ENCLOSURE 2

DOCUMENT NO. 80SDS4244
APRIL 1981
REV. 2

# HYDROGEN CONTAINMENT ANALYZER
# QUALIFICATION AND PERFORMANCE
# TEST REPORT

GENERAL ELECTRIC

SPACE DIVISION

Valley Forge Space Center

P. O. Box 8555 • Philadelphia, Penna. 19101



508-17-18-2

# PRODUCT QUALITY CERTIFICATION

| CUSTOMER/PROJECT | | PRODUCT NAME | |
|---|---|---|---|
| SCE/SONG 2, 3 | | CONTAINMENT POST LOCA $H_2$ MONITORING SYSTEM QUALIFICATION REPORT | |
| PURCHASE ORDER NO. | REV. | PURCHASE ORDER ITEM(S) NO. | QUANTITY |
| V4109581 | 2 | 4 | 6 |

SUPPLIER'S CERTIFICATION

THIS IS TO CERTIFY THAT THE PRODUCTS IDENTIFIED HEREIN HAVE BEEN MANUFACTURED UNDER A CONTROLLED QUALITY ASSURANCE PROGRAM AND ARE IN CONFORMANCE WITH THE PROCUREMENT QUALITY REQUIREMENTS INCLUDING APPLICABLE CODES, STANDARDS AND SPECIFICATIONS AS IDENTIFIED IN THE ABOVE-REFERENCED DOCUMENTS; UNLESS NOTED BELOW. ANY SUPPORTING DOCUMENTATION WILL BE FORWARDED OR RETAINED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS.

SIGNED: J.E. Murphy DATE: 10-23-80

J.E. MURPHY

TITLE: QC PROJECT ENGINEER ORGANIZATION: GE-SD

NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS:

NONE

REMARKS/EQUIPMENT SERIAL NUMBERS:

DOCUMENT NUMBER 80SDS4244

SO23-508-17-16-0

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## INTRODUCTION

The purpose of this Qualification and Performance Test Report is to confirm the adequacy of the equipment design for the performance of Class 1E functions under normal, abnormal, design basis event, post design basis event, and containment test conditions.

A combination of analysis and type testing was used to accomplish the qualification of the Post LOCA Hydrogen Monitoring Equipment for use in a Nuclear Power Generation System. In addition, continuing in plant operation is part of an on-going qualification program to establish longer operational life of the Hydrogen Sensor.

## SUMMARY

The test results presented in this report were performed on two analyzer designs and an optional configuration housed in a free standing enclosure. The testing performed included the following.

1. Exposure of the sensor and pressure transducer to a simulated (LOCA) environment (i.e., radiation, temperature, pressure, humidity)
2. Extended Post LOCA analyzer operation
3. Exposure to high $H_2$/air concentrations
4. Seismic tests of the analyzers
5. Long term operation of the transducer at elevated temperature followed by a simulated seismic event

Testing was conducted to provide qualification consistent with the requirements of:

Specification S023-508-17 (Appendix F)
IEEE 323-1974
IEEE 344-1975

No functional failures of the analyzers occurred during the above tests. Performance was acceptable as demonstrated by periodic calibration checks of the analyzer.

The electronics panels and Hydrogen Analyzer assembly supplied by the General Electric Space Division have been seismically tested successfully. Detailed test reports with results are included in Appendices B, C and D for the standard panel mount arrangement and Appendix F for the configuration in a free standing enclosure.

Seismic tests were also performed by component suppliers. Results are presented in Appendices E (Signal Conditioning) and H (Pressure Transducer).

Compatibility of analyzer components to be installed "in containment" was demonstrated by analysis or test in a simulated LOCA. Relevant procedures and reports are provided in Appendices G and I.

## SECTION I

## SYSTEM DESCRIPTION

### 1.1 GENERAL

The Primary Containment Hydrogen Monitoring System is designed to monitor, indicate, and record the volume percent of hydrogen in the primary containment atmosphere following a loss of coolant accident (LOCA). Alarm contacts which actuate when the concentration of hydrogen is not within preselected limits are also provided with the system.

### 1.2 SYSTEM FUNCTION

Functionally the Primary Containment Hydrogen Monitoring System consists of a hydrogen sensor, pressure transducer, signal conditioning and optional recording devices. The hydrogen sensor provides an electrical signal proportional to the hydrogen partial pressure of the containment atmosphere. This signal is fed into the electronics assembly where it is amplified and divided by a second electrical signal which is proportional to the total pressure of the containment atmosphere.

$$\frac{\text{Hydrogen Partial Pressure}}{\text{Total Pressure}} = \%\ \text{Hydrogen}$$

This hydrogen percent signal can be transmitted to recorders and meters which indicate the percent of hydrogen in the containment.

The analyzer is equipped with alarm contacts designed to actuate an annunciator when the hydrogen concentration exceeds predetermined limits.

### 1.3 PHYSICAL DESCRIPTION

The Primary Containment Hydrogen Analyzer may include all of the following subassemblies:

1. $H_2$ sensor/calibration assembly
2. An electronics panel assembly consisting of:
   a. One signal conditioning electronics/alarm panel
   b. One dual pen recorder
   c. Two calibration switches
3. Pressure Transducer
4. Free standing enclosure for the electronics panels

1.3.1 SENSOR/CALIBRATION ASSEMBLY

The $H_2$ sensor/calibration assemblies (Figure 1) consist of a sensor, a calibration cap and actuating piston, and a mounting assembly. Slotted holes are provided in the base of the mounting assembly to permit alignment of the sensor and the calibration cap. Mounting holes for the assembly are located on the side of the base plate.

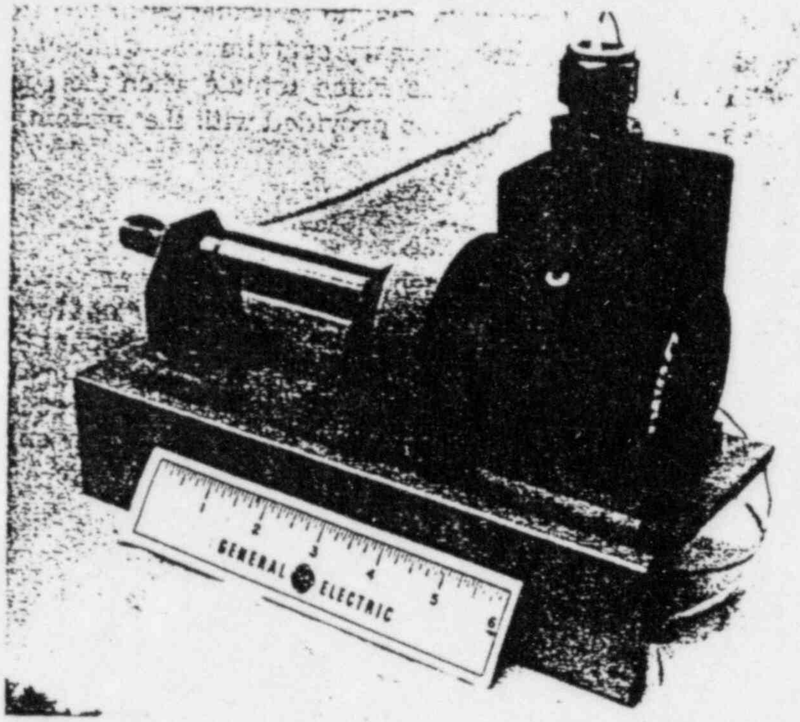


Figure 1. Hydrogen Sensor/Calibration Assembly

Remote calibration of the sensor is provided by the pneumatic actuating cylinder/calibration cap assembly. Calibration gas supplied to the cylinder moves the calibration cap forward to cover the sensing surface of the sensor. A portion of this gas passes through the hollow shaft of the cylinder and is discharged through an orifice onto the face of the sensor. The mechanism retracts when the calibration gas supply is removed, thereby exposing the sensor face to the containment environment.

Electrical interface of the sensor with the electronics assembly is provided for by a 5-foot cable extruded through a conduit fitting as shown in Figure 1.

It is not evident that the system described in ¶'s 1.3.3 and 1.3.4 is that which was supplied to SONGS 2&3. Please clarify.

### 1.3.2 ELECTRONICS PANEL ASSEMBLIES

Two signal conditioning/alarm panel designs have been qualified by test for use in Containment Analyzer Systems. These are shown in the drawings of Appendix A to this report.

| | Title | Dwg. No. |
|---|---|---|
| 1. | Primary Containment Hydrogen Monitoring System | 47E226426 |
| 2. | Hydrogen Analyzer Electronics Assembly | 47C238807 |

Both of these designs meet the performance requirements of the Containment $H_2$ Analyzer and have been extensively tested.

Figure 2 is a photograph of the panel assembly shown in GE Drawing 47E226426.

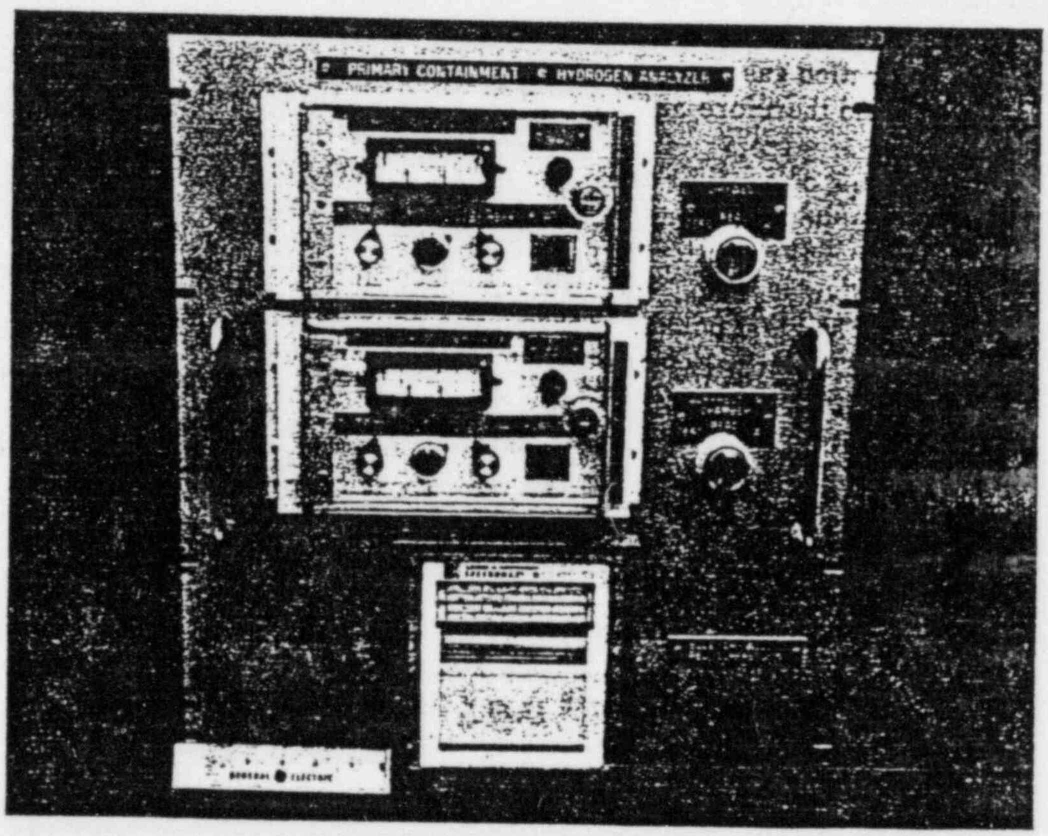


Figure 2. Hydrogen Analyzer Electronics Panel

This panel is a standard 19-inch relay rack panel modified to facilitate mounting two analyzer electronics assemblies and a recorder. The panel assembly measures 19 inches wide by 20.97 inches high by approximately 13.0 inches deep. Each panel assembly contains two electronics assemblies, each designated as a dry well, a suppression chamber electronics assembly, a dual pen recorder and calibration switches for sensors in both the drywell and suppression chamber areas.

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The drywell and suppresssion chamber electronics assemblies are identical except for the name plate. Each assembly measures 5.2 inches high by 8.3 inches wide by 14 inches deep and is mounted on the electronics panel as shown in Figure 2. The face or front of each assembly is covered by a clear plastic door with a key lock to prevent unauthorized tampering and accidental movement of the control knobs.

0-10% supplied to SONGS 2&3

Volume percent hydrogen present in the containment is indicated by the dual scale control meter located on the front of the assembly. Span 1 is 0 to 5 percent full scale and Span 2 is 0 to 20 percent full scale. Alarm set points are indicated by the red pointers on the meter and are adjustable over the full range.

System calibration is provided by a 10-turn dial potentiometer equipped with a lock to prevent accidental changes in the knob setting.

Mounted in the same panel and just below the electronics assemblies is the dual pen recorder. This recorder is driven by the electronics assemblies and simultaneously records the containment hydrogen concentration in both the Drywell and Suppression Chamber areas.

At the right side of this panel, two multi-position switches are provided to power the solenoid valves used for calibration gas control. These valves are not a part of the system supplied by General Electric and therefore are not included in the testing described herein.

Figure 3 is a photograph of a signal conditioning/alarm panel depicted in GE Drawing Number 47E238807 which is functionally identical to the unit shown in Figure 2. This assembly consists of a solid state signal conditioning panel with integral level detection, alarm contact closures, amplifier, divider, etc., and an alarm/readout panel with meter, alarm light, calibration adjustment and test points. These are both suitable for mounting in a standard 19-inch rack with rear electrical connections to each other and field wiring.

In this model, the recorder is supplied by the user.

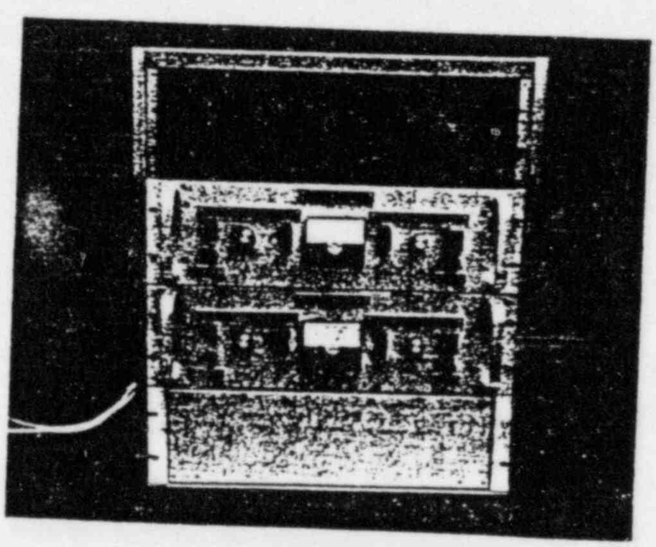


Figure 3. Signal Conditioning Alarm Panel (Dual Channel)

#### 1.3.3 Pressure Transducer

The CEC-1000-04 pressure transducer provides a full scale output of approximately 30 mv for 10V excitation at 100 PSIA. The transducer is installed in-situ thereby avoiding the costly pneumatic containment penetrations and simply vented to containment atmosphere.

#### 1.3.4 Hydrogen Containment Atmosphere Monitoring System With Optional Free Standing Enclosure (Ref. Dwg. 47E240609)

The $H_2$ Containment Atmosphere Monitoring System (Figure 4) consists of the following:

a. A 6' by 2' by 2.5' steel cabinet with an interior finish of white fire retardant paint. All user conduit terminations are located on top of the cabinet and provide all required access to each train.

   Train B is the upper and train A the lower. Isolation between trains is provided by a steel plate and internal conduit.

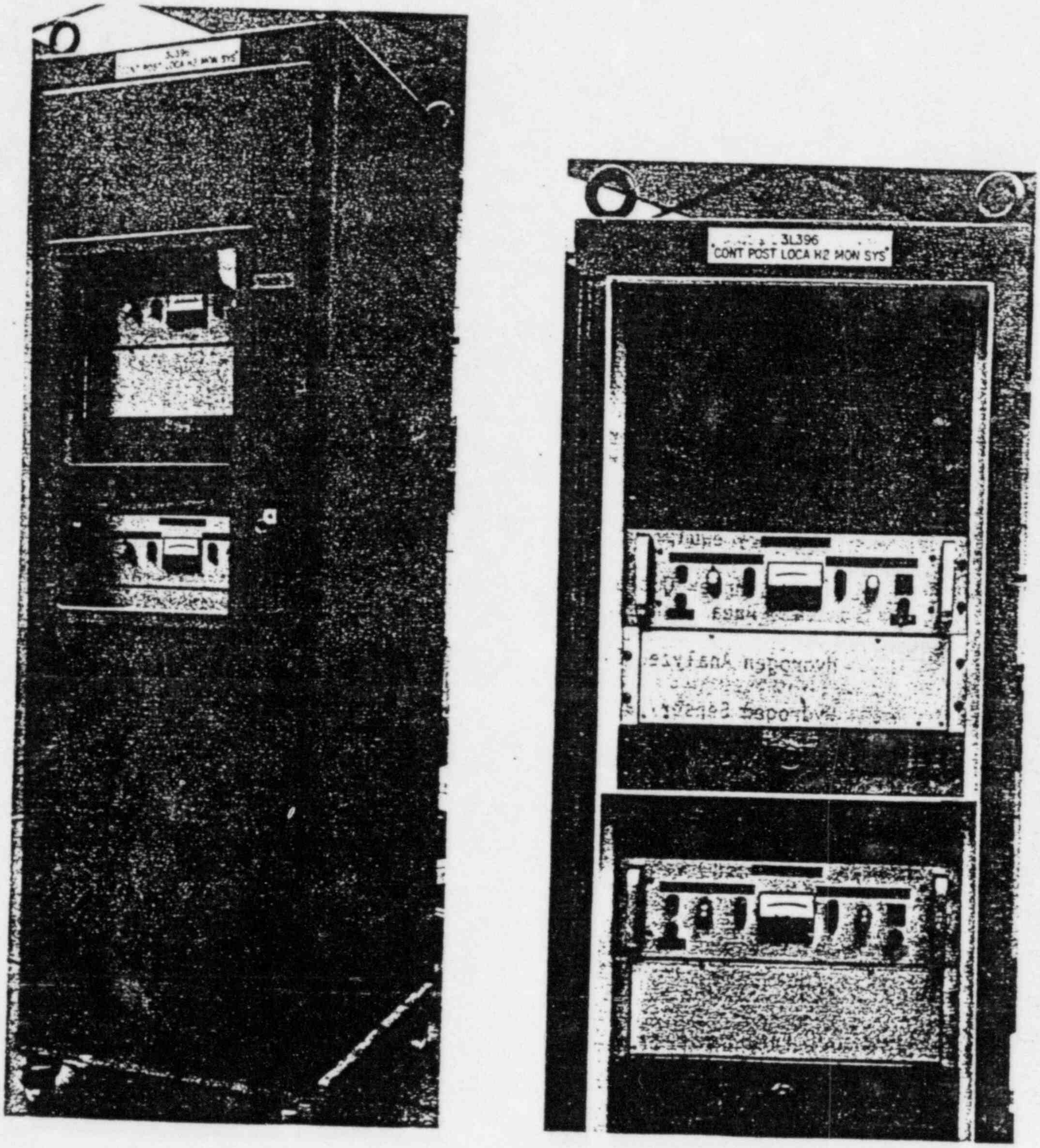
   Auxiliary equipment included with each train is:

   - Duplex Outlet, 120 VAC, 1 PH
   - Area lighting with switch

b. Hydrogen Analyzer Electronics Panel (Figure 3, Except Single Channel, 0 to 10% $H_2$)

c. Hydrogen Sensor/Calibration Assembly

d. Pressure Transducer, 0 to 100 PSIA rated and full scale pressure




ENCLOSURE VIEW

PANEL VIEW

Figure 4. Signal Conditioning Assembly

SECTION 2

THEORY OF OPERATION

## 2.1 GENERAL

The Primary Containment Hydrogen Monitoring System utilizes a hydrogen partial pressure sensor in conjunction with a total pressure sensor and appropriate electronic components to indicate the percent of hydrogen present in the primary containment atmosphere.

## 2.2 SENSOR ASSEMBLY

The hydrogen partial prėssure sensor is galvanic in nature and consists of a platinum black electrode and platinum oxide counter electrode within a polysulfone housing. Figure 5 is a schematic of the sensor configuration. The electrolyte providing the ion conductive path between the two electrodes is separated from the ambient atmosphere by a gas-permeable membrane which is in contact with the sensing electrode. When the ambient atmosphere contains hydrogen an electrical current is generated by the sensor which is directly proportional to the partial pressure of the hydrogen in the atmosphere.

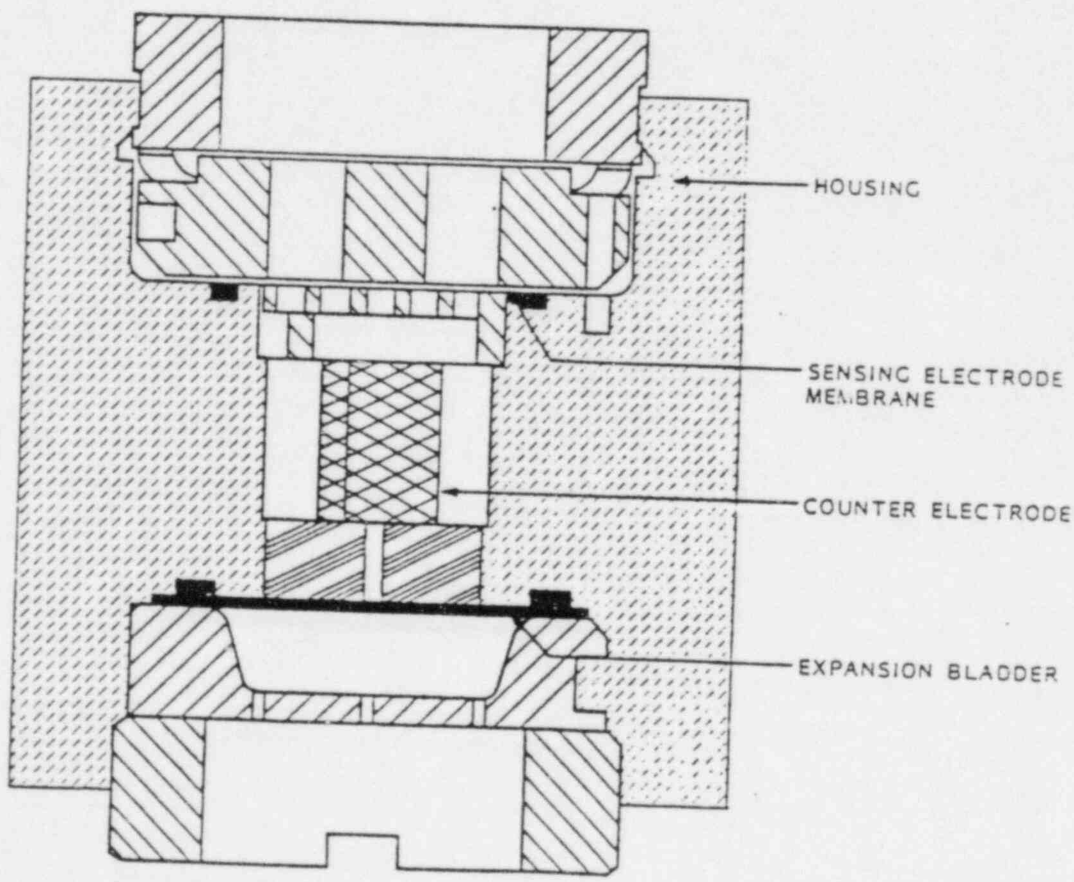



Figure 5. Hydrogen Sensor Schematic

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This current-partial pressure relationship is constant for a specific electrode configuration and constant temperature. For changes in temperature, however, the absolute permeability of the membrane varies resulting in a change in the electrical current generated by the sensor. This change in permeability (hence current) is a first order change increasing logarithmically with increasing temperature. The increased output of the sensor due to increasing temperature is compensated for by matching the sensor with a thermistor/resistor network having the correct temperature/resistance characteristics. When the thermistor/resistor network is attached across the output leads of the sensor the calibration of the sensor is maintained within a comparatively close tolerance over the entire operational temperature range.

### 2.2.1 DESIGN EQUATIONS

The transfer relationships for hydrogen diffusion in the cell are summarized in the generalized equations that follow. First, consider that the rate of diffusion of $H_2$ through a diffusion barrier membrane of a fixed area (A) and thickness (D), is a function of the permeability of the membrane material as expressed by the coefficient, $P_r$; the ambient temperature, and the partial pressure differential ($P_a - P_i$) established across the membrane. The generalized rate equation for the diffusion (N) of hydrogen through the membrane in cc/second is:

$$N = P_{r\,D} (P_a - P_i) \quad (1)$$

For a given membrane material and gas, $P_r$ is a constant (at constant temperature) so that for a specific configuration with a fixed membrane area and thickness the rate equation becomes:

$$N = K (P_a - P_i) \quad (2)$$

when

$$K = \frac{P_r A}{D}$$

The sensor is designed to electrochemically oxidize hydrogen to the ionically active form immediately upon its adsorption on the sensing electrode. As a result, the effective hydrogen partial pressure ($P_i$) on the catalyst side of the membrane approaches zero and the rate equation is further reduced to:

$$N = K P_a \quad (3)$$

The complete electrochemical oxidation of hydrogen in the two half cell reactions in the sensor results in an electrical current whose magnitude is governed solely by the quantity of hydrogen available for reaction. The magnitude of this current is readily computed utilizing the Faraday relationship which states that 26.59 Ampere hours of current will be generated per gram of hydrogen reacted. Having already established the relationship between the hydrogen partial pressure and the rate of hydrogen reacting in the sensor, it is apparent that the current generated is a direct function of the hydrogen partial pressure.

The current thus generated is passed through an external resistance network with a temperature coefficient which is equal in magnitude but negative with respect to the temperature component of $P_r$. The resulting voltage differential across the compensated load network is the sensor output signal which is now only a function of the partial pressure of hydrogen. The DC signal level is of a magnitude which is readily usable with standard solid state instrumentation circuitry to provide a display of hydrogen concentration in volume percent and discrimination of present levels for caution and warning, resulting in alarm contact closures.

The operating life of the sensor is dependent upon the rate at which the counter electrode material is consumed. The rate of consumption is of course, a function of the rate of hydrogen reaction so that in theory if the sensor saw no hydrogen, the life would be infinite. In practicality, however, there are leakage currents and material degradation factors so that the life of the sensor is specified as 1 year of shelf life and up to 4 years of operating life under any reasonable combination of hydrogen environments as defined in the specification for Containment Atmospheres.

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### 2.2.2 ELECTROLYTE SOLUTION

Electrolyte in the sensor is an aqueous solution of sulfuric acid. Two major design considerations requiring specific and detailed design study were the effects of the vapor pressure of the electrolyte on the configuration at the pressure and temperature conditions anticipated in containment, and the selection of materials for compatibility with the $H_2SO_4$ in the combined temperature - humidity - radiation environment.

The electrolyte within the sensor will reach equilibrium with the ambient containment temperature during the LOCA. In order to minimize the outward reacting pressure differential across the sensing electrode/membrane assembly, the electrolyte concentration was selected with the lowest practical vapor pressure consistent with reasonable performance. Obviously, as the concentration of acid increases, the corrosion problems become compounded placing practical limits on the choices. Range of concentrations successfully subjected to LOCA conditions is 25 to 60 percent.

## 2.3 ELECTRONICS ASSEMBLY

The output of each hydrogen analyzer electronics assembly represents true volume percent hydrogen, and is indicated by the panel meter located on the electronics assembly.

Development of the volume percent signal is achieved by first amplifying a millivolt signal received from the sensor, and then dividing the amplified signal by a total pressure signal received from a pressure transducer. The resulting signal is displayed on the analog meter and transmitted to a local or remote recorder as a current (4-20 mA) or voltage signal depending upon user interface requirements, Figure 6.

Access to Alarm contacts are at the rear of the panel for connection to the annunciator panels. Alarm adjustments are over the full range on either the panel meter or solid state level detection module (this depends upon the model in use).

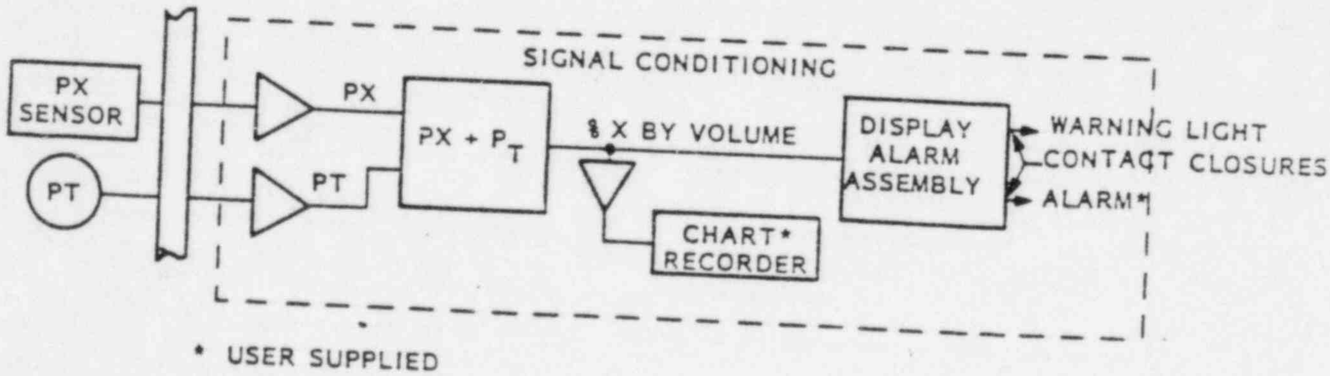


Figure 6. Logic Diagram for GE Single Channel $H_2$ Analyzer

# SECTION 3

# TEST DESCRIPTIONS

## 3.1 GENERAL

The tests conducted to qualify the General Electric Hydrogen Containment Analyzers represent a series of environmental and performance tests and analyses performed by the General Electric Company and some of its suppliers. When integrated into a single test report these data and analyses successfully demonstrate the capabilities of the analyzer over the range of situations required.

### 3.1.1 SIMULATED LOCA

Not included in Appendix A. It is shown in Figure 2 of Section 1

The initial tests conducted by the General Electric Company served to demonstrate the performance of an analyzer through a simulated LOCA. For this test, two hydrogen sensors, two electronics assemblies, and a recorder, were assembled. The electronics used in this test sequence are shown in GE Drawing No. 47E226426 shown in Appendix A. The sensors were subjected to the anticipated containment environments of radiation, temperature, pressure, and relative humidity as summarized in Table 1. The electronics panel was assumed to be in a control room environment. The specific procedure utilized is presented in Appendix B for reference.

### 3.1.2 SEISMIC TESTS

To verify performance to the seismic criteria of IEEE-344, production analyzers of both designs were subjected to vibrations designed to simulate a seismic event. Both analyzer electronics panels described in Section 1 of this report were subjected to these environments. For the analyzer electronics to be supplied by the General Electric Company, the signal conditioners have been successfully tested in two separate evaluations and configurations at the Southwest Research Institute and the General Electric Space Division.

The hydrogen sensor assembly was tested by the General Electric Company. The detailed procedures and results are presented in Appendices C and D. Please note that the pressure transducer tested (although successful) is not the unit to be supplied with the Analyzer. The CEC1000 unit currently being supplied has been successfully tested through a much more vigorous environment. The qualification status of this unit is addressed in Appendices G, H and I of this report.

Table 1. Qualification Test Parameters

| Environment | GE Test Range |
|---|---|
| Acceptance Test | |
| Temperature | 75-185°F |
| Pressure | 14.7 psia |
| RH | 30-100% |
| Duration | 48 hrs |
| Qualification Test | |
| Temperature | 200-340°F |
| Pressure | 14.7-77 psia |
| RH | 30-100% |
| Duration | 92 days |
| Radiation | $3.2 \times 10^7$ rads |
| Seismic | |
| Frequency | 0.1-33 cps |
| Input Level | 0.05-3.0 g |
| Hi $H_2$ Exposure | 12-15% in air |
| Extended Life (Post Qual) | 1 year |

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3.2 GENERAL TEST SEQUENCE

The test sequences utilized in this qualification program are designed to provide simulation of the environments predicted for a LOCA. The sequence of events for this particular test are summarized as follows:

1. Radiation Exposure ($1.6 \times 10^7$ rads). The sensors were fabricated using materials and components which had been previously irradiated to a level of $1.6 \times 10^7$ rads.

2. Abbreviated Performance Test. Upon installation in the chamber, a functional check was made of both sensors.

3. 90 Day Environmental Profile. Following a minimum 24 hour stabilization at approximately 200°F, a simulated LOCA profile was conducted on 10-6-75. Following the high temperature run, the analyzer was left on line for an additional 91 days at 200°F and sea level ambient pressure.

4. Post LOCA Radiation Exposure ($1.6 \times 10^7$ rads). Following this test period, the assembled sensors were exposed to radiation at a rate of $1 \times 10^5$ rads/hour for an additional 160 hours bringing the total integrated dose to $3.2 \times 10^7$ rads.

5. Abbreviated Performance Test. A functional test was performed on the analyzer following this radiation exposure.

6. High $H_2$ Concentration. The analyzer was then tested with the hydrogen sensors being exposed to a hydrogen/air mixture of approximately 13-14% hydrogen at sea level ambient pressure for one hour.

7. Abbreviated Performance Test. To verify proper function, a brief calibration check was performed following the high hydrogen exposure.

8. Seismic Test. Initially, a production analyzer was seismically tested in accord with the requirements of IEEE-344. Subsequent on-going testing on other production units and on aged equipment were conducted to supplement these data.

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Test sequence recommended in IEEE 323-74 is:

Pretest Visual Inspection
Baseline Functional Test
Radiation Exposure
Functional Test
Aging
Functional Test
Seismic Qualification
Functional Test
LOCA Environment

Justifications of variations of the test sequence conducted and those listed above are:

Radiation: Radiation was done in two steps, half before LOCA and half after LOCA followed by a performance test and seismic test. This has three advantages over doing the entire radiation before LOCA simulation:

1. It more accurately simulates the actual condition where the radiation will occur before and after the maximum temperature and pressure extremes.

2. In exposing the sensor to radiation after the stresses of temperature and pressure, any unanticipated synergistic effects of the three stresses are more likely to be identified.

3. By dividing the radiation testing and making a performance measurement after each radiation exposure, any performance degradation trends could be identified. These would be useful in predicting end of life. No degradation due to radiation was detected at after either radiation exposure.

Aging: Because of the limited life of the sensor, aging is not an essential step in the qualification testing. Appendix K provides further data on sensor aging.

The pressure transducer aging is described in Appendix I.

LOCA Before Seismic: The $H_2$ Sensor is a simple device stable in structure and unlikely to be affected by the levels specified for a seismic event. It would be in a most susceptible condition for seismic damage after a LOCA type maximum temperature excursion. Therefore, the seismic testing was conducted post LOCA with subsequent performance testing and inspection.

Chemical spray was not included in the LOCA testing because the exposed materials are the same as those used in Oxygen Sensors which contains a much stronger basic solution of 50% KOH.

3.3 SUPPLEMENTARY TESTS

1. Top Assembly Seismic Test - This test was performed to demonstrate the $H_2$ Containment Atmosphere Monitoring System ability to withstand simulated seismic vibration. Note that all analyzer components described in Paragraph 1.3.4 were included. Detailed test results are presented in Appendix F.

2. Pressure Transducer Tests - The pressure transducer underwent an aging test to demonstrate long term operation. The environment included elevated temperature of 300°F and a radiation exposure of $3.2 \times 10^7$ Rads TID. Detailed description of the test and results are presented in Appendix I.

   The transducer was not subjected to a separate LOCA pressure and temperature profile. The CEC predelivery test environment, Appendix G, exceeds the maximum predicted LOCA conditions for temperature and pressure. The testing in Appendix I includes 14 days of continuous operation above 300°F and 48 PSIA. In addition, the acceptance test on the pressure transducer (Appendix G) includes short term testing at 400°F and two times rated pressure (200 PSI). These combined conditions stress the pressure transducer far beyond the conditions of the SONG 2 and 3 LOCA profile.

## SECTION 4

## TEST EQUIPMENT

### 4.1 TEST CHAMBER

The test chamber used to simulate the LOCA event is a cylindrical aluminum tank, 24 inches long x 6.75 inches in diameter having welded flanges at each end. End plates for the test chamber contain penetrations for sensor signal leads, thermocouples and fittings for calibraion and pressurization gases. A sensor mounting plate is welded to the front end plate. This mounting plate is designed to support two sensors and calibration mechanisms in the same manner as the calibration assembly base plate.

Strip heaters, capable of providing the 340$^{o}$F LOCA test temperature are wrapped around the circumference of the chamber and covered with insulation. The heater's are controlled by a modulating temperature controller, chamber temperature is monitored by five stainless steel jacketed thermocouples.

A steam supply capable of supplying 340$^{o}$F steam to pressurize the test chamber was also available for this test.

### 4.2 INSTRUMENTATION

The test equipment was instrumented to monitor such parameters as: chamber internal and external temperature, chamber pressure, sensor output and electronics output, and simulated total pressure input signal (if required).

Internal and external chamber temperatures were indicated on a multipoint recorder and digital data system. Chamber pressure measurement was provided by a precision pressure gage (Wallace and Tiernan) and/or a pressure transducer.

Sensor output was hardwired to the Analyzer Electronics Assemblies and to the instrumentation Data System. Electronics output signals as well as the total pressure input signal were also recorded on the digital data system.

### 4.3 RADIATION CELL

Radiation exposure of the sensor components was performed at the Isomedix Inc. facility in Parsippany, N.J. Radiation exposure at Isomedix was provided by a Cobalt 60 source in air at ambient temperature and a slight negative pressure (-0.25 inch of water). Radiation doses were provided as follows:

| | |
|---|---|
| Pre LOCA exposure | $1.6 \times 10^7$ rad at $1 \times 10^5$ rad /hr |
| Post LOCA exposure | $1.6 \times 10^7$ rad at $1 \times 10^5$ rad /hr |
| Total | $3.2 \times 10^7$ rad at $1 \times 10^5$ rad /hr |

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## 4.4 SEISMIC EQUIPMENT

Space Division's Ling Electronics 370 shaker system and the MC C-150 shaker system will be used to perform the seismic tests required to comply with the specifications and appropriate IEEE guidelines. The useable ranges for this test equipment are as follows:

Horizontal Coefficient

| | | |
|---|---|---|
| Ling 370 | 0.1 to 2.7 cps | 0.0015 to 1.35 g* |
| | 2.7 to 5 cps | 1.35 g** |
| MB C-150 | 5 to 8 cps | 1.35 to 3.0 g* |
| | 8.5 to 33 cps | 3.0 g |

Vertical Coefficient

| | | |
|---|---|---|
| Ling 370 | 0.1 to 1.2 cps | 0.0015 to 0.29 g |
| | 1.2 to 33 cps | 0.29 g |

*Shaker stroke limited
**Shaker force limited

Because of test equipment limitations, two separate shaker tables are required in order to closely approximate the seismic requirements of the procurement specifications.

Detailed description of test equipment and facilities used during the top assembly seismic test, Paragraph 3.3.1 above, is provided in Acton Test Report, No. 14950, Appendix F.

## SECTION 5

## TEST RESULTS

### 5.1 LOCA PROFILE

It is the intent of this portion of the qualification test to simulate the temperature - pressure - relative humidity profile anticipated in Containment following a "Loss of Coolant Accident". The pressure chamber utilized in conducting this portion of the test was instrumented to monitor and control temperature and pressure. The hydrogen concentration in the chamber was manually adjusted using pre-mixed gas. The relative humidity was allowed to seek its own equilibrium level, that level being preset by the quantity of water added to the chamber prior to the start of the LOCA excursion.

Figure 7 traces the chamber environment through the LOCA test simulation indicating temperature, chamber pressure and hydrogen partial pressure. The circled numbers (1-10) correspond to the event numbers on the test log. The sensors both stayed within tolerance through the LOCA. The initial calibration at 4% $H_2$ after 24 hours showed both units needing a calibration adjustment. Following the adjustment with the panel potentiometer, the chamber was opened for visual inspection. No visual damage was observed and the chamber was closed up again and the chamber environment stabilized at 2 percent hydrogen and 200°F for the 90 day life test.

Periodic calibrationswere performed in accord with the test procedure. Copies of the recorder charts from typical calibration runs are shown in Figure 8. Between calibration runs, the chamber atmosphere was left at ambient pressure (vented to sea level ambient through a water seal) and ~ 200°F. The test log is summarized in Table 2.

### 5.2 HIGH $H_2$ EXPOSURE

Following the environmental and life test of the analyzer, the sensors were exposed to a mixture of approximately 13% hydrogen in air for a one hour period. The object of this test is primarily to verify the safety of the sensors by demonstrating the non-ignition source characteristic of the device. Note that no flame arrestor assembly is necessary with this sensor design.

### 5.3 SEISMIC TESTS

Panel Test, Appendix D. Results of the post test checkout and inspection of the hardware show all assemblies to be fully operational and undamaged by the seismic environment. There was no alarm actuation produced by the 47C238807 electronics assembly. Hence, the hardware tested successfully passed the seismic test criteria. Detailed test results are provided in Appendices C (Original Design) and D (Current Design).

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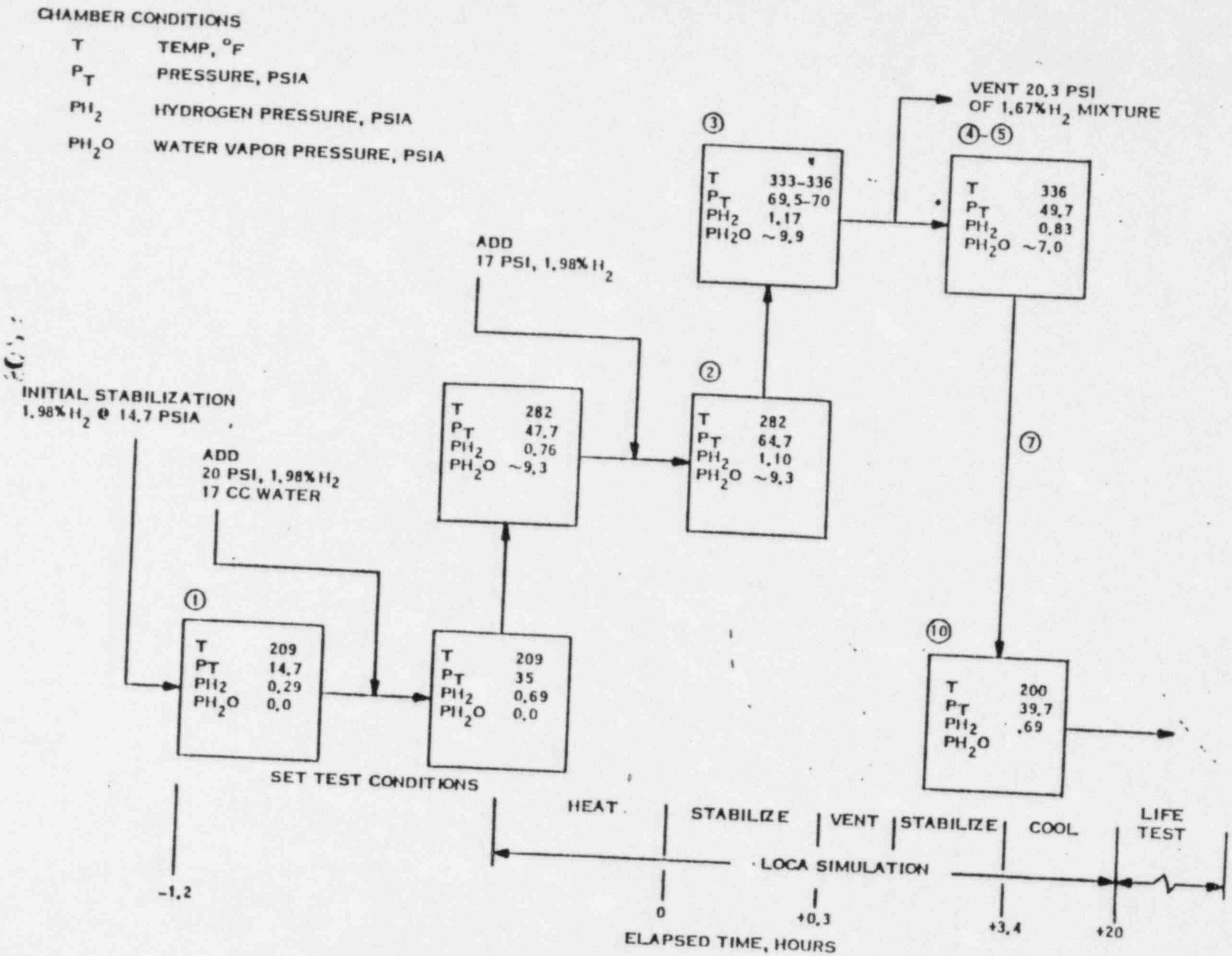


Figure 7. Environmental Profile Through LOCA Test

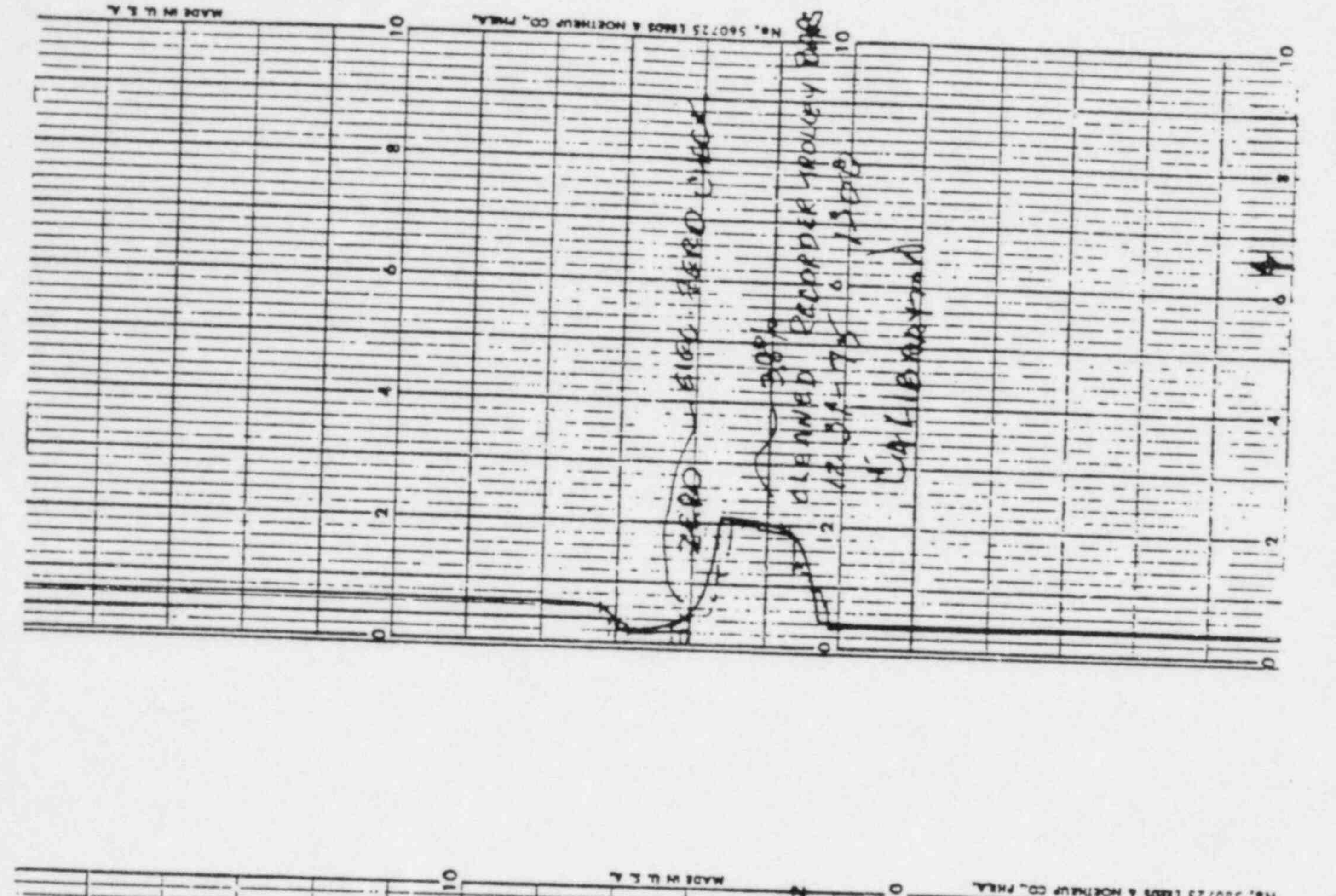

Figure 8. Typical Calibration Checks at Days 45 and 87

Table 2. Test Log $H_2$ Containment Qualifications

| | | | |
|---|---|---|---|
| 10-6 | 1100 | #1 | START TO 340°F, ADD $H_2O$, $H_2$ |
| | 1141 | #2 | $P_T$ = 33 PSIG, ADD 1.98% $H_2$ TO 50 PSIG |
| | 1213 | #3 | REACHED 331°F @ 1213 |
| | 1232 | #4 | REDUCE PRESSURE TO 35 PSIG |
| | 1240 | #5 | REACHED 35 PSIG |
| | 1248 | #6 | ADJUST $P_T$ SIGNAL TO 3.437V |
| | 1538 | #7 | BEGIN TEMP. REDUCTION TO 200°F |
| | 1620 | #8 | $P_T$ = 32 PSIG, T = 275°F |
| | 1710 | #9 | ADJUST $P_T$ SIGNAL TO 3.0 VOLTS (43 PSIA), ADD 1.5 PSIA $H_2/N_2$ METER READS 1.9% BLUE 1.2% RED |
| 10-7 | 0800 | #10 | REDUCE $P_T$ FROM 25 PSIG TO 0 PSIG T = 200°F, ADJUST $P_T$ TO 1.0V METER READS 3.4% BLUE 1.2% RED |
| | 0850 | #11 (A) | CALIBRATE ADJUST SENSOR/AMPLIFIER GAINS TO RED 8.85 TO 10.0 BLUE 8.17 TO 2.48 |
| | | #12 | END CALIBRATION |
| | | #13 | OPEN CHAMBER |

5.4 SYSTEM SEISMIC TEST

The analyzer test specimen included one each 47E240611 Signal Conditioning Assembly, 47E240610 Sensor Assembly and CEC 1000 Pressure Transducer. This combination was tested to the criteria for Seismic Qualification of Class I equipment for use at the Southern California Edison San Onofre Power Station (Units 2 and 3). The test plan, S.I. 250852 included the following:

1. Performance verification.

2. Simulated Seismic Event.

3. Post test performance verification.

Results show all hardware to be fully operational and undamaged by the seismic environment. Note that the analyzer was operating and monitored during each axis of the simulated event. No alarm actuations occurred.

All procedures and reports to document the above test sequence are submitted with this report in Appendix F.

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5.5 PRESSURE TRANSDUCER AGING TEST

The CEC 1000 Pressure Transducer was subjected to the aging environments described in Appendix I. The specimen included the pressure transducer, mating connector and cable.

Log of key events is presented in Table 3.

TABLE 3

PRESSURE TRANSDUCER AGING LOG

| ACTIVITY | DATE |
|---|---|
| CEC Acceptance | 4/9/79 |
| Accelerated Life Environment | 8/3/79 |
| Radiation Exposure | 9/79 |
| Seismic Event | 10/79 |
| CEC Acceptance | 3/2/80 |

Maximum change in performance observed between the 3/2/80 and 4/9/79 acceptance tests was a zero shift of -.413% of Full Scale and was at 350°F.
A detailed description of the test and results is presented in Appendix I.

Testing with chemical spray was not conducted because all exposed surfaces are stainless steel and would therefore not be damaged by the chemical spray.

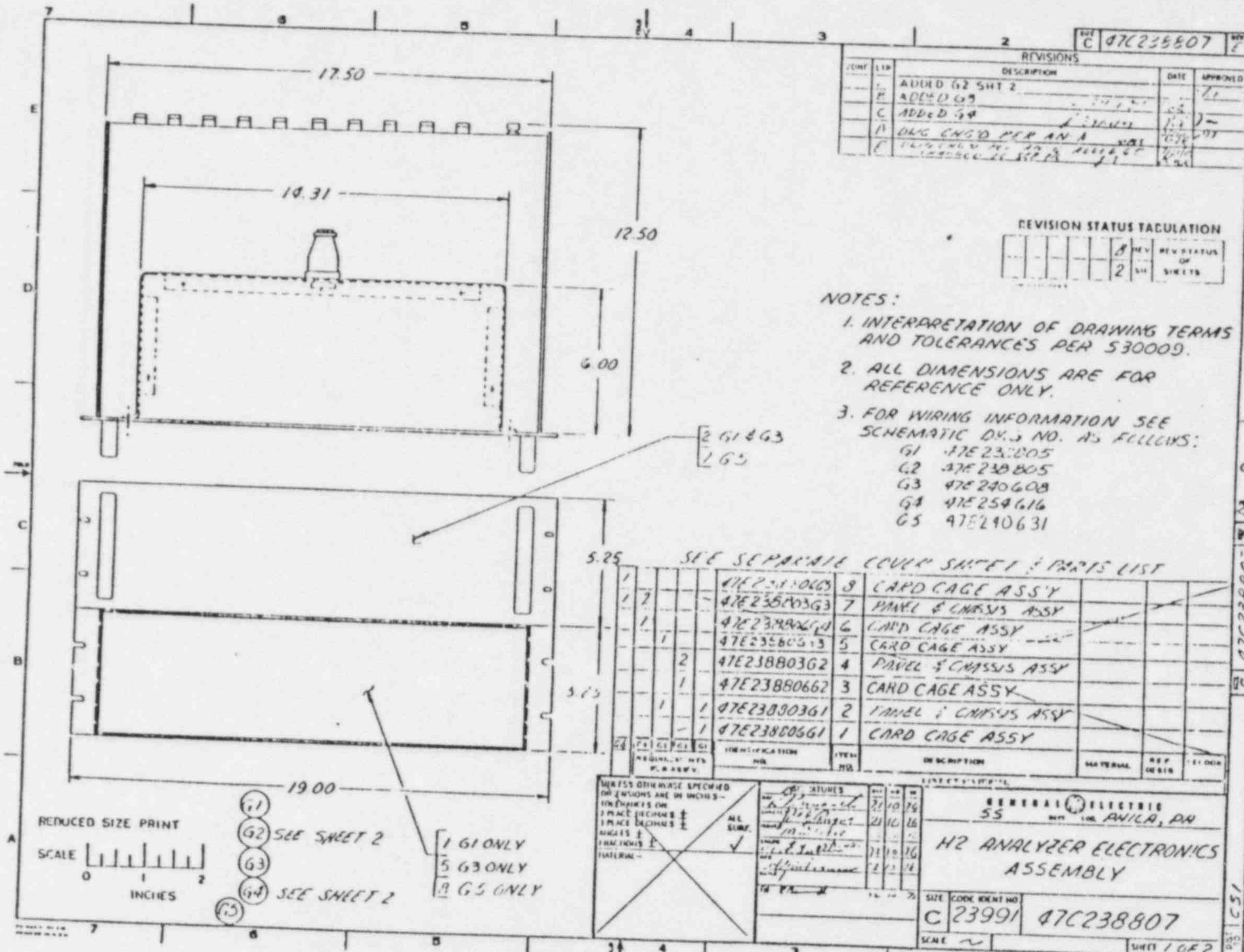


508-17-18-2

# APPENDIX A

## HYDROGEN ANALYZER DRAWINGS

47E226428; $H_2$ SENSOR ASSEMBLY
47C238807; ELECTRONICS AND READOUT/ALARM PANEL
47E240609; $H_2$ MONITORING SYSTEM
47E240610; $H_2$ SENSOR ASSEMBLY
47E240611; $H_2$ ANALYZER ASSEMBLY
47E240612; SCHEMATIC AND LOGIC DIAGRAM
47E226426; $H_2$ MONITTORING SYSTEM

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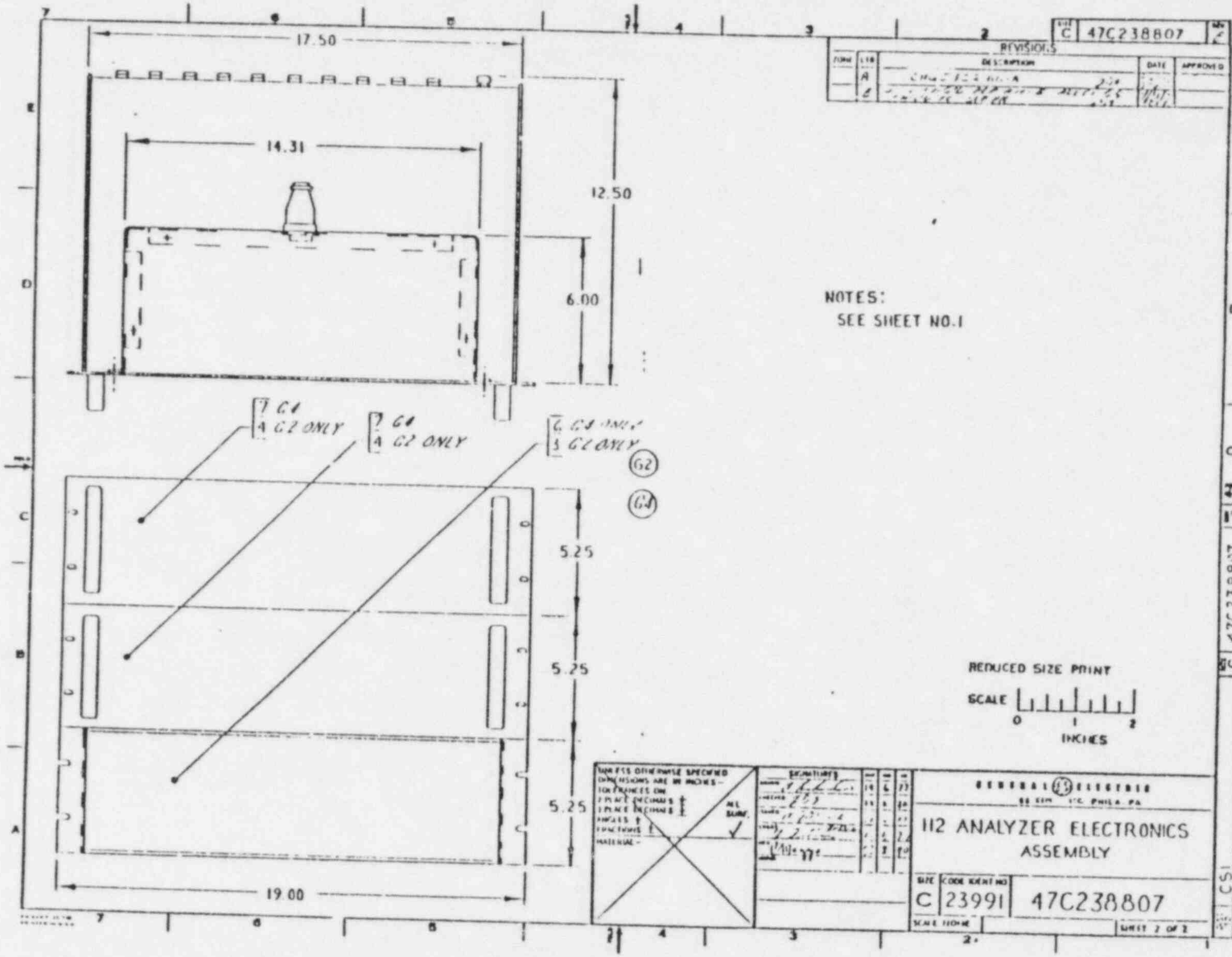

C 47C238807
REVISIONS
DESCRIPTION
DATE
APPROVED
17.50
14.31
12.50
6.00
7 G1
4 G2 ONLY
6 G1 ONLY
3 G2 ONLY
G2
G1
5.25
5.25
5.25
19.00
NOTES:
SEE SHEET NO.1
REDUCED SIZE PRINT
SCALE
0
1
2
INCHES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
GENERAL ELECTRIC
112 ANALYZER ELECTRONICS
ASSEMBLY
SIZE
CODE IDENT NO
C
23991
47C238807
SCALE NONE
SHEET 2 OF 2
C 47C238807

**GENERAL ELECTRIC**
SPACE SYSTEMS PHILA., PA.

| TITLE | COVER SHEET FOR | SH NO | REV |
|---|---|---|---|
| H2 ANALYZER ELECTRONICS ASSEMBLY | 47C238807 | 1 OF 1 | E |

## REVISION STATUS OF PARTS LIST GROUPS

| GRP | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| REV | | | | | | | | | | |
| AN'S | | | | | | | | | | |
| FIRST MADE FOR (NEXT ASSY) | | | | | | | | | | |

## REVISIONS

| LTR | DESCRIPTION | DATE |
|---|---|---|
| E | DWG CHG'D PER AN-B<br>CHG'D TO SEP P/L | 7/31/80<br>JCR |

## REVISION STATUS OF DRAWING SHEETS

| SH | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| REV | E | B | | | | | | | | |
| AN'S | -A<br>-B | -A<br>-B | | | | | | | | |

| MADE BY | ENGINEER | CONTRACT NO | CODE IDENT NO |
|---|---|---|---|
| LINKELSMITH | J FULLER | | 23991 |
| CHECKED | ISSUE/RELEASE: [illegible] 31 (DAY) 7 (MO) 80 (YR) | DIST TO: CSI | COVER SHEET FOR 47C238807 — SH NO 1 OF 1 — REV E |

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A-3

PARTS LIST

# GENERAL ELECTRIC SPACE DIVISION

| TITLE | FSCM NO | DATE | | REV | SH NO |
|---|---|---|---|---|---|
| H2 ANALYZER ELECTRONICS ASSY | 23991 | 7/31/80 | PL 47C238807G1 | | 1 |

| DISTRIBUTION CODE | CONTRACT NO | CPT CODE | CPT CODE-COMPLETE CODE | REV AUTH |
|---|---|---|---|---|
| CS1 | | | 1. GROUP COMPLETE<br>2. GROUP INCOMPLETE<br>3. ADVANCE ORDER LIST | |

| REF DES OR ITEM NO | SEQ NO | ZONE | IDENTIFICATION NUMBER | NOMENCLATURE | FSCM NO | QTY* | UNIT OF MEAS | LINE CHGD CODE |
|---|---|---|---|---|---|---|---|---|
| 1 | 00 | | 47E238806G1 | CARD CAGE ASSY | | 1 | EA | |
| 2 | 00 | | 47E238803G1 | PANEL & CHASSIS ASSY H2 ANALYZER ELECTRO | | 1 | | |
| 9 | 00 | | S30009 | DWG. TERMS | | X | | |

| | LINE CHANGED REVISION CODES | | REV | SH NO | CONT |
|---|---|---|---|---|---|
| | 1 ITEM ADDED<br>2 QTY CHGD<br>3. IDENT NO CHGD<br>4. IDENT NO. AND QTY CHGD<br>5. EDIT CORRECTION | PL 47C238807G1 | | 1 | - |

PARTS LIST

GENERAL ELECTRIC SPACE DIVISION

| TITLE | FSCM NO | DATE | | REV | SH NO |
|---|---|---|---|---|---|
| H2 ANALYZER ELECTRONICS ASSY | 23991 | 7/31/80 | PL 47C238807G2 | | 1 |

| DISTRIBUTION CODE | CONTRACT NO | CPT CODE | CPT CODE-COMPLETE CODE | REV AUTH |
|---|---|---|---|---|
| CS1 | | | 1. GROUP COMPLETE<br>2. GROUP INCOMPLETE<br>3. ADVANCE ORDER LIST | |

| REF DES OR ITEM NO | SEQ NO | ZONE | IDENTIFICATION NUMBER | NOMENCLATURE | FSCM NO | QTY | UNIT OF MEAS | LINE CHGD CODE |
|---|---|---|---|---|---|---|---|---|
| 3 | 00 | | 47E238806G2 | CARD CAGE ASSY | | 1 | EA | |
| 4 | 00 | | 47E238803G2 | CHASSIS ASSY | | 2 | EA | |
| 9 | 00 | | S30009 | DWG. TERMS | | X | | |

| LINE CHANGED REVISION CODES | | REV | SH NO | CONT |
|---|---|---|---|---|
| 1. ITEM ADDED<br>2. QTY CHGD<br>3. IDENT NO. CHGD<br>4. IDENT NO. AND QTY CHGD<br>5. EDIT CORRECTION | PL 47C238807G2 | | 1 | - |

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A-5

PARTS LIST

# GENERAL ELECTRIC — SPACE DIVISION

| TITLE | FSCM NO | DATE | PL | REV | SH NO |
|---|---|---|---|---|---|
| H2 ANALYZER ELECTRONICS ASSY | 23991 | 7/31/80 | 47C238807G3 | | 1 |

| DISTRIBUTION CODE | CONTRACT NO | CPT CODE | CPT CODE-COMPLETE CODE | REV AUTH |
|---|---|---|---|---|
| CS1 | | | 1. GROUP COMPLETE<br>2. GROUP INCOMPLETE<br>3. ADVANCE ORDER LIST | |

| REF DES OR ITEM NO | SEQ NO | ZONE | IDENTIFICATION NUMBER | NOMENCLATURE | FSCM NO | QTY | UNIT OF MEAS | LINE CHGD CODE |
|---|---|---|---|---|---|---|---|---|
| 2 | 00 | | 47E238803G1 | PANEL & CHASSIS ASSY H2 ANALYZER ELECTRO | | 1 | | |
| 5 | 00 | | 47E238806G3 | CARD CAGE ASSY | | 1 | EA | |
| 9 | 00 | | S30009 | DWG. TERMS | | X | | |

| LINE CHANGED REVISION CODES | PL | REV | SH NO | CONT |
|---|---|---|---|---|
| 1. ITEM ADDED<br>2. QTY CHGD<br>3. IDENT NO. CHGD<br>4. IDENT NO. AND QTY CHGD<br>5. EDIT CORRECTION | 47C238807G3 | | 1 | - |

PARTS LIST

GENERAL ELECTRIC — SPACE DIVISION

| TITLE | FSCM NO | DATE | | REV | SH NO |
|---|---|---|---|---|---|
| H2 ANALYZER ELECTRONICS ASSY | 23991 | 7/31/80 | PL 47C238807G4 | | 1 |

| DISTRIBUTION CODE | CONTRACT NO | CPT CODE | CPT CODE-COMPLETE CODE | REV AUTH |
|---|---|---|---|---|
| CS1 | | | 1. GROUP COMPLETE<br>2. GROUP INCOMPLETE<br>3. ADVANCE ORDER LIST | |

| REF DES OR ITEM NO | SEQ NO | ZONE | IDENTIFICATION NUMBER | NOMENCLATURE | FSCM NO | QTY | UNIT OF MEAS | LINE CHGD CODE |
|---|---|---|---|---|---|---|---|---|
| 6 | | | 47E238806G4 | CARD CAGE ASSY | | 1 | EA | |
| 7 | 00 | | 47E238803G3 | PANEL & CHASSIS ASSY H2 ANALYZER ELECTRO | | 2 | | |
| 9 | 00 | | S30009 | DWG. TERMS | | X | | |

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| LINE CHANGED REVISION CODES | | REV | SH NO | CONT |
|---|---|---|---|---|
| 1 ITEM ADDED<br>2 QTY CHGD<br>3. IDENT NO CHGD<br>4. IDENT NO. AND QTY CHGD<br>5. EDIT CORRECTION | PL 47C238807G4 | | 1 | - |

ARTS
IST

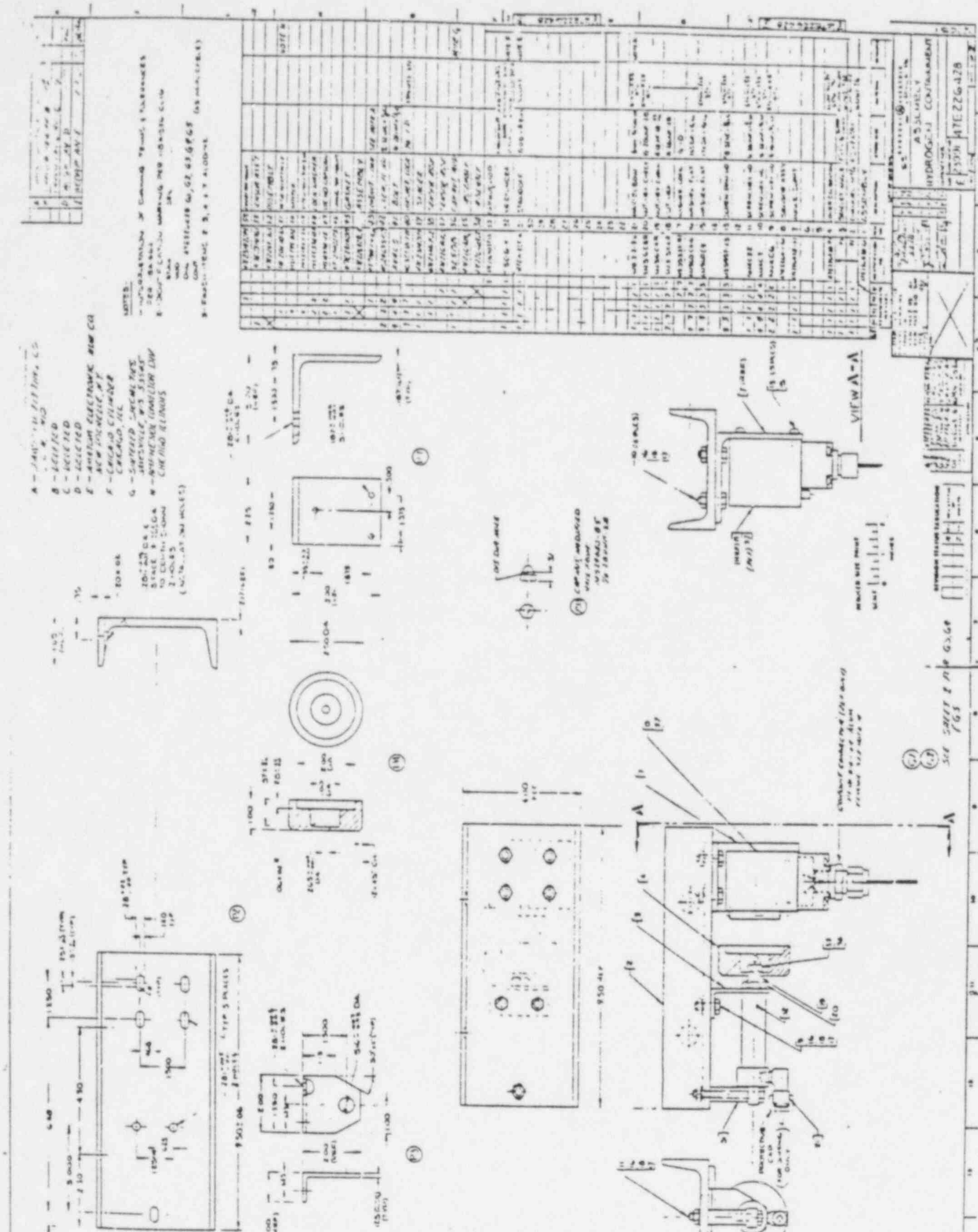
# GENERAL ELECTRIC SPACE DIVISION

| TITLE | FSCM NO | DATE | | REV | SH NO |
|---|---|---|---|---|---|
| H2 ANALYZER ELECTRONICS ASSY | 23991 | 7/31/80 | PL 47C238807G5 | | 1 |

| DISTRIBUTION CODE | CONTRACT NO | CPT CODE | CPT CODE-COMPLETE CODE | REV AUTH |
|---|---|---|---|---|
| CS1 | | | 1. GROUP COMPLETE<br>2. GROUP INCOMPLETE<br>3. ADVANCE ORDER LIST | |

| REF DES OR ITEM NO | SEQ NO | ZONE | IDENTIFICATION NUMBER | NOMENCLATURE | FSCM NO | QTY | UNIT OF MEAS | LINE CHGD CODE |
|---|---|---|---|---|---|---|---|---|
| 7 | 00 | | 47E238803G3 | PANEL & CHASSIS ASSY H2 ANALYZER ELECTRO | | 1 | | |
| 8 | 00 | | 47E238806G5 | CARD CAGE ASSY | | 1 | EA | |
| 9 | 00 | | S30009 | DWG, TERMS | | X | | |

| LINE CHANGED REVISION CODES | | REV | SH NO | CONT |
|---|---|---|---|---|
| 1. ITEM ADDED<br>2. QTY CHGD<br>3. IDENT NO CHGD<br>4. IDENT NO. AND QTY CHGD<br>5. EDIT CORRECTION | PL 47C238807G5 | | 1 | - |

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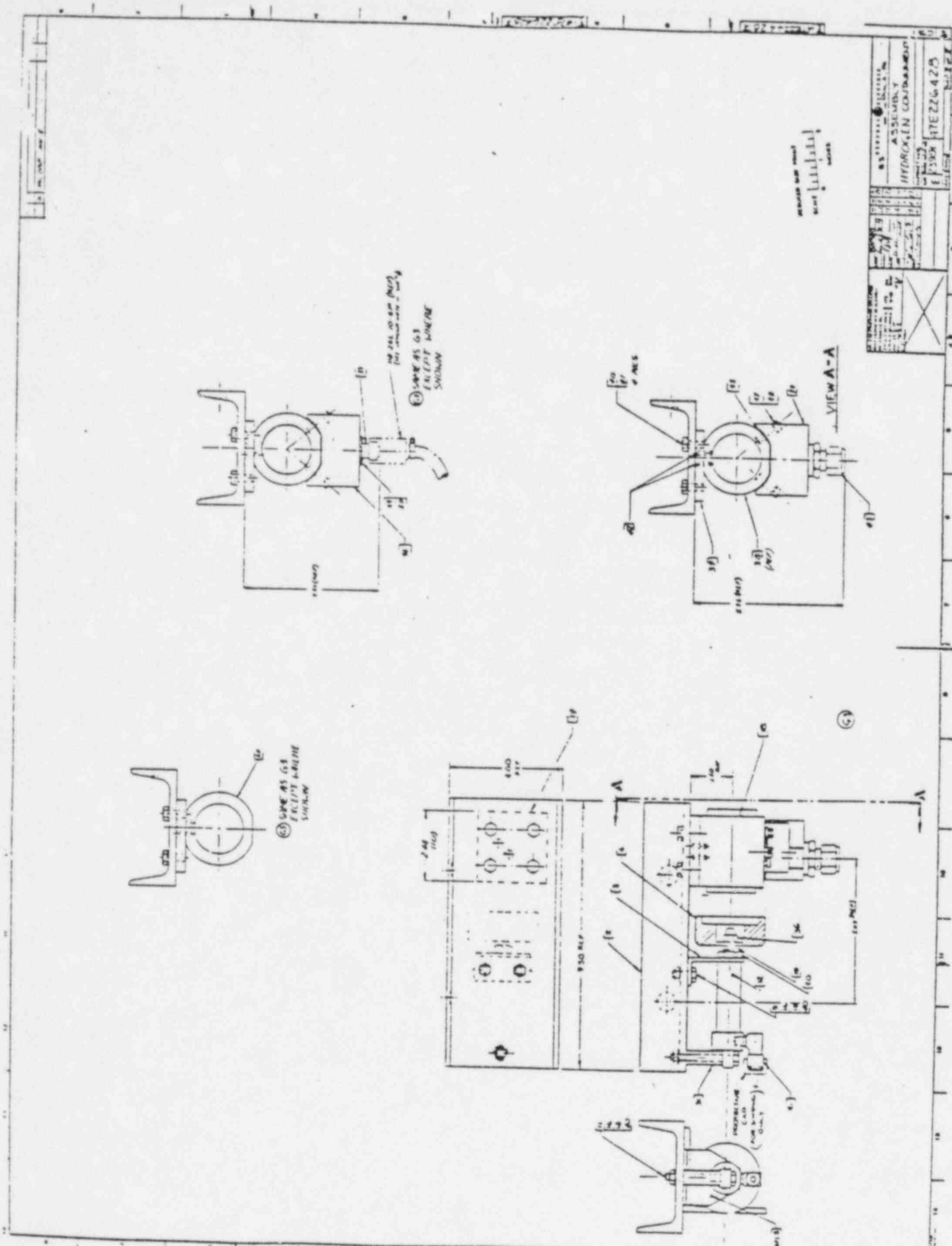
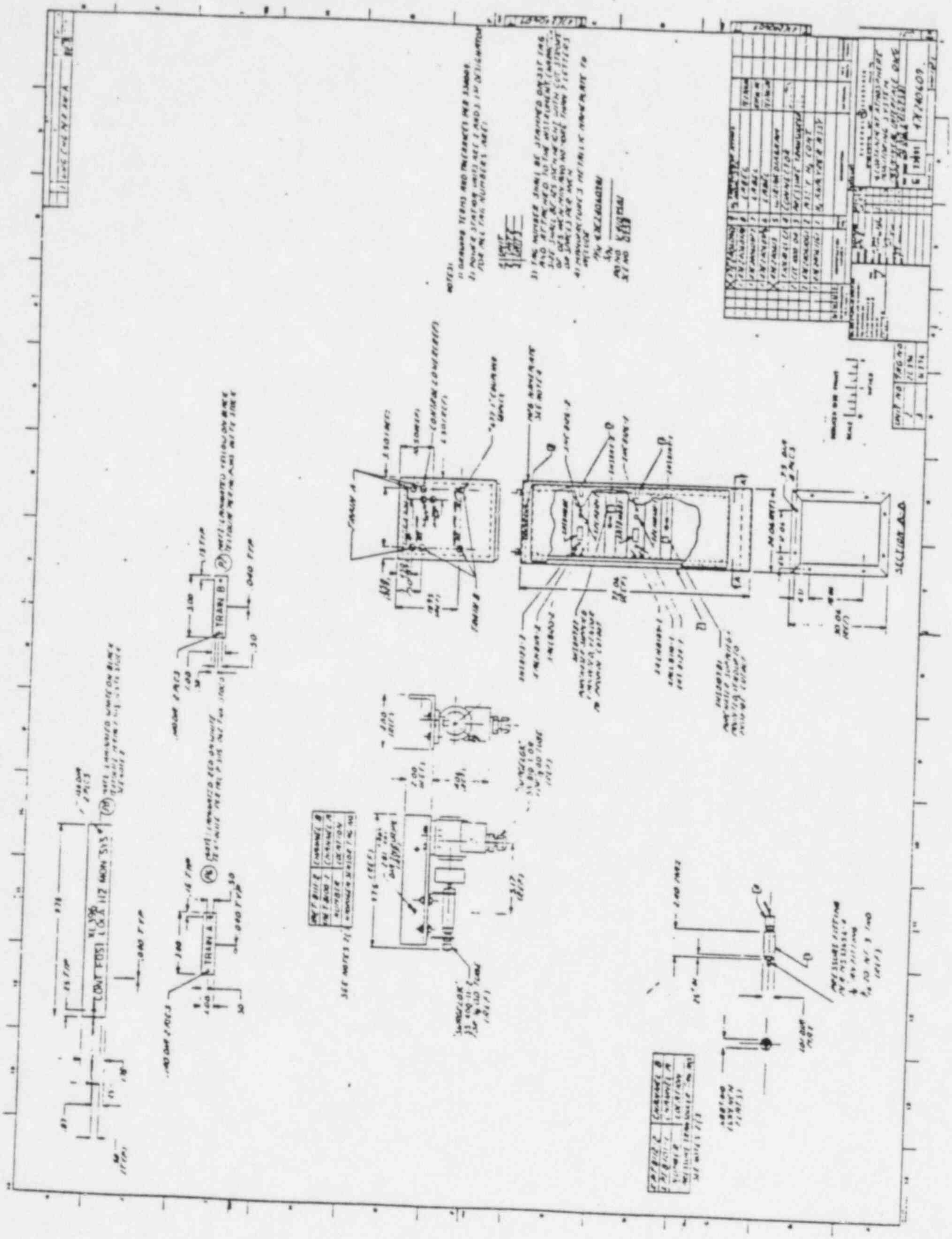

VIEW A-A
ASSEMBLY
SAME AS G3 EXCEPT WHERE SHOWN
SAME AS G3 EXCEPT WHERE SHOWN



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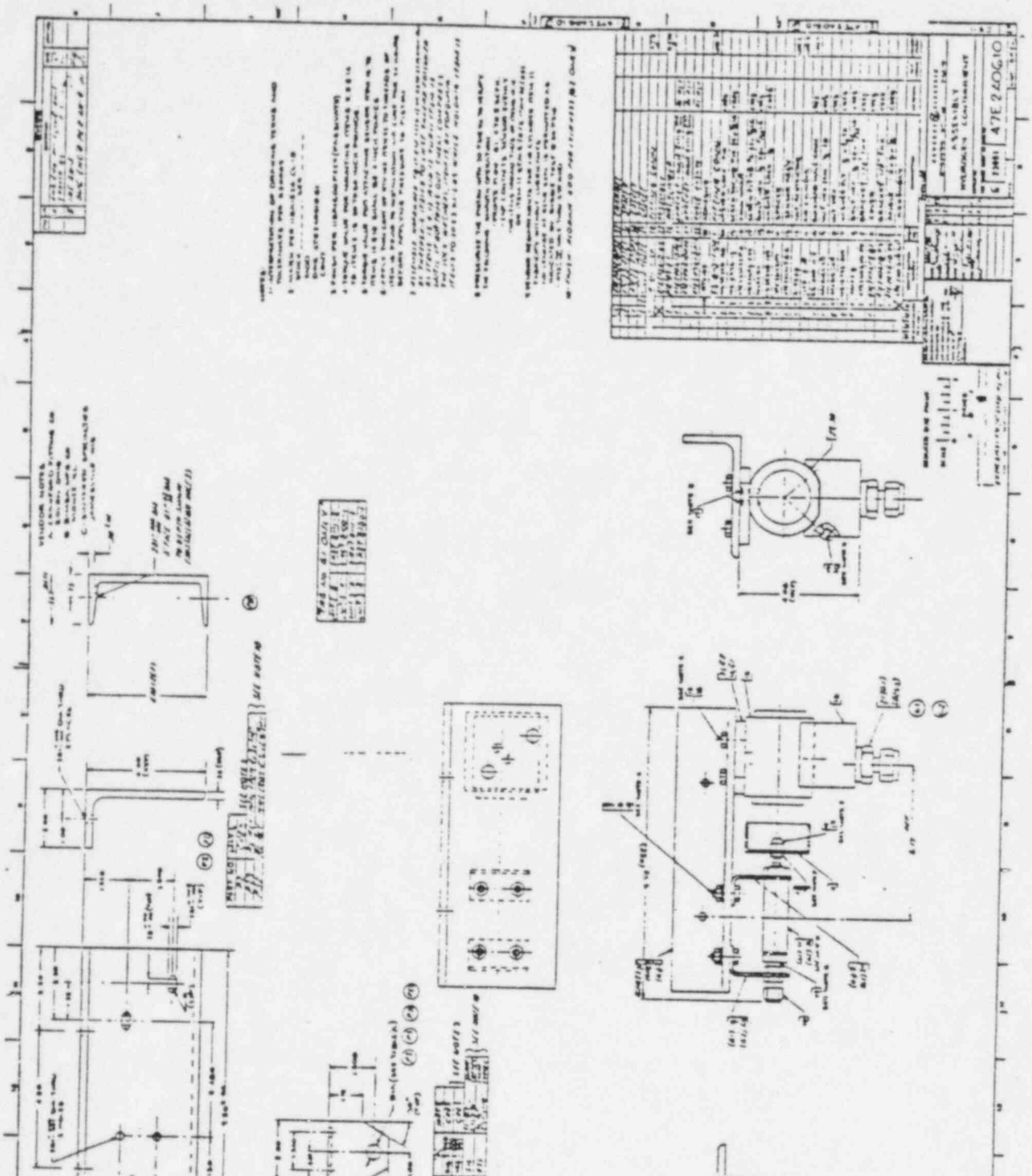

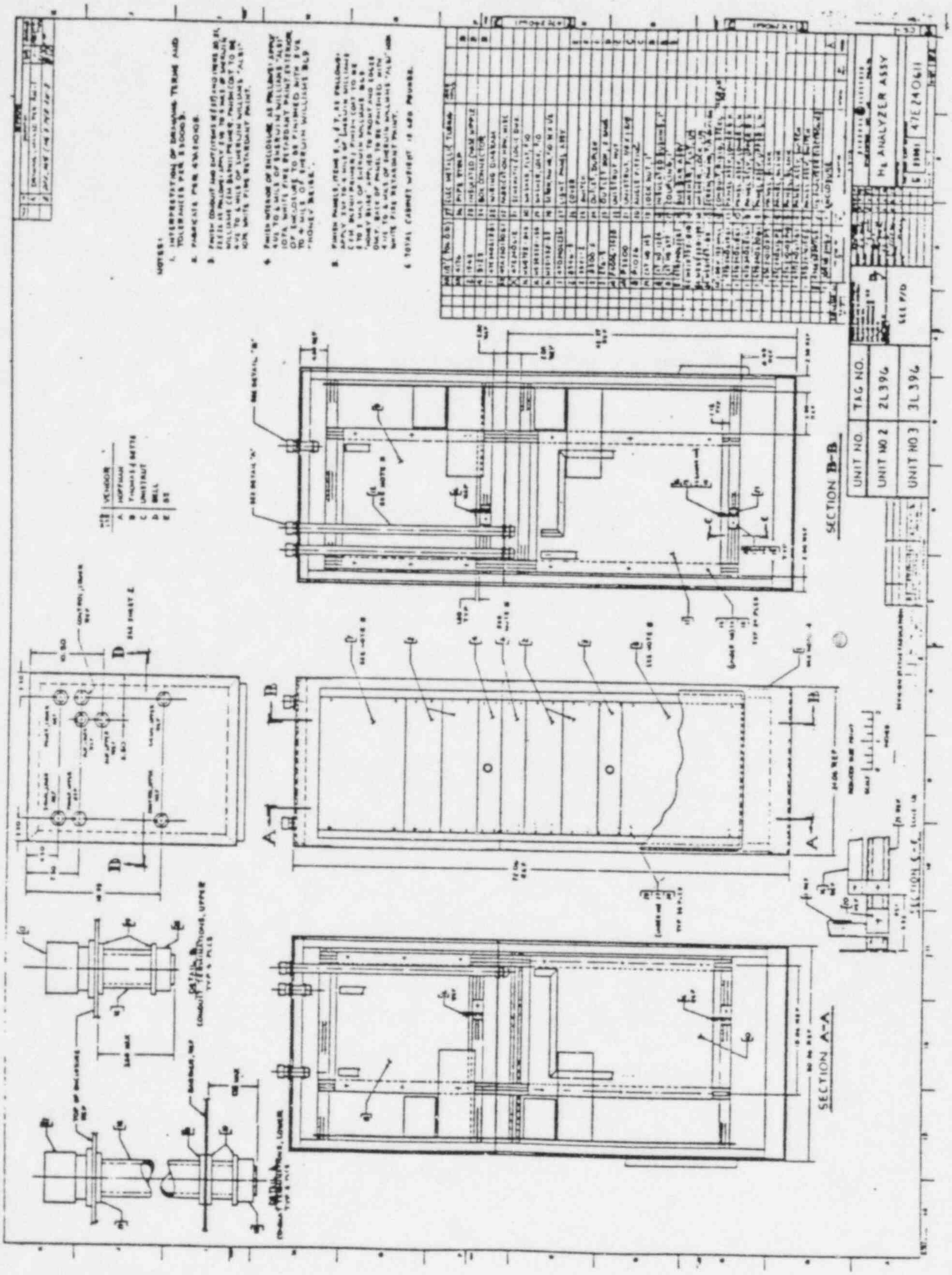


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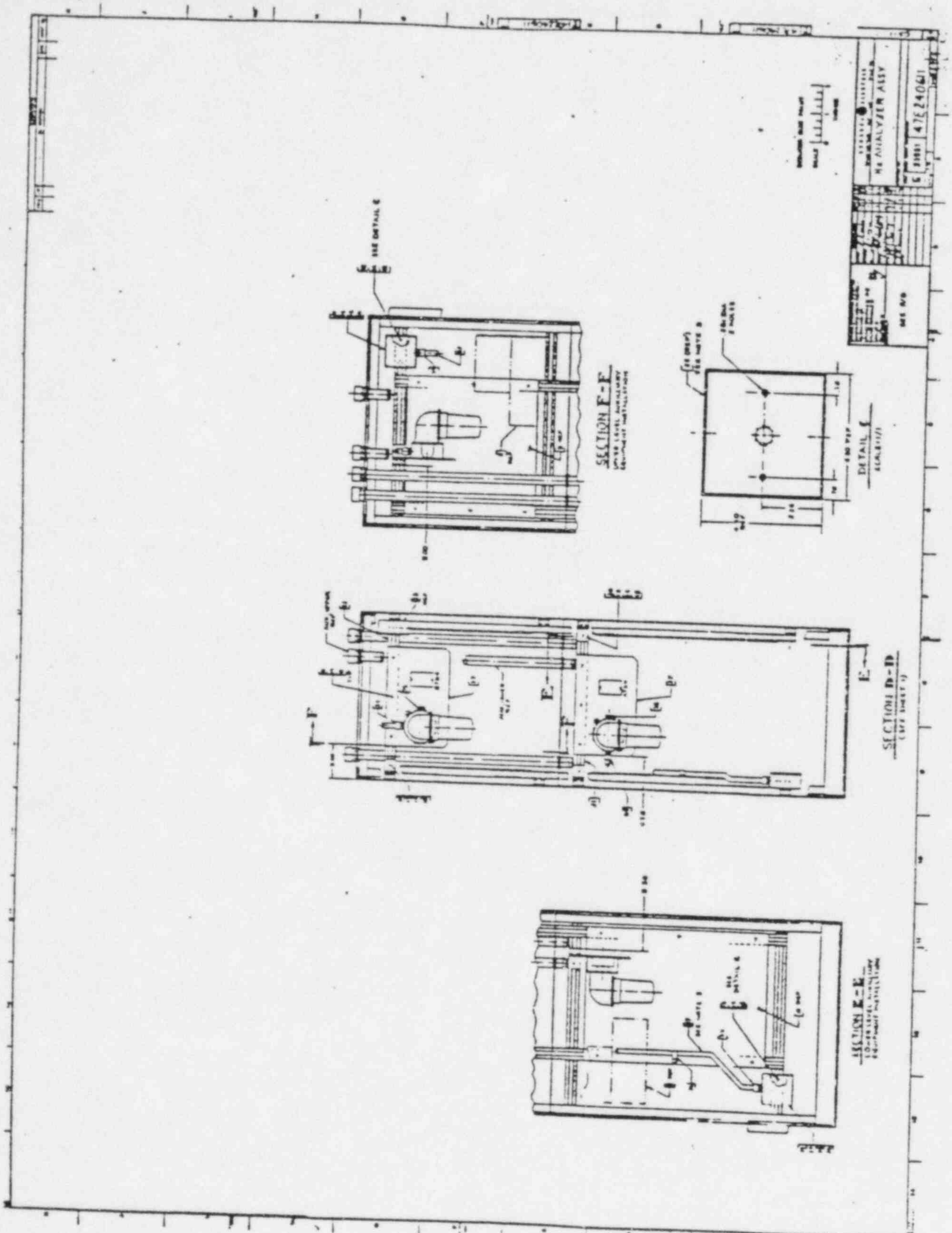
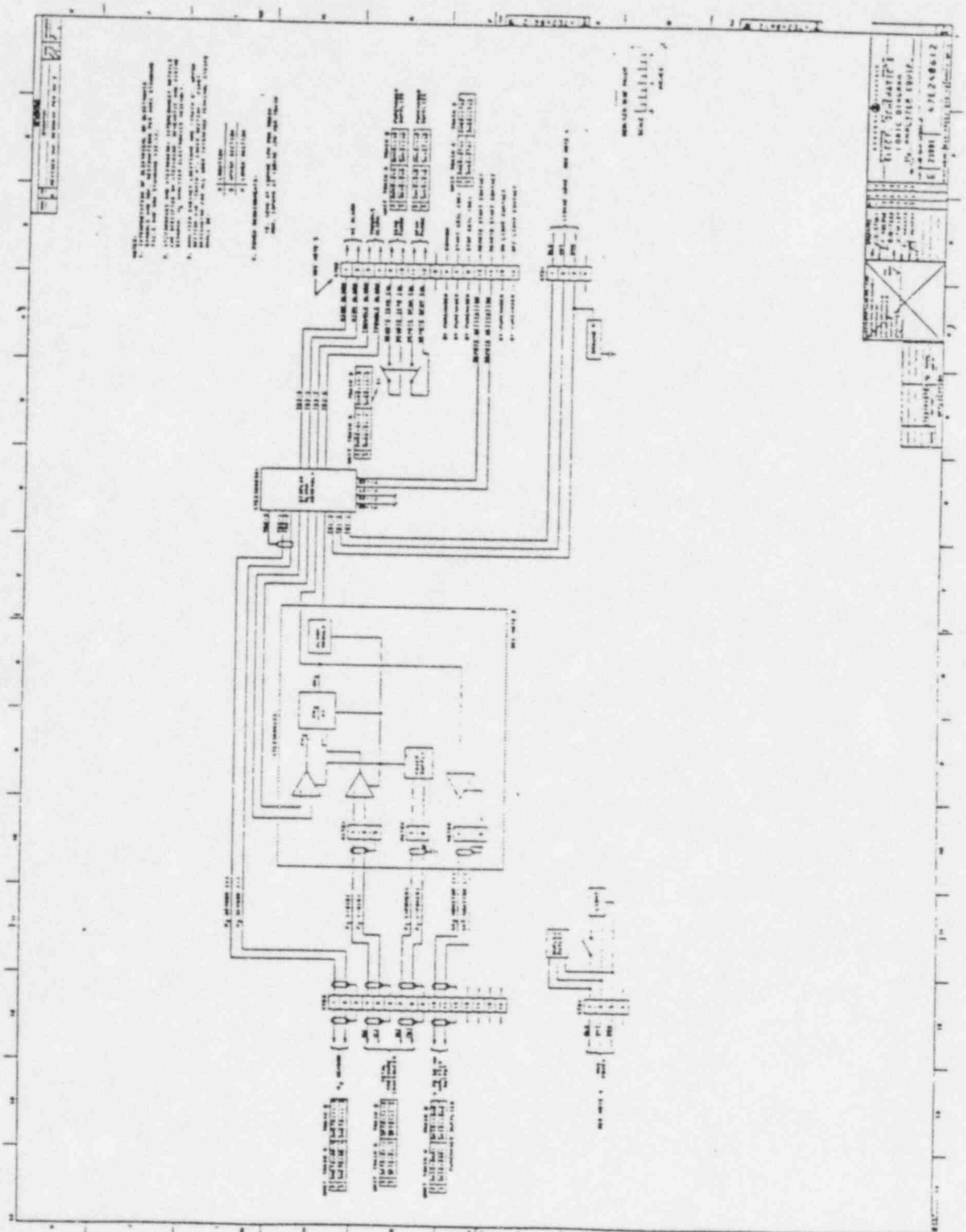
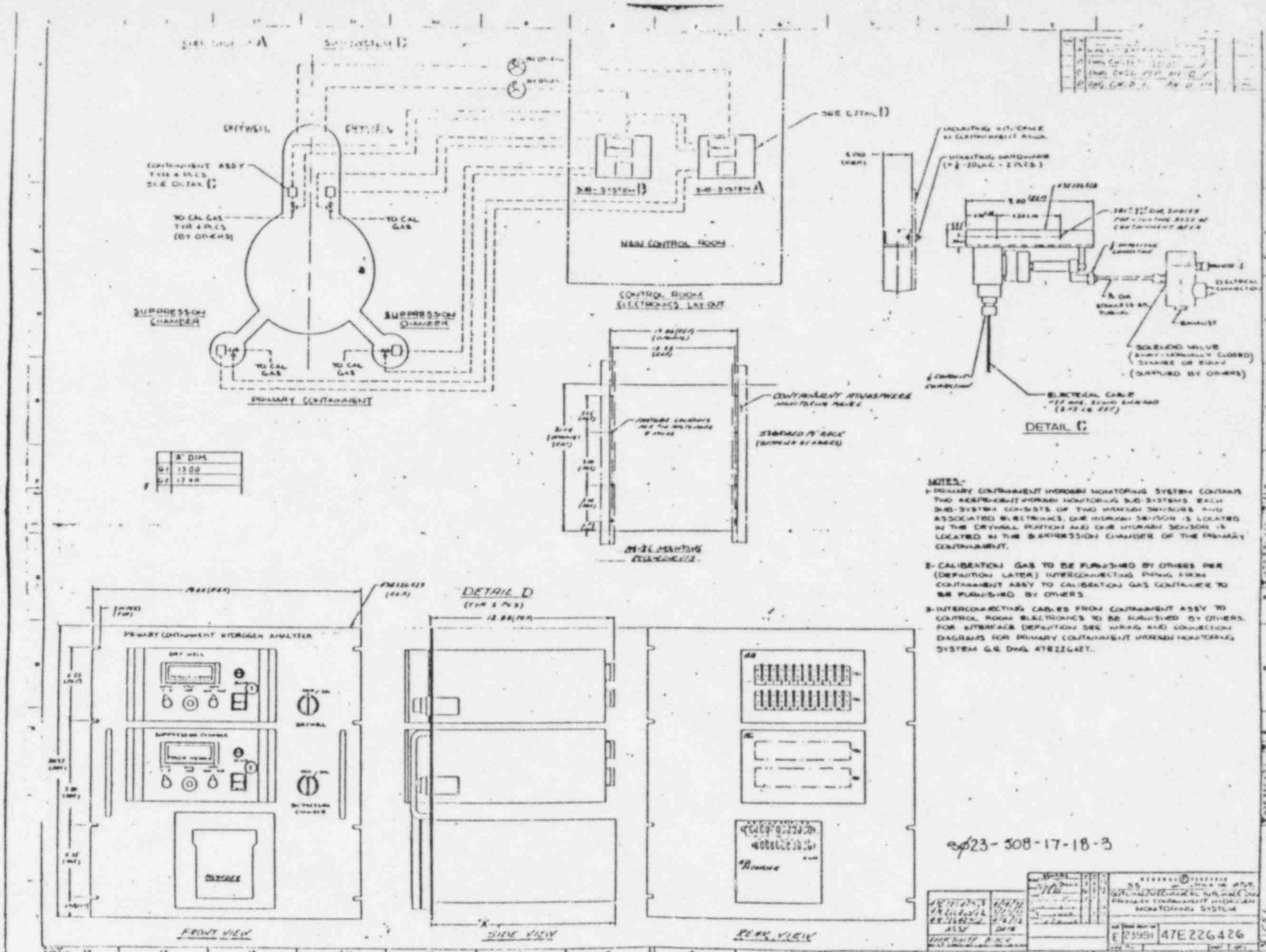


SECTION D-D
SECTION E-E
DETAIL E



SO23-508-17 18-0


SUB-SYSTEM A
SUB-SYSTEM B
DRYWELL
CONTAINMENT ASSY
TYP 4 PLCS
SEE DETAIL C
TO CAL GAS
TYP 4 PLCS
(BY OTHERS)
TO CAL GAS
SUPPRESSION CHAMBER
SUPPRESSION CHAMBER
TO CAL GAS
TO CAL GAS
PRIMARY CONTAINMENT
SEE DETAIL D
SUB-SYSTEM B
SUB-SYSTEM A
MAIN CONTROL ROOM
CONTROL ROOM ELECTRONICS LAY-OUT
CONTAINMENT ATMOSPHERE MONITORING PANEL
STANDARD 19" RACK
DETAIL C
SOLENOID VALVE
(SUPPLIED BY OTHERS)
ELECTRICAL CABLE
EXHAUST
"A" DIM
13.00
17.40
NOTES:-
1-PRIMARY CONTAINMENT HYDROGEN MONITORING SYSTEM CONTAINS TWO INDEPENDENT HYDROGEN MONITORING SUB-SYSTEMS. EACH SUB-SYSTEM CONSISTS OF TWO HYDROGEN SENSORS AND ASSOCIATED ELECTRONICS. ONE HYDROGEN SENSOR IS LOCATED IN THE DRYWELL PORTION AND ONE HYDROGEN SENSOR IS LOCATED IN THE SUPPRESSION CHAMBER OF THE PRIMARY CONTAINMENT.
2-CALIBRATION GAS TO BE FURNISHED BY OTHERS PER (DEFINITION LATER) INTERCONNECTING PIPING FROM CONTAINMENT ASSY TO CALIBRATION GAS CONTAINER TO BE FURNISHED BY OTHERS.
3-INTERCONNECTING CABLES FROM CONTAINMENT ASSY TO CONTROL ROOM ELECTRONICS TO BE FURNISHED BY OTHERS. FOR INTERFACE DEFINITION SEE WIRING AND CONNECTION DIAGRAMS FOR PRIMARY CONTAINMENT HYDROGEN MONITORING SYSTEM G.E. DWG. 47E226427.
DETAIL D
PRIMARY CONTAINMENT HYDROGEN ANALYZER
DRY WELL
DRYWELL
SUPPRESSION CHAMBER
FRONT VIEW
SIDE VIEW
REAR VIEW
8023-308-17-18-3
PRIMARY CONTAINMENT HYDROGEN MONITORING SYSTEM
E 23991 47E226426