UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 2 1976

Docket Nos. 50-338
and 50-339

Ragnwald Muller, ACRS Staff

Enclosed is a list of the NRC staff members who will be available for the July 7, 1976, Subcommittee meeting concerning the North Anna Power Station Units 1 and 2 application for operating licenses.

Walter J. Pike

Walter J. Pike, Project Manager
Light Water Reactors Branch No. 3
Division of Project Management

JUL 2 1976

ENCLOSURE

NRC STAFF AVAILABLE

FOR THE JULY 7, 1976 ACRS

SUBCOMMITTEE MEETING

NORTH ANNA

| | |
|---|---|
| Z. Rosztoczy | J. Knight |
| S. Pawlicki | I. Sihweil |
| C. Stepp | K. Desai |
| F. Litton | S. Bhatt |
| U. Potapovs | S. Chan |
| D. Jeng | S. Isreal |
| S. Kim | R. Meyer |
| M. Dunenfeld | D. Thatcher |
| D. McDonald | B. Mann |
| F. Allenspach | M. Fields |
| J. Kudrick | J. Boegli |
| C. Ferrill | L. Bell |
| K. Campe | L. Heller |
| W. Bivins | A. Cardone |
| J. Fairobent | T. Murphy |
| F. Liederbach | J. Martin |
| J. McMillen | W. Jensen |
| T. Johnson | R. Hofman |
| R. Bosnak | A. Dromerick |
| W. Pike | D. Vassallo |

GUARD'S DESK

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE

NORTH ANNA SUBCOMMITTEE
ROOM 1046 - 1717 H ST. NW.
WASHINGTON, D.C.

JULY 7, 1976

| NAME | AFFILIATION |
|---|---|
| David Okrent | ACRS Member |
| H. Etherington | ACRS Member |
| M. S. Plesset | ACRS Member |
| H. S. Isbin | ACRS Member |
| S. H. Bush | ACRS Member |
| J. Merkle | ACRS Consultant |
| Ivan Catton | ACRS Consultant |
| T. Theofanous | ACRS Consultant |
| W. C. Lipinski | ACRS Consultant |
| J. T. Wilson | ACRS Consultant |
| D. Canonico | ACRS Consultant |

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE

NORTH ANNA SUBCOMMITTEE
ROOM 1046 - 1717 H ST. NW
WASHINGTON, D.C.

JULY 7, 1976

| NAME | AFFILIATION |
|---|---|
| | NRC |
| A. W. Dromerick | NRC Staff |
| Z. Rosztoczy | NRC Staff |
| S. Pawlicki | NRC Staff |
| B. C. Rusch | NRC Staff |
| C. Stepp | NRC Staff |
| ~~D. B. Vassallo~~ | ~~NRC Staff~~ |
| F. Litton | ~~NRC Staff~~ |
| U. Potapovs | " |
| D. Jeng | " |
| S. Kim | " |
| M. Dunenfeld | " |
| D. McDonald | " |
| F. Allenspach | " |
| J. Kudrick | " |
| C. Ferrill | " |
| K. Campe | " |
| W. Bivins | " |

ADVI...RY COMMITTEE ON REA... SAFEGUARDS
MEETING OF THE

GUARDS DESK

NORTH ANNA SUBCOMMITTEE MTG - NRC Staff P-2

| NAME | AFFILIATION |
|---|---|
| J. Fairobent | NRC Staff |
| F. Linderbach | " |
| J. McMillen | " |
| T. Johnson | " |
| R. Bosnak | " |
| W. Pike | " |
| J. Knight | " |
| I. Sihweil | " |
| K. Desai | " |
| S Bhatt | " |
| S. Chan | " |
| S. Isreal | " |
| R. Meyer | " |
| D. Thatcher | " |
| B. Mann | " |
| M. Fields | " |
| J. Boegli | " |

GUARDS DESK

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE

NORTH ANNA SUBCOMMITTEE MTG - NRC STAFF - p-3

| NAME | AFFILIATION |
| --- | --- |
| L. Bell | NRC Staff |
| L. Heller | " |
| A. Cardone | " |
| T. Murphy | " |
| J. Martin | " |
| W. Jensen | " |
| R. Hofman | " |
| | " |

GUARD'S DESK

# ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
## MEETING OF THE
## NORTH ANNA SUBCOMMITTEE
ROOM 1046 - 1717 H ST. NW
WASHINGTON, D.C.

JULY 7, 1976

| NAME | AFFILIATION |
|---|---|
| | VEPCO |
| Mr. W. F. Bennett | Virginia Electric and Power Compar |
| Mr. Sam Brown | |
| W. L. Proffitt | |
| E. A. Baum | |
| W. C. Spencer | |
| B. R. Sylvia | |
| D. W. Speidell | |
| J. M. Davis | |
| J. M. McAvoy | |
| F. M. Alligood | |
| F. C. Prince | |
| W. B. Rodell | |
| W. L. Parker | |
| W. R. Runner | |
| J. L. Perkins | |
| C. M. Robinson | |
| I. Kaplan | |

GUARD'S DESK

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE

NORTH ANNA SUBCOMMITTEE
ROOM 1046 - 1717 H ST. NW
WASHINGTON, D.C.

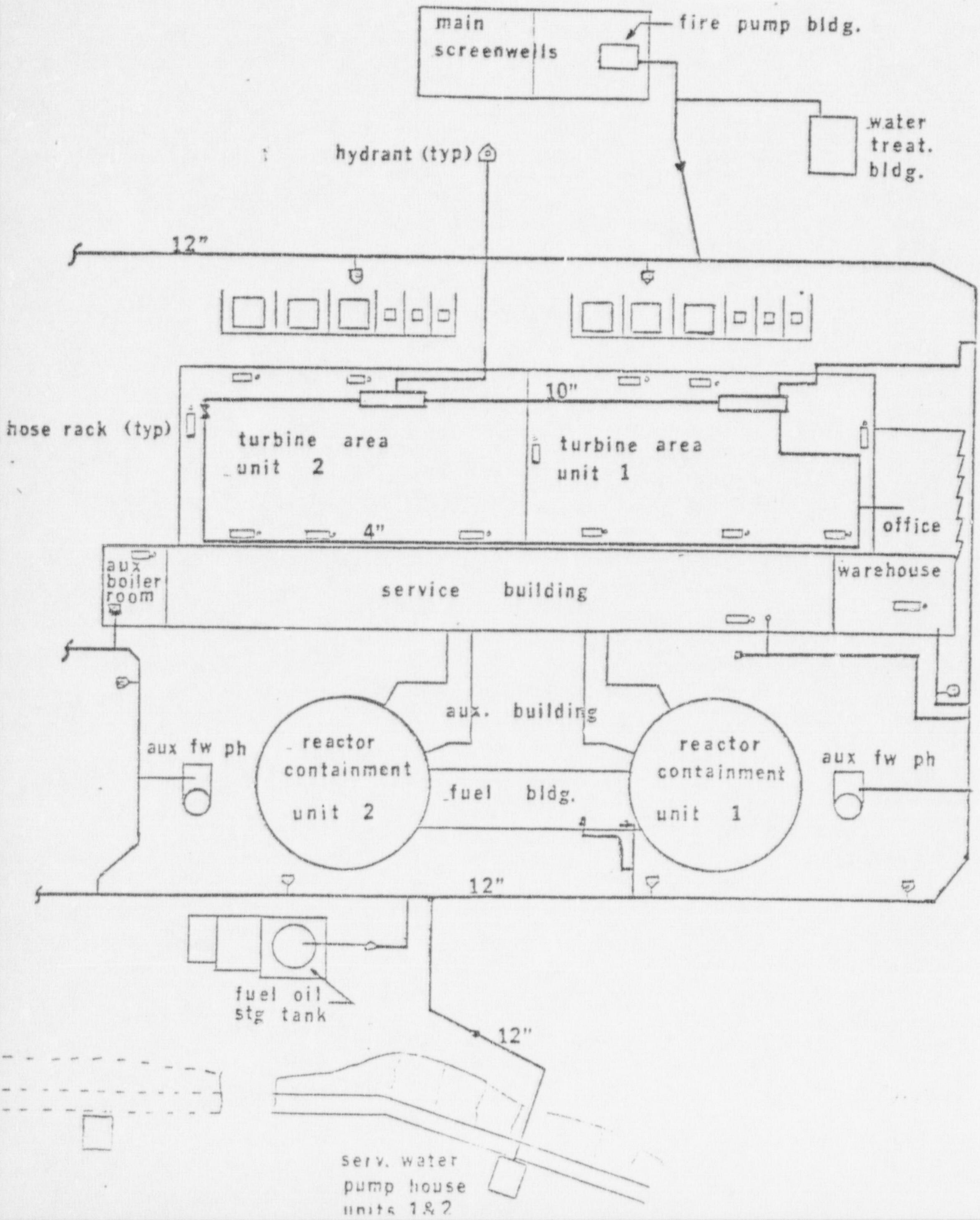
JULY 7, 1976

| NAME | AFFILIATION |
| --- | --- |
| Dr. John Harrison | (Sun Shipbuilding & Dry Dock Co.) British Welding Institute |
| Mr. William Pellini | Sun Shipbuilding & Dry Dock Co. |
| Mr. Richard Bicicchi | Sun Shipbuilding & Dry Dock Co. |
| Mr. Richard Hagan | Sun Shipbuilding & Dry Dock Co. |
| Mr. John Runzer | Sun Shipbuilding & Dry Dock Co. |
| Mr. Peter Hepp | Sun Shipbuilding & Dry Dock Co. |

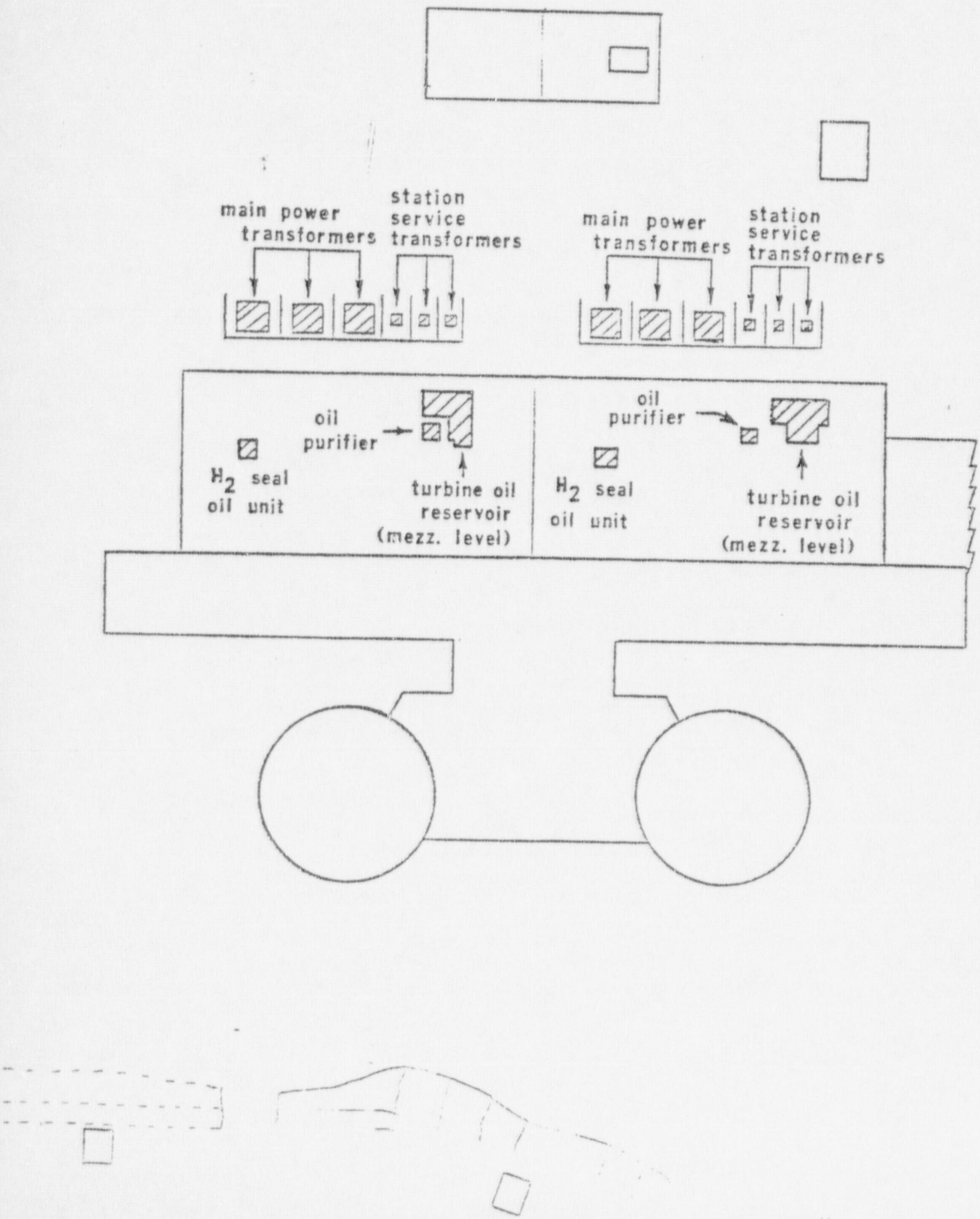
GUARDS' DESK

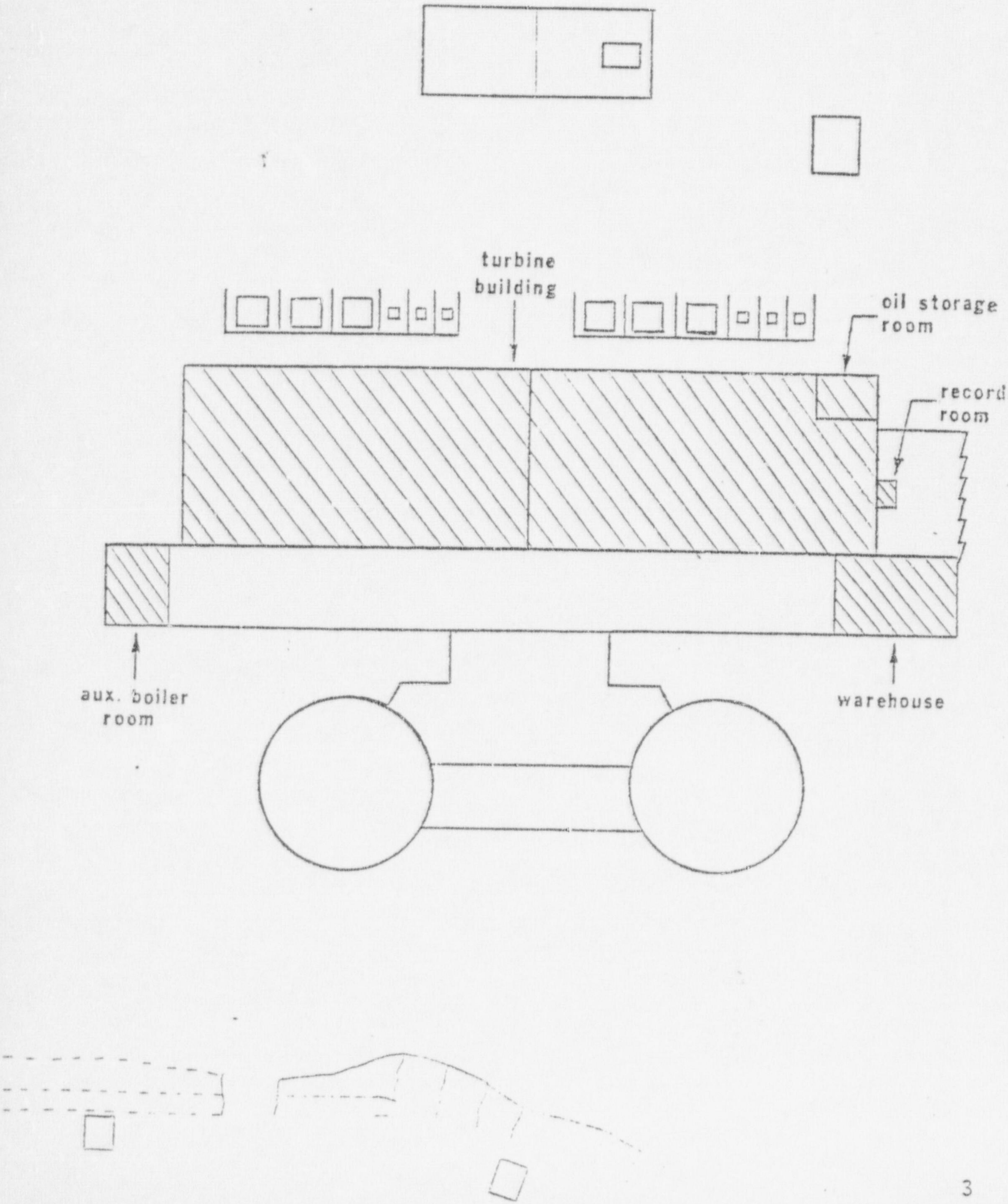
NORTH ANNA SUBCOMMITTEE MTG - VEPCO P-2

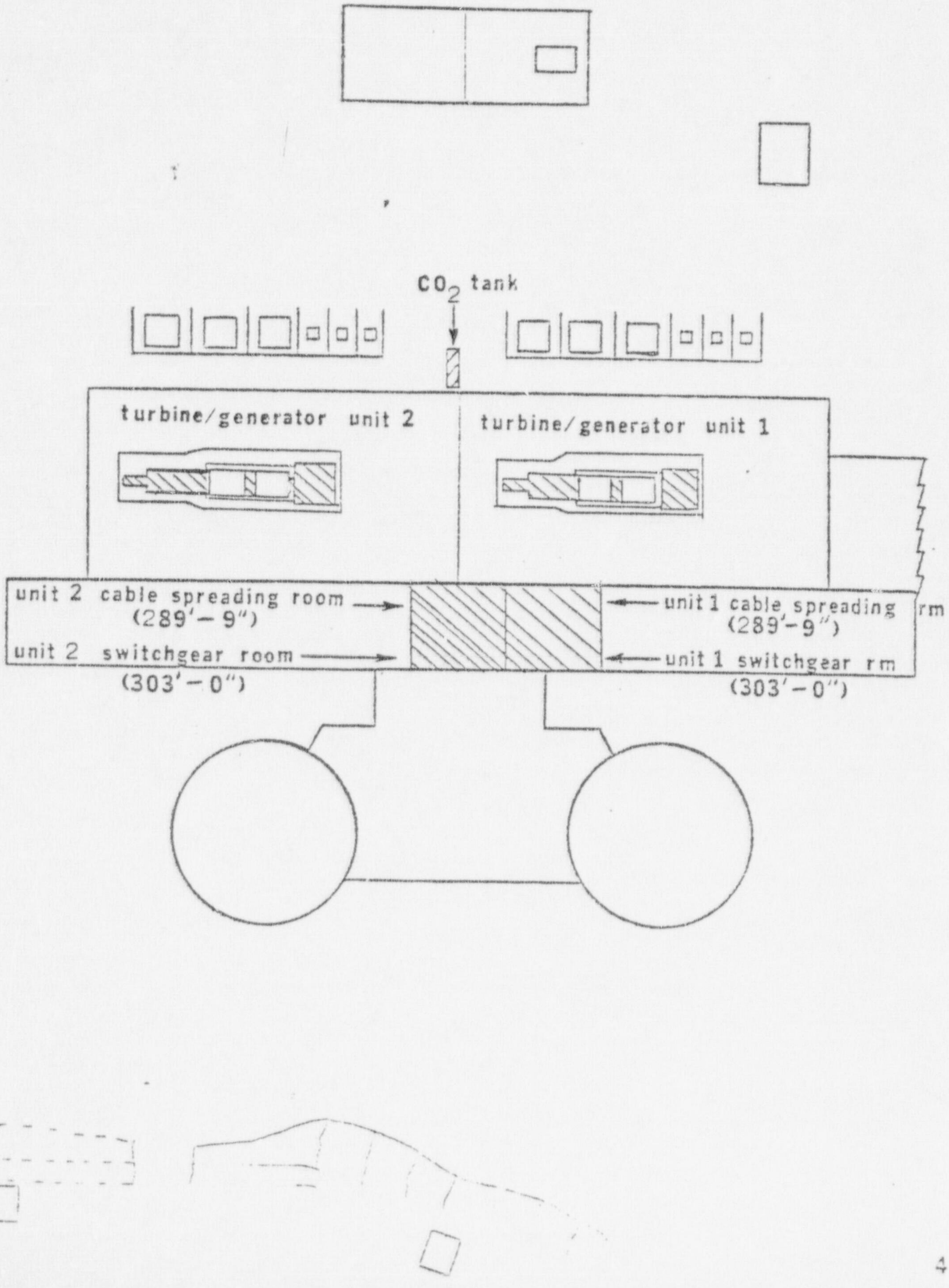
| NAME | AFFILIATION |
|---|---|
| W. H. Chamberlain | STONE & WEBSTER |
| J. Cavallo | " |
| N. Goldstein | " |
| A. Van Sickle | " |
| R. B. Bradbury | " |
| L. Vota | WESTINGHOUSE |
| B. Maier | " |
| Tom Anderson | " |
| Dave Maburger | " |
| W. H. House | " |
| E. Esposito | " |
| D. Essleman | " |
| Kingi Teakuchi | " |
| Dave Kowalski | " |



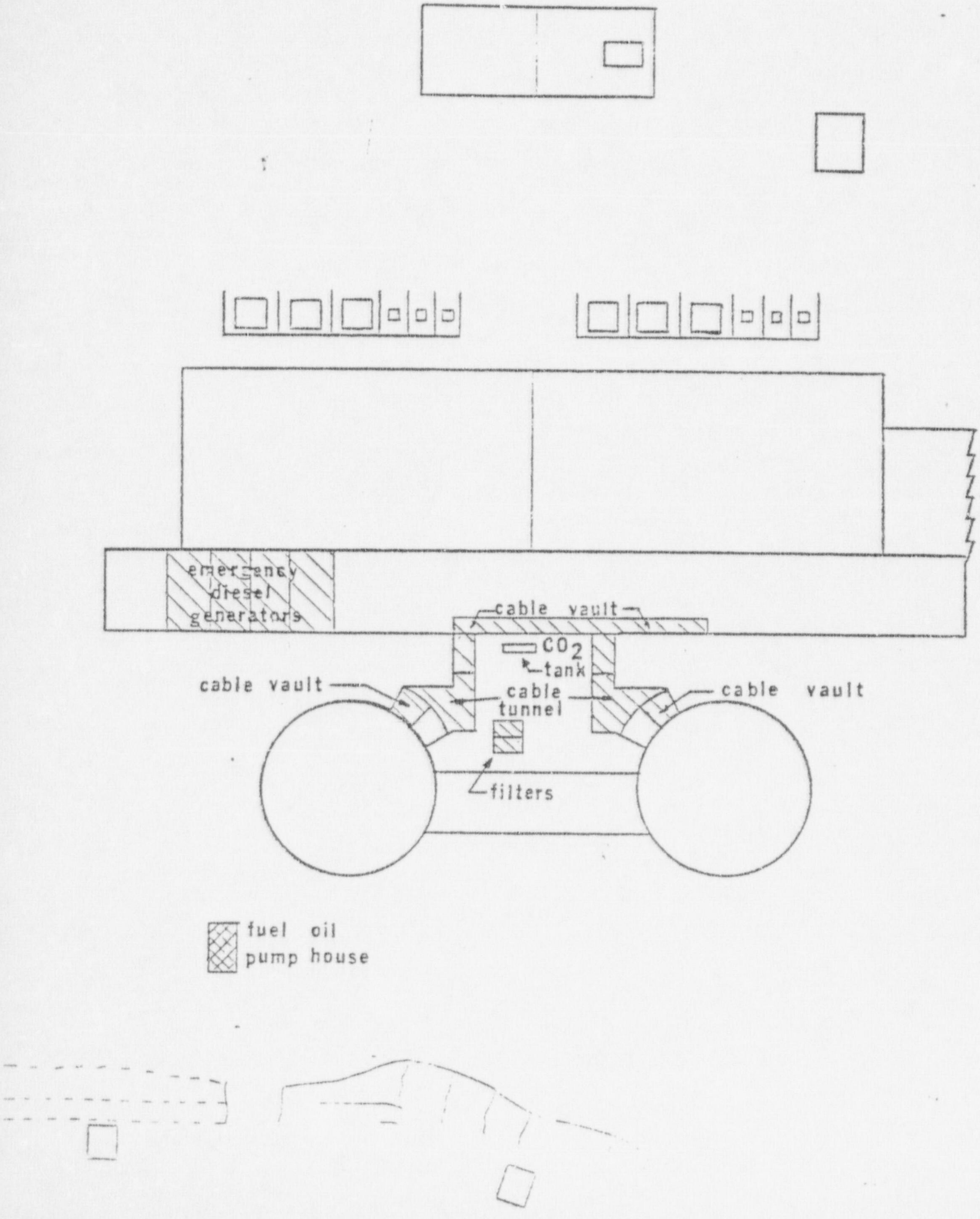
main screenwells
fire pump bldg.
water treat. bldg.
hydrant (typ)
12"
10"
hose rack (typ)
turbine area unit 2
turbine area unit 1
4"
office
aux boiler room
service building
warehouse
aux. building
aux fw ph
reactor containment unit 2
fuel bldg.
reactor containment unit 1
aux fw ph
12"
fuel oil stg tank
12"
serv. water pump house units 1&2

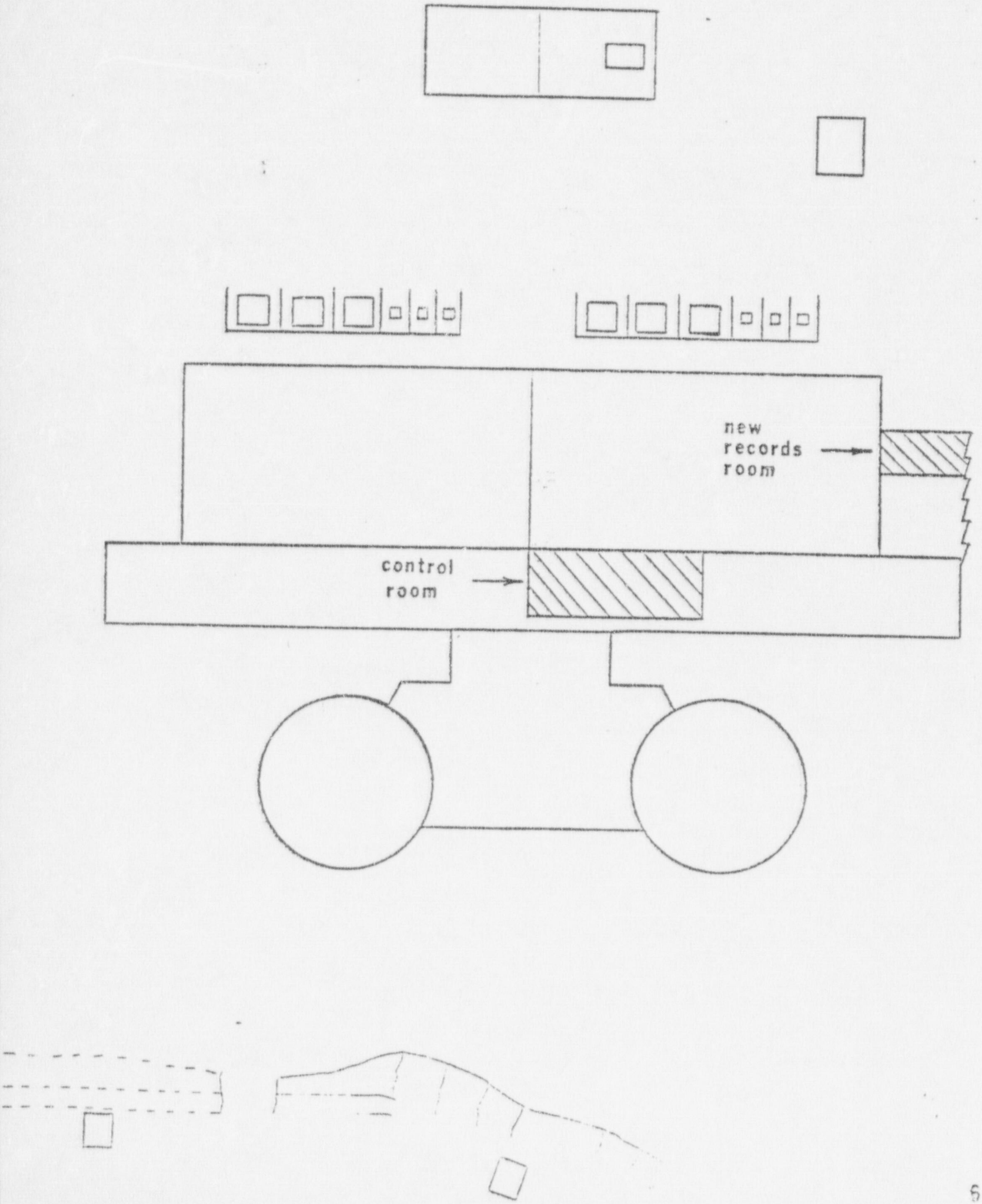

main power transformers
station service transformers
main power transformers
station service transformers
oil purifier
H2 seal oil unit
turbine oil reservoir (mezz. level)
oil purifier
H2 seal oil unit
turbine oil reservoir (mezz. level)


turbine building
oil storage room
records room
aux. boiler room
warehouse



$CO_2$ tank
turbine/generator unit 2
turbine/generator unit 1
unit 2 cable spreading room
(289'-9")
unit 2 switchgear room
(303'-0")
unit 1 cable spreading rm
(289'-9")
unit 1 switchgear rm
(303'-0")


emergency
diesel
generators
cable vault
$CO_2$
tank
cable vault
cable
tunnel
cable vault
filters
fuel oil
pump house


new
records
room
control
room

STATEMENT OF THE ISSUE: What is the Ability of the Station to Withstand Temporary Loss of All A.C. Power?

VEPCO POSITION: North Anna Power Station has the ability to withstand a temporary loss of all A.C. power. Before addressing this subject, however, it should be emphasized that off-site and on-site power sources have been designed and constructed to be extremely reliable. For example, availability of off-site power is insured by (3) redundant reserve station service transformers which provide a very strong tie with the Vepco electrical grid. In addition, availability of on-site power is insured by (4) redundant diesel generators which provide an uninterruptable power source in the event of an area wide system "blackout".

Not withstanding the fact that both sources of power meet the highest standards, it could be hypothesized that all A. C. power is lost. Even with this overly stringent assumption, the results of such an occurence are controllable.

It is a design feature that systems and components necessary to protect the reactor, in the event of loss of power, depend on energy sources other than A.C. power for the actuation.

Consider the following results if all A.C. power is lost, while the reactor is at 100% power:

1. Safe Shutdown of the reactor is assured even without A.C. power, because the reactor protection system does not depend on A.C. power; but utilizes D.C.power from the redundant 125v d-c Batteries for actuation. Therefore, the reactor will be shutdown and auxiliary feedwater flow initiated.

2. Sufficient Removal of Stored and Residual Heat is assured, even without A.C. power, because the mechanically operated code safety valves on the main stream line utilize spring force for actuation. Therefore, excess energy will be removed from the system.

3. Adequate Addition of heat sink is assured, even with no A.C. power because the turbine driven auxiliary feedwater pump does not depend on electrical power, but utilizes stored steam for actuation. Therefore, enough water will be added to remove core residual heat.

NA1-ACRS 1.4-2
7-7-76

III. In conclusion, the station has the ability to temporarily withstand loss of all A.C. power. During a period of time, of at least several hours following the event, the system has the ability to safely maintain hot shutdown. Sufficient time exists to restore normal A.C. powered cooling systems.

INTRODUCTORY REMARKS
BY SAM C. BROWN, JR.
VICE-PRESIDENT, POWER STATION
ENGINEERING AND CONSTRUCTION DEPARTMENT,
VEPCO BEFORE THE NORTH ANNA SUBCOMMITTEE
ACRS, JULY 7, 1976

Gentlemen: My name is Sam C. Brown, Jr., Vice-President, Power Station Engineering and Construction, Vepco. Until about a week ago, we were prepared to appear here today and report to you that there is reasonable assurance that the steam generator supports at North Anna can be used safely without any modification in either the structures or in the conditions under which they will operate.

Based on data obtained within the past week, however, we have concluded that the toughness characteristics of some of the steel in the structures would not be adequate for use in the containment environment in which we had planned to use them.

This afternoon we will describe for you both our earlier data, which we found so reassuring, and the more recent, disappointing results. We will also describe our proposed plan for dealing with this toughness problem. That plan consists of insulating the supports in order to maintain them at temperatures where their toughness will be adequate.

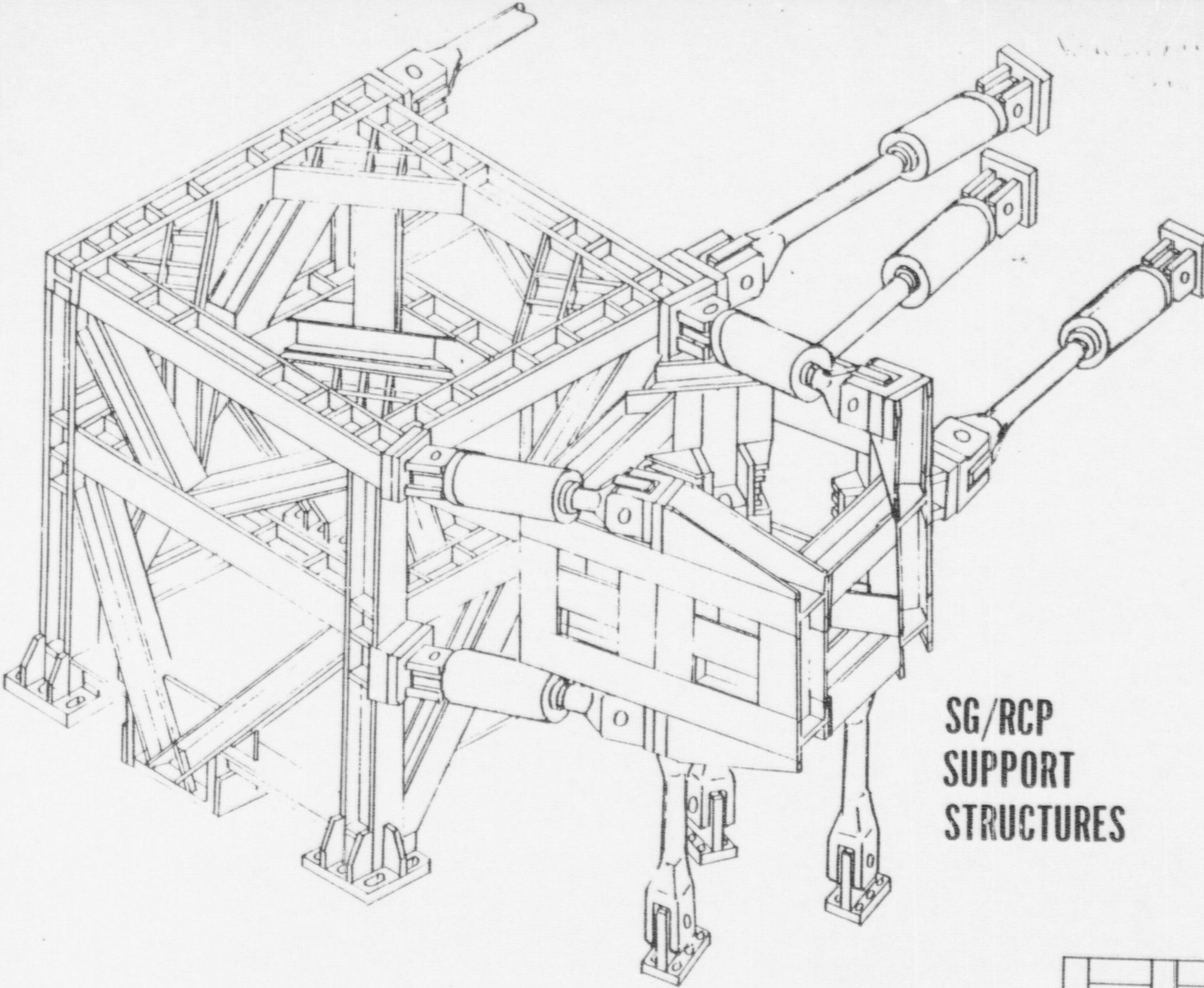
Before our presentation begins, however, I want to address a question that may well have occurred to you. How have we come so far down the road without having detected any problems with the material properties of our steam generator supports? It is important to realize that when these structures were designed, they were designed in accordance with all applicable codes. Those codes imposed no fracture toughness requirements for structures such as these. The steels that were specified for the North Anna steam generator supports were steels commonly used throughout the nuclear industry.

As our litigation with Sun Ship Building and Dry Dock Company progressed, we set out to test any of the steels in the structures that were available to us. There are two types of steels used in these structures - - A-36 and A-572. We found that we had on hand at the North Anna site certain A-36 material that was originally included in the steam generator supports before the rewelding was undertaken. Portions of this A-36 steel had been removed during the repairs, and we were able to perform our tests on these removed portions. You will see the results this afternoon. We were quite pleased with them. Indeed we will demonstrate that insofar as those A-36 steels were concerned we came extremely close to satisfying the presently applicable Section NF even though the supports had been designed before that Section had ever been proposed. As far as we knew at that time, we did not have any A-572 steel on hand for testing. But based on material in the literature, we believed it was reasonable to conclude that the A-572 steel would have toughness characteristics equal or superior to those of A-36. Accordingly, we took the position in our earlier presentations to the NRC that our supports would perform adequately under the conditions planned to exist at North Anna.

Within the last two weeks, however, we discovered that in fact we did have some A-572 material that could be tested. We found some A-572 beams that had not been needed in repairing the steam generator supports but that were from the same heats of material as some of those that had been used in the repairs. We immediately arranged to have this A-572 steel tested for toughness. The results showed that, contrary to our belief, the toughness of the A-572 steel was decidedly inferior to the A-36. About the same time that we found the A-572 material, we discovered in deposing a Sun Ship employee that Sun Ship might have in its possession some A-572 material from our supports. We called them and agreed to exchange our A-572 test results.

While we were satisfied that the supports will perform as designed under normal conditions, the conservatism that is desirable under the unlikely accident condition requires that we make a design modification. Based on collective results, we were informed by our consultants that steps should be taken to increase the operating temperatures in which the steam generator supports would be used. We reported the results of our tests to the NRC immediately and, as I have said, we will discuss them thoroughly with you this afternoon.

I have discussed this background with you because I want there to be no question about Vepco's good faith or its sincere desire to see that these supports have been built and will be used in a way that will not endanger the public health and safety.



SG/RCP SUPPORT STRUCTURES

# CRITERIA FOR DESIGN BY ANALYSIS

## NORTH ANNA 1 & 2 SUPPORTS

| CONDITION | LOAD COMBINATION | ALLOWABLE MEMBER STRESS | A - 36 | A - 572 |
|---|---|---|---|---|
| DESIGN | DW + DBE + PR | $F_t = 0.9 S_y$ | $F_t = 32.4$ | $F_t = 37.8$ |

## ASME III SUBSECTION NF (LINEAR TYPE SUPPORTS)

| CONDITION | LOAD COMBINATION | ALLOWABLE PRIMARY STRESS | SA-36 | SA-572 |
|---|---|---|---|---|
| DESIGN | DW + ½ SSE | $F_T = 0.6 S_Y$<br>(TT) $F_T = 0.3 S_Y$ | $F_T = 21.6$<br>(TT) $F_T = 10.8$ | $F_T = 25.2$<br>(TT) $F_T = 12.6$ |
| NORMAL | DW + ½ SSE + $S_N$ | | | |
| UPSET | DW + ½ SSE + $S_U$ | | | |
| EMERGENCY | DW + ½ SSE + $S_E$ | $F_T = 0.8 S_Y$<br>(TT) $F_T = 0.4 S_Y$ | $F_T = 28.8$<br>(TT) $F_T = 14.4$ | $F_T = 33.6$<br>(TT) $F_T = 16.8$ |
| FAULTED | DW + SSE + PR | LESSER OF:<br>$F_T = 1.2 S_Y$ OR<br>$F_T = 0.7 S_U$<br>(TT) $F_T = 0.6 S_Y$<br>(TT) $F_T = 0.35 S_U$ | $F_T = 40.6$<br>(TT) $F_T = 20.3$ | $F_T = 42.0$<br>(TT) $F_T = 21.0$ |

76-6649

# LOWER STEAM GENERATOR SUPPORT FRAME MATERIALS
# NORTH ANNA 1 & 2

| MATERIAL PROPERTY | MINIMUM SPECIFICATION REQUIREMENTS | | CERTIFIED MIL TEST REPORTS | |
|---|---|---|---|---|
| | A-36 | A-572 | A-36 | A-572 |
| YIELD POINT | 36.0 | 42.0 | 37.3-54.8 | 56.5-63.0 |
| TENSILE STRESS | 58-80 | 60.0 | 65.3-80.0 | 83.5-91.5 |
| ELONGATION | 17.0 | 17.0 | 21.5-33.0 | 24.5-25.0 |
| REDUCTION OF AREA | - | - | 45.3-60.9 | 58.1-62.6 |

SPECIFICATION: ASTM A-36 & A-572 GR 42

ADDED REQUIREMENTS: UT PLATES & SHAPES $t \geq 3"$

## ASME III, SUBSECTION NF

| MATERIAL PROPERTY | MINIMUM SPECIFICATION REQUIREMENTS | |
|---|---|---|
| | A - 36 | A - 572 |
| YIELD POINT | 36.0 | 42.0 |
| TENSILE STRESS | 58 - 80 | 60.0 |
| ELONGATION | 17.0 | 17.0 |
| * LATERAL EXPANSION | 25 | 25 |

* ONLY IF REQUIRED IN THE DESIGN SPECIFICATION

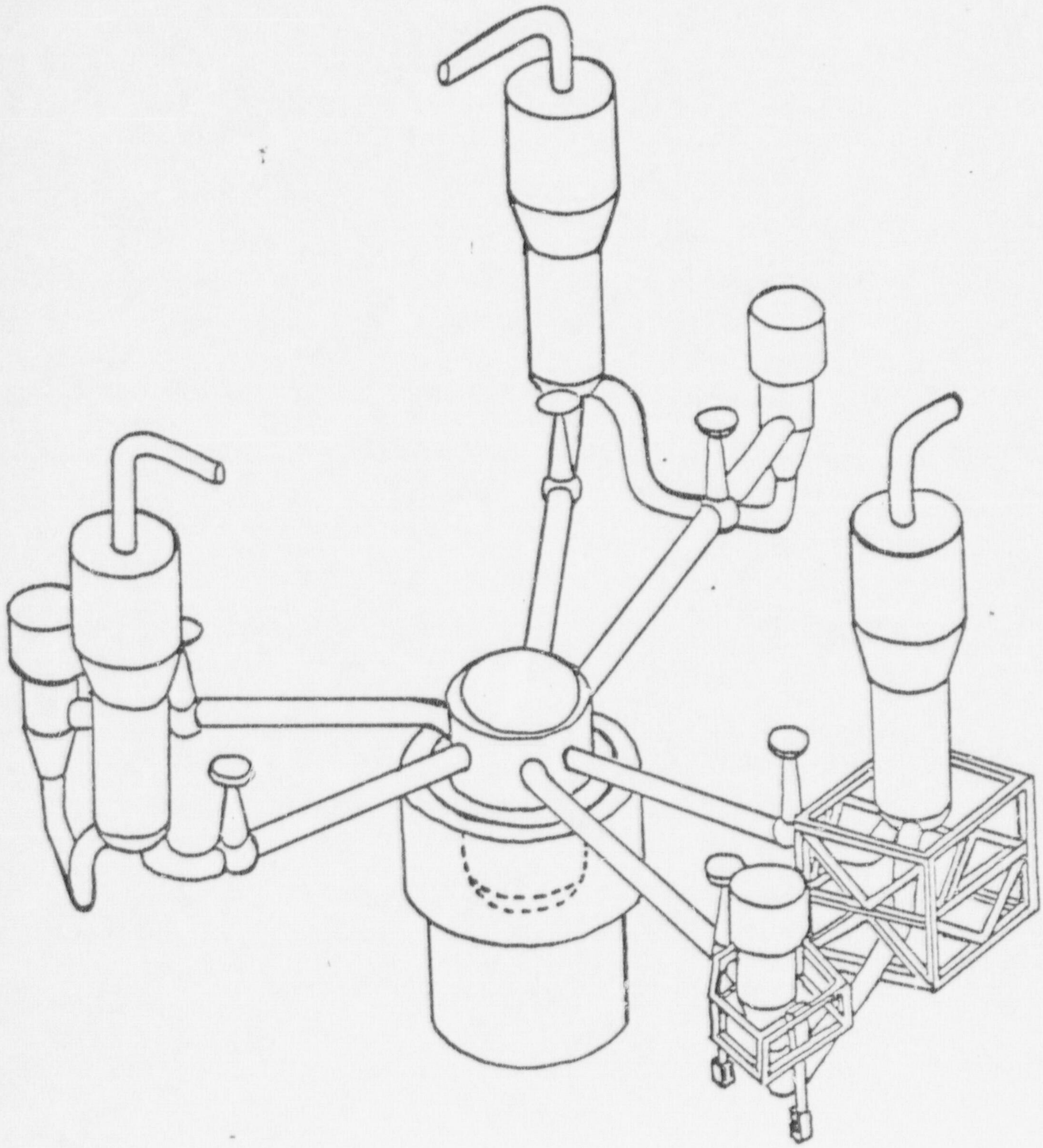
# LOWER STEAM GENERATOR SUPPORT FRAME FABRICATION

| ITEM | NORTH ANNA 1&2 | ASME III. NF |
|---|---|---|
| MACHINED SURFACES | MT OR PT PER APPENDICES VI OR VIII OF ASME VIII | NO SPECIAL REQUIREMENTS |
| WELDING PROCEDURES & WELDING OPERATORS | ASME IX | ASME IX SUPPLEMENTED BY ASME III (NF-4330) IF IMPACT TESTS REQUIRED BY DESIGN SPECIFICATION |
| POST WELD HEAT TREATMENT | UCS-56 OF ASME VIII | ASME III (NF-4620) (BASICALLY SAME AS UCS-56) |

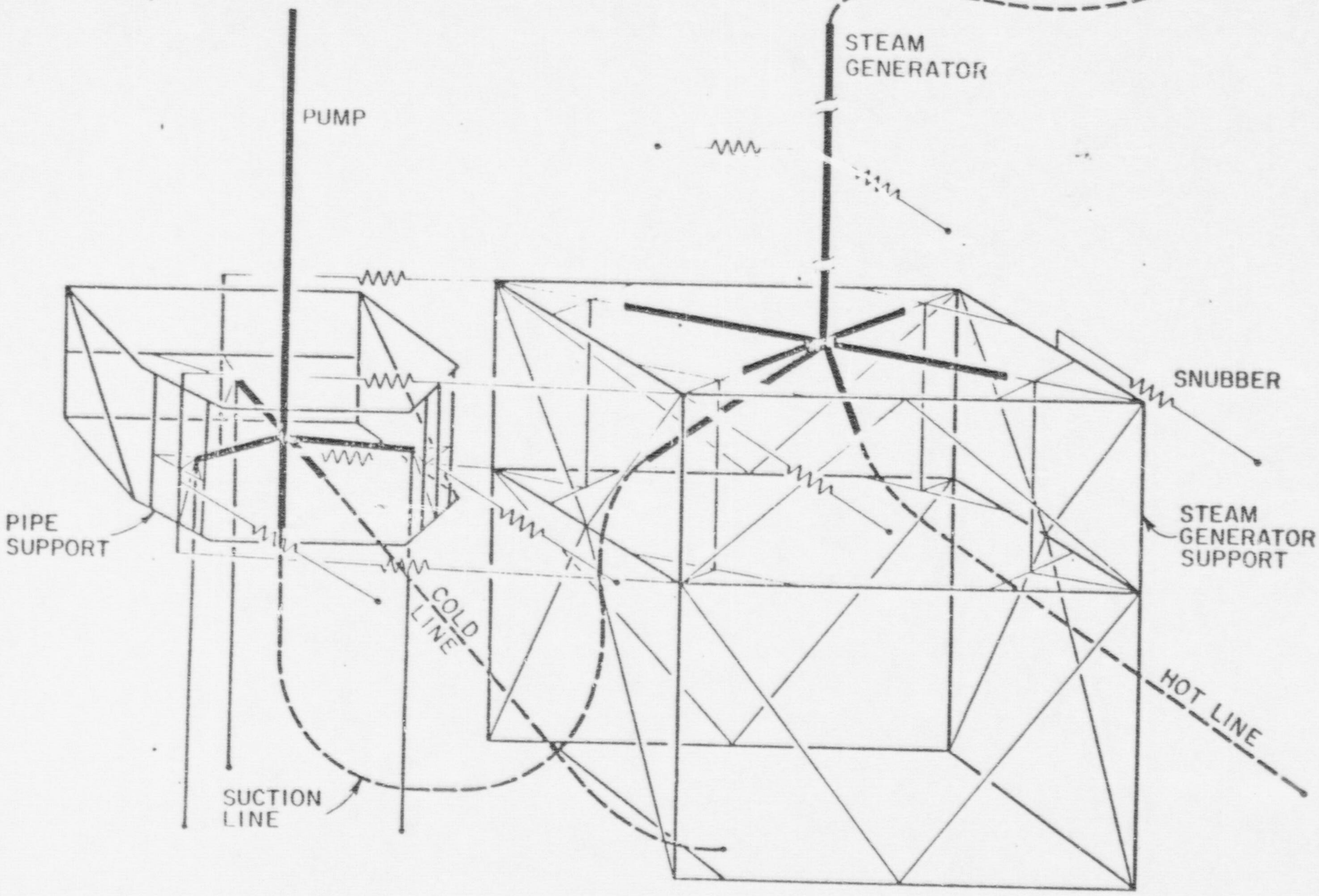
## LOWER STEAM GENERATOR SUPPORT FRAME
## NON-DESTRUCTIVE EXAMINATION

| METHOD | NAS - 170 | ASME III, SUBSECTION NF | |
|---|---|---|---|
| | | PRIMARY MEMBERS | SECONDARY MEMBERS * |
| RADIOGRAPHY | UW-51 OF ASME VIII ON SELECTED WELDS.<br>NO CRACKS, OR INCOMPLETE FUSION OR PENETRATION<br>NO ELONGATED SLAG INDICATIONS > $\frac{3}{4}$" FOR t > $2\frac{1}{4}$"<br>NO POROSITY IN EXCESS OF APPENDIX IV | ALL FULL PENETRATION & FULL FILLET WELDS, IF MEANINGFUL, OTHERWISE UT.<br>NO CRACKS, OR INCOMPLETE FUSION OR PENETRATION, OR ELONGATED INDICATIONS > $\frac{3}{4}$" FOR t > $2\frac{1}{4}$"<br>NO LIMIT ON POROSITY<br>PROCEDURES PER SECTION V | NOT REQUIRED |
| MT OR PT | REQUIRED ON ALL MACHINED SURFACES<br>REQUIRED ON ALL WELDS NOT RADIOGRAPHED<br>REQUIRED ON ROOT, 25% 50%: 75% AND FINAL PASS<br>PER APPENDICES VI OR VIII OF ASME VIII<br>NO CRACKS OR LINEAR INDICATIONS | NOT REQUIRED ON MACHINED SURFACES<br>REQUIRED ON ALL ABOVE WELDS NOT RT OR UT<br>REQUIRED ON FINAL PASS ONLY<br>PROCEDURES PER SECTION V<br>NO CRACKS OR LINEAR INDICATIONS<br>NO ROUNDED INDICATIONS > $\frac{1}{16}$" | NOT REQUIRED |
| VISUAL | NOT REQUIRED | ALL WELDS NOT LISTED ABOVE: REQUIRED (NF-5360)<br>NO CRACKS OR LINEAR INDICATIONS | REQUIRED (NF-5360)<br>NO CRACKS OR LINEAR INDICATIONS |

* BRACING TYPE MEMBERS WITH STRESS $\leq$ 50% OF ALLOWABLE



# RCP/SG DETAILED STRUCTURAL MODEL

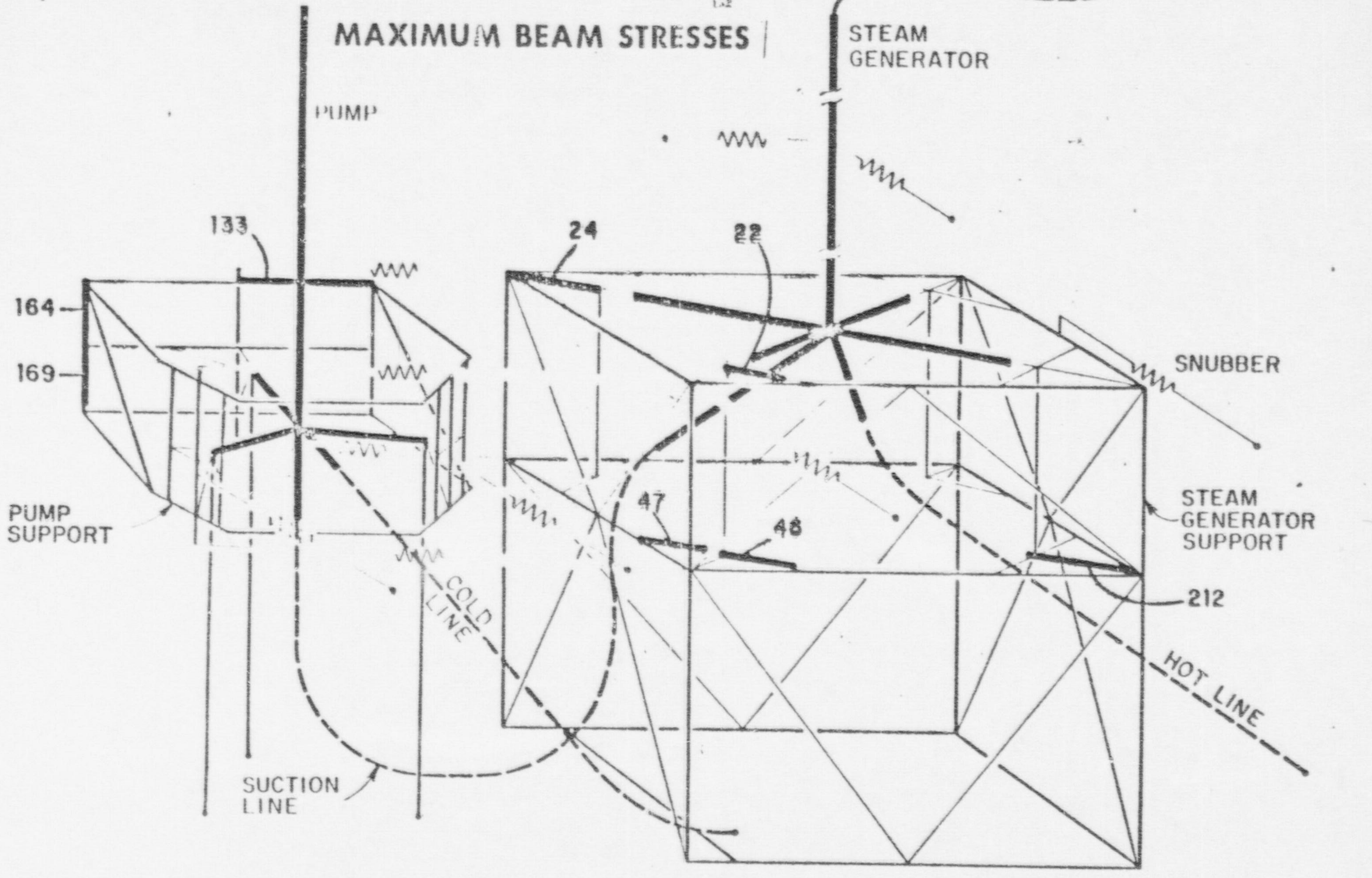


# CONSERVATISMS

1. LEAK BEFORE BREAK
2. FULL D.E.R.
3. FULL SPLIT
4. F.F. RISE TIME (1 ms)
5. SIMULTANEOUS CONSIDERATION OF E.Q. + P.R.
6. USING MAX. P.R. STRESS REGARDLESS OF TIME
7. ABSOLUTE SUMMING OF MAX. E.Q. + MAX. P.R. STRESSES (NOT SRSS)

# RCP/SG DETAILED STRUCTURAL MODEL

## MAXIMUM BEAM STRESSES



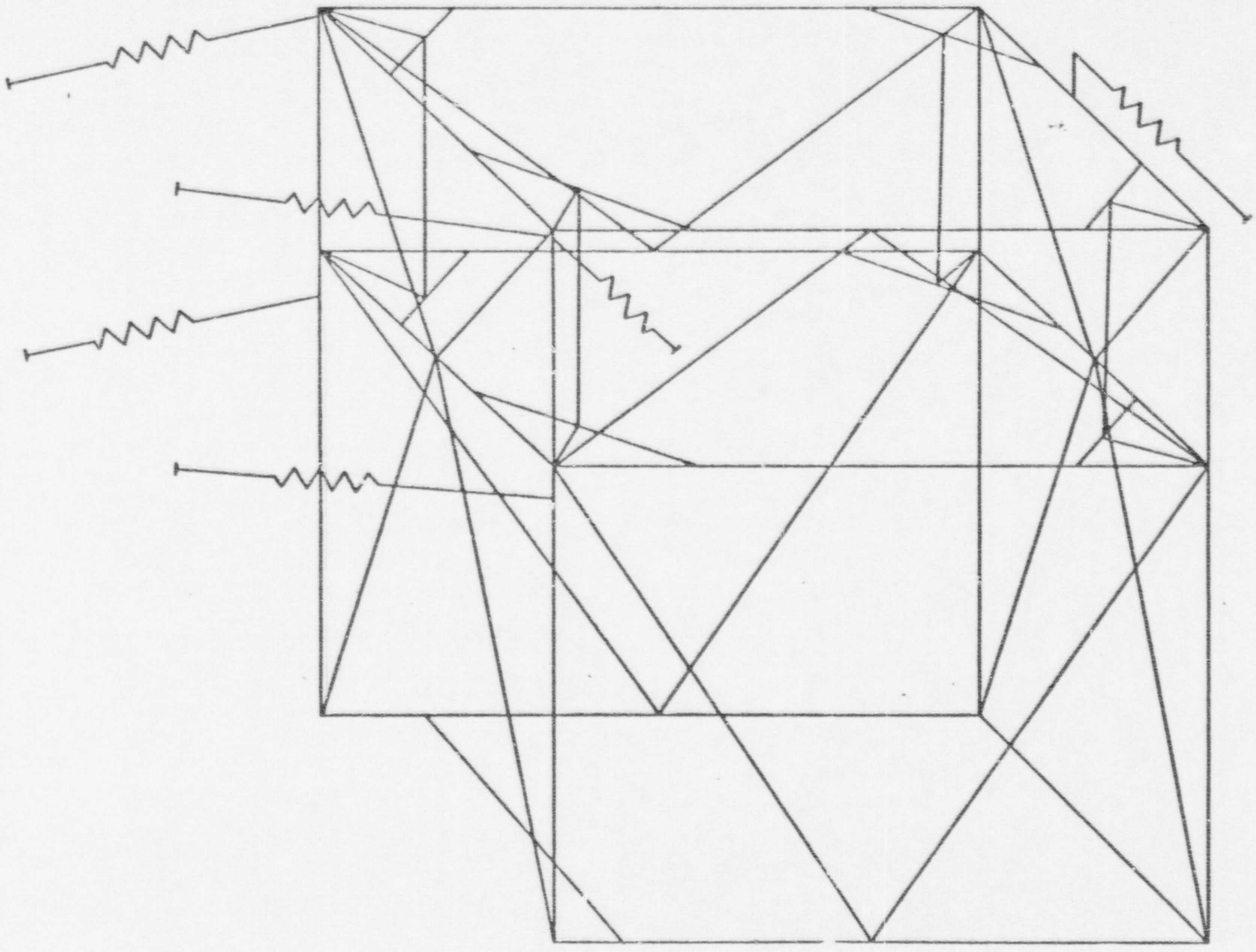
# COMPARISON OF MAXIMUM BEAM STRESSES TO DESIGN CRITERIA

| | | | | INITIAL CRITERIA | | N. F. CRITERIA | |
|---|---|---|---|---|---|---|---|
| | MEMBER NO. | BREAK NO. | TOTAL STRESS (KSI) | ALL. STRESS 90% OF MIN. YIELD KSI | FACTOR OF SAFETY | ALL. STRESS 70% OF ULT. YIELD KSI | FACTOR OF SAFETY |
| STEAM GENERATOR SUPPORT FRAME MEMBERS | 22 | 4 | 30.3 | 0.9(36) = 32.4 | 1.07 | 0.7(58) = 40.6 | 1.34 |
| | 24 | 4 | 18.03 | 0.9(36) = 32.4 | 1.80 | 0.7(58) = 40.6 | 2.25 |
| | 46 | 7 | 30.57 | 0.9(36) = 32.4 | 1.06 | 0.7(58) = 40.6 | 1.33 |
| | 47 | 4 | 20.83 | 0.9(36) = 32.4 | 1.55 | 0.7(58) = 40.6 | 1.95 |
| | 212 | 7 | 20.82 | 0.9(36) = 32.4 | 1.56 | 0.7(58) = 40.6 | 1.95 |
| REACTOR COOLANT PUMP SUPPORT FRAME MEMBERS | 133 | 2 | 35.14 | 0.9(39.8) = 35.5* | 1.01 | 0.7(58) = 40.6 | 1.16 |
| | 164 | 12 | 28.94 | 0.9(36) = 32.4 | 1.12 | 0.7(58) = 40.6 | 1.40 |
| | 169 | 12 | 34.26 | 0.9(39.8) = 35.5* | 1.04 | 0.7(58) = 40.6 | 1.19 |

*90% OF ACTUAL YIELD

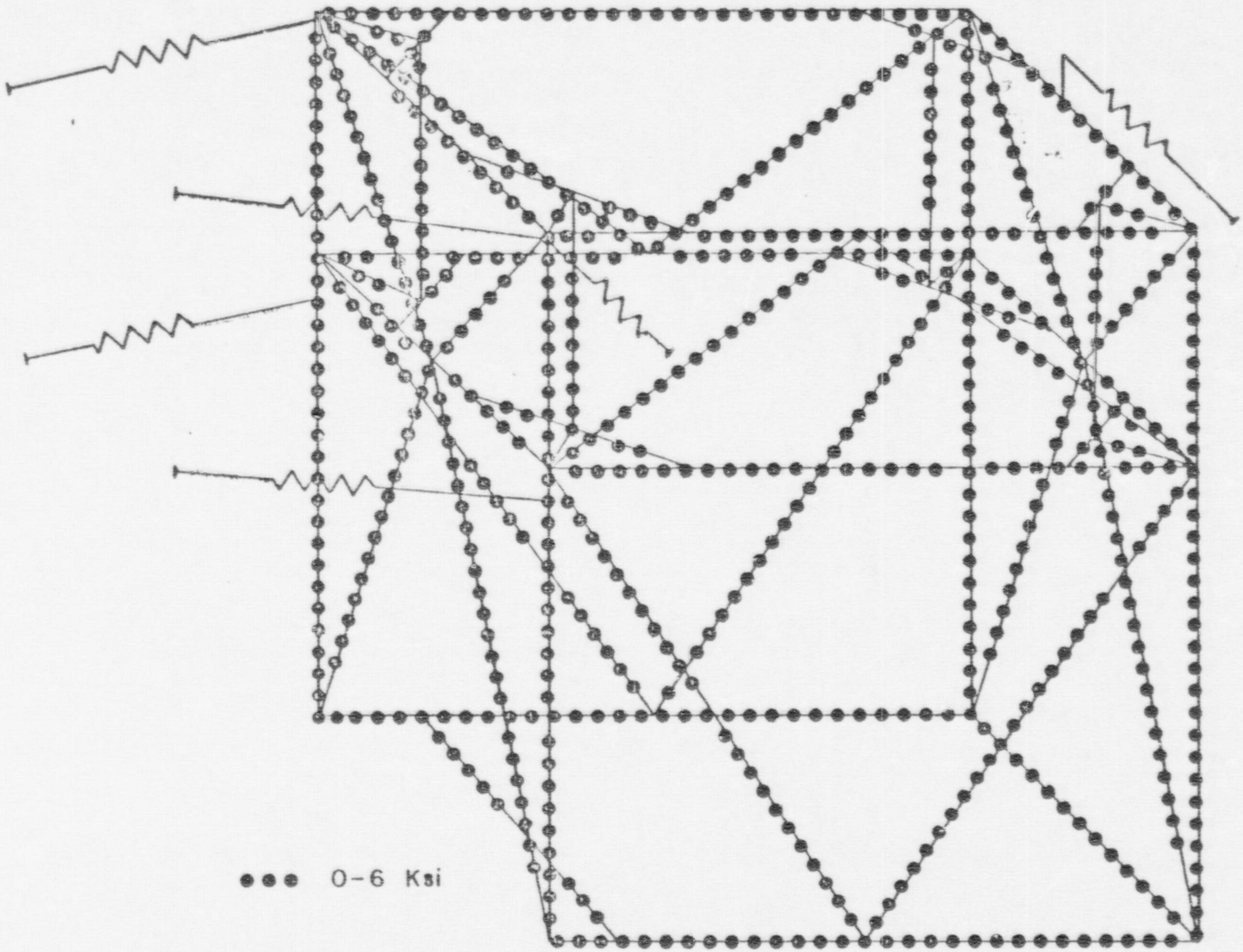
76-6670

# INTEGRAL FRAME



76-6284

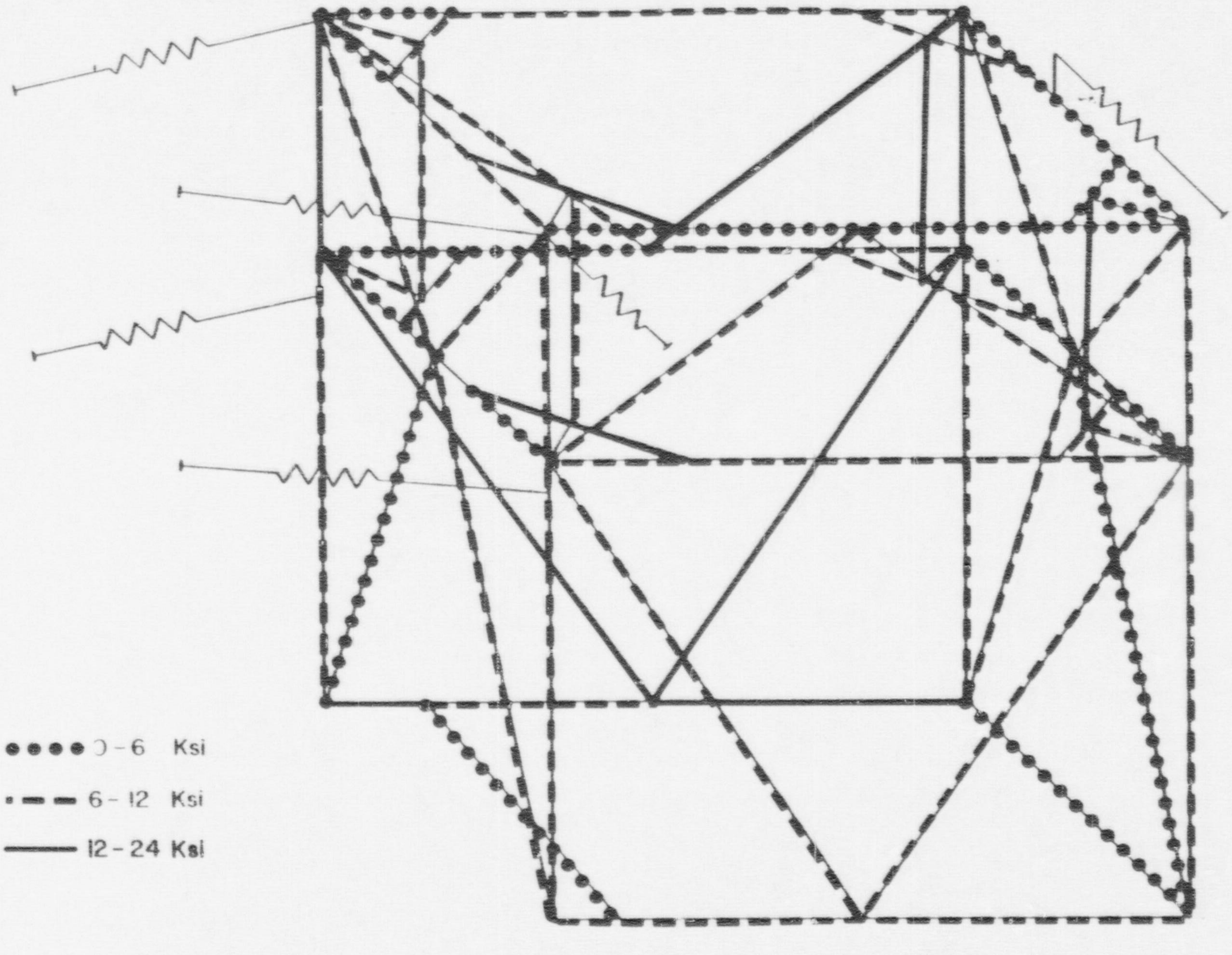
# INTEGRAL FRAME
## DEAD WEIGHT




76-6286

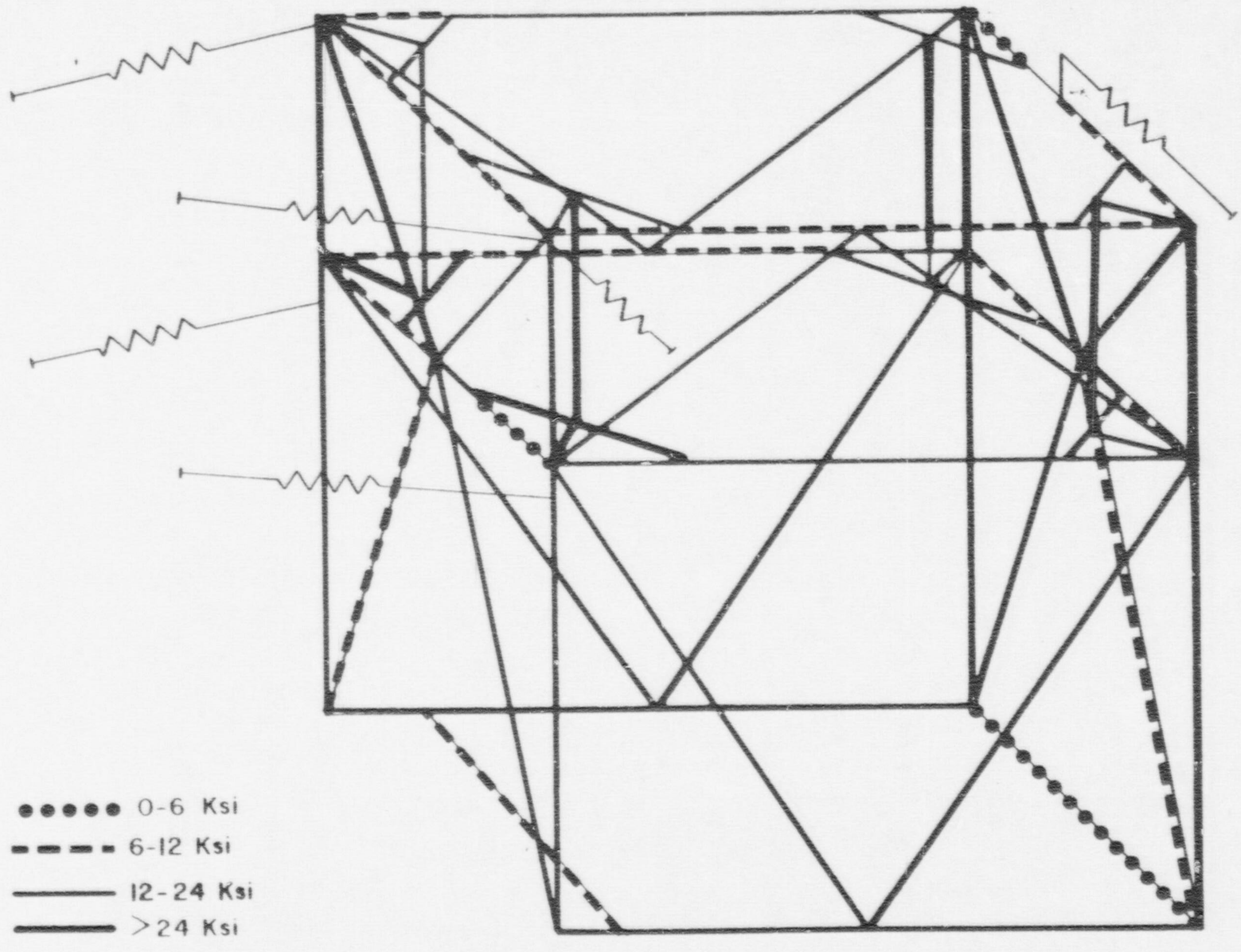
# INTEGRAL FRAME

## DEAD WEIGHT & DBE

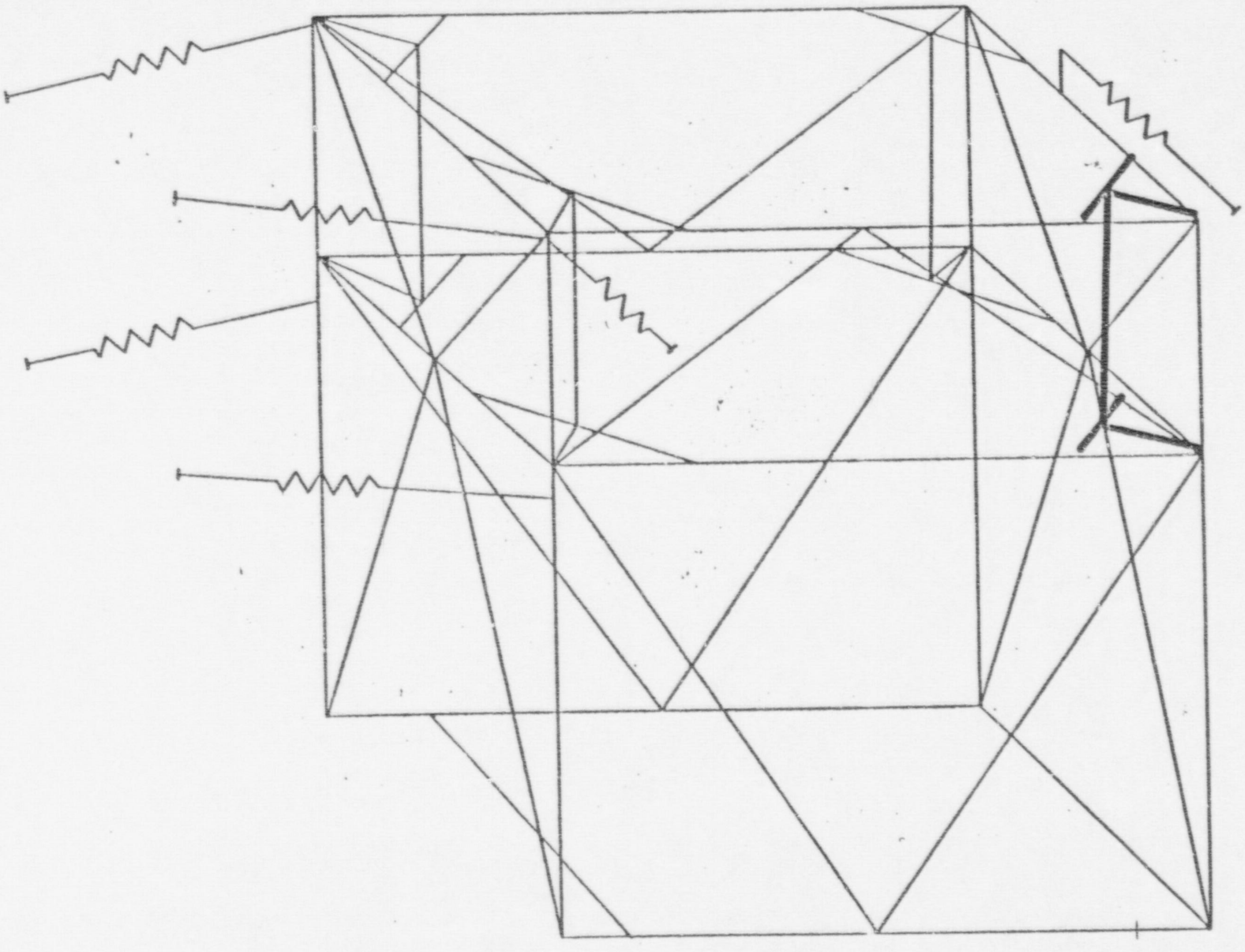


# INTEGRAL FRAME

## DEAD WEIGHT + D.B.E. + LOCA

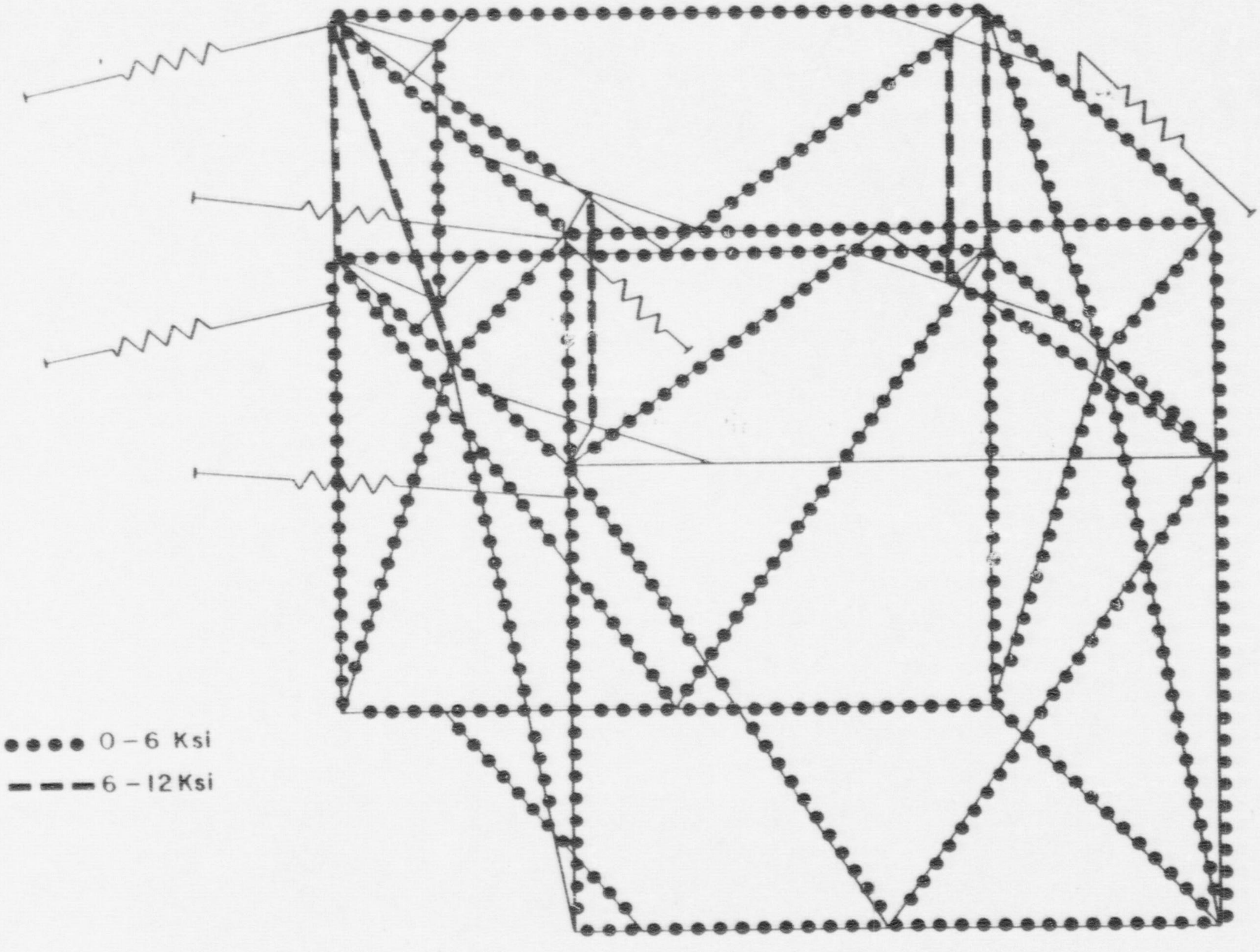


# REDUNDANCY MODEL

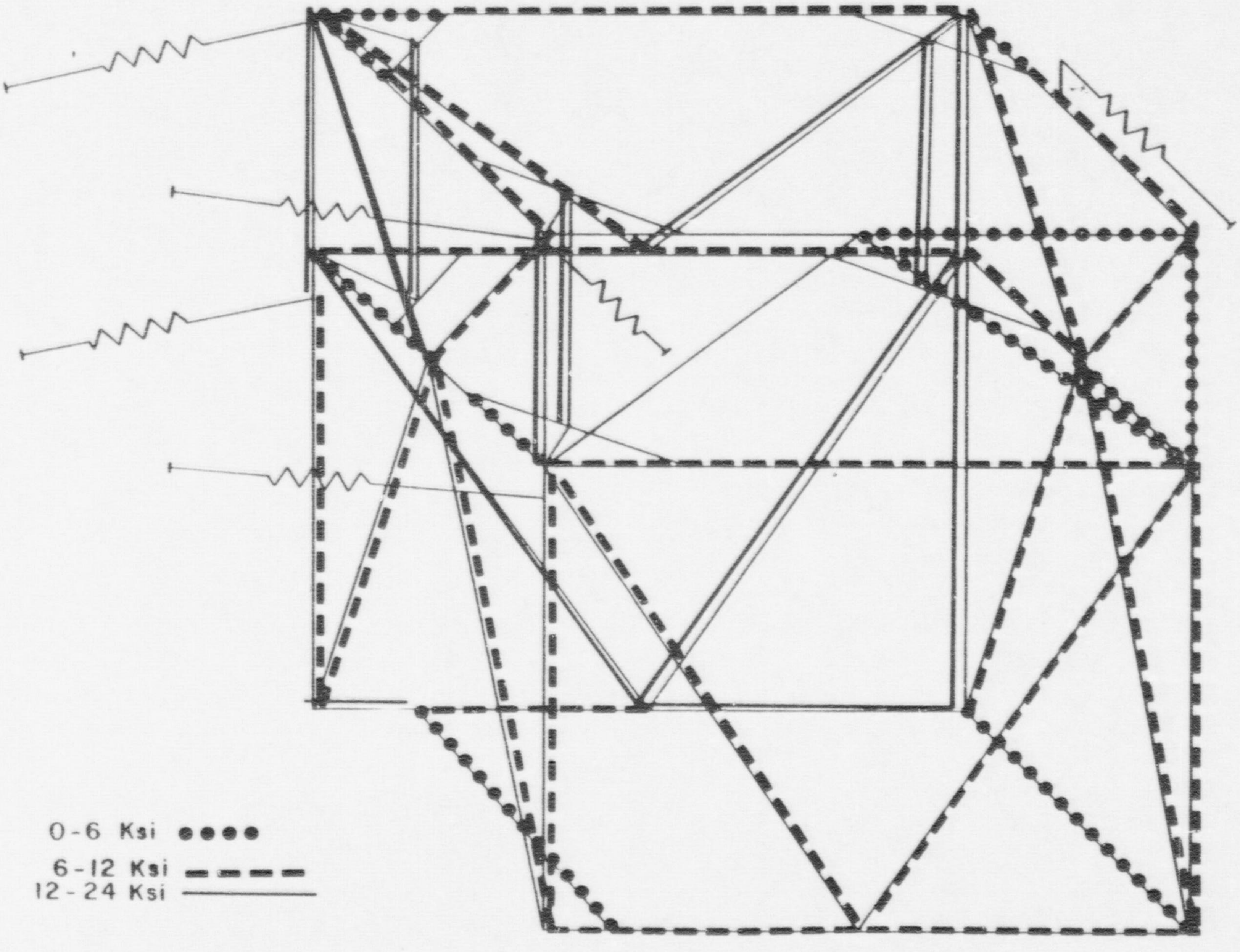


74-6289

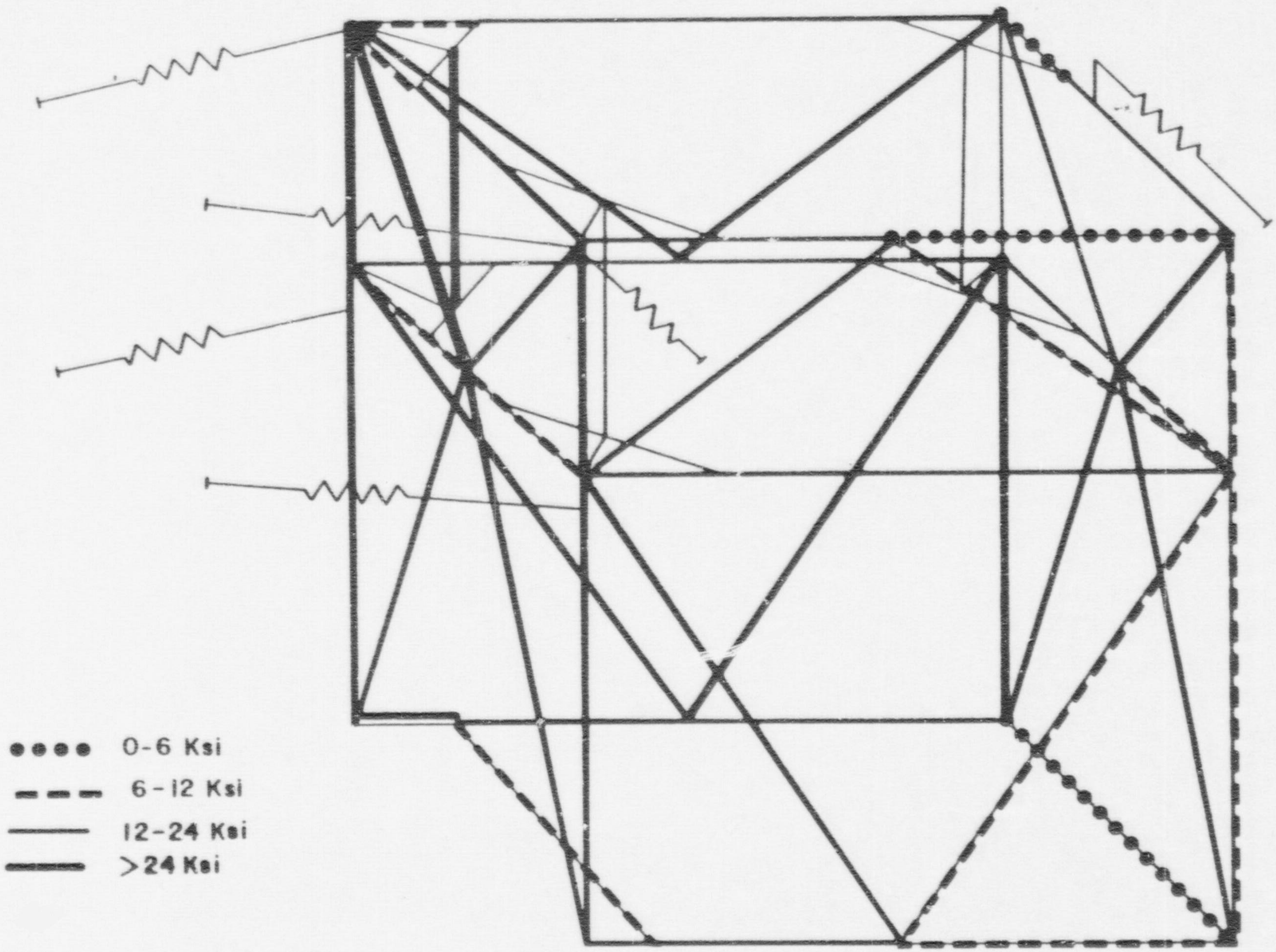
# REDUNDANCY MODEL
## DEAD WEIGHT



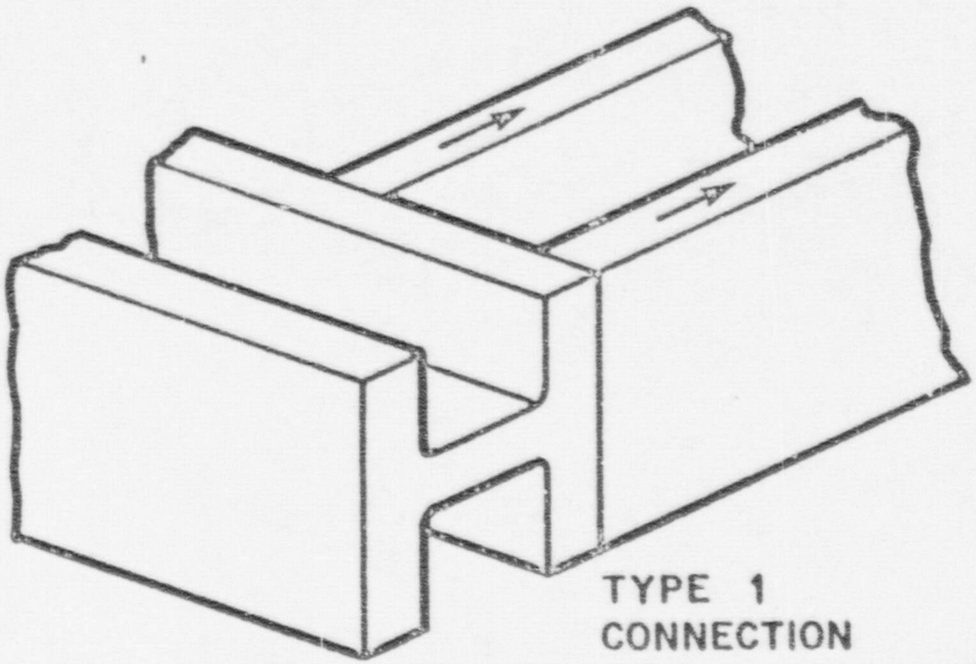
## REDUNDANCY MODEL
### DEAD WEIGHT + DBE



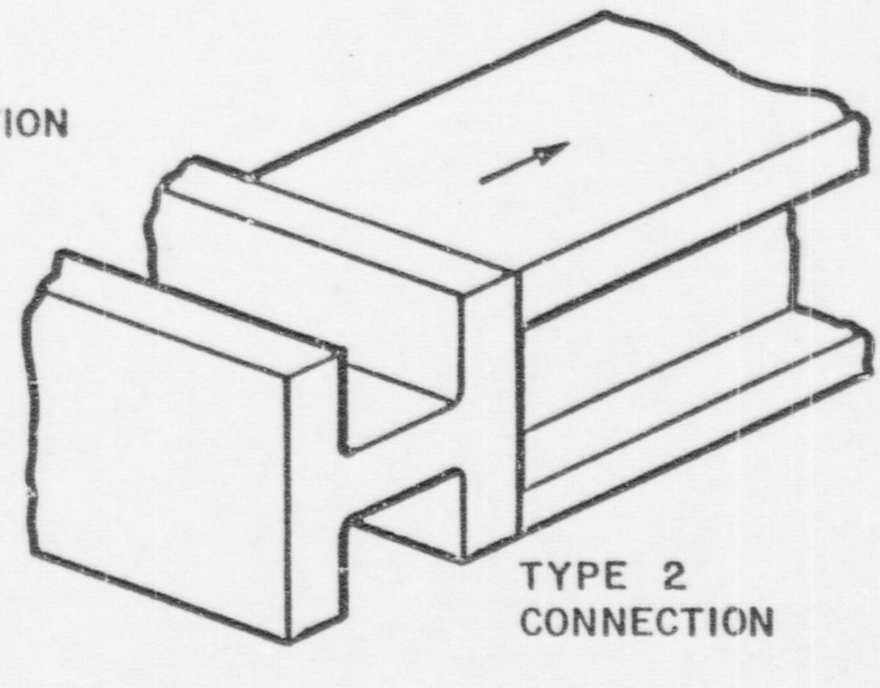
# REDUNDANCY MODEL
## DEAD WEIGHT + D.B.E. + LOCA



# TYPICAL BEAM-TO-BEAM JOINTS CONSIDERING STRESSES IN SHORT TRANSVERSE DIRECTION



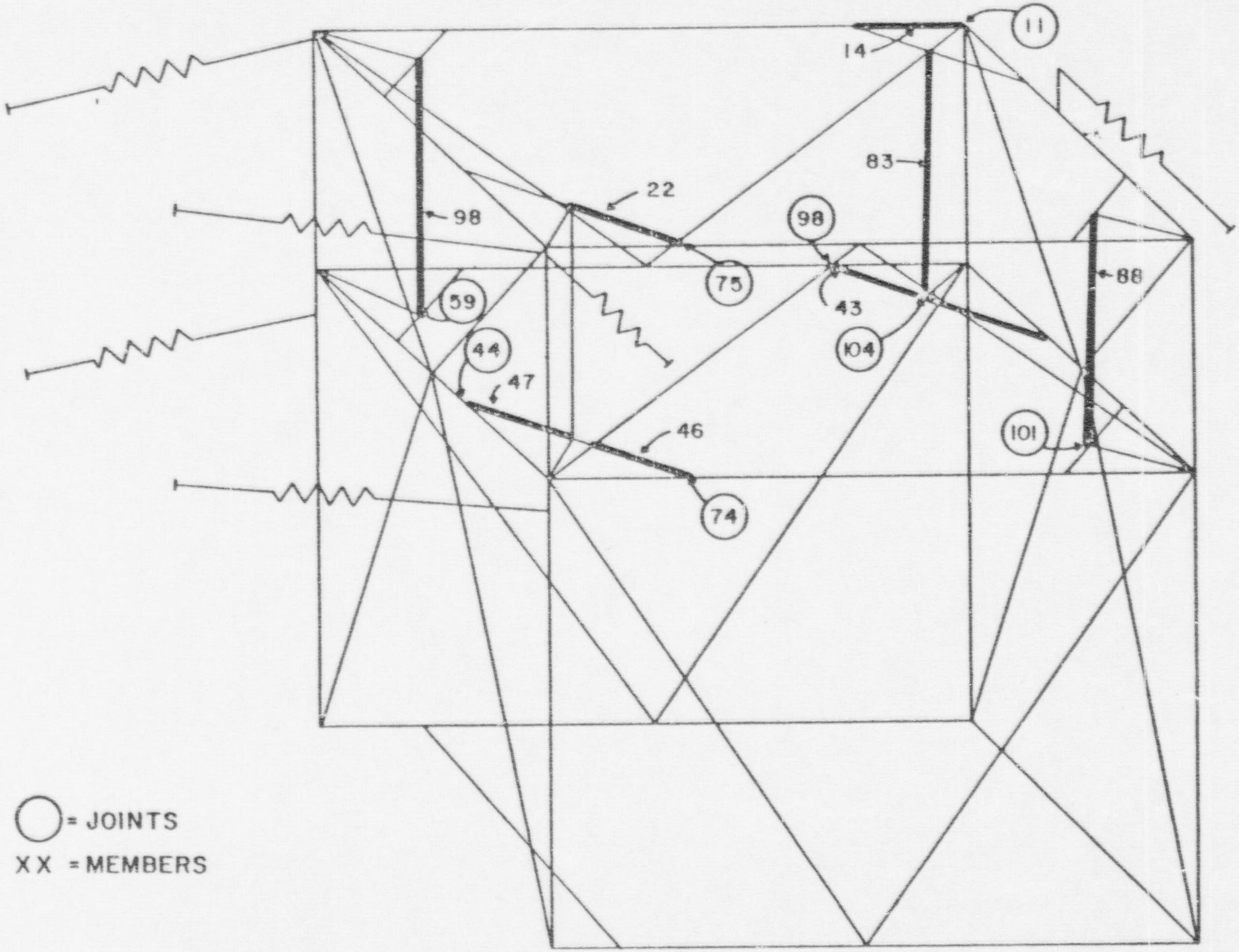
TYPE 1
CONNECTION



TYPE 2
CONNECTION

76-6296

# SELECTED MEMBERS & JOINTS LOADED IN THROUGH TRANSVERSE DIRECTION




◯ = JOINTS

XX = MEMBERS

## THROUGH TRANSVERSE STRESSES AT MEMBER CONNECTION WELDS

| MEMBER NO. | JOINT NO. | PIPE BREAK CASE | DEAD WEIGHT PLUS PIPE BREAK STRESSES | SEISMIC STRESS | TYPE OF CONNECTION | TOTAL STRESS |
|---|---|---|---|---|---|---|
| 14 | 111 | 7 | 6.48 | 5.82 | 1 | 12.30 |
| 22 | 75 | 12 | 1.46 | 1.66 | 1 | 3.12 |
| 43 | 98 | 7 | 3.11 | 2.35 | 2 | 5.46 |
| 46 | 74 | 4 | 8.94 | 2.43 | 2 | 11.37 |
| 47 | 44 | 7 | 5.30 | 2.05 | 2 | 7.35 |
| 83 | 104 | 4 | 3.90 | 4.38 | 2 | 8.28 |
| 88 | 101 | 4 | 3.23 | 4.30 | 2 | 7.53 |
| 98 | 59 | 4 | 4.51 | 4.35 | 2 | 8.86 |

UNITS = KIPS. KSI

(A-36 ALLOWABLE = 20.3 KSI)

# HIGH CYCLE FATIGUE EVALUATION

| MEMBER NO. | LOCATION | DESCRIPTION OF LOADING CASE** | | MAX STRESS (KSI) |
|---|---|---|---|---|
| 68 | STEAM GENERATOR SUPPORT FRAME | THERMAL EXPANSION OF HOT LEG * | ±0.01 IN. DISPLACEMENT AT NODE 100 IN X DIRECTION | ±1.28 |
| 133 | RCP SUPPORT FRAME | RCP MOVEMENT UNDER OPERATING CONDITIONS | 0.003 IN. DISPLACEMENT AT NODE 91 IN X DIRECTION | ±0.25 |
| 169 | | | 0.003 IN. DISPLACEMENT AT NODE 91 IN Y DIRECTION | ±0.37 |

* DUE TO ±3°F THERMAL TRANSIENT

** X & Y ARE GLOBAL COORDINATES OF THE STEAM GENERATOR & RCP SUPPORT FRAME COMPUTER MODEL

X IS ALONG HOT LEG

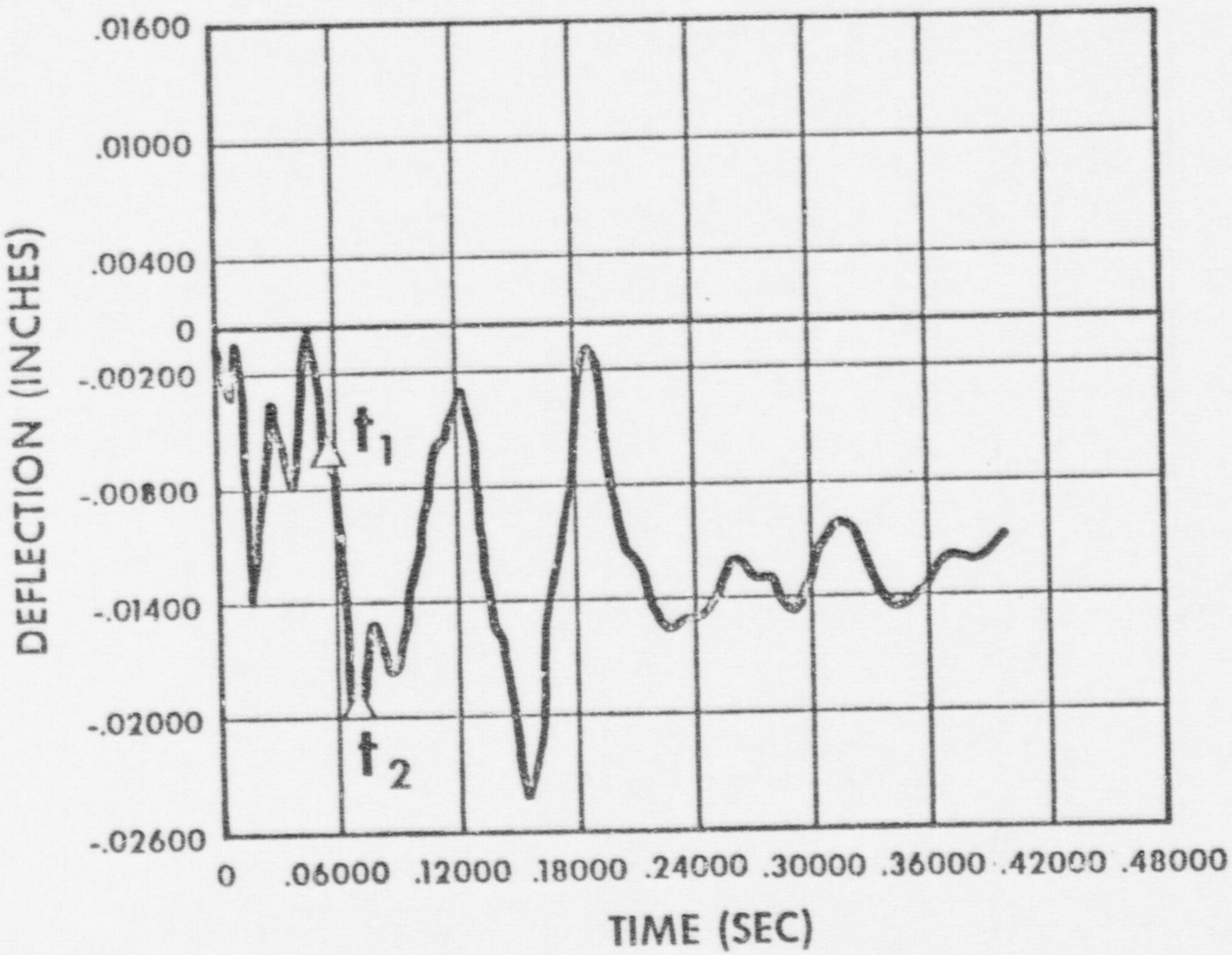
Y ⊥ X

NOTE:

HIGH CYCLE FATIGUE DESIGN (ARTICLE XVII - 3000 OF ASME III, SUBSECTION NA) FOR >2,000,000 CYCLES; ALLOWABLE STRESS IS ±3 KSI

76 - 6669

# TYPICAL STRAIN RATE TIME POINTS




VRA LP1 50 ELBOW
INTRADOS SPLIT

STEAM GENERATOR
NODE 1122
(WESTINGHOUSE)

## FROM DISPLACEMENT TIME HISTORY AT S.G. & RCP

$$\dot{\epsilon}_{MAX} = \frac{\sigma_{t_2} - \sigma_{t_1}}{t_2 - t_1} \times \frac{1}{E}$$

$\sigma_{t_2}, \sigma_{t_1}$ ARE THE STRESS AT TIME $t_2$ AND $t_1$ FOR THE MEMBER WITH THE HIGHEST STRESS IN THE SUPPORT

$t_2, t_1$ ARE THE TIME POINTS WHICH INDICATE THAT THE DISPLACEMENT TIME HISTORY CURVE HAS THE STEEPEST SLOPE BETWEEN $t_1$ AND $t_2$

FOR INSTANCE, FROM THE DISPLACEMENT CURVE, FOLLOWING, AT STEAM GENERATOR FOR BREAK #7, THE TIME POINTS $t_1$ AND $t_2$ ARE DEFINED

76 6617

# SUMMARY OF S.G./RCP SUPPORT MEMBER STRAIN RATE DUE TO LOCA

| | BREAK | MEMBER NO. | STRAIN RATE in/in/sec |
|---|---|---|---|
| STEAM GENERATOR SIDE | 3 | 24 | .02 |
| | 4 | 46 | .04 |
| | 7 | 46 | .14 |
| | 12 | 212 | .08 |
| REACTOR COOLANT PUMP SIDE | 2 | 133 | .10 |
| | 5 | 169 | .02 |
| | 12 | 169 | .24 |

## Repair, Inspection and Quality Assurance
## Steam Generator and Reactor Coolant Pump Repair Program

1. Repair of Steam Generator and Reactor Coolant Pump Supports

The removal and replacement of all welds in these support structures was accomplished using proven procedures and techniques. We say proven, because these were not unique or experimental procedures but those which are widely used in the industry and have been demonstrated by repeated use to produce the desired benefits.

Exhibit 1 summarized these along with the resulting benefits that were achieved by their use:

2. Inspection of Steam Generator and Reactor Coolant Pump Supports

At the outset, in developing the repair procedure, it was decided to rely upon examination by the magnetic particle method (MT) as the primary means of assuring weld quality. Again, this non-destructive testing method is an accepted method and is widely used in the industry; its capabilities are well known.

The introduction of ultrasonic test techniques was to provide assurance that base metal defects such as lamellar tearing were not present and to confirm that the procedures used were effective in preventing such defects.

Exhibit #2 illustrates the extent of such inspections.

Inspection Results

The completed welds in the Unit 1 supports received 3 separate examinations by the magnetic particle method in addition to the "in-process" examinations carried out during welding. Considering that the manual metallic arc welding process was used, the results were considered very good with defects being found in less than 1% of the total lengths of weld inspected. The nature of the defects was also considered routine; that is, slag stringers, undercuts, and some linear indications. There were no gross cracks or other defects to cause concern.

The completed welds in the Unit 2 supports received two separate examinations by the magnetic particle method in addition to the "in-process" examination. These examinations were conducted before and after final post weld heat treatment.

The number of defects found after post weld heat treatment on Unit #2 was greater than that experienced at final MT on Unit 1, with about 13% of the welds requiring some repairs but only about 4% with a repair depth greater than ¼". In some cases the pursuit of these indications caused the removal of welds.

However, it is not unusual on large welded structures such as these to find defects such as slag stringers, slag pockets and other small defects which had been aggravated into cracks or tears during the post weld heat treatment or stress relieving process. The important point is that all of these were found and repaired satisfactorily.

A special re-examination of one structure was made to verify our contention that the MT examination results reported by Sun Ship were not valid and represented non-relevant indications.

The inspections and examinations by the magnetic particle method performed during the repair give adequate assurance that the welds in these structures are sound and will perform their intended function.

The ultrasonic examination of certain welds to verify absence of lamellar tearing adds to this assurance. Although no evidence of lamellar tearing was found, some of the UT reflectors turned out to be weld defects. This was not unexpected because of the sensitivity of the UT procedure. All reportable reflectors were reviewed and evaluated. In some cases additional UT was required to more accurately assess the significance of the reflectors. On three welds the reflectors appeared to have planar characteristics. These were removed, weld repaired and re-examined and determined to be acceptable.

Therefore, the inspections and non-destructive tests performed during the repair cycle provide assurance that the required weld quality is present and the welds comply with the technical requirements.

3. Quality Assurance

The following positive quality control actions were implemented during the repair program:

1. A detailed plan which specified all the technical requirements needed to make the repairs was developed. This specification incorporated the best technology available.

The repair techniques specified were formulated by drawing upon the expertise available within the organization of our Architect-Engineers, in addition to the results of consultation with other fabricators of large structures.

2. The use of a controlled fabrication process whereby a weld "traveller" system was implemented. In this manner, work methods were prescribed in writing, outlining each step in the repair procedure for each weld. Such items as weld techniques, weld bead sequencing, hold points for in-process NDT, pre-heat and post-heat requirements were included. Operations were not left to the discretion of the workman, but were pre-planned by welding engineers and all such actions verified during in-process inspections.

3. Extensive in-process inspections to verify conformance to requirements as the work progressed. It has been estimated that over 150,000 separate inspections were performed during the repair effort.

4. The implementation of a three level quality assurance surveillance plan during the repair effort to verify adequate work performance at all levels.

   The first level was the quality control surveillance imposed by the organization responsible for performing the repair work. They were responsible for the day to day inspections, documentation and work verification. Also, these organizations had full quality assurance organizations with programs complying with Appendix B, 10CFR50.

The second level was a planned audit program carried out by the Virginia Electric and Power Company Quality Assurance Department Engineers. These audits were conducted on a regular basis throughout the repair activity. Seventy-three such audits were conducted and the results confirmed that acceptable quality programs were being implemented.

The third level was the independent overview provided by our consultants, Southwest Research Institute. They participated in the program starting with the review and comment on the repair specification and continuing on with audits of work performance and witnessing of non-destructive tests.

The steam generator and reactor coolant pump support welds were replaced using carefully thought out procedures and a closely controlled quality program. The quality assurance program implemented during the repair of these structures complies fully with the requirements of Appendix B, 10CFR50. All the evidence supports our view that the welds are sound and are in compliance with the technical requirements.

JLP 7-1-76

EXHIBIT 1

| PROCEDURE | BENEFIT |
|---|---|
| AWS and ASME qualified welding procedures | Wide industry usage has demonstrated that the use of such procedures will produce sound welds |
| Stringent preheat and post heat control | Minimizes hydrogen induced cracking, reduces localized restraint stresses, retards cooling rate in weld metal and heat affected base metal which improves metallurgical structure |
| "Buttering" weld passes applied to base material before welding cavities | Provides a buffer of ductile weld metal between base metal and cavity weld |
| Welding technique sheets specified weld bead sequence | Reduces weld shrinkage stresses |
| Weld joint sequence specified | Provides optimum access, reduces overall welding stresses and assists in dimensional control |
| Mechanical peening of all weld layers except buttering, root and cover passes (Unit #1 only) | Distributes and reduces residual welding stresses |
| Post weld heat treatment of completed assemblies (Unit #2 only) | Reduces residual welding stresses, toughens weld heat-affected zones |
| Use of low hydrogen type coated welding electrodes (E-7018) | Minimizes hydrogen induced cracking, all position type electrode in common usage with well documented properties |
| Strict control of electrode issuance and maintenance of heaters to keep electrodes free from moisture | Minimizes hydrogen induced cracking |

July 1, 1976

EXHIBIT 2

## INSPECTIONS CARRIED OUT DURING REPAIRS

VISUAL INSPECTION (VT)

(A) Surfaces and edges of excavations were verified to be smooth, uniform, free from fins, tears, cracks and other defects.

(B) Each pass of weld metal was visually examined.

(C) All completed welds were examined

MAGNETIC PARTICLE (MT)

(A) Excavations examined by MT before welding.

(B) Initial weld layer to base metal and each subsequent ½" of weld thickness or ¼, ½, or 3/4 or weld thickness whichever was more restrictive.

(C) After completion of welding
after 8 hour preheat temp soak → Unit 1
72 hours after the 8 hour soak
after completion of welding → Unit 2
24 hours after PWHT

ULTRASONIC (UT)

(A) Ultrasonic examination of selected high stressed main member welds.

July 1, 1976

# REPAIRS AFTER PWHT

## REPAIR STATISTICS FOR NORTH ANNA STEAM GENERATOR SUPPORTS, UNIT #2

| | | |
|---|---|---|
| 1. | Total number of welds in cubicles A, B, and C | = 8244 |
| 2. | Total number of welds with some MT indications | = 1756 |
| 3. | Total accepted by buffing or grinding | = 670 |
| 4. | Total requiring some welding | = 1086 |
| | a. Repair depth less than 1/4" | 738 |
| | b. Repair depth equal to or greater than 1/4" | 348 |
| | Sum | = 1086 |
| | (1) Linear more than 1/4" | 243 |
| | (2) Non-linear more than 1/4" | 105 |
| | Sum | = 348 |

# EVALUATION OF MATERIALS IN THE STRUCTURES

I. DATA FROM MATERIAL IN THE STRUCTURES

A. CHARPY V-NOTCH TEST DATA, A36 MATERIAL

B. DROP WEIGHT DATA, A36 MATERIAL

C. CHARPY V-NOTCH TEST DATA, A572 MATERIAL

D. DROP WEIGHT DATA, A572 MATERIAL

E. CHEMISTRY DATA FOR SAMPLES MECHANICALLY TESTED (CHARPY AND DROP WEIGHT TESTED)

F. CHEMISTRY DATA FOR MATERIAL IN THE STRUCTURES NOT MECHANICALLY TESTED

G. TEST DATA OBTAINED BY SUN SHIP, KNOWN TO VEPCO

II. RELATED SUBJECTS

A. BRIEF OVERVIEW OF MATERIALS IN THE STRUCTURE AND PROCUREMENT REQUIREMENTS

B. RELEVANCE OF TEST SAMPLES, A36 MATERIAL

C. RELEVANCE OF TEST SAMPLES, A572 MATERIAL

D. NDTT DATA FROM SPECIAL ASME TASK GROUP ON FRACTURE TOUGHNESS, A36 MATERIAL

E. RELEVANCE OF VEPCO DATA BASE, A36 MATERIAL

F. CONCLUSIONS, A572 MATERIAL

# MATERIAL IN THE SUPPORTS

1. Plate: ASTM A36-69, predominantly 1" through 4" thickness

2. Beams: ASTM A36-69, structural steel
   ASTM A572-68, (Gr 42) Low alloy Cb-V structural steel
   ASTM A572-70 A (Gr 50) repair work only

Sizes:

W 14 x 605 (A36 and A572)
W 14 x 426 (A36 and A572)
W 14 x 176 (A36)
W 14 x 142 (A36)

# CHEMICAL AND MECHANICAL TESTS

1) All material - Chemical analysis

   Tensile test

2) Beams

   Chemical analysis

   Tensile Test

   Bend Test

   Hardness test (All beams except the two heats of A572 Gr 50 used for repair)

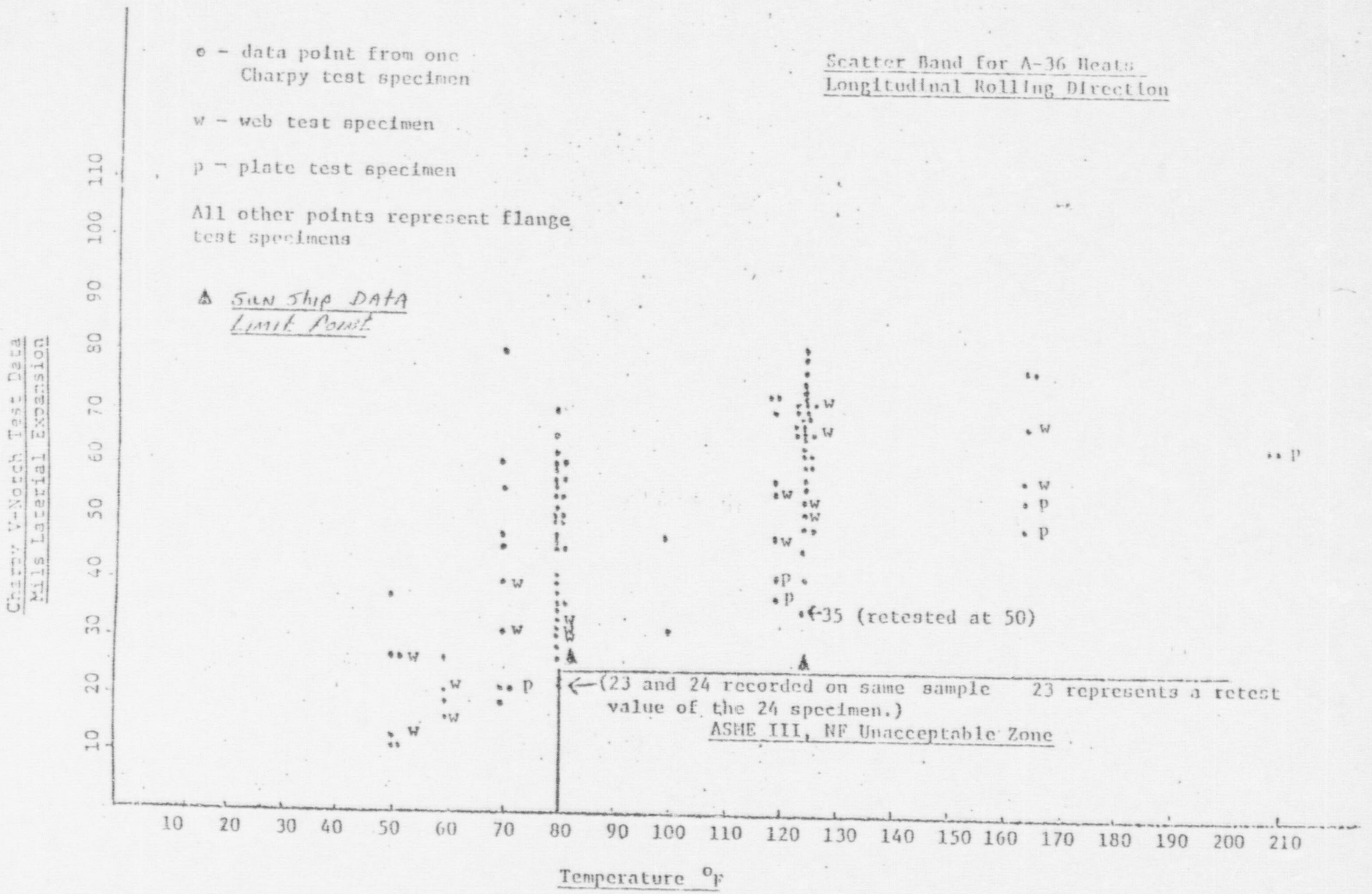
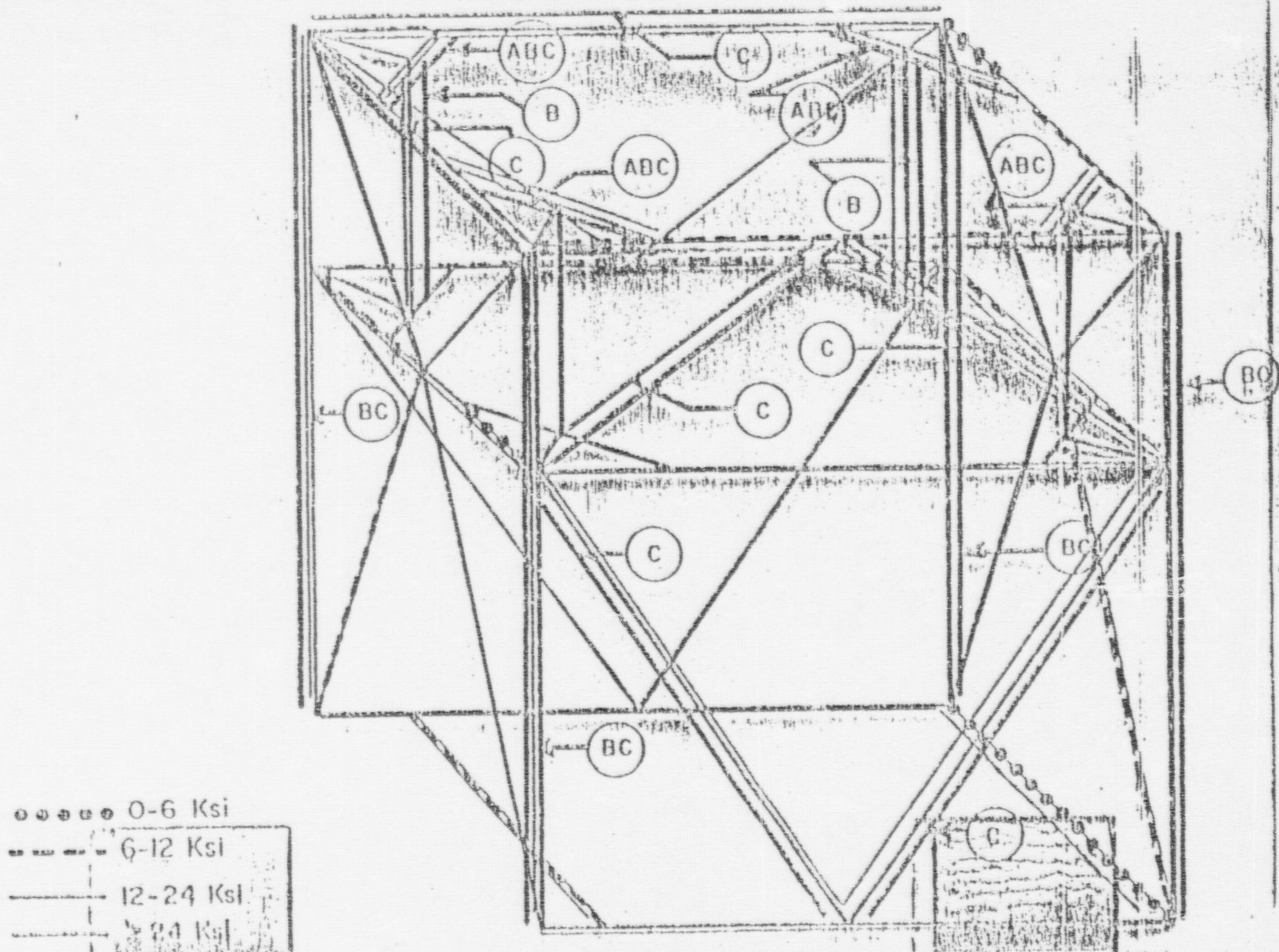
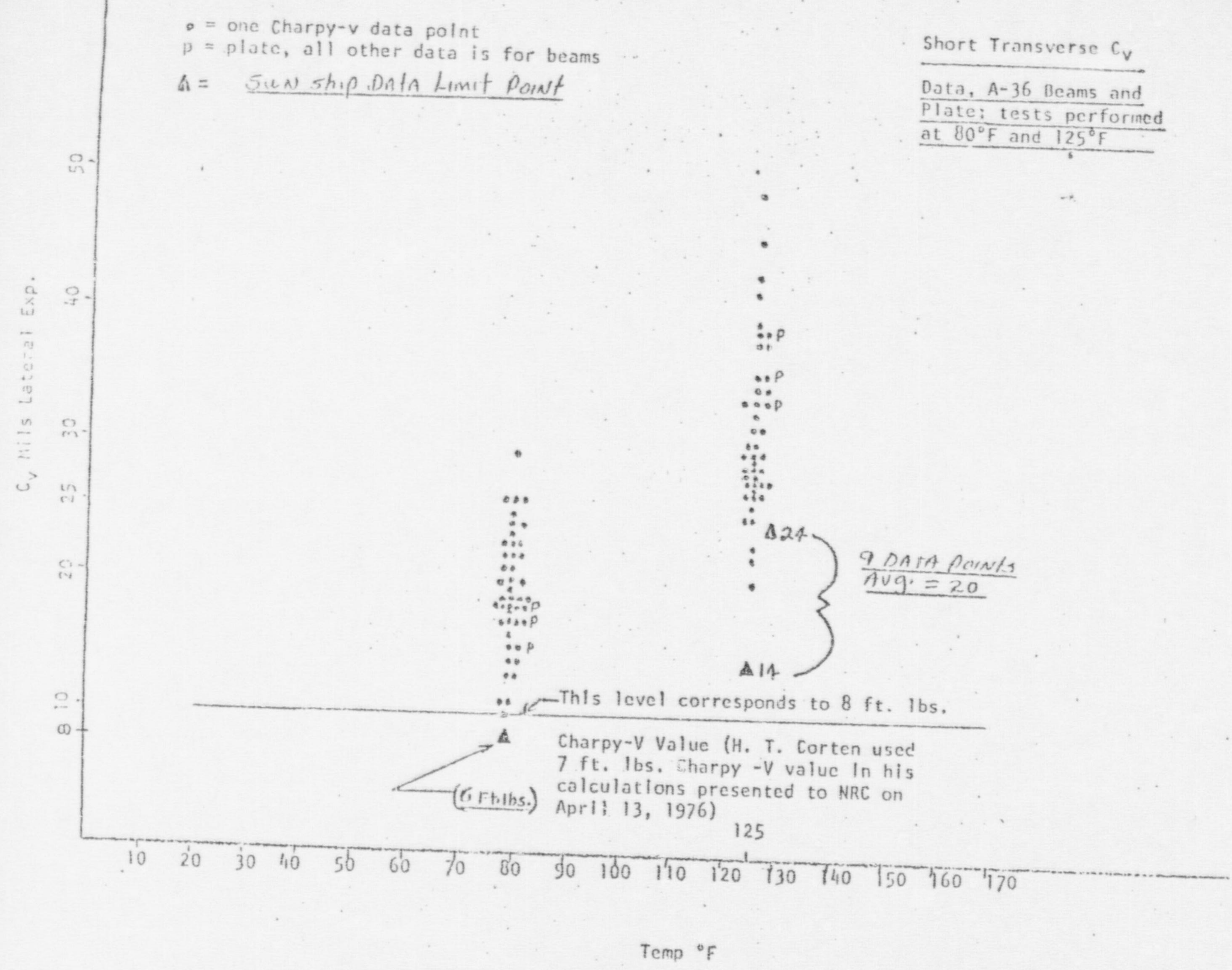



Figure 1 Results from fourteen Charpy samples from ten beams representing two* or three heats of ASTM A-36 426 lb. beams and one heat of 3" A-36 plate in the North Anna Unit 1 and Unit 2 steam generator supports.

*More probably three heats, as shown in the Vepco letter of 5/17/76 to the NRC forwarding Amend. 51 to the FSAR.

# INTEGRAL FRAME
## DEAD WEIGHT + O.B.E + LOCA



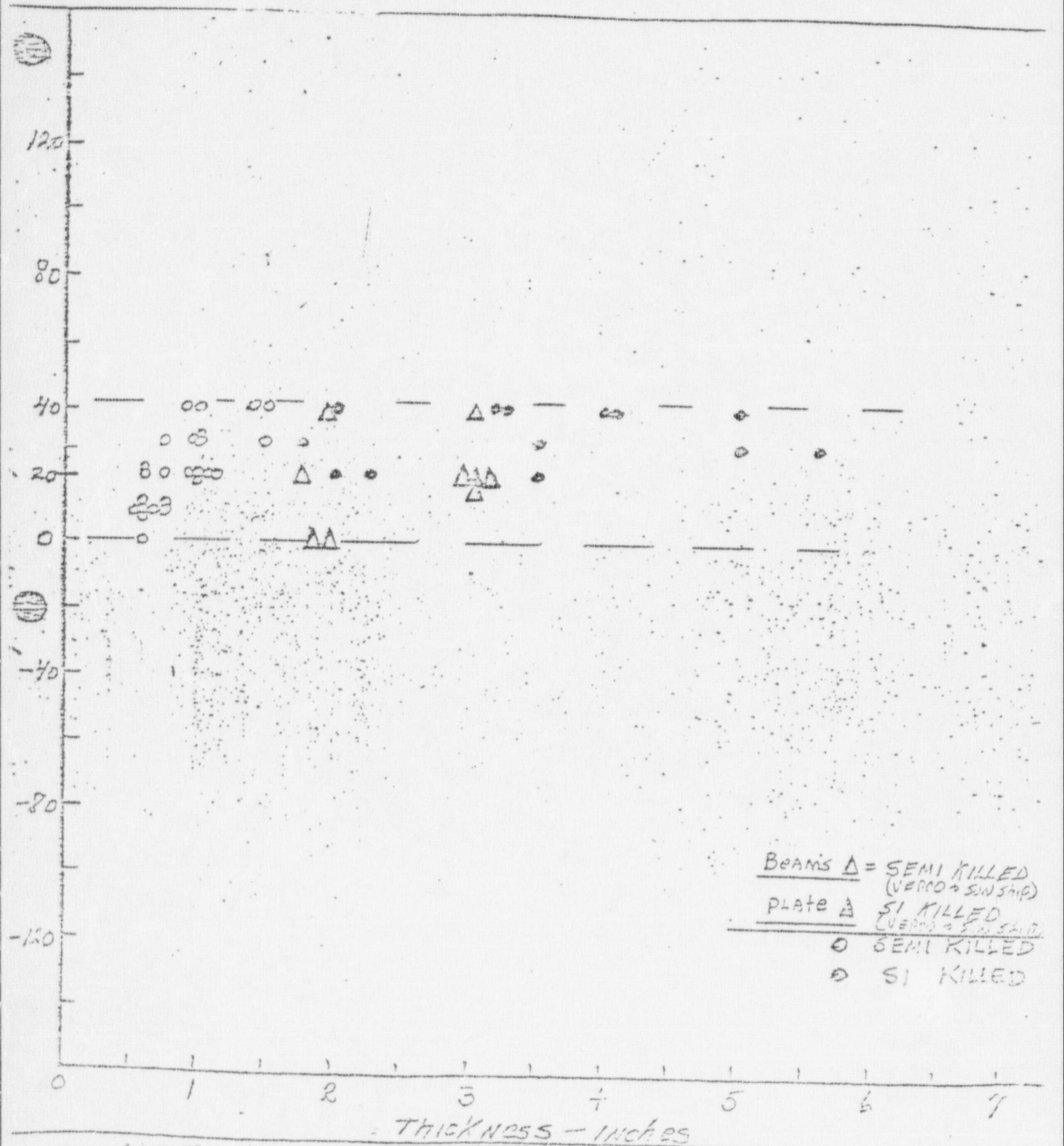


• = one Charpy-v data point
p = plate, all other data is for beams
Δ = Sun ship Data Limit Point
Short Transverse $C_V$
Data, A-36 Beams and Plate; tests performed at 80°F and 125°F
$C_V$ Mils Lateral Exp.
50
40
30
25
20
10
8
Δ24
Δ14
9 DATA Points Avg. = 20
This level corresponds to 8 ft. lbs.
Charpy-V Value (H. T. Corten used 7 ft. lbs. Charpy -V value in his calculations presented to NRC on April 13, 1976)
(6 Ft.lbs.)
125
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Temp °F

TABLE - 1

| SAMPLE | HEAT | ITEM DESCRIPTION | CHARPY V 15 FT. LB. TRANSITION TEMP. | DROP WEIGHT NDTT | %C | %Mn | CHEMISTRY* %P | %S | %Si | %V |
|---|---|---|---|---|---|---|---|---|---|---|
| "F2A" | 182C535 | Flange 3" Thickness From W14 x 426 lb. beam - A36 material | ≈65°F | 40°F | .26 | 1.02 | .024 | .029 | .04 | .04 |
| "CD" | A8225 | Plate 3" Thickness A36 material | ≈ 70 F | 20 F | .18 | .88 | .024 | .022 | .16 | less than .01 |
| "W96" | 182C174, or 171C866 | 2" Thick web from W14 x 426 lb. beam - A36 material | ≈ 50 F | 40 F | .26 | 1.12 | .016 | .022 | .06 | .05 |

* As determined by Vepco




NDT VALUES FOR PLATE OF SA 36 STEEL
(HOT ROLLED CONDITION)

Figure 4 Data furnished by Industry to the Special ASME Task Group on Fracture toughness.

# CHEMICAL ANALYSIS - A36 BEAMS

Element

| ITEM | C | | | Mn | | | P | | | Si | | | V | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. |
| 605 lb. beam A36 | .22 | .22 | .22 | 1.07 | 1.07 | 1.07 | .012 | .012 | .012 | .27 | .27 | .27 | -- | -- | -- |
| 426 lb. beam A36 | .23 | .20 | .26 | 1.15 | 1.10 | 1.20 | .013 | .011 | .016 | .05 | .03 | .06 | .03 | .02 | .05 |
| 176 lb. beam A36 | .23 | .22 | .23 | .66 | .65 | .67 | .011 | .010 | .012 | .06 | .05 | .07 | -- | -- | -- |
| 142 lb. beam A36 | .21 | .18 | .24 | .94 | .81 | 1.06 | .011 | .011 | .011 | .11 | .08 | .14 | -- | -- | -- |

## CHEMICAL ANALYSIS - PLATE

### Element

| Item ASTM A-36 Plate | C | | | Mn | | | P | | | Si | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. |
| 1" | .18 | .17 | 18 | .95 | .88 | 1.01 | .010 | .010 | 010 | .23 | .23 | .23 |
| 1½" | .18 | .16 | 20 | .90 | .85 | .94 | .012 | .011 | 013 | --- | --- | --- |
| 2" | .18 | .17 | 19 | .95 | 90 | .99 | .010 | .010 | 011 | .24 | 23 | .25 |
| 3" | .19 | .17 | 21 | .98 | 89 | 1.09 | .009 | .005 | 010 | .20 | 15 | .23 |
| 4" | .19 | .19 | 19 | 1.09 | 1.09 | 1.09 | .005 | .005 | 005 | .23 | 23 | .23 |
| 4½" | .20 | .20 | 20 | 1.01 | 1.01 | 1.01 | .009 | .009 | 009 | .23 | 23 | .23 |
| 6" | .19 | .18 | 20 | .98 | .94 | 1.01 | .011 | .009 | 013 | .22 | .21 | .23 |
| 8 3/8" | .19 | .19 | 19 | 1.09 | 1.09 | 1.09 | .003 | .003 | 003 | .23 | .23 | .23 |
| 14" | .21 | .21 | .21 | .95 | .95 | .95 | .008 | .008 | 008 | .23 | .23 | .23 |

# VEPCO DATA BASE - A36 MATERIAL

Significant Because:

(1) The critical heavy beams and plate in the structure have Mn to C ratios which exceed 4 to 1 which is beneficial to toughness.

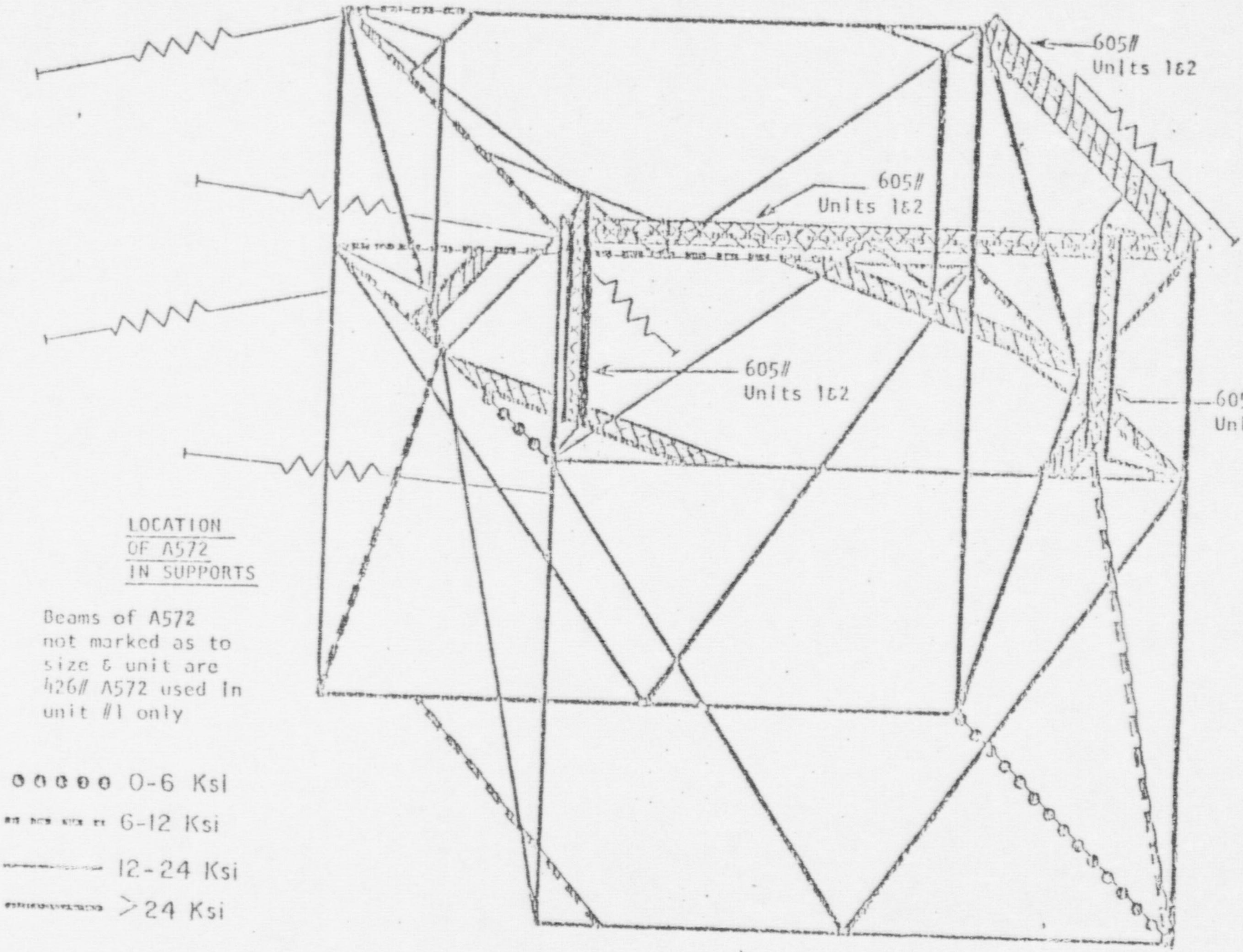
(2) They were produced on the same mill in a period of less than 3 months which gives greater assurance of uniformity of the material.

(3) The drop weight tests displayed low NDT temperatures which is desirable.

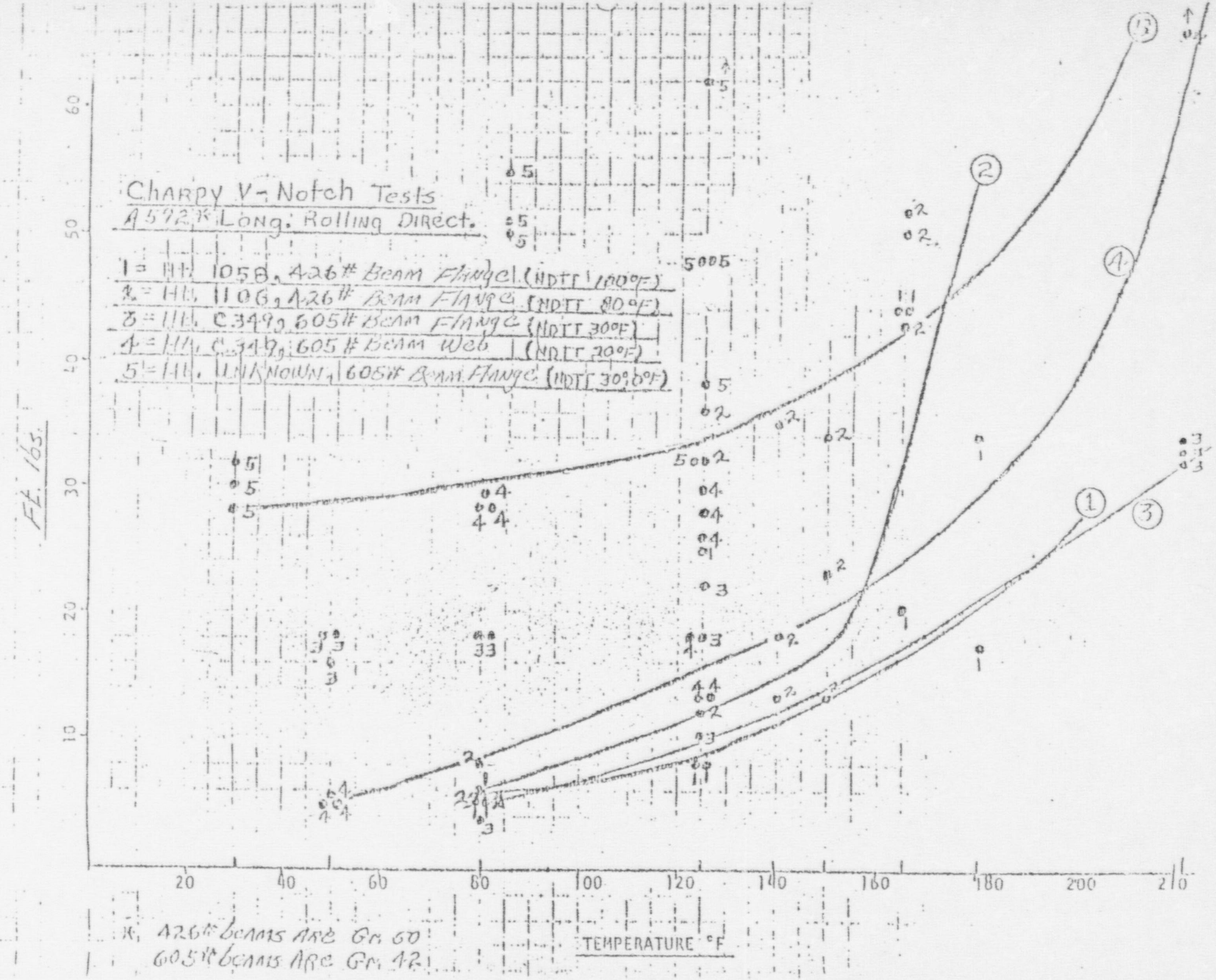
(4) The Charpy tests show high toughness values in the operating temperature range.

(5) The Vepco samples represented the range of shapes used in the structure and included the highest carbon levels encountered.

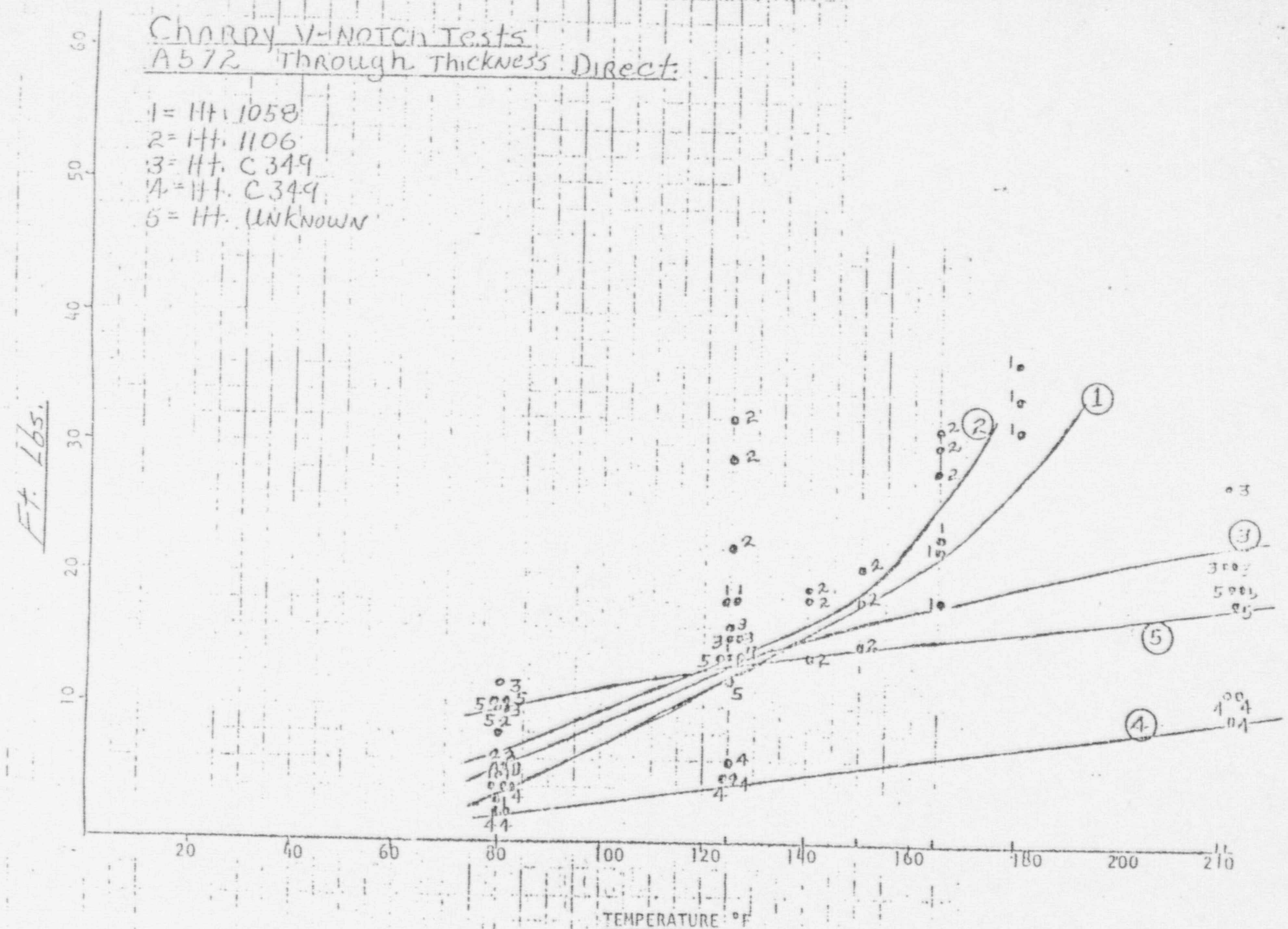
# INTEGRAL FRAME
## DEAD WEIGHT + D.B.E. + LOCA




76-6208



Charpy V-Notch Tests
A572* Long. Rolling Direct.
1 = Ht. 1058, 426# Beam Flange (NDTT 100°F)
2 = Ht. 1106, 426# Beam Flange (NDTT 80°F)
3 = Ht. C349, 605# Beam Flange (NDTT 30°F)
4 = Ht. C349, 605# Beam Web (NDTT 20°F)
5 = Ht. Unknown, 605# Beam Flange (NDTT 30°, 0°F)
Ft. lbs.
TEMPERATURE °F
20
40
60
80
100
120
140
160
180
200
210
10
20
30
40
50
60
* 426# beams are Gr. 60
605# beams are Gr. 42



Charpy V-Notch Tests
A572 Through Thickness Direct.
1 = Ht. 1058
2 = Ht. 1106
3 = Ht. C349
4 = Ht. C349
5 = Ht. Unknown
Ft. Lbs.
10
20
30
40
50
60
20
40
60
80
100
120
140
160
180
200
210
TEMPERATURE °F

## CHEMICAL ANALYSIS - BEAMS A572

Element

| ITEM | C | | | Mn | | | P | | | Si | | | V | | | N | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. |
| 605 lb. Beam A 572 - Gr. 42 | .20 | .18 | .21 | 1.15 | 1.04 | 1.20 | .015 | .008 | .019 | 22 | .20 | .23 | .07 | .06 | .07 | .010 | .007 | 015 |
| 426 lb. Beam A572 - Gr. 50 | .20 | .18 | .21 | 1.18 | 1.16 | 1.20 | .007 | .005 | .009 | 03 | .03 | .03 | .091 | .085 | .097 | .011 | .008 | 013 |

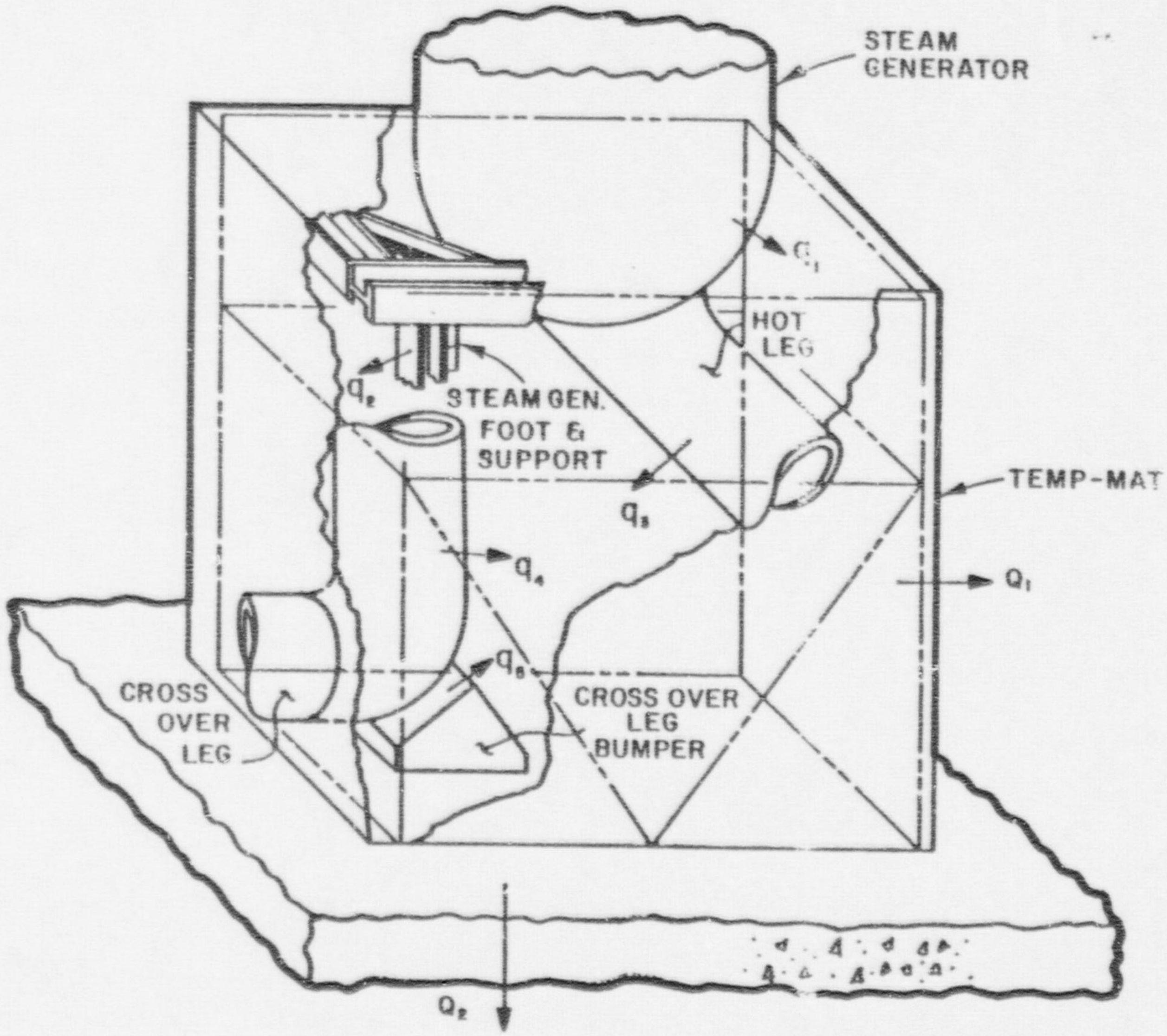
## CONCLUSIONS A572 MATERIAL

1. THE MAXIMUM NDTT AS DETERMINED BY DROP WEIGHT TESTS IS 100 F.

2. NOTCH TOUGHNESS VALUES ARE LOWER THAN FOR A36, BUT NOTCH TOUGHNESS INCREASES TO VALUES OVER 20 FT. LBS. AT APPROXIMATELY 200 F. FOR THE MATERIALS SHOWING THE LOWEST NOTCH TOUGHNESS.

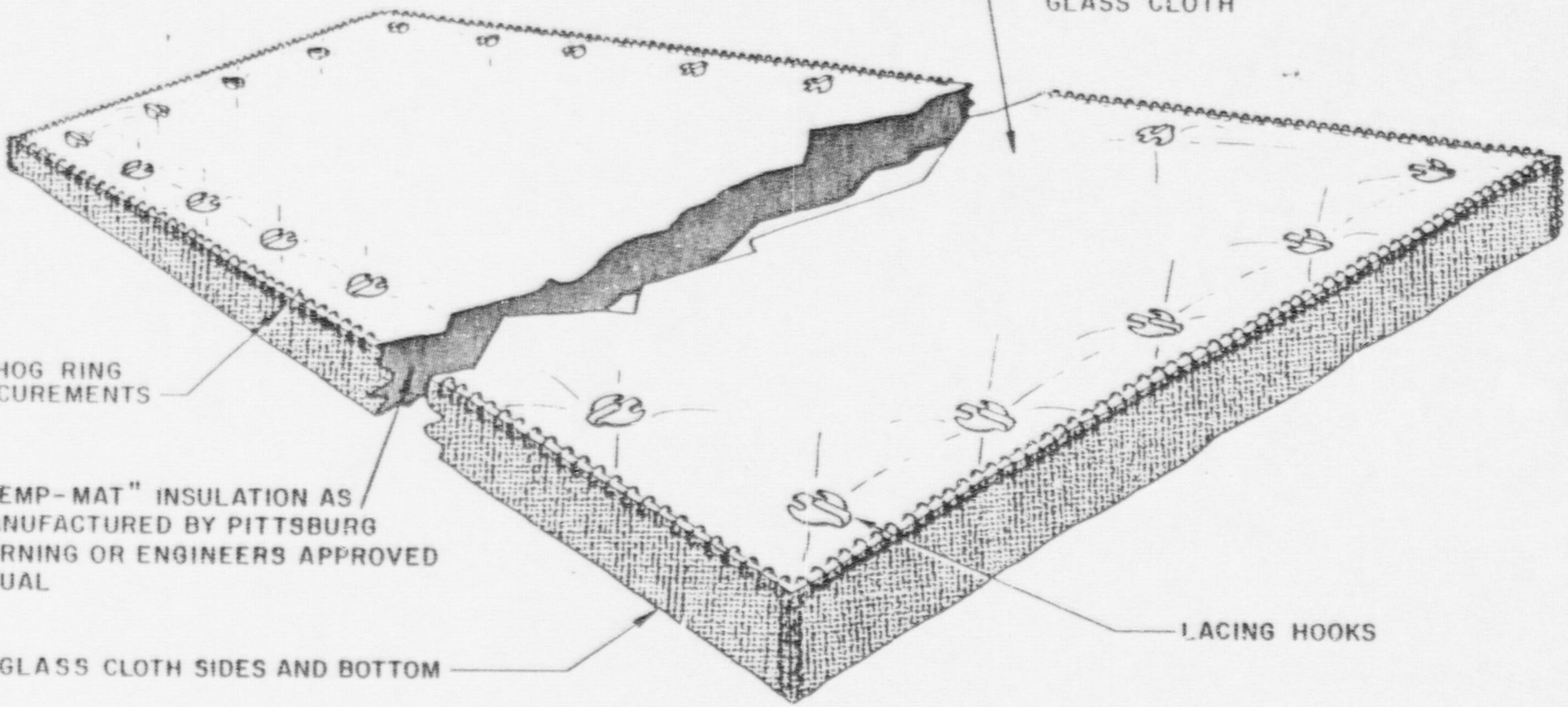
3. DUE TO THIS NEW DATA THE OPERATING TEMPERATURE OF THE A572 MEMBERS IN THE STRUCTURES MUST BE INCREASED.

# HEAT BALANCE MODEL FOR TEMP-MAT TENT




76-6687

# CONSTRUCTION OF REMOVABLE PREFORMED BLANKETS




"TEMP-MAT" HAS A K FACTOR OF $0.28 \frac{\text{BTU in.}}{\text{FT}^2\ \text{HR}\ ^\circ\text{F}}$ AT 200 °F MEAN TEMPERATURE

76-6673

# THERMAL ANALYSIS OF TEMP-MAT TENT
## ASSUMPTIONS

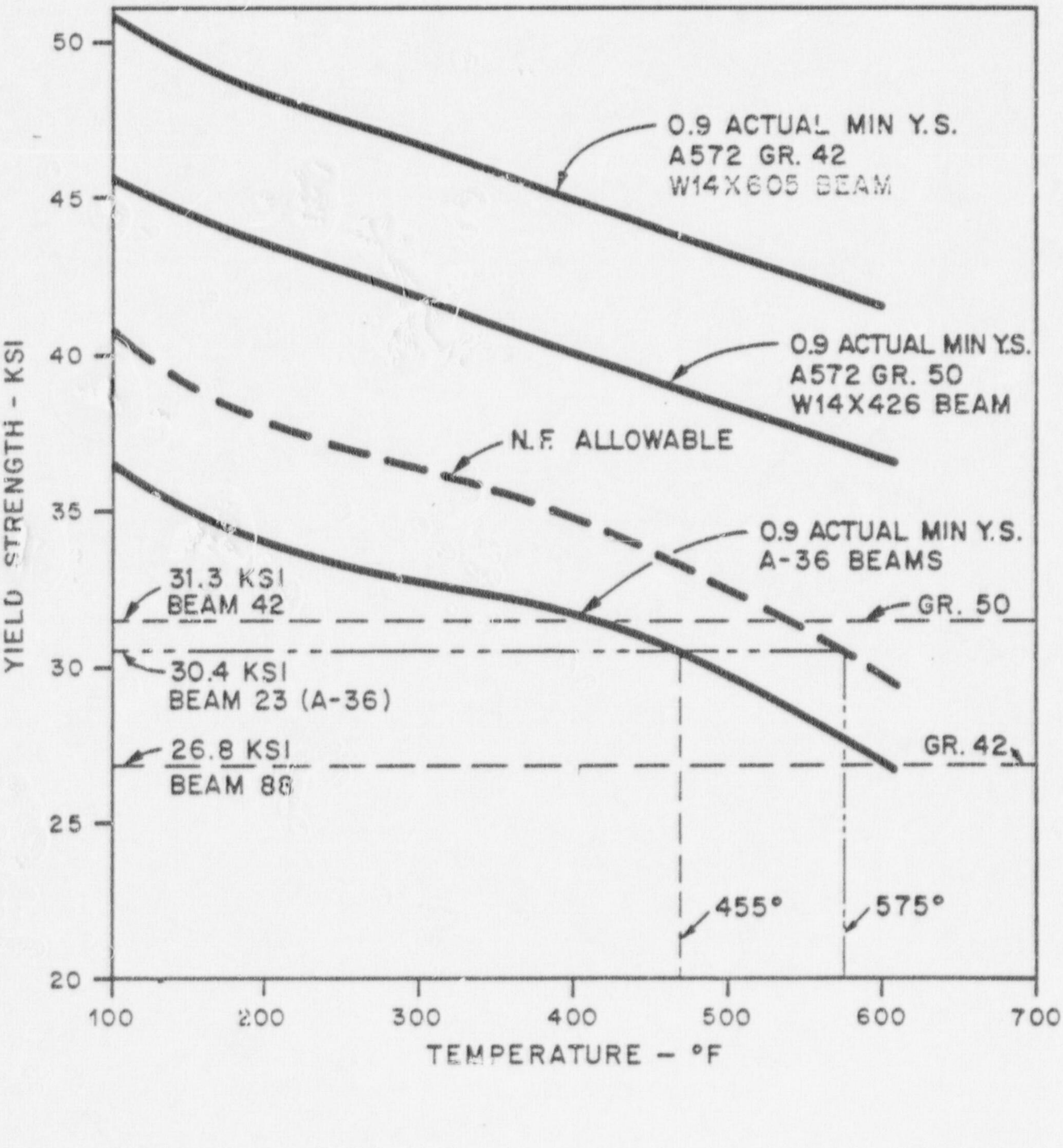
1. NATURAL CONVECTION INSIDE AND OUTSIDE THE TENT IS CONSIDERED:
2. RADIATIVE HEAT TRANSFER FROM TWO HOT, BUT UNINSULATED SURFACES IS CONSIDERED:
    - a) CROSSOVER LEG AT BUMPER
    - b) SUPPORT AT STEAM GENERATOR FEET
3. FIVE HEAT SOURCES ARE RECOGNIZED:
    - a) LOWER STEAM GENERATOR SHELL
    - b) SUPPORT AT STEAM GENERATOR FEET
    - c) HOT LEG
    - d) CROSSOVER LEG
    - e) CROSSOVER LEG AT BUMPER
4. TWO HEAT SINKS ARE RECOGNIZED:
    - a) TO AMBIENT THROUGH THE TEMP-MAT TENT
    - b) TO AMBIENT THROUGH THE FLOOR

76-6686

# HEAT FLOW AND TEMPERATURE OF TEMP-MAT TENT

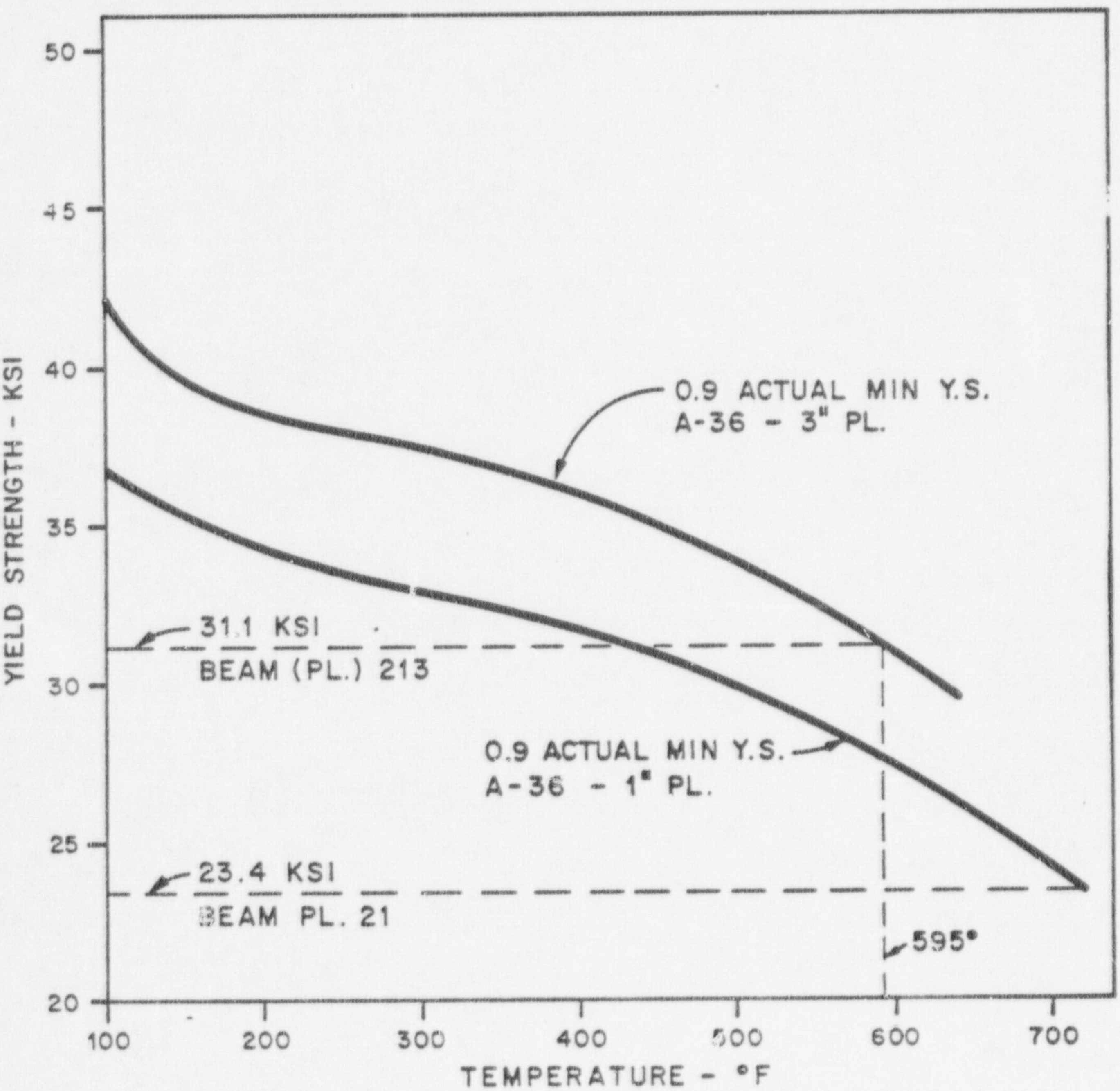
| | | CASE I | CASE II | |
|---|---|---|---|---|
| | | $T_{ambient} = 70°F$ | $T_{ambient} = 105°F$ | |
| HEAT INPUT | $q_1 =$ | 8750 BTU/HR | 8300 BTU/HR | FROM STEAM GENERATOR |
| | $q_2 =$ | 21800 | 17520 | FROM STEAM GENERATOR FEET & SUPPORT |
| | $q_3 =$ | 1960 | 1860 | FROM HOT LEG |
| | $q_4 =$ | 5620 | 5340 | FROM CROSSOVER LEG |
| | $q_5 =$ | 870 | 820 | FROM CROSSOVER LEG BUMPER |
| | $\Sigma =$ | 39000 BTU/HR | $\Sigma =$ 33840 BTU/HR | |
| HEAT OUTPUT | $Q_1 =$ | 29900 BTU/HR | 26000 BTU/HR | THROUGH TEMP-MAT |
| | $Q_2 =$ | 9100 | 7840 | THROUGH FLOOR |
| | $\Sigma =$ | 39000 BTU/HR | $\Sigma =$ 33840 BTU/HR | |
| | $T =$ | 180 °F | 200 °F | TEMPERATURE IN TENT |

# MAXIMUM ALLOWABLE TEMPERATURE NORTH ANNA 1&2 ST. GEN. SUPPORTS




76-6682

# MAXIMUM ALLOWABLE TEMPERATURE NORTH ANNA 1&2 ST. GEN. SUPPORTS



MISCELLANEOUS ITEMS

S.G. SUPPORTS

| ITEM | MAT'L | MIN. SPECIF. Y.S. (KSI) | MIN. ALLOW. (0.9xY.S.) (KSI) | DESIGN STRESS (KSI) | ALLOW. TEMP (°F) |
|---|---|---|---|---|---|
| S.G. FEET BOLTS 1 1/2"-12X9" | 4340 (UNBRAKO) | 155 | 139.5 | 105 | > 600° |
| UPPER PEDEST. BOLTS 2"-8X10" | A490 | 130 | 117 | 17.2 | > 600° |
| VERT. SUPP. BLOCKS | A516 GR. 70 | 38 | 34.2 | 27.5 | 520° |
| VERT. SUPP. PLATE | 4340 | 140 | 126 | 108 | 480° |
| SHEAR BLOCKS | A-36 | 46.8 (ACTUAL) | 42.1 | 28.6 | 540° |
| LUBRITE PL. | ASTM B22-863 MAG. BRZ. | 55 | 49.5 | 13.0 | > 600° |
| LUBRITE | PROPRIETARY MATERIAL | - | - | - | 800 SPECIFIED |
| SNUBBER CLEVIS | 4340 | 90 | 81 | 50.3 | > 600° |

## HOT FUNCTIONAL TEST - STEAM GENERATOR SUPPORT INSULATION

A. STEADY-STATE CONDITION

1. Confirm thermal analysis

   Thermal profile selected beams

2. Modify insulation coverage (if required)

B. TRANSIENT CONDITION

1. Record temperature time-history selected beams (heat-up and cool-down sequence)

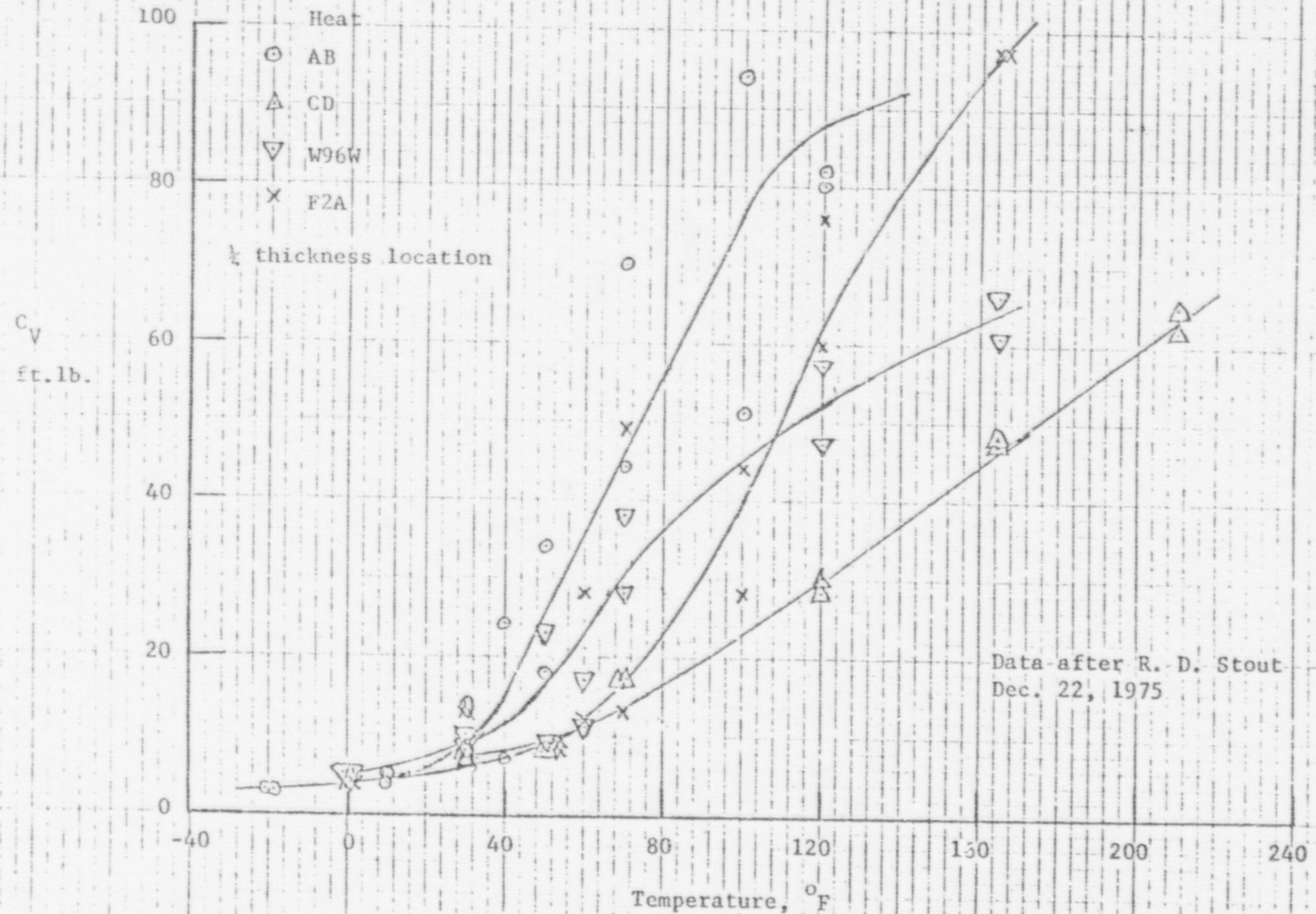
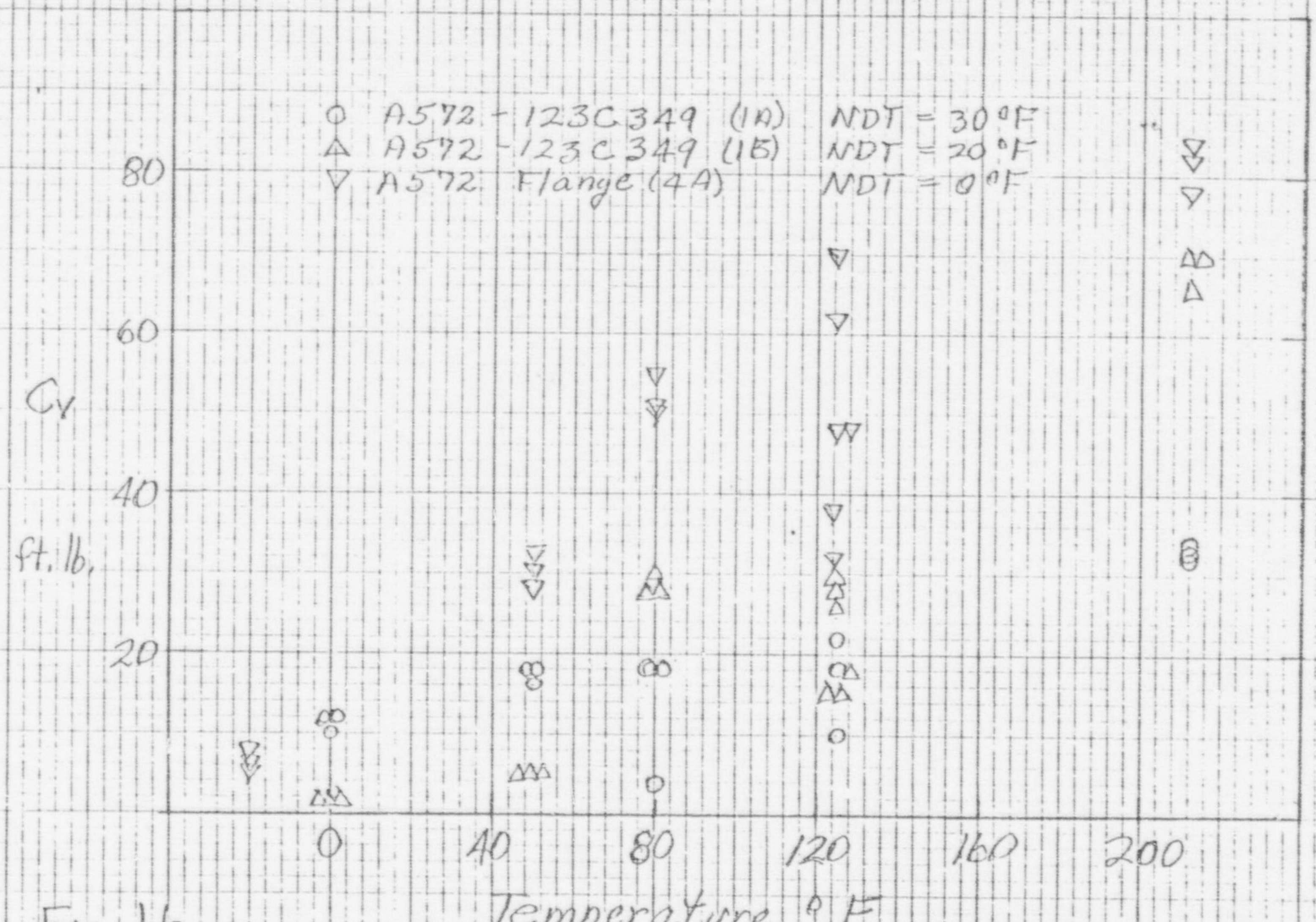



Fig. 1. A-36 Steel from Generator Support Cubicles - North Anna Station



○ A572 - 123C349 (1A) NDT = 30°F
△ A572 - 123C349 (1B) NDT = 20°F
▽ A572 Flange (4A) NDT = 0°F
80
60
40
20
Cv
ft.lb.
0
40
80
120
160
200
Temperature °F


Fig 1b

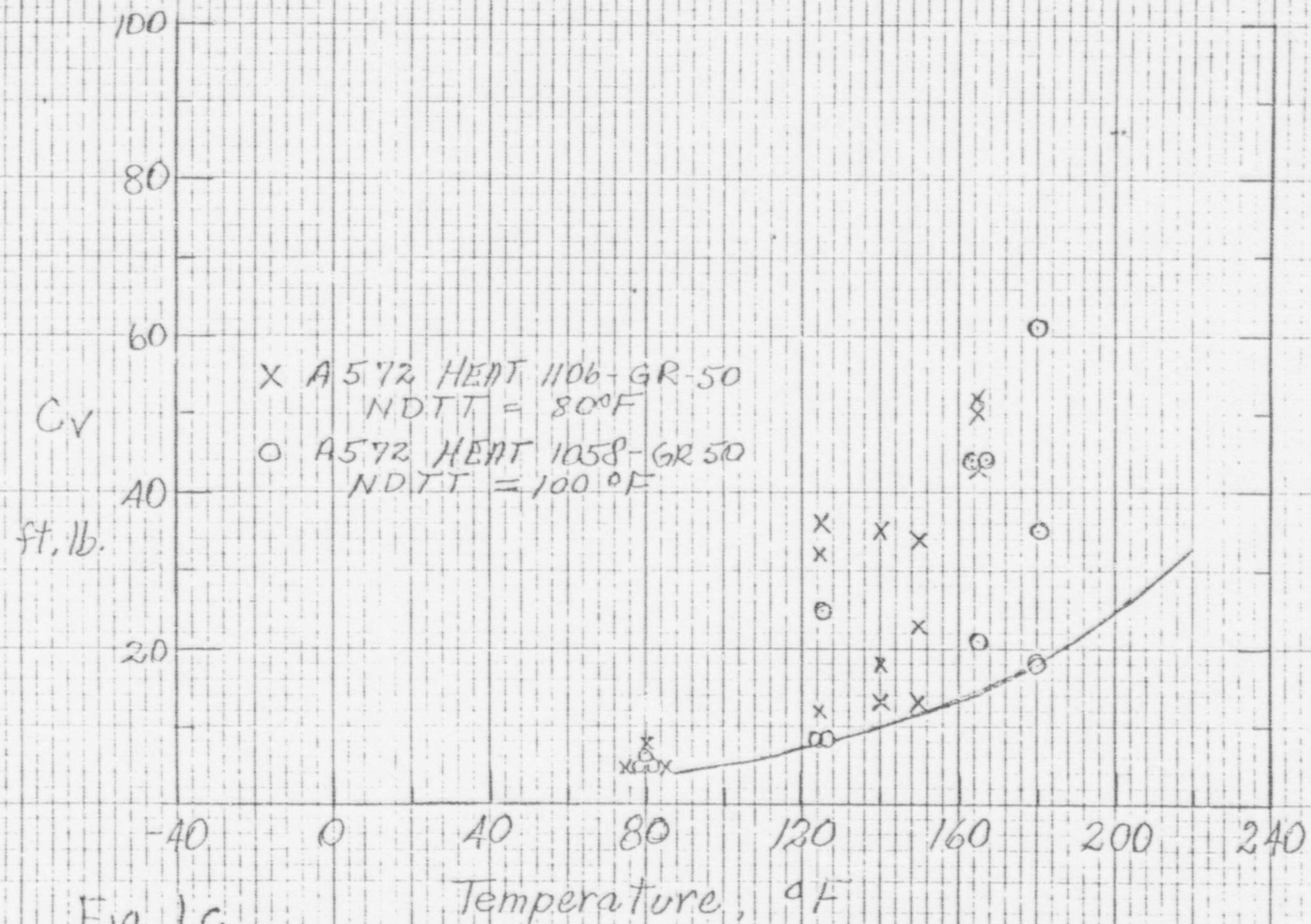

100
80
60
40
20
Cv
ft, lb.
X A572 HEAT 1106-GR-50
NDTT = 80°F
O A572 HEAT 1058-GR 50
NDTT = 100°F
-40
0
40
80
120
160
200
240
Temperature, °F

Fig. 1c

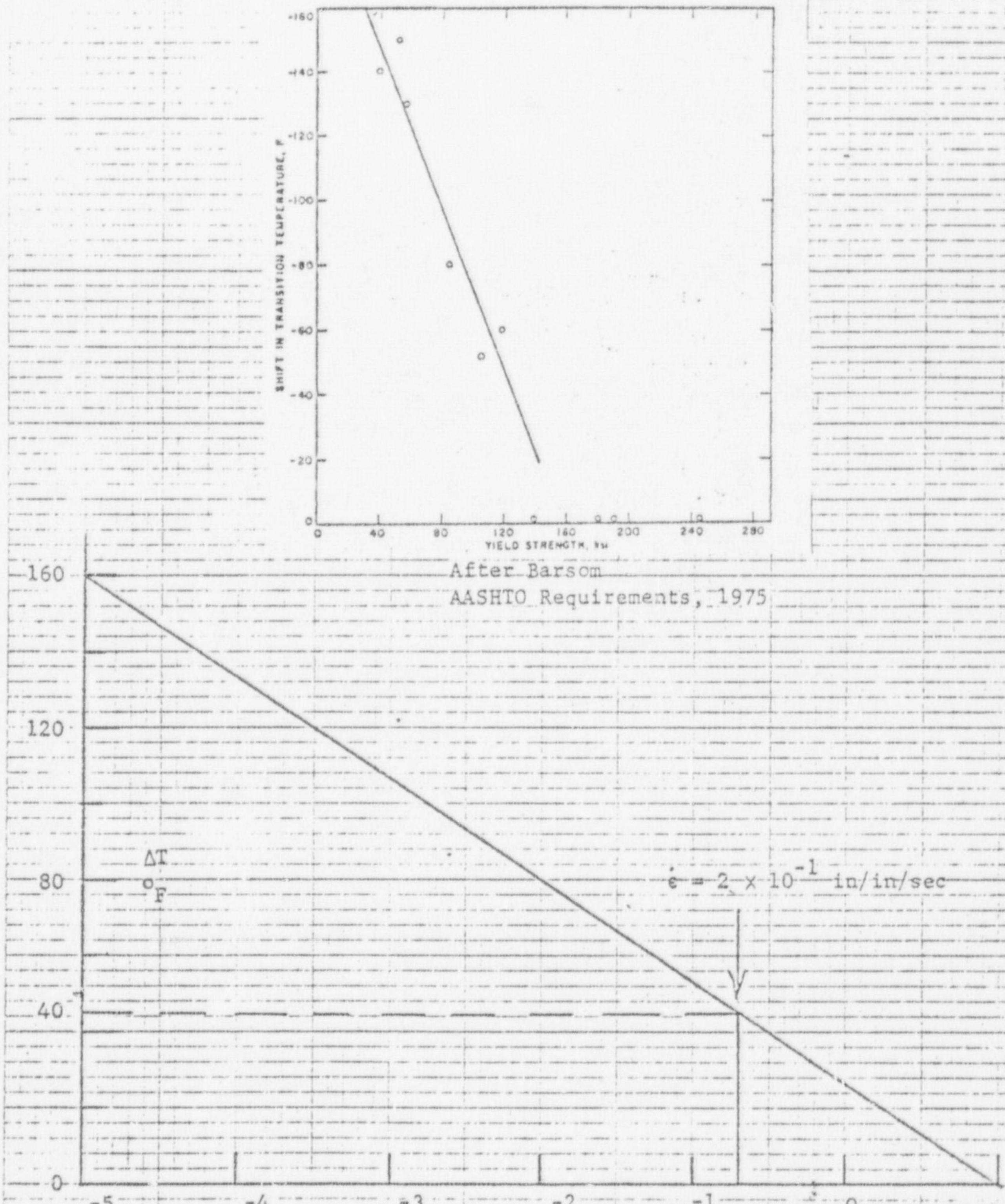
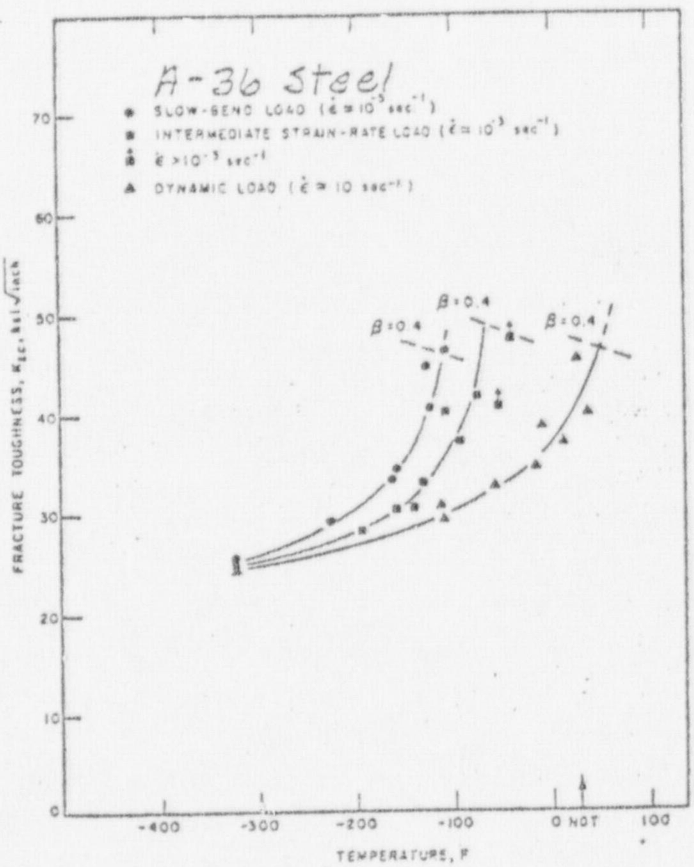
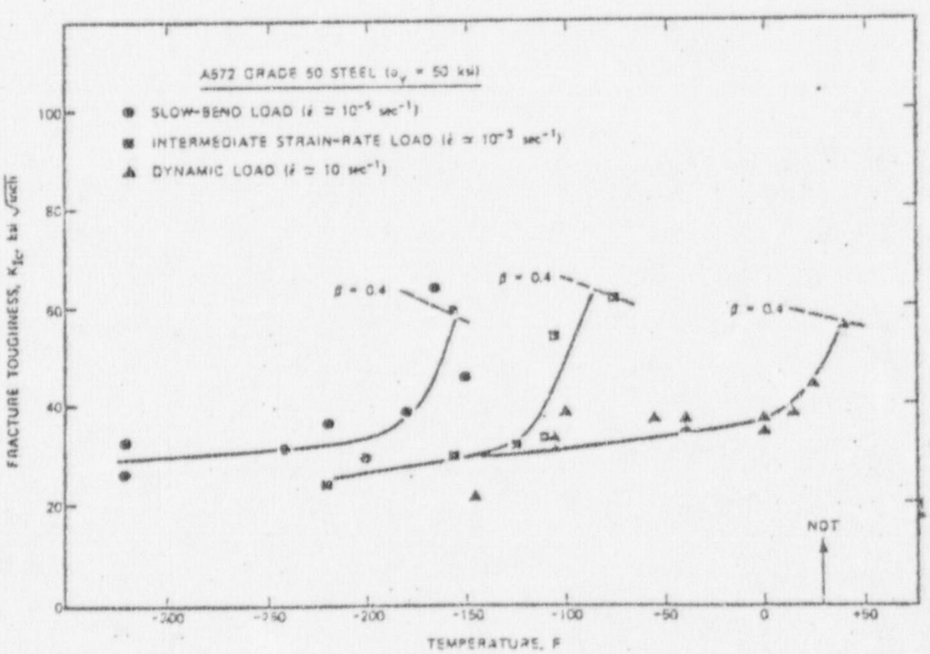



Fig. 2a Temperature Shift for Strain Rates Between Slow ($10^{-5}$) and Dynamic (10')

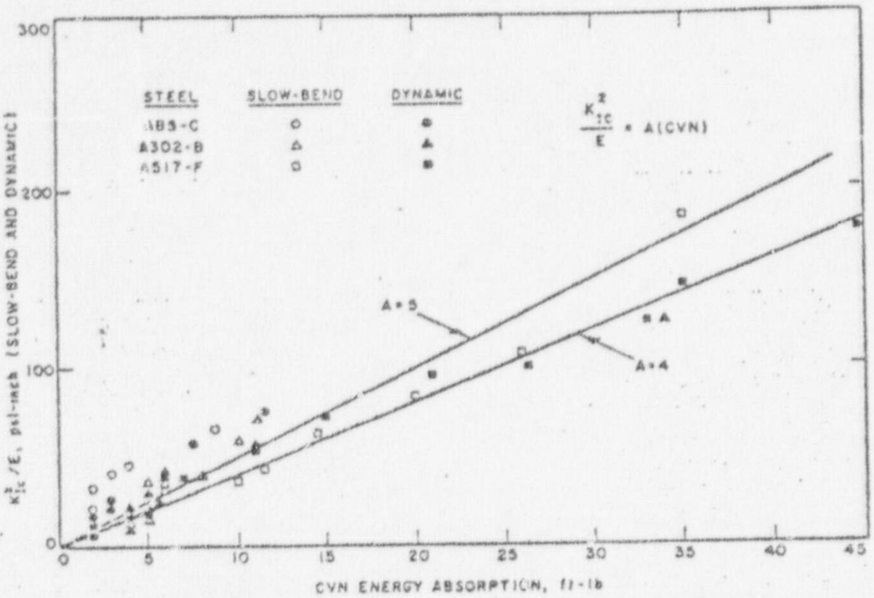
Development of the AASHTO fracture-toughness




After Barsom

Fig. 2b




After Barsom

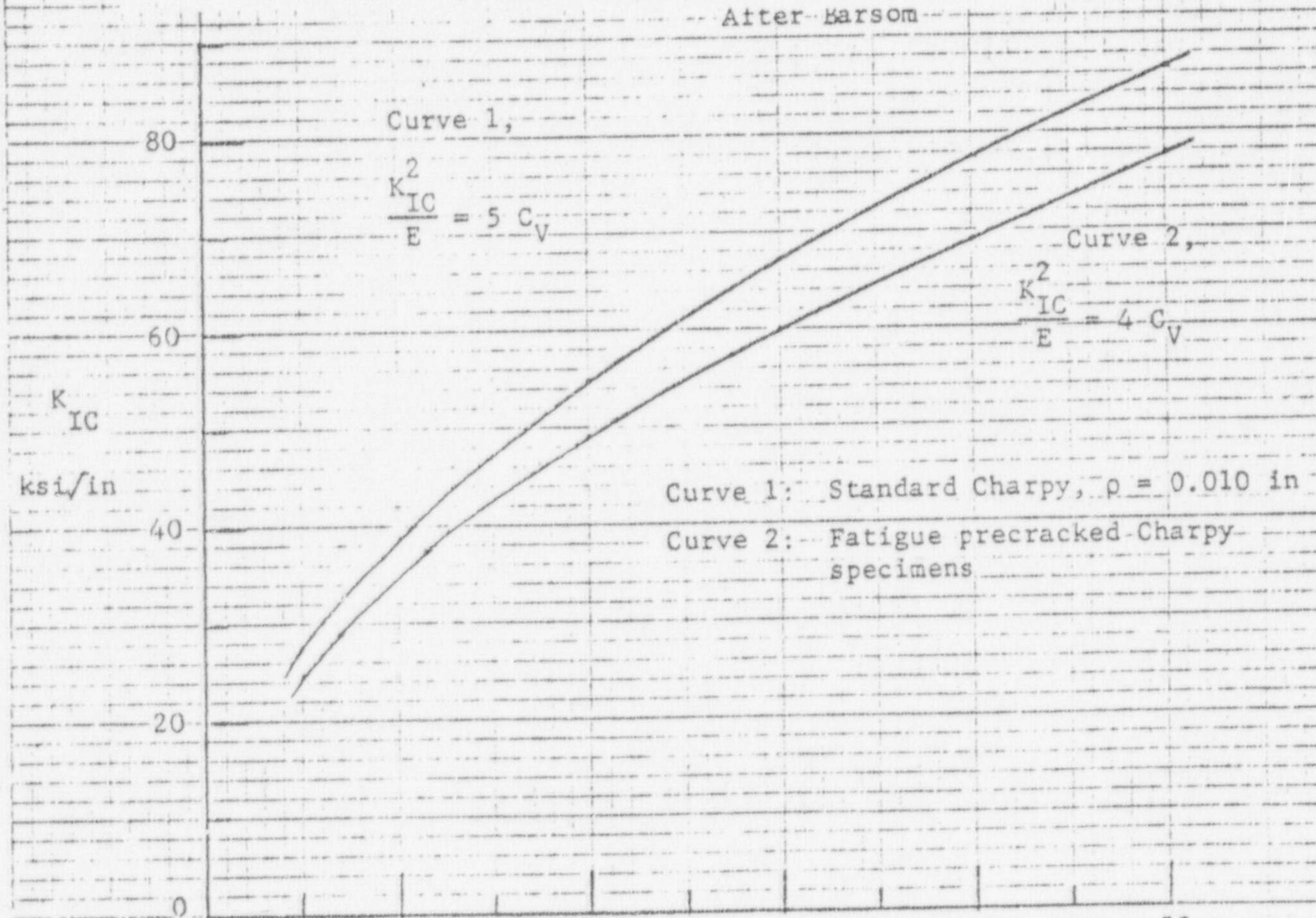
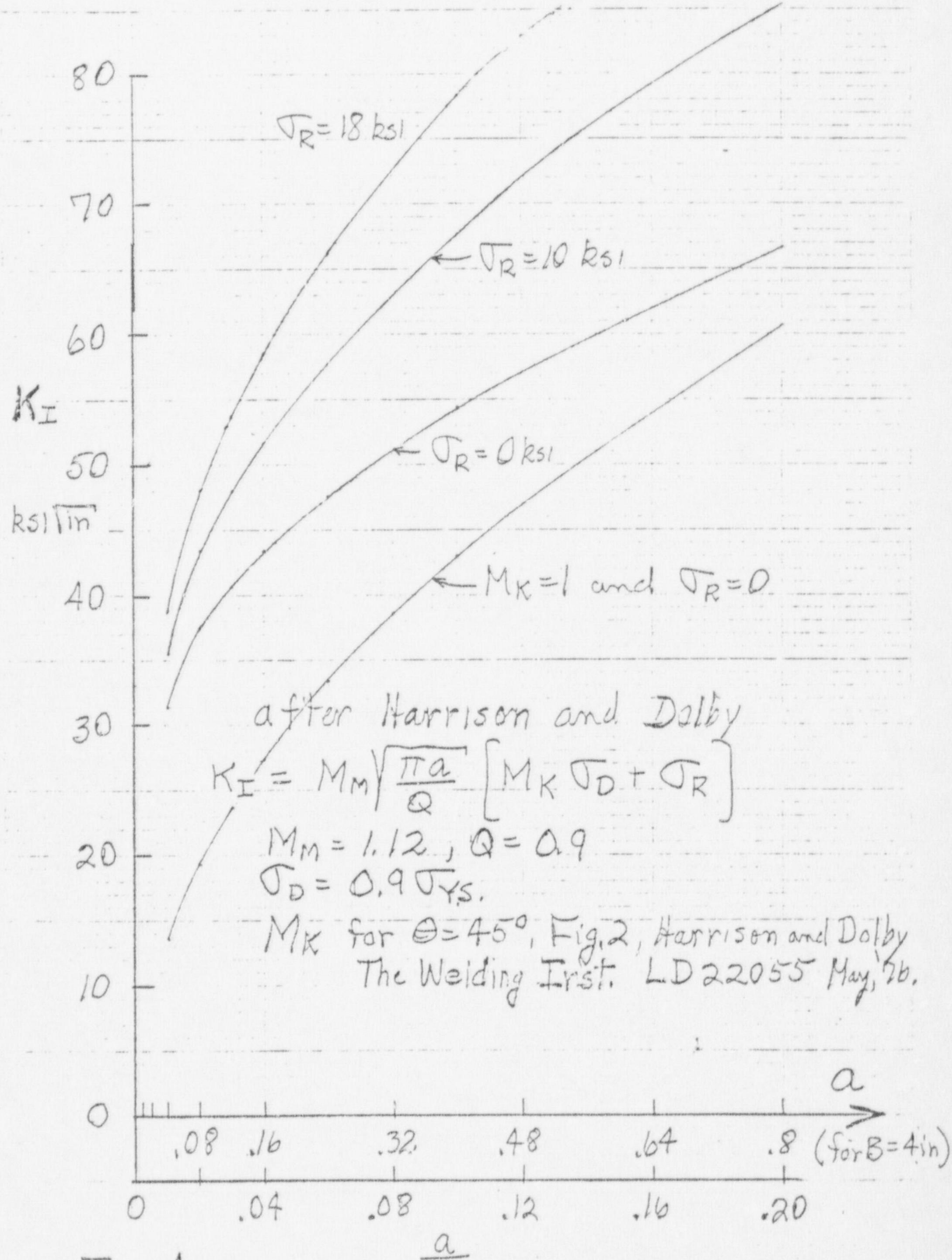
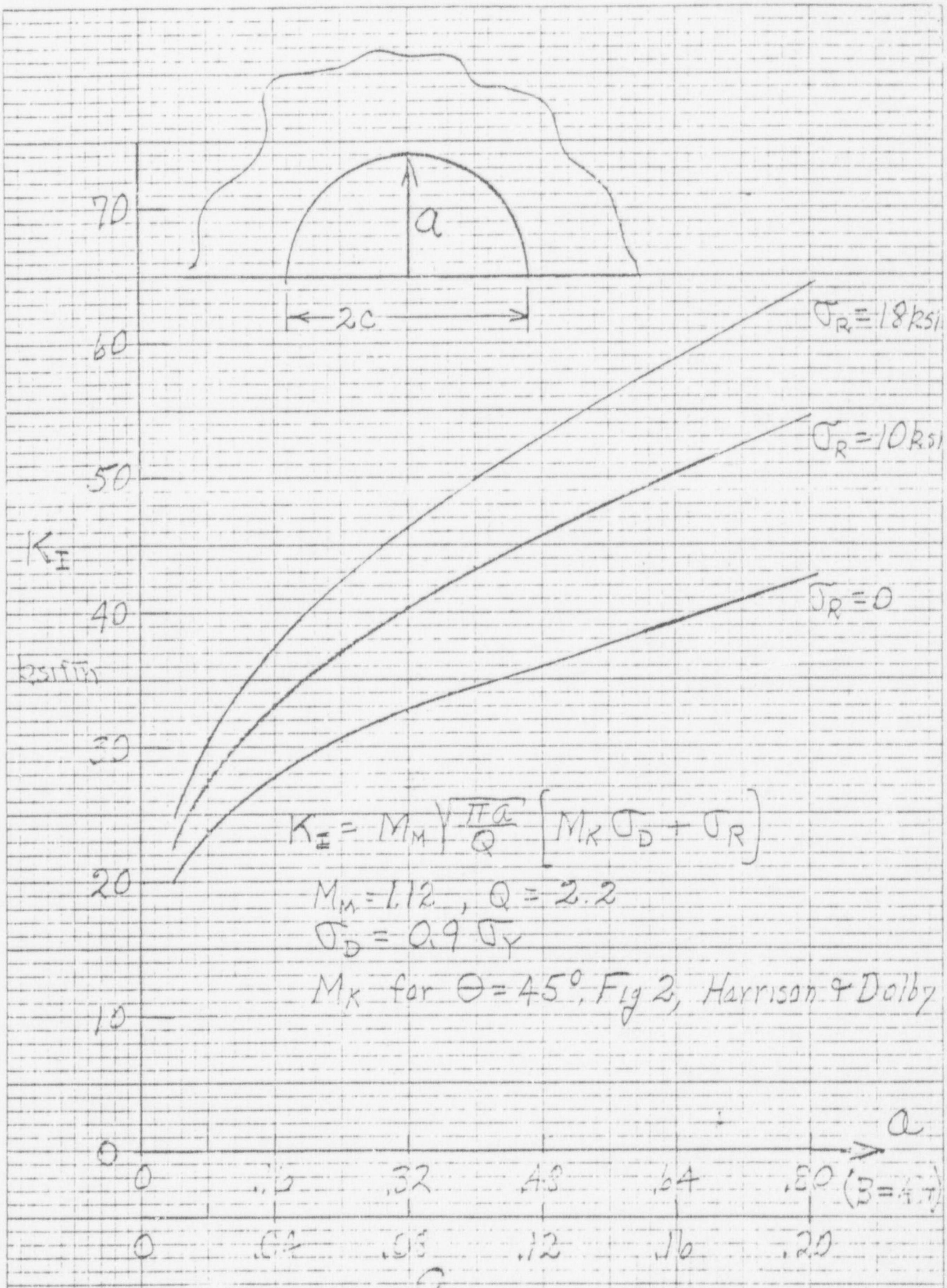



Fig. 3 Relation Between Energy in a Charpy Type Test and $K_{IC}$. Same time to fracture in both tests.



80
70
60
50
40
30
20
10
0
$K_I$
ksi√in
$\sigma_R = 18$ ksi
$\sigma_R = 10$ ksi
$\sigma_R = 0$ ksi
$M_K = 1$ and $\sigma_R = 0$
after Harrison and Dolby
$K_I = M_M \sqrt{\frac{\pi a}{Q}} \left[ M_K \sigma_D + \sigma_R \right]$
$M_M = 1.12$, $Q = 0.9$
$\sigma_D = 0.9 \sigma_{YS}$.
$M_K$ for $\theta = 45°$, Fig. 2, Harrison and Dolby
The Welding Inst. LD22055 May, '76.
a
.08 .16 .32 .48 .64 .8 (for B=4in)
0 .04 .08 .12 .16 .20
$\frac{a}{B}$


Fig. 4 a



a
2c
$\sigma_R = 18$ ksi
$\sigma_R = 10$ ksi
$\sigma_R = 0$
$K_I$
ksi√in
70
60
50
40
30
20
10
0
$K_I = M_M \sqrt{\frac{\pi a}{Q}} \left[ M_K \sigma_D + \sigma_R \right]$
$M_M = 1.12$ , $Q = 2.2$
$\sigma_D = 0.9\, \sigma_Y$
$M_K$ for $\Theta = 45°$, Fig 2, Harrison & Dolby
a
0 .16 .32 .48 .64 .80 (B=4.1)
0 .04 .08 .12 .16 .20
$\frac{a}{B}$


Fig 4b