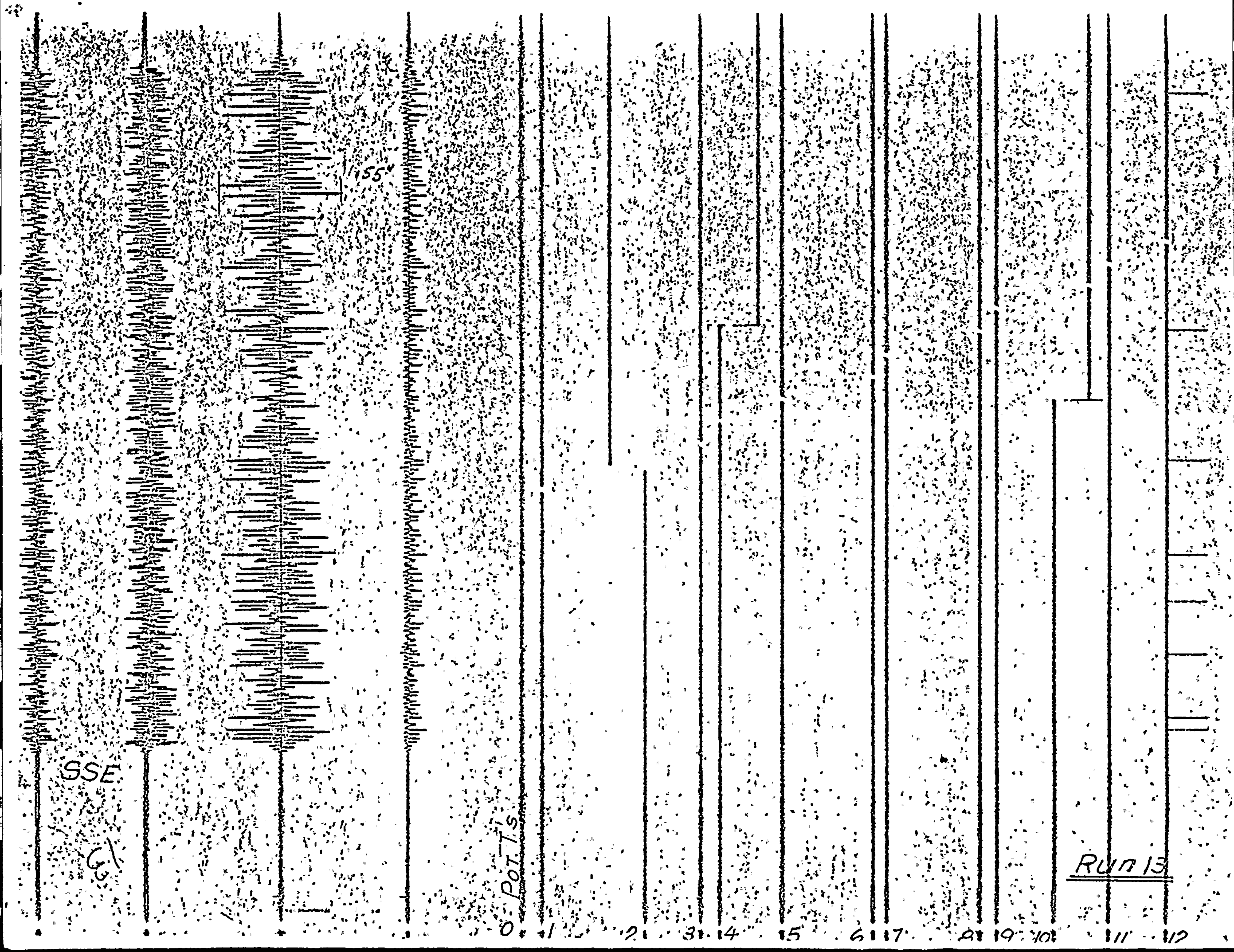

OBE
Cond. 6
Run 8
1
2
3
4
5
6
7
8
9
10
11


OBE
Cond 7
b
Run 9
1
2
3
4
5
6
7
8
9
10
11
12

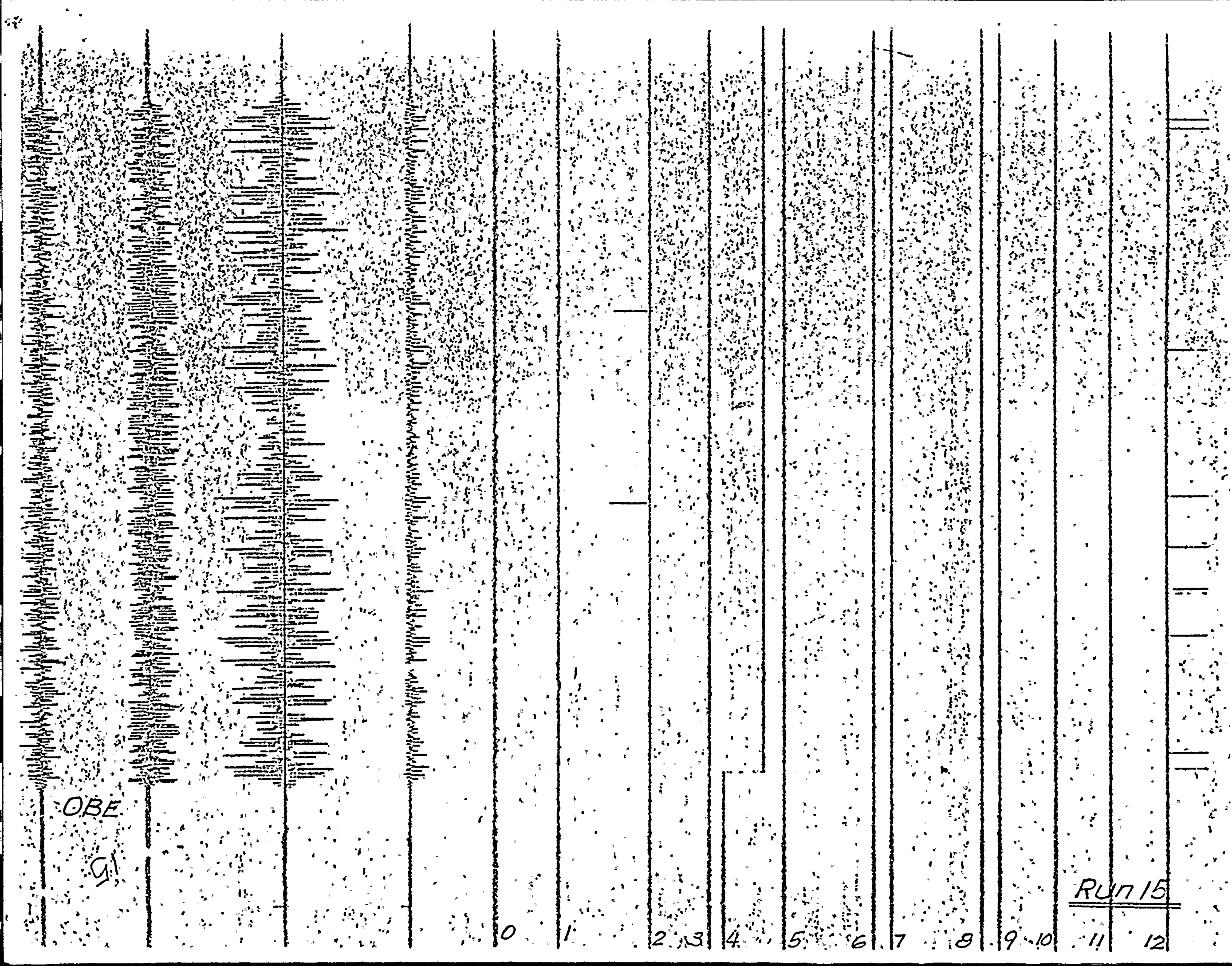

OBE
Cond. 8
See Run 11
See Run 11
1
2
3
4
5
6
7
8
9
10
11
12
Run 10

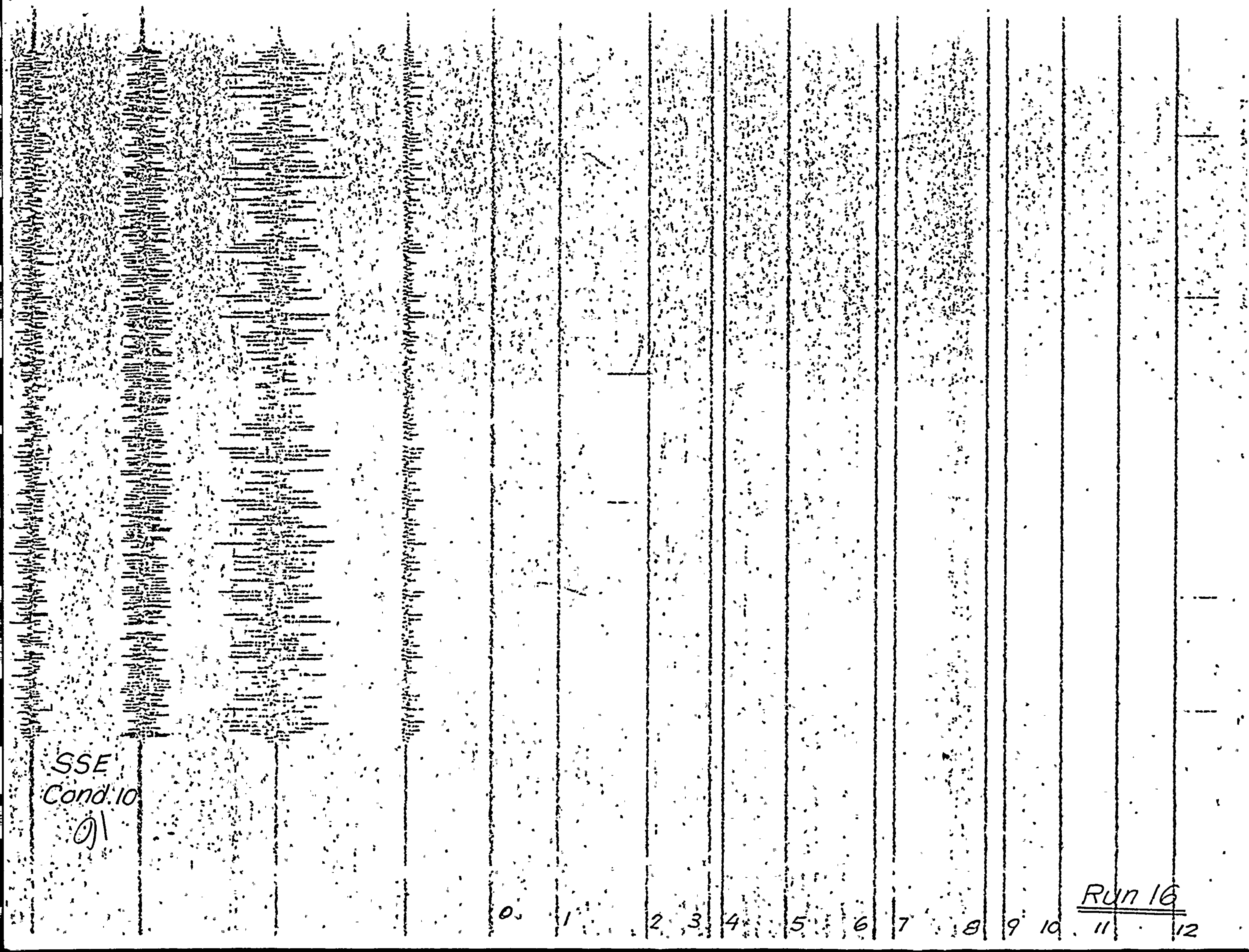

OBE
Cond. 9
1
2
3
4
5
6
7
8
9
10
11
12
Run 11

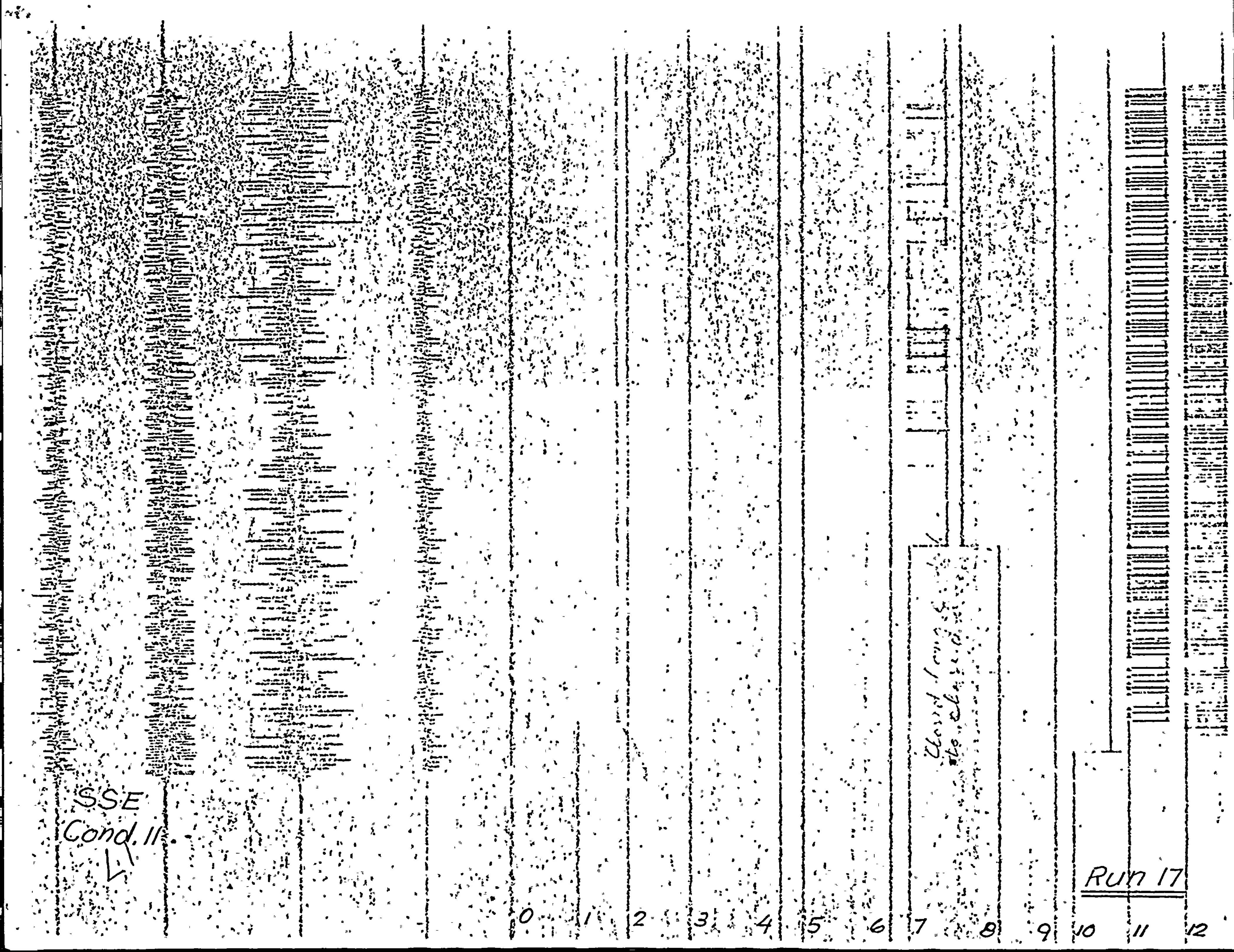

SSE
Run 12
1
2
3
4
5
6
7
8
9
10
11
12

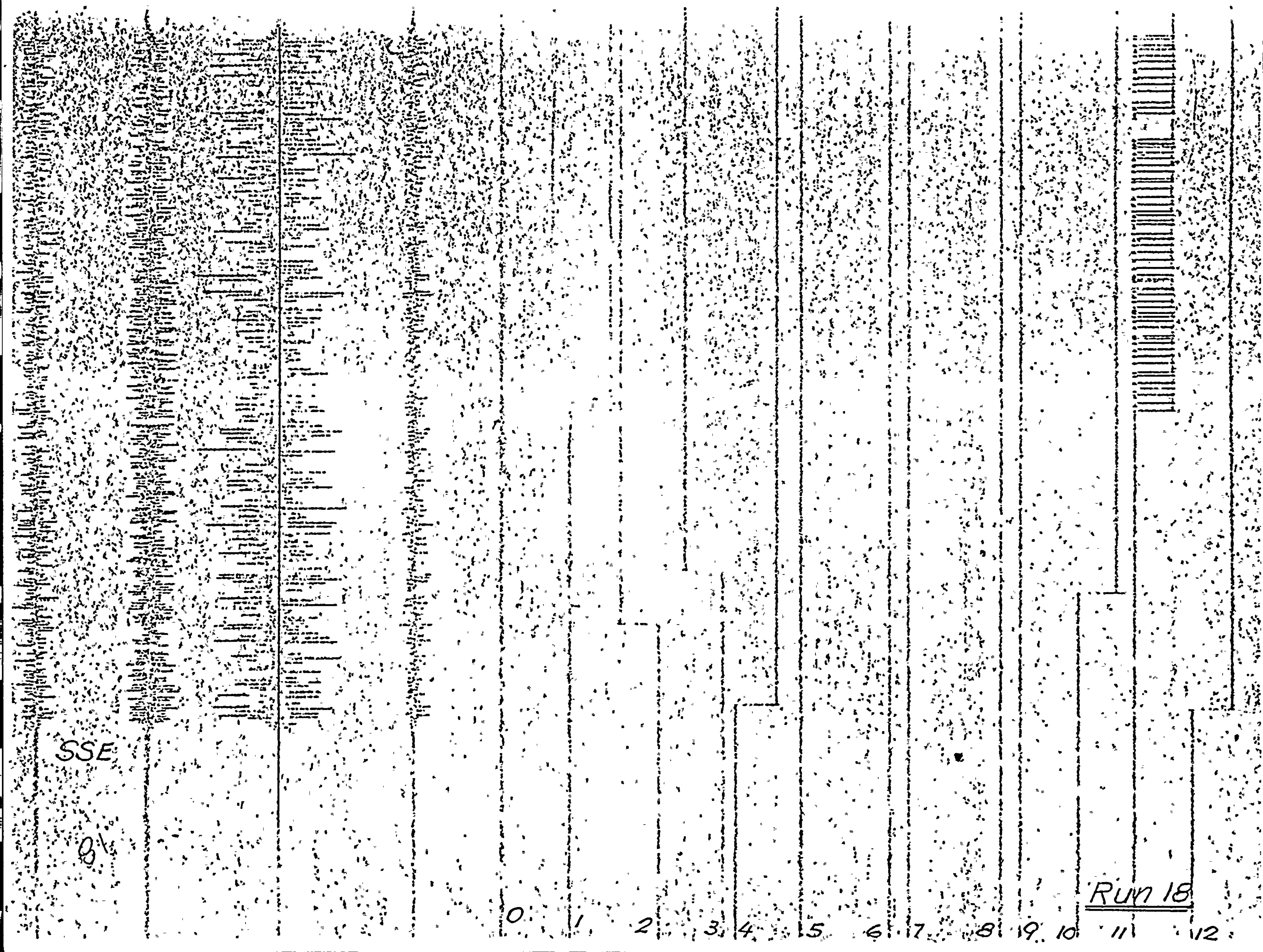


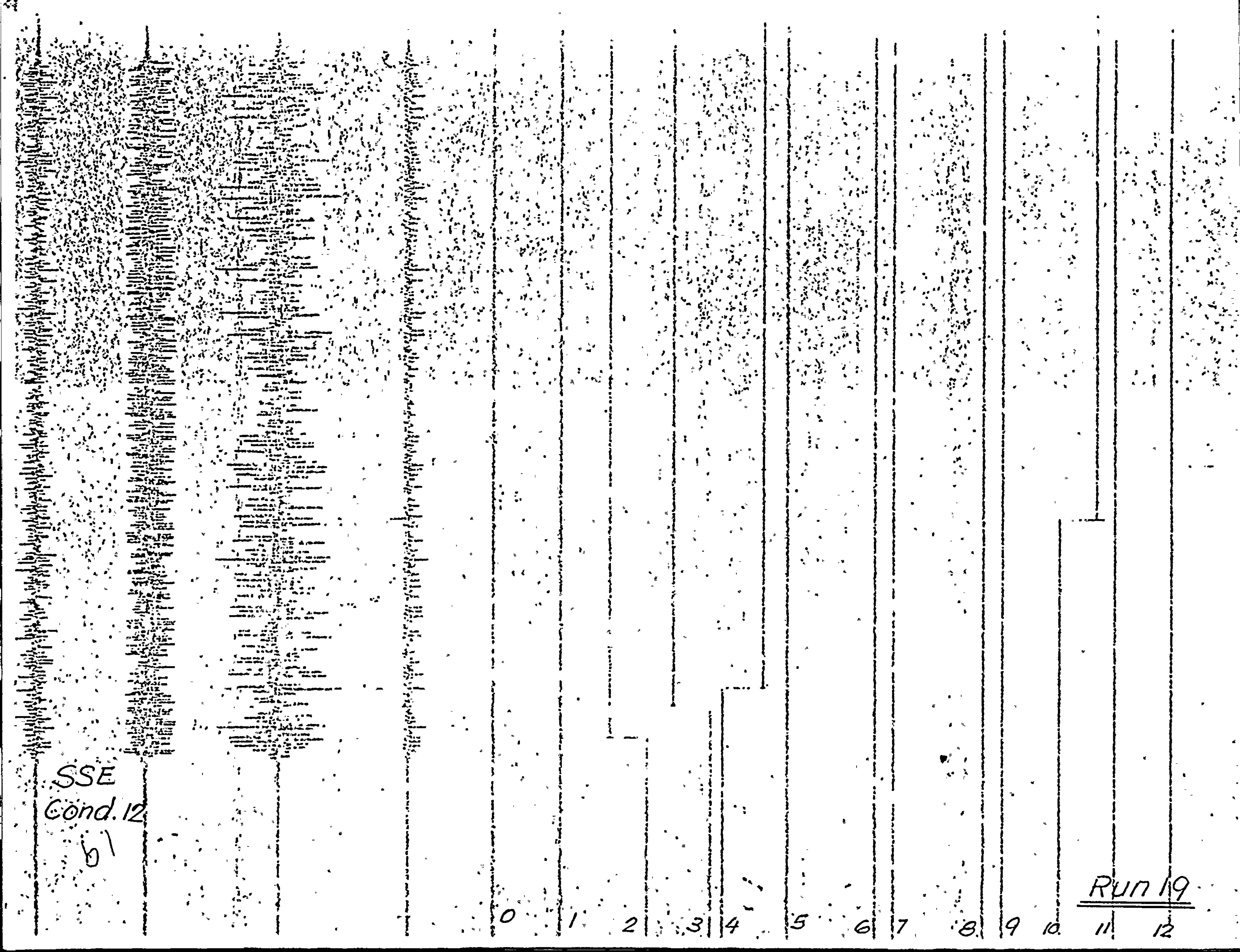
SSE
1.55"
Pot. T.s
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 13

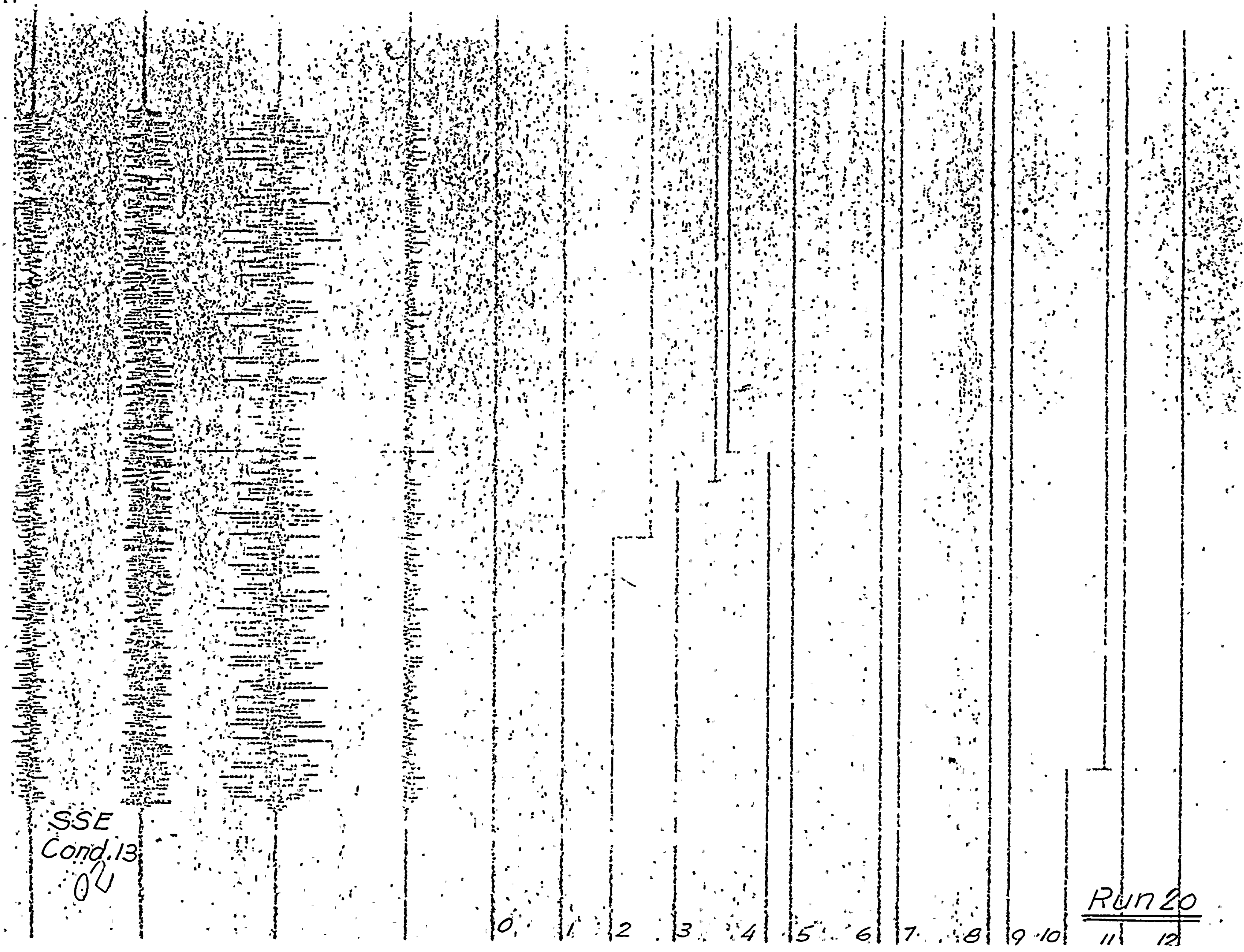

OBE
Run 15
0
1
2
3
4
5
6
7
8
9
10
11
12

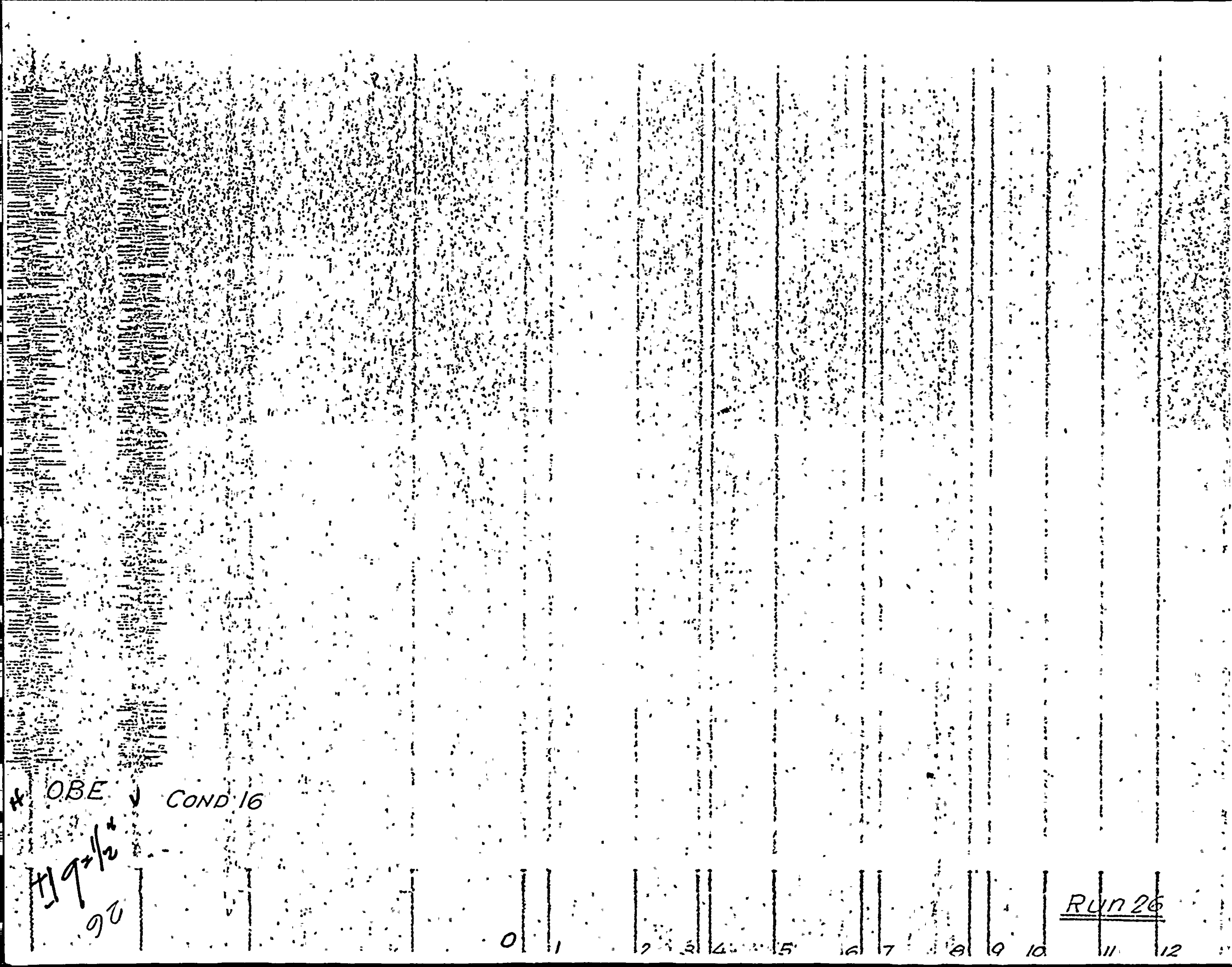

SSE
Cond. 10
Run 16
0
1
2
3
4
5
6
7
8
9
10
11
12


SSE
Cond. 11
Run 17
0
1
2
3
4
5
6
7
8
9
10
11
12

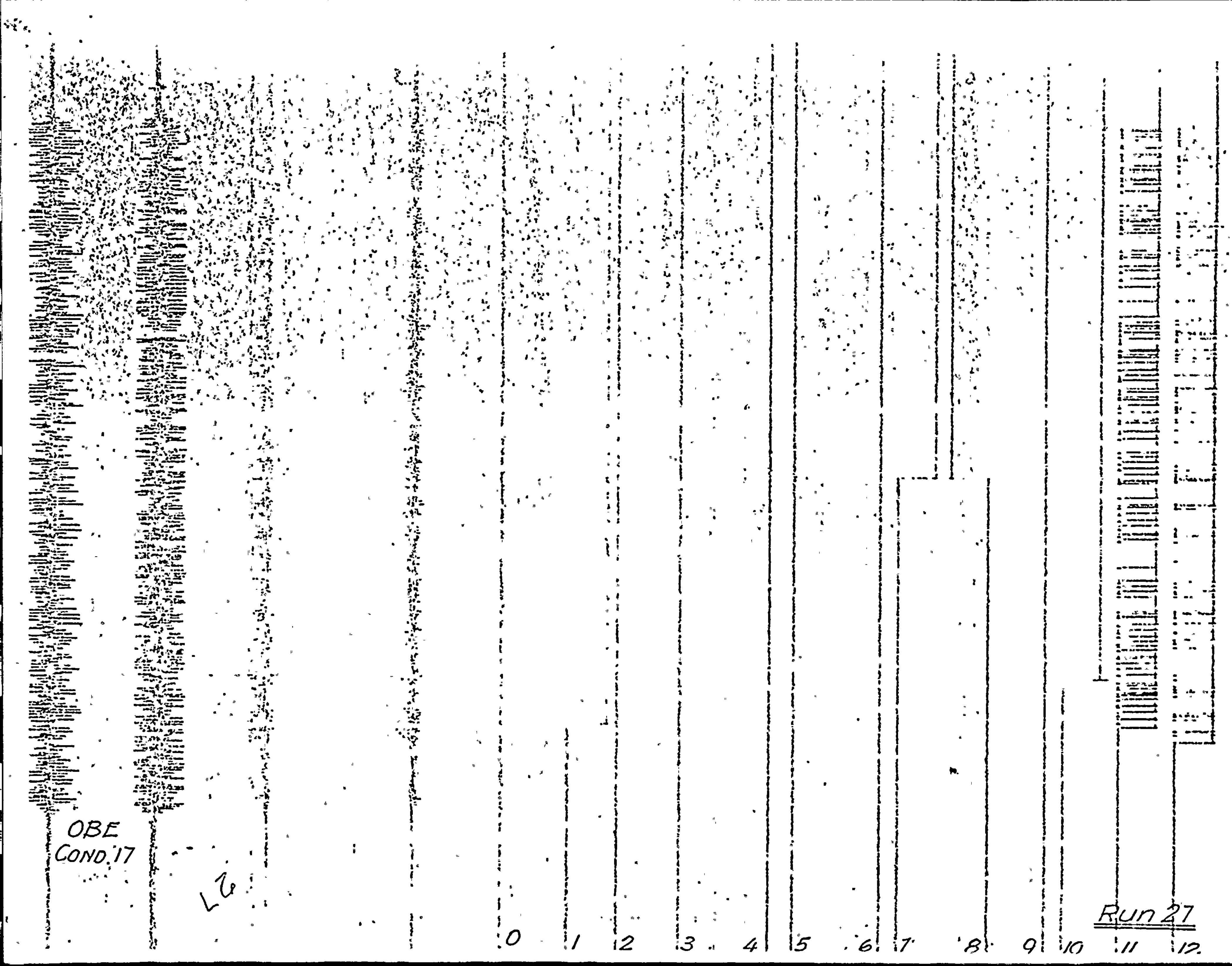

SSE
Run 18
0
1
2
3
4
5
6
7
8
9
10
11
12


SSE
Cond. 12
Run 19
0
1
2
3
4
5
6
7
8
9
10
11
12

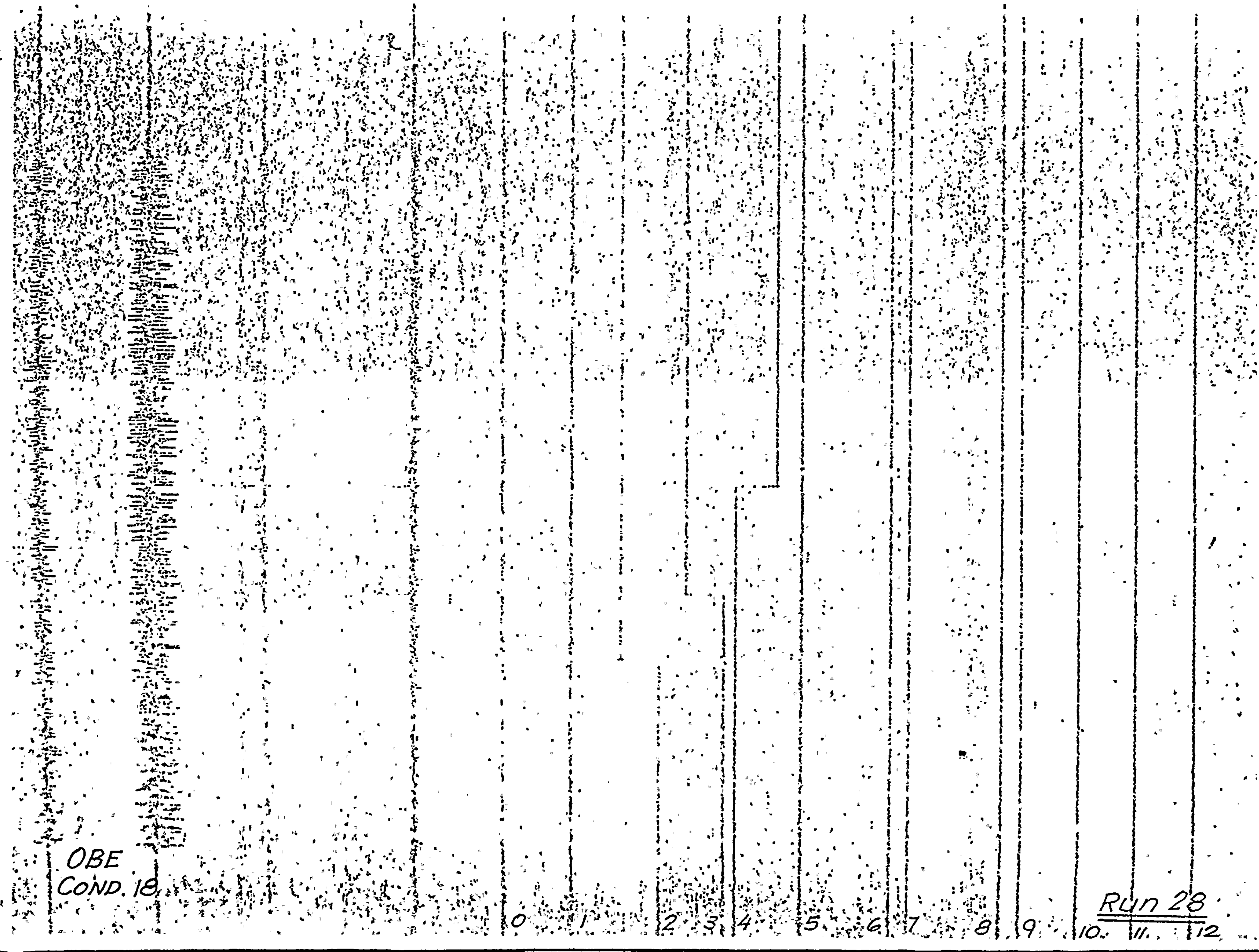

SSE
Cond. 13
02
Run 20
0
1
2
3
4
5
6
7
8
9
10
11
12

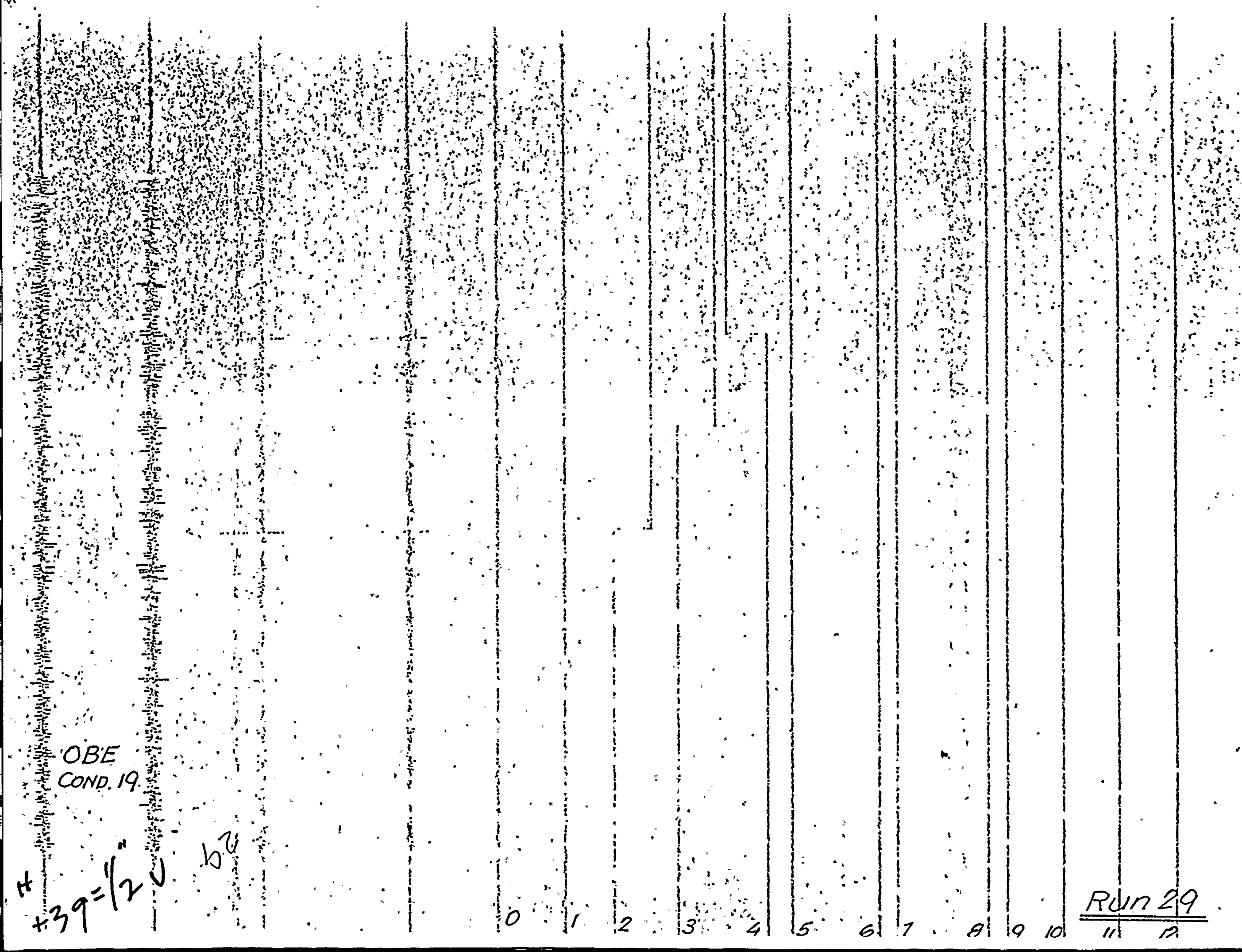


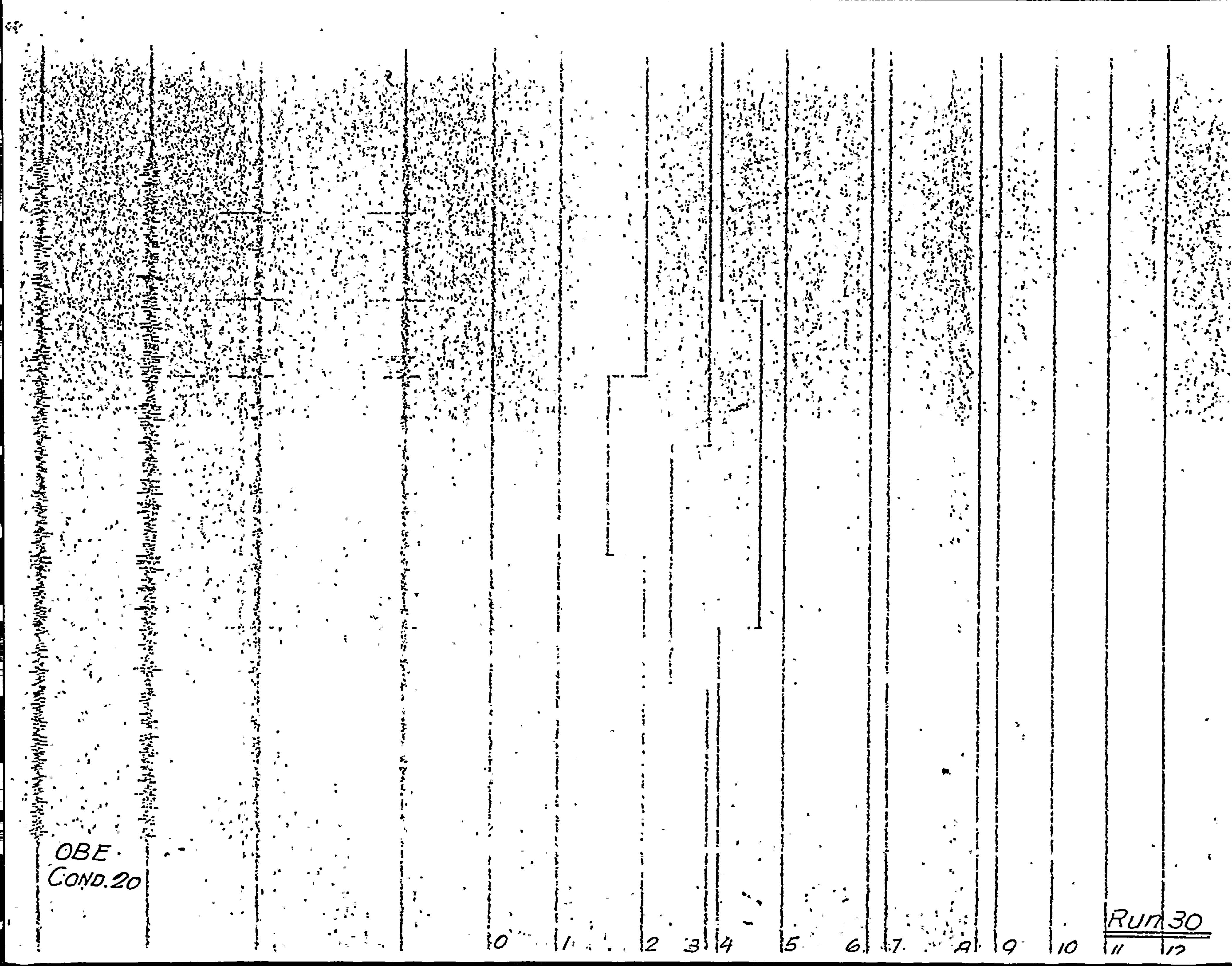
H OBE V COND 16
Run 26
0
1
2
3
4
5
6
7
8
9
10
11
12



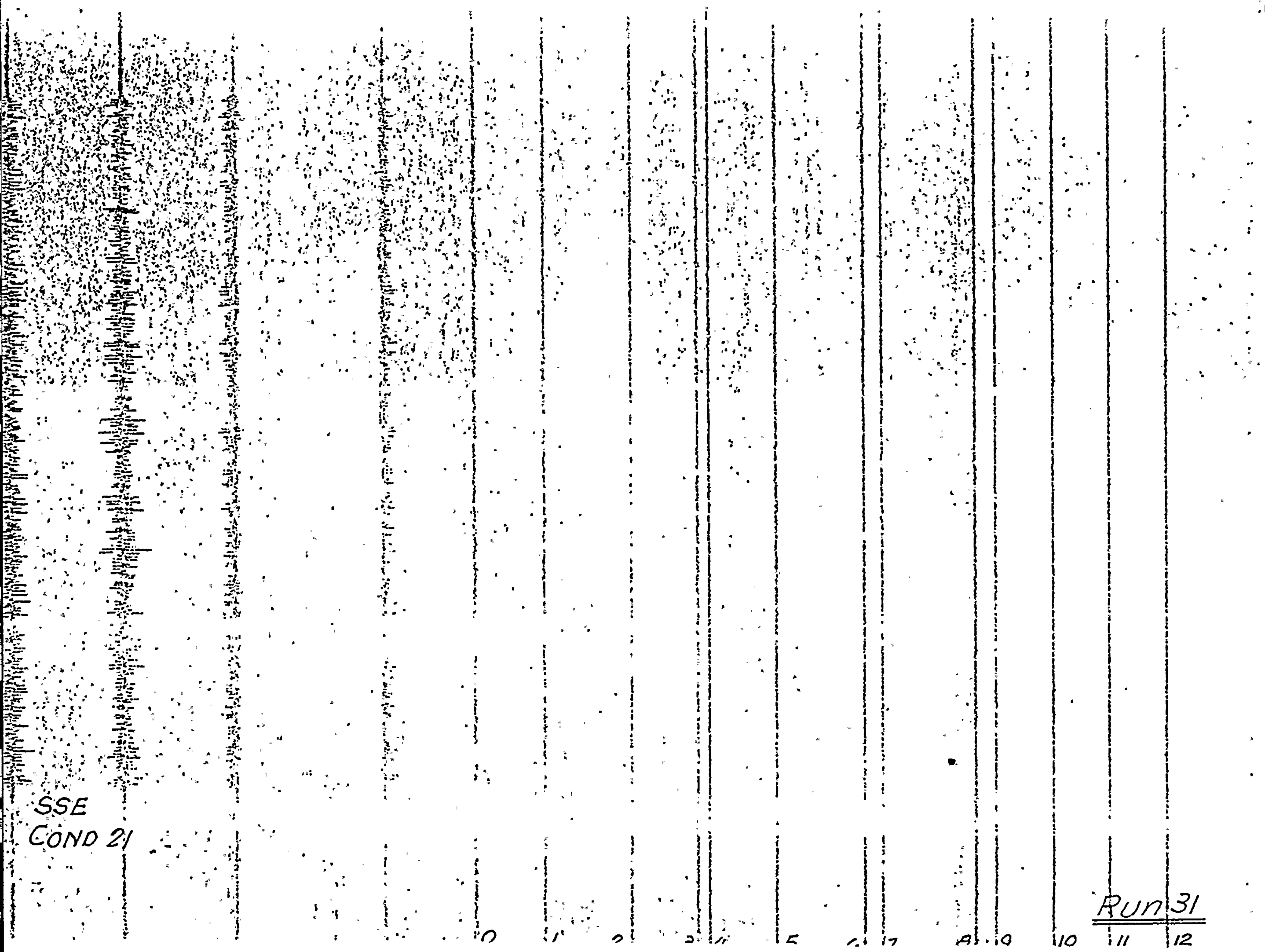
OBE
COND. 17
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 27

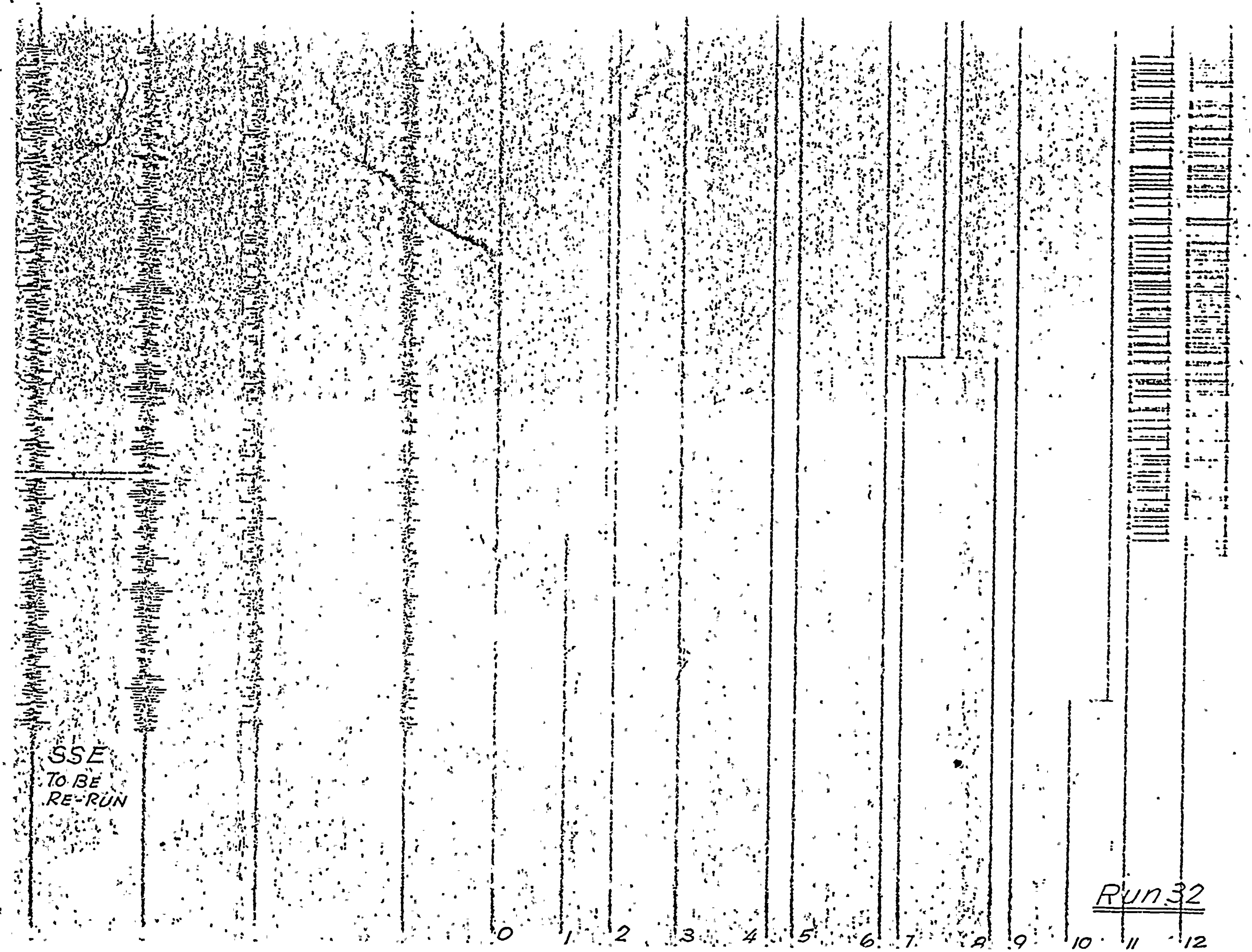

OBE
COND. 18
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 28

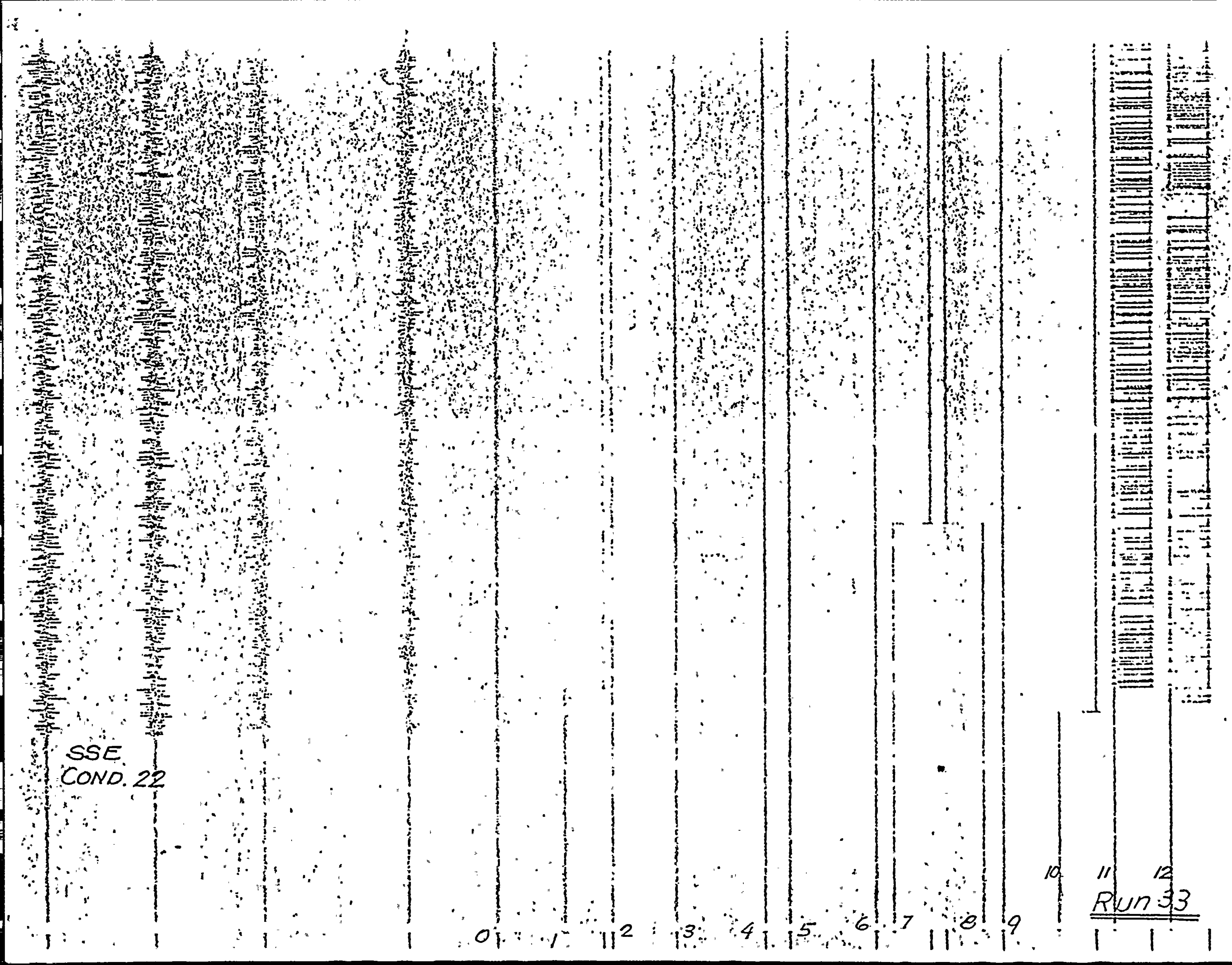

OBE
COND. 19
+39 = 1/2"
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 29

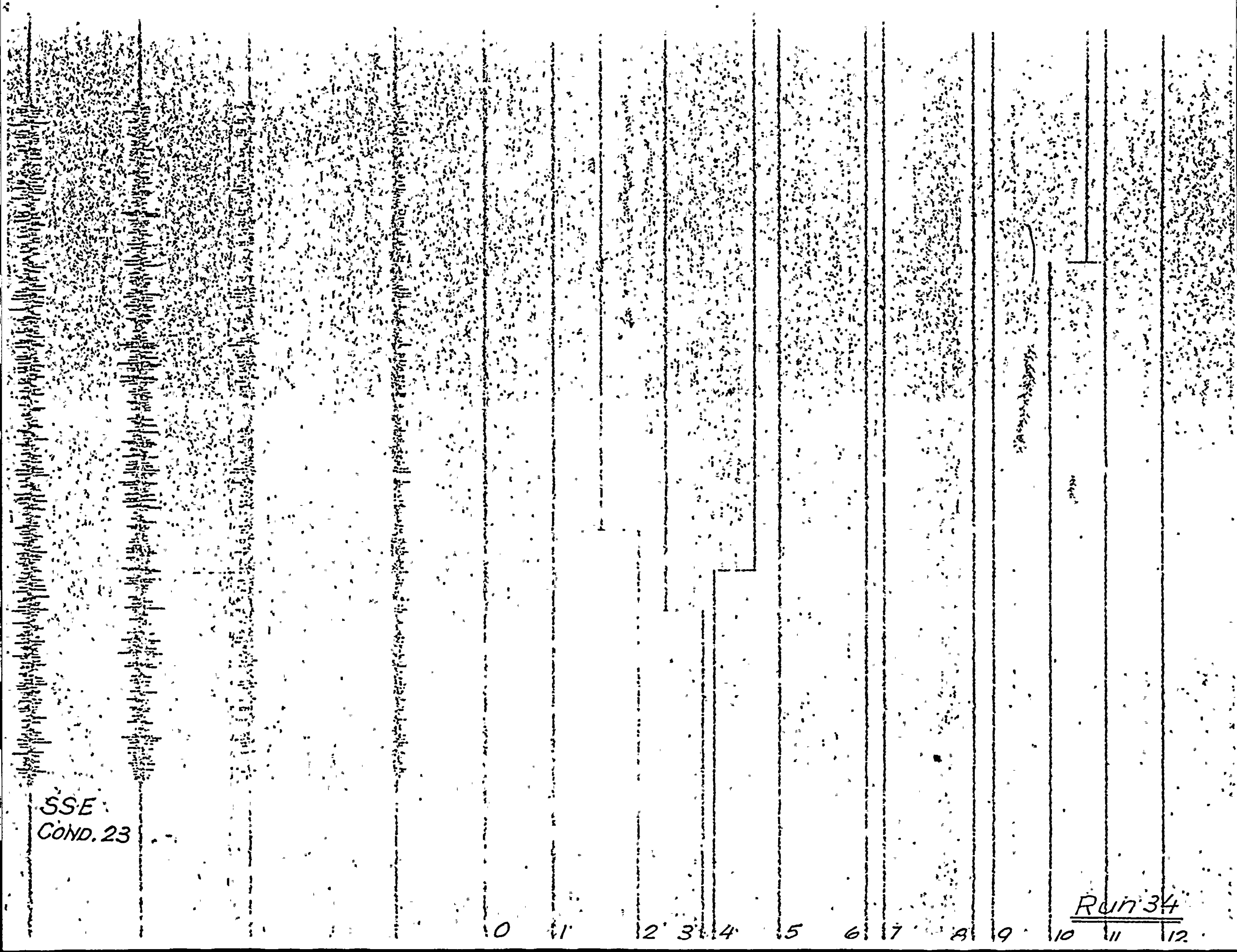


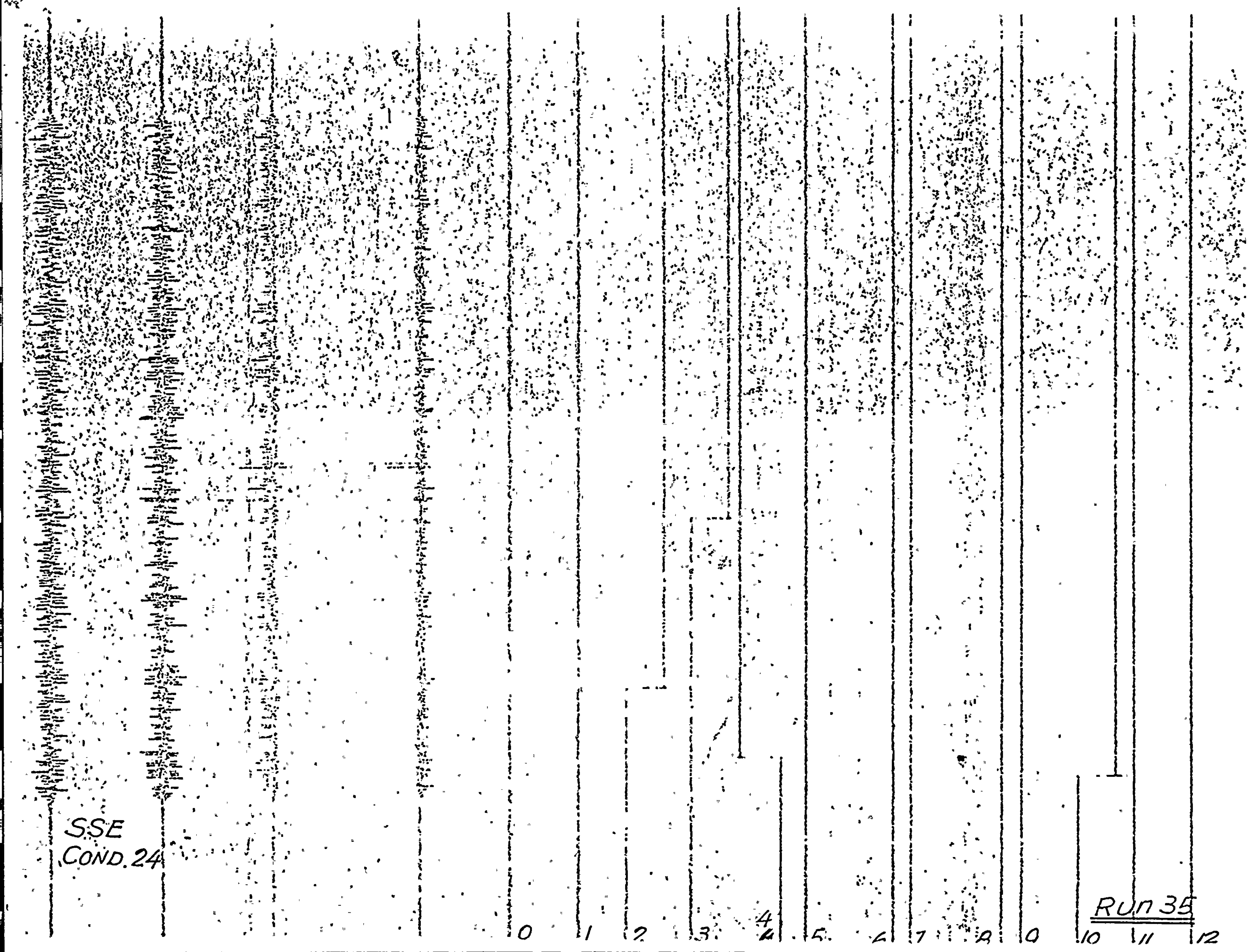
OBE·
COND. 20
Run 30
0
1
2
3
4
5
6
7
8
9
10
11
12

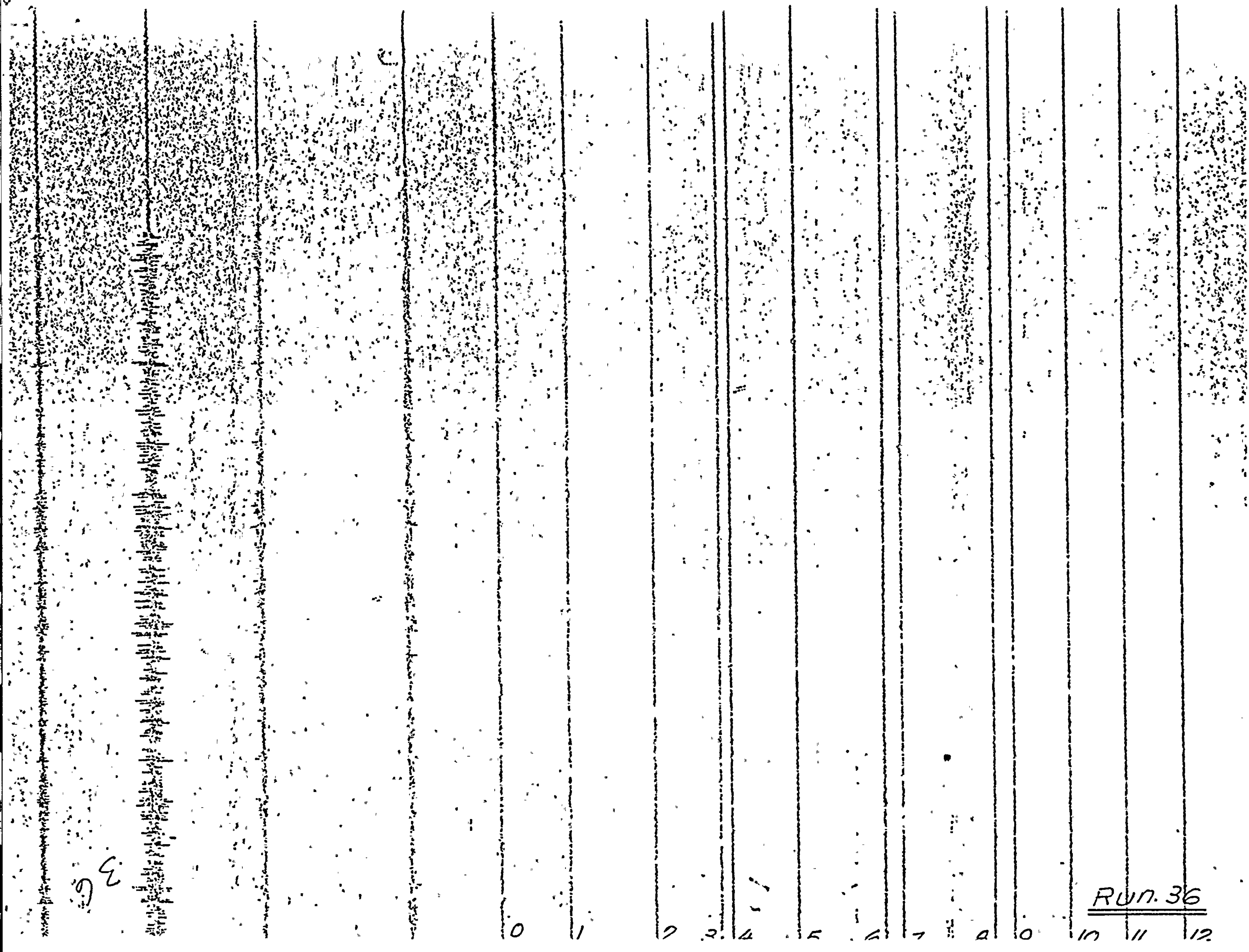

SSE
COND 21
Run 31
0
5
10
11
12

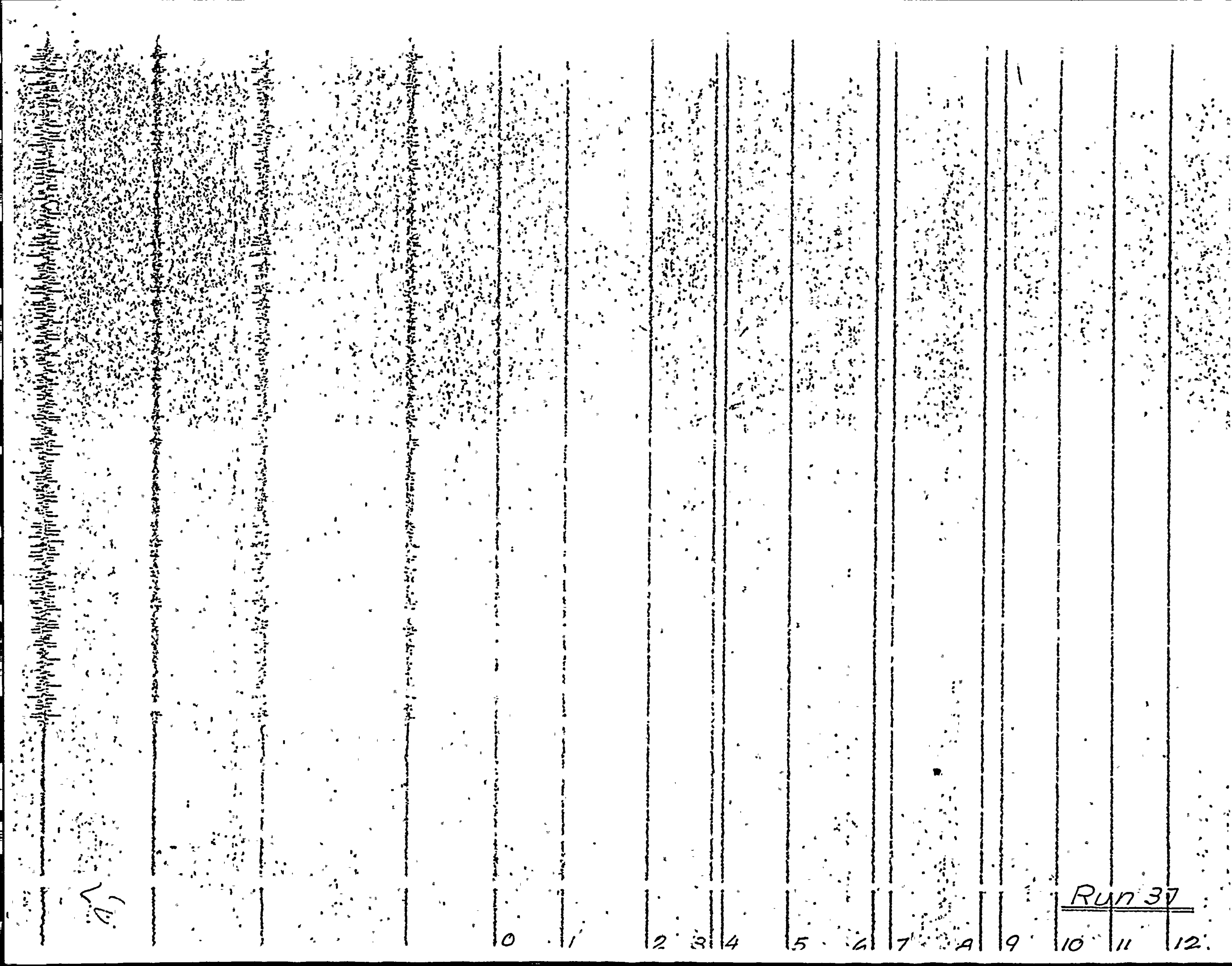

SSE
TO BE
RE-RUN
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 32

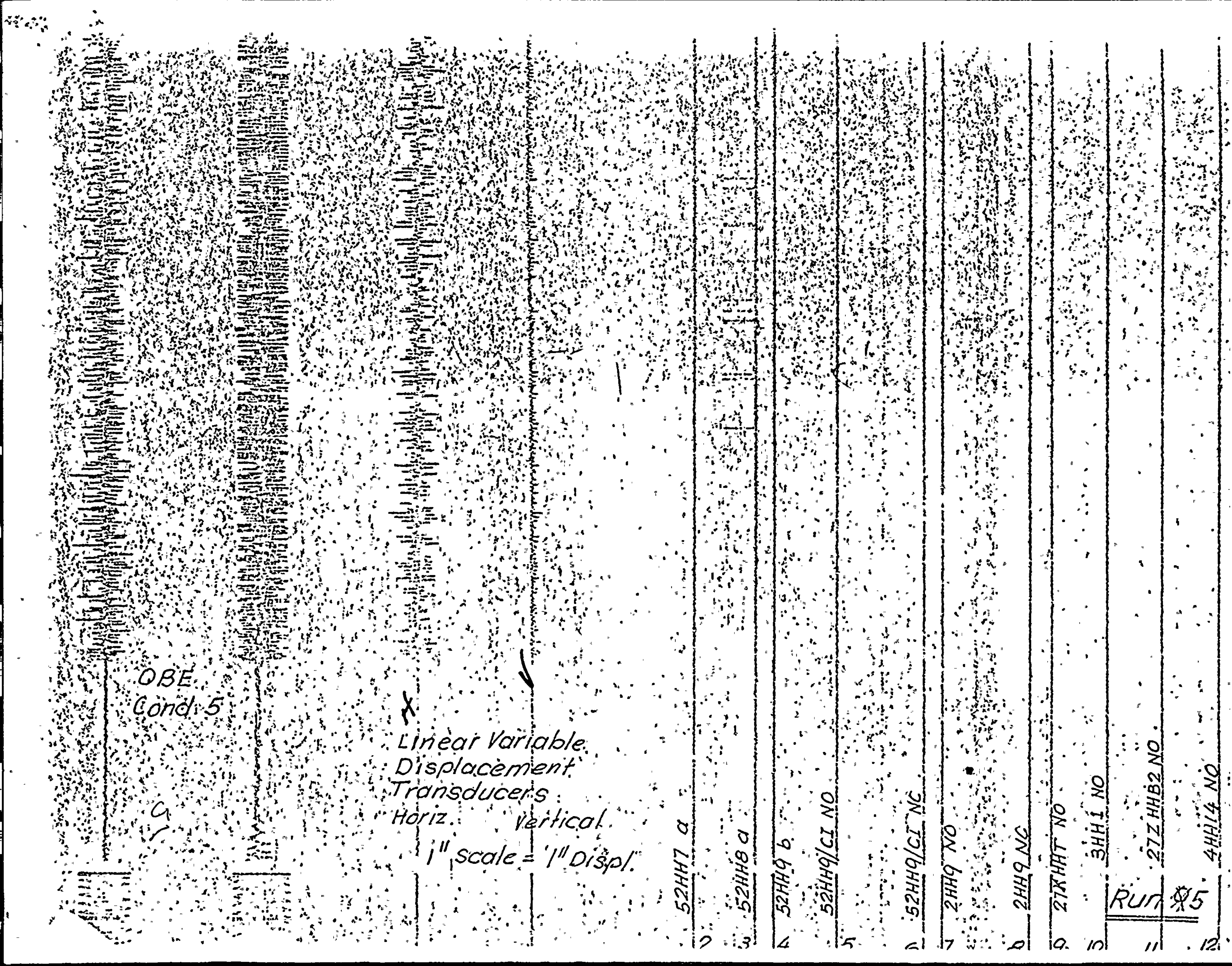

SSE
COND. 22
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 33

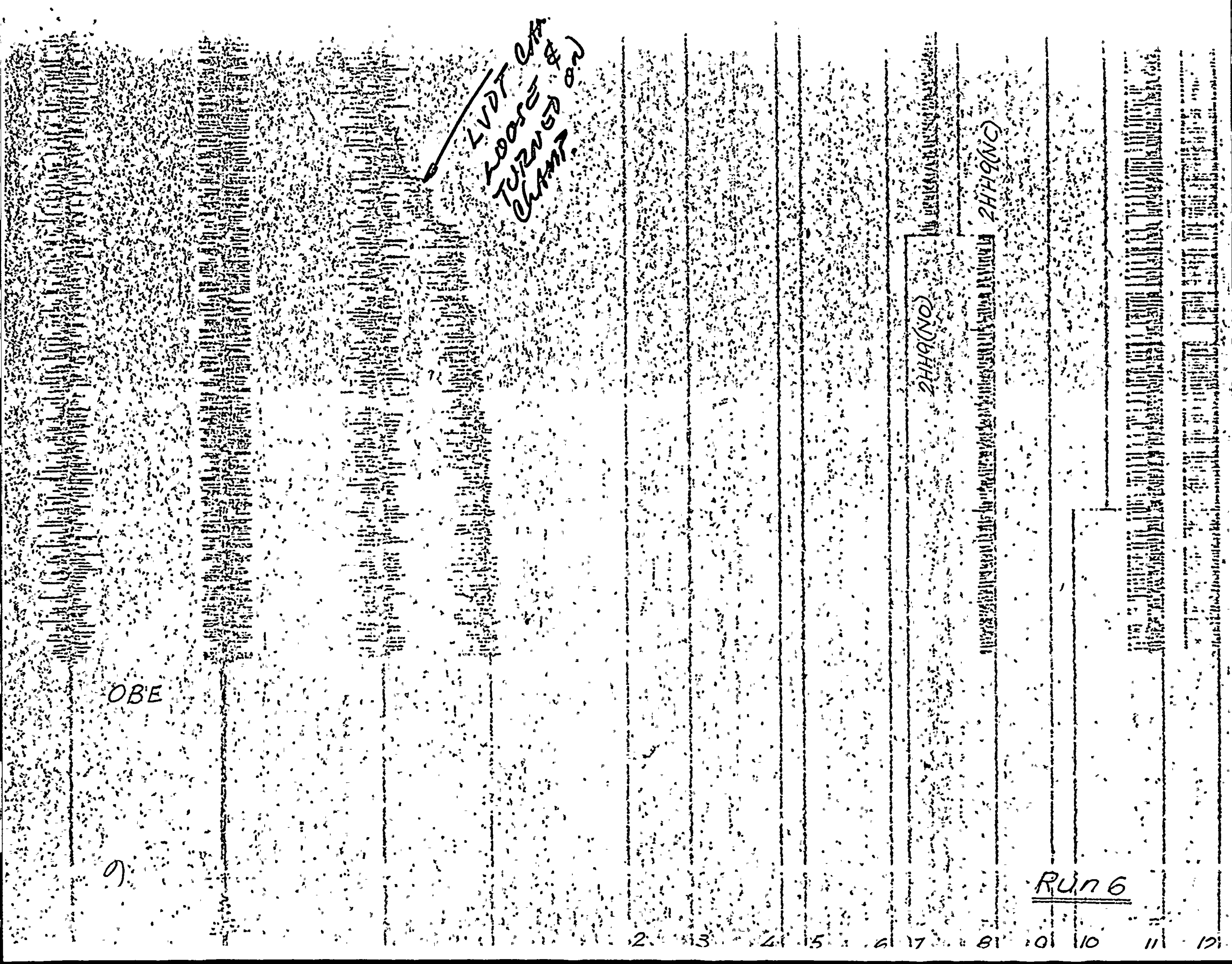

SSE
COND. 23
Run 34
0
1
2
3
4
5
6
7
8
9
10
11
12


SSE
COND. 24
Run 35
0
1
2
3
4
5
6
7
8
9
10
11
12

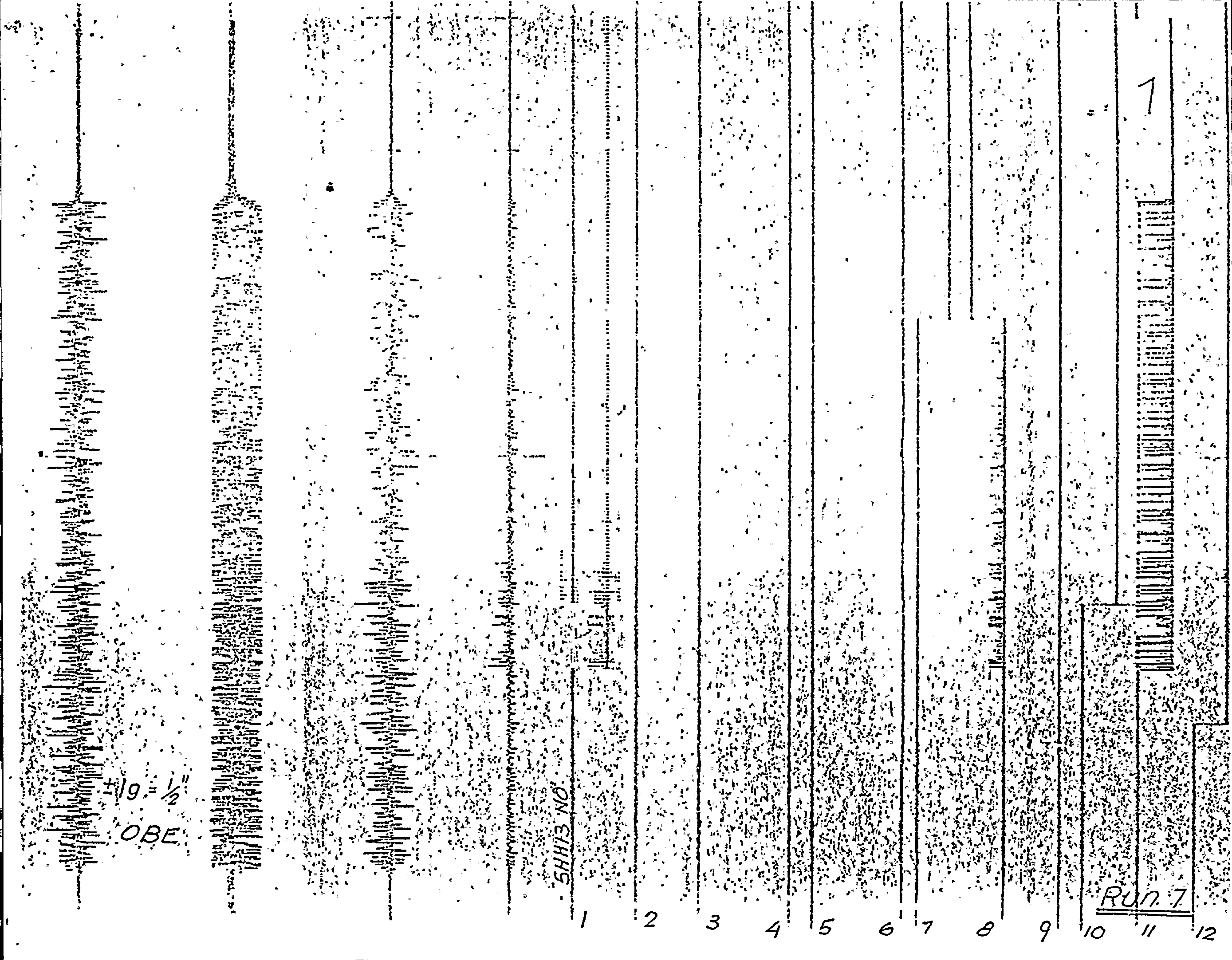

Run. 36
0
1
2
3
4
5
6
7
8
9
10
11
12


Run 37
0
1
2
3
4
5
6
7
8
9
10
11
12

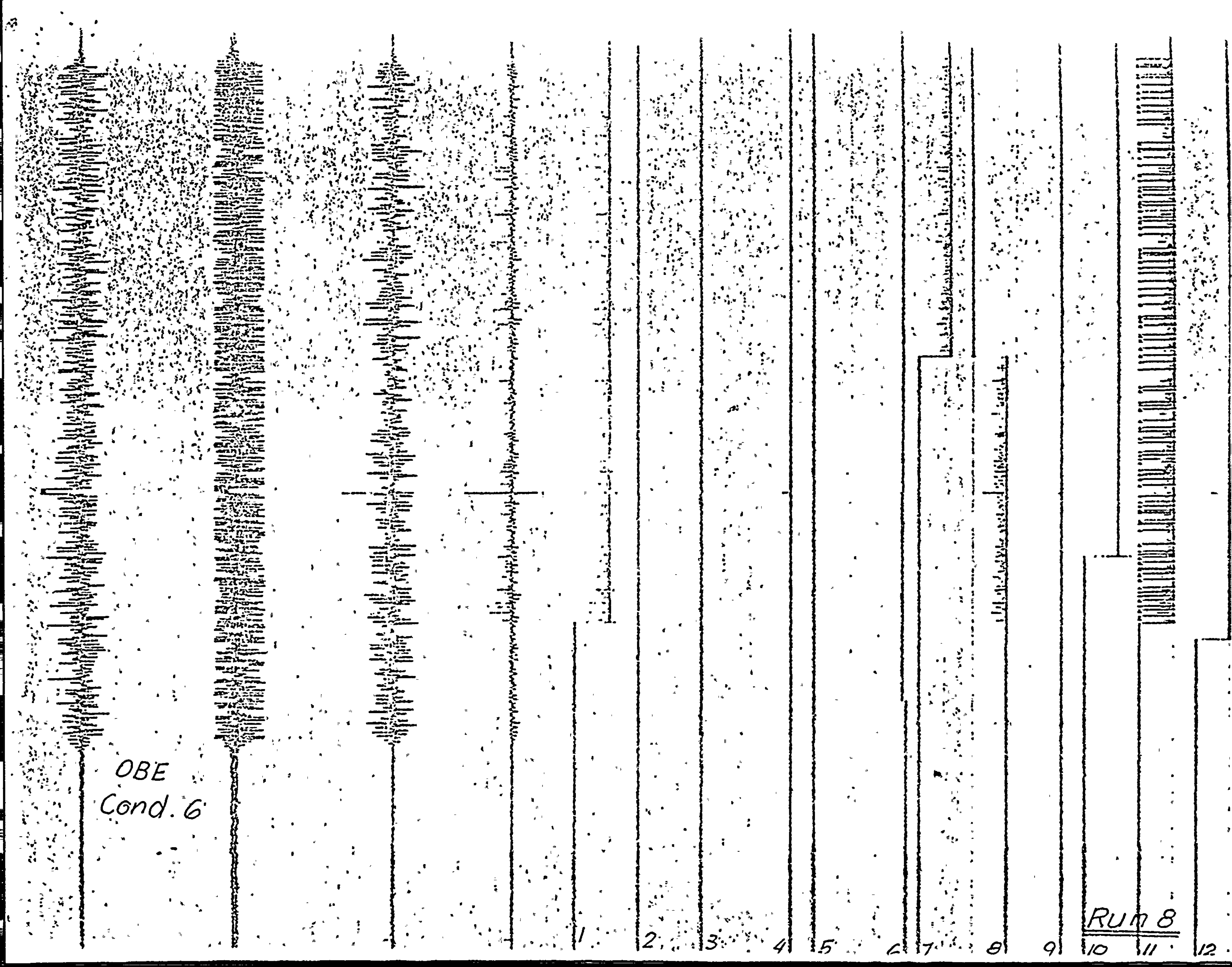

OBE
Cond 5
X
V
Linear Variable
Displacement
Transducers
Horiz.
Vertical
1" scale = 1" Displ.
52HH7 a
52HH8 a
52HH9 b
52HH9/CI NO
52HH9/CI NC
2HH9 NO
2HH9 NC
27Z HHT NO
3HH1 NO
27Z HHB2 NO
4HH14 NO
Run #5
2
3
4
5
6
7
8
9
10
11
12

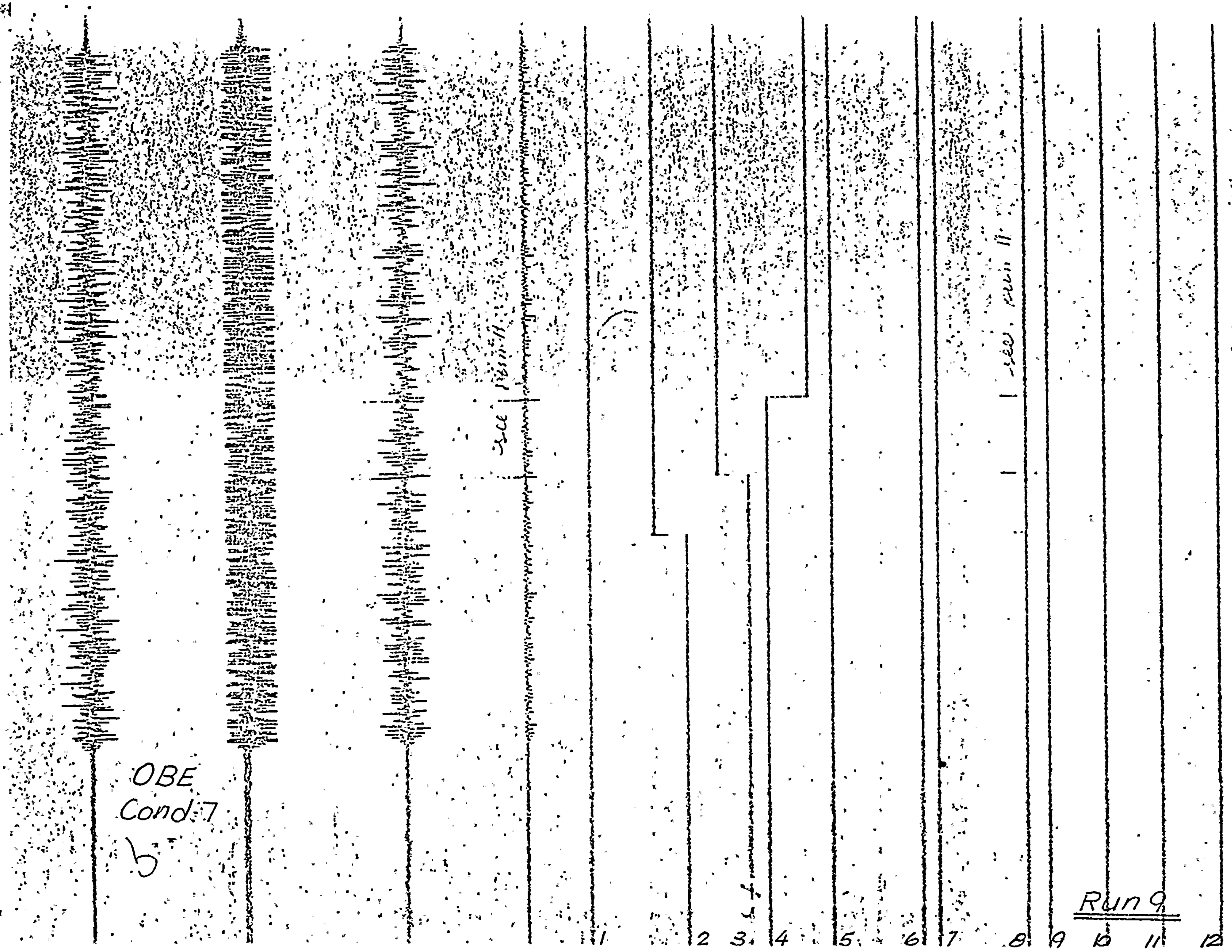


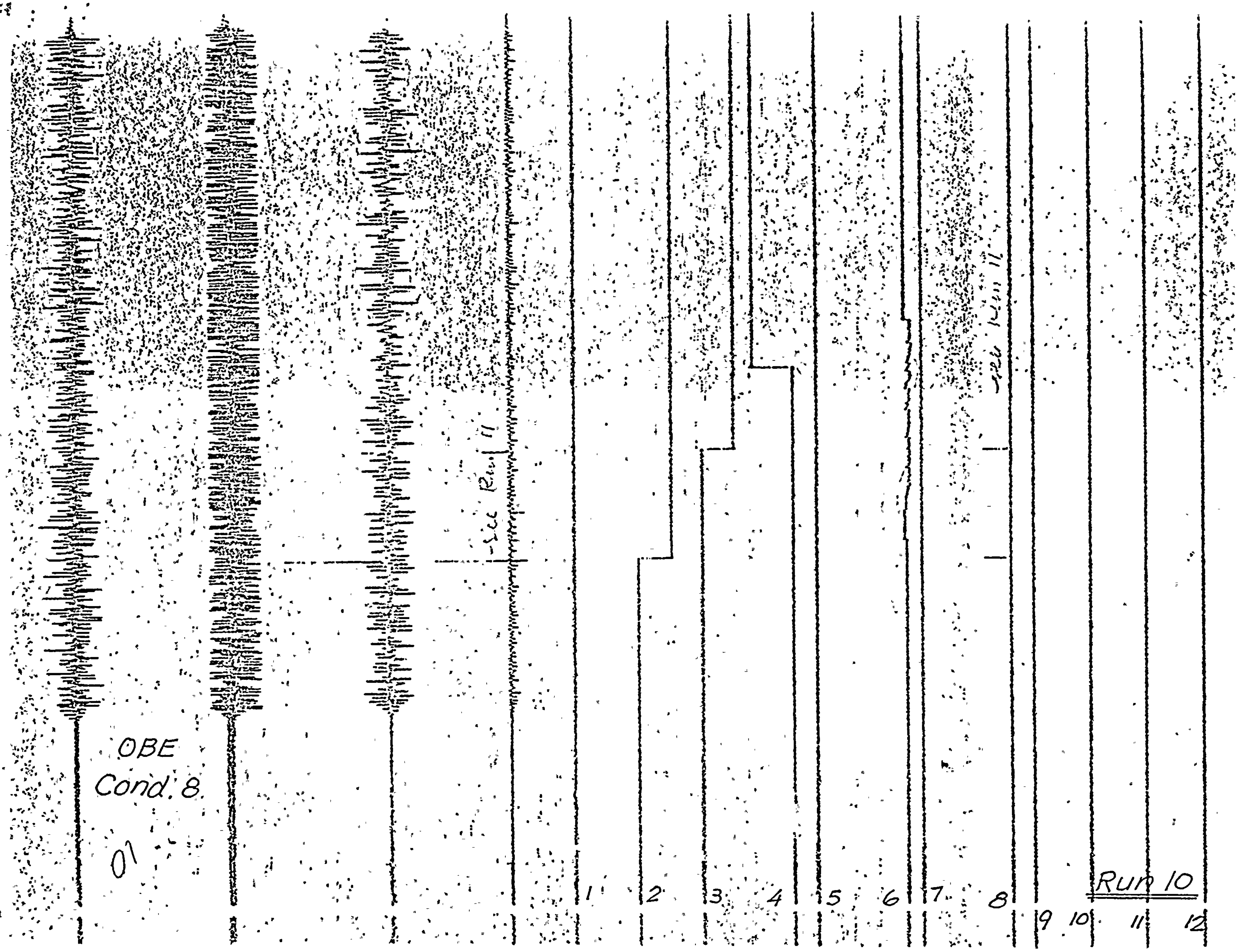
LVDT
OBE
2HH9(NO)
2HH9(NO)
Run 6
2
3
4
5
6
7
8
10
11
12

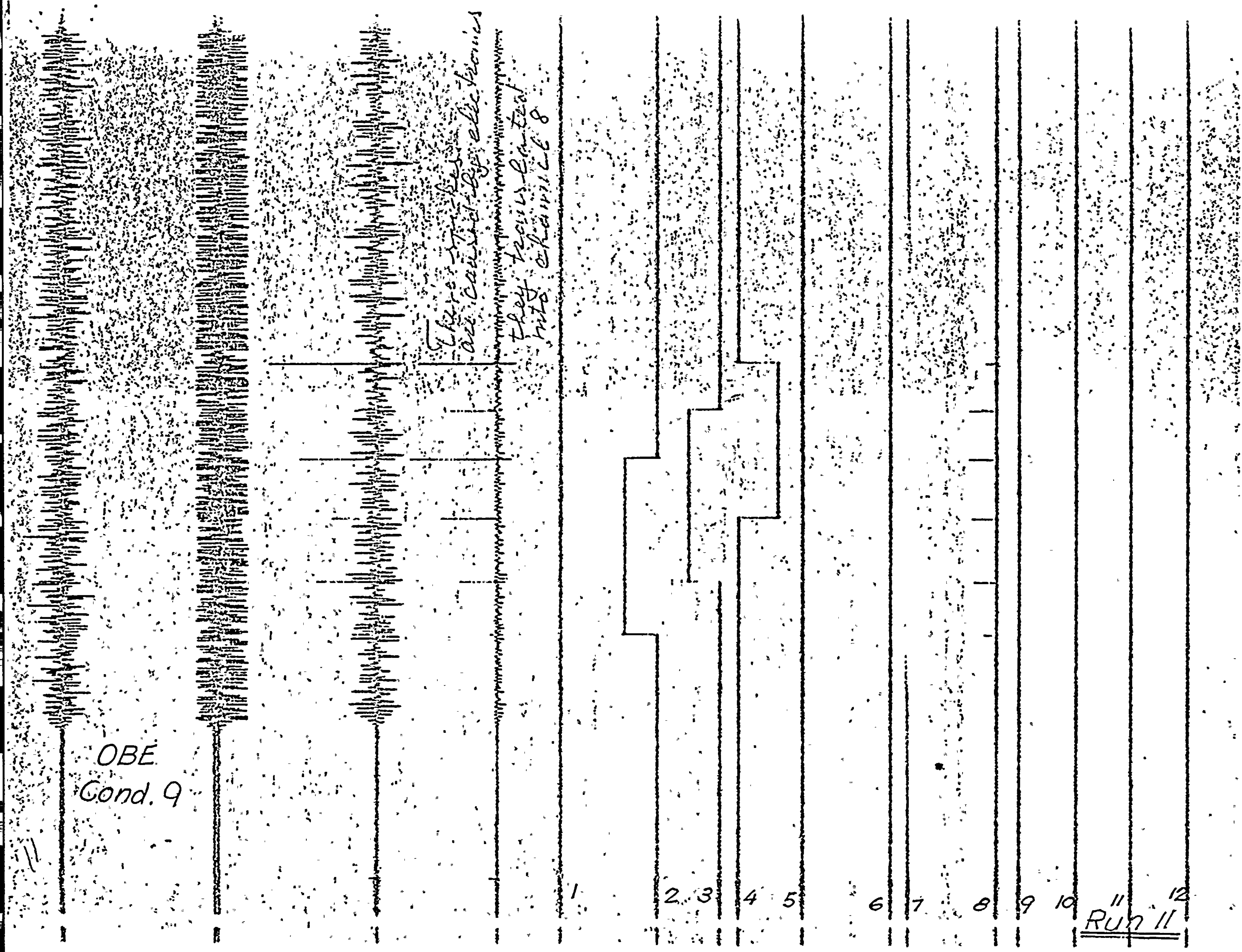


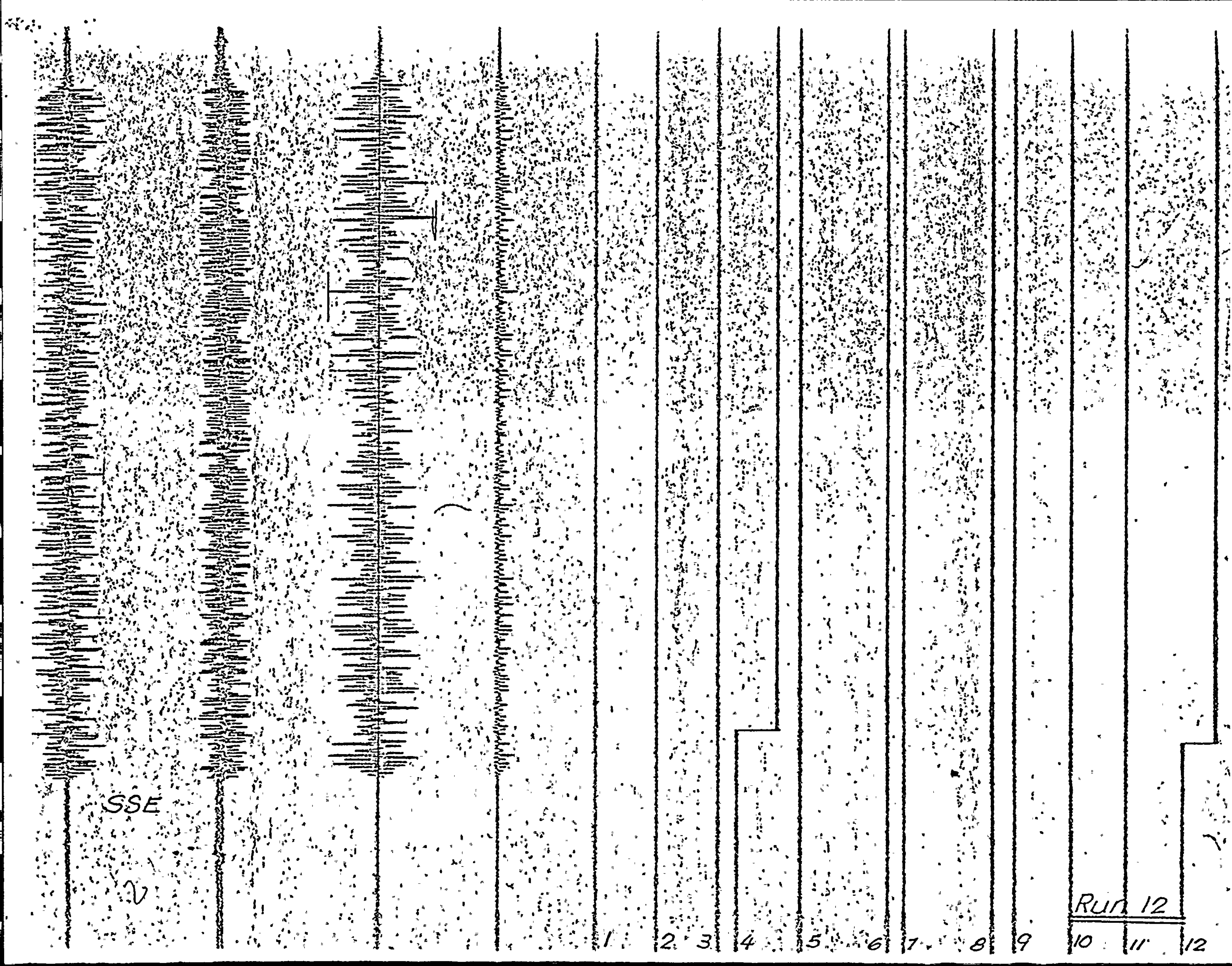
1
±1g = 1/2"
OBE
SHH13 NO
1
2
3
4
5
6
7
8
9
10
11
12
Run 7

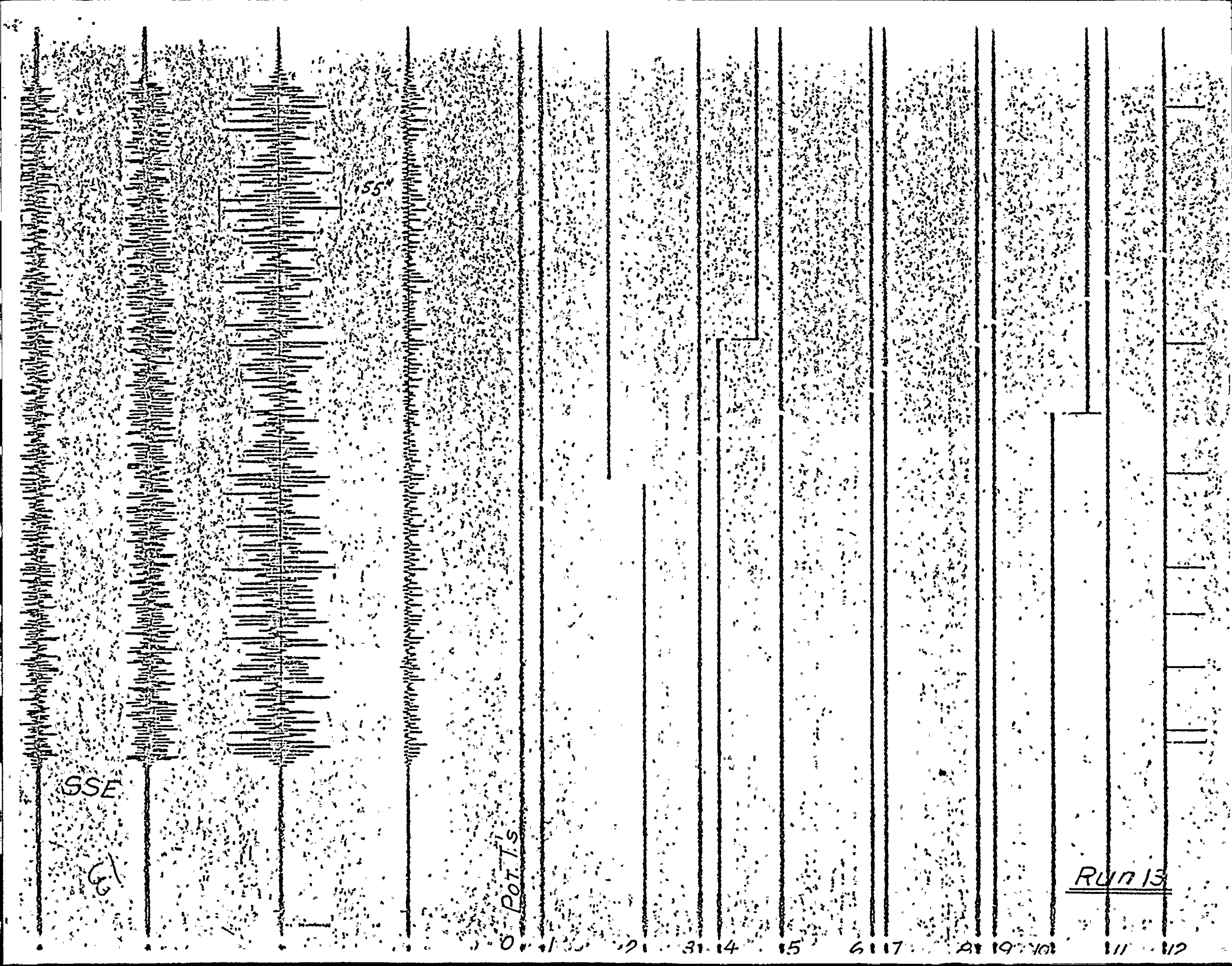

OBE
Cond. 6
Run 8
1
2
3
4
5
6
7
8
9
10
11
12

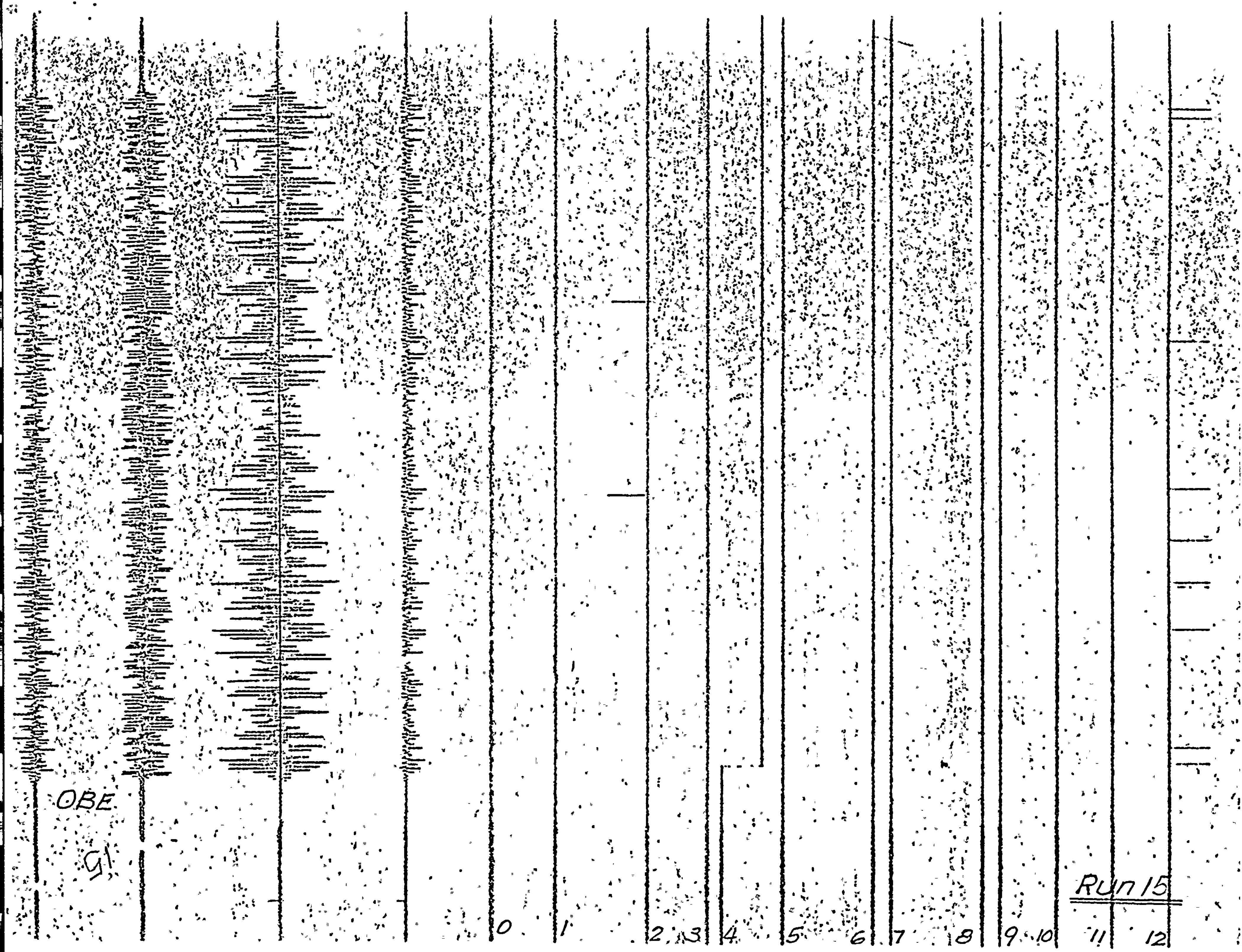

OBE
Cond. 7
see run 11
see run 11
Run 9
1
2
3
4
5
6
7
8
9
10
11
12

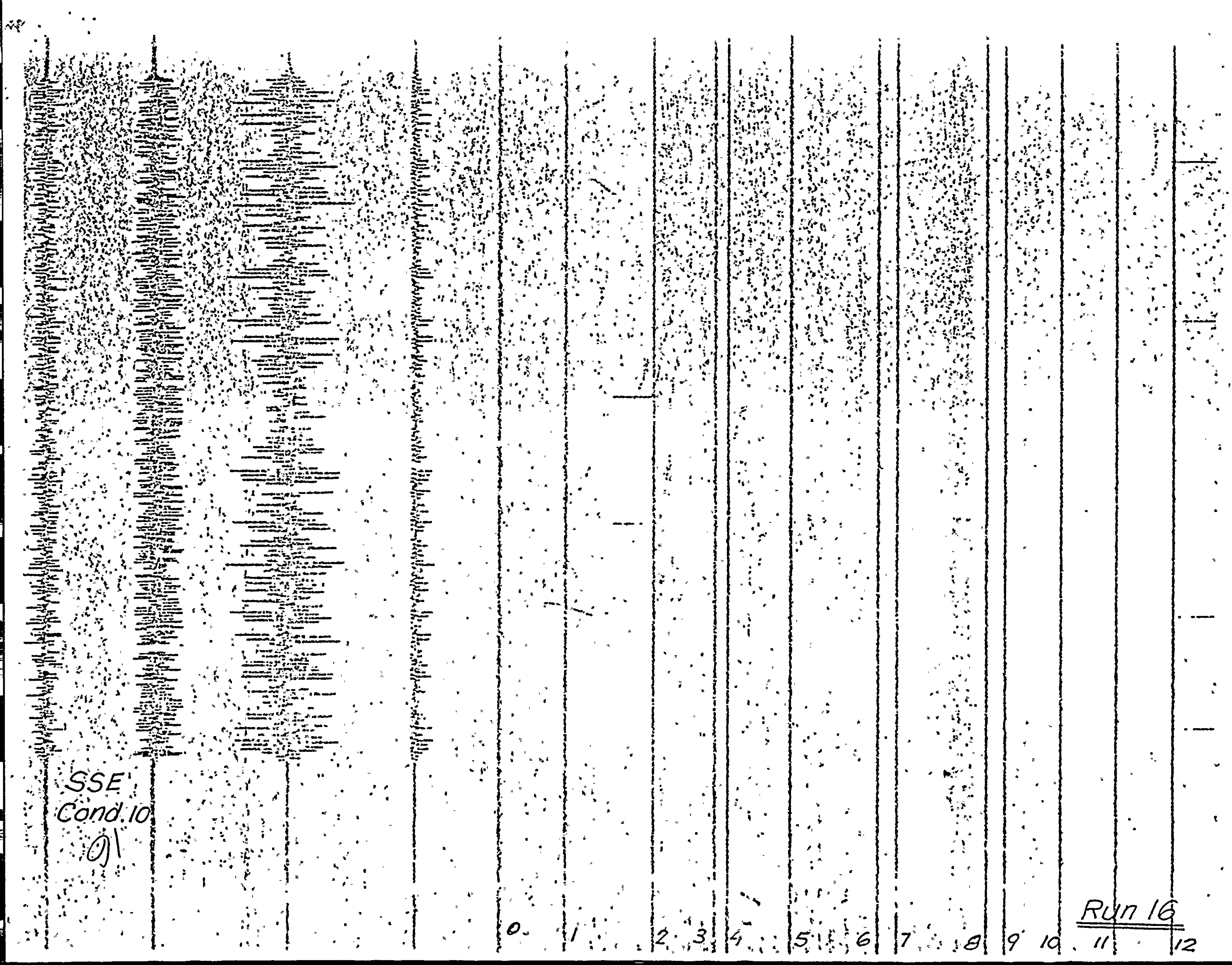

OBE
Cond. 8
See Run 11
See Run 11
1
2
3
4
5
6
7
8
9
10
11
12
Run 10

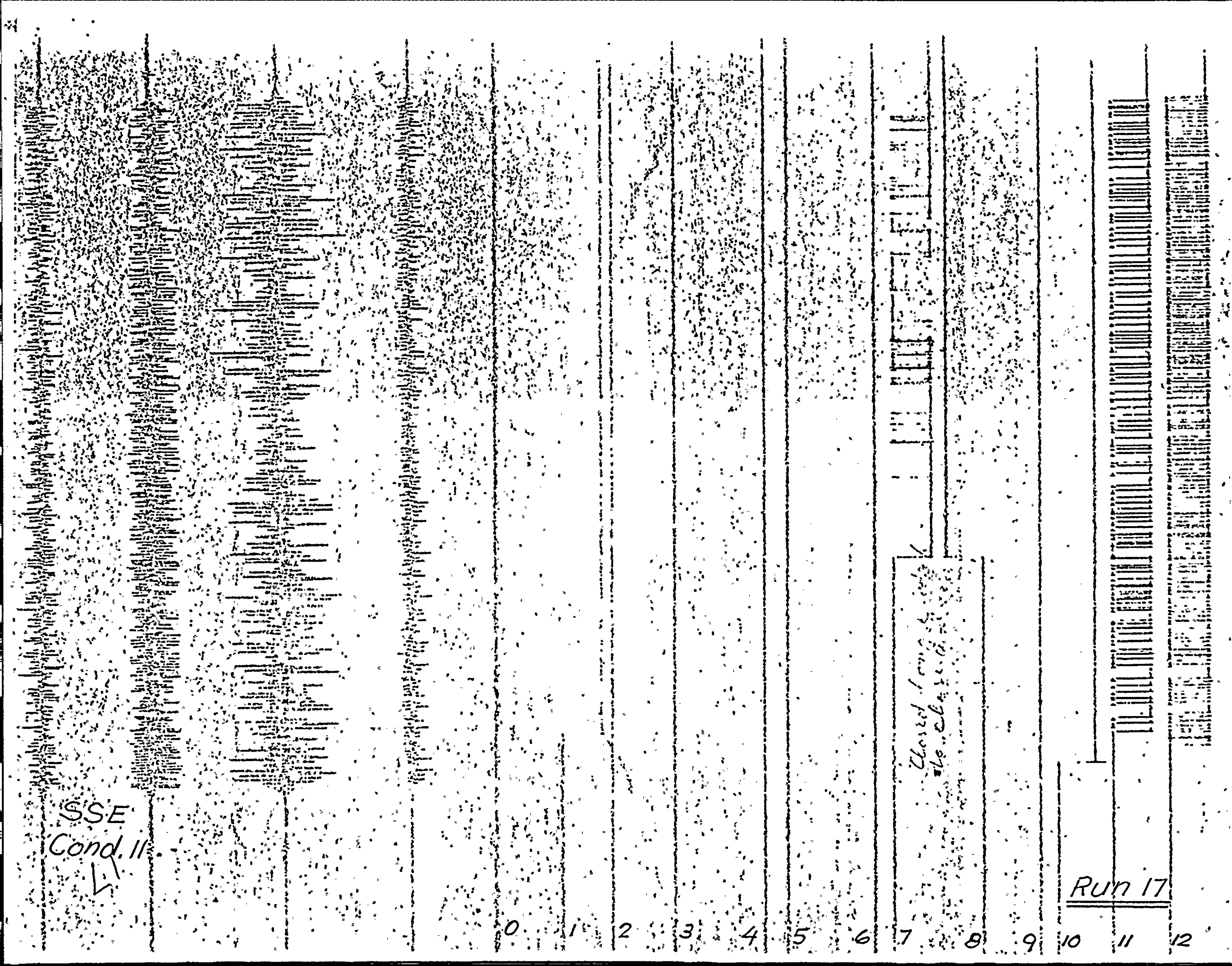

These transients are caused by electronics
they
into channel 8
OBE
Cond. 9
1
2
3
4
5
6
7
8
9
10
11
12
Run 11

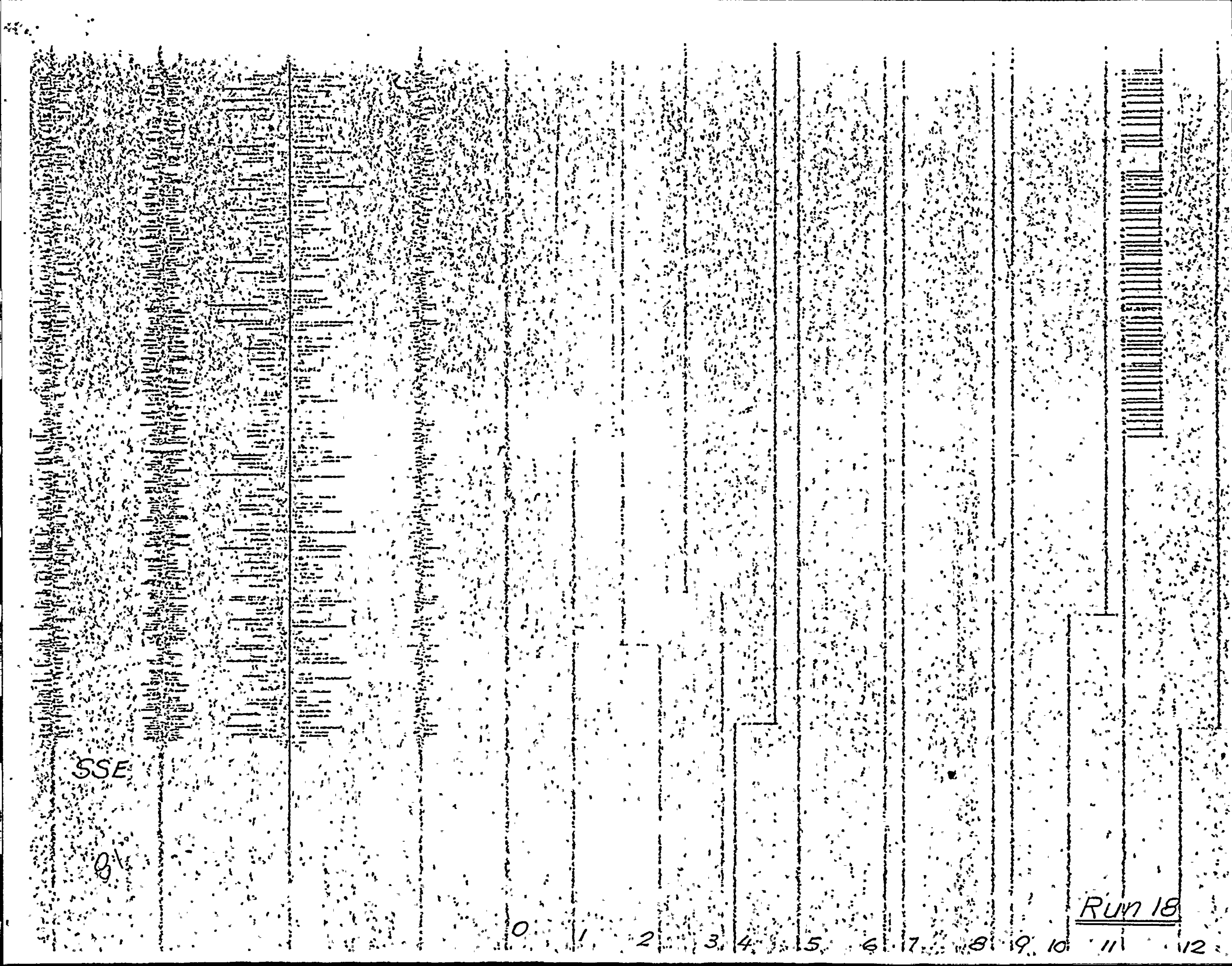

SSE
Run 12
1
2
3
4
5
6
7
8
9
10
11
12

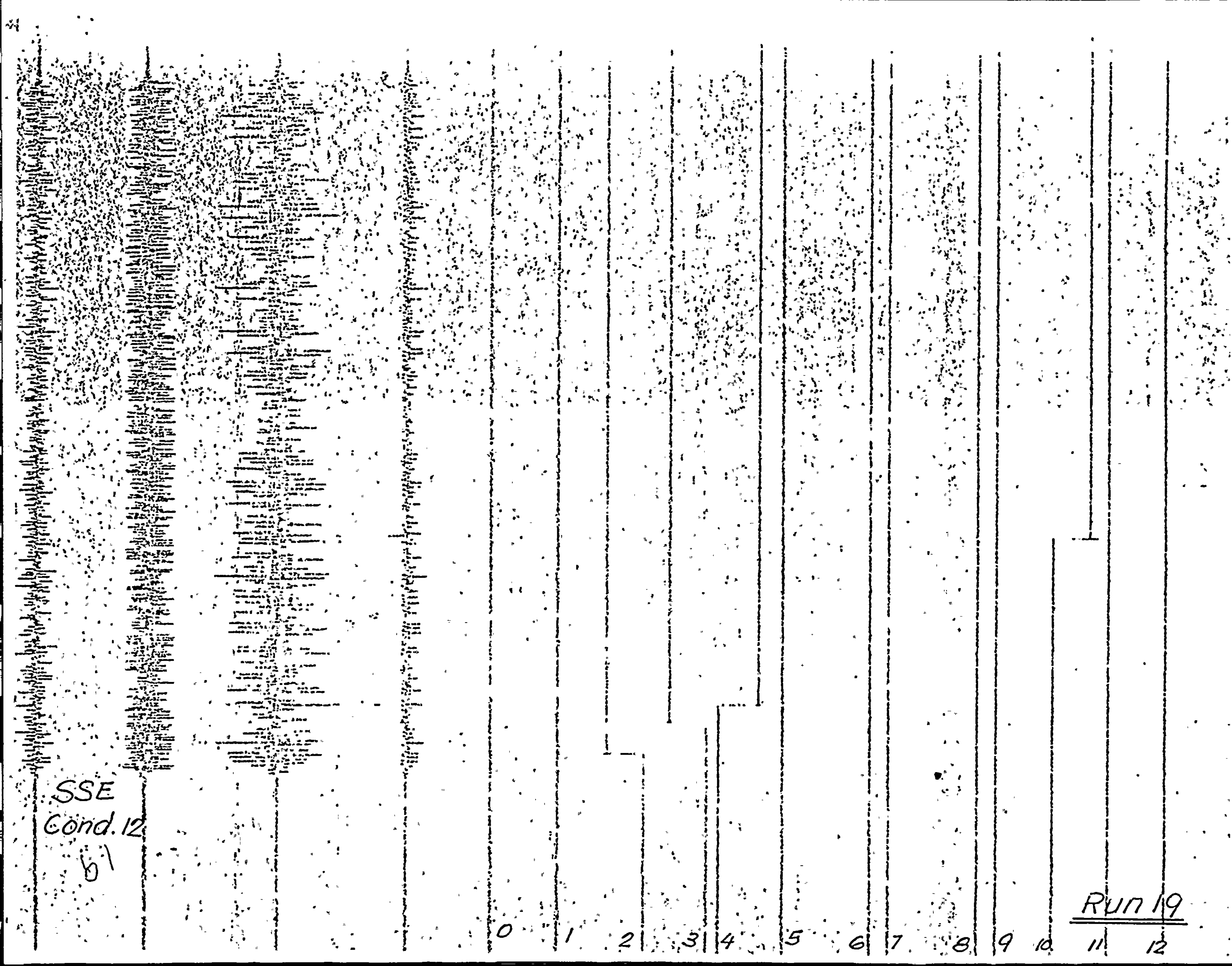

1/55"
SSE
Pot T.s
0 1 2 3 4 5 6 7 8 9 10 11 12
Run 13

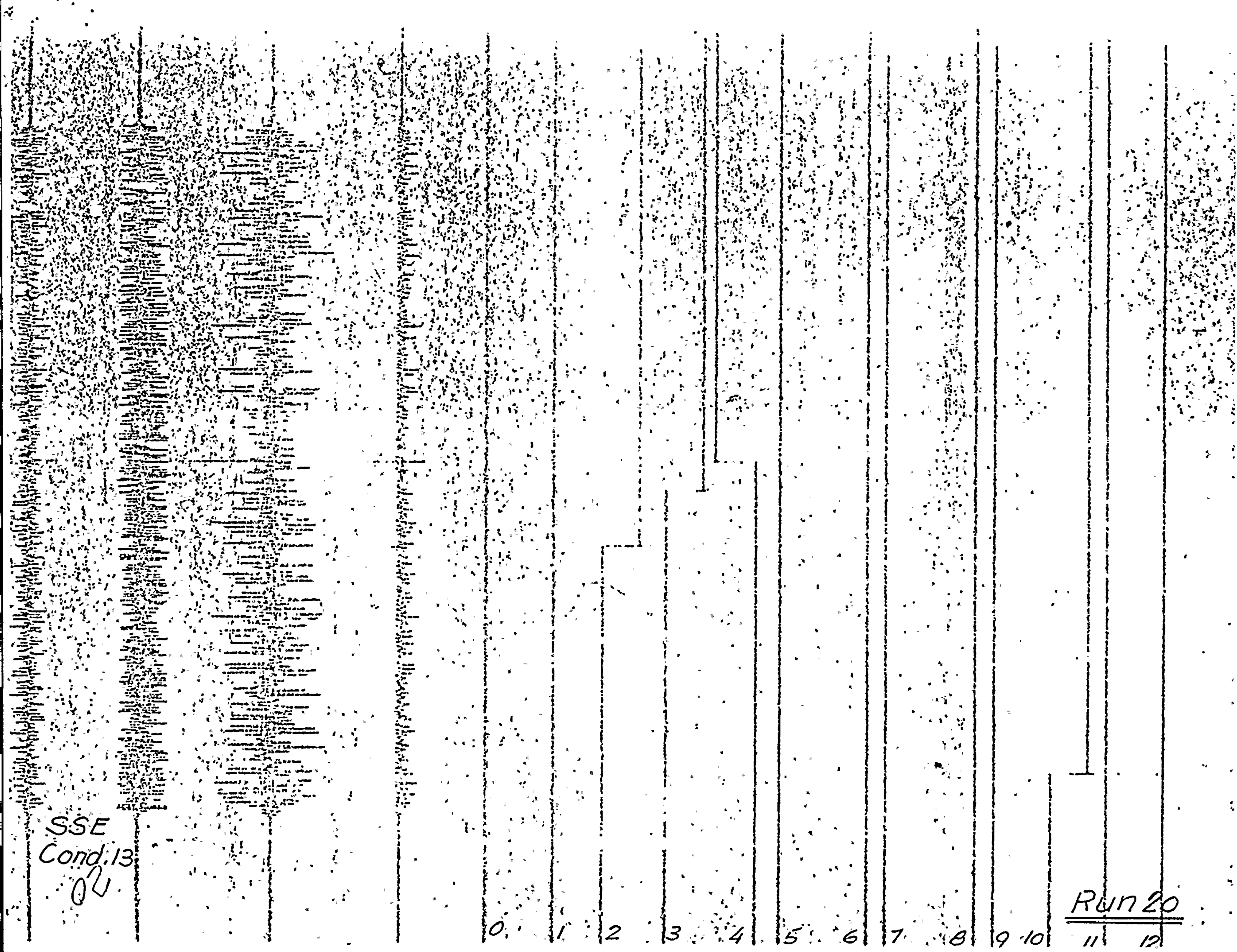

OBE
G1
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 15

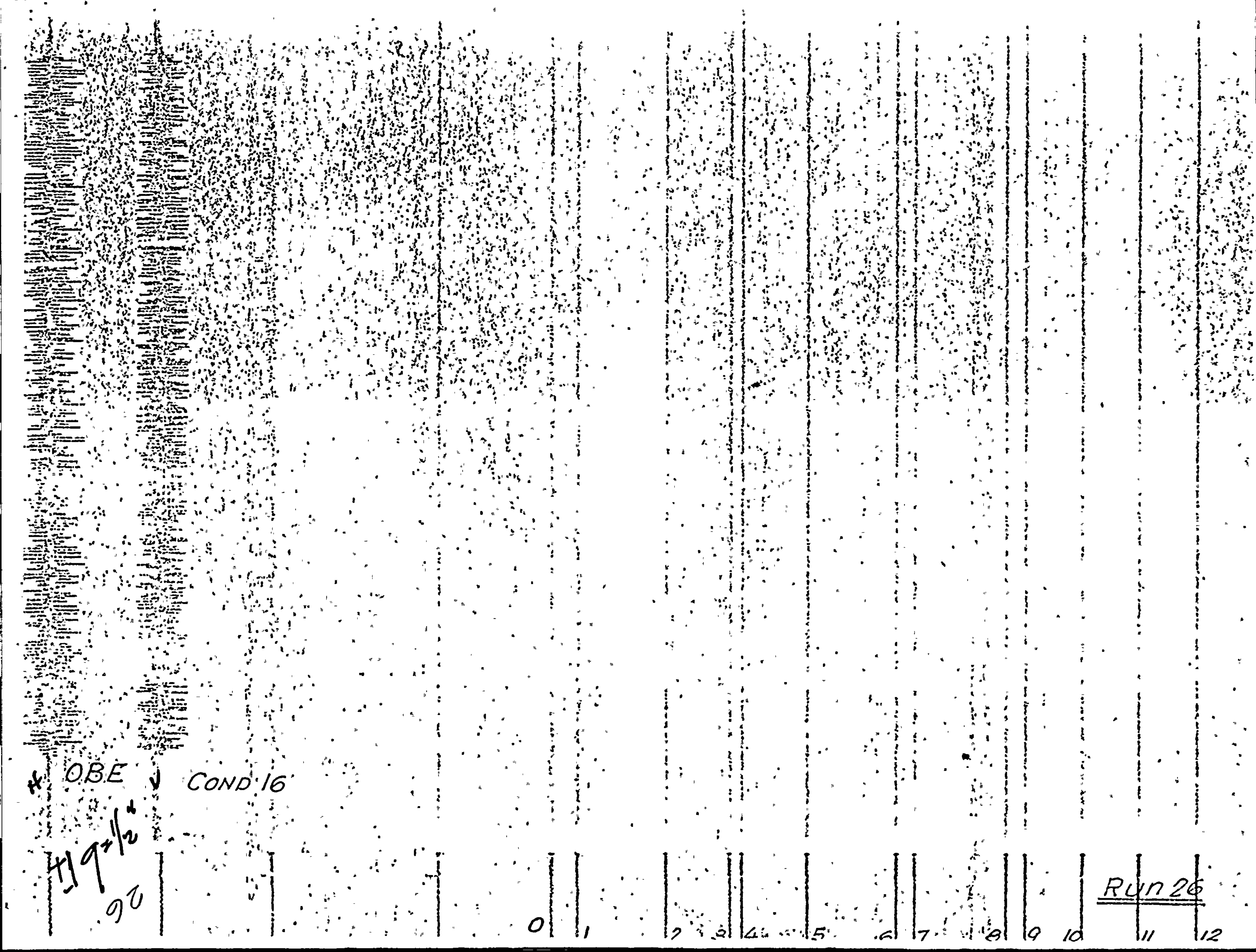

SSE
Cond. 10
Run 16
0
1
2
3
4
5
6
7
8
9
10
11
12

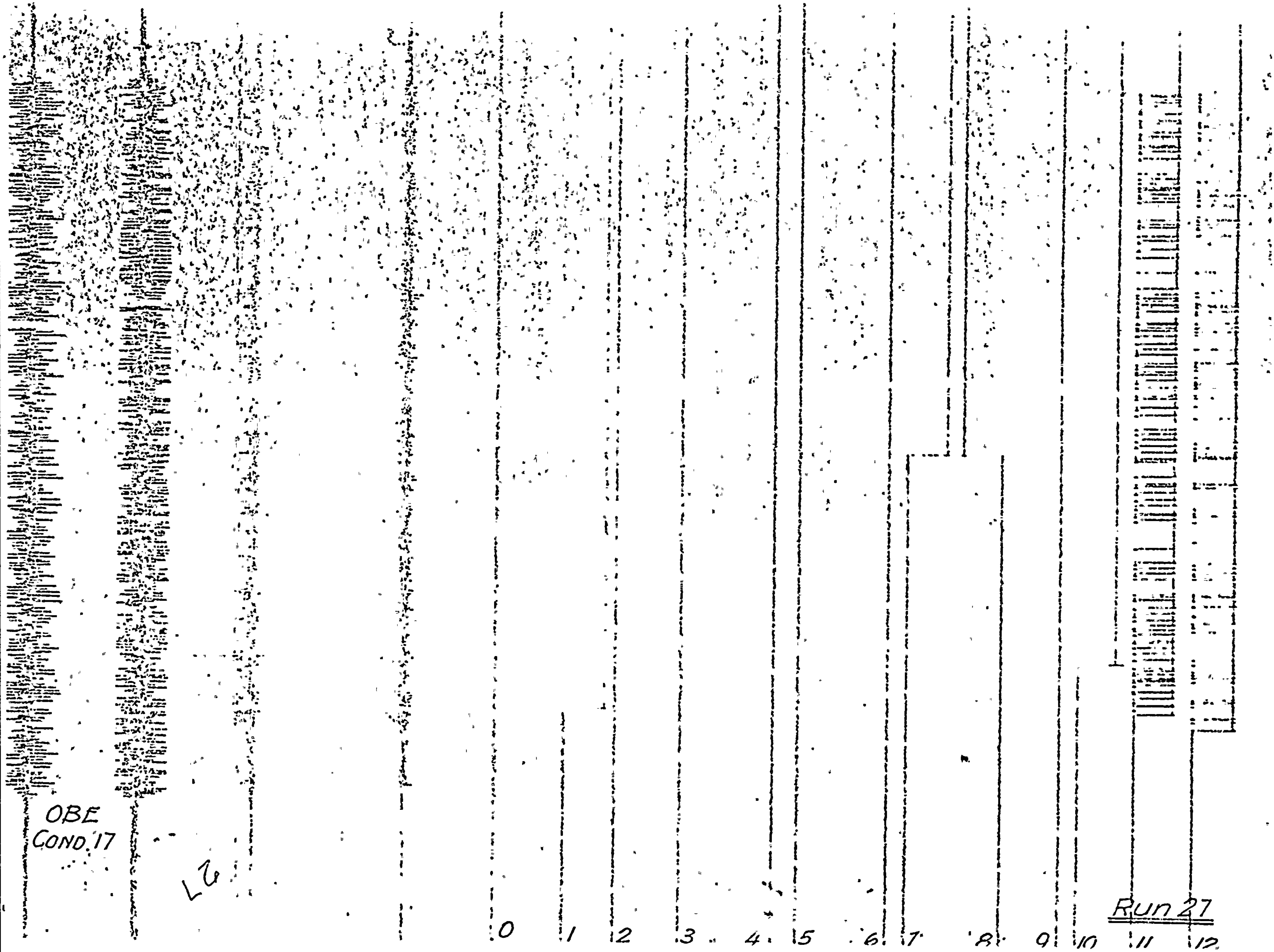

SSE
Cond. II
Run 17
0
1
2
3
4
5
6
7
8
9
10
11
12

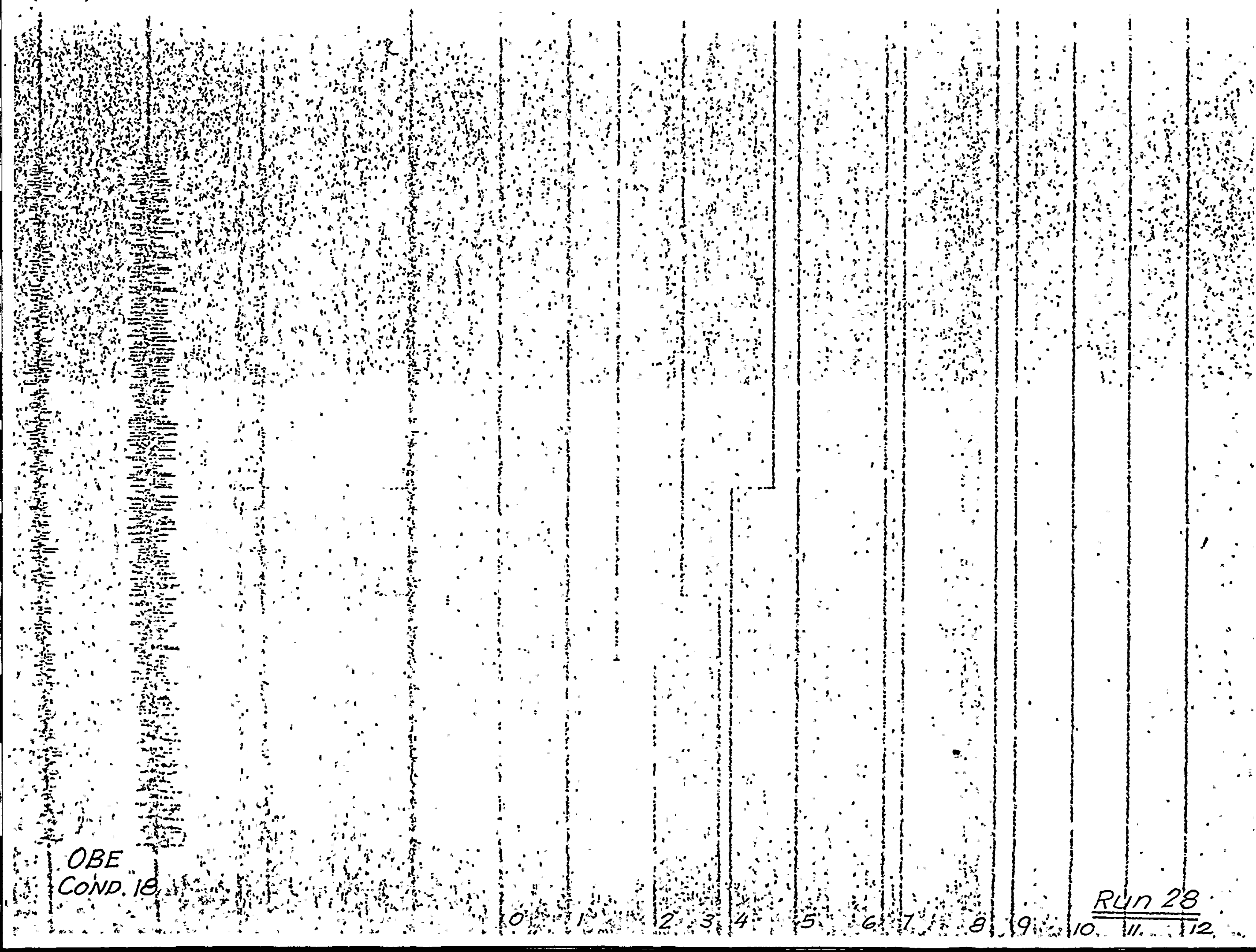

SSE
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 18

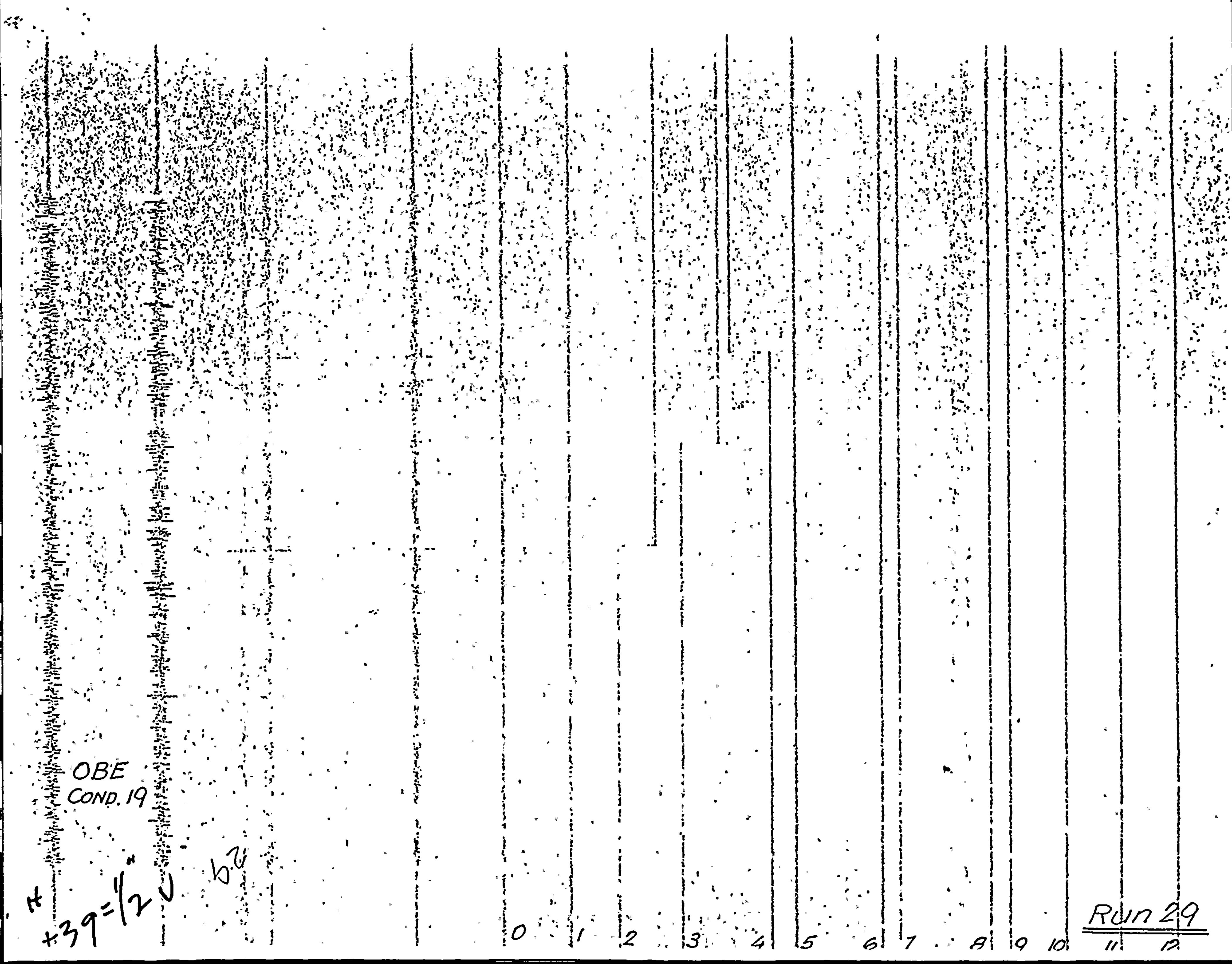

SSE
Cond. 12
61
Run 19
0
1
2
3
4
5
6
7
8
9
10
11
12


SSE
Cond. 13
Run 20
0
1
2
3
4
5
6
7
8
9
10
11
12

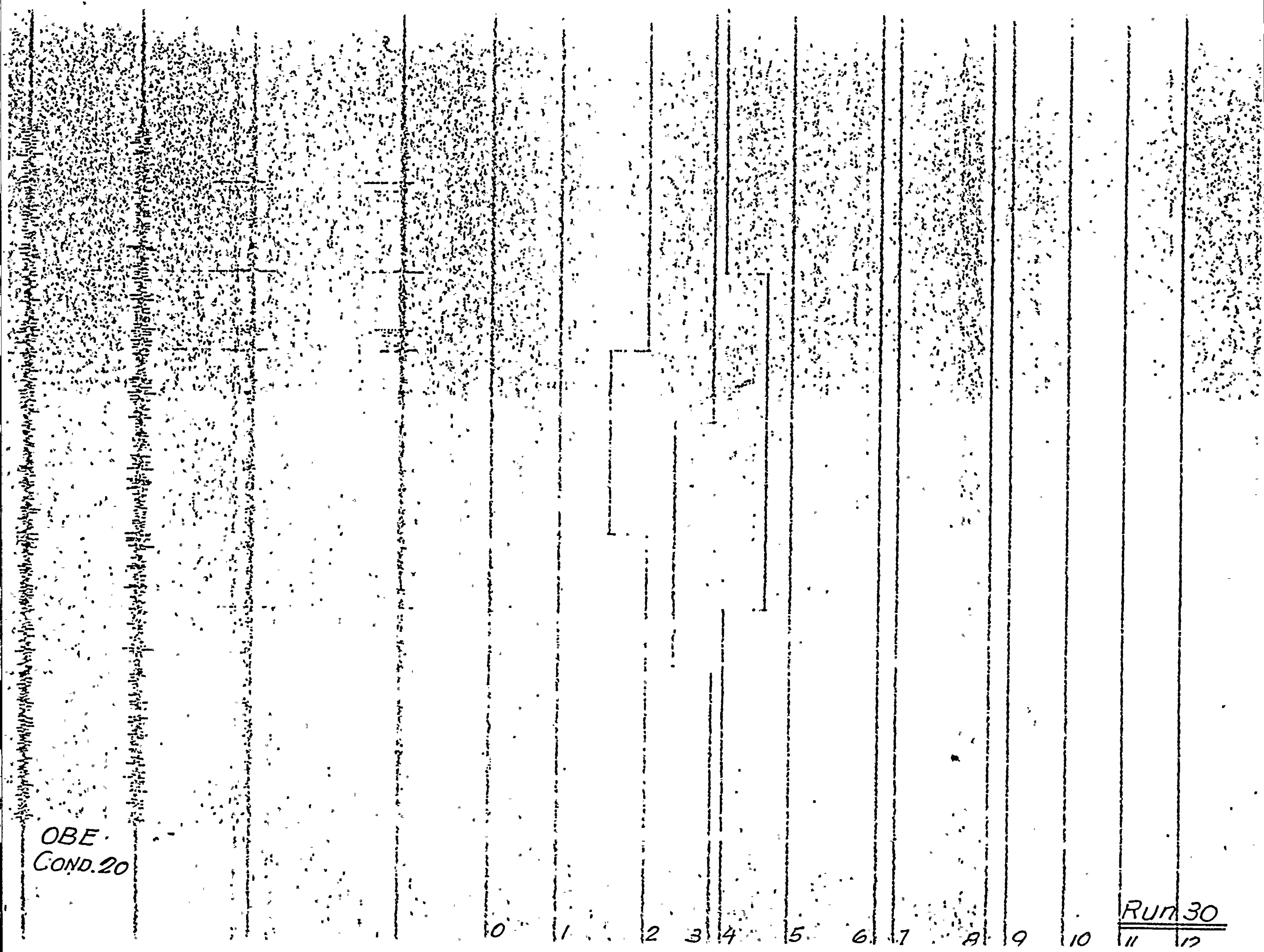

OBE
COND 16
Run 26
0
1
2
3
4
5
6
7
8
9
10
11
12

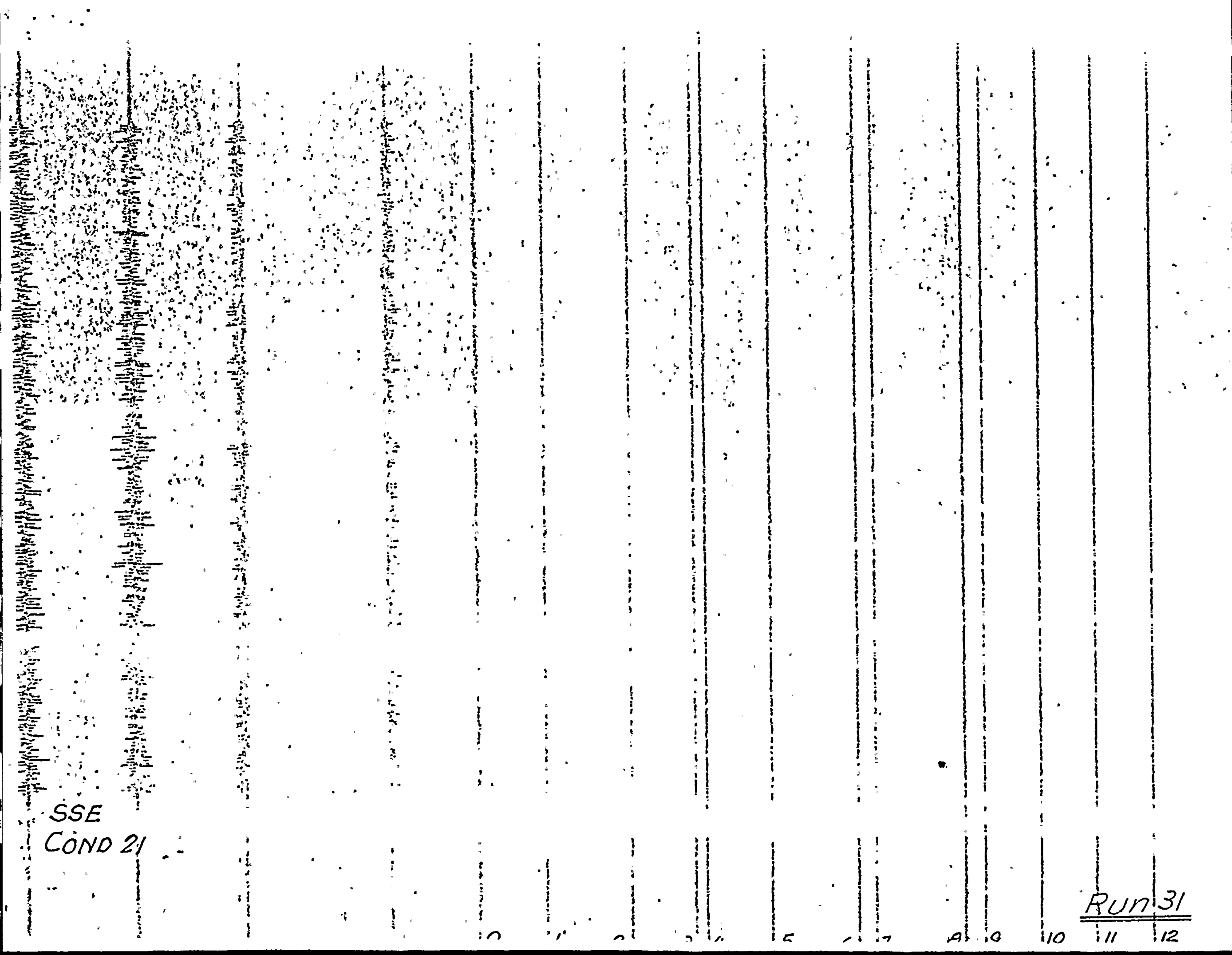

OBE
COND. 17
Run 27
0
1
2
3
4
5
6
7
8
9
10
11
12

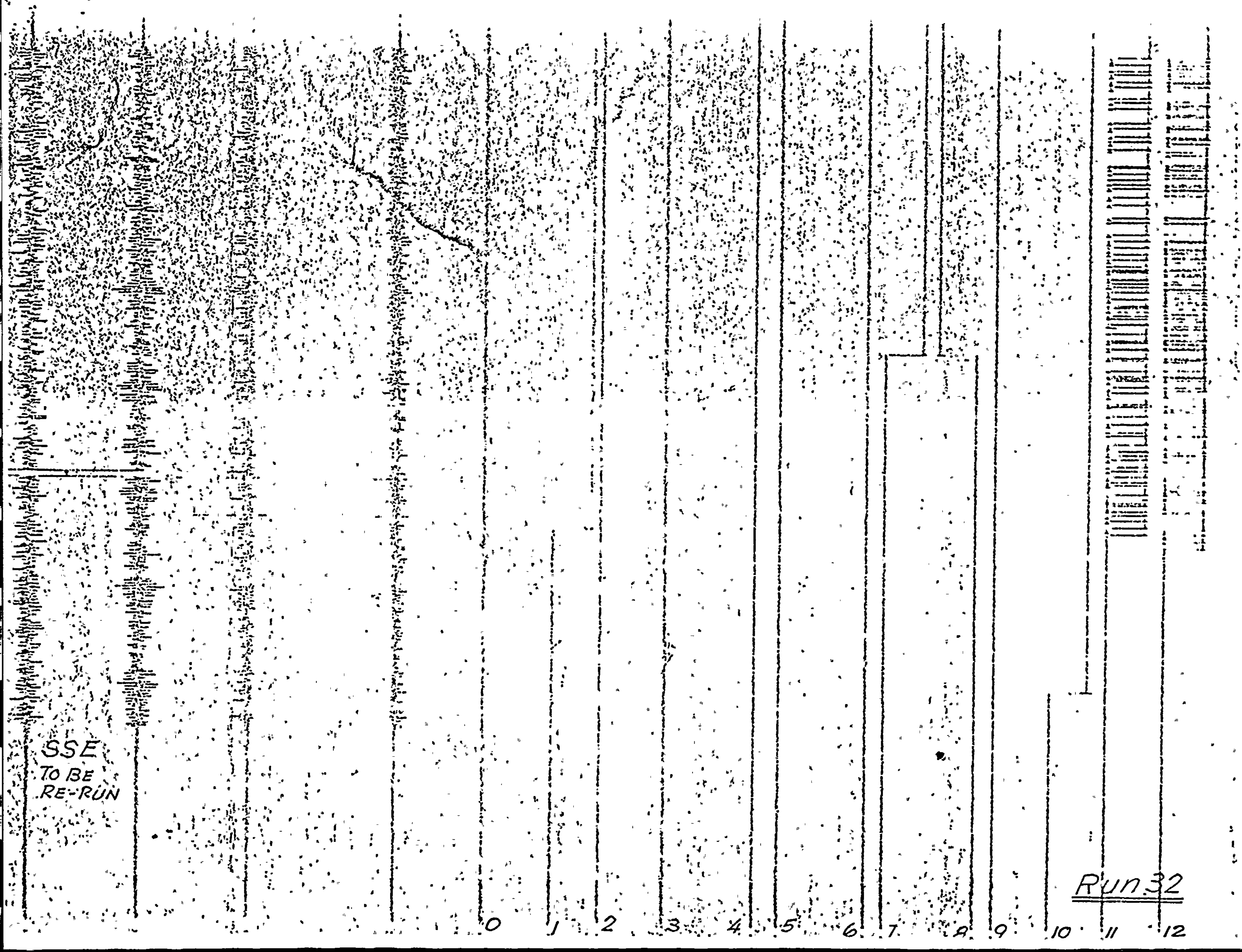

OBE
COND. 18
Run 28
0
1
2
3
4
5
6
7
8
9
10
11
12

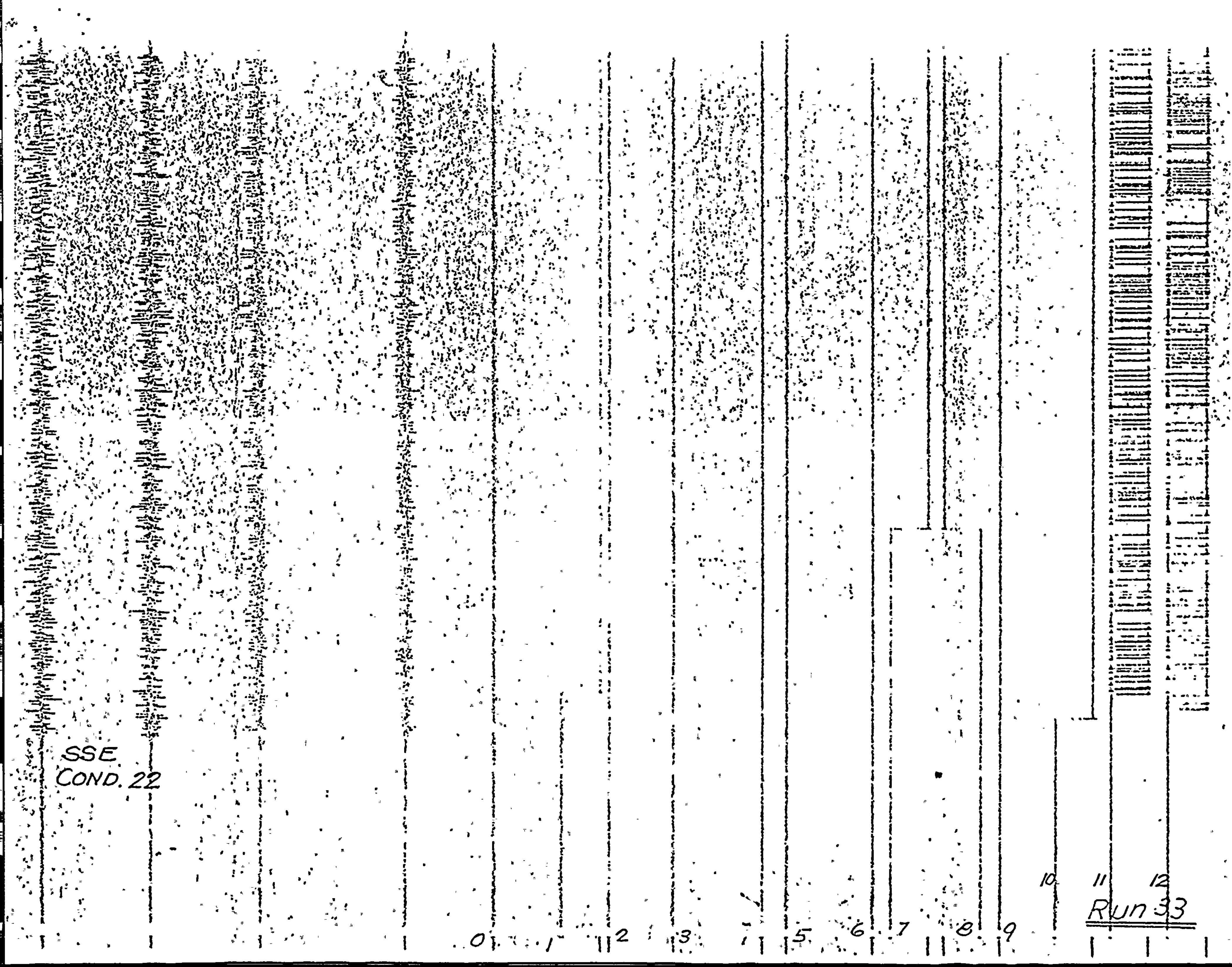


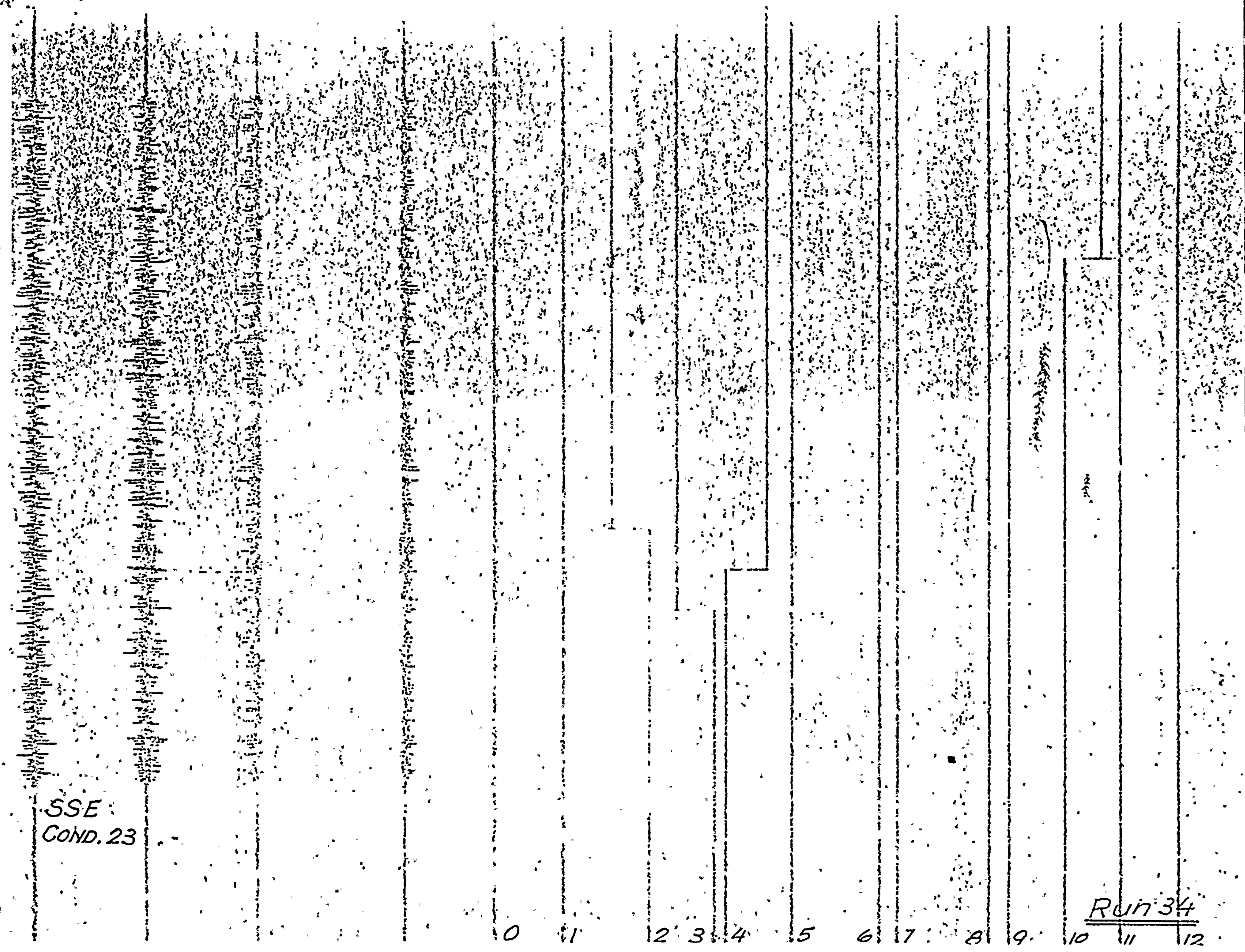
OBE
COND. 19
H
+39=1/2"
V
b.2
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 29

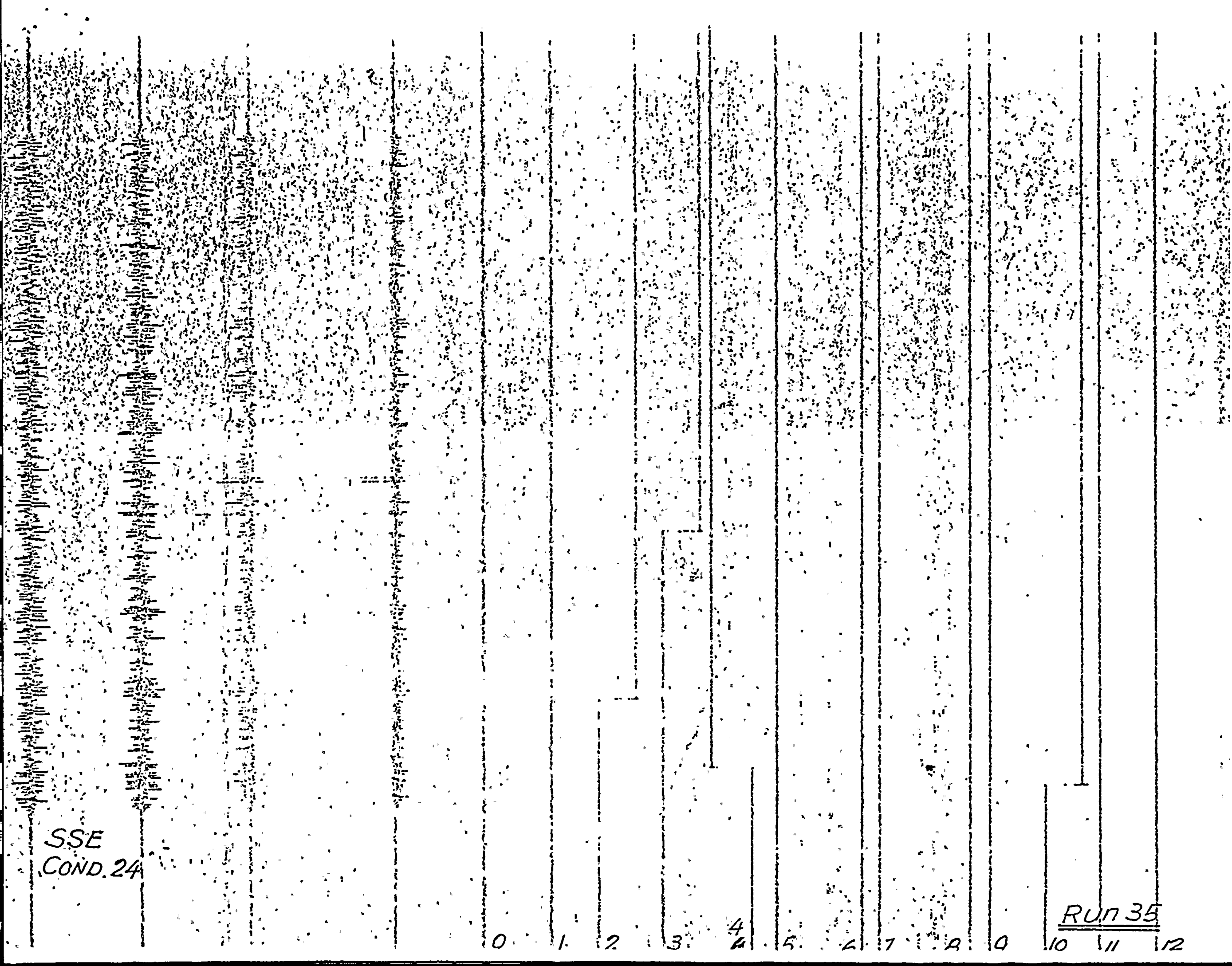

OBE
COND. 20
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 30

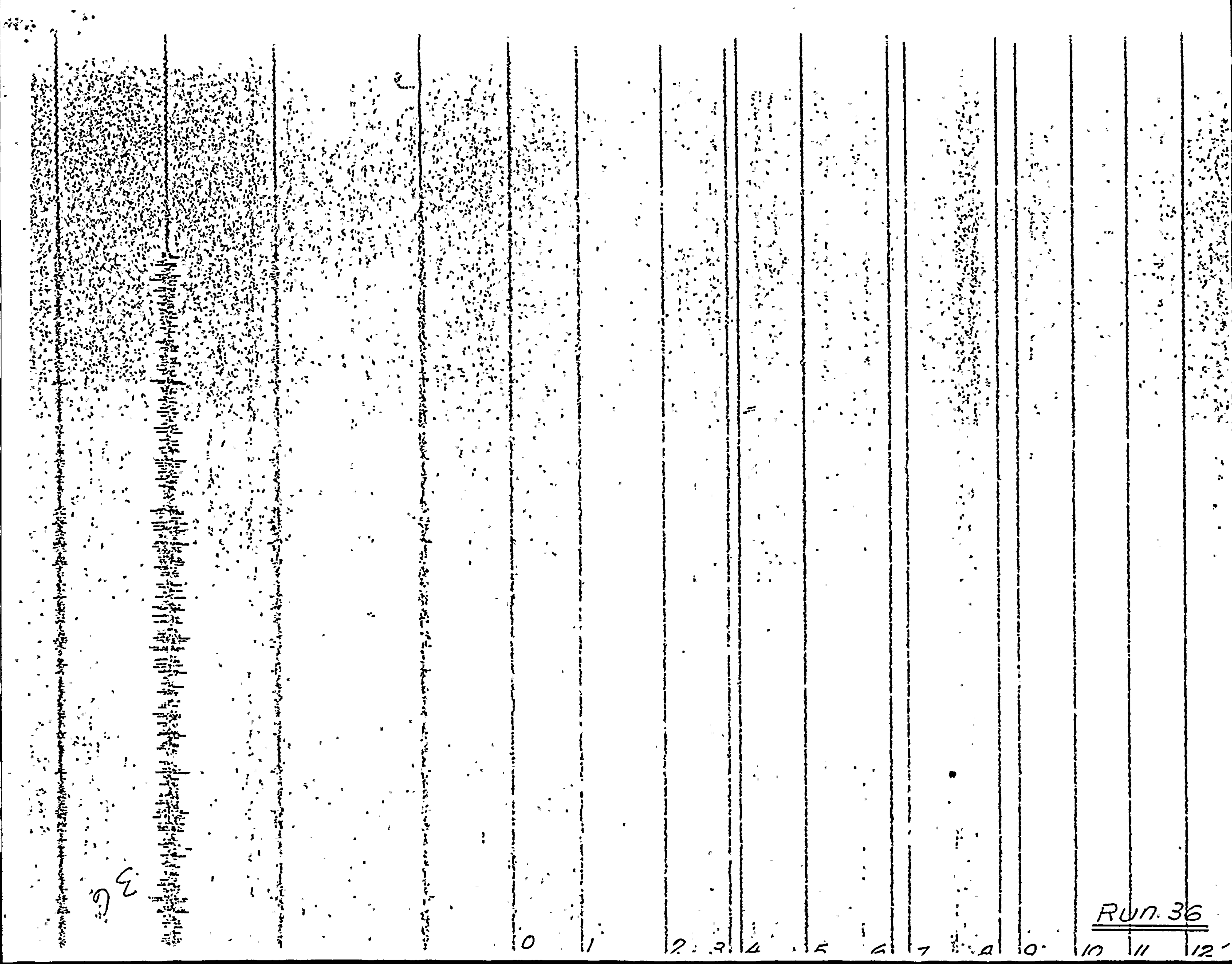

SSE
COND 21
Run 31
10
11
12

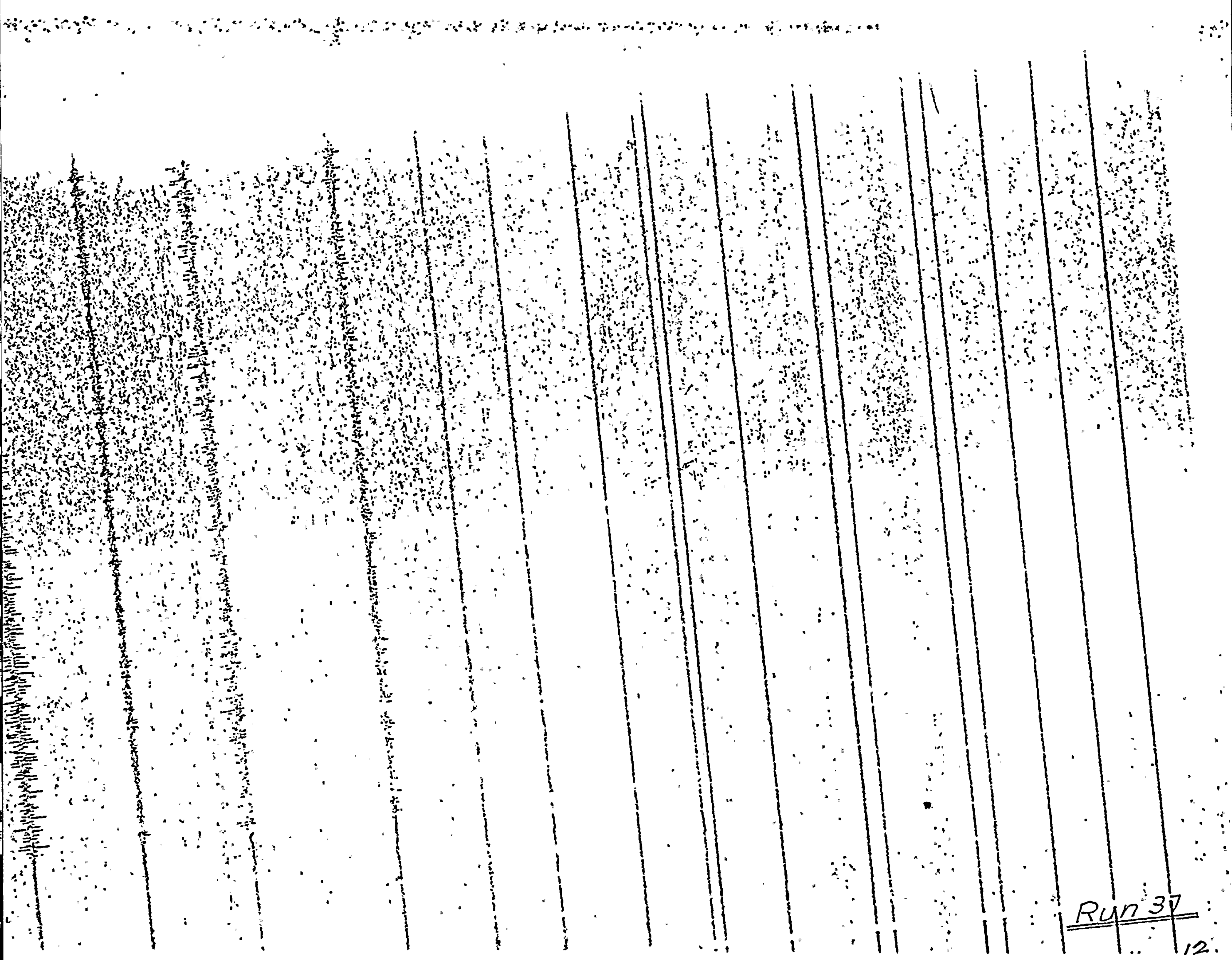

SSE
TO BE
RE-RUN
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 32

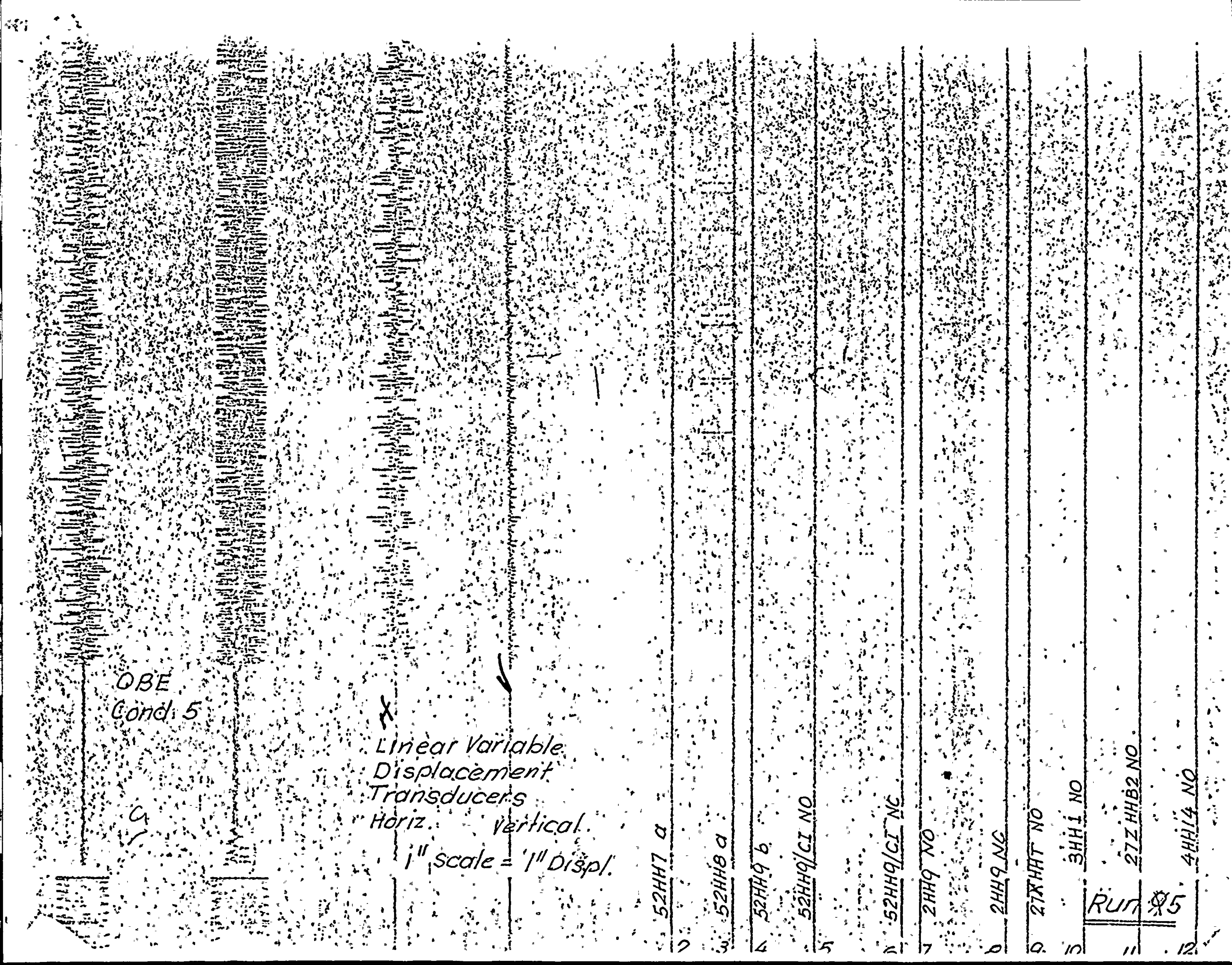

SSE
COND. 22
0
1
2
3
5
6
7
8
9
10
11
12
Run 33

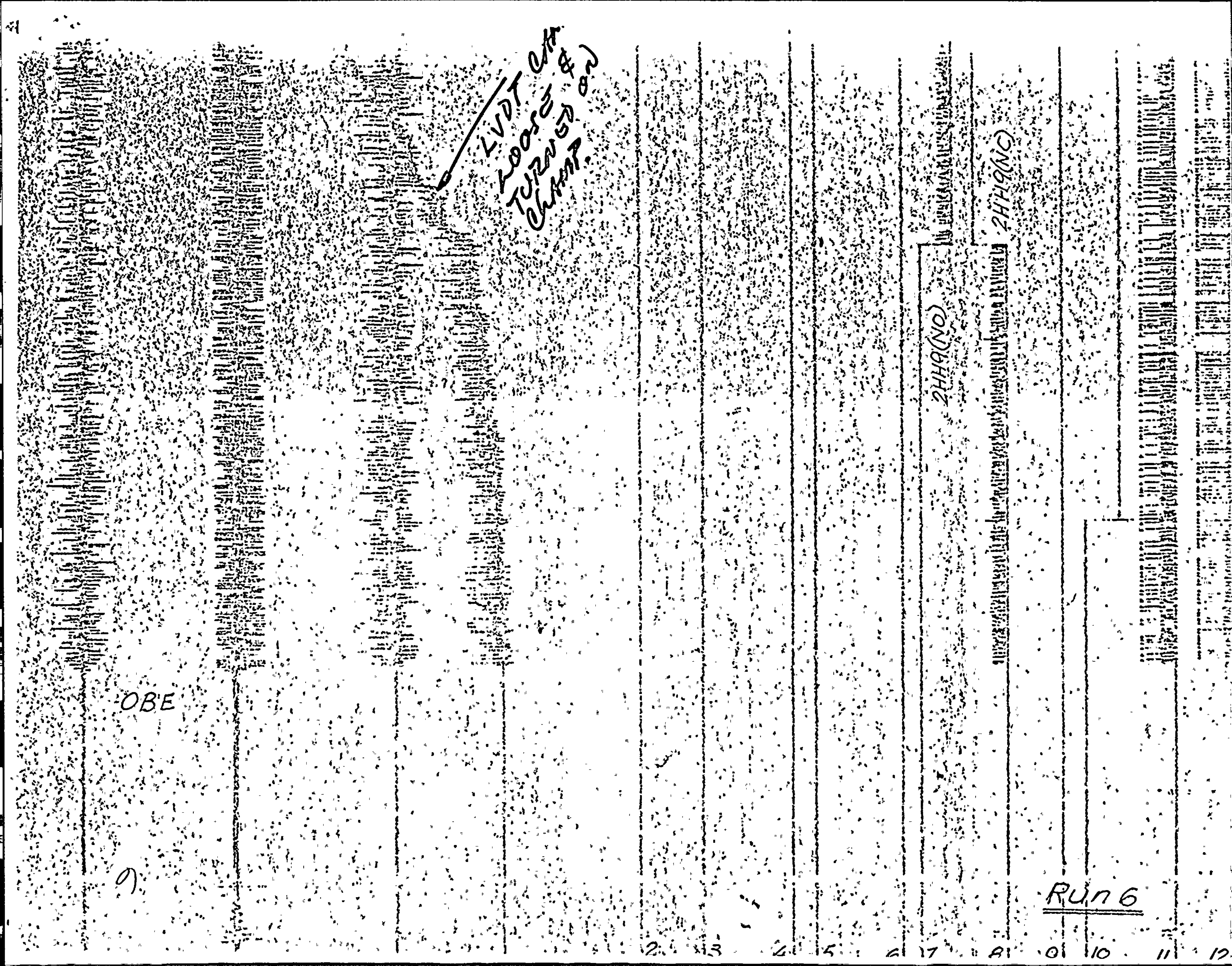

SSE
COND. 23
Run 34
0
1
2
3
4
5
6
7
8
9
10
11
12

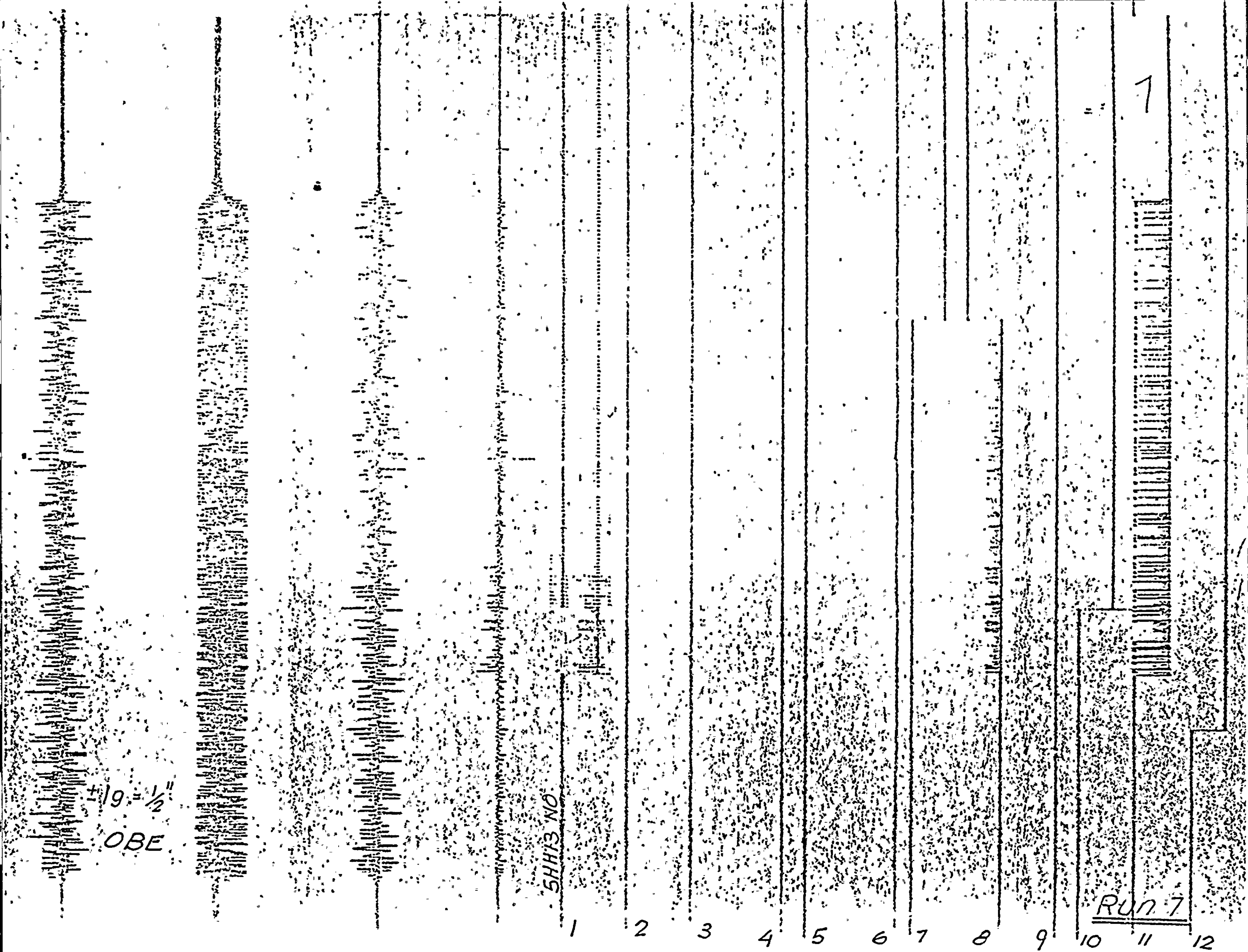

SSE
COND. 24
Run 35
0
1
2
3
4
5
6
7
8
9
10
11
12

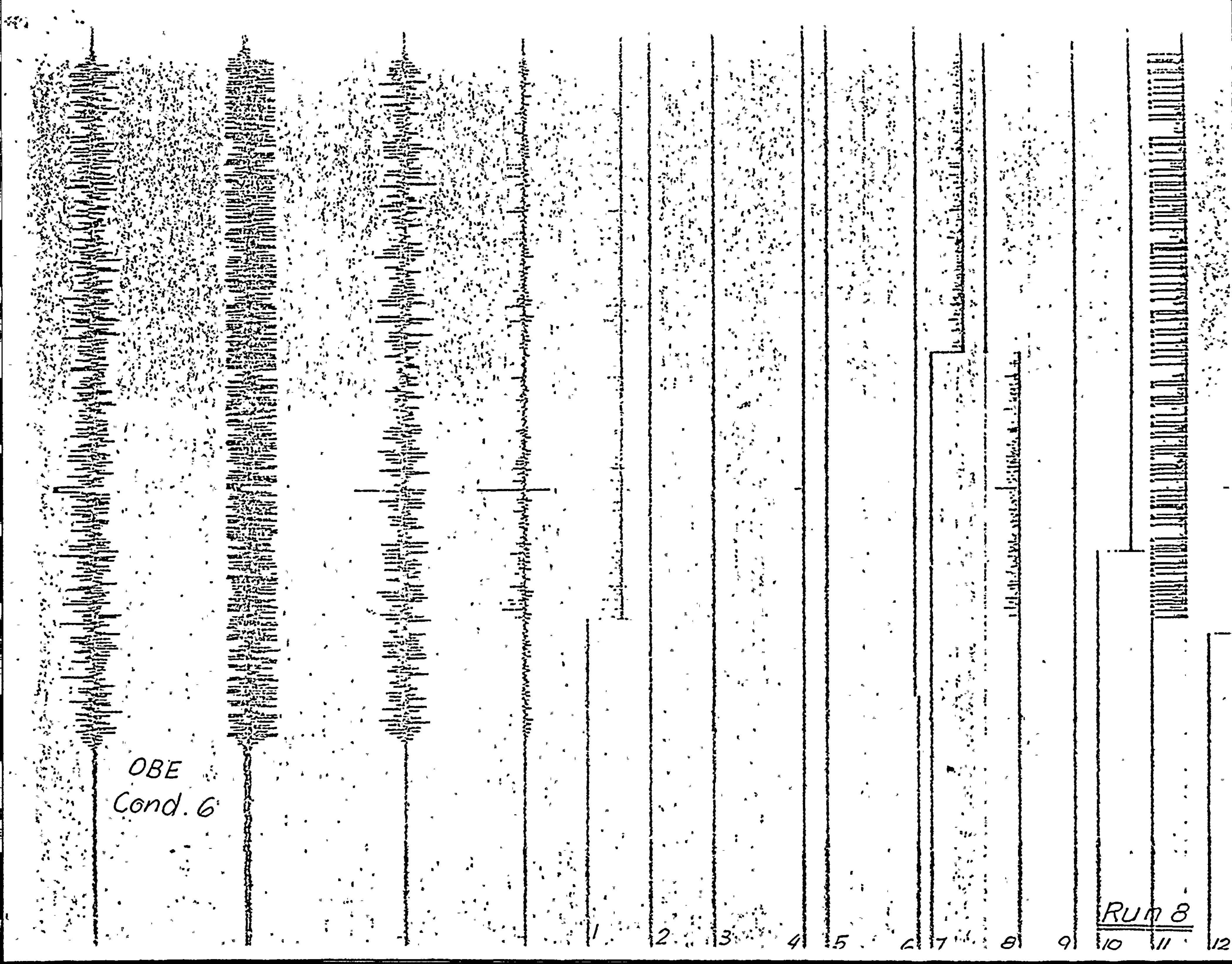

0
1
2
3
4
5
6
7
8
9
10
11
12
Run. 36

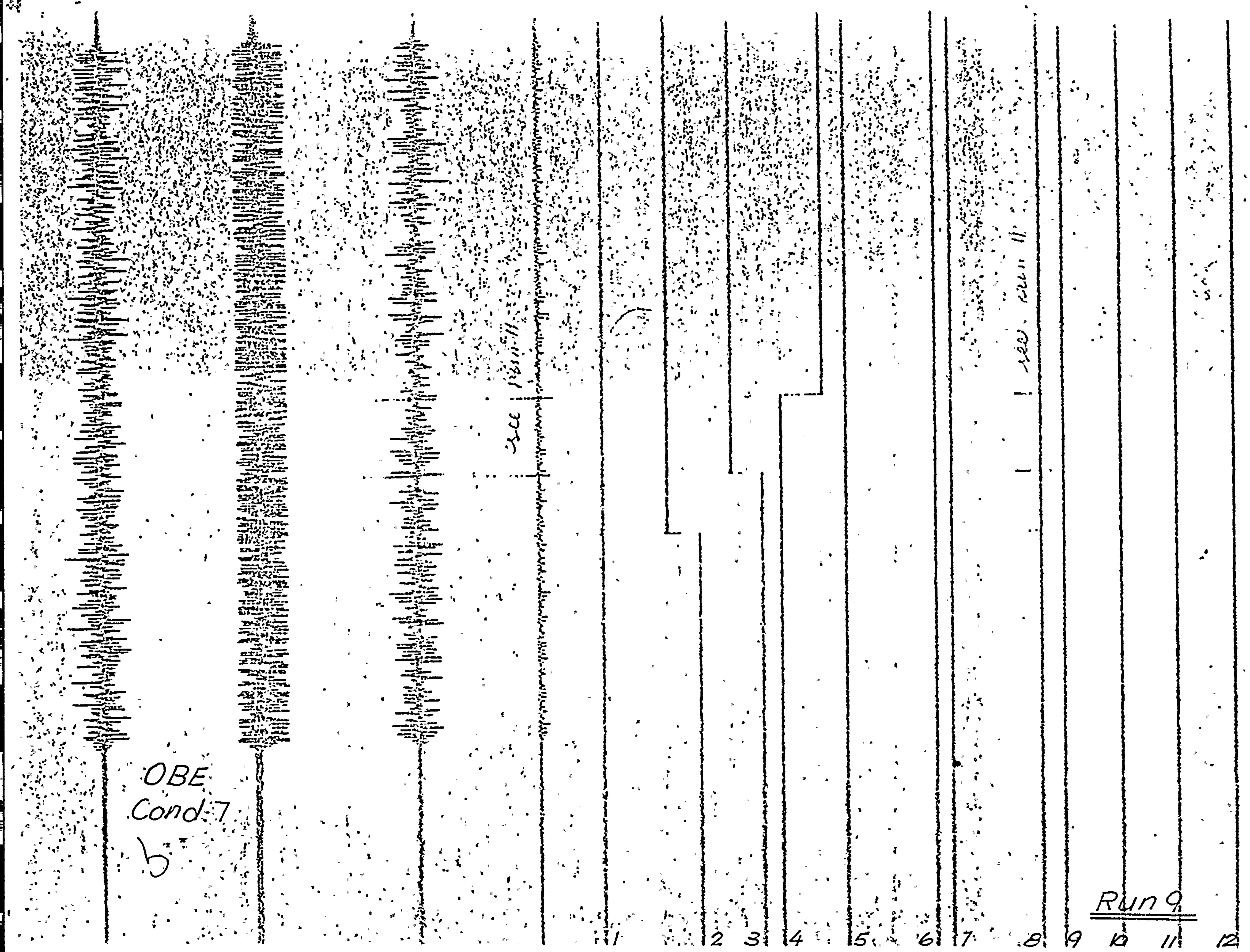

Run 37

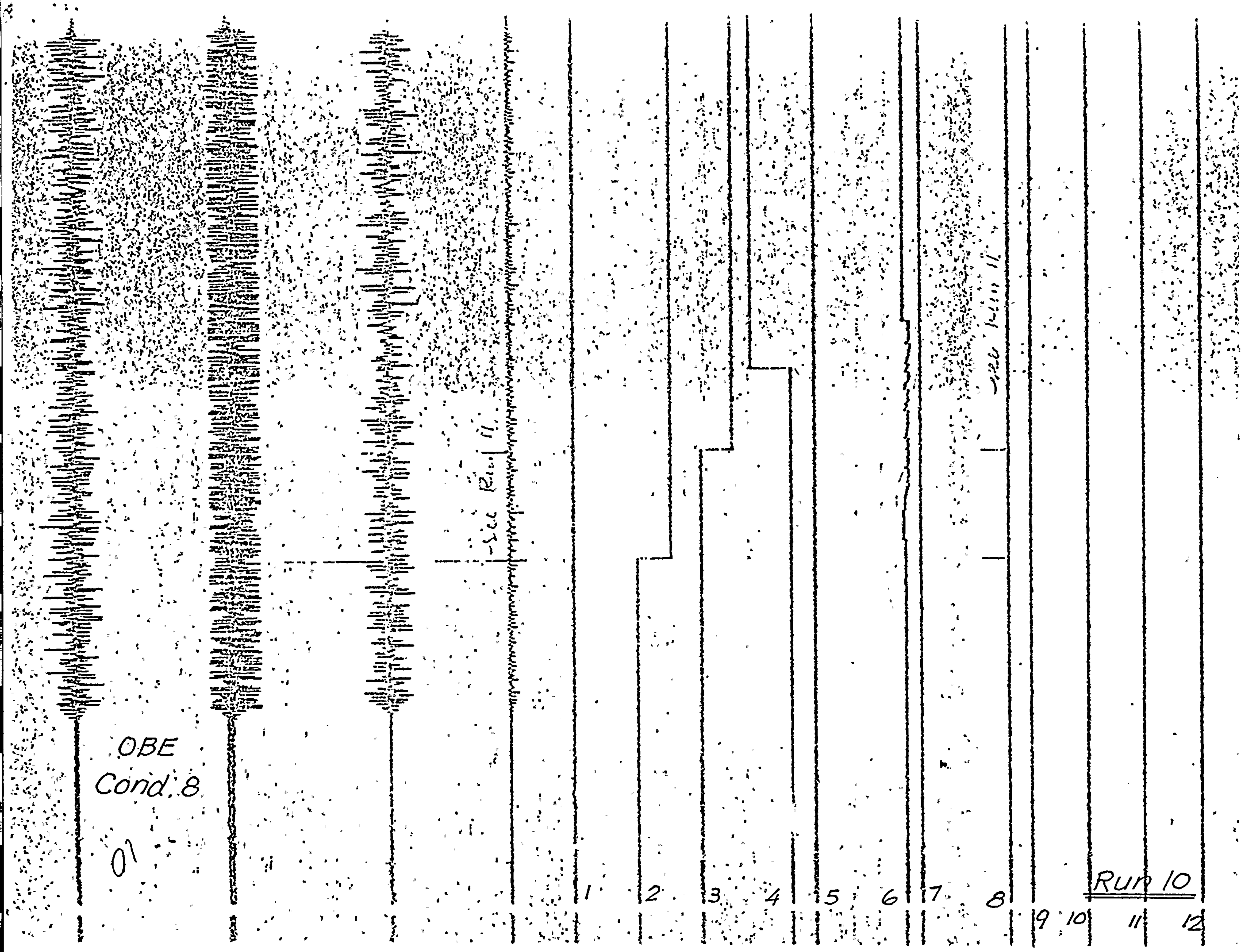

OBE
Cond. 5
X
Linear Variable
Displacement
Transducers
Horiz.
Vertical
1" scale = 1" Displ.
52HH7 a
52HH8 a
52HH9 b
52HH9/CI NO
52HH9/CI NC
2HH9 NO
2HH9 NC
27XHHT NO
3HH1 NO
27Z HHB2 NO
4HH14 NO
Run #5

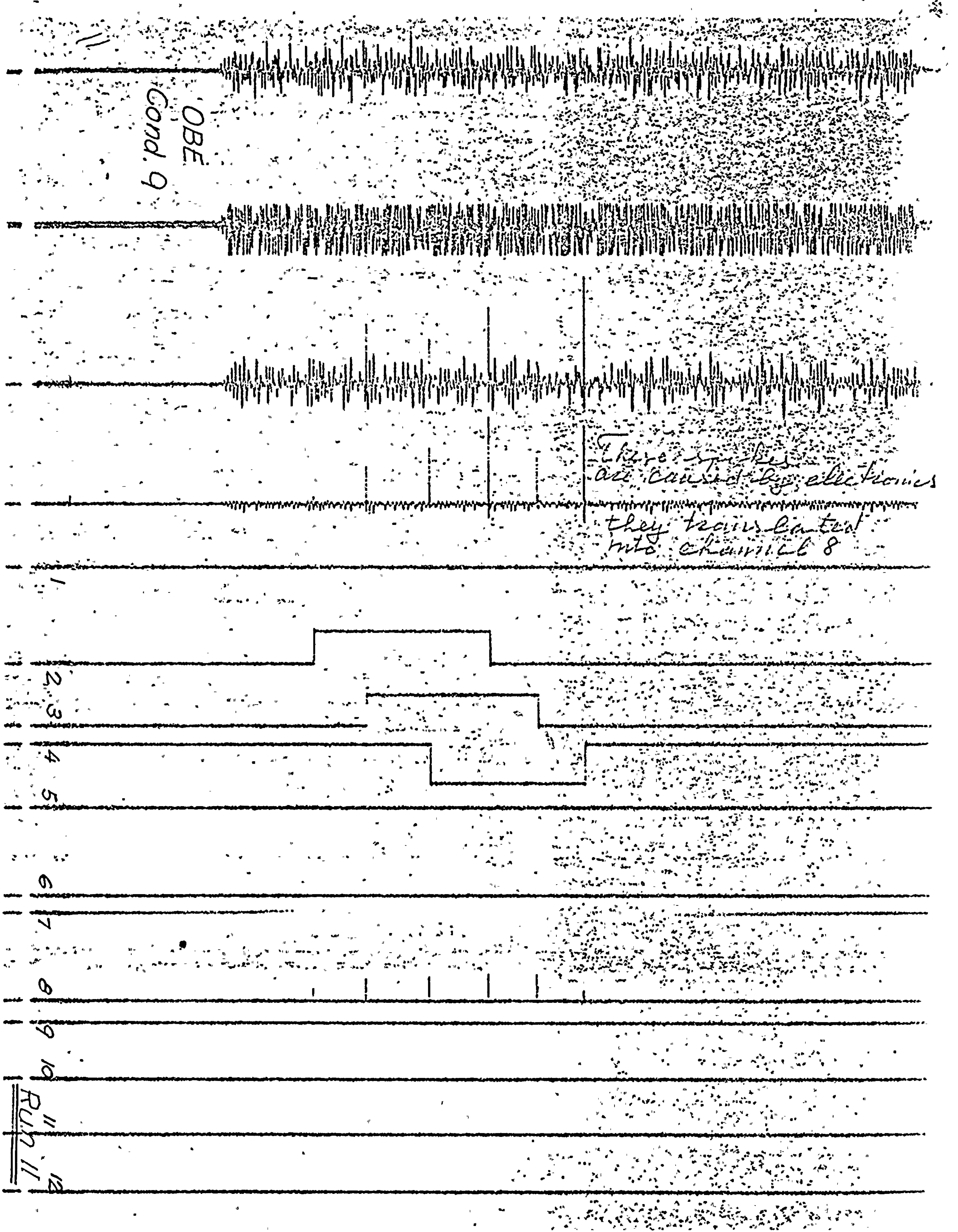

OBE
2HH9(NO)
2HH9(NC)
Run 6
2
3
4
5
6
7
8
9
10
11
12

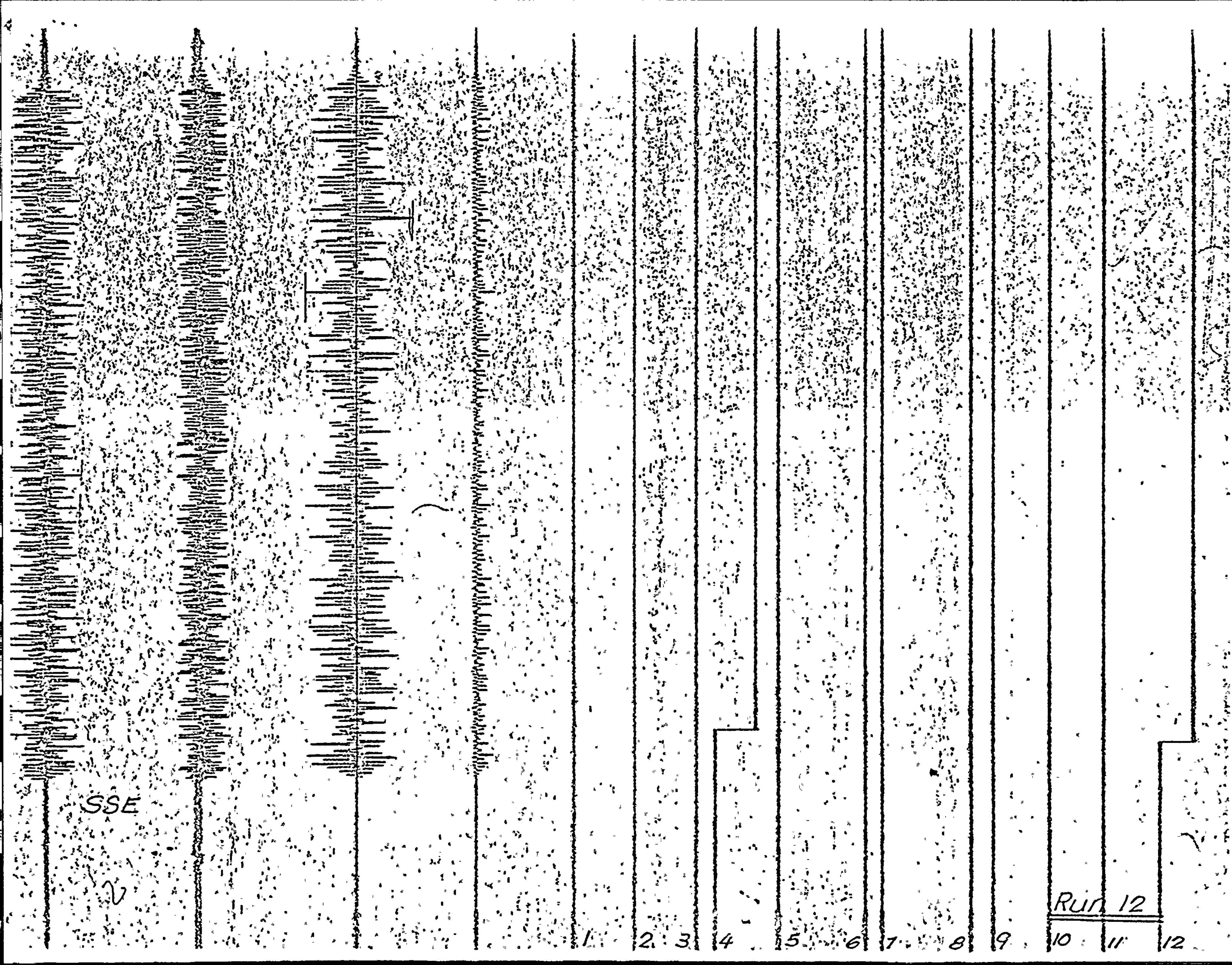

7
±19 = ½"
OBE
1
2
3
4
5
6
7
8
9
10
11
12
Run 7

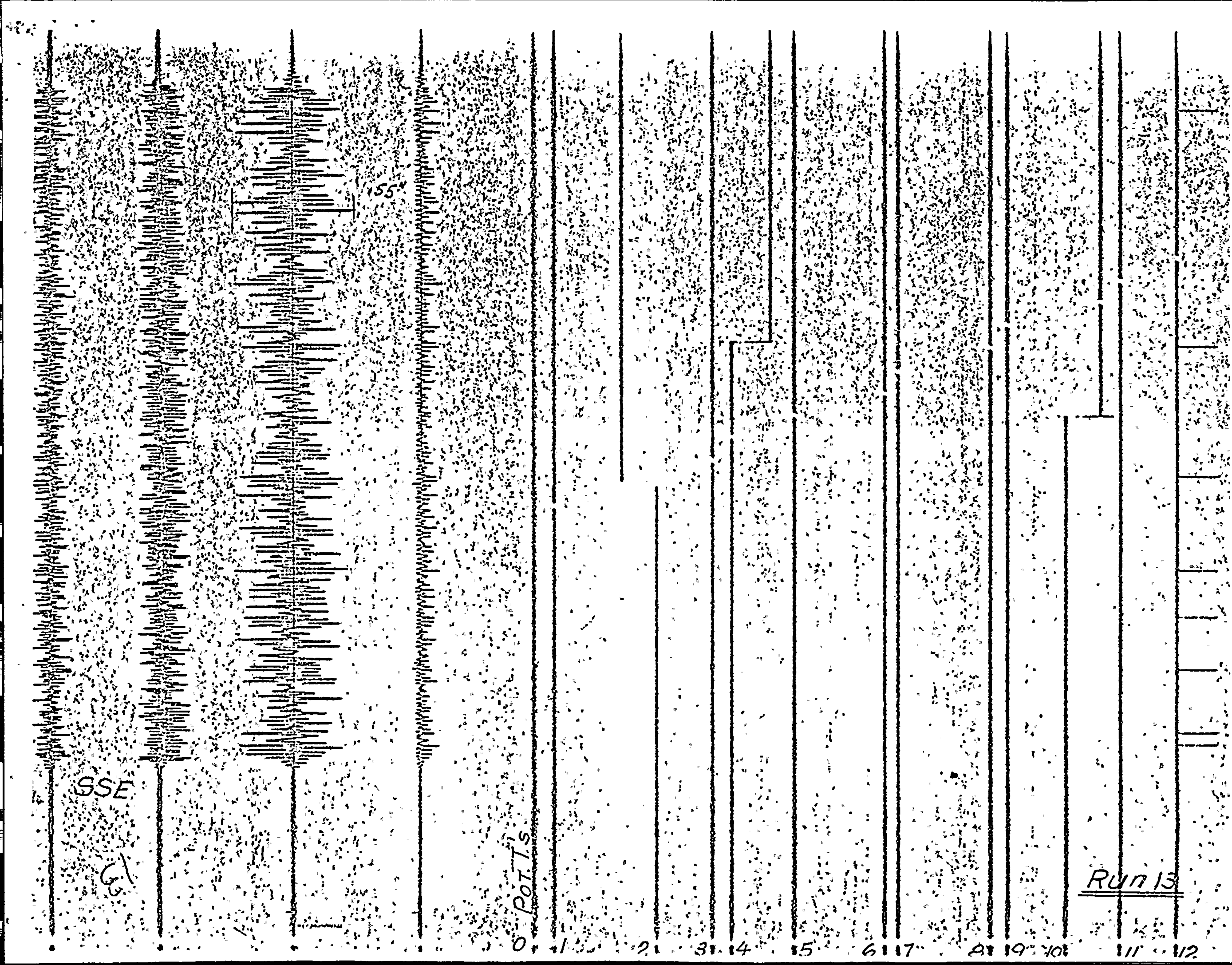

OBE
Cond. 6
1
2
3
4
5
6
7
8
9
10
11
12
Run 8

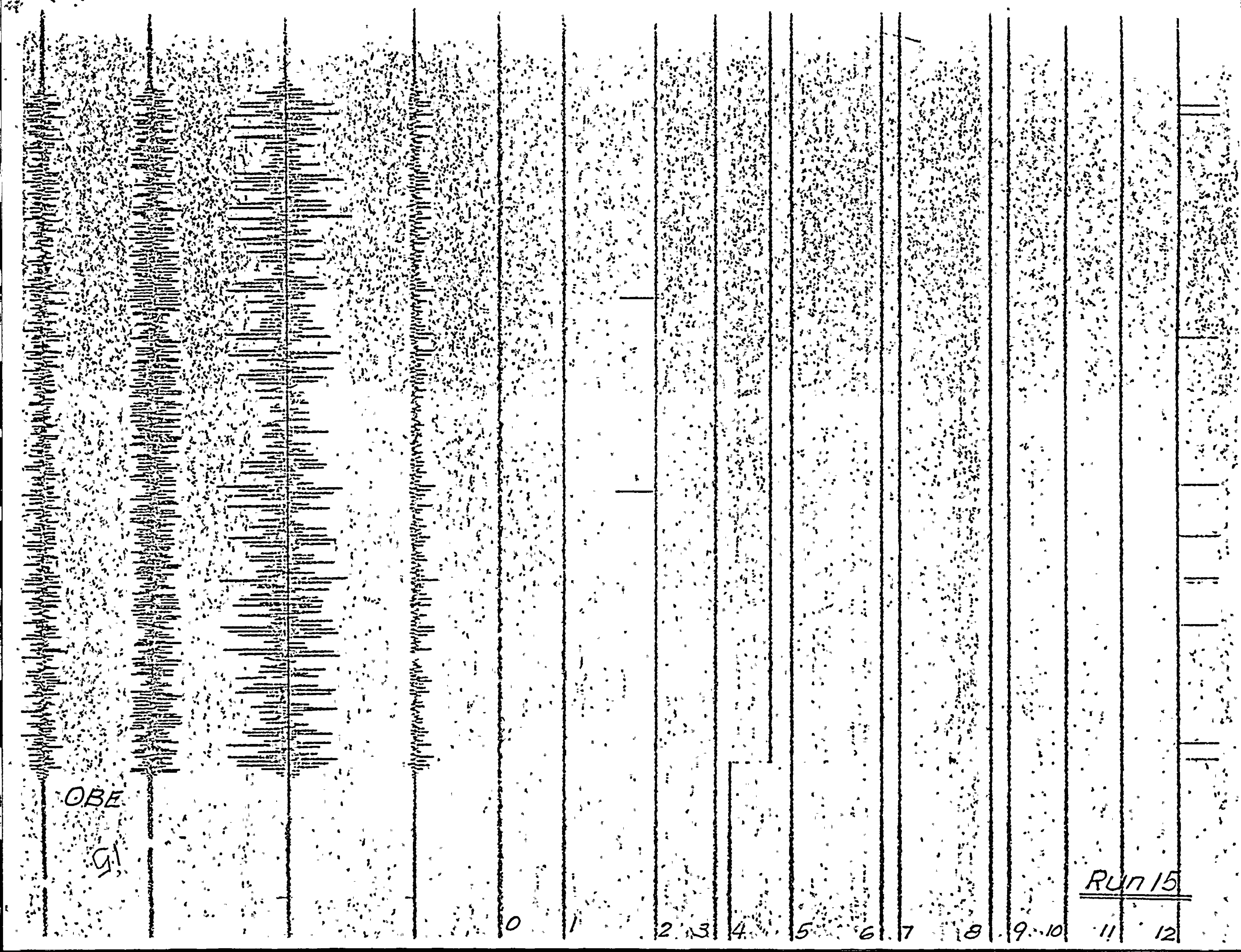

OBE
Cond-7
b
see run 11
see run 11
1
2
3
4
5
6
7
8
9
10
11
12
Run 9

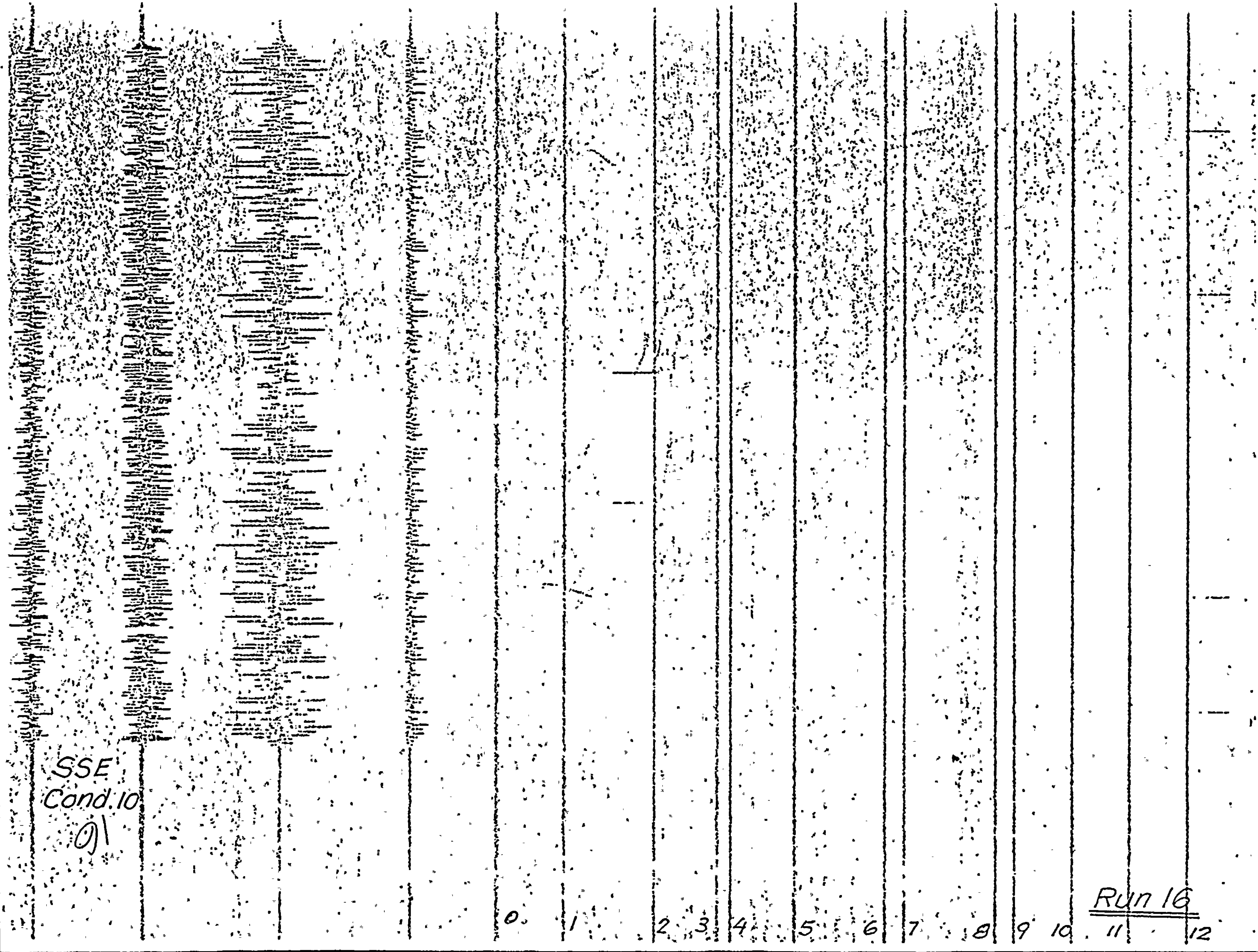

OBE
Cond. 8
Run 10
1
2
3
4
5
6
7
8
9
10
11
12

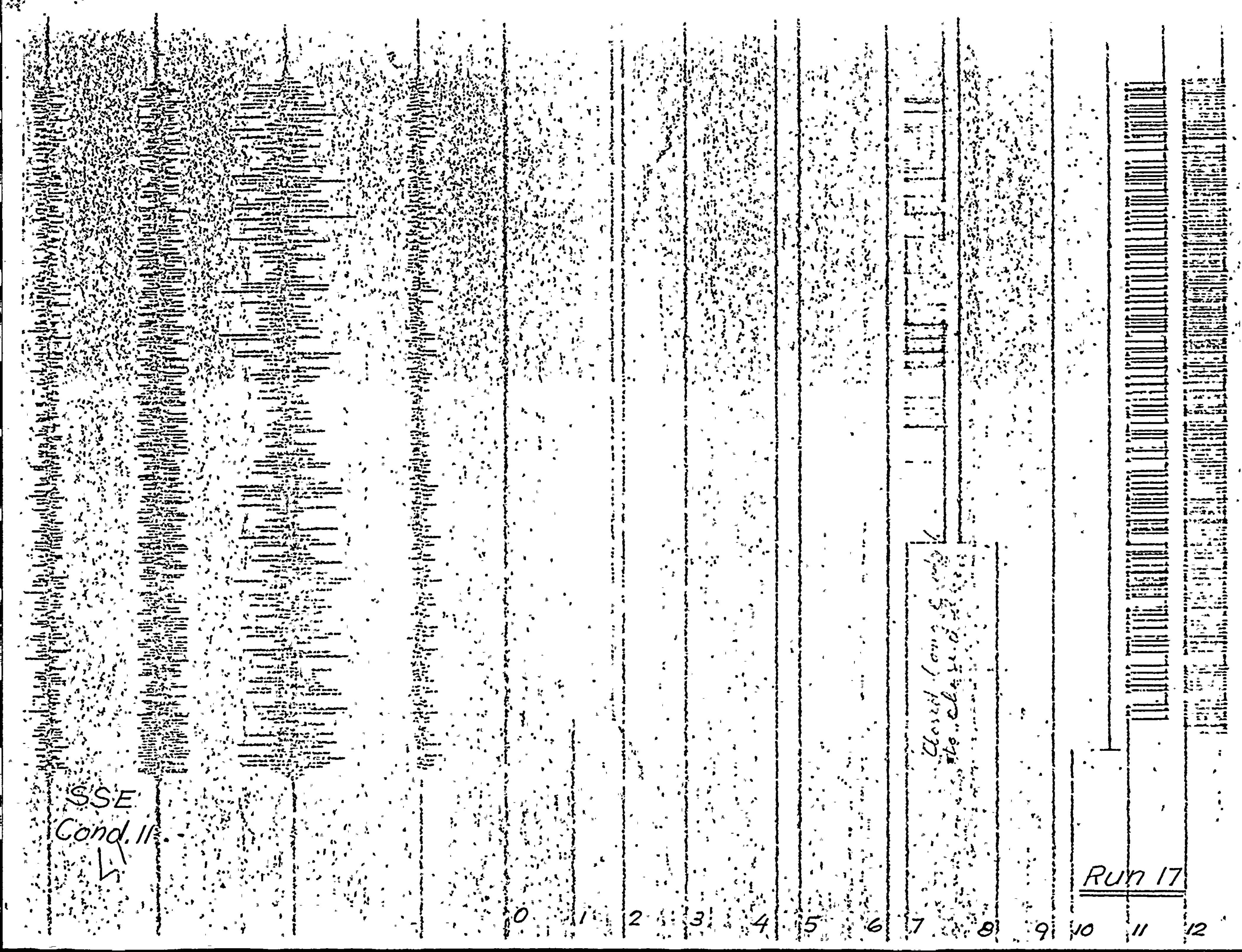

OBE
Cond. 9
These spikes are caused by electronics
they translated into channel 8
1
2
3
4
5
6
7
8
9
10
11
12
Run 11

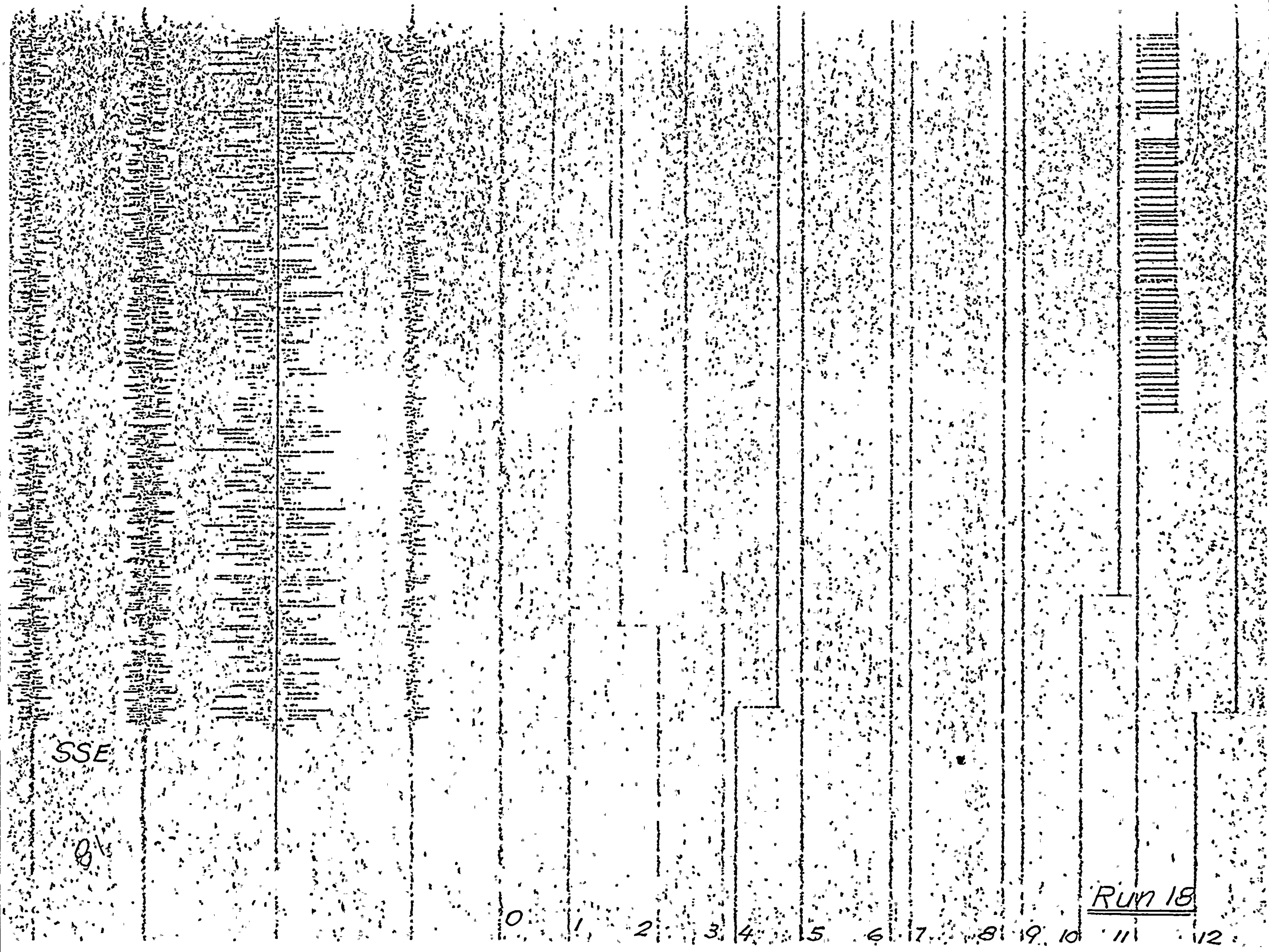

SSE
Run 12
1
2
3
4
5
6
7
8
9
10
11
12

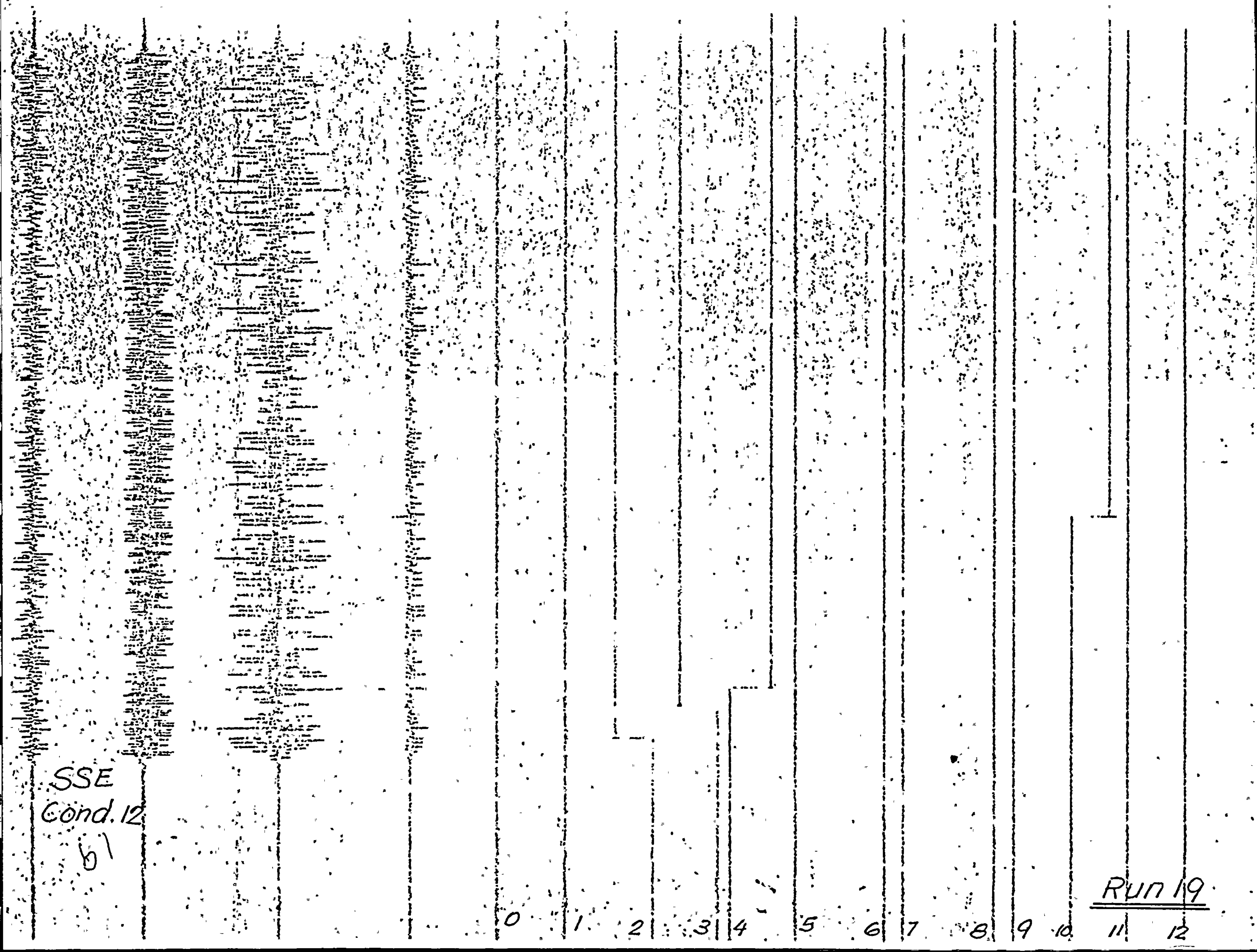

.55"
SSE
Pot. T.s
Run 13
0
1
2
3
4
5
6
7
8
9
10
11
12

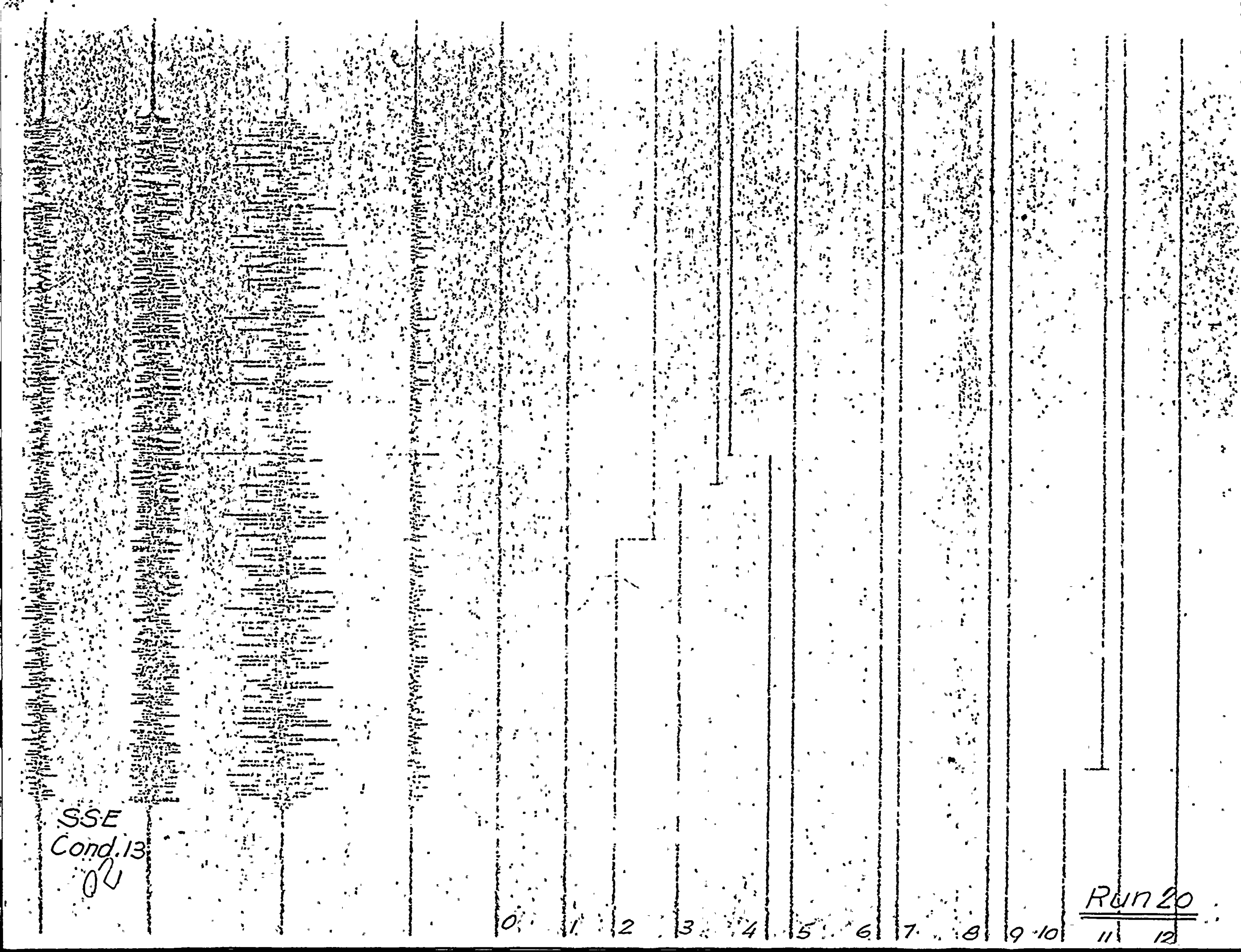

OBE
G1
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 15

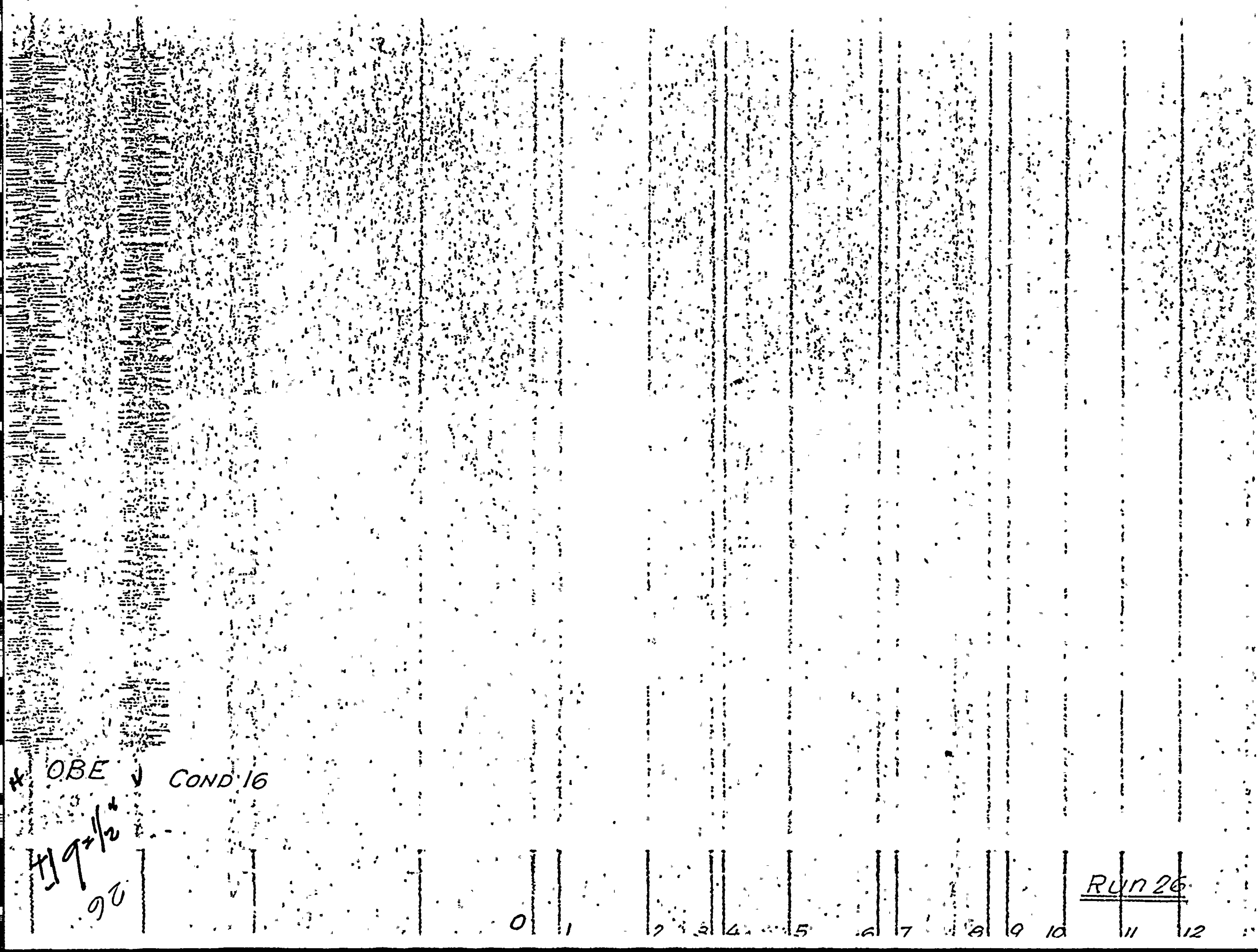

SSE
Cond. 10
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 16


SSE
Cond. 11
Run 17
0
1
2
3
4
5
6
7
8
9
10
11
12

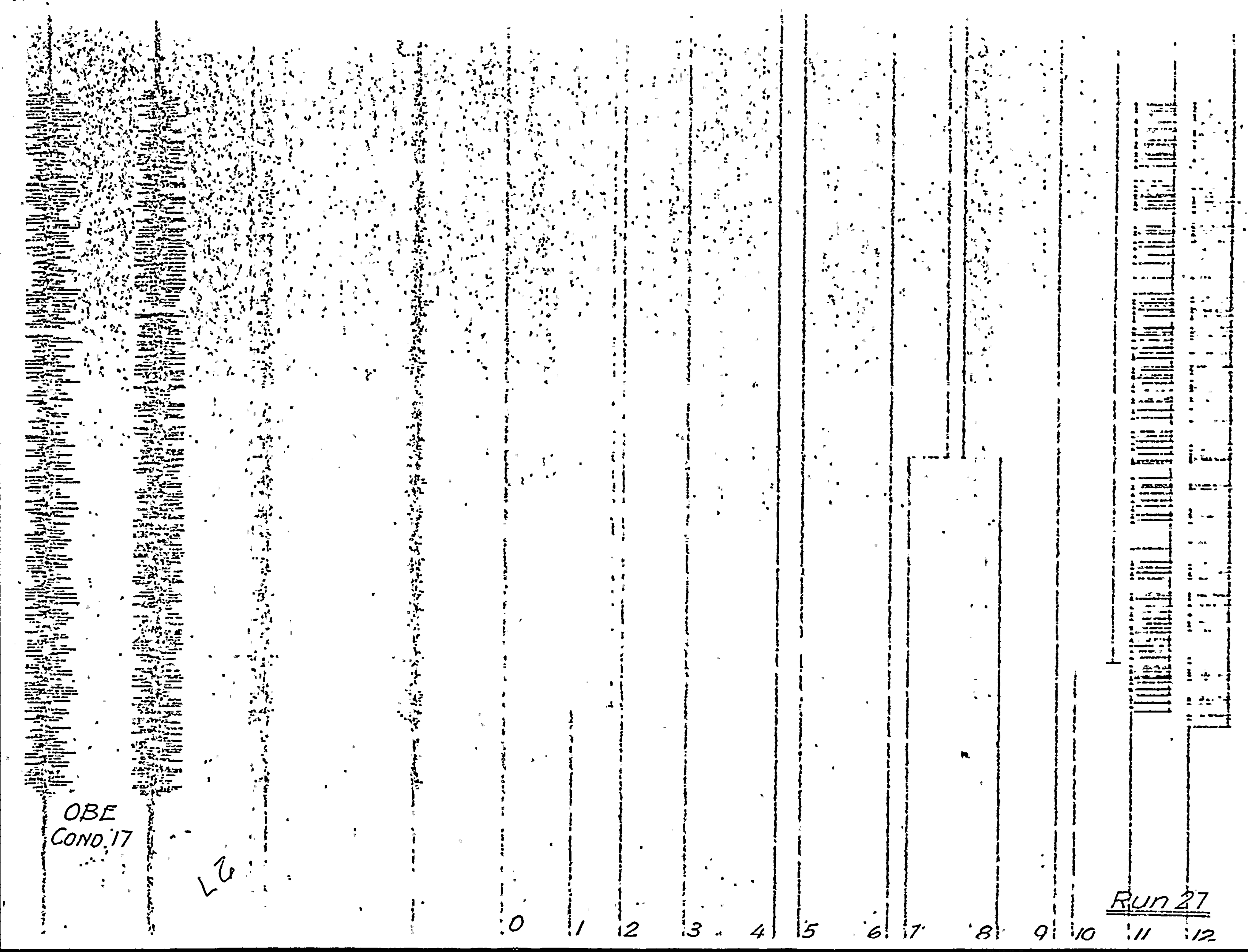

SSE
Run 18
0
1
2
3
4
5
6
7
8
9
10
11
12

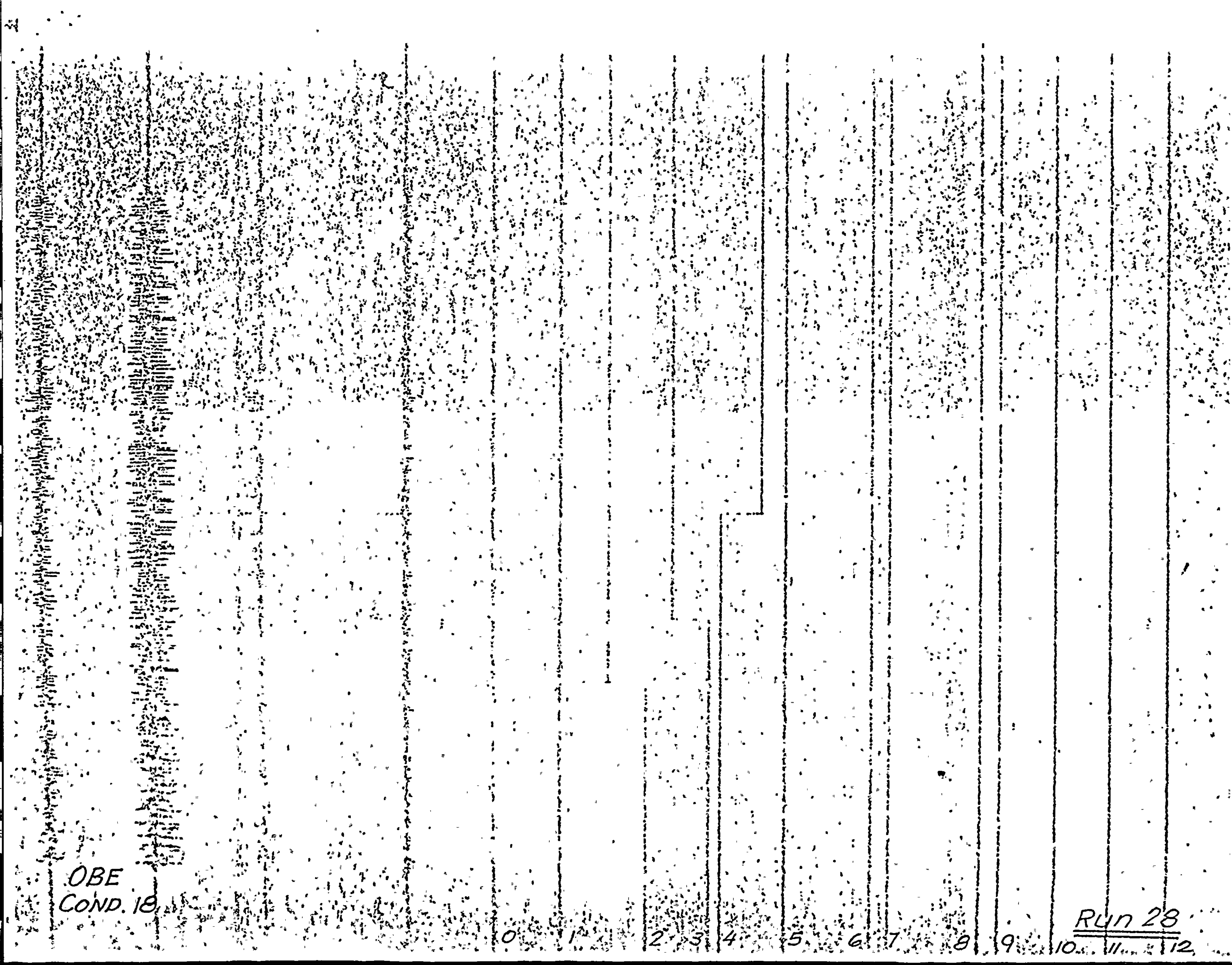

SSE
Cond. 12
61
Run 19
0
1
2
3
4
5
6
7
8
9
10
11
12

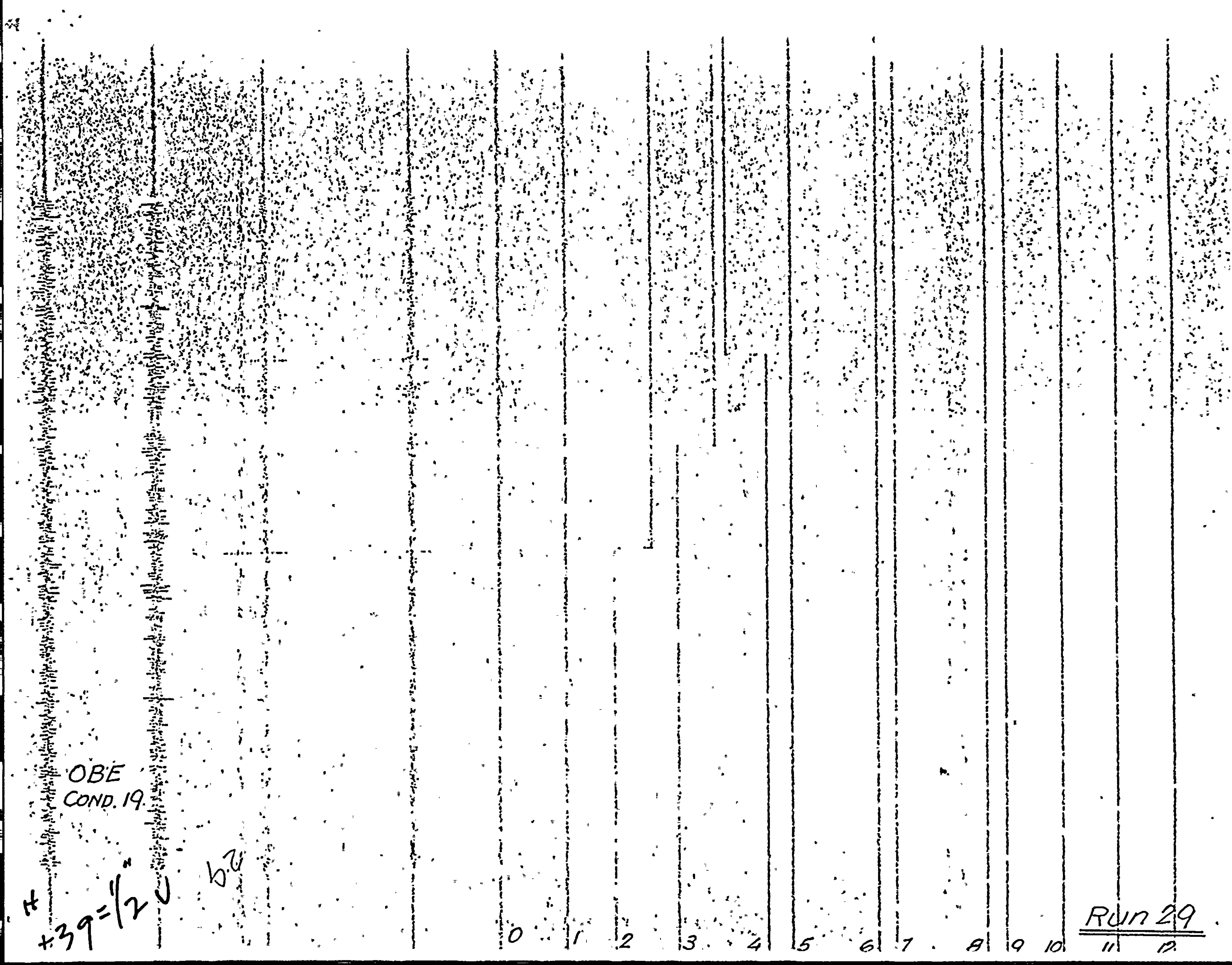

SSE
Cond. 13
02
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 20

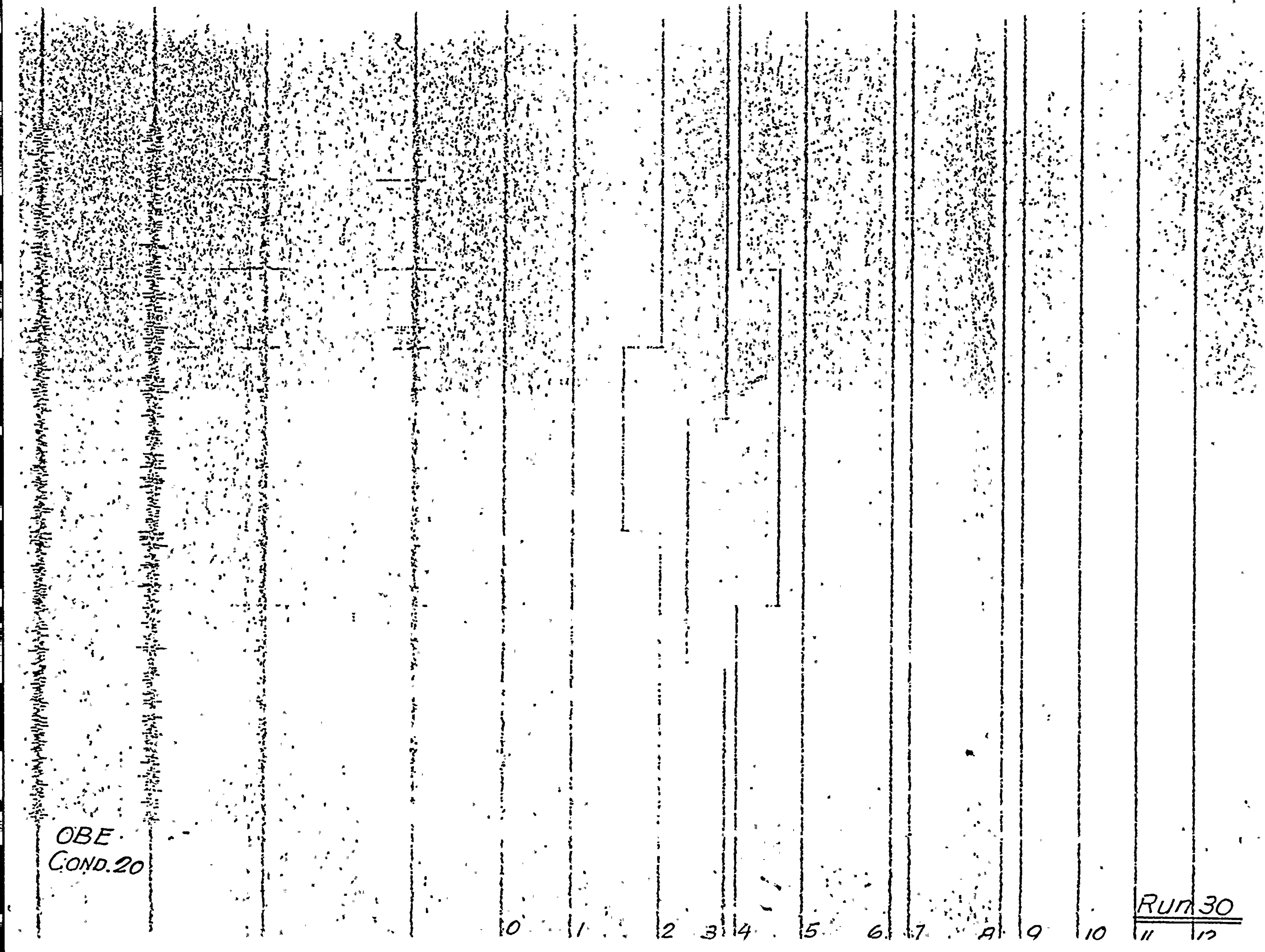


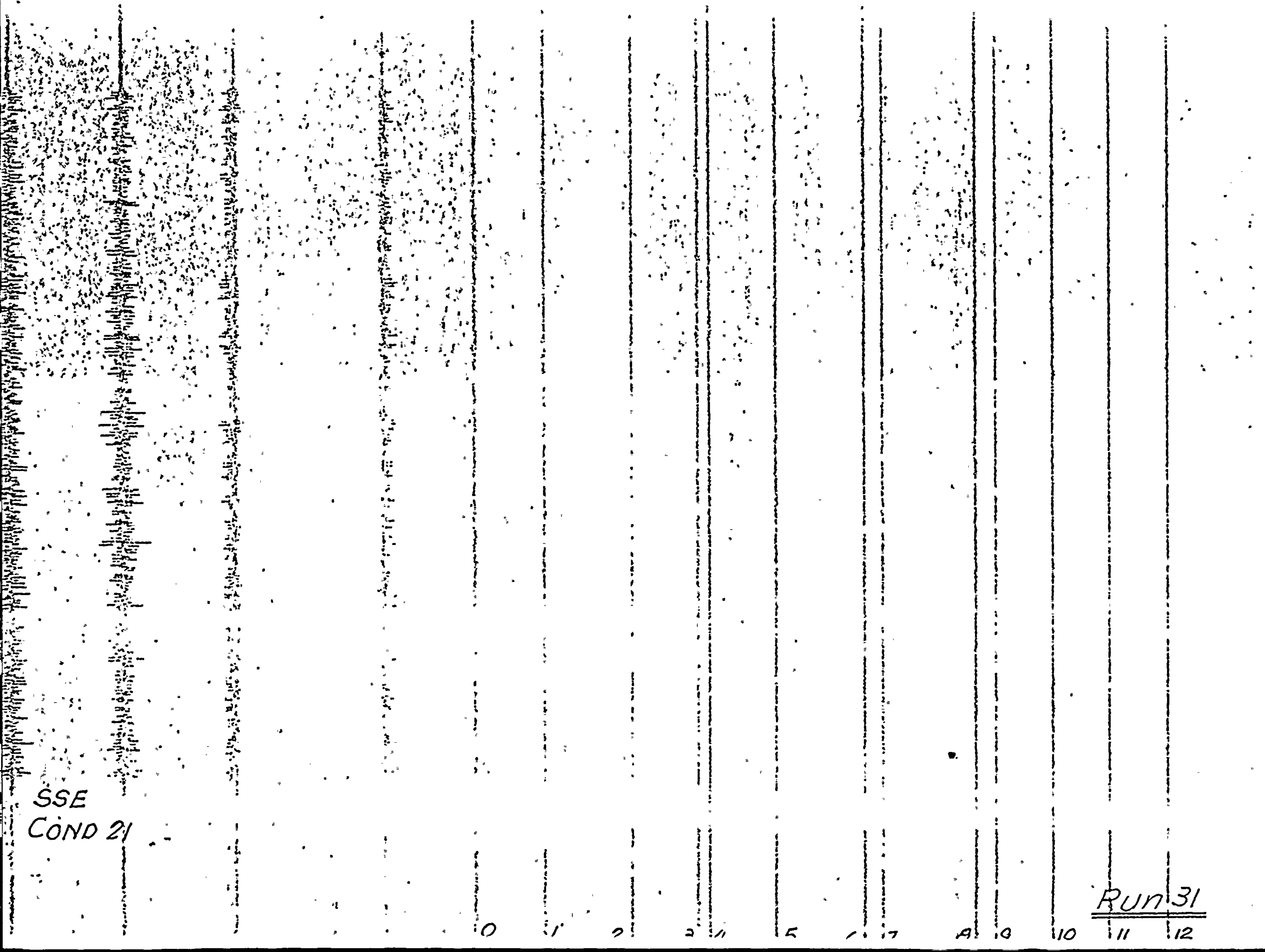
H OBE V
COND 16
Run 26
0
1
2
3
4
5
6
7
8
9
10
11
12

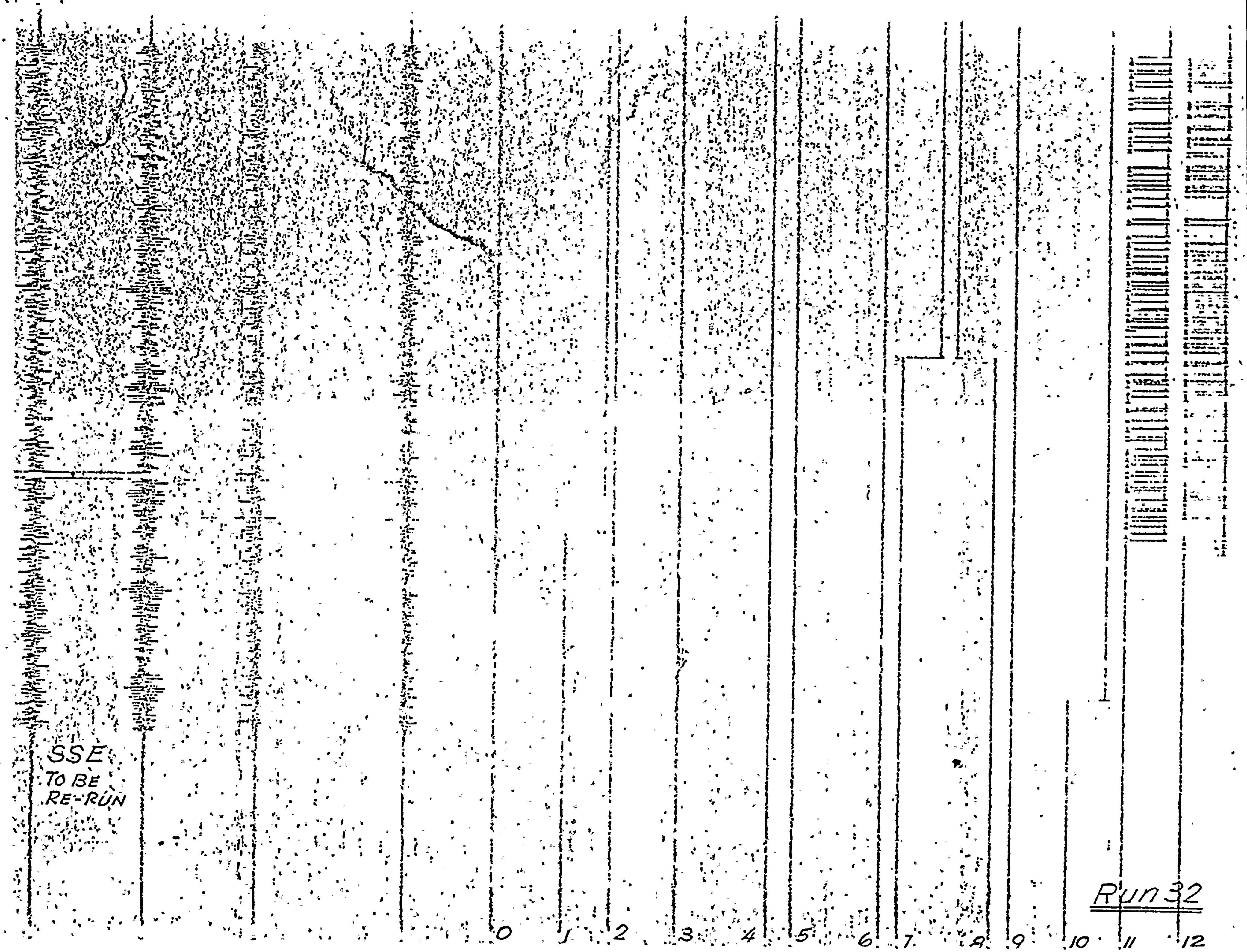

OBE
COND. 17
Run 27
0
1
2
3
4
5
6
7
8
9
10
11
12

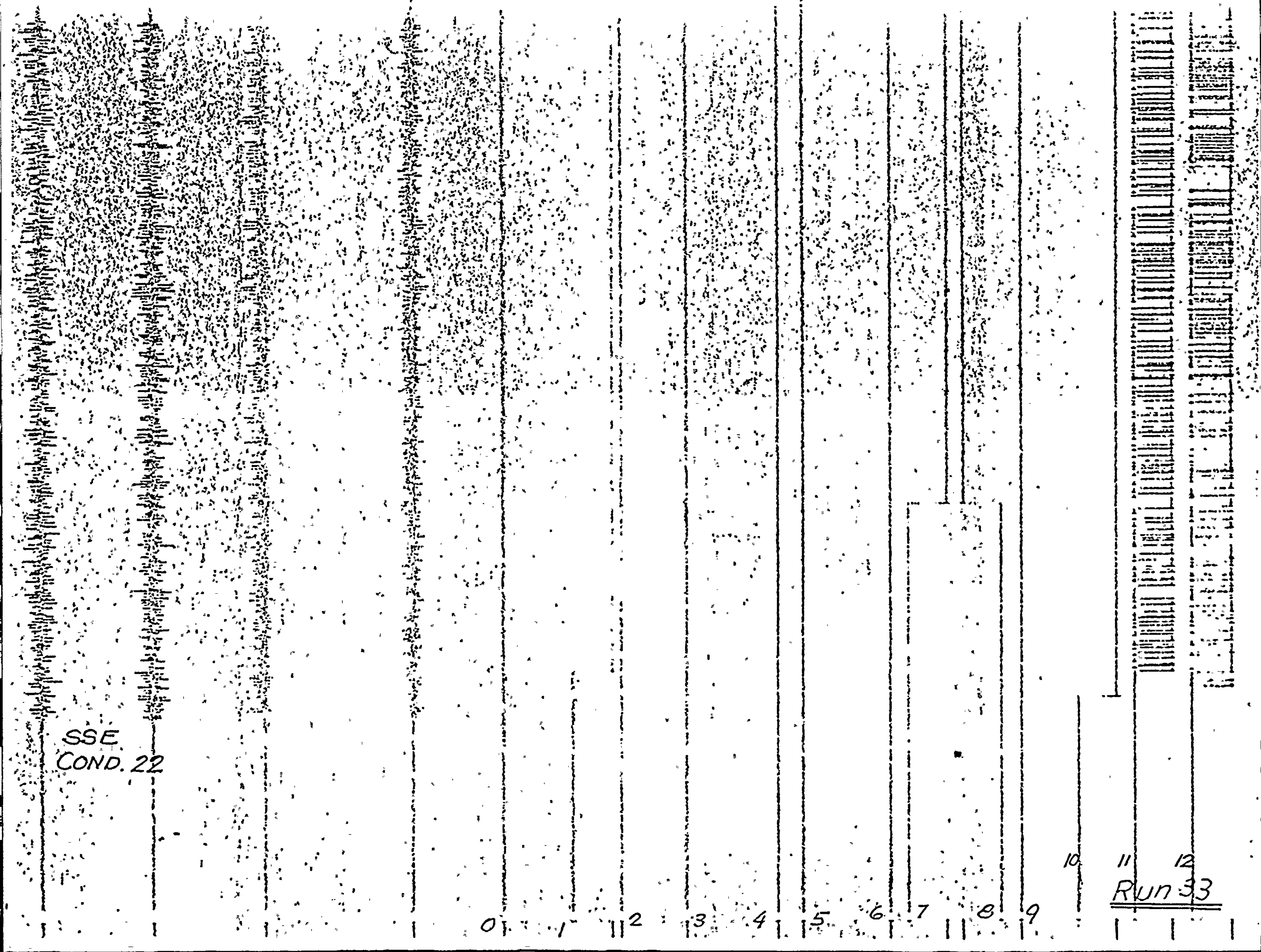

OBE
COND. 18
Run 28
0
1
2
3
4
5
6
7
8
9
10
11
12

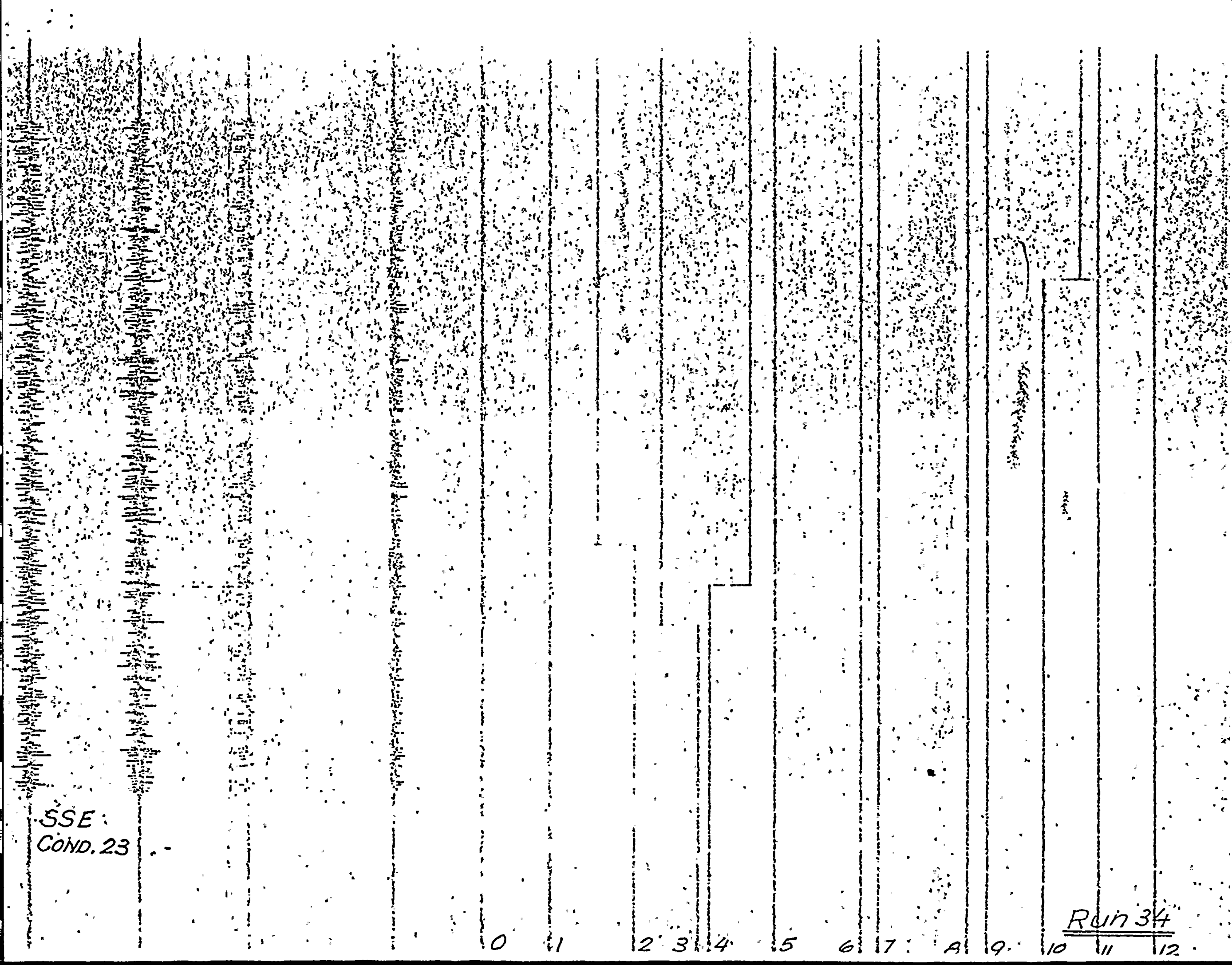

OBE
COND. 19
+39 = 1/2"
Run 29
0
1
2
3
4
5
6
7
8
9
10
11
12

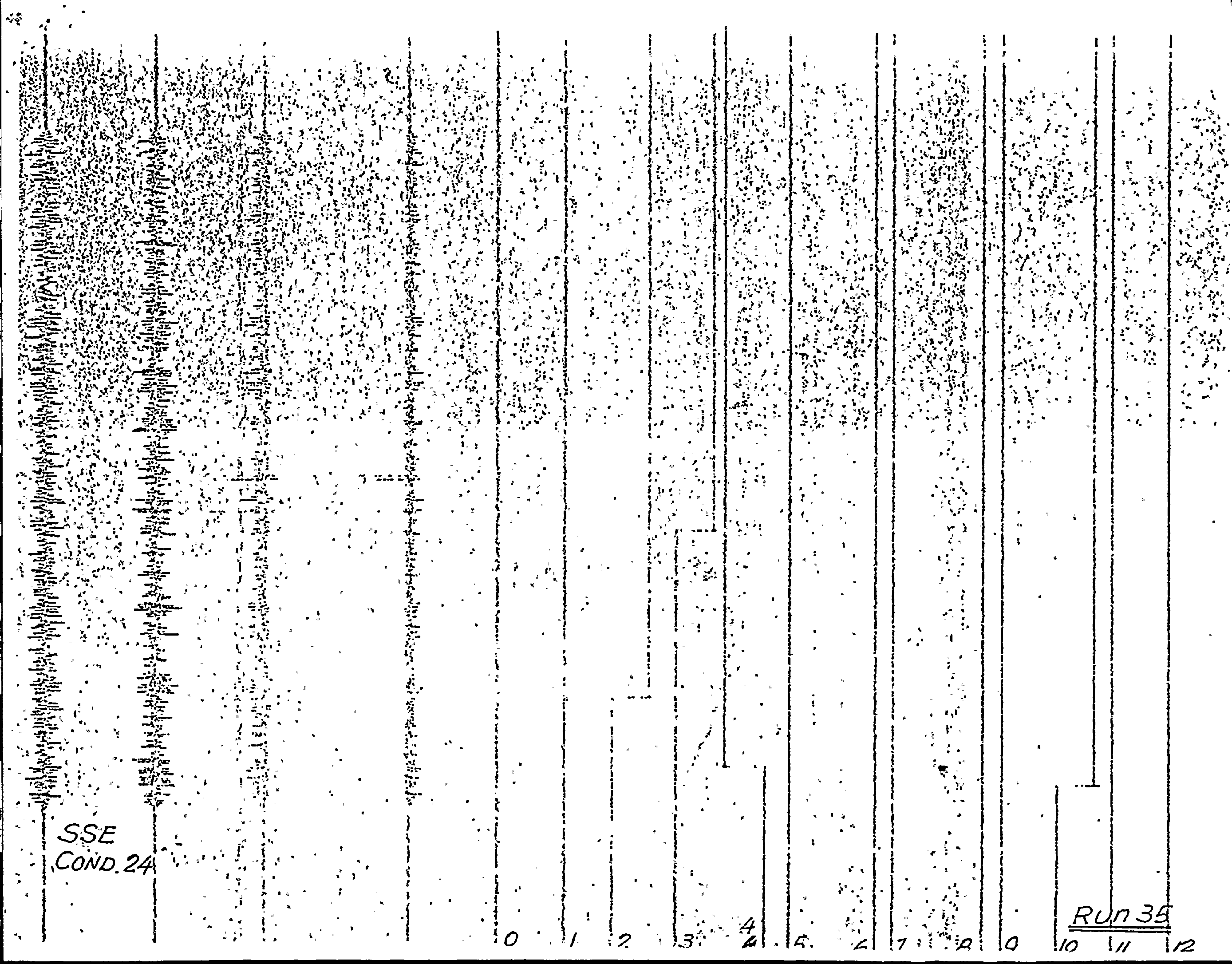

OBE
COND. 20
Run 30
0
1
2
3
4
5
6
7
9
10
11

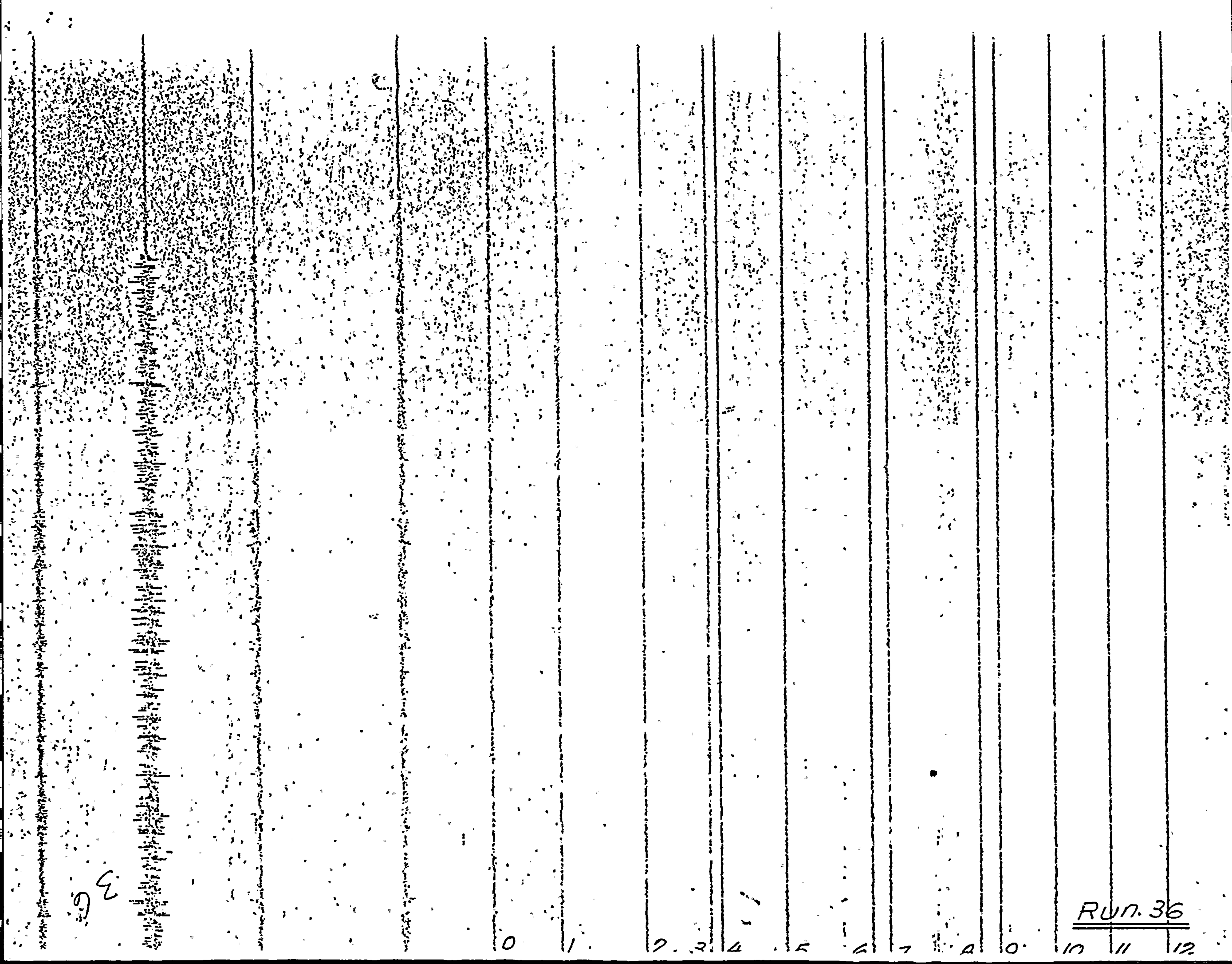

SSE
COND 21
Run 31
0
10
11
12

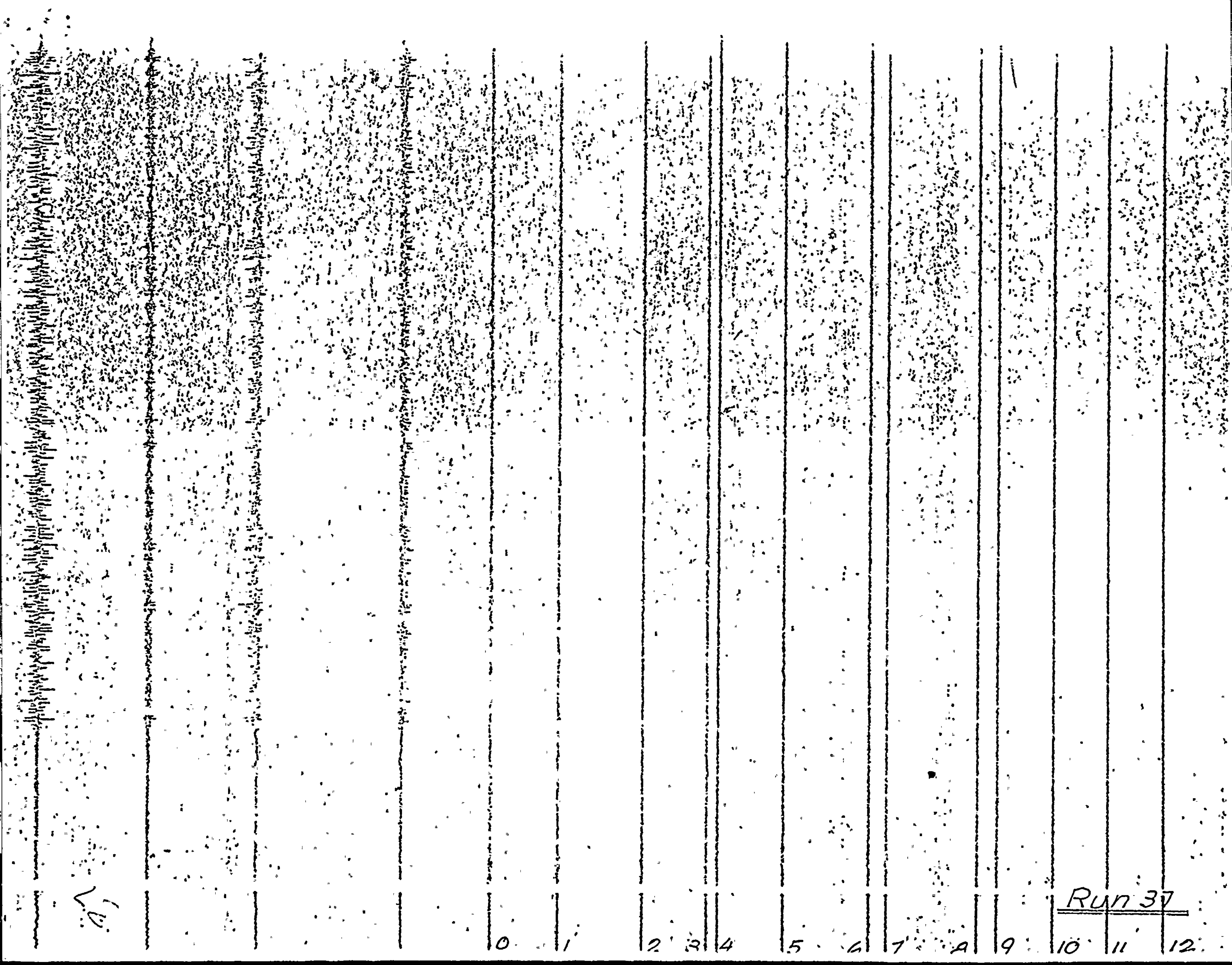

SSE
TO BE
RE-RUN
Run 32
0
1
2
3
4
5
6
7
8
9
10
11
12

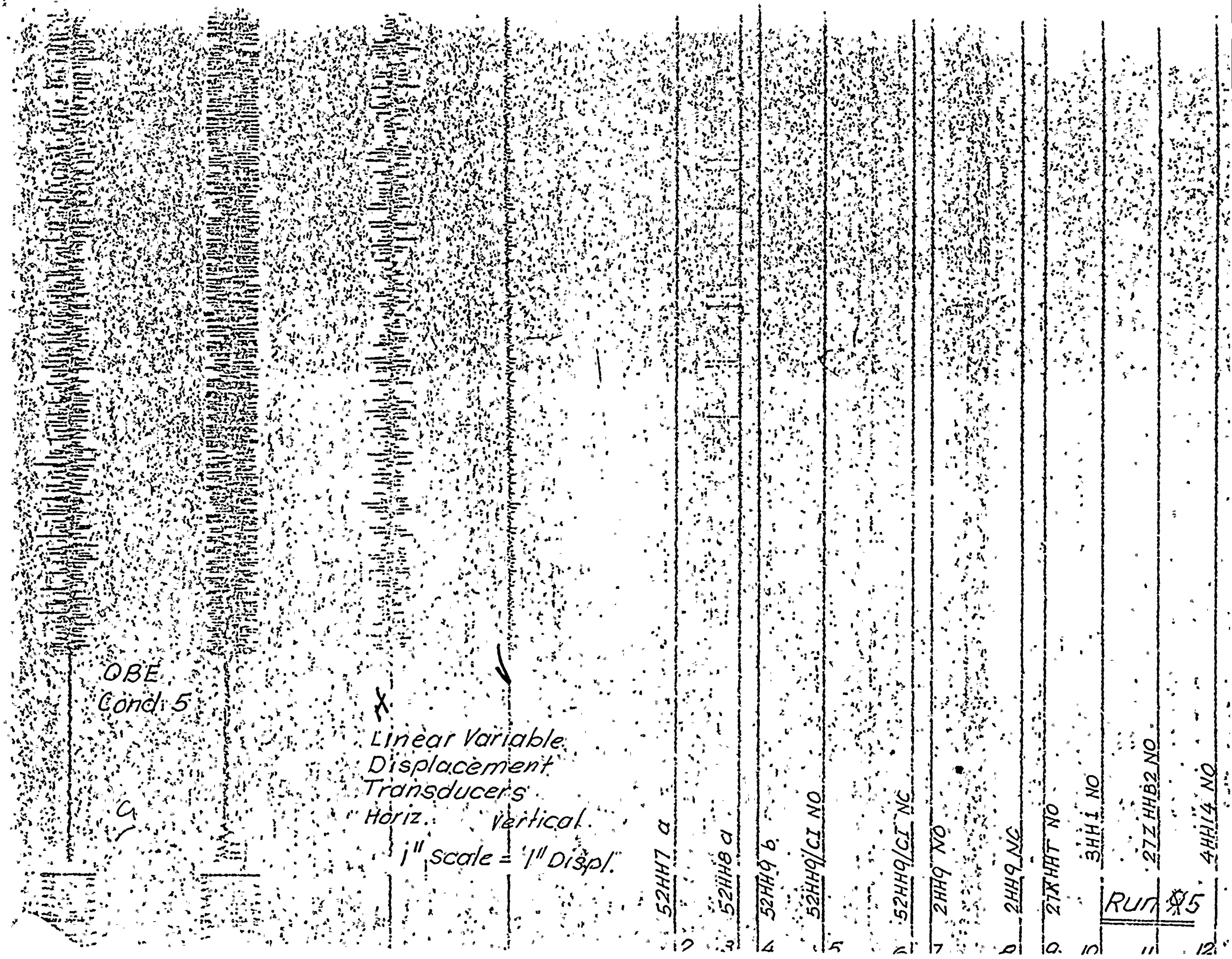

SSE
COND. 22
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 33


SSE
COND. 23
Run 34
0
1
2
3
4
5
6
7
9
10
11
12

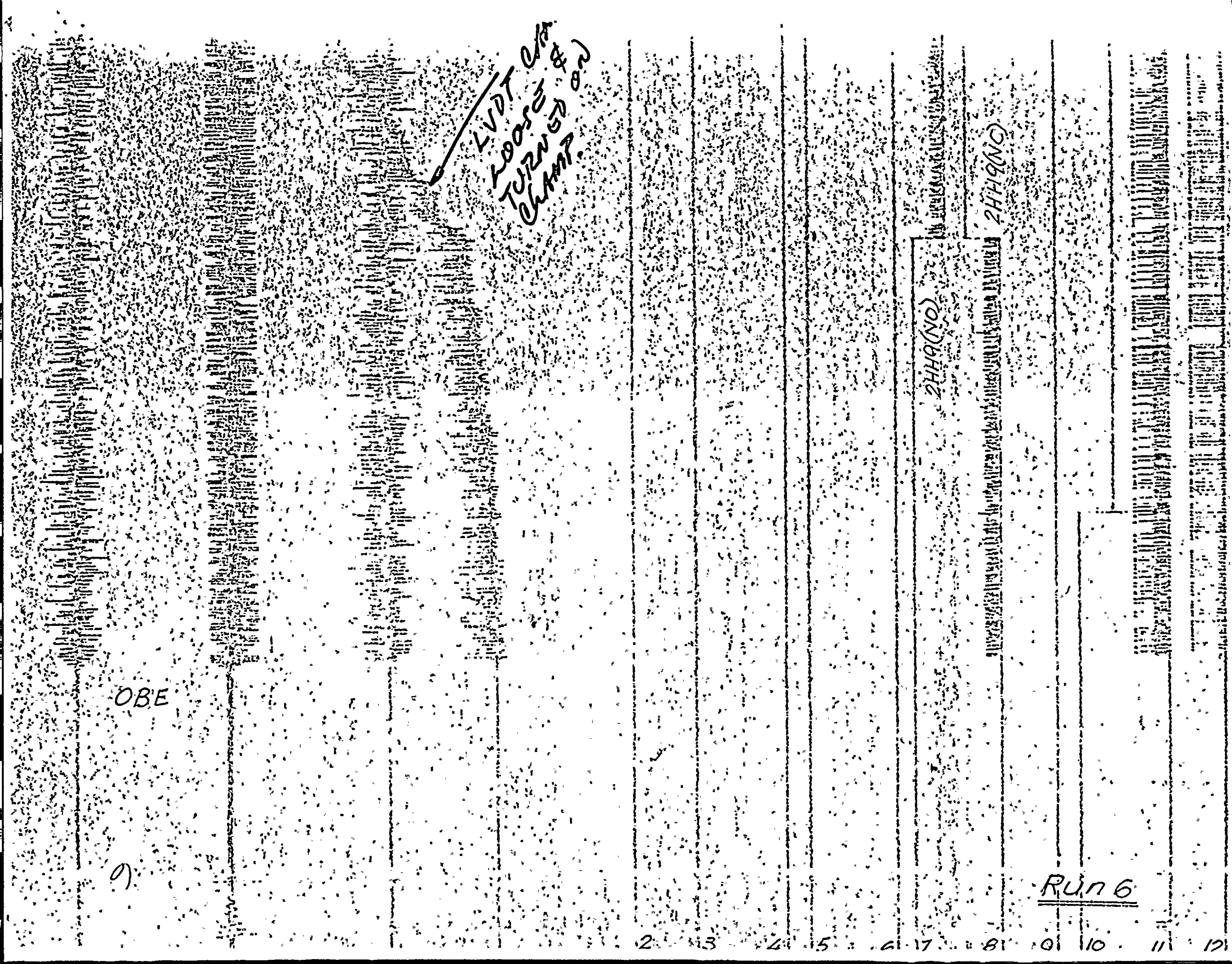

SSE
COND. 24
Run 35
0
1
2
3
4
5
6
7
8
9
10
11
12

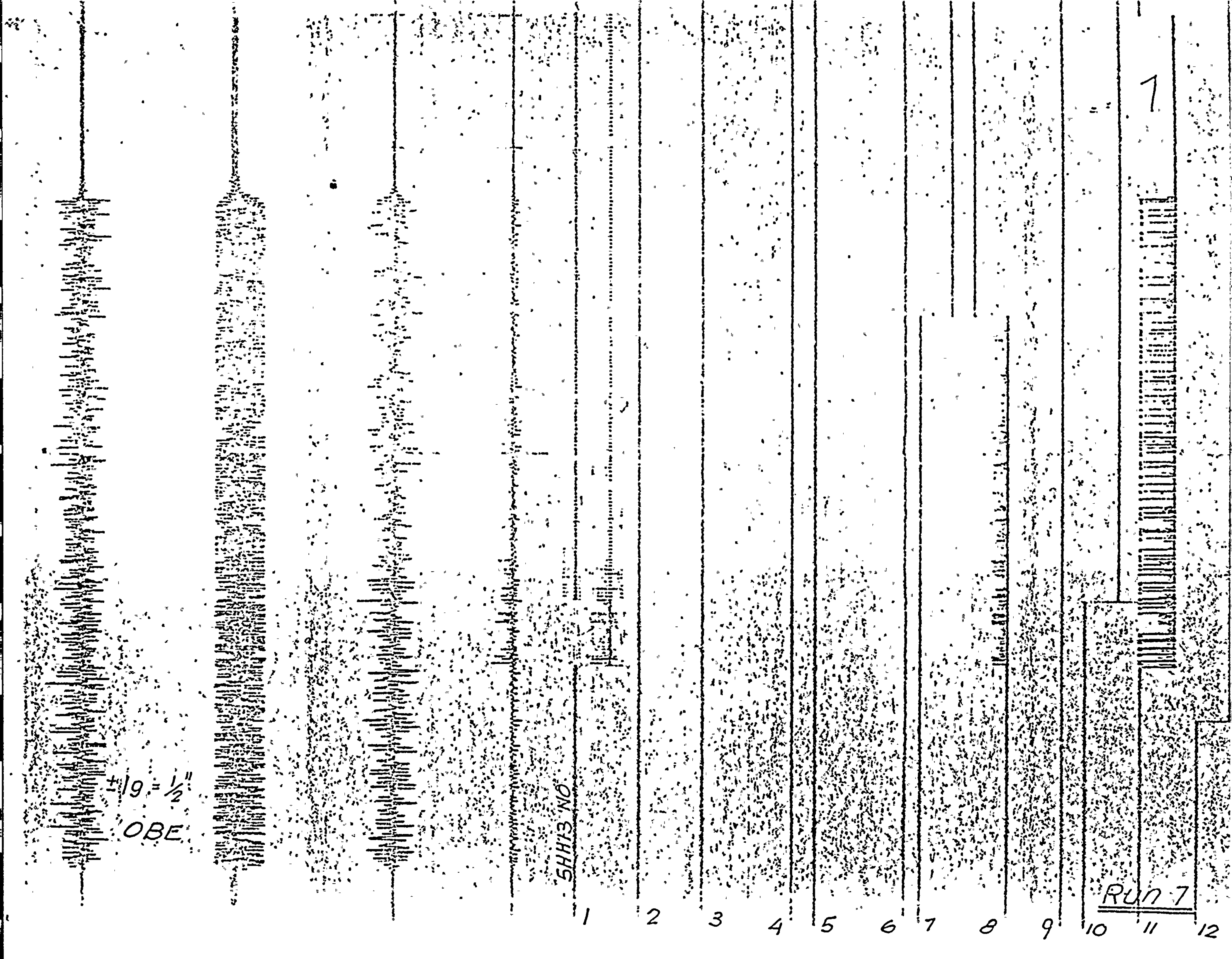

0
1
2
3
4
5
6
7
8
9
10
11
12
Run. 36

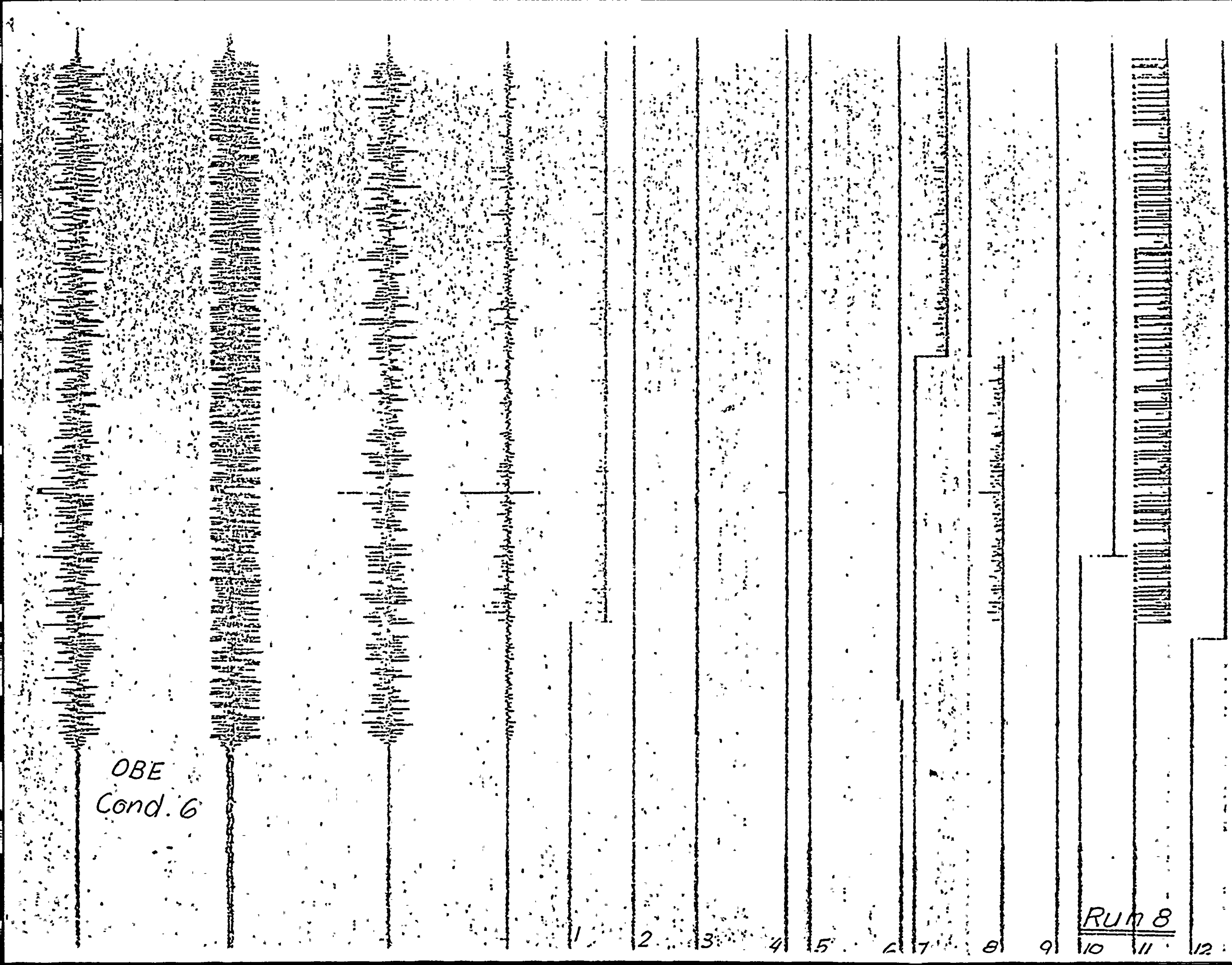

Run 37
0
1
2
3
4
5
6
7
9
10
11
12

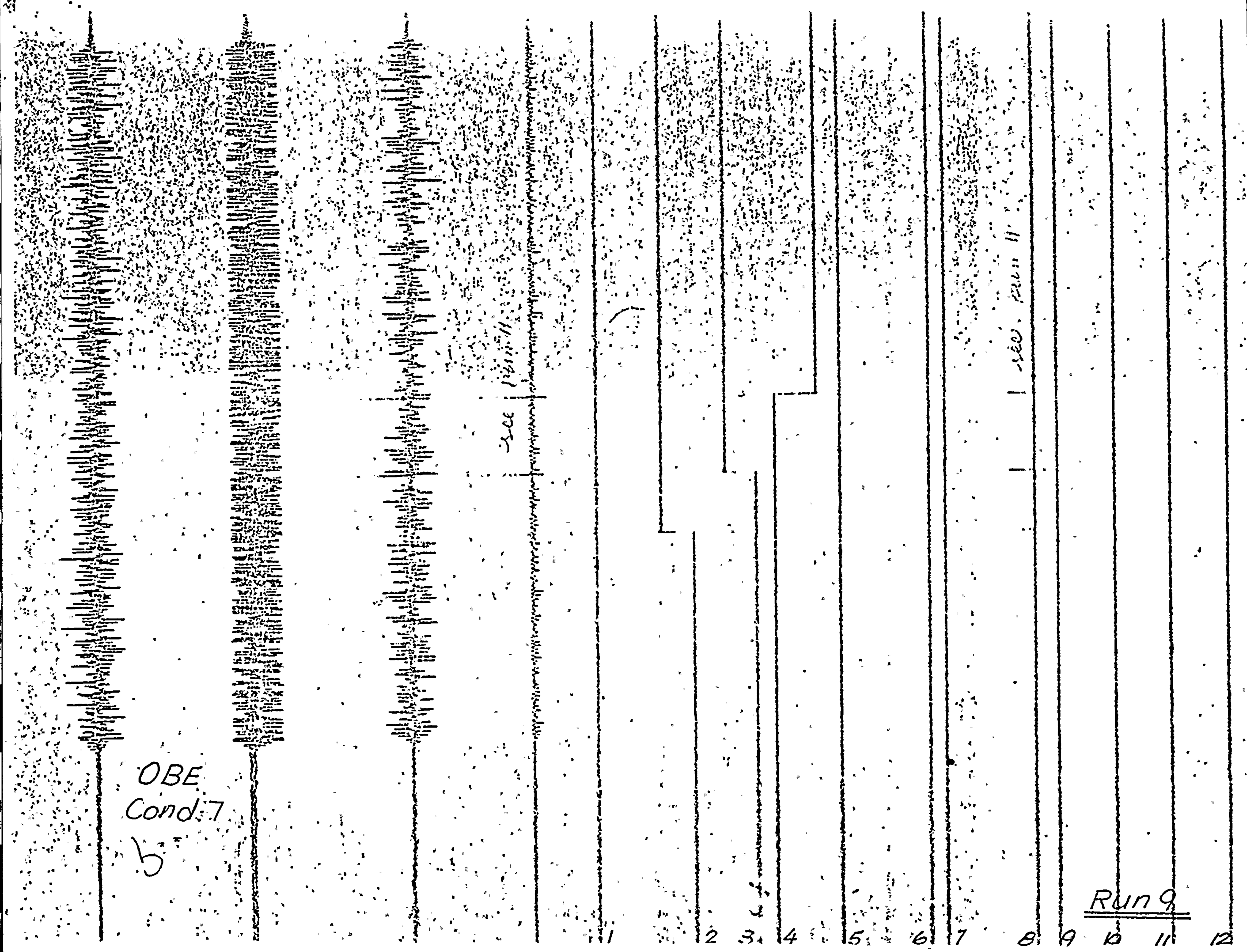


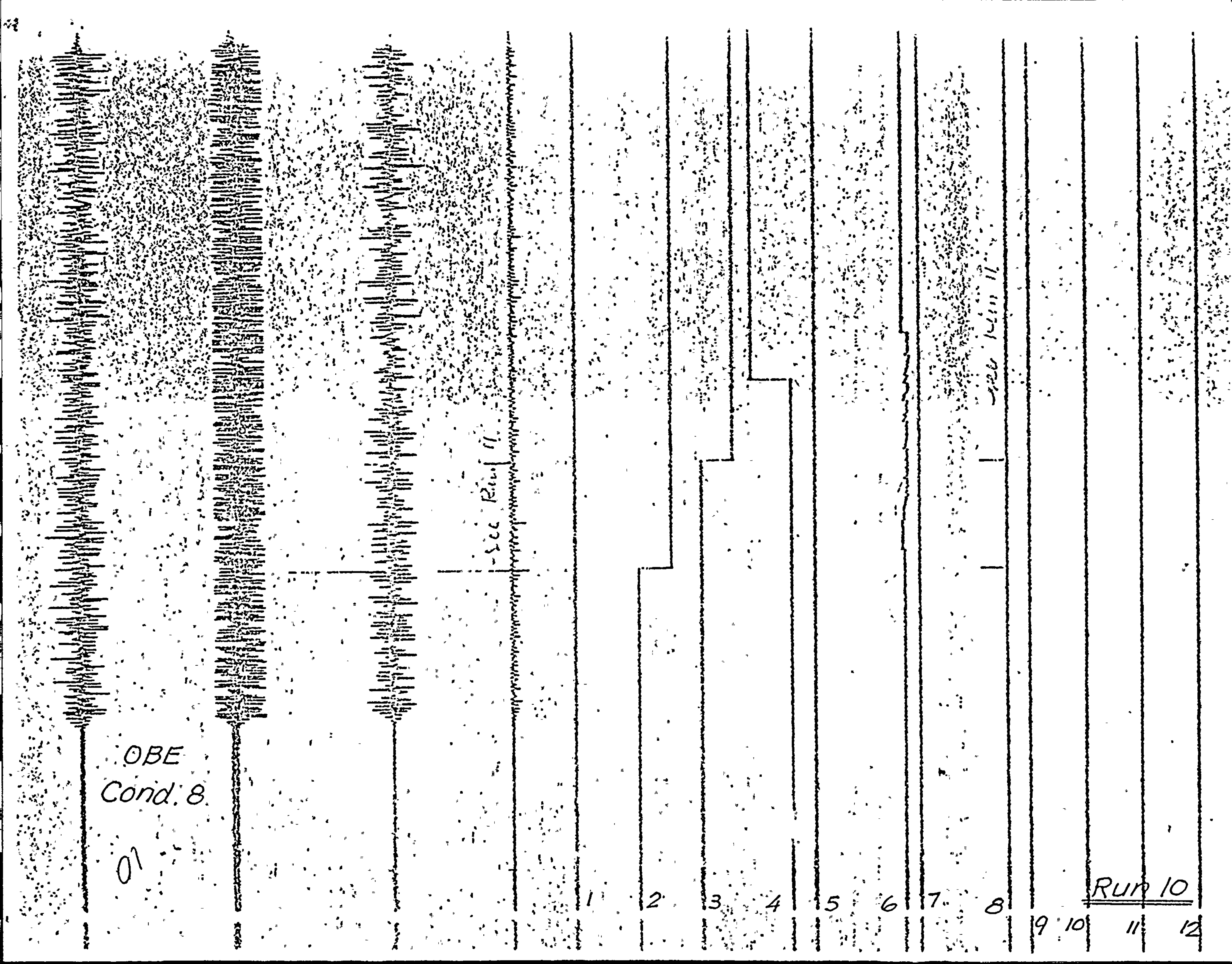
OBE
Cond. 5
Linear Variable
Displacement
Transducers
Horiz.
Vertical
1" scale = 1" Displ.
52HH7 a
52HH8 a
52HH9 b
52HH9/CI NO
52HH9/CI NC
2HH9 NO
2HH9 NC
27XHHT NO
3HH1 NO
27Z HHB2 NO
4HH14 NO
Run #5
2
3
4
5
6
7
8
9
10
11
12


LVDT CH. LOOSE & TURNED ON CLAMP.
2HHA(NO)
2HHA(NC)
OBE
Run 6
2
3
4
5
6
7
8
9
10
11
12

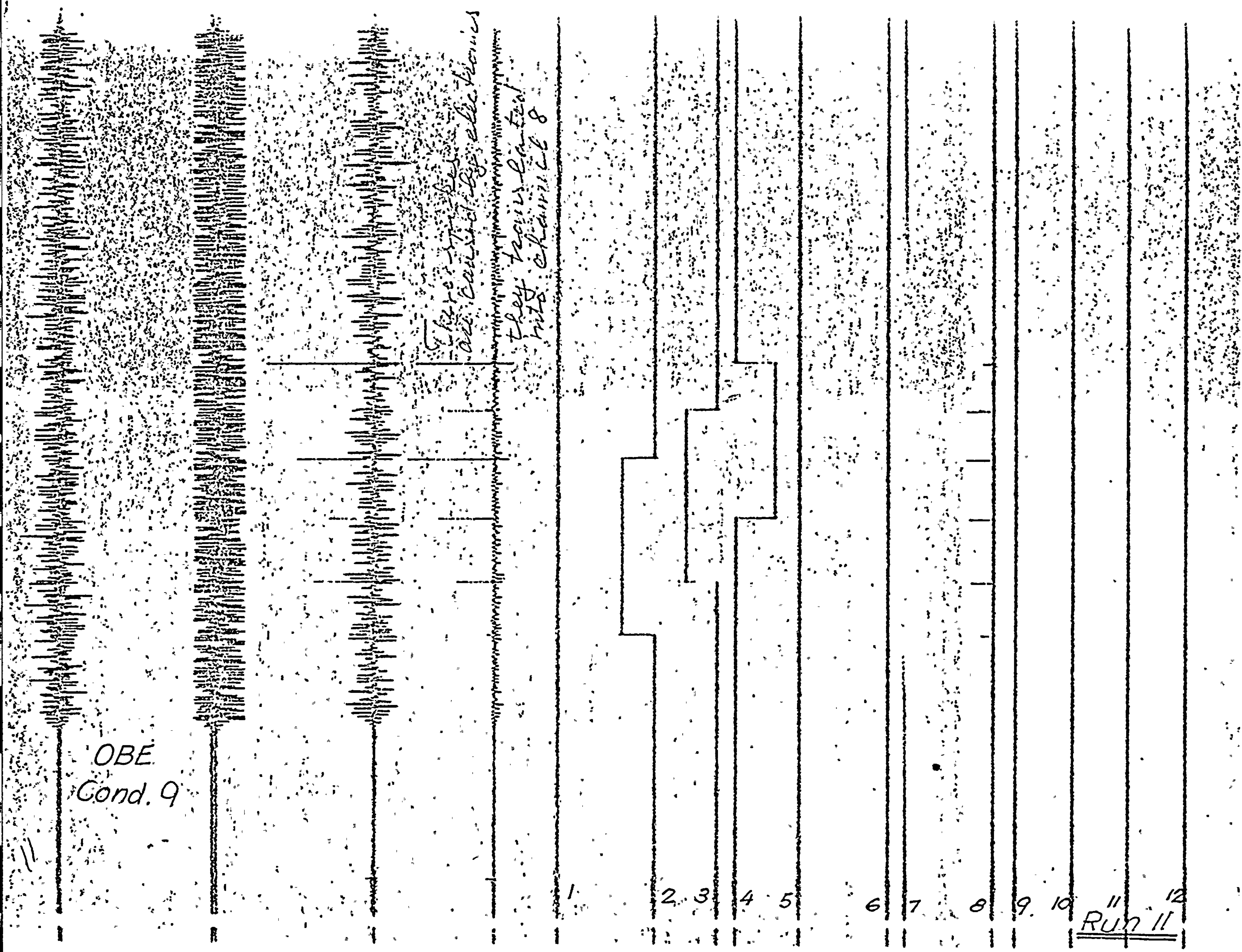

7
±19 = 1/2"
OBE
SHH13 NO
1
2
3
4
5
6
7
8
9
10
11
12
Run 7

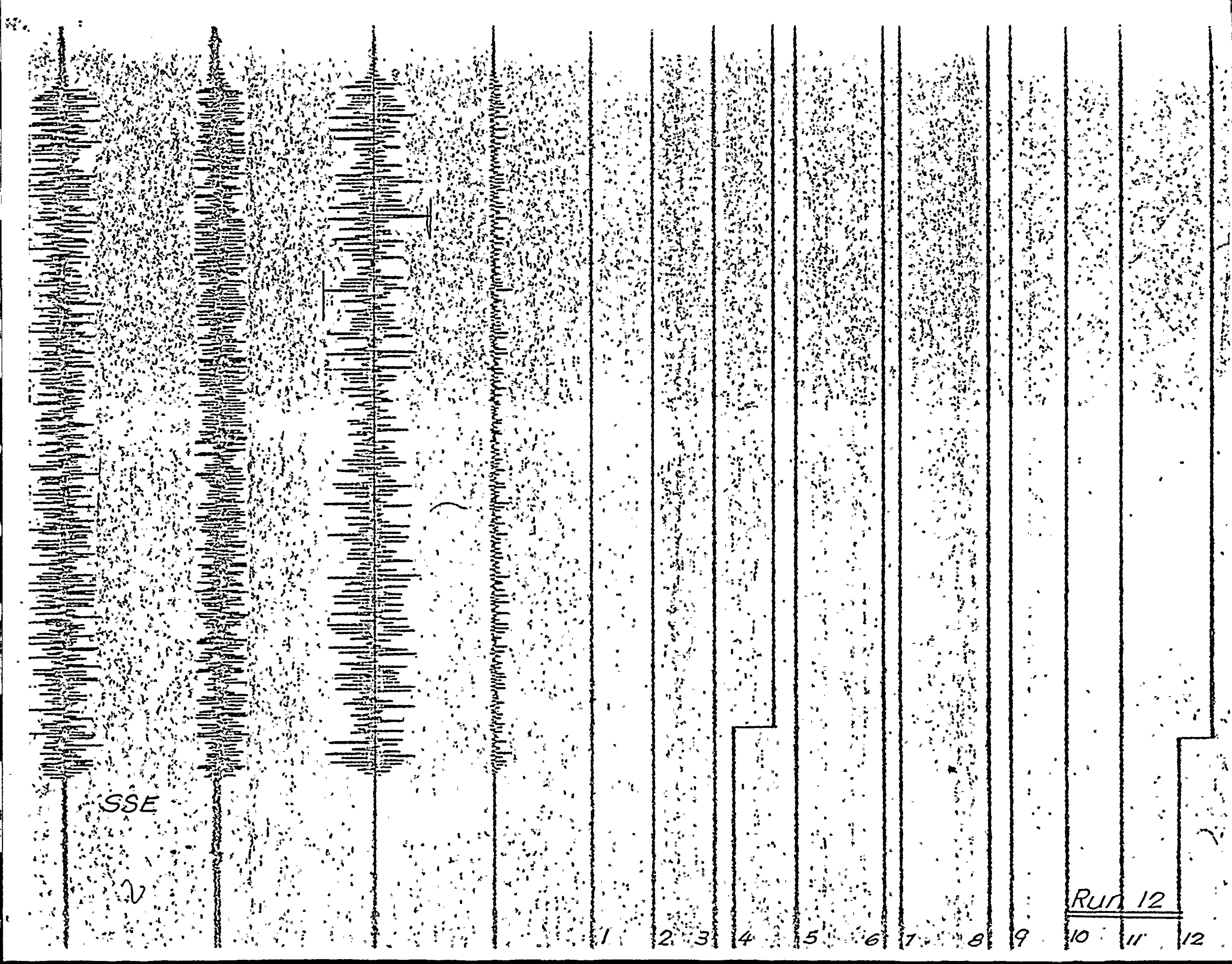

OBE
Cond. 6
Run 8
1
2
3
4
5
6
7
8
9
10
11
12


OBE
Cond:7
b
Run 9
1
2
3
4
5
6
7
8
9
10
11
12

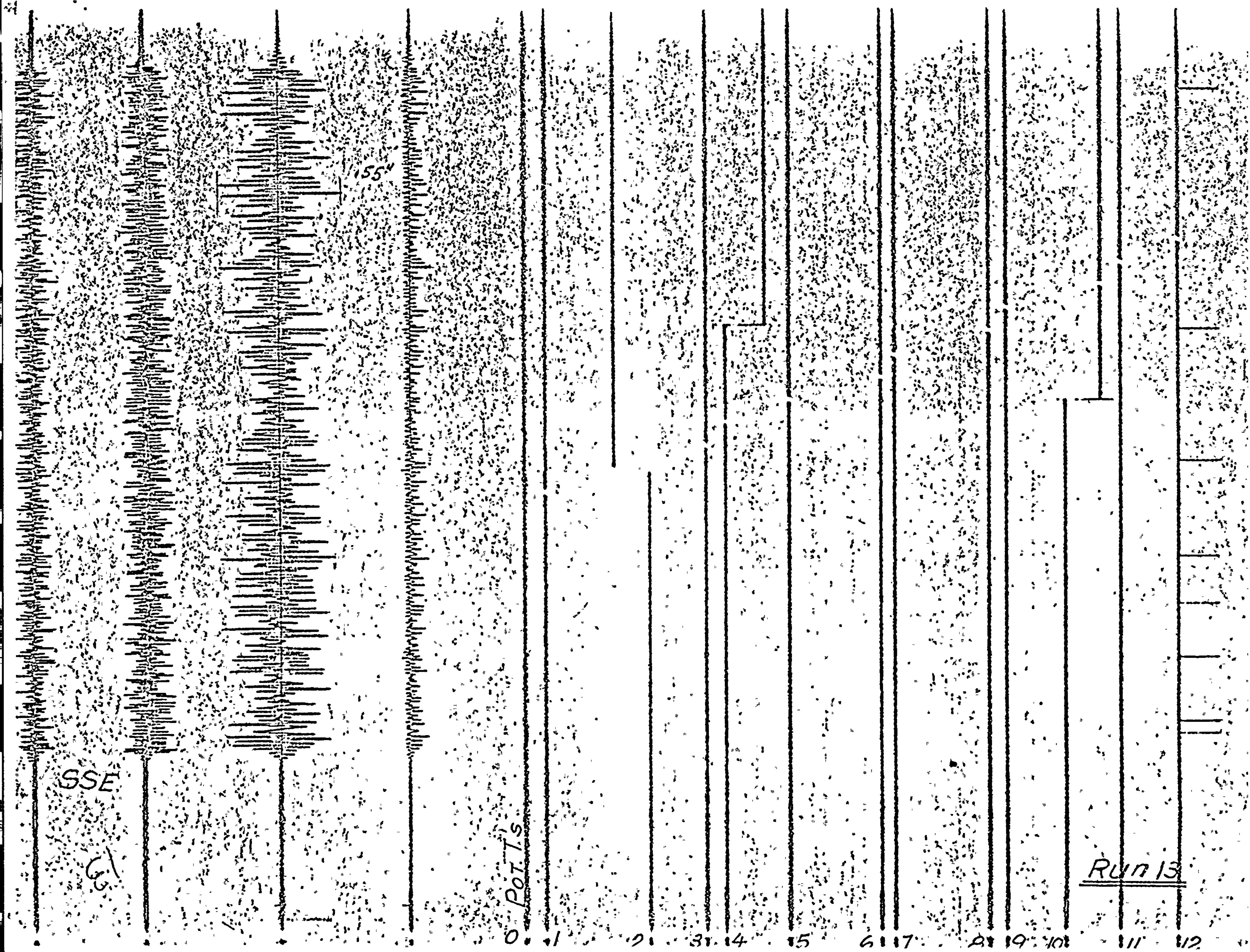


OBE
Cond. 8
01
See Run 11
See Run 11
1
2
3
4
5
6
7
8
9
10
11
12
Run 10

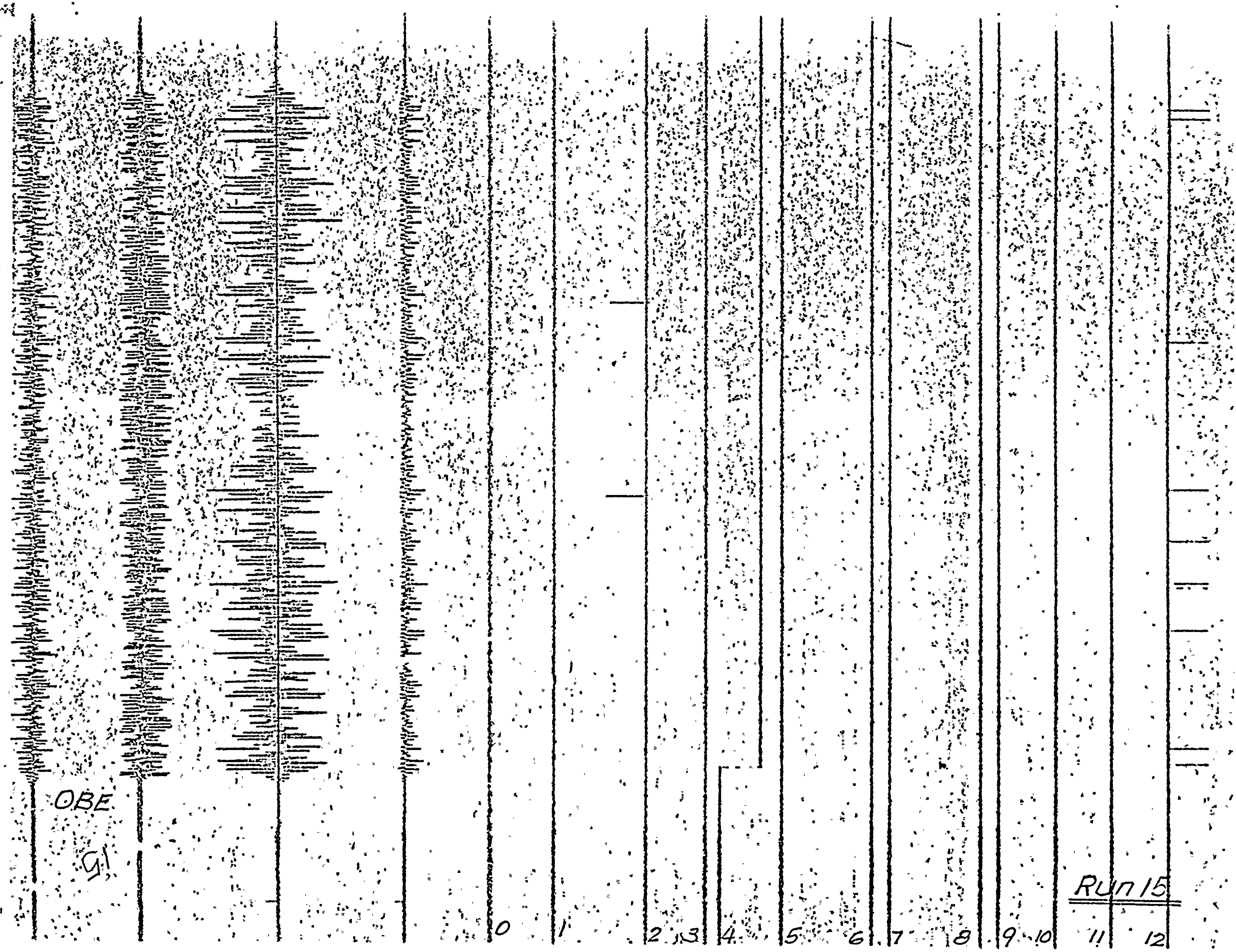

These spikes are caused by electronics
they transferred into channel 8
OBE
Cond. 9
1
2
3
4
5
6
7
8
9
10
11
12
Run II

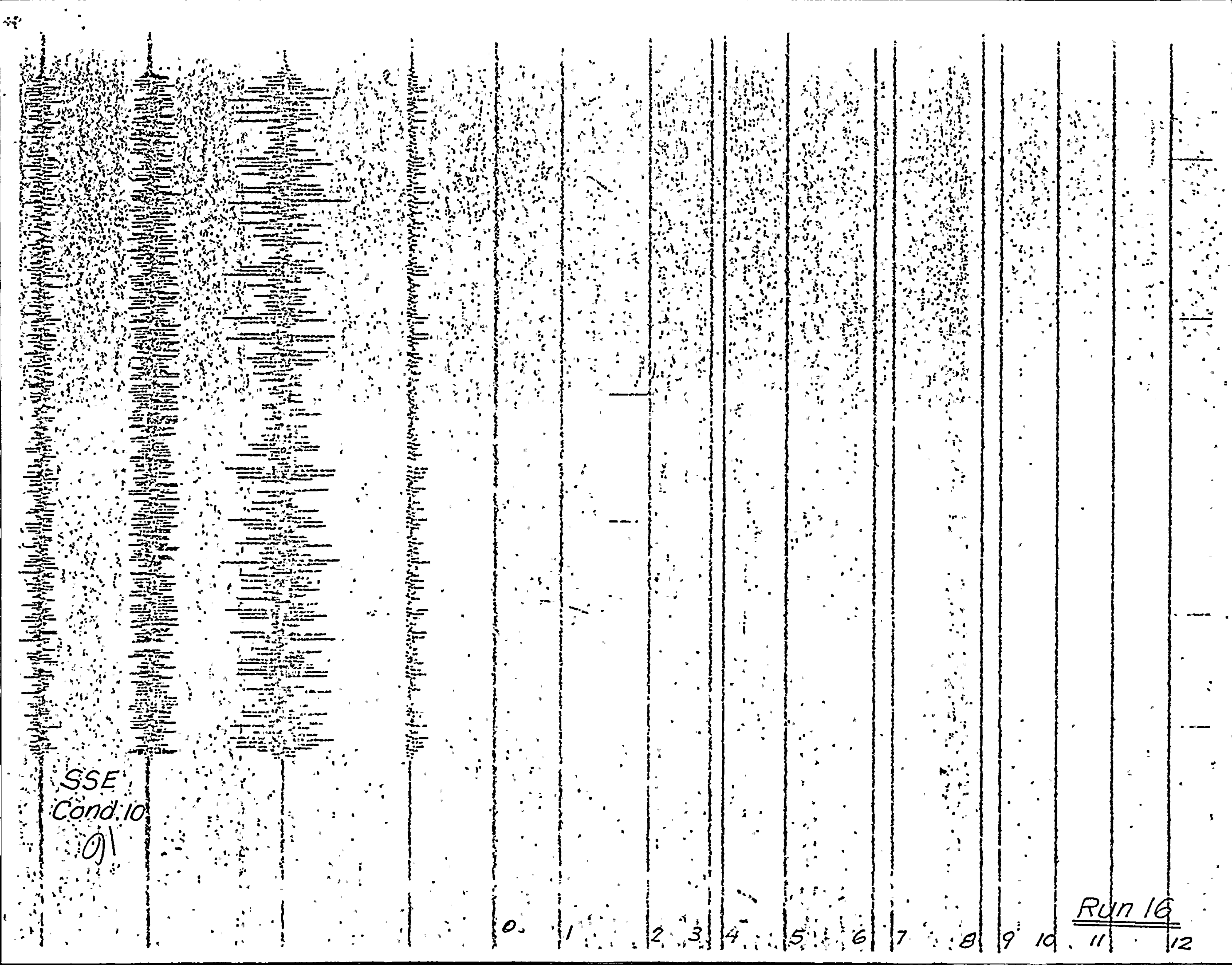


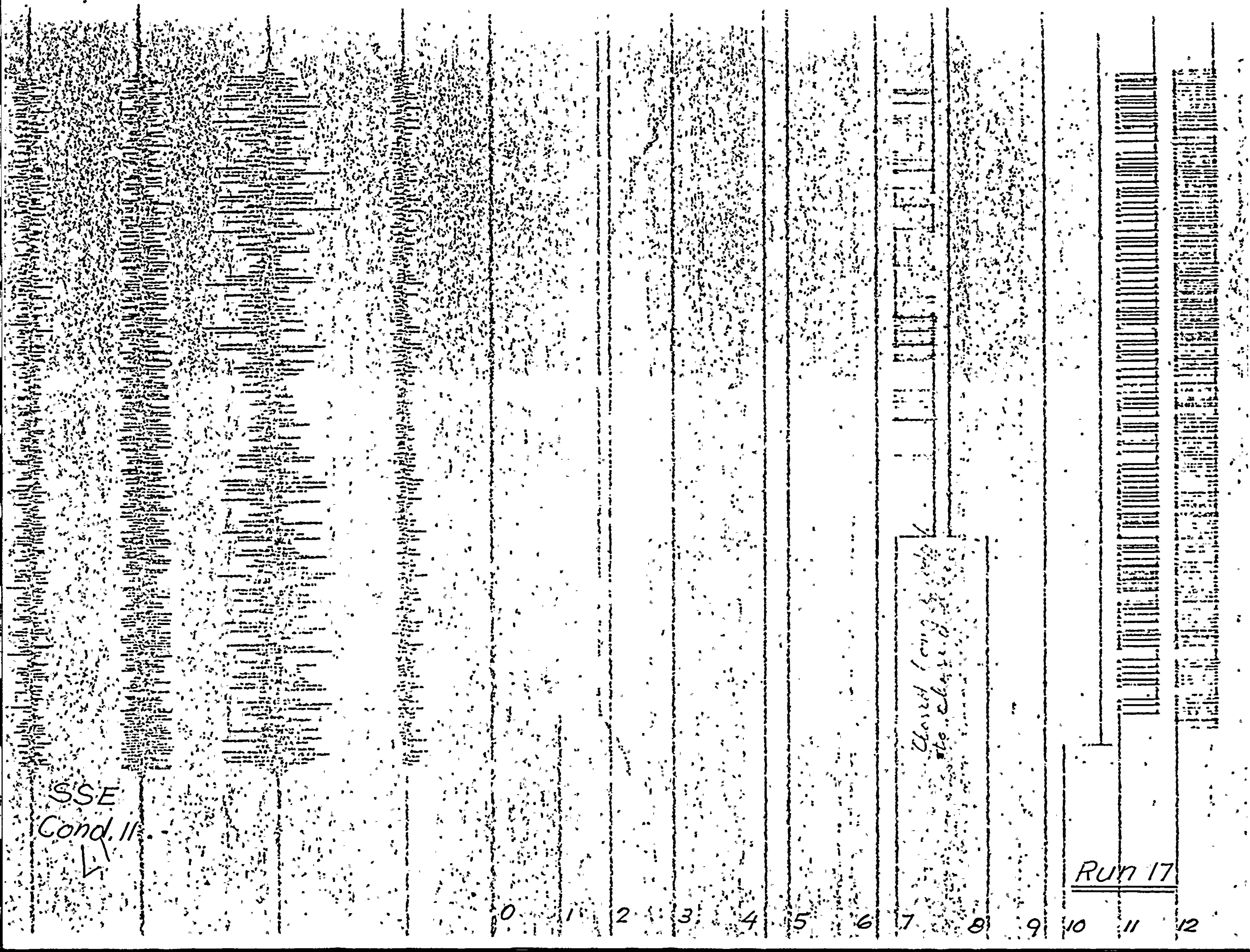
SSE
Run 12
1
2
3
4
5
6
7
8
9
10
11
12



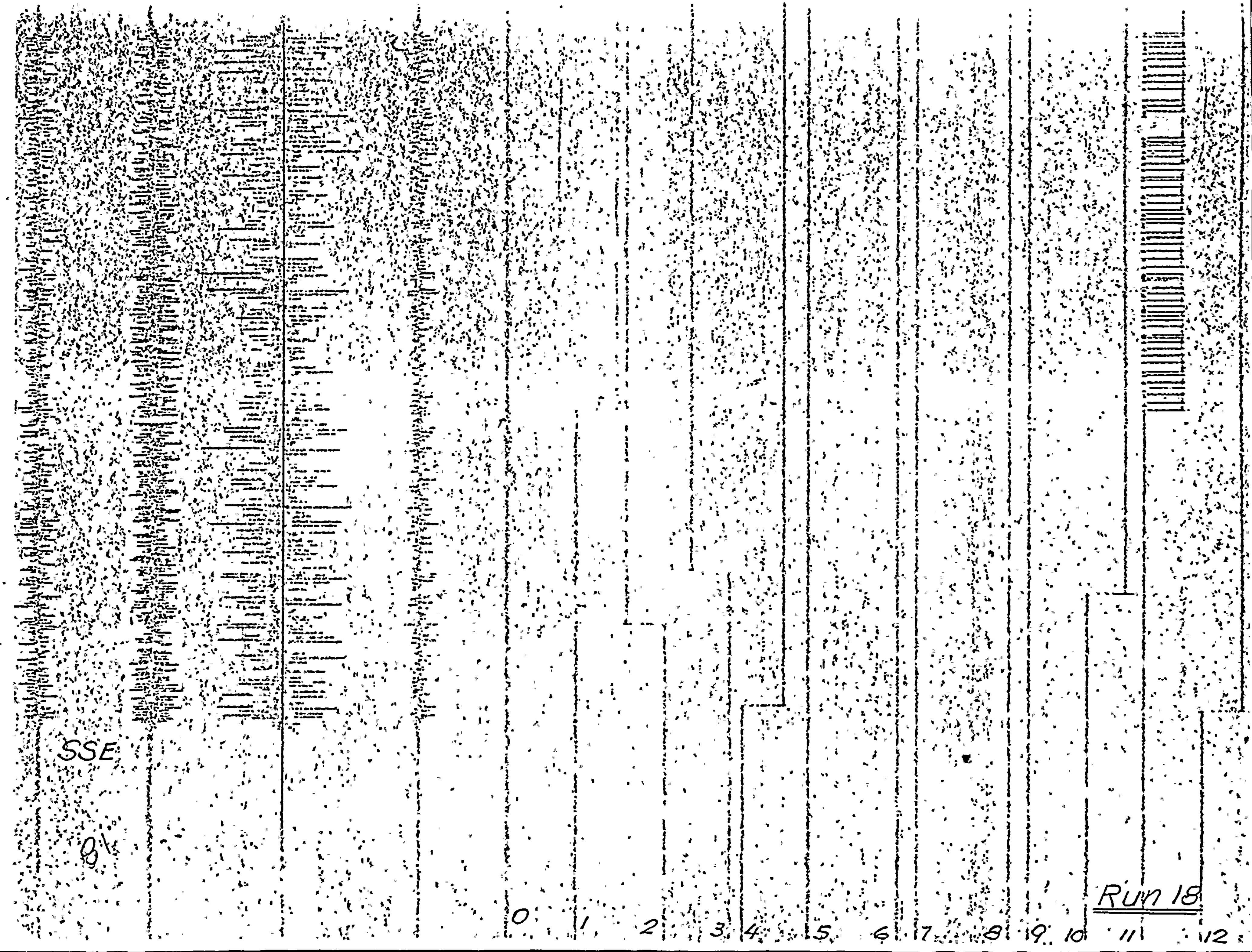
55"
SSE
Pot. T.s
Run 13
0
1
2
3
4
5
6
7
8
9
10
11
12

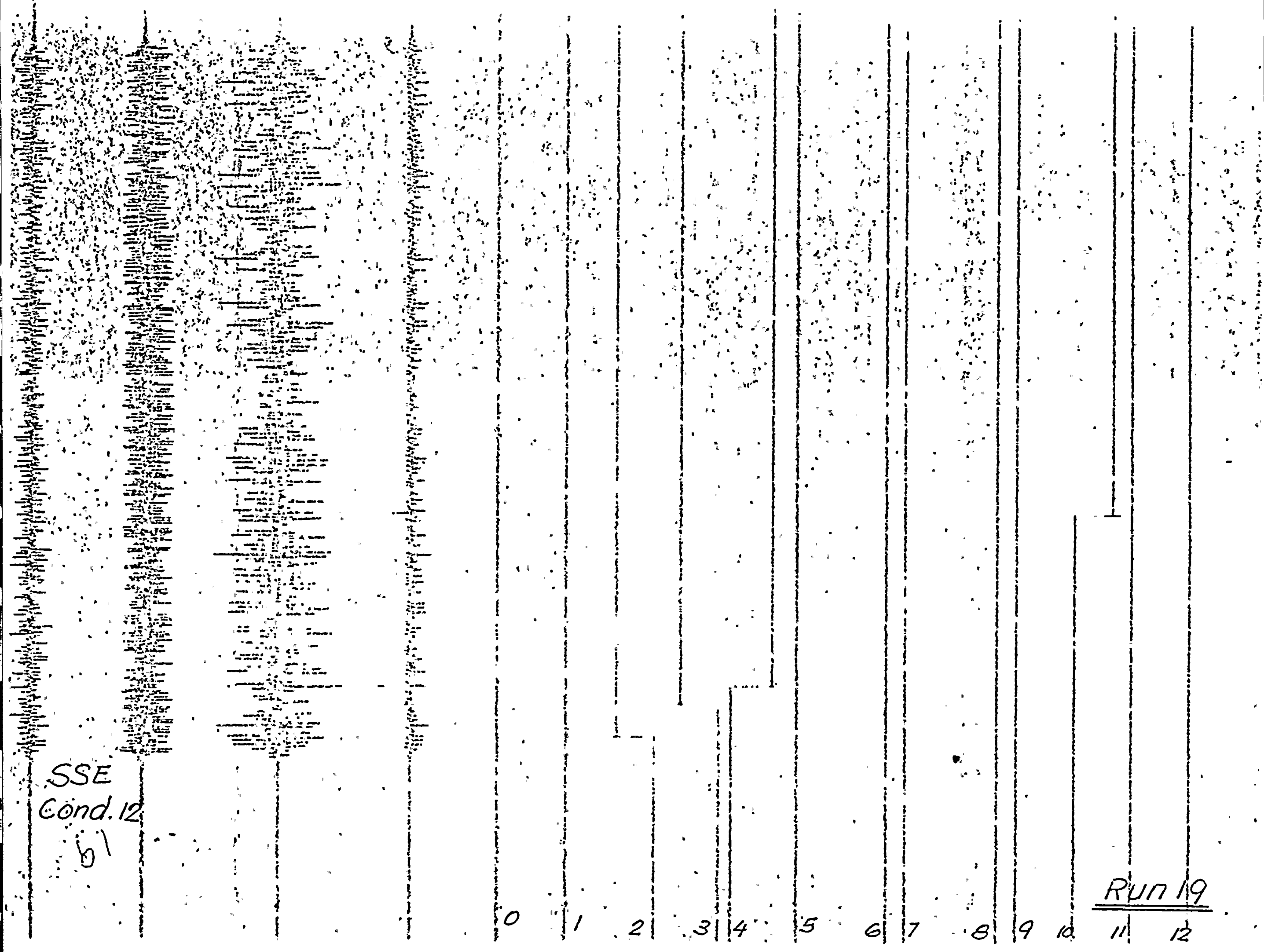

OBE
91
Run 15
0
1
2
3
4
5
6
7
8
9
10
11
12

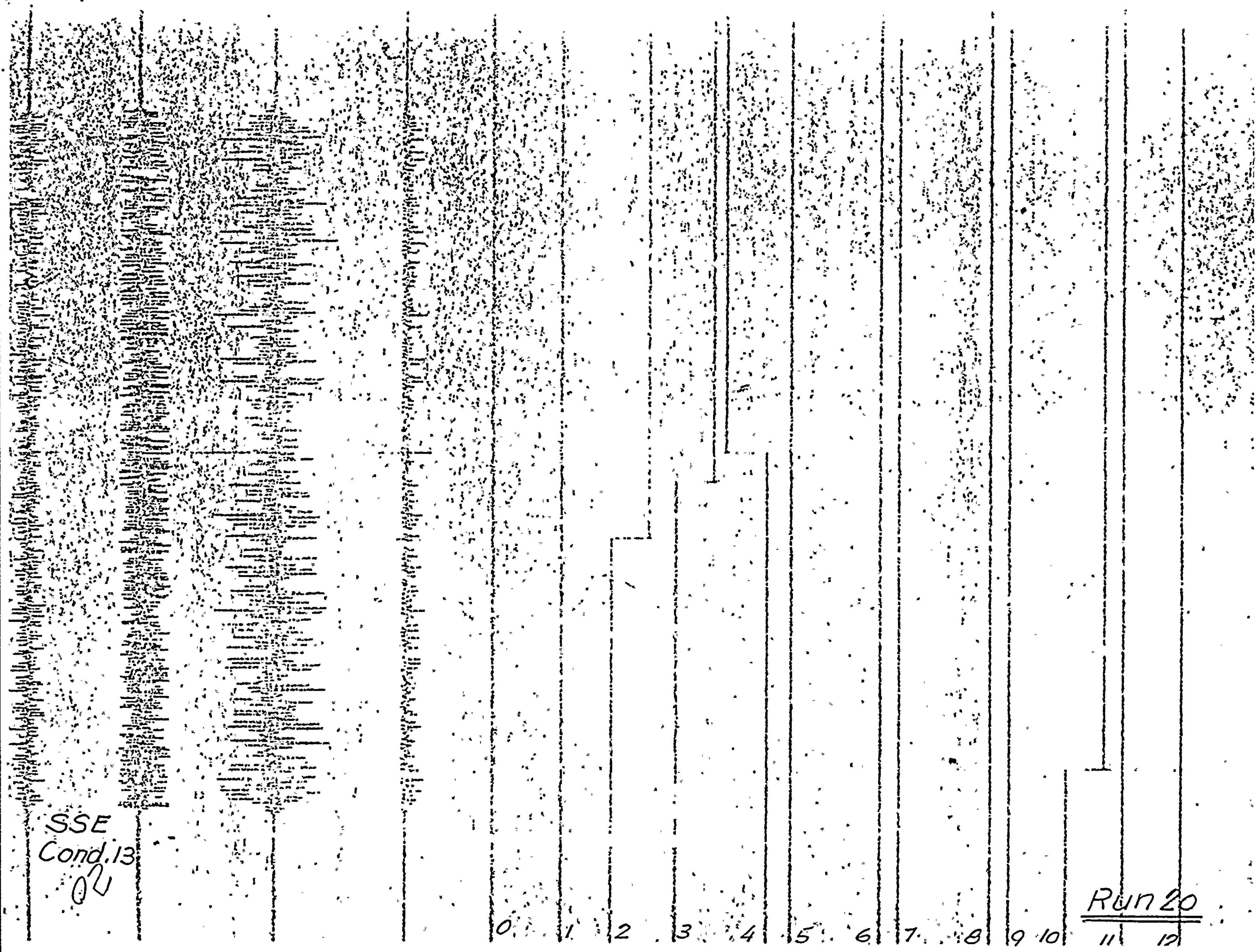

SSE
Cond. 10
01
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 16

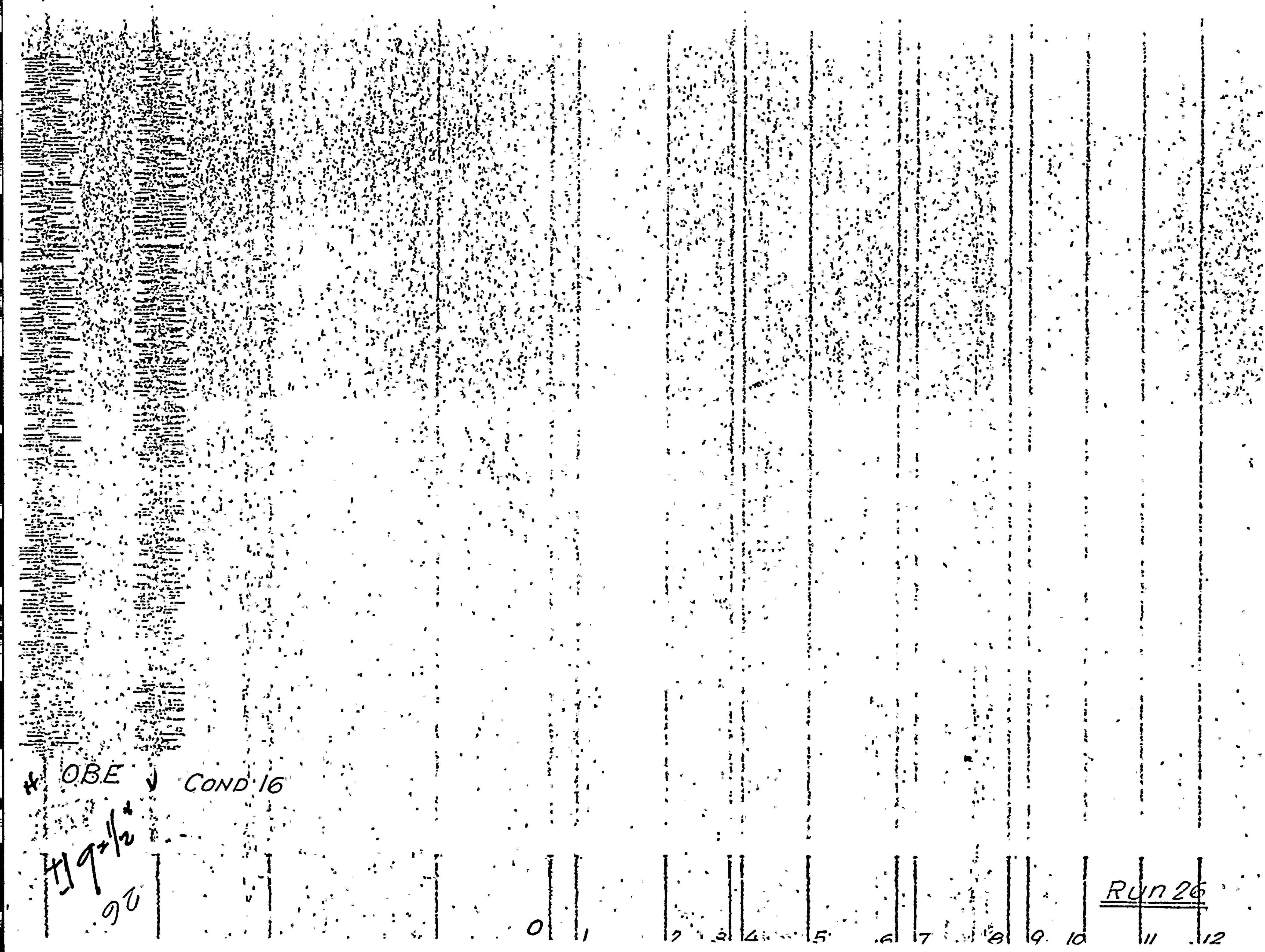


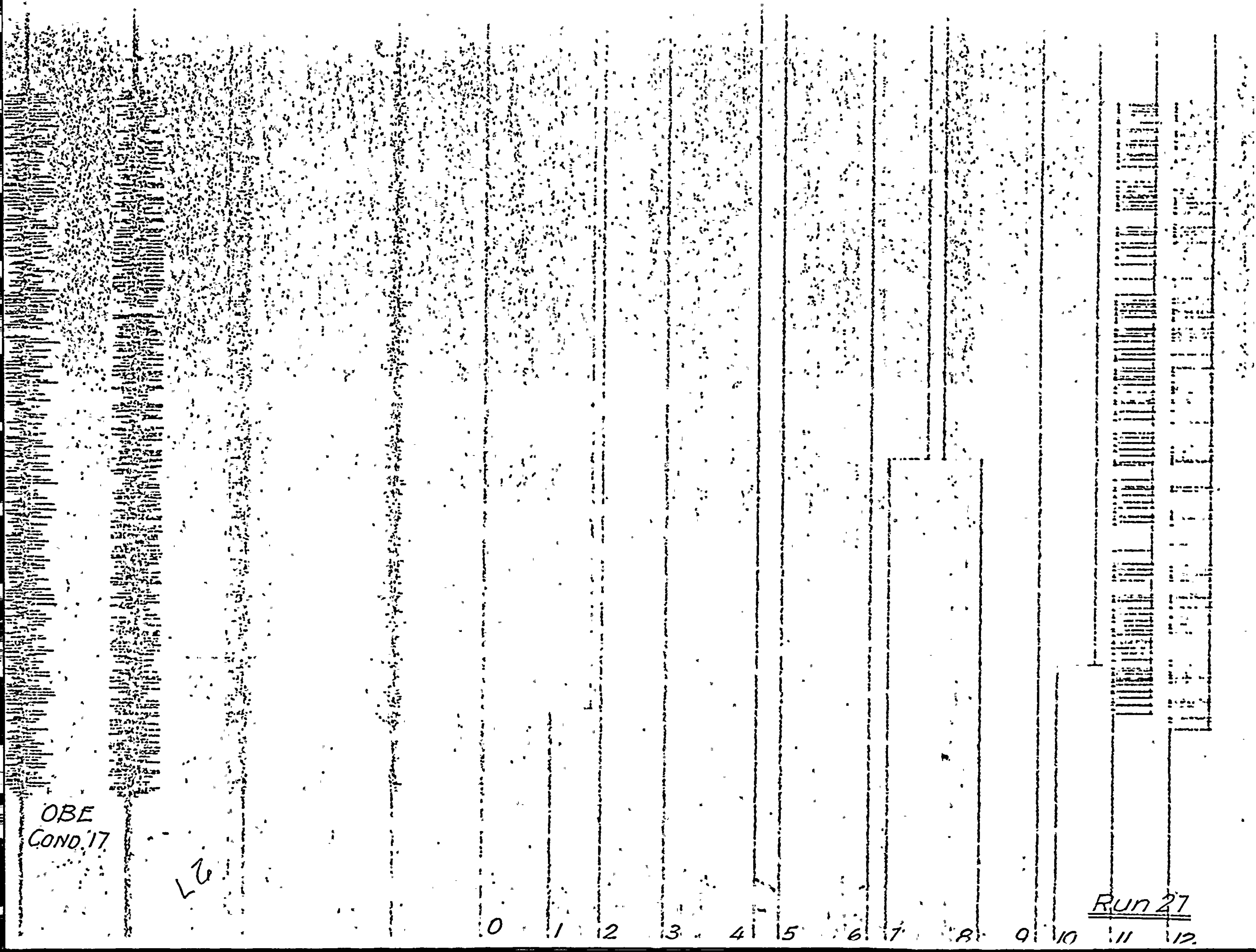
SSE
Cond. 11
Run 17
0
1
2
3
4
5
6
7
8
9
10
11
12

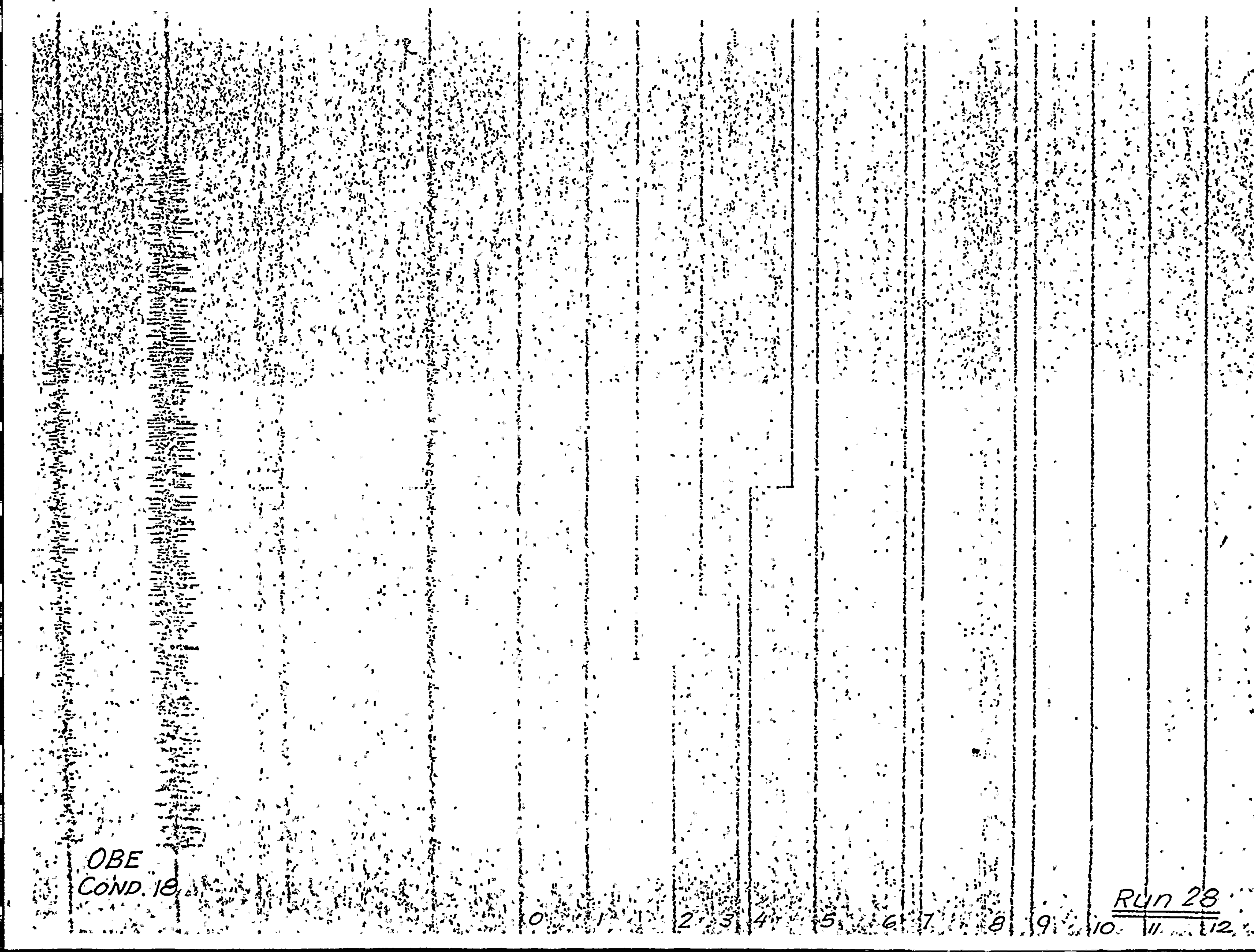

SSE
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 18

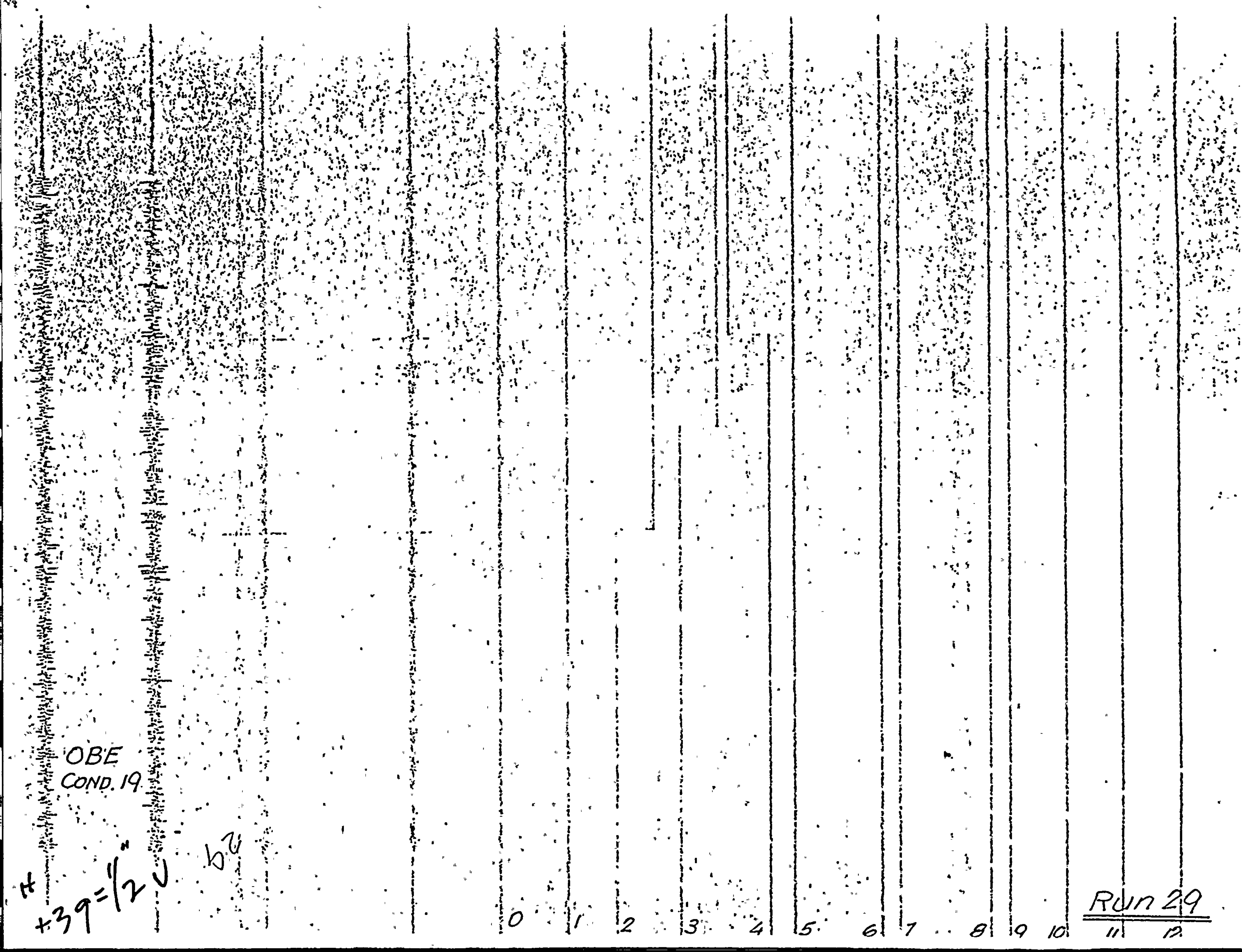

SSE
Cond. 12
61
Run 19
0
1
2
3
4
5
6
7
8
9
10
11
12

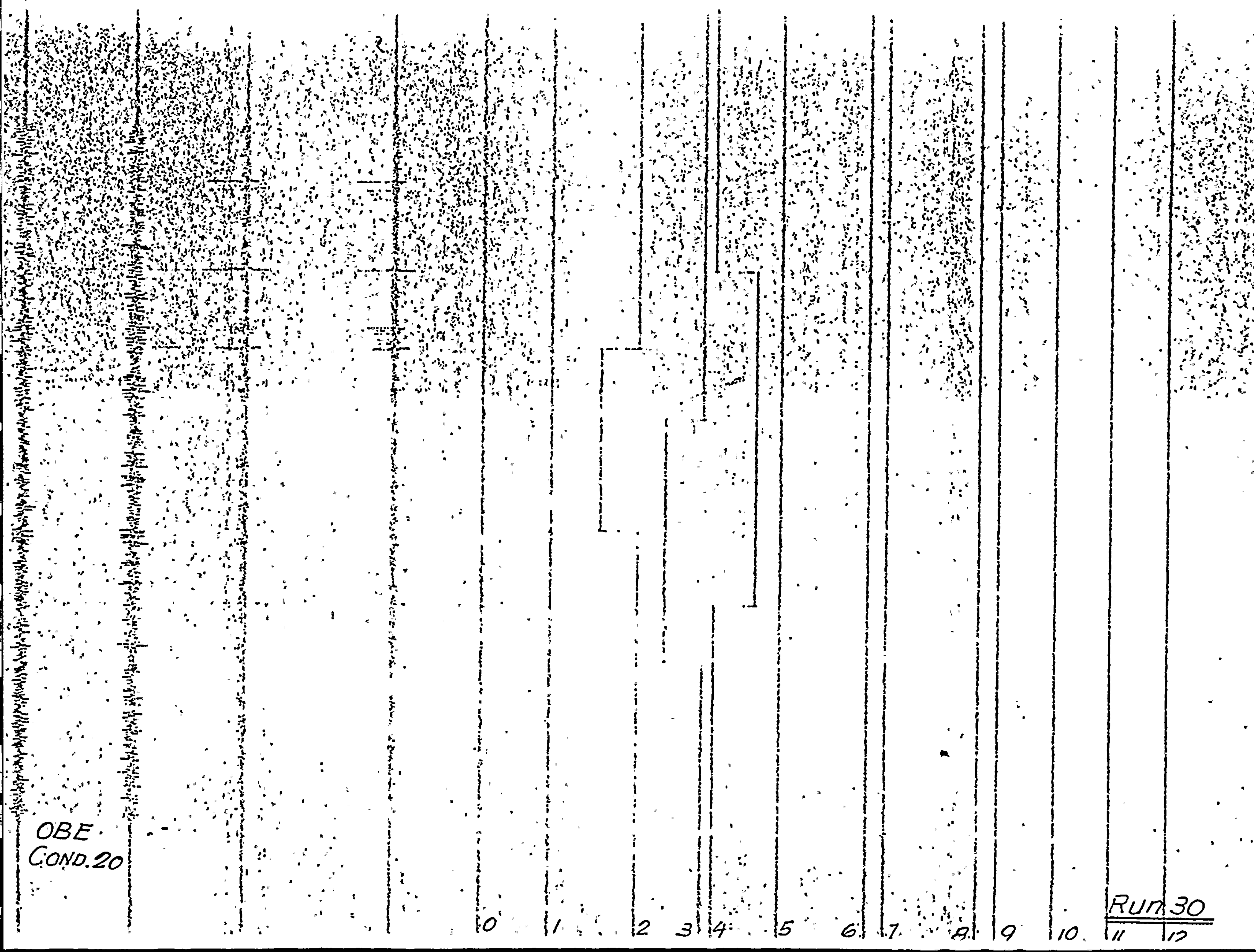

SSE
Cond. 13
02
Run 20
0
1
2
3
4
5
6
7
8
9
10
11
12

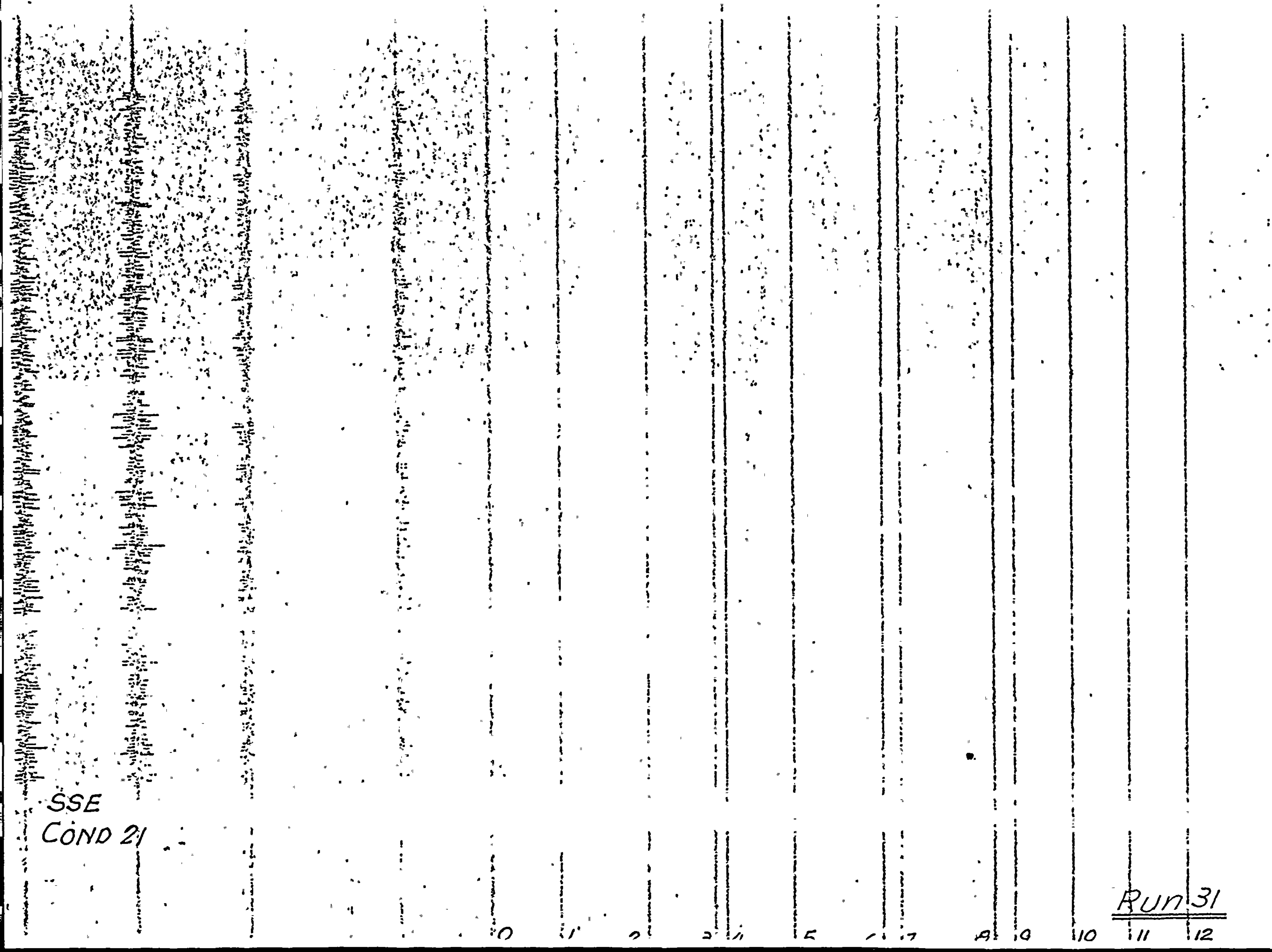

OBE
COND 16
Run 26
0
1
2
3
4
5
6
7
8
9
10
11
12

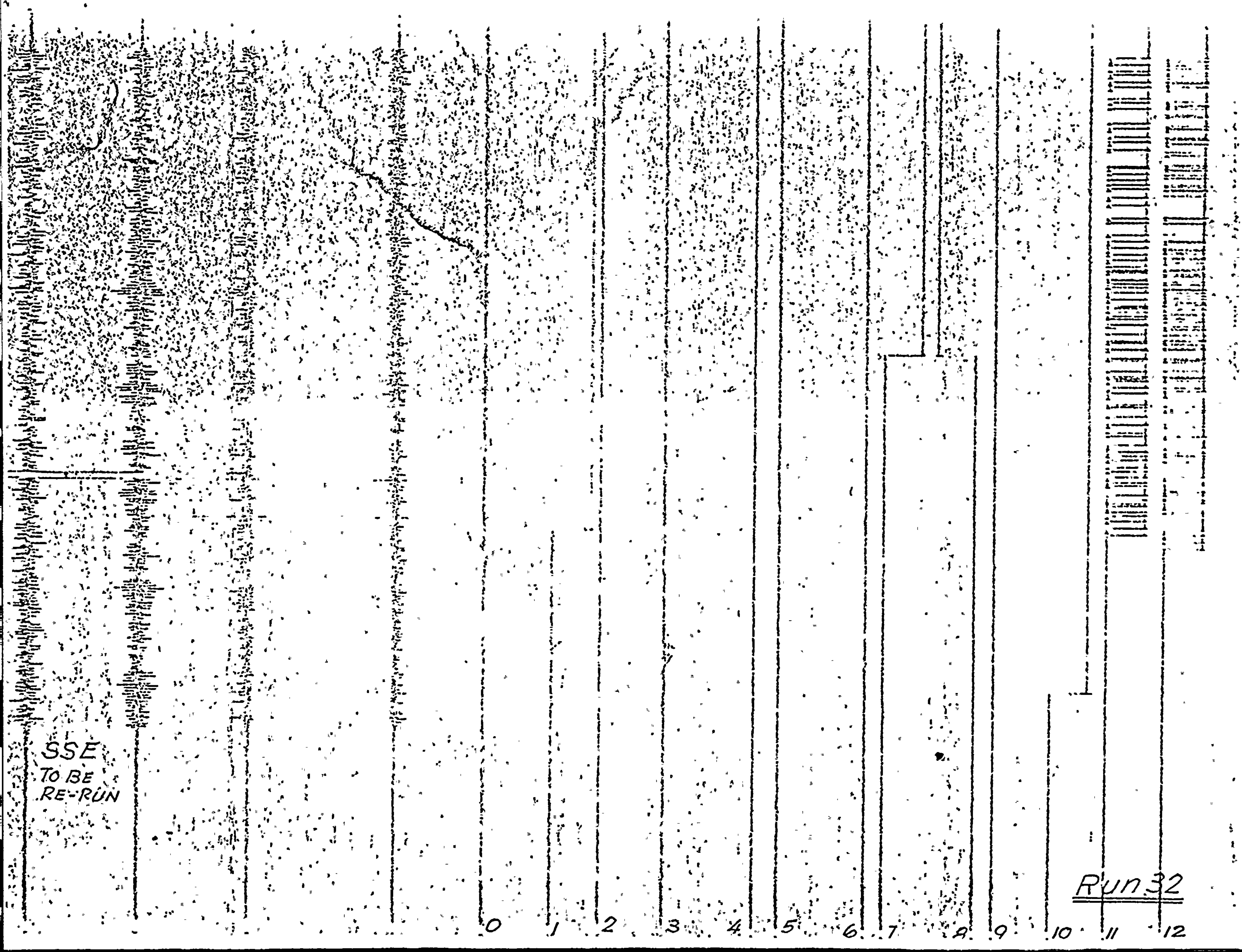

OBE
COND. 17
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 27

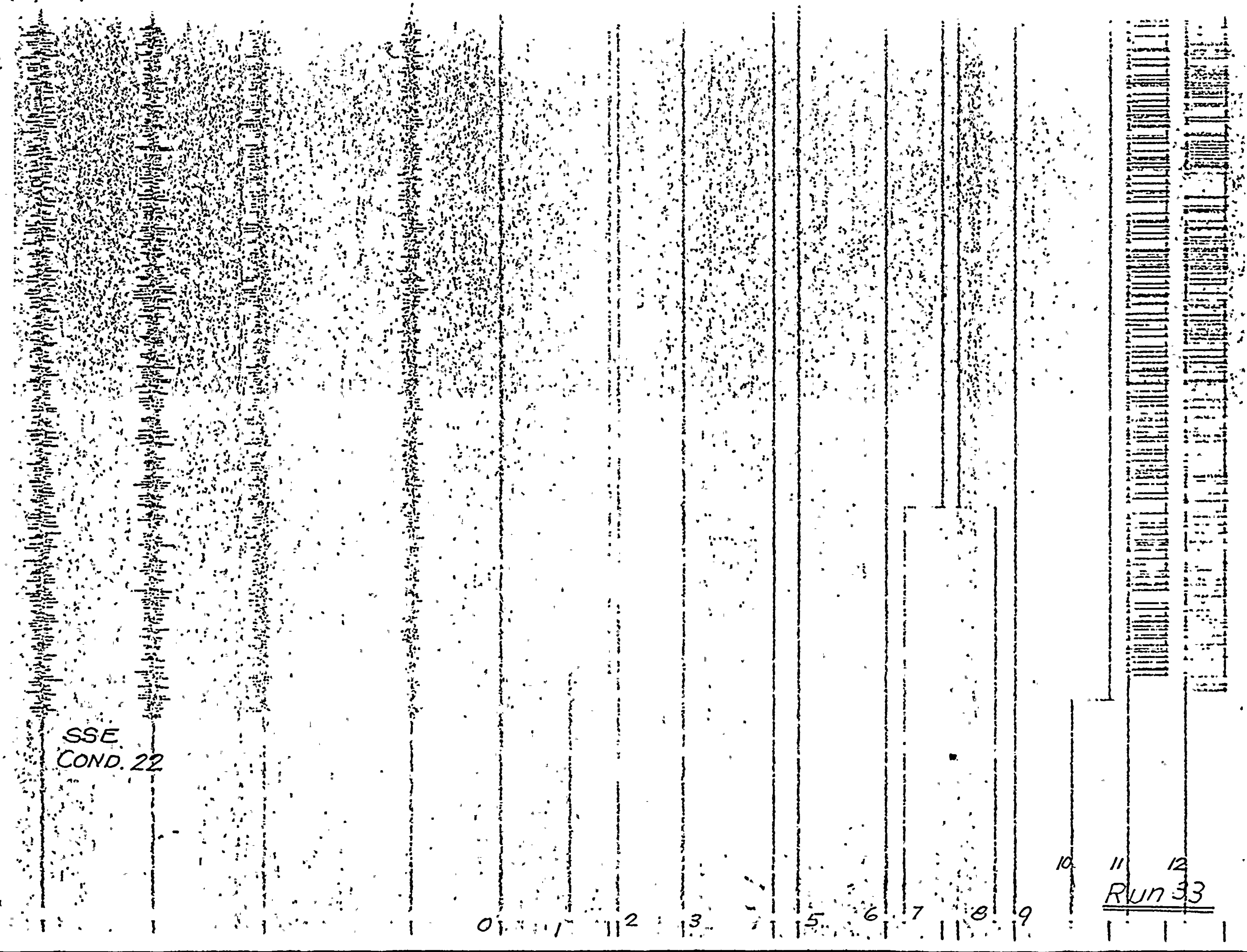

OBE
COND. 18
0 1 2 3 4 5 6 7 8 9 10 11 12
Run 28

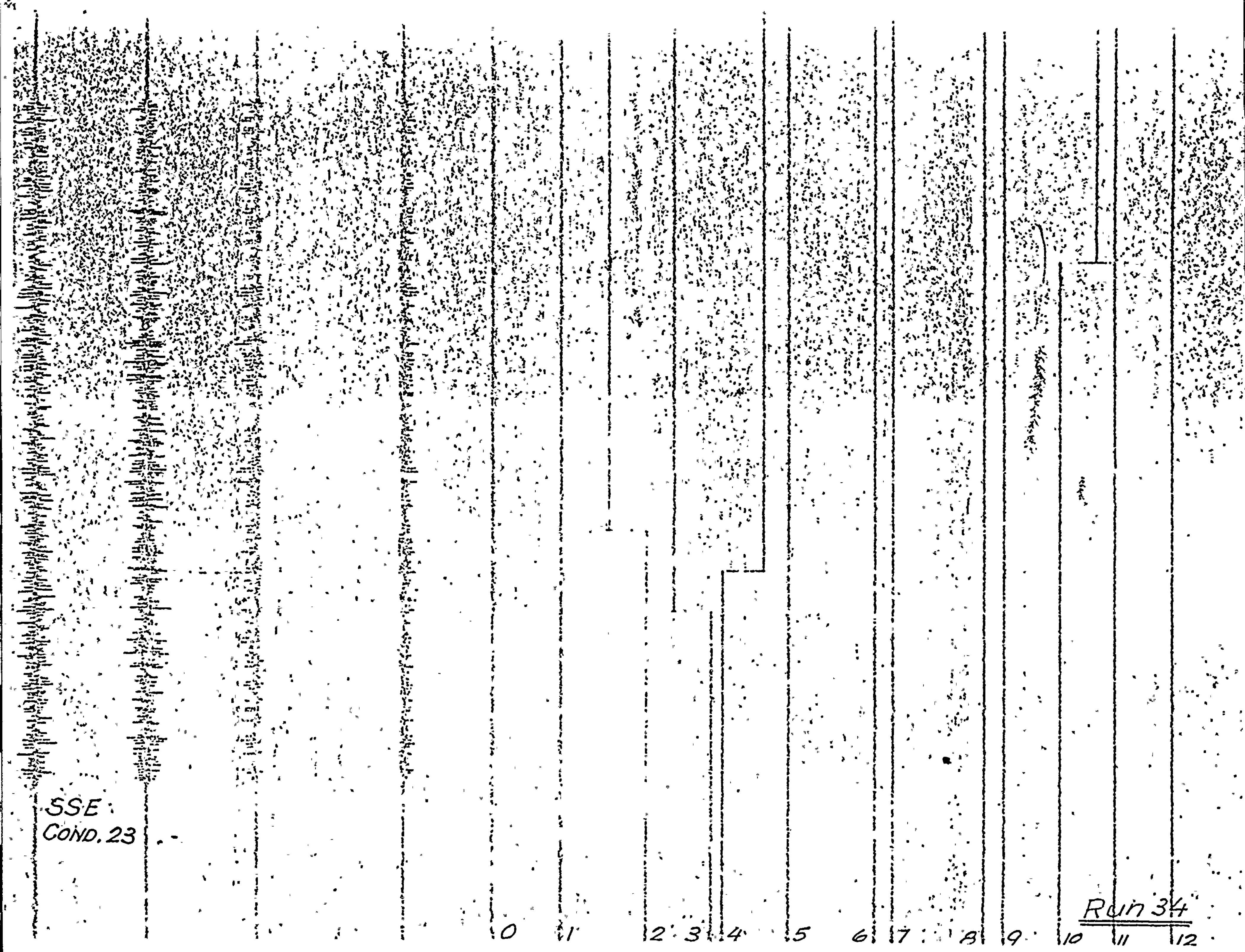

OBE
COND. 19
+39 = 1/2"
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 29

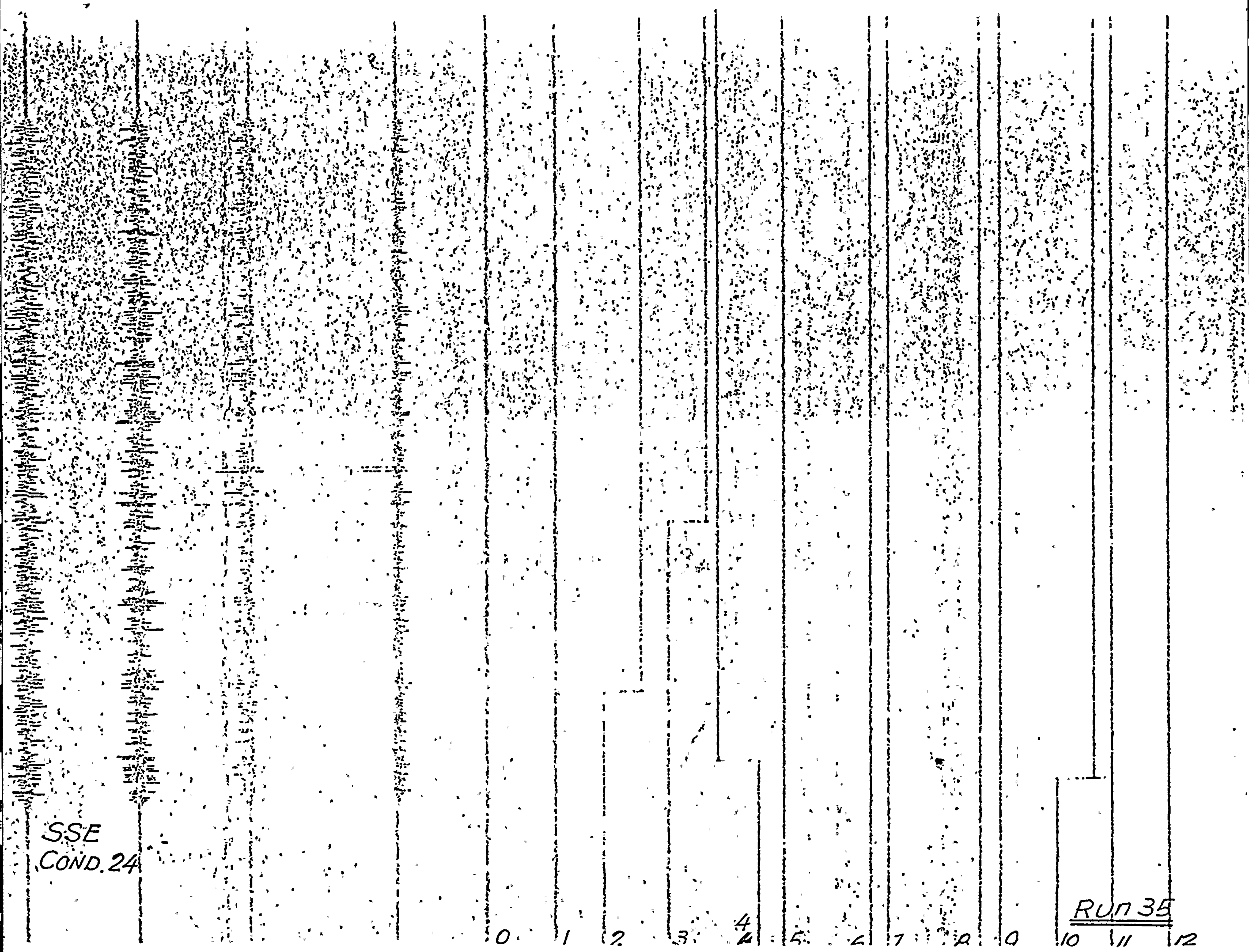

OBE
COND. 20
Run 30
0
1
2
3
4
5
6
7
8
9
10
11
12

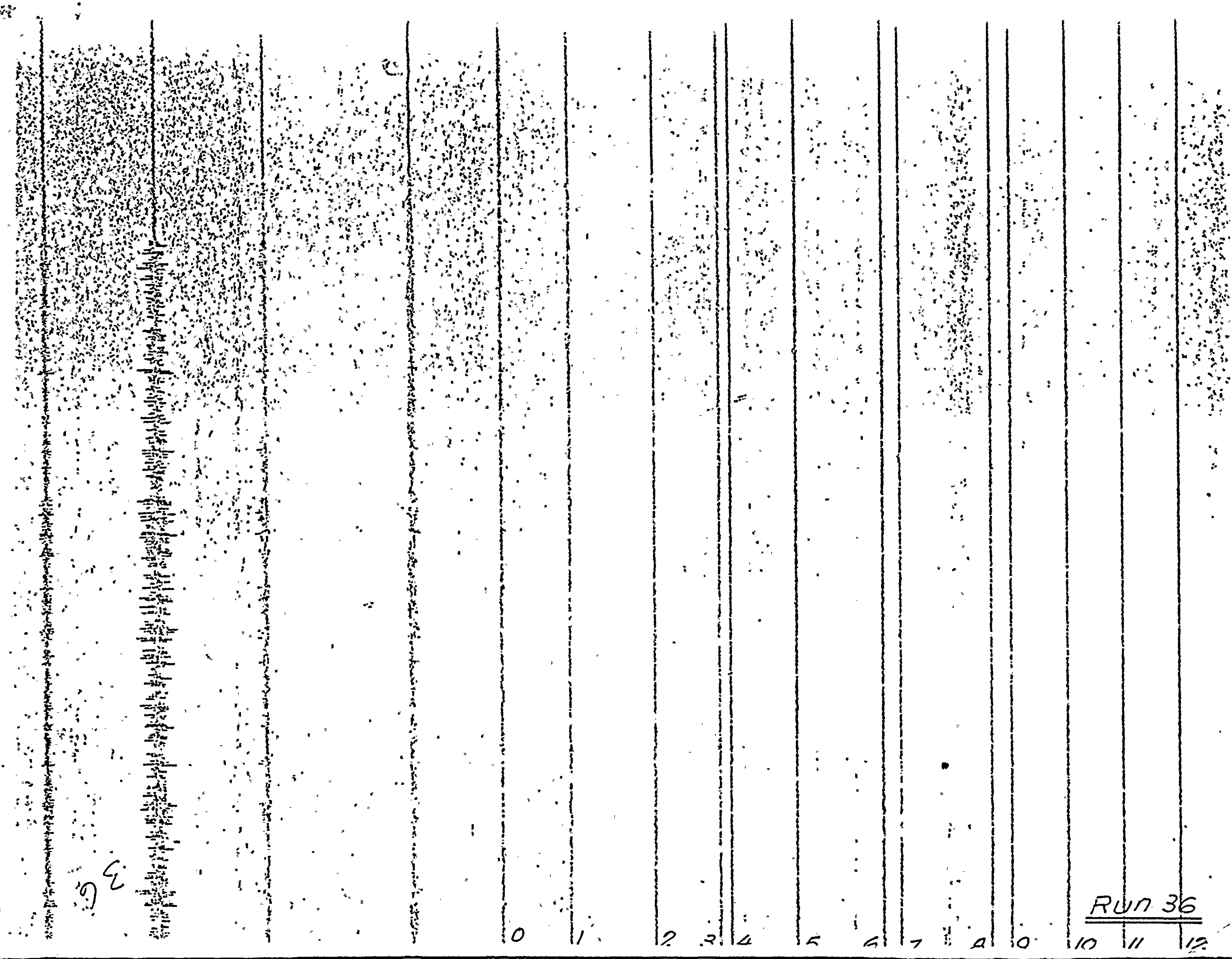

SSE
COND 21
Run 31
0
1
2
3
4
5
6
7
8
9
10
11
12

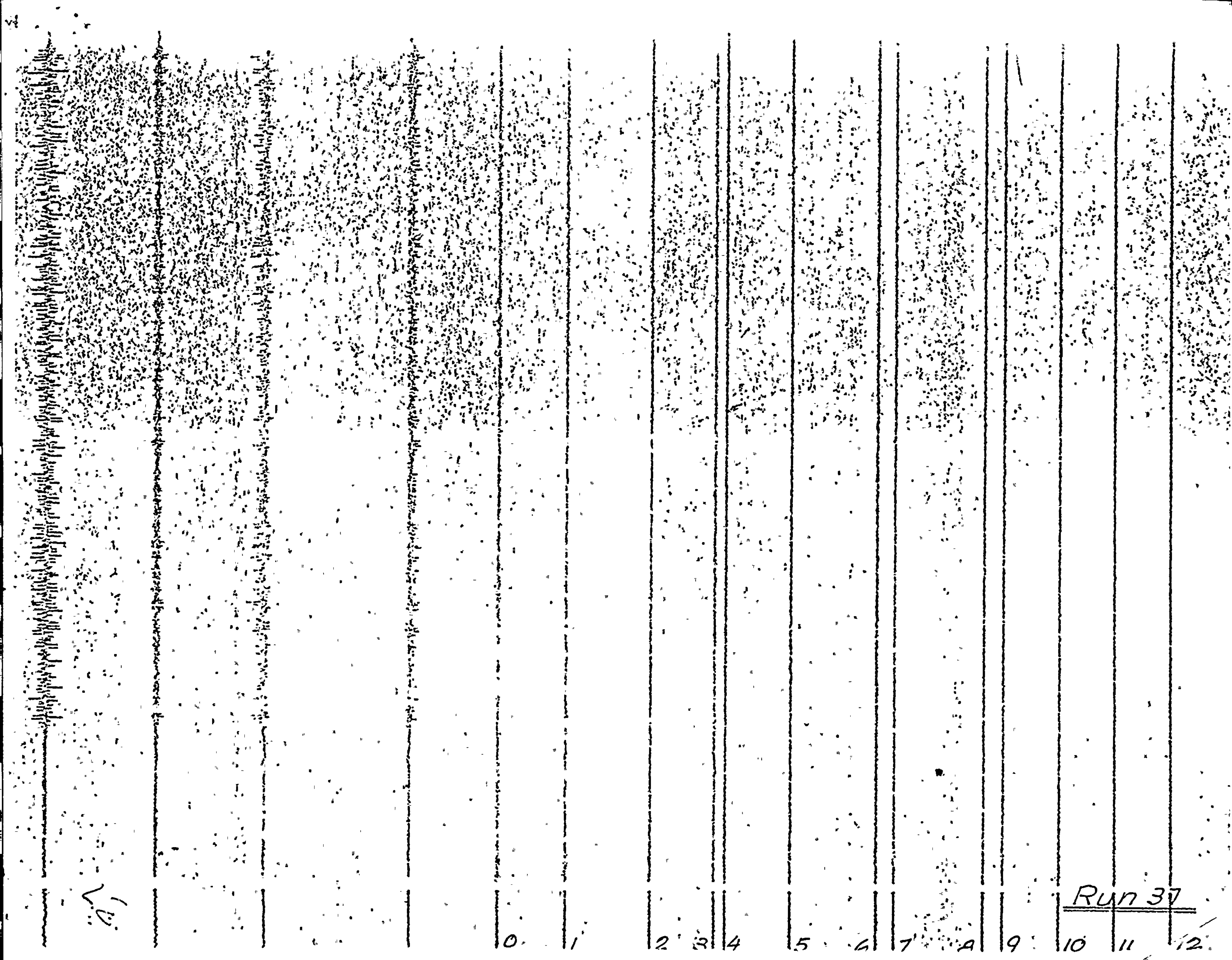

SSE
TO BE
RE-RUN
0
1
2
3
4
5
6
7
8
9
10
11
12
Run 32


SSE
COND. 22
0
1
2
3
5
6
7
8
9
10
11
12
Run 33


SSE
COND. 23
Run 34
0
1
2
3
4
5
6
7
8
9
10
11
12


SSE
COND. 24
Run 35
0
1
2
3
4
5
6
7
8
9
10
11
12


Run 36
0
1
2
3
4
5
6
7
8
9
10
11
12


Run 37
0
1
2
3
4
5
6
7
8
9
10
11
12

#18

ACME-CLEVELAND DEVELOPMENT COMPANY

625 ALPHA DRIVE • HIGHLAND HEIGHTS, OHIO 44143 • (216) 473-0300

QUALIFICATION OF NAMCO CONTROLS LIMIT SWITCH MODEL EA-180 TO IEEE STANDARDS 344 ('75), 323 ('74) AND 382 ('72)

March 3, 1978

Copy # 23

Research Center of Acme-Cleveland Corporation

TABLE OF CONTENTS

I. CERTIFICATION

The undersigned certify that this report presents a true account of the tests conducted and the results obtained.

J. J. Patsey — Date 3/1/78
Research & Development Technician

E. L. Solem — Date 3/3/78
Metallurgical Engineer

Approved by: N. W. Marrotte, P.E. — Date 3/3/78
Corporate Manager
Metallurgical Research, Development & Control

R. L. Nekola, P.E. — Date 3/3/78
General Manager
Acme-Cleveland Development Company

ELS:JJP:ij

Attachment

II. INTRODUCTION

The following tests were carried out at or under contract to Acme-Cleveland Development Company, the research center for Acme-Cleveland Corporation. The switches tested were manufactured by Namco Controls, an Acme-Cleveland Company. The tests were carried out in order to test limit switches to the provisions of IEEE Standards 344 ('75), 323 ('74) and 382 ('72). These standards pertain to Class 1E safety-related equipment for use in nuclear power plants.

The tests consisted of the following parts:

1. Heat aging for 200 hours at 200°F.

2. Mechanical aging for 100,000 actuation cycles under electrical load.

3. Irradiation to a level of 204 megarads of gamma radiation.

4. Seismic testing to a maximum of 9.52 g's in the 1 to 35 Hz range.

5. LOCA testing to a maximum 340°F at 70 PSIG.

III. SAMPLE IDENTIFICATION

From the model EA-180, Type 23, series nuclear switches, one switch with part number EA-180-11302, Rev.-D, was selected for test purposes.

The test facility reference identification number is #61.

In order to verify that the short travel mechanism was not subject to seismic failure, one switch with part #EA-180-14302, Rev. C, was selected for testing through the seismic stage. See Appendix F.

E S S

The test facility reference identification number for this switch was #83.

IV. TEST PROGRAM

The test program will be presented in the order in which it was performed. Throughout the testing the following equipment was used to determine the performance level of the units*. A megohm meter measured the resistance between contacts when open. A test circuit measured the load current between contacts when closed. This circuit consisted of a 100 volt DC power supply, appropriate voltage and current meters, and a load bank set to pass 86 milliamps in parallel with a small current (6 ma) neon light.

Initial inspection. Open and closed circuit performance was measured and recorded for purposes of providing base line data. These measurements were not used in the selection of switches for test. Normal quality control inspection had been performed prior to shipment.

Heat aging. The heat aging test consisted of holding the unit suspended over water in a tank at a temperature of 200°F for 200 hours+. During the time of this test, the conduit opening of the switch was sealed so that the humid air could not penetrate into the switch via this route.

Mechanical aging. The switch was subjected to 100,000 actuation cycles in order to simulate the normal switching functions of the unit during its lifetime. The actuation was accomplished by a cam mechanism operating at 70 actuations

*See Appendix E for calibration dates.
+Heat aging conditions were taken from ANSI Draft Standard N278.2.1 (Draft 3, Rev. 0). The correlation between these conditions and the qualified life is not known.

E L S

per minute. The electrical loading during this part of the test was 500 milliamps at 100 volts DC.

Irradiation. Irradiation was performed by Isomedix, Inc. Their certification is contained in Appendix A. Irradiation was carried out to a level of 204 megarads. Gamma radiation from a cobalt 60 source at 1.25 Mev. was used. The irradiation was carried out at a rate of one megarad per hour.

Seismic testing. Seismic testing was performed by Dr. Edward J. Walter and Associates. The complete description of apparatus and procedure is contained in Appendix B. Single axis tests were performed in each of the three axes. The test spectrum used is given in Table I. Note that either acceleration or displacement may be the independent variable.

TABLE I

SEISMIC TEST SPECTRUM (INPUT MOTION)

Frequency	Peak Acceleration	Peak to Peak Displacement
1-4 Hz	0.6-9.52 g's	12 inches
4-10 Hz	9.52 g's	
10-20 Hz		0.45 inches
20-35 Hz	9.52 g's	

Seismic Testing - Cross Coupling. All of the parts and assemblies of which the switch is comprised may be classified into three categories depending upon the geometric constraints upon their movement within the unit. The first category is components free to revolve about an axis but which have balanced angular masses about that axis. The second

E L S

category is components which are free to rotate about an axis within a range the limits of, which are 9° to either side of a principal axis of the switch. The third category is parts which are constrained to linear movement in a line which is within 9° of a major axis of the switch.

Components falling in the first category are: the contact lever assembly (83) and the rocker arm (65). As the angular moment of inertia for each component of this class is balanced about the central axis, vibration will result in no torque about the axis. Therefore, it is not necessary to consider these components in the analysis of cross coupling.

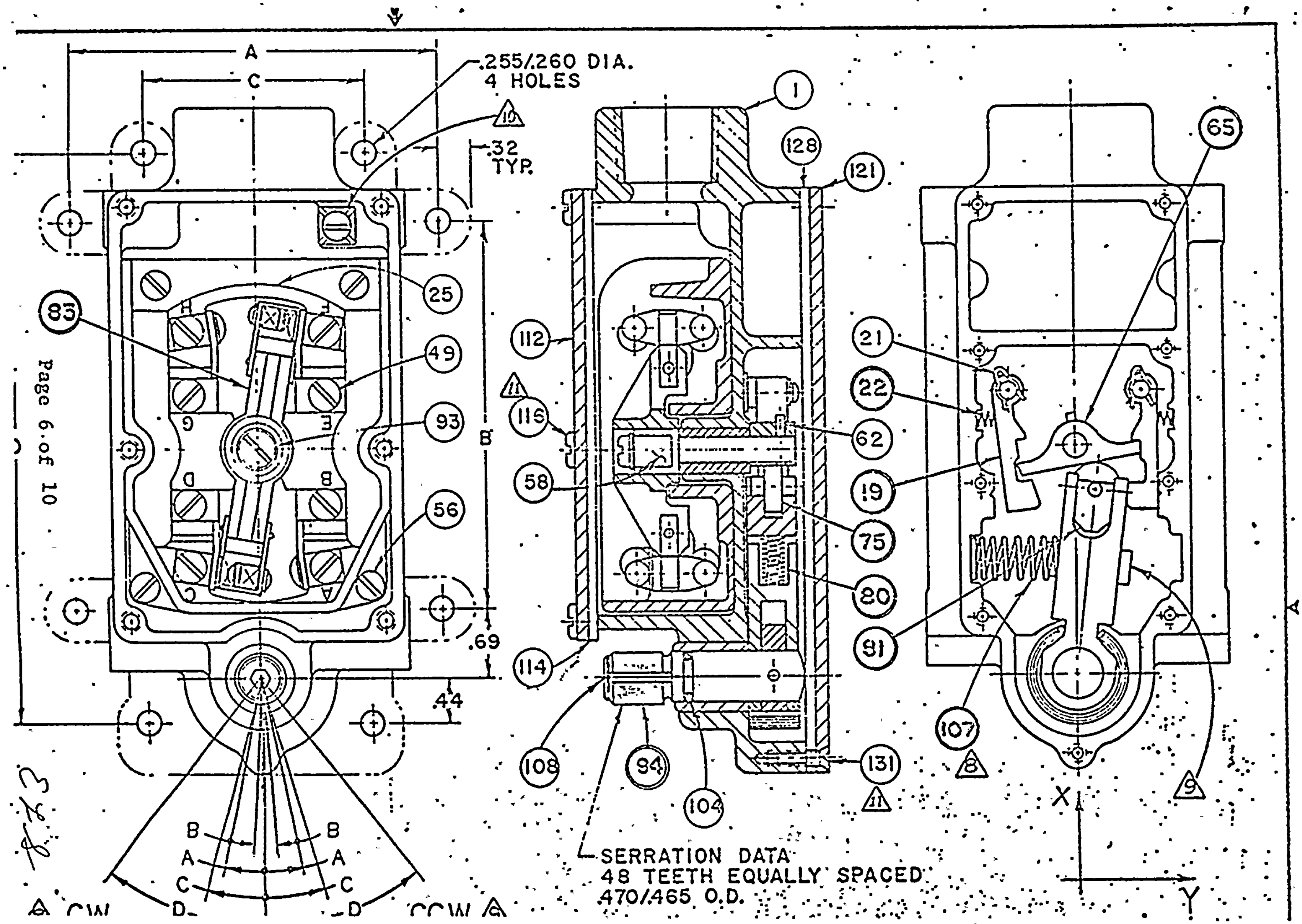
Components belonging to the second category are the lever shaft assembly (94) and the latches (19).

The parts belonging to the third class are the contact carrier plate assemblies which are located at the ends of the contact lever assembly (83) and the roller assembly (75, 80 and 81).

The linear motions of category 3 components except (75, 80 and 81) and the tangential motions of the category 2 components are all within 9° of the Y axis. Therefore, a vibration with a deviation of 9° from the Y axis would cause a higher G loading along the direction of motion of these components than motion directly along the Y axis. Therefore, the G levels used in single axis testing should be multiplied by a factor of .98 (i.e. cosine of 9°) in order to compensate for possible effects due to multi-axis vibration.

Movement of components (75, 80 and 81) is within 9° of the X axis. Therefore, it could cross-couple with the Y axis movements of

E L S


.255/.260 DIA.
4 HOLES
.32
TYP.
A
C
B
.69
.44
CW
CCW
1
128
121
65
25
83
49
93
56
112
116
62
58
75
80
114
91
21
22
19
107
108
94
104
131
X
Y
SERRATION DATA
48 TEETH EQUALLY SPACED
.470/.465 O.D.

the other category 2 and 3 components. The X axis movements of (75, 80 and 81) cannot cause any Y axis movements directly. It can, however, allow Y axis movements of (65) and (94). It is shown below that movements of (94) cannot occur at 10 g's due to the preloaded force of spring (107).

A	B	C	D	E	F	G
Preload* Force (107)	Weight of Non-Cylindrical Parts of (94)	Weight of (81)	Total Off Axis Weight (B+C)	Mechanical Advantage	Effective Weight** (DxE)	Minimum g Loading for Movement (A/F)
3,220 gm	53.9 gm	12.9 gm	66.8 gm	2	133.6 gm	24.1 g's

In order to determine that movement of (65) due to cross coupling was not a factor in these tests a separate test was run with components (75, 80 and 81) completely removed. This conservatively simulates any cross coupling between components (75, 80 and 81) and (65).

Due to the above considerations cross coupling is not considered limiting in this unit and, therefore, single axis vibration testing is considered suitable.

It can be seen from the data in Appendix B that the switch used in the present qualification was not used in the seismic qualification. Switches #32, 33 and 45 which were included in the seismic testing are internally identical to the switch #61 covered in this present qualification. The only difference between switch #61 and switches 32, 33 and 45 was the material for O-rings, lubrication and gaskets. It was not considered necessary, therefore, to

*Blueprint specified minimum.
**All mass is conservatively assumed to be concentrated at the end of the lever shaft assembly.

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take new seismic data on the present switch. In order to simulate the condition of a switch which has undergone a seismic event switch #61 was seismically conditioned by subjecting it to all vibrations contained in the seismic tests. Electrical load was applied during these vibrations, however, the performance of the switch was not monitored during this conditioning (see Appendix C).

LOCA Test. The temperature pressure profile for the test is given in Fig. 1*.

The first four days of LOCA testing was performed in a chamber of 12" height and 8" diameter. The switch was mounted in the chamber in a horizontal position such that the lever shaft pointed upwards. The switch was attached by means of a threaded pipe. Teflon tape was used for sealing the pipe threads. This pipe ran through an O-ring type feed-through in the chamber. The electrical connections from the switch were run through this same pipe. Actuation of the switch was provided by a rotary feedthrough in the top of the chamber.

The switch was subjected to a caustic spray during this portion of LOCA test. The flow rate of the spray was 230 cc's per minute providing the necessary coverage of .015 gallons per minute per foot of cross section. The pH of the spray was maintained between 10 and 11. The spray was composed of boric acid, water, sodium thoiosulfate and sodium hydroxide, and was recycled during the entire time. Spraying was initiated following the second transient temperature rise.

*The recorded pressure temperature data is presented on pages 8-11 of Appendix D.

ESS

The switch was transferred from the high pressure chamber to a low pressure chamber following the first four days of the LOCA test. It remained in this low pressure chamber for the rest of the 30 day LOCA period. During this part of the test the switch was sprayed with distilled water which was continuously recycled.

Two data acquisition methods were used during the LOCA. The temperature was recorded on a strip chart recorder via a thermocouple. During the transient sections of the LOCA the digital readout from the thermocouple, as well as the reading of the pressure gage, were recorded on video tape. The data is recorded on scenes 611 and 612 of this tape which is on file in the library of Acme-Cleveland Development Company.

The switch was actuated ten times during the peak level of the second transient of the LOCA and at other times as noted in Fig. 1. Data were taken twice during the second peak level and at the conclusion of the test.

V. RESULTS

During all phases of the test, the open contact resistance of the switch remained above 50 kilohms. The closed circuit current remained within two milliamps of the specified load. During seismic testing, the trip point (with 1-1/2 inch arm) varied by .108" or less* for all units seismically tested.

Detailed performance data are presented in Appendices B, D and F.

*.0625" for standard travel switches.

E S L

VI. CONCLUSIONS

Switch #61 representing revision level D of model #EA-180-11302 maintained a 50KΩ open circuit resistance with all other performance satisfactory during all sections of the test.

Switch #83 representing revision level C of model #EA-180-14302 maintained trip position within .108" of original with all other performance satisfactory throughout all sections of the test performed on it.*

The tests were carried out from June of 1977 to January of 1978.

ELS:JJP:ij

March 3, 1978

*See Appendix F.

E.L.S.

ISOMEDIX

November 9, 1977

Mr. Edward L. Solem
Metallurgy Engineer
Acme-Cleveland Development Co.
625 Alpha Drive
Highland Heights, Ohio 44143

Dear Mr. Solem:

This will summarize parameters pertinent to the irradiation of two switches per your Purchase Order of October 12, 1977. The units were identified as switches 59 and 61.

The units were placed in a Cobalt-60 gamma field such that the dose rate was .7 Mrad/hr. The units were exposed for 291.5 hours, yielding a minimum dose of 204 megarads.

The samples were rotated and turned during exposure to obtain the most even dose distribution. Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 110°F as indicated by previous measurements on an oil solution in the same relative position.

Dosimetry was performed using an Atomic Energy of Canada, Ltd. (AECL), Red Perspex system with Type BC-2 readout. Calibration of the Perspex is made by AECL using Ceric dosimetry traceable to the U.S. National Bureau of Standards. Isomedix regularly cross-calibrates its AECL system with an inhouse Harwell Perspex system, and makes semi-annual calibrations directly with NBS, using the NBS Radiochromic Dye system. A copy of the dosimetry correlation report is available upon request.

Irradiation was initiated on October 7, 1977 and completed on October 24, 1977.

Very truly yours,

Jonathan C. Young
Production Manager

JCY:iy

Isomedix Inc. • 25 Eastmans Road, Parsippany, New Jersey (201) 887-4700
Mailing Address: Post Office Box 177, Parsippany, New Jersey 07054
CHICAGO DIVISION • 7828 Nagle Ave., Morton Grove, Illinois 60053 (312) 966-1160

SEISMIC QUALIFICATION TEST
OF
LIMIT CONTROL SWITCHES
June 1977

Prepared for

NAMCO Controls
An Acme-Cleveland Company
Jefferson, Ohio

Dr. Edward J. Walter & Associates
Vibration and Sound Consultants
P.O. BOX 171 • CHESTERLAND, OHIO 44026 • (216) 729-7415

Dr. Edward J. Walter & Associates
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1. PURPOSE

Four Limit Control Switches manufactured by NAMCO Controls were subjected to a seismic qualification test for Class 1E equipment to be used in nuclear-powered electrical generating plants. The four switches are a representative sample of EA180-11302 and EA740-80100 limit switches and the seismic test results will be considered as representative of the characteristics of each switch series. The tests involved single-axis sinusoidal vibration in each of three mutually perpendicular axes parallel to the major dimensions of the switch, in accordance with IEEE 382-1972, 323-1974, and 344-1975. The test program was conducted by Dr. Edward J. Walter and Associates at the John Carroll University Seismological Laboratory, Cleveland, Ohio. NAMCO representatives were present during various stages of the tests and monitored parts of the test program.

2. IDENTIFICATION OF SWITCHES

The following switches were subjected to the seismic test procedure. All switches were manufactured by NAMCO

Switch Sample Number	
Switch No. 32	Snap-Lock. Limit Switch EA180-11302 Ampere Rating
Switch No. 33	Same as Switch No. 32
Switch No. 45	Same as Switch No. 32
Switch No. 38	Snap-Lock. Limit Switch EA740-80100 Ampere Rating
Switch No. 58	Same as Switch No. 38

Switch No. 32 — Ampere Rating:

Volts	AC	DC
125	20	5
250	15	1.5
480	10	
600	5	

NAMCO Controls
An Acme-Cleveland Company
Cleveland, Ohio U.S.A.

Switch No. 38 — Ampere Rating:

Volts	AC	DC
125	20	5
250	15	1.5
480	10	
600	5	

NAMCO Controls
An Acme-Cleveland Company
Cleveland, Ohio U.S.A.

3. TEST EQUIPMENT

The test equipment consisted of two different shake tables. The first shake table was a mechanical device for large amplitude - low frequency vibration. Maximum peak to peak displacement was twelve inches, giving a single amplitude of six inches. Displacements down to 0.25 inches single amplitude could be achieved. The mechanical shake table was used to test over the frequency range 1-20 Hz. The second device was an electro-dynamic shake table for small amplitude - high frequency vibration. Peak to Peak displacement up to 0.4 inches could be achieved. The electrodynamic shake table was used to test over the frequency range 20-35 Hz. Both shake tables were monitored for wave form by an accelerometer mounted on the table.

During the test procedure the switch was energized electrically with 125 volts DC at 1/2 amp. and monitored continuously for contact opening of 2 milliseconds or greater. The switch was tripped from the Normally Closed (NC) position to the Normally Open (NO) and back during the test procedure and monitored for contact opening.

4. SEISMIC TEST PROCEDURE

Each switch was individually mounted on the shake table with one of its major axes parallel to the direction of table motion. After completion of this test the switch was reoriented on the table with its second major axis parallel to the table motion, and similarly for the third major axis. Special fixtures for mounting the switches and activating them had to be fabricated.

Part I - Resonance Search

In each orientation each switch was subjected to a continuous sine sweep from 1 to 35 Hz at a rate of one octave per minute. This sine sweep was run as follows:

Frequency Hz	Displacement inches
1-10	1.0
10-35	0.01

Part II - Fragility Test

In each orientation, each switch was subjected to a sine dwell test in 1/3 octave bands over the frequency ranges 1-35 Hz. The switch was vibrated for a minimum of 60 seconds at each dwell point, beginning with 15 seconds of vibration in the unactuated position. The switch was then actuated by a manual tripping device and vibrated for 30 seconds in the actuated position. After this, the switch was released by the manual tripping device and vibrated for 15 seconds in the unactuated position. The switch was the double throw type.

During the vibration test, the switch contacts were monitored for opening by a light indicator circuit. If the light indicator circuit signaled a contact opening, the duration of opening was then monitored on an oscilliscope. The criteria for seismic failure was a contact opening of 2.0 milli-seconds or greater. Both the Normally Open (NO) contacts and the Normally Closed (NC) contacts were monitored during the tests.

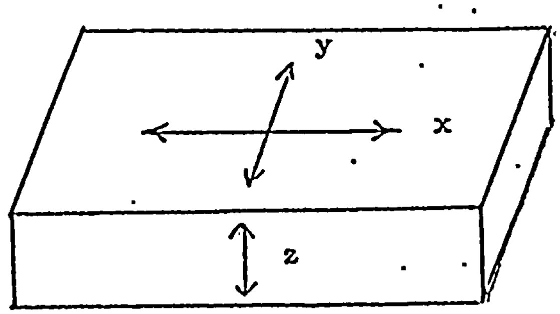
The trip angle of each switch was also monitored during the vibration test. This was done by monitoring the switch angle position on the oscilliscope. The variation in the trip angle position should not exceed 0.060 inches while being subjected to the vibration test.

The dwell test was run in 1/3 octave bands at the following frequencies and vibration specifications.

Dwell Points

Frequency Hz	Vibration Specifications
1.0	$1 \leq f \leq 4$
1.25	Displacement - 12.0 inches pp. giving 9.52 g's at 4 Hz
1.6	
2.0	
2.5	
3.15	
4.0	
	$4 < f < 10$ - acceleration 9.52 g
5.0	Displacement - 8.0 inches pp.
6.3	Displacement - 5.0 inches pp.
8.0	Displacement - 3.0 inches pp.
10.0	$10 \leq f \leq 20$
12.5	Displacement - 0.45 inches pp.
16.0	
20.0	
25.0	$20 < f < 35$ - acceleration 9.52 g
32.0	Displacement - 0.4 inches pp.

The table motion was constrained to specific displacements as specified or as required to produce the specified acceleration. Wave shape was monitored by an accelerometer mounted on the table. The planes of vibration relative to the switch configuration are shown in the following diagram and each switch was subjected to 54 distinct vibration tests.



5. TEST RESULTS

All switches performed with no malfunctions in the sine sweep from 1 Hz to 35 Hz. Also, no resonances were observed during the sine sweep test.

In the sine dwell test of 60 second duration during which the switch was actuated and released, no malfunctions were observed.

The test circuit did indicate a reaction to a small voltage change which when monitored on the oscilloscope was less than 2.0 milli-seconds and hence not within the definition of switch failure.* The various frequencies for each switch at which such an indication occurred is shown in the following table.

f Hz	Switch 33	32	45	38
1.0		x		x
1.25	x			x
1.6	x	x	x	x
2.0	x		x	x
2.5	x	x		x
3.15	x			x
4.0		x	x	
5.0				x
6.3	x	x		
8.0	x			x
10.0	x			
12.5	x			x
16.0	x		x	x
20.0	x			
25.0	x	x	x	x
32.0	x	x		

All the above switch contact openings were of duration less than 2.0 milli-seconds.

*See Appendix for details.

The trip position of each of the switches remained within the required limit and at no time deviated from the original position by more than 0.060 inches at the end of the two inch arm. In fact, the changes noted were small compared to the tolerance limit.

The test results are facility limited and therefore do not indicate the ultimate capability or the vibration level at which switch failure will occur. Each switch was subjected to 54 distinct vibration tests which lasted for 60 seconds or greater so that minimally each switch was vibrated for 54 minutes. Checks for frequency and wave shape and other manual operations extended the total vibration time by perhaps a factor of two or three.

6. CONCLUSIONS

The limit control switches performed satisfactorily without failure when vibration tested in accord with the specifications presented herein.

No contact opening of 2 milli-seconds or greater occurred during the tests.

No resonance frequencies were noted during the test.

7. CERTIFICATION

The undersigned certify that this report presents a true account of the tests conducted and the results obtained.

Edward J. Walter, Ph.D.

Edward J. Walter, Jr.

James DiSiena

EQUIPMENT USED

Calidyne Electrodynamic Shaker, Model B44

Mechanical Shake Table

Tektronix Storage Oscilloscope Type 564

Shure Brothers Accelerometer Model 62CP, calibrated August, 1977

Brush-Clevite Recorder Mark II

Dr. Edward J. Walter & Associates
Vibration and Sound Consultants

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Vibration Tests of Limit Control Switches
NAMCO Controls
An Acme-Cleveland Company
September, 1977

Switch Tested
Switch No. 32 - EA 180-11302

Vibration Tests

The purpose of the test was to determine whether cross-coupling would cause the switch to trip, and thus fail. The roller and spring were removed and the switch was vibrated in the Y-component. No failures were observed during the test procedure. The displacement, maximum frequency, and g-loading at which the switch was vibrated are given in the following table:

Displacement inches pp	Frequency in Hz	Acceleration g's
12.1	4.5	13.6
10.1	5.0	12.6
7.9	5.5	12.0
6.3	6.5	13.4
5.0	6.7	11.6
4.0	7.2	10.6
3.1	10.5	17.5
2.5	12.5	19.8
2.0	14.0	19.8
1.6	16.0	20.3
0.5	21.0	11.0
0.4	22.0	9.6

Test results indicate that failure due to cross-coupling in the Y-component did not occur.

Edward J. Walter

DR. EDWARD J. WALTER AND ASSOCIATES

October 5, 1977

Behavior Of The Test Circuit

The test circuit was designed to detect switch openings of more than a pre-set time. For the purpose of these tests the time was set at 2 milliseconds. During the seismic tests it was reported that the circuit was triggering. Therefore, personnel from Acme-Cleveland Development Company observed the situation.

It was found by use of an oscilliscope that the circuit was responding not to contact openings but to small changes in voltage due to increases in contact resistance as the contacts moved over one another. Although the decrease in voltage may have lasted for considerable times, no contact openings of more than 2 milliseconds were observed in that instance. At that point it was decided that whenever the circuit was triggered the oscilliscope would be used (by Dr. Edward J. Walter & Associates' personnel) to determine if there was a contact opening of more than 2 milliseconds or not.

Edward Solem 7/13/77
E. Solem Date
Metallurgical Engineer

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Vibration Tests of Limit Control Switches
NAMCO Controls
An Acme-Cleveland Company
November 1977

SWITCHES TESTED

Switch No. 59, EA 180-11302
Switch No. 61, EA 180-1132 *

VIBRATION TESTS

The switches were subjected to the following tests:

I - Fragility Test

Frequency Hz	Vibration Specifications
1.0	Displacement - 12.1 inches pp
1.25	giving 9.52 g's acceleration
1.6	at 4 Hz.
2.0	
2.5	
3.15	
4.0	
	Acceleration 9.52 or greater
5.0	Displacement - 8.0 inches pp
6.3	Displacement - 5.0 inches pp
8.0	Displacement - 3.0 inches pp
10.0	Displacement - 2.0 inches pp
12.5	Displacement - 0.45 inches pp
16.0	as above
20.0	as above
25.0	Displacement - 0.40 inches pp
32.0	giving acceleration 9.52 g's
	or greater.

* This switch was manufactured to a bill of materials corresponding to model EA-180-11302 .

II - Plant Induced Vibration Simulation

The switches were vibrated at a non-resonant frequency, 100 Hz at an acceleration 1.3 g for a total of 10^6 cycles, one third of the total cycles in each component, X, Y, and Z.

Component	Frequency Hz	Acceleration g's
X	100	1.3
Y	100	1.3
Z	100	1.3

The switches were tested in each of three mutually perpendicular directions parallel to the major axes of the switches. In each orientation a fragility dwell test and a plant induced vibration simulation test were made.

The dwell test was run for a minimum of 60 seconds duration, beginning with 15 seconds of vibration in the unactuated position. The switch was then actuated by a manual tripping device and vibrated for 30 seconds in the actuated position. After this, the switch was released by the manual tripping device and vibrated for 15 seconds in the unactuated position.

The plant induced vibration simulation test was run for a minimum of 10^6 cycles in all three components. Each component, X, Y, and Z was subjected to one-third of the total number of cycles, e.g. $1/3 \times 10^6$ cycles.

The switches were double throw type and were energized electrically at 125 volts at 1/2 amp. during the tests. Each switch was subjected to 51 distinct vibration tests, 48 of these at a minimum time of 60 seconds each and three of these at a minimum time of 56 minutes each.

Edward J. Walter

DR. EDWARD J. WALTER AND ASSOCIATES
November, 1977

DATE 9-22-77

HEAT AGING

SWITCH # 61
EZ10607-23
MODEL # EA180-11302

J-71

☐ PROTOTYPE
☐ PRODUCTION

FROM 9-22-77 TO 10-3-77

TIME	DATE	TEMP.	COMMENTS
3:45 PM	9-22-77	200°F	Joe Buzogany suggested using stainless steel lock washers instead of Bellevilles.
7:30 AM	9-26-77	"	
"	9-27-77	"	
"	9-28-77	"	
"	9-29-77	"	
"	9-30-77	"	
"	10-3-77	"	

ELECTRICALS LOAD = .086A @ 100 VDC

	Meggar 1	Meggar 3	Meggar 2	Meggar 4	Conductivity (amps) 1	Conductivity (amps) 3	Conductivity (amps) 2	Conductivity (amps) 4
INITIAL	*Inf	Inf	Inf	Inf	.086	.086	.086	.086
FINAL	"	"	"	"	"	"	"	"
OTHER								

(Continue on back)

INTERIOR EXAMINATION (OPTIONAL)

GASKETS:

CONTACTS:

BLOCK:

O-RING:

GREASE:

JB

*Inf. = Open contact resistance above 1000 Megohms.

(Continue on back)

DATE 10-3-77

SWITCH # 61

J-71

MODEL # EA180-11302

EZ10607-23

☐ PROTOTYPE
☐ PRODUCTION

WEAR CYCLING

# OF CYCLES	100,000		LOAD	.5A @ 100 VDC				COMMENTS	
CYCLE RATE	70 RPM						Roller on lever arm wore after 30K cycles.		
METHOD	Cam								
ELECTRICAL MEASUREMENTS; LOAD = .086A @ 100 VDC									
	Meggar				Conductivity (amps)				
	1	3	2	4	1	3	2	4	
INITIAL	Inf	Inf	Inf	Inf	.086	.086	.086	.086	
FINAL	"	"	"	"	"	"	"	"	
OTHER									

INTERNAL EXAMINATION (OPTIONAL) (Continue on back)

GASKETS:

CONTACTS:

BLOCK:

O-RING:

GREASE:

JB

(continue on back)

DATE 10-26-77

SWITCH # 61

MODEL # EA180-11302
EZ10607-23

J-71 ☐ PROTOTYPE
☐ PRODUCTION

IRRADIATION

IRRADIATED AT:	Isomedix, Inc.											
FROM 10-6-77			TO 10-26-77		TOTAL IRRADIATION			204 Mrad.				
ENERGY LEVEL 1.25 Mev			SOURCE Cobalt 60				RATE .7 Mrad/hr					
ELECTRIDAL MEASUREMENTS ;			LOAD	=	.086A @ 100 VDC			COMMENTS				
	Meggar				(Conductivity (amps)				Checked switches for radiation, OK.			
	1	3	2	4	1	3	2	4				
INITIAL 10-5-77	Inf	Inf	Inf	Inf	.086	.086	.086	.086				
FINAL 10-26-77	"	"	"	"	"	"	"	"				
OTHER												

INTERIOR EXAMINATION (OPTIONAL)

Gaskets:

CONTACTS:

BLOCK:

O-RING:

GREASE:

COMMENTS (Cont.)

(continue on back)

DATE 11-15-77

SWITCH # 61

MODEL # EA180-11302
EZ10607-23

J-71 ☐ PROTOTYPE
☐ PRODUCTION

SEISMIC TESTING

TESTED BY: Dr. Edward Walter & Associates

REPORT REF.:
IEEE Standard 323, 344 and 382.

INTERNAL EXAMINATION (OPTIONAL)

GASKETS

CONTACTS

BLOCK

O-RING

GREASE

COMMENTS

Electricals:

	Meggar				Conductivity (Amps)			
	1	3	2	4	1	3	2	4
Before seismic	Inf	Inf	Inf	Inf	.086	.086	.086	.086
After seismic 11-15-77	"	"	"	"	"	"	"	"

DATE 11-15-77 PAGE (1) SWITCH # 61

LOCA #

MODEL # EA180-11302

.EZ10607-23

J-71 ☐ PROTOTYPE

☐ PRODUCTION

LOCA TEST

PROFILE REF.: IEEE Standard 323 and 382

CAUSTIC SPRAY?	NAOH, Boric Acid, Sodiumthiosulphate					CAUSTIC			
THEORETICAL		FROM	TIME	TO	TEMP.	PRESS.	FLOW	TEMP	COMMENTS
PROFILE	1	120°F	2 sec.		225°F	17 PSI Diff.			
	2	"	10 "		328°F	70 PSI "			
	3	"	5 min.		340°F	"			
	4	340	3 hrs.		"	Caustic spray			
	5	"	2 hrs.		120°F				
	6	Repeat Steps 1, 2, 3 & 4							
	7	340	2 hrs.		320°F	40 PSI Diff.			
	8	320	3 hrs.		250°F	25 PSI "			
	9	250	3.5 days		250°F				
	10	200	26 days		200°F	10 PSI			

INTERNAL EXAMINATION (OPTIONAL)

GASKETS: Bottom gasket was cracked at the center housing support. Water drops were in the bottom housing. Torque to remove screws was 4 to 10 lb. inches. The top gasket was moist and had a tacky substance on the inside surface connecting at the center screws. Torque to remove top screws was 8 to 13 lb. inches. The gaskets were hard and brittle.

CONTACTS: The contacts have a residue on the surface but were reasonably clear.

BLOCK: The contact block was reasonably clean but the block had moisture on it.

O-RING: The O-ring was in good condition and was resilient. The oil was present on the shaft and O-ring.

GREASE: The grease was present on the sliding surfaces.

OTHER: The boot cracked when removed from the shaft. The interior of the switch appeared reasonably clean.

DATE 11-15-77 PAGE (2) SWITCH # 61

EA-180-11302

EZ-10607-23

J-71

LOCA # 9 LOCA TEST LOAD .086A @ 100 VDC

TIME	DATE	ELAPSED TIME		ELECTRICAL MEASUREMENTS Meggar 1	Meggar 3	Meggar 2	Meggar 4	Conductivity (amps) 1	Conductivity (amps) 3	Conductivity (amps) 2	Conductivity (amps) 4	COMMENTS
9:30 AM	11-15-77			Inf	Inf	Inf	Inf	.086	.086	.086	.086	Switch out of chamber.
9:45	"			"	"	"	"	"	"	"	"	Switch in chamber.
10:25	"			"	"	"	"	"	"	"	"	Preheat 250°F
10:40	"			900M	"	"	900M	"	"	"	"	"
11:05	"			Inf	"	"	Inf	"	"	"	"	120°F
11:20	"			10M	150M	70M	150M	"	"	"	"	340°F
11:25	"			80M	100M	80M	80M	"	"	"	"	"
12:15 PM	"			110M	130M	100M	120M	"	"	"	"	"
12:40	"			130M	150M	130M	130M	"	"	"	"	"
2:05	"			150M	170M	150M	150M	"	"	"	"	"
2:15	"			Inf	Inf	Inf	Inf	"	"	"	"	130°F
3:35	"			"	"	"	"	"	"	"	"	120°F
4:15	"			"	"	"	"	"	"	"	"	120°F
4:35	"			300K	10M	1.5M	40M	"	"	"	"	340°F (2nd spike)
4:40	"			60M	130M	50M	130M	"	"	"	"	340°F
4:50	"			.75M	90M	80M	90M	"	"	"	"	"
5:25	"			100M	130M	100M	120M	"	"	"	"	"
6:20	"			110M	130M	110M	130M	"	"	"	"	"
6:45	"			100M	130M	100M	120M	"	"	"	"	"
7:55	"			120M	180M	140M	170M					320°F
10:00	"			140M	180M	150M	170M					"
10:55	"			140M	180M	150M	170M					"
11:30	"			1000M	1000M	1000M	1000M					250°F
12:15 AM	11-16-77			"	"	"	"					"
7:35 AM	"			"	300M	300M	900M	.086	.086	.086	.086	"
7:40	"			"	900M	900M	"	"	"	"	"	Removed pins to connector wires 250°F
9:00	"			Inf	Inf	Inf	Inf	"	"	"	"	250°F
10:30	"			"	"	"	"	"	"	"	"	"
11:15	"			"	"	"	"	"	"	"	"	"
12:15 PM	"			"	"	"	"	"	"	"	"	"
6:00	"			"	"	"	"					"
8:00	"			"	"	"	"					"
10:00	"			"	"	"	"					"

DATE 11-17-77 PAGE (2) SWITCH # 61

EA-18011302

EZ10607-23

J-71

LOCA # LOCA TEST LOAD .086A @ 100 VDC

TIME	DATE	ELAPSED TIME	Meggar 1	Meggar 3	Meggar 2	Meggar 4	Conductivity (amps) 1	Conductivity (amps) 3	Conductivity (amps) 2	Conductivity (amps) 4	COMMENTS
12:00 PM	11-16-77		Inf	Inf	Inf	Inf					250°F
7:40 AM	11-17-77		"	"	"	"	.086	.086	.086	.086	"
8:40	"		"	"	"	"	"	"	"	"	"
11:30	"		"	"	"	"	"	"	"	"	"
2:45 PM	"		"	"	"	"	"	"	"	"	"
3:30	"		"	"	"	"	"	"	"	"	"
6:00	"		"	"	"	"					"
8:00	"		"	"	"	"					"
10:00	"		"	"	"	"					"
12:00 AM	11-18-77		"	"	"	"					"
7:35 AM	"		"	"	"	"	.086	.086	.086	.086	"
10:00	"		"	"	"	"	"	"	"	"	"
12:15 PM	"		"	"	"	"	"	"	"	"	"
1:30	"		"	"	"	"	"	"	"	"	"
3:00	"		"	"	"	"	"	"	"	"	"
3:55	"		"	"	"	"	"	"	"	"	"
6:00	"		"	"	"	"					"
8:00	"		"	"	"	"					"
10:00	"		"	"	"	"					"
12:00 AM	11-19-77		"	"	"	"					"
7:30 AM	"		"	"	"	"	.086	.086	.086	.086	"
9:40	"		"	"	"	"	"	"	"	"	"
10:30	"		"	"	"	"	"	"	"	"	"
12:05 PM	"		"	"	"	"	"	"	"	"	Drop temp. removed switch.
12:50	"		"	"	"	"	"	"	"	"	Switch out of chamber.

The open contact resistance on switch #61 was infinite and the closed contact current was .086 amps when removing the switch from the high temperature and pressure LOCA to install in the low pressure and temperature LOCA.

TIME	DATE	ELAPSED TIME	Meggar 1	Meggar 3	Meggar 2	Meggar 4	Conductivity (amps) 1	Conductivity (amps) 3	Conductivity (amps) 2	Conductivity (amps) 4	COMMENTS
	12-16-77		50K	50K	50K	50K	.086	.086	.086	.086	After LOCA test
	Open contact. Leakage Current =						.0025	0025	.0035	.0035	

The closed contacts passed .086 amps current, but the open contact resistance dropped from over 1000 Megohms (Infinity) before installing in the chamber to 50K ohms on the contacts after removing from the low temperature and pressure chamber.

The switch was bubble tested with 12 lbs. of air and no leakage occurred. Before the bubble test the current across the open contacts was 2.5 to 3.5 Milliamps after applying the 12 lbs. of air to the switch the open contact current fell to .5 Milliamps.

JG

DATE 11-15-77 PAGE 3 SWITCH # 61

J-71

EA180-11302
EZ10607-23

LOCA # 9

LOCA TEST

TIME	ELAPSED TIME	DATE	TEMP.	PRESSURE Diff.*	PRESSURE Chamber	CAUSTIC FLOW	CAUSTIC TEMP	WATER LEVEL	Ph	COMMENTS
9:50 AM		11-15-77	63°F					6½"	10.5	Start preheat chamber.
10:20		"	250°F					"	"	@ Preheat 250°F
10:40		"	"					"	"	
10:45		"	"					"	"	Drop temperature
11:05		"	120°F					"	"	Chamber cooled.
11:09		"	"					"	"	Start 1st spike
11:09 min. & 4.5 sec.		"	300°F					"	"	
11:09 min. & 11 sec.		"	328°F	75	115			8"	"	It took 11 seconds to go from
11:09 min. 19.6 sec.		"	340°F	80	123			7½"		120°F to 328°F according to TV
11:09 min. 33 sec.		"	348°F	80	125			"	"	but @ 340°F the pressure was 115 PSIG.
11:09 min. 53 sec.		"	347°F	75	122			"	"	Adjusting thermocouple connection
11:10 "		"	340°F	"	115			"	"	Made temperature jump 6°F
11:15 "		"	"	70	103			"	"	Controller on 340°F
11:25		"	"	"	103	200		"	"	Pump on
11:35		"	340-341	"	103-105	"		"	"	
12:13 PM		"	340-342	75	103-105	"		"	"	
12:40		"	"	70	"	"		"	"	
2:05		"	"	"	"	"		"	"	
2:25		"	"	"	103-105	"		"	"	Drop temp. Pump off.
3:10		"	140°F					4½"	"	Air pressure cooling chamber.
3:25			120°F					4		
3:55			120°F					5½"		Add solution

*The calibration indicates that this instrument reads seven PSI too high.

DATE 11-15-77 PAGE 4 SWITCH # 61

J-71 EA180-11302
EZ10607-23

LOCA # 9

LOCA TEST

TIME	ELAPSED TIME	DATE	TEMP.	PRESSURE Diff.*	Chamber	CAUSTIC FLOW	CAUSTIC TEMP	WATER LEVEL	Ph	COMMENTS
4:20 PM		11-15-77	120°F					5½"	10.5	Start test.
4:24		"	"		–			"	"	"
4:24 min. & 7.5 sec.		"	300°F	75	–			"	"	
4:24 min. & 9.98 sec.		"	328°F	80	100			"	"	
" 12.4 sec.		"	340°F	85	105			8"	"	
" 22.4 sec.		"	349°F	90	125			"	"	
" 57.4 sec.		"	342°F	65	110			"	"	
4:25 PM		"	340°F	70	104			7½"	"	Control at 340°F
4:30		"	340-342	"	103-105	200		"	"	Started control
4:35		"	"	"	"	"		"	"	Steam boiler off. Pump on.
4:40		"	336-338	"	100-101	"		"	"	Controller @ 340°F
4:45		"	340-341	"	103-101	"		"	"	
4:50		"	340-342	"	"	"		"	"	
5:20		"	"	"	"	"		"	"	Controller @ 335°F
5:45		"	"	"	"	"		"	"	"
6:20		"	"	"	"	"		"	"	"
6:50		"	"	"	"	"		"	"	"
7:30		"	"	"	"	"		"	"	Drop control to 330°F
7:35		"	335-336	55	97-99	"		"	"	Controller @ 325°F
7:40		"	330-331	53	90-92	"		"	"	" 320°F
7:45		"	325-326	50	83-84	"		"	"	" 315°F
7:55		"	320-321	40	76-77	"		"	"	" "
10:00		"	"	"	"	"		"	"	" "
11:00		"	311-312	30	67	"		"	"	" 305°F
11:05		"	302-303	25	57	"		7"	"	" 295°F

*The calibration indicates that this instrument reads seven PSI too high.

DATE 11-15-77 PAGE 5 SWITCH # 61

J-71

LOCA # 9

LOCA TEST

TIME	ELAPSED TIME	DATE	TEMP.	PRESSURE Diff.*	PRESSURE Chamber	CAUSTIC FLOW	CAUSTIC TEMP	WATER LEVEL	Ph	COMMENTS
11:10 PM		11-15-77	295-296	13	47	200		7½"	10.4	Controller @ 285°F
11:15		"	286	5	41	"		7"	"	" 275°F
11:20		"	278	0	35	"		"	"	" 265°F
11:25		"	270-271	-5	30			"	"	" 255°F
11:30		"	262-263	-10	25	"		"	"	" 250°F
12:15 AM		11-16-77	251-252	–	27	"		"	"	" 248°F
7:35 AM		"	250-252		25-26	"		6-3/4"	"	" 245°F
7:45		"	"		"	"		"	"	Removed pipe from external electrical connector. Switch showed some leakage, wires moist.
9:00		"	"		"	"		"	"	
10:30		"	"		"	"		"	"	
11:15		"	"		"	"		"	"	
12:15 PM		"	"		"	"		"	"	
3:55		"	"		"	"		"	"	
6:00		"	"		"	"		"	"	
8:00		"	"		"	"		"	"	
10:00		"	"		"	"		"	"	
12:00 AM		11-17-77	"		"	"		"	"	
7:40 AM		"	"		"	"		6½"	"	
8:40		"	"		"	"		"	"	
11:30		"	"		"	"		"	"	
2:45 PM		"	"		"	"		"	10.1	
3:30		"	"		"	"		"	"	
6:00		"	"		"	"		"	"	
8:00		"	"		"	"		"	"	

*The calibration indicates that this instrument reads seven PSI too high

DATE 11-17-77 PAGE 6 SWITCH # 61

J-71

LOCA # ____________

LOCA TEST

TIME	ELAPSED TIME	DATE	TEMP.	PRESSURE	CAUSTIC FLOW	CAUSTIC TEMP	WATER LEVEL	Ph	COMMENTS
				Diff* Chamber					
10:00 PM		11-17-77	250-255	25-26	200		6½"	10.1	
12:00		"	"	"	"		6-3/8"	"	
7:35 AM		11-18-77	250-252	"	"		6½"	"	
12:15 PM		"	"	"	"		"	"	
1:30		"	"	"	"		"	"	
3:00		"	"	"	"		"	"	
3:55		"	"	"	"		"	"	
6:00		"	"	"	"		"	"	
8:00		"	"	"	"		"	"	
10:00		"	"	"	"		"	"	
12:00 AM		11-19-77	"	"	"		"	"	
7:30 AM		"	"	"	"		6"	"	
9:40		"	"	"	"		"	"	
10:30		"	"	"	"		"	"	
12:07 PM		"	"	"	"		"	"	Drop temp. & pressure , turn pump of Switch was very clean inside before installing in low pressure and temperature chamber.
1:10 PM		11-19-77	150°F	10 PSI	96% scale				
1:45		"	200°F	"	"				
3:45		"	"	"	"				
7:35 AM		11-21-77	"	"	"				
8:40		11-23-77	94°C	"	"				
3:45 PM		"	-	0	0				
5:05 PM		"	89°C	8 PSI	96%				
12:05 AM		11-24-77	92°C	12 PSI	95%				

*The calibration indicates that this instrument reads seven PSI too high.

66

DATE 11-28-77 PAGE. 7 SWITCH # 61

J-71

LOCA #

LOCA TEST

Page 12 of 15

TIME	ELAPSED TIME	DATE	TEMP.	PRESSURE	CAUSTIC FLOW	TEMP	WATER LEVEL	Ph	COMMENTS
				Diff. Chamber					
7:55 AM		11-28-77	98°C	12 PSI	92%				
8:00		"	94°C	10 PSI	96%				Shut down system spray not working.
12:30 PM		"							
2:00		"	94°C	10 PSI	96%				System back to temp.
3:45		"	"	"	"				
7:45 AM		11-29-77	"	"	"				
12:45 PM		"	"	"	"				Activated switch spindle on 14th day of LOCA.
1:15		"	"	"	"				Back to temp. and pressure.
3:55		"	"	"	"				
7:35 AM		11-30-77	"	"	"				
3:50 PM		"	"	"	"				
7:35 AM		12-1-77	94°C	"	"				
3:55 PM		"	"	"	"				
7:35 AM		12-2-77	"	"	"				
3:50 PM		"	"	"	"				
7:45 AM		12-3-77	"	"	"				
3:30 PM		"	"	"	"				
7:55 AM		12-5-77	"	"	"				
3:45 PM		"	"	"	"				
7:50 AM		12-6-77	"	"	"				
3:45 PM		"	"	"	"				
8:00 AM		12-7-77	"	"	"				
3:30 PM		"							
8:00 AM		12-8-77	"	"	"				
2:00 PM		"	"	"	"				Removed switch 59 dropped temp. to 150 °F for 1/2 hr.

DATE 12-8-77 PAGE. 8 SWITCH # 61

J-71

LOCA #

LOCA TEST

TIME	ELAPSED TIME	DATE	TEMP.	PRESSURE	CAUSTIC FLOW	CAUSTIC TEMP	WATER LEVEL	Ph	COMMENTS
				Diff. Chamber					
2:30 PM		12-8-77	94°C	10 PSI	96%				
3:40		"	"	"	"				
8:00 AM		12-9-77	60°C	5 PSI	-				Hose broke on system during the night.
11:00		"	94°C	10 PSI	96%				Repaired system will have to remove switch on Friday, 12-16-77 instead of Thursday, 12-15-77.
3:00 PM		"	"	"	"				
7:35 AM		12-12-77	"	"	"				
3:00 PM		"	"	"	"				
7:45 AM		12-13-77	"	"	"				
3:00 PM		"	"	"	"				
8:00 AM		12-14-77	"	"	"				
3:00 PM		"	"	"	"				
7:45 AM		12-15-77	"	"	"				
3:00 PM		"	"	"	"				
7:45 AM		12-16-77	"	"	"				
8:30 AM		"	"	"	"				Remove switch from chamber.

The switch held a large amount of moisture when removing the pipe from the connector end. The moisture was around the lead wires.

December 19, 1977

QUALIFICATION OF IEEE STANDARD 323, 344 AND 382 USING WESTINGHOUSE LOCA PROFILE LIMIT SWITCH #61

The switch passed the heat aging, wear cycle, irradiation, seismic and high pressure LOCA test. Checking the switch on 12/16/77, after the low pressure and temperature LOCA test at 10 PSI and 200°F, the open contact resistance was 50 Kohms. There was a 2.5 to 3.5 Milliampere current leakage on the open contacts. The closed contacts passed .086 amps current.

The switch was heat aged at 200°F in a high humidity chamber from 9/22/77 to 10/3/77.

The open contact resistance on a Meggar instrument measured above 1000 Megohms (Infinity) before and after the heat age test and the closed contacts passed a current of .086 amps at 100 volts DC.

The switch was wear cycle tested for 100,000 cycles at 70 RPM using a cam to accelerate the lever arm. The load on the switch was .5 Amps @ 100 V.D.C. The switch was wear tested from 10/3/77 to 10/4/77.

The open contact resistance was over 1000 Megohms (Infinity) and the closed contact current was .086 amps before and after the test.

The switch was irradiated at Isomedix, Inc. from 10/6/77 to 10/26/77. The switch was irradiated at Isomedix, Inc, with a cobalt 60 source. The total irradiation applied was 204 Mrods with an energy level of 1.25 Mev. at .7 Mrad/hour rate.

The open and closed contact resistance and current were the same value as before the test.

The switch was seismic tested by Dr. Edward J. Walter & Associates.

The seismic tests consisted of resonance scan, fragility test and plant induced vibration simulation.

The switch was LOCA tested on 11/15/77 in a high pressure chamber and on 11/19/77 was removed from the chamber and installed in the low temperature and pressure chamber until 12/15/77. The LOCA was extended to 12/16/77 because the low pressure and temperature chamber was down for repair for part of a day.

The open contact resistance was above 1,000 Meohms (Infinity) before both LOCA spikes of 340°F and 70 PSI differential pressure, but when the temperature and pressure were at the maximum the resistance dropped to a low of 10 Meohms on the first spike and 800Kohms on the second spike.

When the chamber temperature was decreased to 250°F the open contact resistance was 900 Megohms.

The pipe that held the lead wires to the exterior connector was removed exposing the interior of the switch to the outside atmosphere surrounding the chamber. The resistance then increased beyond 1000 Megohms (Infinity) and remained above 1000 Megohms until the switch was removed from the chamber and installed in the low temperature and pressure chamber.

The switch lever arm was activated on the 14th day of the LOCA 11/29/77 while in the low pressure and temperature LOCA 200°F and 10 PSI. The activation was according to IEEE specifications.

The switch was removed from the low temperature and pressure chamber at the end of the LOCA on 12/16/77.

When removing the sealed connector pipe moisture had entered the switch around the contact block but there was no enough of moisture to drip from the switch.

The closed contacts passed .086 amps current and there was a slight leakage of current, 2.5 to 3.5 Milliamps across the open contacts.

The resistance across the open contacts had dropped to 50 Kohms.

The switch was bubble tested with 12 pound of air and there was no detection of leakage.

The open contact leakage current dropped from 3.5 Milliamps to .5 Milliamps after applying the 12 pounds of air to the switch.

The torque to remove the top cover screws was 8 to 13 lb.inches while the torque required to remove the bottom cover screws was 4 to 8 lb.inches.

The top cover gasket was moist and had a tacky substance on the inside surface bridging from one center screw hole to the opposite center screw hole.

The bottom gasket was cracked at the center housing support and moisture was present in the bottom housing. There is a possibility that leakage occurred at one or both bottom cover screws at the connector end of the switch. When the gaskets dried they became very brittle.

The contacts had a residue on these surfaces but were reasonably clean. The contact block was also clean but held film of moisture.

The boot cracked when removing it from the spindle.

The spindle shaft O-ring was in good condition and was resilient. The oil was present on the shaft and O-ring.

The grease was present on all sliding surfaces.

J. J. Patsey JP

ij

EQUIPMENT	CALIBRATED
Tektronix Model 564 Oscilliscope (Time Base)	9/6/77
Shure Model 62 CP Accelerometer	7/77
Seismic Test Circuit (Time Base)	8/10/77
Weston Model 912 A.C. Ammeter (Ser. #1943-27)	7/22/76
Biddle "Megger" Model 8679ARK	10/14/77
Weston Model 912 A.C. Voltmeter (Ser. #93607/26)	11/14/77
Weston Model 912 D.C. Voltmeter (Ser. #93851-26)	11/14/77
Weston Model 912 D.C. Ammeter (Ser. #96127-26)	11/14/77
Brooks Flow Meter Model 110-05F1B1A (Ser. #7608H66892)	9/14/76
Brooks Flow Meter Model 1110-05F1A1A (Ser. #7708H37890)	11/18/77
U.S. Pressure Gauge*	11/21/77
Thermocouple and YEW Type 2809 Digital Readout (Ser. #9028)	8/11/76
Sears Pressure Gauge	11/19/77
Video Logic Video Tape System (Time Base)	11/19/77
Thermometer	11/19/77
Thermometer	11/19/77
Marsh Master Gauge (E0252B)	12/2/76

*The calibration indicates that this instrument reads seven PSI too high. See Appendix D, pages 8-11.

Those switches of the EA-180 series which contain a short travel mechanism differ internally from the standard travel versions in some respects. It was, therefore, felt that it was necessary to test a short travel model up through the seismic portion of the test in order to verify that the internal mechanism of this switch was not subject to seismic failure.

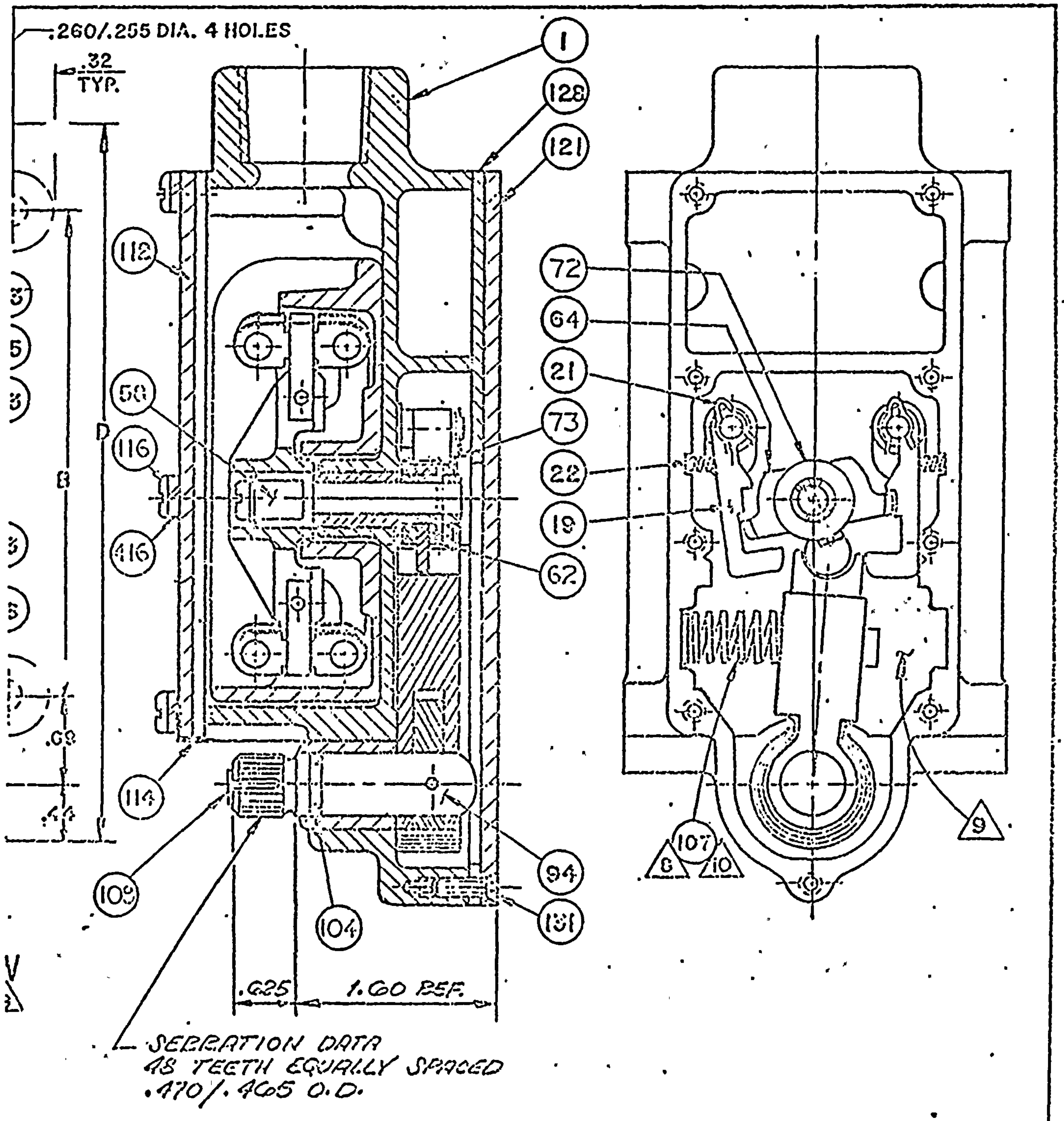
The tests conducted were the same as those conducted on the switch #61 in the body of the report except that the LOCA tests were not performed.

The short travel switch which was tested (#83, Model EA-180-14302, Rev. C) maintained optimal electrical performance throughout all portions of this test. During the seismic testing the trip position of this switch was observed to change - as noted in the seismic report. The maximum change was .107" and the direction of change was such that the switch would actuate earlier in the tripping cycle than it had prior to the seismic testing.

Cross coupling tests were not necessary for this switch as they were for the long travel mechanism. This was because the parts #75, 80 and 81 of the normal long travel mechanism (see page 5 of the main body of the report) are not present in this switch, and part 62 which replaces these parts is not subject to movement in the X axis.

It was not considered necessary to LOCA test this switch because short travel versions of the switch covered in the main body of this report will be built with identical sealing mechanisms (i.e. gaskets and O-rings) to switch #61.

ELS



E. F. S.

SIL. ONE COVER	REF. NO. E210607-15	NAMCO CONTROLS An Acme-Cleveland Company CLEVELAND, OHIO U.S.A.	
UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS .XX ± .01 .XXX ± .005 ANGULAR ± 0°30′ REMOVE ALL SHARP EDGES ALL MACHINED SURFACES	DR. SCOTT	TITLE D2400 NUCLEAR SWITCH SHORT TRAVEL 6 1/2° TRIP	
	CK.		
	DATE	MATERIAL Page 2 of 11	DO NOT SCALE

March 1, 1978

TEST FOR SHORT TRAVEL SWITCH #83-51, EZ1067-51/EA18014302

Switch #83-51 is equivalent, except for the latching mechanism, to the standard version EZ10607-15, #53, which passed the qualification test on November, 1977.

Switch #83-51 was subjected to and passed heat aging, life cycling, irradiation and seismic testing.

The switch has molded silicone (Moxness) top and bottom cover gaskets, three (3) Belleville washers under each top cover screw, EPDM O-ring, D.C. 550 silicone oil and Nye 734-A grease as the lubricant. The switch spindle has no boot.

The switch was heat aged at 200°F in a high humidity chamber from 12/23/77 to 1/1/78.

The open contact resistance on a Meggar instrument measured above 1000 megohms (infinity) before and after the heat age test and the closed contacts passed a current of .086 amps at 100 V.D.C.

The switch was wear life cycle tested for 100,000 cycles at 70 RPM using a cam to accelerate the lever arm. The load on the switch was .5 amps @ 100 V.D.C. The test was from 1/3/78 to 1/4/78.

After the wear cycle test the contact resistance was over 1000 megohms (infinity) and the closed contact current was .086 amps.

The switch was irradiated at Isomedix, Inc. from 1/12/78 to 1/31/78.

The switch was irradiated with a cobalt 60 source. The total irradiation applied was 204 Mrads with an energy level of 1.25 Mev. at 1.2 Mrad/hr. rate.

The open and closed contact resistance and current were the same values as before the irradiation test.

The switch was seismic tested by Dr. Edward J. Walter & Associates from 2/1/78 to 2/13/78.

The seismic tests consisted of resonance scan, fragility test and plant induced vibration simulation.

After the seismic test the open contact resistance was above 1000 megohms (infinity) before and after the seismic test the closed contacts passed a current of .086 amps at 100 V.D.C.

The test program for switch #83-51 was completed on 2/13/78. The data is attached.

J. J. Patsey

ij

DATE 12/23/77

HEAT AGING

SWITCH # 83-51

J-71

MODEL # EA-180-14302

EZ1060751

☐ PROTOTYPE
☐ PRODUCTION

FROM 12-23-77 TO 1-1-78

TIME	DATE	TEMP.	COMMENTS
12:30 PM	12-23-77	200°F	Latching mechanism = short travel. The top cover screws were torqued to 10 lb.in. The gasket bulged .016" from the plate. The bottom gasket had a .044" bulge from the plate.
	12-26-77	"	
	12-28-77	"	
	12-31-77	"	
9:35 AM	1-3-78	"	
	Removed switch		

ELECTRICALS LOAD = .086A @ 100 VDC

	Meggar 1	Meggar 3	Meggar 2	Meggar 4	Conductivity (amps) 1	Conductivity (amps) 3	Conductivity (amps) 2	Conductivity (amps) 4
INITIAL	Inf	Inf	Inf	Inf	.086	.086	.086	086
FINAL	"	"	"	"	"	"	"	"
OTHER								

(Continue on back)

INTERIOR EXAMINATION (OPTIONAL)

GASKETS:

CONTACTS:

BLOCK:

O-RING:

GREASE:

JB

(Continue on back)

DATE 1-3-78

SWITCH # 83-51

MODEL # EA180-14302
EZ10607-51

J-71

PROTOTYPE
PRODUCTION

WEAR CYCLING

# OF CYCLES	100,000		LOAD	.5A @ 100 DC					COMMENTS
CYCLE RATE	70 RPM								
METHOD	Cam								
ELECTRICAL MEASUREMENTS; LOAD = .086A @ 100 VDC									
	Meggar				Conductivity (amps)				
	1	3	2	4	1	3	2	4	
INITIAL	Inf	Inf	Inf	Inf	.086	.086	.086	.086	
FINAL	"	"	"	"	"	"	"	"	
OTHER									

INTERNAL EXAMINATION (OPTIONAL) (Continue on back)

GASKETS:

CONTACTS:

BLOCK:

O-RING:

GREASE:

(continue on back)

DATE 1-31-78

SWITCH # 83-51

J-71 ☐ PROTOTYPE

☐ PRODUCTION

MODEL # EA180-14302

EZ10607-51

IRRADIATION

IRRADIATED AT: Isomedix, Inc.

FROM 1-12-78 TO 1-31-78 TOTAL IRRADIATION 204 Mrad.

ENERGY LEVEL 1.25 Mev. SOURCE Cobalt 60 gamma RATE 1.2 Mrad/Hr.

ELECTRIDAL MEASUREMENTS ; LOAD = .086A @ 100 DC COMMENTS

	Meggar				(Conductivity (amps)			
	1	3	2	4	1	3	2	4
INITIAL	Inf	Inf	Inf	Inf	.086	.086	.086	.086
FINAL	"	"	"	"	"	"	"	"
OTHER								

INTERIOR EXAMINATION (OPTIONAL)

Gaskets:

CONTACTS:

BLOCK:

O-RING:

GREASE:

COMMENTS (Cont.)

JD.

(continue on back)

ISOMEDIX

February 6, 1978

Mr. Edward L. Solem
Metallurgy Engineer
Acme-Cleveland Development Co.
625 Alpha Drive
Highland Heights, Ohio 44143

Dear Mr. Solem:

This will summarize parameters pertinent to the irradiation of three switches per your purchase order no. DC-97214, dated January 12, 1978. The units were identified as switches 81A, 82A, and 83.

The switches were placed in a cobalt-60 gamma field at a dose rate of 1.2 Mrad per hour. The switches were exposed for 170.0 hours, yielding a minimum dose of 204 megarads.

Dosimetry was performed using an Atomic Energy of Canada Limited (AECL) Red Perspex system with Type BC-2 readout. Calibration of the Perspex is made by AECL using Ceric dosimetry traceable to the U.S. National Bureau of Standards. Isomedix regularly cross-calibrates its AECL system with an inhouse Harwell Perspex system, and makes semi-annual calibrations directly with NBS, using the NBS Radiochromic Dye system. A copy of the dosimetry correlation report is available upon request.

Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 100°F, as indicated by previous measurements on an oil solution in the same relative position.

Irradiation was initiated on January 15, 1978, and was completed on January 26, 1978.

Yours very truly,

Jonathan C. Young
Production Manager

JCY/mr

Isomedix Inc. • 25 Eastmans Road, Parsippany, New Jersey (201) 887-4700
Mailing Address: Post Office Box 177, Parsippany, New Jersey 07054

CHICAGO DIVISION • 7828 Nagle Ave., Morton Grove, Illinois 60053 (312) 966-1160

DATE 2-13-78

SWITCH # 83-51

MODEL # EA180-1430
EZ10607-51

J-71 ☐ PROTOTYPE
☐ PRODUCTION

SEISMIC TESTING

TESTED BY:
Dr. Edward Walter & Associates

REPORT REF.: IEEE Standard 323, 344 and 382

INTERNAL EXAMINATION (OPTIONAL)

GASKETS

CONTACTS

BLOCK

O-RING

GREASE

COMMENTS

Electricals

	Meggar				Conductivity (amps)			
	1	3	2	4	1	3	2	4
Before seismic 2-1-78	Inf	Inf	Inf	Inf	.086	.086	.086	.086
After seismic 2-13-78	"	"	"	"	"	"	".	"

CC

Dr. Edward J. Walter & Associates
Vibration and Sound Consultants
P.O. BOX 171 • CHESTERLAND, OHIO 44026 • TELEPHONE: (216) 729-7415

Vibration Test of Limit Control Switch
NAMCO Controls
An Acme-Cleveland Company
January, 1978

Reference

A detailed description of the vibration testing equipment and test procedures is given in our report of June, 1977, Seismic Qualification Test of Limit Control Switches, prepared for NAMCO Controls.

CURRENT SWITCH TEST

Switch No. 83, EA 180-14302

VIBRATION TESTS

The switch was subjected to the following tests:

I - Fragility Test

Frequency Hz	Vibration Specification
1.0	Displacement - 12.1 inches pp
1.25	giving 9.52 g's acceleration
1.6	at 4 Hz.
2.0	
2.5	
3.15	
4.0	
	Acceleration 9.52 or greater
5.0	Displacement - 8.0 inches pp
6.3	Displacement - 5.0 inches pp
8.0	Displacement - 3.0 inches pp
10.0	Displacement - 2.0 inches pp
12.5	Displacement - 0.45 inches pp
16.0	as above
20.0	as above
25.0	Displacement - 0.40 inches pp
32.0	giving acceleration 9.52 g's
	or greater.

II - Plant Induced Vibration Simulation

The switch was vibrated at a non-resonant frequency, 100 Hz at an acceleration 1.3 g for a total of 10^6 cycles, one third of the total cycles in each component, X, Y, and Z.

Test Procedure:

The switch was tested in each of three mutually perpendicular directions, designated X, Y, and Z, parallel to the major axes of the switch. In each orientation, the fragility dwell test and the plant induced vibration simulation test were made.

In the Fragility Dwell test the switch contacts were monitored. Both the Normally Open (NO) contacts and the Normally Closed (NC) contacts were monitored for seismic failure by means of a light indicator circuit. No seismic failure occurred during the tests.

The trip angle of the switch was also monitored during the test at both the normally Open (NO) contacts and the Normally Closed (NC) contacts. The Normally Open (NO) contacts were monitored first. The switch was actuated and subjected to vibration for a minimum of 30 seconds. Next, the Normally Closed (NC) contacts were monitored with the switch unactuated and subjected to vibration for a minimum of 30 seconds. Total vibration time was a minimum of 60 seconds. This procedure was repeated for each frequency of the fragility dwell test.

The trip position remained within 1/16 inch throughout the test procedure with the following three exceptions:

Changes in Trip Position
which exceeded 1/16 inch

Y-comp.

Frequency Hz	Total Change in inches
16	.107 early
25	.080 early
32	.107 early

In the Plant Induced Vibration Simulation test, the switch was vibrated at a non-resonant frequency, 100 Hz, at an acceleration of 1.3 g, for a minimum of 10^6 cycles. Each component, X, Y, and Z was subjected to one third of the total number of cycles, e.g. 1/3 x 10^6 cycles.

The switch was a double throw type and was energized electrically at 125 volts at 1/2 amp. during the test. It was subjected to 51 distinct vibration tests, 48 of these at a minimum of 60 seconds each and three at a minimum of 56 minutes each.

Edward J. Walter

DR. EDWARD J. WALTER AND ASSOCIATES
February, 1978

TEST REPORT

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
WESTERN OPERATIONS, NORCO FACILITY

REPORT NO. 58314
OUR JOB NO. ND 58314
CONTRACT ---
YOUR P. O. NO. 5-28-78

PACIFIC GAS AND ELECTRIC COMPANY
77 Beale Street
San Francisco, California 94106

155 - Page Report

DATE 22 September 1978

RETURN TO REACTOR DOCKET FILES

Docket # 50-275/323
Control # 7811290460
Memo Date 11-21-78 of Document
REGULATORY DOCKET FILE
Memo to Stolz from Allison

SEISMIC TESTING
OF
ONE 14-INCH MOTOR-OPERATED VALVE
PART NUMBER S70DD
FOR
PACIFIC GAS AND ELECTRIC COMPANY

REGISTERED PROFESSIONAL ENGINEER
GEORGE D. SHIPWAY
No. 12157
MECHANICAL
STATE OF CALIFORNIA

STATE OF CALIFORNIA }
COUNTY OF RIVERSIDE } ss.

Roy C. Sadlier, being duly sworn, deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

Roy C. Sadlier

SUBSCRIBED and sworn to before me this 29th day of September, 19 78

Catherine C. Kelty
Notary Public in and for the County of Riverside, State of California

My Commission expires 14 July, 19 79

OFFICIAL SEAL
CATHERINE C. KELTY
NOTARY PUBLIC - CALIFORNIA
RIVERSIDE COUNTY
My comm. expires JUL 14, 1979

W-867A

DEPARTMENT DYNAMICS

DEPT. MGR. J. J. Anderson
J. J. Anderson

TEST ENGINEER Philip Knoll
Philip Knoll

Registered Professional Engineer G. D. Shipway
G. D. Shipway

DCAS-QAR VERIFICATION

QUALITY CONTROL L. Housteau
L. Housteau

1.0 REFERENCES

1.1 Pacific Gas and Electric Company Contract No. 5-28-78 dated 30 June 1978.

1.2 Pacific Gas and Electric Company Test Procedure for Seismic Qualification Testing of a 14-Inch Motor-Operated Valve, Revision 2, dated July 1978, included herein as Exhibit I.

1.3 IEEE Document 344(1975), "IEEE Recommended Practices for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations".

2.0 OBJECTIVES

2.1 To test the structural integrity and substantiate the operability and performance of a 14-inch double disc motor-operated gate valve and its accessories by shaker table testing.

1.2 To qualify seismically this valve and similar valve-actuator assemblies of the Diable Canyon Nuclear Power Plants (Units 1 and 2) for the seismic inputs associated with the postulated 7.5M Hosgri event.

3.0 TEST SPECIMEN

3.1 Valve

Manufacturer: Darling Valve Company

Model: 14-inch - S70DD (weld end, outside screw yoke, double disc, with Limitorque operator)

Series: 300 lbs.

Material: Stainless Steel ASTM A-351, Grade CF-8M
Minimum Yield Strength: 30 ksi
Modulus of Elasticity: E = 29.2E6 psi

3.2 Stem

Material:	17-4 PH Stainless Steel Yield Strength: 100 ksi Tensile Modulus of Elasticity: E = 28.5E6 psi

3.3 Actuator

Limitorque,	Type SMB, Size 0
Serial No.	95918A
Motor by:	Peerless Electric
Frame:	P12M
Volts:	220/440
Amps:	14/7
Cycles:	60
Phase:	3
HP:	2.6
RPM:	1750
Torque:	40 lb. ft.
Insulation:	Class B
Degrees C:	Rise 75 Ambient 40
Duty:	15 minutes

3.4 Yoke

Manufacturer: Darling Valve Company

I.D.: D3132 6LWCB Pool 16VM54SD

Material: ASTM A-216 Grade WCB
Minimum Yield Strength: 36 ksi
Modulus of Elasticity: E = 27.9E6 psi

3.5 Limit Switches

Manufacturer: NAMCO

Model: Snap-Lock D2400X-ST2

3.6 Weights

Valve Empty:	3000 pounds
Valve full of water:	3400 pounds
Mounting Brackets (two):	1450 pounds each
Total weight:	6300 pounds

4.0 TEST PROCEDURES

4.1 Receiving Inspection

Upon receipt at Wyle Laboratories, and prior to any testing, the specimen was visually examined for evidence of damage. Specimen identification information was checked with the shipping document for completeness and conformance.

Results of the visual examination, and specimen identification information are recorded on the receiving inspection data sheet included in this report.

4.2 Operational Test

4.2.1 The manual to electrical mode of operation was performed as follows:

1. Declutch the electric motor by pushing the lever to the direction of the arrow.

4.2.1 (continued)

2. Turn the handwheel two to three full turns and verify that it is engaged and the valve stem moves.

3. Energize the motor and verify that the latch releases automatically and the clutch engages the motor to the drive train.

4. Repeat Steps 1 through 3 above four more times. Record the results in the test data table.

4.2.2 The valve was then pressurized to 350 psig with water to simulate operating conditions.

4.2.3 The actuator was operated electrically for one full cycle (open/close) and the baseline data recorded for comparison with the performance at other stages of the test. The time history of motor volts, amperes, and watts was recorded. Time was recorded in seconds for a full open/close cycle and the maxima of volts, amperes, and watts. The test data table was completed.

4.2.4 After the completion of all dynamic tests, the tests of Paragraph 4.2 were repeated and the data recorded for comparison. Step 1 of Paragraph 4.2.1 was performed once.

4.3 <u>Specimen Mounting</u>

The valve was bolted to two bookend type fixtures (Reference Figure 1). The fixtures were welded to the test table.

4.3.1 Functional Setup

The valve was pressurized to 350psi with water (Reference Figure 2). The position of the valve was indicated by connecting a light bulb to each limit switch.

The voltage and current were recorded on a visicorder and the wattage was recorded on a wattmeter.. The results were recorded on the test data tables.

4.3.2 Instrumentation

Triaxial accelerometers were attached at locations A0 through A7 of Figure 1. The data was recorded on magnetic tape.

PGandE furnished and installed the 27 strain gages shown in Figure 7. It was PGandE's responsibility to monitor and record the strains and reduce the strain gage data. The measured stresses are shown on the test data tables included in this report.

4.4 Input Excitation

4.4.1 Resonance Search

With the valve in the closed position and pressurized to 350 psig, a low level (0.2g) frequency sweep search for resonances from 2 to 35 Hz at a sweep rate of two octaves per minute was performed in each axis.

The resonance search was repeated for each principal axis with the valve in the fully open position. The position of the valve disc (valve fully open/closed) did not affect appreciably the natural frequency in each case. No resonances below 35 Hz were detected in the vertical (Y) axis. The following table summarizes the resonances of the valve/actuator assembly.

TABLE I

VALVE ASSEMBLY NATURAL FREQUENCIES

Axis of Excitation	Natural Frequency (Hz)
X (Pipe centerline)	fx = 29.8
Y (vertical)	No resonance $\leq$ 35 Hz
Z (Orthogonal horizontal)	fz = 30.2

If no resonance frequencies were detected in a direction of excitation, we proceeded with the qualification testing per Paragraph 4.5.

4.4.2 For each resonance between 2 to 35 Hz the mode shape (response) and per cent of critical damping were determined.

The mode shapes (responses) at fx = 29.8 Hz and fz = 30.2 Hz were determined from the relative amplitude and direction of the accelerometer indications.

The accelerometers on the shaker table (A0 in Figure 1) were used as reference. They provided the baseline of phase and amplitude for the other 21 accelerometers shown in Figure 1, Page 12. The amplitudes were normalized and in conjunction with the phase they gave responses for both modes (fx = 29.8 Hz and fz = 30.2 Hz) which resemble the typical deflection of a cantilever beam consisting of segments of different stiffness. The yoke and the neck of the valve bonnet were the most deflected segments.

There was no evidence of significant torsional response of the valve assembly. Figure 5 shows the typical response of the valve assembly for the mode corresponding to fz = 30.2 Hz.

The per cent of critical damping associated with each mode was measured by the band-width method (Reference Section 3.5.1.2 of Reference 1.3.) See Figure 6.

4.4.3 The spectral plots recorded during the test and used for the determination of the per cent critical damping are part of this test report. (Reference Pages 22 through 27.)

Table II shows the experimentally determined damping values.

TABLE II

EXPERIMENTALLY DETERMINED DAMPING VALUES

Forcing Direction	f	(A0)	(A5)	B
X	fx=29.8	0.3	4.5	1.20
Z	fz=30.2	0.2	5.4	1.75
		0.3	7.6	2.50

f = eigenfrequency (Hz)
(A0)= steady state acceleration (peak amplitude, measured at location A0, see figure, Page 12) (g)
(A5)= steady state acceleration (peak amplitude, measured at location A5, see Figure, Page 12) (g)
B = per cent critical damping

4.4.4 We repeated Steps of Paragraphs 4.4.2 and 4.4.3 above with the valve pressurized and the disc of the valve at its fully open position.

4.5 <u>Single Frequency Tests</u>

4.5.1 The valve-actuator assembly was exposed to a series of single frequency sine beat tests at the test frequencies indicated on Figure 3, and at the natural frequencies detected during the resonance search. The excitation at each frequency was in the form of sine beats of ten oscillations per beat. The peak acceleration was the required input motion (RIM) value shown on Figure 3.

Each sine beat test lasted for a maximum of thirty seconds after the prescribed acceleration (RIM) level was reached. During the X and Y axes time was changed to twenty seconds.

During each sine beat test the valve operator was energized. At the end of the shaking, the Limitorque motor was stopped for motor cooldown before proceeding to the next sine beat test.

The next sine beat test was started with the valve stem at the position left at the end of the previous shaking cycle. At the end of its stroke, the stem direction of movement was reversed. The stepwise open/close attempts of the valve actuator were continued until all sine beat tests per axis were completed. PGandE provided a motor controller for the reversal of direction of the actuator motor and technical assistance for the hookup.

The motion was applied at the same frequencies and accelerations on each of the three orthogonal axes separately.

NOTE: The input motion was <u>not</u> limited by accelerometer A4 (to 6g) or strain gage indications (90% yield) as the test procedure (Reference 1.2, Par. 6.1) stated. Instead the full RIM values were used per Figure 3.

4.5.1 (continued)

All sine beat tests were performed with gradually applied input level of excitation. The input was applied at approximately one-third and two-thirds of RIM before full RIM values were applied. Continuous monitoring of stresses was the responsibility of the PGandE Engineer.

4.6 Multi-Frequency Tests (Biaxial)

The actuator was exposed to a biaxial multi-frequency test motion which when analyzed for each axis produced a test response spectrum (TRS) which envelopes the required response spectrum. The required response spectrum (RRS) is shown in Figure 4. The test was performed with one horizontal axis combined with the vertical axis, and then repeated with the orthogonal horizontal axis combined with the vertical.

Independent (non-phase coherent) multi-frequency motions for the horizontal and vertical axes were used. The duration of each test, with simultaneous function of the valve actuator, varied between twenty and thirty seconds.

There were five OBE tests before each SSE. (Although the postulated 7.5M Hosgri seismic event is not the SSE for the plant, where SSE is referred to in this test report, or in the IEEE Std. 344, the seismic inputs associated with the postulated 7.5M Hosgri seismic event were used.)

The results of the test were presented in terms of the TRS at two per cent damping for comparison to the RRS (Figure 4). The results of the test were also presented in terms of the TRS at two additional values of damping: three per cent and four per cent.

5.0 TEST RESULTS

5.1 Receiving Inspection

Thre was no visible evidence of damage to the test specimen upon receipt at Wyle Laboratories. Receiving inspection data sheet is included in this report as Page 20.

5.2 Operational Tests

Operational test data is recorded on the test data tables included in this report as Pages 28 through 105. The paragraph cited in the test data tables corresponds to the paragraph in the test procedure (Reference 1.2).

5.3 Resonance Search

A visual examination of the test specimen upon completion of each sweep showed no physical damage had occurred. Plots made to determine damping are included as Pages 22 through 27. Resonances are listed on the appropriate test data sheets and they are summarized in Table I.

5.4 Single Frequency Tests

During the 24 Hz sine beat test in the Z axis, the Limitorque actuator was was damaged. The actuator was repaired, and multifrequency testing was started per PGandE request. Upon completion of testing in the X-Y axis single frequency testing was resumed at 24 Hz in the X axis. A visual examination of the test specimen upon completion of testing in each axis showed no further damage had occurred due to testing. Data recorded during testing is recorded on the appropriate data sheets.

5.5 Multifrequency Testing

During the second OBE in the X-Y axis, the vertical exciters of the shaker table hit the stops, causing damage to the Limitorque actuator. The damaged parts were replaced and testing was continued. A visual inspection of the test specimen upon completion indicated no further damage had occurred due to testing. Plots of the TRS and RRS are included in this report, together with a set of response accelerometer plots for one OBE and one SSE in each axis of the test.

The time to open or close the valve without shaking was measured about 65 seconds. During the vibration test the open or close time remained essentially the same.

5.5 (continued)

The power drawn by the electric motor of the valve operator was slightly lower when the valve when shaking compared to the power required to open or close the valve under steady state conditions. The number of times the motor was energized was in excess of 150 times.

The number of shaking cycles the valve was subjected to was much higher than that recorded. (i.e. instrument calibration and table calibration)

A test for tightness of valve after all dynamic tests had been completed was performed with no change noted.

5.6 Additional information, such as test plots, equipment used, functional data, accelerometer locations, and test setup photographs are included in the following pages.

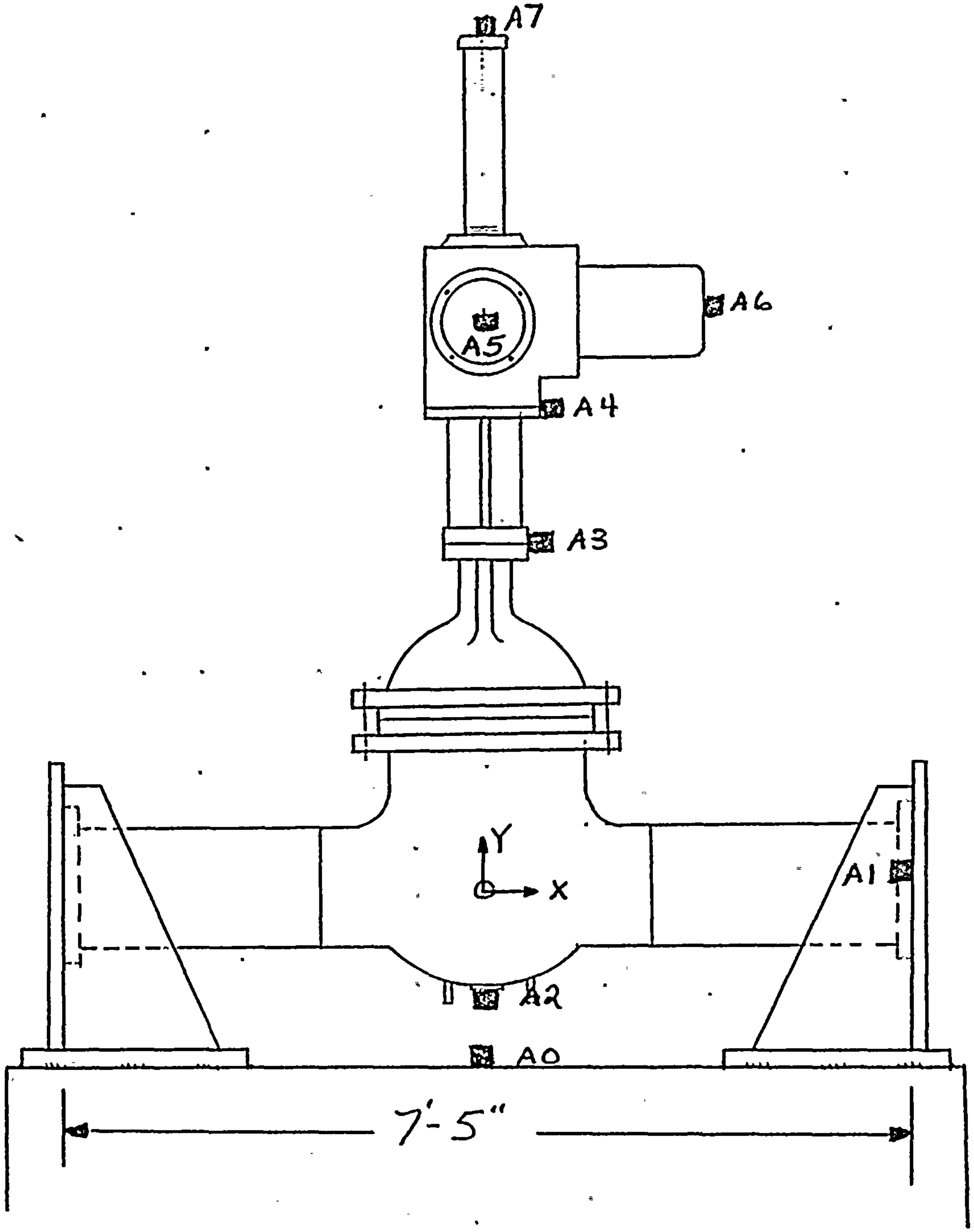
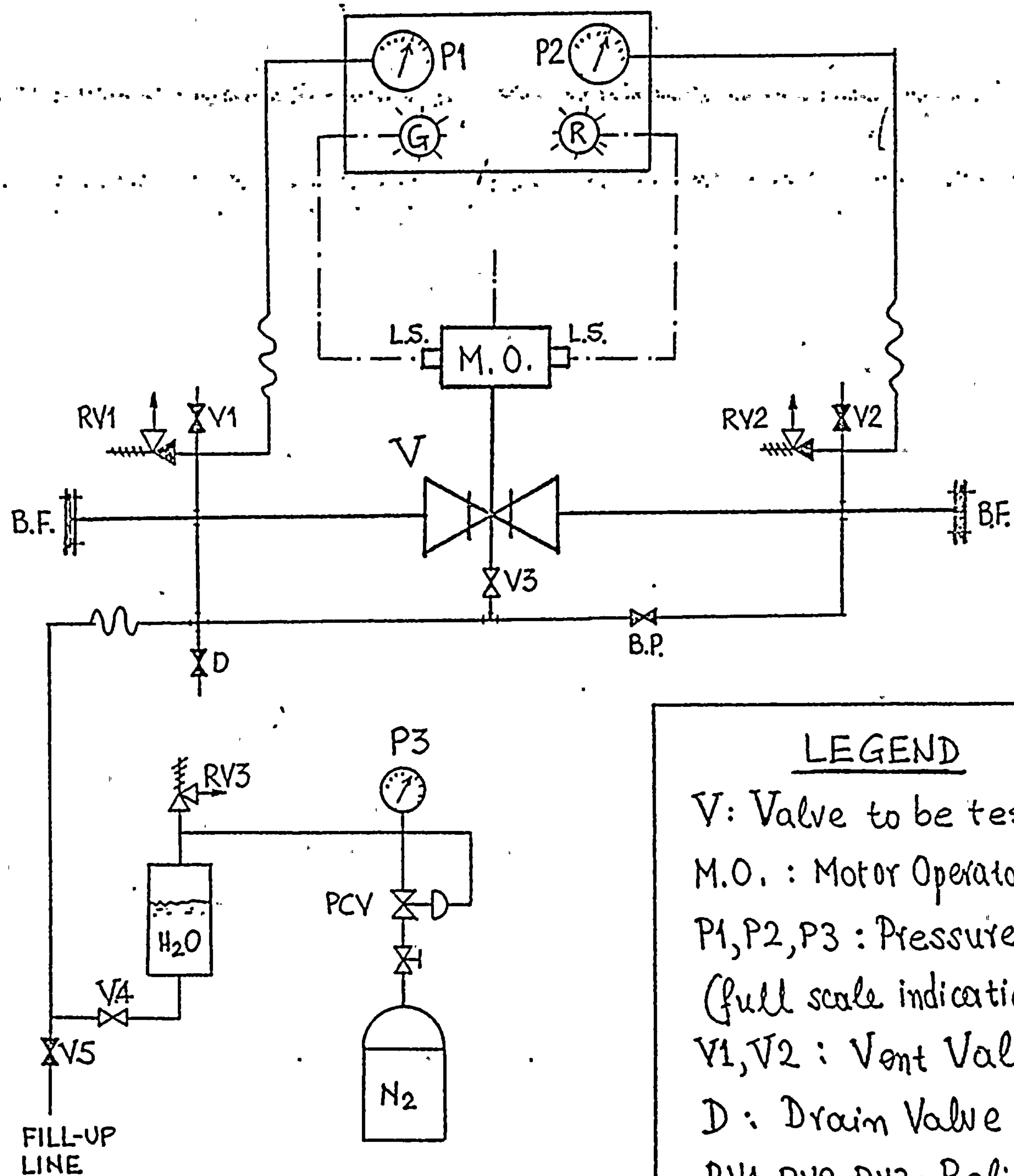


FIGURE 1



LEGEND

V: Valve to be tested

M.O. : Motor Operator (Limitorque)

P1, P2, P3 : Pressure gages (full scale indication 500 psig)

V1, V2 : Vent Valves

D : Drain Valve

RV1, RV2, RV3: Relief valves (set to relieve at 375 psig)

BP : By-pass valve

PCV : Pressure Control Valve

LS : Limit Switch

BF : Blind Flange

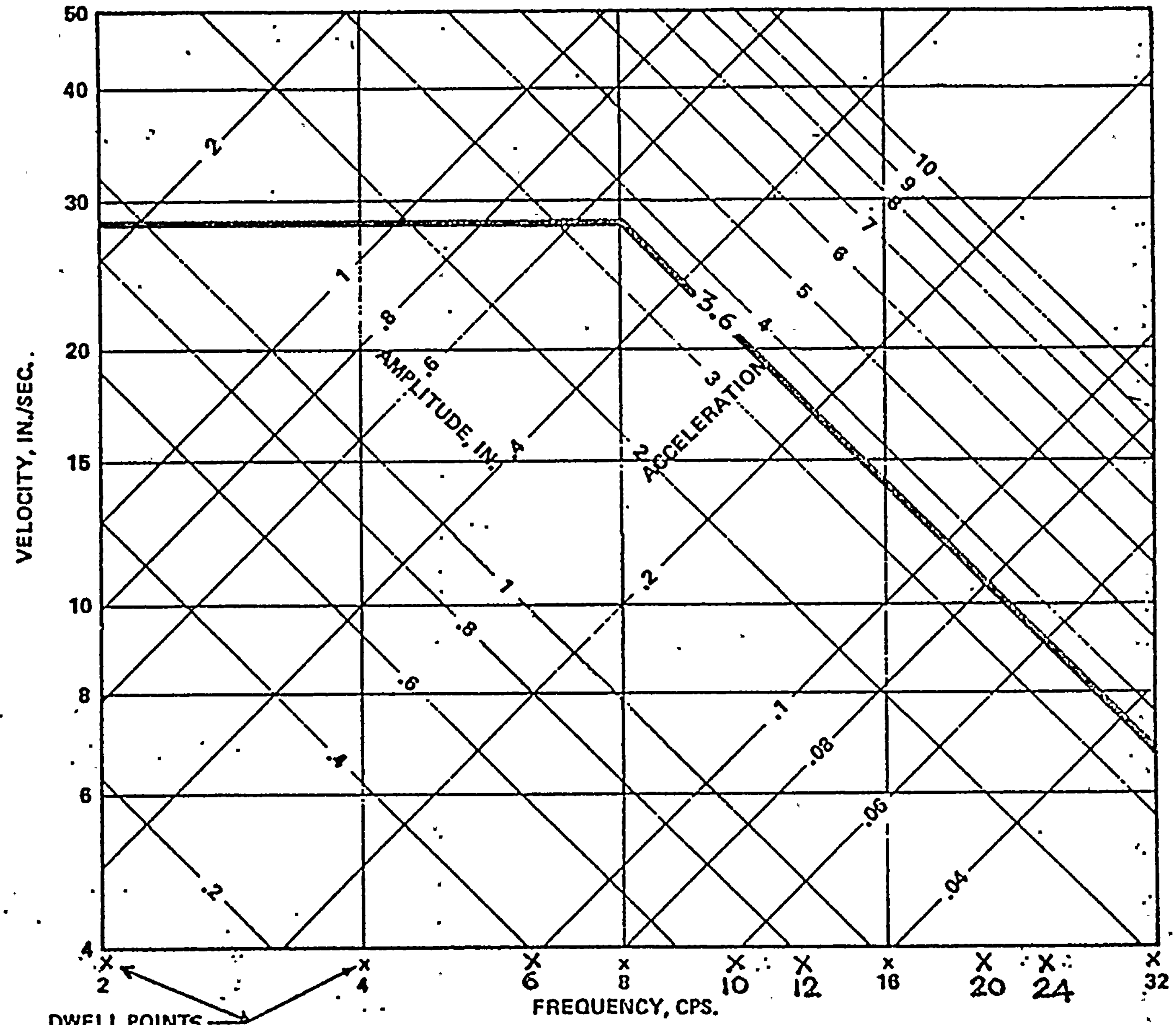
∼ : Flexible Pipe (Hose)

G : Green (100W bulb, valve fully open)

R : Red (100W bulb, valve closed)

Pressurization/Instrumentation Schematic

FIGURE 2



SEISMIC QUALIFICATION REQUIRED INPUT MOTION (RIM)

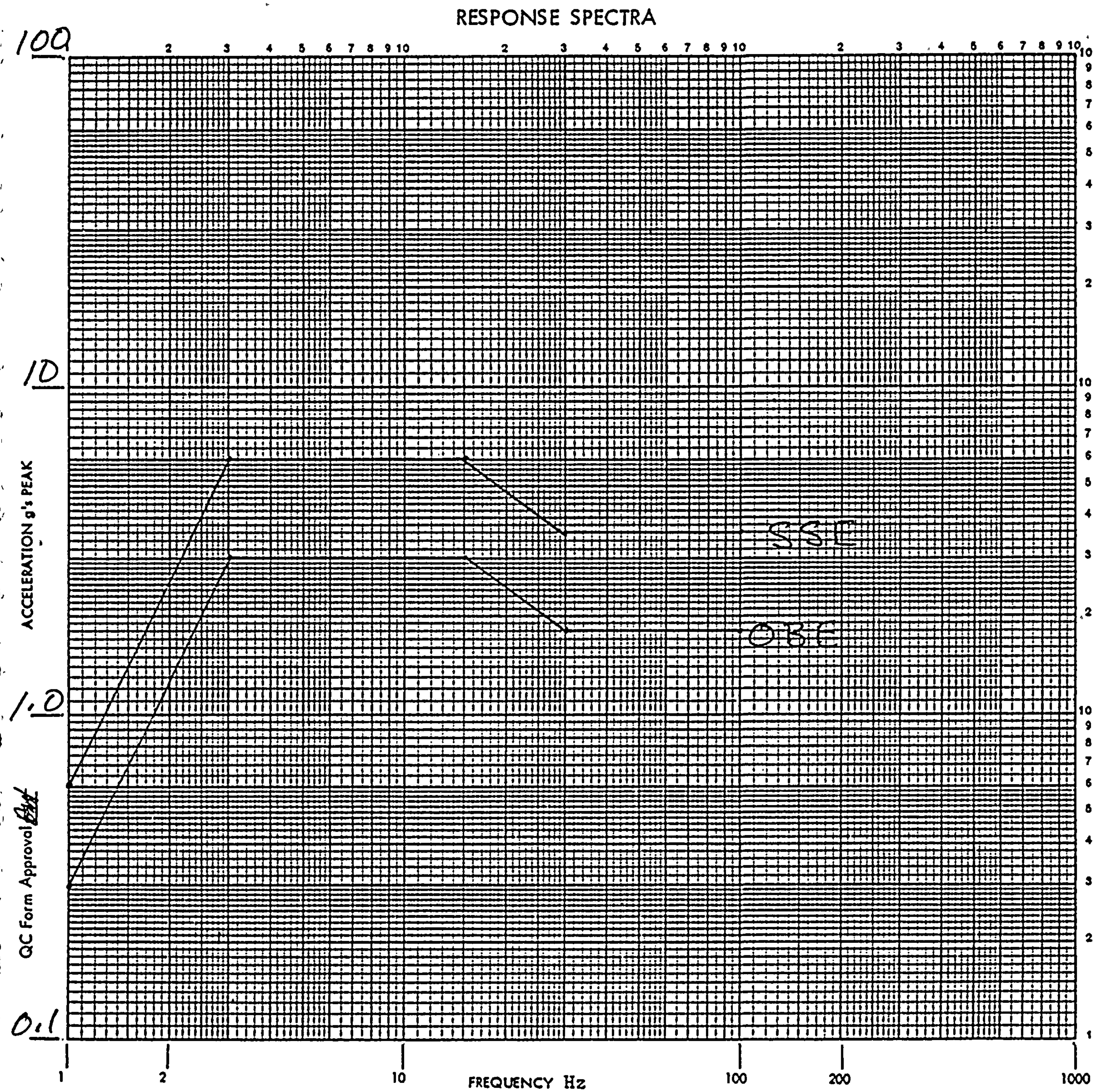
FIGURE 3

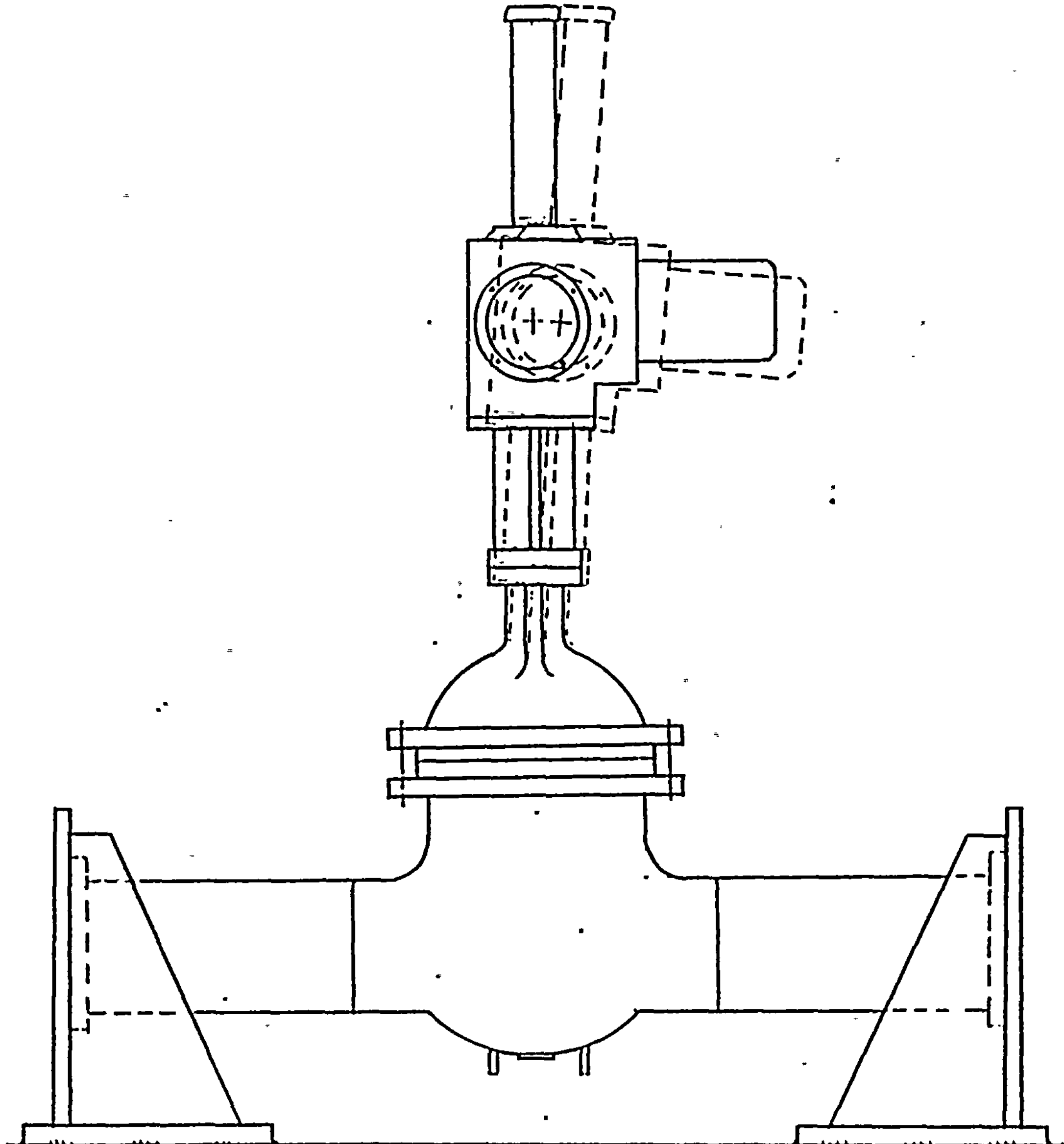
FIGURE 4

HORIZONTAL AND VERTICAL

RRS

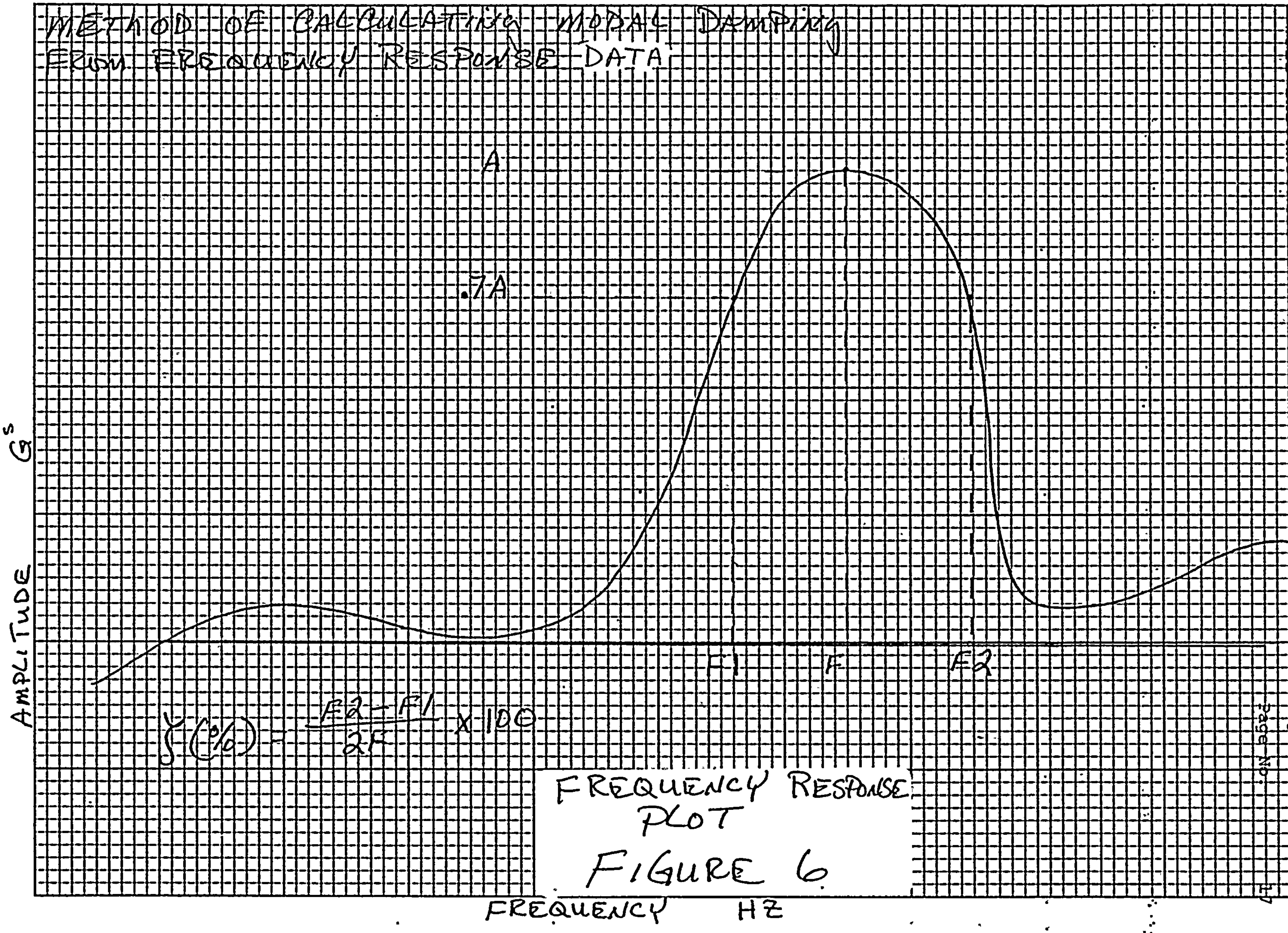
2% Damping.





MODE SHAPE (RESPONSE) CORRESPONDING
TO $F_Z = 30.2$ HZ

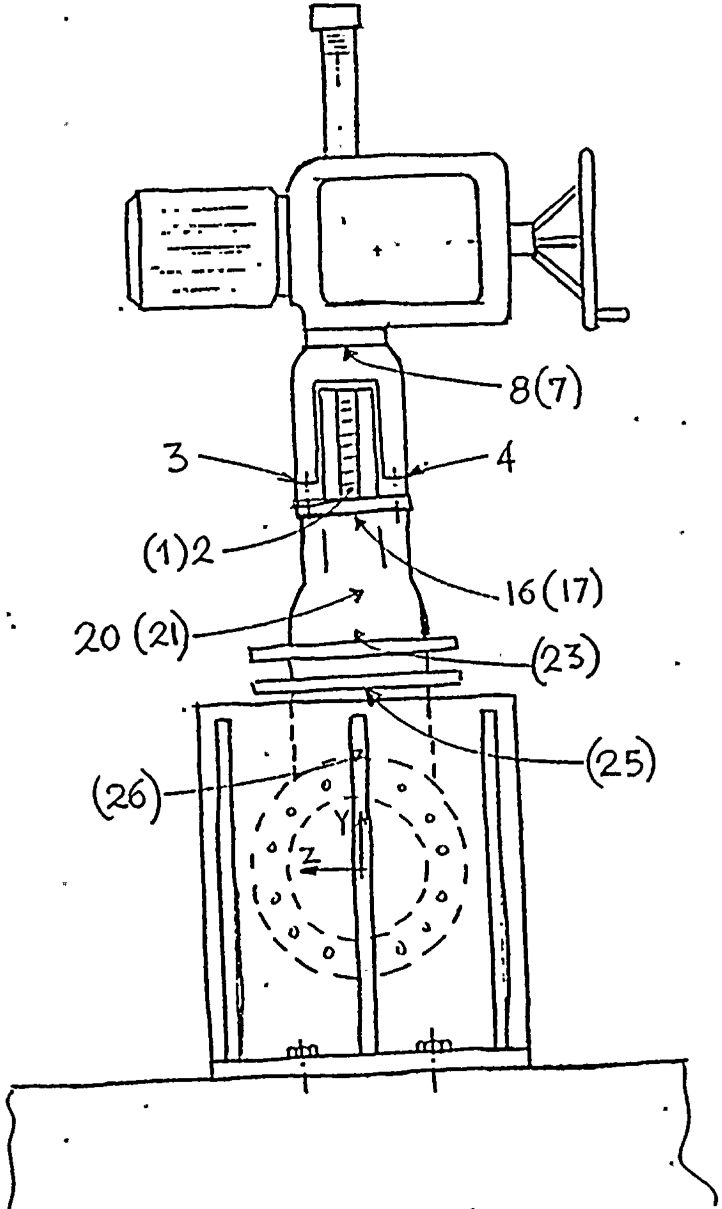
FIGURE 5



$$\zeta(\%) = \frac{F2 - F1}{2F} \times 100$$

FREQUENCY RESPONSE PLOT

FIGURE 6



STRAIN GAGE (SG) IDENTIFICATION

Numbers in ( ) indicate SG on back side of valve.

FIGURE 7

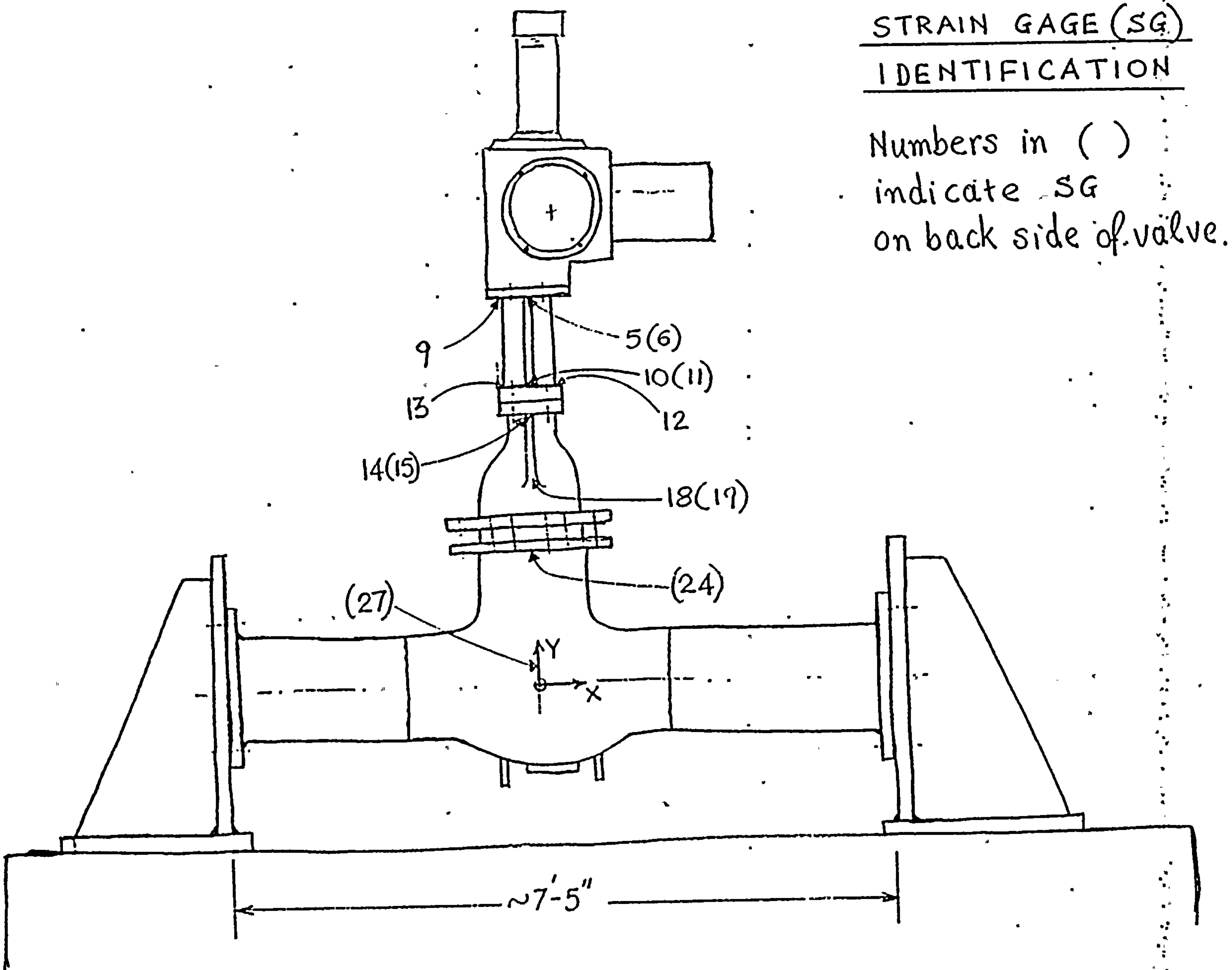

STRAIN GAGE (SG) IDENTIFICATION
Numbers in ( ) indicate SG on back side of valve.
9
5(6)
10(11)
13
12
14(15)
18(19)
(24)
(27)
Y
X
~7'-5"

FIGURE 8

DATA SHEET

Customer PG&E Job No. 58314
Date 5-26-78

Specimen 14" DOUBLE DISC VALVE

RECEIVING INSPECTION

No. of Specimens Received: ONE

Record identification information exactly as it appears on the tag or specimen:

Manufacturer DARLING VALVE CO.

Part Numbers S70DD

How does identification information appear: (name plate, tag, painted, imprinted, etc.)

PAPERWORK

Serial Numbers:* —

Examination: Visual, for evidence of damage, poor workmanship, or other defects, and completeness of identification.

Inspection Results: There was no visible evidence of damage to the specimens unless noted below.

* If additional space is required for serial numbers, use an additional page, or reference first functional test data sheet (if applicable).

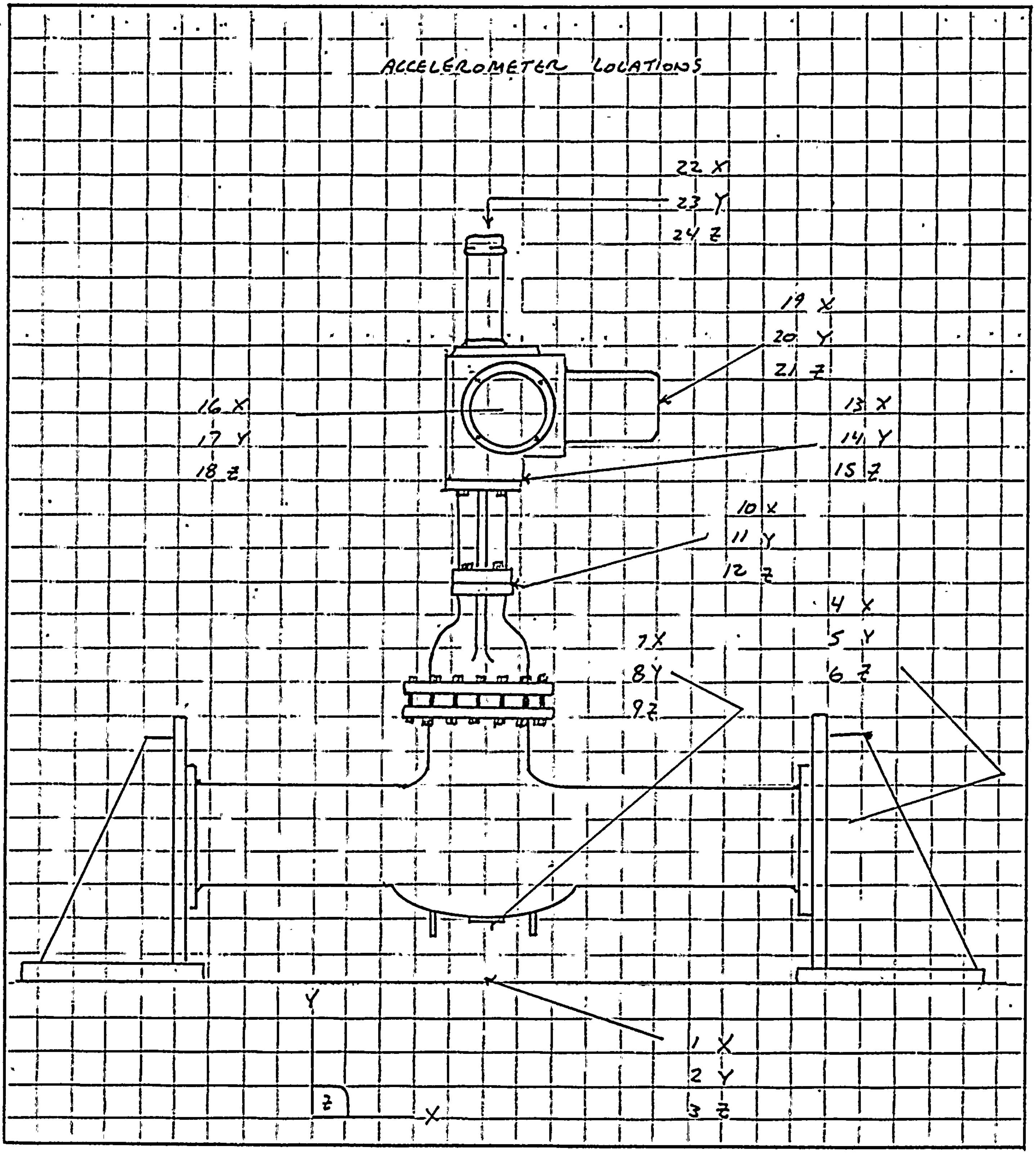
Inspected By [signature]
Sheet No. of
Approved [signature] Date 5-?-78

W-614
Q.C. Form Approval [initials]

WYLE LABORATORIES

DATA SHEET

CUSTOMER PG&E
Test Title: SEISMIC
Specimen 14" DISC VALVE
Job No. 58314
S/N SEE REC INSP
Part No. SEE REC INSP
Date 7-28-78



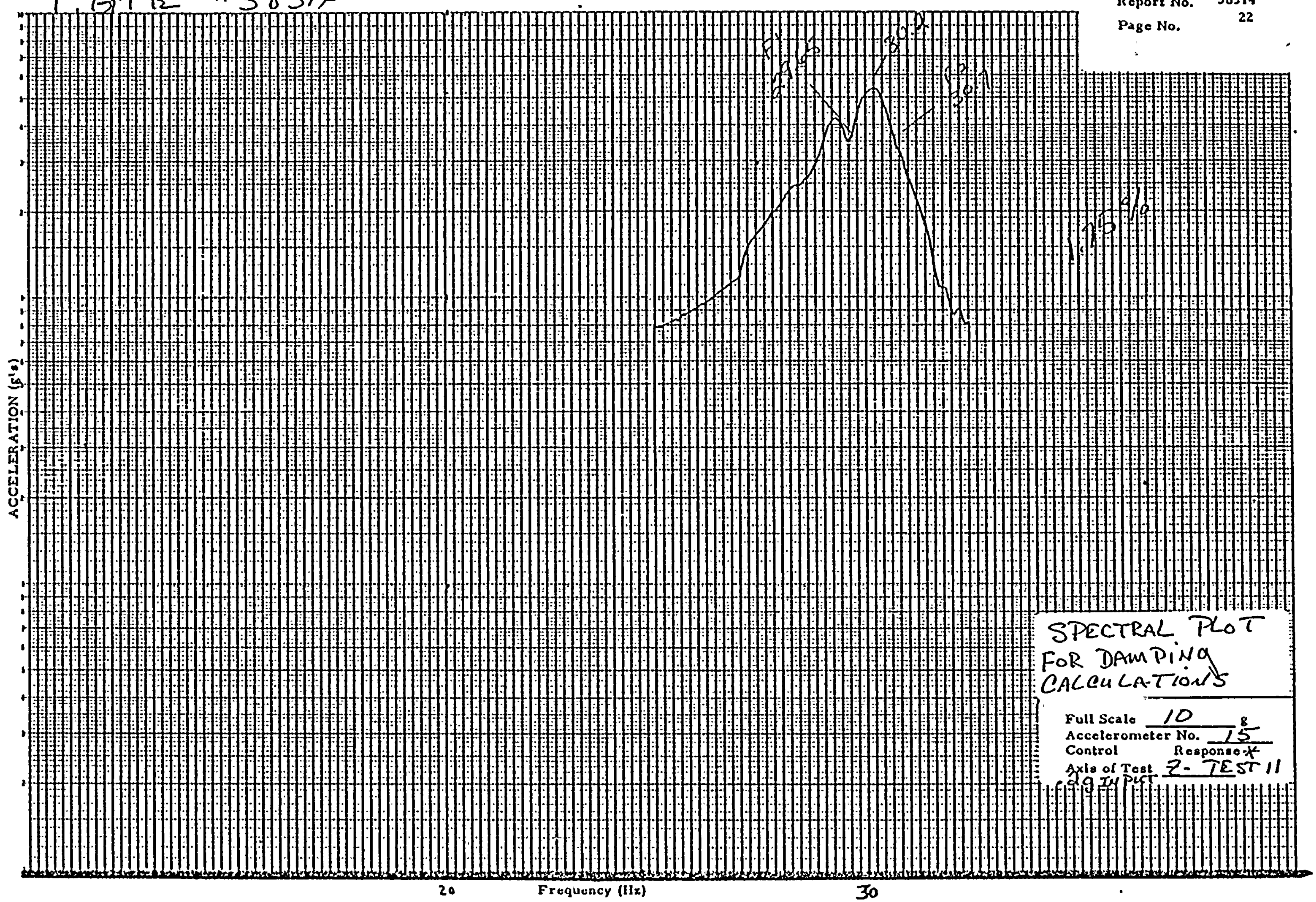
W 614 B

QC Form Approval

SHEET ____ OF ____

P.G+E #58314

Report No. 58314
Page No. 22

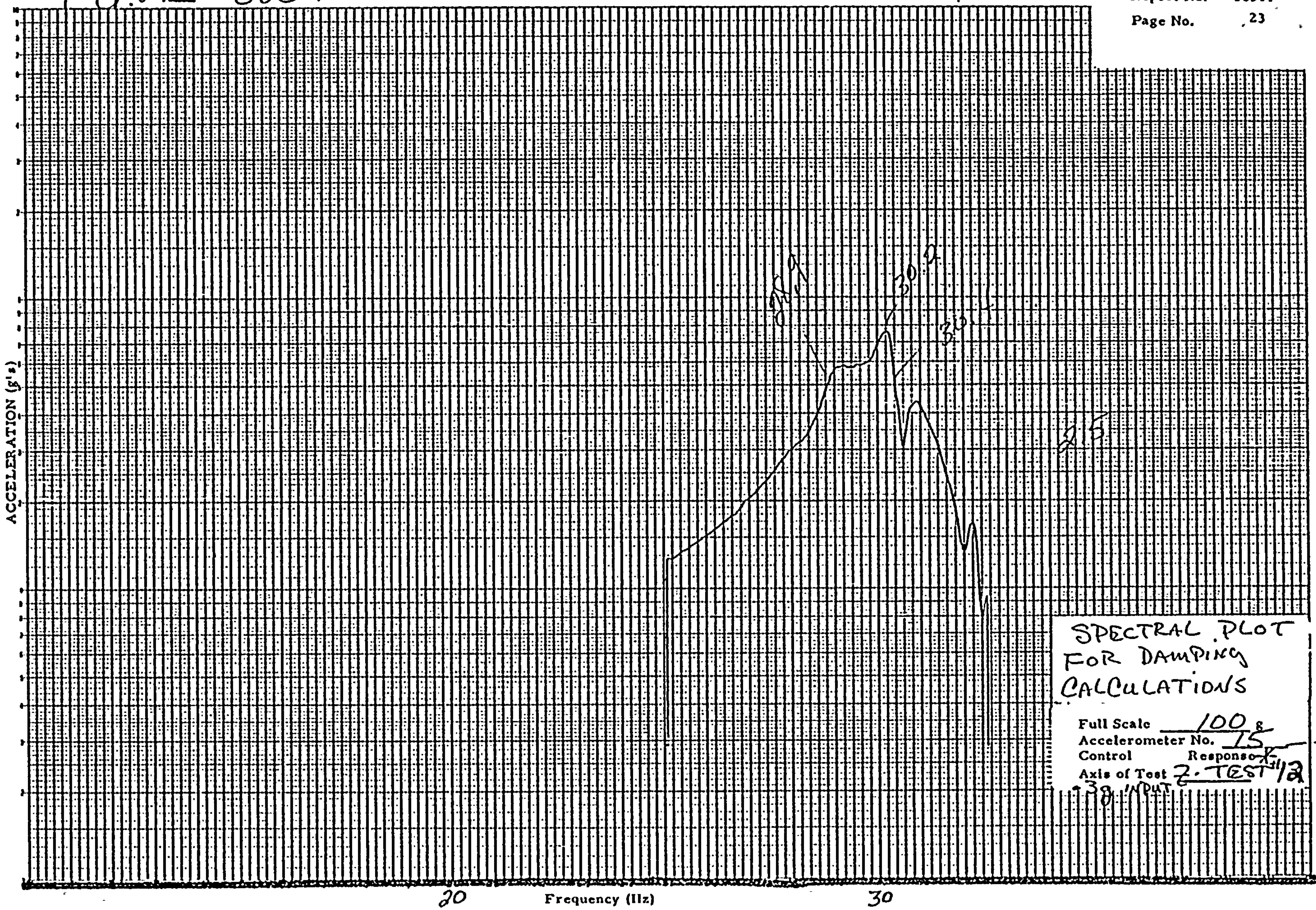


SPECTRAL PLOT
FOR DAMPING
CALCULATIONS

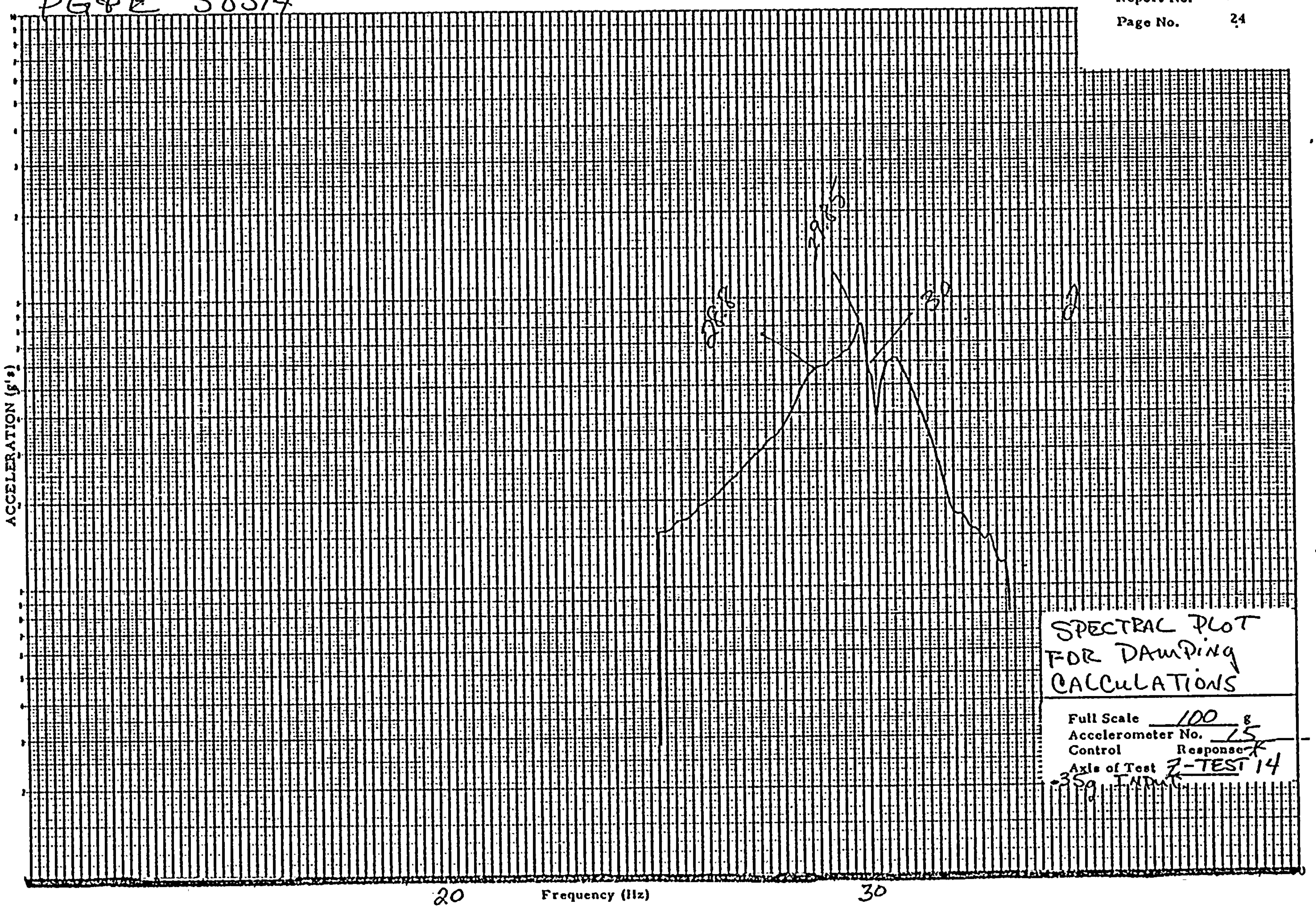
Full Scale 10 g
Accelerometer No. 15
Control Response X
Axis of Test Z- TEST 11
.2g INPUT

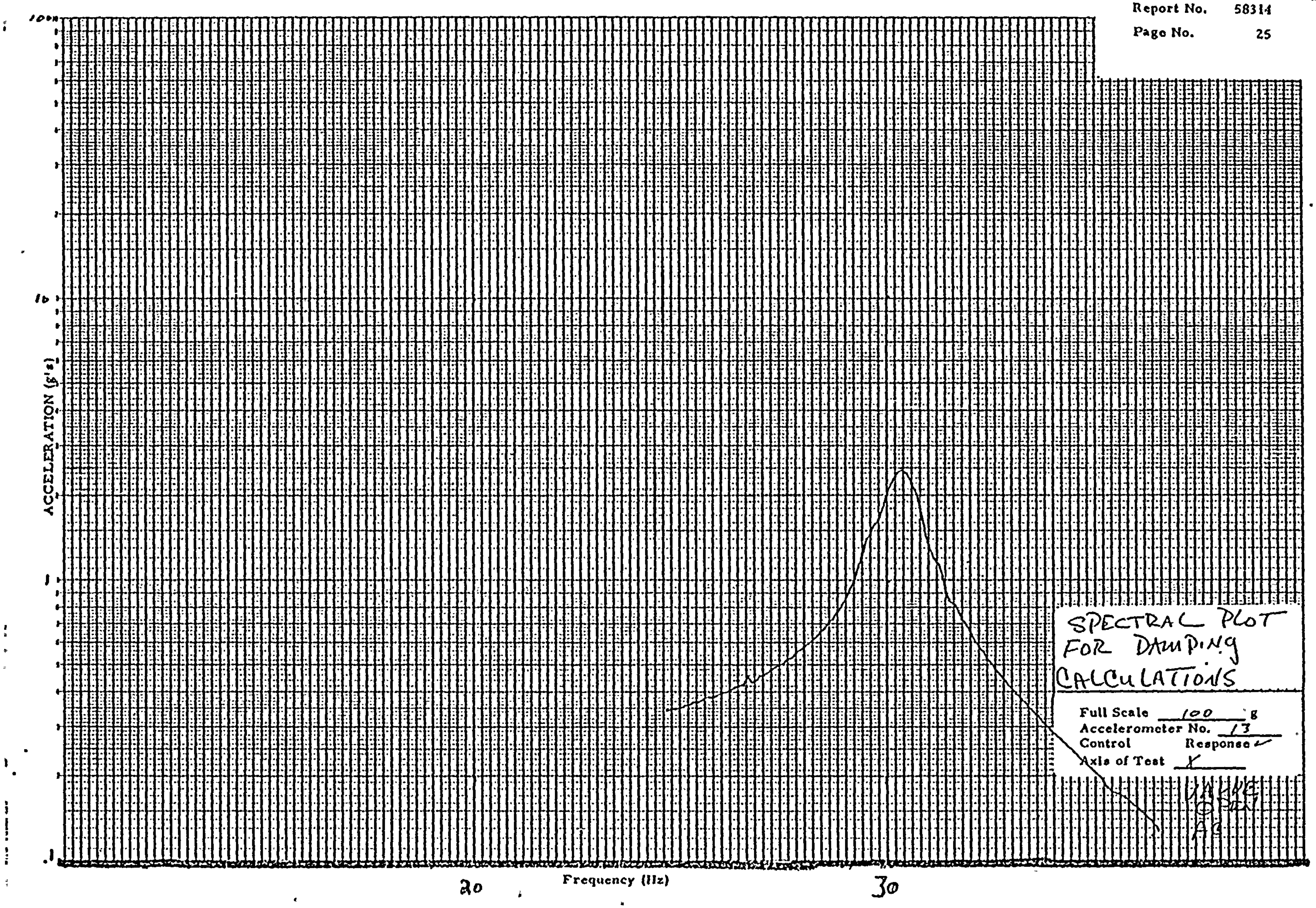
PG+E #58314

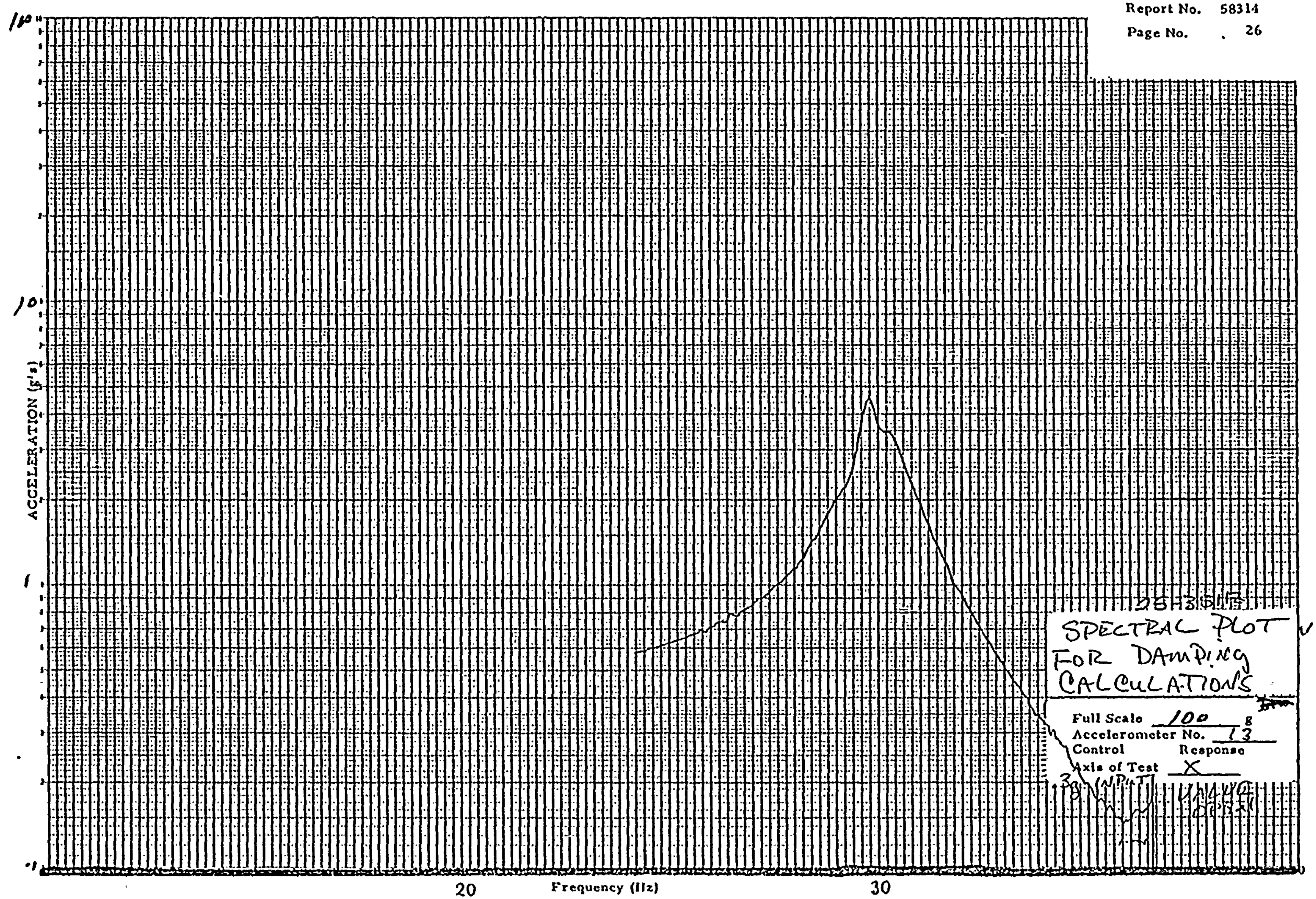
Report No. 58314
Page No. 23

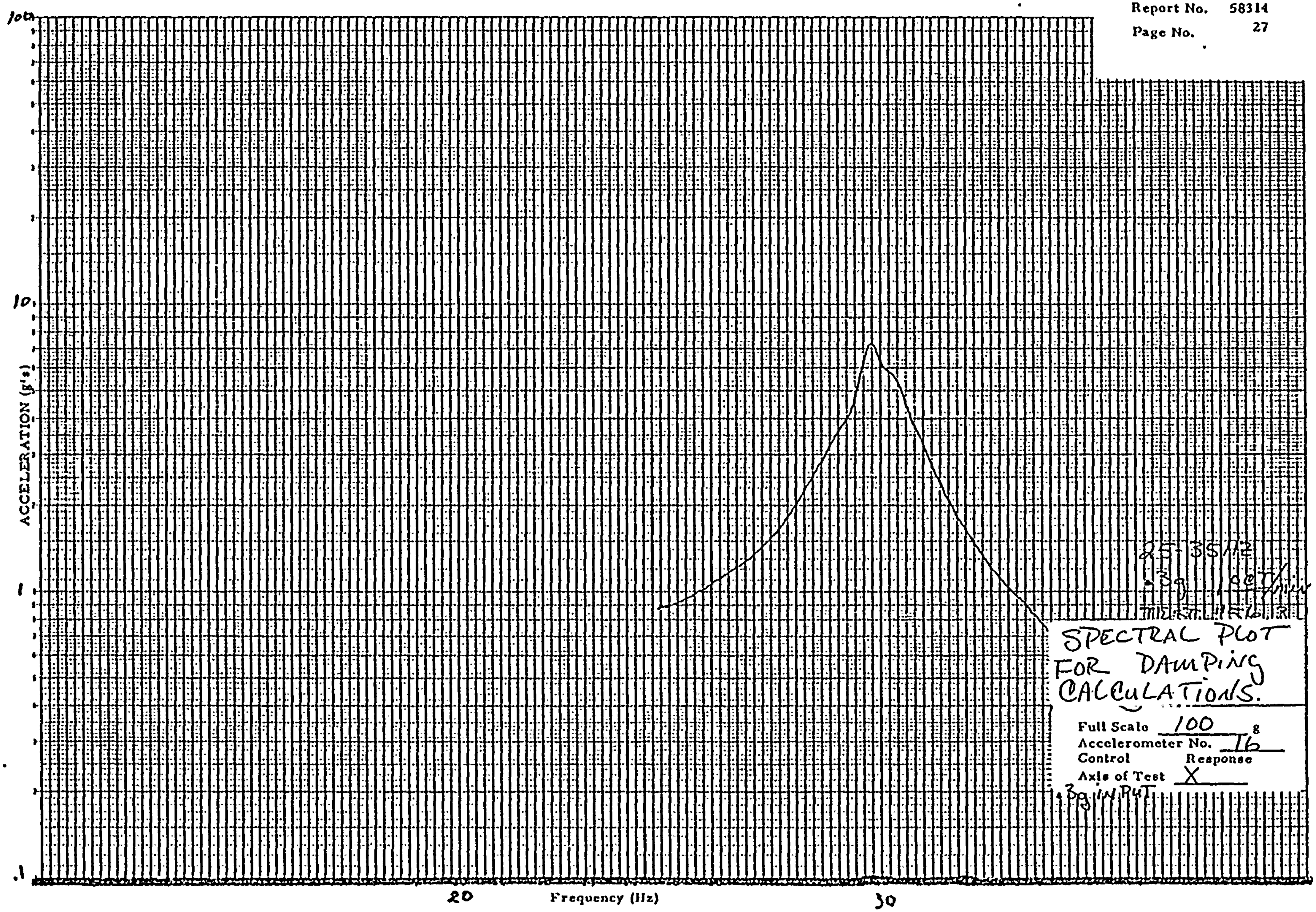


PG&E # 58314


ACCELERATION (g's)
Frequency (Hz)
20
30
28.8
29.85
31
SPECTRAL PLOT FOR DAMPING CALCULATIONS
Full Scale 100 g
Accelerometer No. 25
Control Response X
Axis of Test Z-TEST 14
.35g INPUT


100
10
1
.1
ACCELERATION (g's)
Frequency (Hz)
20
30
SPECTRAL PLOT FOR DAMPING CALCULATIONS
Full Scale 100 g
Accelerometer No. 13
Control Response ✓
Axis of Test X


ACCELERATION (g's)
Frequency (Hz)
20
30
SPECTRAL PLOT FOR DAMPING CALCULATIONS
Full Scale 100 g
Accelerometer No. 13
Control Response
Axis of Test X


10th
10
1
.1
ACCELERATION (g's)
20
Frequency (Hz)
30
25-35 Hz
SPECTRAL PLOT
FOR DAMPING
CALCULATIONS.
Full Scale 100 g
Accelerometer No. 16
Control Response
Axis of Test X
3g INPUT

TEST DATA TABLE

TEST No. 1	DATE: 6-1-78	TIME: 10:00

PRELIMINARY TEST DATA PARA 4.1

TEST RESPONSE SPECTRUM: Fig .... 1 { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: seconds

ACTUATOR MOTOR DATA:
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

MANUAL TO ELECTRICAL CHECK-OUT O.K.

FOR WYLE: JWK
FOR PG&E: PGA.

TEST DATA TABLE

TEST No. 2	DATE: 6-1-78	TIME: 16:15

PARA. 4.3 BASE LINE DATA

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

- Vmax = 480 Volts
- Amax = 7.7 Amps
- Wmax = 2325 Watts
- Runnig Time = 65↑ 66↓ sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

FOR WYLE: DCWK

FOR PG&E: RTK

TEST DATA TABLE

TEST No. 3	DATE: 6-1-78	TIME: 16:42

PARA. 5.1 HORIZONTAL RESONANCE Z-AXIS VALVE CLOSED

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1 & 2	7	11	17	21	—	—	27
DIRECTION						—	—	
STRESS (±)	4630	+1046	21,260	3285	16,848	—	—	9344
% YIELD	4.2%	29%	59%	10.95%	56.16%	—	—	31.15%

NOTES:

30 Hz

FOR WYLE: [signature]
FOR PG&E: RIK

TEST DATA TABLE

TEST No. 4	DATE: 6-1-78	TIME: 17:15

PARA: 5.1 HORIZ. RESONANCE VALVE OPEN Z-AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	11	17	18 & 19	—	—	27
DIRECTION						—	—	
STRESS (±)	11,400	-9067	+14,299	1825	8468	—	—	5606.4
% YIELD	10.36%	25.2%	39.7%	6.1%	28.2%	—	—	18.7%

NOTES:

30 HZ

FOR WYLE: JK

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 5	DATE: 6-1-78	TIME: 17:28

PARA. 5.1 VERTICAL RESONANCE SEARCH VALVE OPEN. Y-AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	11	14	20	—	—	26
DIRECTION						—	—	
STRESS (±)	10,688	10,987	6975	-1460	2920	—	—	73
% YIELD	9.72%	30.5%	19.4%	4.9%	9.7%	—	—	.24%

NOTES:

NO RESONANCES

FOR WYLE: DK

FOR PG&E: RTK

TEST DATA TABLE

TEST No. 6	DATE: 6-1-78	TIME: 17:51

PARA: 5.1 VERTICAL RESONANCE SEARCH VALVE CLOSED Y-AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	8	13	—	20	—	—	—
DIRECTION	—			—		—	—	—
STRESS(±)	—	-697.5	2441	—	730	—	—	—
% YIELD	—	1.9%	6.8%	—	2.4%	—	—	—

NOTES:

NO RESONANCES

FOR WYLE: DK

FOR PG&E: RTK

TEST DATA TABLE

TEST No. 7	DATE: 6-1-78	TIME: 18:03

PARA. 5.1 HORIZ. RESONANCE VALVE CLOSED Z-AXIS

TEST RESPONSE SPECTRUM: Fig .... β = % ; ZPA = g ; PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1 & 2	7 & 8	11	16	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	4275	8704.8	20,228	2555	4380	—	—	—
% YIELD	3.9%	24.2%	56.2%	8.5%	14.6%	—	—	—

NOTES:

30 HZ.

FOR WYLE: DK
FOR PG&E: RK

TEST DATA TABLE

TEST No. 8	DATE: 6-1-78	TIME: 18:27

PARA: 5.4 PEAKING (RESONANCE) (30 Hz) VALVE CLOSED Z AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	11	14	21	—	—	—
DIRECTION						—	—	—
STRESS (±)	3919	9068	18,833	2555	5606	—	—	—
% YIELD	3.6%	25.2%	52.3%	8.52%	18.7%	—	—	—

NOTES:

FOR WYLE: DK
FOR PG&E: RJK

TEST DATA TABLE

TEST No. 9	DATE: 6-2-78	TIME: 13:50

PARAS: 5.4.3 5.4.4 PEAKING RESONANCE FREQUENCY 30 HZ Z AXIS VALVE CLOSED:

TEST RESPONSE SPECTRUM: Fig ....

β = %
ZPA = g
PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

Vmax = Volts
Amax = Amps
Wmax = Watts
Running Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	12	14	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	-8265	20,367	19,612	4088	6570	—	—	—
% YIELD	7.5%	56.6%	53.1%	13.6%	21.9%	—	—	—

NOTES:

FOR WYLE: DK
FOR PG&E: RJK

TEST DATA TABLE

TEST No. 10	DATE: 6-2-78	TIME: 15:05

DAMPING MEASUREMENT
PARA 5.4.4 Z AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	4	7	12	14	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	-6698	20,228	20,018	6351	19,710	—	—	—
% YIELD	6.1%	56.2%	55.6%	21.2%	65.7%	—	—	—

NOTES: Sweep from 2.5-30 HZ @ .2 g
1 OCT/MIN

FOR WYLE: DK
FOR PG&E: RTK

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TEST DATA TABLE

TEST No. 11	DATE: 6-2-78	TIME: 15:55

PARA: 5.4.4 DAMPING MEASUREMENT Z AXIS

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: seconds

ACTUATOR MOTOR DATA { Vmax = Volts ; Amax = Amps ; Wmax = Watts ; Runnig Time = sec }

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	12	14	18	—	—	—
DIRECTION						—	—	—
STRESS (±)	-6911	19,391	20,646	5986	21,170	—	—	—
% YIELD	6.3%	53.9%	57.4%	20.0%	70.6%	—	—	—

NOTES: SWEEP FROM 25-32 HZ @ .2G 1 OCT/MIN

FOR WYLE: [signature]
FOR PG&E: RIK

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TEST DATA TABLE

TEST No. 12	DATE: 6-2-78	TIME: 16:12

PARA: 5.4.4 DAMPING MEASUREMENT Z-AXIS

TEST RESPONSE SPECTRUM: Fig ....
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	12	14	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	6626	24,273	24,831	7796	16,060	—	—	—
% YIELD	6.0%	67.4%	69 %	26.0%	53.5%	—	—	—

NOTES: SWEEP FROM 25-35 HZ @ .3G 1 OCT/MIN

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 13	DATE: 6-2-78	TIME: 16:30

PARA: 5.4.4. DAMPING MEASUREMENT Z AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	12	14	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	-6612	24,971	26,366	7066	20,440	—	—	—
% YIELD	60.1%	69.4%	73.2%	23.6%	68.1%	—	—	—

NOTES: SWEEP FROM 25-35 HZ @ 0.35G 1 OCT/MIN
STOP SWEEP AT 31 HZ DUE TO YIELD FACTOR

FOR WYLE: DK
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 14	DATE: 6-2-78	TIME: 16:35

PARA: 5.4.4 DAMPING MEASUREMENT Z AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	12	15	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	-4133	20,786	20,088	3562	10,950	—	—	—
% YIELD	3.8%	57.7%	55.8	11.9%	36.5%	—	—	—

NOTES: SWEEP FROM 25-35 HZ AT .35G 1 OCT/MIN

FOR WYLE: [signature]
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 15	DATE: 6-2-78	TIME: 17:31

PARA: 6.1 SINE BEAT F=2HZ. Z AXIS

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.7 Amps
- Wmax = 2475 Watts
- Runnig Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.12	.12	.23	.12	.3	.9	1	1.4
Y	.07	.07	.07	.07	4.5	1.4	.9	.8
Z	.95	1.05	1.1	1.1	1.3	1.7	1.8	2.2

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	4	7	10	14				
DIRECTION								
STRESS (±)	-4133	12416	9835	5256				
% YIELD	3.76%	34.5%	27.3%	17.5%				

NOTES: 2HZ SINE BEAT 30 SEC DURATION .85G

FOR WYLE: JK

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 16	DATE: 6-2-78	TIME: 17:51

PARA: 6.1 SINE BEAT F=4 HZ Z AXIS

TEST RESPONSE SPECTRUM: Fig ...... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.7 Amps
- Wmax = 2475 Watts
- Runnig Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.3	.3	.4	.3	.3	1.4	1.7	2.2
Y	.55	.4	.45	.42	.47	2.1	1.1	.9
Z	2.05	2.05	2.25	2.5	2.8	2.8	3	4.9

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	4	5	11	14				
DIRECTION								
STRESS (±)	2351	3418	-6836	3212				
% YIELD	2.1%	9.5%	19.0%	10.7%				

NOTES: SINE BEAT AT 4HZ 30 SEC: 1.8 G's

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 17	DATE: 6.2.79	TIME: 18:14

PARA: 6.1 SINE BEAT F=6 HZ Z AXIS

TEST RESPONSE SPECTRUM: Fig ...... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: seconds

ACTUATOR MOTOR DATA:
- Vmax = 471 Volts
- Amax = 6.8 Amps
- Wmax = 1950 Watts
- Runnig Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER A0	A1	A2	A3	A4	A5	A6	A7
X	.25	.3	.55	.4	.65	2	2	4.6
Y	.5	.4	.52	.48	.6	2.4	1.3	1
Z	2.67	2.61	2.77	2.95	3.5	3.7	3.6	9

MAXIMUM RECORDED STRESS (psi)

LOCATION	S1	S2	S3	S4	S5	S6	S7	S8
GAGE No.	4	5	13	14	18	—	—	—
DIRECTION						—	—	—
STRESS (±)	1283	4046	4185	4263	5110	—	—	—
% YIELD	1.2%	11.2%	11.6%	14.2%	17.0%	—	—	—

NOTES: SINE BEAT AT 6 HZ 30 SEC DURATION 2.5 G

FOR WYLE: [signature]
FOR PG&E: RJK

TEST DATA TABLE

TEST No. 18	DATE: 6-2-78	TIME: 18:29

PARA: 6.1 SINE BEAT F = 8 HZ Z AXIS

TEST RESPONSE SPECTRUM: Fig ....

- β = . %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

- Vmax = 471 Volts
- Amax = 6.8 Amps
- Wmax = 1920 Watts
- Running Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.45	.55	.8	.45	1.5	3	3.3	6.6
Y	.8	.68	.68	.8	.95	3.5	2.1	1.3
Z	3.65	3.64	3.78	4.65	6	6.3	6.6	12.2

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	4	5	10 & 13	14	19	—	25	27
DIRECTION						—		
STRESS (±)	-499	4394	4883	3197	6570	—	4672	2803
% YIELD	0.45%	12.2%	13.6%	10.7%	21.9%	—	15.6%	9.3%

NOTES: SINE BEAT AT 8HZ 30SEC. 3.6 G

FOR WYLE: [signature]
FOR PG&E: RK

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TEST DATA TABLE

TEST No. 19	DATE: 6-2-78	TIME: 19:04

PARA: 6.1 SINE BEAT 10 HZ Z AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.56 Amps
- Wmax = 2340 Watts
- Runnig Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.6	.8	1.05	.6	2.55	7.8	7.8	6.6
Y	.75	.83	.83	.9	1.78	6.4	4.8	2.7
Z	3.4	3.45	3.55	2.18	8.65	9	10.6	10.6

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	7	11	14	19	—	—	27
DIRECTION						—	—	
STRESS (±)	-8693	18135	17,716	7519	17,520	—	—	6541
% YIELD	7.9%	50.4%	49.2%	25.1%	58.4%	—	—	21.8%

NOTES: SINE BEAT 10 HZ 30 SEC 3.6 G

FOR WYLE: DK
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 20	DATE: 6-2-78	TIME: 21:13

PARA: 6.1 SINE BEAT 12 HZ. Z AXIS

TEST RESPONSE SPECTRUM: Fig ...... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

- Vmax = 480 Volts
- Amax = 7.5 Amps
- Wmax = 2310 Watts
- Runnig Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.5	.7	.7	.45	.87	3.6	3.7	6
Y	1.25	.68	.88	.85	.89	5.4	2.2	1.8
Z	3.68	3.43	3.73	4.4	4.8	5.2	5.5	12.9

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	5	11	14	18 & 19	—	—	27
DIRECTION	—					—	—	
STRESS (±)	—	4255	17,019	18,133	5840	—	—	4672
% YIELD	—	11.8%	47.3%	60.4%	19.5%	—	—	15.6%

NOTES: SINE BEAT AT 12 HZ 30 SECONDS : 3.6 G

FOR WYLE:	DK
FOR PG&E:	RK

TEST DATA TABLE

TEST No. 21	DATE: 6-2-78	TIME: 21:35

PARA: 6.1 SINE BEAT 16 HZ Z AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.0 Amps
- Wmax = 2070 Watts
- Runnig Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.92	.78	.74	.49	1.05	4.1	4.5	8.1
Y	1.58	.74	.88	.95	1.1	5.6	2.8	2
Z	4.19	3.63	3.7	4.53	5.9	6.8	7.1	14.7

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	5	11	17	19	—	—	26
DIRECTION						—	—	
STRESS (±)	1710	4185	41,850	4380	9490	—	—	8410
% YIELD	1.6%	11.6%	116 %	14.6%	31.6%	—	—	28.0%

NOTES: Sine Beat 30 Sec. @ 16 Hz 3.6 G

FOR WYLE: [signature]
FOR PG&E: RMK

TEST DATA TABLE

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TEST No. 22	DATE: 6-2-78	TIME: 21:50

PARA: 6.1 SINE BEAT 20 HZ Z AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 6.8 Amps
- Wmax = 2010 Watts
- Runnig Time = 30 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.38	.6	.8	.48	1.56	5.8	3.8	8
Y	1.45	.7	.68	.73	1.3	4.9	2.7	2.3
Z	3.22	3.45	3.27	4.58	7.4	7.8	8.2	17.8

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	5	11	14	19	—	—	27
DIRECTION						—	—	
STRESS (±)	1781	4883	29,016	2847	10,220	—	—	7475
% YIELD	1.6%	13.6%	80.6%	9.5%	34.1%	—	—	24.9%

NOTES: Sine Beat at 20HZ 30sec 3.6G

FOR WYLE: DK
FOR PG&E: RJK

TEST DATA TABLE

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TEST No. 23	DATE: 6-2-78	TIME: 23:39

PARA: 6.1 SINE BEAT 24 HZ Z AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.7 Amps
- Wmax = 2160 Watts
- Runnig Time = 1.2 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.5	1.45	1.3	1.18	6.5	15	11.6	25
Y	2.09	1.87	1.93	2.4	7.4	16.6	8.9	5.7
Z	3.2	4.2	3.59	3.9	19.5	17.4	23.5	46.5

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	1	8	10	14	18	—	—	27
DIRECTION						—	—	
STRESS (±)	-8051	20,646	27,537	9563	24,820	—	—	-4672
% YIELD	7.3%	57.4 %	76.5 %	31.9 %	82.7 %	—	—	15.6 %

NOTES: Sine BEAT 30 SEC 24 HZ 3.6 G.
"ELECTRICAL CONDUIT LINE ON MOTOR CONTROL BROKE OFF. VALVE STOP CYCLING DURING 30SEC. RUN. ACTUATOR SWITCH BROKEN. RETORQUE BOLTS ON MOTOR AND CHECK TORQUE OF ALL BOLTS

FOR WYLE: DK
FOR PG&E: RMK

TEST DATA TABLE

TEST No. —	DATE: 6-3-78	TIME: 14:37

LOW LEVEL SEISMIC RANDOM (Z-Y)

TEST RESPONSE SPECTRUM: Fig —
- β = %
- ZPA = — g
- PEAK = — g

SHAKING TIME: seconds 30

ACTUATOR MOTOR DATA
- Vmax = — Volts
- Amax = — Amps
- Wmax = — Watts
- Running Time = — sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 24	DATE: 6-3-78	TIME: 15:01

PARA: 6-2

1ST OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ....

- β = . %
- ZPA = g
- PEAK = g

SHAKING TIME: 30 seconds

ACTUATOR MOTOR DATA

- Vmax = — Volts
- Amax = — Amps
- Wmax = — Watts
- Runnig Time = — sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	5	10 & 11	15	18 & 19	—	—	—
DIRECTION	—					—	—	—
STRESS(±)	—	1046	1395	1095	2920	—	—	—
% YIELD	—	2.90 %	3.8 %	3.7 %	9.7 %	—	—	—

NOTES:

FOR WYLE: RK
FOR PG&E: RJK

TEST DATA TABLE

TEST No. 25	DATE: 7-26-78	TIME: 10:36

PARA: 6.2 20 SEC.
2ND. OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.5 Amps
- Wmax = 2250 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	—	11	—	19	—	—	27
DIRECTION	—	—		—		—	—	
STRESS (±)	—	—	4185	—	6570	—	—	4380
% YIELD	—	—	11.6 %	—	21.9 %	—	—	14.6 %

NOTES:

FOR WYLE: [signature]
FOR PG&E: RMK

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TEST DATA TABLE

TEST No. 26	DATE: 7-26-78	TIME: 10:47

PARA: 6.2 (20 SEC)
3RD OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.1 Amps
- Wmax = 2220 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A0	A1	A2	A3	A4	A5	A6	A7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S1	S2	S3	S4	S5	S6	S7	S8
GAGE No.	—	—	—	—	19	—	—	27
DIRECTION	—	—	—	—		—	—	
STRESS (±)	—	—	—	—	3285	—	—	4015
% YIELD	—	—	—	—	10.95 %	—	—	13.4 %

NOTES:

FOR WYLE: DK

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 27	DATE: 7-26-78	TIME: 11:01

PARA: 6.2 20 SEC.
4TH OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- V_{max} = 480 Volts
- A_{max} = 7.5 Amps
- W_{max} = 2100 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	—	11	—	19	—	—	27
DIRECTION	—	—		—		—	—	
STRESS (±)	—	—	+ 2790	—	3285	—	—	4015
% YIELD	—	—	7.8 %	—	10.95 %	—	—	13.4 %

NOTES:

FOR WYLE: [signature]
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 28	DATE: 7-26-78	TIME: 11:08

PARA: 6.2

5TH OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 7.35 Amps
- Wmax = 2145 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A0	A1	A2	A3	A4	A5	A6	A7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S1	S2	S3	S4	S5	S6	S7	S8
GAGE No.	—	—	—	—	19	—	—	27
DIRECTION	—	—	—	—		—	—	
STRESS (±)	—	—	—	—	3650	—	—	4015
% YIELD	—	—	—	—	12.2 %	—	—	13.4 %

NOTES:

FOR WYLE: DK

FOR PG&E: RMK

TEST DATA TABLE

TEST No. 29	DATE: 7-26-78	TIME: 11:25

PARA: 6.2
6TH OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.35 Amps
- Wmax = 2085 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	—	—	—	19	—	—	27
DIRECTION	—	—	—	—		—	—	
STRESS (±)	—	—	—	—	3650	—	—	4015
% YIELD	—	—	—	—	12.2 %	—	—	13.4 %

NOTES:

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FOR PG&E: RJK

TEST DATA TABLE

TEST. No. 30	DATE: 7-26-78	TIME: 11:30

PARA: 6.2
7TH OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.5 Amps
- Wmax = 2250 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE. No.	3	7	11	14	19	—	—	27
DIRECTION						—	—	
STRESS (±)	13,538	17,612	10,811	12,483	12,410	—	—	3285
% YIELD	12.3%	48.9%	30.0%	41.6%	41.4%	—	—	10.95%

NOTES:

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FOR PG&E: [signature]

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TEST DATA TABLE

TEST No. 31	DATE: 7-26-78	TIME: 11:39

PARA: 6.2

8TH OBE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig Pg. 106, 107
- β = H-2%, V-2%
- ZPA = H-3.0g, V-3.6g
- PEAK = — g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 6.8 Amps
- Wmax = 2145 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	—	11	—	19	—	—	27
DIRECTION	—	—		—		—	—	
STRESS (±)	—	—	2790	—	3650	—	—	3285
% YIELD	—	—	7.8 %	—	12.2 %	—	—	11.0 %

NOTES:

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FOR PG&E: [signature]

TEST DATA TABLE

TEST No. 32	DATE: 7-26-78	TIME: 11:50

PARA: 6.2

1ST SSE Z-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig Pg. 108, 109
- β = H-2 / V-2 %
- ZPA = H-10.5 / V-6.5 g
- PEAK = — g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 475 Volts
- Amax = 6.7 Amps
- Wmax = 2100 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7 & 8	10 & 11	14	18 & 19	—	—	27
DIRECTION	—					—	—	
STRESS (±)	—	3488	4883	4818	8760	—	—	3285
% YIELD	—	9.7 %	13.6 %	16.1 %	29.2 %	—	—	11.0 %

NOTES:

FOR WYLE: [signature]

FOR PG&E: [signature]

TEST DATA TABLE

TEST No. 33	DATE: 7-26-78	TIME: 14:30

PARA: 6.1 24 HZ SINE BEAT Z AXIS 1/3 LEVEL

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = — Volts
- Amax = — Amps
- Wmax = — Watts
- Runnig Time = — sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.7	.7	.5	.7	.9	4.5	.9	7.0
Y	.8	.8	.6	.6	.7	2.3	1.2	.9
Z	1.5	2.1	1.8	5	6.0	6.3	6.9	21

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	5	10	—	19	—	—	27
DIRECTION	—			—		—	—	
STRESS(±)	—	3125	7812	—	7665	—	—	3650
% YIELD	—	8.7 %	21.7 %	—	25.6 %	—	—	12.2%

NOTES:

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 34	DATE: 7-26-78	TIME: 14:43

PARA: 6.1 24 HZ SINE BEAT 2/3 LEVEL Z-AXIS

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.7 Amps
- Wmax = 1950 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.8	.8	.7	.7	1.0	5.8	1.3	10.0
Y	.9	.9	1.0	1.0	.9	5.8	1.9	1.6
Z	1.9	2.5	2.2	6.0	7	8.5	9.7	23

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3&4	5	10	14	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	3563	5000	10,602	4088	10,950	—	—	—
% YIELD	32.4 %	13.9 %	29.5 %	13.6 %	36.5 %	—	—	—

NOTES:

FOR WYLE: [signature]
FOR PG&E: KTK

TEST DATA TABLE

TEST No. 35	DATE: 7-26-78	TIME: 15:12

PARA 6.1 24 HZ Z AXIS SINE BEAT FULL LEVEL

TEST RESPONSE SPECTRUM: Fig ....

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 466 Volts
- Amax = 6.7 Amps
- Wmax = 1875 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.4	1.5	1.0	2.0	2.8	14.0	4.6	17.5
Y	4.1	2.9	2.9	4.9	3.0	14.5	6.4	3.8
Z	3.3	5.2	4.0	13.5	16.5	17.7	24.0	48.0

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	6	10	14	19	—	24	—
DIRECTION	—					—		—
STRESS (±)	—	11,509	23,157	10,103	24,820	—	6570	—
% YIELD	—	32.0 %	64.3 %	33.7 %	82.7 %	—	21.9 %	—

NOTES:

FOR WYLE:	[signature]
FOR PG&E:	RTK

TEST DATA TABLE

TEST No. 36	DATE: 7-26-78	TIME: 15:35

(2 BEATS)
PARA: 6.1 Z AXIS SINE BEAT 30.2 HZ 1/3 LEVEL

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 2 seconds

ACTUATOR MOTOR DATA
- Vmax = 466 Volts
- Amax = 6.65 Amps
- Wmax = 1875 Watts
- Runnig Time = 2 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.2	1.0	.8	1.0	2.7	9.1	4.6	19.9
Y	1.3	1.1	.8	1.0	1.8	8.0	4.8	1.5
Z	1.2	1.3	1.3	6.1	8.6	9.8	12.0	37.0

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3	7	10	15	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	-11,756	16,043	13,810	7673	27,156	—	—	—
% YIELD	106.9%	44.6%	38.4%	25.6%	90.5%	—	—	—

NOTES:

FOR WYLE: [signature]
FOR PG&E: RJK

TEST DATA TABLE

TEST No. 37	DATE: 7-26-78	TIME: 15:39

(2 BEATS)
PARA: 6.1 Z AXIS 30 HZ 2/3 LEVEL

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 2 seconds

ACTUATOR MOTOR DATA
- Vmax = 456 Volts
- Amax = 6.37 Amps
- Wmax = 1875 Watts
- Running Time = 2 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.8	1.8	1.4	2.0	4.5	20.5	6.6	28.0
Y	1.5	1.2	1.1	0.6	2.9	13.0	6.0	3.8
Z	2.2	2.2	2.4	10.0	13.7	17.0	21.0	50.0

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	6	13	15	19	23	24	—
DIRECTION	—							—
STRESS (±)	—	12,904	21,483	9428	39,055	5548	4380	—
% YIELD	—	35.8 %	59.7 %	33.1 %	130.2 %	18.5 %	14.6 %	—

NOTES:

FOR WYLE: RF
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 38	DATE: 7-26-78	TIME: 1630

30 HZ.

PARA: 6.1 SINE BEAT Z AXIS FULL LEVEL

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: 6 seconds

ACTUATOR MOTOR DATA
- Vmax = 466 Volts
- Amax = 6.5 Amps
- Wmax = 1875 Watts
- Runnig Time = 6 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	3.0	2.9	2.4	3.0	5.6	26.5	8.9	30.5
Y	1.8	1.6	1.0	1.5	3.4	20.2	7.9	4.5
Z	3.9	4.0	3.6	15.6	23.5	23.7	26.0	75.0

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2 & 4	8	11 & 13	14	19	23	24	26
DIRECTION								
STRESS (±)	3563	18,135	30,272	14,162	40,880	6643	8760	7300
% YIELD	32.4 %	50.4 %	84.1 %	47.2 %	136.3 %	22.1 %	29.2 %	24.3 %

NOTES: STOP TEST AFTER FOUR SINE BEATS DUE TO VALVE HANDLE COMMING OFF

FOR WYLE: RK

FOR PG&E: KTK

TEST DATA TABLE

TEST No. 39	DATE: 7-26-78	TIME: 18:00

PARA: 6.1 30 Hz (9) SINE BEATS Z AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.86 Amps
- Wmax = 1995 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	3.8	3.0	2.2	2.4	6.3	21.9	7.1	26.6
Y	2.2	1.8	1.3	3.9	5.4	19.6	6.3	5.6
Z	3.5	3.7	3.7	9.6	22.3	24.8	29.7	76

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3	8	10	14	19	22	24	26
DIRECTION								
STRESS (±)	9619	16,740	31,946	17,082	30,952	5548	4380	6278
% YIELD	87.4 %	46.5 %	88.7 %	56.9 %	103.2 %	18.5 %	14.6 %	20.9 %

NOTES:

FOR WYLE:	RK
FOR PG&E:	RJK

TEST DATA TABLE

TEST No. 40	DATE: 7-26-78	TIME: 18:10

PARA: 6.1 32 HZ SINE BEAT 2 BEATS 1/3 LEVEL

TEST RESPONSE SPECTRUM: Fig .... 1. { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: 2 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.0 Amps
- Wmax = 1950 Watts
- Runnig Time = 2 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.8	.8	.3	.9	2.6	5.6	3.4	26.0
Y	.4	.3	.3	.5	1.8	8.8	3.8	1.2
Z	1.1	1.2	1.8	5.0	6.5	7.0	8.9	38

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	5	12	14	18	—	—	—
DIRECTION	—					—	—	—
STRESS (±)	—	7812	-10,463	4088	9490	—	—	—
% YIELD	—	21.7 %	29.1 %	13.6 %	31.6 %	—	—	—

NOTES:

FOR WYLE: DE
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 41	DATE: 7-26-78	TIME: 18:15

PARA: 6.1 32 HZ 2 BEATS SINE BEATS Z AXIS 2/3 LEVEL

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 2 seconds

ACTUATOR MOTOR DATA
- Vmax = 475 Volts
- Amax = 7.0 Amps
- Wmax = 2010 Watts
- Running Time = 2 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.3	1.2	1.3	1.8	3.7	15.7	5.5	31
Y	1.0	.7	.8	3.0	2.4	14.2	4.8	3.4
Z	2.4	2.0	3.0	7.5	11.9	13.4	18.2	4.5

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3 & 4	7	11	14	19	23	—	26
DIRECTION							—	
STRESS (±)	3919	11,509	17,717	8468	20,732	8030	—	3358
% YIELD	35.6 %	32.0 %	49.2 %	28.2 %	69.1 %	26.8 %	—	11.2 %

NOTES:

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FOR PG&E: RJK

TEST DATA TABLE

TEST No. 42	DATE: 7-26-78	TIME: 18:23

(9 BEATS)
PARA: 61 32 Hz Z AXIS FULL LEVEL SINE BEAT

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 7.07 Amps
- Wmax = 1980 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.8	1.6	2.0	2.5	5.7	21.7	9.1	33.8
Y	1.6	1.2	1.4	4.8	4.8	22.6	6.3	5.4
Z	3.6	3.4	3.8	10.9	16.5	20.1	23.0	69.0

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3	7	11	14	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	3563	13,601	24,692	10,658	30,952	—	—	—
% YIELD	32.4%	37.8 %	68.6 %	35.5 %	103.2 %	—	—	—

NOTES: BROKEN CONTACT BLOCK AUX SWITCHES DUE TO MOUNTING SCREWS WORKING LOOSE

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FOR PG&E: RJK

TEST DATA TABLE

TEST No. 43	DATE: 7-26-78	TIME: 18:45

PARA: 6.1 SINE BEAT (9) FULL LEVEL Z AXIS 32 HZ.

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.35 Amps
- Wmax = 2160 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.8	1.7	1.7	2.6	5.1	19.2	12.9	12.6
Y	1.5	1.3	1.5	5.0	4.8	24.8	11.9	6.4
Z	3.7	3.7	3.8	12.0	16.5	19.1	8.9	71.6

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3	7	10	14	19	—	—	26
DIRECTION						—	—	
STRESS (±)	5700	16,043	24,971	9928	30,952	—	—	3358
% YIELD.	51.8%	44.6 %	69.4%	33.1 %	103.2 %	—	—	11.2 %

NOTES:

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FOR PG&E: RTK

TEST DATA TABLE

TEST No. 44	DATE: 7-27-78	TIME: 11:17

PARA: 6.1 SINE BEAT 2HZ Y AXIS

TEST RESPONSE SPECTRUM: Fig ...... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA:
- Vmax = 480 Volts
- Amax = 7.35 Amps
- Wmax = 2100 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A0	A1	A2	A3	A4	A5	A6	A7
X	.2	.29	.15	.99	.90	1.20	1.45	4.20
Y	.85	.9	.78	.91	1.20	.90	1.30	1.20
Z	.22	.23	.18	.19	.23	.35	.63	1.21

MAXIMUM RECORDED STRESS (psi)

LOCATION	S1	S2	S3	S4	S5	S6	S7	S8
GAGE No.	—	8	12	15	—	—	—	—
DIRECTION	—				—	—	—	—
STRESS (±)	—	3139	-5580	-3796	—	—	—	—
% YIELD	—	8.7 %	15.5 %	12.6 %	—	—	—	—

NOTES:

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FOR PG&E: KTK

TEST DATA TABLE

TEST No. 45	DATE: 7-27-78	TIME: 11:24

PARA: 6.1 SINE BEAT 4HZ Y AXIS

TEST RESPONSE SPECTRUM: Fig ......

β = %
ZPA = g
PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

Vmax = 475 Volts
Amax = 7.14 Amps
Wmax = 1950 Watts
Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.28	.45	.19	.71	1.50	2.15	1.54	4.45
Y	1.58	1.59	1.62	1.73	2.10	2.10	2.20	1.70
Z	.35	.30	.25	.34	.45	.48	1.47	4.55

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7	13	15	20	—	—	—
DIRECTION	—					—	—	—
STRESS (±)	—	3488	-5301	-3796	3285	—	—	—
% YIELD	—	9.7 %	14.7%	12.7 %	11.0 %	—	—	—

NOTES:

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FOR PG&E: RJK

TEST DATA TABLE

TEST No. 46	DATE: 7-27-78	TIME: 11:44

PARA: 6.1 SINE BEAT 6HZ Y AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 480 Volts
- Amax = 7.14 Amps
- Wmax = 2025 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.20	.50	.28	1.11	1.63	2.84	1.79	5.2
Y	2.4	2.2	2.7	2.70	2.80	2.80	2.4	2.7
Z	.49	.45	.35	.50	.76	.73	4.3	4.9

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3	7	13	15	20 & 21	—	—	—
DIRECTION						—	—	—
STRESS (±)	-11,756	14,473	7742	-3796	3504	—	—	—
% YIELD	107.0 %	40.2 %	21.5 %	12.7 %	11.7 %	—	—	—

NOTES:

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TEST DATA TABLE

TEST No. 47	DATE: 7-27-78	TIME: 11:55

PARA: 6.1 8HZ SINE BEAT Y AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- V_{max} = 480 Volts
- A_{max} = 6.8 Amps
- W_{max} = 2100 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.39	.15	4.7	1.5	2.31	4.15	3.00	13.8
Y	3.8	3.8	3.8	3.8	3.7	4.40	4.80	3.4
Z	.9	.7	.6	.95	1.6	1.70	8.6	11.4

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3.	7	12	15	21	—	—	—
DIRECTION						—	—	—
STRESS (±)	-11,756	21,623	-12,555	-4161	6059	—	—	—
% YIELD	106.9%	60.1 %	34.9%	13.9%	20.2	—	—	—

NOTES:

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FOR PG&E: RJK

TEST DATA TABLE

TEST No. 48	DATE: 7-27-78	TIME: 13:37

PARA: 6.1 10 HZ SINE BEAT Y AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 6.65 Amps
- Wmax = 1980 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.4	1.06	.41	1.65	2.25	3.05	2.34	8.90
Y	3.5	3.3	3.70	3.7	4.10	4.00	4.30	3.70
Z	.5	.65	.50	.80	1.30	1.30	5.90	6.80

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7 & 8	13	15	20	—	—	—
DIRECTION	—					—	—	—
STRESS (±)	—	3836	-8091	-3796	4088	—	—	—
% YIELD	—	10.7%	27.5%	12.7%	13.6%	—	—	—

NOTES:

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TEST DATA TABLE

TEST No. 49	DATE: 7-27-78	TIME: 13:42

PARA: 6.1 12 Hz SINE BEAT Y AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 6.3 Amps
- Wmax = 1965 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.48	.79	.40	1.39	2.52	3.2	2.76	8.60
Y	2.6	2.7	3.5	3.5	3.8	4.3	3.80	3.50
Z	.50	.60	.61	.71	1.08	1.15	4.95	8.36

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	6	13	15	20	—	—	—
DIRECTION	—					—	—	—
STRESS (±)	—	5231	-7394	-3796	3723	—	—	—
% YIELD	—	14.5 %	20.5 %	12.7 %	12.4 %	—	—	—

NOTES:

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FOR PG&E: RJK

TEST DATA TABLE

TEST No. 50	DATE: 7-27-78	TIME: 14:25

PARA: 61 16 HZ SINE BEAT Y AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 6.8 Amps
- Wmax = 1875 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.85	1.10	.80	1.11	2.29	4.00	2.95	13.3
Y	3.1	2.9	3.4	3.3	3.2	3.80	4.30	3.2
Z	.80	.79	.51	.93	1.12	1.28	5.70	13.2

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7 & 8	13	15	20	—	—	—
DIRECTION	—					—	—	—
STRESS (±)	—	7673	-10,184	-3796	5548	—	—	—
% YIELD	—	21.3%	28.3%	12.7%	18.5%	—	—	—

NOTES:

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FOR PG&E: KJK

TEST DATA TABLE

TEST No. 51	DATE: 7-27-78	TIME: 14:37

PARA: 6.1 20 HZ SINE BEAT Y AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 466 Volts
- Amax = 6.65 Amps
- Wmax = 1815 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.95	1.24	.70	.88	1.28	3.65	1.79	6.70
Y	3.3	3.10	3.80	4.2	3.8	5.10	4.70	3.98
Z	.49	.68	.63	.98	.95	1.06	5.70	7.10

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	8	12	15	19 & 21	—	—	—
DIRECTION	—					—	—	—
STRESS (±)	—	4534	-5580	-3796	3212	—	—	—
% YIELD	—	12.6%	15.5%	12.7%	10.7%	—	—	—

NOTES:

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TEST DATA TABLE

TEST No. 52	DATE: 7-27-78	TIME: 14:35

PARA: 6.1 24 HZ SINE BEAT Y AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.8 Amps
- Wmax = 1995 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.4	1.79	1.39	1.89	3.05	3.51	3.50	10.5
Y	2.8	2.7	3.60	3.70	3.5	4.90	4.6	3.90
Z	.49	.60	.70	1.11	1.40	1.60	6.8	7.40

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7	12	15	20	23	—	—
DIRECTION	—						—	—
STRESS (±)	—	5580	-8370	-4161	4088	5986	—	—
% YIELD	—	15.5 %	23.25%	13.9%	13.6 %	20.0%	—	—

NOTES:

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FOR PG&E: RJK

TEST DATA TABLE

TEST No. 53	DATE: 7-27-78	TIME: 14:45

PARA: 6.1 32 HZ SINE BEAT Y AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 466 Volts
- Amax = 6.44 Amps
- Wmax = 1905 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.55	1.10	.68	1.10	3.55	4.45	3.45	15.5
Y	2.60	2.40	3.60	3.40	4.10	4.40	6.00	3.60
Z	1.42	.92	.71	1.23	1.25	1.70	5.60	14.50

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2	7	13	15	20	—	—	—
DIRECTION						—	—	—
STRESS (±)	12,825	-23,018	-17,019	-3796	5548	—	—	—
% YIELD	116.6 %	63.9 %	47.3 %	12.7 %	18.5 %	—	—	—

NOTES:

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FOR PG&E: RJK

TEST DATA TABLE

TEST No. 54	DATE: 7-27-78	TIME: 16:24

RESONANT SEARCH SINE SWEEP X AXIS
PARA 5.1 2-35 HZ 2 OCT MIN 0.2 G VALVE CLOSED

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: ~~3.~~ 2 MIN seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2	8	13	16	19	—	—	—
DIRECTION						—	—	—
STRESS (±)	3206	10,462	18,553	3577	10,804	—	—	—
% YIELD	29.1 %	29.1 %	51.5 %	11.9 %	36.0 %	—	—	—

NOTES:

RESONANCE FOUND AT 29.8 HZ.

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 55	DATE: 7-27-78	TIME: 12:17

RESONANT SEARCH 0.2G VALVE
PARA. 5.1 SINE SWEEP 2-35 HZ 2 OCT/MIN (X) AXIS OPEN

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Running Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7	12	15	21	—	—	—
DIRECTION	—					—	—	—
STRESS (±)	—	7847	-10,602	-3358	5694	—	—	—
% YIELD	—	21.8 %	29.5 %	11.2 %	19.0 %	—	—	—

NOTES:

RESONANCE FOUND AT 29.8 HZ.

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 56	DATE: 7-27-78	TIME: 17:23

25-35 HZ
MODE STUDY @ .2G

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps.
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

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FOR PG&E: RTK

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TEST DATA TABLE

TEST No. 57	DATE: 7-27-78	TIME: 20:03

PARA: 6.2 1ST OBE X-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ..... { β = %, ZPA = g, PEAK = g }

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.35 Amps
- Wmax = 1950 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	8	12	15	—	—	—	—
DIRECTION	—				—	—	—	—
STRESS (±)	—	3822	-4883	-2993	—	—	—	—
% YIELD	—	10.6 %	13.6 %	10.0 %	—	—	—	—

NOTES:

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FOR PG&E: RJK

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TEST DATA TABLE

TEST No. 58	DATE: 7-27-78	TIME: 18:11

PARA.
6.2 2ND OBE X-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ......
β = %
ZPA = g
PEAK = g

SHAKING TIME: 15 seconds

ACTUATOR MOTOR DATA
- Vmax = 480 Volts
- Amax = 7.14 Amps
- Wmax = 2175 Watts
- Runnig Time = 15 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2 & 3	7	13	14	—	—	—	—
DIRECTION					—	—	—	—
STRESS (±)	-12,113	18,484	11,439	3066	—	—	—	—
% YIELD	11.0 %	51.3 %	31.8 %	8.5 %	—			

NOTES: 15 SEC STOP TEST SHAKER
EXCEDED OBE LEVELS

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TEST DATA TABLE

TEST No. 59	DATE: 7-28-78	TIME: 10:19

PARA. 6.2 3RD ORE X-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 480 Volts
- Amax = 7.35 Amps
- Wmax = 2250 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3	8	10	14	21	—	—	—
DIRECTION						—	—	—
STRESS (±)	13,908	-16,391	-11,858	-6570	3285	—	—	—
% YIELD	12.6 %	45.5 %	32.9 %	21.9 %	11.0 %	—	—	—

NOTES:

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

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PageNo. 88

TEST No. 60	DATE: 7-28-78	TIME: 10:31

PARA: 6.2 4TH OBE X-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig. ....

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax. = 480 Volts
- Amax = 7.2 Amps
- Wmax = 2250 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7. & 8.	10	—	20 & 21	—	—	—
DIRECTION	—			—		—	—	—
STRESS (±)	—	3488	-8789	—	2920	—	—	—
% YIELD	—	9.7 %	24.4 %	—	9.7 %	—	—	—

NOTES:

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

Report No. 58314
Page No. 89

TEST No. 61	DATE: 2-28-78	TIME: 10:4?

PARA 6.2 5TH OBE X-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig Pg 110, 111 — β = H-2, V-2 %; ZPA = H-2.5, V-3.6 g; PEAK = — g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA:
- Vmax = 480 Volts
- Amax = 7.35 Amps
- Wmax = 2265 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	8	10	—	20 & 21	—	—	—
DIRECTION	—			—		—	—	—
STRESS (±)	—	4534	-8231	—	2920	—	—	—
% YIELD	—	12.6 %	22.9 %	—	9.7 %	—	—	—

NOTES:

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FOR PG&E: [signature]

TEST DATA TABLE

TEST No. 62	DATE: 7-28-78	TIME: 10:54

PARA: 6.2 X-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- V_{max} = 480 Volts
- A_{max} = 7.5 Amps
- W_{max} = 5250 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	8	10	—	20 & 21	—	—	—
DIRECTION	—			—		—	—	—
STRESS (±)	—	3836	-7394	—	2920	—	—	—
% YIELD	—	10.7 %	20.5 %	—	9.7	—	—	—

NOTES:

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FOR PG&E: RK

Report No. 58314

TEST DATA TABLE

Page No. 91

TEST No. 63	DATE: 7-28-78	TIME: 11:10

PARA 6.2 1ST SSE X-Y AXIS SEISMIC RANDOM

TEST RESPONSE SPECTRUM: Fig Pg. 112, 113 — β = H-2% V-2% ; ZPA = H-3.9g V-7.5g ; PEAK = — g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA:
- Vmax = 480 Volts
- Amax = 7.42 Amps
- Wmax = 2175 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER A0	A1	A2	A3	A4	A5	A6	A7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S1	S2	S3	S4	S5	S6	S7	S8
GAGE No.	4	7 & 8	13	14	20 & 21	—	—	—
DIRECTION						—	—	—
STRESS (±)	20,663	6975	-12,974	-2920	5110	—	—	—
% YIELD	18.8 %	19.4 %	36.0 %	9.7 %	17.0 %	—	—	—

NOTES:

FOR WYLE: [signature]

FOR PG&E: KTK

TEST DATA TABLE

TEST No. 64	DATE: 7-28-78	TIME: 13:40

PARA: 6.1 SINE BEAT 2 HZ (3 BEATS) FULL LEVEL X AXIS 1.

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.8 Amps
- Wmax = 1965 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	.90	.96	.89	1.06	1.3	1.3	1.6	2.3
Y	.10	.10	.11	.18	.31	.28	.59	.50
Z	.12	.12	.18	.12	.3	.20	.40	.40

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	—	12	—	—	—	—	—
DIRECTION	—	—		—	—	—	—	—
STRESS (±)	—	—	-2720	—	—	—	—	—
% YIELD	—	—	7.6 %	—	—	—	—	—

NOTES:

FOR WYLE: [signature]
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 65	DATE: 7-28-78	TIME: 13:50

(5 BEATS)
PARA: 6.1 SINE BEAT X AXIS 4HZ.

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 6.65 Amps
- Wmax = 1950 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	2.04	1.98	1.8	2.0	2.5	2.6	2.20	3.4
Y	.12	.16	.20	.29	.35	.45	1.00	.35
Z	.26	.29	.48	.22	.30	.60	.30	1.20

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7 & 8	13	—	—	—	—	—
DIRECTION	—			—	—	—	—	—
STRESS (±)	—	3139	-5929	—	—	—	—	—
% YIELD	—	8.7 %	16.5 %	—	—	—	—	—

NOTES:

FOR WYLE: [signature]
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 66	DATE: 7-28-78	TIME: 14:55

6 BEATS
PARA: C.1 SINE BEAT 6HZ X AXIS

TEST RESPONSE SPECTRUM: Fig ....
β = %
ZPA = g
PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.86 Amps
- Wmax = 1800 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	2.84	2.85	2.5	2.95	3.3	3.8	3.4	5.5
Y	.220	.29	.20	.31	.58	.7	1.7	.12
Z	.22	.22	.49	.22	.2	.3	.3	1.4

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	8	12	—	20 & 21	—	—	—
DIRECTION	—			—		—	—	—
STRESS (±)	—	4534	-8231	—	4015	—	—	—
% YIELD	—	12.6%	22.9%	—	13.4%	—	—	—

NOTES:

FOR WYLE: [signature]
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 67	DATE: 7-28-78	TIME: 15:40

PARA G.I SINE BEAT 8 HZ 1/3 LEVEL X AXIS (7 BEATS)

TEST RESPONSE SPECTRUM: Fig ....
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.65 Amps
- Wmax = 1950 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	3.4	3.7	3.4	4.2	6.8	9.4	7.6	19
Y	.45	.63	.40	.49	1.3	1.1	5.2	.2
Z	.38	.35	.71	.35	.9	1.1	1.5	2.0

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	3	8	12	14	20 & 21	—	—	—
DIRECTION						—	—	—
STRESS (±)	12,839	-25,808	-27,063	-7972	18,250	—	—	—
% YIELD	11.7%	71.7%	75.2%	26.6%	60.8%	—	—	—

NOTES:

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 68	DATE: 7-28-78	TIME: 15.57

PARA: 6.1 10 HZ SINE BEAT 7 BEATS X AXIS

TEST RESPONSE SPECTRUM: Fig .... β = % ; ZPA = g ; PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.6 Amps
- Wmax = 1950 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	3.3	3.3	3.3	3.5	4.0	5.2	4.0	11.0
Y	.45	.50	.35	.40	.8	1.2	2.5	.1
Z	.50	.50	.68	.51	.6	1.0	1.2	2.7

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7 & 8	12	—	20 & 21	—	—	—
DIRECTION	—			—		—	—	—
STRESS (±)	—	6626	13,113	—	5475	—	—	—
% YIELD	—	18.4%	36.4%	—	18.3%	—	—	—

NOTES:

FOR WYLE: [signature]
FOR PG&E: RJK

TEST DATA TABLE

TEST No. 69	DATE: 7-28-78	TIME: 15:03

PARA 6.1 SINE BEAT 12 HZ X AXIS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 6.65 Amps
- Wmax = 1950 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	3.2	3.3	3.2	3.7	3.8	4.9	3.4	10
Y	.64	.72	.47	1.05	.9	1.2	2.3	.28
Z	.45	.41	.69	1.10	.8	.8	1.3	2.3

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	7 & 9	13	17	21	—	—	26
DIRECTION	—					—	—	
STRESS (±)	—	6975	12,974	2920	6643	—	—	3212
% YIELD	—	19.4	36.0 %	9.7 %	22.1 %	—	—	10.7 %

NOTES:

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 70	DATE: 7-28-78	TIME: 15:15

PARA 6.1 16 Hz SINE BEAT X AXIS (8 BEAT)

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 475 Volts
- Amax = 7.0 Amps
- Wmax = 1875 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	3.3	3.3	3.3	3.9	5.2	7.7	5.3	19
Y	.90	.93	.48	.95	1.3	1.4	3.9	1.0
Z	.95	.70	.75	1.15	1.1	1.1	1.9	2.6

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	—	8	13	14	21	—	—	26
DIRECTION	—					—	—	
STRESS (±)	—	9765	19,112	-4526	8468	—	—	3212
% YIELD	—	27.1 %	53.1 %	15.1 %	28.2 %	—	—	10.7 %

NOTES:

FOR WYLE: RK

FOR PG&E: RK

TEST DATA TABLE

TEST No. 71	DATE: 7-28-78	TIME: 15:35

8 BEATS
PARA: 6.1 20 HZ SINE BEAT X AXIS

TEST RESPONSE SPECTRUM: Fig ......

β = %
ZPA = g
PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 6.8 Amps
- Wmax = 1875 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	3.2	3.2	3.1	3.8	5.1	7.0	5.2	17
Y	.83	.95	.49	.80	1.1	1.3	3.4	.2
Z	1.00	.72	.72	.80	1.3	1.3	1.7	3.8

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2	7	13	14	21	—	—	26
DIRECTION						—	—	
STRESS (±)	3206	10453	16,322	-3796	8468	—	—	3212
% YIELD	2.9 %	29.1 %	45.3 %	12.7 %	28.2 %	—	—	10.7 %

NOTES:

FOR WYLE: [signature]
FOR PG&E: RK

TEST DATA TABLE

TEST No. 72	DATE: 7-28-78	TIME: 15:45

Para: 6.1 24Hz 1 BEAT SINE BEAT X AXIS

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: 2 seconds

ACTUATOR MOTOR DATA
- Vmax = — Volts
- Amax = — Amps
- Wmax = — Watts
- Runnig Time = 2 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	2.9	2.6	3.0	5.9	11.6	13.1	11.0	7.0
Y	2.1	3.51	2.1	2.97	5.1	9.8	10.1	.75
Z	1.95	1.49	1.35	1.4	6.0	6.2	9.5	11.1

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

FOR WYLE: [signature]
FOR PG&E: [signature]

TEST DATA TABLE

TEST No. 73	DATE: 7-28-78	TIME: 16:35

9 BEATS
PARA: C.1 24 HZ SINE BEAT X AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 470 Volts
- Amax = 6.8 Amps
- Wmax = 1920 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	2.9	3.4	3.0	5.9	9.2	15.6	10.7	38
Y	2.30	2.41	2.10	2.95	3.1	2.4	11.1	.30
Z	2.1	1.36	1.32	1.45	.7	1.0	2.7	2.4

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2	8	13	14	21	23	25	26
DIRECTION								
STRESS (±)	7481	26,156	46,733	8906	23,068	4234	6132	3942
% YIELD	6.8 %	72.7 %	130 %	29.7%	76.9 %	14.1 %	20.4 %	13.1 %

NOTES:

FOR WYLE: [signature]

FOR PG&E: RK

TEST DATA TABLE

TEST No. 74	DATE: 7-28-78	TIME: 16:45

9 BEATS 2 G INPUT
PARA: 6.1 29.8 HZ SINE BEAT X AXIS

TEST RESPONSE SPECTRUM: Fig ......
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA
- Vmax = 466 Volts
- Amax = 6.5 Amps
- Wmax = 1950 Watts
- Running Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.7	1.7	1.6	2.8	6.6	14.1	8.1	36
Y	.55	.55	.45	.91	3.2	3.1	10.9	.3
Z	.35	.49	.38	.30	1.1	1.0	2.8	3.1

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2	7	13	14	21	—	—	26
DIRECTION						—	—	
STRESS (±)	14,428	31,736	24,273	-7446	13,943	—	—	3212
% YIELD	13.1%	88.2%	67.4%	24.8	46.5%	—	—	10.7%

NOTES:

FOR WYLE: [signature]
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 75	DATE: 7-28-78	TIME: 10:55

PARA: C.L 32 HZ SINE BEAT. 9 BEATS

TEST RESPONSE SPECTRUM: Fig ......

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: 20 seconds

ACTUATOR MOTOR DATA

- Vmax = 470 Volts
- Amax = 6.5 Amps
- Wmax = 1950 Watts
- Runnig Time = 20 sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X	1.9	1.95	2.0	1.5	2.9	6.8	3.9	21
Y	.45	.40	.35	.62	2.1	1.8	6.5	.28
Z	.23	.21	.32	.25	.8	.4	1.5	1.7

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.	2	8	12	17	21	—	—	—
DIRECTION						—	—	—
STRESS (±)	2850	9765	-15,624	3285	8103	—	—	—
% YIELD	2.6 %	27.1 %	43.4 %	11.0 %	27.0 %	—	—	—

NOTES:

FOR WYLE: [signature]

FOR PG&E: RJK

TEST DATA TABLE

TEST No. 7C	DATE: 7-28-78	TIME: 17:05

PARA: 4.4 CHECK OF MANUEL MODE — ELECTRICAL

TEST RESPONSE SPECTRUM: Fig .... β = % ; ZPA = g ; PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA:
- Vmax = 466 Volts
- Amax = 6.7 Amps
- Wmax = 1875 Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

MANUAL TO ELECTRICAL CHECK-OUT O.K.

FOR WYLE: [signature]
FOR PG&E: RTK

TEST DATA TABLE

TEST No. 77	DATE: 7-28-78	TIME: 17:02

CHECKING OF VALUE LEAKAGE

TEST RESPONSE SPECTRUM: Fig ....

- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA

- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

NO LEAKAGE AFTER 10 MIN. UNDER PRESSURE 350 PSIG ON ONE SIDE.

FOR WYLE: [signature]

FOR PG&E: RTK

WYLE LABORATORIES

Report No. 58314

CUSTOMER PG&E Job No. 58314 Page No. 106

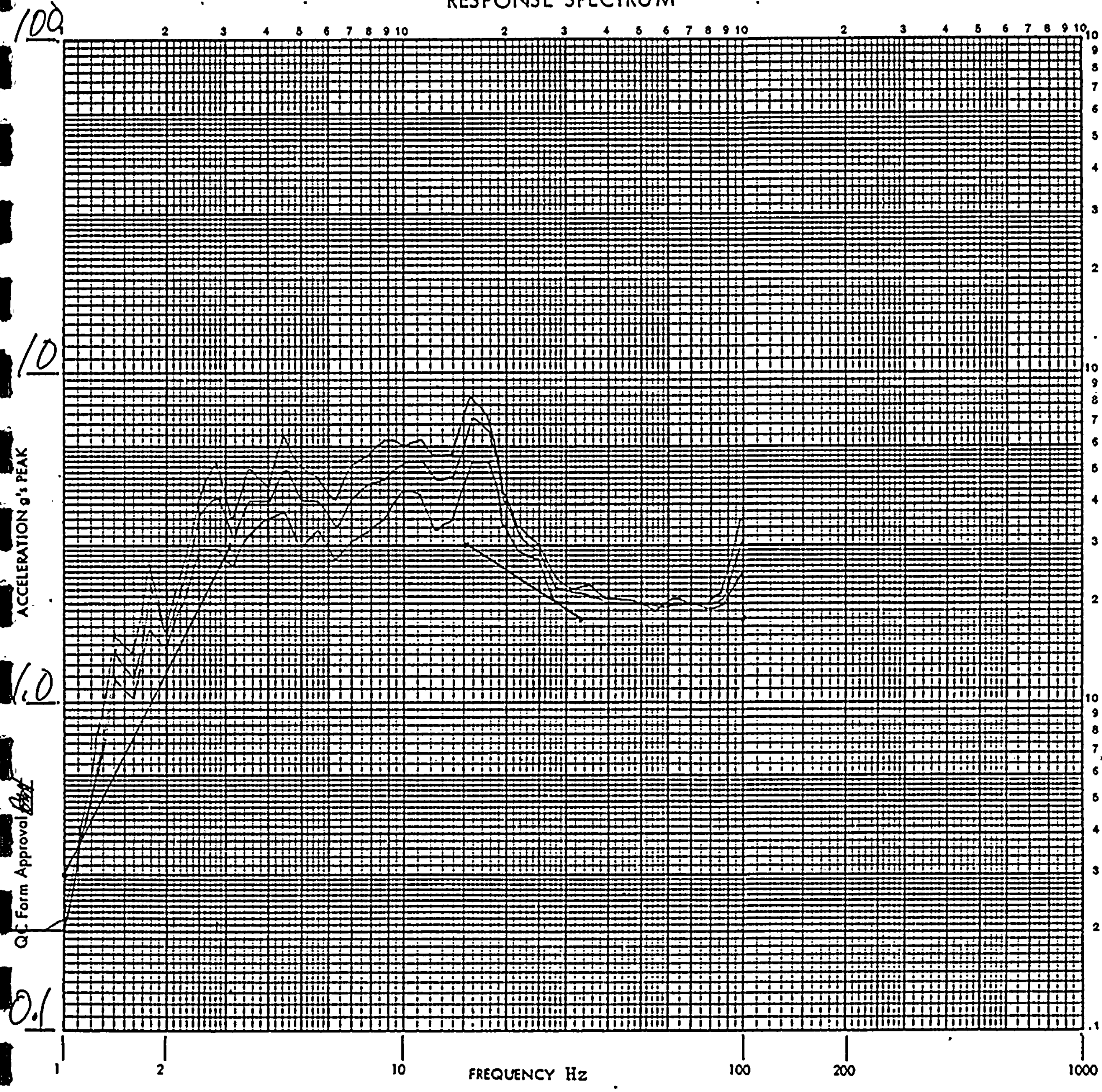
Full Scale 100 g Accel. No. 8 Control (✗) Response ( )

Operator MEEHAN Specimen 14" VALVE

Date 7-26-78 Damping 2, 3, 5 % Axis of Test Y-Z VERT

TEST # 31 8TH OBE

RESPONSE SPECTRUM



WYLE LABORATORIES

Report No. 58314

CUSTOMER PG&E Job No. 58314 Page No. 107

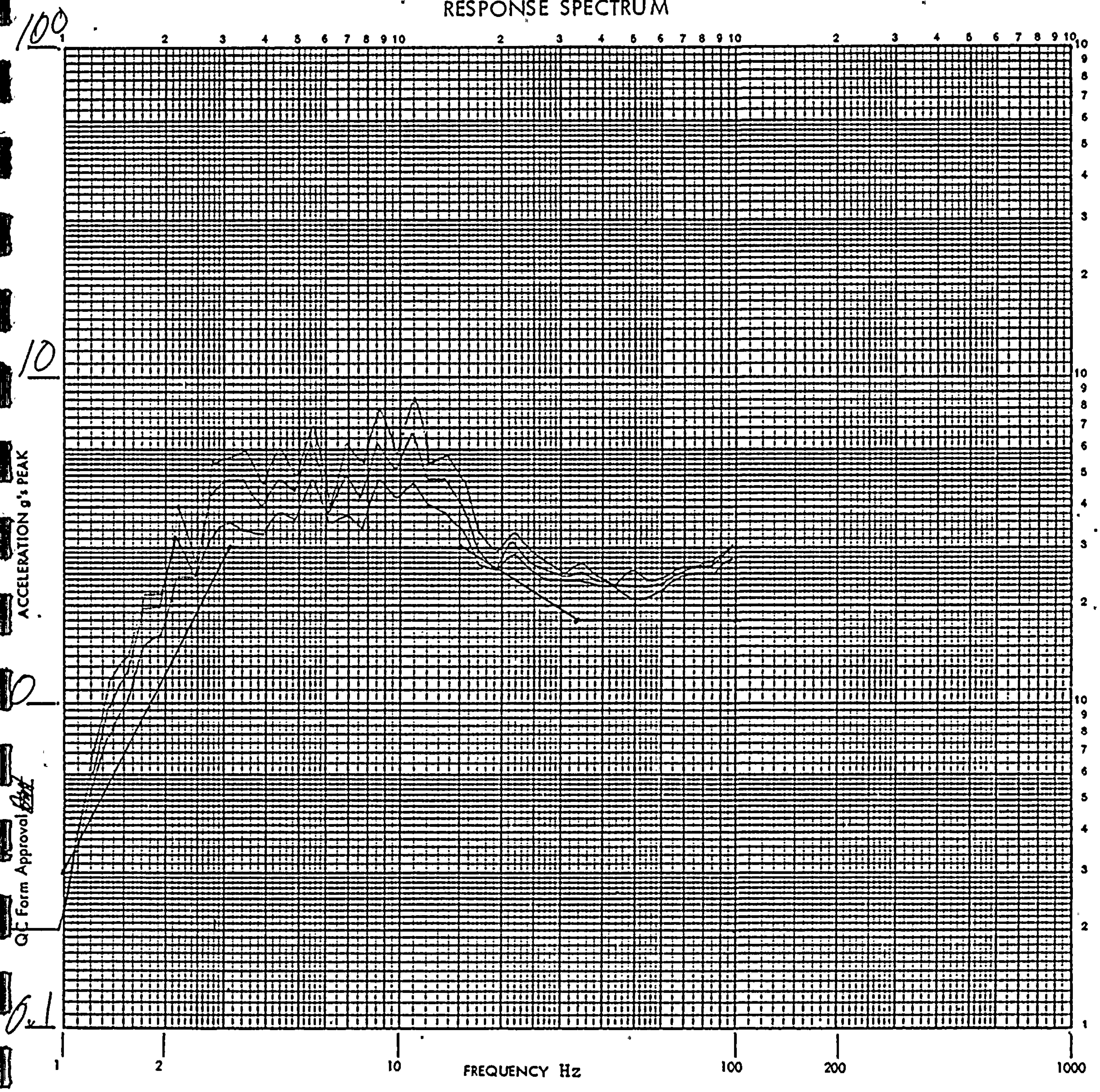
Full Scale 100 g Accel. No. 9 Control (X) Response ( )

Operator MEENAN Specimen 14" VALVE

Date 7-26-78 Damping 2,3,5 % Axis of Test Y-Z HORIZ

TEST 31 8TH OBE

RESPONSE SPECTRUM



WYLE LABORATORIES

Report No. 58314

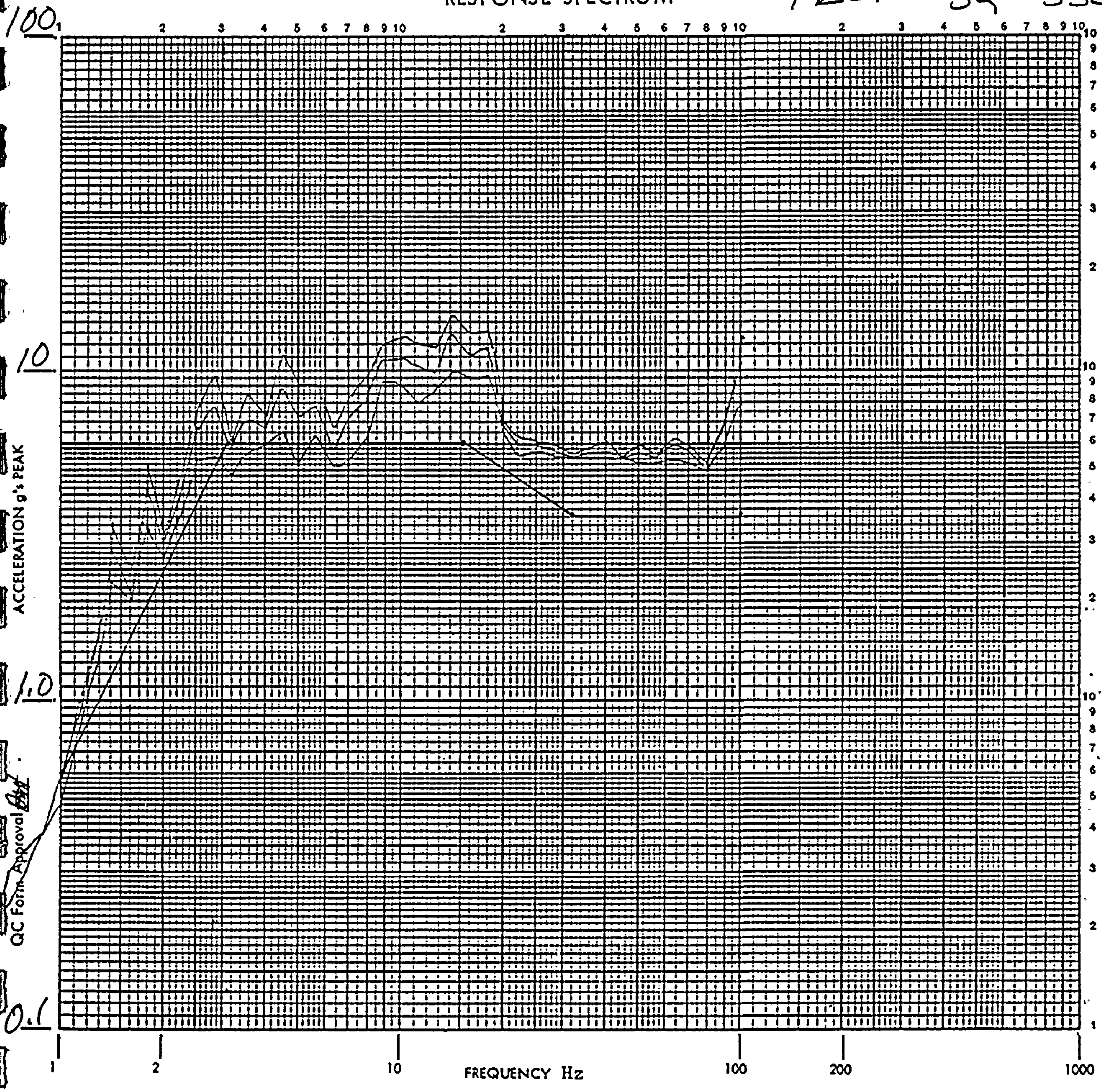
CUSTOMER P.G&E Job No. 58314 Page No. 108

Full Scale 100 g Accel. No. 8 Control (X) Response ( )

Operator MEEHAN Specimen 14" VALVE

Date 7-26-78 Damping 2,3,5 % Axis of Test Z-Y VERT.

RESPONSE SPECTRUM TEST #32 SSE



QC Form Approval

WYLE LABORATORIES

Report No. 58314

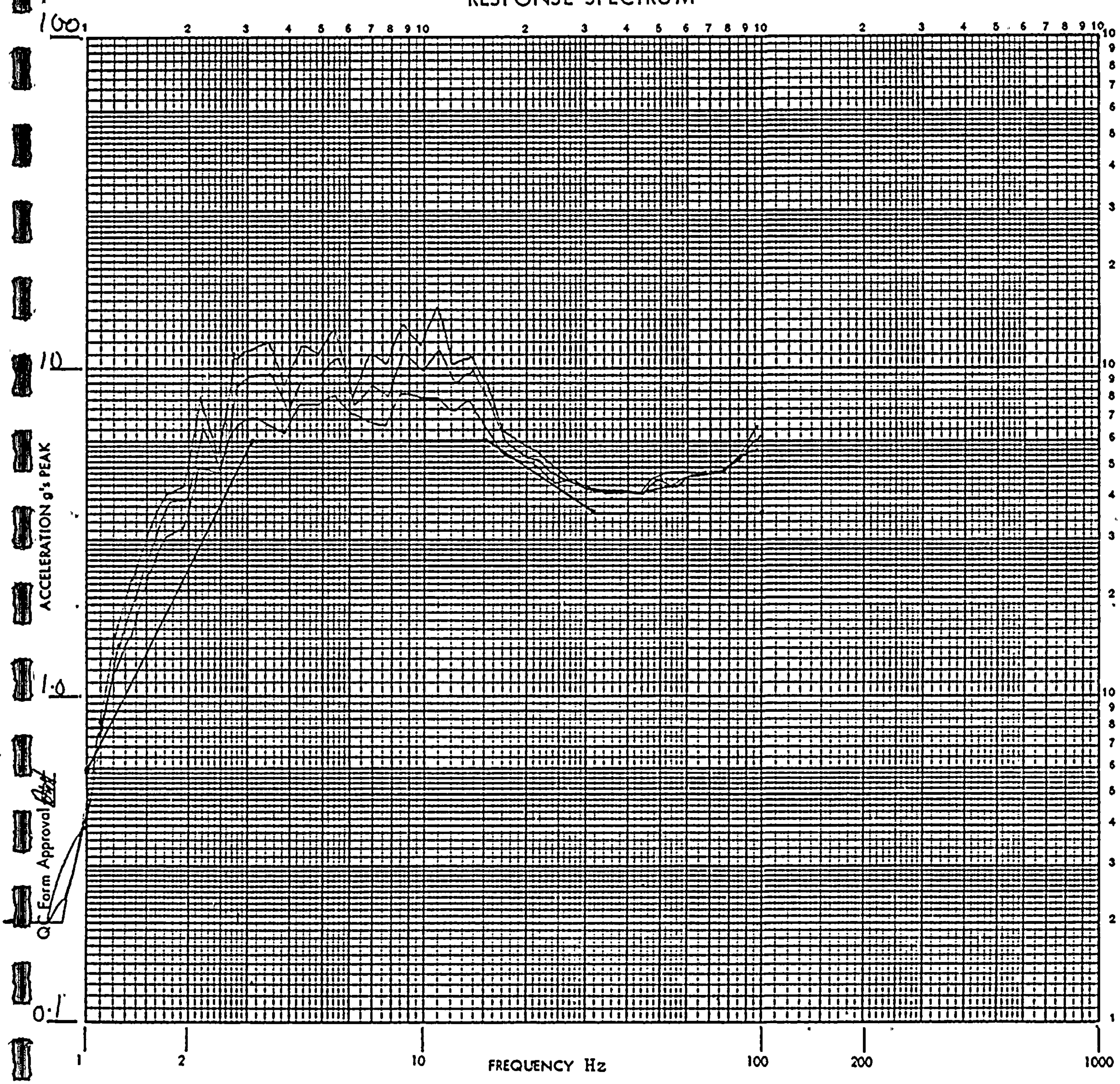
CUSTOMER PG&E   Job No. 58314   Page No. 109

Full Scale 100 g   Accel. No. 9   Control (*)   Response ( )

Operator MEEHAN   Specimen 14" VALVE

Date 7-26-78   Damping 2,3,5 %   Axis of Test Y-Z HORIZ

TEST #32 SSE



WYLE LABORATORIES

Report No. 58314

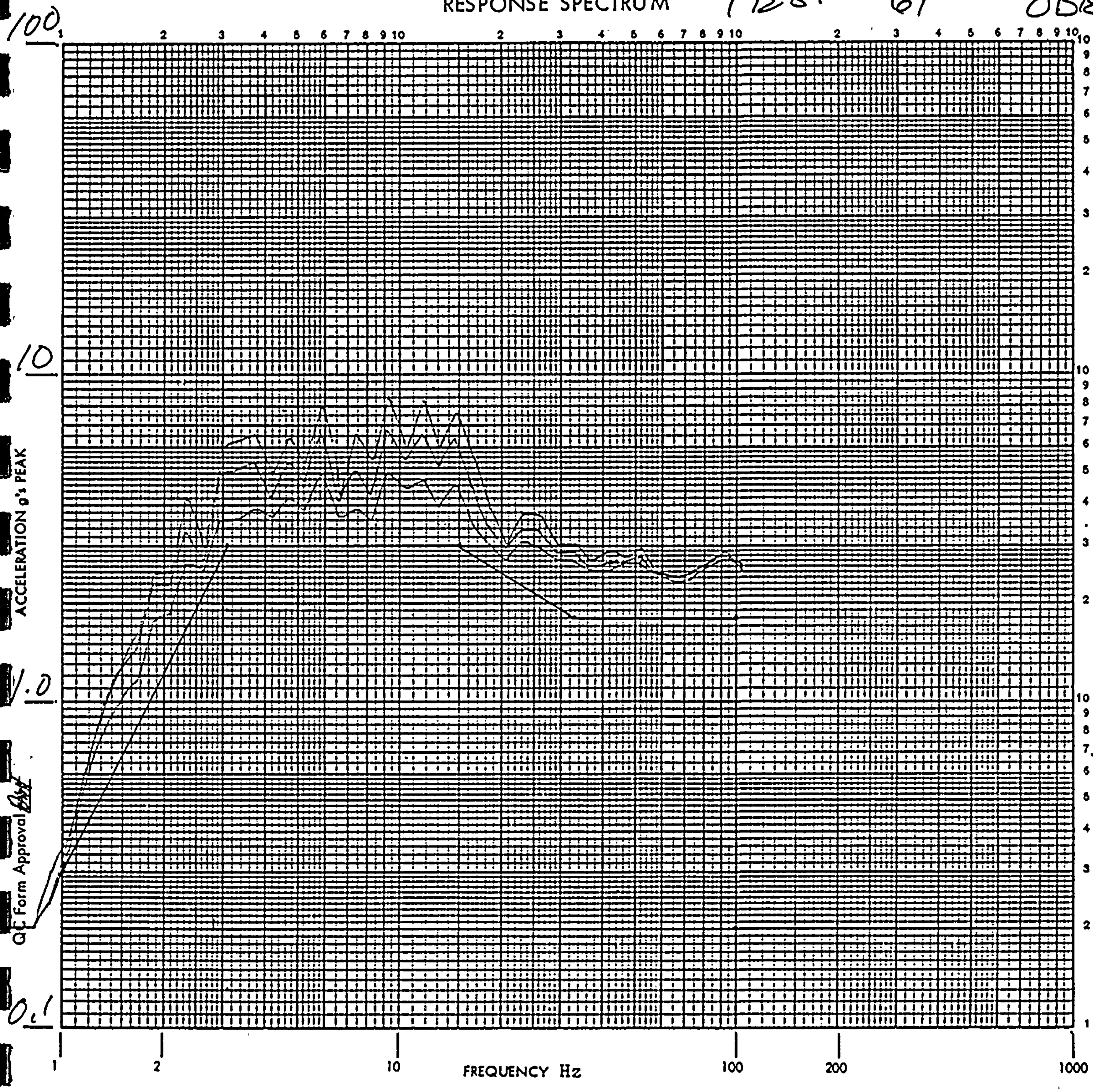
CUSTOMER P.G.&E. Job No. 58314 Page No. 110

Full Scale 100 g Accel. No. 7 Control (✗) Response ( )

Operator MEEHAN Specimen 14" VALVE

Date 7-28-78 Damping 2,3,5% Axis of Test (X·Y) HORIZ.

RESPONSE SPECTRUM TEST #61 5th OBE



WYLE LABORATORIES

Report No. 58314

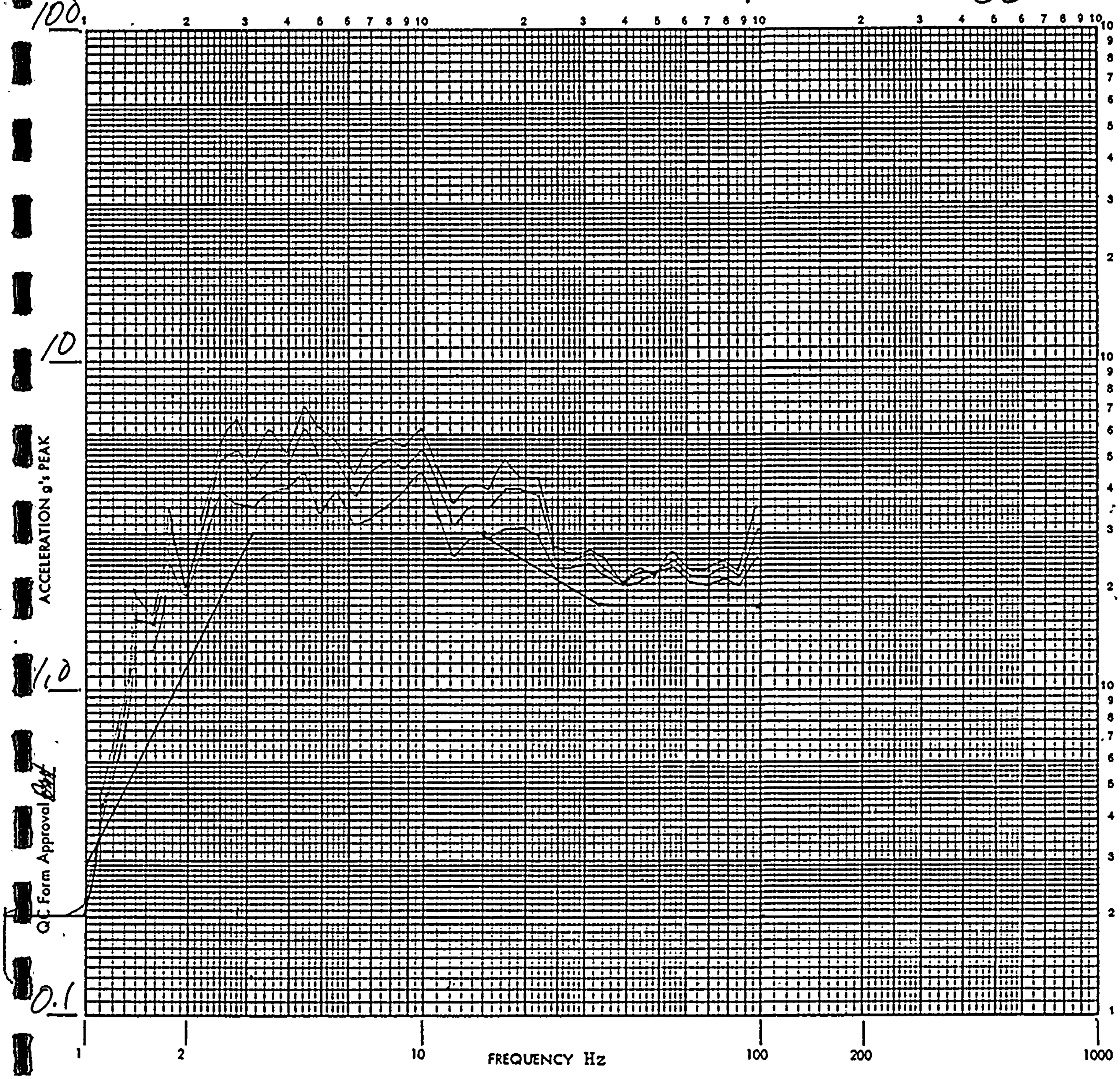
CUSTOMER P.G&E   Job No. 58314   Page No. 111

Full Scale 100 g   Accel. No. 8   Control (X)   Response ( )

Operator MEEHAN   Specimen 14" VALVE

Date 7-28-78   Damping 2,3,5%   Axis of Test (X-Y) VERT

RESPONSE SPECTRUM   TEST #61   5th OBE



WYLE LABORATORIES

Report No. 58314

CUSTOMER P G&E

Job No. 58314

Page No. 112

Full Scale 100 g

Accel. No. 7

Control (X) Response ( )

Operator MEEHAN

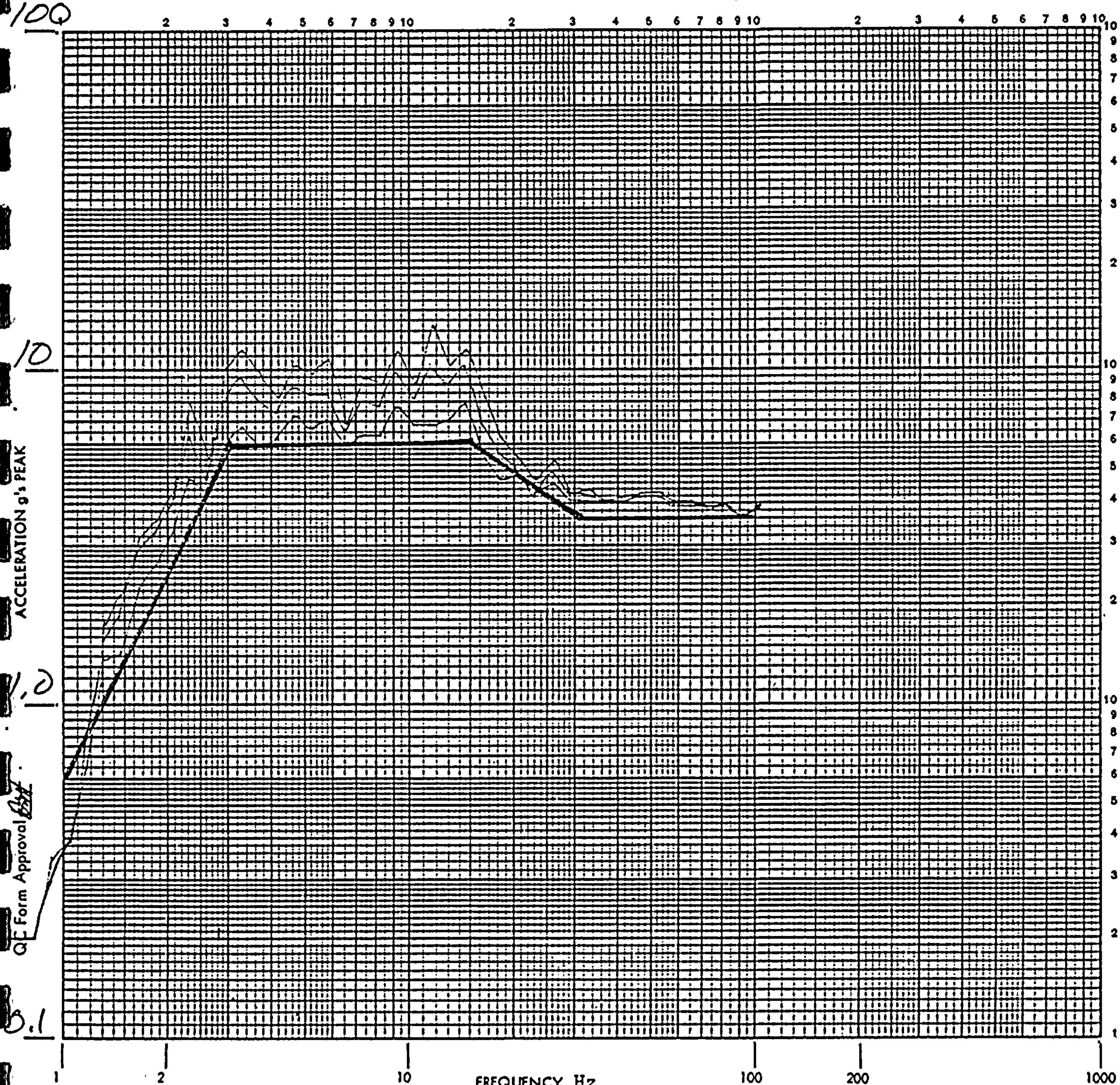
Specimen 14" VALVE

Date 7-28-78

Damping 2,3,5%

Axis of Test (X,Y) HORIZ.

RESPONSE SPECTRUM TEST # 63 SSE



QC Form Approval

WYLE LABORATORIES

Report No. 58314

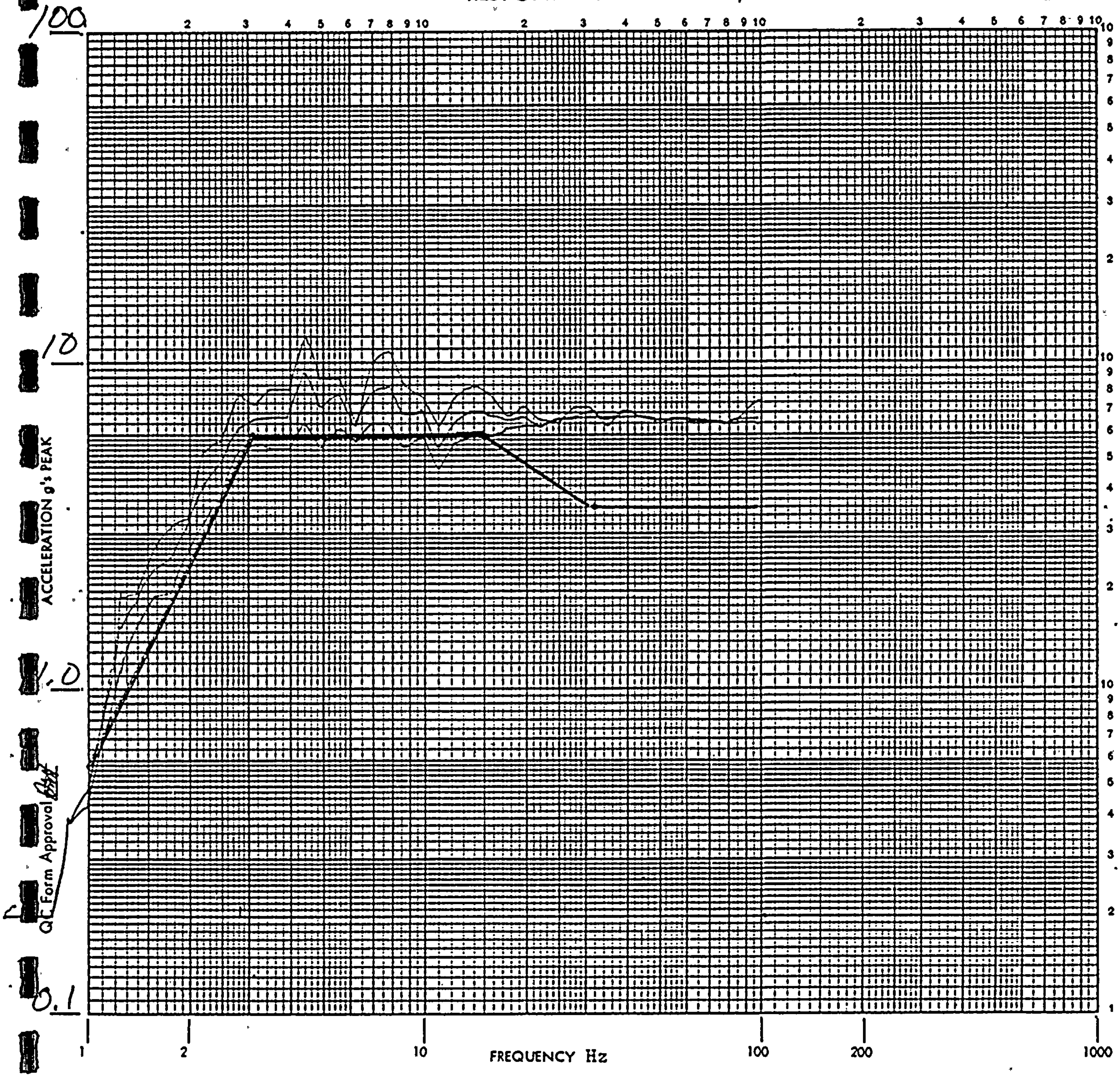
CUSTOMER P G&E Job No. 58314 Page No. 113

Full Scale 100 g Accel. No. 8 Control (X) Response ( )

Operator MEEHAN Specimen 14" VALVE

Date 7-28-78 Damping 3,3,5 % Axis of Test (X·Y) VERT.

RESPONSE SPECTRUM TEST #63 SSE



SPECIMEN 14" DISC VALVE
CUSTOMER PG&E
PART NO. SEE REC INSP
S/N SEE REC INSP
JOB NO. 58314
DATE 6-1-78
TEST BY J McMahon
WITNESS

WYLE LABORATORIES

TEST: SEISMIC RANDOM

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
EXCITER	TEAM CORP	W 3000	12" DA 30,000 FORCE LBS	—	—	—	N/A
EXCITER	TEAM CORP	W 1800	10" DA 18,000 FORCE LBS	—	—	—	N/A
EXCITER	TEAM CORP	W 1800	10" DA 18,000 FORCE LBS	—	—	—	N/A
SERVO CONTROLLER	McFADDEN	152 A	—	—	PRIOR TO	USE	N/A
SERVO CONTROLLER	McFADDEN	152 A	—	—	PRIOR TO	USE	N/A
SERVO CONTROLLER	McFADDEN.	152 A	—	—	PRIOR TO	USE	N/A
AMPLIFIER	McFADDEN	152 A	—	—	PRIOR TO	USE	N/A
AMPLIFIER	McFADDEN	152 A	—	—	PRIOR TO	USE	N/A
AMPLIFIER	McFADDEN	152 A	—	—	PRIOR TO	USE	N/A
SHOCK SPECTRUM ANALYZER	SPECTRAL DYNAMICS	13231	120 CHANNEL	7530	SYSTEM	CALIBRATION	MFG. SPEC.
SPECTRUM SHAPER	BRUEL KJAER	123	12.5 TO 40 KHZ	31337	PRIOR TO	USE	N/A
SPECTRUM SHAPER	BRUEL KJAER	123	12.5 TO 40 KHZ	31570	PRIOR TO	USE	N/A
EQUALIZER SHAPER	TRACOR	822	1.25 TO 10 HZ	31534	PRIOR TO	USE	N/A
EQUALIZER SHAPER	TRACOR.	822	1.25 TO 10 HZ	31574	PRIOR TO	USE	N/A
X-Y RECORDER	HEWLETT PACKARD	7005B	X = 30 "/SEC Y = 20 "/SEC	L99992	PRIOR TO	USE	MFG. SPEC.
OSCILLOSCOPE	HEWLETT PACKARD	122 AR	DUAL TRACE	7333	3-27-78	9-24-78	±5%
ELECTRONIC VOLTMETER	BRUEL KJAER	2416	0.01 TO 1000 VOLTS	30606	4-27-78	8-27-78	±4% AVF

W 614 C Q.C. Approval RW

Page No. 114

Report No. 58315

SHEET OF

SPECIMEN 14" DISC VALVE

CUSTOMER PG&E

PART NO. SEE REC INSP

S/N SEE REC INSP

TEST: SEISMIC

JOB NO. 58314

DATE 6-1-78

TEST BY J Mahan

WITNESS

WYLE LABORATORIES

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7893	4-5-78	7-5-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7533	4-4-78	7-4-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7598	5-8-78	8-8-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7532	3-31-78	6-31-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7898	4-10-78	7-10-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7572	3-23-78	6-23-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7303	5-24-78	8-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7566	3-23-78	6-23-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7800	5-31-78	8-30-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7571	5-31-78	8-31-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7567	5-31-78	8-30-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7897	5-4-78	8-4-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7523	5-24-78	8-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7377	5-24-78	8-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7632	5-24-78	8-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7866	5-31-78	8-30-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7599	5-31-78	8-30-78	± 2%

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SHEET OF

SPECIMEN 14" DISC VALVE
CUSTOMER PG&E
PART NO. SEE REC INSP
S/N SEE REC INSP

JOB NO. 58314
DATE 6-1-78
TEST BY [signature]
WITNESS

WYLE LABORATORIES

TEST: SEISMIC

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
ACCELEROMETER	UNHOLTZ DICKIE	7502I	0-1000G	7320	3-16-78	6-16-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	7502I	0-1000G	7362	2-7-78	5-7-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	7502I	0-1000G	7865	3-6-78	6-6-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	7502I	0-1000G	7155	2-24-78	5-24-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	7502I	0-1000G	7398	3-23-78	6-23-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	7502I	0-1000G	7302	2-7-78	5-7-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	7502I	0-1000G	7360	3-6-78	6-6-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7338	1-17-78	7-15-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7344	1-17-78	7-15-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7342	1-17-78	7-15-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7340	2-28-78	9-3-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7337	2-14-78	8-15-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7339	2-28-78	9-3-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7345	1-17-78	7-15-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	31490	1-26-78	7-23-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7343	1-17-78	7-15-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7336	2-28-78	9-3-78	±2%

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SHEET OF

SPECIMEN 14" DISC VALVE
CUSTOMER PG&E
PART NO. SEE REC INSP
S/N SEE REC INSP

JOB NO. 58314
DATE 6-1-78
TEST BY J Mulcahy
WITNESS

WYLE LABORATORIES

TEST: SEISMIC

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7335	2-28-78	9-3-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7346	1-17-78	7-15-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	51042	1-13-78	7-16-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMC	0-1000G	30880	1-13-78	7-16-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMC	0-1000G	30885	1-13-78	7-16-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8P	0-1000G	30770	1-13-78	7-16-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	51047	1-13-78	7-16-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	4531	1-13-78	7-16-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	51057	2-1-78	7-30-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	51043	2-1-78	7-30-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	4532	2-1-78	7-30-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	4527	2-1-78	7-30-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	4543	2-1-78	7-30-78	±2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000G	4544	2-1-78	7-30-78	±2%
AMPLITUDE SERVO/ MONITOR	SPECTRAL DYNAMICS	SD105A	N/A	31304	PRIOR TO	TEST	MFG SPEC
SWEEP OSCILLATOR	SPECTRAL DYNAMICS	SD104A-5	.005 TO 50,000 Hz	7996	3-21-78	9-24-78	±2%
OSCILLOGRAPH	HONEYWELL	1012	36 CHANNEL	5366	4-3-78	10-1-78	±2%

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SHEET OF

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Page No. 117

SPECIMEN 14" DISC VALVE
CUSTOMER PG&E
PART NO. SEE REL INSP
S/N SEE REL INSP

JOB NO. 58314
DATE 6-1-78
TEST BY J Mechan
WITNESS

WYLE LABORATORIES

TEST: SEISMIC

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
OSCILLOGRAPH	HONEYWELL	1012	24 CHANNEL	30502	4-7-78	10-8-78	±2%
TAPE RECORDER	SANBORN	3924B	12 CHANNEL	31265	PRIOR TO TEST		MFG SPEC
TAPE RECORDER	SANBORN	3924B	12 CHANNEL	31266	PRIOR TO TEST		MFG SPEC
SINE BEAT GENERATOR	MCFADDEN	209-A	.5 TO 50 HZ	N/A	PRIOR TO TEST		N/A
GRAPHIC WATTMETER	ESTERLINE ANGUS	AW	0-7.5 KW	30604	4-14-78	10-15-78	±1.0%
CURRENT TRANSFORMER	WESTON	461	0-10 AMPS	30432	4-14-78	4-15-79	±.25%
CURRENT TRANSFORMER	WESTON	461	0-10 AMPS	30433	4-14-78	4-15-79	±.25%
NOTE: THE FOLLOWING EQUIPMENT WAS RECALIBRATED OR ADDED TO REPLACE EQUIPMENT THAT WENT OUT OF CALIBRATION.							
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000G	7320	7-8-78	10-8-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000G	7865	7-10-78	10-10-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000G	7155	6-5-78	9-5-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7566	6-27-78	9-27-78	±2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7398	6-27-78	9-27-78	±2%

W 614 C Q.C. Approval PMH

SHEET OF

SPECIMEN 14" DISC VALVE
CUSTOMER PG & E
PART NO. SEE REC INSP
S/N SEE REC INSP

JOB NO. 58314
DATE 6-1-78
TEST BY [signature]
WITNESS

WYLE LABORATORIES

TEST: SEISMIC

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000G	7302	6-5-78	9-5-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7360	6-23-78	9-23-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000G	7892	7-24-78	10-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000G	7893	7-24-78	10-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7898	7-24-78	10-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7533	7-24-78	10-24-78	± 2%
ACCELEROMETER	UNHOLTZ DICKIE	75D21	0-1000 G	7359	6-27-78	9-27-78	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000 G	7338	7-15-78	1-14-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7344	7-15-78	1-14-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7342	7-15-78	1-14-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7345	7-15-78	1-14-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	11	0-1000G	31490	7-15-78	1-21-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7343	7-15-78	1-14-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	D22	0-1000G	7346	7-15-78	1-14-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMC	0-1000G	30880	6-19-78	12-17-78	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMC	0-1000G	30885	7-18-78	1-21-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8P	0-1000G	30770	7-18-78	1-21-79	± 2%

W 614 C Q.C. Approval [initials]

SHEET OF

SPECIMEN 14" DISC VALVE

CUSTOMER PG & E

PART NO. SEE REC INSP

S/N SEE REC INSP

JOB NO. 58314

DATE 6-1-78

TEST BY [signature]

WITNESS

WYLE LABORATORIES

TEST: SEISMIC

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION		ACCY.
					LAST	DUE	
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000 G	51047	7-18-78	1-21-79	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8PMCV	0-1000 G	7696	6-19-78	12-17-78	± 2%
CHARGE AMPLIFIER	UNHOLTZ DICKIE	8P	0-1000 G	30998	6-19-78	12-17-78	± 2%

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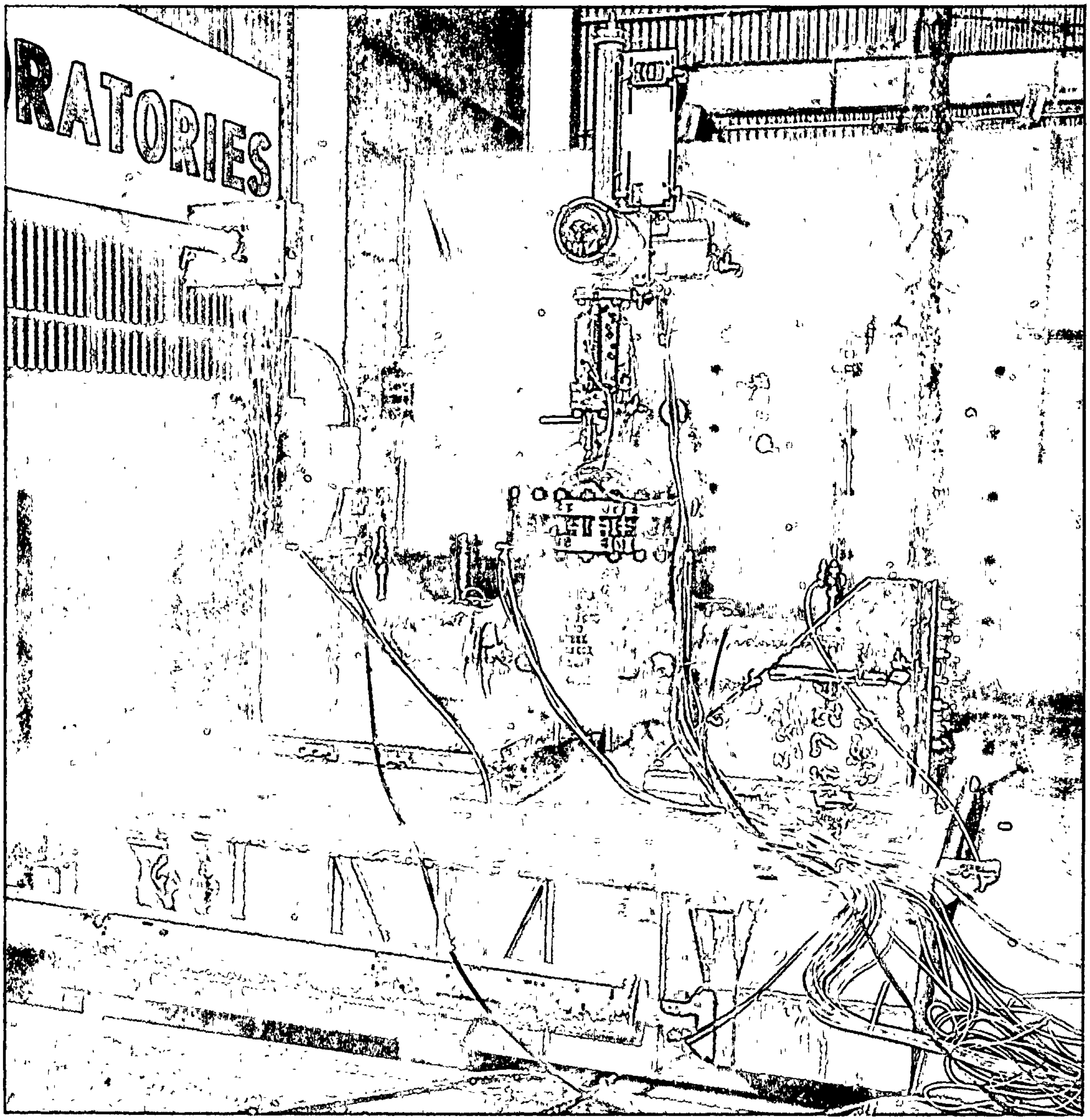
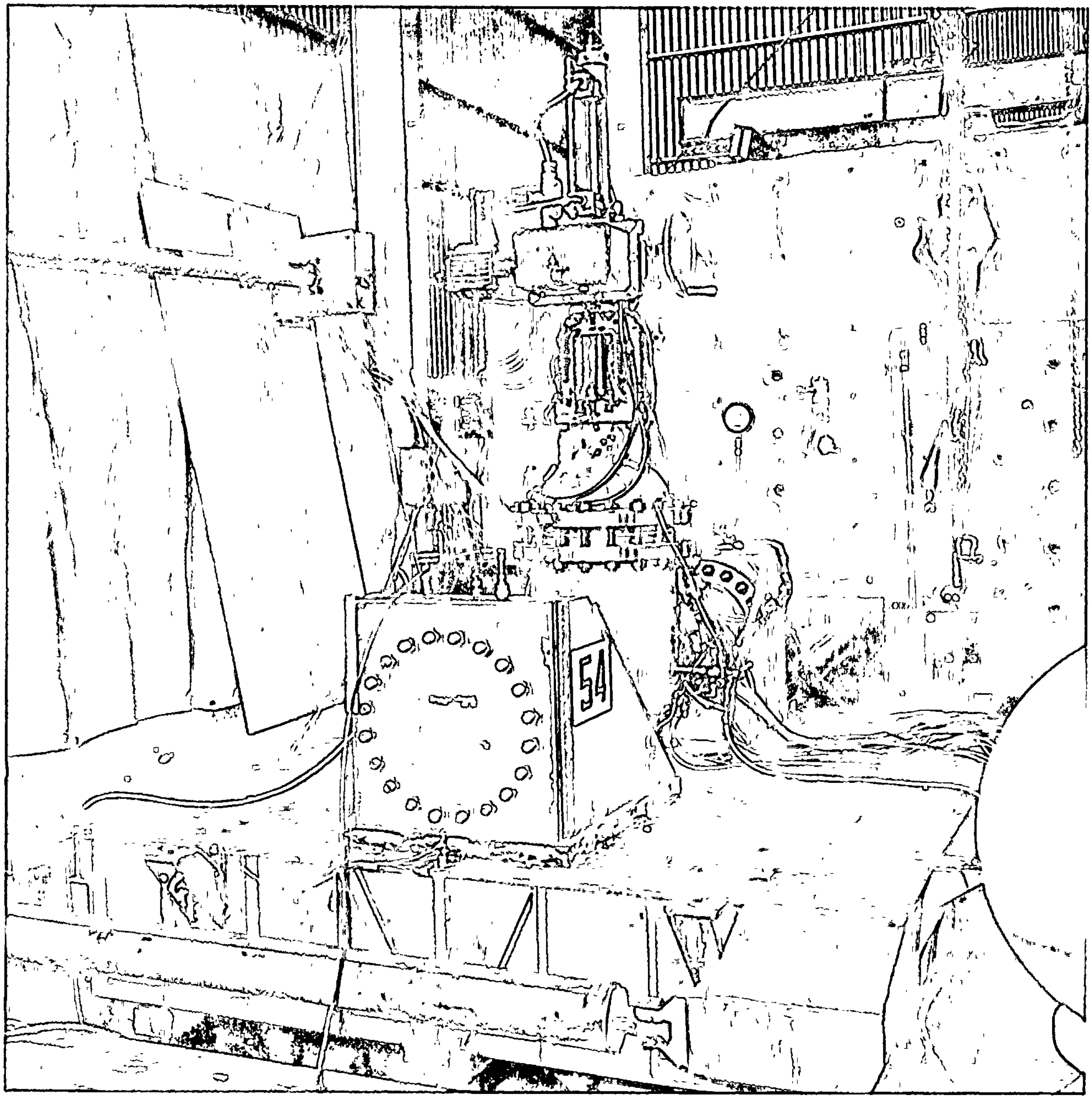
SHEET OF



PHOTOGRAPH 1

TYPICAL TEST SETUP - Z-Y AXIS



PHOTOGRAPH 2

TYPICAL TEST SETUP - X-Y AXIS

PHOTOGRAPH 3

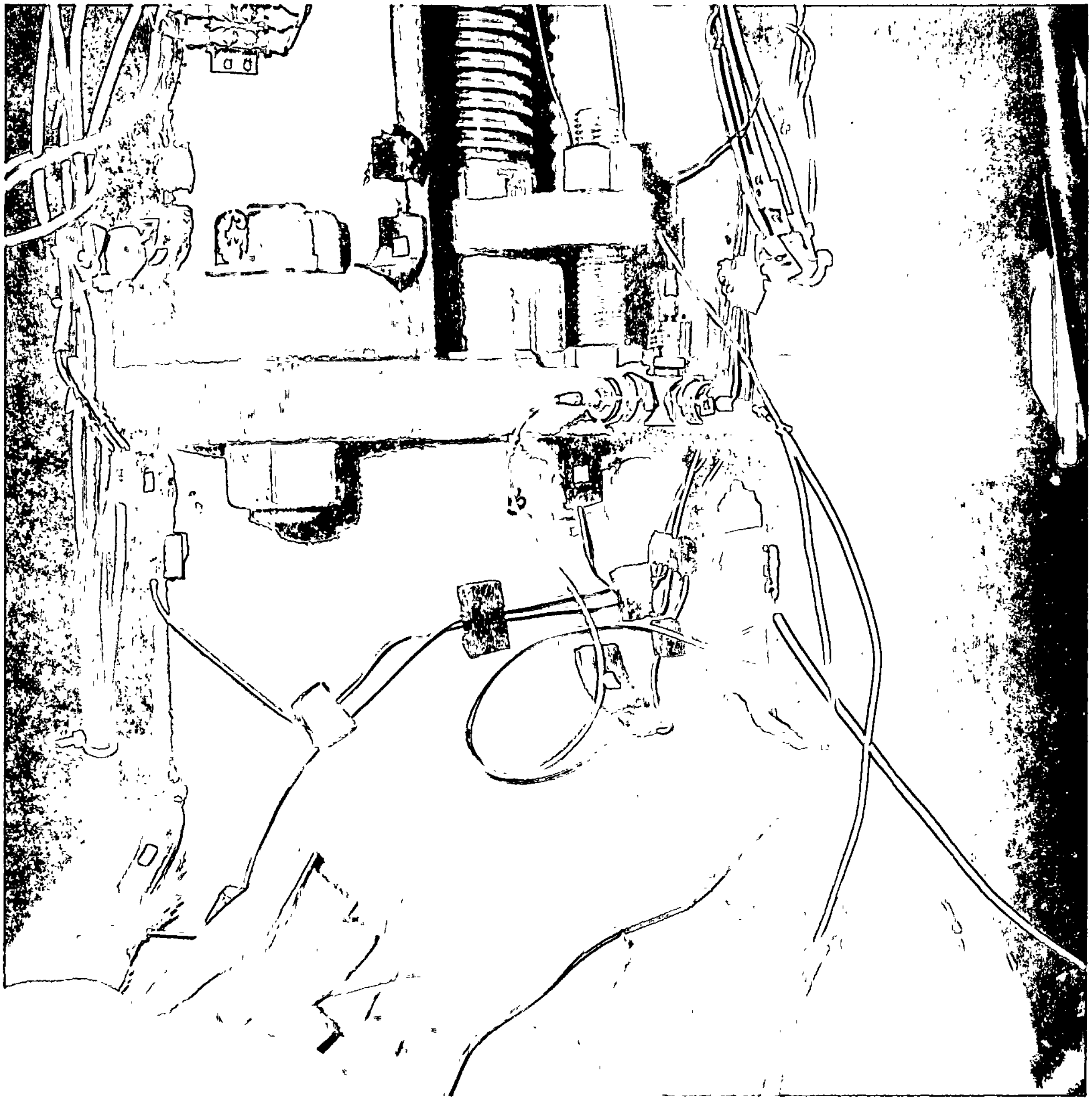
ACCELEROMETERS 1, 2, AND 3
LOCATION AO

PHOTOGRAPH 4

ACCELEROMETERS 4, 5, AND 6
LOCATION A1

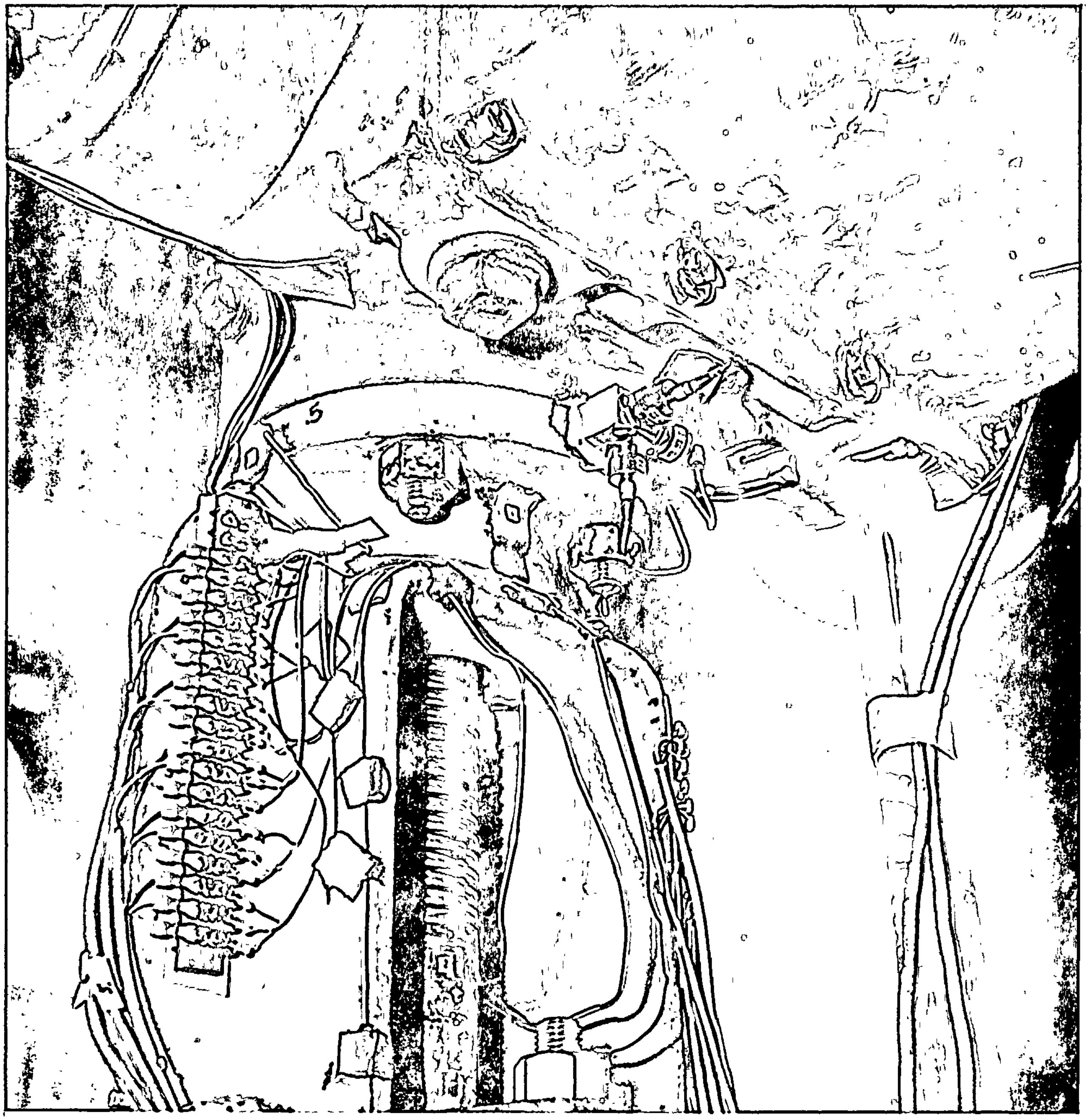
PHOTOGRAPH 5

ACCELEROMETERS 7, 8, AND 9
LOCATION A2



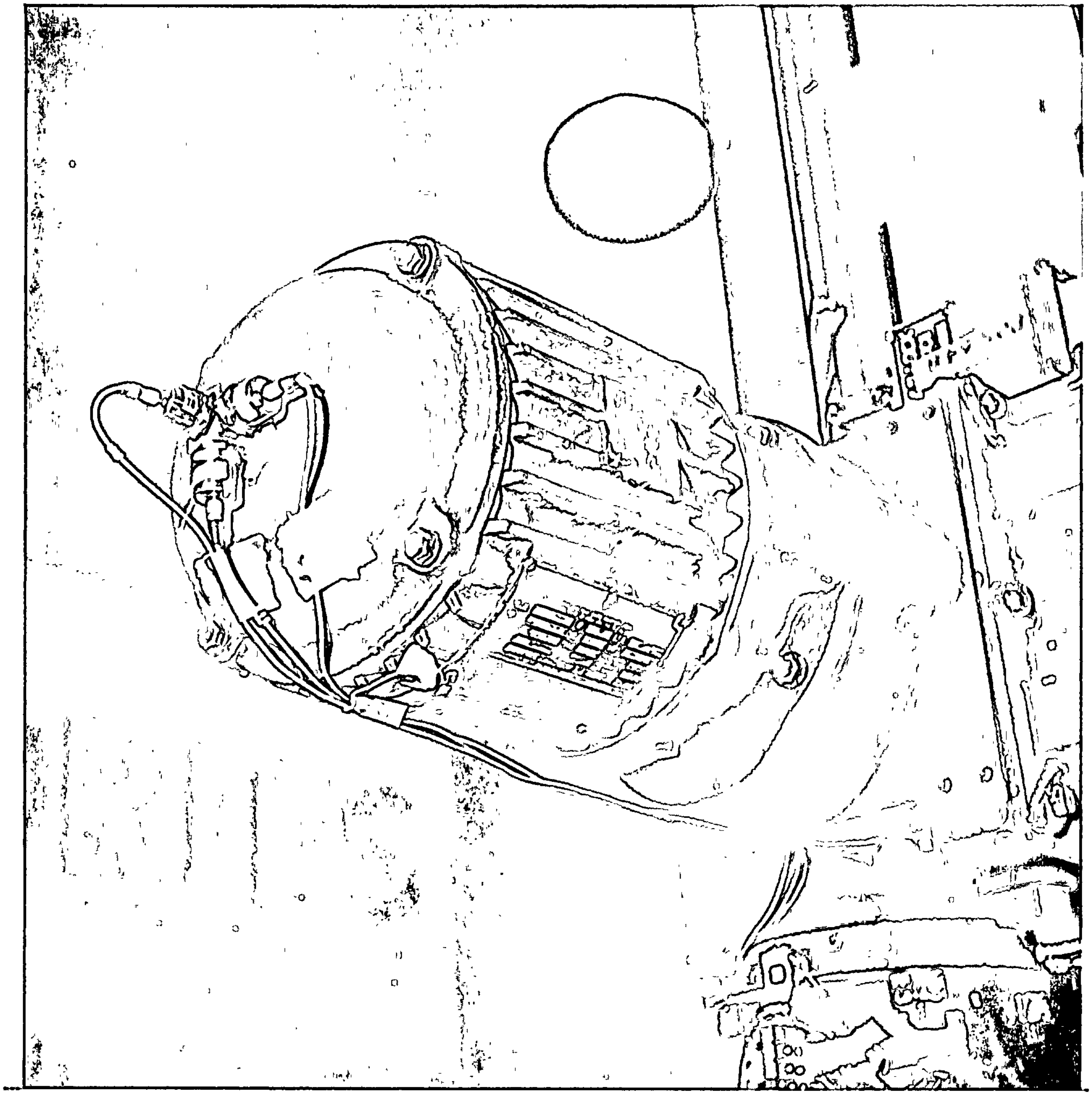
PHOTOGRAPH 6

ACCELEROMETERS 10, 11, AND 12
LOCATION A3



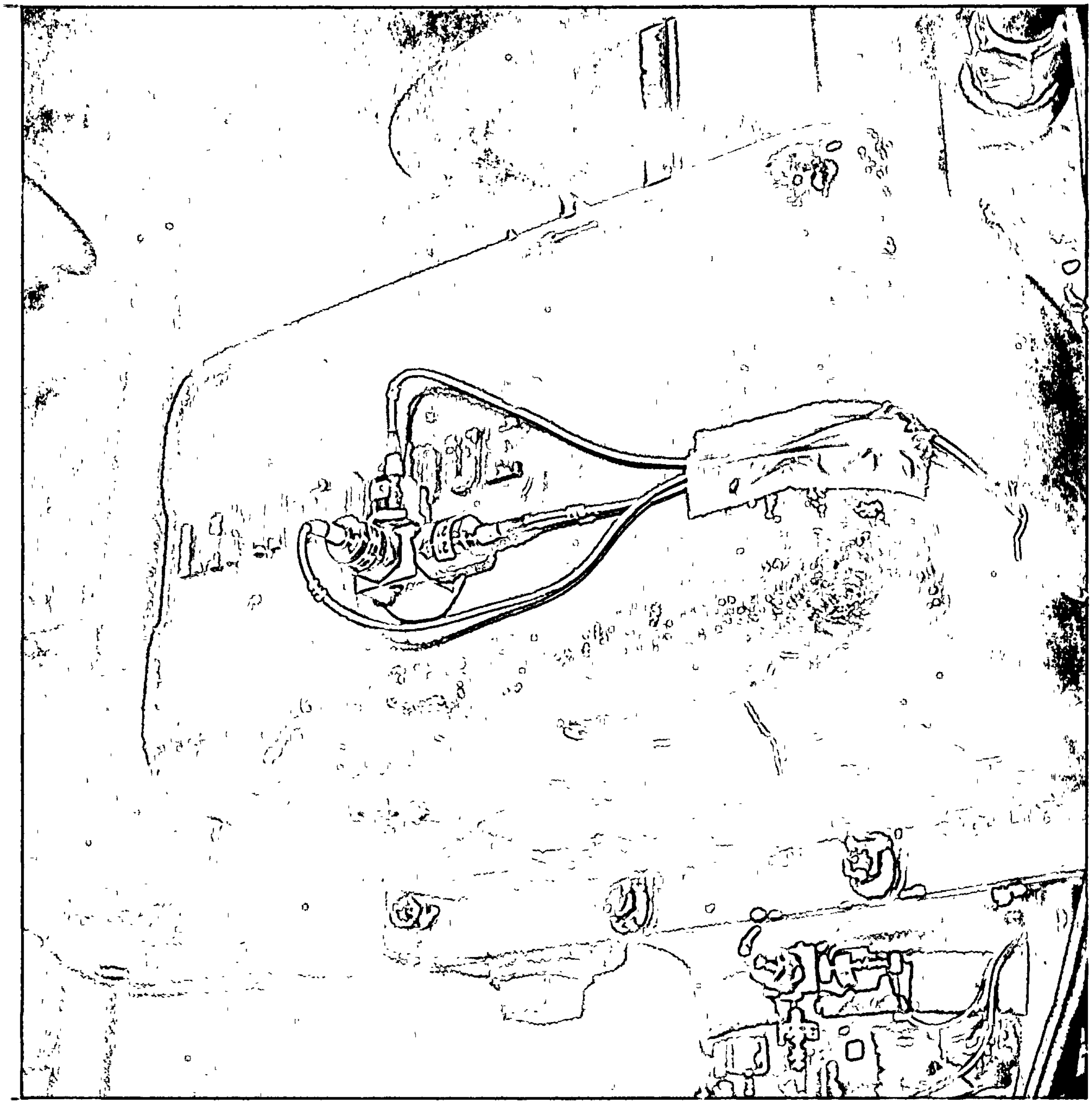
PHOTOGRAPH 7

ACCELEROMETERS 13, 14, AND 15
LOCATION A4



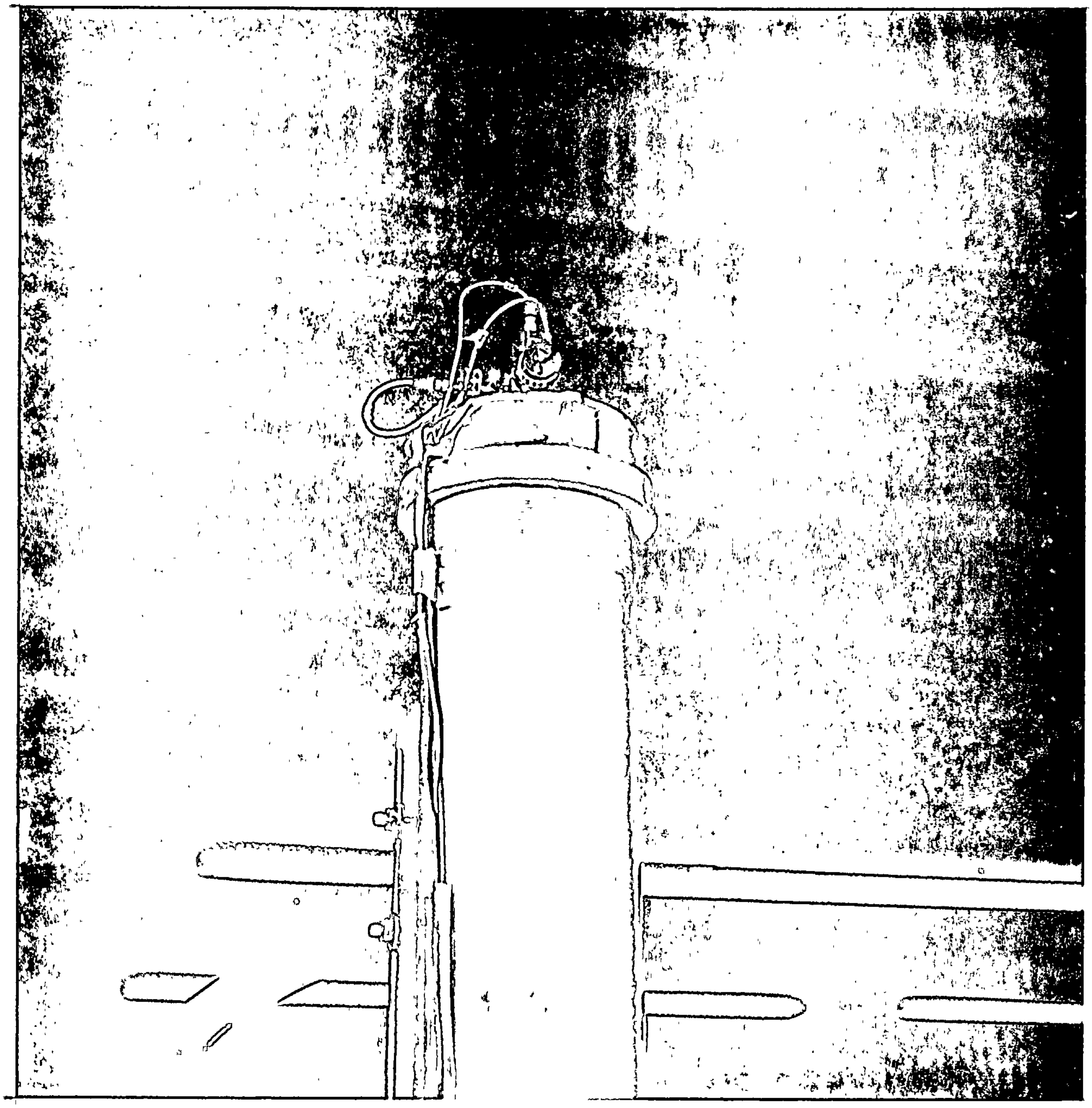
PHOTOGRAPH 8

ACCELEROMETERS 16, 17, AND 18
LOCATION A5



PHOTOGRAPH 9

ACCELEROMETERS 19, 20, AND 21
LOCATION A6



PHOTOGRAPH 10

ACCELEROMETERS 22, 23, AND 24
LOCATION A7

PACIFIC GAS AND ELECTRIC COMPANY

Procedure

for

Seismic Qualification Testing

of a

14 Inch Motor-Operated Valve

Revision 2

by

Panos G. Antiochos

July 1978

APPROVED: H. J. Gormly ____________________
Supervising Mechanical Engineer

APPROVED: D. V. Kelly ____________________
Chief, Mechanical & Nuclear Engineering Dept.

1. OBJECTIVES

1.1 To test the structural integrity and substantiate the operability and performance of a 14 inch double disc motor-operated gate valve and its accessories by shaker table testing.

1.2 To qualify seismically this valve and similar valve-actuator assemblies of the Diablo Canyon Nuclear Power Plants (Units 1 and 2) for the seismic inputs associated with the postulated 7.5M Hosgri event.

1.3 To document the testing in accordance with this procedure.

2. NAME PLATE DATA OF EQUIPMENT TO BE TESTED

2.1 VALVE

Manufacturer: Darling Valve Company

Model: 14 inch - S70DD (Weld end, outside screw yoke, double disc, with Limitorque operator)

Series: 300 lbs.

Material: Stainless Steel ASTM A-351, Grade CF-8M
Minimum Yield Strength: 30 ksi
Modulus of Elasticity: E = 29.2E6 psi

2.2 STEM

Material: 17-4 PH Stainless Steel
Yield Strength: 110 ksi
Tensile Modulus of Elasticity: E = 28.5E6 psi

2.3 ACTUATOR

Limitorque, Type SMB, Size 0

Serial No: 95918A

Motor by Peerless Electric

Frame: P12M

Volts: 220/440

Amps: 14/7

Cycles: 60

Phase: 3

HP: 2.6

RPM: 1750

Torque: 40 lb. ft.

Insulation Class B

Degrees C Rise 75

Degrees C Ambient 40

Duty: 15 min.

CAUTION: The maximum allowable number of starts of the actuator motor is 4 per hour. Allow at least 15 minutes cooldown time between successive start attempts.

2.4 YOKE

Manufacturer: Darling Valve Company

I.D.: D3132 6LWCB Pool 16VM54SD

Material: ASTM A-216 Grade WCB
Minimum Yield Strength: 36 ksi
Modulus of Elasticity: E = 27.9E6 psi

2.5 LIMIT SWITCHES

Manufacturer: NAMCO

Model: Snap-lock D2400X-ST2

2.6 Estimated weight of valve assembly flooded, without the mounting brackets: 4000 lbs.

Test Laboratory to weigh the valve assembly dry and flooded.

2.7 Time to open or close the valve (one full travel of the stem), about 70 seconds. Test Laboratory to measure and record the exact time.

3. EQUIPMENT PREPARATION

3.1 PGandE will ship the valve with the pipes and flanges welded, and with provision for vent and drain outlets.

3.2 Test Lab to design and fabricate fixtures (mounting brackets) to attach valve assembly on test table.

3.3 Inspect valve and actuator for possible damage during shipment and handling, before installation on shaker table.

3.4 Assemble valve, yoke and actuator as shown in attached sketches (Figures 1, 2, 3).

3.5 Torque the nuts of bolts and studs to the following specifications (with lubricated threads):

3.5.1 1-1/8" valve bonnet studs: 389 ft. lb.

3.5.2 1" yoke legs studs: 265 ft. lb.

3.5.3 3/4" actuator to yoke studs: 110 ft. lb.

3.5.4 1/2" motor to actuator bolts: 31 ft. lb.

NOTE: Check periodically, in-between tests, the tightness of bolts and studs. Re-torque if needed.

3.6 Weigh valve assembly (valve, actuator, yoke, brackets) dry as well as flooded with water. Record the weights.

3.7 Make all electrical and pipe connections to valve and actuator. Test Lab to provide hydrotest gear to keep valve pressurized with water at 350 psig. See Figure 9 for proposed piping and instrument schematic.

3.8 Install and calibrate triaxial accelerometers at the points shown on sketches (Figures 4, 5, 6).

3.9 PGandE Engineer will furnish, install and calibrate the strain gauges shown on Figures 4 and 5.

4. PRELIMINARY TEST DATA

4.1 Check manual to electrical mode of operation of actuator:

4.1.1 Declutch the electric motor by pushing the lever to the direction of the arrow.

4.1.2 Turn the handwheel 2 to 3 full turns and verify that it is engaged and the valve stem moves.

4.1.3 Energize the motor and verify that the latch releases automatically and the clutch engages the motor to the drive train.

4.1.4 Repeat 4.1 four more times. Record results in test data table (Figure 11).

4.2 Pressurize valve to 350 psig with water to simulate operating conditions. Refer to Figure 10 for procedure.

4.3 Operate actuator electrically for one full cycle (open/close) and record baseline data required for comparison with performance at other stages of the test. Record the time history of motor volts, amperes and watts. Give the time in seconds for a full open/close cycle and the maxima of volts, amperes and watts. Complete test data table (Figure 11).

4.4 After the completion of all dynamic tests:

4.4.1 Repeat 4.1 and record the data for comparison.

4.4.2 Check the tightness of the valve as follows:

4.4.2.1 Close valve, fill-up and vent both sides.

4.4.2.2 Pressurize the +x side to 350 psig.

4.4.2.3 Close the vent of the -x side.

4.4.2.4 After 10 minutes, read and record the indication of the pressure gauges on both sides.

4.4.2.5 The valve will be considered tight if there is no indication of pressure build-up at the -x side.

5. DEFINE DYNAMIC PARAMETERS

With the valve in the closed position and pressurized to 350 psig:

5.1 Perform a low level (0.2g) frequency sweep search for resonances from 2 to 35Hz at a sweep rate of not more than two octaves per minute. Record resonances, if any.

5.2 Repeat resonance search for each of the other two orthogonal axes.

5.3 If no resonance frequencies are detected in a direction of excitation, proceed with the qualification testing per Paragraph 6.

5.4 For each resonance between 2 to 35Hz the mode shape (response) and percent of critical damping shall be determined.

5.4.1 The level of the single frequency excitation applied for each resonance shall not exceed that which causes the stress at the lower part of the yoke legs (strain gauges S3) to go above 90% of yield or the acceleration as measured by accelerometer A4 to exceed 3g's, whichever occurs first. (90% yield = 32400 psi)

5.4.2 Due to the asymmetry of the valve/actuator assembly, torsional modes are possible and they should be investigated.

5.4.3 Each mode shape shall be plotted with clarity and with reference to forcing direction and the system of coordinates as shown on the layout sketches, Figures 1, 2, 3.

5.4.4 The percent of critical damping associated with each mode shall be measured by the band-width method (see IEEE Standard 344-75 § 3.5.1.2).

5.4.5 The spectral plots recorded during the test and used for the determination of the percent critical damping shall be part of the test report.

5.5 Repeat Steps 5.1 to 5.4 with the valve pressurized and the disc of the valve at its fully open position.

6. QUALIFICATION TESTING

6.1 SINGLE FREQUENCY TESTS

Expose the valve/actuator assembly to a series of single frequency sine beat tests at the test frequencies indicated on Figure 7 and at the natural frequencies detected during the resonance search (§5.1). The excitation at each test frequency shall be in the form of a series of sine beats of 10 oscillations per beat with sufficient pause between two successive beats. Refer to IEEE Std. 344-1975. The peak acceleration shall be the Required Input Motion (RIM) value shown on Figure 7.

Each sine beat test shall last for at least 20 seconds, after the prescribed acceleration (RIM) level is reached. Monitor and control RIM using accelerometer A2.

During the time of each sine beat testing, the valve operator shall be energized. At the end of each shaking cycle, stop the Limitorque motor. Allow time for motor cooldown before proceeding to the next sine beat test. See note under § 2.2 for duty of operator and allowable starts per hour.

Start the next sine beat test with the valve stem at the position left at the end of the previous shaking cycle. At the end of its stroke, the stem direction of movement shall be reversed. The stepwise open/close attempts of the valve actuator shall continue until all sine beat tests per axis are completed. PGandE will provide motor controller for the reversal of direction of the actuator motor and technical assistance for the hookup.

Apply motion at the same frequencies and accelerations on each of the three orthogonal axes separately. Monitor and limit the input motion to the actuator using:

(a) Accelerometer A4 located on the upper flange of the yoke (it should not exceed 6 g's), or

(b) Strain gauge indications. (No stress should be allowed to exceed 90% yield. See § 5.4.1 for yield values).

All sine beat tests shall be performed with gradually applied input level of excitation. It is suggested that the input is applied at 1/3 and 2/3 of RIM before full RIM values are applied. Continuous monitoring of stresses will be the responsibility of PGandE Engineer.

At this point, re-torque the nuts of the studs per 3.5.

6.2 MULTI-FREQUENCY TESTS (BIAXIAL)

Expose the actuator to a biaxial multi-frequency test motion which when analyzed for each axis produces a Test Response Spectrum (TRS) which envelopes the Required Response Spectrum (RRS) shown in Figure 8. The test shall be performed with one horizontal axis combined with the vertical axis and then repeated with the orthogonal horizontal axis combined with the vertical.

Independent (non-phase coherent) multi-frequency motions for the horizontal and vertical axes shall be used. The duration of each test, with simultaneous function of the valve actuator, shall be 30 seconds. Count the shaking time after the prescribed vibration level is reached, as monitored by accelerometer A2.

There shall be 5 OBE tests before each SSE. For definition of OBE and SSE tests, as well as for other terms used in this procedure, see IEEE Std. 344-1975 § 2. (Although the postulated 7.5M Hosgri seismic event is not the SSE for the plant, where SSE is referred to in this test procedure, or in the IEEE Std. 344, the seismic inputs associated with the postulated 7.5M Hosgri seismic event will be used).

The 5 OBE tests, each 30 seconds long, shall be done with simultaneous, continuous opening/closing of the valve.

The results of the test shall be presented in terms of the TRS at 2% damping for comparison to the RRS (Figure 8). The results of the test shall also be presented in terms of the TRS at two additional values of damping: 3% and 5%.

7. DOCUMENTATION

7.1 The valve test and the test data shall be treated as information proprietary to PGandE. Information about the test shall not be disclosed in any form to any third party without written approval by the Diablo Canyon Project Engineer.

7.2 The test shall be witnessed by PGandE Engineers and USNRC staff.

7.3 All phases of the test shall be video-taped by PGandE crew on 3/4 inch color cassette tape with audio channel.

7.3.1 Each test run shall be announced briefly before or during the execution. For example:

"Resonance Search in X direction" or
"Biaxial Random Input Test in the Y & Z axes," or
"Resonance dwell at 16Hz in Z axis," etc.

7.3.2 For scaling and perspective reasons, a person about 5'-10" to 6 feet tall shall appear moving for a few seconds in front of the test table with the valve fully instrumented and ready to be tested.

7.3.3 Each test run shall be identified by a number. The number shall be written with heavy red digits, about 6" high, on a white 8½"x 11" label. The label shall be placed on a prominent position on the valve (or actuator, or test table) so that it can be clearly seen and video-taped. PGandE will furnish the labels.

7.4 In addition to video-taping, the setup shall be photographed in color by PGandE crew from various angles of perspective.

7.5 The test data from the 8 triaxial accelerometers and all strain gauges shall be recorded on multi-track magnetic tape. One track shall be used for audio signals, to record the announcement of the test, first by its number (§7.3.3) and then by its brief description (§7.3.1). PGandE will provide manpower, equipment and tapes for the recording of the strain gauge data only.

7.6 For each test run, there shall be a completed table of the test data, shown on Figure 11, supplemented with the appropriate spectrum analyzer plots. Each plot shall indicate:

7.6.1 The test run number.

7.6.2 The required response spectrum and the test response spectrum plotted for the same value of critical damping.

7.6.3 The % of critical damping.

7.6.4 The axis or axes of excitation.

7.6.5 The scale of acceleration in g units.

7.6.6 The I.D. (number) of accelerometer(s) from which it was derived.

7.7 After the completion of the test and the evaluation of the data, the Testing Laboratory shall submit to PGandE two copies of a draft report. The report shall contain:

7.7.1 Sketches or photographs of the test setup.

7.7.2 Brief description of the test.

7.7.3 Instrumentation diagrams (accelerometers, strain gauges pressurization setup, etc.).

7.7.4 Test procedures in accordance with this specification.

7.7.5 Completed test data table for each test run.

7.7.6 Plots of TRS and RRS for each run.

7.7.7 Table of resonances - if any - the associated damping for each mode, and plots of the responses (mode shapes) per Paragraph 5.

7.7.8 Identification of instruments and equipment used to carry out the test: By Item Name, Manufacturer, Model No., Range, etc.

7.7.9 Calibration history of instruments used.

7.7.10 Test results, comments, conclusions.

7.7.11 Sketches showing design details of the mounting brackets (dimensions, materials, welds, weights).

7.7.12 The exact weight of the valve assembly as tested (dry and flooded with water).

7.8 PGandE Engineer shall return to Test Laboratory one copy of the draft report with comments or approval.

7.9 After approval of test report, the Testing Laboratory shall:

7.9.1 Ship the valve and its accessories, properly protected, back to Diablo Canyon.

7.9.2 Submit to PGandE 10 copies of the final report.

7.9.3 Submit the magnetic tape(s) with the test data.

7.10 PGandE's Department of Engineering Research (DER) will reduce the strain gauge data and transmit to Engineering 10 copies of stress report to be incorporated to the report of the Test Laboratory.

7.11 PGandE's DER will transmit to Engineering the video-tape(s) and the photographs taken during the test.

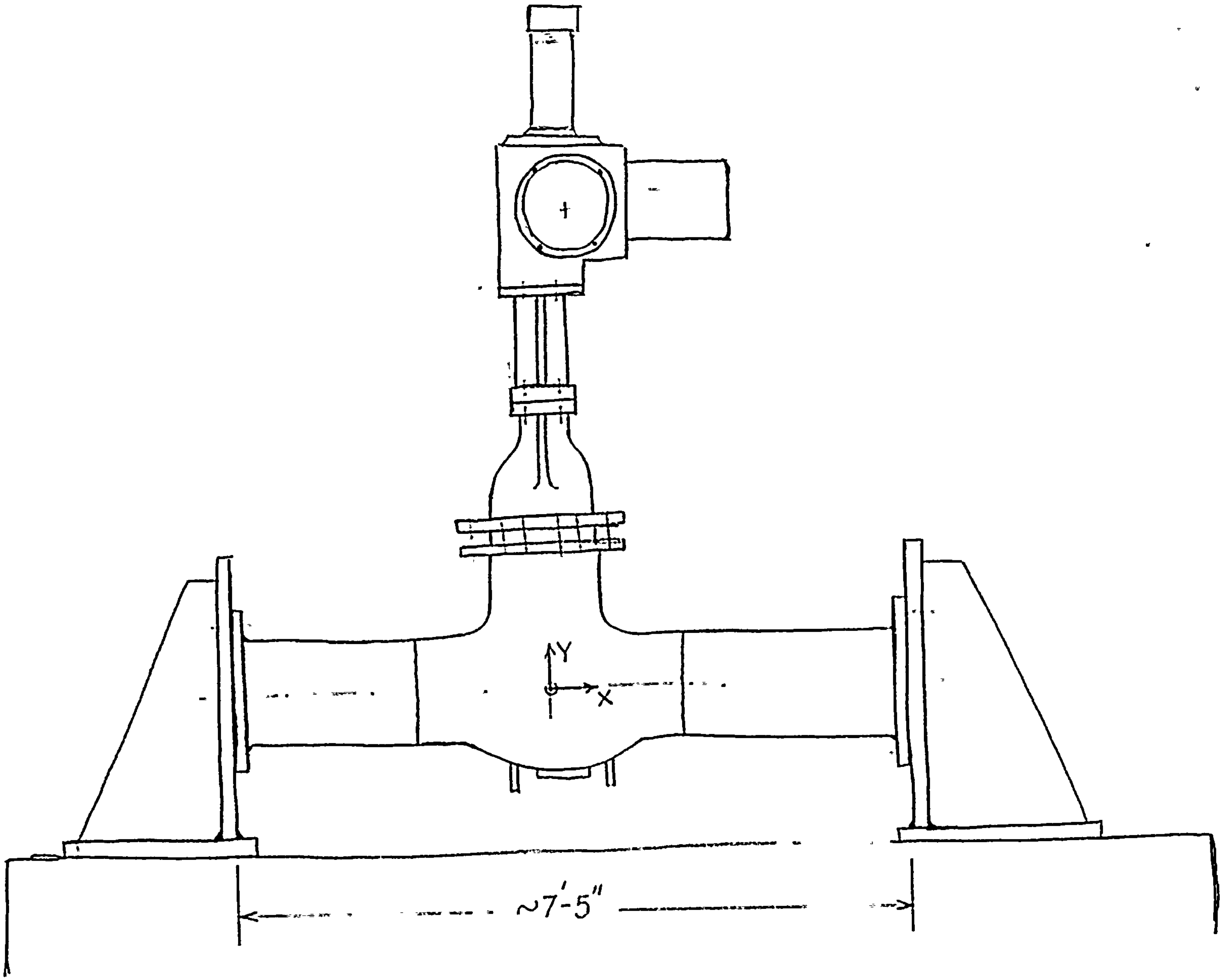


FIGURE 1

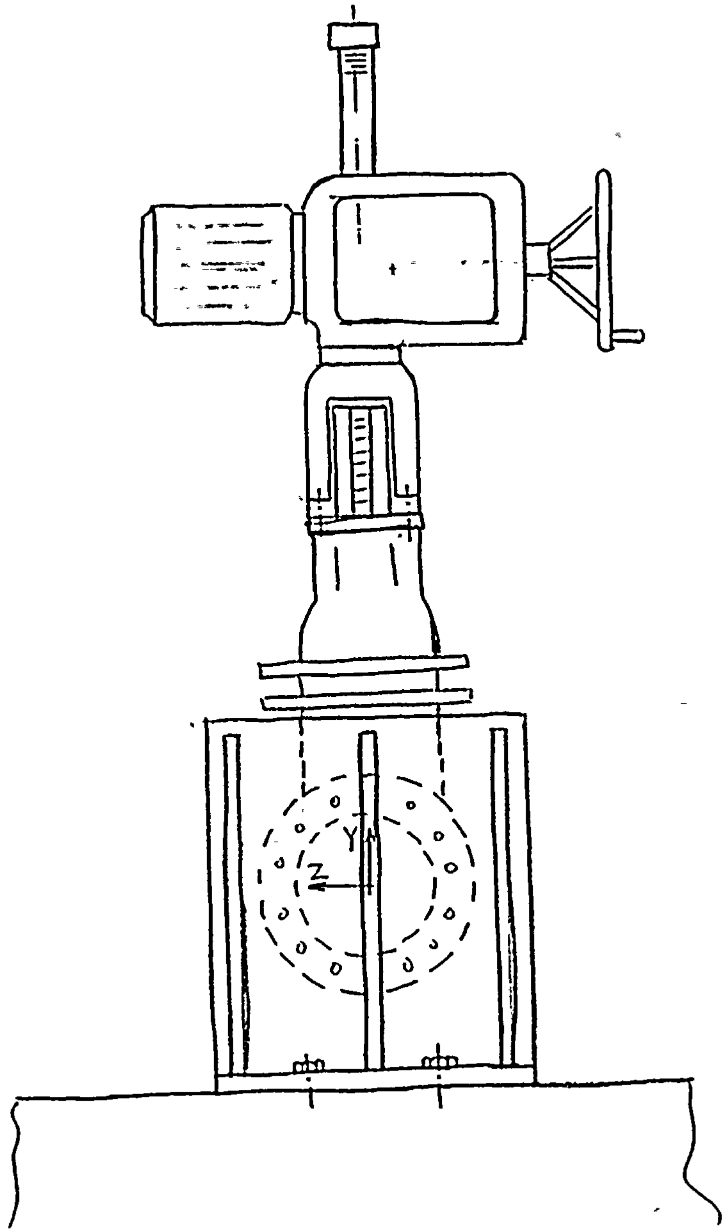


FIGURE 2

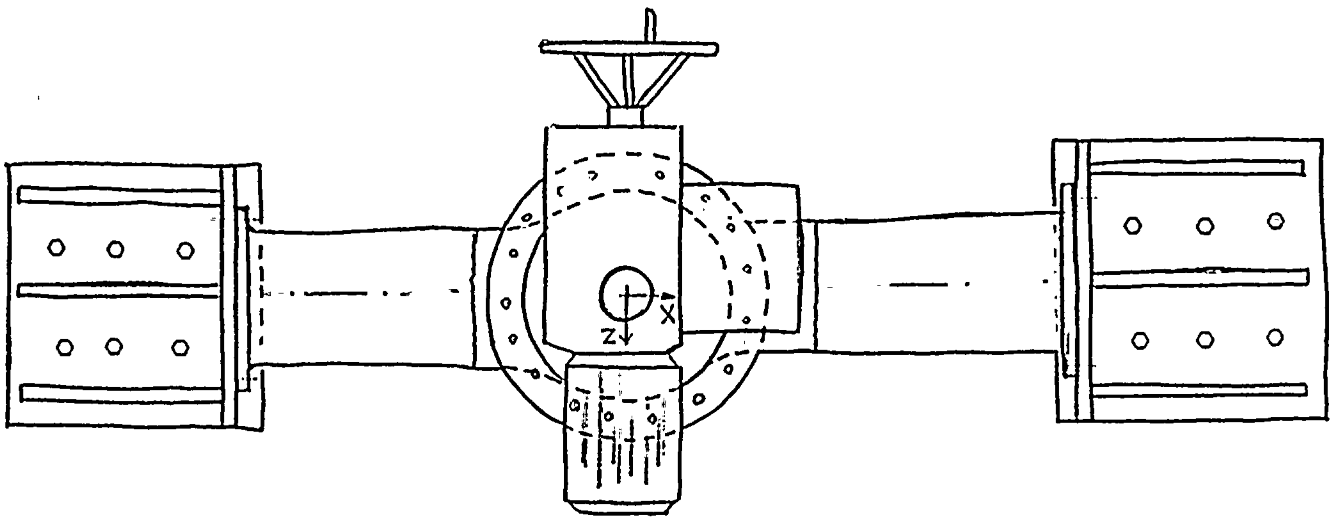


FIGURE 3

STRAIN GAGES	
POSITION	No. OF GAGES
#1	4
#2	4
#3	4
#4	4
#5	4
#6	2
#7	2
#8	2

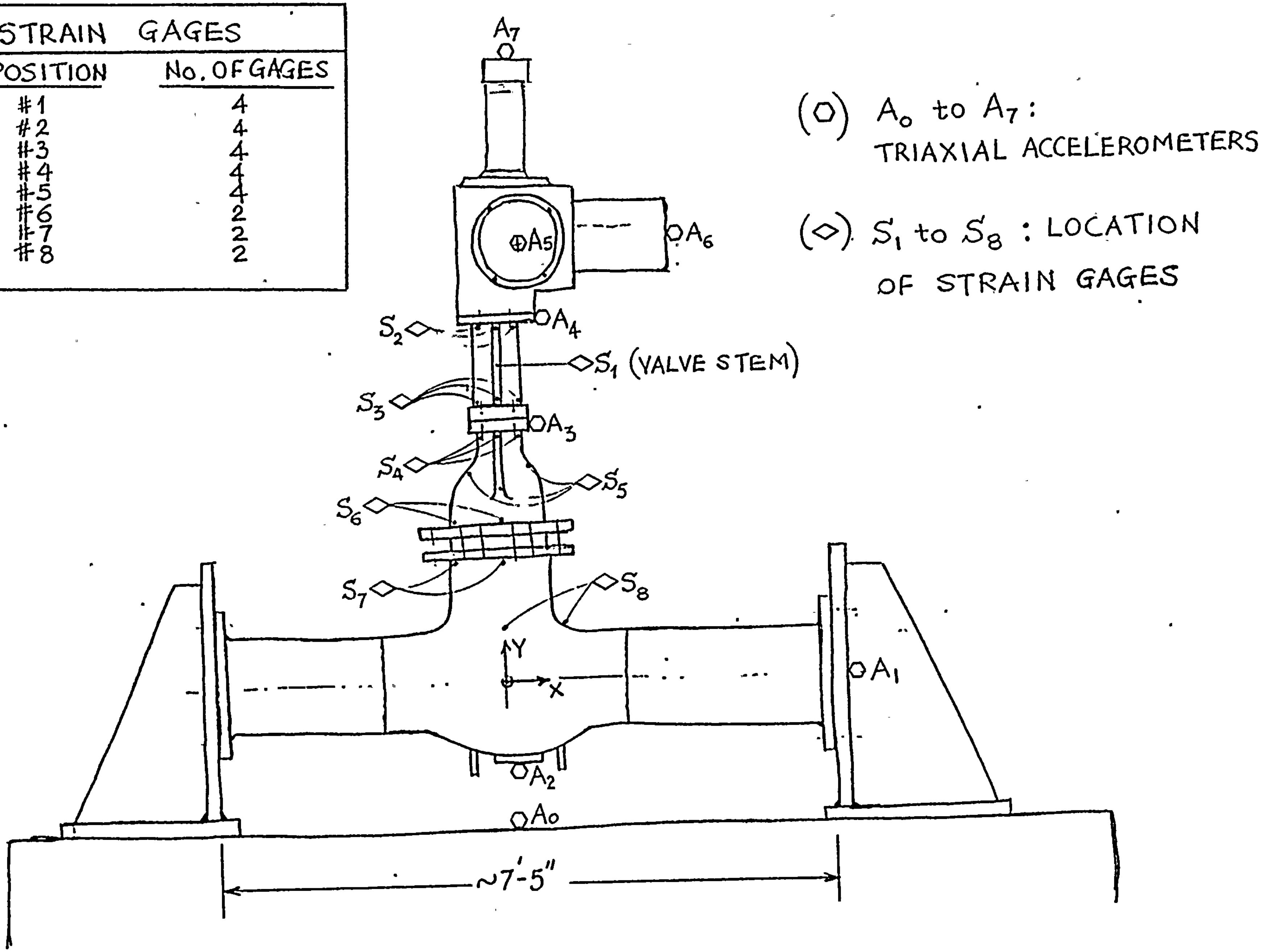


FIGURE 4

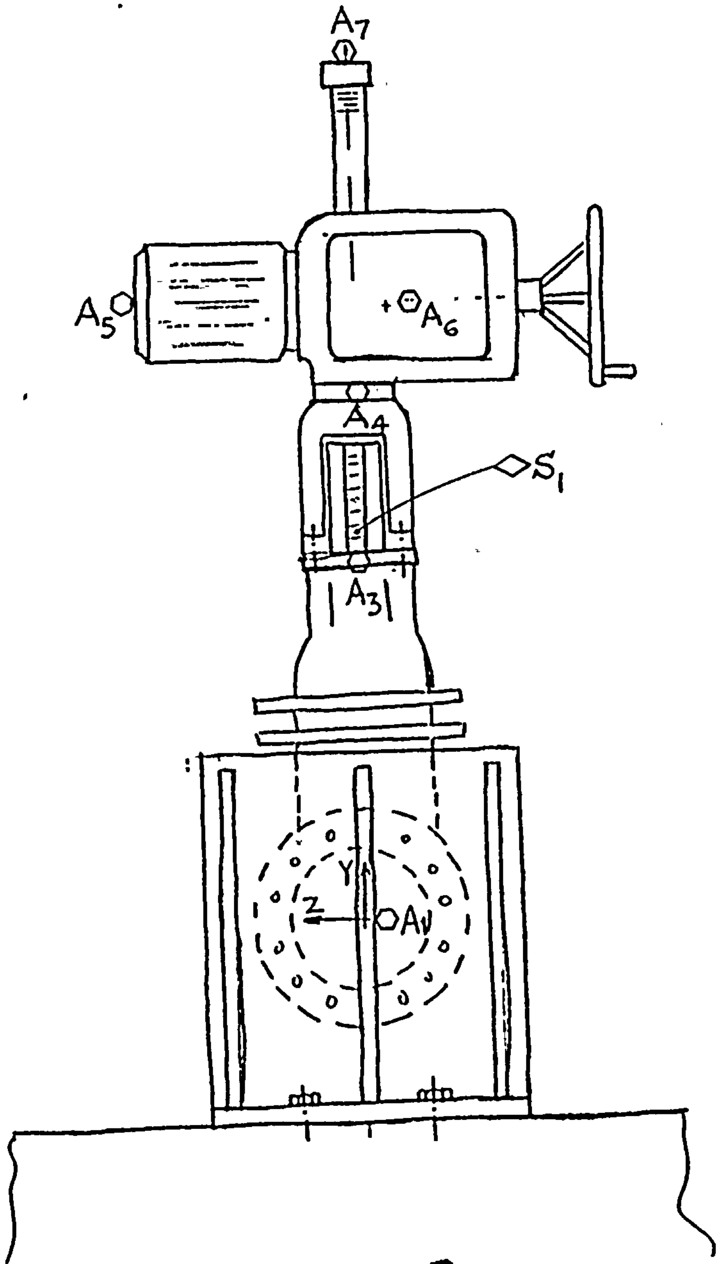


FIGURE 5

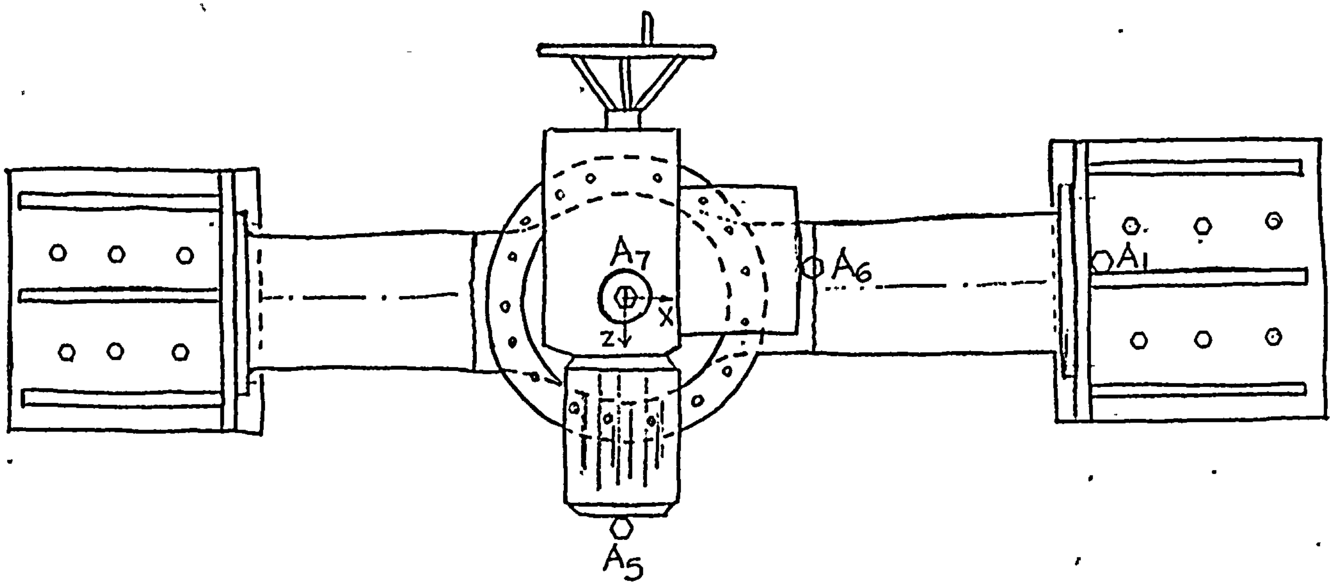
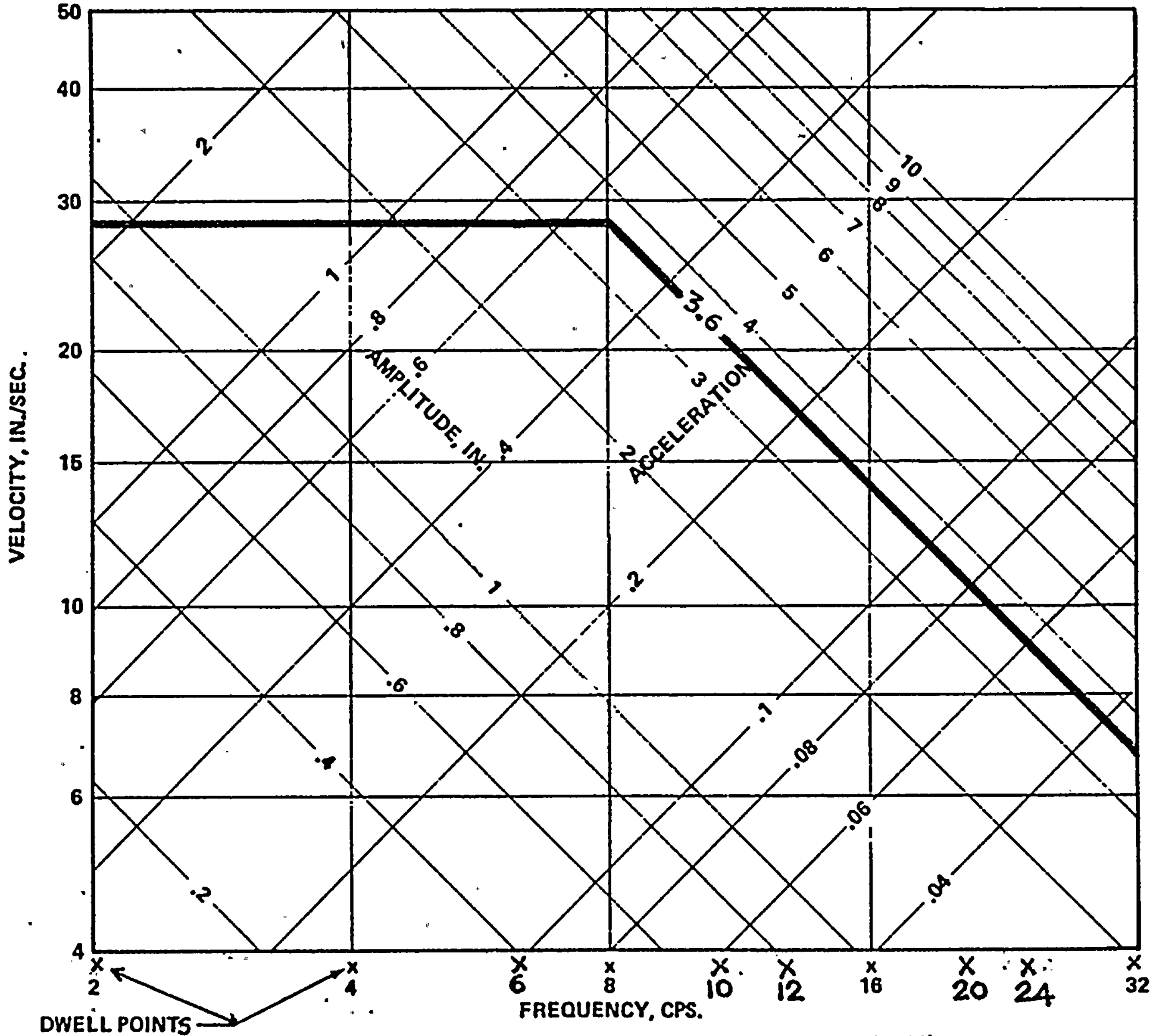
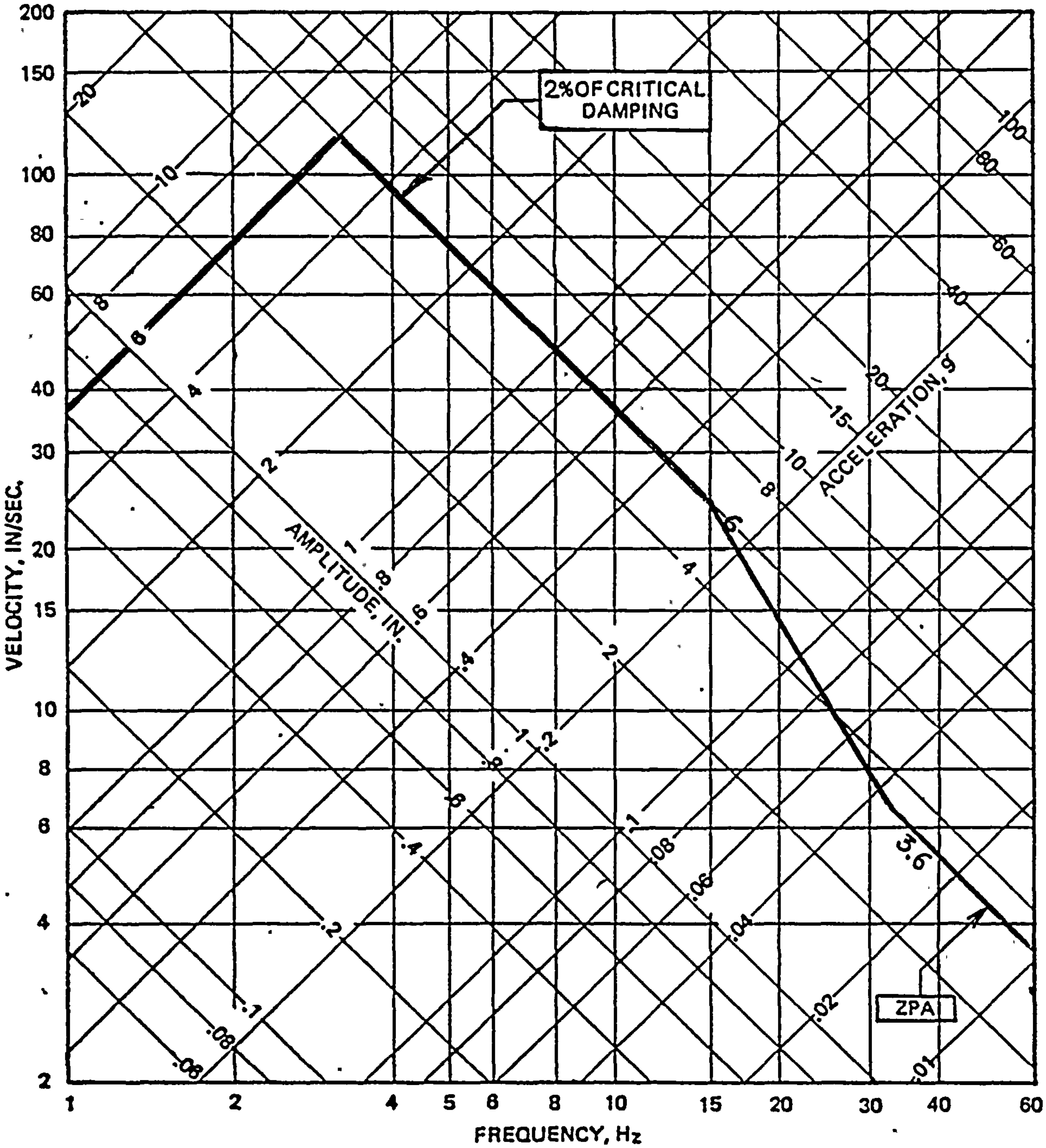


FIGURE 6

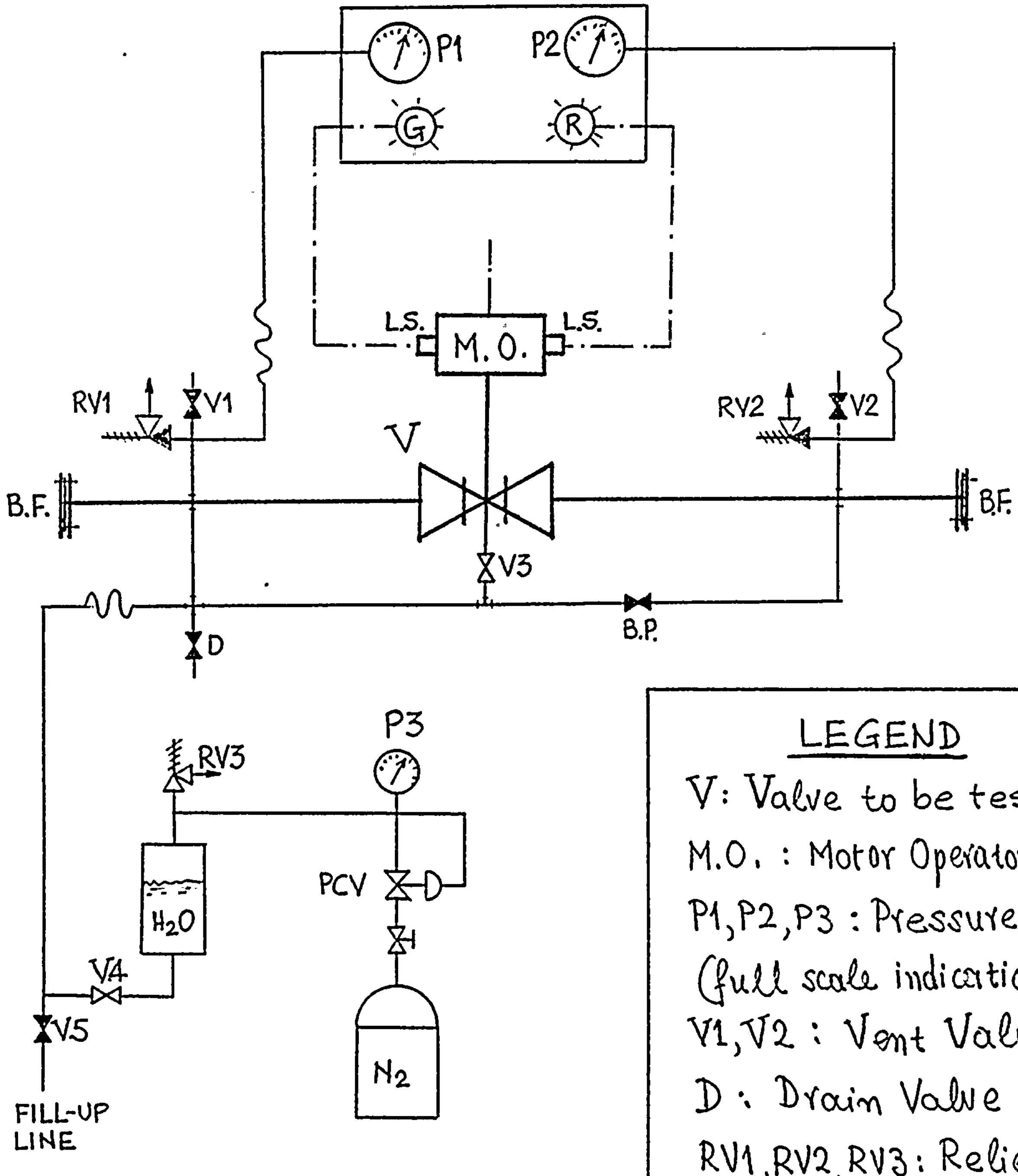


SEISMIC QUALIFICATION REQUIRED INPUT MOTION (RIM)

FIGURE 7



SEISMIC QUALIFICATION
REQUIRED RESPONSE SPECTRUM (RRS)
FIGURE 8



LEGEND

V: Valve to be tested
M.O. : Motor Operator (Limitorque)
P1, P2, P3 : Pressure gages (full scale indication 500 psig)
V1, V2 : Vent Valves
D : Drain Valve
RV1, RV2, RV3 : Relief valves (set to relieve at 375 psig)
BP : By-pass valve
PCV : Pressure Control Valve
LS : Limit Switch

BF : Blind Flange
~ : Flexible Pipe (Hose)
G : Green (100W bulb, valve fully open)
R : Red (100W bulb, valve closed)

Proposed Pressurization/Instrumentation Schematic

FIGURE 9

PREPARATION & FUNCTIONAL PERFORMANCE CHECKLIST

(see Figure 9 for component identification)

x ≡ closed O ≡ open s ≡ start e ≡ end m ≡ midpoint

		V	V1	V2	V3	V4	V5	BP	D	P1	P2	P3	G	R
Fill-Up, Pressurize	s	O	O	O	O	X	O	O	X	—	—	—	ON	OFF
	e	X	X	X	O	O	X	X	X	350	O	350	OFF	ON
Operator Baseline Data	s	X	X	X	O	O	X	X	X	350	O	350	OFF	ON
	m	O	X	X	O	O	X	X	X	350	350	350	ON	OFF
	e	X	X	X	O	O	X	X	X	350	350	350	OFF	ON
Resonance Search (Valve Closed)	s	X	X	X	O	O	X	X	X	350	O	350	OFF	ON
	e	X	X	X	O	O	X	X	X	350	O	350	OFF	ON
Resonance Search (Valve Open)	s	O	X	X	O	O	X	X	X	350	350	350	ON	OFF
	e	O	X	X	O	O	X	X	X	350	350	350	ON	OFF
Sine Beat Tests	s	X	X	X	O	O	X	X	X	350	O	350	OFF	ON
	m	O	X	X	O	O	X	X	X	350	350	350	ON	OFF
	e	X	X	X	O	O	X	X	X	350	350	350	OFF	ON
Multi-Frequency Tests (Biaxial)	s	X	X	X	O	O	X	X	X	350	O	350	OFF	ON
	m	O	X	X	O	O	X	X	X	350	350	350	ON	OFF
	e	X	X	X	O	O	X	X	X	350	350	350	OFF	ON

FIGURE 10

TEST DATA TABLE

TEST No.	DATE:	TIME:

"Brief Description of Test" See §7.3.1

TEST RESPONSE SPECTRUM: Fig .... { β = % ; ZPA = g ; PEAK = g }

SHAKING TIME: seconds

ACTUATOR MOTOR DATA {
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Runnig Time = sec
}

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

FOR WYLE:

FOR PG&E:

FIGURE 11

TEST DATA TABLE

TEST No.	DATE:	TIME:

TEST RESPONSE SPECTRUM: Fig ....
- β = %
- ZPA = g
- PEAK = g

SHAKING TIME: seconds

ACTUATOR MOTOR DATA
- Vmax = Volts
- Amax = Amps
- Wmax = Watts
- Running Time = sec

MAXIMUM RECORDED ACCELERATION (g)

AXIS	ACCELEROMETER							
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7
X								
Y								
Z								

MAXIMUM RECORDED STRESS (psi)

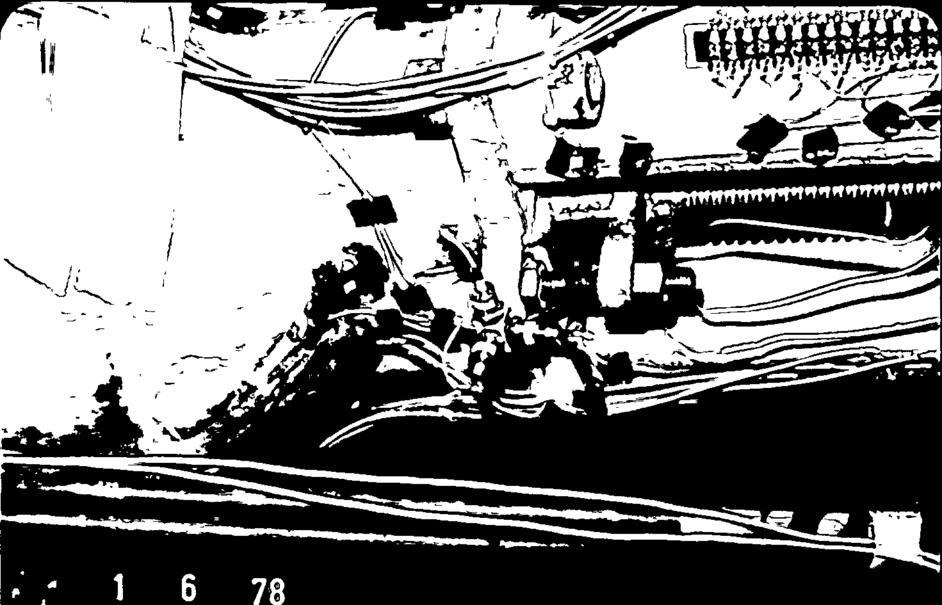
LOCATION	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
GAGE No.								
DIRECTION								
STRESS (±)								
% YIELD								

NOTES:

FOR WYLE:

FOR PG&E:

FIGURE 11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SEP - 78
SHARPSHOT ®


CAUTION

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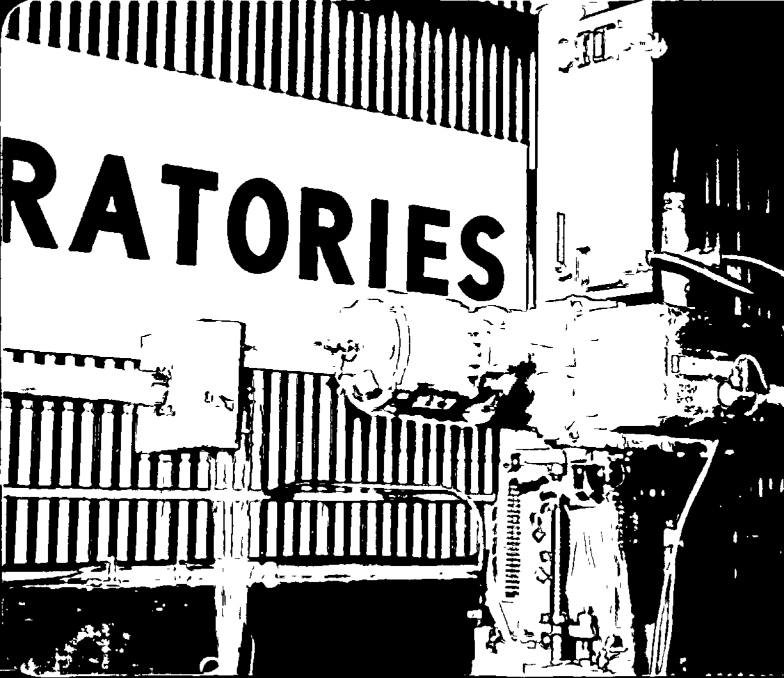
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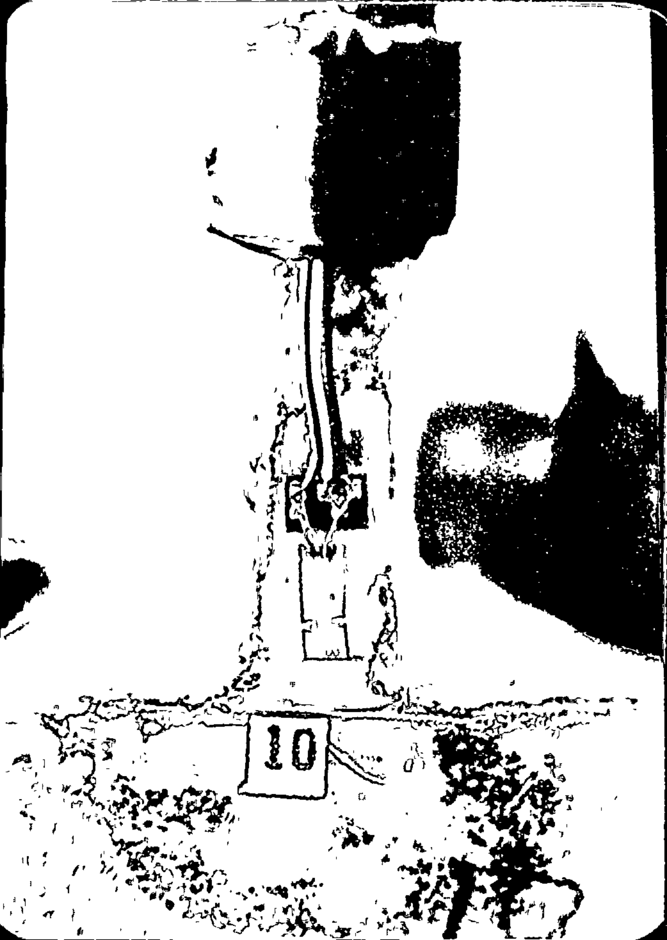
SHARPSHOT ®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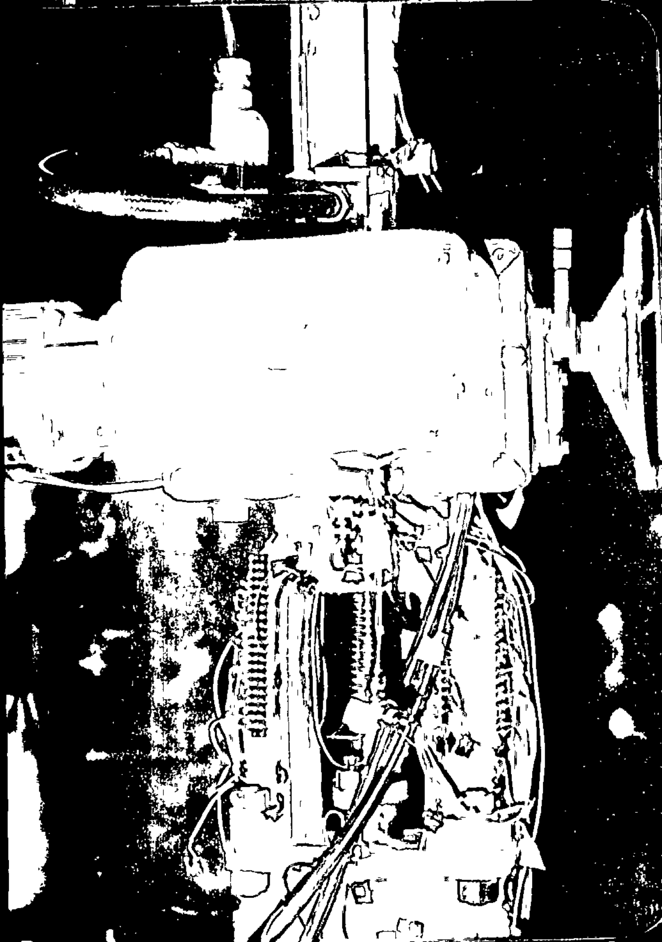

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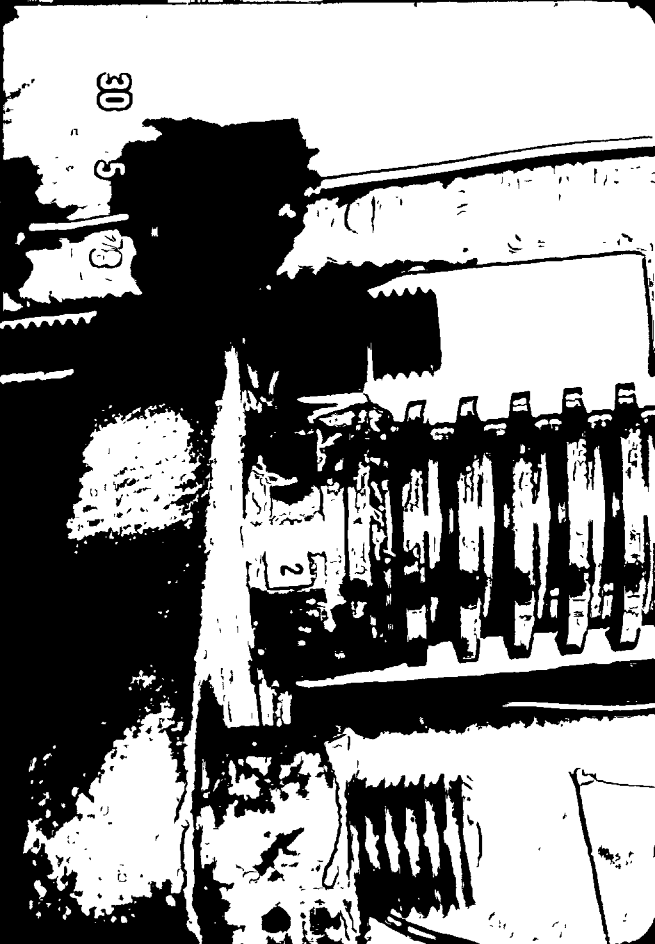

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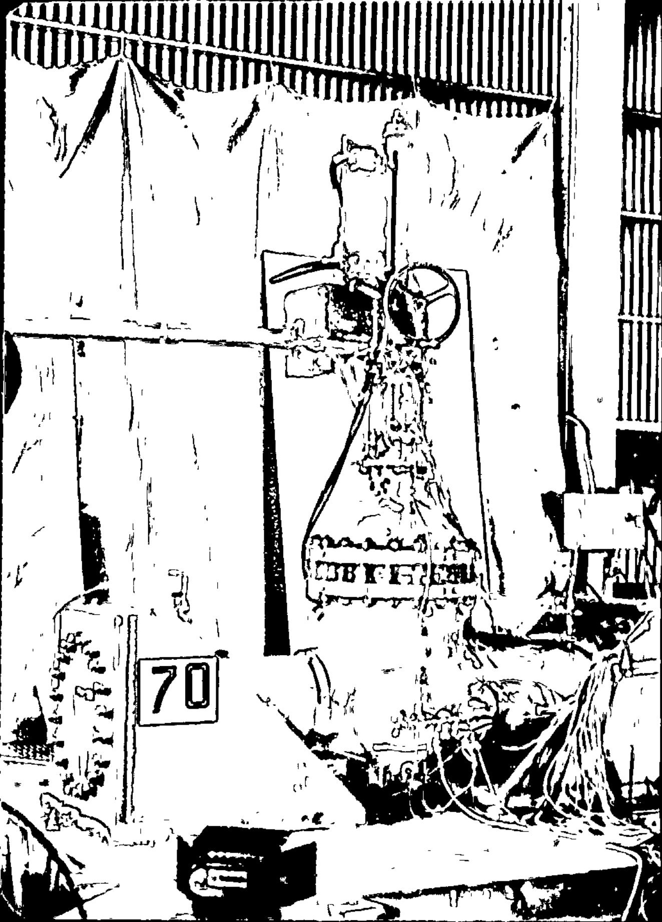
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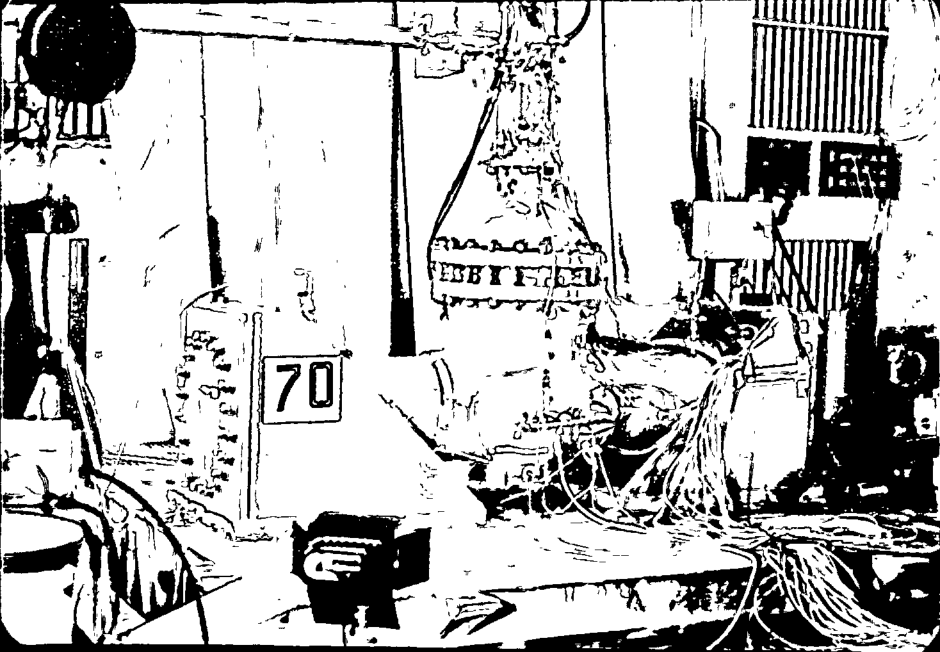
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#10

Oct 20, 1978

Mr D.P. Allison

The enclosed material has been transmitted informally by PG+E to the NRC staff. The purpose of this note is to transmit copies to you for placement in the public document rooms.

Enclosure

1. Electrical Equipment Functionality rewrite (3.10.6)

CHAPTER 10

ELECTRICAL EQUIPMENT AND INSTRUMENTATION

INDEX

INDEX (Cont'd)

INDEX (Cont'd)

10/17/78

INTRODUCTION

The safety related electrical equipment for Diablo Canyon Units 1 and 2 was originally seismically qualified in accordance with IEEE Std. 344-1971. Recently the Diablo Canyon equipment was re-evaluated to newly established criteria based on response spectra derived from the postulated 7.5M Hosgri event. In the process of this re-evaluation, PG&E committed to perform any additional testing on certain plant equipment to the spectra derived from the postulated 7.5M Hosgri event and according to the methods for seismic qualification of electrical equipment contained in IEEE Std. 344-1975 and NRC Regulatory Guide 1.100. This additional testing has been completed, and the results have been presented to the NRC Staff in several licensing review meetings. At the most recent such meeting PG&E was requested by the NRC Staff technical reviewers to provide summary information on the results of these tests to facilitate the Staff's review. The attached material is provided in response to that request. For each type of equipment tested, the following information is presented:

1. Name of Equipment
2. Description of Equipment
3. Safety Function
4. Test Criteria and Plan
5. Test Procedure and Setup
6. Test Results
7. Conclusions

The equipment was tested in seven groups, with one seismic required response spectra per group. The required response spectra is given in attached Figures 1 through 7 of Wyle Test Report 3642. Complete test results are given in Wyle Reports 58255 and 58255-1.

Table 1 lists the balance of plant equipment tested to the Hosgri seismic spectra and to IEEE 344-1975.

Table I

GROUP I ✓4160 Volt Metalclad Switchgear

✓4160 Volt Potential Transformer

✓Vital Relay Board

✓Emergency Light Units

GROUP II ✓Diesel Generator Excitation Cubicle

✓Diesel Generator Control Panel Door

✓Diesel Generator Control Cabinet Sub-Panel with the following items mounted on the panel:

1. Differential Pressure Switch (two)
2. Contactor (one)
3. Switching Tachometer (one)
4. Time Delay Relays (two)
5. Relays (four)
6. Industrial Control Relays (four)

GROUP III Ventilation System Printed Circuit Board and Power Supply

Ventilation System Relay Sub-Panel

Annunciator Components consisting of:

Power Transfer Panel

Printed Circuit Boards (four)

Printed Circuit Board Rack

Constant Voltage Transformer

Power Transformer

Logic Power Supply

Auxiliary Logic Power Supply

Relays (four: two dc and two ac)

Table I

(Continued)

GROUP III (Cont'd.)		DC to DC Converter
		DC to AC Inverter
		Typewriter
GROUP IV	DC Distribution Panel	
	Battery Charger	
	Turbine Lube Oil Starter	
	Fire Pump Controller	
	Local Starter (LPF 37)	
	Battery Cells (two)	
GROUP V	Vital Load Center (480v)	
	Local Starter (LPG66)	
	Circuit Breakers 100 Amp (two)	
	Motor Starters (seven)	
	Auxiliary Relay Panel (480v Bus 2H)	
	Auxiliary Relay Panel (Bus G)	
GROUP VI	Local Starter (LPF 36)	
GROUP VII	Switches (six)	
	Ammeter	

FIGURE 1

REVISION A

GROUP I - VITAL RELAY BOARD AND 4160 SWITCHBOARD
Turbine Building 119 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE - 3% Damping
OBE = 60% SSE

A

RESPONSE SPECTRA

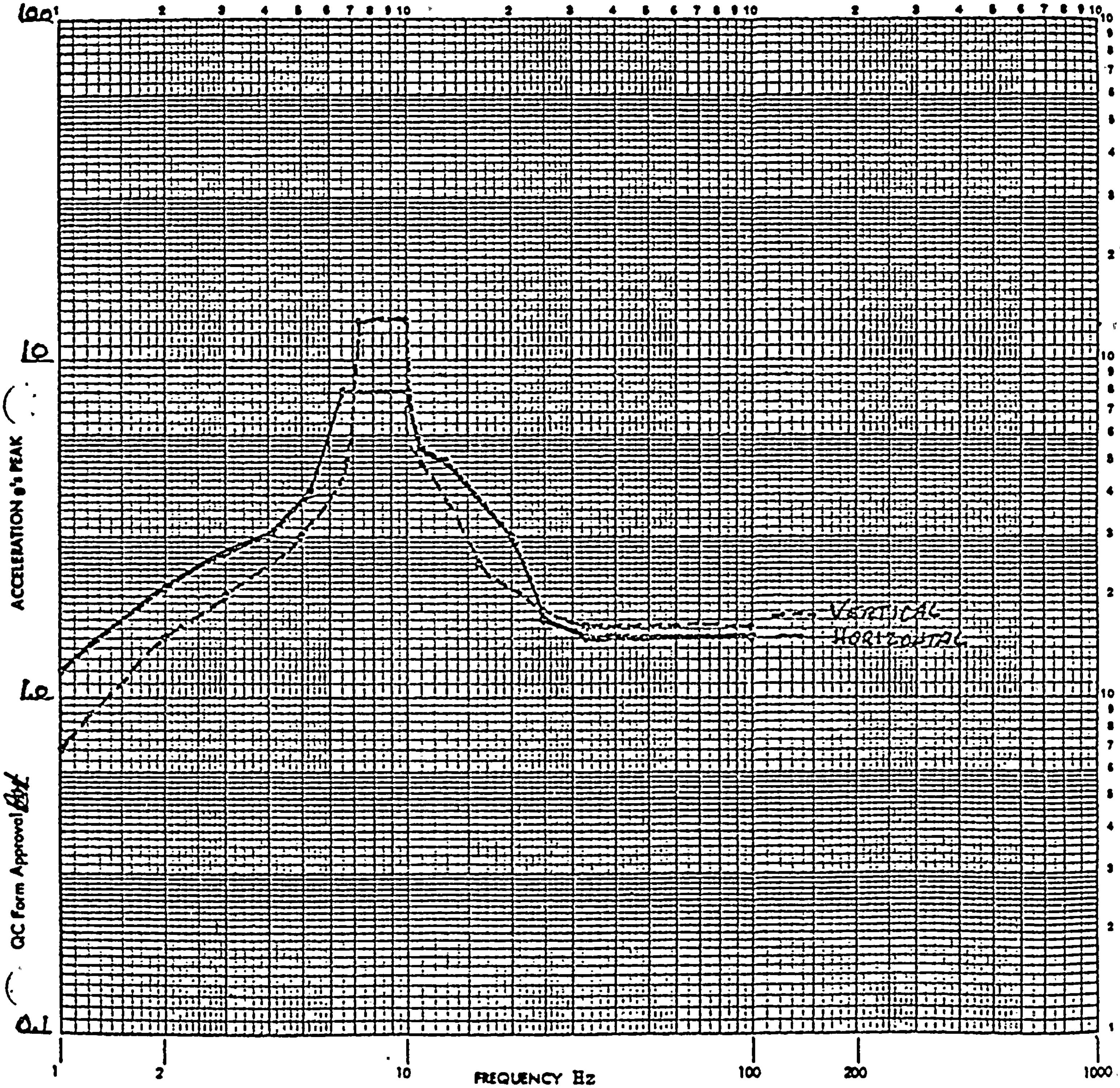


FIGURE 2

GROUP II - DIESEL GENERATOR CONTROL CABINET
AND DIESEL GENERATOR EXCITATION CUBICLE
Turbine Building 85 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE
3% Damping
OBE = 60% SSE

A

RESPONSE SPECTRA

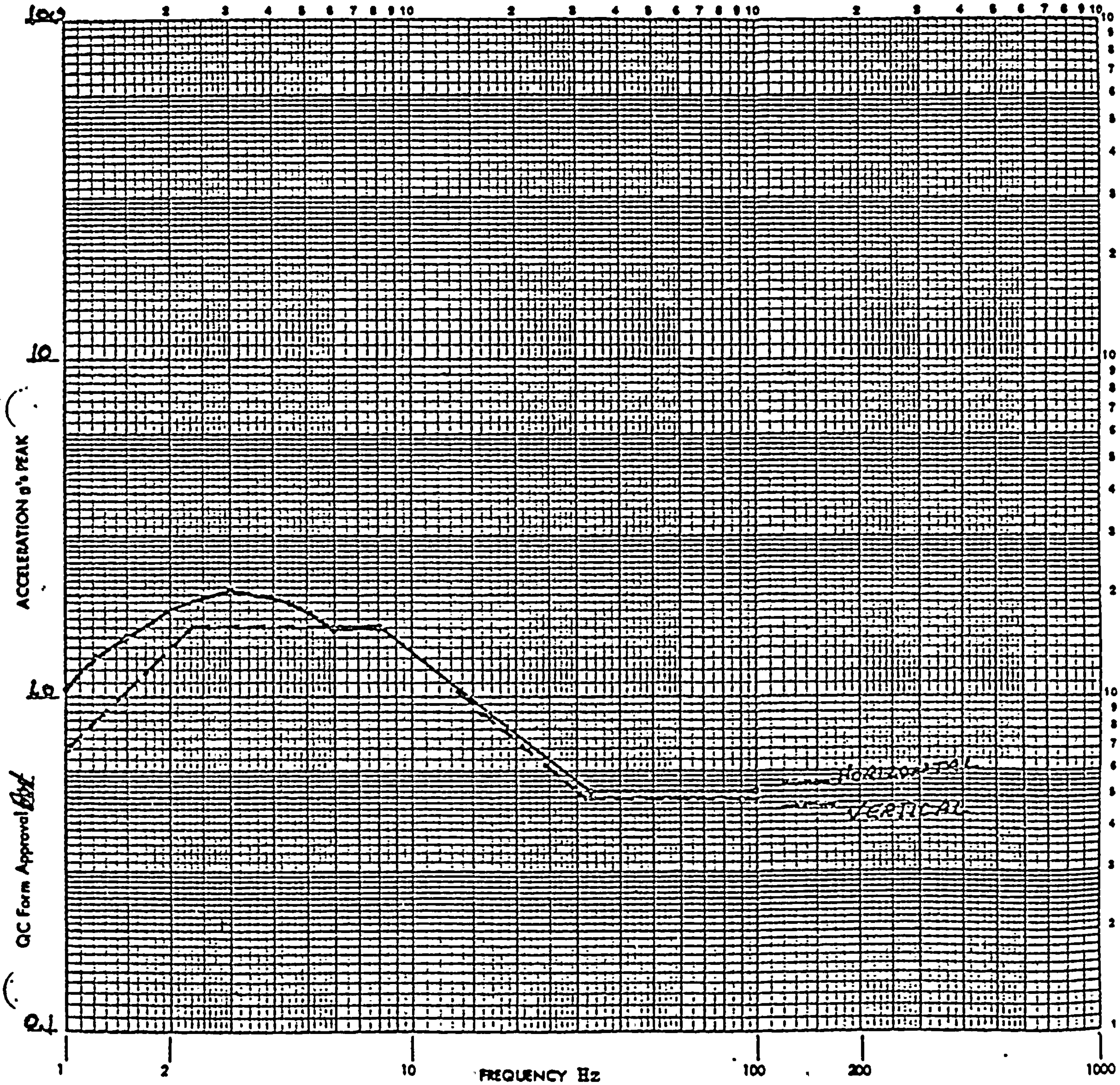
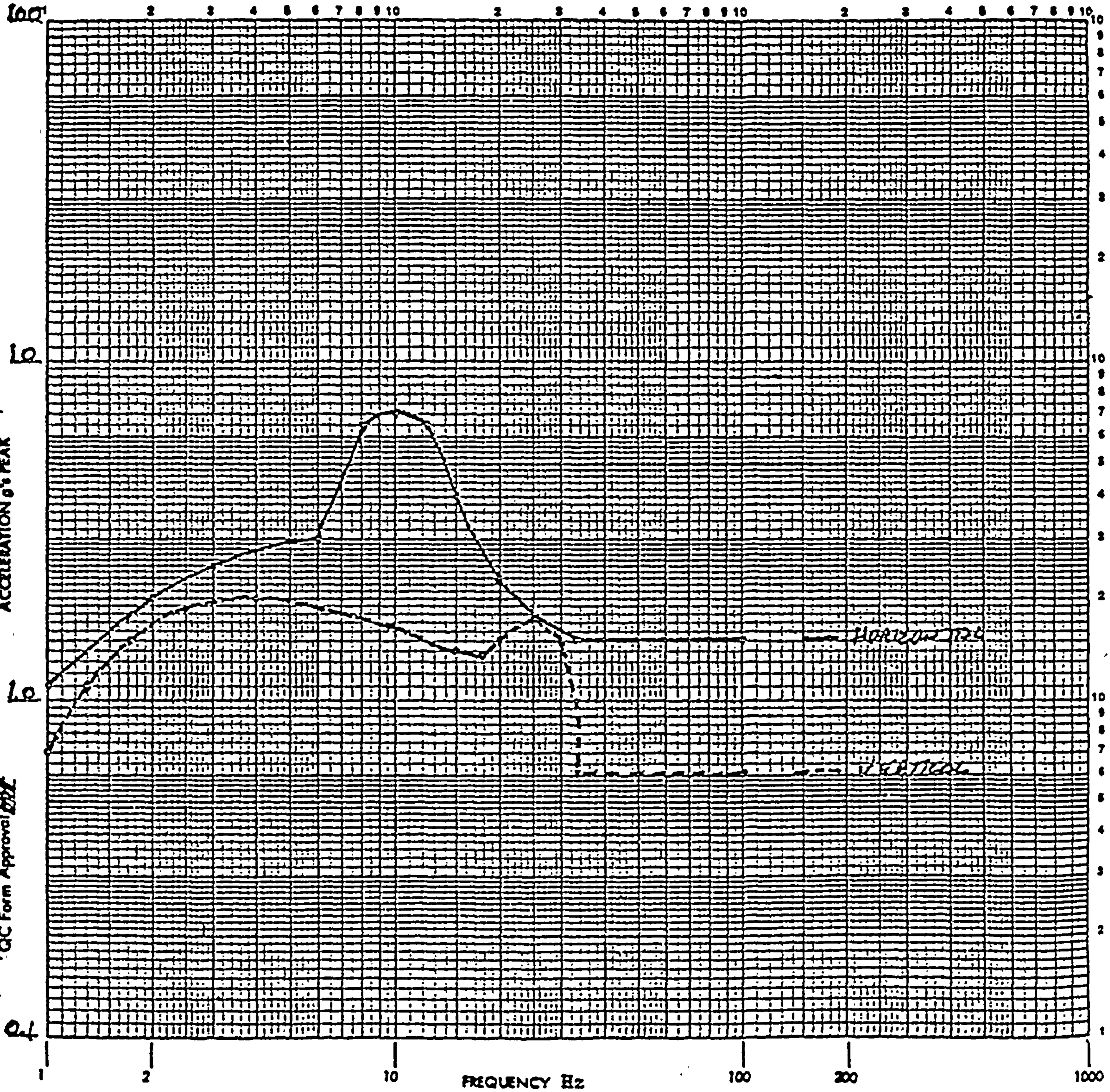


FIGURE 3

GROUP III - VENTILATION SYSTEM RELAY PANEL, VENTILATION SYSTEM LOGIC PANEL AND MAIN ANNUNCIATOR
Auxiliary Building 140 and 128 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE - 3% Damping
OBE = 60% SSE

A

RESPONSE SPECTRA



QC Form Approval

6

REVISION A

FIGURE 4

GROUP IV - LOCAL STARTER LPF37, FIRE PUMP CONTROLLER, 125-250vdc M.C.C., DC SWITCHGEAR, AND BATTERY CHARGER
Auxiliary Building 115 feet
HORIZONTAL AND VERTICAL SSE
CRITERIA HOSGRI EARTHQUAKE - 3% Damping
OBE = 60% SSE

RESPONSE SPECTRA

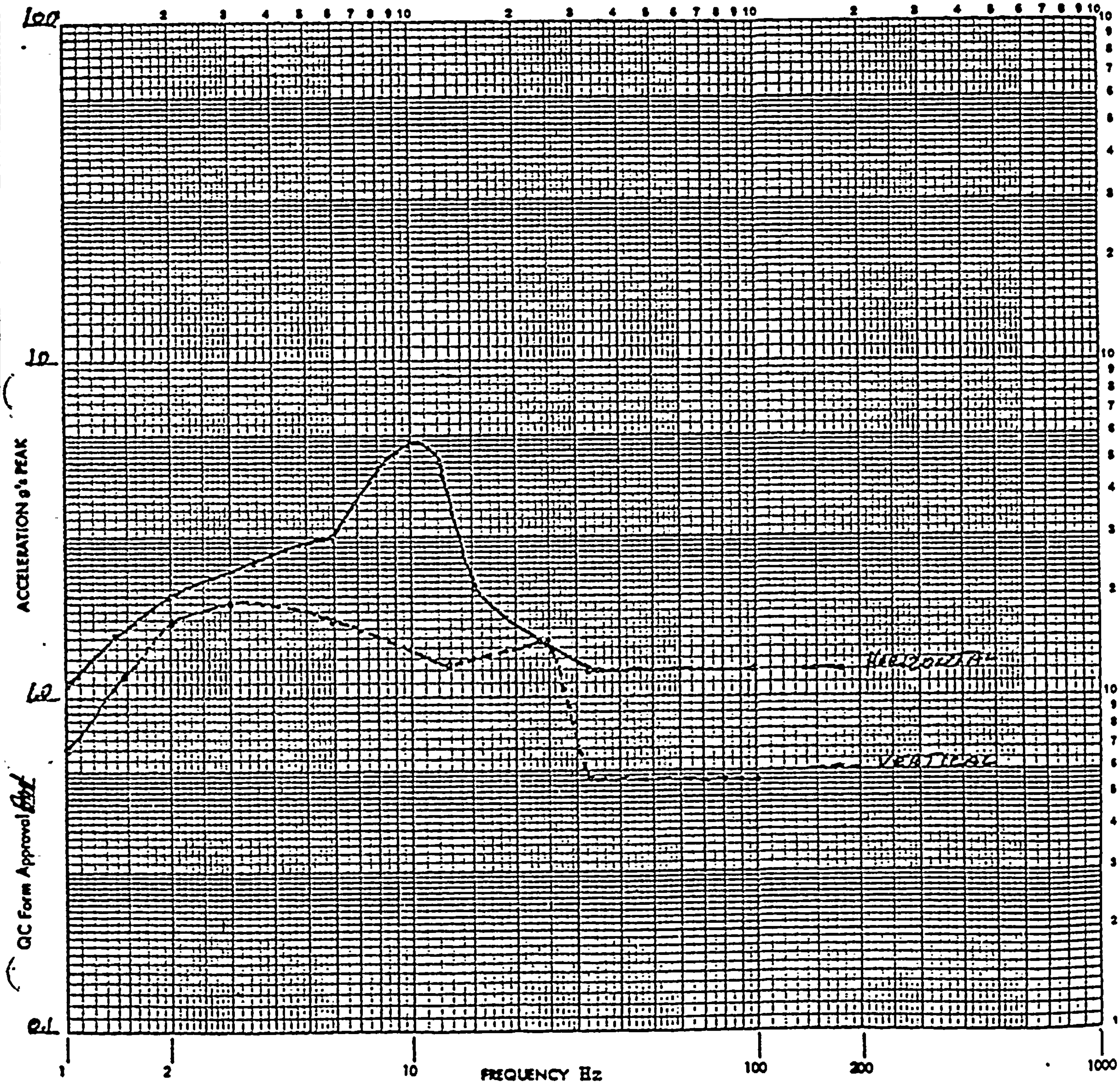


FIGURE 5

GROUP V - FISHER CONTROLLER, LOCAL STARTER LPG66, VITAL LOAD CENTER
Auxiliary Building - 100 feet B
HORIZONTAL AND VERTICAL SSE - CRITERIA HOSGRI EARTHQUAKE A
3% Damping
OBE = 60% SSE

RESPONSE SPECTRA

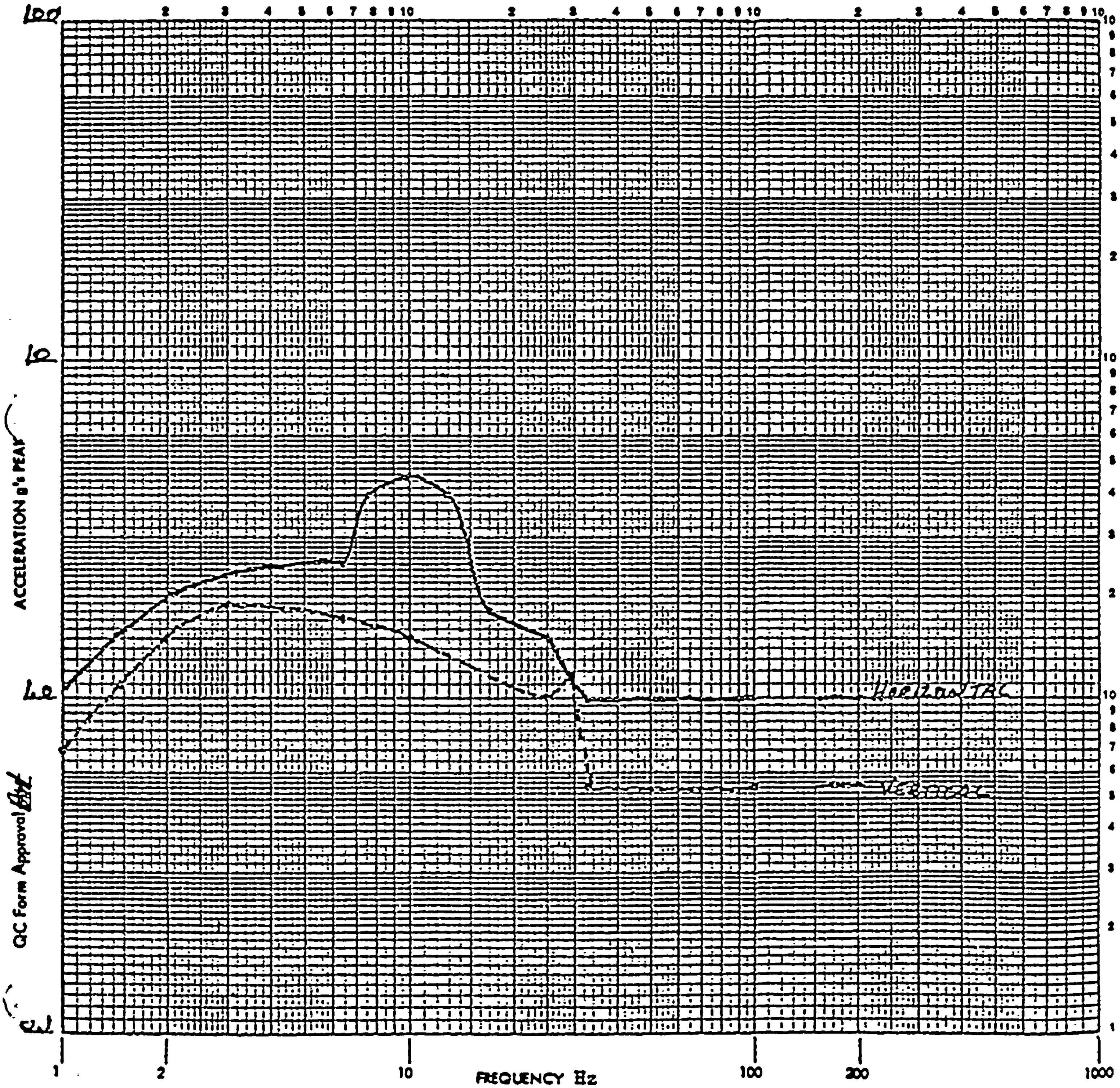
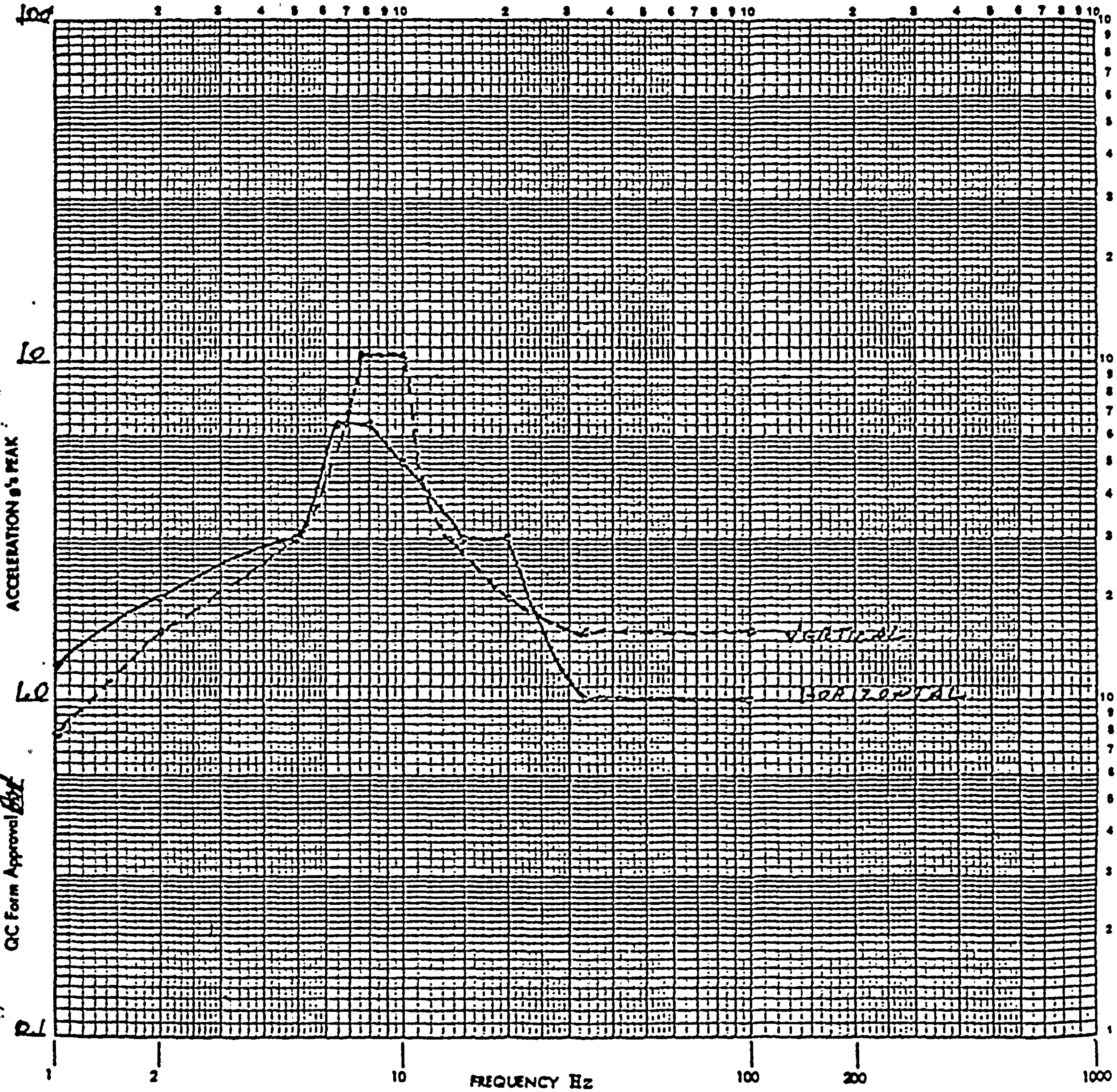


FIGURE 6

GROUP VI - LOCAL STARTER LPF36 AND LIMIT SWITCHES
Auxiliary and Turbine Building - 110 feet B
HORIZONTAL AND VERTICAL SSE - CRITERIA HOSGRI EARTHQUAKE
3% Damping A
OBE = 60% SSE

RESPONSE SPECTRA

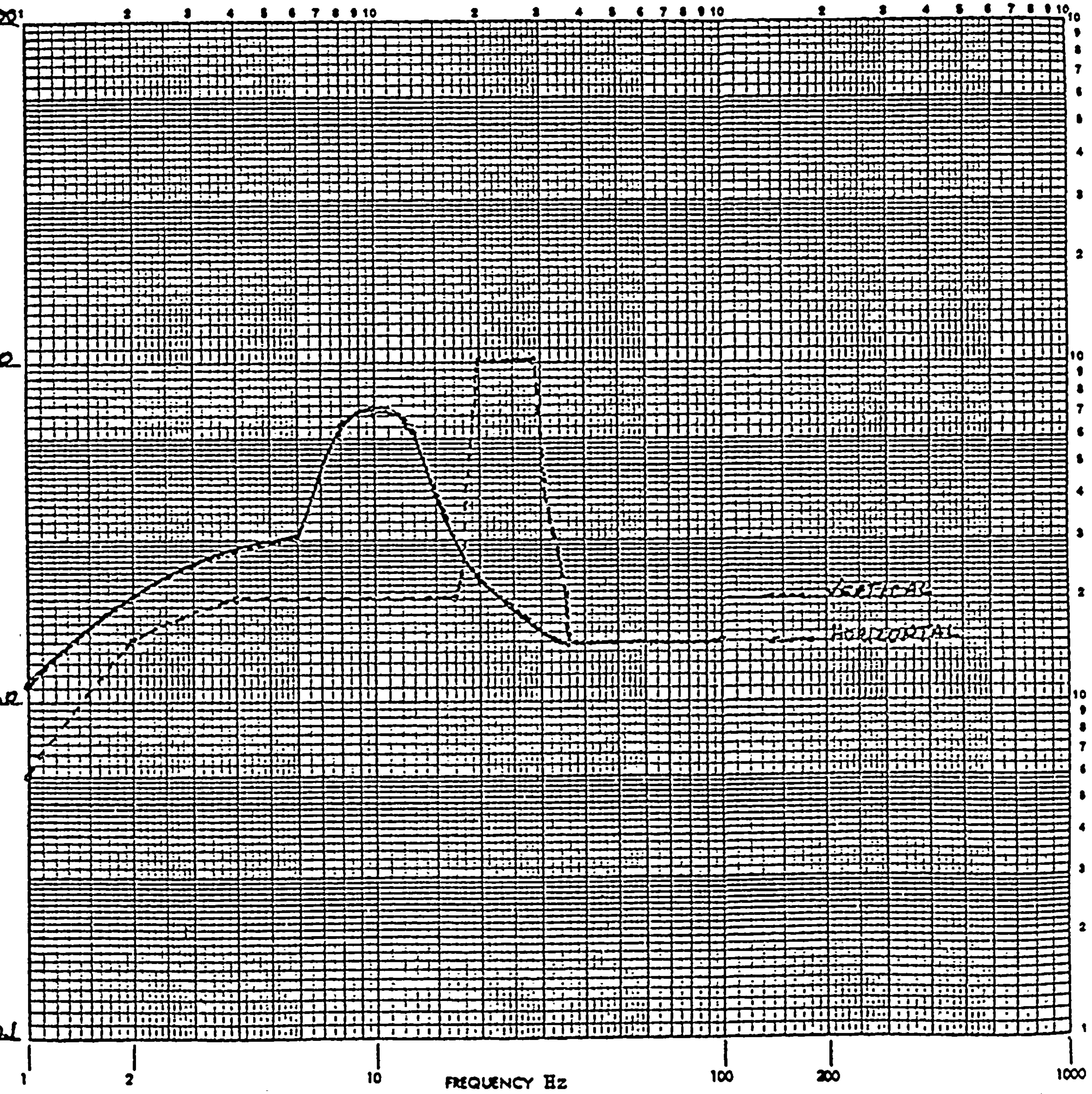


9

FIGURE 7

GROUP VII - SWITCHES AND AMMETER
AUXILIARY BUILDING MAIN CONTROL ROOM - 140 Feet
HORIZONTAL AND VERTICAL SSE - CRITERIA HOSGRI EARTHQUAKE
3% Damping
OBE = 60% SSE

RESPONSE SPECTRA



10.3.26.1 Name of Equipment

4160V Class IE Switchgear

10.3.26.2 Description of Equipment

The 4160V switchgear consists of three bus sections (F, G and H) for each of the two Diablo Canyon units. The switchgear is metalclad, rated 250 MVA interrupting capacity and 80,000A momentary. The circuit breakers are in individual cells and separated from each other by a metal barrier. Doors in the front provide access to the individual breakers and control wiring. Doors in the back provide access to the 4.16 kV power connections. Protective relays, meters, control switches, indicating lights, auxiliary relays and voltage relays are mounted on the upper portion of the front doors. Potential transformers for sensing bus or feeder voltages are mounted in back on top of cells F7, G5, H7, F12, G12 and H12, and in front and top of cells 13 and 14 of each of the bus sections F, G, and H. All circuit breakers are rated 1200A continuous with the exception of G15 which is rated 2000A.

The bus sections F, G and H are interconnected by overhead bus ducts. The bus ducts do not have a Class IE function. However, their rigid tie to the switchgear would have an effect on the switchgear qualification. For that reason it has been decided to dynamically decouple the two by inserting an earthquake joint at the point of entry of the bus duct into the switchgear. The required amount of deflection the joint must provide will be determined by the measuring the amount of horizontal and vertical deflection on top of the test specimen during the seismic test.

10.3.26.3 Safety Function

The 4160 VAC bus sections F, G, and H control and distribute electric power to the engineered safeguard load.

The safety functions of the individual devices are as follows:

a) Power circuit breakers switch 4160V power on or off; either incoming power from one of three sources, the station auxiliary transformer, the stand-by start-up transformer and if necessary the diesel generator or outgoing power for the engineered safe-guard loads. The breakers must operate during a seismic event if required to do so and must not change state inadvertently at any time.

b) Overcurrent relays, designated "51" with additional bus and cell designation, must not cause the circuit breaker to trip inadvertently at any time.

c) Potential transformers must stay operative at all times and provide a signal for control and instrumentation which is proportional to the level of the high voltage bus or feeder to which they are connected. While the transformer itself has no moving parts which could compromise this safety feature the contact fingers connecting the transformer windings to the high voltage and low voltage terminals must stay closed at all times.

d) Voltage relays must sense the signal voltage of the potential transformers to which they are connected. Their contacts must open or close as required at any time. Contact chatter must not prevent downstream devices from operating and conversely must not operate downstream devices inadvertently.

e) The 2HH9 timing relay closes the breaker after time delay on a safety injection signal. It must operate during or after a seismic event.

10.3.26.4 Test Criteria and Plan

The test criteria and plan are detailed in the Test Plan for the Seismic Qualification of the Switchgear, Revision 2, dated July 27, 1978. The

test plan is now part of WYLE's Test Procedure No. 3642, Addendum 1 and is contained at the end of WYLE's Test Report No. 58255-1, dated August 22, 1978. The following is an abstract of this test plan emphasizing the electrical criteria.

The object of the seismic qualification test is to demonstrate that the Class IE switchgear retains it normal function, during and after the seismic event. In addition, any non-class IE equipment must not fail in a manner to jeopardize the Class IE function. To demonstrate normal function of the switchgear all control circuits must be energized to duplicate exactly during the test their normal state, and power must be applied to the trip coils and operating mechanisms of the circuit breakers. During the seismic event circuit breakers are tested in the open, closed and in the actual tripping and closing operation to demonstrate the Class IE function. As a backup, the state of selected relay contacts is recorded for monitoring purposes and also sometimes for chatter duration. However, by itself chatter duration does not conclusively demonstrate normal function or lack of normal function. If a relay contact is an input to a Class IE device not located on the switchgear then the relay contact must be monitored and the chatter or change of state record analyzed to demonstrate Class IE function.

10.3.26.5 Test Procedure and Set-Up

The test procedure and set-up are also detailed in the before mentioned Test Plan, Revision 2, dated July 27, 1978.

Selected for the test were Cells H7, H8 and H9 of Unit 2 with front doors from Cells H12 and H13 mounted on Cells H8 and H9 respectively. This arrangement represented all the relay types installed in the Diablo Canyon Units 1 and 2 Class 1E 4160V switchgear. The devices on the doors were wired to the cells to such an extent that all Class IE circuits were complete and their function could be demonstrated.

Early in the test it was decided to remove potential transformer roll out units from top of Cells H8 and H9 since their mass and motion appeared to

induce chatter of the switchgear relays. These potential transformers are normally located on top of Cells H13 and H14. They will be permanently removed from this location and are qualified separately.

The test specimen was 78 inches wide (3 cells each 26 inches), 90 inches high and 75 inches deep.

The three cell test specimen was welded to a special base with the same amount and type of welding as is done at the Diablo site. The base with the test specimen than was welded to the test machine.

The seismic test sequence is shown in Attachment "A". ✓

The switchgear and its devices were wired per attached wiring instructions contained in Attachment "B". ✓

Following are illustrations which expand on the test set-up wiring beyond the termination points.

a. 125 VDC was applied to the switchgear DC bus energizing the control and overcurrent protection circuits of all three cells.

b. 3 phase current and 3 phase 120 VAC restraining potential were applied to the three 51 overcurrent relays of Cell H7. Single phase current was applied to the 51 overcurrent relays of Cells H8 and H9. This simulated the actual operating conditions of these relays by normal 4160V power flow. See Attachment "F" and "G".

c. The same 120 VAC from "b" above also provided potential to the following relays:

59HHG1, 59HHG2	Diesel Generator Voltage Relays
27HHB1	4160V Bus Undervoltage Auto Transfer Relay

27HHB2 4160V Bus Undervoltage Diesel Start Relay

27HHT1, 27HHT2 4160 Bus Undervoltage

See Attachment "G".

d. The same 120 VAC energized the potential transformer on top of Cell 7 and subsequently energized the whole high voltage portion of the test specimen with 4160V providing the breaker of Cell 7 was closed. See Attachment "G".

e. All output contacts of the relays listed under "c" above were connected to secondary devices to demonstrate or simulate their safety functions. Contacts of the secondary devices were than connected to direct readout recorder to monitor change of state and chatter. Some of these secondary or auxiliary relays were part of the Safeguard Relay Board. The relay board was standing at the side off of the shake table. See Attachment "G".

f. The coil of the 2HH9 Containment Spray Signal Timing Relay was connected to a 120 VAC supply via a switch "H". A normally closed contact was connected to the direct readout recorder to monitor its operation and contact chatter. See Figure 10-26G.

g. Two linear variable displacement transducers were installed near the top of the switchgear to measure the maximum vertical and horizontal displacement of the switchgear structure. This measurement was taken as an input to the design of the earthquake joints of the bus ducts.

10.3.26.6 Test Results

The equipment was subjected to a total of 37 runs in both the side to side and front to back orientation. Table IV of the Test Plan (WYLE Test Report 58255-1, Test Procedures 3642, Addendum 1) shows that only 24 conditions needed to be met. And of these conditions 1, 2, 3, 4, 14 and 15 were low level sweeps.

The following table indicates the runs during which a given condition was met.

Run	Condition	Comments
5	5	OBE SS/V Runs 5-11
6		All Breakers open, added Channel No. 1 to monitor
7		5HH13 relay contact in safeguard panel.
8	6	
9	7	
10	8	
11	9	
12		SSE SS/V Runs 12-20
13		After Run 13 two elevated PTs were removed.
14		Vertical only
15		After Run 15 replaced HIg IAC 53 Relay in Cell 9
16	10	
17	11	
18		Overtest trip in Cell 8, IAC 66 Phase B target
19	12	
20	13	
26	16	OBE FB/V Runs 26-30
27	17	
28	18	
29	19	
30	20	
31	21	SSE FB/V Runs 31-37
32		Under test
33	22	
34	23	
35	24	
36		Vertical only
37		Horizontal only

For the evaluation of the Contact Chatter Data Sheets, WYLE's Test Report No. 58255-1 pages 26 and 27, only chatter indicated on runs 5, 8, 9, 10, 11, 16, 17, 19, 20, 26, 27, 28, 29, 30, 31, 33, 34 and 35 need to be considered. These are the runs which meet test conditions in the above table. In cases where chatter accured during a given condition, discussion is provided below.

- Run 5, Channel 3,
a-Contact of Auxiliary Switch, Breaker 52HH8 -

Chatter was caused by inadequate wipe of the switch contact. After switch mechanism adjustment, no further chatter occurred.

- Run 8, Channel 1, 5HH13 Relay Contact -

This indication of chatter was caused by noise in the electronics of the monitoring recorder and not by chatter of the 5HH13 relay contact itself.

Referring to Attachment "G2" it is obvious that the rotary lockout relay itself could not chatter since it was located in the relay board off of the shake table. The test hook-up demonstrated that relay 27HHB2, located on the switchgear, on sensing no voltage, would pick up relay 27ZHHB2, located in the relay board, and that 27ZHHB2 in turn would trip relay 5HH13. This safety function was satisfactorily demonstrated during the test sequences.

- Run 8, Channel 7, 2HH9 Timing Relay -

Apparently chatter is indicated on WYLE's data sheet; however an analysis of the signal trace shows that a full separation of the closed contact did not take place. The contact was closed definitely during most of the time the relay was energized and for that reason, it can be concluded, that the relay would perform its safety function.

- Run 8, Channel 11,
27ZHHB2 Bus Undervoltage Auxiliary Relay -

The 27ZHHB2, located in the relay board, pulsated because of chatter of the 27HHB2 bus undervoltage relay when sensing no voltage. However, another contact of the 27ZHHB2 relay performed its safety function and operated the 5HH13 lockout relay as described in Run 8, Channel 1 above.

- Run 16, Channel 2,
a-Contact of Auxiliary Switch, Breaker 52HH7 -

The spurious opening of this contact is of no significance. The auxiliary switch mechanism needed minor additional adjustment.

- Run 16, Channel 12, 4HH14 Start-Up Auto Close Relay -

Chatter of this relay by itself does not adversely affect a Class IE function. The test setup was to demonstrate that the 27HHB1 Bus Undervoltage Relay would pick up 4HH14 on undervoltage (which was demonstrated during the test sequences). Refer to Attachment "G2."

- Run 17, Channel 7, 2HH9 Timing Relay -

See Run 8, Channel 7, above.

- Run 17, 27, and 22, Channel 11,
27ZHHB2 Bus Undervoltage Auxiliary Relay -

See Run 8, Channel 11, above.

- Runs 17, 19, 20, 27, 32, and 33, Channel 12,
4HH14 Start-Up Auto Close Relay -

See Run 16, Channel 12, above.

The 4160V switchgear and the associated relays met the test criteria specified in section 10.3.26.4 above during and after the seismic testing while being operated per the test procedure described in section 10.3.26.5 above. It is worthy of note that the equipment was subjected to more than the minimum number of test runs for qualification, demonstrating that there is a substantial margin in the equipment's resistance to seismic damage.

No physical damage to the switchgear structure or the associated devices was observed.

Maximum horizontal displacement of the structure was measured to be .55 inches; maximum vertical displacement was .2 inches.

As a result of this test the following actions will be taken:

a) Potential transformers on top of Cells 13 and 14 of all 4160V Class IE switchgear sections will be removed and relocated to a separate stand next to the respective switchgear. Electrically they will be wired to the switchgear as they were connected before.

b) Bus duct earthquake joints will be installed in all joints at the top of the Class IE switchgear sections. The test measurement will be used in the design criteria.

10.3.26.7 Conclusion

A representative sample of the 4160V Class IE Switchgear of Diablo Canyon Unit 2 was seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report Number 58255-1 dated August 22, 1978, pp. 139-323. Thus qualification of this sample will apply to all Diablo Canyon 4160V Class IE Switchgear.

The test results presented in section 10.3.26.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 4160V Class IE Switchgear are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

TABLE IV. SEISMIC TEST SEQUENCE DIABLO CANYON UNITS 1 AND 2 4.16 KV SWITCHGEAR

Condition	Axes	Horizontal RM ZPA g	Horizontal RM Figure No.	Vertical RM or RM + SB ZPA g	Vertical RM or RM + SB Figure No.	Sine Beat Freq. Hz.	Bkr. Pos.	Remarks
1	SS	.2	-	-	-	-	C	1-33 Hz-Sweep
2	SS	.2	-	-	-			33-1 " "
3	V	-	-	.2	-	↓	↓	1-33 " "
4	V	-	-	.2	-			33-1 " "
5	SS-V	.75	50%-1	.8	50%-2			1 OBE
6							0	2
7		↓	↓	↓	↓		CO	3 ↓
8							OC	4
9	↓						COC	5
10		1.5	1	1.6	2	7.1	C	1 SSE
11						8	0	2
12		↓	↓	↓	↓	9	CO	3 ↓
13						10	OC	4
		Rotate Sample 90°						
14	FB	.2	-	-	-	-	C	1-33 Sweep
15	FB	.2	-	-	-		C	33-1 "
16	FB-V	.75	50%-1	.8	50%-2	↓	C	1 OBE
17							0	2
18		↓	↓	↓	↓		CO	3 ↓
19							OC	4
20	↓						COC	5
21		1.5	1	1.6	2	7.1	C	1 SSE
22						8	0	2
23		↓	↓	↓	↓	9	CO	3 ↓
24						10	OC	4

Legend

RM - Random Motion
RM & SB-Random Motion with Sine Beat
ZPA - Zero Period Acceleration
SS - Side to Side
V - Vertical
FB - Front to Back
Bkr.Pos. - Breaker Movable Contact Position

Notes

The circuit breaker should be lowered and re-raised after selected tests at the direction of the General Electric Company Representative. At such times, the PTRO's will also be opened and inspected.

ATTACHMENT "A"

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July 12, 1978

WIRING INSTRUCTIONS

DIABLO CANYON SWITCHGEAR TEST SAMPLE

4.16 KV-1200-250 MVA

A. Diagrams

Cell	Skematics	Connection Diagrams
7	441356	441589
8	Marked copy 441302	HH53078
9	Marked copy 441307	HH53178

B. Control Power Connections

<u>Cell 7</u> (441589)

a) 2W-DC-125V-20A Supply, (+) to DC3, (-) DC1

b) 3W-AC-120V-3Ø-60 Hz Supply, Leg A to X5, Leg B to X7, Leg C to X6

4W-AC-5A-3Ø-60 Hz Supply, Leg A to CG4, Leg B to CG5, Leg C to CG6, Neutral to CG1

Both supplies needed for IJCV Relays. Leg A, Leg B and Leg C for voltage and current sources are related to Wyle's Ø1, Ø2 and 0/3 respectively.

<u>IMPORTANT</u> The 3Ø 120 volt circuit should not be energized when primary compartment covers or panels are removed so that primary conductors are exposed. If interaction effects between primary conductors and Wyle instrumentation can not be readily resolved, the PTRO primary fuses will be removed to de-energize the primary conductors.

c) Wyle is to provide a remote 3Ø switch to disconnect power to the 59HHG 1 & 2(SV relay) coils. This switch will be open for the majority of tests to simulate the Diesel Generators not being energized.

d) Connect NO "Close" Push Button to B5 and B6.
Connect NO "Trip" Push Button to DD7 and DD8.

e) Remove and tape ground leads from ground bus in rear of cell

<u>Cell 8</u> with Cell 12 door (53078)

a) 2W AC 1Ø 5A 60 Hz supply, Leg 1 to C18, Leg 2 to CD4 (IAC66 source)

b) 3W AC 3Ø 120V 60 Hz supply, Leg A to AK8, Leg B to AK9, Leg C to AK10(RA\
Jumper AK8 to AH15 and AK9 to AH16 (IAV)

c) Connect NO "Close" Push Button in series with a NC 43 X HH12 contact to DD4 and BB9, PG&E to provide connection details.
Connect NO "Trip" Push Button to DD4 and DD7. Jumper DD9 to EE1

d) Remove and tape ground leads from ground bus in rear of cell.

Rev 1 7/21/78
CWB.

B. Control Power Connections (Cont'd.)

Cell 9 with Cell 13 door (53178)

a) 2W AC1Ø 5A 60 Hz., Leg 1 to C18, Leg 2 to CD4 (IAC53)

b) 2W AC1Ø 120 60 Hz., Leg A to AF15, Leg B to AF16 (Øs A & B to IAV)

c) 2W AC1Ø 120 60 Hz., Leg A to AG9, Leg B to AG8 (Øs B & C to SV)

d) PG&E to provide details for 120V AC energization of Agastat Relay.

e) Connect "Close" Push Button to DD9 and BB6
Connect "Trip Push Button to DD9 and BB9

f) Remove and tape ground leads from ground bus in rear of cell.

C. Electrical Monitoring

Cell 7 (441589)

52HH7 Aux. Sw.	A contact	GG5 & GG6
3HH1 lockout NO contact from Safe Guard Panel PG&E to furnish connection details for 3HH1 relay to be energized by the 59HHG 1 & 2 SV relay contacts.		G6 C17

Cell 8 with Cell 12 door (53078)

52HH8 Aux. Sw.	A contact	FF11 & FF12
27ZHHB2 W SG contact on Safeguard Panel PG&E to furnish connection details for 27ZHHB2 to be energized from IAV relay		AA8 AA12
4HH14 W SG contact on Safe Guard Panel PG&E to furnish connection details for 4HH14 to be energized by the RAV relay.		C6 C4

Cell 9 with Cell 13 door (53108)

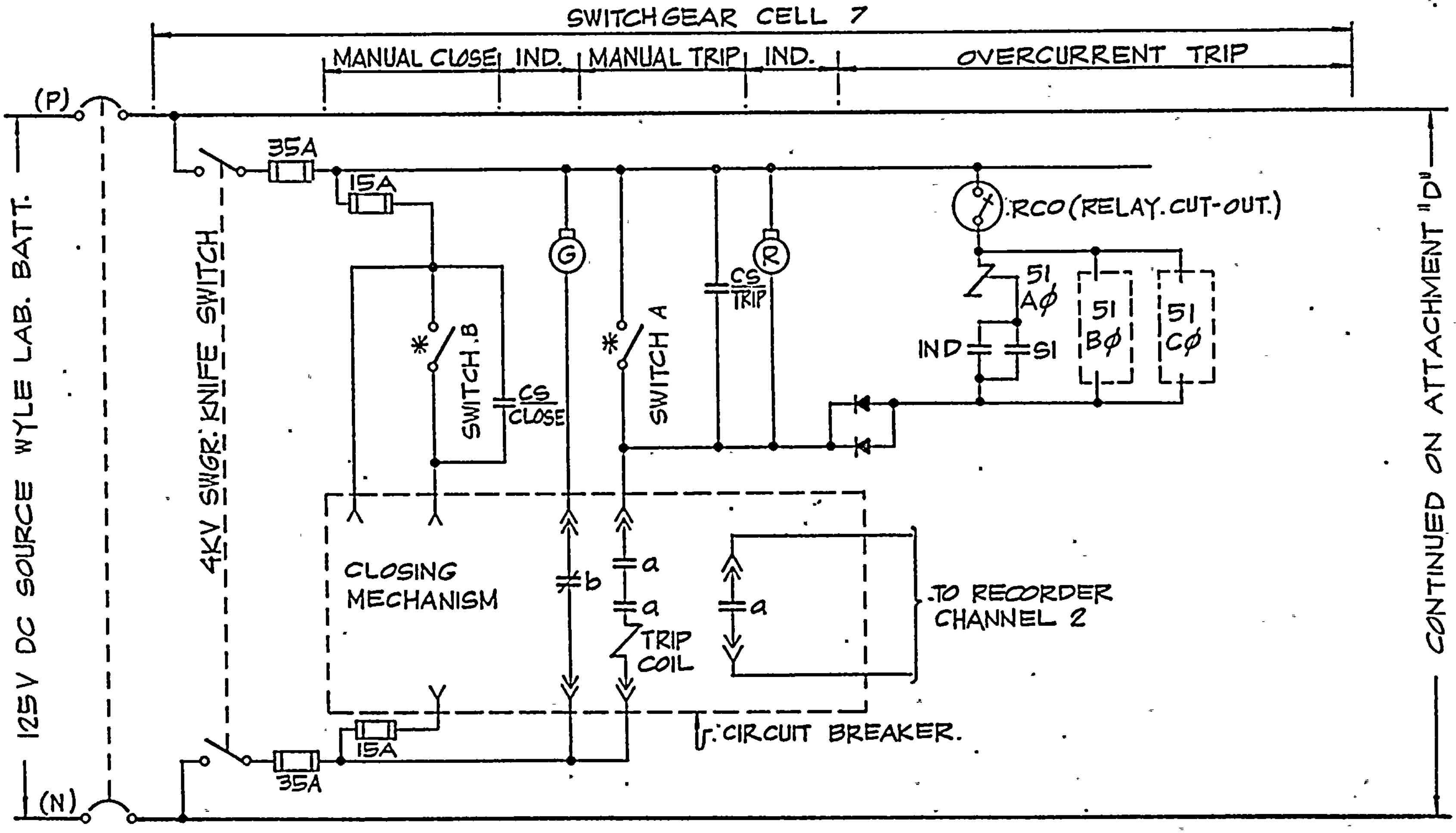
52HH9 Aux. Sw.	B contact	FF9 & FF10
52HH9 CI	NO breaker raised	HH1 & HH2
52HH9 CI	NC breaker raised	HH3 & HH4
2HH9 AGA	NO	DE2 & DE6
2HH9 AGA	NC	DE2 & DE4

D. Non Electrical Monitoring

PG&E to provide connection details to energize blue lights from 51X HH7, HH8 and HH9. HFA relays. Not class 1E.

E M Fitzgerald
July 14, 1978
Rev 1 7/27/78 EMF

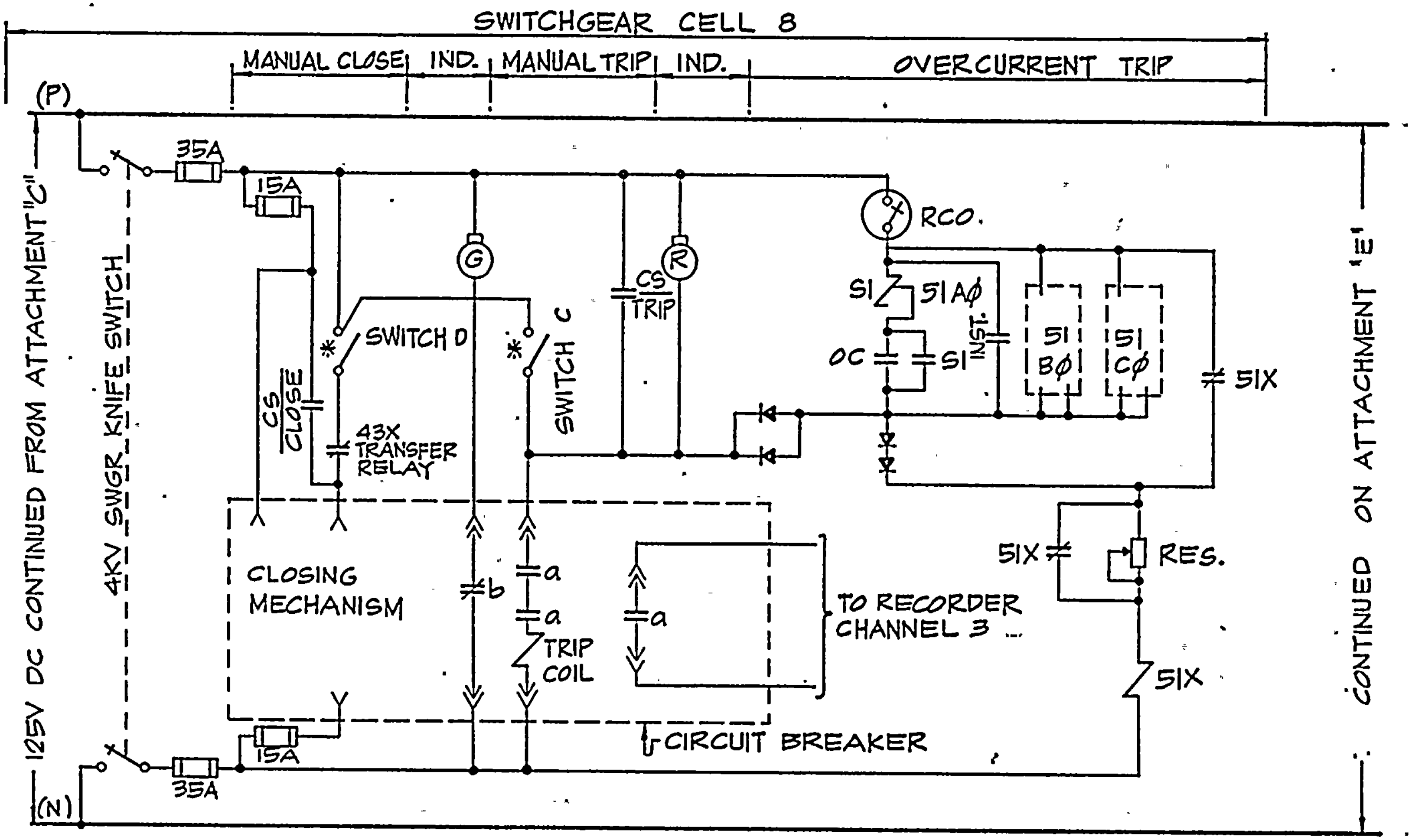
ATTACHMENT "B" SH.2



* LOCATED AT TEST BENCH

ATTACHMENT "C"

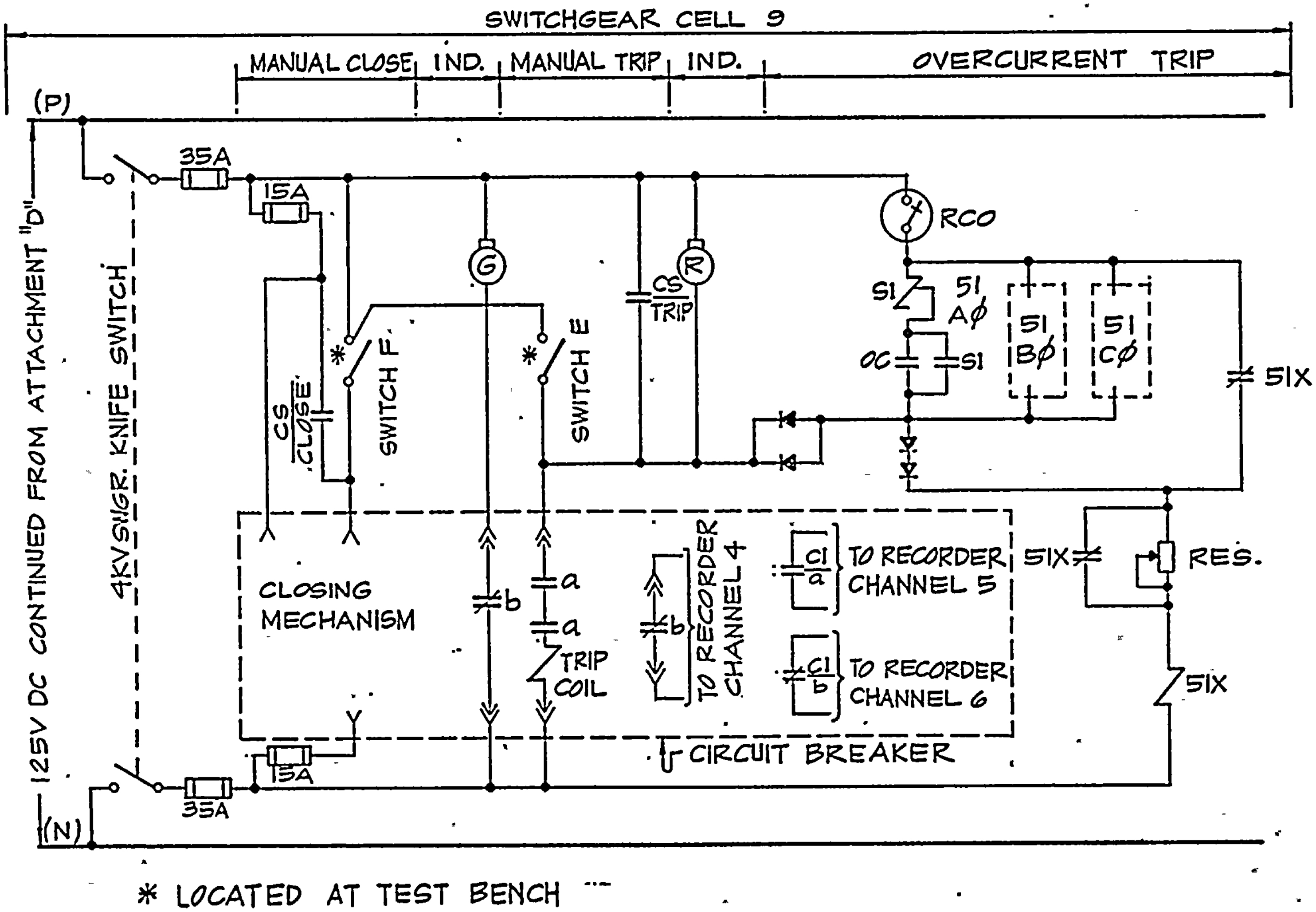
REV. CHANGE SW. DESIGNATION A TO B & B TO A



* LOCATED AT TEST BENCH.

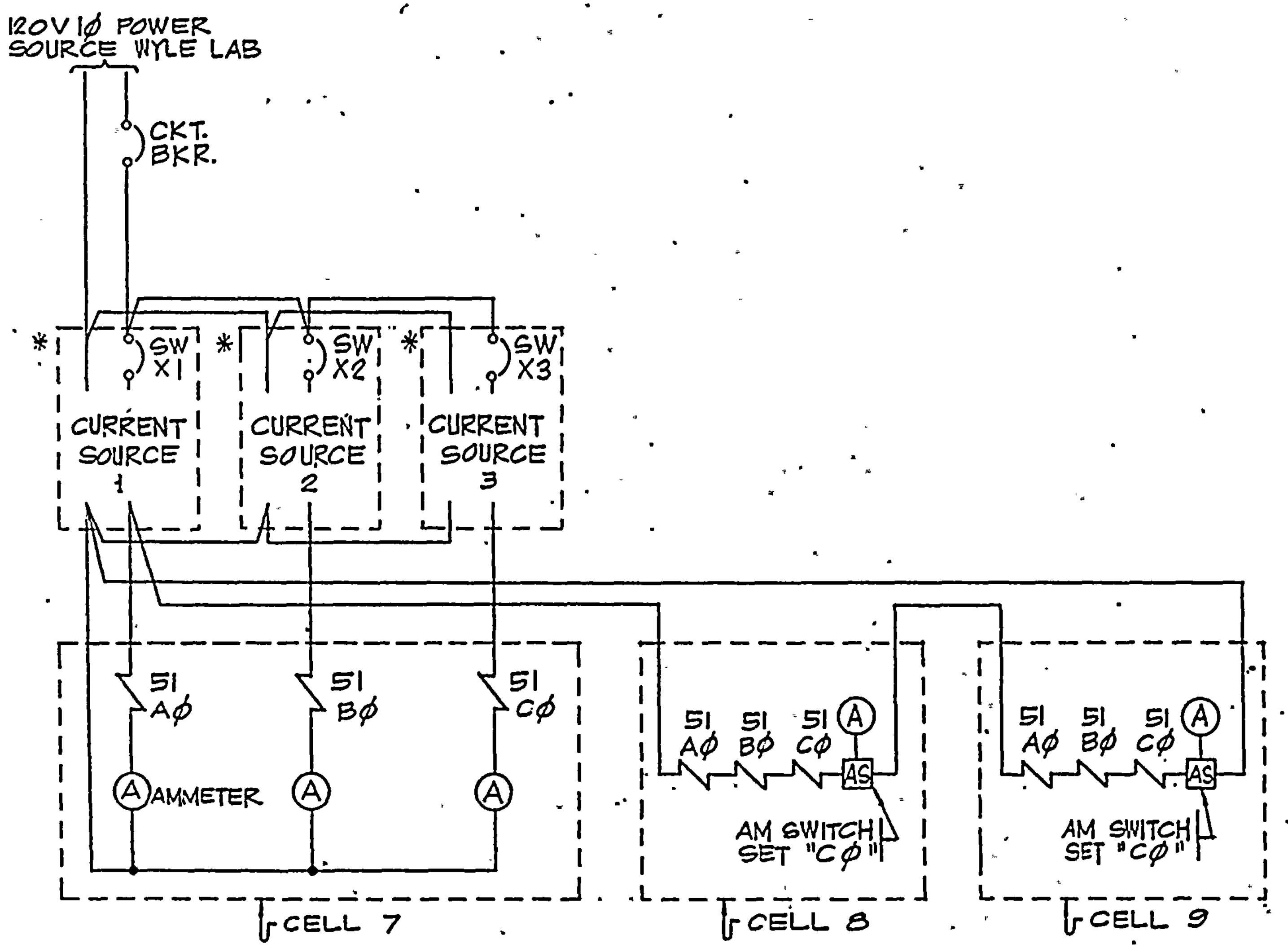
ATTACHMENT "D"

REV. : CHANGE SW. DESIGNATIONS C TO D & D TO



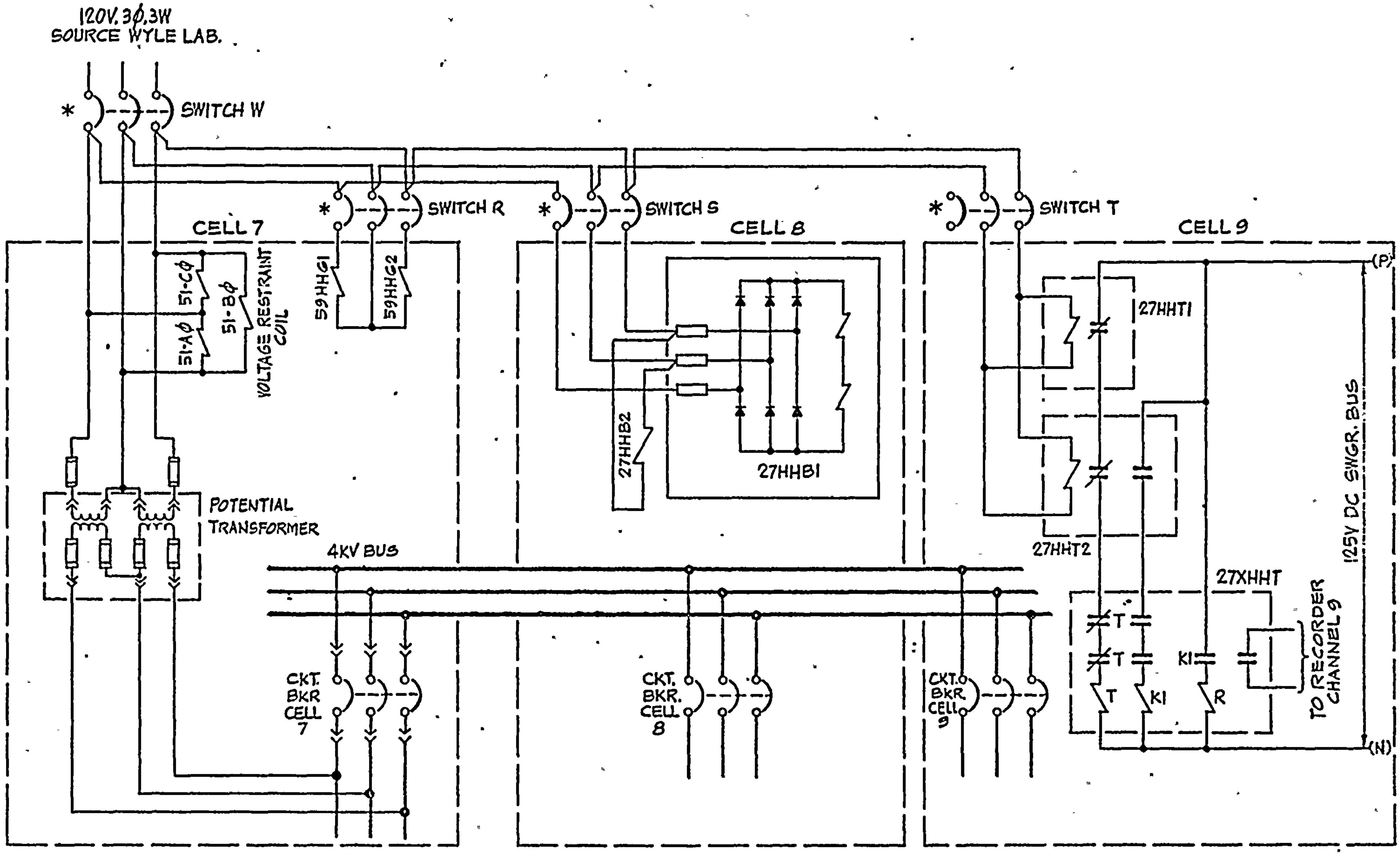
ATTACHMENT "E"

REV. CHANGE SW. DESIGNATIONS E TO F & F TO E



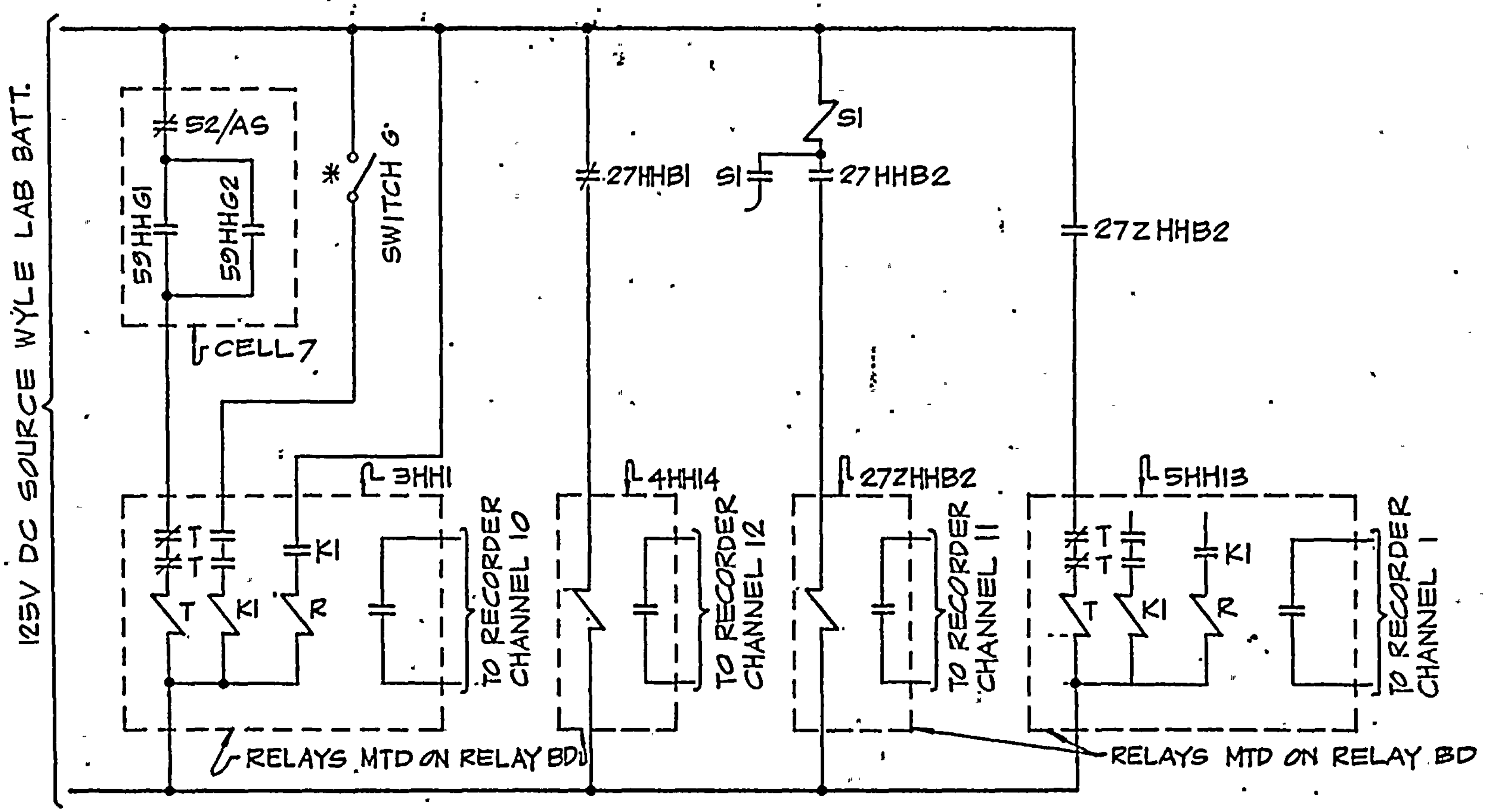
* LOCATED AT TEST BENCH

ATTACHMENT "F"



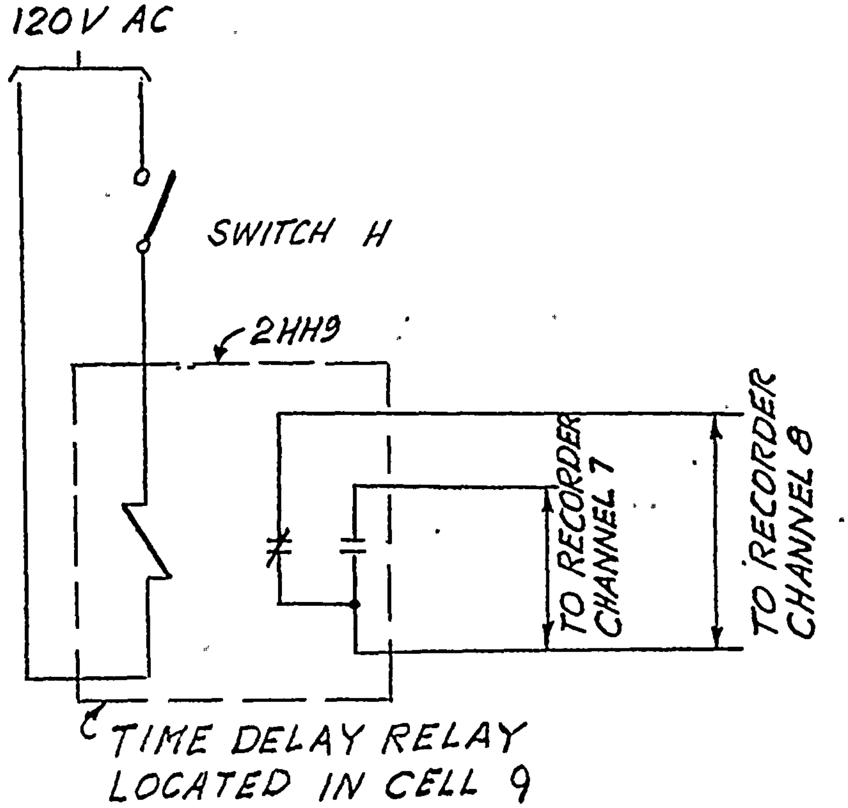
* LOCATED AT TEST BENCH

ATTACHMENT 'G1'



* LOCATED AT TEST BENCH

ATTACHMENT "G2"



ATTACHMENT "H"

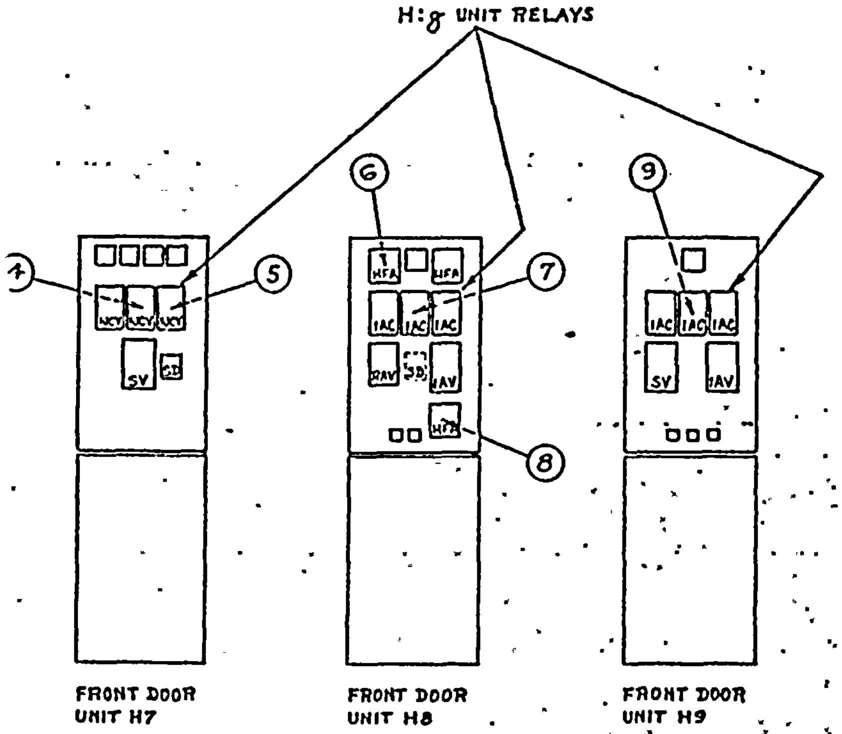
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING: APPLIED PRACTICES | SURFACES ✓ | TOLERANCES ± ± ±

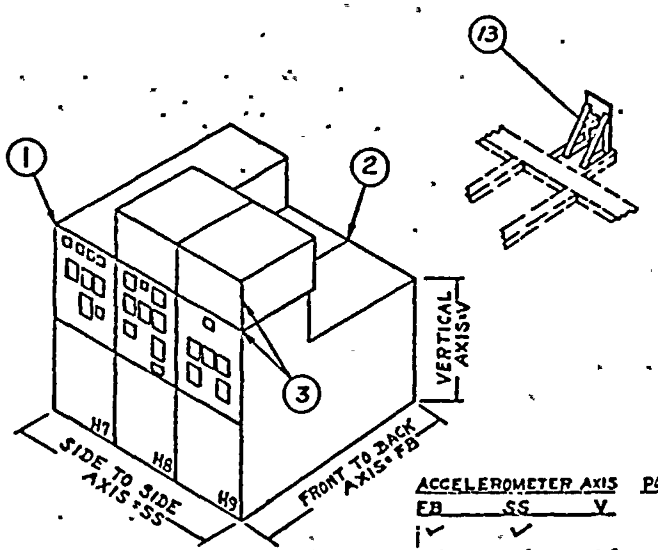
ACCELEROMETER LOCATIONS

FIRST MADE FOR 250 MVA 4.16 KV SWITCHGEAR

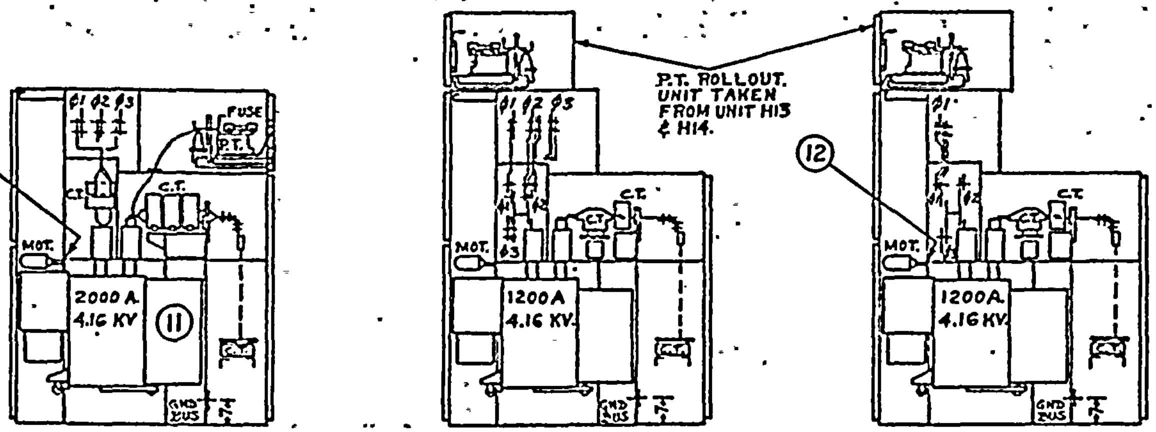
PG&E DIABLO CANYON

G.E. REQ'N 474-68849





ACCELEROMETER AXIS FB	SS	V	POSITION NO.	LOCATION
✓	✓		1	TOP FRONT LEFT CORNER H7
✓	✓	✓	2	TOP REAR JUNCTION OF H8 & H9, MOTION AT EARTHQUAKE JOINT
✓	✓	✓	3	P.T. ROLLOUT TRAY
✓	✓	✓	4	BACK OF MIDDLE IJCV RLY H7
✓	✓	✓	5	BACK OF RIGHT IJCV (H:8 UNIT) RELAY H7
✓	✓	✓	6	BACK OF TOP LEFT HFA RELAY H8 (H12 DOOR)
✓	✓	✓	7	BACK OF MIDDLE IAC RELAY H8 (H12 DOOR)
✓	✓	✓	8	BACK OF LOWER HFA RELAY H8 (H12 DOOR)
✓	✓	✓	9	BACK OF MIDDLE IAC RELAY H9 (H13 DOOR)
✓	✓	✓	10	INSIDE FRAME RIGHT SIDE 44 INCH LEVEL H7
✓	✓	✓	11	ARC CHUTE 2000 A BRKR H7
✓	✓		12	INSIDE FRAME RIGHT SIDE 44 INCH LEVEL H9
✓	✓	✓	13	RIGID RELAY MOUNTING LOCATION.



SIDE VIEW UNIT H7

SIDE VIEW UNIT H8

SIDE VIEW UNIT H9

REVISIONS: 1 R. Heier 7-19-78 ADDED ACS. #13

PRINTS TO

R. Heier 6-2-70 SWGR PHILA. 0156C1250 SH 1/2 CONT ON SH 111

1 2 3 4 5 6

2631

10.3.30.1 Name of Equipment

Potential Transformers 4160/120V.

10.3.30.2 Description of Equipment

The potential transformers are housed in a metal cabinet 26 inches wide, 22 inches high and 33.5 inches deep. The butyl molded transformer is fastened to a roll-out slide which can be pulled forward with the cabinet front. Contact fingers mounted to the stationary housing provide the electrical connections to the primary and secondary windings of the slide mounted transformers. The potential transformers are usually mounted on top of the switchgear of which they are an electrical accessory. The potential transformers discussed here were removed from the top of the switchgear and will be mounted on a rigid stand and fastened to the floor near the 4160V Class 1E switchgear.

10.3.30.3 Safety Function

The safety function of the potential transformer is to provide a signal, for control and instrumentation, which is proportional to the level of high voltage of the bus or feeder to which it is connected.

10.3.30.4 Test Criteria and Plan

The potential transformer must provide the signal, proportional to the level of high voltage it monitors, without interruption at all times. X

The transformer itself has no moving parts which could compromise its safety function. However, the primary and secondary contact fingers could cause an interruption of the voltage signal.

The plan is to test the integrity of the contact fingers while subjecting the potential transformer assembly to simulated seismic events in accordance with IEEE Standard 355-1975.

10.3.30.5 Test Procedure and Setup

One potential transformer cabinet was rigidly bolted to a steel plate which in turn was welded to the shake table thus simulating its future installation at the plant. Two primary and two secondary contact finger assemblies were connected in series and wired to direct readout recorder for monitoring. See Attachment "A".

The seismic test sequence was the same as for the safeguard relay board see 10.3.21.5. "Test Procedure and Setup" for the safeguard relay board. The potential transformer was tested alongside the safeguard relay board.

10.3.30.6 Test Results

At no time during the seismic test sequences did any chatter of the contact finger occur.

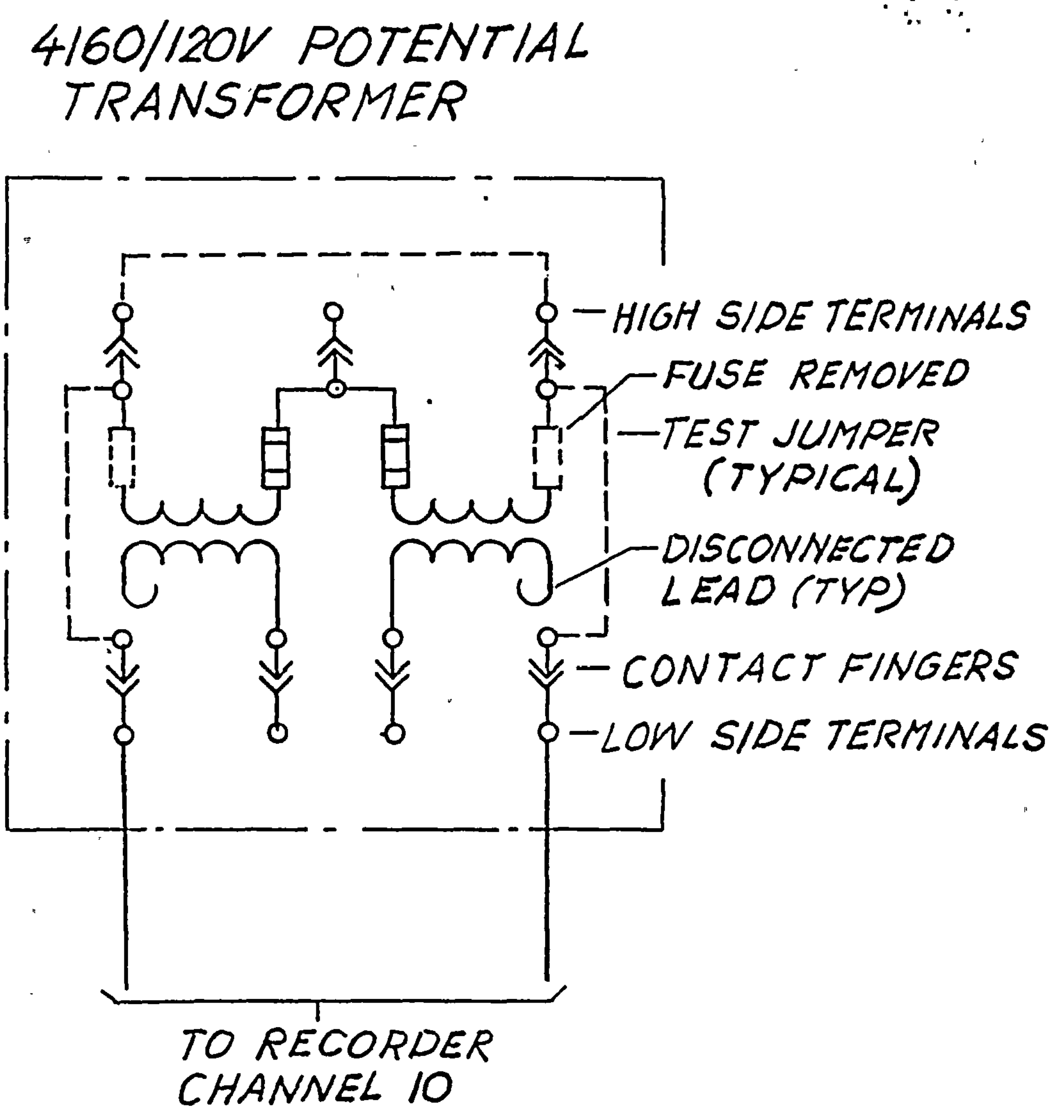
No physical damage to the equipment was observed.

10.3.30.7 Conclusion

A typical Potential Transformer Cabinet with its contents was seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report No. 58255-1, dated August 22, 1978.

The test results presented in section 10.3.30.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 4160/120V Potential Transformers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.



ATTACHMENT "A"

10.3.21.1 Name of Equipment

Safeguard Relay Boards.

10.3.21.2 Description of Equipment

The safeguard relay boards are steel cabinets 7'-10" high 3'-7" wide and 2'-0" deep. Mounted semi flush on their front are an array of electrical relays, switches and lights. Doors in the back provide access to the wiring and secondary devices such as fuses, test and cut-out switches, and a timing relay.

Of the six boards installed in the Diablo Canyon Power Plant, five boards are identical to each other. These are Safeguard Relay Boards F, G and H of Unit 1 and G and H of Unit 2. Safeguard Relay Board F of Unit 2 has the same physical outline but does not contain the diesel generator protective relays contained in the other five boards since there are only five diesel generators at Diablo Canyon.

Safeguard Relay Board H of Diablo Canyon Unit 2 was chosen to be tested to qualify all Safeguard Relay Boards. Relays of Board H, Unit 2 are listed in Attachment A, "Device Table". The "Device Number" is PGandE's designation of the relay. "Type" is the manufacturers designation. "Use" indicates the application of the device in the plants electrical system. "Schematic Diagram" is PGandE's drawing number where the device appears. "Affect on a Class IE function" is shown with yes or no and explanatory remarks.

10.3.21.3 Safety Functions

The Devices on the safeguard relay boards perform the following safety functions:

a. Initiate start of diesel generators in case of loss of the off-site stand-by power source and loss of 4.16 kV bus voltage.

b. On loss of 4160 volt bus voltage, initiate transfer of the 4160V bus from the station auxiliary transformer to the stand-by start-up transformer, and if necessary to the diesel generators.

c. Stop the diesel generator and trip its output breaker on sensing differential phase current.

d. Initiate start of the component cooling water pump on cooling water low pressure.

The test acceptance criteria specified in section 10.3.21.4 below have been established based on these safety questions.

10.3.21.4 Test Criteria in Plan

The test criteria are based on the evaluation of all devices on the safeguard relay board as shown on the attached device table. The devices shall not inadvertently operate or its contacts chatter during a seismic event. If contact chatter occurs during the seismic testing, it shall be evaluated to demonstrate that the equipment safety function is not comprised. Devices which can have an adverse affect on Class IE function if they malfunction during or after a seismic event, are discussed below.

a. Device 87HHG, Diesel Generator Differential Relay: Must trip diesel generator and open 4.16 kV diesel generator breaker on diesel generator differential current flow. Must not operate inadvertently.

b. Devices 32XHH7, 32YHH7, 87XHHG, 87YHHG, 40XHH7 and 40YHH7, Auxiliary Relays normally open contacts must not close (chatter) during a seismic event. Such a contact closure could seal in the respective auxiliary relay, and cause the diesel generator breaker to open and in the case of the 87XHHG and 87YHHG relay could cause the diesel generator itself to trip. The 87X and Y relays must also operate during and after a seismic event.

c. Devices 4HH, 3HH1 and 5HH13 Transfer-, Interlocking-, and Trip Relays: Must operate during and after a seismic event. They must not change state inadvertently at any time.

d. 27ZHHB2 4.16 kV Switchgear Bus Undervoltage Auxiliary Relay: Must operate during and after a seismic event on contact closure of the 27HHB2 bus undervoltage relay.

e. 62HH2 Diesel Auto Transfer Timer shall operate on demand during a seismic event.

The following test procedure tests all the above requirements during and after a simulated earthquake as required to qualify the equipment to IEEE Standard 344-1975 and USNRC R.G. 1.100.

10.3.21.5 <u>Test Procedure and Setup</u>

The relay board was bolted to the seismic test machine to simulate its rigid floor mounting at elevation 119' in the turbine building. Attachment "B" describes the test mounting.

Two strain gages were installed on structural members inside the relay board to monitor structural performance during the test as shown in Attachment "C". The seismic test sequence shown in Attachment "D" was modeled after the one for the 4.16 kV switchgear as described in Addendum 1 of WYLE's Test Report No. 58255-1, August 22, 1978.

The devices on the relay board were wired per attached wiring instructions. See Attachment "E".

Following are illustrations which show the test setup wiring beyond the termination points.

a. 125 VDC energizes the diesel generator protective circuitry (see Attachment "F") and the automatic transfer circuitry (see Attachment "J").

b. 3 phase current was applied to the circuitry of the 46HH7, negative sequence. See Attachment "H".

c. Single phase current was applied to the 87HHG Differential Relay via a switch to demonstrate the diesel generator differential relay operation. See Attachment "H".

d. One normally open contact each of relays 87XHH7, 40XHH7 and 32XHH7 were wired to trip a 4.16 kV switchgear breaker to demonstrate their function as outlined in the test criteria above. In addition a second contact of each relay was wired to a direct readout recorder to monitor chatter. See Attachment "F".

e. Relays 4HH and 3HH1 were wired to trip and reset via separate switches. Relay 5HH13 was wired such that the operation of relay 3HH1 conversely tripped and reset 5HH13 which simulated the interaction of these relays in the plant. In addition one normally open and one normally closed contact of the 3HH1 relay were wired to the direct readout recorder to monitor chatter and indicate change of state when operated. See Attachment "J".

f. 120 VAC, single phase, was connected to relay 27HHB2, which was mounted rigidly to the shake table by means of a stand. The output contact was connected to the 27ZHHB2 relay in such a manner that deenergization of 27HHB2 would pick-up 27ZHHB2, energization would drop out 27ZHHB2. One normally open contact of 27ZHHB2 was connected to the direct reading recorder to monitor chatter and indicate change of state when operated. See Attachment "K".

g. 125 VDC was connected to the 62HH2 Diesel Auto Transfer Timing Relay via a switch to demonstrate its timing function and that it permits the 4HH7, Diesel Auto Transfer Close Relay, to be energized which in turn initiates the closure of the diesel generator breaker. A second contact of above switch was directly connected to the direct reading recorder to indicate the start of timing. Relay 4HH7 was connected to a normally open contact of 62HH2. A normally open contact of 4HH7 than was monitored on the direct reading recorder to demonstrate the end of timing. See Attachment "L".

10.3.21.6 Test Results

With the exception of anomalies discussed below for certain relays, all relays met the test criteria specified in Section 10.3.21.4 above during and after the seismic testing while being operated per the test procedure described in Section 10.3.21.5 above. It is worthy of note that the equipment was subjected to more than the minimum number of test runs for qualification, demonstrating margin in the equipment's resistance to seismic damage.

Contact chatter was documented on the Contact Chatter Log Data Sheet, WYLE's Test Report No. 58255-1, pages 28 and 29. Of the runs listed, runs 4 through 8 met our front to back OBE conditions; runs 10 through 13 met our front to back SSE conditions; runs 17, 18, 20, 21, and 22 met our side to side OBE conditions; and runs 24 through 27 met our side to side SSE condition.

Chatter indicated on Channel 7 is caused by the 59HHG1&2 relay which is not part of the relay board and for that reason need not to be addressed here.

-Channel 1, 87XHH7 Differential Auxiliary Relay, Runs 11, 18, and 25.-

The relay contact chattered only after it had performed its safety function, namely the tripping of the connected 4.16 kV switchgear breaker.

-Channels 2 and 3, 32XHH7 and 40XHH7 Auxiliary Relays, Runs 10 through 14.-

Momentary change of state of the contacts of the 32XHH7 auxiliary relays was observed during a portion of the testing. This was demonstrated to be pulsation of these relays due to chatter of the prime relays 32HH7 (Reverse Power Relay) and 40HH7 (Loss of Field Relay) since the anomaly did not occur when the cut out switches for the prime relays had been opened. This anomaly would not occur in the event of a seismic event during plant operation, since these relays are normally cut out.

Note that relays 32XHH7 and 32YHH7 are housed in one case and that they are connected in parallel. For that reason all comments apply to both relays simultaneously. The same applies to relays 40XHH7 and 40YHH7.

-Channel 6, 27ZHHB2 Relay.-

During the testing, pulsation of the 27ZHHB2 relay, caused by chatter of the deenergized 27HHB2 relay was observed. Testing performed on the 4.16 kV switchgear (see Section 10.3.26) has demonstrated that pulsations of the 27ZHHB2 relay will not prevent the pickup of the 5HH13 relay, and thus will not compromise the safety function of power transfer of the 4160V bus from the station auxiliary transformer to the stand-by start-up transformer, and if necessary to the diesel generators.

Momentary chatter of the 27ZHHB2 auxiliary relay during runs 10, 11 and 13, when the 27HHB2 prime relay was not deenergized, can be traced back to the high ZPA level of the SSE test runs. During a high level seismic event, the seismic protection system will cause the plant to shut down. The 4160V safeguard buses would then transfer to the stand-by start-up source. Chatter of relay 27ZHHB2 would only expedite this transfer.

The evaluation of the strain gage traces showed that the structural members of the relay board were exposed to stresses well within their design limits.

No physical damage to the relay board or its devices was observed.

10.3.21.7 Conclusion

Safeguard Relay Board H of Diablo Canyon Unit 2 was seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report Number 58255-1, dated August 22, 1978, pp. 92-138. This board contains devices representative of the contents of all Diablo Canyon Unit 1 and 2 Safeguard Relay Boards. Thus qualification of this board will apply to all Diablo Canyon Safeguard Relay Boards.

The test results presented in section 10.3.21.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 Safeguard Relay Boards are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

DEVICE TABLE

SAFEGUARD RELAY BOARD "H".

Device	Type	Use	Affect Class 1E Function	Remarks	Schematic Diagram No.
25HH	IJS	Synchronism Check	no	Used during tests only	441341
32HH7	CRN-1	Reverse Power	no	Used during test only	441356
46HH7	COQ	Negative Sequence	no	Alarm only	441355
59HHU	SV	Start-up Voltage	no	Chatter will not produce abnormal operation	441354
27HHU	CV-2	Start-up Under Voltage	no	Chatter could start diesel. This is failsafe	441354
62HH1	TD-5	Start-up Auto Transf. Timer	no	Chatter will not produce abnormal operation	441354
87HHG	SA-1	Diesel Gen. Differential	yes	Monitor Aux. Relays	441356
40HH7	KLF	Loss of Field	no	Used during tests only	441356
32XHH7	AR	Rev. Pwr. Auxiliary	yes	Monitor NO contact	441356
32YHH7	AR	Rev. Pwr. Auxiliary	yes	of 32YHH7	441356
87XHHG	AR	Diesel Gen. Diff.	yes	Monitor NO contact	441356
87YHHG	AR	Auxiliary Relays	yes	of 87YHHG	441356
40XHH7	AR	Loss of Field	yes	Monitor NO contact	441356
40YHH7	AR	Auxiliary Relays	yes	of 40YHH7	441356
4HH	LORE	Diesel Gen. Auto Transf. Control Relay	yes	See 3HH1	441354
3HH1	LORE	Diesel Gen Auto Transf. Interlocking Relay	yes	Monitor 1NO & 1NC cont. (typ. for 4HH & 5HH13)	441354
5HH13	LORE	St-up Auto Transf. Trip Relay	yes	See 3HH1	441354
PS190XH	SG	Comp. Cool Wtr. Low	no	Chatter would start	441311
PS191XH	SG	Press. Aux. Relay		Comp. Cool. Wtr. Pp. This is failsafe	441311
27XHHB2	SG	Bus UV Aux. Relay (st.-up & 4kV Bus)	no	Chatter would start diesel. This is failsafe	441354
25XHH	SG	Synch. Check Aux. Rel.	no	Used during test only	441340

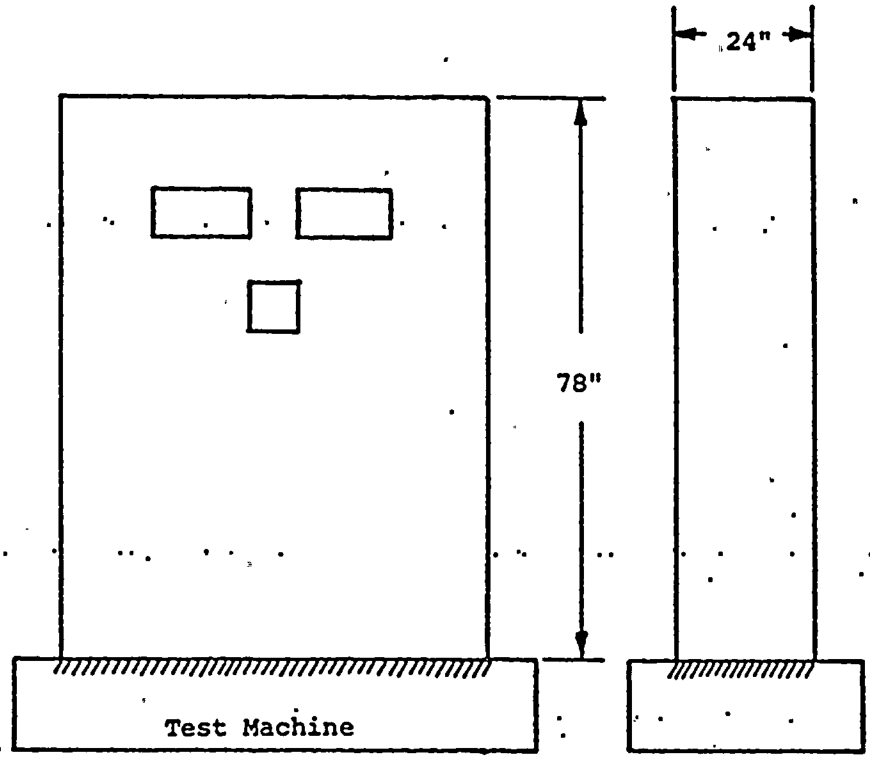
DEVICE TABLE

SAFEGUARD RELAY BOARD "H"

Device	Type	Use	Affect Class 1E Function	Remarks	Schematic Diagram No.
4HH7	SG	Diesel Gen. Auto Transf. Close Relay	no	Chatter will not produce abnormal operation	441354
27HHDC	SG	DC Contr. Bus UV Rel.	no	Alarm only	441354
27GHDC	SG	DC Contr. Bus UV Rel.	no	Alarm only	441356
27ZHHB2	SG	4kV Bus UV Aux. Rel.	yes	Connect NO Cont. to 5HH13 and monitor trip	441354
27YHHB2	SG	Same as 27XHHB2	no	Same as 27XHHB2	441354
4HH14X	SG	Start-up Auto Transfer	no	Chatter will nor produce	441354
4HH14	SG	Close Aux. Relays	no	abnormal operation	
62HH2	AGASTAT	Diesel Auto Transfer Timer	no	Chatter will not produce abnormal operation	441354

SAFEGUARD RELAY BOARD
GROUP I

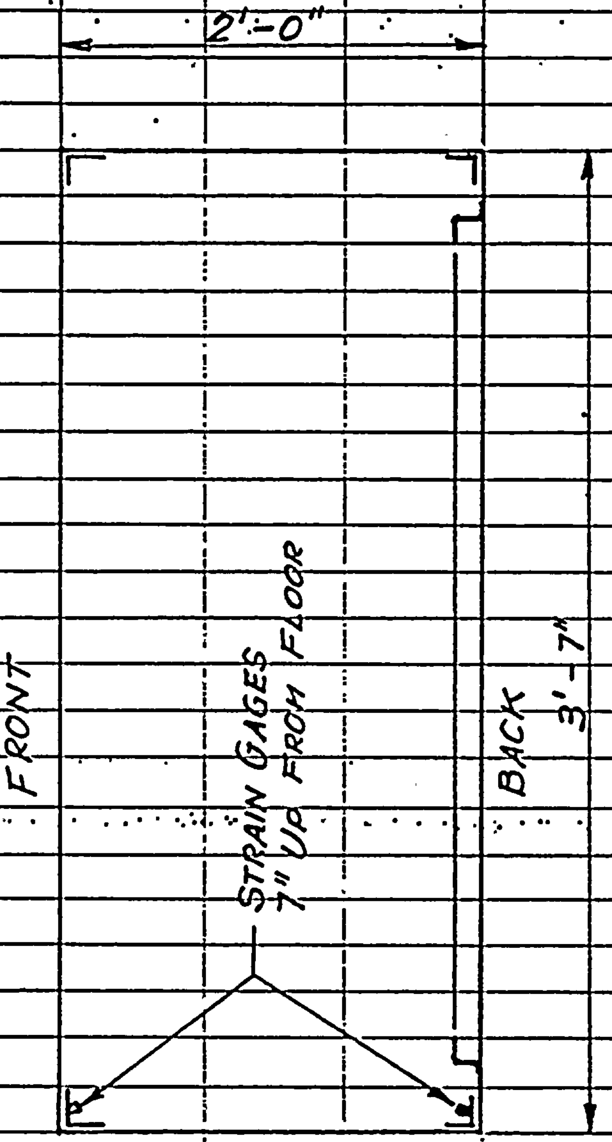
C
B



Bolt to the seismic test machine with eight 1/2 x 13 bolts.

C

STRAIN GAGE LOCATION SAFEGUARD RELAY BOARD "H"



HORIZ. SECTION THROUGH
RELAY BOARD
LOOKING DOWN

J. E. HERBST
8/7/78

SEISMIC TEST SEQUENCE
FOR SAFEGUARD RELAY BOARD "H"

CONDITION	AXES	HORIZONTAL RM ZPA 9	HORIZONTAL RM FIG. NO.	VERTICAL RM or RM + SB ZPA 9	VERTICAL RM or RM + SB FIG. NO.	SB Hz	REMARKS
1	FB	.2	-	-	-	-	1-33 Hz Sweep
2	V	-	-	.2	-	-	1-33 Hz Sweep
3	FB+V	.75	50% - 1	.8	50% - 2	-	1 OBE
4							2
5							3
6							4
7							5
8		1.5	1	1.6	2	7.1	1 SSE
9						8	2
10						9	3
11						10	4
ROTATE RELAY BOARD 90°							
12	SS	.2	-	-	-	-	1-33 Hz Sweep
13	SS-V	.75	50% - 1	.8	50% - 2	-	1 OBE
14							2
15							3
16							4
17							5
18		1.5	1	1.6	2	7.1	1 SSE
19						8	2
20						9	3
21						10	4

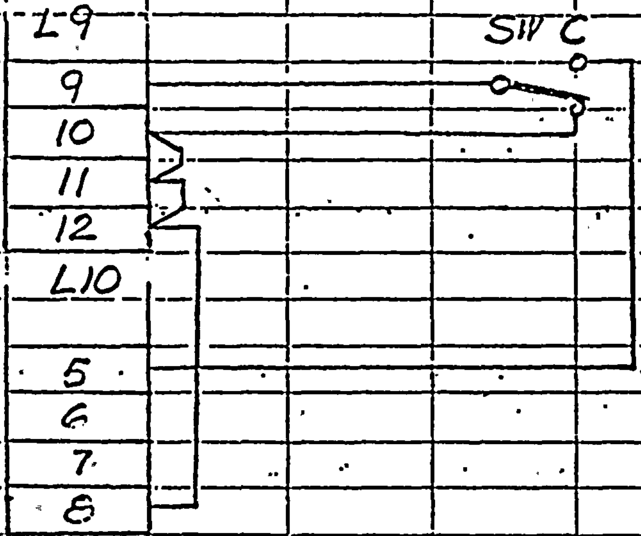
LEGEND:

RM	Random Motion
RM+SB	Random Motion plus Sine Beat
ZPA	Zero Period Acceleration
FB	Front to Back
SS	Side to Side
V	Vertical
FB+V	Front to Back and Vertical (Biaxial)
SS+V	Side to Side and Vertical (Biaxial)

ATTACHMENT "D"

WIRING INSTRUCTIONS
FOR SEISMIC TEST OF
SAFEGUARD RELAY BOARD "H"
POTENTIAL TRANSFORMER COMPARTMENT
EMERGENCY LIGHT UNIT
RELAYS DEVICE NO 59HHG1, 59HHG2 AND 27HHB2

SW. NO.								
A	125V	DC	TERM.	TBA-1	POS	(W. IND. LT. ON)		
				TBA-2	NEG			
B	5A, 3ϕ, 4 WIRE			CURRENT		RELS	46HH7	
							40HH7	
			TERM	L10-1	Aϕ		32HH7	
				L10-2	Bϕ			
				L10-3	Cϕ			
				L10-4	GND			
		JUMPER AS FOLLOWS:						
C								



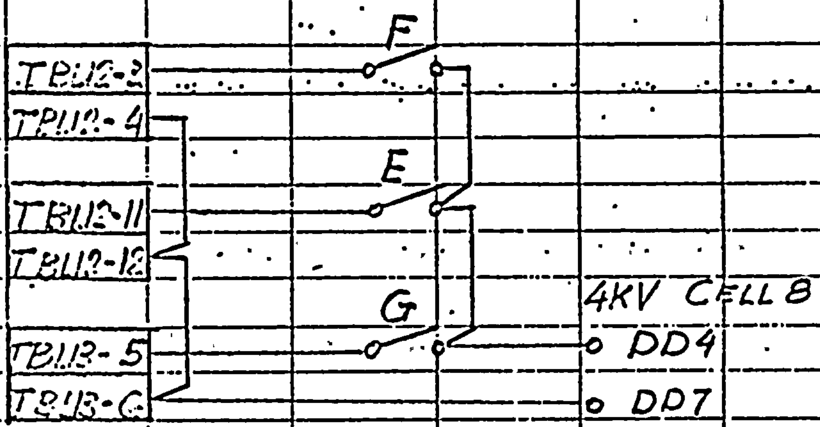
OPERATION OF SW D ~~WILL CAUSE~~ 87HHG (DIFF. REL) TO OPERATE.

D	120V	AC, 3ϕ	TERM	L8-10		Aϕ	POT FOR:	
				L8-11		Bϕ	40HH7	
				L8-12		Cϕ	32HH7	

ATTACHMENT "E" SH. 1

* IND. CHANGE FROM PRELIM.

Sw. No			
	87XHH7	TO TRIP 4KV BKR. 8	
E		TERM: TBL12-11 VIA CUT-OUT	
		TBL12-12 TO PREVENT BKR TRIP	
	40XHH7	TO TRIP 4KV BKR 8	
F		TERM: TBL12-3 VIA CUT-OUT	
		TBL12-4 TO PREVENT BKR TRIP	
	32XHH7	TO TRIP 4KV BKR 8	
G		TERM: TBL13-5 VIA CUT-OUT	
		TBL13-6 TO PREVENT BKR TRIP	



*

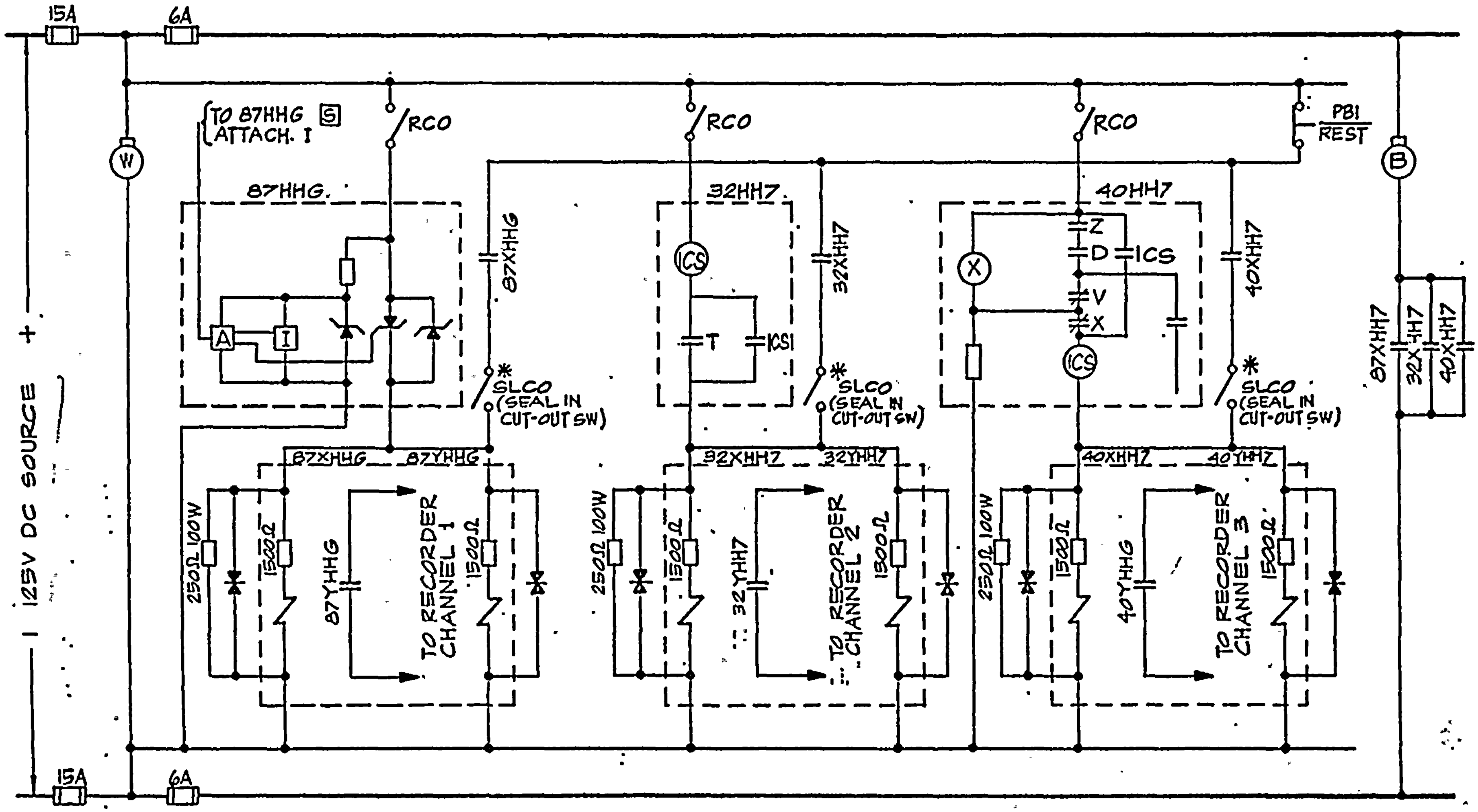
87XHH7	MONITOR	TBL15-1 AND TBL15-2	
40XHH7	"	TBL14-11 AND TBL14-12	
32XHH7	"	TBL15-3 AND TBL15-4	
		LIFT POSSIBLE JUMPER	
		AT TBL15-1, -3, -11	

SW. NO.

H	4HH	(TRIP)	125V DC POS. TO TERM TBR10-2 VIA SW. "H"
I	3HH1	(TRIP	" " " " TERM TBR5-11 VIA SW. "I"
			RESET IS ONLY MANUAL AND NEED NOT BE TESTED DURING SHAKE
	5HH13	(TRIP)	125V DC P JUMPER TBR10-4 TO TBR7-3 NO SWITCH OPERATION. 3HH1 WILL CONVERSELY TRIP AND RESET 5HH13
J	4HH 3HH1	(RESET)	125V DC POS TO TERM TBR5-3 VIA SW. "J"
	3HH1		MONITOR TBR1-7 AND TBR1-8 NC; TBR1-9 " TBR1-10 NO. THIS IS TYP. MONITORING FOR LORE RELAYS 3HH1, 4HH, AND 5HH13
	27ZHHB2		CONNECT TERM 12 OF 27HHB2 (IAC) TO TBR9-3. CONNECT TERM 1 OF 27HHB2 (IAC) TO 125V DC POS. (NO SW. REQ'D)
			MONITOR 27ZHHB2 TERM 3 AND 7

* INDICATES CHANGE FROM PREL.

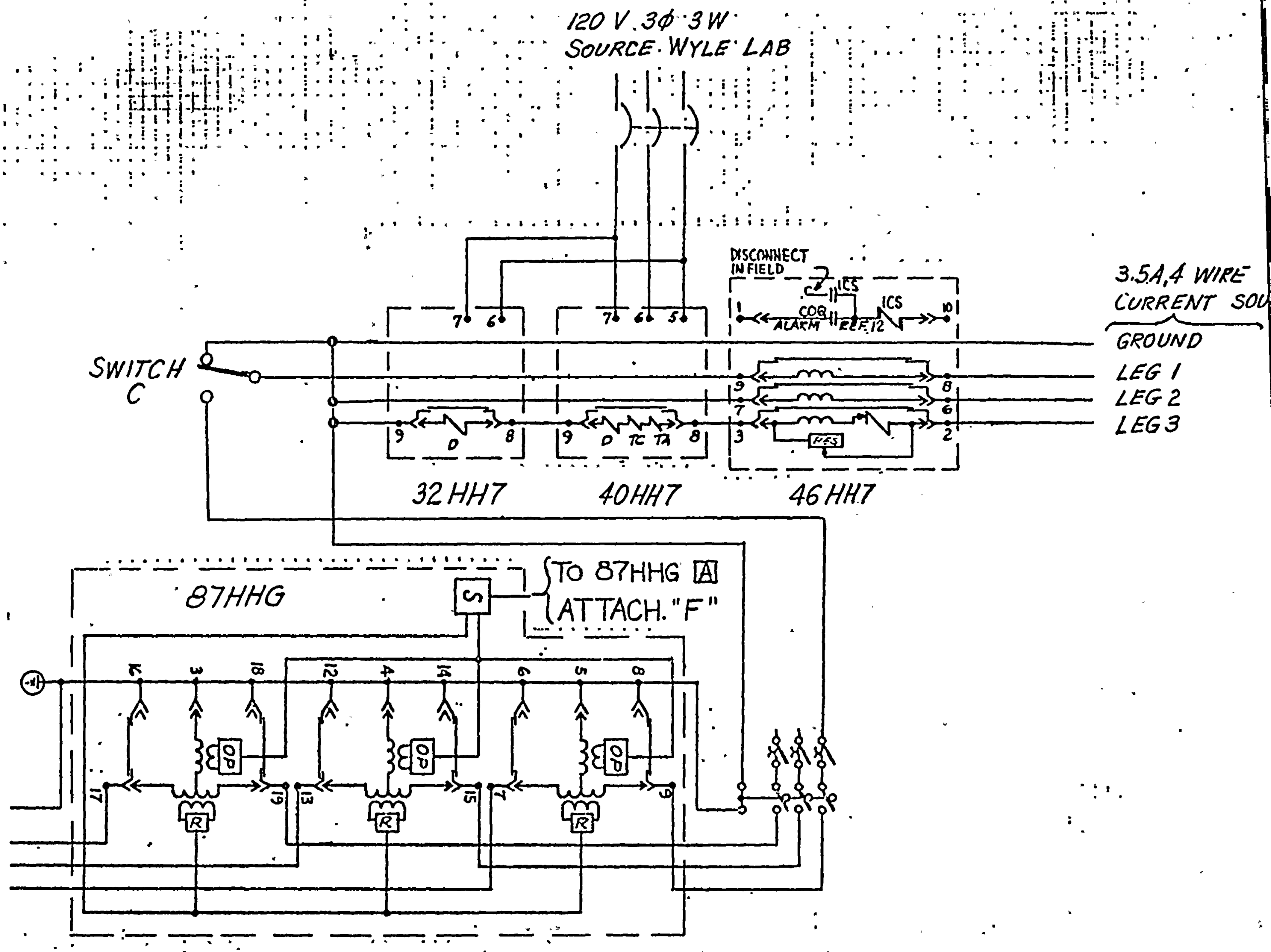
SW. NO.					
K	120V AC 3∅ TO 59HH1 & 2	TERM. 2	(A∅ 4)		
		" 8	(C∅ 8)		
		" 3+9	(B∅ 9)		
	1∅ TO 27HHB2	" 15	A∅		*
		" 16	B∅		*
	59HH1 & 2 MONITOR TERM'S 1-5 AND 7-10				
	27HHB2 CONNECT 125V DC TO TERM. 1				*
	" TERM. 12 TO TBR9-3				
	P.T. COMPARTMENT				*
	CONNECT SECONDARY - PRIMARY - SECONDARY DISCONNECT SWITCHES IN SERIES AND MONITOR CONTINUITY.				
	EMERGENCY LIGHT UNIT				*
L	CONNECT 120V AC TO JUNCTION BOX VIA DISCONNECT SWITCH "L"				
A	125V DC TO 4.16kV SWITCHGEAR DC BUS				
M	MAN. CLOSE SWGR DD4 - CONTROL SW - BB9				*
N	MAN. OPEN SWGR DD4 - CONTROL SW - DD7				*
P	62HH2 125V DC POS TO TERM. TBR5-10 VIA DOUBLE POLE SW. P MONITOR 1 POLE OF SW P				*
	4HH7 JUMPER TBR5-5 TO TBR7-4 (POS) MONITOR TBR3-7 AND TBR3-8				*



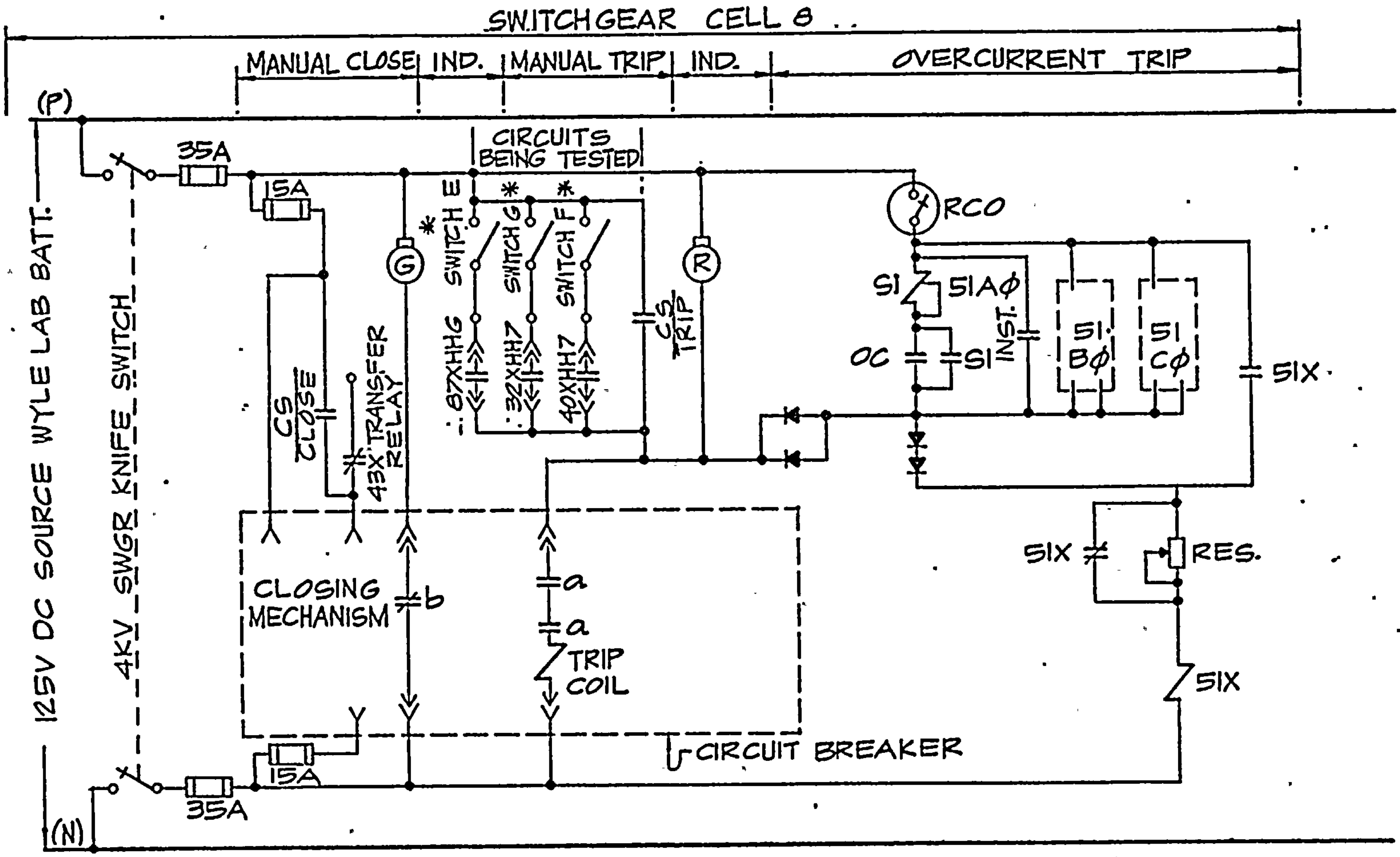
125 V.D.C. CONTROL SCHEMATIC DIAGRAM
DIESEL GENERATOR Nº 22 PROTECTIVE
RELAYING-SEISMIC TEST CONNECTIONS-

* SLCO SWITCHES WERE CLOSED DURING TESTS

ATTACHMENT "F"

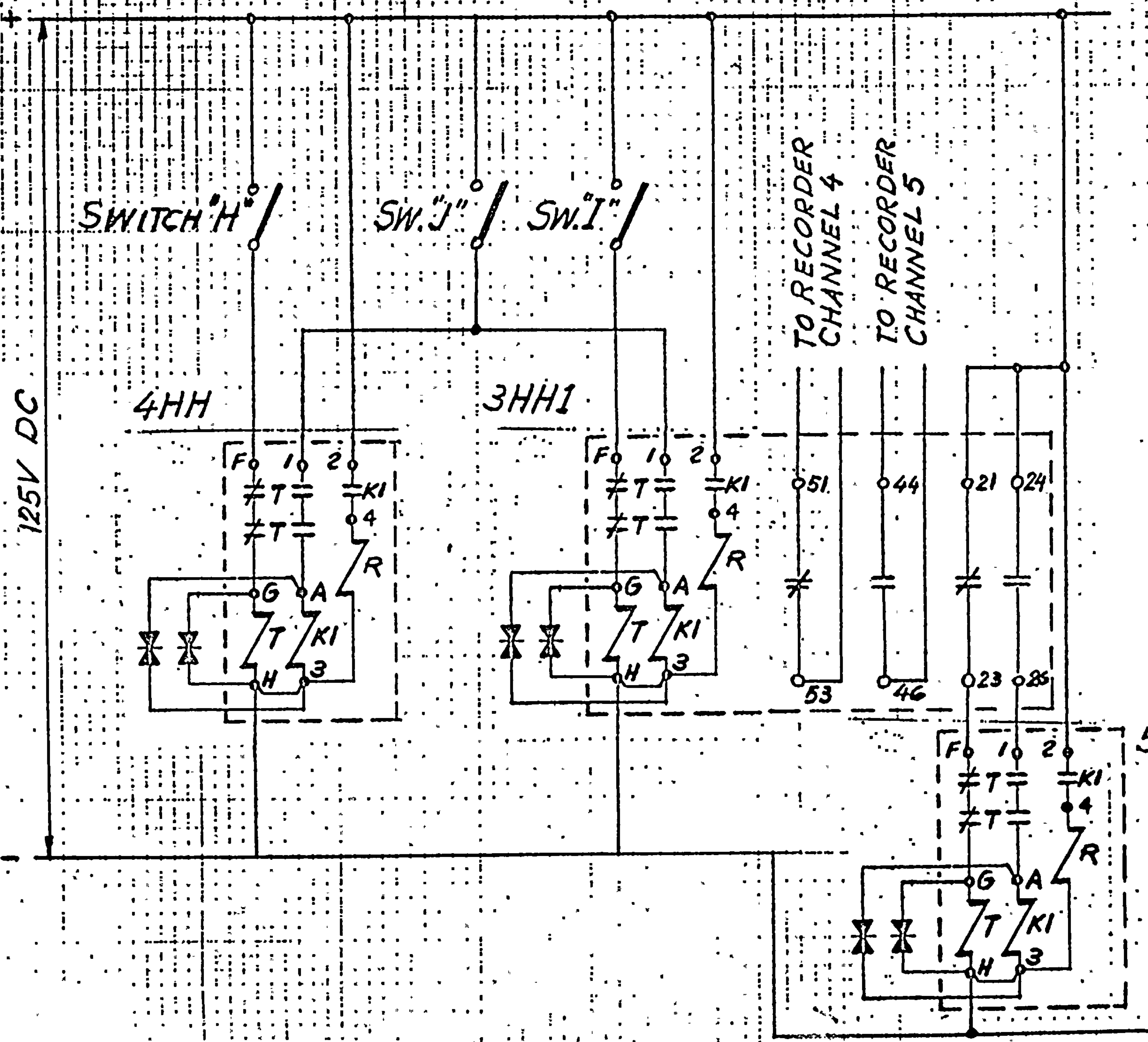


ATTACHMENT "H"

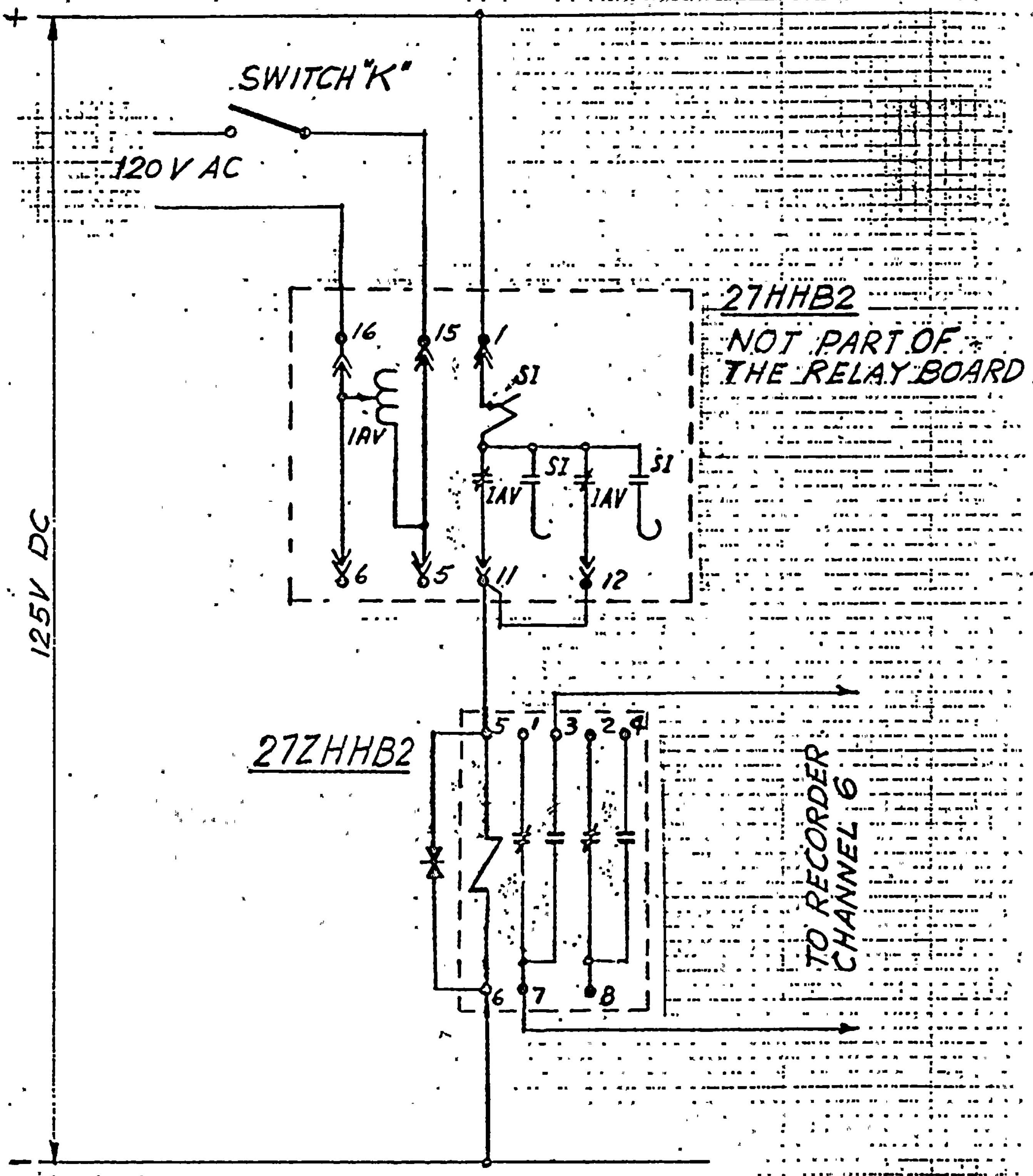


* LOCATED AT TEST BENCH

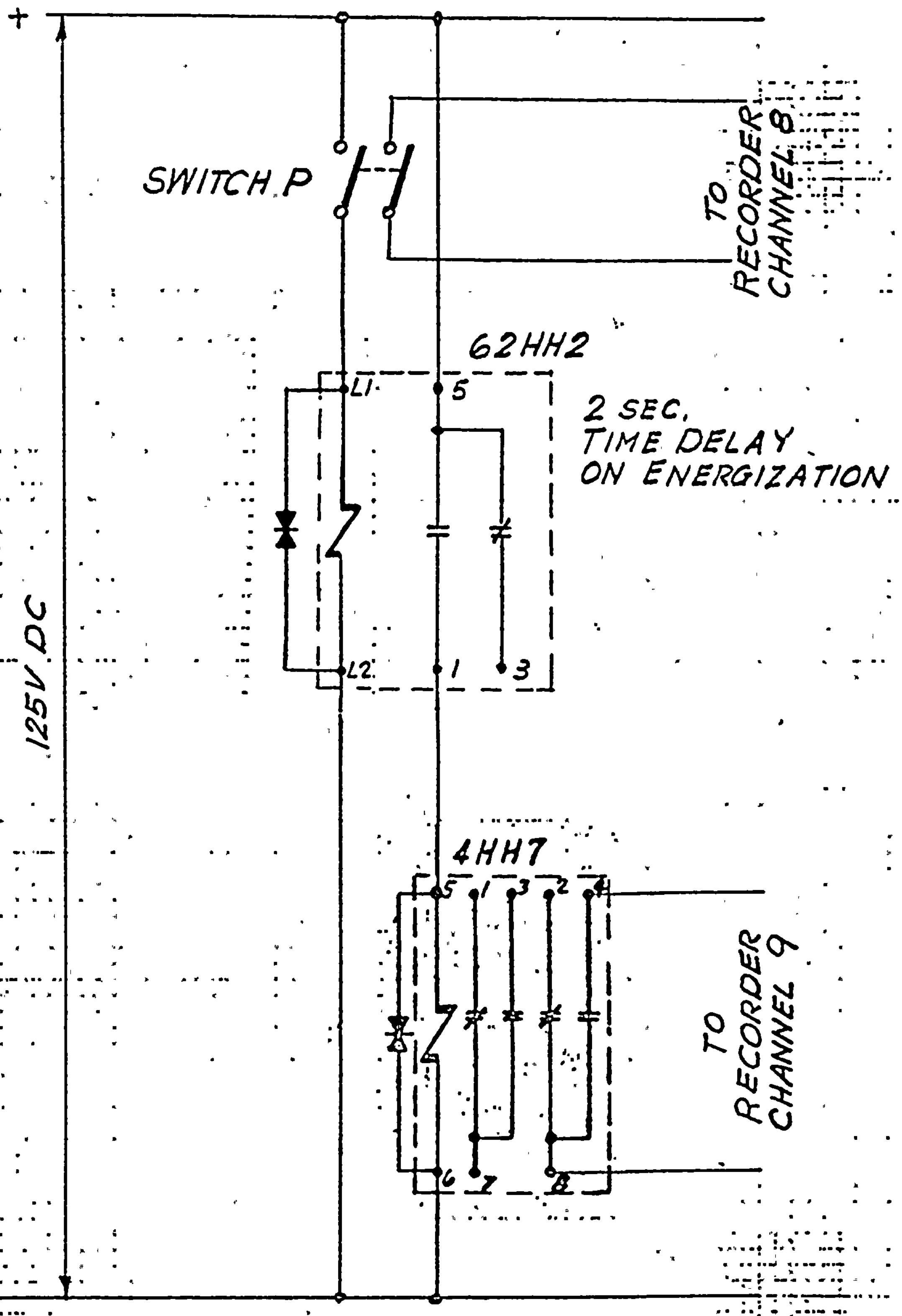
ATTACHMENT "I"



ATTACHMENT "J"



ATTACHMENT "K"



ATTACHMENT "L"

1. Name of Equipment Tested

Teledyne Big Beam 2S6N70-80 8 hour rated Emergency Light Battery Pack.

2. Description of Equipment

The Emergency Light Battery Pack is a metal chassis 8 hour rated nickel-cadmuim battery with a battery charger and two 6 VDC sealed beam lights.

3. Safety Function

The safety function of the Emergency Light Battery Pack is to provide 8 hours of lighting if the (3) redundant normal AC, Emergency AC, and 125 VDC lights are lost due to seismic or fire in designated class IE operating areas.

4. Test Criteria and Plan

The test criteria for this unit is that it perform its safety function during, and after a seismic event. The unit shall demonstrate this as follows:

a) On loss of emergency AC power the unit will automatically revert to the battery and light the sealed beam lights.

b) On return of AC power the unit lights will turn off and its charter will recharge the battery at the high charge rate, equalizing change rate or the trickle charge rate.

c) After testing the unit powered the sealed beam lights for 8 hours.

d) The battery charger recharged the battery in 12 hours.

5. Test Procedure and Set-Up

See the attached Procedure for Testing one Teledyne Big Beam 8 hour rated Battery Back Emergency Lights Unit for Hosgri 7.5M. Before testing, (2) 1/8 x 1 inch steel straps were placed across the top of the battery and bolted to the mounting shelf using 1/4 inch threaded rod with standard nuts and washers. This modification was done before the seismic test to assure a successful test.

6. Test Results

This unit was run thru 10 OBE's and 13 SSE's and demonstrated that:

a) On loss of AC input the sealed beam units energized.

b) On return of AC power the sealed beam lights go off.

c) The unit operated the sealed beam lights for 8 hours.

d) After discharge in (c) above the charger recharged the battery in 12 hours.

e) Attached find Test Run Data Sheet on the testing.

7. Conclusions

Based on the above test and functional qualification this Emergency Light Battery Pack is qualified as an emergency light battery pack with an 8 hour rating, and rechargeable in 12 hours.

The same modifications are being done to the battery packs being put into the plant as were done on this unit before seismic testing.

1.0 <u>Procedure for Testing one Teledyne Big Beam 8 Hour rated Battery Pack Emergency Lights Unit for Hosgri 7.5M</u>

1.1 Model No. 2S6N70-80

1.2 Before seismic testing hook-up the 120 VAC power circuit to the junction box for conduit connection.

1.3 On first energizing with 120 VAC input observe which of the following lights come on:

1.3.1 Red light only, indicating a high rate charge (low charge on battery)

1.3.2 Red and Green light indicating an equalizing charge rate

1.3.3 Green light indicating a trickle charge rate (fully charged battery).

1.4 Depress the momentary test switch for 90 seconds simulating power failure. Verify that:

1.4.1 The amber indicating light goes off.

1.4.2 The emergency light comes on.

1.4.3 Read voltmeter under load and record the value.

1.5 Check the electrolyte level. Electrolyte level should be between the top maximum "full" line, and the lower "add" line. If not, record the level and adjust the electrolyte level.

1.6 Test Reference:

1.6.1 This equipment shall be tested to either the requirements specified in the contract for seismic testing of the:

1.6.1.1 4 kV switchgear

1.6.1.2 or the safeguards relay board

1.7 Mount the Battery Pack Emergency D.C. Light by its seismic type mounting including the securement type mounting shelf to the seismic table fixture simulating wall mounting of the unit. Mounting to approved by P.G.& E. before testing.

1.7.1 Connect 120 VAC power to the unit with external to the table means for deenergizing.

1.8 Perform seismic testing as specified in paragraph 1.6.1 or

1.8.1 Perform 5 OBE's and 1 SSE in the North-South direction to envelope the RRS as developed for 119' El. Area A, Turbine Bldg. for Hosgri 7.5M.

1.8.2 Perform 5 OBE's and 1 SSE in the East-West direction to envelope the PSS as developed for 119' El. Area A, Turbine Bldg. for Hosgri 7.5M.

1.9 During one OBE and one SSE in each direction perform the following:

1.9.1 Deenergize the 120 VAC power input.

1.9.1.1 Observe and record the initation of the sealed beam lights.

1.9.1.2 Observe the seal beamed lights for continuous output.

1.9.1.3 Observe and record if the amber lights goes off.

1.9.1.4 Take voltmeter readings if possible.

1.9.2 Reenergize the 120 VAC power to the Unit.

1.9.2.1 Observe and record the turn-off of the sealed beam units.

1.9.2.2 Note and record if the amber, red, red and green, or green lights come on.

1.9.3 Record any of the following during the test.

1.9.3.1 Leakage of electrolyte

1.9.3.2 Excessive deformation of Unit of its parts.

1.9.3.3 Recommendations for additional structural supports.

1.10 During the remaining four OBE's

1.10.1 Have the Unit energized by 120 VAC for 2 OBE test.

1.10.2 Have the Unit deenergized with the Seal Beam Units on for 2 OBE tests.

1.11 After the seismic test and upon removal of the Unit from the shake table deenergized the 120 VAC and run 8 hour emergency light duration test.

1.12 After the 8 hour emergency light duration test reenergized the 120 VAC and recharge the Unit up with the 12 hour recharge cycle.

1.12.1 Observe and record times when the indicating light are red, red and green, and green only.

1.13 The following conditions must be satisifed for the Unit to be qualified.

1.13.1 The Unit shall exhibit no observable damage, structural or otherwise.

1.13.2 There shall be no electrolyte leakage indicated by external moisture or change in level.

1.13. Upon deenergization of the 120 VAC the unit shall meet the requirements of paragraphs 1.9.1.1, 1.9.1.2, 1.9.1.3

1.13. Upon reenergization of the 120 VAC to the unit the Sealed Beam units shall go off, the amber light shall come on, and the red, red and green, or green light shall come on indicating that the charger is operating.

1.13. Unit shall meet the requirements of paragraphs 1.11 and 1.12.

TEST RUN
DATA SHEET

RUN NO.	OBE or SSE	AXIS	SEALED BEAM LIGHTS	AMBER	RED	GREEN	VDC
5	OBE	F.B.-V	OFF	125 VAC-ON	OFF	OFF	6.5
6	OBE	F.B.-V	6 VDC-ON	125 VAC-OFF	OFF	OFF	6.5
7	OBE	F.B.-V	6 VDC-ON	125 VAC-OFF	OFF	OFF	6
8	OBE	F.B.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
9	SSE	F.B.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
10	SSE	F.B.-V	OFF	125 VAC-ON	OFF	TRICKLE CHGE. ON	7
11	SSE	F.B.-V	OFF TO 6 VDC ON	OFF	OFF	OFF	6
12	SSE	F.B.-V	6 VDC ON TO OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
13	SSE	F.B.-V	OFF TO 6 VDC ON	OFF	OFF	OFF	7
14	SSE	F.B.-V	6 VDC ON-OFF - 6 VDC ON-OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
15	SSE	F.B.-V	6 VDC ON-OFF - 6 VDC ON-OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
16		S.S.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	8
17	OBE	S.S.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
18	OBE	S.S.-V	OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
19	OBE	S.S.-V	OFF-6 VDC ON	OFF	OFF	OFF	6
20	OBE	S.S.-V	OFF-6 VDC ON	125 VAC ON-OFF	HIGH CHGE. ON-OFF	OFF	6
21	OBE	S.S.-V	6 VDC ON	OFF	OFF	OFF	6
22	OBE	S.S.-V	6 VDC ON-OFF	125 VAC-ON	HIGH CHGE. ON	OFF	7
23	SSE	S.S.-V	OFF	125 VAC ON	HIGH CHGE. ON	OFF	7
24	SSE	S.S.V	OFF	125 VAC ON	HIGH CHGE. ON	OFF	7.5
25	SSE	S.S.V	OFF-6 VDC ON	125 VAC ON-OFF	HIGH CHGE. ON-OFF	OFF	7
26	SSE	S.S.-V	6 VDC ON-OFF	125 VAC OFF-ON	HIGH CHGE. OFF-ON	OFF	7
27	SSE	S.S.-V	6 VDC ON	OFF	OFF	OFF	7

10.3.6.1 Name of Equipment

a. Diesel Generator Excitation Cubicle.

b. Diesel Generator Control Cabinet.

10.3.6.2 Description of Equipment

a. The Excitation Cubicle is a steel cabinet 90" high, 48" wide and 46" deep with a 56" high front door. It contains the series boost exciter-voltage regulator for the associated diesel generator. Mounted on the door are various indicating instruments, indicating lights, control switches, and pushbuttons. These are used to monitor and manually control the generator. The front door permits access to the control wiring terminals and the low voltage chassis. A bolted back panel provides access to the high voltage chassis at the top and high voltage power connections with current transformers below. A bolted lower front panel also provides access to the power connections and current transformers.

b. The Diesel Generator Control Cabinet is 72" high, 30" wide, and 22" deep with a full front door. Mounted on the door are an annunciator, various control switches and pushbuttons, indicating lights, and a lockout relay. These are used to monitor and manually control the diesel engine. The front door provides access to a subpanel with various types of relays, a side panel with more relays and a tachometer, and another side panel with terminals for external control connections.

There are 5 diesel generator excitation cubicles and diesel generator control cabinets at the Diablo Canyon Site. Three are located in Unit 1 and two are located in Unit 2 next to the respective diesel generator.

10.3.6.3 Safety Functions

a. The exciter - regulator provides and controls the field current of the diesel driven generator to maintain the generator voltage within the regulator band. The diesel driven generator provides power to the engineered safeguard load in the event were all other power sources fail.

b. The devices of the diesel generator control cabinet initiate and control the start of the associated diesel engine on receiving a start signal. The annunciator monitors the status of the diesel engine system during on and off periods and alerts the plant operator of any occuring malfunctions.

10.3.6.4 Test Criteria and Plan

a. The test shall demonstrate that the excitation-voltage regulator equipment and the devices of the diesel engine control cabinet perform their safety functions during and after a seismic event.

The exciter-regulator itself is a static control device using transformers, reactors, semiconductors, resistors and capacitors. The exciter-regulator contains all silicon semiconductors and no electrolytic capacitors. The exciter-regulator is not subject to wear from moving parts and is relatively unaffected by temperature, humidity, vibration, and shock. However, the total assembly must maintain its integrety and function during and after seismic events.

b. The devices of the diesel generator control cabinet must perform their safety functions during and after a seismic event. The cabinet was found to be rigid during earlier insitu testing. For that reason only the devices need to be tested seismically.

The plan is to test the performance of the equipment by subjecting one complete excitation cubicle, the door of one engine control cabinet with all door mounted devices, and also typical relays of the subpanels to a seismic simulation test. This shall qualify all excitation cubicles and diesel generator control cabinets for their Class 1E functions to IEEE Standard 344-1975 and USNRC R.G. 1.100.

10.3.6.5 Test Procedure and Setup

The diesel generator excitation cubicle was skip welded to a one-inch steel plate which in turn was welded to the seismic test machine. Braces consisting of four-inch square tubing were bolted using one-half inch bolts to the top of the cubicle and welded to the test machine to simulate the cabinet bracing to the concrete wall at Diablo Canyon.

The control cabinet door was attached to a four-inch square tubing fixture using the normal bolt holes in the door hinge (1/4" bolts) on one side and the door closing mechanism on the other side. Thus simulating its in-service attachment.

The typical relays selected from the subpanel of the control cabinet were mounted on a 1/4 inch steel plate, 68 inches high and 30 inches wide. The plate was in turn bolted (four 3/8-inch bolts) to a rigid bookend type fixture. Spacers were used on the bolts to maintain a gap between the test fixture and steel plate. This was to simulate in-service attachment.

The selected devices were bolted to the steel plate using the same size bolts that are in normal use. See Attachment "B". The size of the shake table required two separate test set-ups. One with the excitation cubicle and the control cabinet door and a second one for the simulated subpanel with the selected typical devices.

The exciter-regulator was connected to 3 phase 4160VAC, 3 phase 120VAC, and 120VDC per attached wiring instructions. See Attachments "C", "D" and "E." All devices listed in Attachment "F" were monitored for chatter in both the energized and deenergized state, switches were monitored in the appropriate position.

Three switches of the control cabinet door (see Attachment "F") were monitored for chatter in the appropriate positions. The annunciator was observed for physical damage.

Devices from the subpanel were connected to appropriate power sources and monitored per attachment "G." The devices are listed in Attachment "H."

10.3.6.6 Test Results

The test specimens demonstrated their integrety to withstand without compromise of structure or safety functions the simulated seismic environment of seismic random biaxial motion performed to the required response spectra.

10.3.21.7 Conclusion

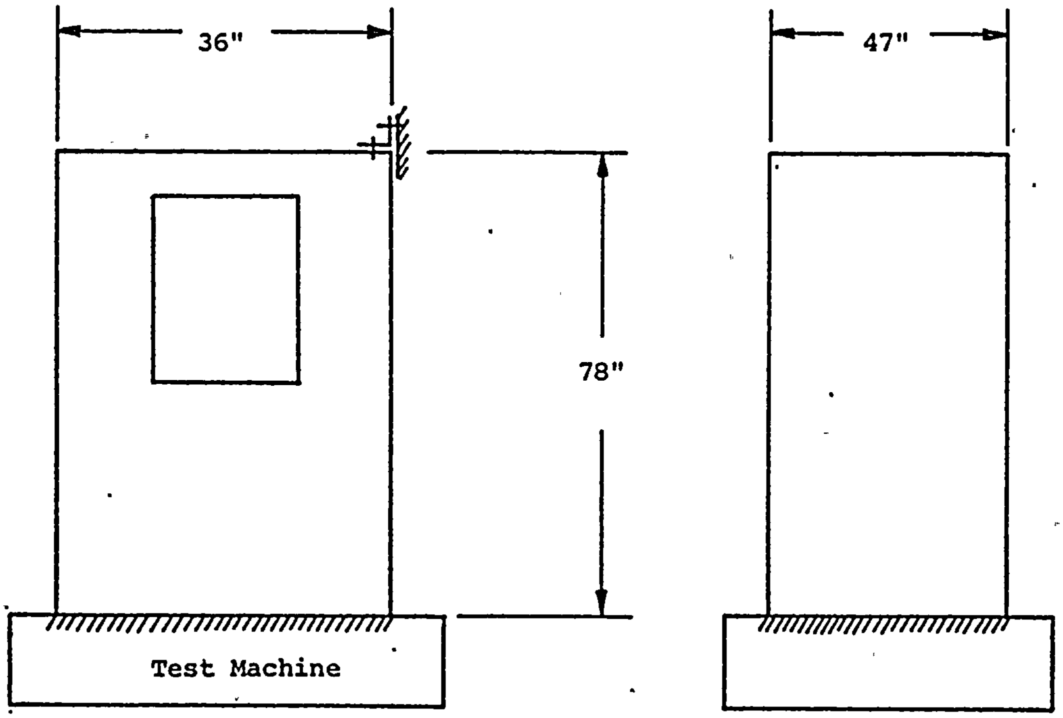
One Diesel Generator Excitation Cubicle and pertinent parts of the Control Cabinet of Diablo Canyon Unit 2 were seismically tested by a multi-axis, multi-frequency seismic simulation described in WYLE Report Number 58255, dated April 19, 1978. The equipment contained devices representative of the contents of all Diablo Canyon Unit 1 and 2 Diesel Generator Control. Thus qualification will apply to all Diesel Generator Exitation Cubicles and Diesel Generator Control Cabinets.

The test results presented in section 10.3.6.6 above demonstrate that the test criteria are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS derived from the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 Diesel Generator Exitation and Control Equipment are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

DIESEL GENERATOR EXCITATION CUBICLE
GROUP II

B



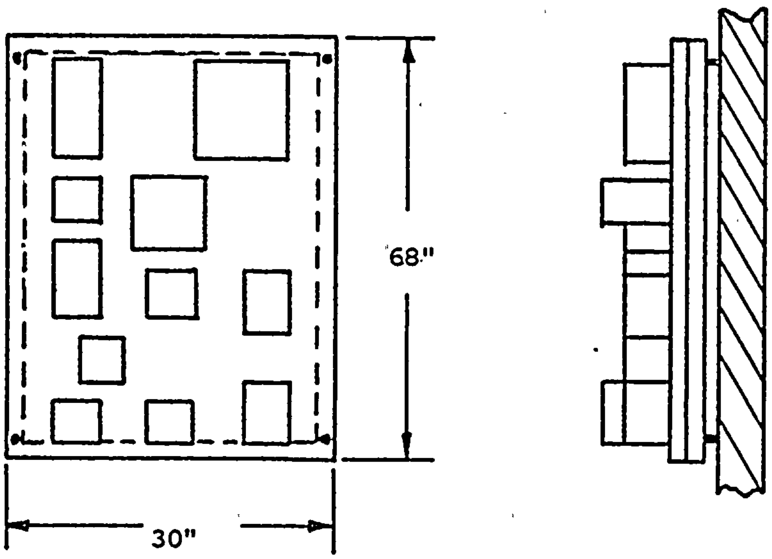
Weld to test machine with supports bolted at top.

B

DIESEL GENERATOR CONTROL CABINET
GROUP II

B

Sub-Panel

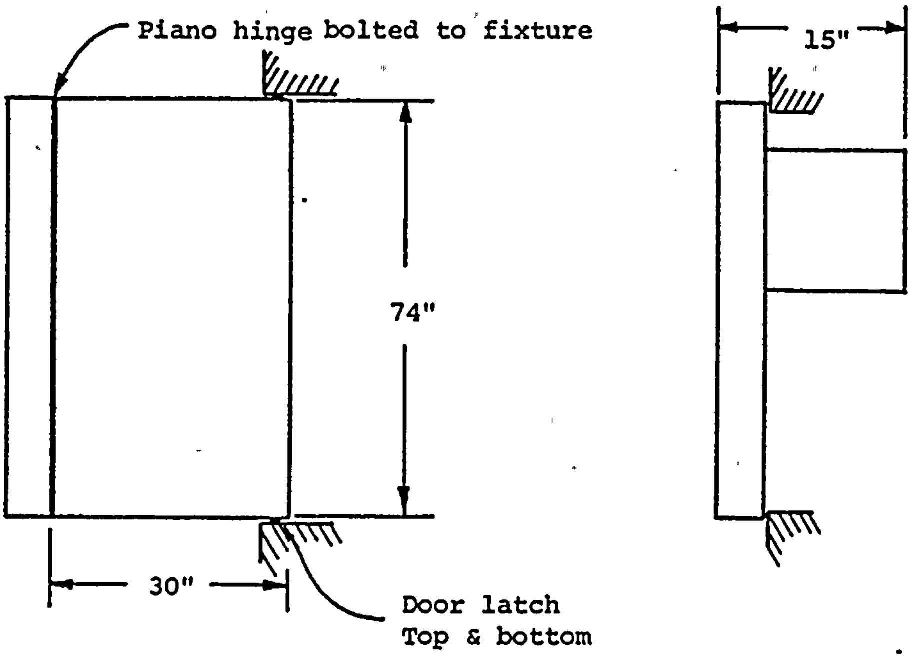


4 bolt mounting

Support at or near bolts only.

Control Cabinet Door

B



WIRING INSTRUCTIONS

Seismic testing of series boost exciter D9067100

In voltage regulator 90-78600-100, connect temporary jumper across capacitor C6 so that voltage regulator can be operated in steady ε ate mode sensing DC generator field voltage.

Connect resistive load to F+ F- terminals 0.60 to 1 ohm, 10 KW rating.

Apply +120VDC to terms B82 and B84. Apply minus side of 120VDC to terms 13 and 123 relays K1C and K1AC should pull in.

Connect 120V, 60 hertz, three phase, one ampere to terminals B16, B17, B18, check that K3 pulls in.

Connect 4160V, 60 hertz, three phase bused for 10A. Terminals CT11, CT12, CT13.

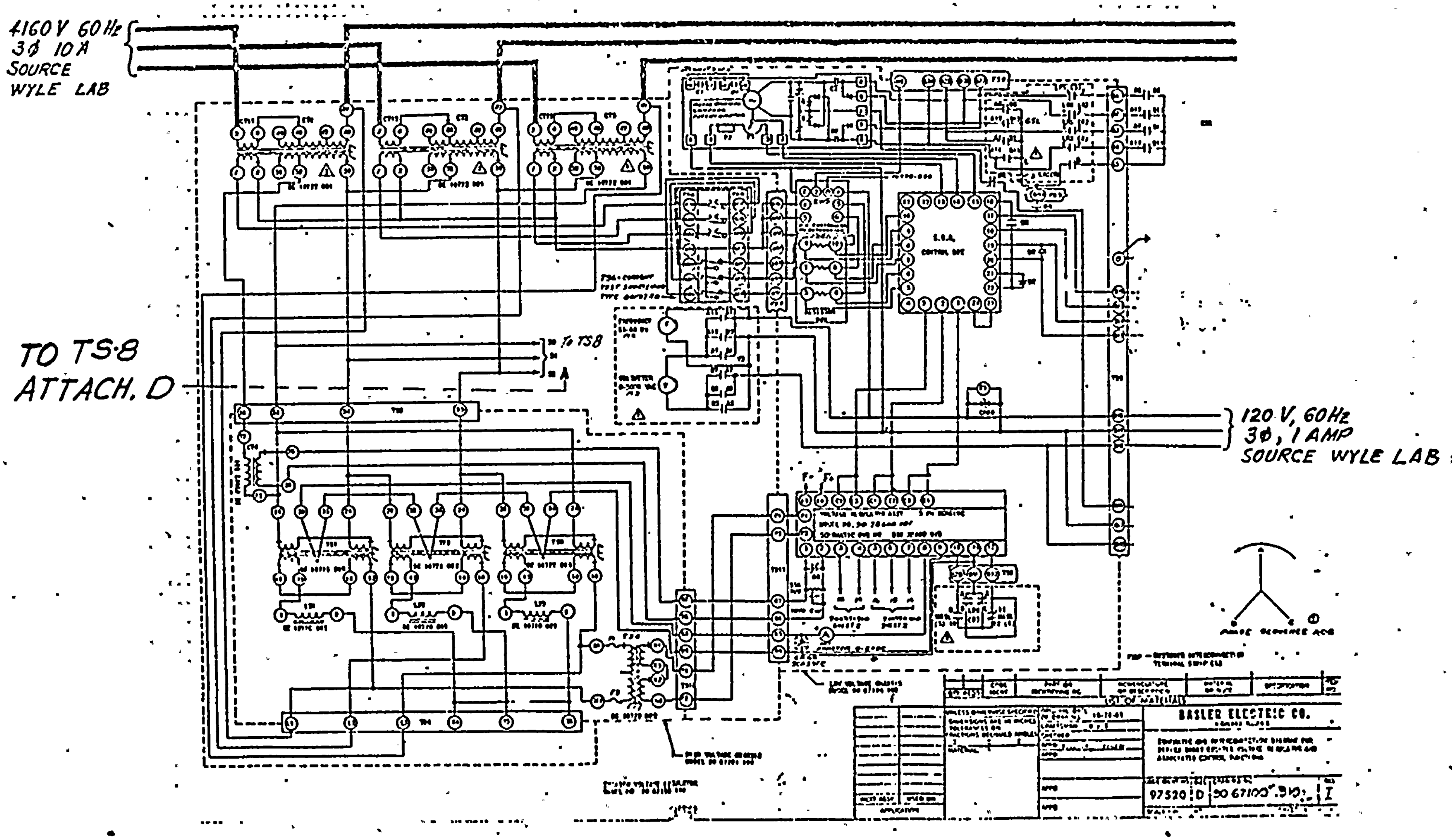
Adjust local raise lower voltage adjust for F+ F- voltage to 50 VDC and control current ammeter to 1 to 2A during vibration.

Monitor following:

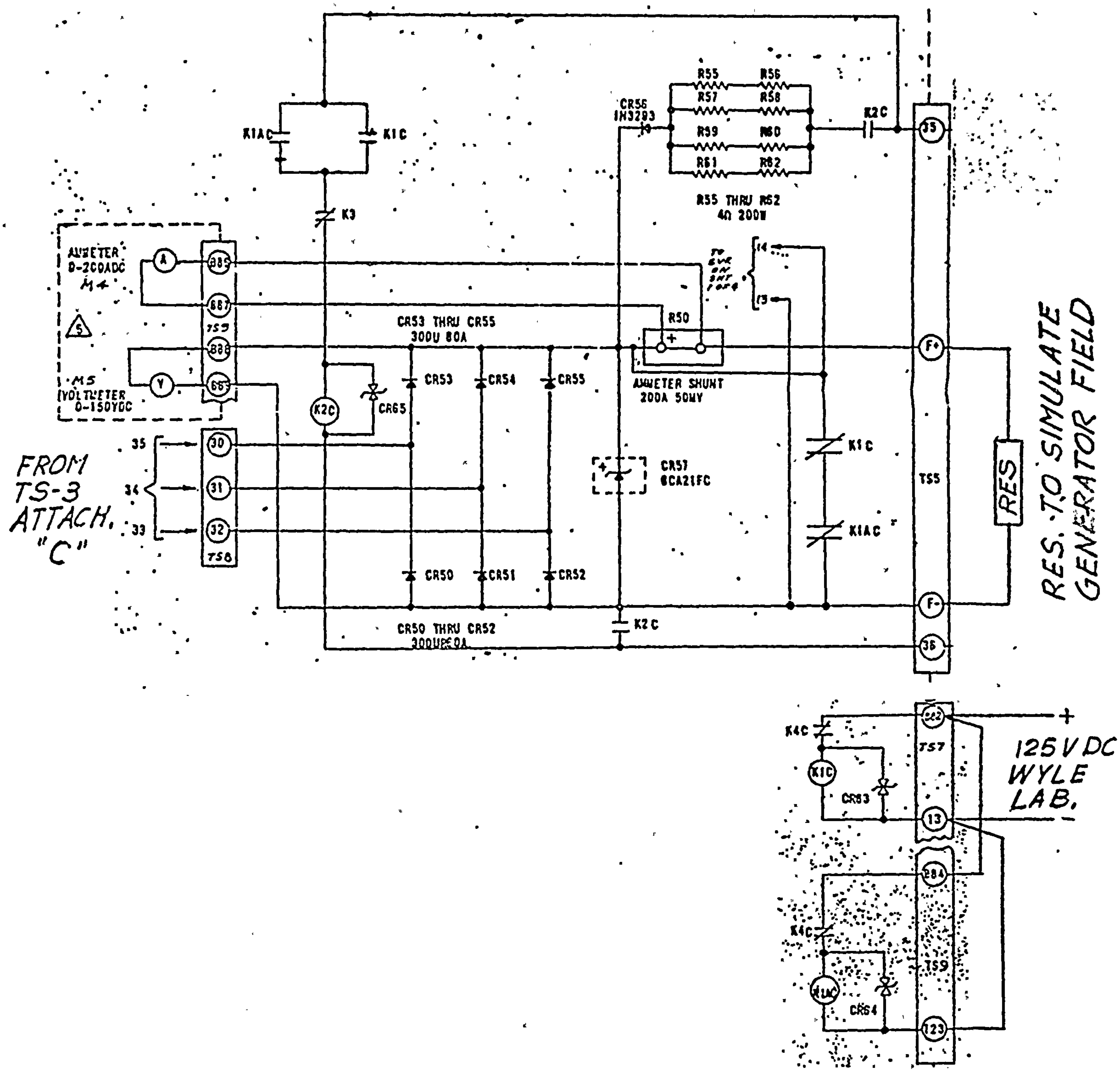
1) F+ F- voltage (If K4 or K1 relays malfunction, voltage will change)
2) K2C contacts: should not close.
3) K3 (normally closed) contact should not close.
4) Contacts of air controller at its terminals 7 and 8 should remain open.
5) Monitor contacts of DR relay connected to terminals 16 - 22, 22 - 21, 19 - 20 of EGA for change or state. Also contact across 1 - 2 of voltage regulator 90 78600 101.

The best test is to have the complete system operative, but this usually cannot be done. This suggested procedure should evaluate the main functions. It assumes that switch contacts are not affected by vibration, but relay contacts are.

ATTACHMENT "C"



ATTACHMENT "D"



ATTACHMENT "E"

DEVICE TABLE

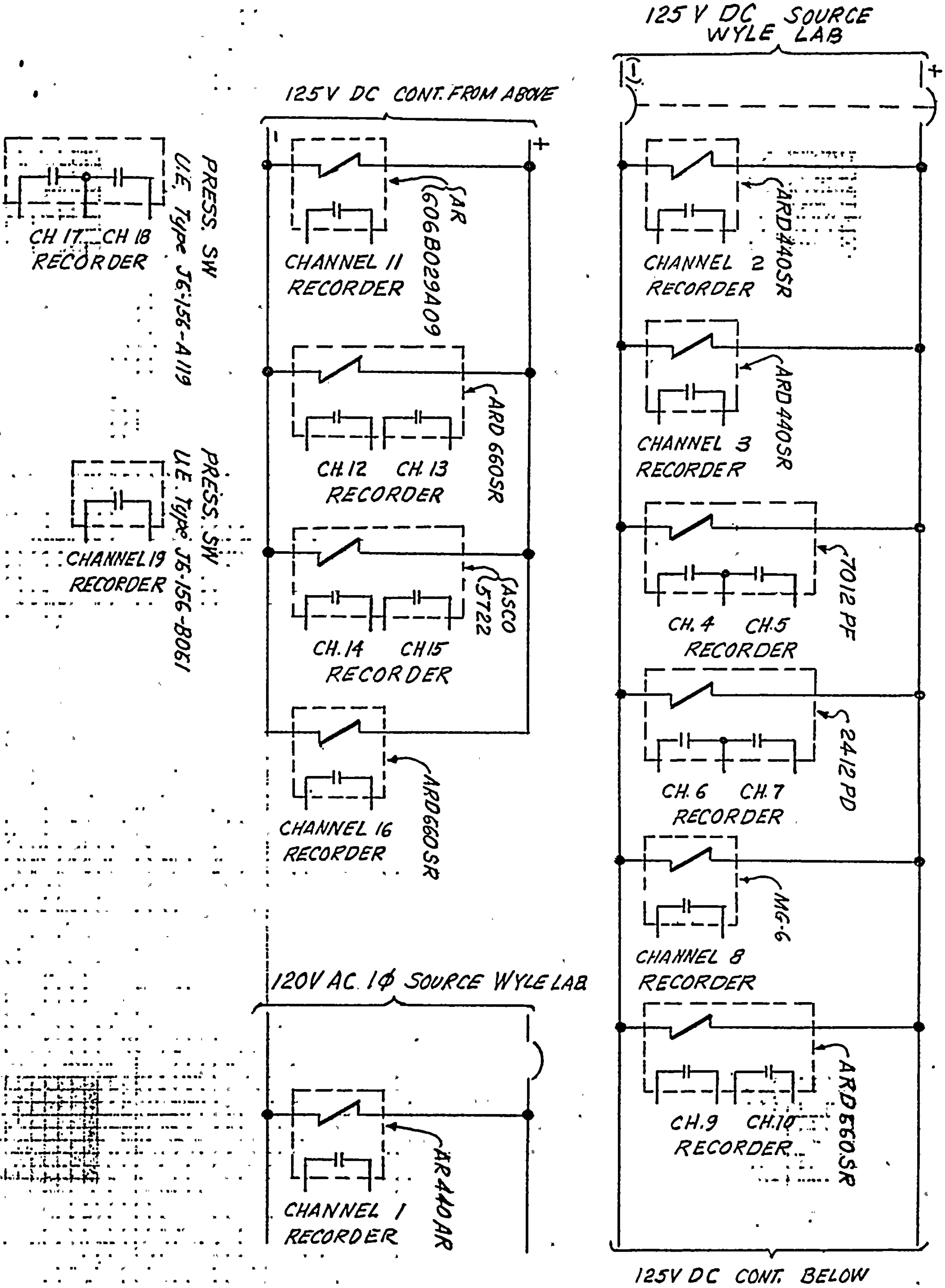
DIESEL GENERATOR CONTROL

EXCITER CUBICLE AND CONTROL CABINET DOOR

Device	Type	Use	Affect on Class 1E Function	Remarks	P.G.& E. Schematic Diagram No.
KWS-22	BE 907200	Voltage Regulation	Yes	Excitation Cubicle	437665
DR-22	ARD	" "	Yes	"	437579
DSL-22	S-1515A	Droop switch	Yes	"	437579
PB		Voltage Shutdown Push-button	Yes	"	437579
MASL Man/Auto	W-2	Voltage Regulator manual auto switch	Yes	"	437580
K-3	PR11AY	Field Flash cutout Relay	Yes	"	437665
29-22	W-2	Local Remote Switch	Yes	"	437579
K2C	M493	Field Flashing Contactor	Yes	"	437579
MASL-22X	SG	Voltage regulator selector switch auxiliary relay	No	"	437579
K4C	PR11DY	Generator Voltage shutdown relay	Yes	"	437579
43-22	W-2	Auto-Test switch	Yes	Control Cabinet Door	437579
43-DC	W-2	Normal-Backup DC supply voltage switch	Yes	"	437579
SDR-22	LOR/ER	Diesel Shutdown Lock-out relay	Yes	"	437580

ATTACHMENT "F"

ATTACHMENT "G"



DEVICE TABLE

DIESEL GENERATOR CONTROL

CONTROL CABINET SUB PANEL

Device	Type	Use	Affect on Class 1E Function	P.G.& E. Schematic Diagram No.
LOLR	AR440	Oil level auxiliary relay	No	437674
JWLR-22	ARD440	Jacket water level alarm relay	No	437580
OPR-22	ARD440	Oil pressure auxiliary relay	Yes	437580
2ADG-22	7012PF	Annunciator timer relay	No	437580
OCT1-22	2412PD	Engine crank timer	Yes	437579
CR1-22	MG-6	Engine cranking relay	Yes	437579
ESR1-22	ARD660	Engine start relay	Yes	437579
OCR-22	606B	Over crank trip relay	Yes	437580
ESR2-22	ARD660	Engine start relay	Yes	437580
DCC1-22	5722	Undervoltage transfer contactor	Yes	437579
spare	ARD660	Jacket water pressure relay	Yes	437579
PS-218	J6-156	Jacket Water pressure switch	Yes	437579
PS-204	J6-156	Oil pressure switch	Yes	437580

ATTACHMENT "H"

10.3.23.1 - Name of Equipment

Ventilation Control Logic

10.3.23.2 - Description of Equipment

The Ventilation Control Logic consists of a rigid steel cabinet housing 2 hinged card racks each containing approximately 80 printed circuit cards. The system utilizes solid state components to perform logic functions and operate output relays and solenoid valves. There is also a power supply with multiple outputs for each rack.

The logic system receives input information in the form of contact closures from air flow switches and limit switches and actuates from motor controllers and solenoid valves which control air to position air flow dampers.

During normal plant operation some fans are running and a normal air flow path is established. If ESF equipment should be called upon to operate, the logic system will adjust the air flow as necessary to provide adequate ventilation.

10.3.23.3 - Safety Function

The ventilation control logic must control ventilation fans and dampers to maintain acceptable ventilation to Engineered Safety Feature equipment and to direct air flow through charcoal filters on demand in order to reduce plant emissions.

Momentary delays in signaled changes in the logic output during seismic testing are acceptable, however the equipment must not be damaged by the seismic event, and must assume the proper operating mode following the seismic event.

10.3.23.4 - Test Plan and Criteria

The following test criteria have been established to demonstrate that the ventilation control logic will perform its safety function during and after a seismic event:

1. The logic shall not be damaged by the seismic testing and shall be capable of normal operation following the seismic testing.

2. The logic shall be tested energized with inputs simulated and outputs monitored. The outputs shall not inadvertently change state as a result of the seismic testing.

3. Multi-axis, multi-frequency seismic tests shall be conducted per the RRS contained in Wyle Report No. 58255, pp. 182-197.

10.3.23.5 - Test Procedure and Set-Up

1. Mount the hinged panel housing the printed circuit cards, and the power supply rigidly in a manner equivalent to plant mounting. See Wyle Report No. 58255, for details of equipment mounting for test.

2. Apply 120 Volts AC to the power supply.

3. Apply 125 Volt DC to typical input converters and monitor output signals on a strip chart recorder.

4. Conduct five OBE tests and two SSE tests.

5. Rotate the equipment 90 degrees, and repeat test with five OBE's and two SSE's.

6. Test the equipment completely after the completion of seismic testing to verify normal functional capability.

10.3.23.6 - Test Results

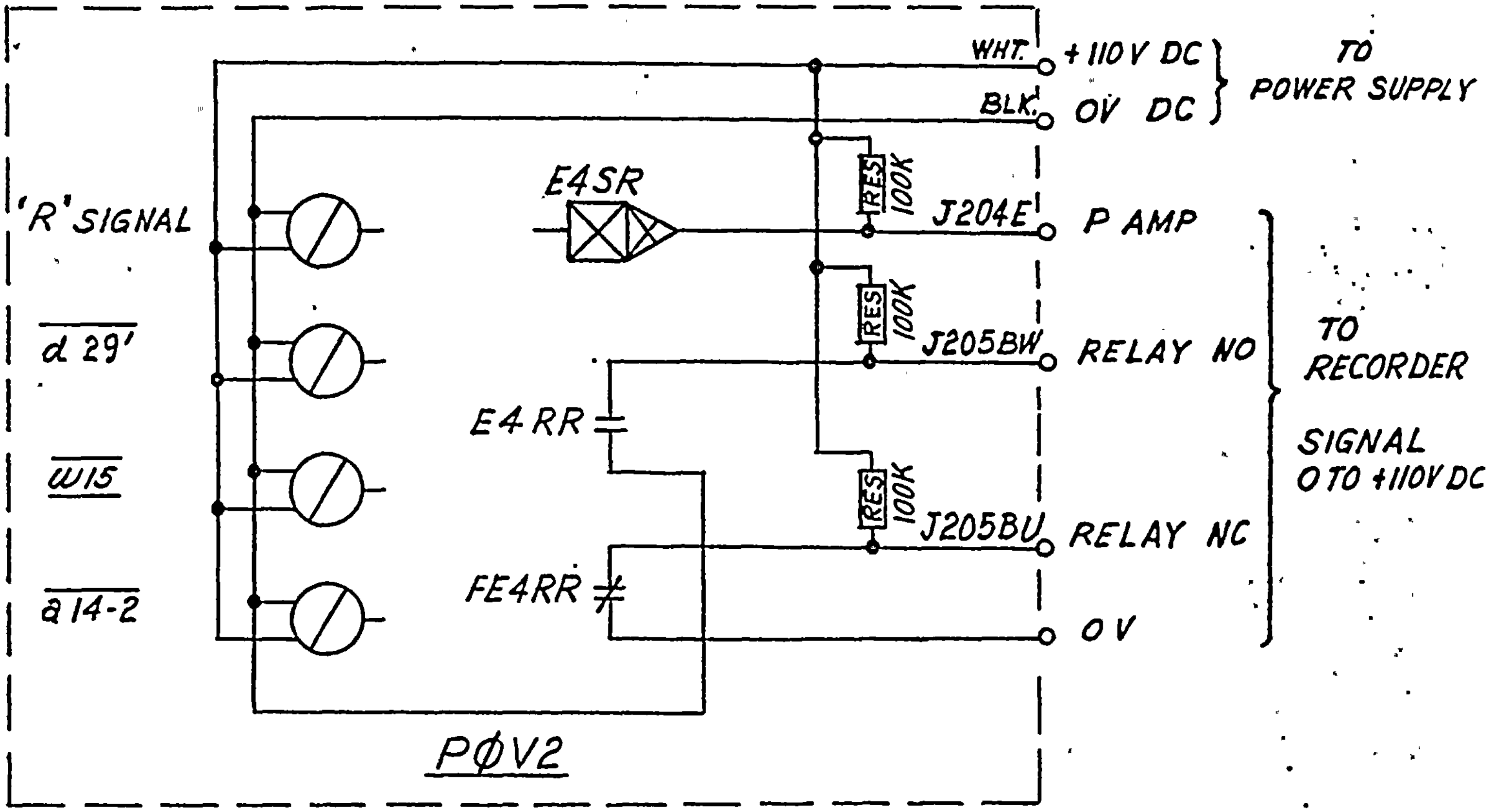
The ventilation control logic was undamaged by the seismic testing, as verified by functional testing after completion of the seismic shaking. The typical outputs monitored maintained the proper relationship to the logic input during and after the tests.

10.3.23.7 - Conclusions

The Ventilation Control Logic cabinet from Diablo Canyon Unit 2 was tested by a multi-axis, multi-frequency seismic simulation described in Wyle Report No. 58255, pp. 182-197. This Ventilation Control Logic Cabinet is identical to that installed in Diablo Canyon Unit 1.

The test results in section 10.3.23.6 demonstrate that the test criteria specified in section 10.3.23.4 are met and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 Ventilation Control Logic Cabinets are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and NRC RG 1.100.



WIRING LIST

	SIGNAL	CARD	+	−
INPUTS:	"R" SIGNAL	D 12 6	J202 CC	J200 L
	a 14-2	D 13 4	J202 CJ	J200 P
	d 29'	D 13 10	J202 CM	J200 P
	w 15	C 7 4	J201 CB	J200 U
OUTPUTS:	E4SR	A 2 3	J204 E	J204 BF
	FE4RR	A 8 3	J205 BU	J205 BV
	E4RR	A 11 6	J205 BW	J205 BX

SEISMIC TEST MONITORING

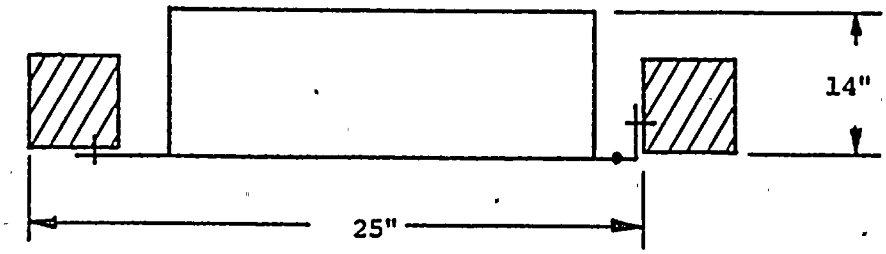
VENTILATION CONTROL LOGIC

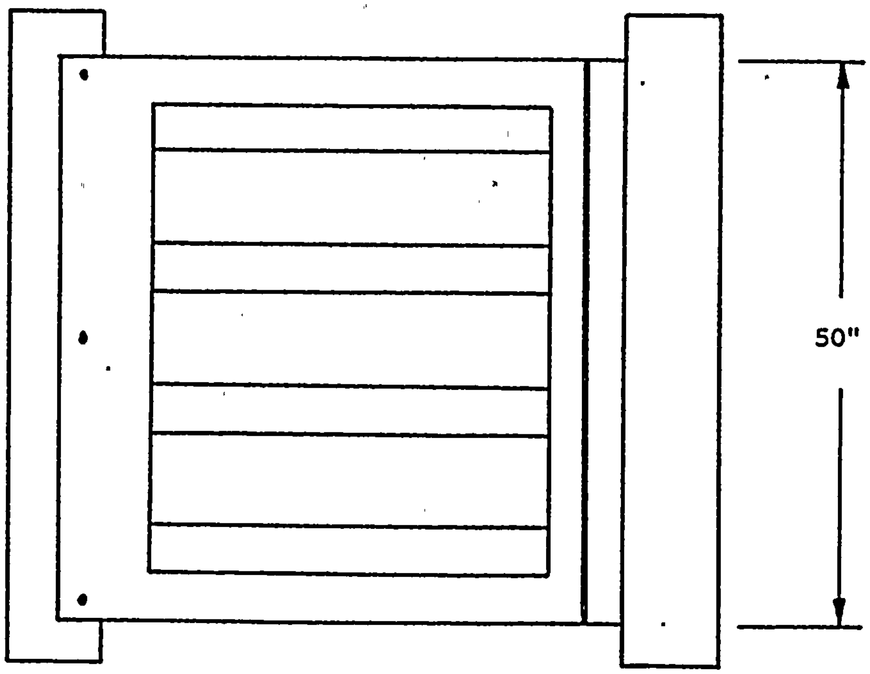
DIABLO CANYON UNITS 1 & 2.

9/18/78

ATTACHMENT

VENTILATION SYSTEM P. C. BOARD AND
POWER SUPPLY
GROUP III B





Test fixture welded to test machine and test specimens bolted to fixture. B

Ventilation Control Relay Panel

Description

The Ventilation Control Relay Panel consists of rigid steel electrical enclosure containing relays which provide interface between the Ventilation Control Logic described in Section 10.3.2.3 and the 480 Volt Vital Load Center described in Section 10.3.2.5. The panel is located in the Auxiliary Building on elevation 128'. Analysis and in-situ testing has determined that the cabinet is rigid.

Safety Function

Relays with a safety function are activiated by the Ventilation Control Logic system and in turn provide 'start' signals for ventilation fans. The fans are not required to started or operated during the short period of the seismic event. Therefore, if the equipment is capable of responding properly and starting the required fans after the seismic event it will have met its safety function. Other relays in this cabinet have no safety function to perform. They provide undervoltage alarms only and momentary misoperation has not effect on safety.

Test Criteria and Plan

The purpose of the seismic that is to verify that the equipment is capable of performing its safety function during and after a seismic event.

The plan was to test a relay cabinet subpanel containing representative relays of the type used for control of the ventilation system. Relay contacts were to be monitored for contact chatter in both the energized and deenergized state.

Five Operating Base Earthquakes (OBE) and two Safe Shutdown Earthquakes (SSE) were to be applied to the equipment in each axis. Required Response Spectra (RRS) developed for the plant location where the relay cabinet is mounted were used. Random bi-axial motion was to be applied to the equipment supports.

All testing was to be conducted in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100.

Test Procedure and Set-Up

A relay cabinet subpanel was removed from the plant and mounted to the shake table in the same manner as it is mounted in the field.

Fan control relays E1SR and S1SR are typical for safety related relays and were monitored for contact chatter. Each relay had one normally open (N.O.) and one normally closed (N.C.) contact connected to the chatter detector set at 2 milliseconds. Undervoltage relay 27-11UV also had one N.O. and one N.C. contact monitored for chattered.

The Test Response Spectrum (TRS) was developed which enveloped the RRS (see Wyle Report 58255, pages 150-156 and 162-168). Fine OBE and three SSE test runs were then conducted. During two OBEs and one SSE the relays were energized. The subpanel was then rotated 90 degrees and the test runs repeated.

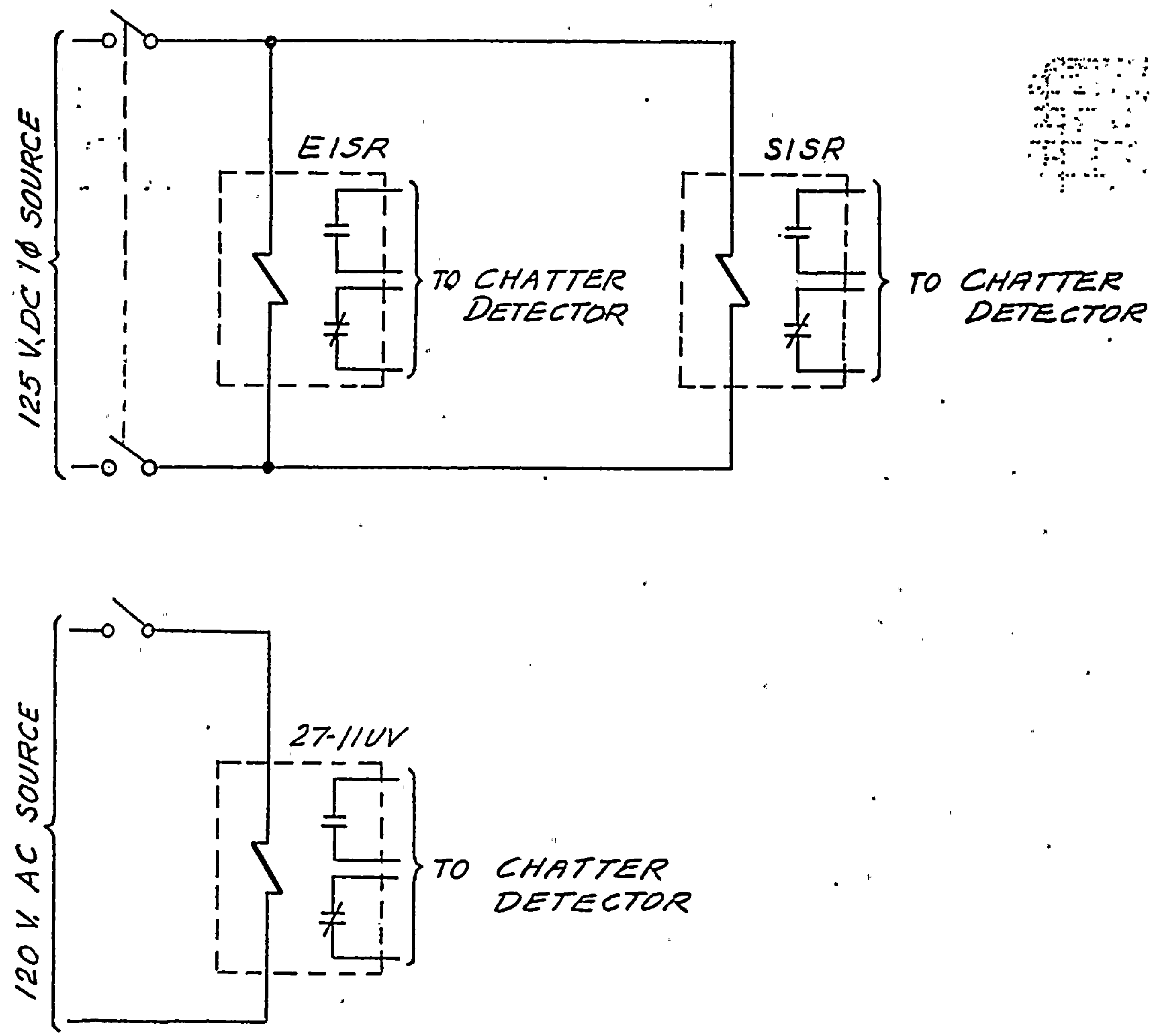
All relays were tested for satisfactory operation after the testing was completed.

Test Results

No physical damage was observed or detected and no relay contact chatter was detected in either the energized or deenergized state.

Conclusions

As a result of the above described testing which demonstrated satisfactory operation of the relay subpanel and the relays it can be concluded that the Ventilation Control Relay Cabinet is qualified to perform its safety function during and after a Hosgri fault seismic event.

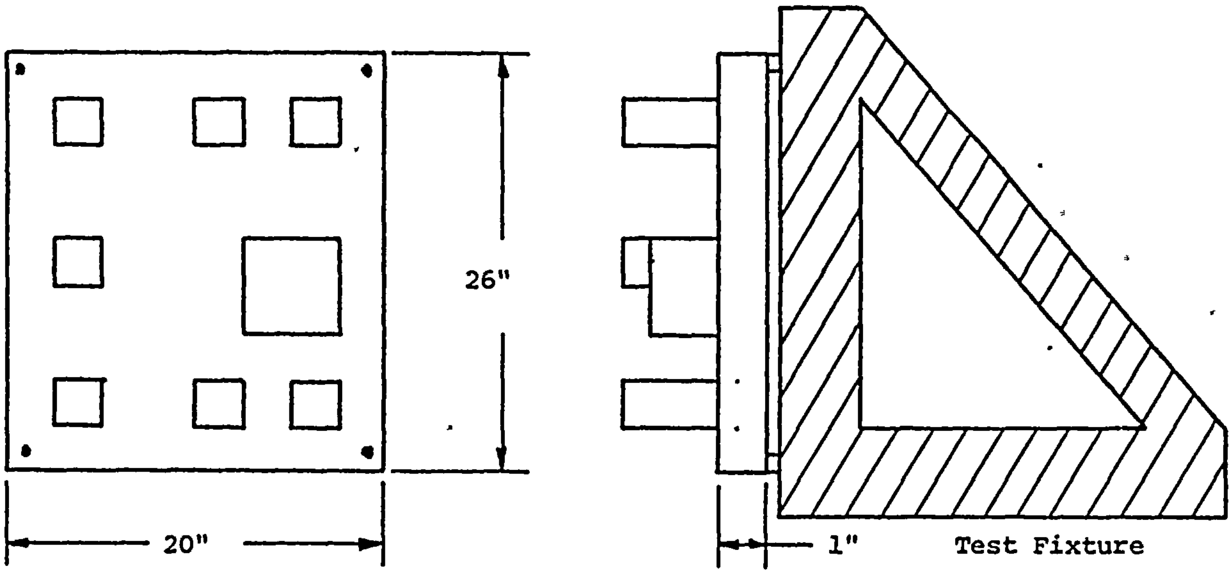


TEST SETUP
VENTILATION CONTROL RELAY PANEL

ATTACHMENT 83

VENTILATION SYSTEM RELAY SUB-PANEL
GROUP III

B



Four mounting bolts

Fixture support at mounting bolts only.

10.3.1.1 Main Annunciator Components Tested

The following Main Annunciator Components were tested on a biaxial seismic test table.

1.	Constant Voltage Transformer	- Sola #20-22-159 480 VAC/120 VAC
2.	Power Transfer Panel	- RIS-RA-189 117 VAC/125 VDC in 117 VAC OUT.
3.	50 R02-SCO-K1	- Sigma Relay, 115 VAC 115 VAC inputs pick-up the relay.
4.	50 R02-SCO-K2	- Sigma Relay, 115 VAC 115 VAC inputs pick-up the relay.
5.	Power Transformer	- Signal Transformer Co. #120-20 120 VAC input 120 VAC output.
6.	Logic Power Supply	- RIS RA-875A 117 VAC in.
7.	Aux. Logic Power Supply	- RIS RA-897A 117 VAC in.
8.	DC to DC Converter	- RIS-UNK AN 159 125 VDC input +12, -28, +125 VDC output.
9.	DC to AC Inverter	- Lorain WBA 102 H1 125 VDC in, 117 VAC out.
10.	Typewriter	- IBM 735 Selectric Ser. #926026740.
11.	Printed Circuit Bd	- RIS 139B-Reflasher Module.
12.	Printed Circuit Bd	- RIS RA847-Input Module 10 N.O. contacts.

13. Printed Circuit Bd - RIS RA848A-Input Module 10 N.C. contacts.

14. Printed Circuit Bd - RIS RA849-Input Buffer Module.

15. Printed Circuit Bd - RIS RA851-Status Memory Module.

16. Printed Circuit Bd - RIS RA852-Sequential Memory Module.

17. Printed Circuit Bd - RIS RA853-Oscillator and Interface Module.

18. Printed Circuit Board Card Tray Rack - RIS 1009-273.

19. 62R2-24 VDC - Sigma Relay-24 VDC To Monitor Annun. Power.

20. 62R2-110 VDC - Sigma Relay 110 VDC To Monitor Annun. Power.

The above components were judged to be the most limiting components in the Main Annunciator from a seismic standpoint based on in-situ inspection and testing at the site.

The solid state RIS RA-800L system was added to this annunciator in event of drum failure. Alarm No's are available on loss of Drum and English Print-Out.

The Main Annunciator is located at elevation 128'0", area H, of the Auxiliary Bldg.

10.3.1.3 - Safety Function

The Main Annunciator functions to provide alarms to the plant operator on plant conditions. While the Main Annunciator has no direct safety function, it has been designed and qualified as Seismic Class I equipment to minimize the potential for confusion of the plant operators during and after a seismic event. The information necessary for the operator to diagnose plant conditions and take any manual action required is provided via position lights, status lights, monitor lights and gages displaying the key plant process variables; thus the Main Annunciator is not required even for operator information.

Nevertheless it is desirable to have accurate alarm information conveyed to the operator via the Main Annunciator during a seismic event, and to have the Main Annunciator functioning normally after a seismic event, such that any spurious alarms generated during the seismic event can be easily cleared and the remaining alarms and their sensors evaluated.

10.3.1.3 Test Criteria and Plan

The test criteria and plan for the individual components tested are as follows:

1. The Constant Voltage Transformer mounting shall be tested during the seismic shaking.
2. The Power Transfer Panel shall be operated in both the By-pass mode with 117 VAC in and 117 VAC out, and also in the Auto Position for input power (117 VAC in shall be removed, the 125 VDC inverter shall automatically supply 117 VAC out). The unit shall be

switched to auto position during the 4th and 5th OBE and the 1st SEE. The unit shall be demonstrated to perform the above functionally during and after the seismic test.

3. The Sigma Relay, 50 R02-SCO-K1 shall be cycled before, during energized test, and after seismic testing. The relay contacts shall be monitored for contact chatter.

4. The Sigma Relay, 50 R02-SCO-K2 shall be tested the same as item 3 above.

5. The Power Transformer shall be energized during the seismic testing. The output shall be monitored before and after the seismic test. Any change in output shall be recorded.

6. The Logic Power Supply, RIS RA-875A shall have 117 VAC input. The input power shall be turned on and off twice during the deenergized tests (1st, 2nd, 3rd OBE, and the 2nd SSE) and the output voltages observed. During energized tests with 117 VAC input (4th, 5th OBE, and 1st SSE) the output voltage shall be monitored.

7. The Auxiliary Logic Power Supply, RIS-RA 897A shall be tested the same way as item 6.

8. The DC to DC Converter RIS-UNK AN 159 shall have 125 VDC input and its outputs shall be +12, -28, and +125 VDC. During 1st, 2nd, 3rd OBE and 2nd SSE unit to be deenergized. During the 4th and 5th OBE, and 1st SSE unit to be energized, and the -28 VDC outputs monitored for voltage. Before and after seismic tests the Unit shall be functionally tested.

9. DC-AC Inverter, Lorain WBA 102 H1 shall be mounted as in the actual equipment. 125 VDC in shall be applied and the output monitored for continuous 122 VAC output. The unit functions continuously, and shall be energized continuously before, during, and after the seismic testing.

10. Typewriter - IBM 735 Selectric shall be mounted on the seismic table to simulate on site mounting. Four mounting screws shall be used to attach the typewriter to its mounting platform. The mounting platform shall be rigidly attach to roll out side rails. The side rails shall be rigidly locked and attached to the structural steel mounting rails on the seismic table to simulate the cabinet mounting at the site.

    An IBM, On Line Selectric Analyzer, OLSA, shall operate the typewriter before the tests. During the seismic shake on the table the typewriter shall be powered. Between shakes the typewriter shall be actuated manually by its keys. After the shake the typewriter shall again be operated by the IBM, OLSA.

11. Printed Circuit Board, RIS 139B-Reflasher Module shall be inserted in the Printed Circuit Board Card Tray Rack, RIS 1009-273. Common voltage inputs shall be supplied by the logic power supply and the board shall be energized during energized test run. The printed circuit boards shall be returned to Diablo Canyon and tested and operated as before being shipped to Wyle Laboratories.

12. Printed Circuit Board, RIS RA 847 Input Module for 10 remote N.O. circuits shall be tested the same as item 11.

13. Printed Circuit Board, RIS-RA84A, Input Module with 10 N.C. contacts shall be tested the same as item 11.

14. Printed Circuit Board, RIS-RA849, Input Buffer Module shall be tested the same as item 11.

15. Printed Circuit Board, RIS-RA851 Status Memory Module shall be tested the same as item 11.

16. Printed Circuit Board, RIS-RA852 Sequential Memory Module shall be tested the same as item 11.

17. Printed Circuit Board, RIS-RA853 Oscillator and Interface Module shall be tested the same as item 11.

18. Printed Circuit Board Card Tray Rack RIS-1009-273 shall be mounted the same as in the Main Annunciator on the shake table. The Printed circuit boards listed on items 11 thru 18 shall be inserted in the card tray during the seismic tests and energized as stated above.

19. Sigma relay 62R2-24 VDC shall be monitored for contact chatter, unenergized during 1st, 2nd, 3rd OBE and 2nd SSE, and energized during the 4th and 5th OBE and the 1st SSE.

20. Sigma relay 62R2 110 VDC shall be tested the same as Item 19.

Test Procedure and Set-Up

1. Mount the Annunciator tested components in the same configuration and orientation as in the Diablo Canyon plant, (See Wyle Report No. 58255, April 19, 1978, Test Procedure No. 3642, dated November 30, 1977, pp. 29-37.)

2. Supply the required inputs and monitor the outputs or contact chatter as required per the test criteria.

Component	Input	Output or Chatter
Constant Voltage Transformer	480 VAC in	120 VAC out
Power Transfer Panel	117 VAC/	117 VAC out
	125 VDC in	117 VAC out
50 R02-SCO-K1	115 VAC in	Contact Chatter
50 R02-SCO-K2	115 VAC in	Contact Chatter
Power Transformer	120 VAC in	120 VAC out
Logic Power Supply	117 VAC in	Monitor on
Aux Logic Power Supply	117 VAC in	Direct Rendant Recorder
DC to DC Converter	125 VDC in	-28 VDC out
DC to DC Inverter	125 VDC in	117 VAC out
Typewriter	125 VAC in	Manual typing
Printed Circuit Bds		
RIS 139B	24 VDC in	Various
RA 847	24 VDC in	outputs
RA 848A	24 VDC in	tested on
RA 849	24 VDC in	return to
RA 851	24 VDC in	plant
RA 852	24 VDC in	
RA 853	24 VDC in	
62 R2-24 VDC	24 VDC in	Contact Chatter
62 R2-110 VDC	110 VDC in	Contact Chatter

3. Visually monitor the input and output on meters or record on direct readout recorder.

6. Results of Tests

The tested components on the Annunciator were run through the series of OBE's and SSE's and the results are as follows:

1. The mounting of the Constant Voltage transformer was adequate for the seismic tests.
2. The Power Transfer Panel operated as required in the By-Pass and Automatic modes during and after the seismic testing.
3. The Sigma Relay 50R02-SCO-K1 did not chatter when cycled during and after the seismic testing.
4. The Sigma Relay 50R02-SCO-K2 did not chatter when cycled during and after the seismic testing.
5. The Power Transformer did not have a loss of output during or after the seismic testing.
6. The Logic Power Supply, RIS-RA 875A did not show any loss of output on the direct readout recorder.
7. The Auxiliary Logic Power Supply, RIS RA 897A did not show any loss of output in the direct readout recorder.
8. The DC to DC converter, RIS-UNK AN159 had a continuous -28 VDC output during and after the seismic test.
9. The DC-AC Inverter, Lorain WBA 1021-1 had a malfunction on the 1st series of test. After repair at suppliers facility and at Wyle Laboratories the Inverter operated continuously at 122 VAC out during and after the seismic tests.
10. The typewriter - IBM 735 Selectric operated manually between seismic tests and after the testing by the On Line Selectric Analyzer.

11.-17. The Printed Circuit Boards item 11 through 17 were not damaged during the seismic tests when energized with common voltage inputs from the logic power supply.

18. The Printed Circuit card tray rack, RIS-1009-273 with all the above card inserted retained the cards without damage during the seismic tests.

19. The Sigma relay 62R2-24 VDC contacts did not chatter during the seismic testing.

20. The Sigma relay 62R2-110 VDC did not chatter during the seismic testing.

The above components performed their functional requirements before, during, and after the seismic testing.

7. Conclusions

1. The Main Annunciator components were tested by a multi-axis multi-frequency seismic simulation described in Wyle Report Number 58255, April 19, 1978, pp. 143-213. The test results described in section 6 above demonstrate that the test criteria of section 4 are met, and thus the tested components operability has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. On this basis the Diablo Canyon Unit 1 and 2 Main Annunciators tested components are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Std. 344-1975 and USNRC Regulatory Guide 1.100. The Main Annunciator rigid cabinet qualification for the postulated 7.5M Hosgri event in accordance with IEEE Std. 344-1975 and USNRC Regulatory Guide 1.100 is documented in paragraph 10.3.1 Main Annunciator, page 10-10a - 10-10b of Volume III of the Seismic Evaluation of the 7.5M Hosgri Earthquake.

2. All the equipment listed under items 1 through 20 above have been returned to Diablo Canyon and retested at the site. No malfunction was detected in the equipment. Equipment has been placed back in service on the Unit 2, Main Annunciator or placed in spare stores.

3. The DC-AC Inverter, Lorain WBA 102H1 (3) identical units, 2 in Unit 1 Main Annunciator, and the second one in Unit 2, Main Annunciator have been checked for proper mounting of the SCR mounting panel and proper clamping by the mounting screws.

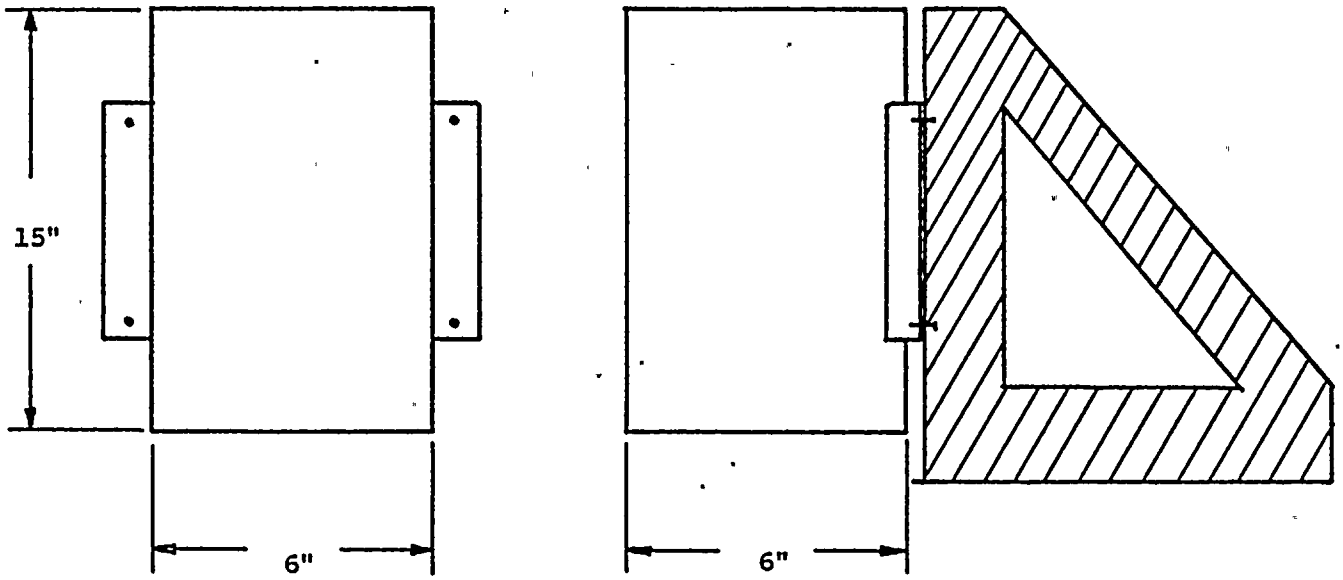
4. The typewriter mounting at the plant has been modified to match the mounting on the seismic test table.

5. The printed circuits boards have been retested at Diablo Canyon. No malfunction was detected. The boards have been returned to service in spare stores.

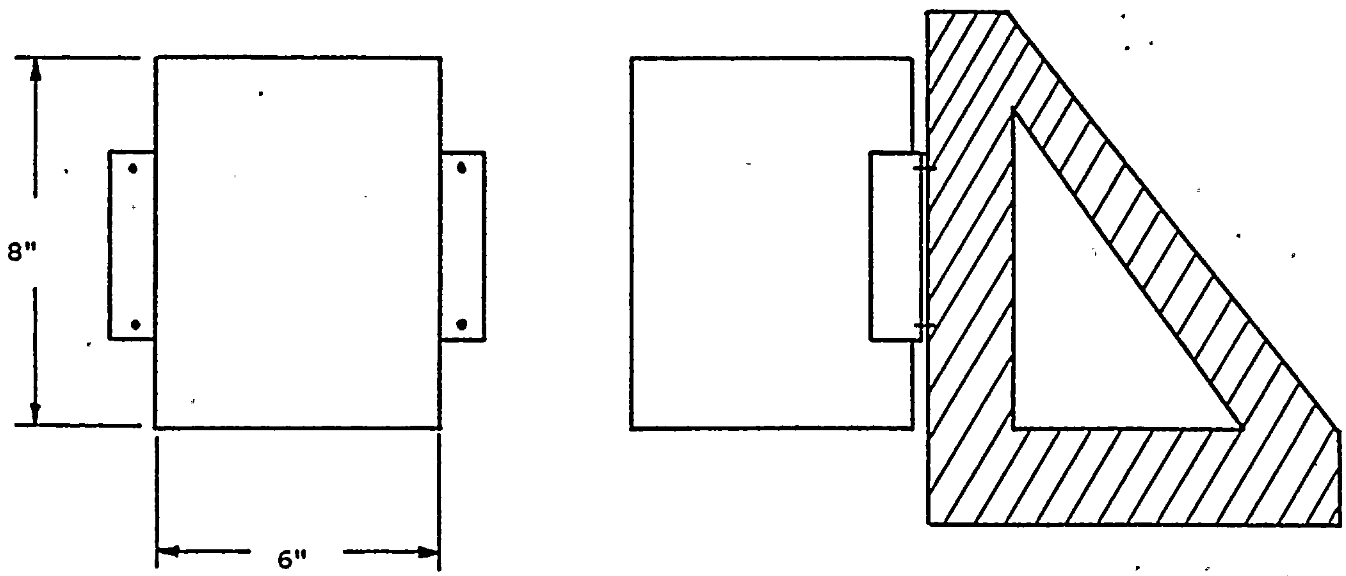
6. The Printed Circuit card tray rack has been returned to service on Unit 2, Diablo Canyon.

MAIN ANNUNCIATOR
TWO TRANSFORMERS
GROUP III

B



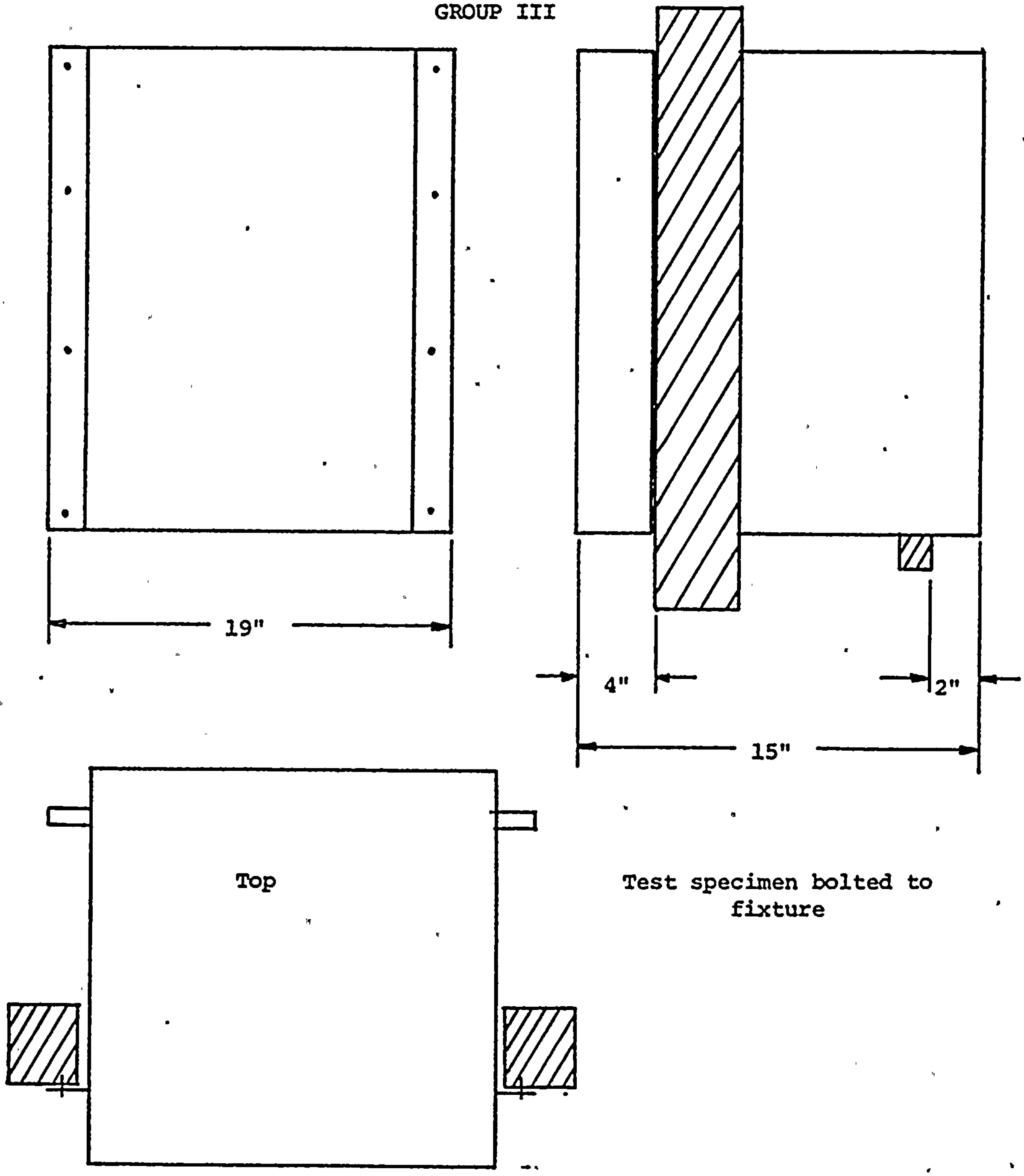
Four 5/16" bolts



Four 1/4" bolts

MAIN ANNUNCIATOR
INVERTER
GROUP III

B

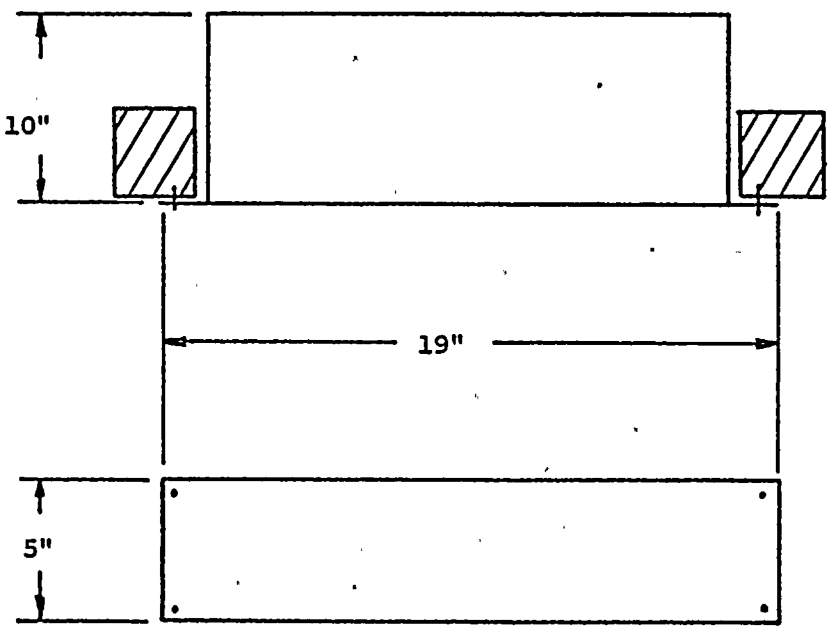


Test specimen bolted to fixture

B

MAIN ANNUNCIATOR
POWER TRANSFER UNIT
GROUP III

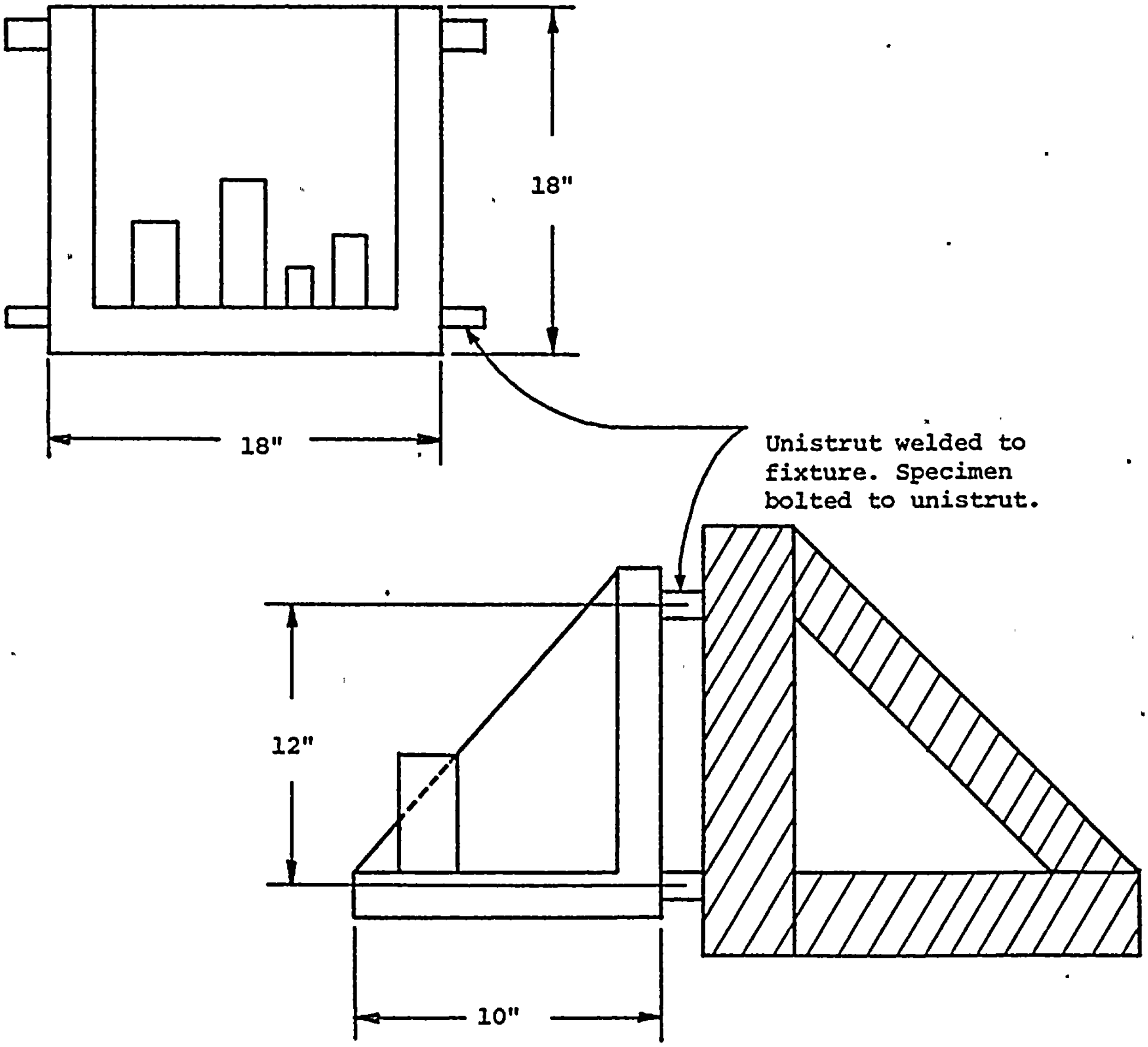
B



Test specimen bolted to fixture B

POWER SUPPLY
GROUP III

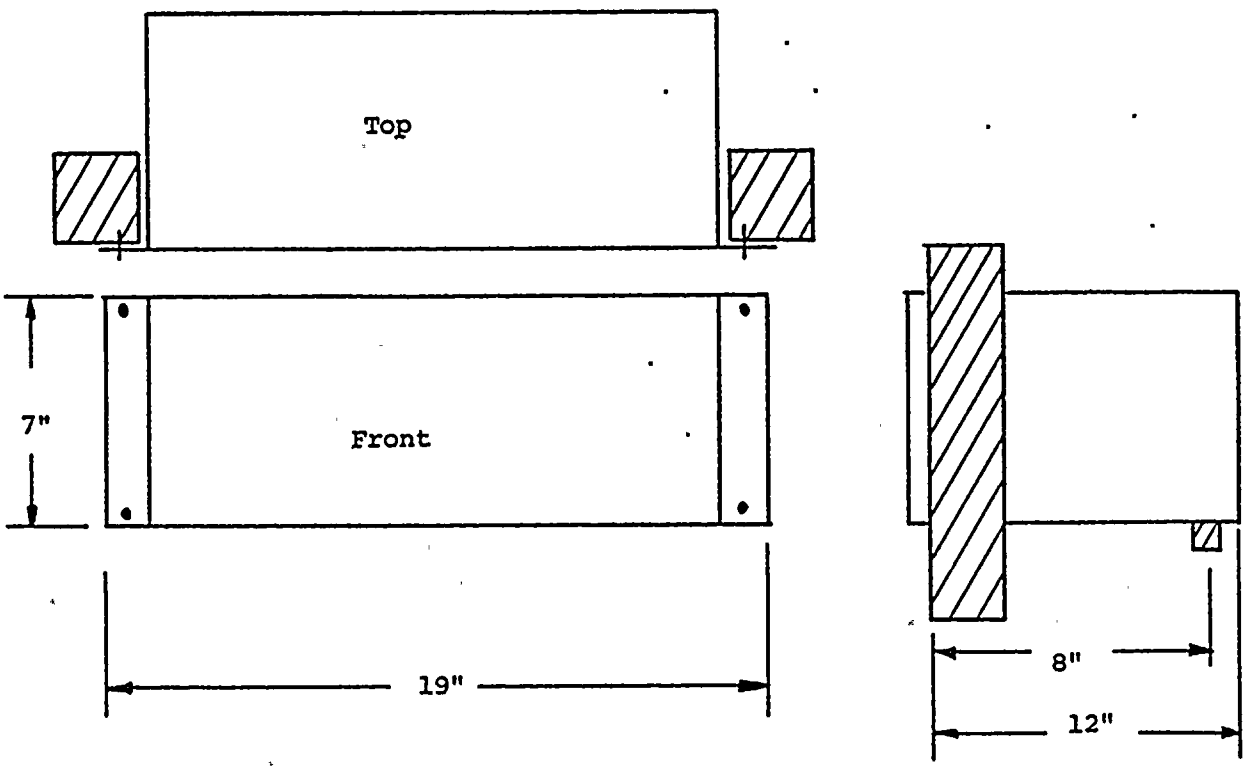
B



B

MAIN ANNUNCIATOR
LOGIC POWER SUPPLY
GROUP III

B

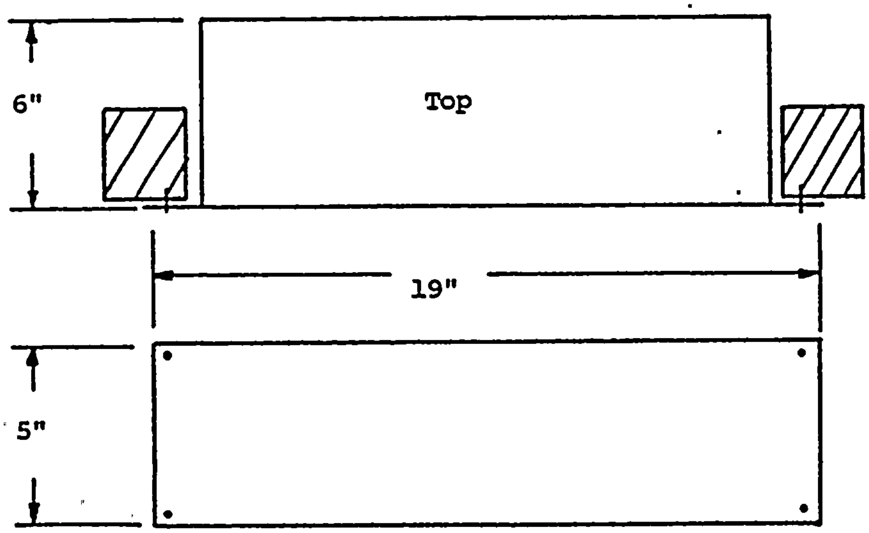


Test specimen bolted to fixture

B

MAIN ANNUNCIATOR
AUXILIARY LOGIC POWER SUPPLY
GROUP III

B



Test specimen bolted to fixture

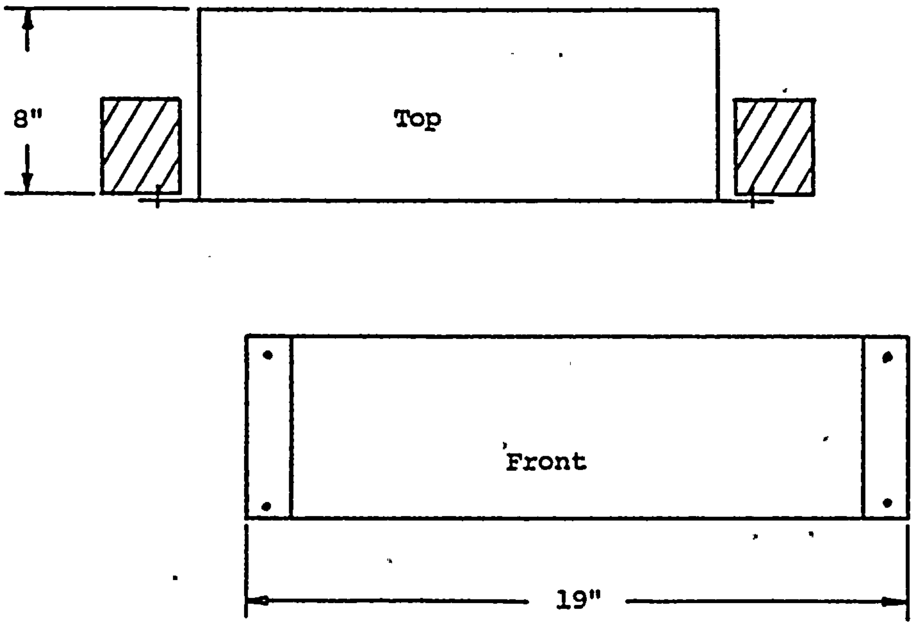
B

MAIN ANNUNCIATOR

PRINTED CIRCUIT BOARD RACK

GROUP III

B

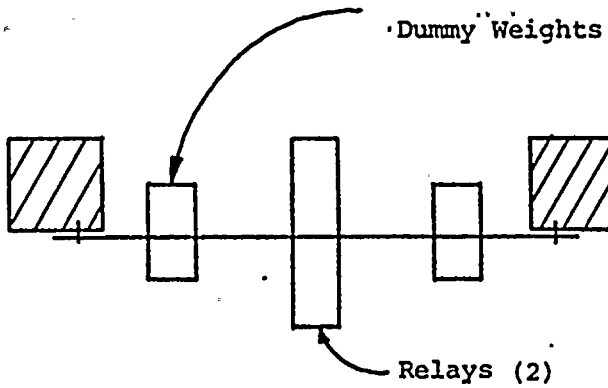


Test specimen bolted to fixture.

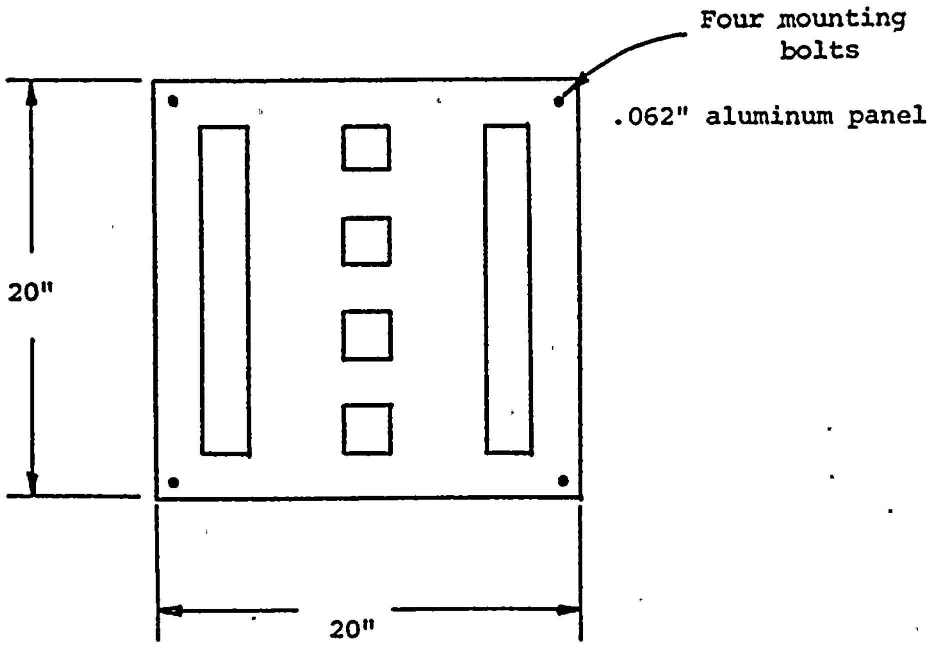
B

MAIN ANNUNCIATOR
AC INPUT RELAYS AND SOCKETS
GROUP III B

B

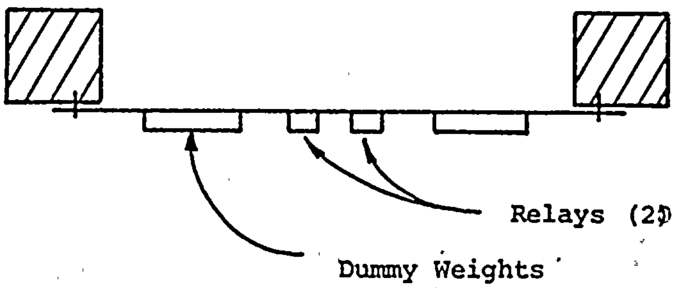


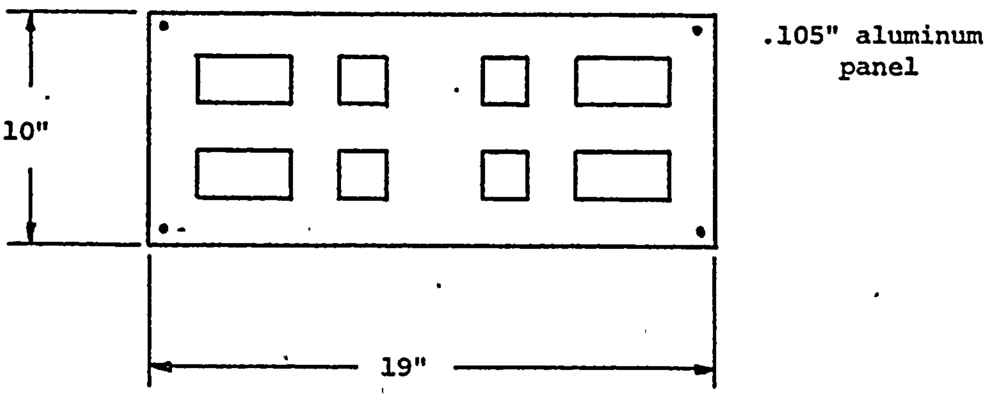
B



Panel bolted to fixture; test specimens bolted to panel. B

GROUP III
MAIN ANNUNCIATOR
SIGMA RELAYS AND SOCKETS B

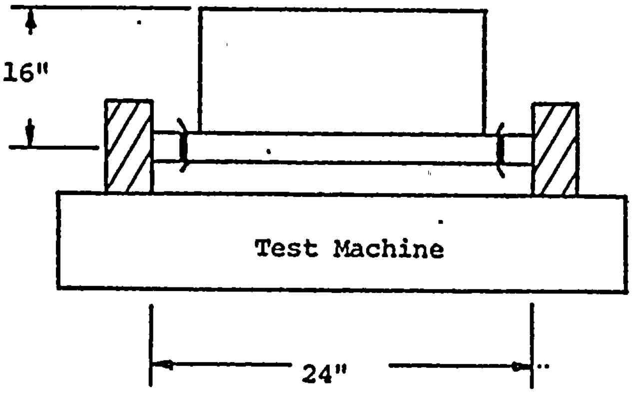




Panel bolted to fixture; test specimen bolted to panel. B

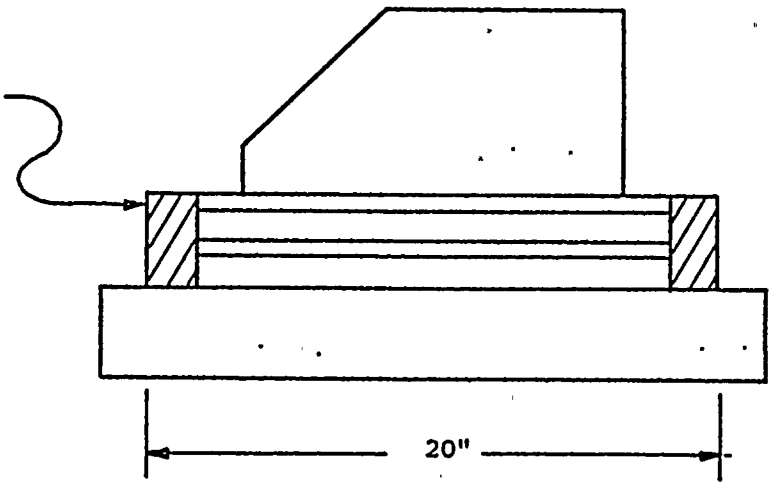
B

GROUP III
MAIN ANNUNCIATOR
TYPEWRITER ASSEMBLY



1-1/2 x 1-1/2 x 3/16
angles; 4 places

Welded to test
machine; type-
writer assembly
bolted to angles.



B

Fixture four corners only

ROUGH DRAFT
10-17-78

10.3.5.2.1 - Name of Equipment

125 VDC Distribution Panelboard, (ITE DC SWITCHGEAR)

10.3.5.2.2 - Description of Equipment

This electrical switchgear consists of a three section, welded frame construction cabinet with a 125 VDC bus arrangement, 3000 ampere input fuse from the battery, and two 600 ampere molded case input breakers for primary and backup battery chargers. A 600 ampere draw-out breaker from the main bus supplies the circuit breaker panelboards. The circuit breaker panelboard consists of molded case breakers rated for 20 to 150 amperes. This equipment is located on El 115'0", area H of the Auxiliary Building. The center section of the SWGR has a SV-Undervoltage Relay which picks-up at 125 VDC as the bus voltage increases, (27DCB21). This relay would drop out at 90% or 112 VDC signaling bus undervoltage, alarm only. The center section also has a 0-150 VDC range voltmeter. This voltmeter and the battery charger voltmeter during this switchgear testing read the same voltage 132 VDC the Battery Charger output setting. At this same time the battery charger ammeter read 50 amperes output, before, during and after the seismic testing. The 125 VDC bus also has a white light to indicate bus voltage, a W minalite.

10.3.5.2.3 - Safety Function

The 125 VDC Distribution Panelboard is required to continuously distribute 125 VDC power to plant DC loads (power, control protection, instrumentation, and monitoring before, during and after a seismic event.

10.3.5.2.4 - Test Plan and Criteria

In order to assure the performance of the safety function specified in 10.3.5.2.3 above, the following specific test criteria shall be met:

1. Circuit breakers shall maintain their position before, during, and after the seismic event; no circuit breakers are required to operate during the seismic event.

2. The following components and positions shall be monitored:

a. Breaker 72-2100 (I.T.E. KM 2B600); 125 VDC Bus input breaker, fed from the Battery Charger, monitor the following auxiliary switch contacts (see figures 10.3.5.2-1 and 10.3.5.2-2) to ensure the breaker maintains its closed position: (50 amperes shall be flowing thru this breaker during energized tests)

(1) Terminals 17 and 18: Closed

(2) Terminals 19 and 20: Open

(3) Terminals 21 and 22: Closed

b. Breaker 72-2102 (I.T.E. K600); monitor the following auxiliary switch contacts (see figures 10.3.5.2-1 and 10.3.5.2-2) to ensure the breaker maintains its closed position. (50 amperes shall be flowing thru this breaker during test. Battery Charger Ammeter read 50 Amperes, Battery Charger Voltmeter 132 volts, and 125 VDC Swgr Voltmeter read 132 volts, observed visually.)

(1) Terminals 9 and 10: Open

(2) Terminals 15 and 16: Closed

(3) Terminals 5 and 6: Open (no overcurrent alarm)

c. Undervoltage Relay 27DBG21 Westinghouse SV type 125 VDC. Monitor the following contacts to verify that bus voltage is maintained during and after the test: (SV Relay should pick-up at 125 VDC with the voltage going up. Drops out at 112 VDC on undervoltage).

Contact Terminal 2 and 3: Open

d. HE2-B070 I.T.E. Molded Case Circuit Breaker. Visually monitor the status of this breaker to verify the breaker remained closed (Breaker had a load bank load on it equivalent to about 34 amps of the 50 amp charger output.)

e. HE2-B020 I.T.E. Molded Case Circuit Breaker. Visually monitor the status of this breaker to verify the breaker remained closed. (Breaker had a load bank load on it equivalent to about 16 amperes of the 50 ampere battery charger output.)

f. Verify that the 0-150 VDC voltmeter indicates that the bus was continuously energized during and after the tests. (Visually observed bus voltmeter at 132 VDC.)

g. Verify that the white indicating light stays on, indicating that the bus was continuously energized during and after the test. (White light stayed on all the time when 1st turned on the battery charger and hooked in the 125 VDC Wyle battery until the battery charger was tripped and the battery disconnected.)

10.3.5.2.5 - Test Procedure and Set-up.

1. Mount the 125 VDC Distribution Panelboard, SD-21 on the seismic test table in the same configuration as in the power plant as shown in Wyle Report No. 58255, Appendix I, Test Procedure 3642, dated November 30, 1977, pp. 41.

2. Supply 125 VDC power to the 72-2100 input breaker to bus No. 21.by the P.G.& E. 125 VDC Battery Charger, ED-21. Supply 50 amperes by the Battery Charger (read battery charger Ammeter) to load bank Item 4 thru the Switchgear.

3. Supply 125 VDC battery power (Wyle 125 VDC battery) to the bus on the supply side of the 3000 ampere bus fuse.

4. Connect the 70A and 20A output breakers in panel SD-21 to the P.G.& E. resistor load bank with approximately 16 amperes at 125 VDC on the 20A breaker and 34 amperes at 125 VDC on the 70A breaker.

5. Close breakers 72-2100, 72-2102, and the 70A and 20A load breakers. Energize Battery Charger, ED-21. (Everything observed visually to read correctly before seismic shaking.)

6. Perform multi-axis, multi-frequency seismic testing per the RRS in Wyle Report No. 58255 dated April 19, 1978, pp. 255-280.

7. See figures 10.3.5.2-1 and 10.3.5.2-2 for testing set-up.

10.3.5.2.6 - Test Results

The equipment was energized during all the seismic tests, 5 OBE's and 2 SSE's in the Z-Y and X-Y axis. The components listed on Table 10.3.5.2-1 were either monitored before, during and after the seismic tests. No malfunction of any of the components occurred during the tests. All contacts of auxiliary switches and relays remained in the equipment energized position during all tests. All breakers remained in the proper positions during the testing. Indicating meters and lights on the front of the panelboard indicated that the bus remained energized during and after the test. (Also meters on battery charger indicated a load of 50 amperes was on the battery charger.)

Results are listed per sub-paragraphs of 10.3.5.2.4 - Test Plan & Criteria:

1. No. breakers tripped open. 132 VDC output of the battery charger did not change. Battery charger ammeter continually read 50 amperes. If either breaker 72-2100 or 72-2102 had tripped the Battery Charger ammeter would go to zero with 72-2100 tripping (no load), or to nearly zero with 72-2102 tripping, (this would cut out the distribution panel load & the load bank & would only charge the Wyle Lab. Battery).

2a. (1) Closed auxiliary switch contacts remained closed.

(2) Open auxiliary switch contacts remained open. (this contact is for alarm to Annun) Annunciator

(3) Closed auxiliary switch contacts remained closed.

2b. Both Battery Charger Ammeter maintained 50 amperes & Battery Charger Voltmeter and the 125 VDC Swgr Bus Voltmeter maintained 132 VDC. Breaker did not trip to indicate loss of load.

5

2c. The SV relay picked-up as the battery charger energized the switchgear with breakers 72-2100 and 72-2102 closed. (125 VDC). At no time during the testing or after the testing did the SV contact ~~pick-up~~ except when the breakers or the battery charger was tripped off. SV contacts did not pick-up during the energized time to indicate a drop in voltage below 112 VDC setting of the SV relay.

2d. If breaker had tripped off the battery charger output would have dropped by the amount of load bank resistance lost with open breaker.

2e. If breaker had tripped off the battery charger output would have dropped by the amount of load bank resistance lost with the open breaker.

2f. At no time by visual observation did the DC SWGR or the Battery Charger Voltmeter, reading drop, when the switchgear and Battery Charger were energized and the 125 VDC battery connected.

2g. White light stayed on indicating bus potential.

Following the seismic tests, the SD-21 Distribution Panelboard was shipped back to Diablo Canyon Unit 2, its functional performance was tested and verified, and it it was placed back in service in the plant.

10.3.5.2.7 - Conclusions

A 125 VDC Distribution Panelboard (SD-21) from Diablo Canyon Unit 2 was tested by a multi-axis, multi-frequency seismic simulation described in Wyle Report No. 58255, April 19, 1978. pp. 255-280. This panelboard is identical to the other five 125 VDC Distribution Panelboards installed in Diablo Canyon Units 1 and 2. The test results described in 10.3.5.2.6 above demonstrate that the test criteria specified in section 10.3.5.2.4 are met, and thus that the equipments' safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event.

Thus it is concluded that the Diablo Canyon Unit 1 and 2 125 VDC Distribution Panelboards are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Std 344-1975 and NRC Regulatory Guide 1.100.

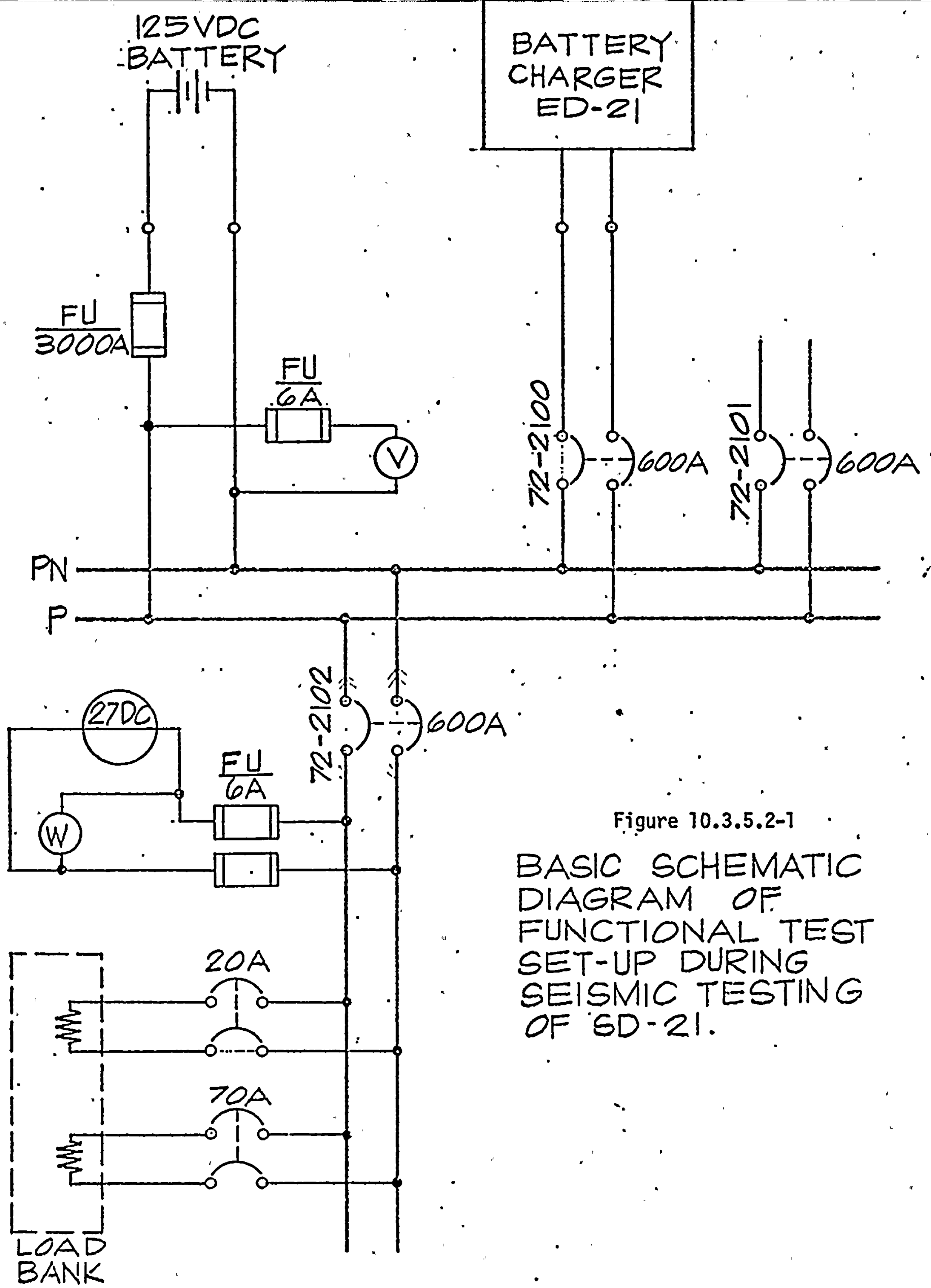


Figure 10.3.5.2-1

BASIC SCHEMATIC DIAGRAM OF FUNCTIONAL TEST SET-UP DURING SEISMIC TESTING OF SD-21.

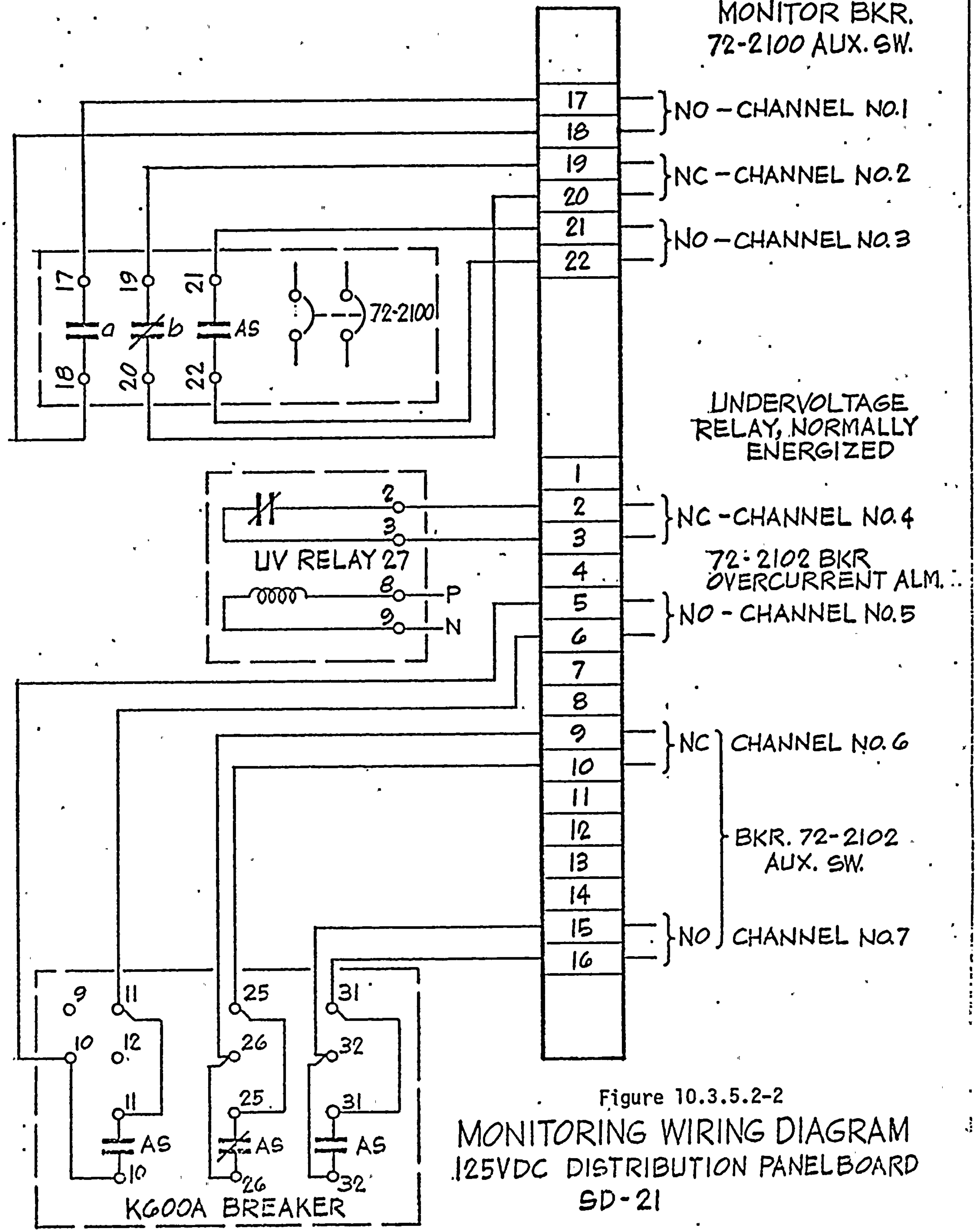


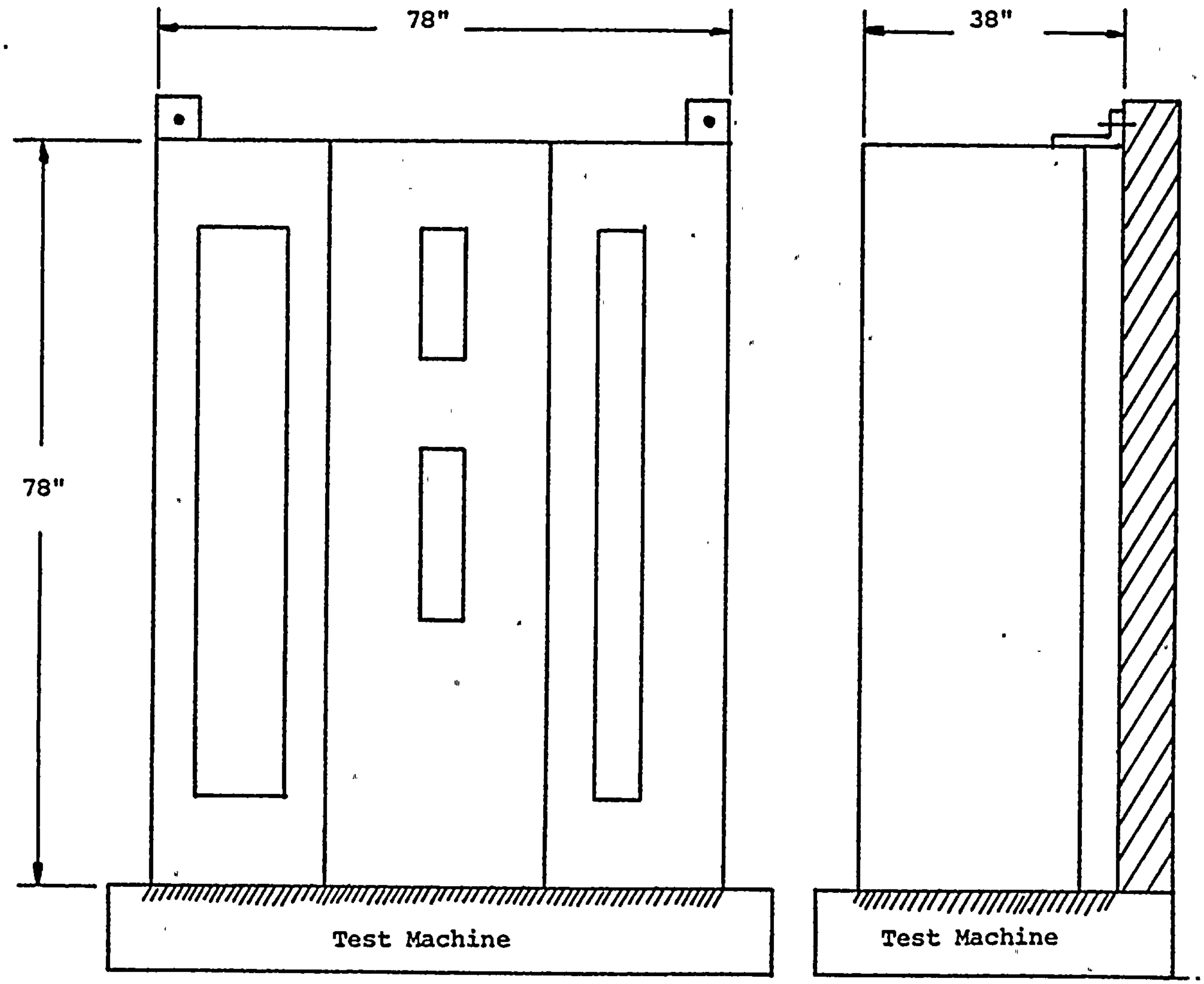
Figure 10.3.5.2-2

MONITORING WIRING DIAGRAM
125VDC DISTRIBUTION PANELBOARD
SD-21

10

		SWITCH, RELAY POSITION, OR CONTACT O=OPEN C=CLOSED													
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE	
DEVICE	SW. NO.	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y
72-2100, I.T.E. KM 2B600 BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C
AUX. SW. TERMINALS	17 & 18	C	C	C	C	C	C	C	C	C	C	C	C	C	C
AUX. SW. TERMINALS FOR ALARM	19 & 20	O	O	O	O	O	O	O	O	O	O	O	O	O	O
AUX. SW. TERMINALS	21 & 22	C	C	C	C	C	C	C	C	C	C	C	C	C	C
27DGB21 UV RELAY W SV	2 & 3	O	O	O	O	O	O	O	O	O	O	O	O	O	O
72-2102 I.T.E. K600 BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C
AUX. SW. OVERCURRENT ALM. TERMINALS	5 & 6	O	O	O	O	O	O	O	O	O	O	O	O	O	O
AUX. SW. TERMINALS	9 & 10	O	O	O	O	O	O	O	O	O	O	O	O	O	O
AUX. SW. TERMINALS	15 & 16	C	C	C	C	C	C	C	C	C	C	C	C	C	C
HE 2B070 I.T.E. CIRCUIT BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C
HE 2B020 I.T.E. CIRCUIT BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C
VOLTMETER 0-150 VDC	VDC	125	125	125	125	125	125	125	125	125	125	125	125	125	125
125 VDC BUS INDICATING LT.	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON

GROUP IV
DC SWITCHGEAR CABINET



Test specimen will be welded to the test machine with supports bolted at the top.

B

10.3.3.1 Name of Equipment Tested

Battery Charger, ED-21 (Exide UPC 130-3-400, 400 amp.) of Unit 2 Diablo Canyon was tested on January 31, 1978.

10.3.3.2 Description of Equipment

The battery charger is a welded frame construction 2 section cabinet with solid-state components. The charger provides rated direct current continuously at a voltage smoothly adjustable from 125 to 140 volts. The charger has a locally mounted voltmeter, ammeter, d-c undervoltage and overvoltage relays for alarm, adjustable controls for both normal and equalizing charge settings, and an equalize timer manually adjustable from 0 to 24 hours. The charger has a SCR Failure Pilot Light, AC Power Available Light, AC Power on Light, Fuse Failure Light, and a Manual Control on Light, all on the left front door.

10.3.3.3 Safety Function

The safety function of the battery charger is to provide 125 VDC power to the 125 VDC bus, and to provide 125 VDC charging current to the bus battery during any condition of plant operation, whenever the charger output breaker is closed, and also the input breaker is closed and being supplied with 480 VAC.

10.3.3.4 Test Criteria and Plan

The test criteria for this battery charger is that it perform its safety function during, and after a seismic event. The charger shall demonstrate this as follows:

1. The charger shall provide continuous power to the 125 VDC bus 21.
2. Monitoring of the following devices shall be performed to verify proper, continous operation of the battery charger:
   a. Monitor Power Input 480 VAC circuit breaker 52.21 in the closed position to verify that breaker remained closed during and after seismic testing (monitoring of breaker to be done visually to see that it does not trip if closed or

close if open during the seismic tests). Monitoring is also to be done by visual observation that the A.C. Power on Light does not go off during energized testing. Monitoring shall also be done by the chatter detector channels, channel 8 NC contact of relay PLR-1, and channel 9 NO contact of relay PLR-1.

b. Monitor Power Output, 125 VDC circuit breaker 72-21, in the closed position to verify the breakers remained closed during and after the seismic testing when the charger is energized. Monitor that the breaker remained open during the times the charger was deenergized.

c. Verify that the A.C. failure relay, PLR-1, contacts did change state when the charger was energized, NO contacts switched to NC, and NC contacts switch to NO.

d. Verify that the A.C. fuse failure relay, PLR-2, contacts did not change state when the relay was in the normal deenergized condition. Also verify that the contacts did not change state when the charger was energized or deenergized.

e. Verify that the 125 VAC Manual Control Relay, Normally Open contacts did not change state during the seismic shaking and switch Battery Charger Control to manual. Verify the normally open contact did not close and light-up the On Manual Control Light on the left hand front door of the charger.

f. Verify that the 125 VDC low voltage auxiliary relay contacts did not change state indicating a loss of 125 VDC output. (The LVRA relay coil drops out when the LVR, 27DC/21, coil voltage drops below 120 VDC and opens its contact in series with the LVRA coil to bring in the alarm.) On drop of 125 VDC output to 120 VDC the LVR relay would pick-up.

3. The seismic test spectra (RRS) are contained in Wyle Report 58255, April 19, 1978, pp. 288-293.

10.3.3.5 Test Procedure and Setup

1. Mount the 125 VDC Battery Charger ED-21 on the seismic test table in the same configuration as in the auxiliary building 115' elevation plant location.
2. Supply 480 VAC power to the input side of the 52-21 input breaker.
3. Connect the 125 VDC output breaker, 72-21 to the 125 VDC load bank.
4. Connect the Wyle Laboratory 125 VDC battery to the output terminals of the battery charger.
5. Connect a Normally Closed contact of the A.C. Failure relay, PLR-1, to the chatter detector.
6. Connect a normally open contacts of the A.C. Failure relay, PLR-1, to the chatter detector.
7. Connected a normally closed contact of the A.C. fuse failure relay, PLR-2, to the chatter detector.
8. Connect a noramlly open contact of the A.C. fuse failure relay, PLR-2 to the chatter detector.
9. Connect a Normally Closed, and a normally open contact of the manually control relay, MCR to the chatter detector.
10. Connect a normally closed contact of the Low Voltage Relay, LVRA, to the chatter detector.
11. Close breakers on the battery charger in the following sequence.
    a) Close the 125 VDC output breaker 72-21, first, to supply dc control signal to the control unit, and to charge up the output filter capacitors.
    b) Then close the 480 VAC input breaker 52-21.

12. Close resistor bank toggle switches until the charger is loaded with 60 ampere load.
13. After energizing the battery charger and loading the charger deenergize the charger, before doing item 14 deenergized tests.
14. Perform the seismic tests with the battery charger deenergized during 1st and 3rd OBE and with the charger energized during the 4th and 5th OBE and the 1st and 2nd SSE.
15. After the seismic tests deenergize, energize, and again deenergize the battery charger to verify the charger functioned normally after the seismic testing.

10.3.3.6 Test Results

The battery charger was run through the test series with the following results:

1. The input 480 VAC breaker 52-21 remained closed during and after the seismic testing. During all periods when the battery charger was energized, output LVR and LVRA relays remained energized. If the charger had tripped off the LVRA relay contacts would open and give a undervoltage alarm. Undervoltage on the secondary of the 480/120 VAC control voltage transformer (AVT) caused by the 480 VAC breaker 52-21 tripping would close auxiliary (a) contact of 52-21/a, and pick up the coil of PLR-1 (AC failure relay). This PLR-1 coil would in turn close the NO contact connected to channel 9 of the chatter detector, and open the NC/a contact connected to channel 8 of the chatter detector. This did not happen on any of the energized periods of the battery charger.
2. The output 125 VDC breaker, 72-21 remained closed during and after the seismic testing. LVRA contact monitored by the chatter detector channel 14 did not open and alarm an output undervoltage during any battery charger energized testing.

3. The 125 VAC failure relay PLR-1, was seismically tested with the charger nergized, and the normally closed contact picked up in its normal operating position of normally open. The seismic tests did not cause this contact to chatter shut to give false indication of a loss of A.C. power, nor did the contact close to indicate 480/120 VAC power failure.

4. During the seismic testing the 125 VAC Manual Control Relay did not chatter, and thus did not cause the battery charger to switch from automatic to manual control. The 125 VAC Manual Control Switch did not move from the Charger on Automatic Control position.

5. The 125 VDC low voltage relay, LVRA, did not change state to indicate a loss of 125 VDC output. N.O. contacts which are closed when the charger is operating, did not chatter nor did they open to indicate loss of 125 VDC output. Table 10.3.3-1 shows the functional performance of these devices during seismic testing.

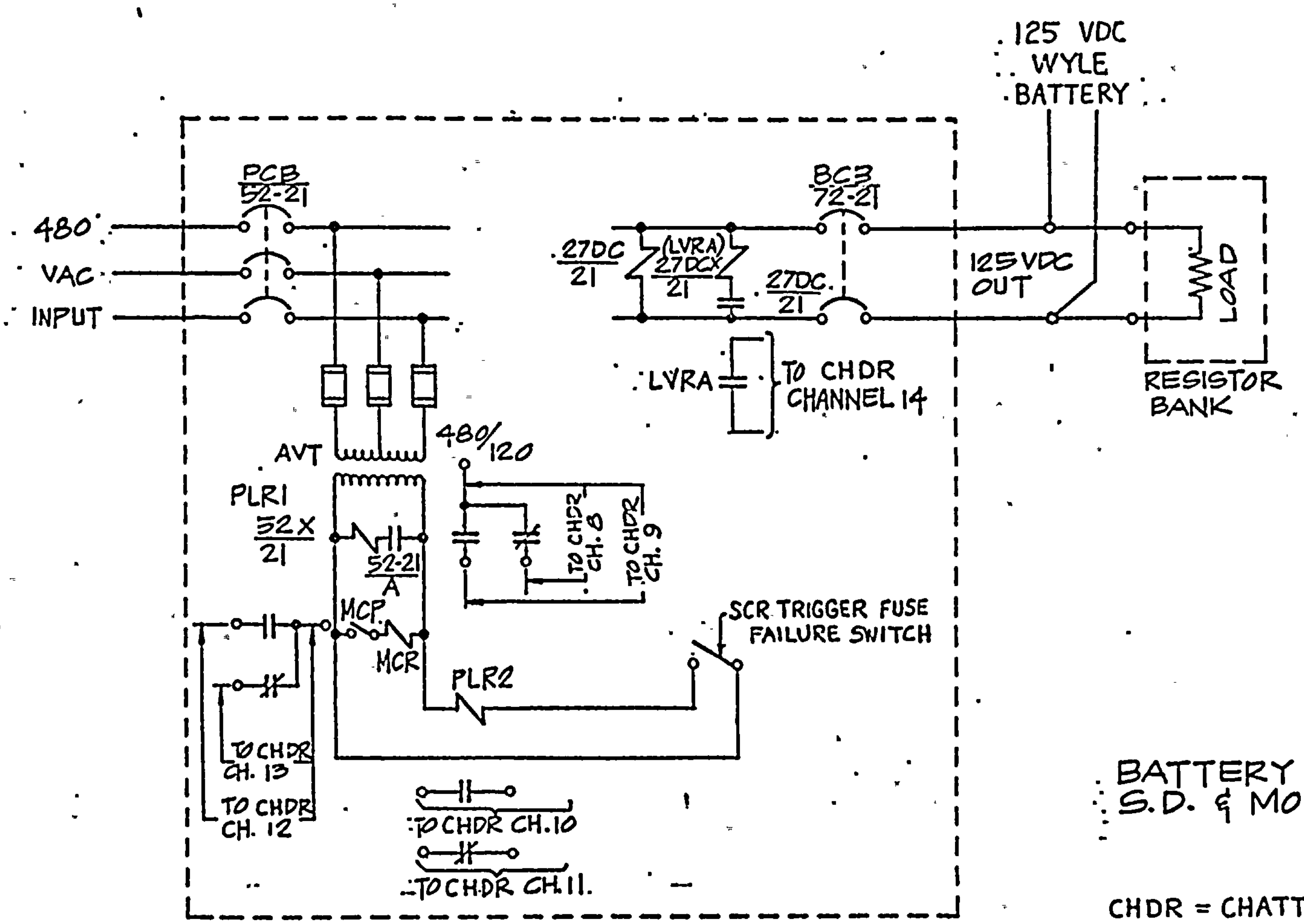
6. All left front door indicating lights showed proper indication for all conditions. On when required to be on and off when required to be off.

10.3.3.7 Conclusions

Battery charger ED-21 from Diablo Canyon Unit 2 was tested by a multi-axis multi-frequency seismic simulation described in Wyle Report Number 58255, April 19, 1978, pp. 288-293. This battery charger is identical to the other nine battery chargers installed in Diablo Canyon Units 1 and 2. The test results described in section 10.3.3.6 above demonstrate that the test criteria of section 10.3.3.4 are met, and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. On this basis the Diablo Canyon Units 1 and 2 battery chargers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100.

BATTERY CHARGER - TABLE 10.3.3-1

		SWITCH, RELAY POSITION OR CONTACT O=OPEN C=CLOSED															
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE		3RD SSE	
DEVICE	SW. NO.	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-
52-21 I.T.E. FJ3-B175	BKR	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
72-21 I.T.E. KM-2-B500	BKR	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
PLR-1 125 VAC FAILURE RELAY	N.C.	C	C	C	C	C	C	0	0	0	0	0	0	0	0	C	C
	N.O.	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0
PLR-2 125 VAC FUSE FAIL. RELAY	N.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N.C.	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
MCR, ROWAN TYPE E 125 VAC	N.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	N.C.	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
27-DC 21 LVRA	N.O.	0	0	0	0	0	0	C	C	C	C	C	C	C	C	0	0

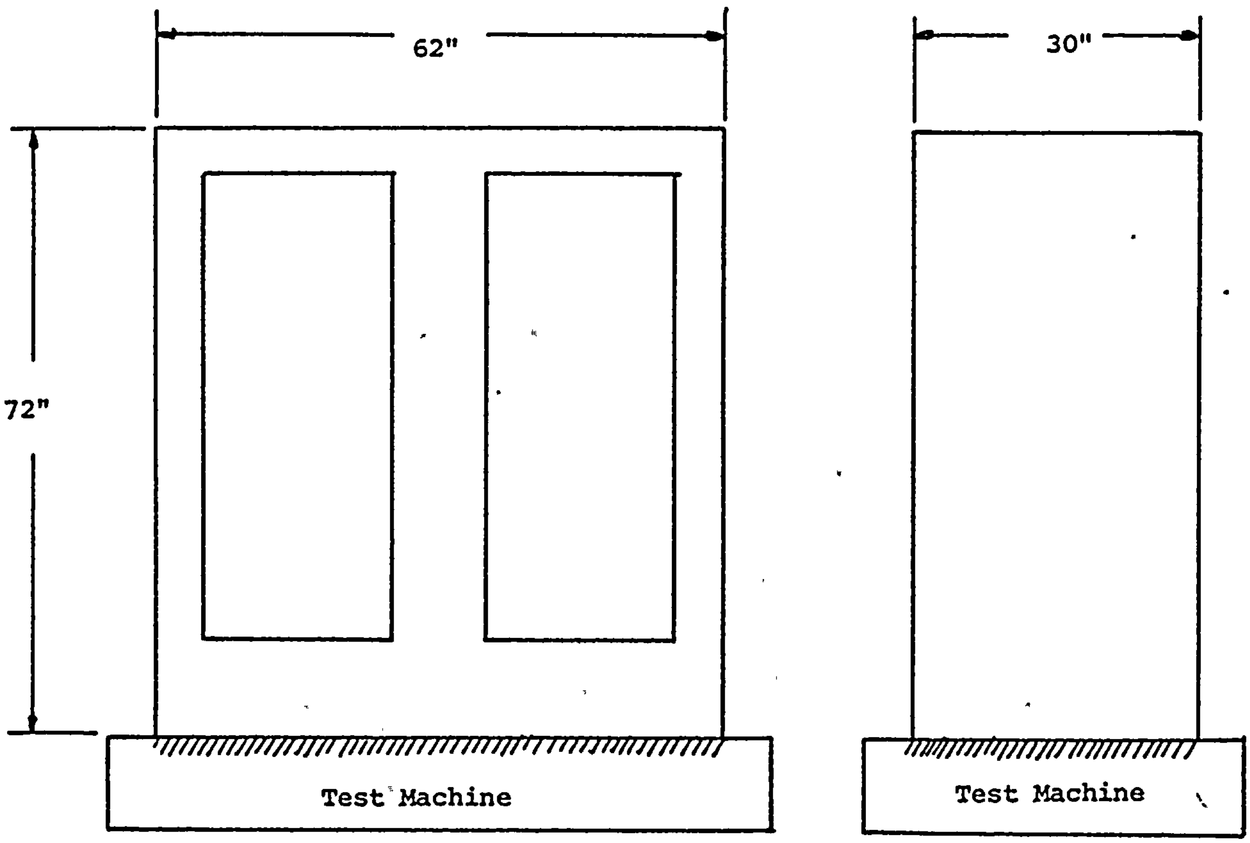


BATTERY CHARGER ED-21
S.D. & MONITORED CHANNELS

CHDR = CHATTER
DETECTOR

AMENDMENT NO. 1

GROUP IV
BATTERY CHARGER CABINET



Test specimen will be bolted to the test machine. B

10.3.5.1.1 - Name of Equipment

125/250 VDC Motor Control Center

Description of Equipment

The 250 VDC Turbine Lube Oil Pump motor starter is mounted in the 250 VDC Motor Control Center. The Motor Control Center is a four section welded construction control cabinet; it is welded to floor plates at elevation 115 ft. in the auxiliary building. The Motor Control Center also contains three other, 250 VDC motor starters similar to the Turbine Lube Oil Pump motor starter.

The starter consists of a vertical panel, on which are mounted the following components:

a. Input power breaker 72-2008; Westinghouse adjustable magnetic only HLA 2700 TM breaker.

b. Four contactors that apply progressively lower starting resistance:

   1. Contactor 42-2008; 3 pole, 250 VDC contactor ITE Type A103G12.
   2. Contactors 18A2008, 18B2008, and 18C2008; (2 pole, 250 VDC contactors) ITE Type P102F11.

c. Time delay relays that time out to energize both the contactor to shunt out a portion of the starting resistance and the next time delay relay, 2A 2008, 2B 2008, and 2C 2008; Agastat Type 2412 PN.

The input power breaker is normally closed. When the Turbine Lube Oil Pump is signaled to start either by low lube oil pressure or by a manual start, contactor 42-2008 closes, applying voltage to the motor armature through the full series starting resistance, and time delay relay 2A 2008 is energized. When relay 2A 2008 has timed out, it energizes contactor 18A 2008 to shunt out a portion of the starting resistance and energizes

the next time delay relay, 2B 2008. This sequence is continued until all the starting resistance in series with the motor armature has been shunted out. The operation of the starter is shown schematically in Figure 10.3.5.1-1.

Safety Function

This equipment has no direct safety function. However, during a seismic event the starters must not apply full voltage to the D.C. motor before it has had time to accelerate. Otherwise, a current surge could result in damage to the motor and voltage dip on the D.C. bus.

Test Criteria and Plan

The functional test criteria for this motor starter are as follows:

1. The contactors shall not close during the seismic test except when required.

2. The timers shall not initiate and time out except when required to do so during the seismic test.

3. The contactors shall drop out, and motor starter shall trip out when signaled to stop.

4. The motor starter functions described above shall be demonstrated during, and after the seismic test.

The test plan is to monitor, visually or electrically the following during, and after seismic testing to simulate 5 OBE's and an SSE with the multi-axis, multi-frequency inputs applied to envelope the required response spectra described in Wyle test report 58255, April 19, 1978, pp. 214-239.

a) 42-2008 Contactor stays open during shaking, closes when energized, stays closed when energized, and trips off when deenergized.

b) 18A 2008, 18B 2008, and 18C 2008 shall be monitored the same as item (a).

c) 2A 2008, 2B 2008, 2C 2008 shall be monitored the same as item (a).

Testing Procedure and Set-Up

1. Mount the Motor Starter in the same configuration and orientation as in the Diablo Canyon plant, (See Wyle Report No. 58255, April 19, 1978 pp. 570-571 for test mounting).

2. Supply 125 VDC to the input terminals of the input breaker 72-2008.

3. Provide a 125 VDC rated switch for energizing or deenergizing the 42-2008 contactor coil to simulate starting and stopping signals.

4. Visually monitor during seismic testing the proper sequence and timing for closure of the motor starter contactors and timers.

Test Results[1]

After mounting on the seismic test table, the starter was functionally tested by applying 125 VDC control power to the input of the starter breaker 72-2008, then manually closing this breaker. The manual switch on the test set-up was closed to provide a signal to start the motor. Contactor 42 energized, starting the time delay relay sequences. Upon completion of all contactors closing, the manual switch was returned to open and the motor starter returned to its motor tripped state.

During the 1st, 2nd, 3rd, and 4th OBE and the SSE in the X-Y (east-west and vertical plant orientation) the starter was observed in its motor-tripped state. The timers, relays and contactors did not close or chatter to inadvertently start the motor starter sequences during the seismic test. The starter did not operate in its deactivated state during the 1st, 2nd, 3rd, and 5th OBE, and the 1st SSE in the Z-Y direction.

During the 5th OBE and the 2nd SSE in the X-Y direction, and the 4th, 5th, OBE's and 2nd SSE in the Z-Y direction, the manual switch was closed energizing contactor 42 and started the time delay relay contactor sequence. Upon completion of the sequence, the stop switch was opened releasing all the contactors. The entire sequence was completed before the end of each 30 second test.

Upon completion of the last SSE, the manual switch was again closed and the starter run through its sequence and again, deenergized.

The above seismic and functional testing verifies that this representative direct current motor starter was not inadvertently activated by the seismic shaking. Functionally, during a seismic event, the starter would remain off, would start the motor if switched on in the automatic position or manually, and would trip off if switched automatically or manually.

Table 10.3.5.1-1 shows a list of components contained in this starter and summarizes their functional performance during the seismic testing.

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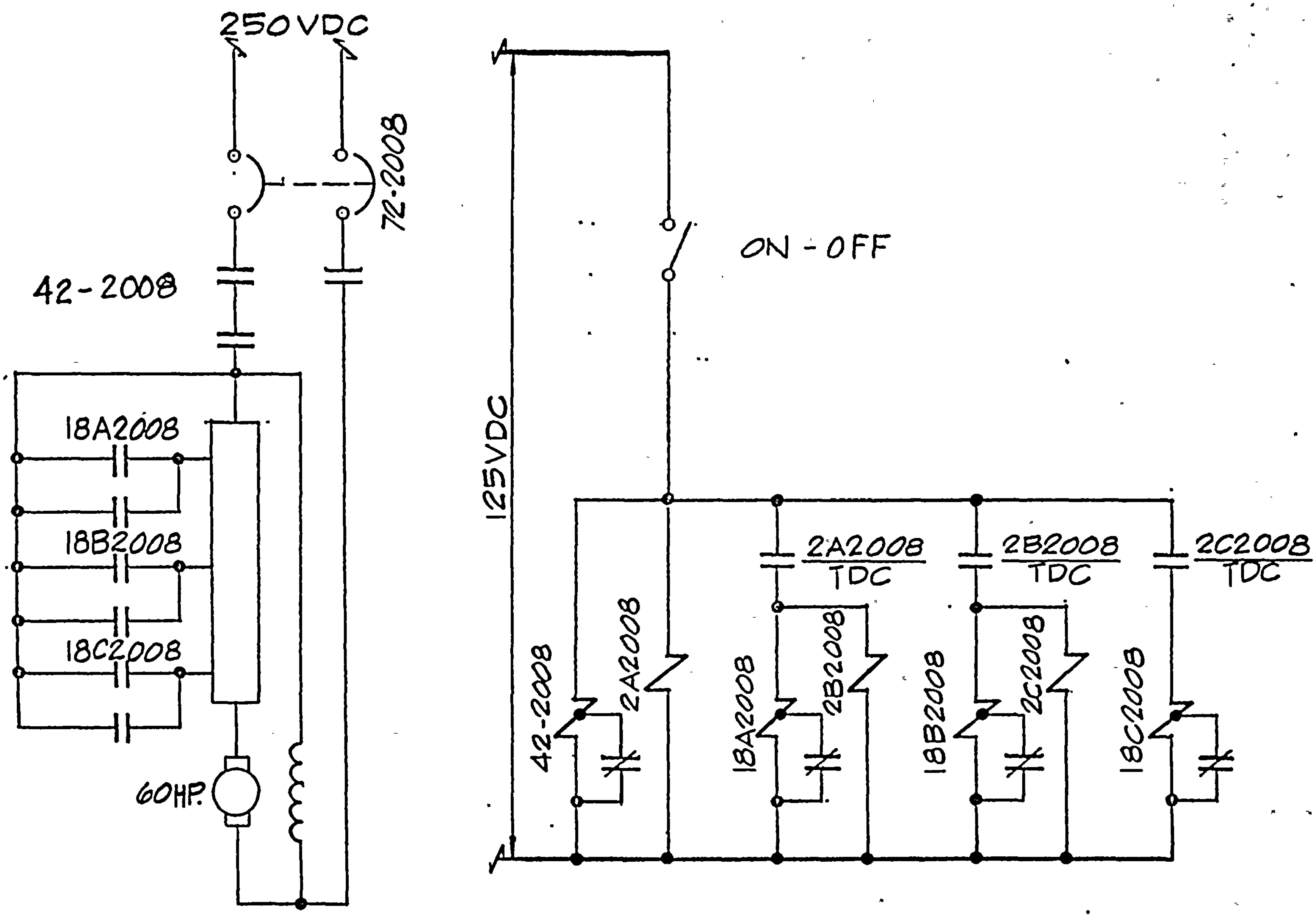
1. Detailed test results are contained in Wyle test report 58255, April 19, 1978, pp. 214-239.

Conclusions

The results of the tests of the 250 VDC Turbine Lube Oil Pump motor starter subjected to a multi-axis, multi-frequency seismic simulation bounding the 7.5M Hosgri event have demonstrated that the test criteria specified above have been met.

Thus it is concluded that the 250 VDC Turbine Lube Oil motor starter is qualified for service in the Diablo Canyon plant for the 7.5M Hosgri event in accordance with IEEE-344-1975 and USNRC Regulatory Guide 1.100.



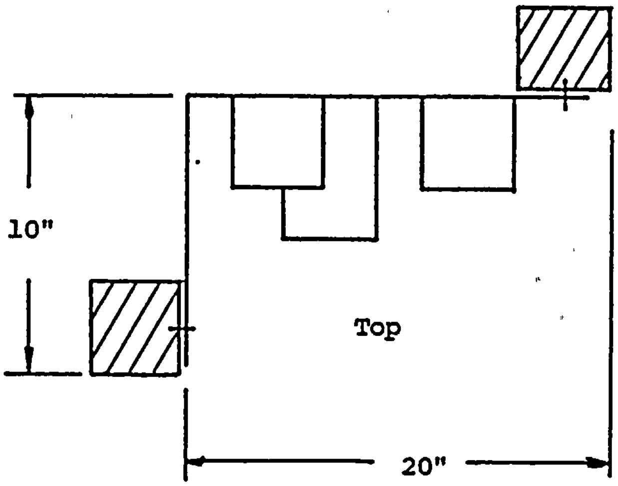
S.D. TURBINE GEN. EMERGENCY BEARING OIL PUMP Nº 21
TEST-SET-UP AT WYLE

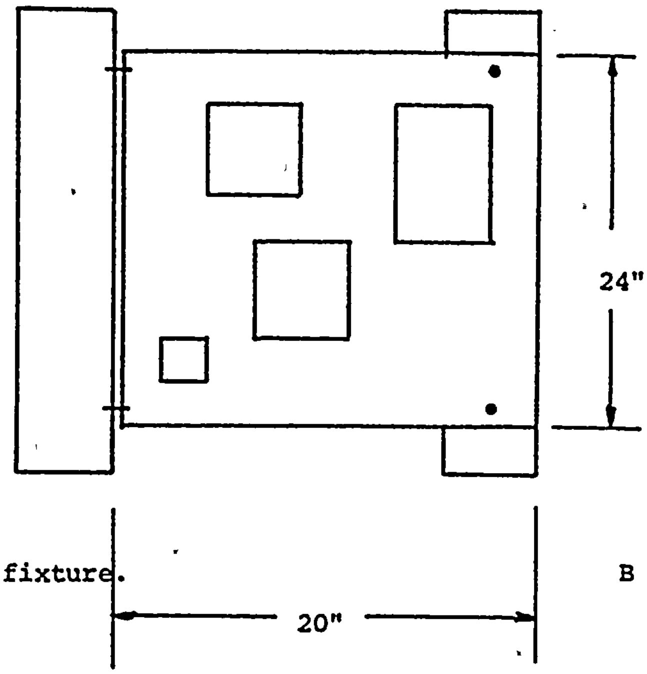
Figure 10.3.5.1-1

TABLE 10.3.5.1-1

		SWITCH, RELAY POSITION, OR CONTACT O=OPEN C=CLOSED													
TABLE RUN NO.		1ST OBE		2ND OBE		3RD OBE		4TH OBE		5TH OBE		1ST SSE		2ND SSE	
DEVICE	SW. NO.	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y	X-Y	Z-Y
72-2008 W ADJ. MAG. ONLY BKR	BKR	C	C	C	C	C	C	C	C	C	C	C	C	C	C
42-2008 I.T.E. A103G12 CONTACTOR	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
2A2008 AGASTAT 2412PN T.D. RELAY	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
18A2008 I.T.E. CONTACTOR P102F11	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
2B2008 AGASTAT 2412PN T.D. RELAY	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
18B2008 I.T.E. CONTACTOR P102F11	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
2C2008 AGASTAT 2412PN T.D. RELAY	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C
18C2008 I.T.E. CONTACTOR P102F11	CONTACTS	O	O	O	O	O	O	O	C	C	C	O	O	C	C

GROUP IV
125-250vdc M.C.C.
TURBINE LUBE OIL STARTER





Test specimen bolted to fixture.

B

Fixture 4" tubing .

ROUGH-DRAFT 10-10-78
AMENDMENT #1

10.3.4.1 - Name of Equipment

Station Battery and Racks.

10.3.4.2 - Description of Equipment

Diablo Canyon Units 1 and 2 each have three identical batteries each made up of 60 C&D Inc. LCU-27 cells installed in battery racks at the 115' elevation in the Auxiliary Building.

The battery racks have been braced such that there are no natural frequencies below 35 hz, and such that they are structurally capable of withstanding 3.0g Horizontal and 0.65g Vertical accelerations.

The average operating current on a typical Diablo Canyon Battery bus is about 100 amperes. In actual operation this current is supplied by the battery charger and the battery is floating on the charger and connected to the bus. If the battery charger should trip the battery would supply the 100 amperes.

10.3.4.3 - Safety Function

The Station Batteries must provide nominal 125 vdc power to supply the station dc loads in the event that the ac source to one or more battery charger becomes unavailable.

10.3.4.4 - Test Criteria and Plan

The following test criteria have been established to demonstrate that the station battery will perform its safety function during and after a seismic event.

1. The cells shall provide continuous current output at a steady voltage during and after the seismic test. Voltage to be read on a digital voltmeter and visually observed. Use a 1 resistor for a load.

2. Battery cells shall not be damaged by the seismic testing.

3. Two battery cells shall be tested. The battery cells shall have an current load on them during the seismic testing. A 1 ohm load shall be used on the two cells in series, or an approximate current of 3.4 amperes shall be established.

4. The battery shall be able to accept charging current after the seismic tests.

5. The battery shall meet its discharge requirement per IEEE-Std-450 after seismic testing.

10.3.4.5 - Test Procedure and Setup

1. The two battery cells to be tested shall be mounted in a rigid test fixture to simulate their service mounting. The test fixture to be used is the same test fixture used in the earlier test at Wyle Laboratories (.4g SSE test) on June 18, 1978, except it was modified to satisfy the postulated 7.5M Hosgri Earthquake requirements, and also to simulate as closely as possible the existing battery racks at Diablo Canyon Units 1 and 2. Side diagonal braces and side rail shims were added to the test fixture. The test mounting for the cells is illustrated in Wyle Report No. 58255, dated April 19, 1978, pp. 577 and 578.

2. Testing shall be performed using the multi-axis, multi-frequency test inputs described in Wyle Report Number 58255, dated April 19, 1978, pp. 240-254.

3. The two batteries shall be connected in series to a 1 ohm load. Use the standard battery straps and bolts and nuts provided with the 60 cell battery.

4. Monitor the current and voltage of the two cells before, during, and after the seismic tests.

10.3.4.6 - Test Results

The two battery cells functioned as required during, and after the seismic testing. The batteries provided a continuous current flow at 3.4 amperes through the 1 ohm resistor. The starting two cell battery voltage was 3.79 vdc and ending two cell battery voltage was 3.75 vdc. Before test and before application of the 1 ohm load the two cell battery voltage was 4.12 vdc. After the test and after disconnecting the load the battery volts was 4.07 vdc. Voltage was measured by a digital voltmeter continuously, before , during and after the testing, and observed visually. The cells tested exhibited no damage and they have been returned to the Diablo Canyon Unit 2 Battery 21. A discharge test of Battery 21 will be performed with these two cells included to verify that the cells will meet their discharge and charging requirements after the tests.

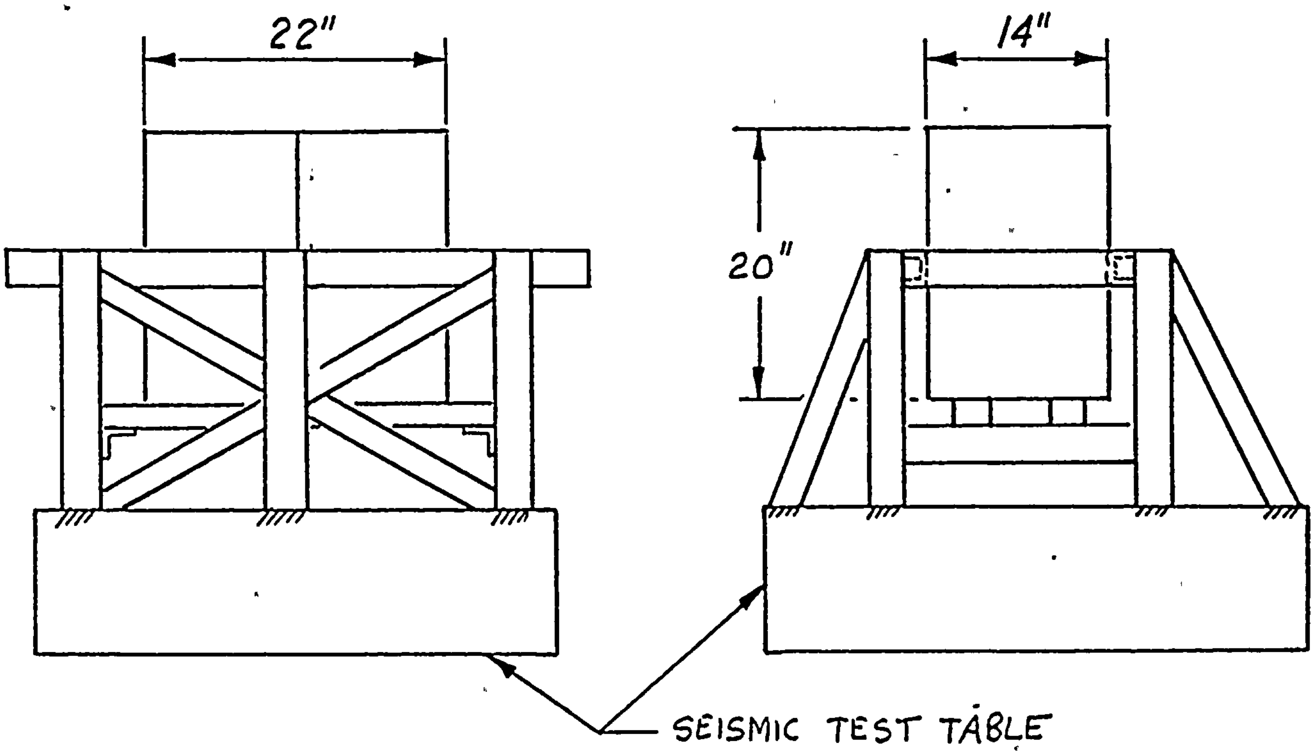
Following the previous test of two identical cells to qualify the station batteries to the 0.4g DDE (See Wyle Report No. 43255-1, 6-18-76) the test cells passed an eight hr. rated capacity discharge test and were then recharged to their original capacity.

10.3.4.7 - Conclusions

Two C&D, Inc. LCU-27 station battery cells have been tested by multi-axis, multi-frequency seismic simulation as described in Wyle Report No. 58255, 4-19-78, pp. 240-254. These cells are identical to the other cells contained in the 6-60 cell station batteries in Diablo Canyon Units 1 and 2. The test results show that the test cells continued to supply dc power at the

average load during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. The cells were not damaged by the test. Discharge testing following this seismic test will be completed at the Diablo Canyon Site by October 27, 1978; however discharge and charging capability following a seismic event has previously been demonstrated on two identical LCU-27 cells tested earlier (see Wyle Report No. VL-762-02, August 4, 1976.

On this basis it is concluded that the six Diablo Canyon station batteries are qualified for the postulated 7.5M Hosgri event in accordance with IEEE-Std 344-1975 and USNRC RG 1.100.



BATTERY SEISMIC TEST RACK

To: [illegible] Room 1805

Work Request No. ____

Laboratory Test No. VL-762-02

B. E. No. ____

R. M. A. No. ____

LABORATORY REPORT

BATTERY SECTION

QUALIFICATION TEST
TYPE LCU-27

Prepared for: Pacific Gas & Electric Co.
77 Beale Street
San Francisco, CA 94106

P.G.&E. Purchase Order No. T4R-93205
P.G.&E. Specification 0132
P.G.&E. File No. 128.061
P.G.&E. Record No. 663343-4

C&D BATTERIES
DIVISION OF ELTRA CORPORATION

Distribution:
(10) Pacific Gas & Electric Co.
(1) L. K. Isbill, P.G.&E. Inspector
(1) H. J. Schaetzle, C&D
(1) F. Wagner, C&D
(1) File

Prepared Graham Walker [signature]
Date Prepared 4 Aug 76
Approved H.J.Schaetzle [signature]
Date Approved 4 Aug 76

FORWARD

Two cells, C&D type LCU-27, identical to the Diablo Canyon Unit 1 and 2 battery were tested as follows:

1. After filling, forming and conditioning the specimen cells, an 8 hour capacity discharge test was conducted in accordance with IEEE 450-1975 directives. This is shown as discharge number 4.

2. Seismic testing was performed per Wyle Laboratories' Seismic Test Plan 541/4024/ES, dated 16 June 76, Rev. A. Seismic Test results are provided in Wyle Report No. 43255-1.

3. Upon return of the specimen cells from Wyle Laboratories, boost charging followed by an 8 hour capacity discharge test was conducted in accordance with IEEE 450-1975. This is shown as discharge number 5.

3 HR. RATE
.75 AMPS. TO
5 FINAL VOLTS

an Eltra company
BATTERY LABORATORY
DISCHARGE RECORD

TYPE
DATE 4-19-76
DIS. NO. 4
CIRCUIT NO. 27

CELL NO.-	1	2								
T @ 100 MA	2.240	2.270								
TEMP / Sp. GR.	71° 1.220	1.220								
E STARTED 8:40										
8:50	1.987	1.985								
9:40	1.982	1.980								
10:40	1.971	1.968								
11:45	1.956	1.954								
12:25	1.938	1.936								
13:45	1.908	1.905								
14:40	1.872	1.871								
15:40	1.818	1.824								
15:55	1.795	1.805								
16:22	1.75	1.761								
16:28		1.75								
@ FV	74° 1.090	74° 1.087								AVER. TEMP. 72. FACTOR .97
L HRS. TO FV	7.70	7.80								TESTED BY: CN
NT RATED ITY @ 77°F										

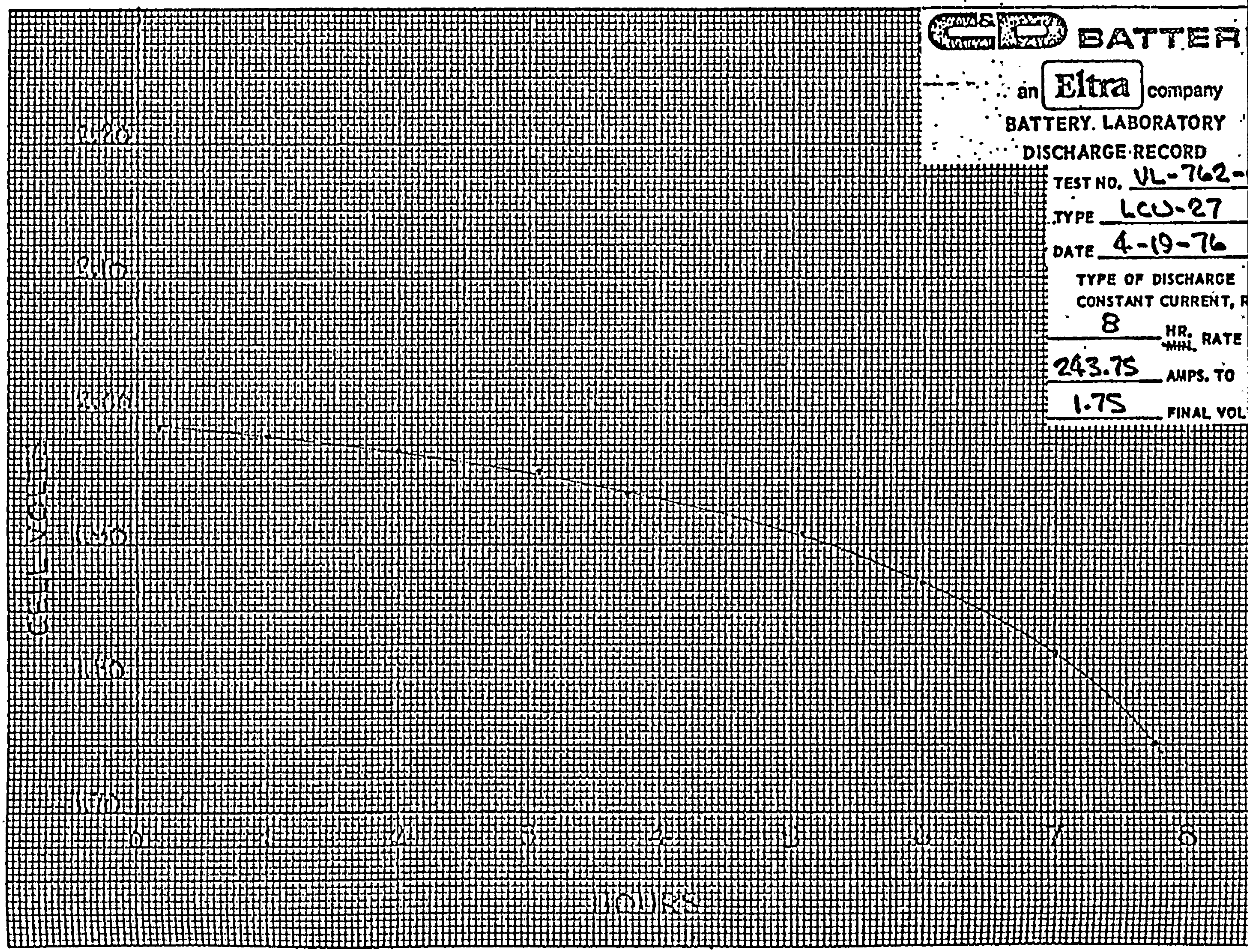
PERCENT CAPACITY @ 77°F = $\frac{T_A}{T_S K_1} \times 100$

WHERE T_A = ACTUAL TIME
T_S = RATED TIME
K_1 = TEMP. FACTOR

% CAPACITY = $\frac{7.75}{8 \times .978} \times 100$

= 99.05%

737


C&D BATTER
an Eltra company
BATTERY LABORATORY
DISCHARGE RECORD
TEST NO. VL-762-
TYPE LCW-27
DATE 4-19-76
TYPE OF DISCHARGE
CONSTANT CURRENT,
8 HR. RATE
243.75 AMPS. TO
1.75 FINAL VOL
2.20
2.10
2.00
1.90
1.80
1.70
0
2
3
7
8
HOURS

75 AMPS. TO

5 FINAL VOLTS

BATTERY LABORATORY
DISCHARGE RECORD

DIS. NO. 5

CIRCUIT NO. 1 & 2

CELL NO.-	1	2								
T @123MA	2.235	2.238								
TEMP.. Sp. Gr.	76° 1.216	1.216								
STARTED 8:35										
8:45	1.983	1.982								
9:35	1.982	1.982								
0:35	1.969	1.969								
1:25	1.955	1.955								
2:30	1.935	1.936								
3:35	1.908	1.909								
4:50	1.872	1.873								
5:40	1.829	1.832								
6:15	1.787	1.793								
6:28	1.750	1.761								
6:30		1.750								
@ FV	76° 1.080	76° 1.078								AVER. TEMP. 76° FACTOR .99
HRS. TO FV	7.88	7.92								TESTED BY: [illegible]
NT RATED										

Percent capacity @ 77°F =

$$\frac{T_A}{T_S K_1} \times 100$$

where T_A = Actual duration

T_S = Rated time

K_1 = Temp. factor

$$\% \text{ capacity} = \frac{7.90}{8.0 \times .996} \times 100$$

= 99.15%

C&D BATTERI

an Eltra company

BATTERY LABORATORY

DISCHARGE RECORD

TEST NO. VL-762-

TYPE LCU-27

DATE 7-23-76

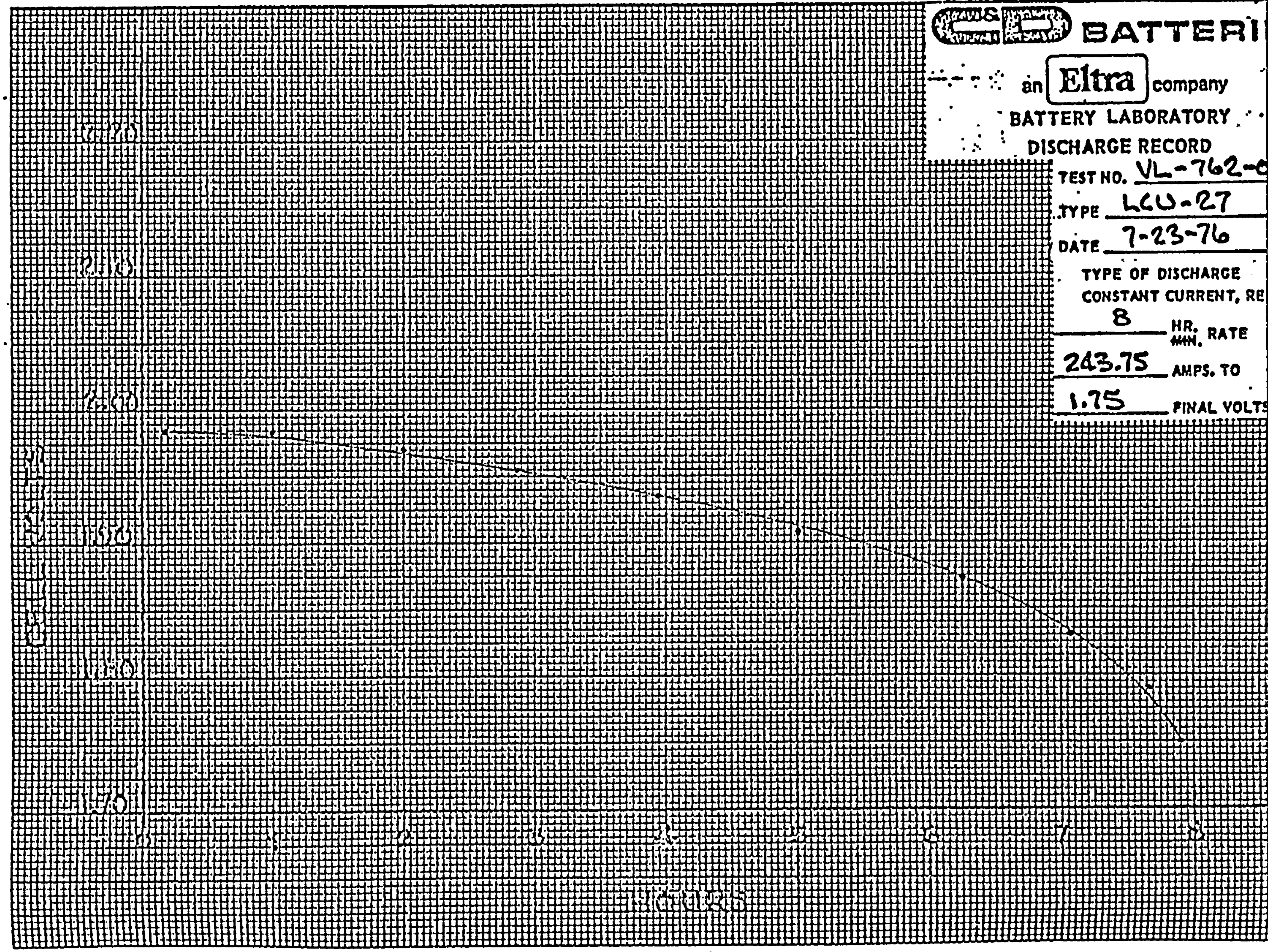
TYPE OF DISCHARGE

CONSTANT CURRENT, RE

8 HR. ~~MIN.~~ RATE

243.75 AMPS. TO

1.75 FINAL VOLTS



CONCLUSION

It is demonstrated that the specimen cells suffered no reduction of capacity as a result of the prescribed simulated seismic environment for the Diablo Nuclear Power Plant, Unit 1 and 2.

10.3.25 VITAL LOAD CENTERS

10.3.25.1 - Description of Equipment

The Vital Load Centers (480 volt MCC, bus, F, G and H) consists of draw-out modules containing combination motor controllers or feeder breakers. These modules are arranged in vertical stacks with vertical stacks bolted together to make a line-up. Electrical bussing is provided both horizontally between stacks and vertically between modules. Each combination motor controller consists of a molded case magnetic-only circuit breaker, contactor and overcurrent relay. Feeder breakers are simply molded case thermal-magnetic circuit breakers. The Vital Load Centers are located at elevation 100' in the auxiliary building.

10.3.25.2 - Safety Function

The Vital Load Centers must provide power on demand for Engineered Safety Features equipment. The major loads are electric motor operated valves and ventilation fans. In orderly accomplish this basic function, feeder breakers must remain closed, contactors must close on demand and remain closed, and overload relays must not spuriously operate to interrupt power inadvertently.

10.3.25.3 - Test Plan and Criteria

The specific test criteria to be met in order to demonstrate that the equipment safety function is assured during and after a seismic event are the following:

a. Feeder breakers must remain closed during and after the seismic testing.

b. Controllers must close on demand, and only on demand, and remain closed during and after the seismic testing.

c. Overload relays (except for those bypassed per NRC Regulatory Guide 1.106) must not inadvertently interrupt power to the load.

10.3.25.4 - Test Procedure and Set-Up

One vertical section from a Vital Load Center was removed from Diablo Canyon Unit 2 for seismic testing. Each NEMA size controller and representative feeder breakers will be placed in the vital load center section and seismically tested.

1. Mount the Vital Load Center vertical section to the test table to simulate field mounting by welding at base and rigidly supporting at top.

2. Mount three Size 1 reversing controllers, used for motor operated valves, in the vertical section; fill the remainder of the section with typical equipment that will not be monitored during the tests.

3. Connect and monitor each controller as shown in Figure 10.3.25-1.

4. Perform multi-frequency, multi-axis seismic testing to the RRS shown in Wyle Report No. 58255, Appendix I, pg. 19.

   a. Run three OBE test with the equipment deenergized.

   b. Run one OBE test, energizing all "forward" contactors.

   c. Run one OBE test, energizing all "reverse" contactors.

   d. Run one SSE test, energizing the "reverse" contactors.

   e. Run one SSE test with the equipment deenergized.

   f. Run one SSE test, energizing the "forward" and "reverse" contactors 3 times each.

5. Rotate equipment 90 degrees and repeat steps 3 and 4.

6. Mount NEMA Size 2 reversing and non-reversing controllers, NEMA Size 3, 4, and 5 controllers, and two 100 amp feeder breakers in the vertical section.

7. Connect and monitor each device as shown in Figure 10.3.25-2.

8. Perform seismic testing with inputs as described in 4 above:

   a. Run five OBE tests with the equipment deenergized.

   b. Run two SSE tests with the equipment deenergized.

   c. Run one SSE test with the equipment energized.

9. Rotate equipment 90 degrees and repeat steps 7 and 8.

10. Check normal functional operation of each controller and feeder breaker on completion of the seismic testing.

10.3.25.6 - Test Results

With the exception of the anomalies discussed below, all Vital Load Center equipment met the test criteria specified in section 10.3.25.4 during and after the seismic testing while being operated per the test procedure described in 10.3.25.5 above.

During the initial tests it was determined that the draw-out modules required additional hold down brackets to eliminate excessive movement during the seismic testing. Hold down brackets were fabricated and utilized throughout the complete test sequence.

During one SSE one N.O. and one N.C. auxiliary contact on the size 4 controller chattered. Analysis determined that the axuiliary contacts are used only for indication. This chatter could at most result in momentary actuation of indicating lights. Momentary actuation of indicating lights during seismic shaking, with the contacts and indicating lights returning to proper status on cessation of the seismic motion has been judged not to have unacceptable impact on plant safety.

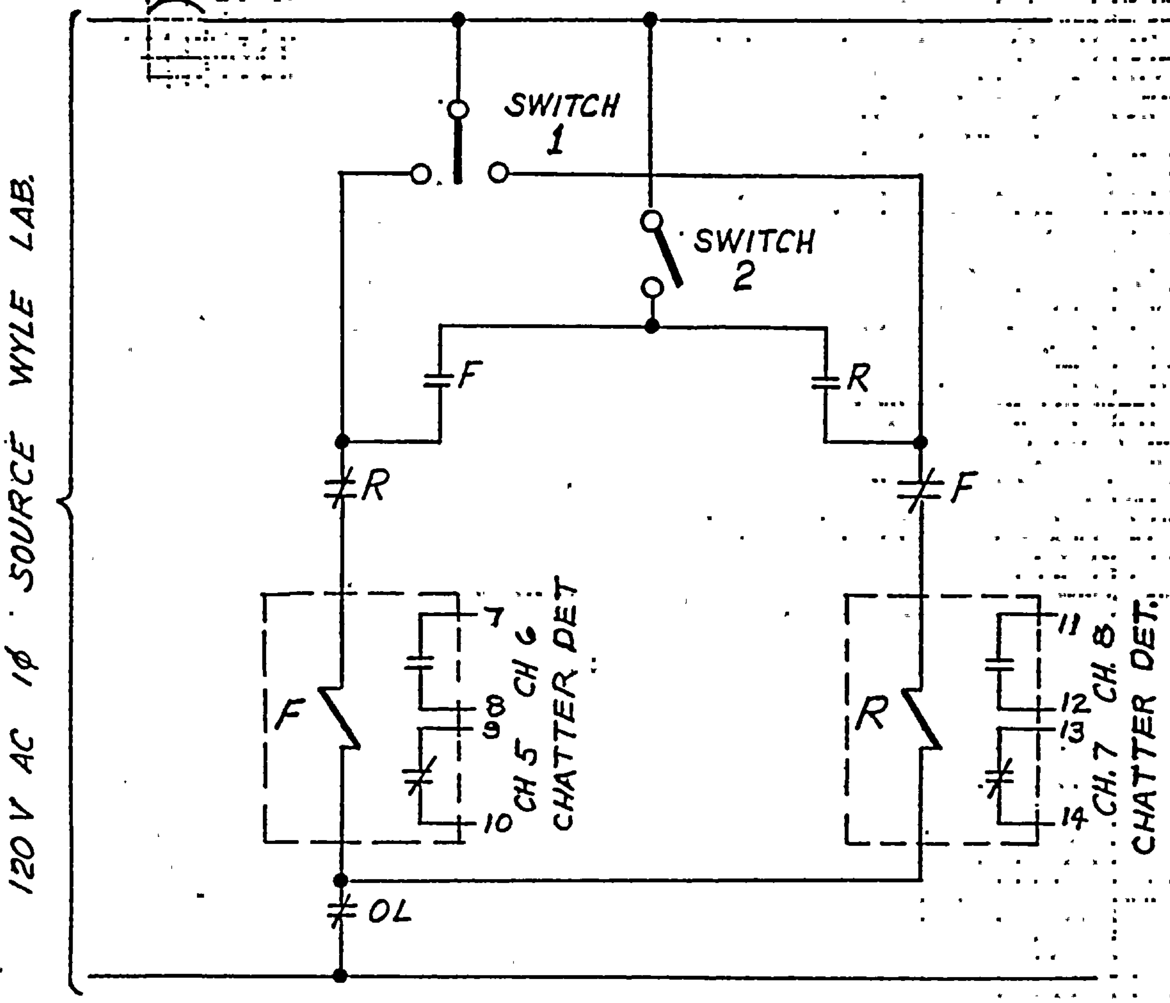
In addition, one N.C. contact chattered with the size 2 reversing controller deenergized. This effect has been analyzed and determined to present no degradation of any safety function. The primary reason for this is that all safeguards initiation signals are sealed-in until manually reset. Therefore, if the N.C. contact chattered and momentarily caused a motor operated valve to stop, (a fraction of a second) it would immediately resume travel as directed by the safeguards initiation signal.

10.3.25.7 - Conclusions

A vertical section of the Vital Load Center was tested, with each NEMA size controller and representative circuit breakers installed, by a multi-axis, multi-frequency seismic simulation as described in Wyle Report No. 58255, pp. 318 to 410. Based on the components tested and the test procedure employed, these qualification tests are judged to be bounding for all Vital Load Center equipment.

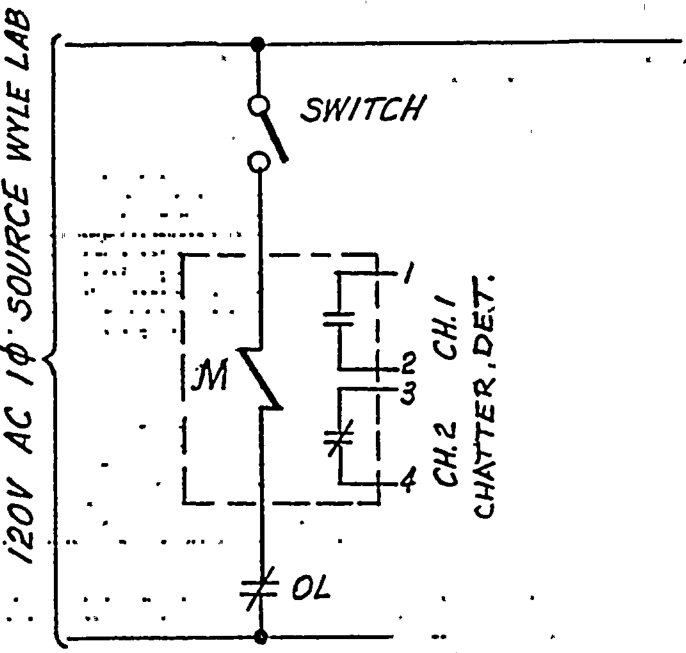
The test results described in 10.3.25.6 above rely upon additional hold-down brackets to maintain the integrity of the draw-out module stacks. These additional hold-down brackets have been provided in Diablo Canyon Units 1 and 2 Vital Load Centers to ensure that the test results are applicable.

The test results described in section 10.3.25.6 above demonstrate that the test criteria of section 10.3.25.4 are met, and the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event. Thus it is concluded that the Diablo Canyon Unit 1 and 2 Vital Load Centers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

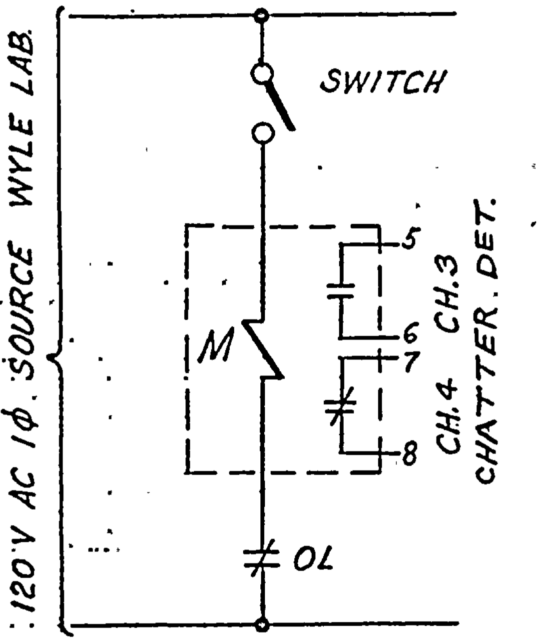


SIZE 2R CONTACTOR

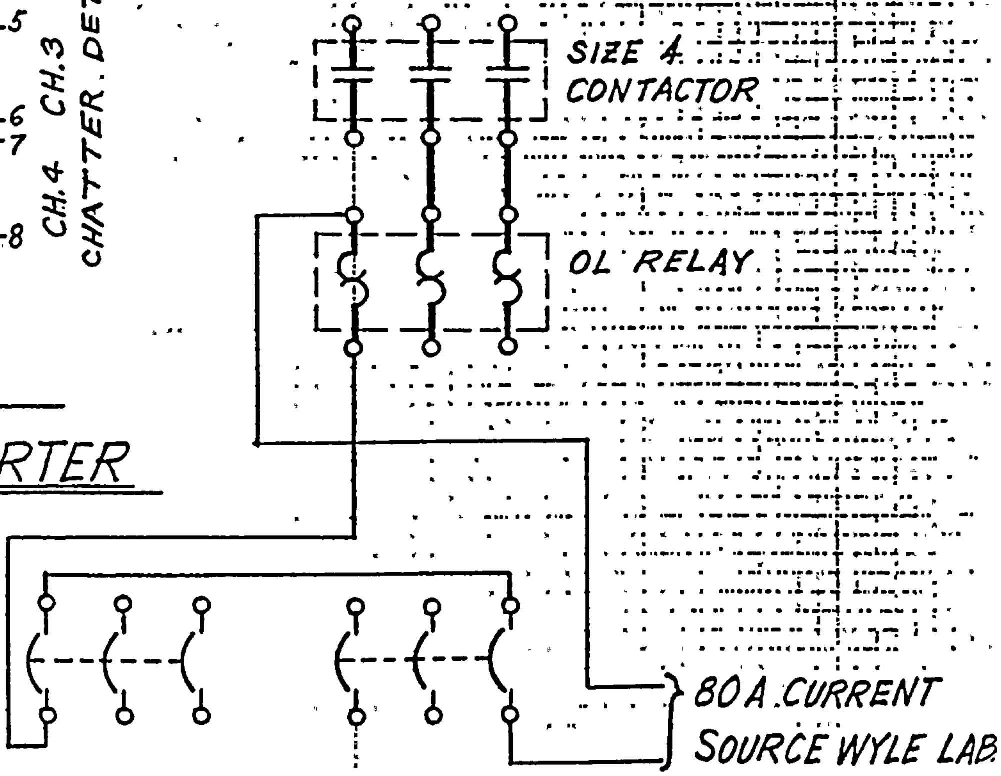
FIG. 10.3.25-1



SIZE 3 STARTER



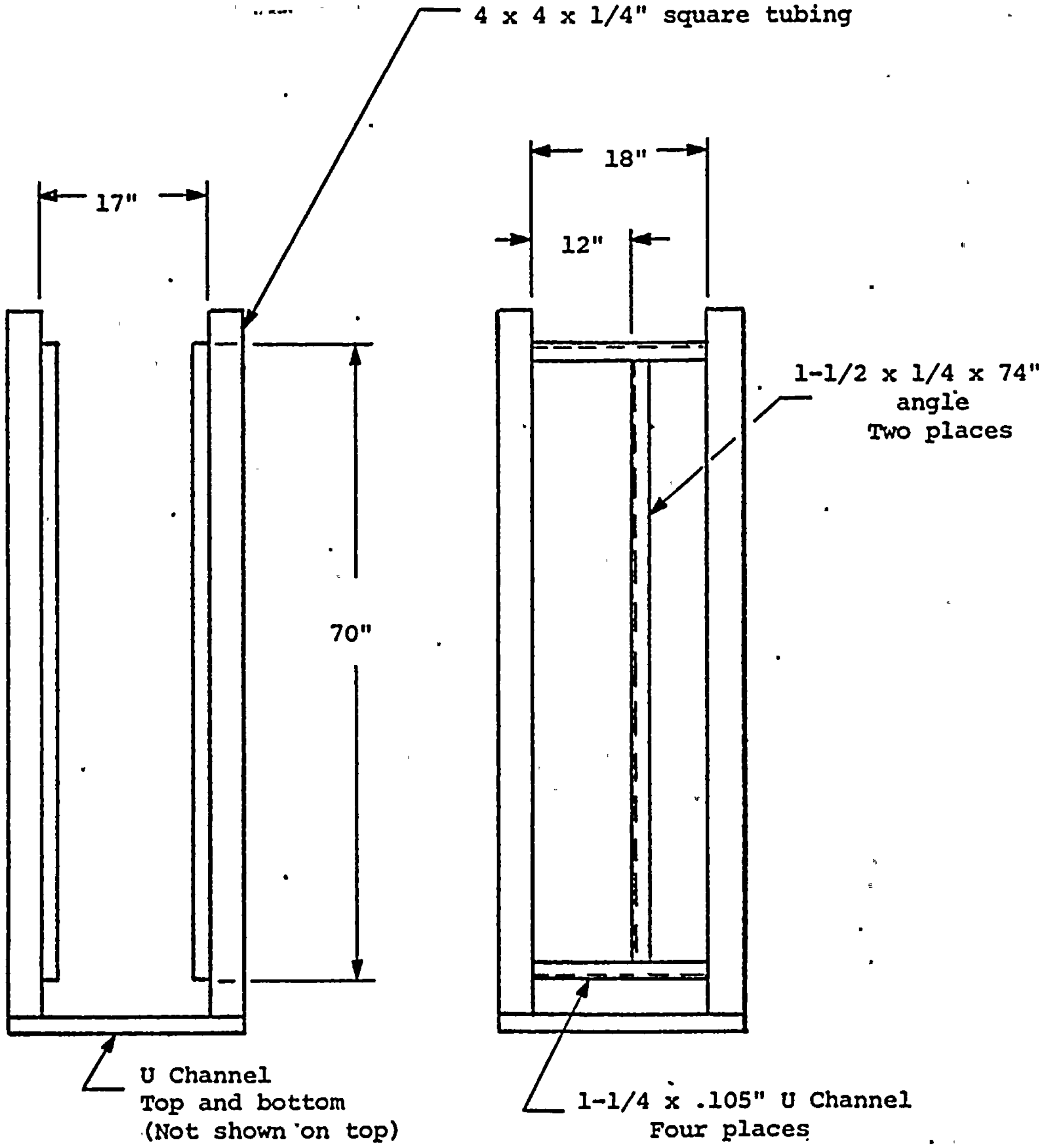
SIZE 4 STARTER



2 - 3P 100 AMP. BREAKERS

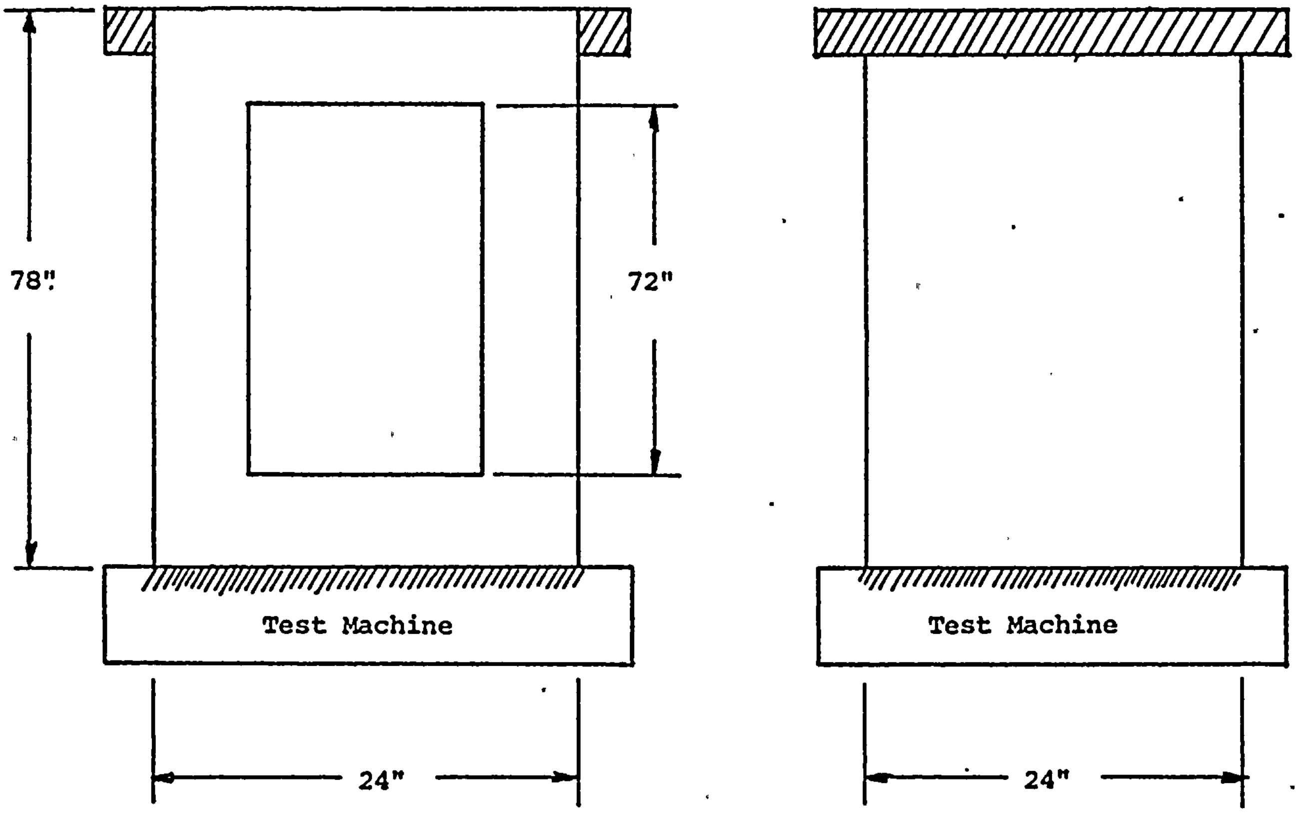
FIG. 10.3.25-2

GROUP V
VITAL LOAD CENTER
FAN COOLER STARTER - UNIT NO. 1



NOTE: Fan cooler starter from Unit 2 will be mounted on 1-1/8 x 3-3/8 x .105" angle and supported in the same fixture at top, bottom, and middle.

GROUP V
VITAL LOAD CENTER
SINGLE CELL CABINET



Test specimen will be bolted to the test machine with supports bolted at the top.

B

10.3.25A VITAL LOAD CENTER AUXILIARY RELAY PANELS

10.3.25A.1 DESCRIPTION

The Auxiliary Relay Panels are rigid sheet metal enclosures houring auxiliary relays for the 480 volt Vital Load Centers F, G & H. There is one panel per bus and each panel is mounted adjacent to its associated Vital Load Center. Relays included are control transfer, sequence timers, overcurrent by-pass and feedwater control signal isolation relays. Two sizes of panels are employed one 48 inches by 36 inches and one 48 inches by 24 inches. All are 16 inches deep.

10.3.25A.2 Safety Function

The safety function of the equipment is dependent on the relay application.

Control Transfer Relays: These relays transfer control of certain safety related equipment from the control room to the Hot Shutdown Panel. Their safety function is to stay in their normal position and maintain circuit integrity.

Sequence timers: These timers receive safeguards actuation signals and control the starting of the containment Fan Coolers. Their safety function is to actuate correctly and maintain the integrity of connections and circuits.

Overcurrent Bypass Relay: These relays provide overcurrent bypass signals for motor operated valve controllers in accordance with USNRC Regulatory Guide 1.103. Their safety function is to close on a Safety Injection Signal.

Feedwater Control Isolation Relays: These relays provide Train A and Train B isolation for start signals to the Turbine Driven Auxiliary Feedwater Pump. Their safety function is to start the AFP when required by the Solid State Protection System due to Lo-Lo Steam Generator level or Reactor Coolant Pump bus undervoltage.

10.3.25A.3 Test Criteria and Plan

The test criteria to be met in order to demonstrate that the safety function is assured during and after a Hosgri seismic event are as follows:

1. All components must remain intact and maintain circuit integrity.
2. Control transfer relays must remain in normal position and contacts must not transfer.
3. Sequence timers must pick up, time out and operate contacts normally.
4. Overcurrent bypass relays must close and remain closed.
5. Feedwater control isolation relays must close on loss of off site power. Relays need to be closed by the time the diesel generator has restored voltage to the 480 volt vital load center.

10.3.25A.4 Test Setup and Procedure

Two relay panels, one of each size, were removed from the plant and sent to Wyle Laboratories for testing.

Test Setup:

1. Mount relay panels to rigid support on test table. Mounting to simulate normal in-service attachment.
2. Connect one N.O. and one N.C. contact of relays 43X-2H-1 and 43X-2G-49 (Electroswitch LOR) to chatter detector.
3. Connect one N.O. and one N.C. contact of relays 2H1, 2-2G-64 and 2G2A (Agastat time delay relay) to chatter detector.
4. Connect one N.O. contact of relays CIAX-H and CIAX1-G (Cutler-Hammer Type M) to chatter detector.
5. Connect one N.O. and one N.C. contact of relay K632AX (Cutler-Hammer Type R) to chatter detector.

Procedure:

1. Run three OBE* tests with all relay coils deenergized.
2. Run two OBE* test with all relay coils energized.
3. Run one SSE* with all relay coils deenergized.
4. Run one SSE* with all relay coils energized.
5. Rotate equipment 90 degrees, maintaining connections and mounting and repeat steps 1, 2, 3 and 4.
6. Verify that all relays work properly and all circuits and connections have remained intact.

*All Test Response Spectra to envelope Required Response Spectra.

10.3.25A.5 Test Results

All test response spectra (TRS) are given in Wyle Test Report 58255, pages 454 to 475. All relays performed satisfactorily, exhibited no chatter and maintained all connection and circuit integrity.

The relays were not switched during the seismic test runs. Agastat timers and other similar relays have been switched during other tests and have operated satisfactorily. In addition, the forces generated by the electromagnetic operating coils excede by many times the forces generated by seismic accelerations. Seismic forces are vibratory in nature and at very short intervals pass through zero and reverse in direction which would allow or aid in relay operation.

10.3.25A.6 Conclusion:

As a result of the testing conducted as described in section 10.3.25A.4 and the results described above the Vital Load Center Auxiliary Relay Panels are seismically qualified, in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100, for service at the Diablo Canyon site.

10.3.25B FAN COOLER MOTOR CONTROLLER

10.3.25B.1 Description

The Fan Cooler Motor Controller is a two speed circuit breaker type combination motor controller. The complete controller is an integral part of the Vital Load Center described in section 10.3.26. High and low speed contactors are NEMA size 6 and 5 respectively. The equipment is mounted in full heighth section of the Vital Load Center. There are five controllers, two on Bus F, two on Bus G and one on Bus H.

10.3.25B.2 Safety Function

The safety function of these controllers is to control the flow of power to the fan cooler motors. Design calls for all fans to run on slow speed upon receiving a Safety Injection Signal (SIS). The Fan Cooler Motor Controllers are designed to switch operating fans from high to low speed and start non-operating fans at low speed upon receipt of an SIS.

10.3.25B.3 Test Plan and Criteria

One Fan Cooler Motor Controller was to be removed from each unit at Diablo Canyon sent to Wyle Laboratories for seismic qualification testing.

The test criteria to be met in order to demonstrate that the safety function is assured during and after a seismic event are as follows:

a) Circuit breaker must remain closed during and after the seismic test.

b) Slow speed controller must be capable of closing and staying closed 15 to 25 seconds after receiving an SIS.

c) Time delay relay must be capable of picking-up and timing out.

NOTE: Low speed overcurrent relay is bypassed upon initiation of SIS.

10.3.25B.4 Test Procedure and Setup

1. Remove typical Fan Cooler Controller from plant.

2. Mount controller on test table in a manner simulating field mounting. See WYLE Report 58255, Appendix 1, pg. 46.

3. Connect 440 volts through circuit breaker and contactor to 440V-6V transformer. The secondary was connected to a strip chart recorder.

4. Run three OBE tests with the controllers deenergized (open).

5. Run two OBE tests with controllers energized (closed).

6. Run two SSE tests with low or high speed controller energized (closed).

7. Run one SSE test with controller deenergized (open).

8. Rotate equipment 90 degrees and repeat steps 2 through 7.

9. Verify equipment operability prior to placing in service.

10.3.25B.5 Test Results

The Fan Cooler Motor Controllers meet the criteria specified in section 10.3.25A.3. No unwanted operation was detected during the test. All breakers and contactors stayed closed as required.

10.3.25B.6 Conclusions

The testing has demonstrated the Fan Cooler Motor Controllers are capable of providing control for the fan motors.

Although the contactors were not switched during the test there is no reason to anticipate they would not close as required as the closing forces greatly excede the seismic forces. In addition the seismic forces reverse very rapidly which would allow closure.

Size 5 contactors were switched satisfactorily during the Vital Load Center Tests. Thus it is concluded that the Diablo Canyon Unit 1 and 2 Vital Load Centers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.

10.3.8 FIRE PUMP CONTROLLER

10.3.8.1 - Description:

The Fire Pump Controller is a circuit breaker type combination motor controller. It is equipped with a manually operated bypass switch. A pressure switch is provided to automatically start the pump should low system pressure occur. The cabinet is 90 inches high by 30 inches wide by 25 inches deep.

10.3.8.2 - Safety Function

The Fire Pump Controller provides no direct reactor system safety function. The Fire Pump Controller controls the power to the fire pump motor. The fire pump provides fire system water pressure as a backup only to the reservoir. The safety function is therefore that the equipment be capable of operation after the seismic event.

10.3.8.3 - Test Criteria and Plan

The following test criteria has been established to demonstrate that the Fire Pump Controller is able to perform its safety function during and after a Hosgri seismic event:

1. The equipment should not sustain any damage which renders it inoperative:

2. The equipment should be capable of starting the fire pump after the test. Operational testing shall demonstrate this.

The seismic testing shall be multi-axis, random frequency tests conducted in accordance with IEEE Standard 344-1975 and USNRC Regulatory guide 1.100 using RRS developed for the equipment plant location. The Required Response Spectra are given in Wyle Laboratories Report 58255, Appendix I, page 18.

10.3.8.4 - Test Procedure and Set-up

One Fire Pump Controller was removed from the plant and sent to Wyle Laboratories for testing.

Set-up:

1. Mount controller on test table simulating field mounting.

2. Connect 440 volts, 1 phase to circuit breaker input.

3. Connect air pressure to pressure switch sufficient to open switch and deenergize contactor.

4. Connect the following to chatter detection: ITR(N.O.), ITR-TD(N.C.), DVR(N.C.), ICR(N.C.), 3TR(N.O.), CONTACTOR (AUX. N.O.)

5. Run five OBE and two SSE tests (reduce pressure to actuate controller prior to one OBE and one SSE)

6. Rotate equipment 90 degrees on table and repeat steps 1 through 5.

7. Test equipment to verify proper operability prior to placing in service.

10.3.8.5 - Test Results

No physical damage was observed as a result of the testing. Relays ICR, 3TR and the auxiliary contact of the main contactor demonstrated chatter during one SSE. As control power was available and no undesirable actuation occurred, the chatter presents no problem.

Functional testing has verified that the equipment is capable of starting the fire pump after the seismic test.

10.3.8.6 - Conclusions

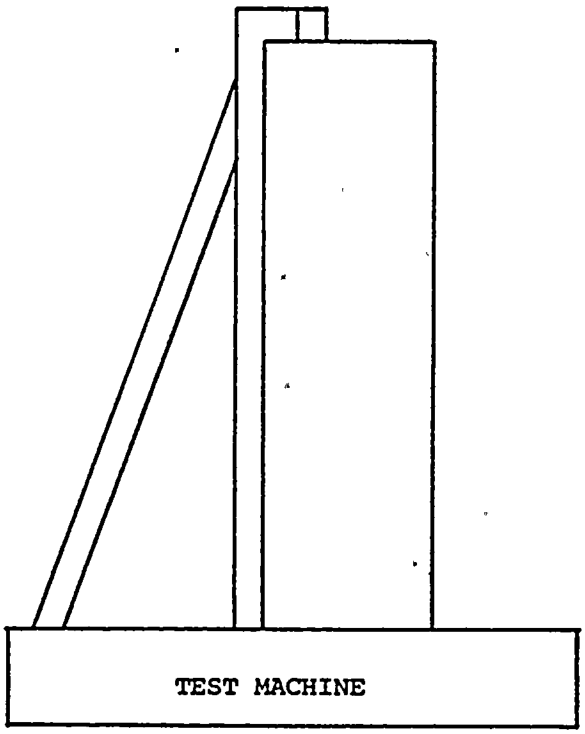
One of two Fire Pump Controllers from Diablo Canyon was tested by a multi-axis, random frequency, seismic simulation as described in Wyle Test Report 58255, pp. 217-224 and 229-234.

The test results in section 10.3.8.5 demonstrate that the test criteria specified in section 10.3.8.3 are met and thus that the equipment's safety function has been demonstrated during and after seismic testing to the RRS based on the postulated 7.5M Hosgri event.

It is therefore concluded that the Diablo Canyon Units 1 and 2 Fire Pump Controllers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and NRC RG 1.100.

GROUP IV

FIRE PUMP CONTROLLER CABINET



Test specimen will be bolted to test machine with supports bolted at the top.

10.3.14 Local Starters

10.3.14.1 Description:

Local starters are non-fused, disconnect-type combination motor controllers housed in small sheet metal enclosures. Local starters are mounted in the area of the motors they control and are fed power from the Vital 480V Load Center.

Each local starter consists of disconnect switch and motor controller. Four units control tank heaters and do not have overcurrent relays. There are a total of 18 local starters fed from the vital busses.

10.3.14.2 Safety Function:

The local starters are used to control electric power for the following functions: ventilation fans for electrical equipment, auxiliary salt water gates operators, tank heaters, lube oil pumps for component cooling water and charging pumps, and spent fuel pool pumps. None of these are required to perform any active function during any seismic event. Their safety function is, therefore, to be able to perform their design function after the seismic event.

10.3.14.3 Test Criteria and Plan:

The criteria was that the equipment should maintain its state during the seismic testing and that the equipment be capable of operation after the seismic event.

The testing was to be conducted in accordance with IEEE Standard 344-1975 and USNRC Regulatory Guide 1.100 with support accelerations greater than the RRS developed for the location of the equipment.

10.3.14.4 Test Procedure and Setup:

Representative starters were removed from the plant and sent to Wyle Laboratories for seismic testing.

Test Setup:

1. Mount starter to rigid support on table according to the applicable mounting shown in the attached Wyle Test Procedure 3642, Figs. 23, 30 and 33. This mounting simulates field mounting.

2. Connect starter auxiliary contacts, one normally open and one normally closed and also a relay contact (N.C.) to a chatter detector.

3. Connect 480 volts through disconnect switch and motor controller power contacts to 480V-6V transformer. Connect transformer output to strip chart recorder. Refer to the diagrams given in the Attachment.

Procedure:

1. Run three OBE tests with controller coils de-energized.

2. Run two OBE tests with controller coils energized.

3. Run one SSE test with controller coil de-energized.

4. Run one SSE test with controller coil energized. Repeat test for both high and low speeds on two speed starters.

5. Rotate equipment 90 degrees on table.

6. Repeat steps 1, 2, 3, and 4.

7. Verify equipment operability prior to placing in service.

10.3.14.5 Test Results:

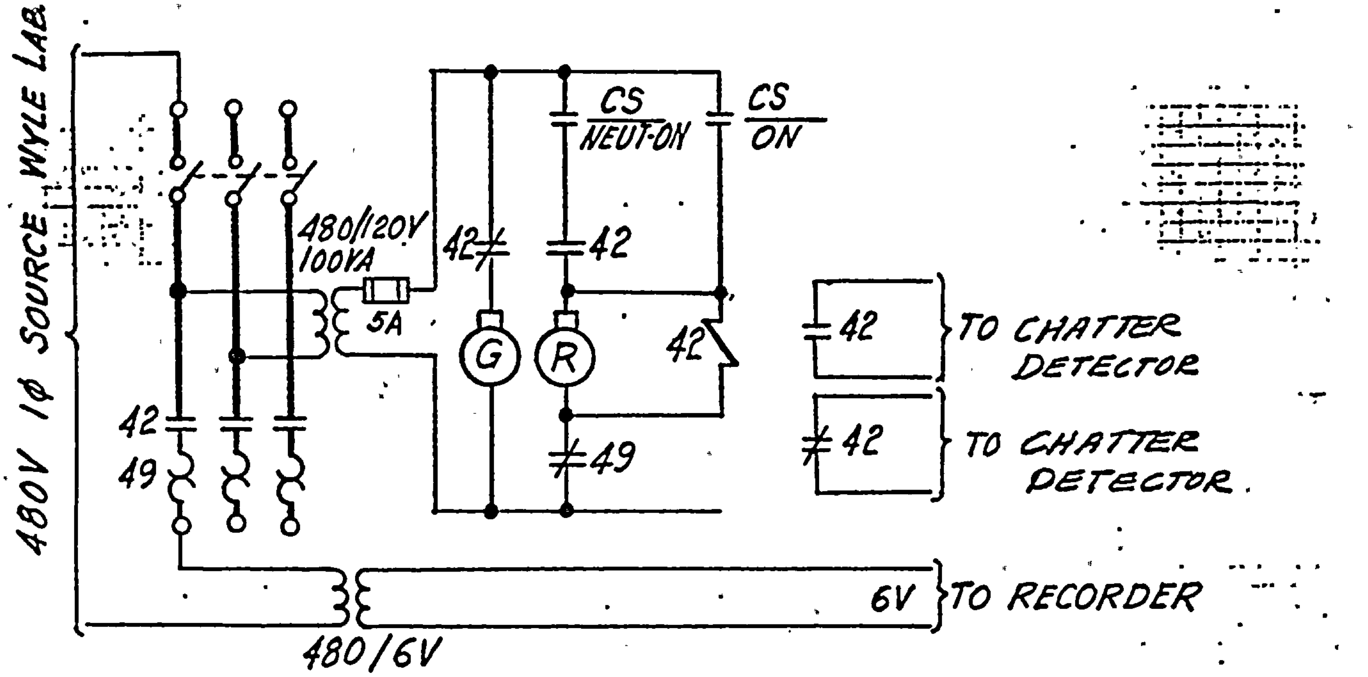
All local starters met the test criteria specified in section 10.3.14.3. No contact chatter or interruption was detected. All Test Response Spectra enveloped Required Response Spectra.

10.3.14.6 Conclusion:

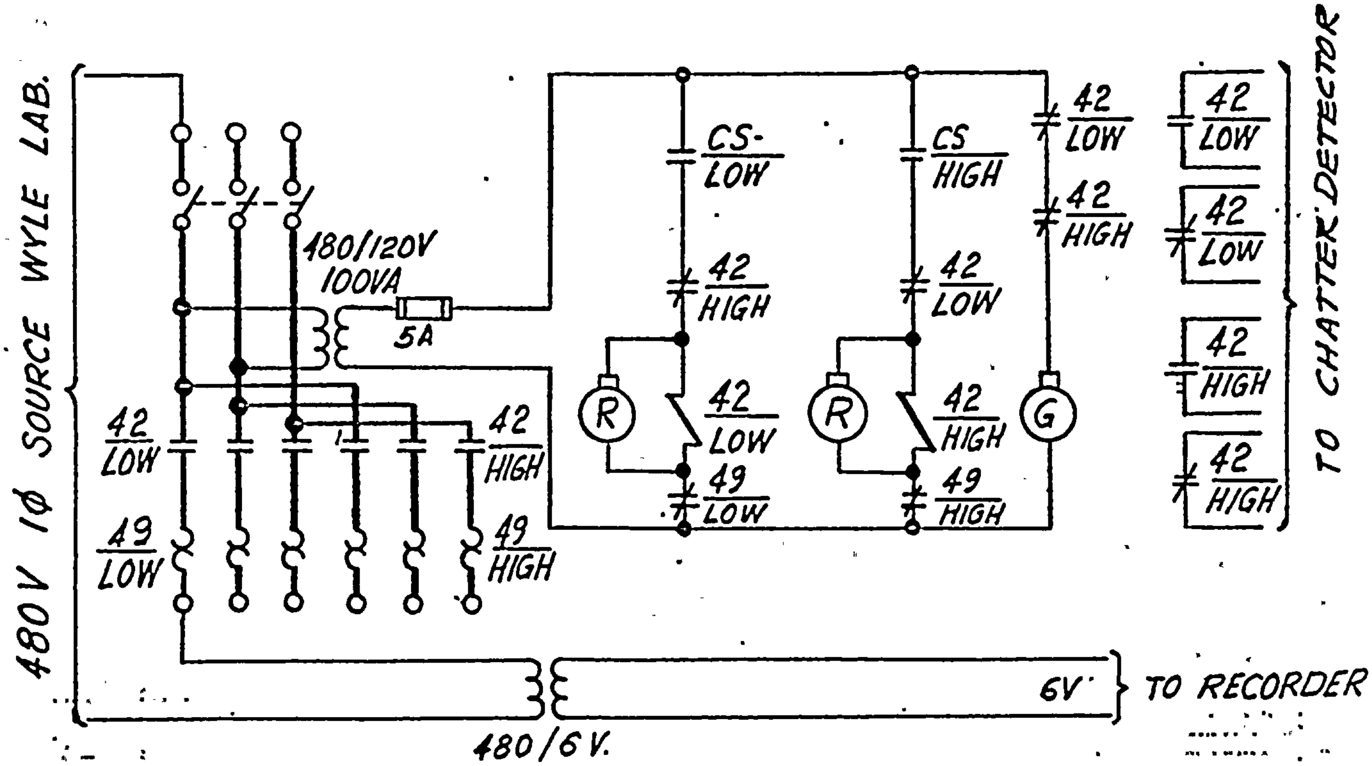
Representative local starters were tested by a multi-axis multi-frequency seismic simulation described in Wyle Report 58255.

Based on the equipment tested and the test procedure employed, these qualification tests bound the seismic requirements for all local starters.

The test results described above show that the test criteria and the equipment's safety function have been demonstrated during and after seismic testing to the RRS based on the postulated 7.4M Hosgri event. Thus it is concluded that the Diablo Canyon Unit 1 and 2 Vital Load Centers are qualified for the postulated 7.5M Hosgri event in accordance with IEEE Standard 344-1975 and USNRC R.G. 1.100.



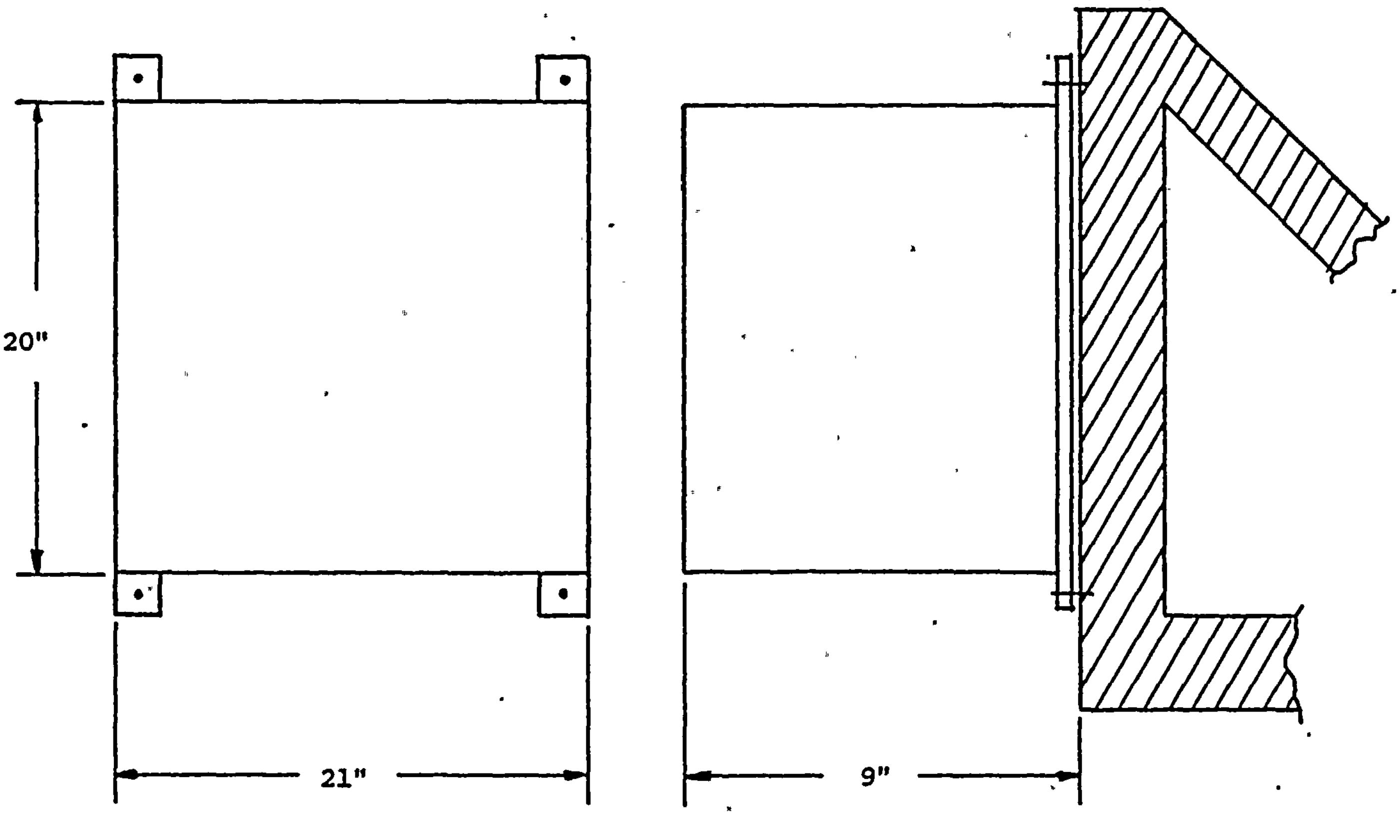
FULL VOLTAGE NON REVERSING STARTER



TWO SPEED STARTER

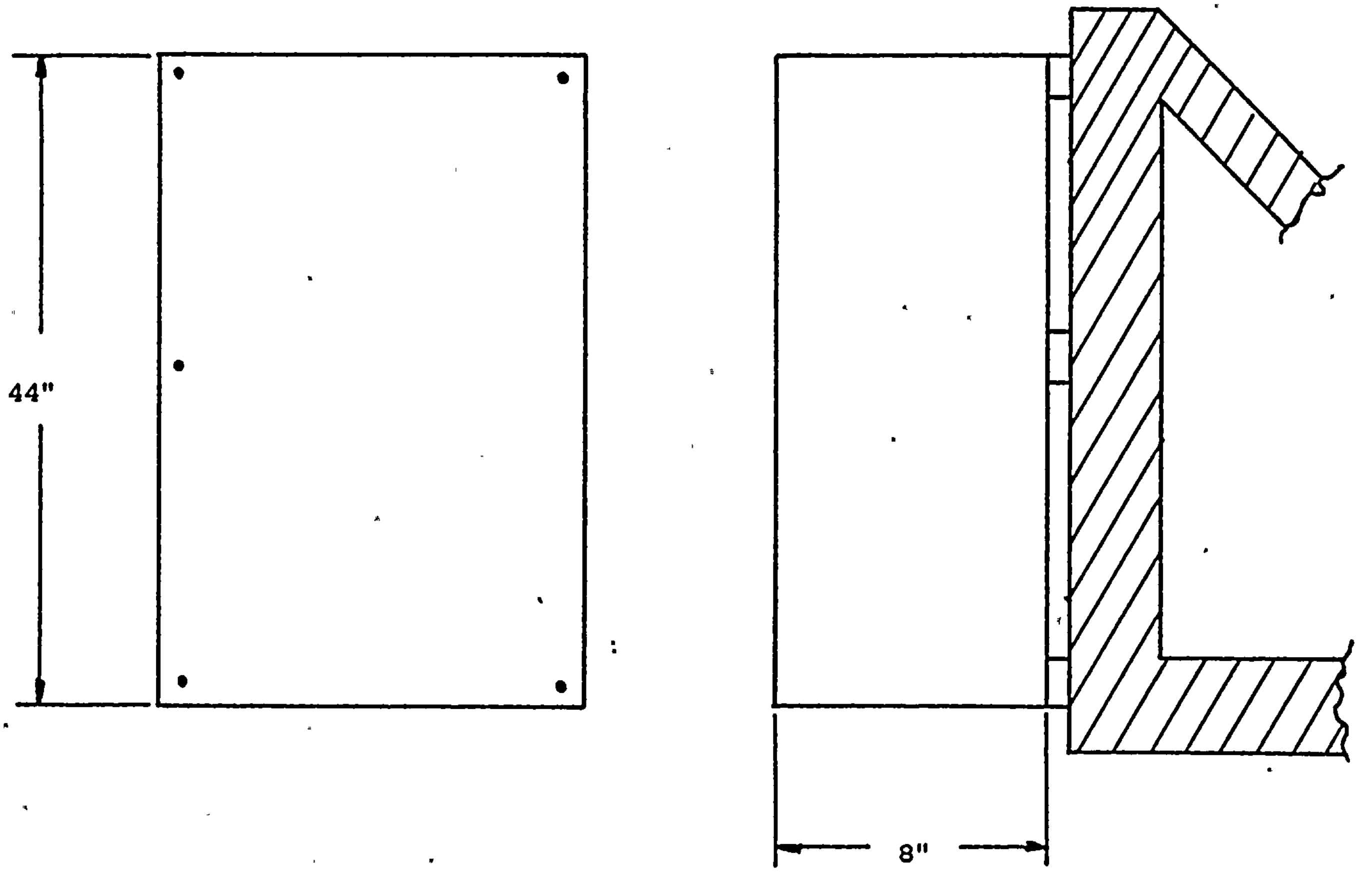
ATTACHMENT

GROUP IV
LOCAL STARTER LPF37



Test specimen bolted to fixture B

GROUP V
LOCAL STARTER LPG66

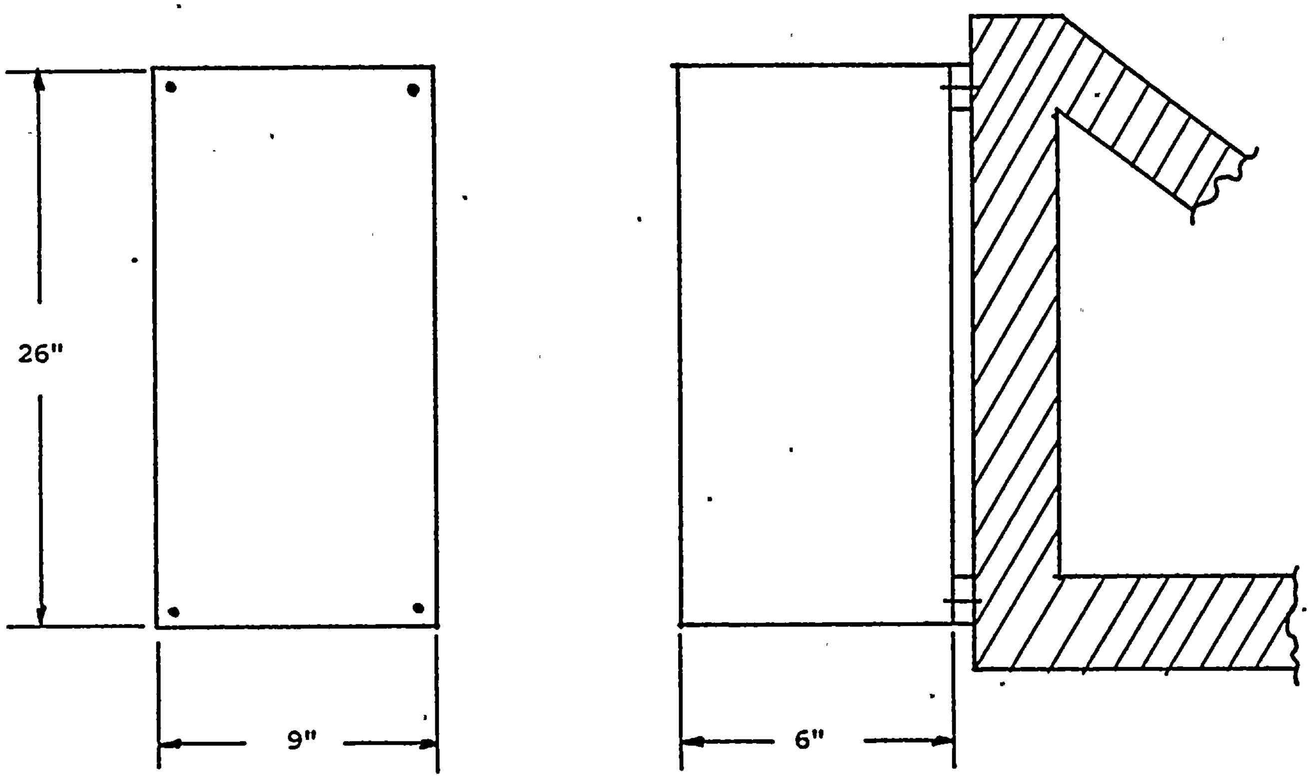


Five mounting bolts

Test specimen will be bolted to fixture.

B

GROUP VI
LOCAL STARTER LPF36



Four mounting bolts
Fixture support only
near bolts.

1. Name of Equipment Tested

Main Control Board Components tested were the following:

Vertical panel:

a) Control Switch Module, 13" deep, with one Westinghouse Type W-2 control switch and 3 indicating lights.

b) One indicating meter, Westinghouse Type VX 252

c) One selector switch, Oil Tight, Cutler-Hammer Type 10250T, 3 position, maintained right, spring return from left to center with 1 - 2 pole N.C. and 1 - 2 pole N.O. contacts.

d) One Control Switch Module, 6" deep, with Westinghouse Type OT2 control switch, 3 position, maintained right, spring return from Left to Center with one 2 pole N.C. and one 2 pole N.O. contacts, also with 1 red and 1 green indicating light.

Bench Board Section:

a) One Control Switch Module with Westinghouse Type W-2 control switch and two indicating lights.

b) One selector switch, Oil Tight, Cutler-Hammer Type 10250T, 2 Position, maintained, with 2 N.C. & 2 N.O. contacts.

c) One control switch module with Westinghouse Type OT2 control switch, two position, with 2 N.C. contacts, also with one red and one green indicating light.

2. Description of Equipment

The Main Control Board Components listed above are mounted in the Vertical Panel and the Bench Board Section of the Main Control Board. These panels are part of the all welded frame of the MCB. The panels are .25 inch thick steel.

3. Safety Function

None of these components perform an automatic safety function. The safety function of these Main Control Board switch components is to remain in the normal operating position or the maintained position, during a seismic event.

The indicating meter is used for indicating class I levels (i.e., Steam Generator level, etc.). Its safety function is to maintain its reading during a seismic event.

4. Test Criteria and Plan

The test criteria for the Main Control Board Switches and indicating meter and lights are that they perform their safety function during and after a seismic event. The components shall demonstrate as follows:

1. The control and selector switches shall maintain their position and continuity of contacts in:

   a) Mode 1, Switches in position turned too far left, counterclockwise, and allowed to come to rest in their normally position left turn, or their spring return to center position left turn, or their spring return to center position.

   b) Mode 2, Switches in position turned too far right, clockwise, and allowed to come to rest in their normally positioned right turn position or spring return to center position.

2. The switch modules shall maintain their structural integrity during the tests.

3. The indicating meter shall maintain its mid-scale readings.

4. The Switch contacts shall be monitored for chatter, if any, during the seismic tests.

5. Test Procedure and Setup

1. Mount the switches and meter on the seismic table in the same configuration as in the Main Control Board in the Auxiliary building 140' Elevation.

2. Connect the Normally Open, (N.O.) contacts, of the switches to chatter detection with approximately two volts across the contacts.

3. Connect the Normally Closed, (N.C.) contacts of the switches to the chatter detector with approximately 1.5 microamps flowing.

4. Set the chatter/transfer detector to monitor 2 milliseconds or greater change of state.

5. Connect the meter to a power supply and visually observe the meter.

6. Test Results

The switches and meter were run through the series of seismic tests with the following results:

1. During the 1st, 2nd, 3rd OBE's and the 2nd SSE in both X-Y and Z-Y axis the switches were tested in Mode 1 without any contact chatter of the N.O. or N.C. contacts.

2. During the 4th, 5th OBE's and the 1st SSE in boty X-Y and Z-Y axis the switches were tested in Mode 2 without any contact chatter of the N.O. or N.C. contacts.

3. The switch contacts, N.O. or N.C., are tabulated below:

4. The switches and modules retained their structural integrity.

5. The indicating Meter maintained its mid-scale readings during and after the seismic tests.

Switch	Mode 1		Mode 2	
	N.O.	N.C.	N.O.	N.C.
Vertical Panel				
Westinghouse Type W-2 in 13" deep module	O	C	C	O
Cutler-Hammer Type 10250T Oil Tight	O	C	C	O
Westinghouse Type OT2 Oil Tight in 6" deep module	O	C	C	O
Benchboard Section				
Westinghouse Type W-2	O	C	C	O
Cutler-Hammer Type 10250T Oil Tight	O	C	C	O
Westinghouse Type OT-2	O	C	C	O

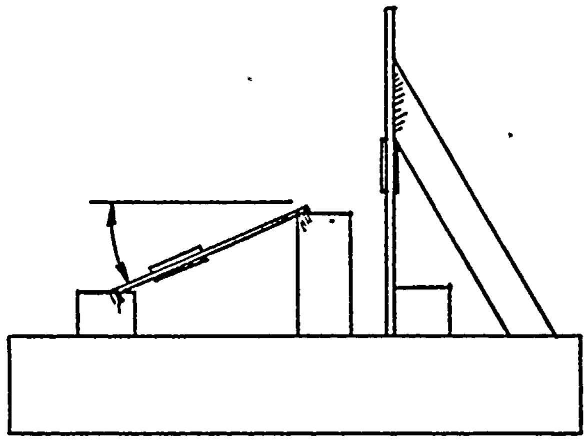
6. The switches operated as required after the test.

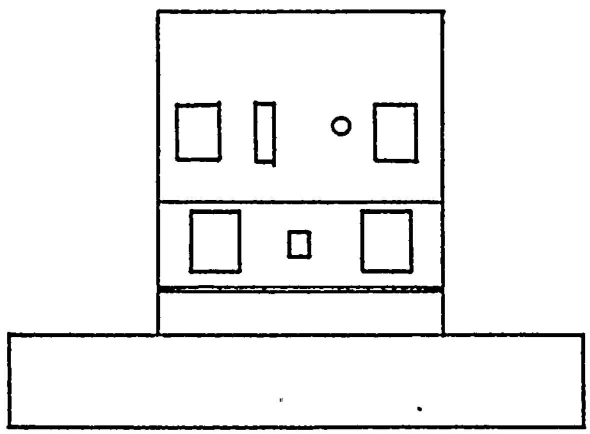
7. Test documentation is shown in Wyle Report 58255 dated April 19, 1978 on pages 509 through 529.

7. Conclusions

The test results show that the items tested perform their safety function under Hosgri seismic criteria and meet the requirements of IEEE Std. No. 344-1975, and USNEC Regulatory Guide 1.100.

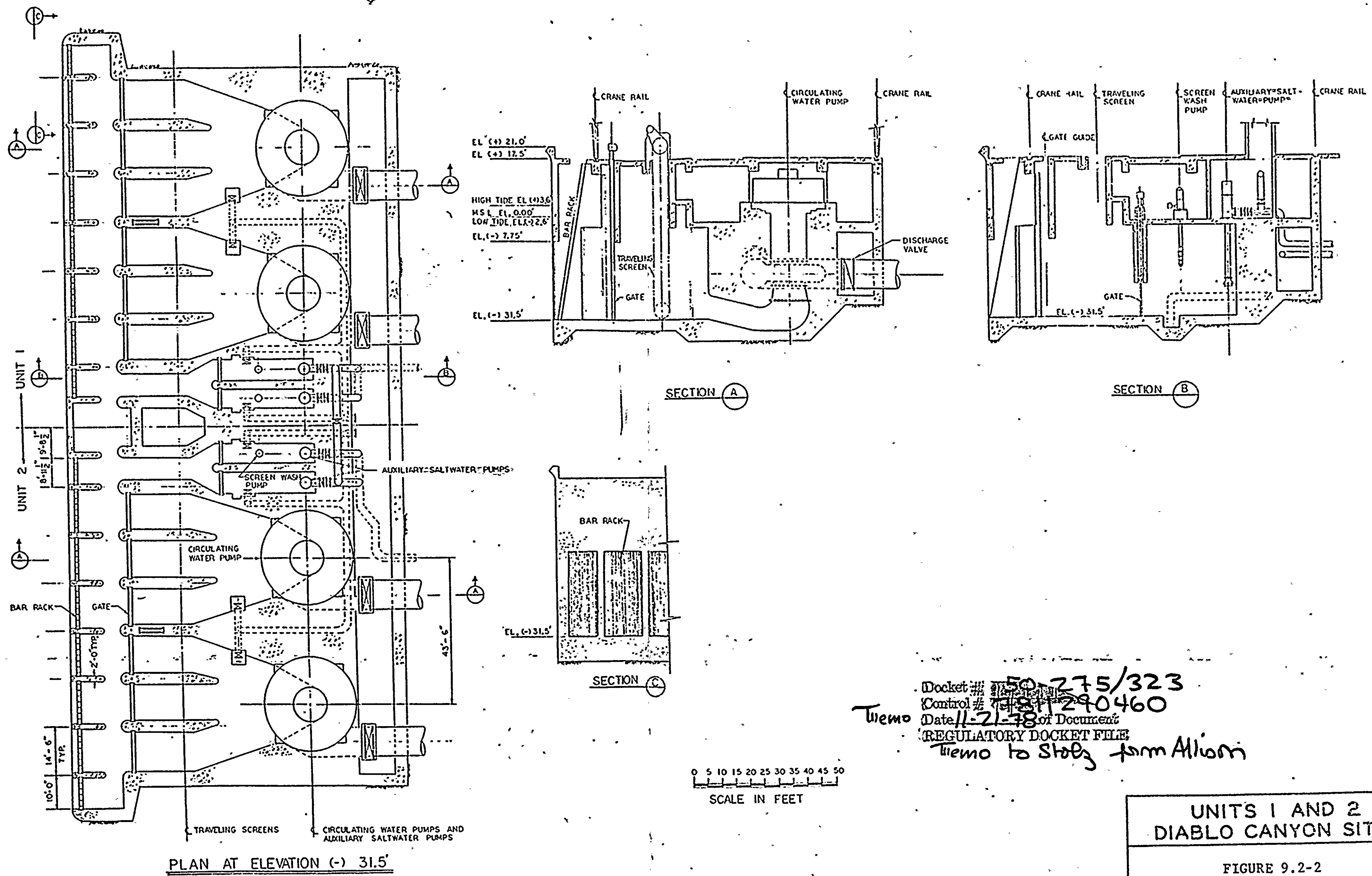
GROUP VII - Switches and Ammeter





Test specimens will be secured in the 1/4-inch steel plate using the in-service hardware.

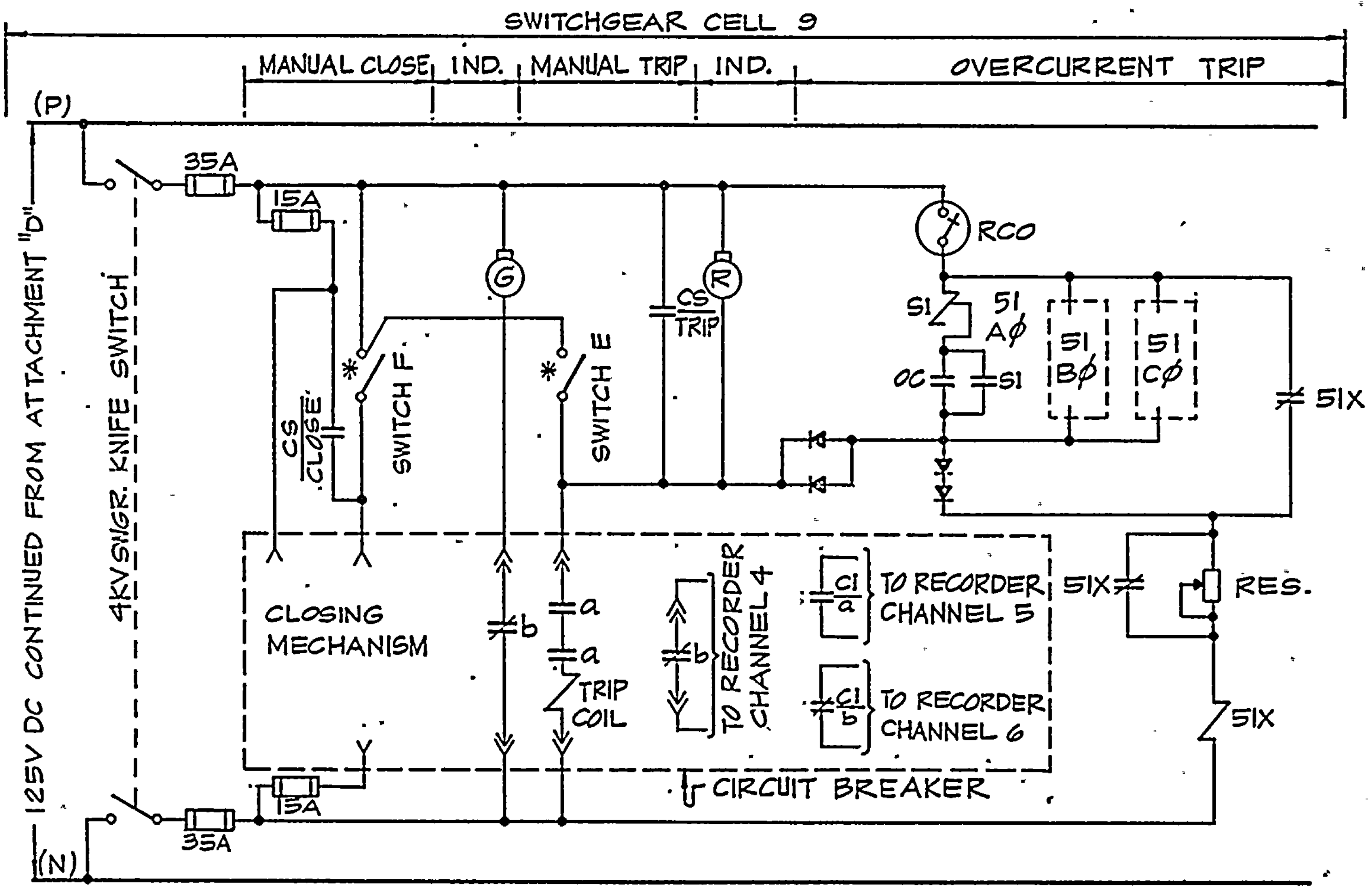
#12



Docket # 50-275/323
Control # 7811290460
Memo Date 11-21-78 of Document
REGULATORY DOCKET FILE
Memo to Stolz from Allison

UNITS 1 AND 2
DIABLO CANYON SITE

FIGURE 9.2-2
ARRANGEMENT OF INTAKE STRUCTURE



* LOCATED AT TEST BENCH

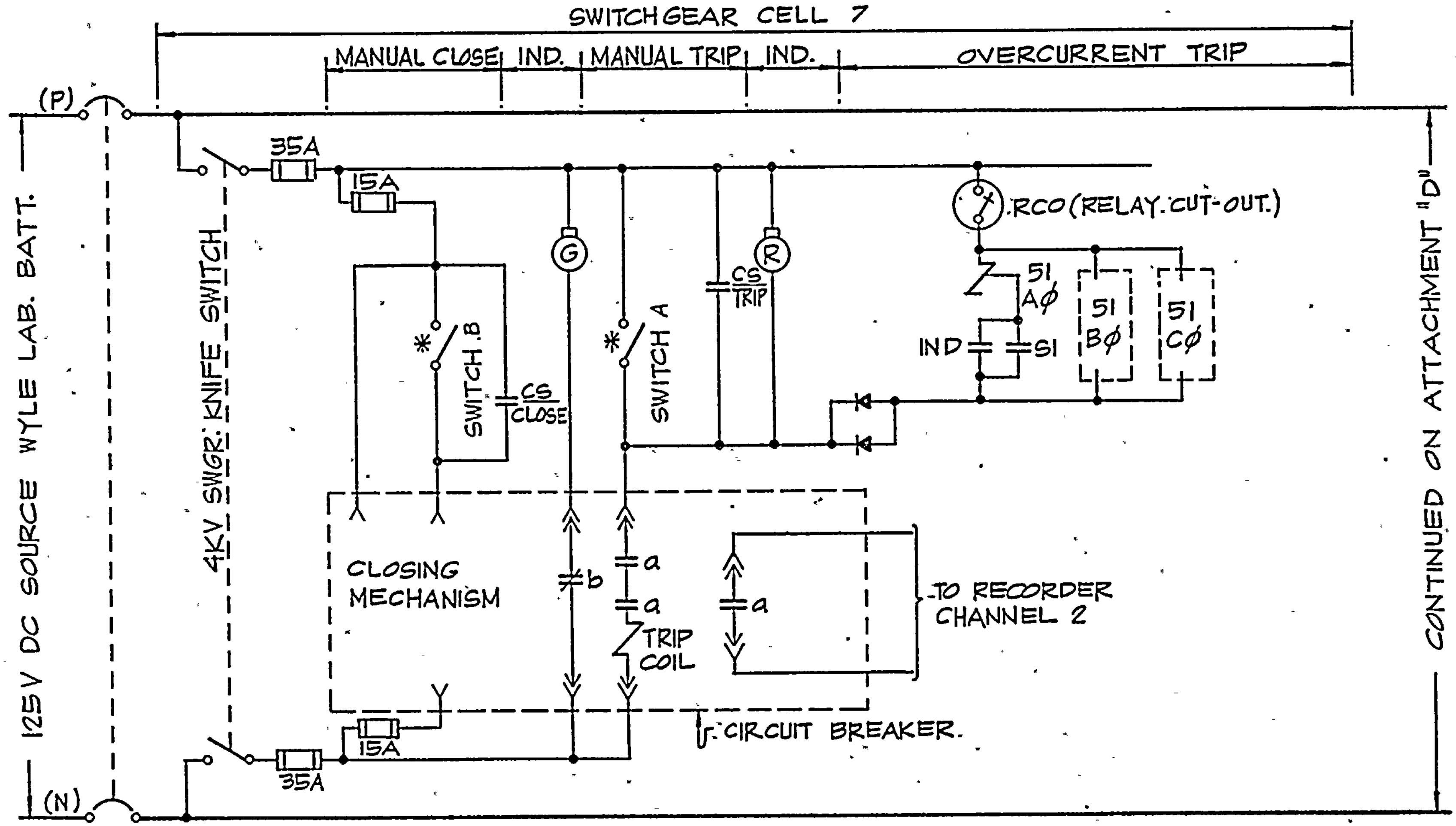
#13

7811290460

ATTACHMENT "E"

REV. CHANGE SW. DESIGNATIONS E TO F & F TO E

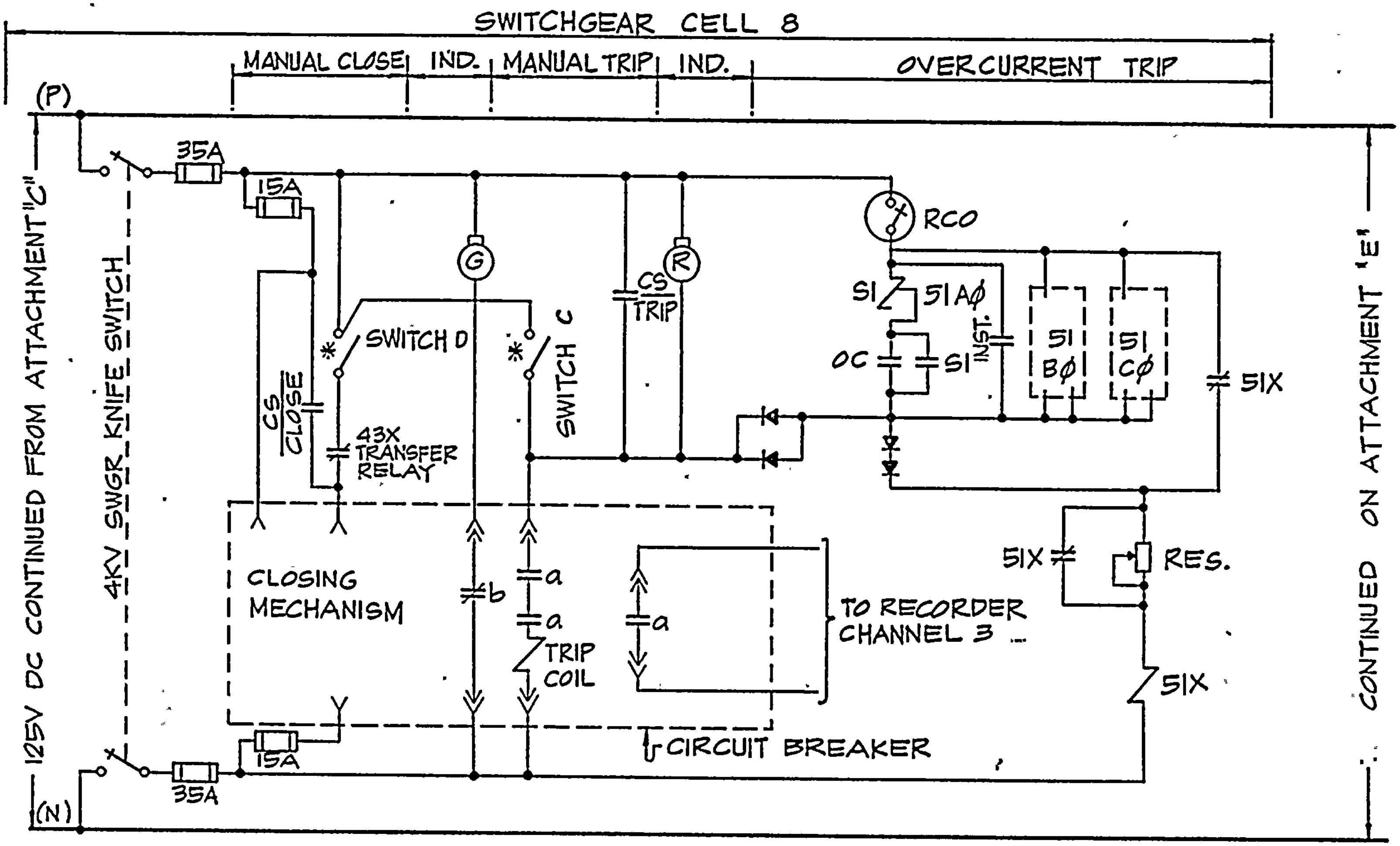
[illegible]
[illegible]
[illegible]
[illegible]



* LOCATED AT TEST BENCH

ATTACHMENT "C"

REV. CHANGE SW. DESIGNATION A TO B & B TO A



* LOCATED AT TEST BENCH .

ATTACHMENT "D"

REV. CHANGE SW. DESIGNATIONS C TO D & D TO C

#14

10.3.21.6 Test Results

With the exception of anomalies discussed below for certain relays, all relays met the test criteria specified in Section 10.3.21.4 above during and after the seismic testing while being operated per the test procedure described in Section 10.3.21.5 above. It is worthy of note that the equipment was subjected to more than the minimum number of test runs for qualification, demonstrating margin in the equipment's resistance to seismic damage.

Contact chatter was documented on the Contact Chatter Log Data Sheet, WYLE's Test Report No. 58255-1, pages 28 and 29. Of the runs listed, runs 4 through 8 met our front to back OBE conditions; runs 10 through 13 met our front to back SSE conditions; runs 17, 18, 20, 21, and 22 met our side to side OBE conditions; and runs 24 through 27 met our side to side SSE condition.

Chatter indicated on Channel 7 is caused by the 59HHG1&2 relay which is not part of the relay board and for that reason need not to be addressed here.

-Channel 1, 87XHH7 Differential Auxiliary Relay, Runs 11, 18, and 25.-

The relay contact chattered only after it had performed its safety function, namely the tripping of the connected 4.16 kV switchgear breaker.

-Channels 2 and 3, 32XHH7 and 40XHH7 Auxiliary Relays, Runs 10 through 14.-

Momentary change of state of the contacts of the 32XHH7 auxiliary relays was observed during a portion of the testing. This was demonstrated to be pulsation of these relays due to chatter of the prime relays 32HH7 (Reverse Power Relay) and 40HH7 (Loss of Field Relay) since the anomaly did not occur when the cut out switches for the prime relays had been opened. This anomaly would not occur in the event of a seismic event during plant operation, since these relays are normally cut out.

Note that relays 32XHH7 and 32YHH7 are housed in one case and that they are connected in parallel. For that reason all comments apply to both relays simultaneously. The same applies to relays 40XHH7 and 40YHH7.

-Channel 6, 27ZHHB2 Relay.-

During the testing, pulsation of the 27ZHHB2 relay, caused by chatter of the deenergized 27HHB2 relay was observed. Testing performed on the 4.16 kV switchgear (see Section 10.3.26) has demonstrated that pulsations of the 27ZHHB2 relay will not prevent the pickup of the 5HH13 relay, and thus will not compromise the safety function of power transfer of the 4160V bus from the station auxiliary transformer to the stand-by start-up transformer, and if necessary to the diesel generators.

Momentary chatter of the 27ZHHB2 auxiliary relay during runs 10, 11 and 13, when the 27HHB2 prime relay was not deenergized, can be traced back to the high ZPA level of the SSE test runs. During a high level seismic event, the seismic protection system will cause the plant to shut down. The 4160V safeguard buses would then transfer to the stand-by start-up source. Chatter of relay 27ZHHB2 would only expedite this transfer.

The evaluation of the strain gage traces showed that the structural members of the relay board were exposed to stresses well within their design limits.

No physical damage to the relay board or its devices was observed.

#16 Intake Str. A 5 (Supplement)
SER #1, 3.8.5.4.4 (4)

Memo did 11-21-78 Memo to Stolz From Allison

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130 Jessie Street (at New Montgomery)
San Francisco, California 94105

JOB NO. 7302-19	JOB DIABLO INTAKE	BY DLL	DATE 10-2-78
CLIENT P.G.&E.	SUBJECT STABILITY	CHK'D	DATE

SHEET NO.

SUPPLEMENT TO SLIDING ANALYSIS. 8.1.78

THE 8.1.78 ANALYSIS OF FACTORS OF SAFETY AGAINST SLIDING FOR THE INTAKE STRUCTURE IS HEREIN REVISED TO INCLUDE THE RESTRAINING FORCES PROVIDED BY THE REINFORCED CONCRETE CONDUITS EXTENDING FROM THE INTAKE STRUCTURE TO THE TURBINE BUILDING. THE RESTRAINING FORCE AMOUNTS TO THE TOTAL TENSILE CAPACITY OF THE LONGITUDINAL BARS IN THE CONDUIT. TWO CASES (SAME AS 8.1.78) WERE STUDIED:

(1) INCLUSION OF SKIN FRICTION AS A RESISTING FORCE, WHILE COMBINING THE MAXIMUM VERTICAL AND HORIZONTAL EARTHQUAKE COMPONENTS

(2) EXCLUSION OF SKIN FRICTION, COMBINING 40% OF THE VERTICAL COMPONENT WITH THE MAXIMUM HORIZONTAL COMPONENT.

BOTH CASES YIELDED FACTORS OF SAFETY AGAINST SLIDING OF 1.17, QUITE ADEQUATE CONSIDERING THE ABSOLUTE SUM OF STATIC AND DYNAMIC SOIL PRESSURES WITH DYNAMIC STRUCTURE FORCES IN COMPUTING SLIDING FORCES.

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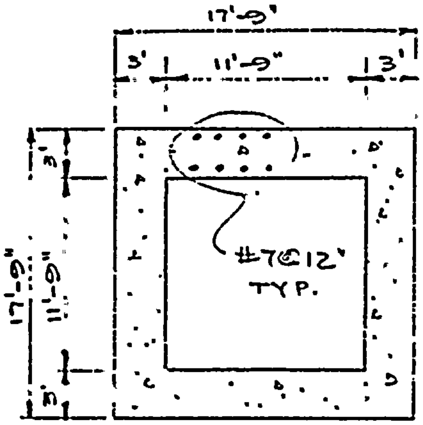
JOB NO. 0902-19	JOB DIABLO INTAKE	BY DAL	DATE 10-2-78	SHEET NO.
CLIENT P.G.&E.	SUBJECT STABILITY	CHK'D	DATE	

SLIDING ANALYSIS

ASSESS THE EFFECT OF THE REINFORCED CONCRETE INTAKE CONDUITS ON THE RESISTANCE TO SLIDING FOR THE INTAKE STRUCTURE.



TYPICAL SECTION
(ONE OF FOUR)

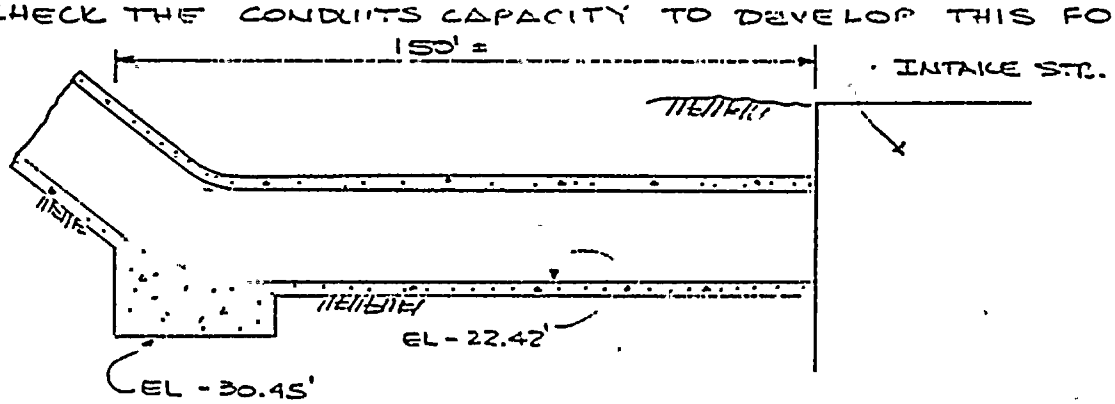
TOTAL NO. OF BARS (LONGITUDINAL) IN CONDUIT SECTION

$4(17.75) + 4(11.75) = 118$ - #7 BARS

TOTAL TENSILE CAPACITY

$118 \times 40\text{KSI} \times 0.60\text{IN}^2 = 2832$ KIPS.

CHECK THE CONDUITS CAPACITY TO DEVELOP THIS FORCE.



PROFILE OF CONDUIT
(TYPICAL)

SLIDING ANALYSIS (CONT)

TOTAL WEIGHT OF 150' OF CONDUIT

CONDUIT	$(17.75^2 - 11.75^2)(150')(0.15)$	=	3982.5^k
KEY	$5' \times 17.75' \times 40' \times 0.15$	=	532.5^k
		TOTAL	4515^k

COMPUTE FRICTION FORCE ($\phi = 30°$)

$$W \tan\phi = 4515 \tan 30° = 2607^k$$

THE KEY SHOWN ON THE PREVIOUS PAGE COULD EASILY RESIST THE DIFFERENCE BETWEEN THE FRICTION FORCE (2607^k) AND THE TENSILE CAPACITY OF THE CONDUIT REINFORCING (2832^k)

ASSESS THE EFFECT OF THE CONDUITS ON THE FACTOR OF SAFETY AGAINST SLIDING.

2832 KIPS × 4 CONDUITS = 11328 KIPS

APPLYING THIS RESISTING FORCE TO THE TWO CASES EXPLORED IN STABILITY CALCULATIONS DATED 8.1.78

(1)

TOTAL RESISTING FORCES = $72528 + 11328 = 83856^k$

TOTAL SLIDING FORCES = 71902^k

FACTOR OF SAFETY = 1.17

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CLIENT P.G.&E	SUBJECT STABILITY	CHK'D	DATE		

SLIDING ANALYSIS (CONT)

(2) FOR THE CASE SUGGESTED BY DR. NEWMARK (NO SKIN FRICTION; 40% OF THE VERTICAL EARTHQUAKE SIMULTANEOUS WITH THE MAXIMUM HORIZONTAL EARTHQUAKE)

TOTAL RESISTING FORCES = 73015 + 11328 = 84343^k

TOTAL SLIDING FORCES = 71902^k

FACTOR OF SAFETY = 1.17

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SHEET NO. 1

JOB NO. 2992-26 JOB DIABLO INTAKE BY DAL DATE 8-1-79

CLIENT P.G.&E. SUBJECT STABILITY CHK'D DATE

SUPPLEMENT TO STABILITY ANALYSIS 3/31/78

IN THE PREVIOUS STABILITY ANALYSIS FOR THE INTAKE STRUCTURE, DATED 3/31/78, AN ASSUMED FRACTURE SURFACE FOR THE ROCK WAS USED TO CALCULATE THE RESISTING FORCES TO SLIDING. THAT FRACTURE SURFACE ASSUMED A 45° SURFACE NEAR THE CENTER OF THE STRUCTURE WHERE THE SHEAR KEY IS NON-EXISTANT. THIS ASSUMED FRACTURE SURFACE IS SHOWN ON SHEET 3 OF THE REFERENCED CALCULATIONS.

THE ENCLOSED PAGES PRESENT A REVISED PROCEDURE FOR CALCULATING SLIDING RESISTANCE. THIS PROCEDURE UTILIZES THE "PATH OF LEAST RESISTANCE" AS AN ASSUMED FRACTURE SURFACE. THE RESULT IS A LOWER VALUE FOR TOTAL SLIDING RESISTANCE OF THE STRUCTURE.

AT THE SAME TIME, THE CONSERVATIVE ASSUMPTION OF THE WATER TABLE AT THE TOP OF THE STRUCTURE WAS REVISED TO REFLECT THE ACTUAL ELEVATION OF THE WATER TABLE. THE RESULT IS A LOWER SLIDING FORCE. THE CALCULATED FACTORS OF SAFETY AGAINST SLIDING ARE UNCHANGED FROM THE PREVIOUS ANALYSES.

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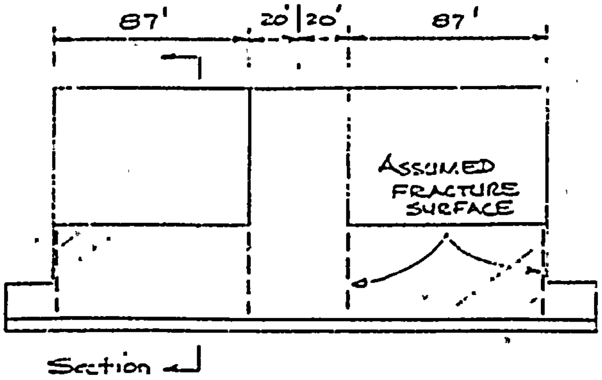
SHEET NO. 2

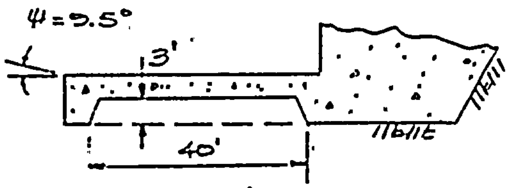
JOB NO. 0902.76 JOB DIABLO INTAKE BY DAL DATE 8.1.78

CLIENT P.G.&E. SUBJECT STABILITY CHK'D DATE

SLIDING



PLAN



Section

RESISTING FORCES

1) $W' \tan\phi = 38{,}450^k(\tan 30°) = 22{,}199^k$

2) $S_u \times$ AREA FRACT $= (3.0\,\text{KSF})(2\times87\times40 + 4\times40\times3) = 22{,}320^k$

3) $\tfrac{1}{2}\tan 9.5°(W') = \tfrac{1}{2}(\tfrac{1}{6})(38{,}450) = 3204^k$

4) PASS. PRESS. $= (6\,\text{KSF})(7')(239.33') = 10{,}052^k$

5) SOIL FRICTION ON SIDES (NO DYN. SOIL IN N-S DIRECTION) $= 2(\tan\phi)(0.09(\tfrac{1}{2})52^2\times105) = 14{,}753^k$

TOTAL $= 72{,}528^k$

BASE SHEAR

BASE SHEAR FROM EQ

BLUME	23536^k	+	6820^k	=	30356^k	→ 30356^k
NEWMARK	21077^k (pedestal)	+	6535^k (walls)	=	27612^k	

SOIL PRESSURES

STATIC : $P = 0.090(1/2)(36)^2 \times 238' = 13880^k$

SEISMIC : $P = (0.086)(36')^2 \times 238' = 26526^k$

$(0.014)(18.5)^2 \times 238' = 1140^k$

TOTAL = 71902^k

FACTOR OF SAFETY
AGAINST SLIDING $= \frac{72,528}{71,902} = 1.01$

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San Francisco, California 94105

SHEET NO. 4

JOB NO. 0302.26 JOB DIABLO INTAKE BY DAL DATE 8.1.76

CLIENT P.G.&E. SUBJECT STABILITY CHK'D DATE

SLIDING

AT THE SUGGESTION OF DR. NEWMARK, AND COMPLYING WITH THE OBJECTIONS OF THE NRC STAFF REGARDING THE USE OF SKIN FRICTION AS A RESISTING FORCE, THE ANALYSIS WAS REVISED TO INCLUDE A 40% VALUE OF THE VERTICAL ACCELERATION (0.4 x 0.5g = 0.2g) AND NEGLECTING THE EFFECT OF SKIN FRICTION FROM EARTH PRESSURE.

NET WEIGHT = $76,897^k$

$W' = 0.8W = 0.8(76,897) = 61518^k$

RESISTING FORCES

1) $W' \tan \phi = 61518^k(\tan 30°) = 35517^k$

2) S_u x AREA FRACT = $(3.0 \text{ KSF})(2 \times 87' \times 40' + 4 \times 40' \times 3') = 22320^k$

3) $\frac{1}{2} \tan 9.5° (W') = \frac{1}{2}(\frac{1}{6})(61518^k) = 5126^k$

4) PASS. PRESS = $6 \text{ KSF} (7')(239.33') = 10052^k$

TOTAL = 73015^k

SLIDING FORCES

71902^k (FROM SHEET 3)

FACTOR OF SAFETY AGAINST SLIDING $= \dfrac{73015^k}{71902^k} = 1.02$

DECOUPLING OF THE REACTOR PRESSURE
VESSEL WITH THE SUPPORTING INTERIOR CONCRETE STRUCTURE

To further substantiate that the coupling effect is small at the Reactor Pressure Vessel (RPV) elevation, two floor response spectra (Figures 1 and 2) have been generated for a decoupled interior concrete structure model and a coupled RPV and the interior concrete structure model, respectively.

The interior concrete structure model is idealized, from the Diablo Canyon design, by a five mass stick. The RPV model is a simplified one degree-of-freedom system where its natural frequency matches with the fundamental mode of the Diablo Canyon vessel. The RPV model is attached to Node 2 of the interior concrete structure model at the vessel support elevation by the spring of the vessel model.

The time history input used is a synthesized time history which is consistent with the Blume's Hosgri response spectra.

As can be seen from Figures 1 and 2, floor response spectra for the decoupled (Figure 1) and the coupled (Figure 2) model are very similar, indicating that the coupling effect at this low elevation is very small. More importantly, a close examination shows that the response spectral magnitudes of the decoupled model (Figure 1) is consistently higher than the coupled model (Figure 2) in between 0.05 to 0.40 seconds, and is equal at all other natural periods. This shows that indeed the decoupled model is more conservative.

In summary, the floor response spectra generated using the Diablo Canyon design fully demonstrates that the decoupled analysis conducted is conservative.

FCCGI E/F1
Fig. 1 W/O RFV
TH-3

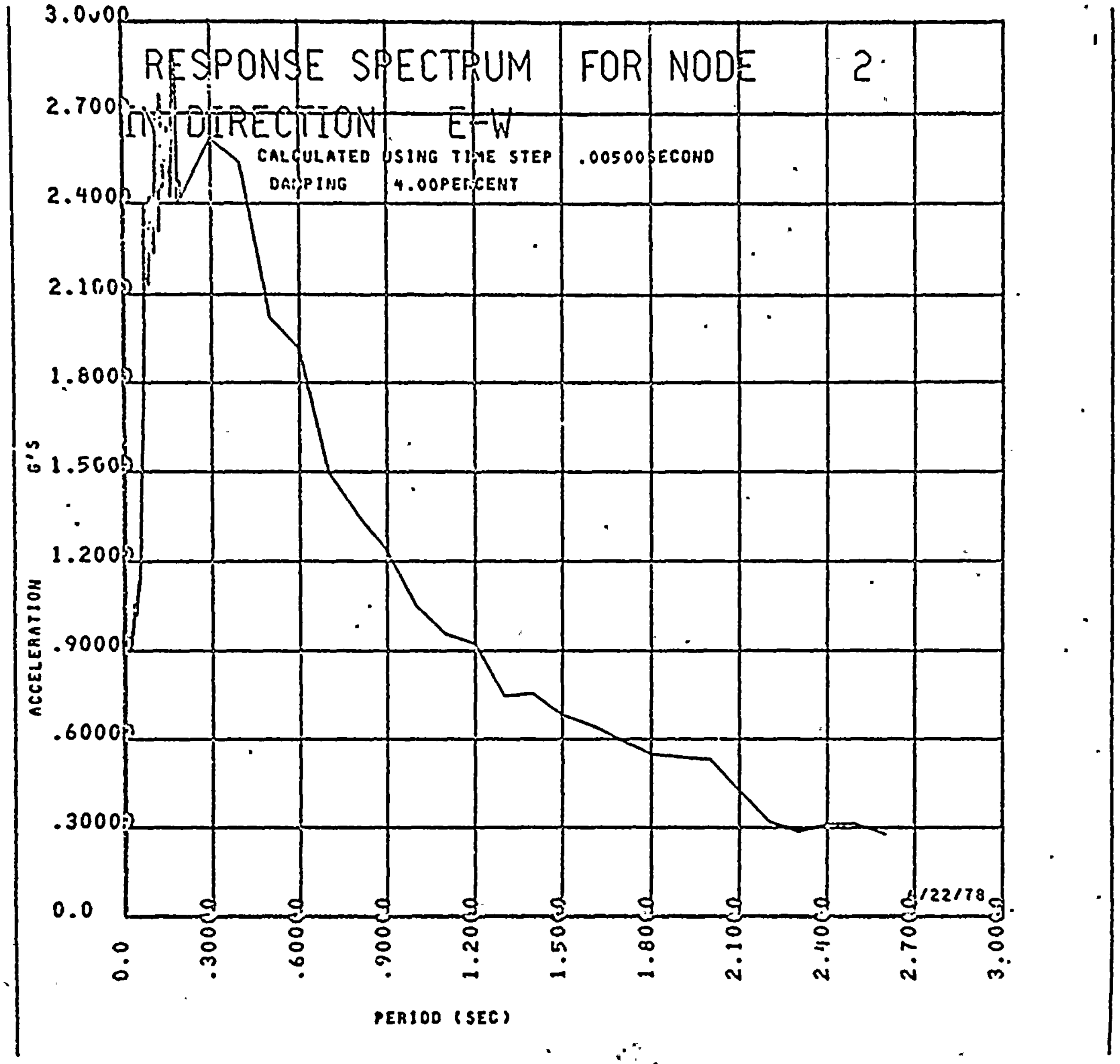
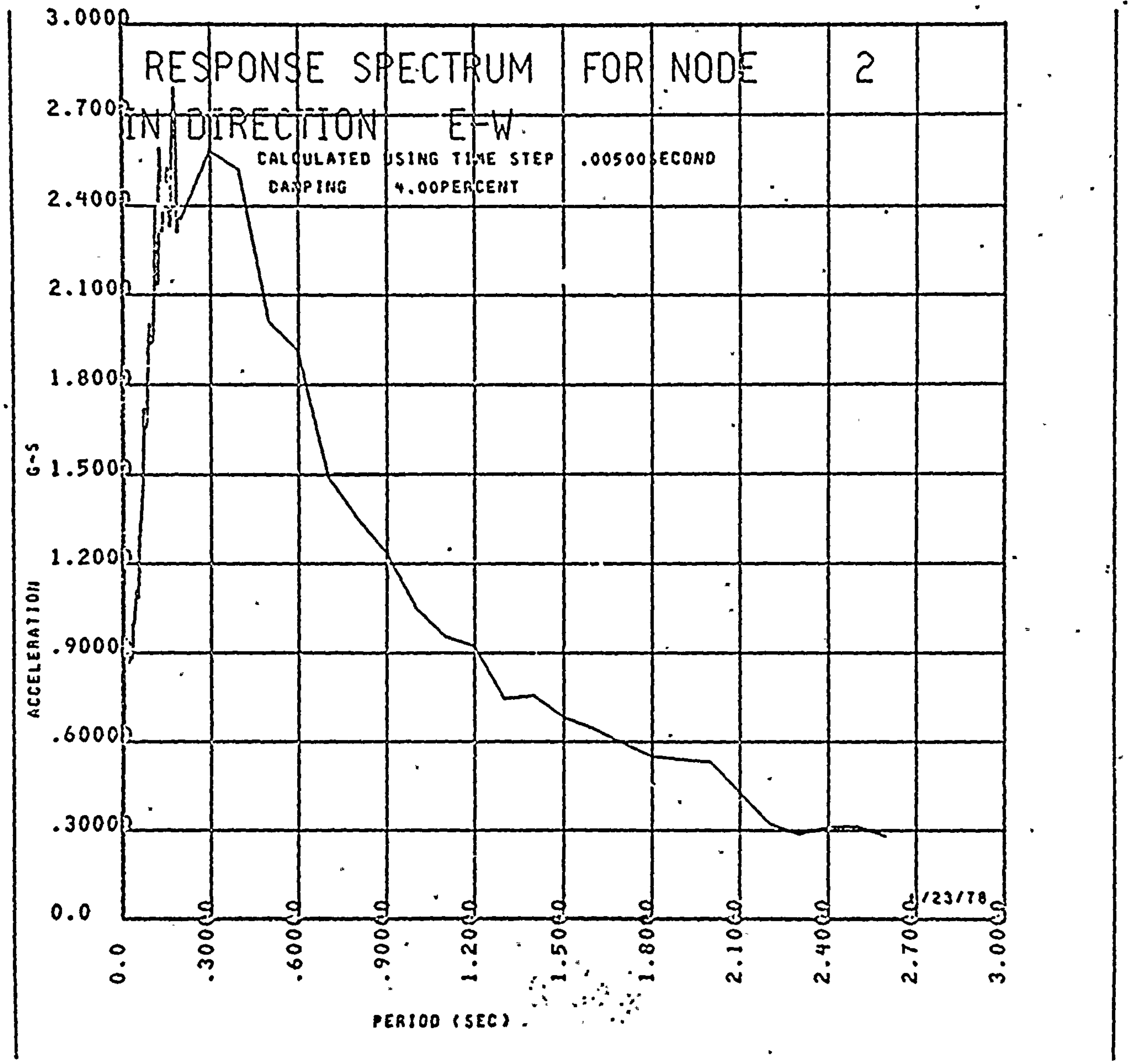


Fig. 2 With RPV
TH-3



DIABLO CANYON UNITS 1 & 2
INTAKE STRUCTURE
PATHWAY TO ASW PUMPS

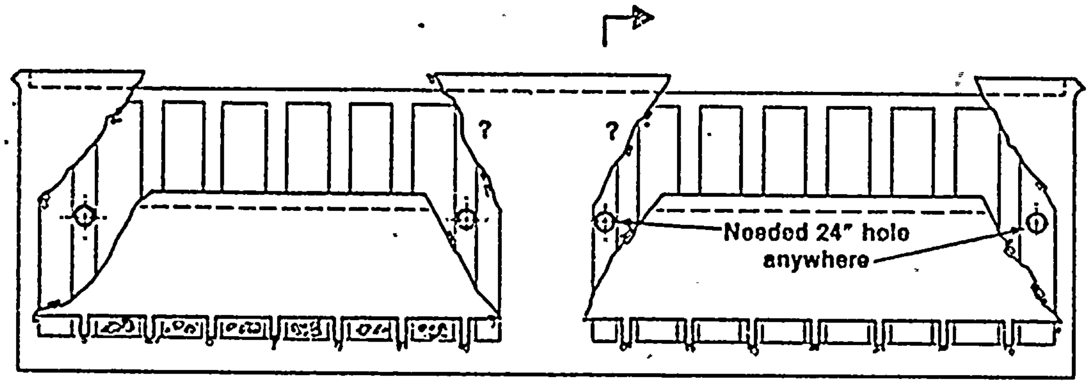
The auxiliary salt-water system is described in FSAR 9.2.1 and the intake is shown in Figure 9.2-2.

Piers supporting curtain wall are overstressed. The consequences of this are nil from several viewpoints. The attached sketch shows some possible modes of extreme collapses of wall. Our conclusion is that there is insufficient volume of concrete to plug all pathways to pumps. Some factors to support this conclusion are:

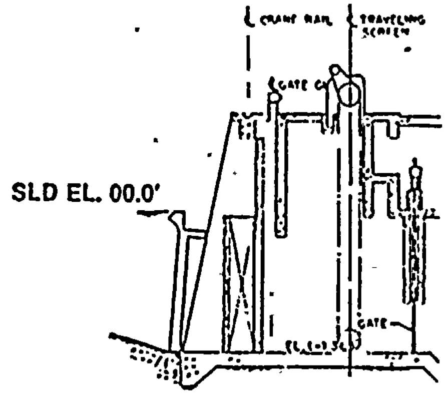
1. A Guillotine-type drop of the curtain wall would have to seal like a gate for the entire face of the intake (over 200 ft. in length). An equivalent area of a 24" pipe/unit in 6,000 ft.^{2} of face is all that is required. The back-flush effect of the water in the main cooling water lines above sea level (ten times the sea water volume in the intake) will clear face.

2. A Rubble-mound type plug would have to fill the entire auxiliary salt-water bay and have a porosity of less than coarse sand (0.4 - 3cm per second). This is not possible since there is insufficient volume of concrete involved.

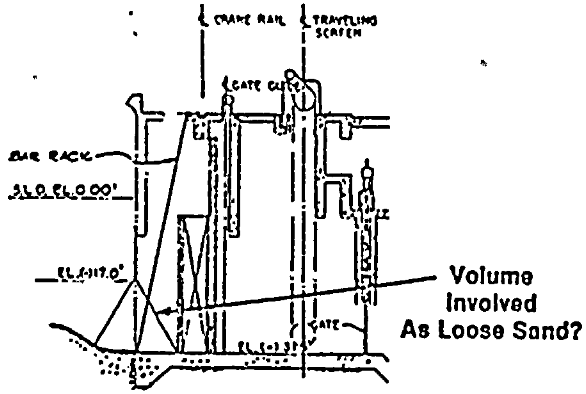
3. Domino effect of wall collapsing bar rack, which hits traveling water screens, will be retained or deflected by walls of gate well. While it is possible for debris to get into pump bay, the pump bell is 8.5 ft. above the bottom and near the back wall. Approach velocities are less than 1 ft/sec. Thus, turbulant suspension of debris large enough to damage empellor is not possible.



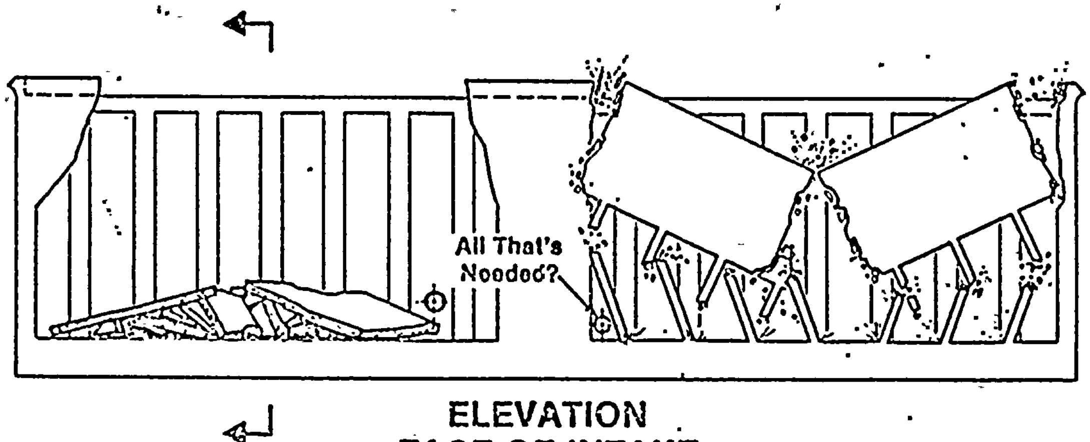
ELEVATION
FACE OF INTAKE



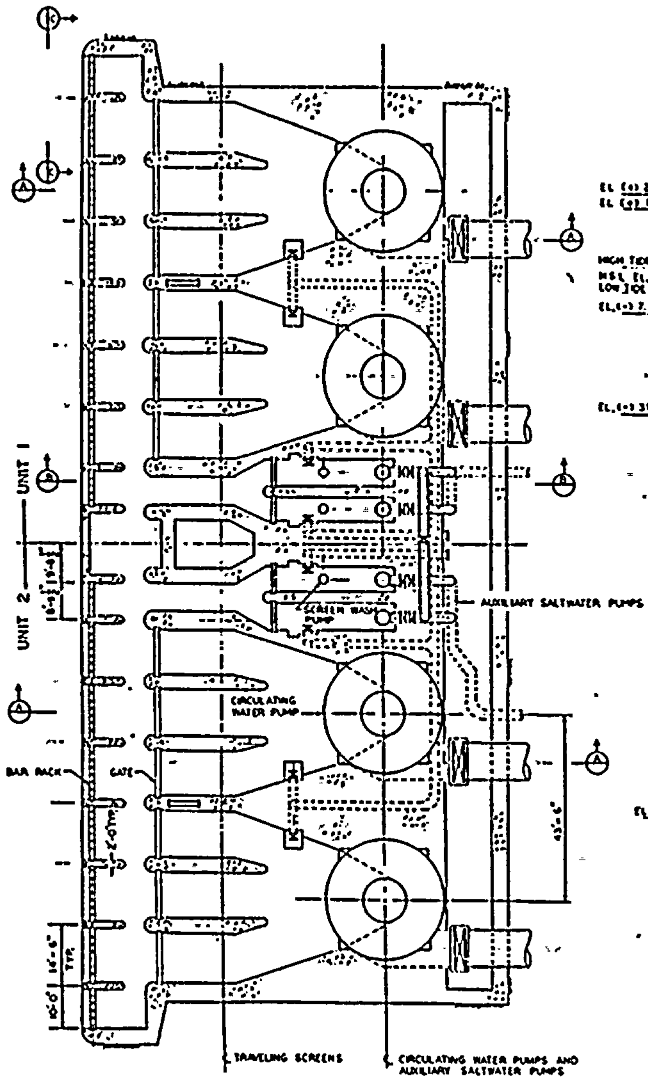
SECTION



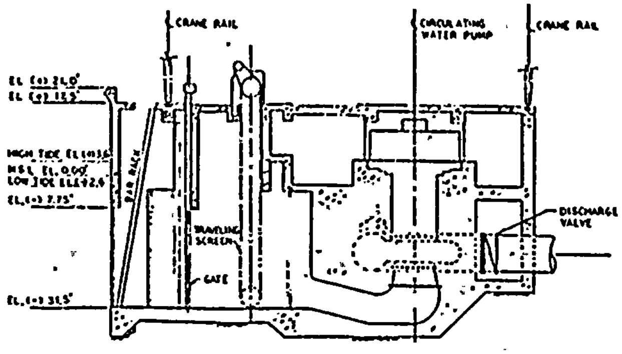
SECTION



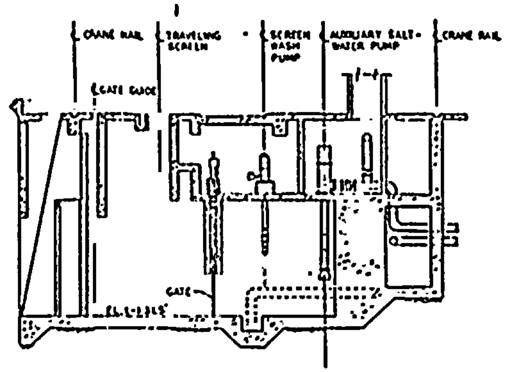
ELEVATION
FACE OF INTAKE



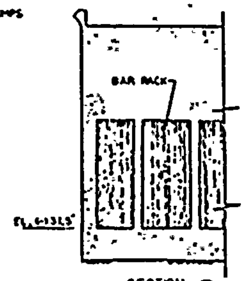
PLAN AT ELEVATION (-) 31.5'



SECTION A



SECTION B



SECTION C

0 5 10 15 20 25 30 35 40 45 50

SCALE IN FEET

UNITS 1 AND 2
DIABLO CANYON SITE

FIGURE 9.2-2
ARRANGEMENT OF INTAKE STRUCTURE

PRELIMINARY
0902-19

DIABLO CANYON
NUCLEAR POWER PLANT
UNIT 1

OUTDOOR WATER STORAGE TANKS
DYNAMIC SEISMIC ANALYSES FOR THE 7.5M HOSGRI CRITERIA

September 29, 1978

prepared for

Pacific Gas & Electric Co.

prepared by

URS/John A. Blume & Associates, Engineers

130 Jessie Street (at New Montgomery)

San Francisco, California

TABLE OF CONTENTS

1. INTRODUCTION

This report summarizes the dynamic seismic analyses of Class 1 outdoor water storage tanks of Units 1 and 2 of the Diablo Canyon Nuclear Power Plant for the postulated 7.5 magnitude (M) earthquake on the Hosgri fault. The plant is located in San Luis Obispo County, California, on the coast near Diablo Creek. A site plan is shown in Figure 1. The tanks were originally investigated by PG&E for the 0.40g Double Design Earthquake (DDE). Subsequent to the DDE analysis, it has been necessary to reevaluate the plant for the postulated 7.5M Hosgri event.

The outdoor water storage tanks which are considered Class 1 structures are the Refueling Water Storage Tanks, the Firewater and Transfer Tank and the Condensate Tanks. Each tank consists of a steel liner and a proposed concrete cover. The Firewater and Transfer Tank, in addition, has an inner steel tank.

The reevaluation of the tanks has been accomplished according to the February 8, 1977, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake.*[1] Maximum shears, overturning moments and shell forces were calculated at specific nodal point elevations of the mathematical models of the tanks. Based on the results of this investigation, stresses in the existing steel liner were checked and the required steel reinforcement in the concrete cover was determined.

The investigation being presented here consisted of two sets of analysis. Initially, an axisymmetric model, which ignored all non-axisymmetric features in the tank, was made and analyzed using ~~and~~ the AXIDYN[2] computer program. The AXIDYN dynamic analysis run for effects of horizontal earthquake considered ~~third~~ fluid-structure interaction approximately. Secondly, a three-dimensional half-tank model, which considered the non-axisymmetric vault opening in the concrete shell, was made and analyzed using the computer program SAPIV[3]. For the latter analysis, loads due to horizontal earthquake were partly based on results obtained from the AXIDYN analysis and were analyzed as equivalent static loads.

The tanks were analyzed for effects of gravity loading, hydrostatic pressure and the two horizontal components and one vertical component of the 7.5 M Hosgri ground motion. The different loading conditions, particularly the effects of horizontal ground motion, are discussed in subsequent sections. The finite element models used and the results of each analysis are discussed in Sections 4, 5.2 and 5.4 of this report. Modeling, loading and stress calculations are provided in Appendices A, B, C and D.

Results of the analyses presented here were used by PG&E to design the foundation. PG&E's foundation design calculations are presented in Appendix E. Soil properties used are based on the findings presented in the report[4] by Harding-Lawson.

2. DESCRIPTION OF TANKS

The Class 1 outdoor water storage tanks are located just outside the Fuel Handling Building. They were designed for the DDE as steel tanks, that is, without concrete cover. The present plan is to provide a concrete cover which varies in thickness from three feet at the base to twelve inches up to mid height, then eight inches up to the dome. The existing steel tanks are anchored to the foundation base slab. In addition, studs will also be provided to tie the steel liner and the concrete cover together.

There are two Refueling Water Storage ~~Tansk~~ Tanks; one to service each unit of the plant. Each Refueling Water Storage Tank is forty feet in diameter, and is intended to store water up to a depth of 51.75 feet. The tanks' overall height is approximately 58 feet. The thickness of the steel liner varies from 0.578 inch at the base to 0.25 inch at the dome.

The Firewater and Transfer tank, intended to service both Units 1 and 2 of the plant, is made up of two concentric steel cylindrical tanks connected by a common dome roof, and a concrete cover on the outer tank. The inner cylindrical tank, called the Firewater Tank, is 32.67 feet in diameter and made of steel plates with thickness varying from 0.802 inch at the base to 0.375 inch at the top. The outer tank, called the Transfer tank, is 40.0 feet in diameter and made of steel plates with thickness varying from 0.627 inch at the base to 0.25 inch at the top.

The structure configuration of the Condensate Tank is similar to the Refueling Water Storage Tank. Each of the two Condensate Tanks is forty feet in diameter and is intended to store water up to a depth of 46.5 feet. The thickness of the cylindrical steel liner varies from 0.60 inch at the base to 0.25 inch at the top. The dome is made of 0.263 inch plates.

On Figures 2a, 2c, and 2d are shown typical sections of the Refueling Water Storage Tank, Firewater and Transfer Tank and Condensate Tank, respectively. Thicknesses of the steel liner plates are indicated. Figure 2.b shows the 14-foot x 14-foot vault opening in the Refueling Water Storage Tank concrete shell. The vault openings in the other tanks are slightly smaller.

The steel plates in the Refueling Water Storage Tanks are made of SA-240 Type 304L plates whereas the steel plates in both Firewater and Transfer Tank and Condensate Tanks are specified to be SA-516-55 to SA300 plates. The concrete cover will have a minimum compressive strength of 4,000 psi at 28 days. The concrete fill under the existing base slab will have a minimum compression strength of 3,000 psi at 28 days.

3. ANALYSIS CRITERIA

3.1 Seismic Input

Two different postulated 7.5M Hosgri free-field smooth ground response spectra have been developed for the Diablo Canyon Nuclear Power Plant site: one by URS/John A. Blume & Associates, Engineers (URS/Blume), and another developed independently for the staff of the United States Nuclear Regulatory Commission (NRC) by Nathan M. Newmark Consulting Engineering Services. Figures 3 and 4 illustrate the Blume and Newmark 0.75g free-field horizontal spectra for 7% and 5% damping, respectively. Also shown in the figures is the 5% damped 0.4g DDE free-field spectrum. The vertical input to the outdoor water storage tanks was taken as two-thirds of the 0.75g horizontal free-field ground spectrum.

Comparison of the Blume and Newmark spectra on Figures 3 and 4 shows that the Newmark spectrum is generally higher than the Blume spectrum. Thus, for the analysis of the outdoor water storage tank, only one set of analysis using the Newmark spectrum was made.

3.2 Dynamic Effects of a Horizontal Earthquake

The behavior of liquid-filled ground supported tanks subjected to horizontal seismic excitation is a complex problem. G. W. Housner[5] presented an approximate method to determine the hydrodynamic pressures developed when a rigid cylindrical tank is subjected to seismic motion. A. S. Veletsos and V. Y. Yang[6] offered modifications to Housner's approach to consider the effects of tank flexibility. In their paper, Veletsos and Yang presented an approach to analyze a tank-fluid system as a single-degree-of-freedom system by assuming that the system vibrates in a fixed configuration along its height. The investigation being presented here was based on the Veletsos and Yang approach. A half-sine vibration configuration, the most conservative of three configurations suggested by Veletsos and Yang, was used in the analysis.

Due to a horizontal earthquake, three types of dynamic load are generated in a tank-fluid system. They are:

1. Structure inertia forces which are associated with structure mass;

2. Impulsive pressures exerted by the fluid on the tank; and

3. Convective pressures also exerted by the fluid on the tank.

Impulsive pressure represents the effects of the portion of the liquid which moves in unison with the tank, whereas convective pressure represents the effects of the sloshing action of the liquid. Both structure inertia forces and impulsive pressures are dependent on the structure vibration configuration and on the accelerations produced on the walls of the tank during the earthquake. Impulsive pressure, including the derivation of the equivalent fluid impulsive mass, m_{eff}, is further discussed in the next section. Discussion of convective pressure follows.

3.2.1 Impulsive Pressure

Hydrodynamic loads consisting of impulsive and convective pressures caused by a horizontal earthquake were calculated by A. S. Veletsos and J. Y. Yang who investigated the effects of a horizontal component of ground motion on circular cylindrical tanks, fixed at the base, of a radius a and a height H_s, and filled to a height H with a liquid of density ρ. The surface of the liquid was considered to be free. The fluid was considered to be incompressible and inviscid, and only linear effects were investigated. Distortion of the tank cross section was not considered.

Veletsos and Yang gave the following equation for the impulsive component, p_o, of the hydrodynamic pressure exerted on the tank wall:

$$p_o(z, \theta, t) = C\ b_o(z)\rho H\ A_o\ (t) \cos \theta \qquad (1)$$

in which C is a dimensionless coefficient, $b_o(z)$ also a dimensionless function and defines the pressure distribution along the height of the tank, and $A_o(t)$ represents the pseudo-acceleration corresponding to the natural frequency of the tank-fluid system for the assumed mode of vibration.

Veletsos and Yang plotted the pressure distribution function, b_o, for tanks with values of H/a of 0.5 and 3. The b_o values used in the present investigation were interpolated from Veletsos' plots of b_o.

The factor C in Equation 1 is a function of the ratio of the mass of the structure and the contained liquid, and is defined in the following equation:

$$C = \frac{m_x}{m_w} = \frac{m_{x,s} + m_{x,\ell}}{m_{w,x} + m_{w,\ell}} \qquad (2)$$

The symbol m_x in this equation represents the effective mass of the structure-fluid system for a rigid body motion of the tank, and $m_{x,s}$ and $m_{x,\ell}$, represent the components contributed by the structural mass and the liquid mass, respectively. In an analogous manner, m_w represents the effective mass of the system when vibrating in a deflection configuration specified by the function $\psi(z)$, and $m_{w,s}$ and $m_{w,\ell}$ are the components contributed by the structural mass and the liquid mass. These quantities are defined by the equations

$$m_{x,s} = \int_o^{H_s} \mu_s(z)\ \psi(z)\ dz + m_r\ \psi(H_s) \qquad (3)$$

$$m_{w,s} = \int_o^{H_s} \mu_s(z)\ \psi^2(z)\ dz + m_r\ \psi^2(H_s) \qquad (4)$$

in which $\mu_x(z)$ is the mass per unit of height of the structure without the liquid, and m_r is the mass of any concentrated roof loading that may be

presented at $z = H_s$.

Assuming that the tank-fluid system vibrates in a half-sine curve configuration along its height, values for $m_{x,s}$ and $m_{w,s}$ based on Equations 3 and 4 respectively, are calculated. Values of $m_{x,\ell}$ and $m_{w,x}$ were determined from the $m_{x,\ell}$ and $m_{w,\ell}$ plots made by Veletsos and Yang for tanks with different H/a values. With values of C and b_o known, the impulsive pressures could now be calculated.

3.2.2 Convective Pressure

In their paper[2], Veletsos and Yang also gave the following equation for the convective pressure p_k, exerted on the tank wall by the sloshing motion of the liquid:

$$p_k\ (z,\ \theta,\ t) = \sum_{k=1}^{\infty} c_k(z)\ A_k(t)\ \rho\ \dot{H} \cos \theta \qquad (5)$$

where

$$c_k(z) = \frac{2}{\lambda_k^2 - 1} \frac{a}{h} \frac{\cosh(\lambda_k\ z/a)}{\cosh(\lambda_k\ H/a)} \qquad (6)$$

and λ_k are the zeros of the first derivative of the Bessel function of first kind and first order. $A_k(t)$ is the spectral acceleration which corresponds to the natural frequency of the liquid in sloshing motion.

The individual terms of the series in Equation 5 represent the modal contribution of the portion of the liquid in sloshing motion. Veletsos and Yang showed that effects for larger values of H/a, particularly of the component associated with the second sloshing mode, are concentrated near the free surface and the values of $c_2(z)$ are substantially smaller than those for $c_1(z)$. Consequently, for the analysis being presented here, only effects of the first sloshing mode were considered and convective pressures were analyzed as static loads.

3.3 Gravity Load and Hydrostatic Pressure

Gravity load refers to the self weight of the tank whereas the hydrostatic pressure at a point is equal to the product of the liquid density and the height, h, of the liquid. Both gravity load and hydrostatic pressure are static loads and are constant around the circumference of the tank. The net inplane shear and torsion due to these loads are zero. The hydrostatic pressures which were input to the computer program are calculated on A-9.

3.4 Vertical Earthquake

It was found that the fundemental mode of the empty Refueling Water Storage Tank in the vertical direction is 0.033 second. Thus, it was assumed initially that the tank and the fluid act as a rigid mass during vertical motion so effects of vertical earthquake were obtained by scaling the stresses caused by gravity load and hydrostatic pressure by 0.5 (2/3 of maximum horizontal ground acceleration, i.e., 2/3 x 0.75g = 0.50g). This assumption was used in the axisymmetric phase of this investigation.

At the present time, there is no accepted procedure to analyze the ~~third~~ fluid motion in a tank due to a vertical earthquake. To consider the possibility that the fluid may not act as a rigid mass during vertical motion, an amplification factor of 2.0, i.e., the acceleration at zero period of 0.5g is amplified to a value of 1.0g, was used in the non-axisymmetric phase of this investigation. Effects of vertical earthquake were then obtained by scaling the sum of the dead ~~used~~ load and hydrostatic pressure stresses by 1.0.

3.5 Load Combination

Responses due to the two horizontal components and one vertical component of the 7.5M Hosgri ground motion are combined by the square-root-of-sum-of-squares (SRSS) method. That is:

$$EQ = (HE_1)^2 + (HE_2)^2 + (VE)^2 \qquad (7)$$

where EQ = total earthquake response

HE_1, HE_2 = the responses due to the two horizontal components of the ground motion, respectively, and

VE = response due to the vertical component of the ground motion.

Each of the responses HE and HE_2, is obtained by taking the absolute sum of the responses due to structure inertia forces, impulsive pressure and convective pressure.

The total load used to calculate stresses is obtained as follows:

$$TL = DL + HS + EQ \quad (8)$$

where TL = Total Load

DL = Dead Load

HS = Hydrostatic Pressure, and

EQ = Earthquake Response, and defined by Equation 7.

3.6 Allowable Stresses

3.6.1 Reinforced Concrete

The capacities of reinforced concrete structural members were determined in accordance with "Structural Analysis and Proportioning of Members - Ultimate Strength Design" given in ACI 318-71,[7] escept that unit load factors were used for combining loads.

3.6.2 Structural Steel

The capacities of structural steel members other than plates were based on the seventh edition of the American Institute of Steel Construction (AISC) Code.[8] The capacities of strucural steel plates were based on ASME Boiler and Pressure Vessel Code, Section VIII, Division 2.[9]

4. AXISYMMETRIC ANALYSIS

4.1 Refueling Water Storage Tank

4.1.1 Finite Element Model

The basic axisymmetric finite element model used in the analysis of the Refueling Water Storage Tank is shown on Figure 5. The tank is assumed fixed at the base. The model consists of 30 nodes, 29 steel shell elements and 29 concrete shell elements. The steel shell liner and the concrete cover were modeled as axisymmetric shell elements parallel to each other. The global coordinates (R,Z) of the nodal points are given on A-1. Material properties for steel and concrete are given on A-2. The model was used to analyze for effects of gravity loading, hydrostatic pressure, structure inertia forces and hydrodynamic loads consisting of impulsive and convective pressures caused by a horizontal earthquake. AXIDYN, a computer program for the static and dynamic analysis of axisymmetric structures by the finite element method, was used in all the analysis runs.

4.1.2 Analysis Approach

Due to horizontal ground motion, structure inertia forces and hydrodynamic pressures (consisting of impulsive pressure and convective pressure acting on the tank wall) are generated. For the analysis being presented here, the combined dynamic effects of both structure inertia forces and impulsive pressures are determined in one computer run. Effects of convective pressures are determined in a separate run. This two-step procedure is done because the frequency differences between the tank motion and the liquid sloshing motion are expected to be large, thus, coupling between the two motions would be negligible. The total effect caused by a horizontal earthquake is obtained by taking the absolute sum of the results of the two runs.

To be able to determine the combined dynamic effects of both structure inertia forces and impulsive pressure in one computer run, the method adapted here is to determine an equivalent effective fluid (impulsive)

mass, m_{eff}, add it to the structure mass, and subject the tank with the combined mass to the horizontal earthquake. The resulting stresses would thus include effects of both inertia forces and impulsive pressures.

The impulsive pressures as calculated from Equation 1 act normal to the tank wall, and the magnitude varies over the circumference as a cosine function of the angle 0 from the direction of the applied ground motion. The impulsive pressure, p_o, variation around the circumference is shown in Figure 6. Initially, the procedure adapted in the dynamic analysis of the Refueling Water Storage Tank for impulsive pressures was to simulate the computed impulsive pressure in terms of an equivalent shell with mass density ρ_e, thickness t, and radius a, but no stiffness.

From Equation 1, the effective fluid mass, m_{eff}, causing an impulsive pressure, p_o, can be expressed as follows:

$$m_{eff} = \frac{p_o}{A_o} = C\ b_o(z)\ \rho H \cos\theta \tag{9}$$

By definition, the mass of a shell per foot of circumference per foot of height is

$$m_{eff} = \rho_e t \tag{10}$$

Therefore

$$\rho_e\ t = \frac{p_o}{A_o} \tag{11}$$

and

$$\rho_e = \frac{C\ b_o(z)\ \rho H \cos\theta}{t} = \frac{\tilde{p}_o}{t} \tag{12}$$

where $\tilde{p}_o$ is pressure for A_o equal to a unit acceleration.

The above equation for the equivalent fluid density, ρ_e, was used in the calculations on A-7, assuming a shell thickness of 0.25 feet. In the final

computer run, however, the fluid inertia (mass) were assumed attached to the concrete shell elements. The equivalent fluid inertia (mass) previously calculated were therefore modified as in the following equation, so that the fluid density would be based on a thickness that is the same as the corresponding concrete element thickness:

$$\rho_{e_{mod}} = \rho_e \frac{t}{t_c} \qquad (13)$$

where t_c is the thickness of the concrete element. The concrete plus fluid element mass density is obtained by adding the concrete density ρ_e and the fluid density, $\rho_{e_{mod}}$.

According to Equation 9, the equivalent mass m_{eff} varies as cos θ over the circumference. However, the computer program AXIDYN used in the analysis assumes an axisymmetric structure thus requiring a constant value of m_{eff}, hereinafter designated as m^k_{eff}, over the circumference.

The constant equivalent mass, m^k_{eff} is defined as follows:

$$m^k_{eff} = \frac{m_{eff}}{\cos \theta} = C\ b_o(z)\ \rho H \qquad (14)$$

The horizontal pressure, p_h, exerted by a constant equivalent mass, m^k_{eff}, on the tank wall due to a horizontal acceleration is given by:

$$p_h = m^k_{eff}\ A \qquad (15)$$

and is shown on Figure 7a as a constant pressure over the circumference. The horizontal pressure p_h is analyzed by AXIDYN as the sum of two components: (1) a radial component, p_r, (see Figure 7b), which varies over the circumference as the cosine function of the angle θ and (2) a tangential component, p_t (see Figure 7c), which varies as the sine function of θ. Figure 7d shows the resultant pressure, p_h, and its components p_r and p_t. From Figure 7d and

from Equations 14 and 15, it follows that:

$$p_r = p_h \cos \theta = m^k_{eff} A \cos \theta = C\ b_o(z) \rho H A \cos \theta \qquad (16)$$

and

$$p_t = p_h \sin \theta = m^k_{eff} A \sin \theta = C\ b_o(z) \rho H A \sin \theta \qquad (17)$$

Note that the impulsive pressure defined in Equation 1 and shown in Figure 6 is equal to the radial pressure defined in Equation 17 and shown in Figure 7b. The tangential pressure, p_t, shown in Figure 7c is an additional loading being considered here. Thus, because of the use of a (heavier) constant mass m^k_{eff} instead of an m_{eff} which varies with cosine θ and also because of the additional effects of the tangential pressure shown in Figure 7c, the procedure adapted here would give conservative results.

The impulsive pressure determined from Equation 1 represents only the contribution of the mode being considered with $A_o(t)$ representing the spectral acceleration corresponding to the assumed mode of vibration. It was therefore necessary to determine and consider contributions of all significant modes of vibration. Calculations for the impulsive pressure defined by Equation 1 are given on Sheets A-3 to A-7. A value of C equal to 1.37 was determined. Calculations for the fluid density, $\rho_{e_{mod}}$, are given on Sheet A-8.

With the combined structure mass and equivalent effective fluid mass as input, a dynamic analysis of the tank for effects of structure inertia forces and impulsive pressure was done using the computer program AXIDYN. The response spectrum modal superposition approach was used with a cut-off period of 0.30 seconds. The periods of vibration and the percentage modal participation factors obtained are summarized on A-17. A damping ratio of 0.07 was used for all the seven (7) significant modes.

Studies indicate that consideration of the foundation and soil flexibility would lengthen the periods of vibration, mainly that of the fundamental node. To consider this lengthening of the fundamental period of vibration due to

the foundation and the soil, the peak ground spectral acceleration is used as the spectral acceleration corresponding to the fundamental mode of vibration no matter what the value of the fundamental period is.

Only the combined structure inertia forces and impulsive pressure loading caused by a horizontal earthquake was treated as a dynamic load. The other loads, such as gravity, hydrostatic pressure and convective pressure loads, were analyzed as static loads. Effects of vertical earthquake were obtained by scaling the results of the analysis for gravity loading and hydrostatic pressure by 0.5.

The calculations for convective pressures, based on Equation 5, are given on A-10 to A-13. The fundamental period of the sloshing motion of the liquid was calculated to be 3.65 seconds (see A-12) and, for 1% damping, the corresponding spectral acceleration is 0.171g or 5.51 ft/sec^2. Note that the fundamental mode of the tank motion has a period of 0.144 seconds (see A-17). As expected, the frequency difference of the tank motion and the sloshing motion of the liquid is large, thus, the assumption that coupling between the two motions is negligible is justified.

4.1.3 Discussion of Results

Longitudinal forces and moments, circumferential forces and moments, and in-plane shears at critical points in the steel liner and concrete cover obtained from the analysis runs are summarized on A-18 to A-21 respectively. The summary indicates that the impulsive pressure loading and, to a lesser degree, the hydrostatic pressure loading, contribute the most to the total forces and moments. Moments in the steel liner are negligible. Longitudinal and circumferential forces and moments due to the impulsive pressure loading are plotted on A-22 to A-25.

Preliminary design of the concrete cover and checking of stresses in the steel liner were made using the results of the axisymmetric analysis.

4.2 Firewater and Transfer Tank

The Firewater and Transfer Tank model, shown on Figure 8, is analyzed for

effects of gravity loading, hydrostatic pressure, horizontal earthquake and vertical earthquake. The same analytical procedures used in the analysis of the Refueling Water Storage Tank are used in the analysis of the Firewater and Transfer Tank and are not discussed here.

The Firewater and Transfer Tank model and analysis results presented here are based on the preliminary sizing of the thickness of the concrete cover. Thickness was changed originally the 12-inch section starts approximately 8 feet above the base. Based on the analysis results of the Refueling Water Storage Tank, the concrete cover should have a 12-inch thickness up to the mid-height of the tank, which is about 25 feet above the base.

Modeling, loading and stress calculations are provided in Appendix B. The basic axisymmetric finite element model used to analyze the Firewater and Transfer Tank is shown on B-1. The steel sections and the concrete cover are modeled as axisymmetric shell elements. The model consists of 46 nodes, 27 concrete shell elements and 45 steel shell elements. The exterior tank is assumed fixed at the base whereas the inner steel tank is considered pinned at the base.

Two loading conditions are considered:

1. Case 1 where both inner and outer cylindrical tanks are filled with water up to design level; and
2. Case 2 where inner tank is filled to design level while the outer tank is empty.

A set of analyses for effects of hydrostatic pressure, horizontal earthquake and vertical earthquake is made for each case. For the first case, hydrostatic pressure, impulsive pressure and convective pressure are assumed exerted by the fluid on the outer tank only. For the second case, hydrostatic pressure, impulsive pressure and convective pressure are exerted by the fluid on the inner tank only.

Because fluid impulsive pressure was being exerted essentially only on the exterior concrete tank and because large inertia forced will also be

generated on the concrete shell, damping of 7%, which is the NRC Regulatory Guide 1-61 specified damping for concrete structures, was used in the Case 1 dynamic analysis for the combined effects of structure inertia forces and impulsive pressure.

For the case 2 analysis, however, large inertia forces will be generated on the concrete shell while impulsive forces will be also eating on the interior steel tank. Thus, a modified damping value was calculated to consider the lower damping value specified for steel structures. NRC Regulatory Guide 1.61 specifies 4% damping for steel structures.

Based on the first mode, the modified damping value was calculated using the following:

$$\lambda = \frac{\varepsilon m_c \phi^2{}_{c} \lambda_c + \varepsilon m_s \phi^2{}_{s} \lambda_s}{\varepsilon m_c \phi^2{}_{c} + \varepsilon m_s \phi^2{}_{s}} \qquad (18)$$

where

λ	=	The modified damping value,
m_c, m_s	=	Mass of the concrete and steel shell elements, respectively, and
λ_c, λ_s	=	NRC Reg. Guide 1.61 specified damping for concrete and steel, respectively.

The calculation on Sheet B- gives a modified damping value of 6.3%. Because there is no spectrum specified for 6.3% damping, the more conservative 5% damped Newmark spectrum shown on Figure 7 was used in the Case 2 analysis.

Longitudinal forces and moments, circumferential forces and moments and in-plane shears at critical points in the two steel tanks and concrete cover for Case 1 and Case 2 are summarized on B- to B- . The more critical of the two sets of total forces and moments were used to check critical sections in the tank. The summary indicates that the impulsive pressure loading and the hydrostatic pressure loading contribute the most to the total forces and moments. Moments in the steel sections are negligible.

The maximum stress intensity at each steel liner section is determined and compared with the allowable stress intensity at the section on sheets B- and B- . Calculations indicate that the steel sections are adequately designed.

Comparison of the design forces and moments for concrete elements, given on B- , with those given on A- for the corresponding preliminary Refueling Water Storage Tank model, indicate that the values for the former are less than for the latter tank, that is, at corresponding concrete elements. Therefore, the same steel reinforcement provided for the concrete cover of the Refueling Water Storage Tank will be adequate for the Firewater and Transfer Tank.

4.3 Condensate Tank

The structure configuration of the Condensate Tank is very similar to the Refueling Water Storage Tank. Both tanks have the same inside diameter. The height of the structure, as well as the design liquid depth of the Condensate Tank, is less than those for the Refueling Water Storage Tank by 5.25 feet. Because of the similarity between the two tanks, it is felt that analysis results of the Refueling Water Tank should apply to the Condensate Tank. The steel plates specified for the Condensate Tank are slightly thicker and made of stronger material than those for the Refueling Water Storage Tank, thus, they should be adequate. A concrete cover with steel reinforcement, the same as those specified for the Refueling Water Storage Tank, would also be adequate for the Condensate Tank.

5. NON-AXISYMMETRIC ANALYSIS OF THE REFUELING WATER STORAGE TANK

5.1 Purpose

In the earlier dynamic analysis, the tank was assumed to be an axisymmetric shell structure and was analyzed using the AXIDYN program. That analysis, however, did not take into account a 14-foot x 14-foot vault opening in the concrete shell. To get a clearer understanding of the stress distribution in the concrete and steel shell elements around and in the opening area, a more comprehensive three-dimensional model, with thin shell elements, and including the concrete shell opening, was made and analyzed using the computer program SAPIV. Loads were applied statically.

Two distinct features of the SAPIV static analyses of the tank were (1) the consideration of the 14-foot x 14-foot opening in the concrete shell, and (2) the simulation of the impulsive pressure exerted on the structure by applying normal fluid pressures, that varies cosinusoidally along the circumference. The impulsive pressures were calculated using the square-root-of-sum-of-squares (SRSS) values of accelerations obtained from the earlier AXIDYN analysis.

5.2 Finite Element Model

Symmetry of the tank about the centerline through the opening was utilized and only one-half of the tank was modeled. Quadrilateral shell elements were used to model all steel and concrete members except for the concrete framing around the opening. Beam elements were used to model the heavy concrete framing. The three-dimensional half-tank model is shown in Figure . It consists of 427 nodes, 360 steel shell elements, 348 concrete shell elements and 13 concrete beam elements. The tank was fixed at the base against all six degrees of freedom. Because of computer program restrictions, and for modeling convenience, a small one-foot diameter opening was left at the crown of the dome.

Appropriate boundary conditions at the plane of symmetry of the tank structure, i.e., at nodes located on the z-y plane (see Figure 16), were determined by the nature of loading considered, i.e., whether the loading is symmetric or anti-symmetric. Dead load and the horizontal earthquake along the z-z direction are loads symmetric with respect to the z-y plane. On the other hand, horizontal earthquake along the x-x direction is anti-symmetric with respect to the z-y plane.

For symmetric loading, joints on planes of symmetry are restrained such that they displace only in those planes. Thus, for dead load and horizontal earthquake along the z direction, joints of the y-z plane, for example, were allowed to displace only in the y and z directions and to rotate only about the x direction. For anti-symmetric loading, joints on planes of symmetry were compelled to displace in an anti-symmetric manner. Thus, for the case where the horizontal earhtquake is acting along the x direction, joints located on the y-z plane were restrained against translations in the plane of anti-symmetry and rotational normal to the plane. This modeling technique is discussed further elsewhere.[10]

5.3 Analysis Approach

Using the SAPIV three-dimensional model, a new set of static analysis runs was made to determine the effects of gravity loading and hydrostatic pressure. Calculations for the hydrostatic pressure input to the program are given on Sheet .

Effects of convective pressure caused by horizontal ground motion were observed to be small in the AXIDYN analysis, and, thus, were not considered significant to require a new analysis using the SAPIV model. The seismic forces due to horizontal ground motion, thus, principally consist of: (1) the lateral forces due to the impulsive pressure, and (2) the lateral forces due to inertia forces.

The SAPIV model was analyzed for the two cases in which the horizontal ground motion acts: firstly along the x-x direction, and secondly along

the z-z direction. Calculations for the effects of structure inertia forces and impulsive pressures were simplified by using the accelerations obtained from the earlier axisymmetric analysis. Loads due to structure inertia forces were calculated by multiplying the mass of an element by the corresponding acceleration obtained from the AXIDYN analysis, and the results then applied statically to the SAPIV model.

In the earlier axisymmetric analysis, impulsive pressure was input into the AXIDYN program in terms of an equivalent impulsive mass density. This method did not allow for a cosine θ variation along the circumference of the tank. For the SAPIV analysis, the cosine θ variation in the fluid impulsive pressure is taken into account.

A plot of the variation of the impulsive mass density along the height of the tank structure is shown on the left hand side of Sheet No. . The impulsive mass density plotted is for θ equal to zero and based on a unit acceleration. On the right hand side of Sheet No. , is a plot of the SRSS values of radial accelerations obtained from the earlier AXIDYN analysis. Corresponding SAPIV nodes and AXIDYN nodes are also indicated along the vertical axis of the plot.

From Equation , the radial impulsive pressure acting on an element can be expressed as follows:

$$P_o = \rho_e \, t \, A_o$$

where

ρ_e = As defined in Equation , and varies as a cosine function along the circumference

t = The assumed fluid thickness

A_o = The acceleration of the element based on AXIDYN results.

The calculations for the impulsive pressures acting on the steel and concrete shell elements are given on Sheets and . These impulsive pressure loads were then applied statically to the model shown in Figure , and analyzed using SAPIV.

5.4 Discussion of Results

Direct stresses and moments, obtained from the SAPIV analysis runs for dead load, hydrostatic pressure and horizontal earthquake along the x-x and z-z directions, at critical points in the steel liner and concrete cover are given on Sheets and . The vertical earthquake responses correspond to an amplification of ; that is, from the zero period acceleration of 0.5g to a value of 1.0g. The vertical earthquake responses are thus equal to the sum of the dead load and hydrostatic pressure analysis results.

Table and give the stress intensity values at critical points in the steel liner section, including the concrete steel opening area. The allowable stress intensity is exceeded at two sections in the concrete shell opening area. To take care of this overstress, a 1/4" plate is welded to the existing section where the overstress occurs.

The concrete cover, including the concrete framing around the vault opening, was designed for the more critical of the two analyses (axisymmetric and finite element). Design calculations are given on Sheet and A typical section of concrete cover, showing the required steel reinforcement, is shown on Figure 4. Steel reinforcement details for the concrete framing are shown on Figure .

6. REFERENCES

1. URS/John A. Blume & Associates, Engineers, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake,* (Preliminary) revised February 8, 1977.

2. Ghosh, Sukamar, and Edward Wilson, *Dynamic Stress Analysis of Axisymmetric Structures Under Arbitrary Loading,* EERC 69-10, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, September 1969.

3. Bathe, K-J., E. L. Wilson, and F. E. Peterson, *SAPIV, A Structural Analysis Program for Static and Dynamic Response of Linear Systems,* EERC 73-11, College of Engineering, University of California, Berkeley, June 1973.

4. Harding-Lawson Associates, *Geotechnical Studies - Intake Structure, Water Storage Tanks, Diesel Fuel Oil Storage Tanks - Diablo Canyon Nuclear Power Plant, San Luis Obispo County, California*, April 12, 1978.

5. U. S. Atomic Energy Commission, *Nuclear Reactors and Earthquakes,* TID 7024, Washington, D.C., August 1963.

6. Veletsos, A. S., and J. Y. Yang, *Dynamics of Fixed-Base Liquid Storage Tanks*, Proceedings of U. S. - Japan Seminar on Earthquake Engineering Research with Emphasis on Lifeline Systems, Tokyo, Japan, November 1976.

7. American Concrete Institute, *Building Code Requirements for Reinforced Concrete*, ACI 318-71, Detroit, Michigan, 1971.

8. American Institute of Steel Construction, *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings*, New York, N.Y., February 12, 1969.

9. American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Alternative Rules for Pressure Vessels*, 1974.

10. Weaver, William Jr., *Computer Programs for Structural Analysis*, D. Van Nostrand Co., Inc., Princeton, N. J., 1967.

DIABLO CANYON UNITS 1 & 2
FIREWATER TANK
MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

Nodal Points	Plate Thickness, inches	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
		DL + HS	DL + HS + HE + VE	DL + HS	DL + HS + HE + VE
46 - 43	0.813	8.20	21.49	18.3	21.96
43 - 40	0.688	5.59	17.85	18.3	21.96
40 - 37	0.625	5.20	16.37	18.3	21.96
37 - 34	0.531	4.59	17.64	18.3	21.96
34 - 28	0.438	3.89	20.51	18.3	21.96
28 - 22	0.375	3.17	18.13	18.3	21.96

NOTE:

DL - DEAD LOAD
HS - HYDROSTATIC PRESSURE
HE - HORIZONTAL EARTHQUAKE
VE - VERTICAL EARTHQUAKE

DIABLO CANYON UNITS 1 & 2
TRANSFER TANK
MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

Nodal Points	Plate Thickness, inches	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
		DL + HS	DL + HS + HE + VE	DL + HE	DL + HS + HE + VE
1 - 6	0.627	3.63	16.22	18.3	21.96
6 - 9	0.522	3.55	16.49	18.3	21.96
9 - 12	0.417	3.39	14.76	18.3	21.96
12 - 15	0.313	2.70	12.63	18.3	21.96
15 - 33	0.250	1.60	8.76	18.3	21.96

NOTE:

DL - DEAD LOAD
HS - HYDROSTATIC PRESSURE
HE - HORIZONTAL EARTHQUAKE
VE - VERTICAL EARTHQUAKE

DIABLO CANYON UNITS 1 & 2
CONDENSATE TANK
MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

Plate Thickness, inches	Maximum Stress Intensity, ksi		Allowable Stress Intensity, ksi	
	DL + HS	DL + HS + HE + VE	DL + HS	DL + HS + HE + VE
0.600	3.84	20.66	18.3	21.96
0.500	5.07	21.24	18.3	21.96
0.398	4.87	21.11	18.3	21.96
0.297	4.26	18.78	18.3	21.96
0.250	2.89	14.31	18.3	21.96

NOTE:

DL - DEAD LOAD
HS - HYDROSTATIC PRESSURE
HE - HORIZONTAL EARTHQUAKE
VE - VERTICAL EARTHQUAKE

DIABLO CANYON UNITS 1 & 2
COMPARISON OF FORCES AND MOMENTS IN CONCRETE ELEMENTS BETWEEN REFUELING WATER STORAGE TANK AND FIREWATER AND TRANSFER TANKS

Nodal Point	Force/Moment K/K-F	Refuel Water Storage Tank	Firewater and Transfer Tanks
1	LONG. FORCE	206.6	157.3
	CIRC. FORCE	46.1	31.5
	LONG. MOM.	83.9	72.5
	CIRC. MOM.	16.7	14.5
	SHEAR	102.9	87.3
2	LONG. FORCE	168.8	160.4
	CIRC. FORCE	40.8	46.8
	LONG. MOM.	37.5	25.0
	CIRC. MOM.	7.6	6.9
	SHEAR	95.4	82.9
4	LONG. FORCE	139.3	103.1
	CIRC. FORCE	63.1	68.6
	LONG. MOM.	5.1	5.0
	CIRC. MOM.	1.1	1.1
	SHEAR	89.9	74.7
6	LONG. FORCE	125.6	86.2
	CIRC. FORCE	57.0	56.6
	LONG. MOM.	4.2	2.2
	CIRC. MOM.	1.0	0.6
	SHEAR	90.8	74.6
22 (18 FOR F&T TANKS)	LONG. FORCE	3.6	2.6
	CIRC. FORCE	41.9	31.9
	LONG. MOM.	1.7	3.4
	CIRC. MOM.	0.5	0.6
	SHEAR	4.6	5.8

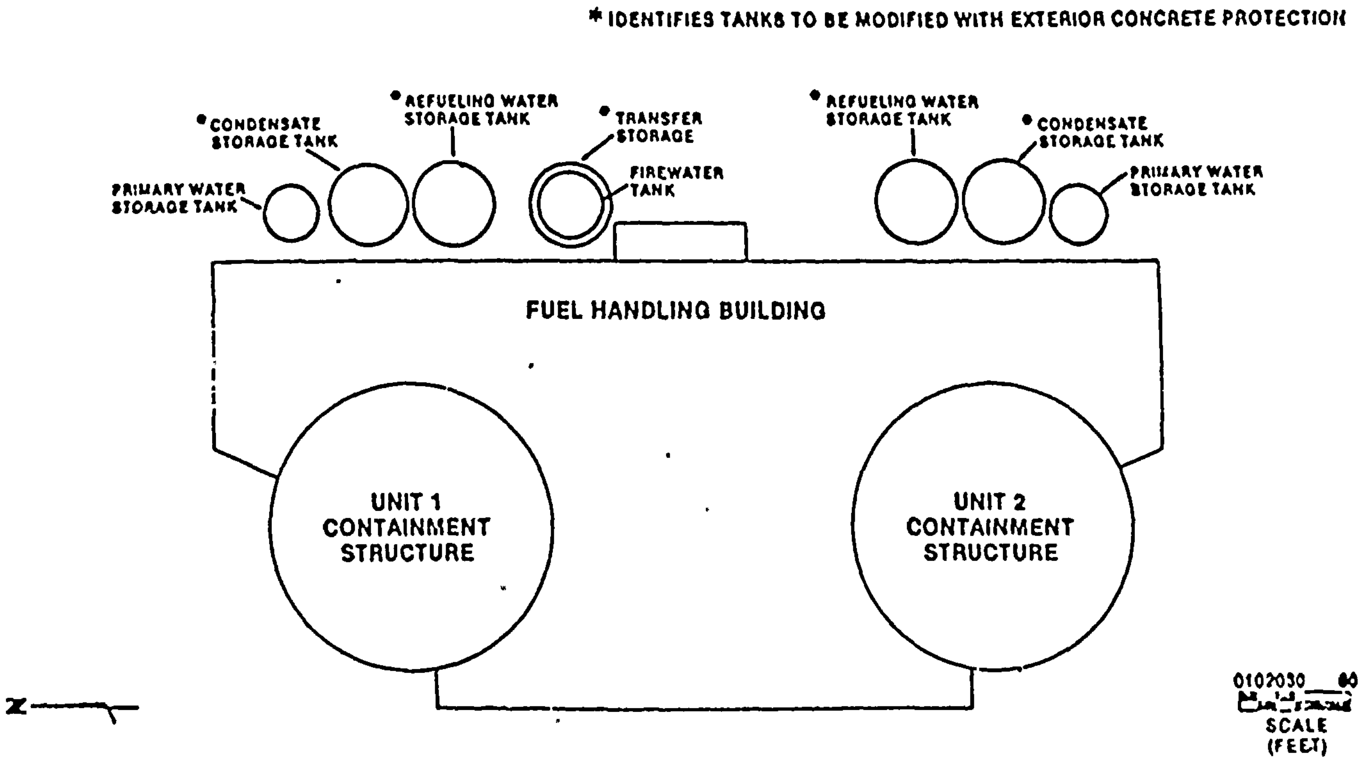
TABLE 1
DIABLO CANYON UNITS 1 & 2
REFUELING WATER STORAGE TANK
MAXIMUM STRESS INTENSITIES IN STEEL ELEMENTS

ELEMENT NO.	PLATE THICKNESS, INCHES	MAXIMUM STRESS INTENSITY, KSI		ALLOWABLE STRESS INTENSITY, KSI	
		DL + HS	DL + HS + HE + VE	DL + HS	DL + HS + HE + VE
49	0.578	11.12	26.51*	16.7	20.04
65	0.490	12.22	29.74*	16.7	20.04
156	0.356	2.59	9.52	16.7	20.04
196	0.275	2.82	11.42	16.7	20.04
231	0.250	2.05	8.43	16.7	20.04

NOTE:

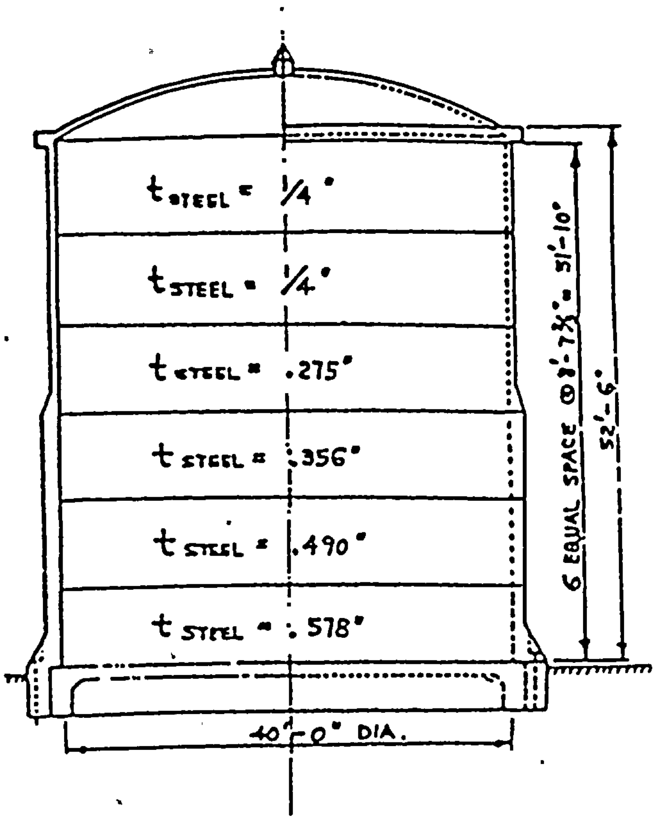
DL - DEAD LOAD
HS - HYDROSTATIC PRESSURE
HE - HORIZONTAL EARTHQUAKE
VE - VERTICAL EARTHQUAKE

*0.25-INCH THICK PLATE WILL BE WELDED TO THE EXISTING STEEL SHELL IN THE VAULT OPENING AREA TO REDUCE STRESSES WITHIN ALLOWABLE STRESS INTENSITY.

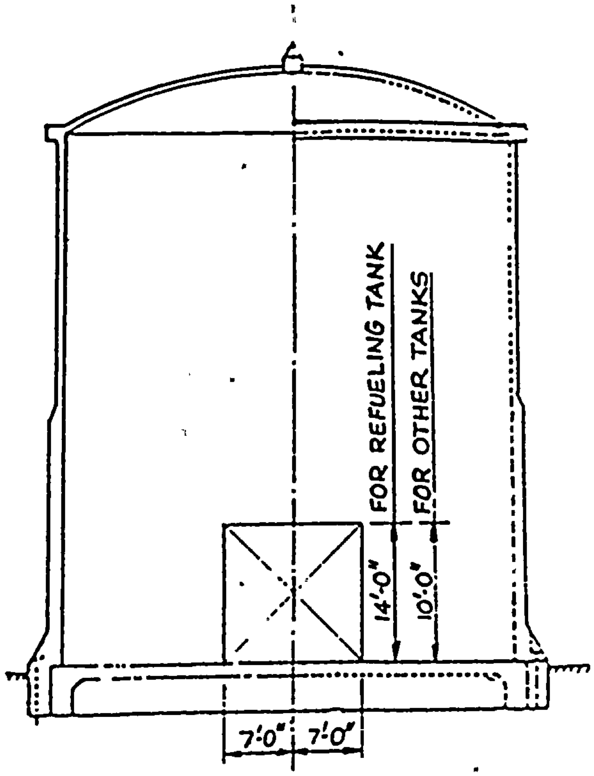


DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
SITE PLAN

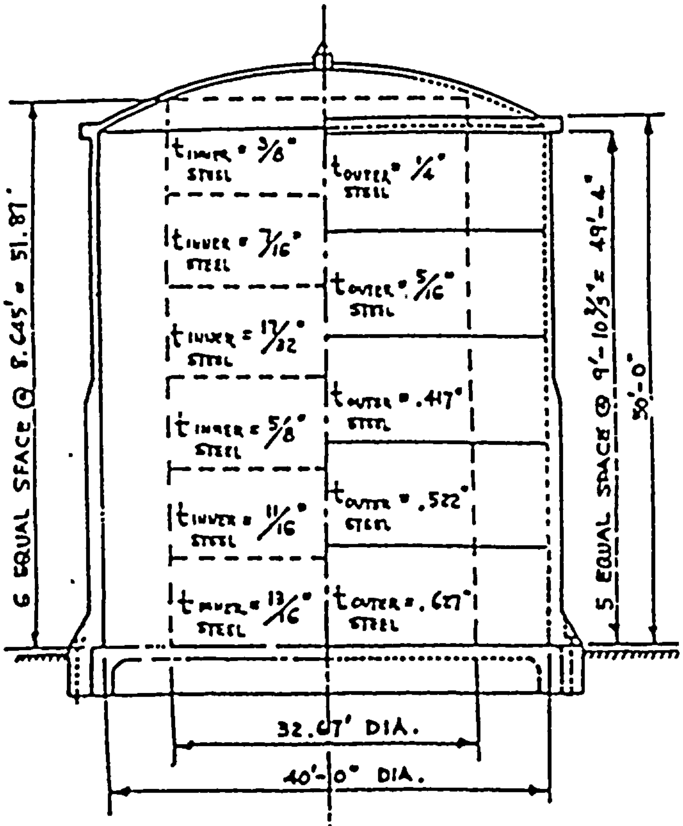
FIGURE 1



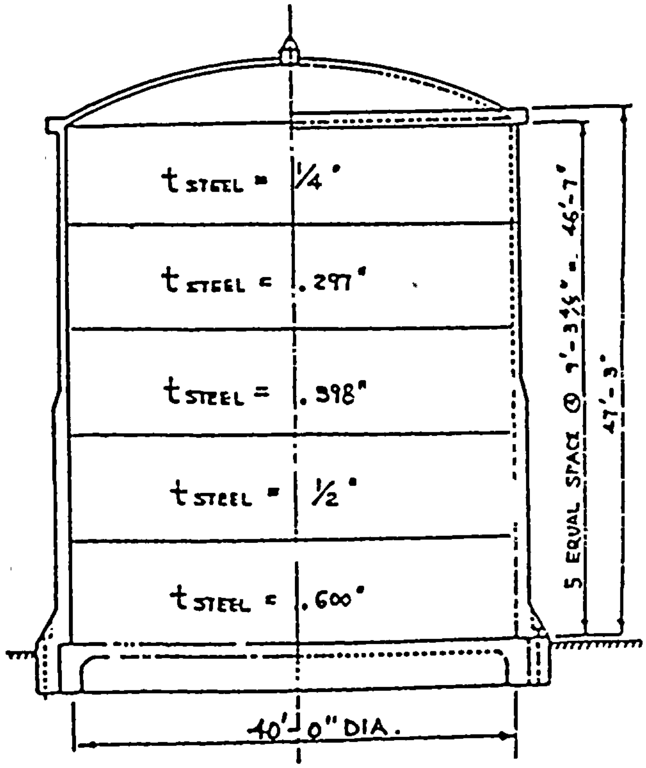
2a. REFUELING WATER STORAGE TANK



2b. TYPICAL VAULT OPENING IN CONCRETE SHELL OF STORAGE TANKS



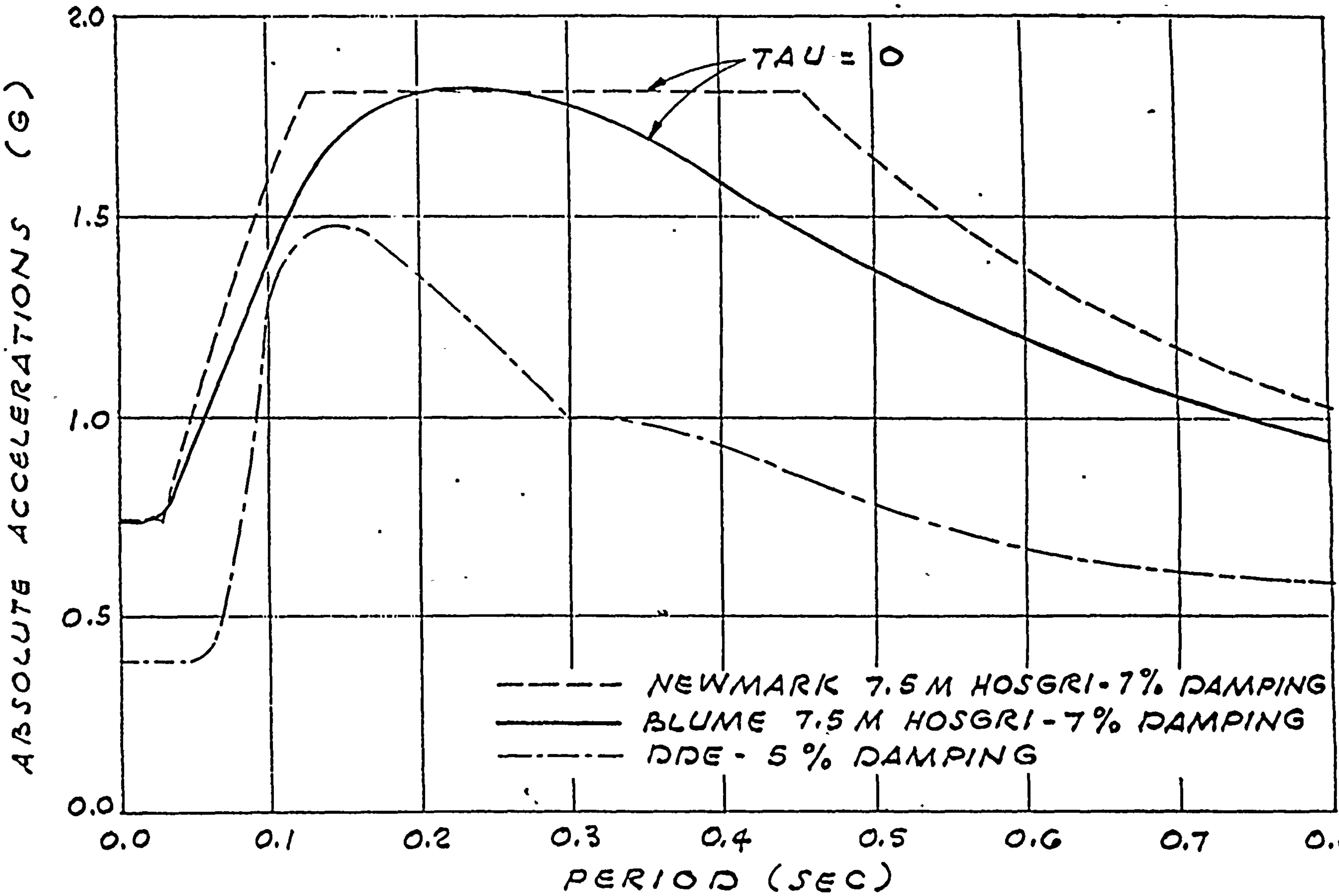
2.c. FIREWATER & TRANSFER TANK



2.d. CONDENSATE TANK

DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
SECTIONS OF TANKS

FIGURE 2



DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
BLUME & NEWMARK 7.5M HOSGRI SPECTRA - 7% DAMPING

FIGURE 3

DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
BLUME & NEWMARK 7.5M HOSGRI SPECTRA - 5% DAMPING

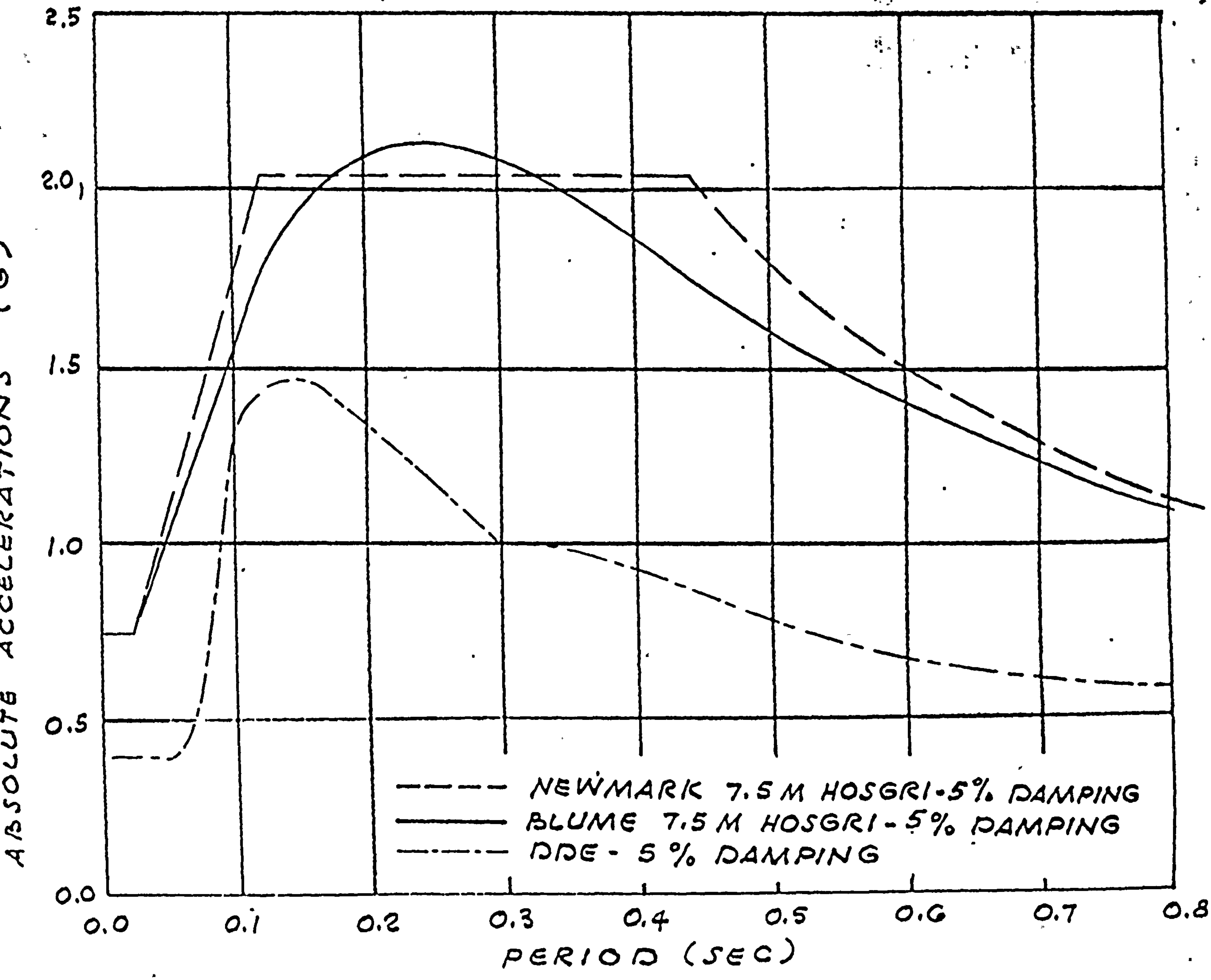
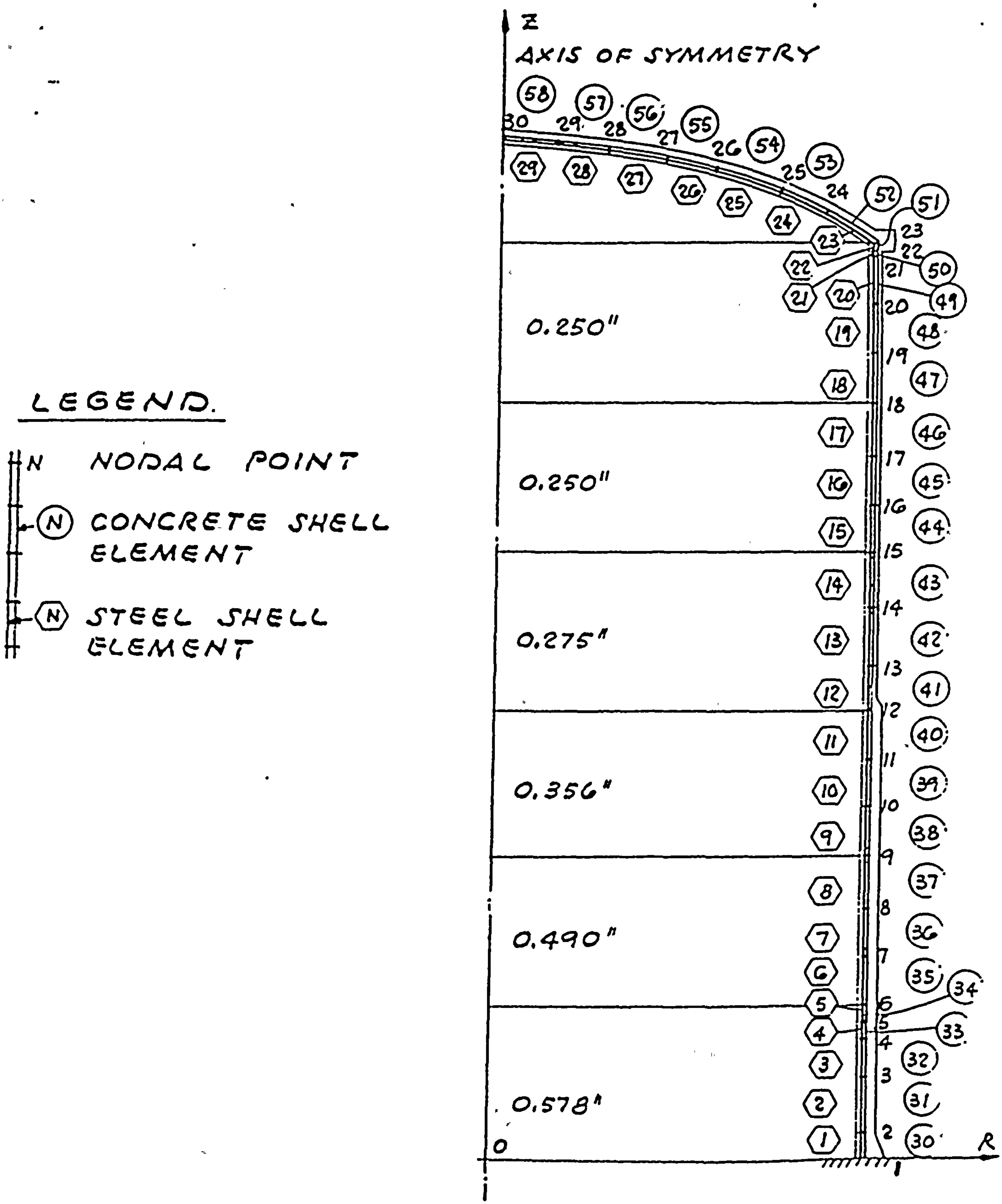
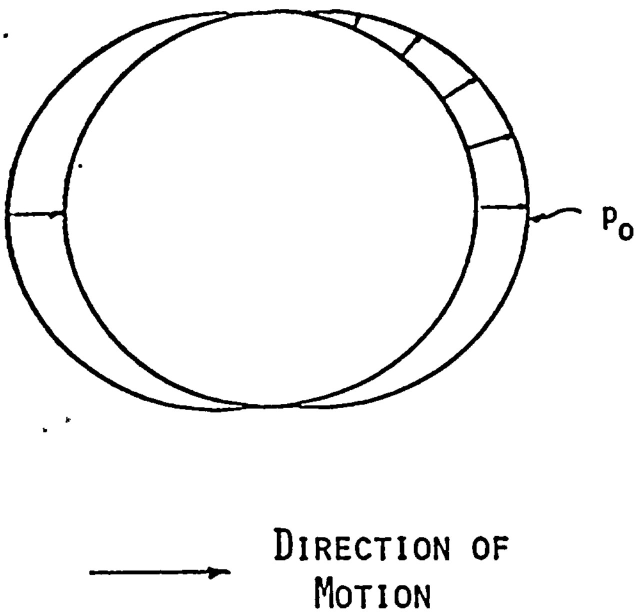


FIGURE 4



DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
REFUELING WATER TANK - AXISYMMETRIC MODEL

FIGURE 5



$$p_o(z, \theta, t) = C\, b_o(z)\, \rho H\, A_o(t) \cdot \cos\theta.$$

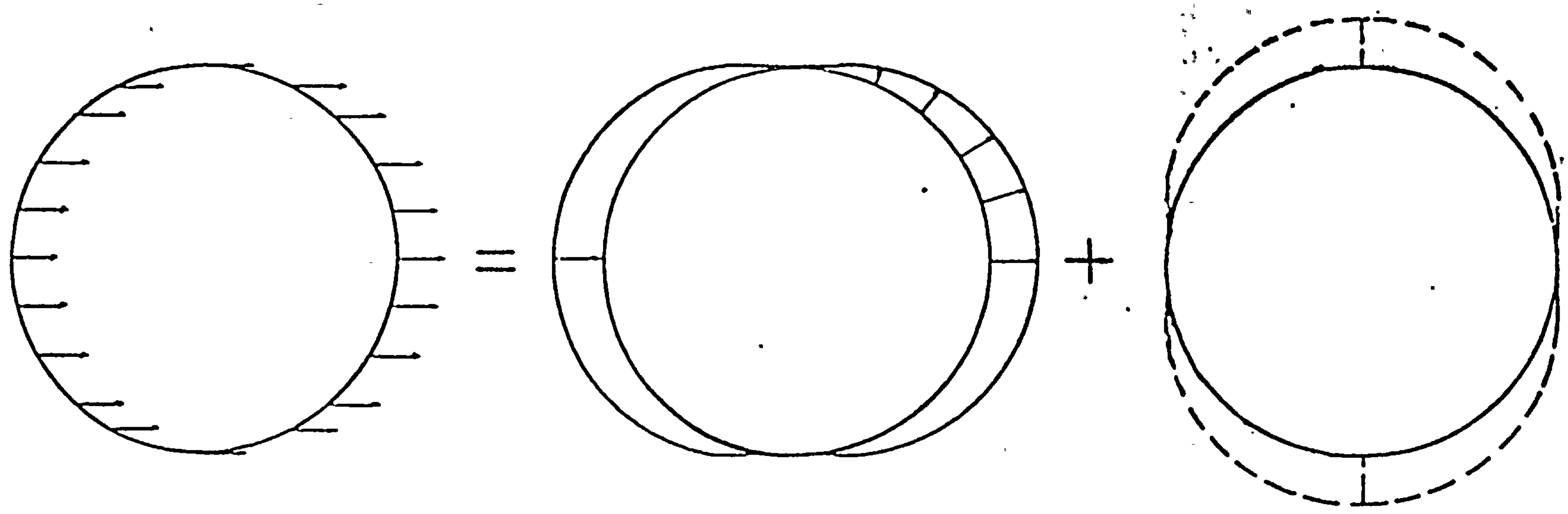
VARIATION OF IMPULSIVE PRESSURE, p_o, OVER THE CIRCUMFERENCE

DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
VARIATION OF IMPULSIVE PRESSURE

FIGURE 6

DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
COMPONENTS OF HORIZONTAL PRESSURE

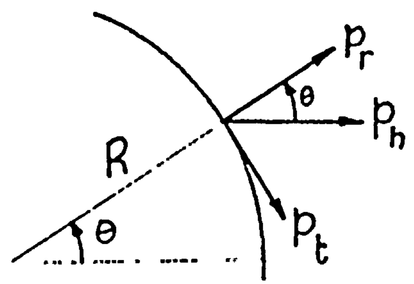
FIGURE 7



7a. HORIZONTAL PRESSURE, p_h

7.b. RADIAL PRESSURE, p_r

7.c. TANGENTIAL PRESSURE, p_t

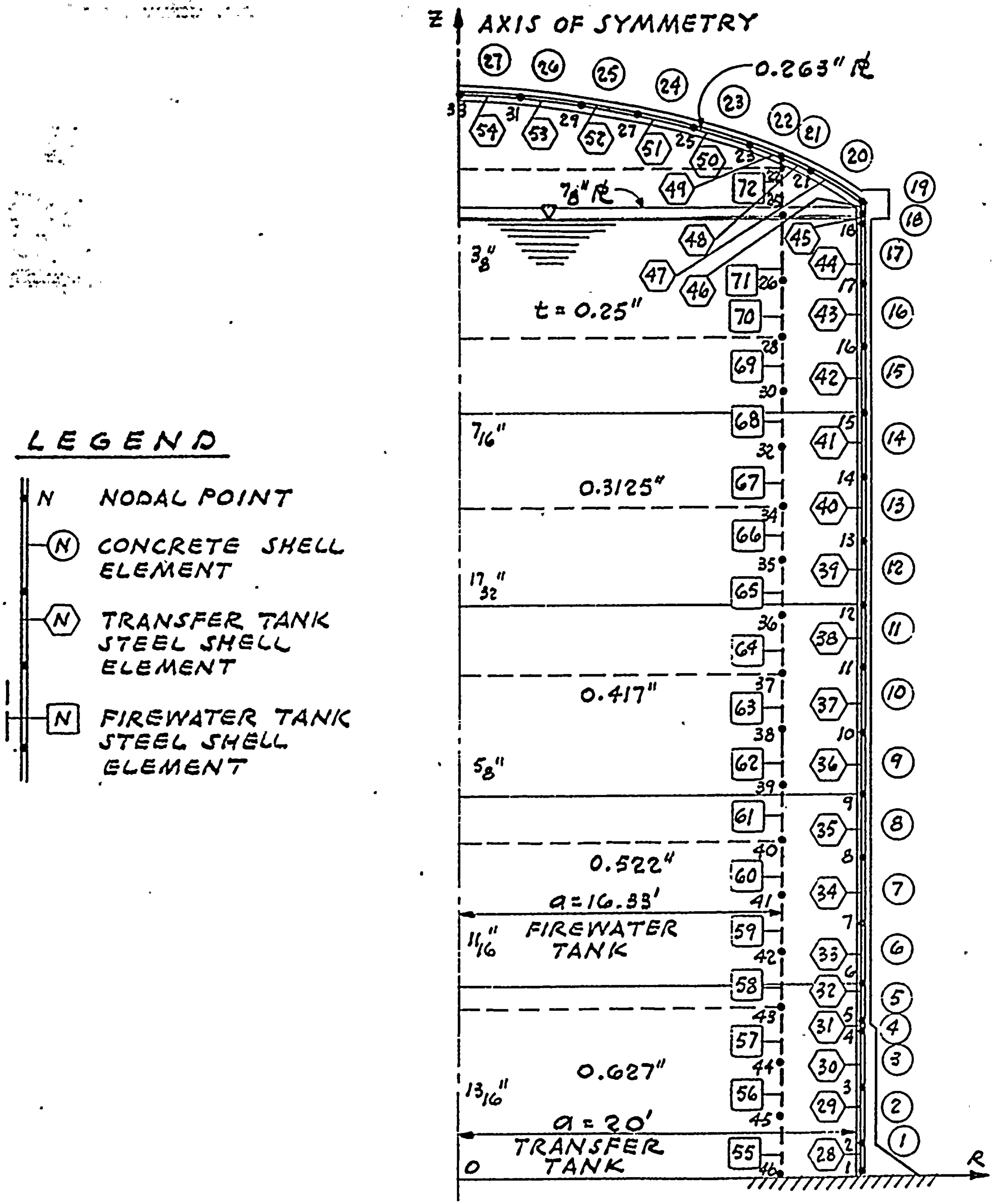


7.d. RESOLUTION OF FORCES

$$p_h = m\ A_o(t) = C\ b_o(z)\ \rho H\ A_o(t)$$

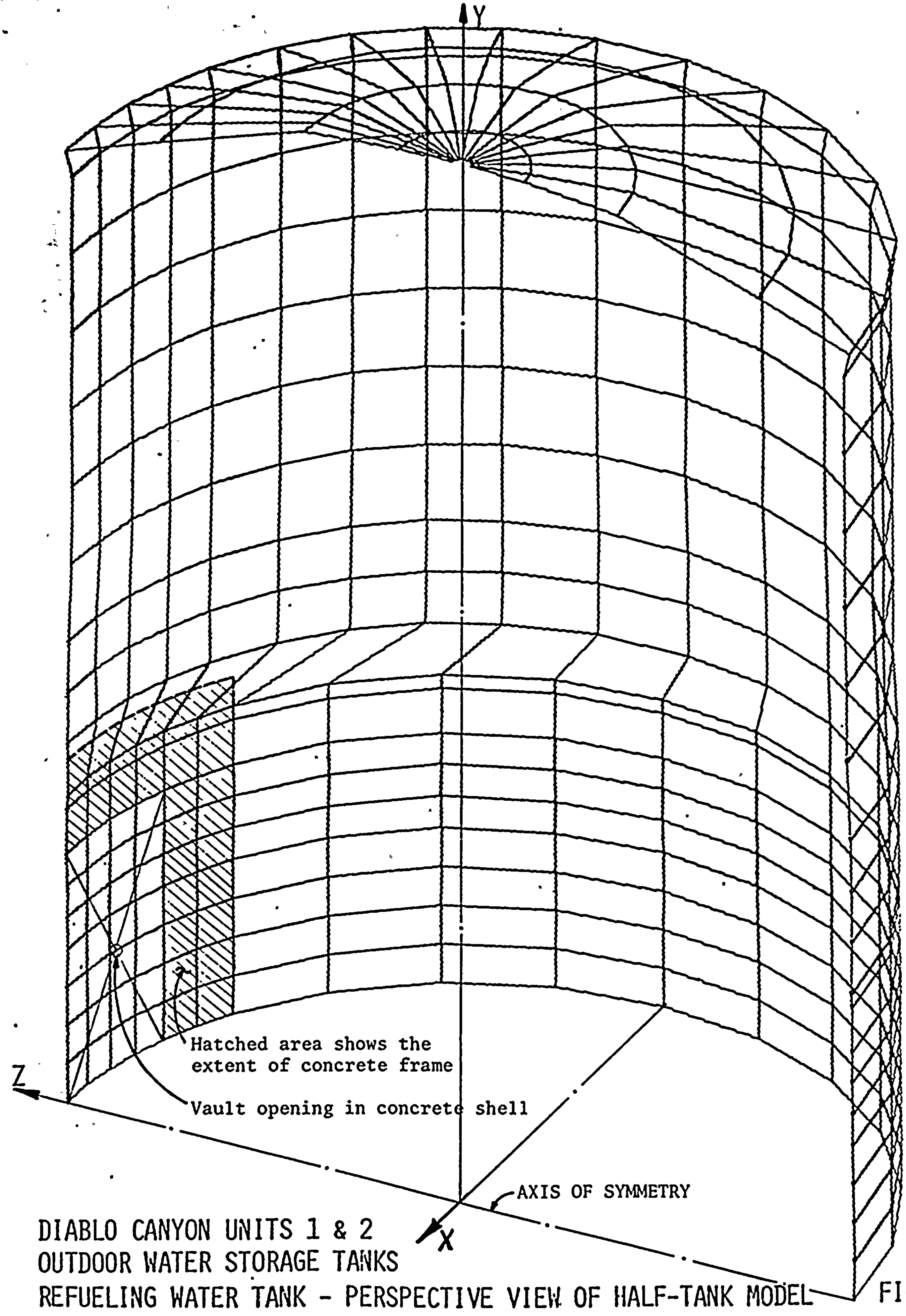
$$p_r = p_h \cos\theta = C\ b_o(z)\ \rho H\ A_o(t) \cos\theta$$

$$p_t = p_h \sin\theta$$



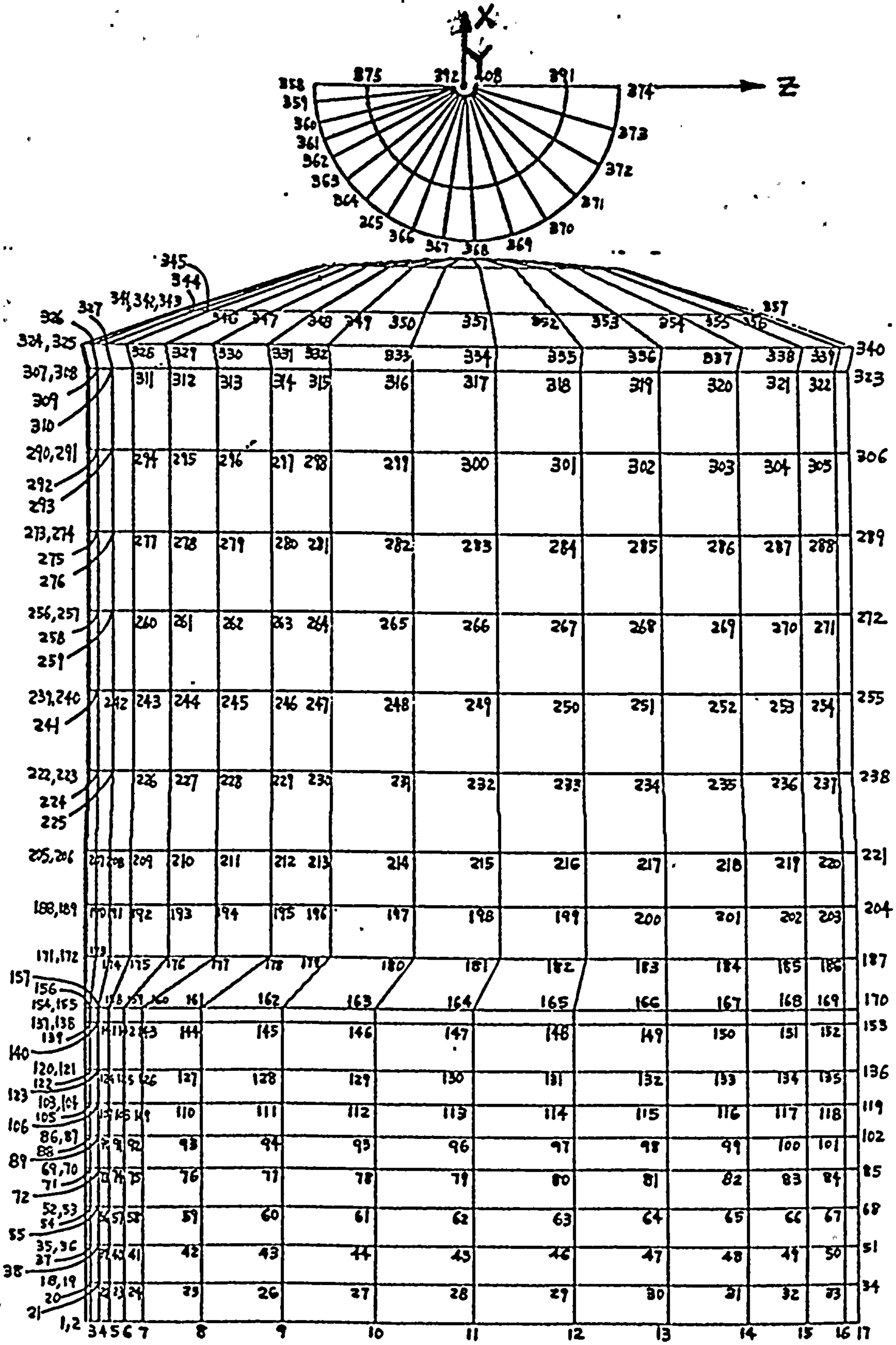
DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
FIREWATER AND TRANSFER TANK

FIGURE 8



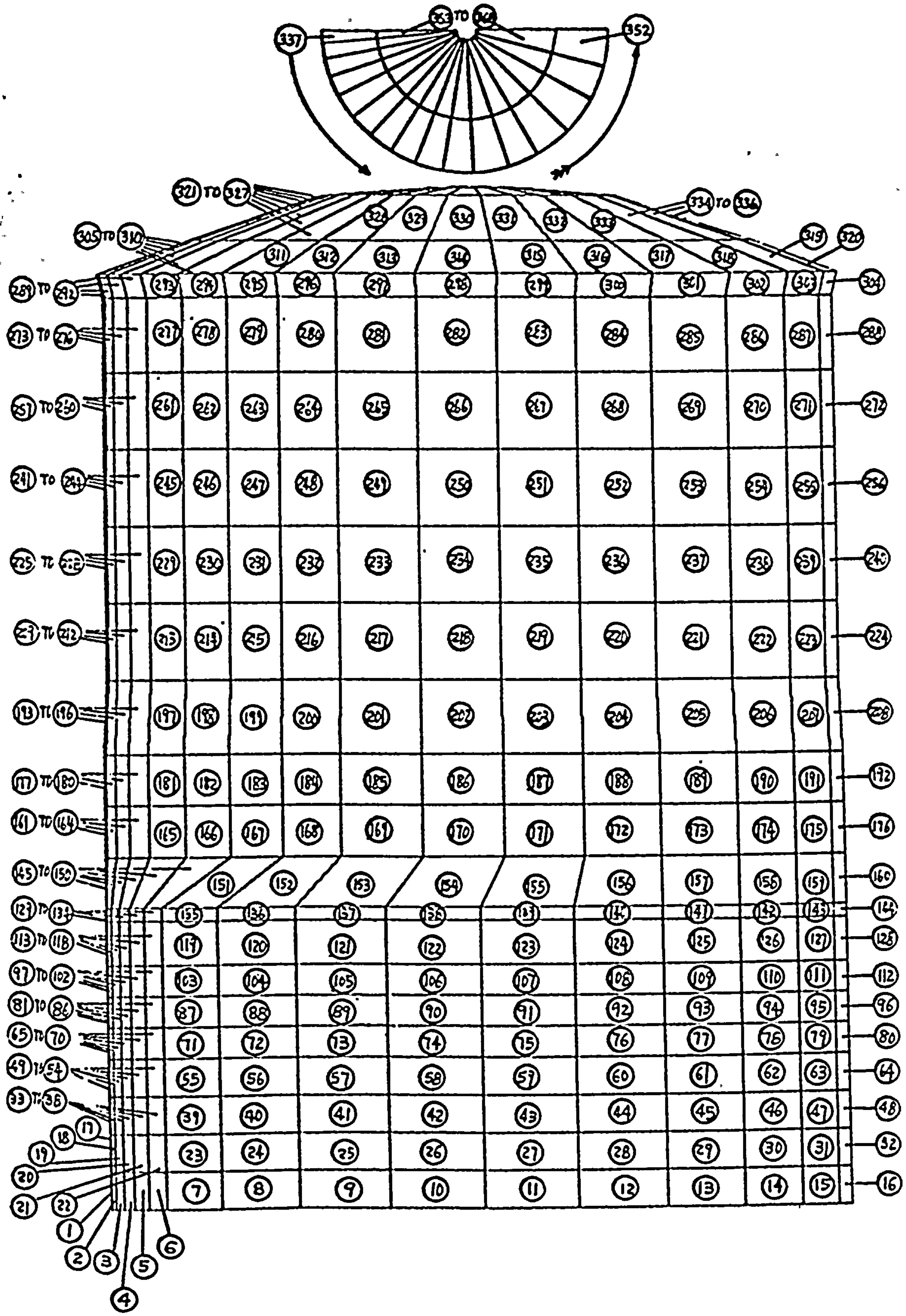
DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
REFUELING WATER TANK - PERSPECTIVE VIEW OF HALF-TANK MODEL

FIGURE 9



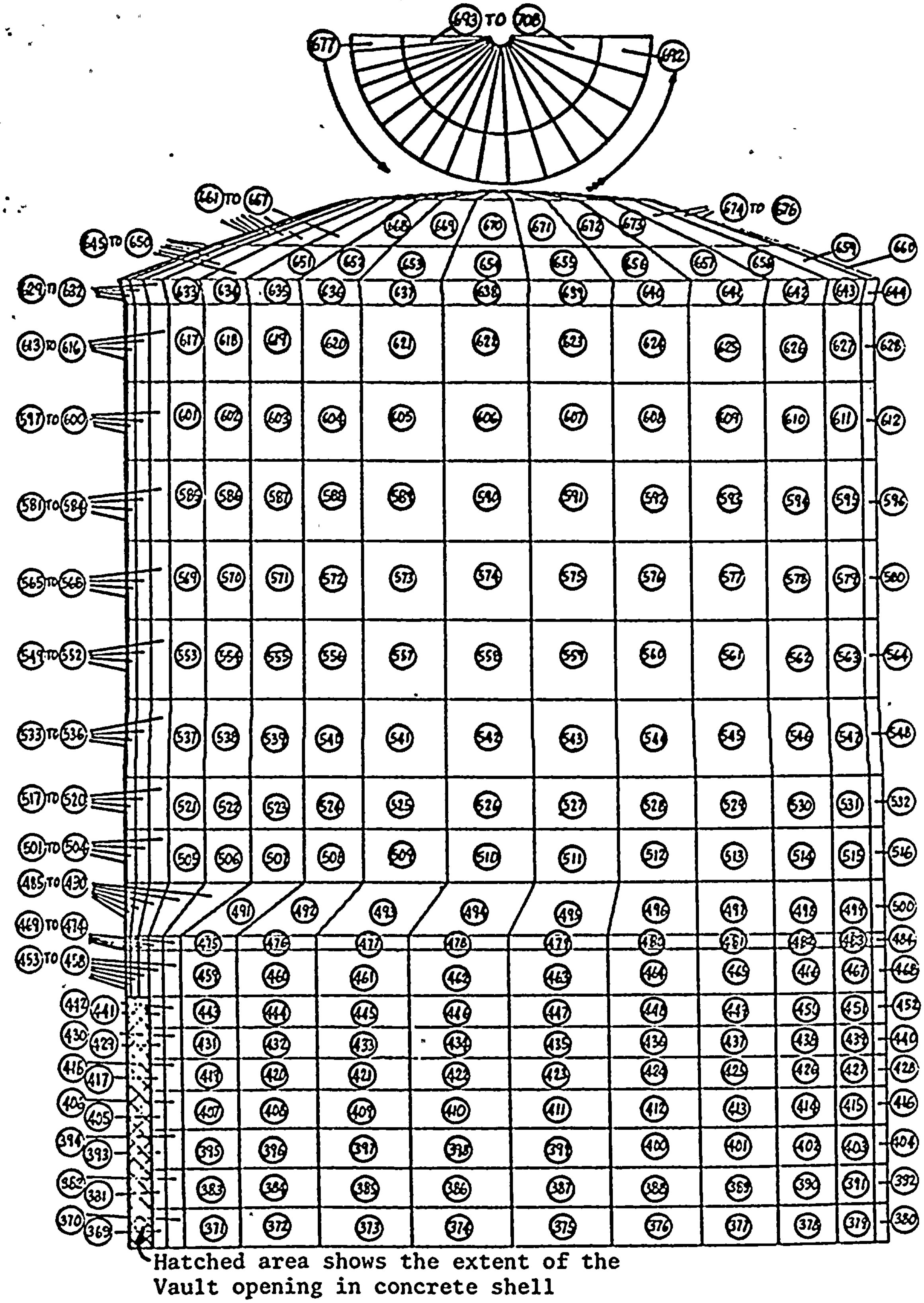
DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
REFUELING WATER TANK - NODE NUMBERS

FIGURE 10



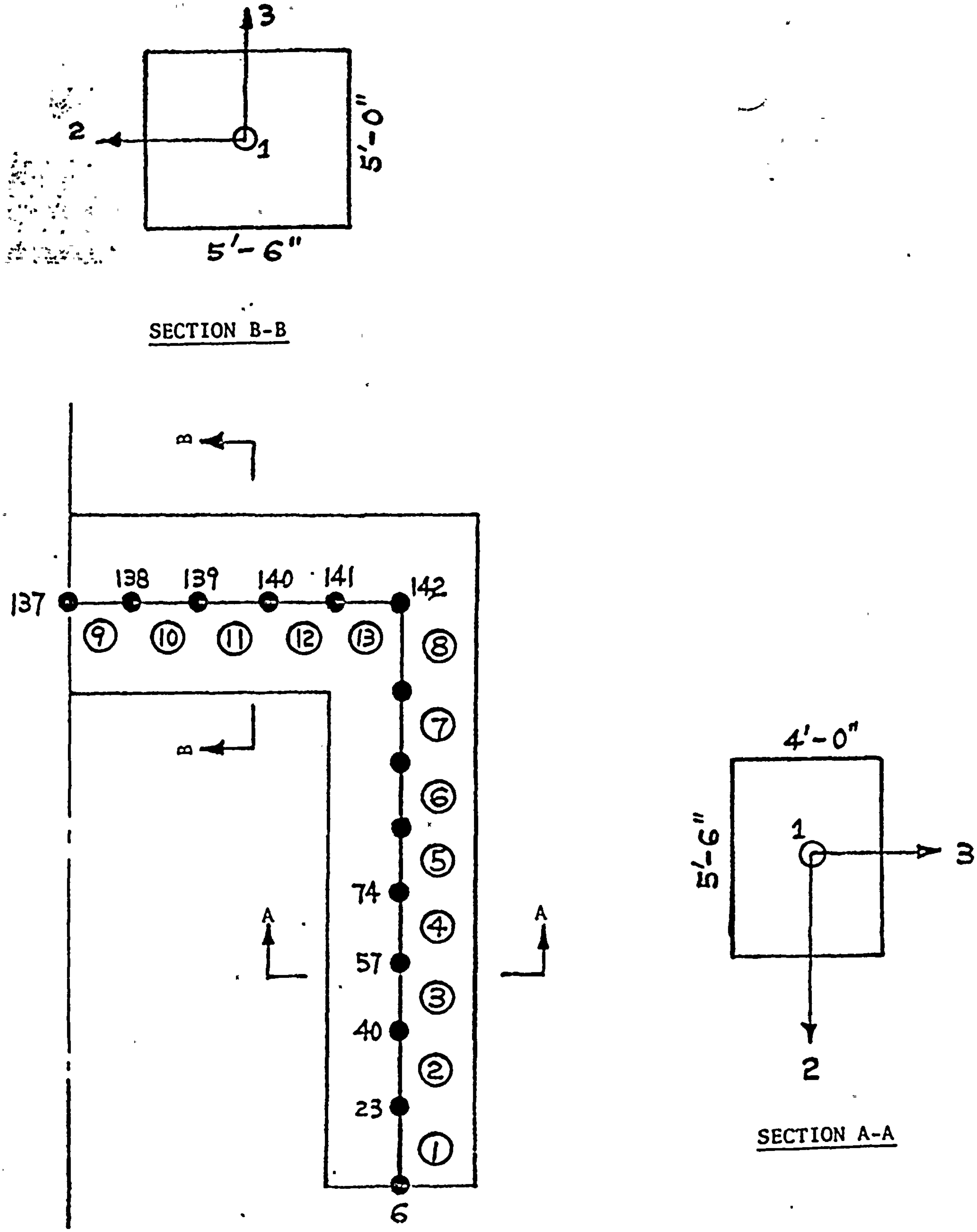
DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
REFUELING WATER TANK - STEEL SHELL ELEMENTS

FIGURE 11

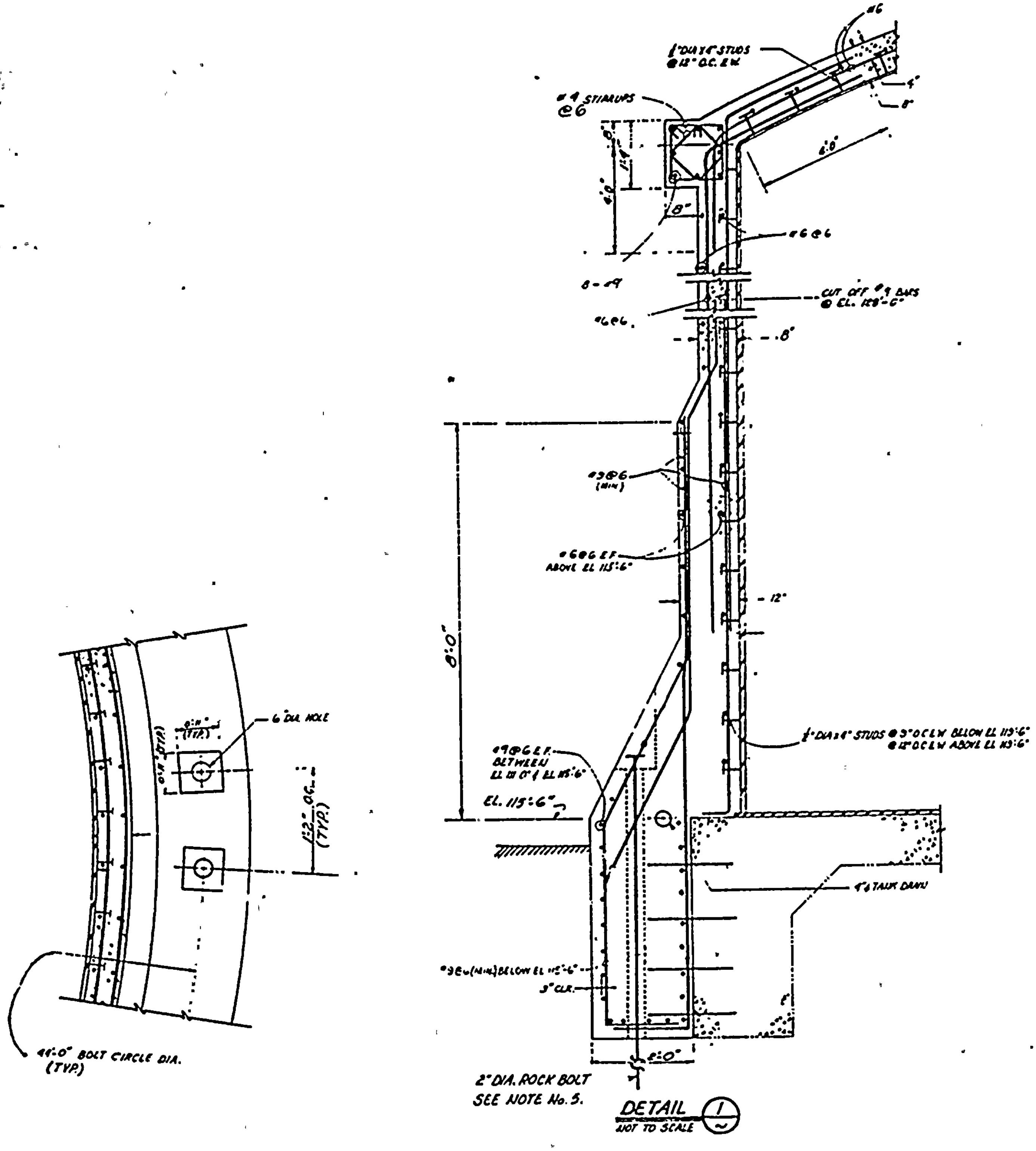


DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
REFUELING WATER TANK - CONCRETE SHELL ELEMENTS

FIGURE 12



DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
REFUELING WATER TANK - BEAM ELEMENTS IN CONCRETE FRAME FIGURE 13



DIABLO CANYON UNITS 1 & 2
OUTDOOR WATER STORAGE TANKS
TYPICAL REINFORCEMENT DETAILS IN CONCRETE SHELL

FIGURE 14

Preliminary

DIABLO CANYON
NUCLEAR POWER PLANT

INTAKE STRUCTURE CRANE
EVALUATION FOR THE 7.5M HOSGRI EARTHQUAKE

October 3, 1978

prepared for
Pacific Gas & Electric Company

by
URS/John A. Blume & Associates, Engineers
130 Jessie Street
San Francisco, California

1. INTRODUCTION

This report summarizes the seismic analysis and structural design evaluation used in reviewing the intake structure crane of the Diablo Canyon Nuclear Power Plant for response to the postulated 7.5M Hosgri earthquake. The 50 ton gantry crane travels on rails running north-south along the entire length of the top deck of the intake structure. The crane, designed for outdoor and marine environment service, is used for handling pumps, motors, traveling screens, gates and bar racks during routine equipment maintenance and overhaul. A trash rake, mounted on the ocean face of the gantry, is used for routine cleaning of the bar racks.

The Intake Structure, which serves both Units 1 and 2, is a seismic Class II structure and was originally designed under seismic criteria which called for seismic forces to be determined on the basis of an equivalent static force coefficient of 0.20g with a one-third increase in allowable stresses. However, because it houses the four Class I auxiliary saltwater pumps, two for each unit, it was reviewed for the postulated 7.5M Hosgri motions. Except for the relatively small auxiliary saltwater pumps, safe shutdown in the event of a major earthquake disturbance is not considered essential for any part of the structure or its four main circulating water pumps.

The evaluation of the crane has been accomplished according to the February 8, 1977, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake.*[1] A modal superposition response-spectrum dynamic analysis was performed through the use of finite-element model representations of the structure.

This report contains a description of the salient structural features of the intake structure crane and a presentation of the analysis criteria, mathematical modeling and results.

2. DESCRIPTION OF STRUCTURE

The Intake Structure Crane is a three-dimensional bolted and fabricated structural steel gantry crane with trolley. It is 40 ft tall and 100 ft long, spanning 88.9 ft between rails in the east-west direction with the upper girders cantilevered a further 11 ft. The trolley is supported on two 5 ft deep steel plate box girders at 14.5 ft centers which in turn are supported by tapered box section legs which are inclined to 26 ft centers at the lower end. Each lower end tie accommodates two bogies which together contain one driver wheel and three idlers.

The structure was designed in accordance with Standard No. 6 of the Association of Iron and Steel Engineers. Members not covered by that Standard were designed and fabricated in accordance with the current Specification for the Design, Fabrication and Erection of Structural Steel for Buildings by the American Institute of Steel Construction.

The gantry crane design load is 50 tons. Erection, startup, and initial operation of the crane were performed at the job site under the direction of a qualified engineer from the Manufacturer. The crane was given a load test at 1.25 design load. The hoist mechanism includes an 8-part tackle of 1 1/8"ϕ galvanized wire ropes.

3. ANALYSIS CRITERIA

General

The basic approach to the 7.5M Hosgri evaluation of the intake structure crane is outlined in the February 8, 1977, specification.[1] The evaluation for seismically-induced forces was performed with the crane in a typical parked or operating position, and for the situation with and without the rated operating load.

Stress evaluation for noncontinuous members was undertaken according to AISC Specification,[2] Part 1 (Elastic design), with the following exceptions:

> Allowable bending stress, $F_b^* = F_y = 36$ ksi
>
> Allowable uniaxial stress, $F_a^* = 1.7\ F_a$ (F_a is the code computed value)
>
> Allowable shear stress, $F_v^* = F_y/\sqrt{3}$

This is merely equivalent to determination of the elastic limit instead of a working stress approach which is consistent with application of the postulated Hosgri 7.5M seismic event.

Strength determination for continuous members was undertaken according to AISC Code, Part 2 (Plastic design), with the yield strength of $F_y = 36$ ksi.

Seismic Inputs

The horizontal base motion input applied to the intake structure crane at the crane rail was the structurally modified structure-specific, 7 percent damped horizontal response spectra developed for the intake structure from the Blume and Newmark 0.75g free-field ground spectra, by spatial averaging of accelerations, a method dependent on shear-wave velocity and structural foundation size.

The vertical input was taken as two-thirds of the 0.75g, 7 percent damped horizontal Newmark free-field ground spectrum.

Modeling Parameters

Modal damping equal to 7 percent of critical was used in the Hosgri analysis of the intake structure crane. This is in accordance with the currently accepted Regulatory Guide 1.61[3] recommendations and is further substantiated by conclusions of a URS/Blume study.[4]

The adopted breaking strength for each wire rope was 48.5 tons. The elastic modulus was 1,200 ksi.

4. METHOD OF ANALYSIS

Linear three-dimensional finite element response spectrum analyses were undertaken using the SAP IV[5] structural analysis computer code. The model consisted entirely of beam elements and mass was applied at appropriate nodes (Figure 1).

The model was subjected to dead and seismic loading, with and without hook loads. Seismic loading in the horizontal direction corresponds to the Newmark elastic spectrum for 7 percent damping and $\tau = 0.04$ in the east-west direction and the elevation 17.5 ft modified response spectrum derived from the equivalent Blume spectrum in the north-south direction. Crane inertial forces are limited in the north-south direction by sliding response with a coefficient of friction, $\mu = .25$, for each braked wheel (1/4 per side).

Seismic loading in the vertical direction corresponds to 2/3 of the Newmark free-field elastic spectrum for 7 percent damping which was again more severe than the equivalent Blume spectrum.

The resulting N/S and E/W responses and the vertical seismic results were combined on a SRSS basis. This total effect was in turn combined with dead load and hook load.

For the case with operating load nonlinear analyses of the crane with the cable suspended hook load were undertaken for vertical motion using the DRAIN-2D[6] computer code. The model is shown in Figure 2. Structural damping of 4 percent in the first two modes was adopted for these analyses. Pendulum motion of the suspended load was also determined using DRAIN-2D and the response spectrum method. Resulting horizontal loads were insignificant.

5. DISCUSSION OF RESULTS

The natural periods of vibration and participation factors for the north-south, east-west, and the vertical response spectrum analyses of the unloaded and loaded crane, are summarized in Tables 1 and 5 respectively. In accordance with the requirements of the NRC, only those modes with associated periods of vibration greater than or equal to 0.03 sec are considered significant for response computations. The fundamental frequencies of the system in the north-south, east-west, and vertical directions are 1.1 Hz, 2.1 Hz, and 5.6 Hz, respectively for the unloaded system and ~~on~~ 1.1 Hz, 2.1 Hz, and 3.6 Hz respectively for the loaded system.

The predicted seismic-induced displacements for the unloaded and loaded system are summarized in Tables 2 and 6. The maximum estimated displacements in the east-west ~~is estimated maximum~~ and north-south directions are approximately 3 in.

Maximum bending moments and axial loads for the crane legs, girders, and end ties resulting from the SRSS combined effects of the separate response spectrum analyses added directly to the dead load effects for the unloaded and loaded case are shown in Tables 3 and 7 respectively. The ratios of the computed bending moment and axial stresses to allowable values are shown in Tables 4 and 8. For any member, the ratios are additive to obtain the combined stress effect. None of the combinations result in a ratio greater than 1.

Shear stresses were insignificant in all members. ¶ The element and node numbers shown in the tables correspond to the computer model shown in Figure 1. Stability analyses of the crane indicated uplifting and possible overturning in the north-south direction where sliding was prevented.

6. SUMMARY

The results presented in this report are intended to provide information regarding the seismic adequacy of the intake structure crane under the postulated 7.5M Hosgri earthquake motions.

Results of the seismic analyses show that the intake crane is capable of carrying its maximum rated load of 50 ton without overstressing of any structural members or the hoist cable.

Sliding of a few inches can be expected along the crane runway during the postulated earthquake. If the crane is parked at the end of the runway, and sliding is thus prevented, seismic overturning moments may cause overstressing of the anchors, although in this position the unlikely event of overturning might result in the crane falling into the ocean which does not pose a risk to the function of any safety related equipment.

7. REFERENCES

1. URS/John A. Blume & Associates, Engineers, *Diablo Canyon, Specification for Seismic Review of Major Structures for 7.5M Hosgri Earthquake* (preliminary), revised February 8, 1977.

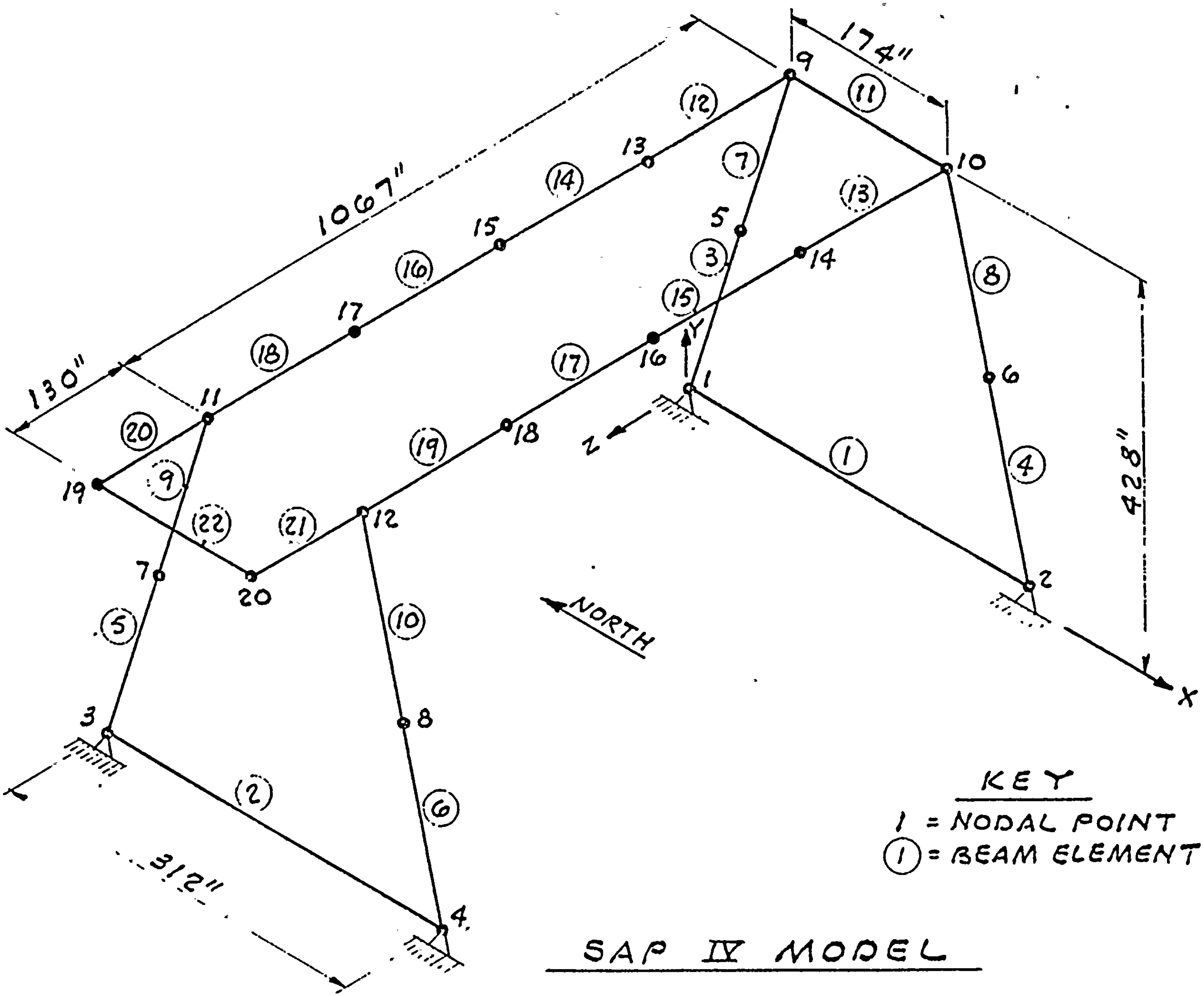
2. AISC Specification for the Design Fabrication and Erection of Structural Steel for Buildings, American Institute of Steel Construction, New York, 1969.

3. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61, *Damping Values for Seismic Design of Nuclear Power Plants*, October 1973.

4. Blume, J. A., and Kabir, A. F., *Data on Damping Ratios*, LL9.

5. Bathe, K. J., Wilson, E. L., and Peterson, F. E., "SAP IV: A Structural Analysis Program for Static and Dynamic Response of Linear Systems," Report No. EERC 73-11, Earthquake Engineering Research Center, University of California, Berkeley, June 1973.

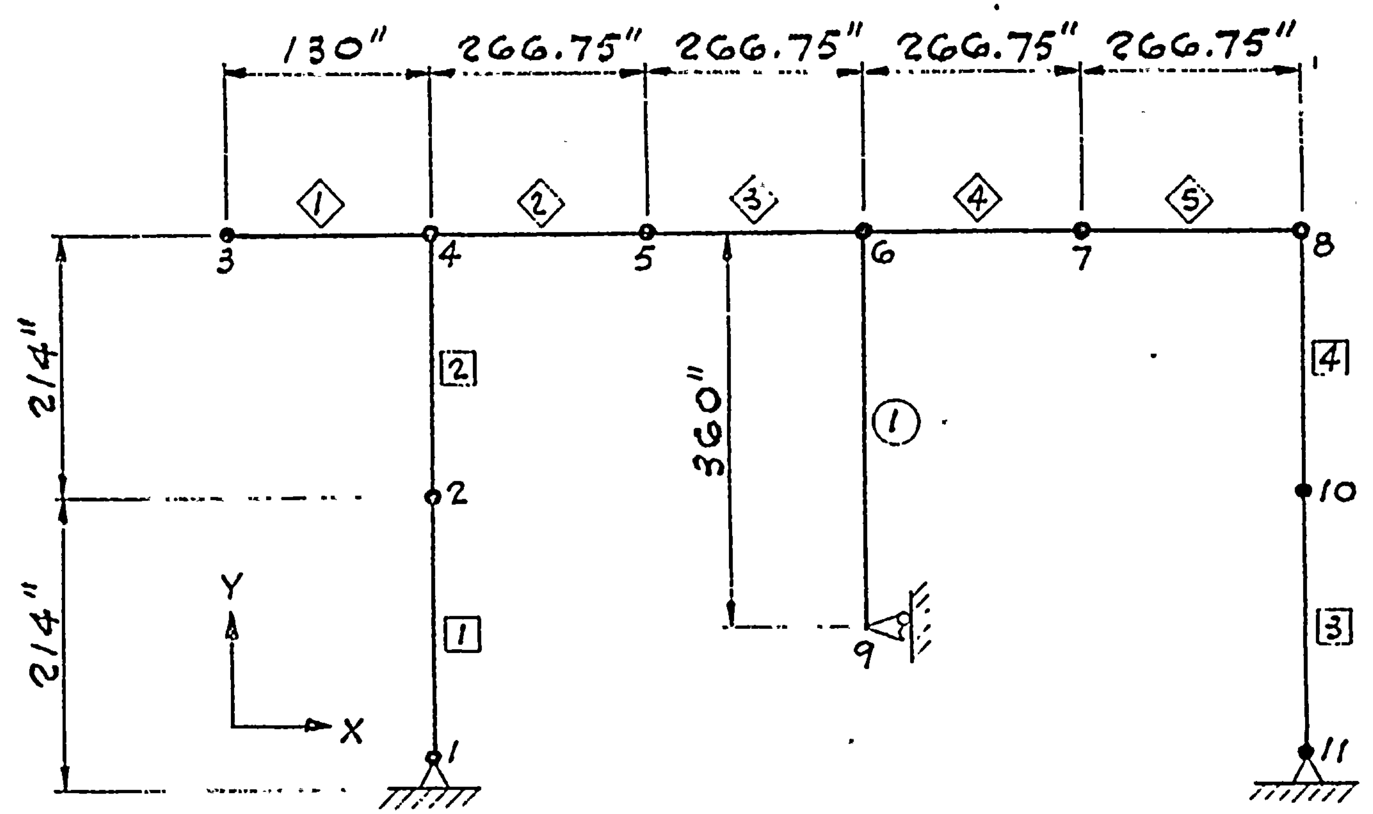
6. Kanaan, A. E., and Powell, G. H., "General Purpose Computer Program for Inelastic Dynamic Response of Plane Structures," Report No. EERC 73-6, Earthquake Engineering Research Center, University of California, Berkeley, April 1973.



SAP IV MODEL

DIABLO CANYON
INTAKE STRUCTURE CRANE

Figure 1



DRAIN 2-D MODEL

KEY

1 = NODAL POINT
(1) = TRUSS ELEMENT
[1] = BEAM-COLUMN ELEMENT
◇1 = BEAM ELEMENT

DIABLO CANYON
INTAKE STRUCTURE CRANE

Figure 2

TABLE 1

INTAKE STRUCTURE CRANE

PERIODS OF VIBRATION AND PARTICIPATION FACTORS

UNLOADED CASE

MODE	PERIOD (sec)	PARTICIPATION FACTOR (%) N/S DIRECTION	E/W DIRECTION	VERTICAL DIRECTION
1	0.924	39.3	0.3	0.4
2	0.481	0.3	72.2	0.7
3	0.349	1.2	5.7	2.7
4	0.304	17.4	-	0.2
5	0.181	0.9	-	19.2
6	0.177	0.4	0.3	25.4
7	0.155	3.0	0.1	0.6
8	0.148	13.1	0.1	0.4
9	0.097	0.2	1.7	1.1
10	0.070	4.2	-	2.0
11	0.066	1.9	0.2	0.3
12	0.057	2.4	1.8	5.1
13	0.055	1.4	4.8	10.1
14	0.051	4.0	0.2	0.8
15	0.050	3.1	0.1	0.1
16	0.048	0.8	4.1	4.1
17	0.040	0.6	0.8	6.1
18	0.039	0.1	0.1	2.0
19	0.037	0.8	0.1	7.6
20	0.035	1.7	1.6	8.8
21	0.032	1.9	0.6	0.7
22	0.032	0.6	3.4	0.5
23	0.031	0.6	1.5	1.1

TABLE 2

INTAKE STRUCTURE CRANE

MAXIMUM DISPLACEMENTS

UNLOADED CASE

NODAL POINT	NORTH-SOUTH DIRECTION (in.)	EAST-WEST DIRECTION (in.)	VERTICAL DIRECTION (in.)
6	0.09	2.21	0.02
8	0.56	2.26	0.10
10	0.12	3.28	0.03
12	1.35	3.28	0.23
14	0.47	3.28	0.60
16	0.94	3.28	0.78
18	1.22	3.28	0.60
20	1.45	3.28	0.43

TABLE 3

INTAKE STRUCTURE CRANE

MAXIMUM MEMBER FORCES

UNLOADED CASE

ELEMENT	AXIAL LOAD (KIPS)	MOMENT M_2 (KIP-IN)	MOMENT M_3 (KIP-IN)
1	-	6	463
2	-	6	2223
4	79.8	13187	444
6	98.9	13302	2223
8	75.8	25507	991
10	91.7	25003	940
11	-	991	2493
13	-	25179	2536
15	-	15035	1712
17	-	14647	1712
19	-	26032	2153
21	-	2057	3946
22	-	-	3951

TABLE 4

INTAKE STRUCTURE CRANE

MAXIMUM STRESS RATIOS

UNLOADED CASE

ELEMENT	f_a/F_a	f_{b2}/F_b	f_{b3}/F_b	TOTAL
1	-	-	0.04	0.04
2	-	-	0.21	0.21
4	0.04	0.39	0.02	0.45
6	0.06	0.39	0.05	0.50
8	0.04	0.52	0.04	0.60
10	0.04	0.51	-	0.55
11	-	0.01	0.09	0.10
13	-	0.37	0.09	0.46
15	-	0.22	0.06	0.28
17	-	0.21	0.06	0.27
19	-	0.38	0.08	0.46
21	-	0.03	0.14	0.17
22	-	-	0.14	0.14

TABLE 5

INTAKE STRUCTURE CRANE

PERIODS OF VIBRATION AND PARTICIPATION PACTORS

LOADED CASE

MODE	PERIOD (sec)	PARTICIPATION FACTOR (%) N/S DIRECTION	E/W DIRECTION	VERTICAL DIRECTION
1	0.929	36.3	0.3	0.3
2	0.481	0.3	71.6	0.9
3	0.351	1.0	5.8	7.6
4	0.304	15.5	-	0.8
5	0.276	4.4	0.2	26.9
6	0.274	5.0	0.3	24.3
7	0.155	3.2	0.1	0.2
8	0.149	11.8	0.1	0.3
9	0.097	0.3	1.6	1.0
10	0.070	3.9	-	1.5
11	0.066	1.7	0.3	0.3
12	0.057	2.3	2.3	4.6
13	0.056	1.0	4.5	7.0
14	0.051	3.7	0.2	0.7
15	0.050	2.9	-	0.1
16	0.048	0.7	4.1	3.0
17	0.041	0.4	1.1	3.6
18	0.039	-	0.1	1.4
19	0.038	0.5	-	3.5
20	0.035	1.3	1.4	8.3
21	0.033	1.5	3.1	2.3
22	0.032	0.9	1.7	0.8
23	0.031	1.2	1.0	0.5

TABLE 6

INTAKE STRUCTURE CRANE

MAXIMUM DISPLACEMENTS

LOADED CASE

NODAL POINT	NORTH-SOUTH DIRECTION (in.)	EAST-WEST DIRECTION (in.)	VERTICAL DIRECTION (in.)
6	0.25	2.33	0.05
8	1.10	2.38	0.19
10	0.31	3.29	0.07
12	2.65	3.29	0.45
14	0.94	3.30	1.59
16	1.79	3.30	2.38
18	2.31	3.30	1.63
20	2.85	3.29	0.83

TABLE 7
INTAKE STRUCTURE CRANE
MAXIMUM MEMBER FORCES
LOADED CASE

ELEMENT	AXIAL LOAD (KIPS)	MOMENT M_2 (KIP-IN)	MOMENT M_3 (KIP-IN)
1	-	8	618
2	-	8	4357
4	143.5	15952	594
6	177.4	16058	4357
8	135.2	31144	1339
10	162.1	30720	1933
11	-	1339	4153
13	-	16439	2789
15	-	41083	2025
17	-	41083	2259
19	-	19779	2870
21	-	3248	5496
22	-	-	5536

TABLE 8

INTAKE STRUCTURE CRANE

MAXIMUM STRESS RATIOS

LOADED CASE

ELEMENT	f_a/F_a	f_{b2}/F_b	f_{b3}/F_b	TOTAL
1	-	-	0.06	0.06
2	-	-	0.41	0.41
4	0.08	0.47	0.02	0.57
6	0.10	0.47	0.10	0.67
8	0.07	0.63	0.06	0.76
10	0.08	0.63	-	0.71
11	-	0.02	0.14	0.16
13	-	0.24	0.10	0.34
15	-	0.60	0.07	0.67
17	-	0.60	0.08	0.68
19	-	0.29	0.10	0.39
21	-	0.05	0.19	0.24
22	-	-	0.19	0.19

DIABLO CANYON NUCLEAR POWER PLANT

UNIT 1

MANIPULATOR CRANE

HOSGRI SEISMIC REPORT

July 31, 1978

K. J. Swidwa

Kenneth J. Swidwa

Refueling Equipment

Westinghouse PWR-SD

TABLE OF CONTENTS

I. INTRODUCTION

The manipulator crane for the Diablo Canyon Nuclear Power Plant was seismically analyzed for a Hosgri earthquake. The crane is used inside containment and is used to handle fuel assemblies, thimble plugs, and control rod drive shafts. The crane runs on rails located at the operating deck level (Elev. 140 feet).

A three-dimensional linear analysis was performed using the Westinghouse Electric Computer Analysis (WECAN)[1] Finite Element Program to determine deflections, loads, and stresses for dead weight, operating and seismic loads. These results were then compared to the allowables from the ASME Boiler and Pressure Vessel Code[2] Section III Division 1 Article XVII-2000 for Level D service limits.

II. ANALYSIS CRITERIA

A. Load Combinations

Level D Service

Trolley and Monorail Hoist at Center Span

DW + OL + SSE

DW + SSE

Trolley and Monorail Hoist at Travel Limits

DW + OL + SSE

DW + SSE

where:

DW = Dead Weight of Equipment

OL = Operating Loads

SSE = Safe Shutdown Earthquake

B. Elevation Criteria

Level D Service

The structural stresses resulting from the loadings in Section A are not to exceed the Level D service limits for linear elastic analysis as specified in the ASME Code.

III. MATHEMATICAL MODELS AND ANALYTICAL METHODS

A. Modeling

A detailed finite element model was made of the Manipulator Crane structure using the WECAN computer code. The structure was supported at the four wheels which were modeled as hinged supports.

Member sizes were determined from manufacturer's drawings and as-built sketches.

B. Method of Analysis

A. Dead Weight and Operating Loads

Dead weight and operating load stresses were determined using the static analysis feature of WECAN. The stresses were stored on tape for later use.

B. Seismic Loads

Seismic stresses were determined using the Reduced Modal Seismic Analysis option of WECAN for each shock direction. This option uses the response spectrum analysis technique. The spectra are 7% damping curves developed from the Newmark spectra at an elevation 140 feet in containment given in the Hosgri report(3). 7% equipment damping is in accordance with the NRC Regulatory Guide 1.61(4) for bolted construction. Dynamic modes for each shock were combined by SRSS method with consideration for close spaced mode being accounted for in margins of safety. The results from the three directions were then combined by SRSS and added and subtracted from the static results to obtain the peak cyclic values.

IV. RESULTS

The initial analysis revealed a few areas where the stresses exceed allowables. These were the monorail structure column joints, the bridge trucks and the cable support tower.

The excessive stresses in the monroail structure were due to the lack of crossbracing on the structure. This caused excessive bending in the individual columns and an overstressing of the joints attaching them to the bridge trucks. This problem was corrected by the addition of crossbracing to the structure.

Overstressing in the bridge truck was caused by the low torsional constant from two open channels back to back. This was corrected by locally boxing in the channels to increase the torsional constant.

The cable support structure was overstressed because of the type of crossbracing used as well as several shop modifications made to the structural members due to interferences with other equipment. The tower was, therefore, redesigned along with other interfering equipment to strengthen the structure.

The modified crane was reanalyzed to determine the effect of the modifications on the response of the structure. The results confirm that all the main structural members and joints are adequately designed for the Hosgri Earthquake. The maximum stress ratios for these members are given in Appendix D.

High stress ratios were found in certain secondary members of the structure such as the bridge back handrail and trolley floor support, however, these were caused by buckling and the loads are not large enough to separate them from the structure nor will their failure adversely affect other structural members.

V. REFERENCES

1. WECAN Computer Code, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.

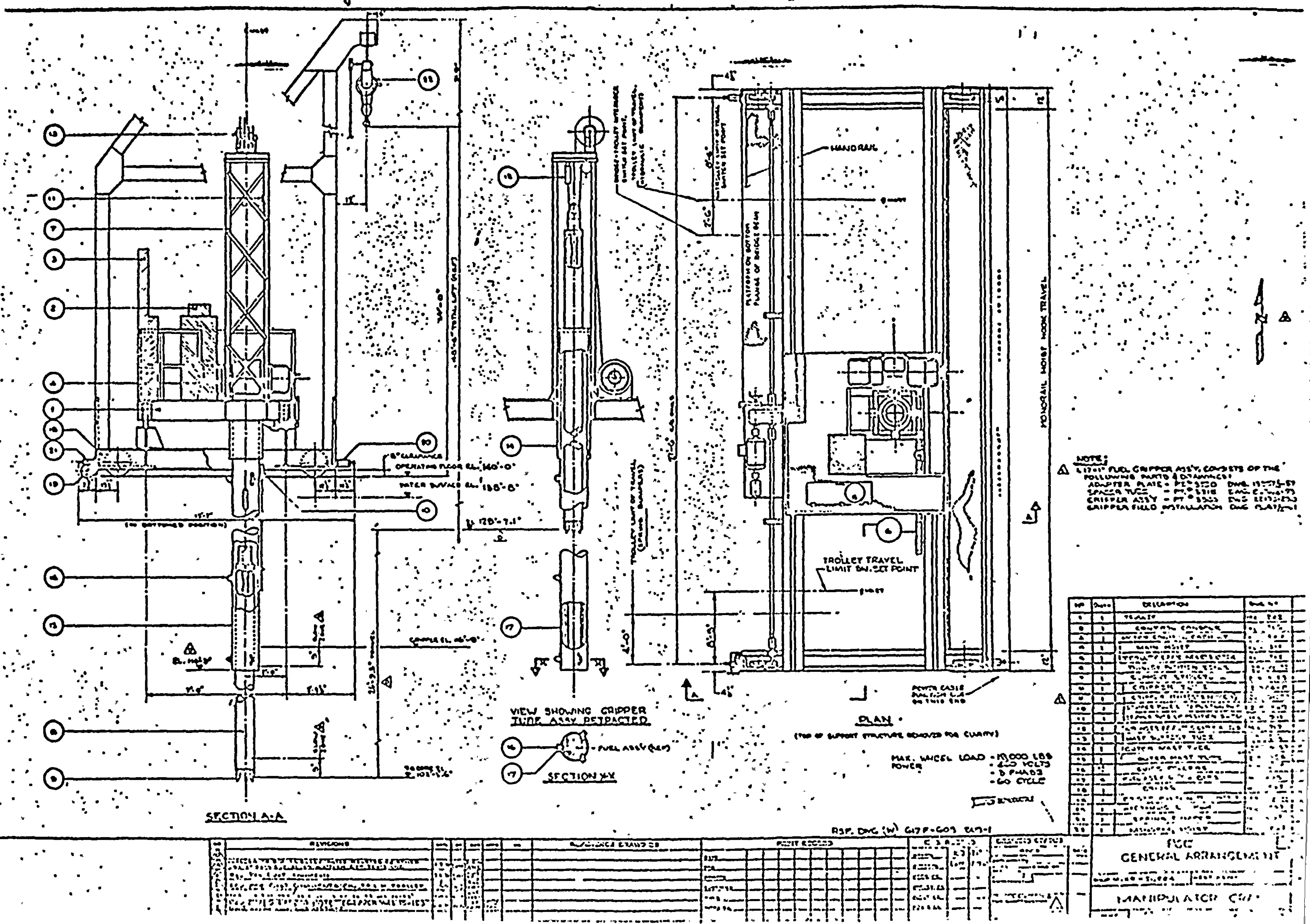
2. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, 1977 Edition, ASME, New York.

3. "Seismic Evaluation for Postulated 7.5M Hosgri Earthquake" Unit 1 and 2, Diablo Canyon Site, 1977, Pacific Gas and Electric Company.

4. NRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants" (October 1973), U.S. Nuclear Regulatory Commission, Washington, D.C.

APPENDIX A

MANIPULATOR CRANE
GENERAL ARRANGEMENT DRAWING


SECTION A-A
VIEW SHOWING GRIPPER
TUBE ASSY RETRACTED
SECTION X-X
FUEL ASSY (REF)
PLAN
HANDRAIL
TROLLEY TRAVEL
LIMIT SW. SET POINT
MONORAIL HOIST HOOK TRAVEL
OPERATING FLOOR EL. 160'-0"
WATER SURFACE EL. 158'-0"
NOTE:
MAX. WHEEL LOAD - 10,000 LBS
POWER - 440 VOLTS
- 3 PHASE
- 60 CYCLE
GENERAL ARRANGEMENT
MANIPULATOR CRANE

APPENDIX B

SEISMIC RESPONSE SPECTRA

INTERIOR STRUCTURE OPERATING FLOOR ELEVATION

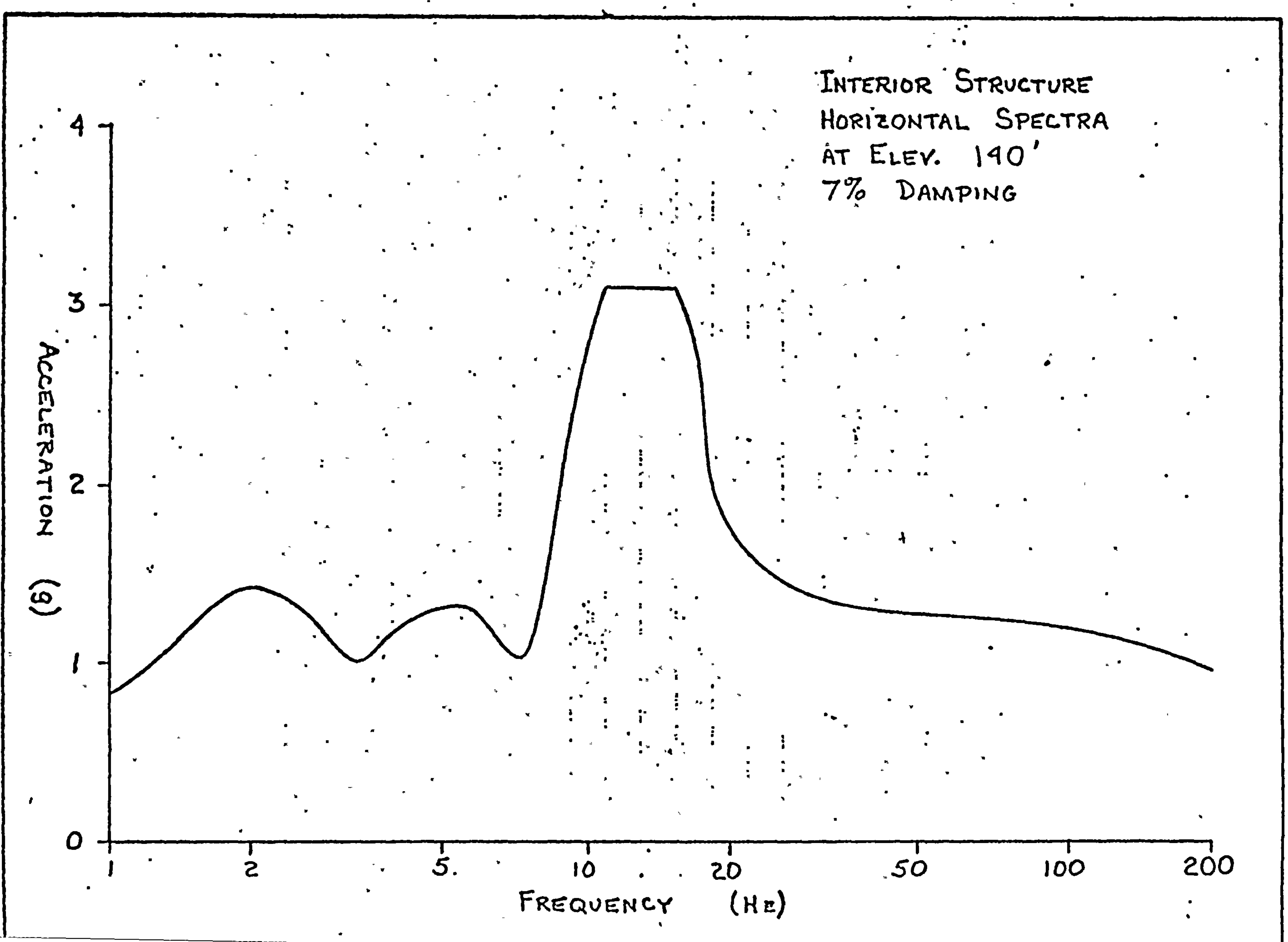
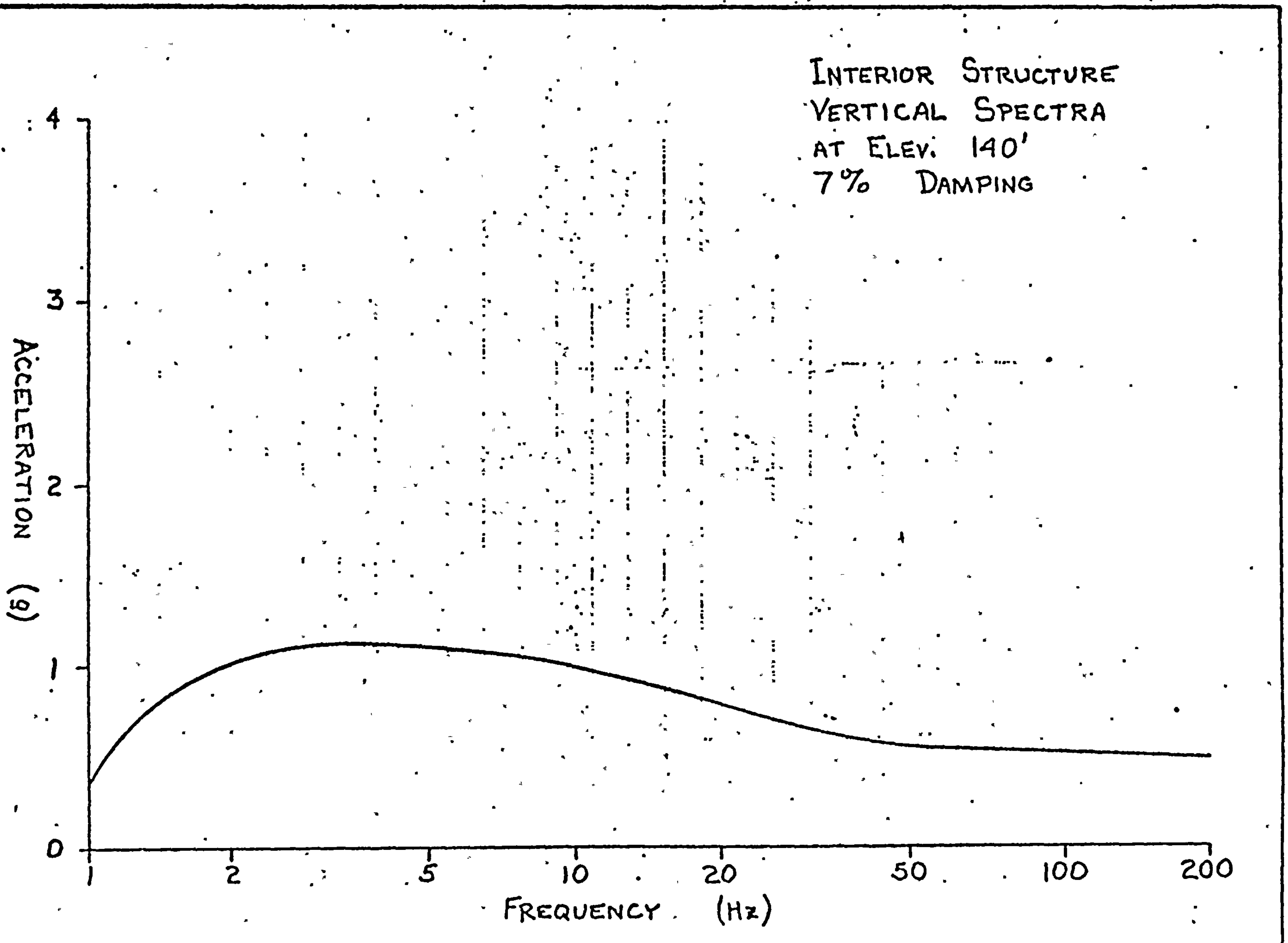


FIGURE B-1

WESTINGHOUSE ELECTRIC CORPORATION

SKETCH SHEET
FORM 28577



WESTINGHOUSE ELECTRIC CORPORATION

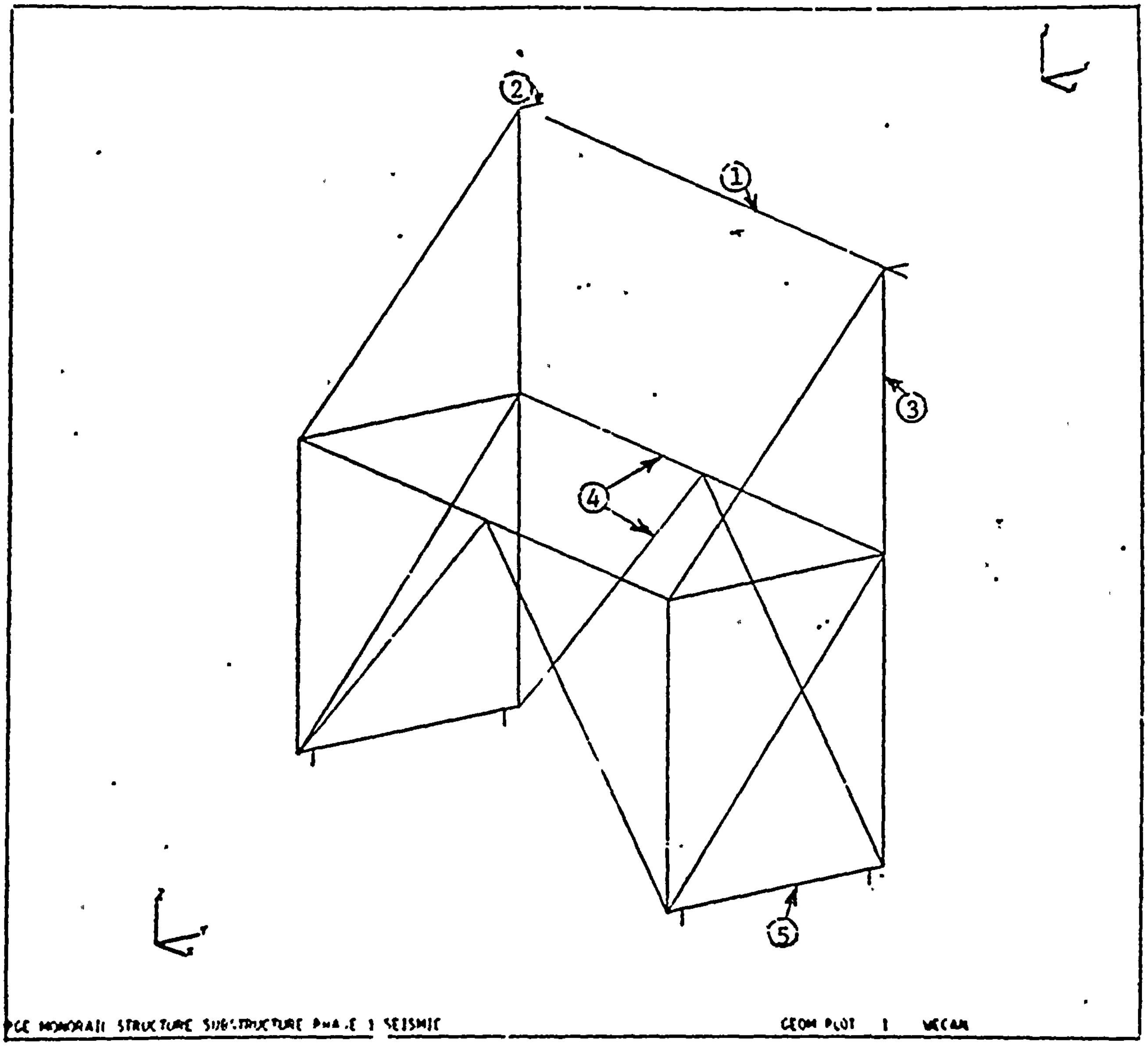
FIGURE B-2

APPENDIX C

MANIPULATOR CRANE
SUBSTRUCTURE GEOMETRY PLOTS
(WECAN)

Figure C-1

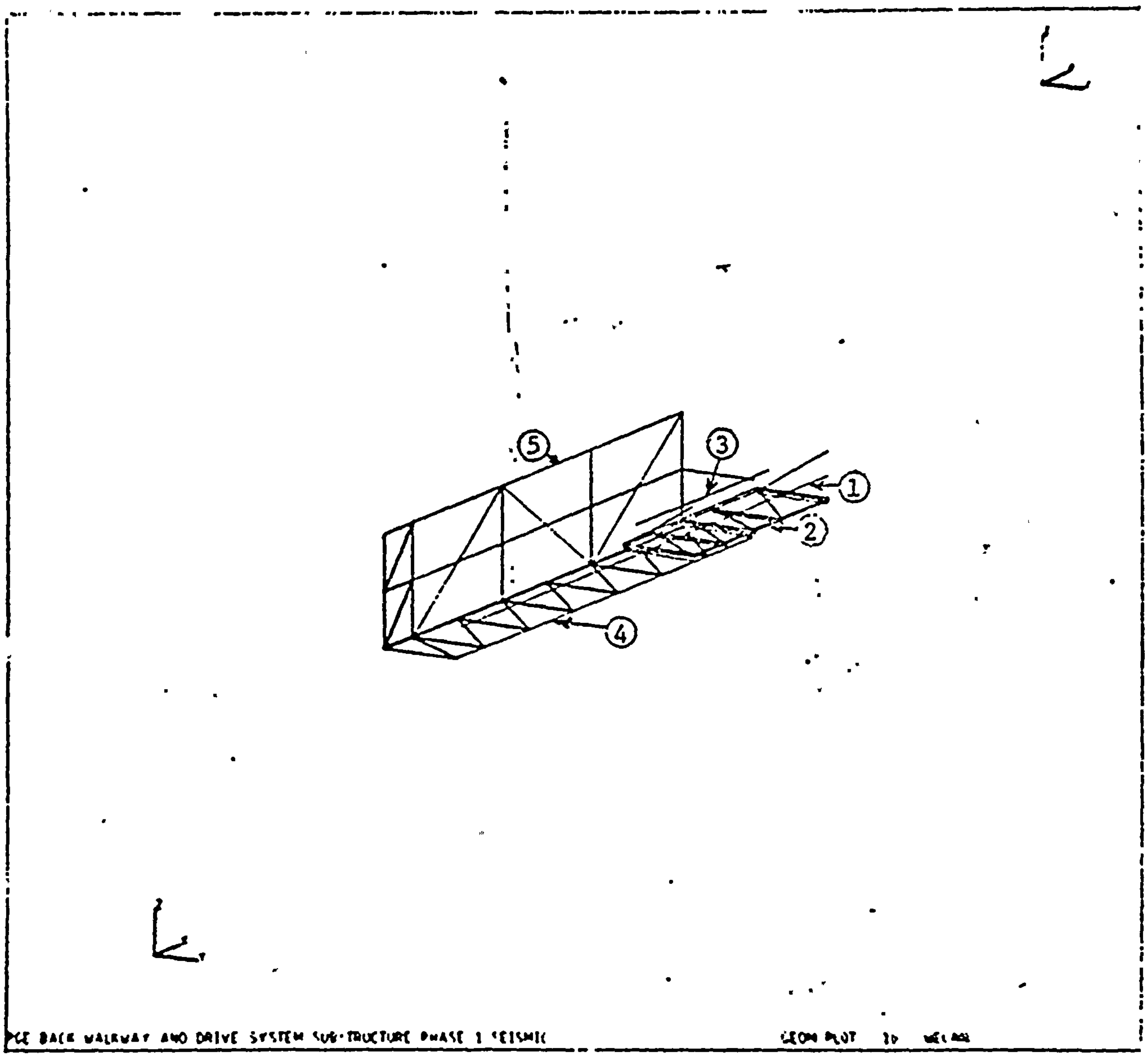
Monorail Structure



1. Monorail Beam
2. Monorail Brackets
3. Monorail Columns
4. Monorail Bracing
5. Bridge Trucks

Figure C-2

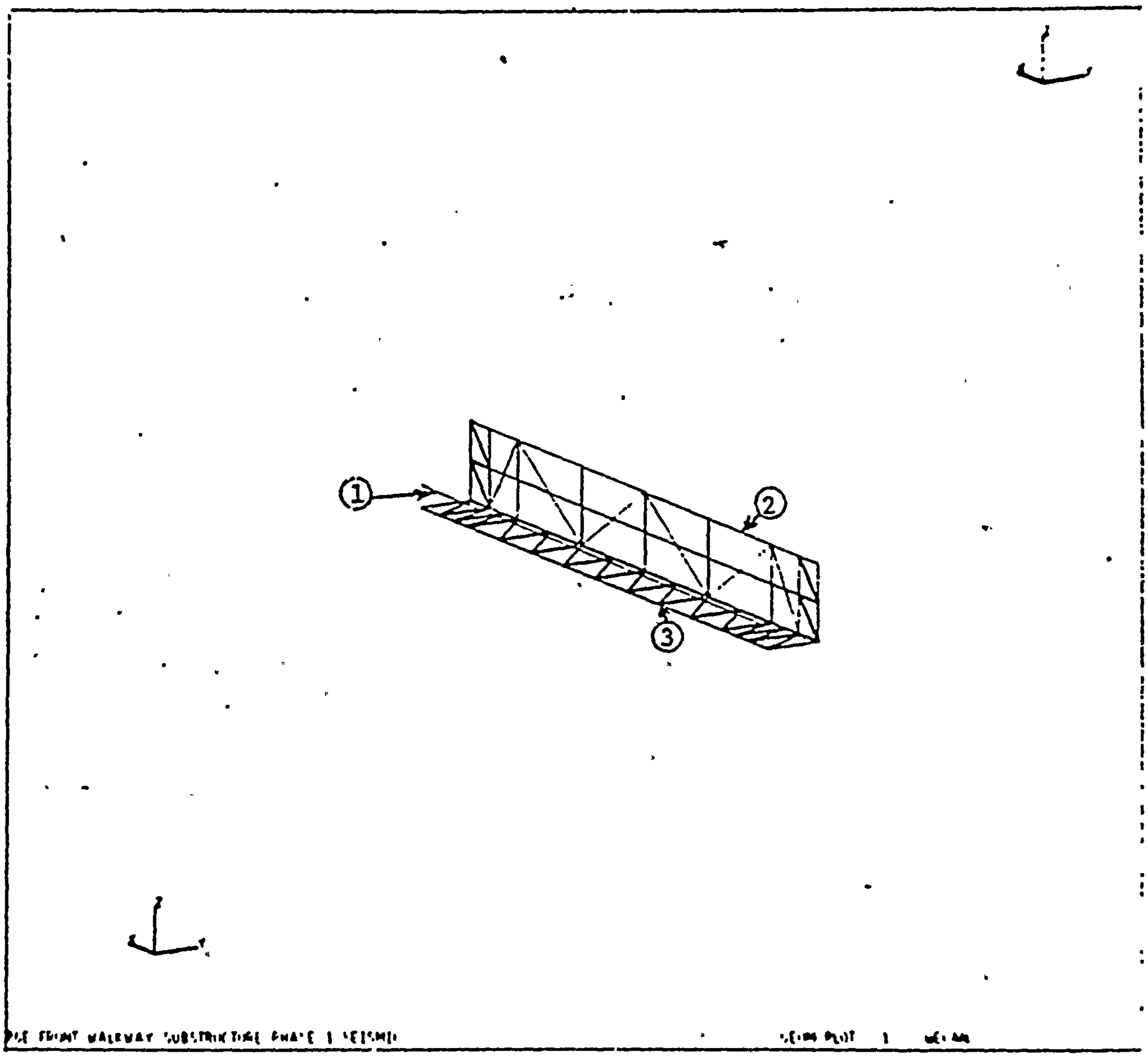
Back Walkway, Girder and Drive Support



1. Back Girder
2. Bridge Drive Support
3. Bridge Drive
4. Back Walkway
5. Back Handrail

Figure C-3

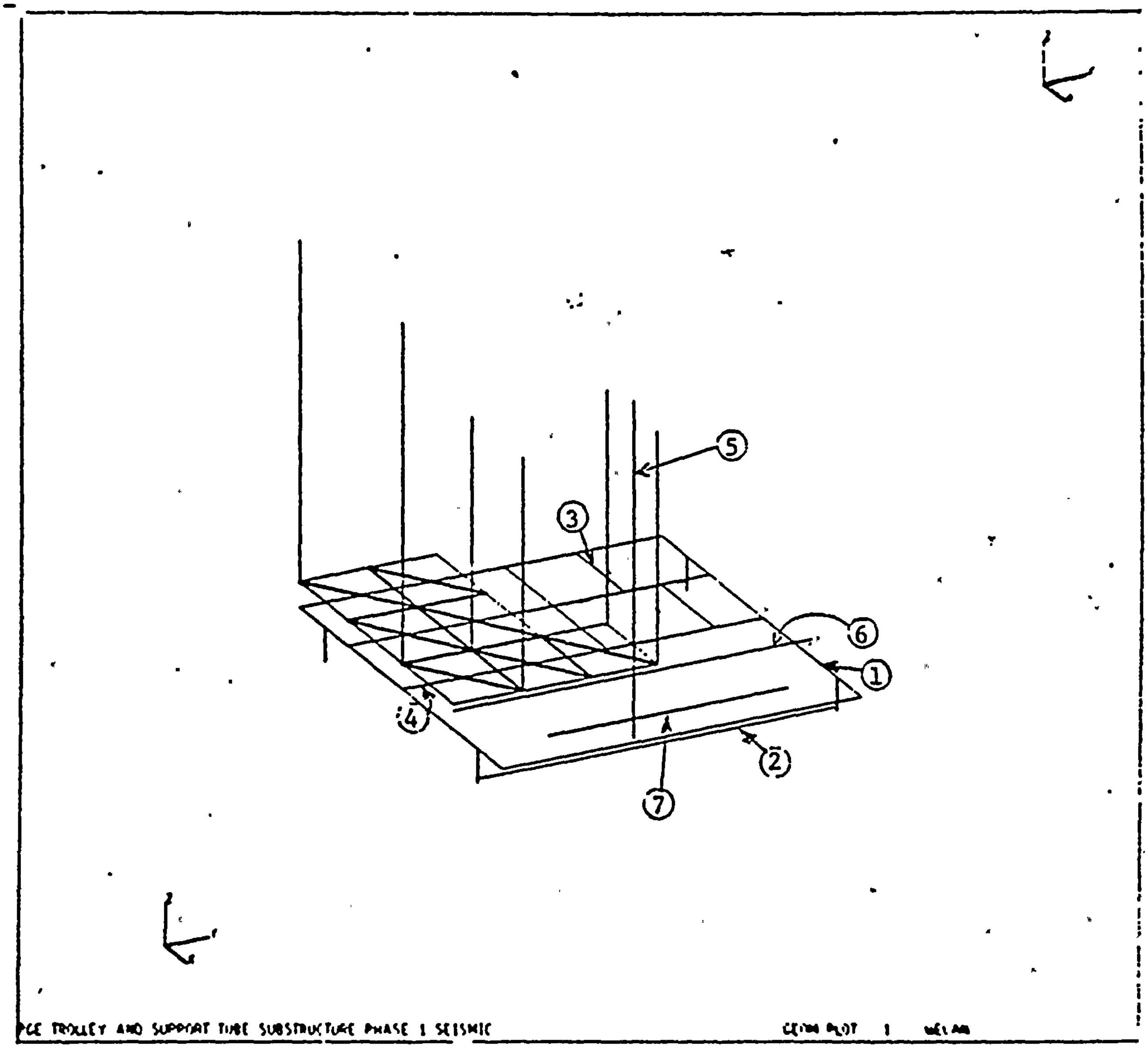
.Front Walkway and Girder



1. Front Girder
2. Front Walkway
3. Front Handrail

Figure C-4

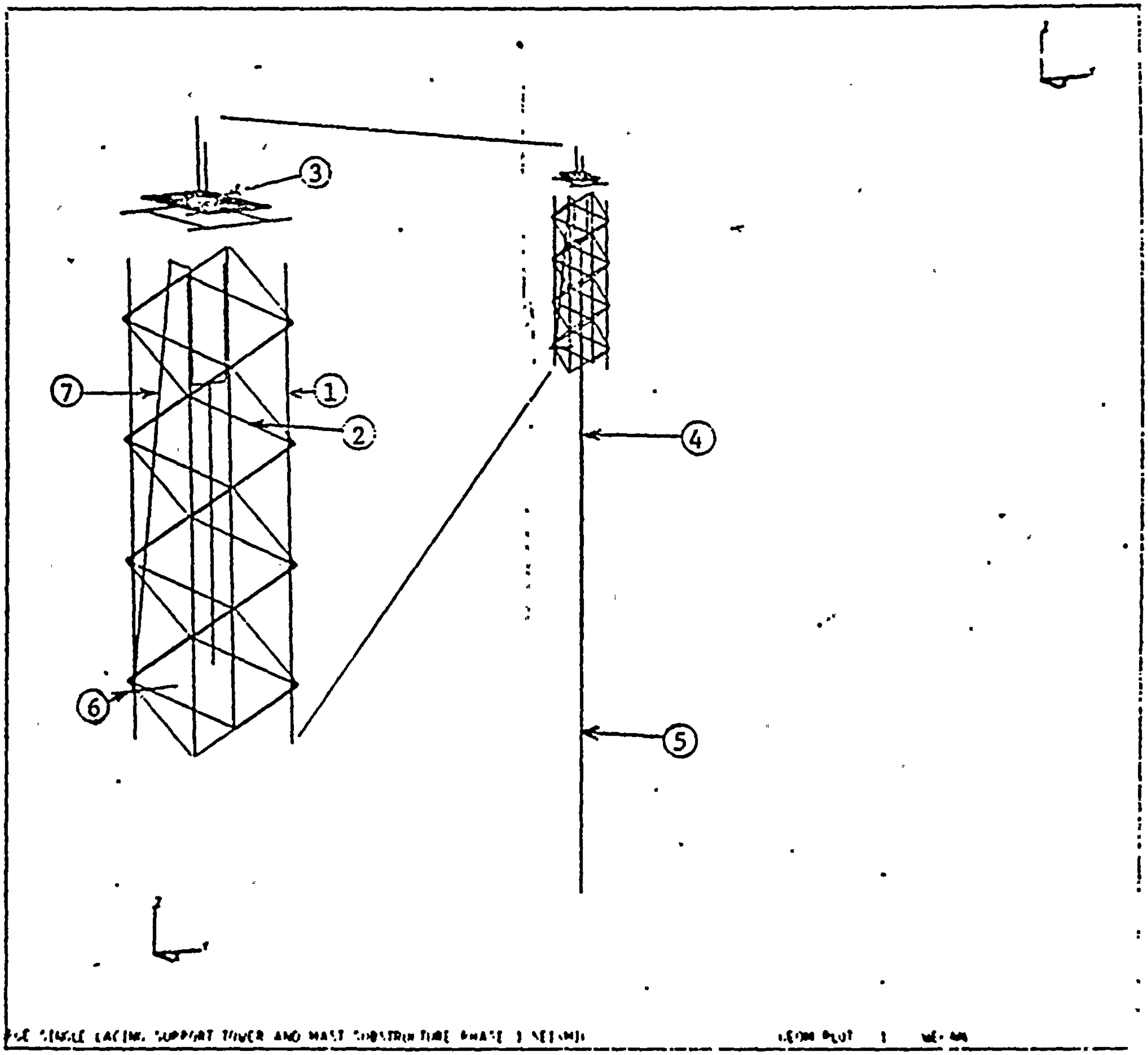
Trolley and Mast Support Tube



1. Trolley Trucks
2. Trolley Drive Support
3. Fuel Hoist Support
4. Mast Support Beam
5. Mast Support Tube
6. Floor Support
7. Trolley Drive

Figure C-5

Cable Support Tower and Mast



1. Tower Corner Angles
2. Tower Lacing Angles
3. Pulley Support Channels
4. Gripper Tube
5. Stationary Mast
6. Fuel Hoist
7. Cable

APPENDIX D

MANIPULATOR CRANE
CRITICAL MEMBER STRESS RATIOS

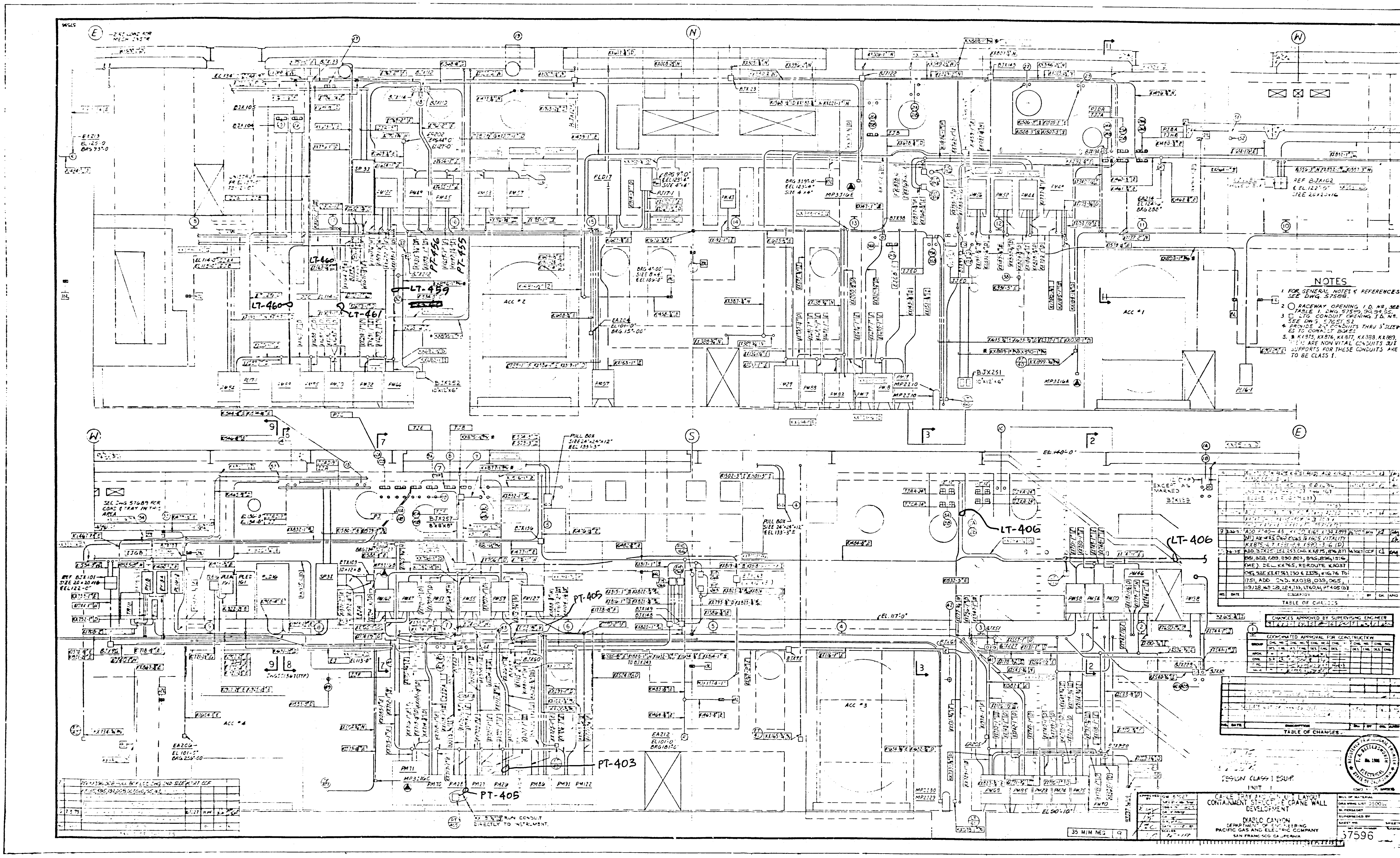
TABLE D-1

MAXIMUM MEMBER STRESS RATIOS*

Member Description	Stress Ratio for Cases Analyzed**			
	A	B	C	D
Monorail Beam	.35	.32	.16	.16
Monorail Brackets	.15	.15	.15	.15
Monorail Columns	.44	.43	.45	.44
Monorail Bracing	.40	.30	.40	.39
Bridge Trucks	.19	.18	.21	.19
Back Girder	.46	.45	.44	.45
Bridge Drive Support	.90	.88	.75	.88
Front Girder	.25	.24	.42	.24
Trolley Trucks	.41	.40	.59	.40
Trolley Drive Support	.38	.37	.55	.37
Fuel Hoist Support	.40	.29	.43	.29
Mast Support Beam	.52	.41	.51	.40
Mast Support Tube	.11	.08	.11	.08
Tower Corner Angles	.26	.18	.26	.18
Tower Lacing Angles	.27	.21	.30	.21
Pulley Support Channels	.53	.20	.50	.20
Gripper Tube	.22	.22	.28	.22
Stationary Mast	.26	.19	.26	.19

* Stress Ratio is the ratio of calculated stress divided by the allowable.

**Cases analyzed are listed in Section II-A, Page 2.



#26

RETURN TO REACTOR DOCKET FILES

RM INDEXED REV.______

PG&E 33.75 X JAN MAR MAY JULY SEPT NOV FEB APR JUNE AUG OCT DEC 78

PT-403, RCS pressure (Ch III, H bus)
PT-405, RCS pressure (Ch II, H bus)
PT-455, PZR pressure (Ch I, F bus)
PT-456, PZR pressure (Ch II, G bus)
LT-406, PZR Level
LT-459, PZR Level Ch. I
LT-460, PZR Level Ch II
LT-461, PZR Level Ch III

Docket # 50-275/323
Control # 7811290460
Memo Date 11-21-78 of Document
REGULATORY DOCKET FILE

#26 Memo to Stolz from Allison

Question 9

#20

Docket # 50-275/323
Control # 7811290460
Date 11-21-78 of Document
REGULATORY DOCKET FILE
Memo to Stolz fm Allison
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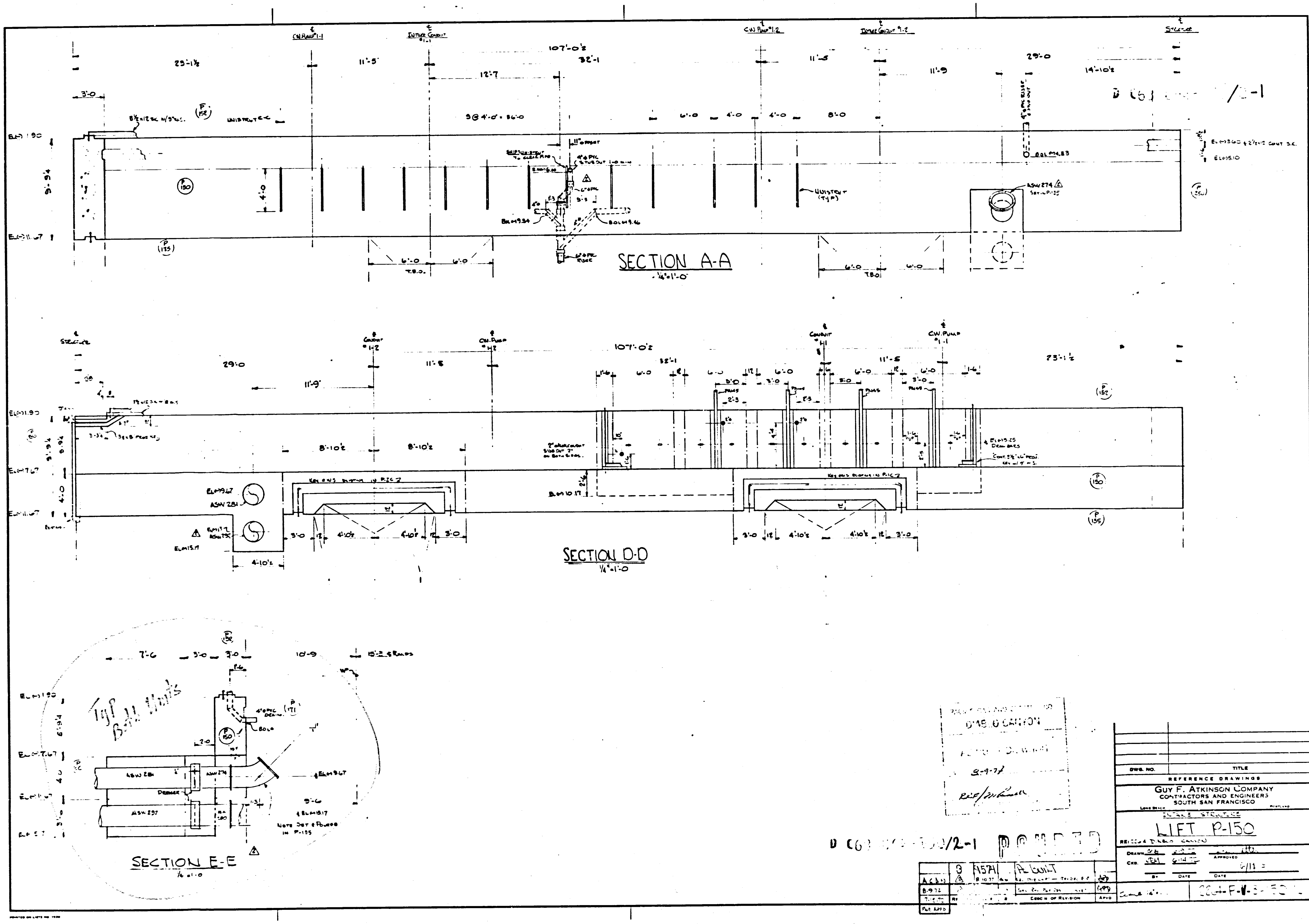
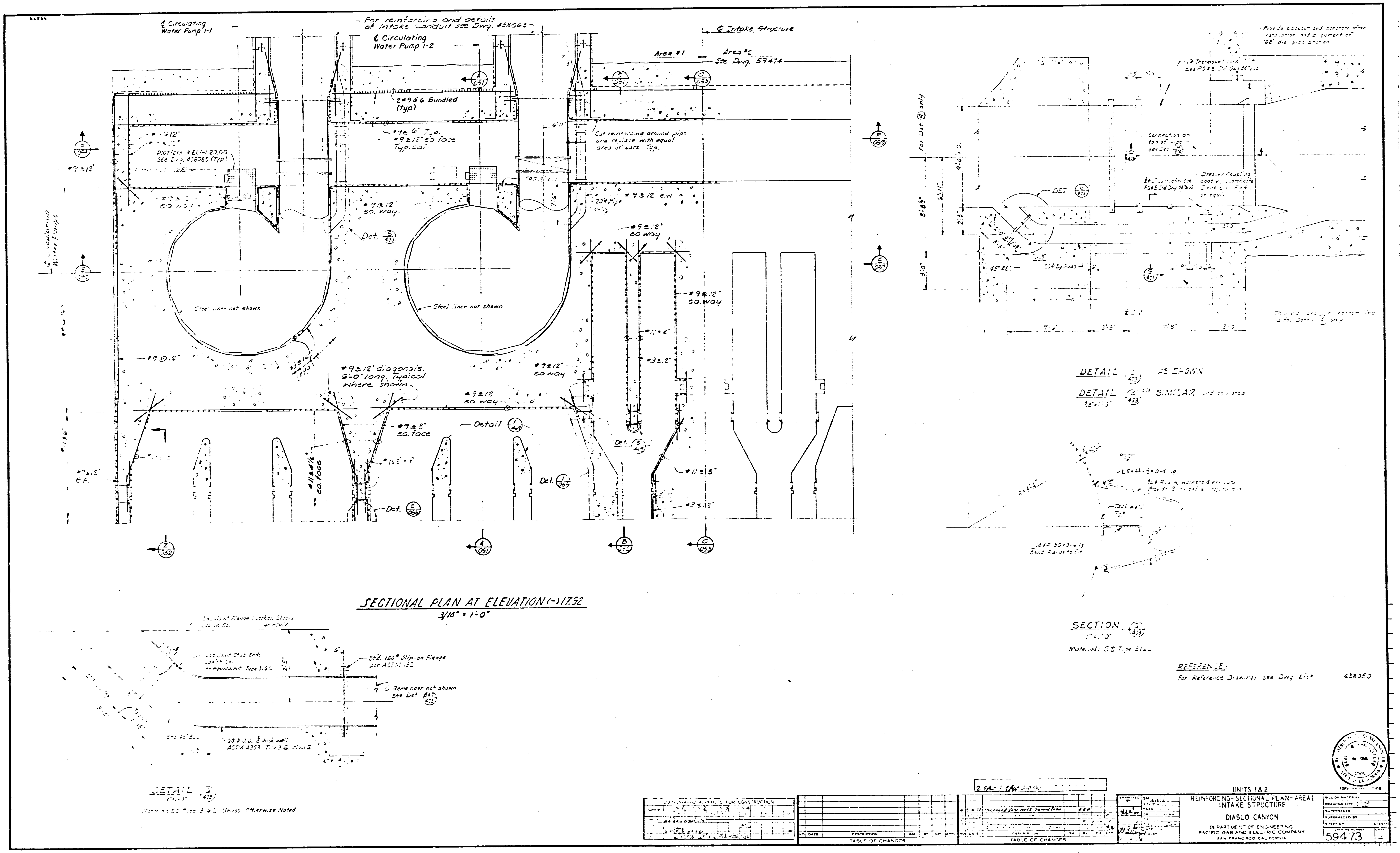


P. G. and E. 7X 75

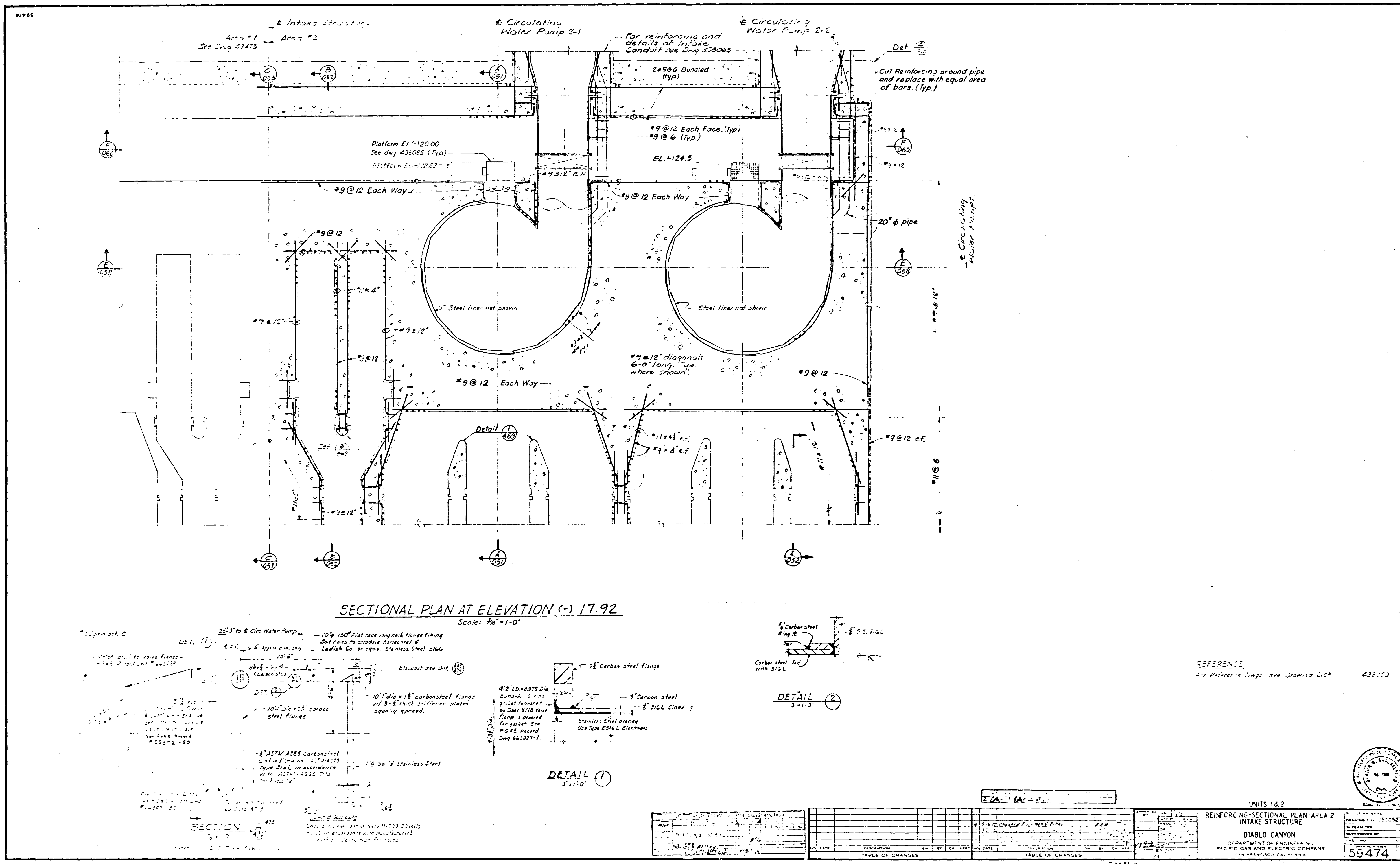
D

SHEET NUMBER-IS FIRST, CHANGE IS LAST.



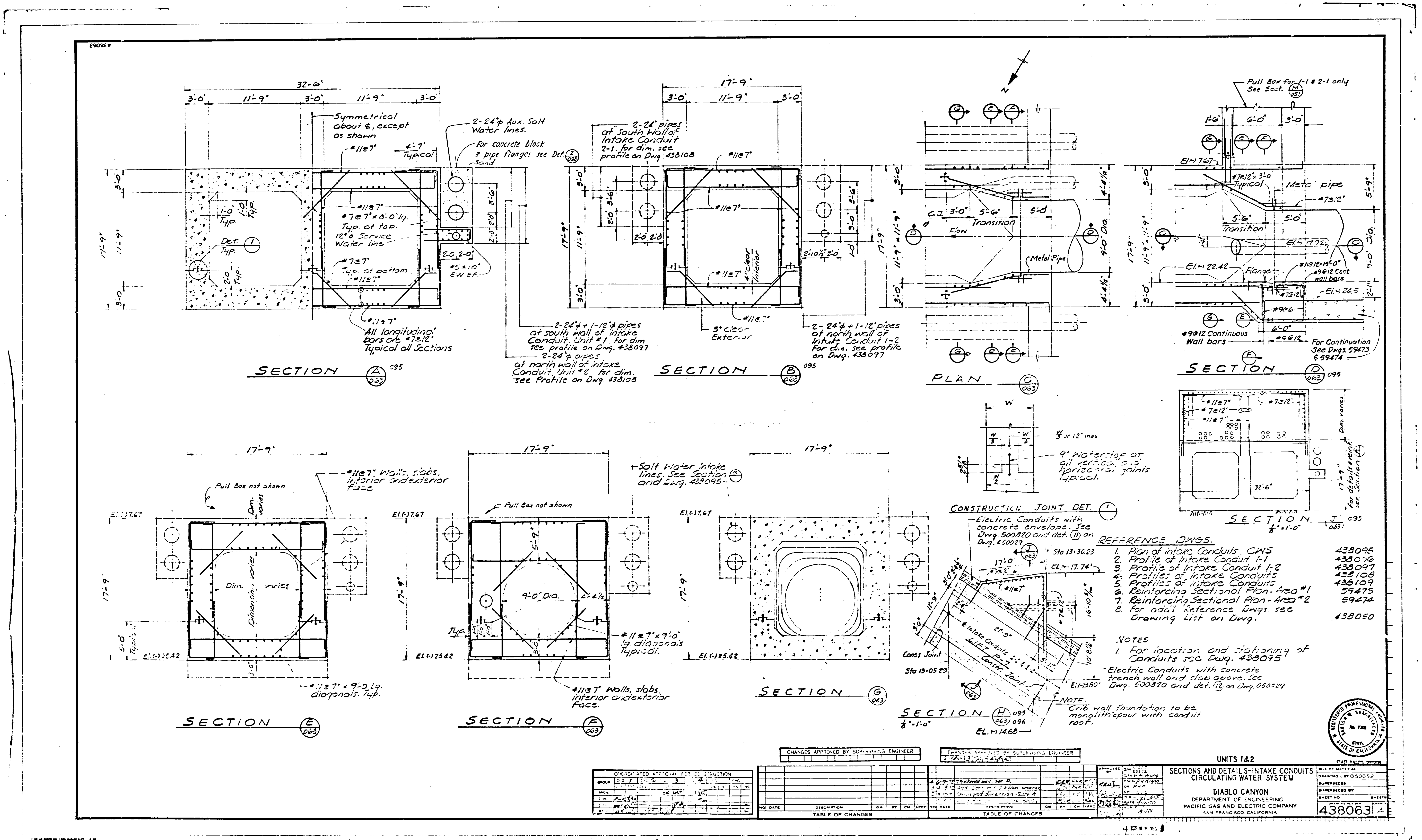
℄ Circulating Water Pump 1-1
For reinforcing and details of Intake Conduit see Dwg. 438062
℄ Circulating Water Pump 1-2
℄ Intake Structure
Area #1
Area #2 See Dwg. 59474
2#9@6 Bundled (typ)
Cut reinforcing around pipe and replace with equal area of bars. Typ.
Steel liner not shown
#9@12" diagonals 6'-0" long. Typical where shown
Detail
SECTIONAL PLAN AT ELEVATION (-)17.92
3/16" = 1'-0"
Std. 150# Slip-on Flange per ASTM 182
DETAIL
AS SHOWN
SIMILAR
SECTION
REFERENCE:
For Reference Drawings see Dwg List
Materials: CS Type 316L Unless Otherwise Noted
UNITS 1&2
REINFORCING-SECTIONAL PLAN-AREA1
INTAKE STRUCTURE
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO CALIFORNIA
TABLE OF CHANGES
BILL OF MATERIAL
DRAWING LIST
SUPERSEDES
SUPERSEDED BY
SHEET NO.
SHEETS
59473

7,



memo

memo to Stolz frm Allison



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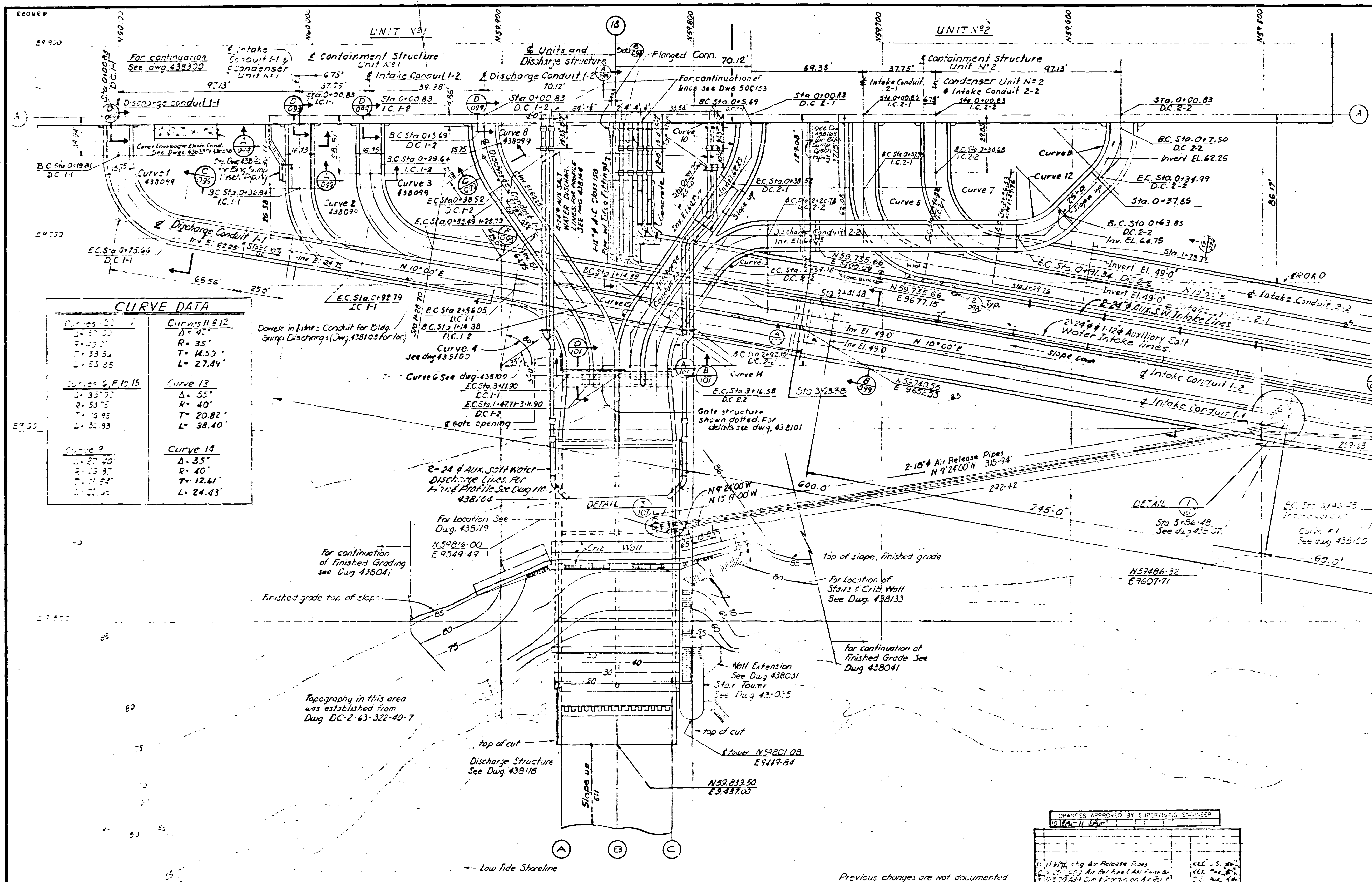
11-21-78
memo to Stolz fm Allison



NOTES

1. For limits of excavation by Spec 8226 See dwg. 438002.
2. For coordinates see dwg 59455.
3. Contours shown are original grade contours established by photogrammetry and are based on Mean Sea Level Datum 1929 Adj. See Dwg 57927

REFERENCES

Drawing List CIVS 435050

Previous changes are not documented

TABLE OF CHANGES

UNITS 1 & 2

PLAN OF INTAKE AND DISCHARGE CONDUITS
CIRCULATING WATER SYSTEM

DIABLO CANYON

DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

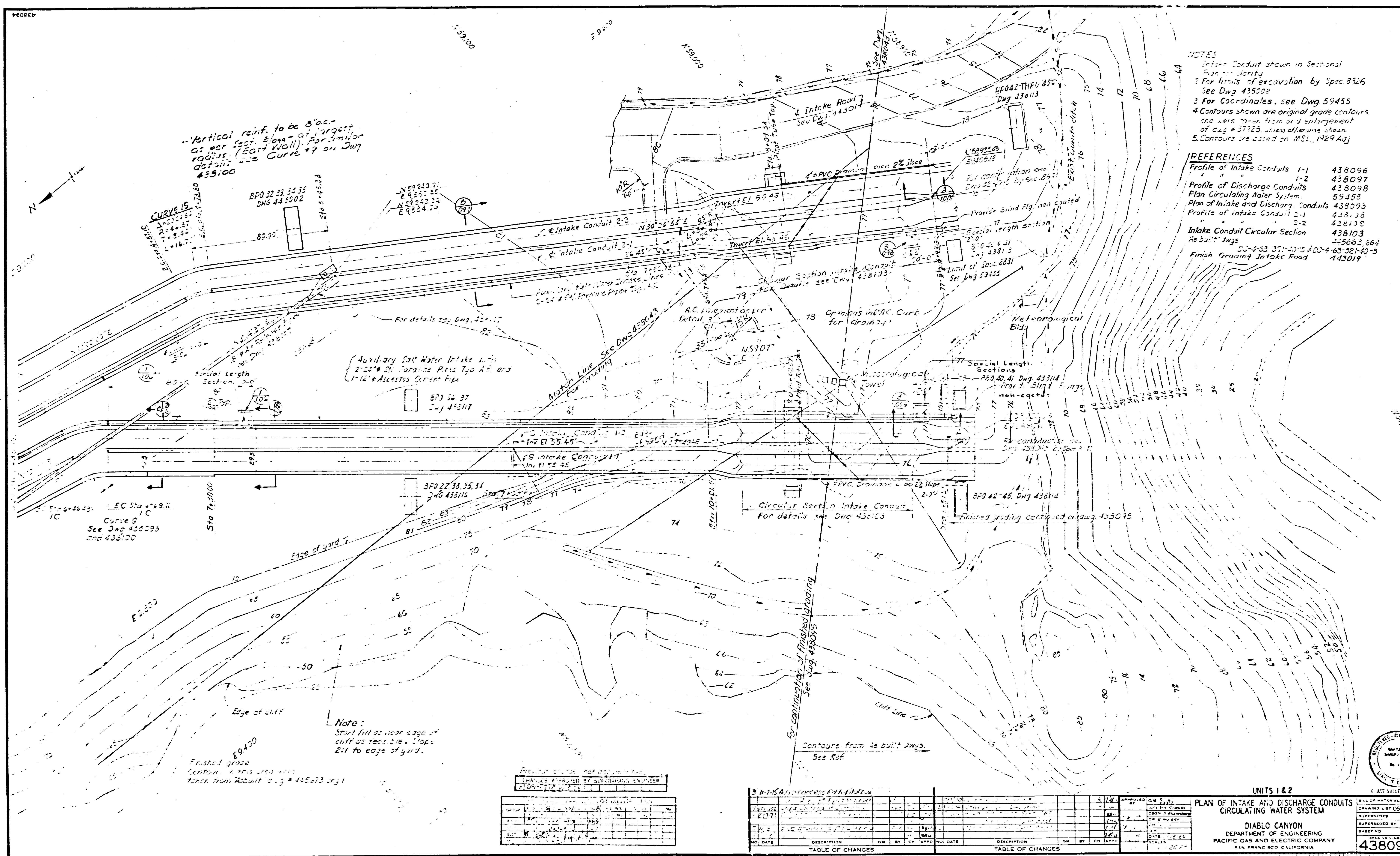
DRAWING LIST 050052

438093

50-275/323
7811290460

Memo 11-21-78

Memo to Stolz from Allison



PG&E 30 X JAN MAR MAY JULY SEPT NOV FEB APR JUNE AUG OCT DEC 75

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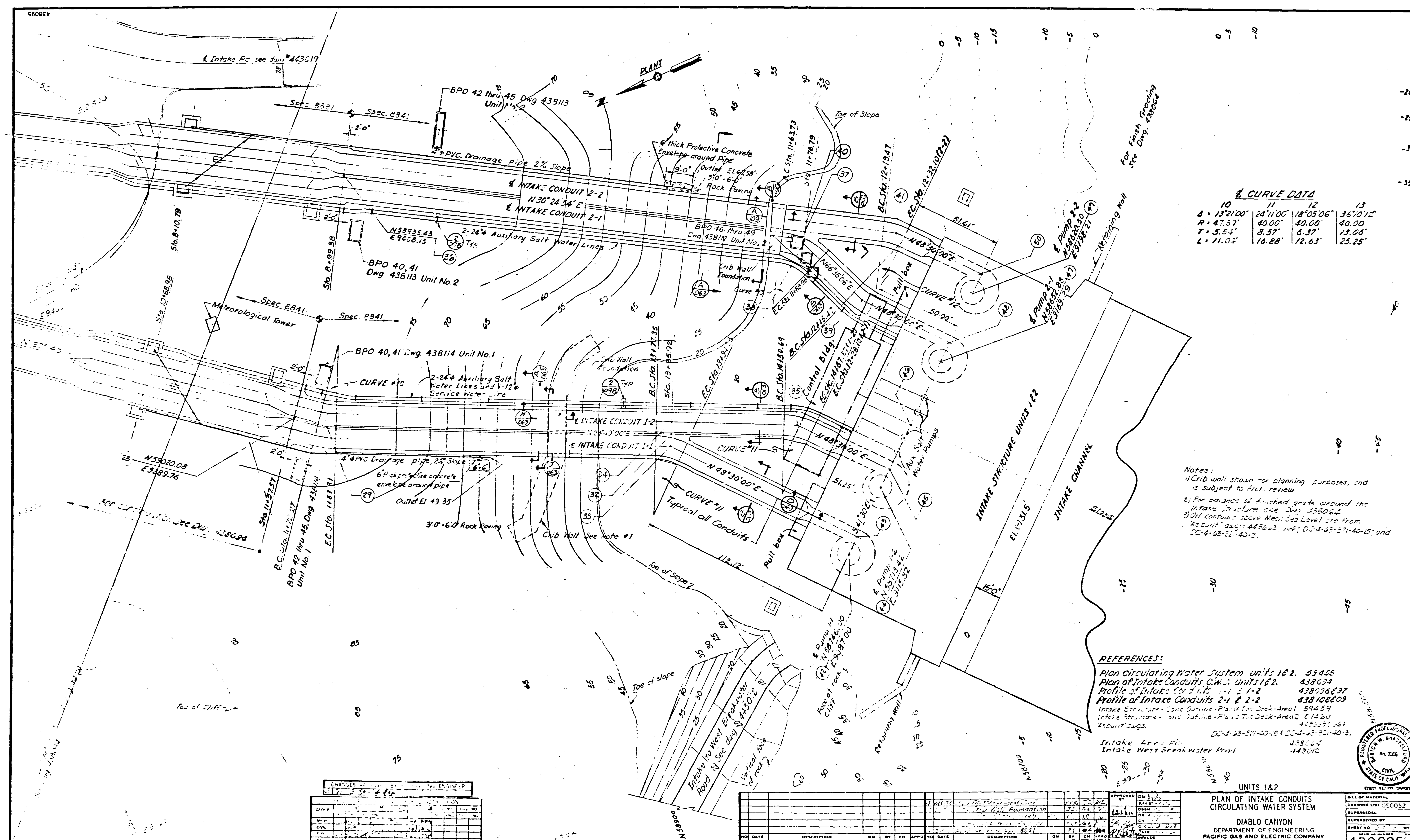
11-27-78
Ttemo from Allison to Stolz



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Control # 7811290460
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REGULATORY DOCKET FILE
Tiiemo to Stolz from Allison
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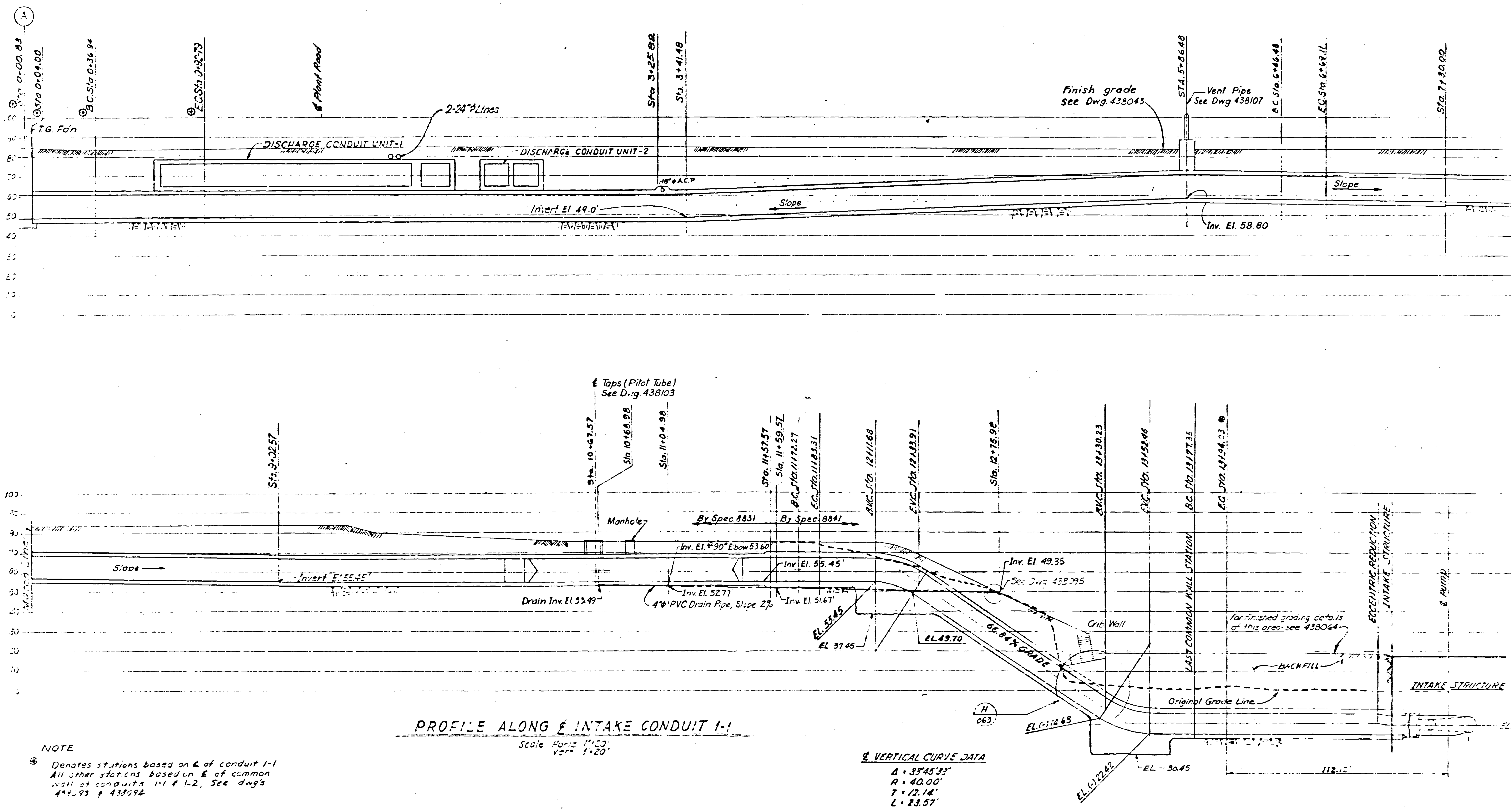

PROFILE ALONG ℄ INTAKE CONDUIT 1-1

Scale Horiz 1"=50'
Vert 1"=20'

NOTE

⊛ Denotes stations based on ℄ of conduit 1-1
All other stations based on ℄ of common wall of conduits 1-1 & 1-2, See dwg's 4??_93 & 438094

REFERENCES

Plan Circulating Water System	59455
Profile of Intake Conduits. CWS	438097
Circular Section - Intake Conduit	438103
Intake Conduit Details	438107
Plan of Intake Conduits C.W.S.	438095

Previous Changes are not documented.

TABLE OF CHANGES

TABLE OF CHANGES

UNIT 1

PROFILE OF INTAKE CONDUIT 1-1
CIRCULATING WATER SYSTEM

DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO CALIFORNIA

COAST VALLEYS DIVISION

DRAWING LIST 050052
SUPERSEDES
SUPERSEDED BY
SHEET NO 1 2 SHEETS
DRAWING NUMBER 438096

50-275/323
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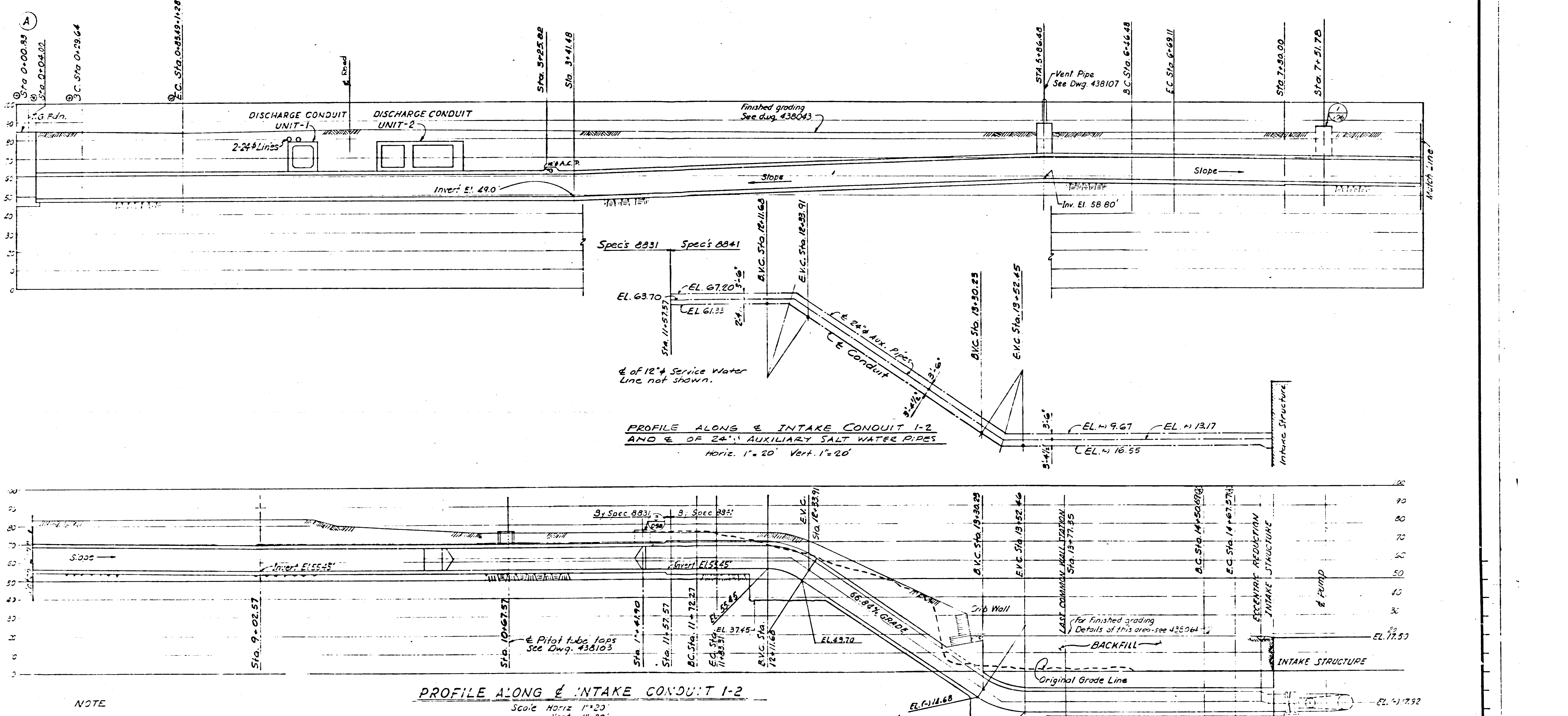
11-21-78
Memo to Stolz from Allison



NOTE

● Denotes stations based on ℄ of conduit 1-2. All other stations based on ℄ of common wall of conduits 1-1 & 1-2 see dwg's 438093 & 438114

℄ VERTICAL CURVE DATA

Δ = 33°45'33"
R = 40.00'
T = 12.14'
L = 23.57'

REFERENCES

Plan Circulating Water System	59455
Profile of Intake Conduits C.W.S.	438096
Circular Section Intake Conduit	438103
Intake Conduit Details	438107
Plan of Intake Conduits C.W.S.	438095

Previous changes are not documented

TABLE OF CHANGES

UNIT 1

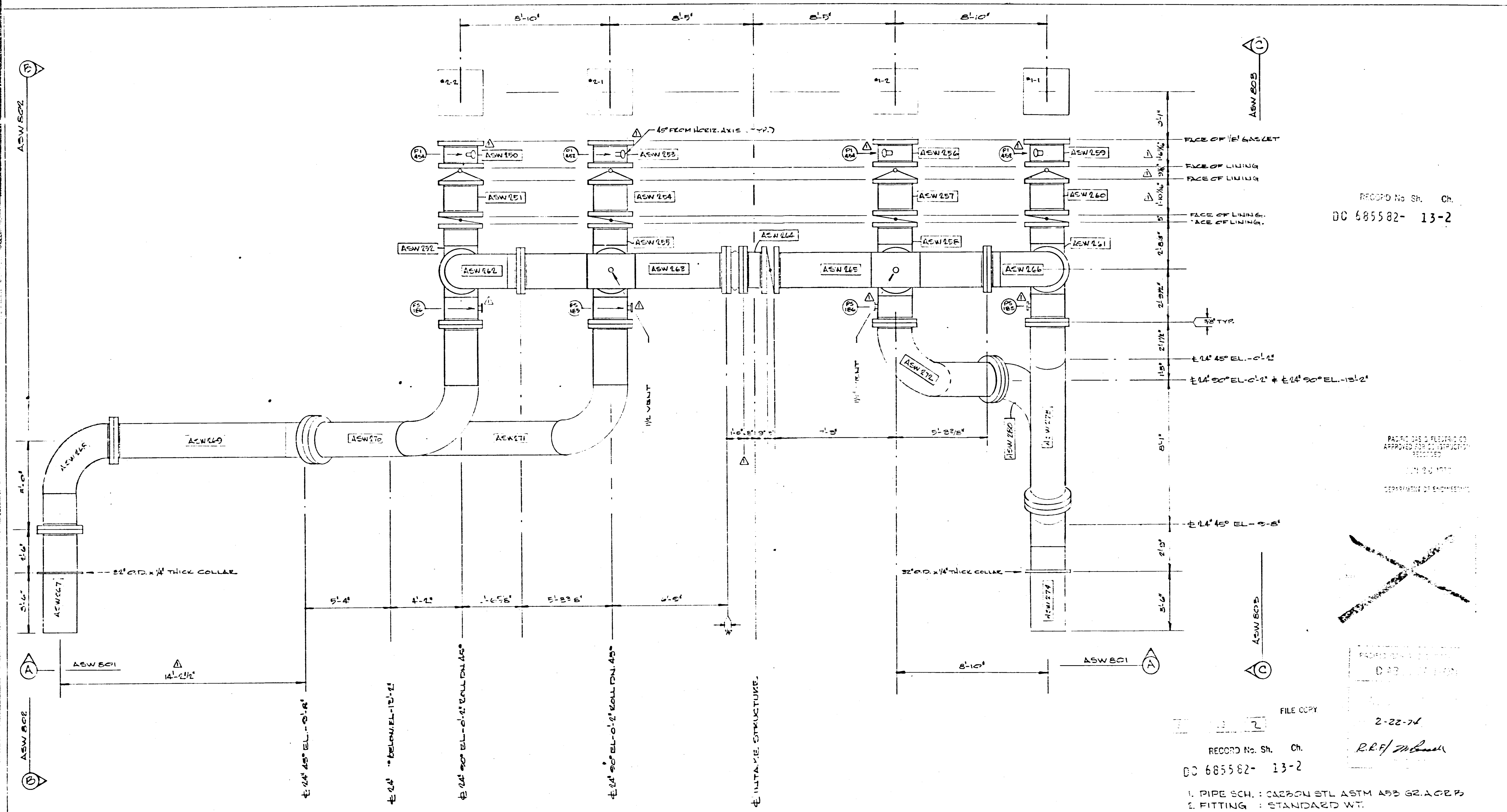
COAST VALLEYS DIVISION

PROFILE OF INTAKE CONDUIT 1-2
CIRCULATING WATER SYSTEM

DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DRAWING LIST 050052
SHEET NO 2
438097

Docket # 50-275/323
Control # 7811290460
Memo 11-27-78
Memo to Stolz from Allison



FILE COPY

2-22-76

RECORD No. Sh. Ch.

DC 685582- 13-2

R.R.F/ [signature]

1. PIPE SCH. : CARBON STL ASTM A53 GR. A OR B
2. FITTING : STANDARD WT.
3. FLANGES : 125# C.S. LIGHTWEIGHT SLIP ON ASTM A181

PACIFIC GAS AND ELECTRIC COMPANY
DEPARTMENT OF ENGINEERING

This drawing has been approved for construction by a Responsible Engineer.

12-74 — Erwin P. Kollak
Date — Supervising Civil Engineer

FINAL APPROVED DWG.

REVISIONS		AUX. SALT WATER PIPING UNIT 1 & 2 PLAN VIEW
NO.	DATE	JOB: P.G.&E DIABLO CANYON
1		**SCOTT CO. OF CALIFORNIA** MECHANICAL CONTRACTORS
2	11-1-72	1601 ANDERSON AVE. COMPTON, CALIF. 90220 (213) 537-5100
		SCALE / DRAWN BY / DATE / DWG NO.

D

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11-21-78

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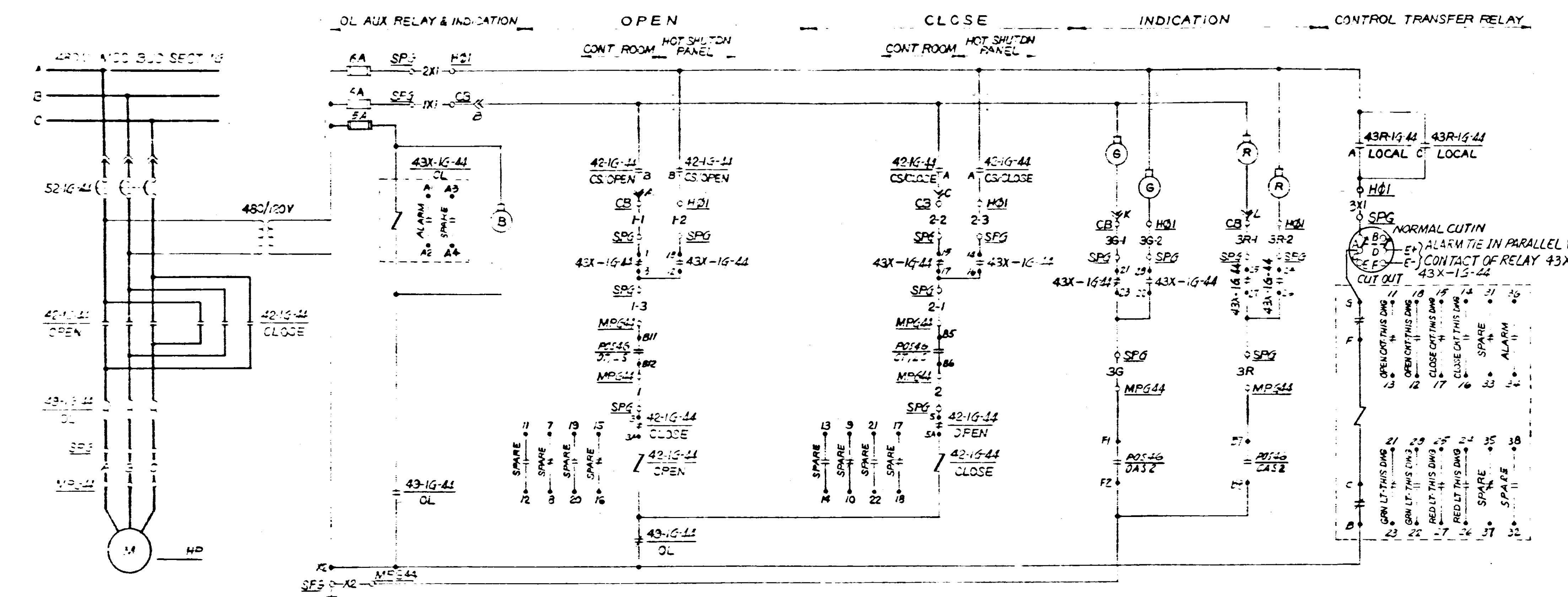
FEB APR JUNE AUG OCT DEC 78

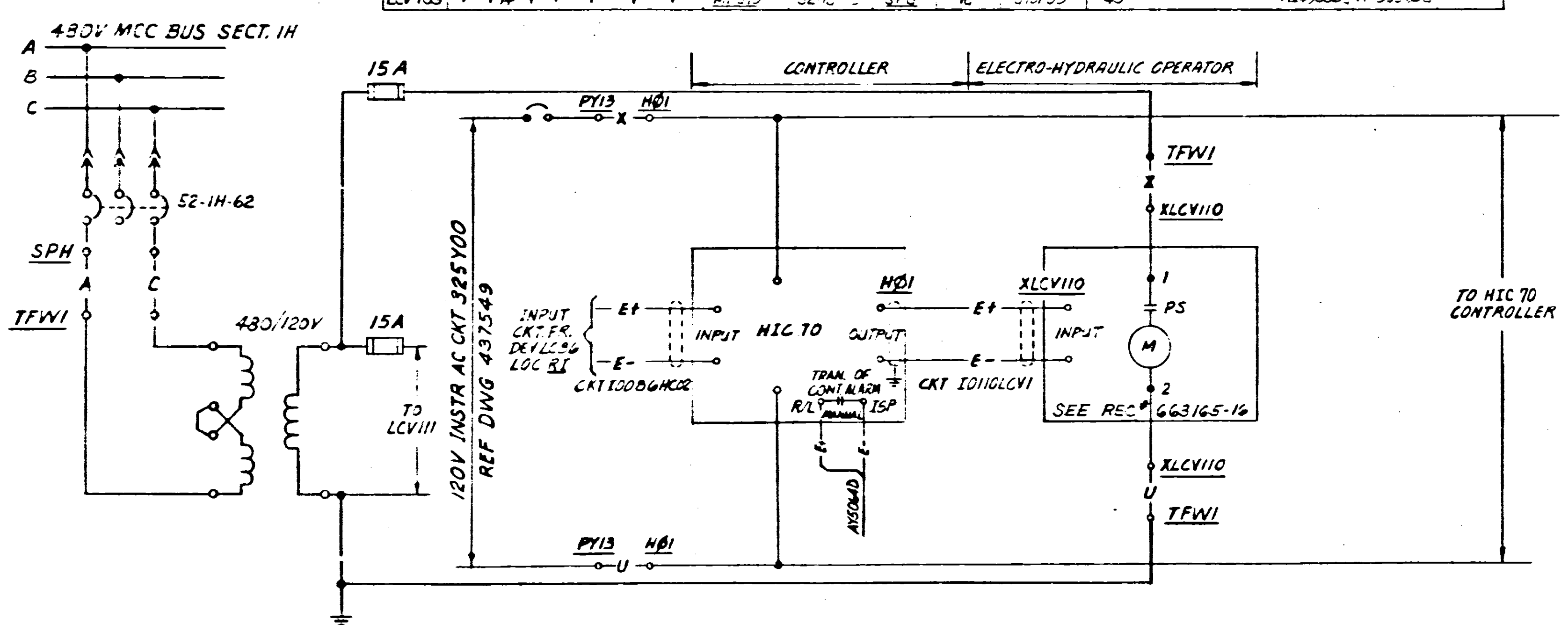


120V AC SCHEMATIC

LCV 106 STEAM GEN. 11 AUX. FEEDWATER SUPPLY MOV - CKT Nº G44P00

STEAM GEN AUX. FEEDWATER SUPPLY MOV'S SIMILAR EXCEPT AS SHOWN IN TABLE

VALVE Nº	DESCRIPTION	FW PUMP DISCH	MOTOR LOC.	CIRCUIT BREAKER Nº	CIRCUIT BREAKER LOC.	BUS SECT.	CIRCUIT Nº	VALVE POS SWITCH Nº	ALARM CKT Nºs OVER-CURRENT	ALARM CKT Nºs TRANSFER OF CONT
LCV 106	STM GEN 11 AUX FW SUPPLY MOV	11	MPG44	52-1G-44	SPG	1G	G44P00	46	AI4308DS	AY5066DG
LCV 107	12		MPG68	52-1G-68	SPG	1G	G68P00	47	AI4308DS	AY5066DG
LCV 108	13		MPG69	52-1G-69	SPG	1G	G69P00	48	I4308DS	AY5066DG
LCV 109	14		MPG70	52-1G-70	SPG	1G	G70P00	49	AI4308DS	AY5066DG



LCV 110 STEAM GEN 11 AUX FEEDWATER SUPPLY VALVE

STEAM GEN AUX FEEDWATER SUPPLY VALVES SIMILAR EXCEPT AS SHOWN IN TABLE

VALVE Nº	DESCRIPTION	FW PUMP DISCH	VALVE LOC.	120V INSTR AC CKT Nº	120V INSTR AC LOC	CONTROLLER DEVICE Nº	CONTROLLER INPUT CKT	ELECTRO-HYDRAULIC OPERATOR MODULATING SIGNAL CKT	ELECTRO-HYDRAULIC OPERATOR 120VAC PWR	LOC	CIRCUIT BREAKER Nº	CIRCUIT BREAKER LOC.	TRAN OF CONTROL ALARM
LCV 110	STM GEN 11 AUX FW SUPPLY	12	XLCV110	325Y00A	PY13	HIC 70	I0085HC02	I0110LCV1	H62P00A	TFW1	52-1H-62	SPH	AY5064D
LCV 111	12	12	XLCV111	325Y00A	PY13	HIC 71	I0087HC02	I0111LCV1	H62P00B	TFW1	52-1H-62	SPH	AY5064D
LCV 115	13	13	XLCV115	122Y00	PY11	HIC 72	I0089HC02	I0115LCV1	F54P00A	TFW2	52-1F-54	SPF	AY5064D
LCV 113	14	13	XLCV113	122Y00	PY11	HIC 73	I0089HC02	I0113LCV1	F54P00B	TFW2	52-1F-54	SPF	AY5064D

CONTACTS		POSITION CLOSE	POSITION STOP	POSITION OPEN	REMARKS
—‖—	A	X			THIS DWG
—‖—	B			X	THIS DWG

CONTROL SWITCH - 42-1G-44/CS, 42-1G-68/CS, 42-1G-69/CS, 42-1G-70/CS
USED AT LOCATION CB, HØ1
SPRING RETURN TO STOP

CONTACTS		POSITION CONT ROOM	POSITION LOCAL	REMARKS
—‖—	A		X	THIS DWG
—‖—	B	X		SPARE
—‖—	C		X	THIS DWG
—‖—	D	X		SPARE

TRANSFER SWITCH - 43R-1G-44, 43R-1G-68, 43R-1G-69, 43R-1G-70
USED AT LOCATION HØ1
NO SPRING RETURN

CONTACTS		VALVE POSITION FULL OPEN	VALVE TRAVELING	FULL CLOSED	FUNCTION	REMARKS
B12 —‖— B11	OT/LS		X	X	OPEN TORQUE & LIMIT SWITCH	
B5 —‖— B6	CT/LS	X	X		CLOSED TORQUE & LIMIT SWITCH	
15 —‖— 16	OAS1	X			SPARE	
6 —‖— 7	CAS1			X	SPARE	
F1 —‖— F2	OAS2		X	X	GREEN LIGHT	
B8 —‖— B7	CAS2	X	X		RED LIGHT	
10 —‖— 11	IAS1		X	X	SPARE	SEE NOTE 1
12 —‖— 13	IAS2		X	X	SPARE	SEE NOTE 1
19 —‖— 20	IAS3		X	X	SPARE	SEE NOTE 1
21 —‖— 22	IAS4	X	X		SPARE	SEE NOTE 2
28 —‖— 29	IAS5	X	X		SPARE	SEE NOTE 2
30 —‖— 31	IAS6	X	X		SPARE	SEE NOTE 2

TYPICAL VALVE POSITION SWITCH CONTACT DEVELOPMENT

TABLE OF DEVICES

DEVICE Nº	FUNCTION	RATING	MFR	TYPE	CAT/DWG#	REMARKS
42-1G-44, -68 42-1G-69, -70	480V AC MOTOR STARTER REVERSING	—	W.E.Corp.	—	REF DWG# 10	
43X-1G-44, -68 43X-1G-69, -70	CONTROL TRANSFER RELAY	120V AC	ELECTRO SWITCH CORP.	[illegible]	7903 F	HAND RESET
49-1G-44, -68 49-1G-69, -70	MOTOR OVERLOAD RELAY	—	W.E.Corp.	—	—	PART OF MOTOR STARTER
49X-1G-44, -68 49X-1G-69, -70	MOTOR OVERLOAD AUXILIARY RELAY	—	W.E.Corp.	—	—	PART OF MOTOR STARTER
52-1G-44, -68 52-1G-69, -70	480V AC AIR CIRCUIT BKR	—	W.E.Corp.	—	REF DWG# 10	
LCV 106, 107, 108 109, 110, 111, 113, 115	STM. GEN AUX FW SUPPLY LEVEL CONT V.	—	—	—	—	
HIC	HAND INDICATING CONTROLLER					SEE TABLE FOR Nº
PCS	LCV POSITION SWITCH					SEE TABLE FOR SW Nºs

EQUIPMENT LOCATION NUMBERS

SPG - 480V MOTOR CONTROL CENTER BUS SECTION 1G
MPG44 - MOTOR OPERATED VALVE LCV106
CB - CONTROL BOARD, CONDENSATE & FEEDWATER
HØ1 - HOT SHUTDOWN CONTROL PANEL, FEEDWATER
XLCV110 - INSTR Nº LCV110, LOCAL MOUNTED

NOTES

1. ADJUSTABLE TO OPERATE TOGETHER AT ANY POINT DURING OPENING TRAVEL.
2. ADJUSTABLE TO OPERATE TOGETHER AT ANY POINT DURING CLOSING TRAVEL.

REFERENCE DRAWINGS

1. DESCRIPTION OF ELECT SCHEMATIC DIAG'S, SYMBOLS & CKT DESIG. DWG# 050003
2. EQUIPMENT LOCATION NUMBER LIST 101300
3. SINGLE LINE METER & RELAY DIAG., 480V SYSTEM BUS SECT. 1F 437316
4. SINGLE LINE METER & RELAY DIAG., 480V SYSTEM BUS SECT 1H 437543
5. PIPING SCHEMATIC FEEDWATER SYSTEM 102003
6. INSTRUMENT SCHEMATIC [illegible] 102036
7. SCHEMATIC DIAGRAM MAIN ANNUNCIATOR UNIT 1 [illegible]
8. SINGLE LINE METER & RELAY DIAG 120V INSTR AC SYSTEM 1 437547
9. LCV 110, 111, 113 & 115 ELECTRO-HYDRAULIC ACTUATOR REC# 663165
10. SINGLE LINE METER & RELAY DIAG, 480V SYSTEM BUS SECT 1G DWG 437542

NUCLEAR SAFETY RELATED

VALVE Nºs LCV106, LCV107, LCV108, LCV109, LCV110, LCV111, LCV113, LCV115
UNIT 1

P.G.&E. SYSTEM PHASE SEQUENCE A-C-B

T. A. Bettencourt No. 1366 ELECTRICAL
COAST VALLEYS DIVISION

CHANGES APPROVED BY SUPERVISING ENGINEER

TABLE OF CHANGES

COORDINATED APPROVAL FOR CONSTRUCTION

SCHEMATIC DIAGRAM
AUXILIARY FEEDWATER MOTOR OPERATED VALVES
DIABLO CANYON
DEPARTMENT OF ENGINEERING
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DATE 12-9-70
SCALES NONE
DRAWING NUMBER 437507

PG&E 30X

JAN MAR MAY JULY SEPT NOV
FEB APR JUNE AUG OCT DEC
78

Memo to Stolz from Allison
Docket # 50-275/323
Control # 7811290460
Date 11-21-78

RETURN TO REGULATORY DOCKET FILES