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Large-Scale Pressurizable Fire Test Facility—Fire I

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The Naval Research Laboratory has constructed a 324 m^3 pressurizable fire test facility. The chamber, equipped with multiports for electrical and gas feed-throughs and viewing, is pressurizable to over 6 atmospheres. Class A, B, and C fire tests can be conducted with real-time data collection, manipulation, graphical display, and mass storage. Continuous monitoring of CO, CO_2, O_2, HCN, and HBr is accomplished spectroscopically. Mass burning rates are followed through continuous weighing techniques. Smoke particles are monitored with laser and light scattering techniques. The chamber is also equipped with a nitrogen pressurization system for fire suppression.

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LARGE-SCALE PRESSURIZABLE FIRE TEST FACILITY—FIRE I

INTRODUCTION

The Naval Research Laboratory (NRL) maintains two pressurizable fire test chambers, 0.27 m^3 (9.5 ft^3) [1] and 5 m^3 (177 ft^3) [2]. In addition, a one-sixth scale model of the 5 m^3 chamber is maintained at the University of Washington, Seattle, under Professor R. C. Corlett [3]. These chambers support studies concerning the effects of confinement on fire but are not limited to this use. The sizing of the chambers traditionally was from small to large due to costs and lack of support for large-scale experiments. As time passed it became obvious that there was little apparent relation between small- and large-scale experiments. This then necessitated the development of scaling laws if one were to predict from small inexpensive tests the outcome of full-scale actual fire situations. For this purpose a large pressurizable chamber was proposed.

The chamber's atmospheric conditions would be variable, allowing the simulation of various starting atmospheric conditions and pressures as could be experienced below decks in a ship, submarine, undersea laboratory, aircraft cabin, or in space.

In the spring of 1979 onsite assembly of a 324 m^3 (11,640 ft^3) chamber was started along with assembly of its associated support equipment. This was done after it was determined that a suitable facility did not exist [4].

CHAMBER AND ASSOCIATED HARDWARE

Various manufacturers of large pressure vessels were contacted to determine if a standard vessel existed that would meet the general requirements of NRL; however, such a vessel was not available because of size and internal pressure requirements. This meant that a chamber would have to be manufactured. The chamber was designed primarily as a mechanical device; however, many electrical feed-throughs were incorporated to provide power-assisted operations and automatic control functions for pressurization, venting, and pressure relief. Proposed instrumentation would record temperature, pressure, and mixing rates. A fixed gas suppression system in the form of a pressurization system was designed capable of charging the vessel to 2 atm with nitrogen within 10 s to decrease the oxygen concentration to 10.5%. Special bottles, manifolds, and nozzles for the suppression system would have to operate at more than 102 atm.

A site was selected adjacent to NRL Building 112 that provides railroad and motorized vehicles access; in addition, it was centrally located within the NRL fire test complex to facilitate multiuse of test equipment.

To support the vessel, NRL's Public Works Division was awarded a task to provide piers. Because of loading requirements, two massive steel reinforced concrete foundations were required with each being 0.91 m (3 ft) high, 2.10 m (7 ft) wide, and 4.88 m (16 ft) long located below the frost line. Steel reinforced rods tie the 0.91 m long concrete saddles to the foundation. A rubber matting in the saddle radiuses provides a flexible base for the completed vessel. After installation of the vessel, metal shields were welded to restrict water flow into the saddle area; thereby, reducing problems during freezing temperatures.

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Youngstown Steel Tank Company of Youngstown, Ohio was selected as the prime contractor to manufacture the vessel in the fall of 1978 with delivery in early January 1979 under Contract Number N00173-78-C-0300. Figure 1 is the blueprint. Youngstown Steel Tank shipped the unassembled vessel to NRL in sections (Fig. 2(a)) and awarded a subcontract to Prairie Tank and Construction Company of Plainfield, Illinois to assemble (Fig. 2(b)), pressure test, and paint the completed vessel (Fig. 2(c)). In early May 1979, NRL accepted the vessel.

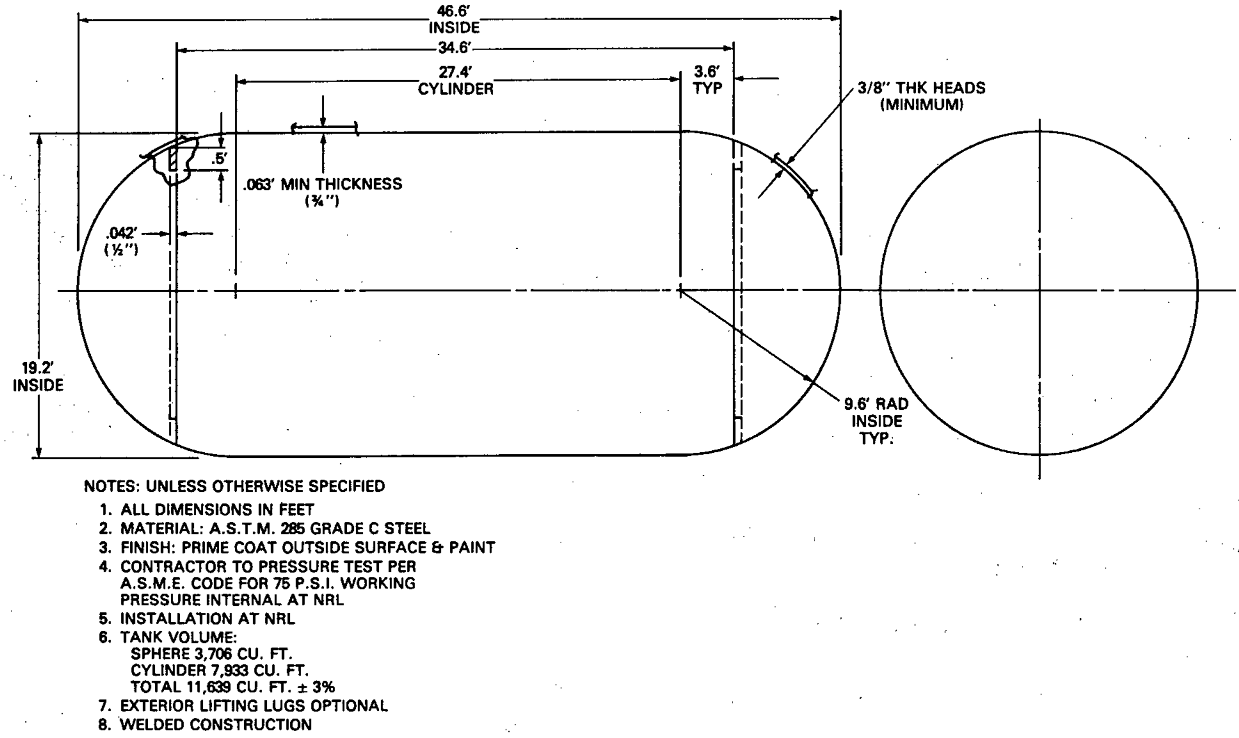


Fig. 1 — Blueprint drawing of 324 m^3 chamber

The general design of the pressure vessel had a length over diameter (L over D) ratio to scale the 5 m^3 chamber and was constructed in accordance with ASME Code, Section VII, Division 1, with National Board stamping. A design pressure of 618 kPa (89.7 psia) at 232°C (450°F) was required with the hydrostatic test pressure set at 877 kPa (127.2 psia). Spot x-ray radiograph inspection was conducted to determine joint efficiency with a requirement of greater than 85% weld penetration. The vessel has an internal diameter of 5.85 m (19 ft 2.375 in.) and an internal length of 14.8 m (48 ft 7.25 in.). The hemispherical heads and walls are manufactured with 0.95 cm (0.375 in.) thick steel per SA 285C. A calculated empty weight of 32,100 kg (70,785 lb) with a volume of 324 m^3 (11,640 ft^3) was expected (Fig. 2(c)).

After completion of the final welding and prior to the hydrostatic pressure test, four flanges were added to the vessel with two 1.14 MPa (150 psig), 15.3 cm (6 in.) raised face flanges located at the top and a single 1.14 MPa, 15.3 cm raised face flange at the bottom for draining purposes; in addition, one end of a hemispherical section has a 45.7 cm (18 in.) manway flange installed to provide access during final welding. Upon completion of all welding and spot X-ray operations, the vessel was filled with water with a calculated weight of 359,843 kg (793,454 lb) for hydrostatic pressure testing. After a satisfactory pressure test, a flowmeter was installed in the lower drain flange to measure volume flow prior to draining. A volume of 324 m^3 at ambient temperature (293°K) and atmospheric pressure was measured. A final exterior surface coating of L5962B Gray Primer and two coats of L7530 white exterior enamel manufactured by the Mahoning Paint Corporation was applied (Fig. 2(c)).

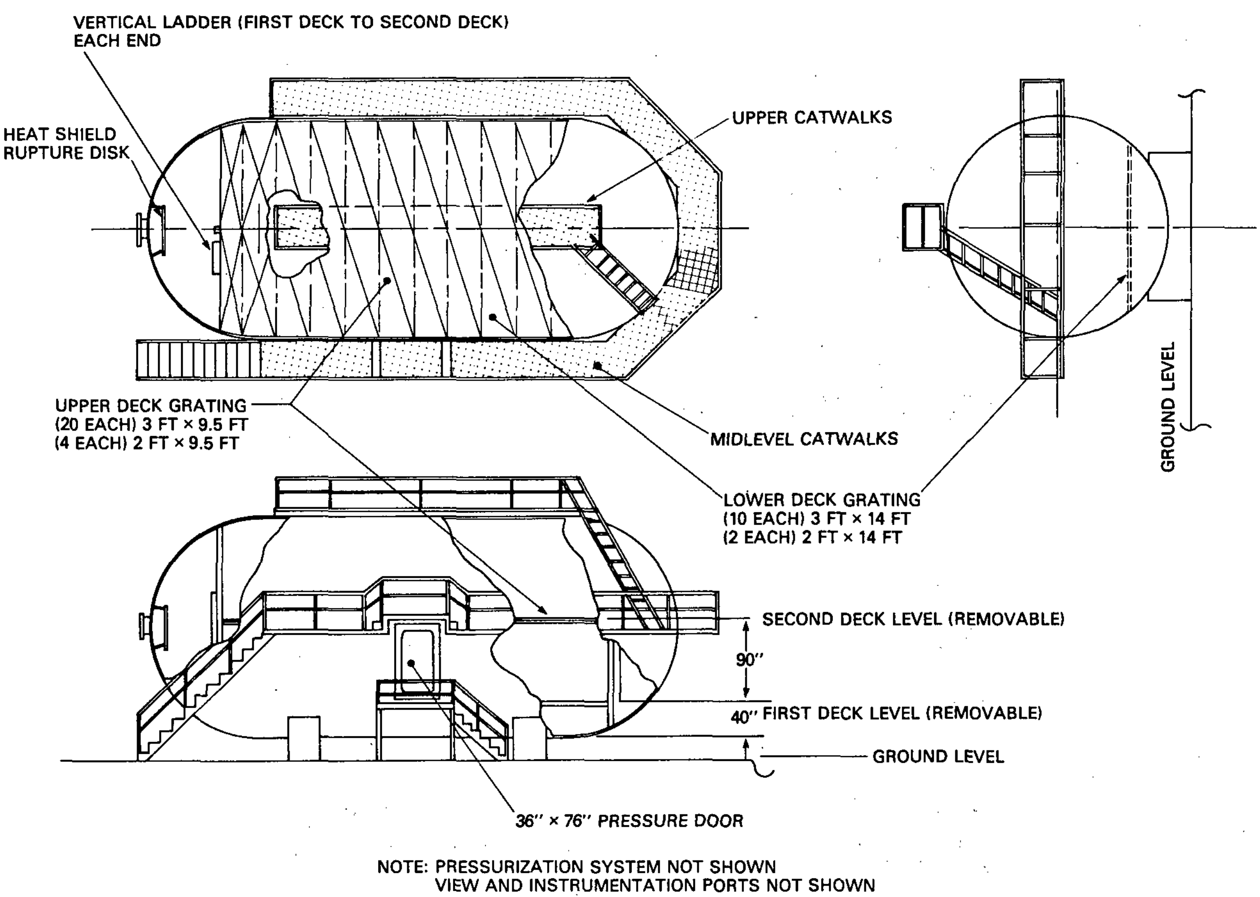
Fig. 2(a) — Performed parts as shipped to NRL

Fig. 2(b) — Assembly of the chamber by Prairie Tank and Construction Company

Fig. 2(c) — Chamber as delivered to NRL

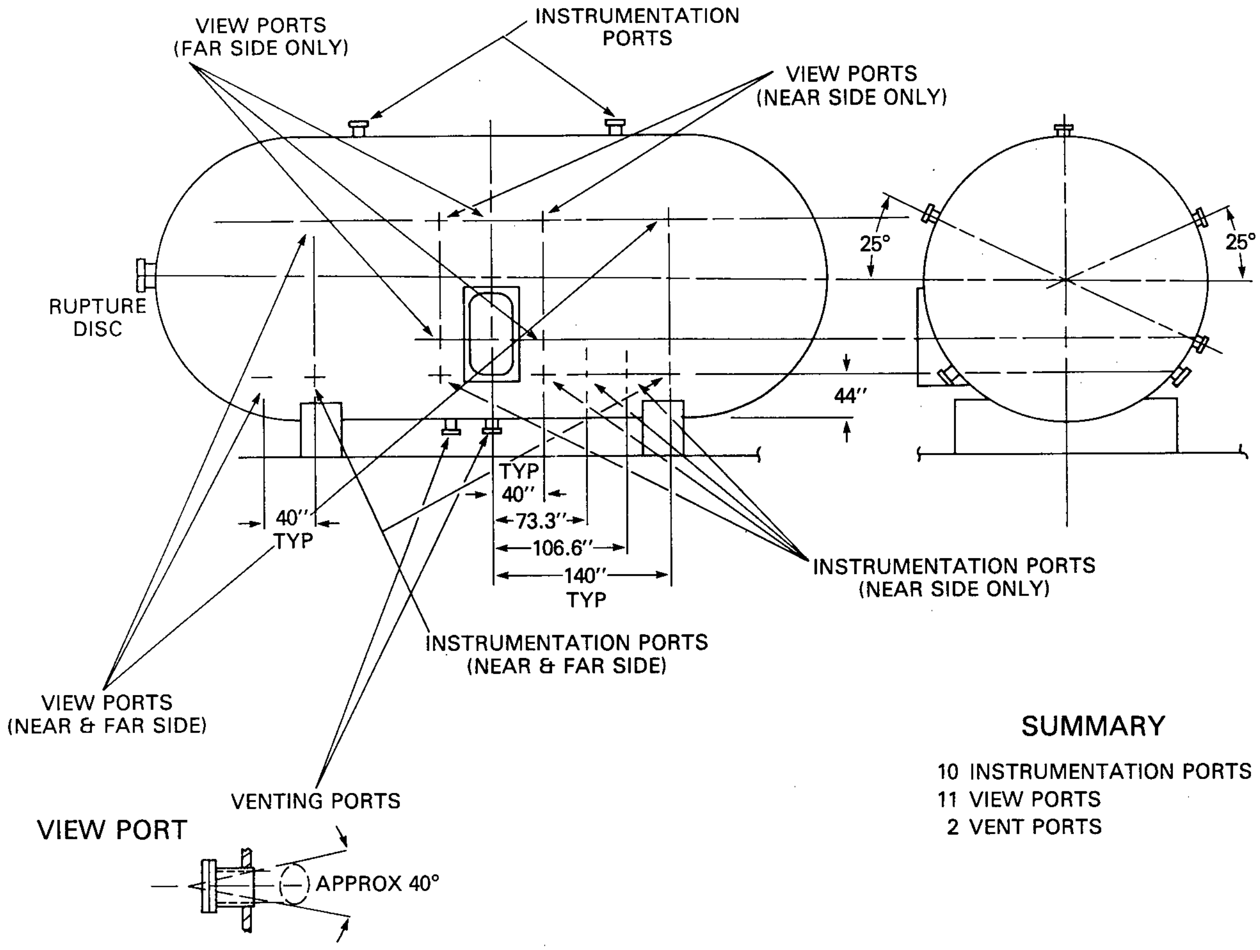
NRL's Engineering Services Division (ESD) extensively modified the chamber (Fig. 3). ESD made access to the vessel by the installation of a 0.91 m (36 in.) wide by 1.93 m (76 in.) pressure rated door, 618 kPa (89.7 psia) (Fig. 4(a)). This basic 8-dogged door was purchased from Julius Mock & Sons Incorporated of Brooklyn, New York and its frame made by NRL. As a safety feature a 5.1 cm (2 in.) gate valve was added to the door for internal venting. Other safety features include the installation of a rupture disc assembly rated 618 kPa and a temperature limitation of 260°C (500°F) on the hemispherical end of the vessel (Fig. 4(b)). This item utilized holder number FA-7R 45.7 cm (18 in.) and rupture disc 0.48 cm (0.19 in.) thick CRES PLD with Teflon seals on the atmospheric side. The manufacturer is BS&B Safety Systems of Tulsa, Oklahoma.

Venting can be accomplished through the use of two 30.5 cm (12 in.) flanged end Walworth ball valves with gear activators located on the top of the vessel (Fig. 4(a)). To expedite venting, two Fan-Blowers Type KS 803, Series 894AS, Flow R; manufactured by ROTRON Incorporated provide the necessary circulation to clear smoke, dust, and gases from the chamber. Located at the bottom of the vessel is a 7.6 cm (3 in.) Jamesbury Ball Valve D22TT in series with a 7.6 cm Atkomatic Solenoid Valve No. 31590 which provides remote operation of the vent system (Fig. 3(b)). Additional safety features include an electric grounding system that employs two 2.44 m (8 ft) ground rods embedded into the ground and brazed to the vessel. A continuous number 4 AWG copper wire ties the rods together along with ties to the instrumentation trailer and the electric service ground.

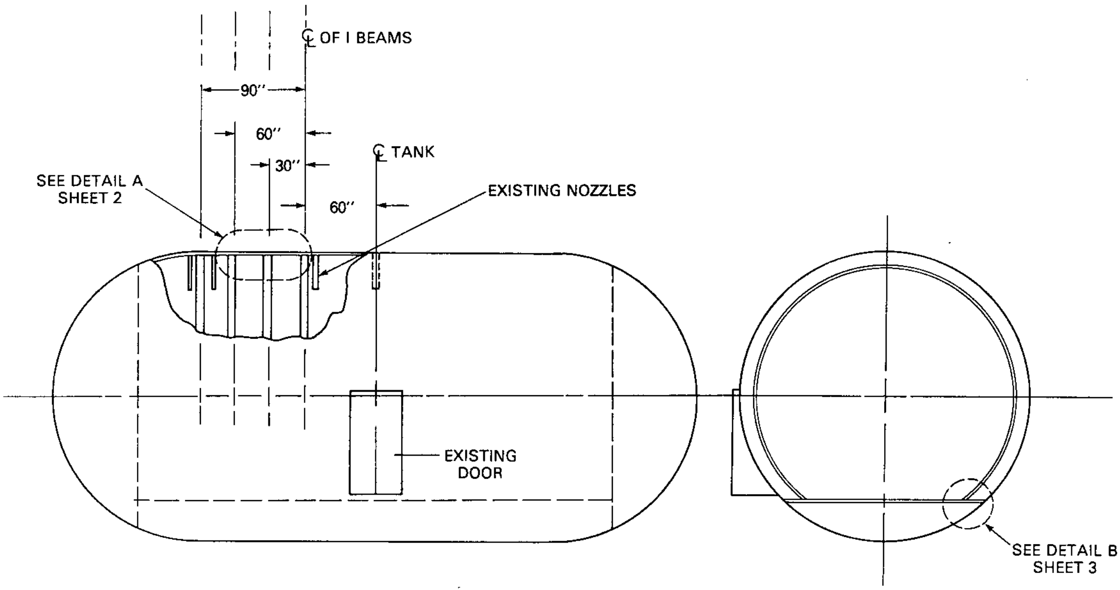


(a) Decking added to the chamber along with access hatch

Fig. 3 — Blueprint drawings of ESD-modified 324 m^3 chamber

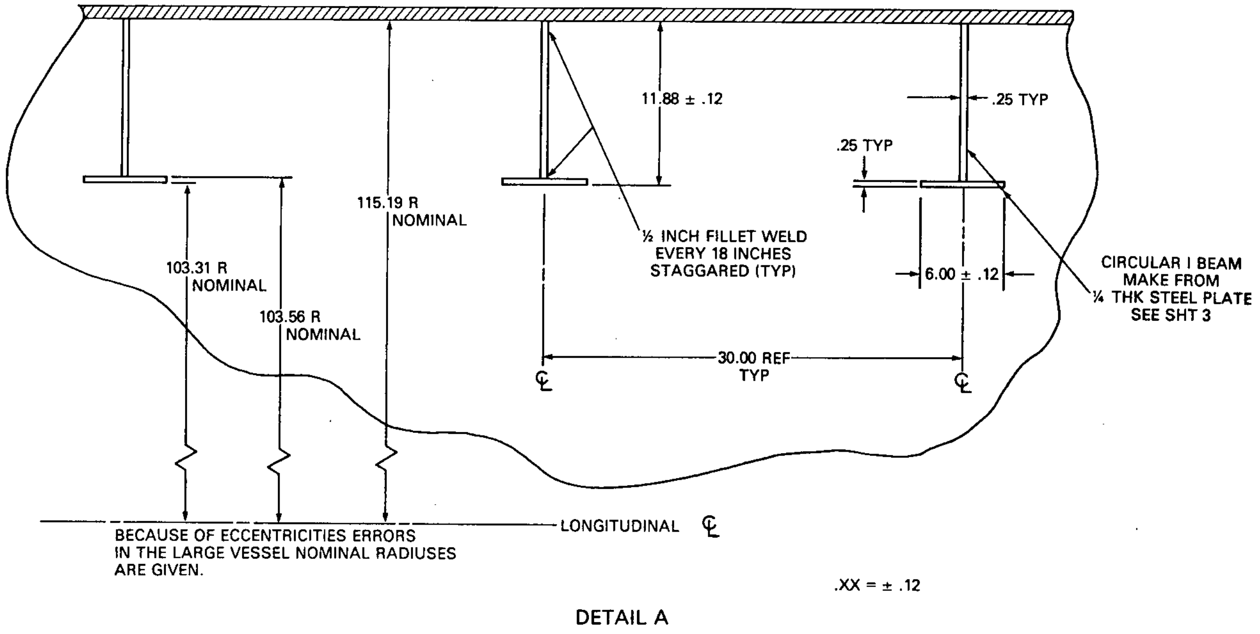


(b) View and instrumentation ports

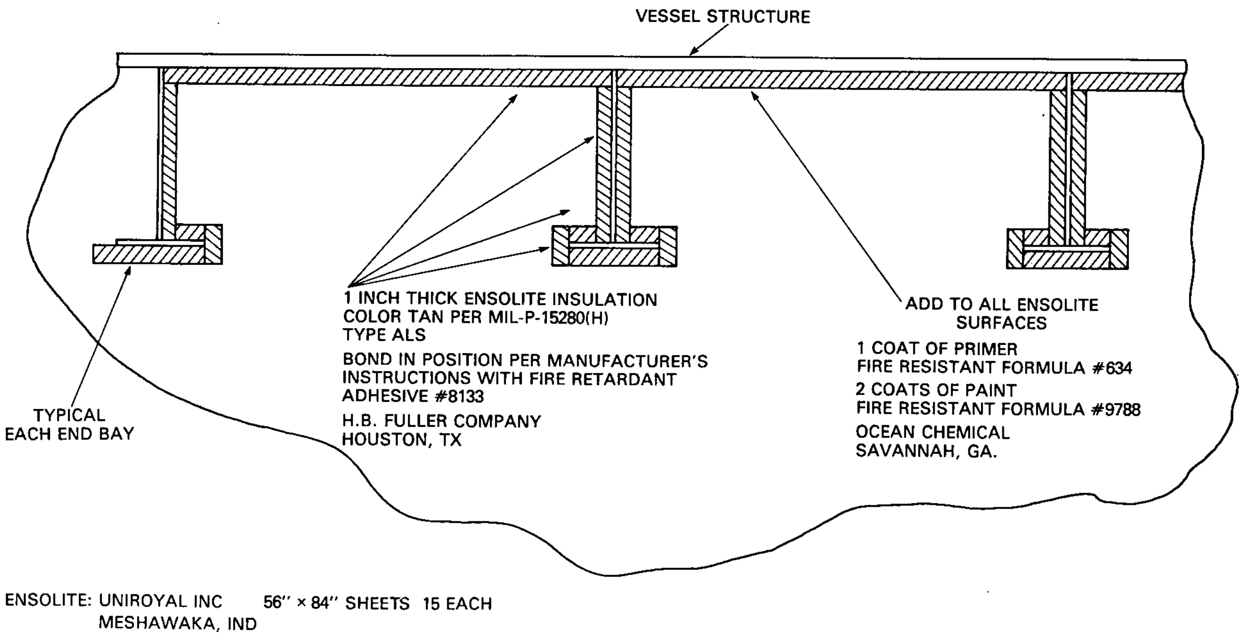


(c) Frame bay location inside the chamber

Fig. 3 (Continued) — Blueprint drawings of ESD-modified 324 m^3 chamber

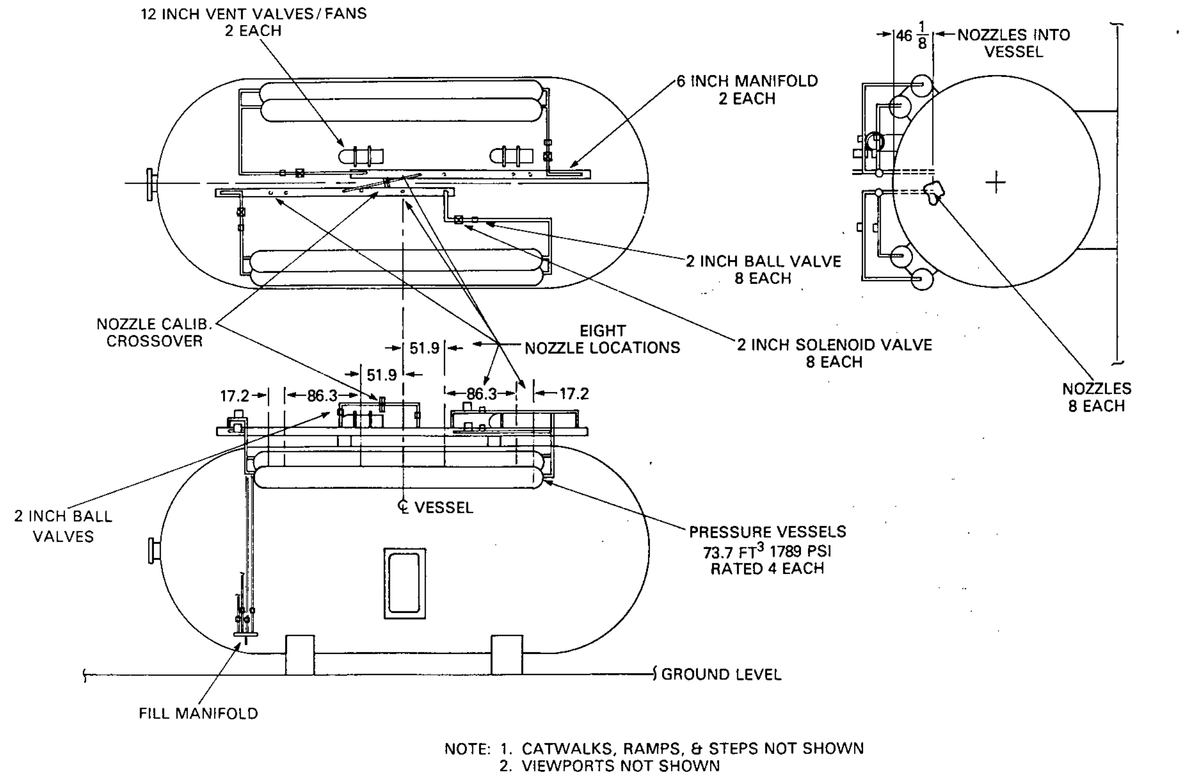


(d) Frame detail inside the chamber



(e) Typical installation of insulation in the frame bay and in the frames

Fig. 3 (Continued) — Blueprint drawings of ESD-modified 324 m^3 chamber



(f) Gas pressurization system for chamber

Fig. 3 (Continued) — Blueprint drawings of ESD-modified 324 m^3 chamber

To provide visual observation during tests, initially eight view ports were added and capable of temperatures of 260°C (500°F) and pressures to 877 kPa (127.2 psia). The windows are a flat borosilicate glass. These sight ports were purchased from Eugene Earnest of Farmingdale, New York, model EEP W5000 with a visible area of 16.5 cm (6.5 in.) diameter. Two additional view ports were added in August 1981 (Fig. 3(b)). Additional ports were added to provide instrumentation feed-throughs for electric sensing and pressure measurements within the vessel (Fig. 3(b)). Instrumentation lines are located in a duct system that surrounds the pressure vessel with lead-in to the instrumentation trailer. The duct is divided into two parts, one half for the power and the other for low-level dc signal (Fig. 4). Figure 4 illustrates the various catwalks that provide access to view ports and the top of the vessel.

The interior configuration has been designed to provide end baffle rings welded to the interior hemispherical sections. These rings provide the necessary support for tests requiring a cylindrical section of greater than 5.80 m (19 ft) diameter and a length of greater than 10.36 m (34 ft). Additional steel angles were added to these rings vertically to support various tests. A removable grate type flooring was added to simulate various test configurations. Available are solid 0.64 cm (0.25 in.) thick painted steel plates to cover the entire floor (Fig. 3). Figure 5(a) is an interior view of the chamber. A second deck was added in the spring of 1981 (Fig. 5(b)). Figure 5(c) is a view of the upper level. Other features include electric lights attached to the side walls to provide lighting and which are enclosed in clear soft glass containers with metal shields; in addition, outlets near the floor level provide power to ensure adequate electric service within the vessel. Remote actuators in the instrumentation trailer control power to the lights and outlets. Eight nozzle outlets from the pressurization system are also located in the ceiling of the vessel (Fig. 6). Two of the nozzles can be seen in Fig. 5(a) and six can be seen in Fig. 5(c). To assure a clean interior environment for various tests, all surfaces were sandblasted, primed, and painted with two coats of white enamel manufactured by DURON Paint Company.

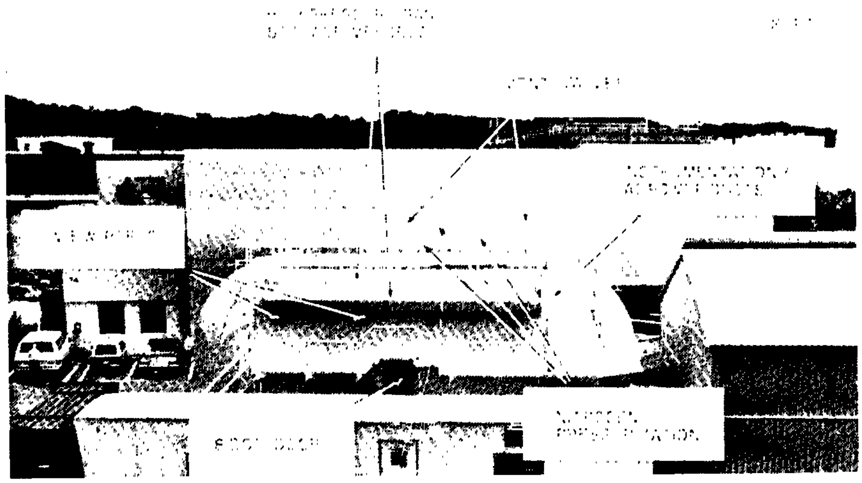


Fig. 4(a) — Southeast view of the chamber after modification by NRL's Engineering Services Division

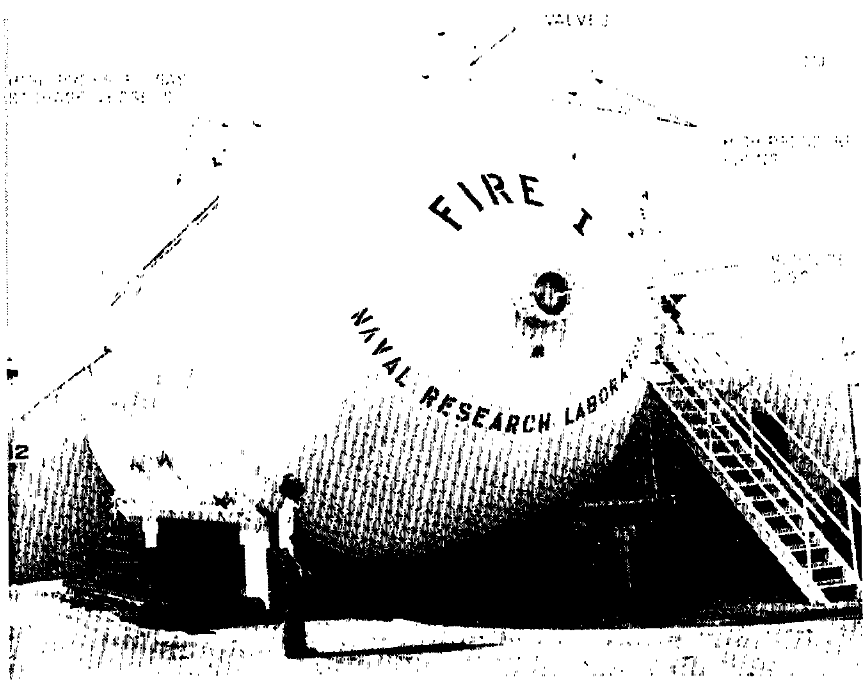


Fig. 4(b) — West view of the chamber after modification by NRL's Engineering Services Division

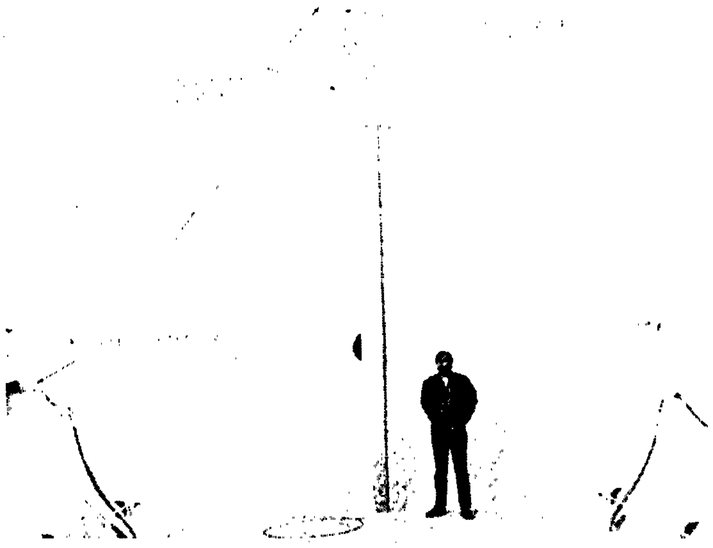


Fig. 5(a) — Interior view of chamber before second deck was added

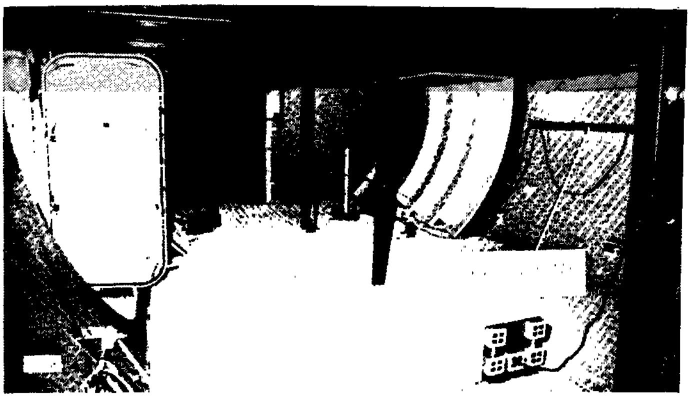


Fig. 5(b) — Interior view of chamber with deck installed, lower level

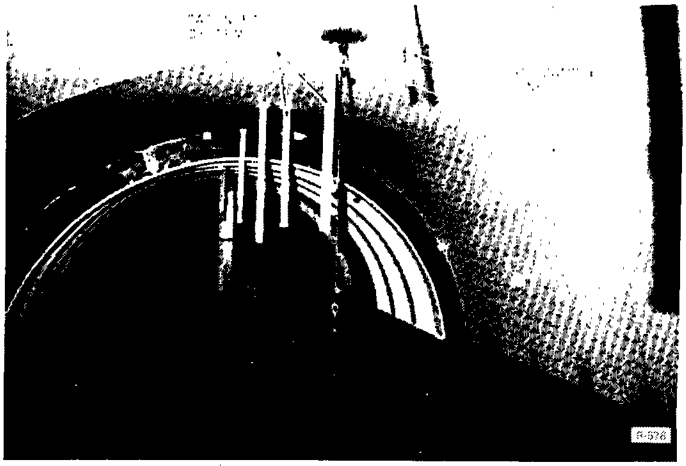


Fig. 5(c) — Interior view of chamber with deck installed, upper level

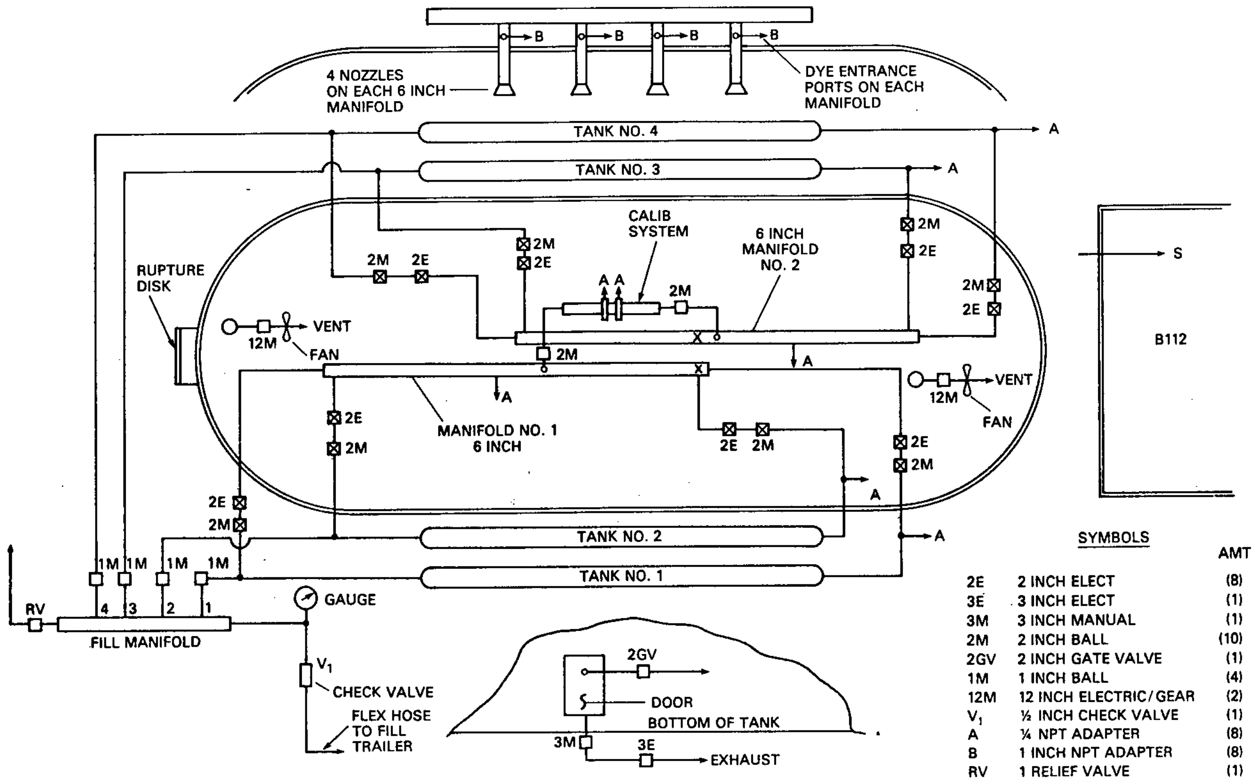


Fig. 6 — Schematic of the pressurization feed system for the 324 m^3 chamber

The gas supply or pressurization system is designed to raise the pressure in the chamber with an inert gas, such that the oxygen concentration would be lowered to the point that flaming combustion could not exist. This technique of fire suppression using nitrogen is based on an extensive experimental program conducted at NRL [5]. The system is not limited to nitrogen; in fact any gas could be supplied from this system.

The pressurization system consists of four tanks mounted on the upper section of the large pressure vessel (Fig. 4). Each tank is over 8.5 m (28 ft) in length with a 0.6 m (2 ft) nominal diameter; in addition, a design pressure of 10.3 MPa (1500 psia) and a volume of 2.09 m^3 (73.7 ft^3). Construction conforms to the ASME Boiler and Pressure Code, Section VIII, Division 1, Code Case 1205. These pressure tanks were manufactured and certified by the U.S.S. Christy Park Works located at McKeesport, Pennsylvania. Each end of these pressure tanks is provided with a 5.1 cm (2 in.) exit—which directs the high pressure through 5.1 cm (2 in.) Schedule 80 steel pipe to the control valves. These pressure tanks are filled according to a procedure in Appendix A. Individual pressure taps are provided to determine tank pressure, and pressure is recorded in the instrumentation trailer. In each of the Schedule 80 steel pipes leading from the pressure tanks are valves to control the gas flow into the large vessel. Various elbows, couplings, and unions make up the gas flow system with each pipe system containing a Jamesbury Corporation 5.1 cm (2 in.) ball valve, number HP22GT and a 5.1 cm (2 in.) Solenoid valve, part number 31871, manufactured by Atkomatic Valve Co. of Indianapolis, Indiana (Fig. 3). Appendix A, under Blowdown Procedure, gives the pretest procedure to make the high-pressure tank ready for use. All eight Solenoid valves could be operated simultaneously or individually depending on switch positions within the instrumentation trailer. If the system is not in continuous operation or intermittent use, the Jamesbury ball valves should be closed. Prior to opening these ball valves, a small bypass valve located nearby should be opened to allow the high-pressure gas to charge the Atkomatic Solenoid valve thus allowing this pressure to equalize and prevent hammering of the solenoid valve, which damages the stem assembly seats. Appendix B describes valve operation and defines a maintenance procedure for the solenoid valves.

Two 15.2 cm (6 in.) schedule 80 steel pipe manifolds are located on the top of the vessel (Fig. 6). As gases exit the control valves they enter a distribution manifold that directs gases to any or all of the four nozzle positions associated with each manifold. Located on each exit pipe between the manifold and the vessel are dye entrance ports. These ports could be used for various purposes or could be capped when experiments require another configuration. Each manifold has a pressure tap line to monitor manifold pressure during experiments. Figure 6 illustrates the general arrangement of the pressurization feed system.

Directly overhead in the large vessel are eight nozzle outlets. Four of the nozzles are controlled by one manifold or, as previously noted, two high-pressure tanks (Fig. 4). Eight nozzles could be installed or as experiments dictate, various locations could be used or capped depending on the experiment.

The high-pressure tanks are filled by attaching a flexible hose from a nitrogen tube trailer (Fig. 6) located near the test facility to the fill manifold. The fill manifold is equipped with a check valve in series with the flexible hose to prevent a back pressure problem occurring during hookup. Also associated with the fill manifold is a pressure gauge and safety relief valve preset at 12.2 MPa (1765 psia) to provide the safety margin for the high-pressure tanks; in addition, a drain or vent valve is provided to relieve pressure in the manifold and fill hose. This is shown in the schematic of the pressurization feed system (Fig. 6). The four pressure tanks are usually filled to 10.4 MPa (1515 psia). During tests or experiments all the fill 2.5 cm (1 in.) Jamesbury ball valves (part number HP22GT) must be in the closed position to prevent cross-feeding within the high-pressure tank system. Figure 6 illustrates this general arrangement, and, as previously noted, individual tank pressures are indicated in the instrumentation trailer.

Figure 7 illustrates the general construction of a typical nozzle. Flow through the nozzle is guided by the beveled surface into the throat with the throat machined to within plus or minus one thousandths of an inch and made of high-density polyethylyene. These nozzles are screwed into couplings with 5.1 cm (2 in.) national pipe threads rated at 20.7 MPa (3000 psi).

Each nozzle can be calibrated in situ by an ASME squared-edged orifice. It is mounted between two flanges equipped with pressure taps [6]. A two-manifold (north and south) design that delivers pressurant gas to the two corresponding sets of nozzles permits this calibration. The ASTM calibration system connects by ball valves between the two manifolds illustrated in Fig. 6. To calibrate any selected nozzle of a set, pressurant gas is directed through the opposite manifolds, the calibration system, and the manifold of the selected nozzle with all other nozzles capped.

CHAMBER ELECTRONIC CONTROL SYSTEM

The electronic control system serves three principal functions: it controls (a) the chamber gas discharge (gas dumping) and recharge system, (b) all ac powered chamber gas devices, and (c) the system safeguards. In addition to these controls, selected functions and their states provide the experimenter through logic with a record of system configuration and parameters.

Physically, the system consists of two separate units with front panel legends indicating their functions. One panel is designated N_2 Pressurization Control (Fig. 8(a)) although some other gas may be employed; the second is called Suppression Control (Fig. 8(b)). Each unit has front panel push-botton switches placed in groups according to functions as seen in Fig. 8. A lighted switch lens indicates a selected device or functions. Thumbwheel switches are grouped as "Event Start Time, Event Stop Time," and "Temp. Cont. Events" as seen in Fig. 8(b). The digital panel meter located at the upper

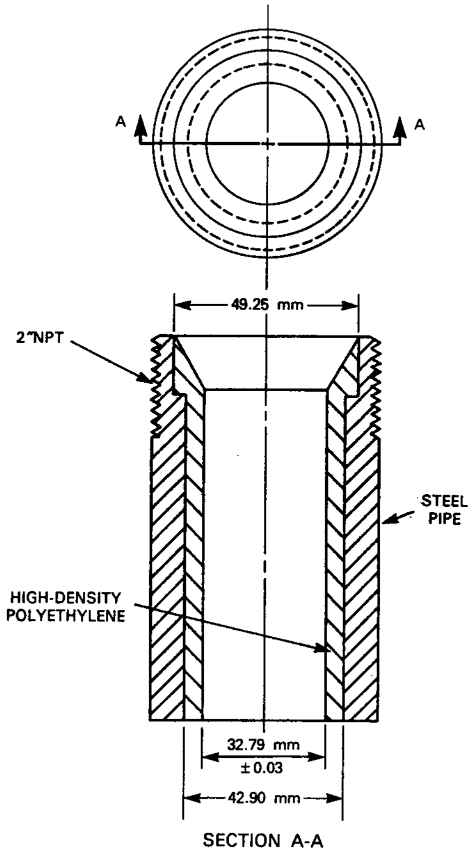


Fig. 7 — Schematic of the pressurization nozzle in chamber

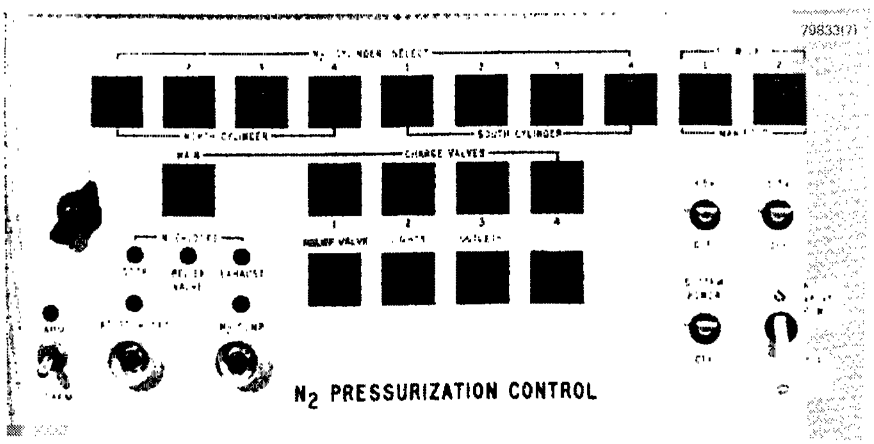


Fig. 8(a) — Chamber nitrogen pressurization control console

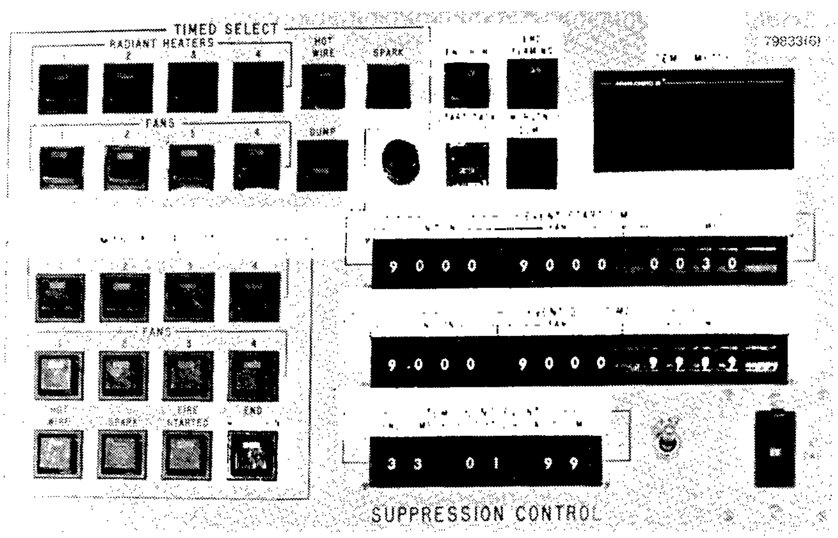


Fig. 8(b) — Chamber suppression control console

right-hand portion of this unit indicates fire-pan temperature and acts as an instant indication of whether the fire source is still active. To the rear of each unit are provided data output jacks, cable connectors for system interconnections, dc power supply fuses, and ac power line connectors. A schematic for this console can be found in Appendix C.

There are four high-pressure gas storage cylinders with eight electrically activated valves, one at each end of a cylinder connected to the discharge manifolds. These cylinders are designated North 1-4 and South 1-4 (Fig. 8(a)). Selection of any combination of these valves is possible by depressing the appropriate push-button panel switch, although selection will be dictated by experimental criteria. When a valve is activated, gas from the high-pressure cylinder will be discharged through its manifold, i.e., north valves to north manifold or south valves to south manifold then through a discharge nozzle into the chamber.

Actual dumping (gas discharge to chamber) is possible only when system safeguards have been satisfied, a mode of dumping has been selected, and required procedures have been followed. This means that the chamber door, relief valve (valve under the chamber), and vent valves (two valves on top of the chamber) are closed as indicated by lighted panel interlock lamps (Fig. 8(a)). Also the system must be armed by the "Arm/Disarm" switch then reset by the "Abort/Reset" switch (Fig. 8(a)). Dumping is then enabled and can be initiated depending upon what mode has been selected. If timed dumping is used, the gas discharge valves will be activated after depressing Start Data Loggers switch (Fig. 8(b)) which establishes zero time at the selected time in seconds under Event Start Time. Termination of this dump may be initiated by several means. Of the several means, automatic termination by chamber pressure will dominate unless the Event Stop Time precedes the chamber pressure threshold or the operator chooses to manually abort or disarm the system. This chamber pressure threshold is selected by the operator prior to an experiment which serves two purposes: automatic termination of a dump at a preselected chamber pressure and a means to avoid chamber overpressure. To avoid premature termination by chamber pressure when using any mode, the operator should, if in doubt, set the pressure to its maximum point. Detailed procedures are given in Appendix D under the section "Using Chamber Pressure for Dumping."

Another method of dumping is by sensing temperature within the chamber. The thumbwheel switches under panel heading "Temp. Cont. Events" and "Auto Dump" (Fig. 8(b)) are set to the °C temperature at which dumping is required. This sensed temperature will be the sum of a thermocouples array in the chamber which are input to an amplifier whose output is an average of the overall points sensed.

When the sensed temperature equals the °C setting of the thumbwheel switches, dumping will take place. Again the dump may be terminated by chamber pressure or manually as stated above. If, however, it is required to terminate via temperature, then the °C setting for "End Dump" under "Temp. Cont. Events" will be set accordingly. Finally, dumping may be controlled manually by using N_2 (nitrogen) Dump switch and, as before, terminated by chamber pressure. It should be pointed out that when a new mode of dumping is selected the system must be reset before the new mode is enabled. The procedure is given in Appendix D. Also having terminated a dump, resetting the system is required before another is enabled. An emergency dump push-button switch, however, is provided which will override all other modes. This emergency dump feature is available in the event a selected mode fails to operate or dumping be required before temperature or time dictates.

All experimental apparatus within the chamber are also controlled by the Electronic Control System. These devices may be activated in the same manner as dumping and are subject to interlocks and system inhibits also, with the exception that auto-pressure termination has no effect. As seen in Fig. 8(b) for the Suppression Control Panel, switches are grouped under "Timed Select" and "Manual Select." Ignition sources (radiant heaters, hot wire, and spark) and fans are selected to either timed or manual activation. As before, if a timed device is selected, the appropriate thumbwheel switches under "Event Start Time" and "Event Stop Time" are set. When the "Start Data Loggers" switch is depressed—again establishing zero time—the device will be energized after the set elapsed time and terminated at the set stop time. Manual Select may also be used to energize and de-energize ignition sources and fans. Depressing a push-button switch once to energize is indicated by illuminating the switch lens (depress again to de-energize).

The "Start Data Loggers" switch has been mentioned in connection with timed events. Its designation, as implied, starts the data loggers (for more discussion on data loggers see the chapter on Data Collection) but at the same time starts the total data collection system. As indicated above, it establishes zero time by enabling the system clock for timed events.

Four panel switches (Fig. 8(b)) under legends Fire Started, End Smouldering, End Run, and End Flaming, are used by the experimenter manually to indicate the implied. Event "Fire Started" may also be indicated by setting thumbwheel switch "Temp. Cont. Events" under "pyrolysis" legend to the °C temperature at which fire is expected. When this temperature is reached "Fire Start" signal is set. This signal will indicate the point in time that the temperature in the vicinity of the fire pan has reached pyrolysis conditions.

A general system diagram for the Electronic Control System is shown in Appendix C As shown all chamber apparatus are energized via solid state relays. Also chamber lights and service outputs, providing a total current of 80 A, are controlled through solid state relays.

In Appendix C are the detailed Electronic Control System schematics. Also procedures for using this system are contained in Appendix D in the section on "Nitrogen Pressurization and Fire Suppression Controls."

GAS SAMPLING SYSTEM

The Gas Sampling System serves to extract gas samples from the chamber continuously during an experimental run. This sampling system consists of two independent loops, one handling the north end, the other the south end of the chamber (Figs. 5(a), 5(c), and 9). Teflon tubing, 1.27 cm (0.5 in.)

in diameter is used to transport the gas to the analyzers. The gas is filtered through Gilmont filters. Gas is returned to the chamber by using 1.27 cm outside diameter stainless steel tubing, the length of which comprises about half the total loop lengths—north loops about 18.3 m (60 ft), south loops about 14.6 m (48 ft). Gas is pumped in each loop by using Bellows Company (Sharon Division) Model MB-602 diaphragm pump in the compressor mode supplying 70 liters per minute of gas per loop. A Dwyer Visi-Float Flow meter Model VFA 27 SSV 0-100 LPM is used to adjust and monitor each loop flow. Figure 9 is a schematic of the gas sampling system. These pressures are measured by using two 0 to 344 kPa (0 to 50 psia) Validyne Model P24 differential pressure transducers whose output is applied to the transducer panel meter (Fig. 10, Panel II).

Between the diaphragm pump and the loop flow meter (see Fig. 9) a portion of this loop flow is bypassed to a stainless steel three-way ball valve (two positions with three ports) used to select sample gas or analyze calibration gases. The gas output from this valve is fed to a Matheson Model 7S regulator which establishes primary analyzer manifold pressure. From the manifold there are four lines, one to each analyzer flow meter (Visa-Float flow meter), then to each analyzer. The analyzers employed are Beckman models as follows: O_2, Model 755; CO and CO_2, Models 865 Infrared; and NO_2, Model 951. In addition to the regulator mentioned above, a Gilmont Instruments Model C2200 Cartesian Diver provides precision pressure regulation for the analyzer manifold. Also a 0 to 172 kPa (0 to 25 psia) Validyne Model P24 pressure transducer monitors this same pressure, one for each manifold, and displays the output on digital panel meters (Fig. 10, Panel II).

Of the total flow in each loop (70 liters/minute), the sum of 3.2 liters/minute of gas passes to the four analyzers (O_2, CO, CO_2, and NO_2) and then is vented to the atmosphere outside of the trailer. This represents 4.6% of the total loop flow, the remainder of which is returned to the chamber.

Sample gases are taken from each end of the 324 m^3 chamber as stated above; however, one may sample a specific region in the chamber. This is done through five sample tubes into five regions within the chamber by selecting the region or regions using two-way stainless ball valves which can be seen in Fig. 11. This arrangement is depicted in Fig. 9. Also each loop has two filters in parallel (Gelmont Product 2220) placed in the 1.27 cm line directly after the selection manifold. Ahead of the filters is a trap which was placed in the line to remove larger particles. The trap was installed just prior to the 1 July 1981 Hull Insulation Test.

All pressure transducers may be standardized by turning the three-way ball valves located on the uppermost panel (Fig. 10, Panel I) as described in Appendix E for Transducer Calibration. This will connect the vacuum pump to each reference port. Positions for the valves using atmospheric reference (gauge pressure) are also described. This is shown schematically in Fig. 9.

A precision 0-2 ATM Absolute Heise H20913 Bourdon tube gauge is used to monitor the north and south end of chamber pressure (Fig. 10, Panel IV) by a three-way ball valve. This gauge may be adjusted to atmospheric conditions prior to a run for accurate gas discharge and termination pressures. The pressure transducers can be compensated by using the pressure-regulated air supply bottle shown in Fig. 9 in place of chamber pressure and then adjusting a potentiometer as outlined in Appendix E.

The Gas Handling System also includes a 0 to 13.8 MPa (0 to 2000 psia) Validyne Model P24 pressure transducer, a 0 to 172 kPa (0 to 25 psia) transducer, same model, for measuring differential pressure used for the discharge flow calibration and a 0 to 10.3 MPa (0 to 1500 psia) Heise H46291 precision bore gauge which is selectively controlled to monitor gas discharge cylinders 1 through 4, north and south manifolds and north and south static pressures in the flow calibration manifold. Both the 0 to 10.3 MPa (0 to 1500 psia) Heise gauge and the 0 to 13.8 MPa (0 to 2000 psia) transducer see the same pressures as selected by two five-way ball valves and one three-way ball valve as can be seen in Figs. 6 and 9.

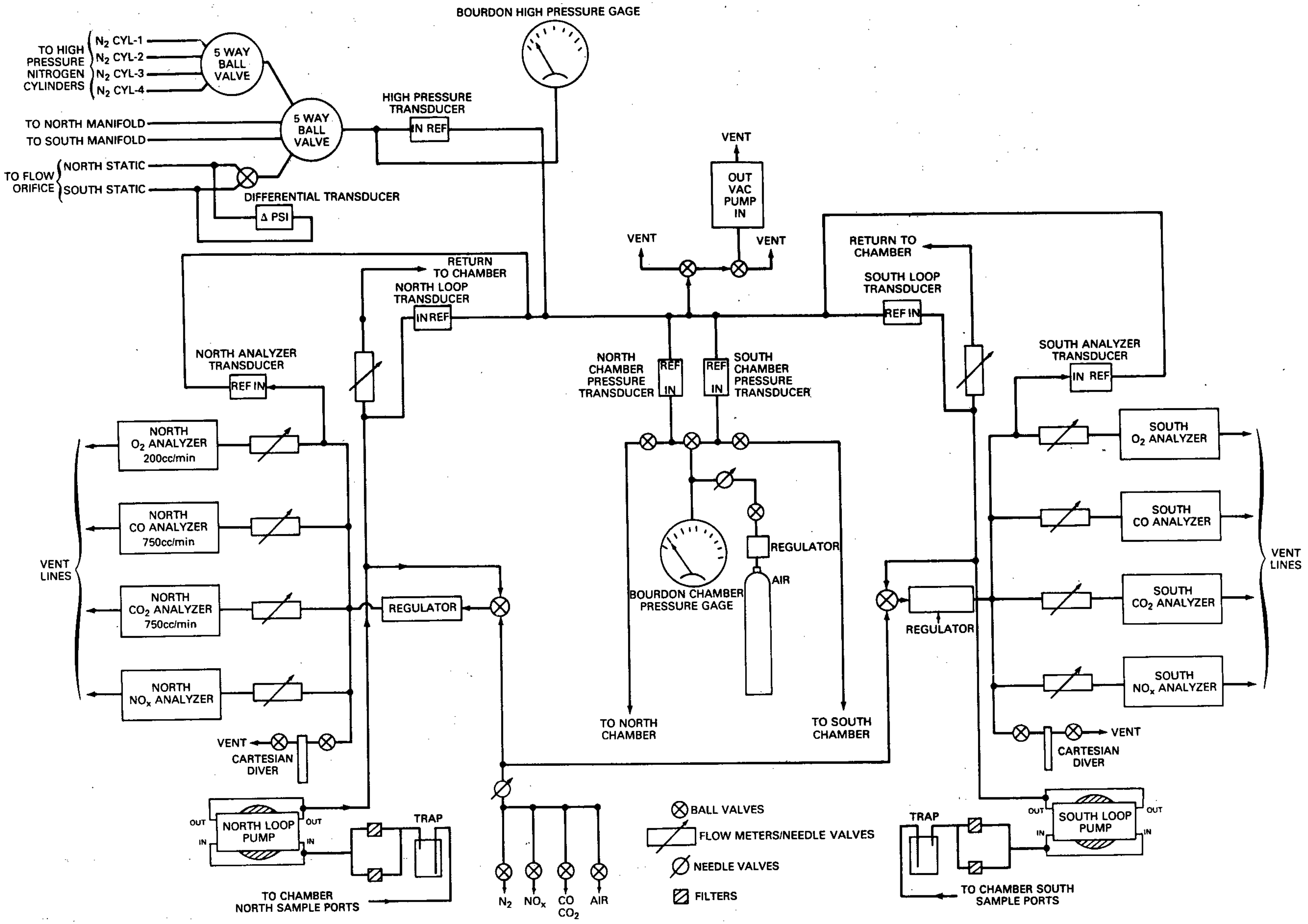


Fig. 9 — Schematic of the gas sampling system

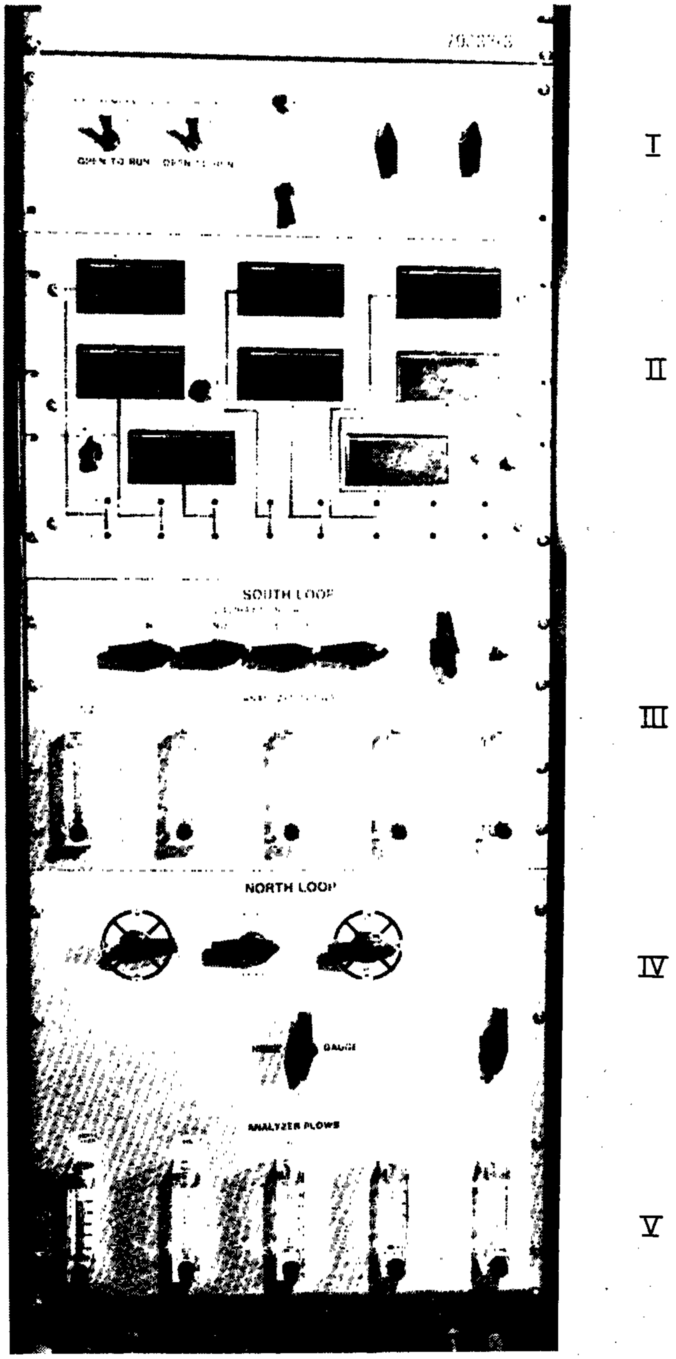


Fig. 10 — Gas sampling console

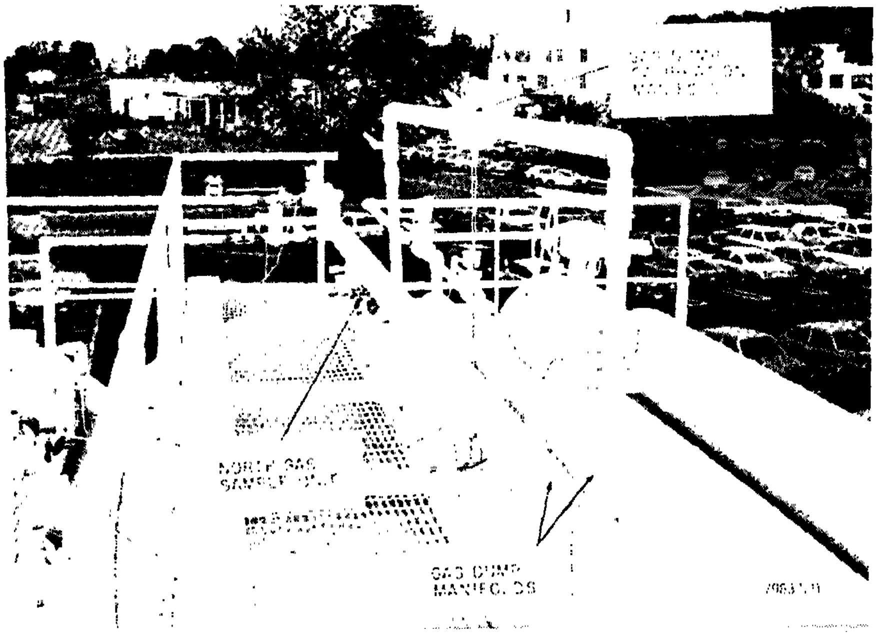


Fig. 11 — Picture taken from top of the chamber showing gas sampling paris and gas dump calibration manifold

On 3 November 1981, two additional filters (Gelman Product 2220) were added to each loop directly after the trap as shown in Fig. 9. This was necessary to reduce buildup of foreign matter in these loops as evidenced by discoloration in loop flow meters and the 1.27 cm Teflon loop lines. There was, however, no apparent buildup in the analyzer flow meters or their Teflon lines. Most importantly, the analyzers continued to function properly during runs and gave accurate readings during calibrations. In connection with analyzer calibration, refer to Appendix E for this procedure which must be performed prior to experimental runs.

DATA COLLECTION

A multitude of data is available during combustion experiments in the 324 m^3 chamber. Obviously the collection and storage of these data is crucial in analyzing and understanding combustion and extinguishment processes occurring during various tests. Although selection and placement of each type of sensor, within the experimental chamber, are important, this area of the report concerns itself with the collection, distribution, and storage of these data. Data must be recorded and stored in such a way as to facilitate the analysis and evaluation of all its significant aspects.

Data sensors, logic functions, and monitoring systems are routed through a matrix distribution network (Fig. 12). Table 1 gives the input and output assignments for the matrix board. This network accommodates all data to be recorded and routes it to either of two data loggers, Doric Digitrend Model 220, for storage on magnetic tape. Selected signals from the matrix board may be routed to a high-speed A/D converter, Hewlett Packard 2313B. This in turn directs the data to a minicomputer (CPU) and magnetic tape or disc mass storage. This arrangement allows real-time data processing. All inputs to the matrix are terminated on terminal strips which are connected by wiring, to one side of the matrix labeled "inputs 0-100." The output is attached to the other side, "output 0-100" of the matrix. Then by location of pins in the pin board any incoming data source may be routed to either data logger or the CPU input. The matrix also affords changes in experimental data collection depending on the requirements of the experimenter.

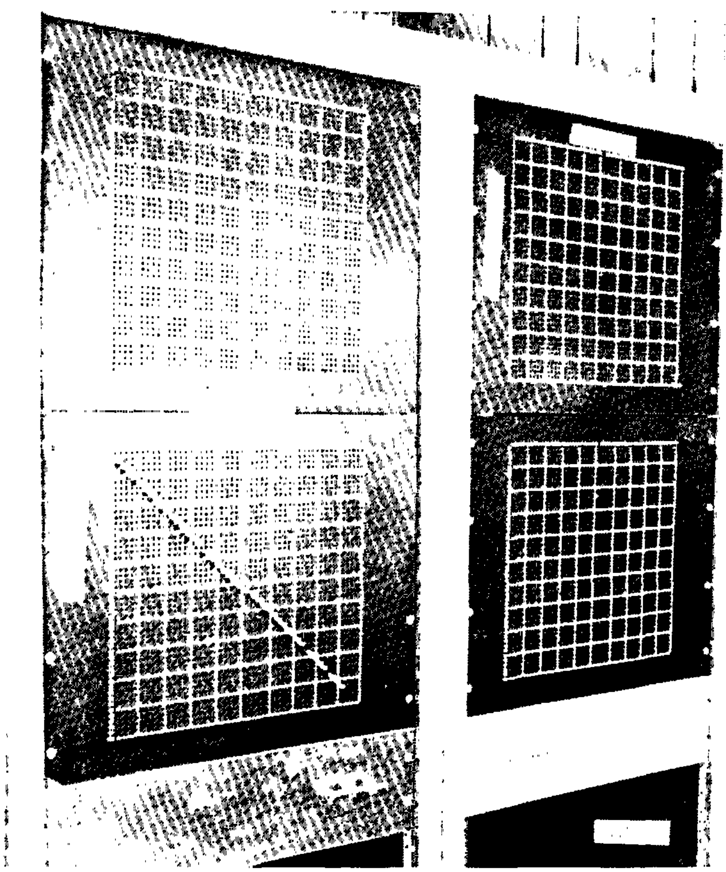


Fig. 12 — 100 × 100 Data Input Matrix

Mass storage of pertinent data from the data loggers, i.e., thermocouples, radiometers, light obscuration, humidity, gas analyzers, and control functions is accomplished by using two Cipher model 70M/9 magnetic tape recorders, which record the data in IBM EBCDIC format on nine tracks. Each Cipher recorder receives its input from a separate Digitrend 220 Data Acquisition System. Two complete data collection and magnetic tape storage systems are used to facilitate the large data set. This is necessary for the collection speed required to attain the maximum number of data points possible during each experiment. Although the Cipher magnetic tape recording units are the primary mass data storage medium (20 points/s), a backup mass storage paper tape punch system is available. The Facet model paper tape punch system collects approximately 6.8 points/s. The paper tape collected may then be read, by computer, and transferred to magnetic tape at a later date. If data must be recorded using the Facet paper tape punch, the speed of collection may be increased through a reduction in the number of points being scanned by the Doric 220s.

A printer report is also available on the Doric 220s for data collection at a speed of up to 2 points/s if needed. Normally this printer is used to evaluate the data points for accuracy before an experimental run begins and for trouble-shooting.

Each Digitrend accepts up to 100 analog input signals from a variety of sensors, automatically scans these signals sequentially, digitizes and displays the results in engineering units, and logs the data on storage mediums. Input multiplexer and analog to digital cards installed in the 220 determine its input voltage range capabilities for each channel. Each of the multiplexer cards handles 20 scanning channels each 0-19, 20-39, 40-59, 60-79, 80-99. A typical channel assignment is given in Table 2 which was used for the 1 July Hull Insulation Fire Test. Inputs may be selected to be millivolts (0 to 300), volts (0 to 3), or degrees centigrade.

Table 1 — Matrix Input Data Assignment Numbers and Matrix Output Numbers with Data Logger Channel Assignments

Fixed Matrix Input No.	Data	Programmable Matrix Output No.
1	Spark	2
2	South CYL 1	3
3	End Smoldering	4
4	South CYL 4	5
5	North O_2	6,82
6	South CYL 2	7
7	East Humidity	8
8	North CYL 4	9
9	Fan #1	10
10	North CYL 2	11
11	Dump	12
12	Ignition	13
13	End Run	14
14	Radiometer #1	15
15	Radiometer #3	16
16	End Preburn	17
17	Chamber PSI Max	18
18	Radiometer #2	19
19	Hot Wire	20
20	South CYL 3	21
21	Fan #3	22
22	North CYL 3	23
23	South CO	24,86
24	West Humidity	25
25	North CYL 1	26
26	Fan #2	27
27	Fire Start	28
28	South O_2	29,85
29	South CO_2	30,87
30	North CO	31,83
31	Fan #4	32
32	End Flame	33
33	Radiometer #4	34
34	North CO_2	35,84
35	North PSI	36,88
36	South PSI	37,89
37	Hi Pressure	38
38	North Loop PSI	39,93
39	South Loop PSI	40,94
40	East Obscuration	41
41	West Obscuration	42
42	Manifold	
43	South Analyzer PSI	92
44	North Analyzer PSI	91
45	Digimetric Scales	46
46	Pressurant Thermocouple	Not Used
47	Pressurant Thermocouple	Not Used
48	Pressurant Thermocouple	Not Used
49	Pressurant Thermocouple	Not Used
50	Pressurant Thermocouple	Not Used

Table 1 (Continued) — Matrix Input Data Assignment Numbers and Matrix Output Numbers with Data Logger Channel Assignments

Fixed Matrix Input No.	Data	Programmable Matrix Output No.
51	North Thermocouple #1	62
52	North Thermocouple #2	63
53	North Thermocouple #3	64
54	North Thermocouple #4	65
55	North Thermocouple #5	66
56	North Thermocouple #6	67
57	North Thermocouple #7	68
58	North Thermocouple #8	69
59	North Thermocouple #9	70
60	North Thermocouple #10	71
61	Spare Thermocouple	Not Used
62	Spare Thermocouple	Not Used
63	Spare Thermocouple	Not Used
64	Spare Thermocouple	Not Used
65	Spare Thermocouple	Not Used
66	Spare Thermocouple	Not Used
67	South Thermocouple #1	72
68	South Thermocouple #2	73
69	South Thermocouple #3	74
70	South Thermocouple #4	75
71	South Thermocouple #5	76
72	South Thermocouple #6	77
73	South Thermocouple #7	78
74	South Thermocouple #8	79
75	South Thermocouple #9	80
76	South Thermocouple #10	81
77	Fire Pan Thermocouple	50
78	Fire Pan Thermocouple	51
79	Radiometer A	90
80	Spare Thermocouple	Not Used
81	Spare Thermocouple	Not Used
82	Spare Thermocouple	Not Used
83	North Radiometer 1	52
84	North Radiometer 2	53
85	Radiometer C	54
86	North Radiometer 4	55
87	North Radiometer 5	56
88	South Radiometer 1	57
89	South Radiometer 2	58
90	Radiometer B	59
91	South Radiometer 4	60
92	South Radiometer 5	61
93	Pressurant Thermocouple	Not Used
94	Pressurant Thermocouple	Not Used
95	Pressurant Thermocouple	Not Used
96	Pressurant Thermocouple	Not Used
97	Pressurant Thermocouple	Not Used
98	Pressurant Thermocouple	Not Used
99	Pressurant Thermocouple	Not Used
100	Pressurant Thermocouple	Not Used

Table 2 — Data Logger Channel Assignments

Data	Lower Logger Channel No.	Upper Logger Channel No.
Burner Thermocouple	1	
Burner Thermocouple	2	
End Smoldering	3	
South CYL 4	4	
South CYL 2	6	
North O_2	7	
North CYL 4	8	
Fan #1	9	
North CYL 2	10	
Dump	11	
Ignition	12	
End Run	13	
West Light Lower Deck	14	
East Light Lower Deck	15	
Upper Deck Light	16	
Chamber PSI Max	17	
Hot Wire	19	
South CYL 3	20	
South CYL 1	21	
North CYL 3	22	
South CO	23	
North CYL 1	25	
Fire Start	27	
South O_2	28	
South CO_2	29	
North CO	30	
End Flame	32	
North CO_2	34	
North PSI	35	
South PSI	36	
South Loop PSI	39	
East Obscuration	40	
West Obscuration	41	
North Loop PSI	42	
South Analyzer PSI	43	
North Analyzer PSI	44	

Table 2 (Continued) — Data Logger Channel Assignments

Data	Lower Logger Channel No.	Upper Logger Channel No.
North Radiometer 1		1
North Radiometer 2		2
Tree Radiometer C		3
North Radiometer 4		4
North Radiometer 5		5
South Radiometer 1		6
South Radiometer 2		7
Tree Radiometer B		8
South Radiometer 4		9
South Radiometer 5		10
North Thermocouple #1		11
North Thermocouple #2		12
North Thermocouple #3		13
North Thermocouple #4		14
North Thermocouple #5		15
North Thermocouple #6		16
North Thermocouple #7		17
North Thermocouple #8		18
North Thermocouple #9		19
North Thermocouple #10		20
South Thermocouple #1		21
South Thermocouple #2		22
South Thermocouple #3		23
South Thermocouple #4		24
South Thermocouple #5		25
South Thermocouple #6		26
South Thermocouple #7		27
South Thermocouple #8		28
South Thermocouple #9		29
North Thermocouple #7		30
North O_2		31
North CO		32
North CO_2		33
South O_2		34
South CO		35
South CO_2		36
North PSI		37
South PSI		38
Radiometer A		39
North Analyzer PSI		40
South Analyzer PSI		41
North Loop PSI		42
South Loop PSI		43

The Doric 220 has an internal clock and a fixed data word input to the data stream. Time is continually updated giving the data and time reference for each scan. The fixed data word allows the optional input of the day, month, year, run number, etc. automatically with each scan. The data word format for a scan of one channel on magnetic tape is as follows:

Fixed Data Word	Time	Channel	Data
b D D D D D D D D b b	b b H H b M M b S S b	b C C C	P D D D D D X

b = space
D = numerical numbers only, 0-9
H = hour, determined by internal clock
M = minute, determined by internal clock
S = second, determined by internal clock
C = channel number
P = polarity
D = data, numerical numbers 0-9
X = negative exponent to base 10.

The channel number and data then repeat for the number of channels selected to scan. At the end of a single scan, an end of record is put on the tape before repeating the fixed heading data word. At the end of a run there is an end of file.

Chamber control functions such as selection of valves, start/stop dumping, and start/stop of flaming are recorded to provide a method of determining when certain sequences have occurred. Pressures are monitored and recorded as follows: north and south of the chamber, north and south gas analyzers (CO, CO_2, O_2, and NO_x), north and south gas sampling loops, north and south pressure manifolds, and finally a pressure differential for the flow calibration systems.

Sensors within the chamber which are monitored and recorded include thermocouples, radiometers, laser obscuration, humidity, radiant heaters, and circulation fans. Future systems and sensors—like the laser Doppler Velocimeter, hot wire anemometer, and Fourier analyzer—will also be used to gather and process chamber data.

Commencing with the 1 July 1981 Hull Insulation Test, selected data channels from the matrix board were routed to the high-speed A/D converter, Hewlett Packard 2313B. The A/D converter is installed in a Hewlett Packard HP Measurement and Control System using Series F processor. This allows real-time display of data being collected during the fire. Selected data channels then can be displayed with a graphics translator on a CRT, Model 1350A and Model 1321A. Data may be directed to an HP 2648 graphics terminal for further monitoring. Data may also be stored either on magnetic tape (HP Model 7970B) 9 track or on disc files (HP Model 7925). The high-speed collection and mass storage of the data allows instant replay. Figure 13 is a typical real-time data plot.

The computer programs used for data collection and manipulation are given in Appendix F.

CLOSED-CIRCUIT TELEVISION

The physical arrangement of the test chamber and the requirement to isolate experimenters from the effects of the experiment require some form of visual monitoring. A closed-circuit television system has been installed in the 324 m^3 chamber for this purpose. This system can: (1) record the activities from outside the chamber during experiments, (2) provide visual examination of experiments in progress, (3) provide a permanent record including time and data, and (4) introduce the ability to recreate these parameters repeatedly to explain abnormalities with data recorded.

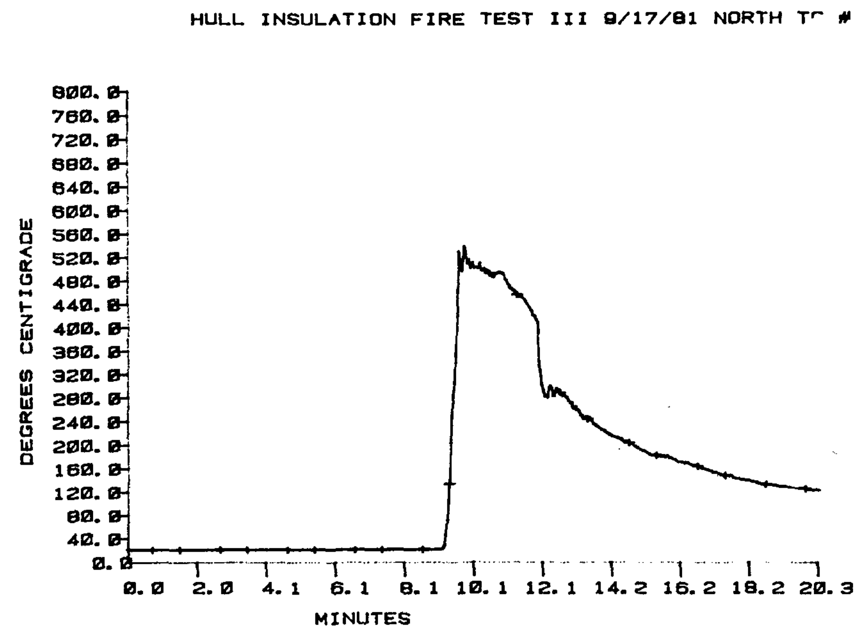


Fig. 13 — Real-time data display on graphics translator

Initially three cameras, one color, model FP-3030G, and two black and white, Sony Model AVC-3450, were used. Commencing with the 17 September 1981 Hull Insulation Test, six cameras monitored the chamber. Figure 14 gives the camera port numbers. The camera mounts are specially designed to accept either camera and to allow movement of the camera for whatever angle is required. The camera mount is connected to the viewing port flange.

Currently six Panasonic, Model NV-8310 UHS video recorders record the camera data during experiments. A video cabinet was constructed to house four recorders and monitors and associated equipment for viewing during and after experiments. Permount camera cables are installed allowing operation of the cameras from multiple angles and variable ports.

A microphone mixer, located in the trailer, combines the microphones from selected video cameras with microphones used within the trailer to record experimenter's comments during tests. The microphone mixer is then input to video tape recorders #1 via an additional microphone input and mixed with the color camera audio.

LIQUID FUEL SUPPLY SYSTEM

The objective is to burn liquid fuels in FIRE I at steady burning rates and measure the rates. To do this, we designed an array of round, tapered-edge fire pans with various cross-sectional areas, and a constant-level, liquid fuel supply system that allows the measure of fuel-loss (burning-rate) history.

In this chapter, the design of the fuel pans and the constant-level fuel supply system, calibration of the latter is described, and finally the determination of burning rates and their accuracy are discussed.

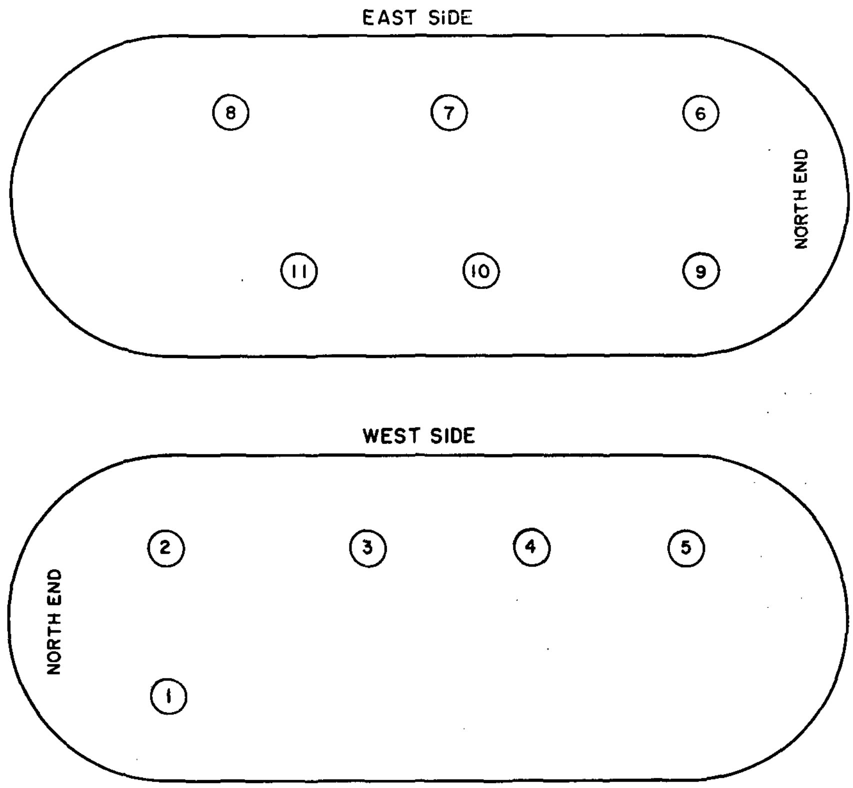


Fig. 14 — Schematic location of view port number assignments

Description of Apparatus

Fuel Pans

Figure 15 shows a drawing for the 7-cm diameter fuel pan 7.6 cm deep. Notice that the upper edge of the stainless-steel pan is of reduced thickness for 25 mm and is tapered the last 6 mm to a final thickness of 0.3 mm (0.01 in.). The other pans with diameters of 2, 15, 50, and 100 cm were of similar construction, except the upper edge of the largest pan was not reduced in thickness.

Liquid Fuel Supply System

The liquid fuel supply system is a constant-head device. Its purpose is twofold: to maintain firepan fuel level at the full mark and to indicate fuel consumption rate.

The weir reservoir has two separate compartments, the constant-head side and the supply side (see Fig. 16), formed by a common dividing wall. A vertically adjustable weir at the top of this wall connects the two sides. A pump with adjustable capacity pumps fuel from the bottom of the supply side to the bottom of the constant-head side, and fuel flows across the weir when the latter side fills. Additionally, the constant-head side connects to a fuel pan through large diameter tubing, and the supply side connects to the scale reservoir.

Two fuel supply systems are used, a large one for the 50- and 100-cm diameter fire pans and a small one for the smaller pans. Each side of the large-system weir reservoir has a square cross section of 929 cm^2 (144 $in.^2$) with a depth of 43.2 cm (17 in.). The square cross section of the scale reservoir

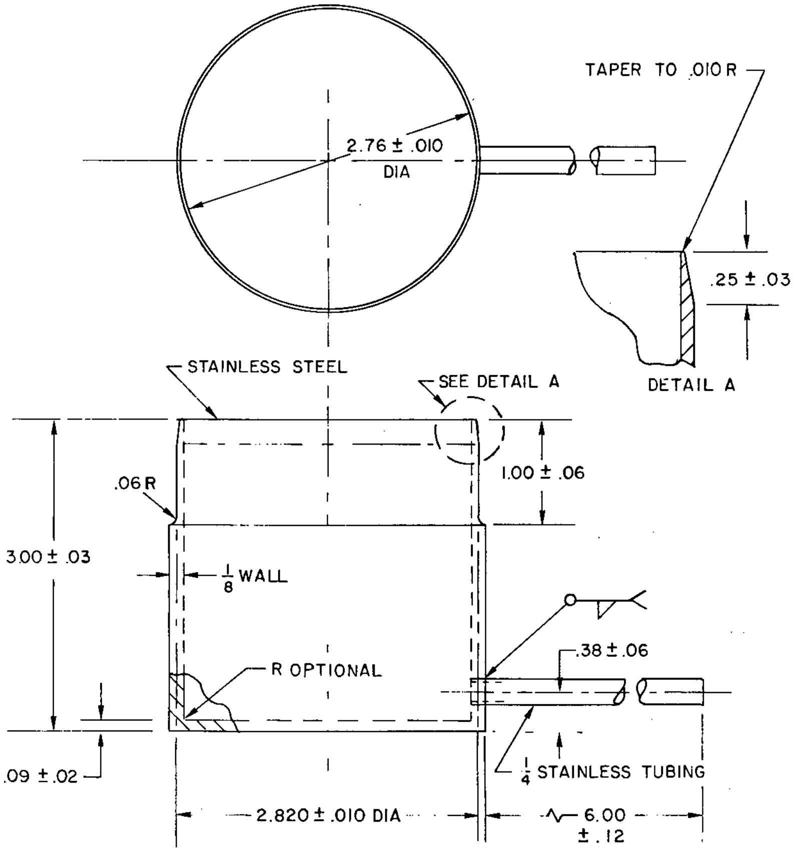


Fig. 15 — Drawing of 7 cm liquid fuel pan

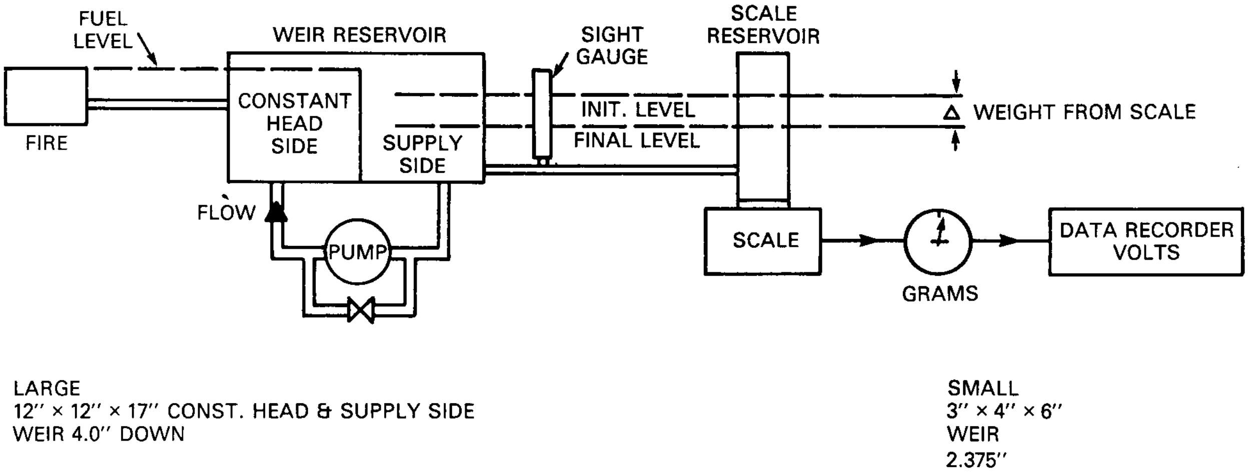


Fig. 16 — Schematic of liquid fuel supply system

is 232 cm^2 (36 $in.^2$) with the same 43.2 cm depth. From normal initial working levels, the system can deliver about 36 liters of fuel.

The cross section of each side of the small fuel supply system is 77.4 cm^2 (12.0 $in.^2$) with a working depth of about 11.4 cm (4.5 in.). Cross section of the small-scale reservoir is 28.3 cm^2 (4.4 $in.^2$). This system can deliver about 1.2 liters of fuel.

Top Loading Balance

The scale reservoir, described above, rests on a top loading balance (Digimetric, Model 30DKI, by Sybron Corporation). The weighing capacity of the balance is from 0.1 to 10,000 grams, in two ranges, with a manufacturer claimed accuracy of 1 in 20,000. It has a digital display and an analog voltage output. The voltage output is recorded.

The analog voltage output of the Digimetric top loading balance is recorded at frequent time intervals by a Digitrend 220 (Doric Scientific Corporation). In calibrations described later, the printout capability is used to record time and voltage observed at 1-s intervals. During actual fire tests, the Digitrend 220 records data on magnetic tape.

Calibration of Fuel Supply System

For convenience, only calibration of the large (36 liter) supply system with the 50 cm diameter pan is described. Nonetheless, both large and small systems are calibrated at or above their maximum demand rates.

Operation of either system is simple. The fuel is pumped from the supply side to the constant-head side of the weir reservoir, and fuel flows over the weir back to the supply side. With a level fire pan, the weir is adjusted vertically so that the pan fills to the desired level. Fuel level in the supply side should be below that in the constant-head side by about 2 cm initially. As a fire (or leak) consumes fuel from the pan, more fuel flows from the constant-head side of the reservoir to maintain the set level in the pan. The rate of pumping must exceed the fuel consumption rate so as to maintain a proper flow rate over the weir (and a constant-head). As the supply-side fuel level falls, the scale-reservoir level falls correspondingly, and the weight loss history of the scale-reservoir is recorded.

To obtain the fuel-consumption rate, the factor F = fuel-consumption rate/scale-reservoir-loss rate is required.

Procedure to Determine Factor F

The ratio of fuel-consumption (or leak) rate to scale-reservoir-loss rate gives the factor F. To determine this ratio, fluid was withdrawn from the pan at a measured rate and the corresponding weight loss of the scale reservoir was recorded.

Tap water at 26°C was the initial calibration fluid. Levels with a full fire pan were adjusted to initial values as described above with the pump operating. Water was withdrawn from the fire pan at a constant rate and collected in 1-liter volumetric flasks. Each of the 33 flasks was numbered, washed, and drained. To drain, each flask was inverted and allowed to drip for 30 s after dripping had begun; a repeatable wet tare was thus obtained. At time $t = 0$, water was withdrawn through the constant leak into flask No. 1. At time $t = 60$ s, the leak was directed to flask No. 2. At time 120 s it was directed to No. 3, and so on until at the end of 33 min, flask No. 33 was filled and the leak stopped. To transfer the leak from one flask to another required 1 ± 0.5 s.

During the 33-min period, the scale reservoir weight 30 s after each leak transfer was obtained. The voltage output of the top-loading balance was recorded using the Digitrend 220; the scale reservoir rested on this balance. Column 3 of Table 3 gives these voltages; their calibration is described below.

Table 3 — Large Fuel Supply System Calibration Data

		Scale Reservoir Weight: Top Loading Balance		Fire Pan Loss: Torbal Balance Data					
Time (min)	Flask No.	V (volts)	G (g)	Gross Wt. (g)	Tare W_2 (g)	Net Wt. W_2 (g)	W_1 (g)	W_2/W_1	W_2 (g)
0		1.0710	10541						
1	1	1.0688	10519	1146.2	266.0	880.2	22		
2	2	1.0541	10377	1142.2	269.0	873.2	142		
3	3	1.0372	10213	1129.6	257.0	872.6	164	5.32	872
4	4	1.0197	10044	1168.1	289.3	878.8	169	5.20	879
5	5	1.0012	9865	1106.4	244.1	862.3	179	4.82	863
6	6	0.9832	9691	1151.8	279.6	872.2	174	5.01	872
7	7	0.9650	9515	1201.6	327.1	874.5	176	4.97	875
8	8	0.9474	9345	1146.3	265.0	881.3	170	5.18	881
9	9	0.9289	9166	1137.6	256.4	881.2	179	4.92	881
10	10	0.9112	8995	1137.2	257.7	879.5	171	5.14	879
11	11	0.8934	8822	1142.2	260.0	882.2	173	5.10	882
12	12	0.8759	8553	1142.9	258.8	884.1	169	5.23	884
13	13	0.8585	8485	1131.6	246.7	884.9	168	5.27	885
14	14	0.8406	8316	1164.9	286.5	878.4	169	5.20	379
15	15	0.8225	8136	1150.6	233.0	882.6	180	4.90	883
16	16	0.8049	7966	1164.3	279.5	884.8	170	5.20	884
17	17	0.7871	7794	1184.1	300.5	883.6	172	5.14	884
18	18	0.7694	7623	1179.3	291.8	887.5	171	5.19	887
19	19	0.7518	7452	1168.8	288.6	880.2	171	5.15	881
20	20	0.7339	7279	1146.4	260.0	886.5	173	5.12	886
21	21	0.7159	7105	1212.9	321.1	891.8	174	5.13	893
22	22	0.6982	6934	1144.8	262.3	882.5	171	5.16	882
23	23	0.6803	6761	1205.2	314.0	891.2	173	5.15	891
24	24	0.6625	6588	1158.6	271.7	886.9	173	5.13	887
25	25	0.6445	6414	1209.6	320.5	889.1	174	5.11	889
26	26	0.6268	6243	1190.2	301.8	888.4	171	5.20	889
27	27	0.6089	6070	1215.6	324.7	890.9	173	5.15	891
28	28	0.5912	5899	1158.1	269.4	888.7	171	5.20	889
29	29	0.5731	5724	1192.0	306.6	885.4	175	5.06	886
30	30	0.5545	5544	1169.2	278.1	898.1	180	4.95	891
31	31	0.5374	5378	1179.2	292.4	886.8	166	5.34	886
32	32	0.5194	5204	1138.8	244.1	894.7	174	5.14	894
33	33	0.5014	5030	1212.4	318.2	894.2	174	5.14	894

Following the 33-min run, each of the 33 one-liter flasks of collected water was weighed, emptied, and tared. A 2-kg Torbal balance was used, Model DH-2 (Torsion Balance Company) which weights to 0.1 g. Table 3 shows the gross, tare, and net weights.

To calibrate the top-loading balance, weight versus voltage, a platform for the balance was constructed to be used for all weighing; the platform weighed 431.7 g on the Torbal balance. Then, class "C" brass weights were added to or removed from the platform 1 kg at a time. Column 1 of Table 4 shows these known weights, and Column 2 shows the output in volts displayed by the Digitrend 220. The output of the top-loading balance was known to be linear, and a least-squares linear regression yielded

$$G = 178.7 + 9675.1\ V \tag{1}$$

where G is the weight (g) and V is the output voltage (volts). The standard error of estimate of G on V is 1.24; the standard error of the intercept is 0.61 and that of the slope is 1.43.

Table 4 — Calibration of Top Loading Balance

Weights on Top Loading Balance (g)	Display on Digitrend 220 (volts)
431.7	0.0263
1431.7	0.1295
2431.7	0.2328
3431.7	0.3361
4431.7	0.4395
5431.7	0.5429
6431.7	0.6463
7431.7	0.7500
6431.7	0.6462
5431.7	0.5429
4431.7	0.4395
3431.7	0.3362
2431.7	0.2328
1431.7	0.1295
431.7	0.0263

Determination of Burning Rate

In the foregoing, we described the liquid fuel supply system, how it operates, and its calibration. In this section, let us discuss determination of burning rate and its accuracy.

If the rate of fuel consumption varies minimally following an initial transient, then a mass rate balance yields the desired burning rate. On the other hand, if time to achieve a steady burning rate exceeds ca 600 s or if a steady rate is never achieved, then response time of this present fuel supply system (180 s) is slow and would require improvement.

For a steady burning rate, a material balance of the fuel yields

$$W_2 = FW_1 \tag{2}$$

where the factor F is the mean of the ratio W_2/W_1; W_2 is the weight per unit time of fluid leaving the fire pan, g/min; W_1 is the weight per unit time of fuel leaving the scale reservoir, g/min; FW_1 is the mean weight per unit time of fuel entering the fire pan, g/min.

Table 3 gives the scale-reservoir weights G in grams (Column 4) as obtained from Eq. (1) and the corresponding value of the voltage output V (Column 3) of the top loading balance. The differences W_1 of successive values of G for 1-min time intervals are given in Column 8 of Table 3. Excluding the first two values of W_1 which were obtained during the initial transient, the mean value $\overline{W}_1 = 173$ g/min with a standard deviation s.d. = +3.5 g/min is obtained.

Column 7 gives the net weight per minute W_2 of water leaked from the fire pan. This mean measured value $\overline{W}_2 = 883.4$ g/min with s.d. = ±7.1 g/min.

For each of the last 31 cases (excluding the first two), from Eq. (2) the ratio of $F = W_2/W_1$ is obtained. The mean of these values is $\overline{F} = 5.13$ with s.d. = ±0.12. Buoyancy corrections [7] would affect the value of $\overline{F}$ only 1 part in 1020 and are thus ignored.

Finally, after $\overline{F}$ is determined, Eq. (2) may be rewritten

$$\hat{\overline{W}}_2 = \overline{F}\ \overline{W}_1 \tag{2a}$$

where $\hat{\overline{W}}_2$ is the mean value of the calculated burning rate. According to Wilson [8] the standard deviation of $\overline{W}_2$ can be determined from the relation

$$\left(\frac{\text{s.d. of } \overline{W}_2}{\overline{W}_2}\right)^2 = \left(\frac{\text{s.d of } \overline{F}}{\overline{F}}\right)^2 + \left(\frac{\text{s.d. of } \overline{W}_1}{\overline{W}_1}\right)^2$$

$$\text{or s.d. of } \hat{\overline{W}}_2 = 883.7 \left[\left(\frac{0.12}{5.13}\right)^2 + \left(\frac{3.5}{173}\right)^2\right]^{1/2} = \pm 27.4 \text{ g/min.}$$

Then, 95% of the $\hat{W}_2$ values are expected to fall within two s.d. of $\hat{\overline{W}}_2$ of ±6.2%, and it is concluded that the accuracy of the burning rate is ±6.2%.

Summary

Application of the above information is straightforward. The weight rate W_2, that fuel is consumed from the 50- or 100-cm fire pans when supplied from the large supply system, is

$$\hat{\overline{W}}_2 = 49600\ [V(t_1) - V(t_2)]/(t_2 - t_1) \tag{3}$$

where $V(t_1)$ and $V(t_2)$ are successive voltages as recorded by the Digitrend 220 for the time interval $(t_2 - t_1)$ and t is in minutes. The units of W_2 then are g/min with an estimated standard deviation of ±3.1%. This accuracy is valid for regression rates of 0.11 mm/min in the 100-cm pan and 0.44 mm/min in the 50-cm pan. Response time of the fuel supply system is limiting.

In the small fuel supply system, the top-loading balance is limiting; low values of W_2 cannot be accurately determined. As a result, only the 15-cm fire pan is suitable if used with the small supply system. For this system-pan combination, the weight rate W_2 of fuel consumption is

$$\hat{\overline{W}}_2 = 967.6\,[V(t_1) - V(t_2)]/(t_2 - t_1) \tag{4}$$

where these symbols are described as in Eq. (3). Estimated standard deviation for Eq. (4) is ±7.6%.

CHAMBER SENSORS

Temperatures in the chamber are monitored with thermocouple arrays in each end of the chamber. These thermocouples have chromel-alumel wires with diameters of 0.2 mm (8 mils) and have ceramic insulation enclosed in 304 stainless steel jackets 1 mm in diameter; they were purchased from Omega. Figure 17 shows the exact location and assigned designators.

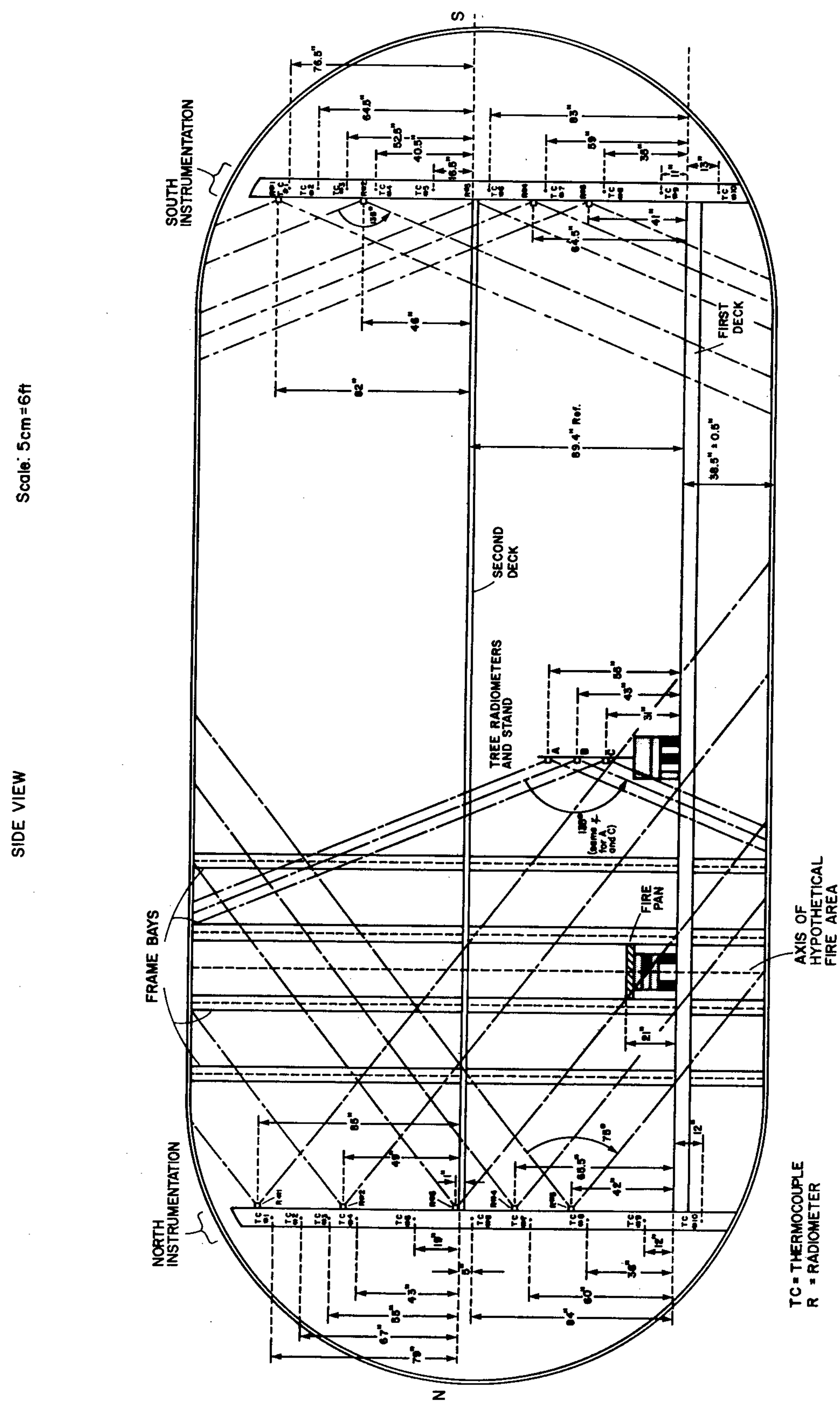


Fig. 17 — Chamber side view—Thermocouple and radiometer locations in 324 m^3 chamber

Radiation measurements are made with wide and narrow angle radiometers purchased from Concept Engineering Model Mark U-1354 (135° view) and Mark U-0754 (75° view) with viewing angles and locations of the radiometers as shown in Figs. 17 and 18. Commencing with the 17 September 1981 Hull Insulation Fire Test, wide angle radiometers were installed in the north end of the chamber. Moveable radiometers A, B, and C were mounted on a stand as shown in Figs. 17 and 18.

Smoke obscuration levels are measured by three methods: visual obscuration with video cameras, particle analysis, and obscuration with laser detectors. Video cameras located in the northwest, view port #1 and northeast, view port #9 windows view four metal plates inside the chamber. From the northeast view port, the four plates are located 0.97 m (3.17 ft), 2.51 m (8.25 ft), 2.19 m (7.17 ft), and 2.82 m (9.25 ft), respectively, and are 0.30 m (1 ft), 0.48 m (1.58 ft), 0.69 m (2.25 ft), and 0.91 m (3.0 ft) high with respect to the first deck grating. From the northeast view port, these plates are 2.51 m (8.25 ft), 3.0 m (9.83 ft), 3.66 m (12.0 ft), and 3.96 m (13.0 ft), respectively. The cameras show real time; smoke density levels are judged as the view of each plate is obscured.

Particle analyzers (Climet Model CI-208) sample smoke particles and classify them according to size and number density. Particle counts may then be correlated with the visual smoke obscuration. One particle analyzer samples from the northwest corner of the chamber, while another samples outside air. The minimum particle size detected is 0.3 μm. Samples are collected continuously and displayed at 1-min intervals, with a 15-s period between scans. The particle analyzer has its own data collection system, Climet Model CI-210 which is also clocked in real time. An eight channel monitor categorizes the particles into eight size ranges: 0.3 to 0.5, 0.5 to 0.7, 0.7 to 1, 1 to 2, 2 to 3, 3 to 5, and 5 to 10 μm, and greater than 10 μm, at 8.48-s intervals, and records the data in real time on magnetic tape (Kennedy Model 1600/360).

Laser/detector systems located on the east wall of the first deck and west wall of the second deck, Fig. 5, measure up to 9% smoke density. Figure 19 shows the calibration curve of the east detector.

SAFETY CONSIDERATIONS

Numerous safety considerations are built into the chamber and are described throughout this report. For convenience they are summarized here. These safety aspects can be divided into two general areas—hardware and procedures.

The chamber is designed to withstand 658 kPa (6.5 atmospheres). It was hydrostatically tested to 775 kPa (112.5 psia) pressure with a blowout plug which will relieve pressure at 618 kPa (89.7 psia). The gas dump system, in addition to having automatic valves which are activated inside the trailer, has manual valves which are closed except during experiments with the pressurization system. The automatic valves are normally closed when the power is off. Thus inadvertent pressurization is not possible. A bleed valve which can be operated from within the chamber is located in the hatch. This feature is designed to protect personnel in the chamber if the hatch were to close. Small changes in temperature result in a chamber overpressure such that the hatch could not be opened without the bleed valve. Two interior ladders at each end of the chamber allow quick departure from the second deck.

Signs are provided to limit access to chamber grounds during an experiment as well as to chamber doors and ladders. Posttest gases are quite toxic, and frequently chamber atmospheres have too little oxygen to sustain life. Special signs are provided for these conditions. Six video cameras serve as real-time monitors in the control trailer. Radio communication is also provided for people inside the chamber; a public address system warns if an experiment is in progress. Safety interlocks at chamber vent valves and chamber hatch prevent the start of an experiment unless these interlocks are closed. Exhaust gases from the chamber are routed remote to the chamber. Two sets of breathing apparatus are provided with 12.2 m (40 ft) of hose. A charged fire hose and two sets of fireman's clothes are available during a test. The fire department also stands by.

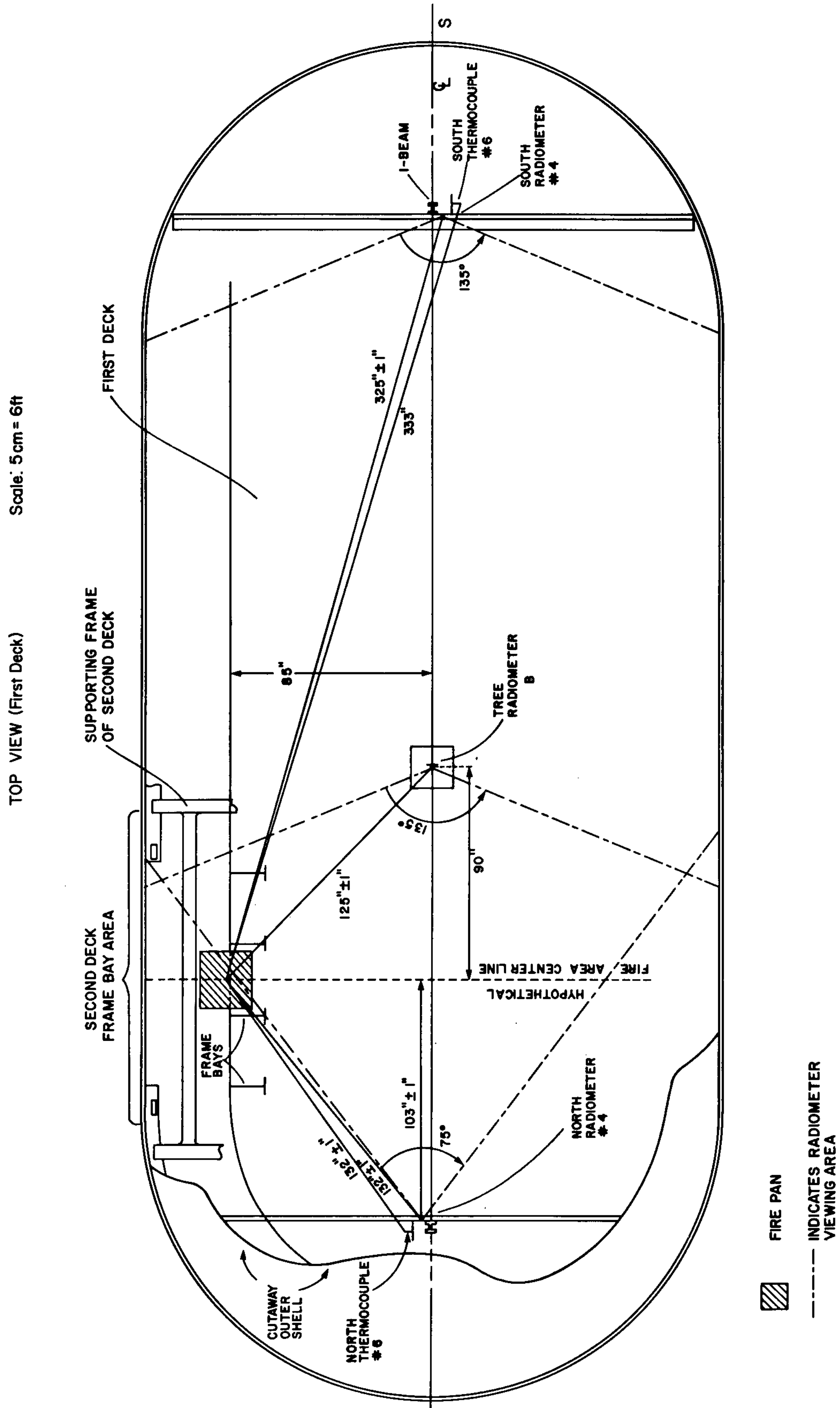


Fig. 18 — Chamber top view of radiometers viewing angle

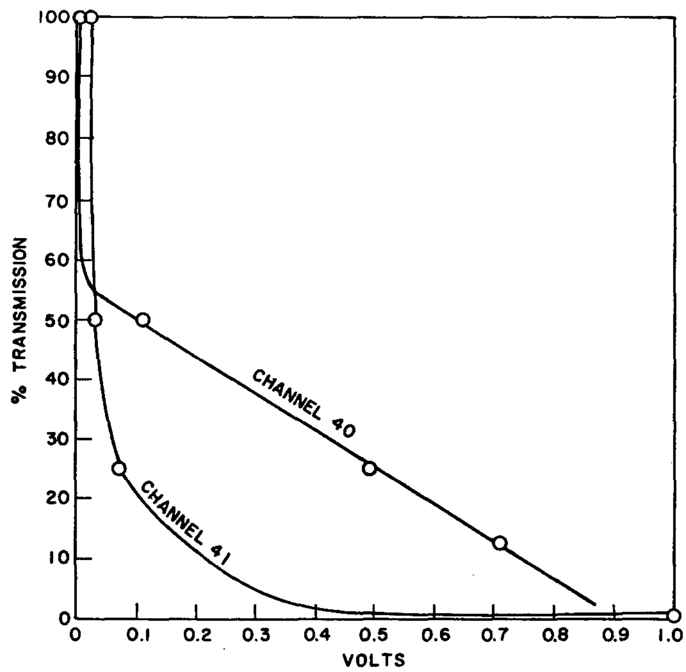


Fig. 19 — Cal curve smoke obscuration as measured with Laser-Detector Monitor

A script for each major fire test is developed in detail and rehearsed. The team leader maintains strict control. Each team member reports directly to the leader. The team leader controls all aspects of a fire test including visitor safety.

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Appendix A
SAMPLE PROCEDURE FOR OPERATING FIRE-I

FILLING PROCEDURE FOR HIGH-PRESSURE GAS TANKS

When we start the following procedures, we verify that all valves are in their closed position.

Procedure for Adding Nitrogen Gas from the Tube Trailer to the Pressure Cylinders (positioned on the chamber)

1. Connect high-pressure hose to chamber filling manifold through a check valve.

2. Connect high-pressure hose to tube-trailer outlet, also through a check valve.

3. Open outlet valve at tube trailer.

4. Open lower tube-bank manifold valve to outlet manifold of tube trailer.

5. Open bleed valve on chamber filling manifold.

6. Crack valve on lower left-hand tube on trailer and flush pressure hose briefly to expel any moisture. Close valve on tube; close bleed valve on filling manifold.

7. Select pressure cylinder to be pressurized, No. 1, 2, 3, or 4. For example, select pressure cylinder No. 4.

8. Open 1-in. ball valve above filling manifold marked 4. On control panel in trailer, Fig. 11, Panel IV, select cylinder No. 4. This connects Heise Gauge 0-10.3 MPa (0-1500 psia) to pressure cylinder No. 4.

9. Partially open valve on left-hand tube in lower bank of tube trailer and adjust to the desired filling rate. Allow pressure to equalize, then close tube valve.

10. Now open valve on second tube from left in the lower bank and allow its pressure to equalize with pressure in pressure cylinder No. 4. Continue this procedure, always using one cylinder at a time, until the pressure in pressure cylinder No. 4 reaches 10.3 MPa (1500 psia). When necessary, change to another tube bank.

11. Close 1-in. ball valve No. 4 at filling manifold.

12. Select another pressure cylinder to fill, say No. 2. Open 1-in. ball valve No. 2 at filling manifold.

13. Begin filling from tube trailer as before, again starting at the left-hand tube in the lower bank. Fill from one tube at a time; after pressure equalizes, move to the next tube until pressure cylinder No. 2 is filled to the desired pressure.

14. Now fill the third pressure cylinder in the same manner.

15. When pressure cylinders are filled to approximately the same pressure, equalize their pressures by opening the appropriate 1-in. ball valves at the filling manifold.

Blowdown Procedure

Normally we blow from three pressure tanks through three nozzles. At present, two of the nozzles connect to the north manifold, while the third nozzle connects to the south manifold. Pressure cylinders No. 1 and 2 connect to the north manifold. Each end of each pressure cylinder connects, so that four 2-in. schedule 80 pipes feed gas to the manifold. Likewise, cylinders No. 3 and 4 connect to the south manifold. In the present configuration with two nozzles from the north manifold and one nozzle blowing from the south manifold, we use pressure cylinders No. 1 and 2 for the north manifold and either pressure cylinder No. 3 and 4 for the south manifold. Flow through each of the 2-in., schedule 80 pipes connecting the pressure cylinders to the manifolds is controlled by two 2-in. high-pressure valves connected in series. The first valve is a hand-operated ball valve by Jamesbury. Just downstream of the Jamesbury ball valve is an Atkomatic Solenoid valve. In addition to these two valves, there is a 1/4-in. valve in parallel with the Jamesbury ball valve. These three valves are normally closed. To set valves for a blowdown:

1. Slowly open the 1/4-in. valve that is parallel with the Jamesbury ball valve. This allows nitrogen pressure from the charged cylinder to engage the upstream side of the Atkomatic Solenoid valve without causing the Solenoid valve to knock. Sudden pressurization of these valves damages their control mechanism.

2. When the Solenoid valve is pressurized, open the Jamesbury ball valve and then close the 1/4-in. bypass valve.

3. Do items 1 and 2 for each end of each pressure cylinder that is selected for the blowdown, i.e., six sets of valves.

4. The blowdown control valves are now ready.

Appendix B
ATKOMATIC VALVE OPERATION AND MAINTENANCE

The Atkomatic Solenoid valves are normally closed and remain in the closed position when the coil is de-energized. When the coil is energized, the magnetic force pulls the plunger and stem assembly up toward the top of the cylinder cap assembly, compressing the return spring, lifting the stem off the piston rod seat link. This relieves the pressure above the piston, through the orifice in the piston rod link and piston; and the line pressure, combined with the upward force of the plunger and stem assembly, lifts the piston, opening the valve. In case of little or no pressure drop at time of opening, the upward magnetic force of the plunger and stem assembly lifts the piston by itself. At this point, the plunger and stem assembly is held against the top of the cylinder cap assembly attraction and holds the valve fully open, regardless of the pressure drop through the valve.

When the coil is de-energized, the magnetic pull on the plunger is cut off, thereby releasing the force of the compressed return spring. The spring then expands, pushing the plunger and stem assembly downward, seating the stem on the piston rod link. The line pressure then builds up over the piston and, combined with the force of the return spring, closes the valve. In the absence of line pressure, the return spring itself closes the valve.

To examine the internal parts, shut off electric power and line pressure. To provide the necessary space required for disassembly of the two lower valves, a large 2-in. union must be taken apart and the pipes lifted to provide the necessary clearance for the lower valves. Unscrew the large bonnet lock nut and remove housing cover coil, and yoke. Be careful not to drop parts since the plunger assembly and return spring will now be free. Inspect the stem seat for nicks, burrs, or worn sections. To free the piston assembly, lift straight up through the cylinder and inspect piston rings for dirt or deposits. Clean with methyl alcohol the cylinder walls and seat insert prior to reassembly. Replace parts as needed and reassemble in reverse order. Valve failures causing opening and closing problems can be attributed to the piston rod link seat clogged with foreign matter, valve disc worn, or valve seat damaged. The Teflon O-rings used in the valves should be replaced with new ones each time the valve is disassembled.

Appendix C
ELECTRICAL SCHEMATICS OF THE CONSOLE CONTROL SYSTEM

Schematics

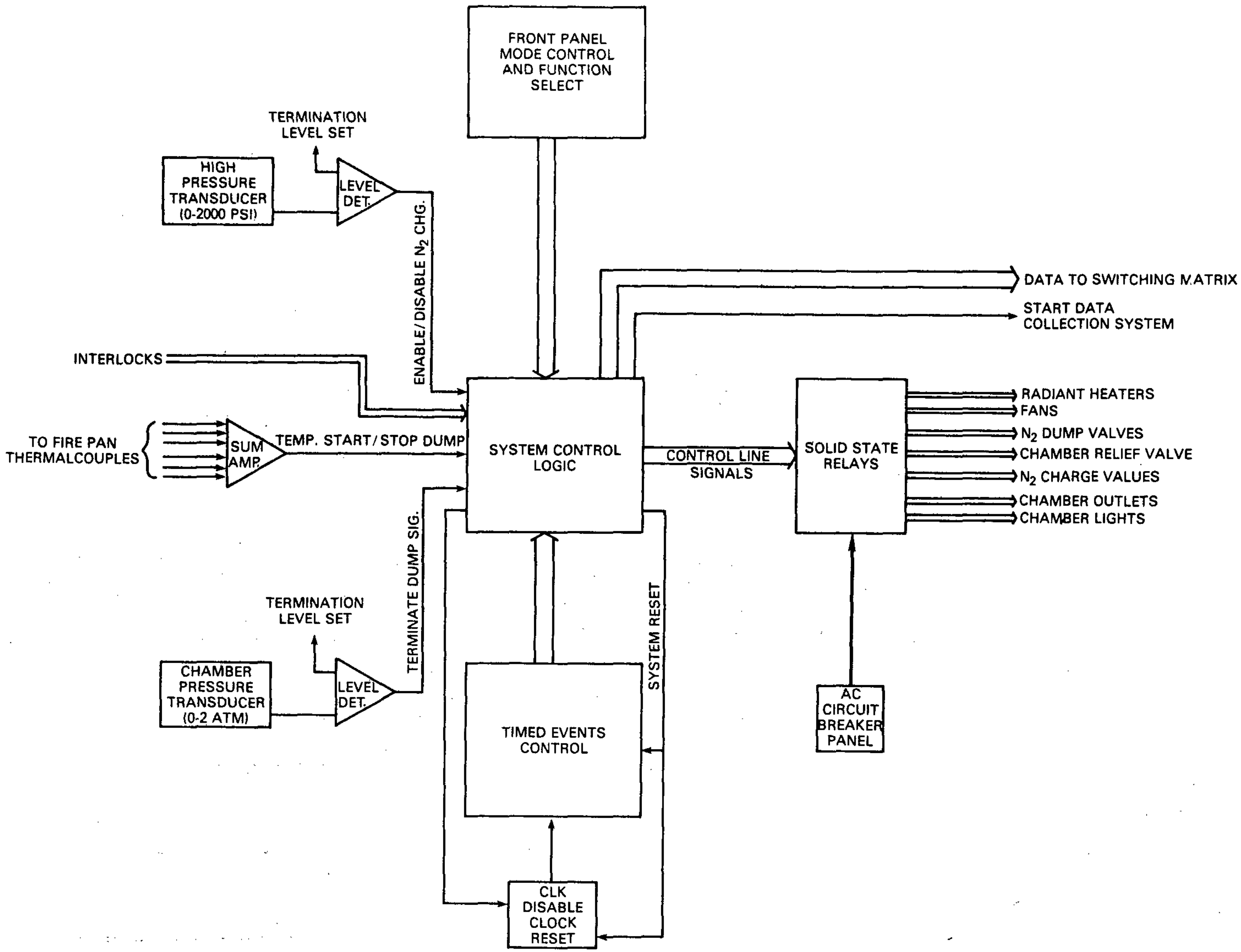


Fig. C1 — Electronic block diagram

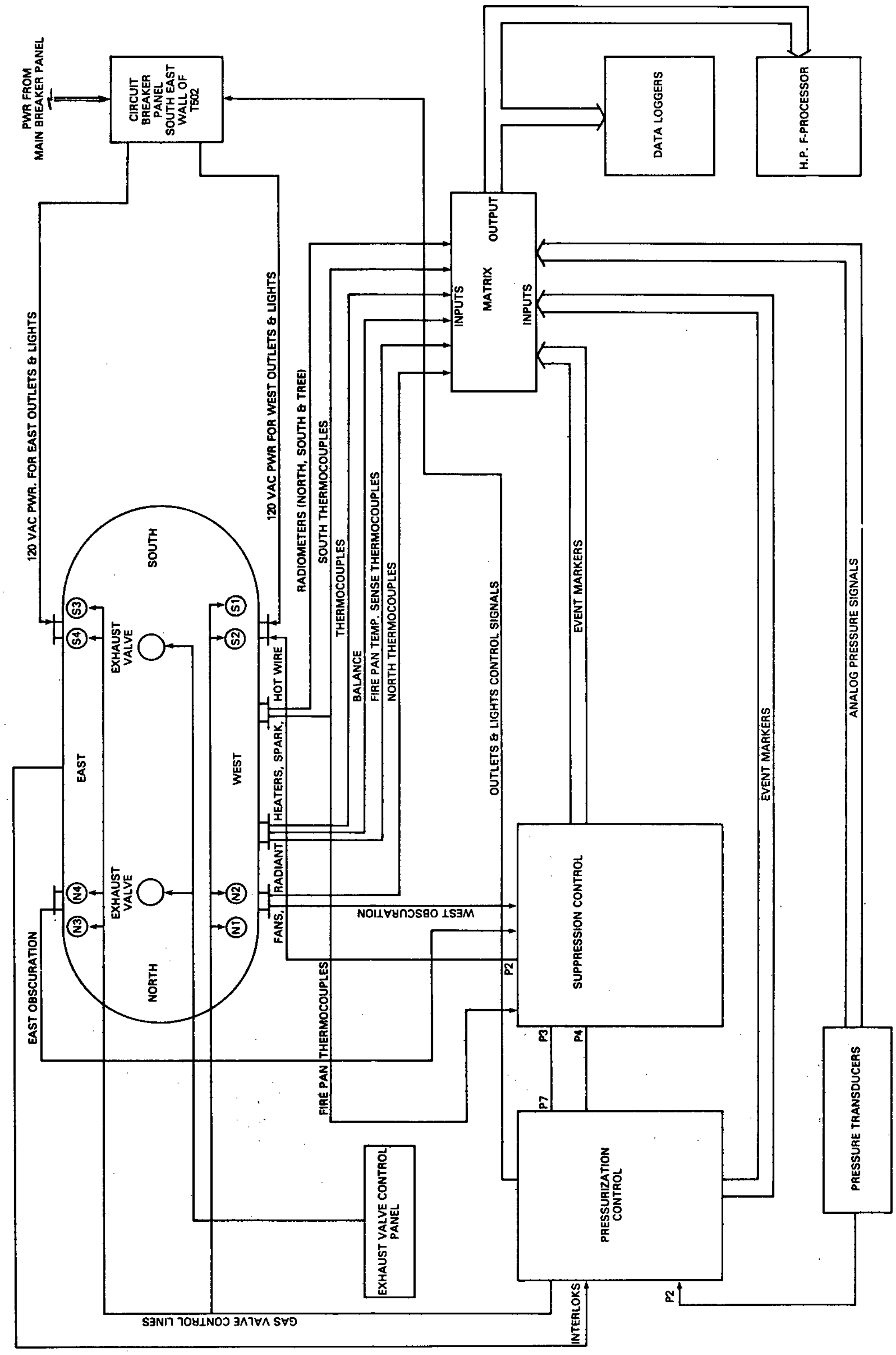


Fig. C2 — System data and control routing

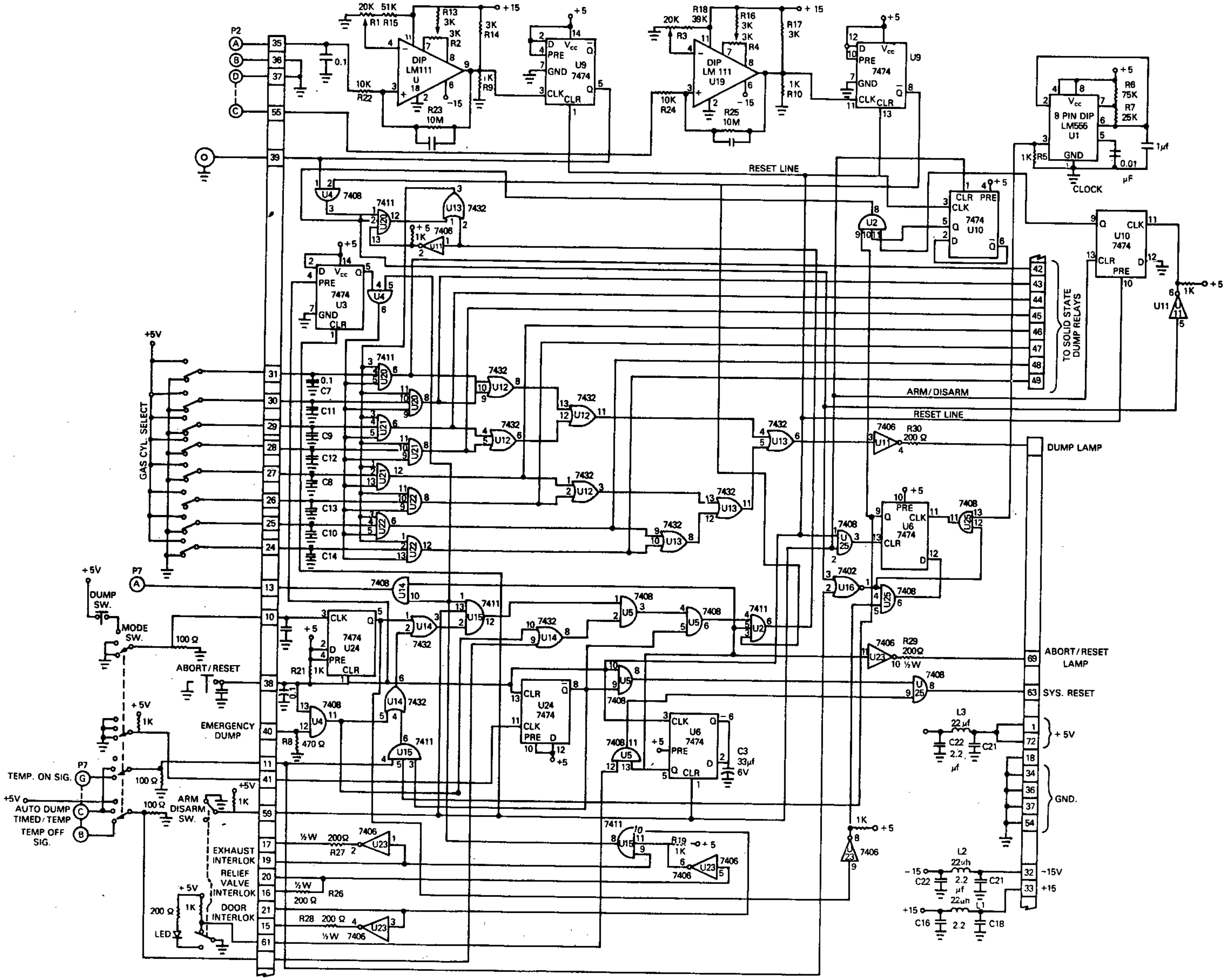


Fig. C3 — Suppression control

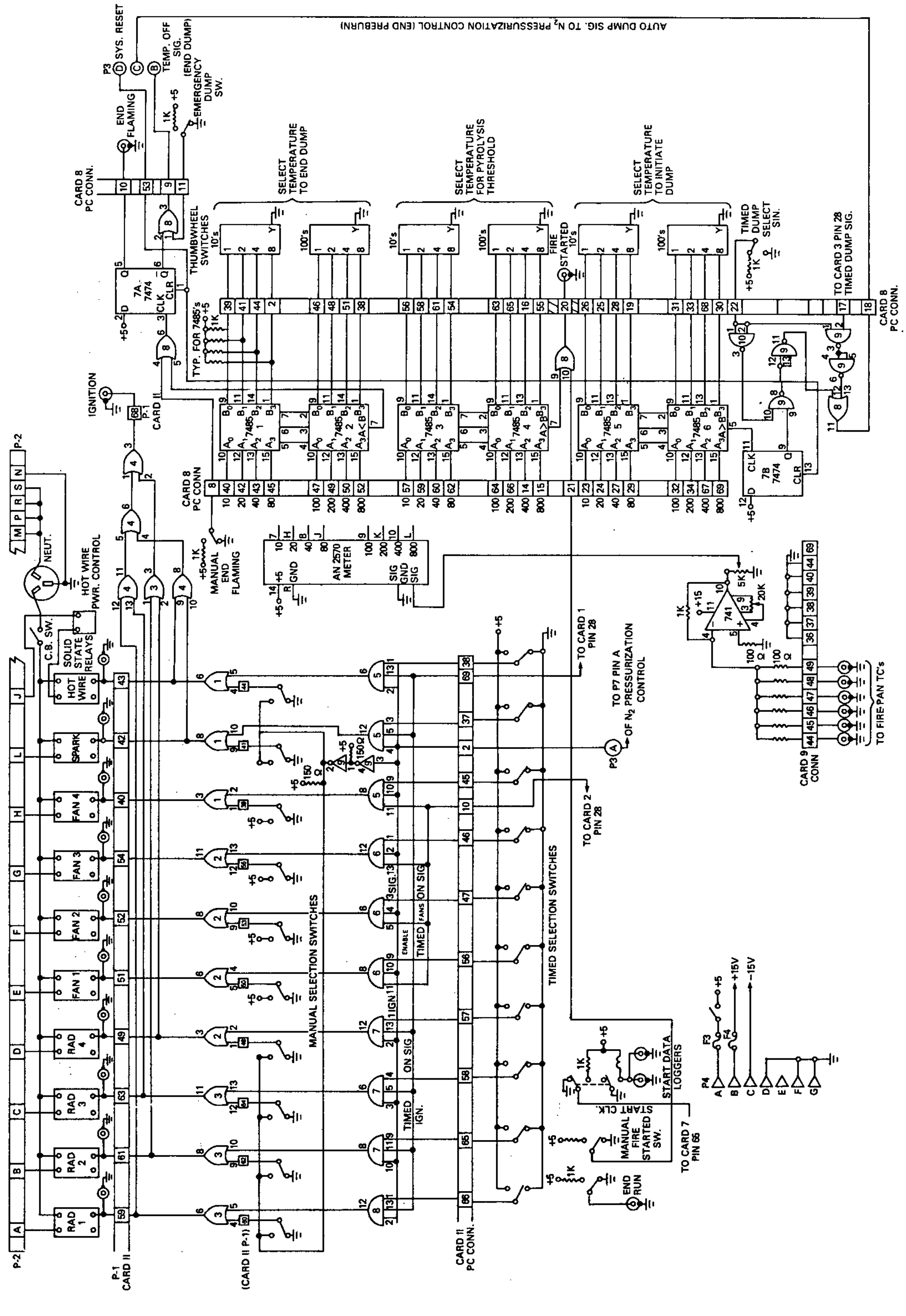


Fig. C4 — N_2 pressurization control

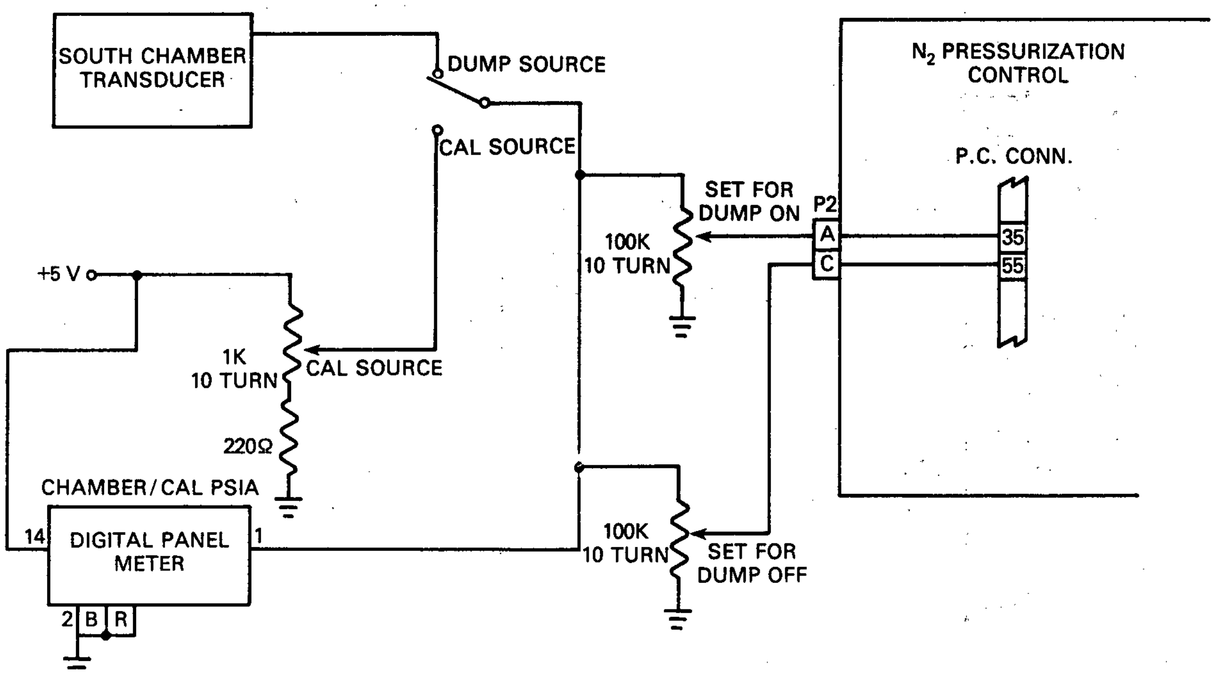


Fig. C5 — Autodump by chamber pressure

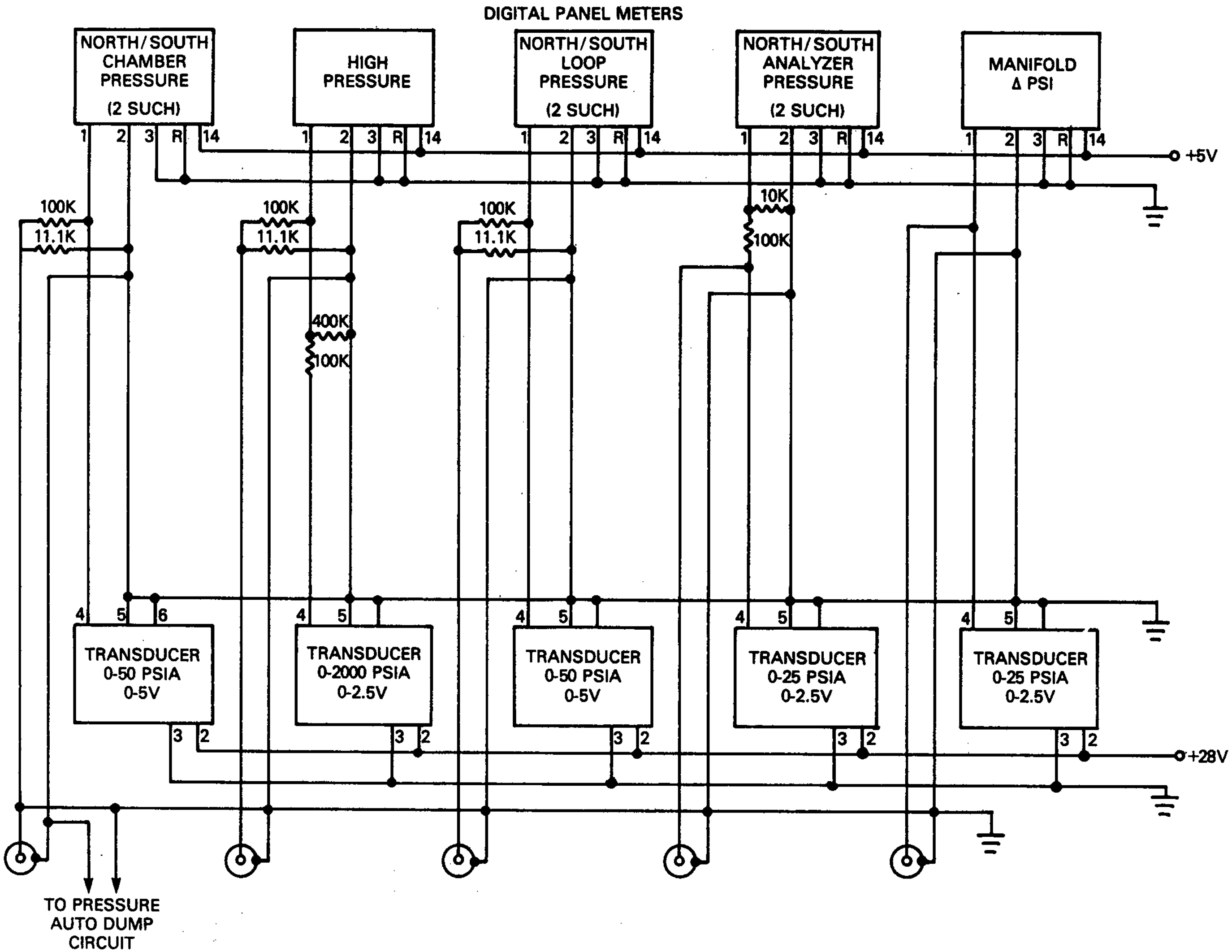
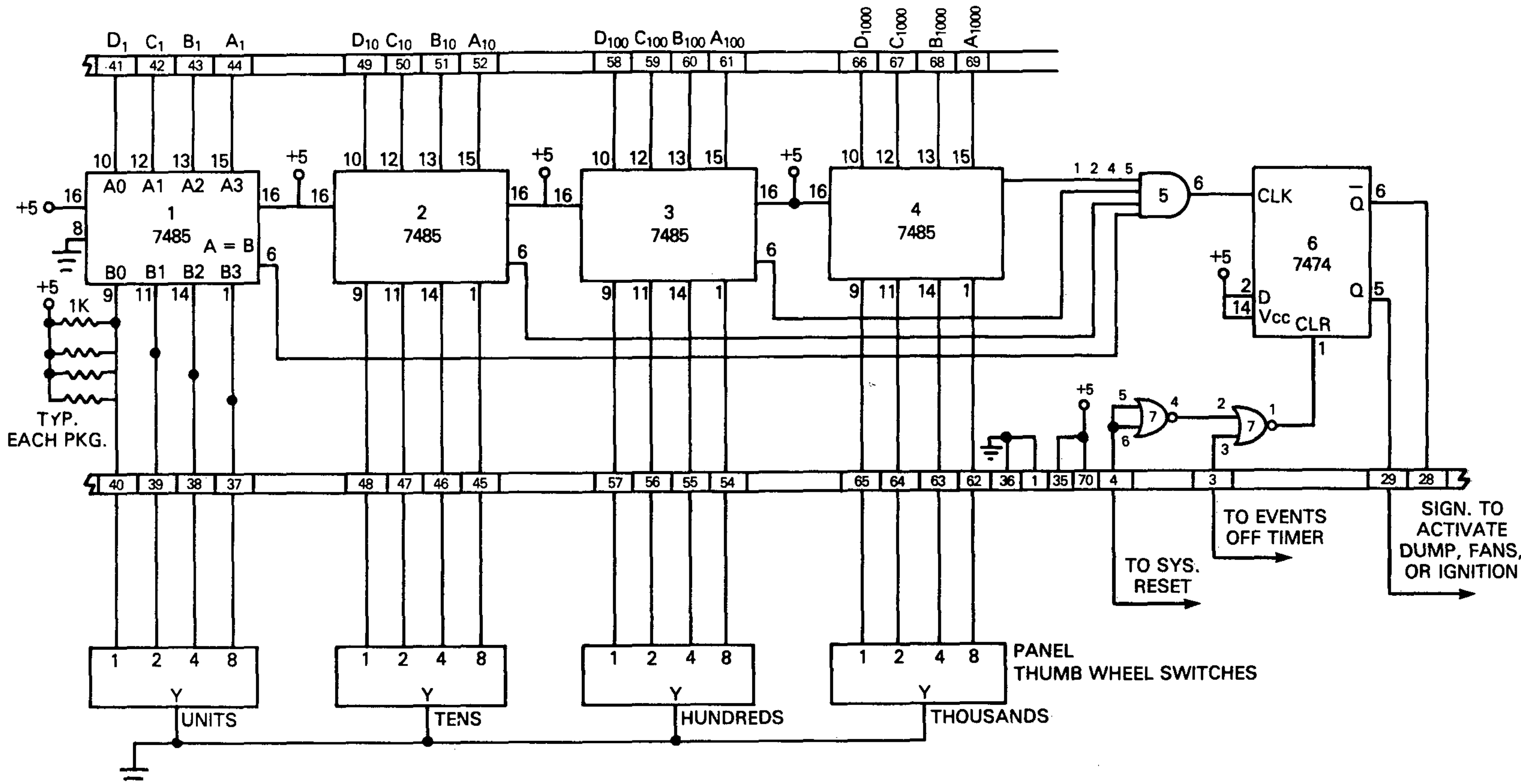
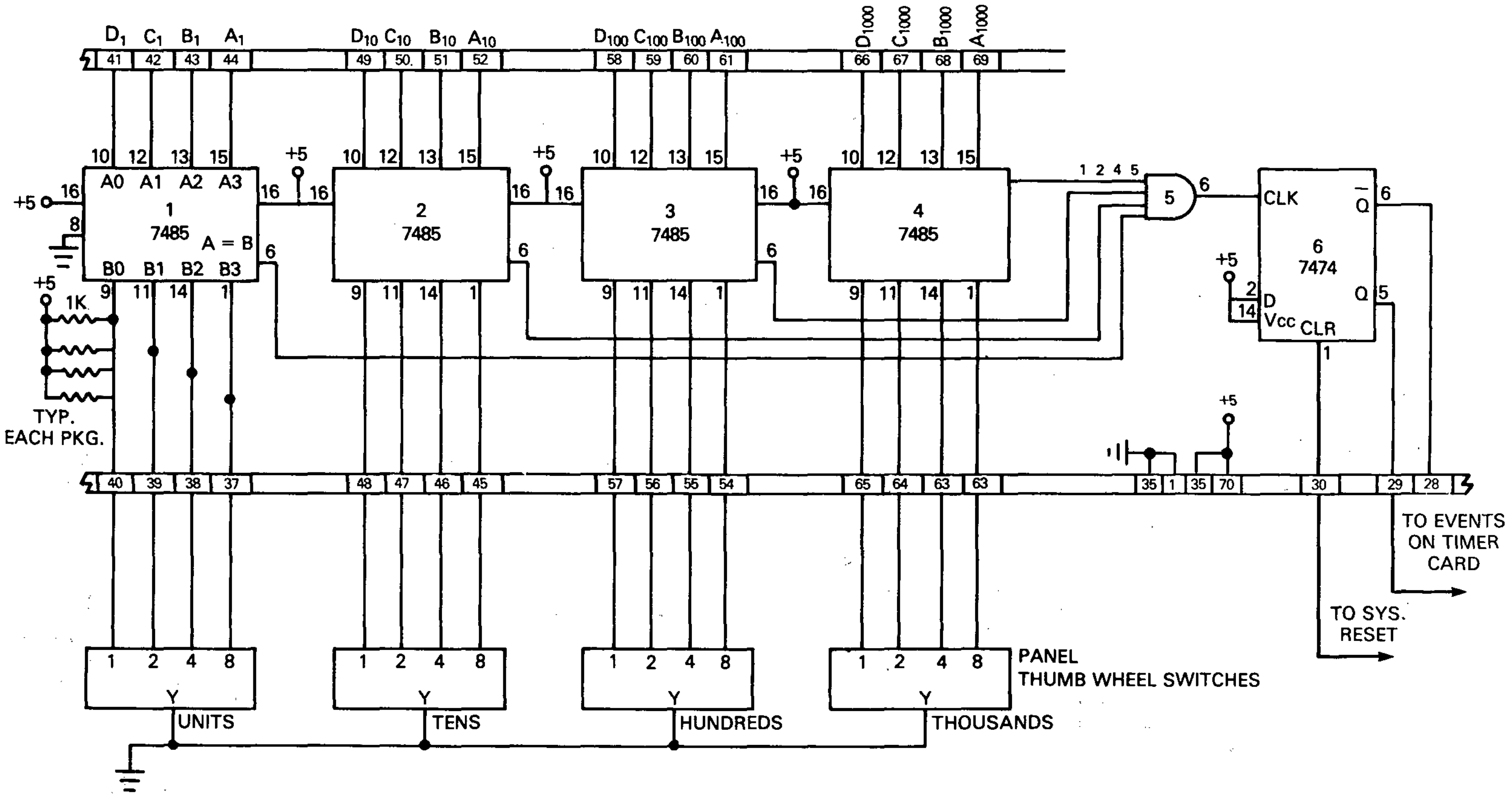


Fig. C6 — Pressure transducer meter panel



EVENTS OFF TIMER CARDS (#4, 5, 6)

Fig. C7 — Events on timer



EVENTS OFF TIMER CARDS (#1, 2, 3)

Fig. C8 — Events off timer

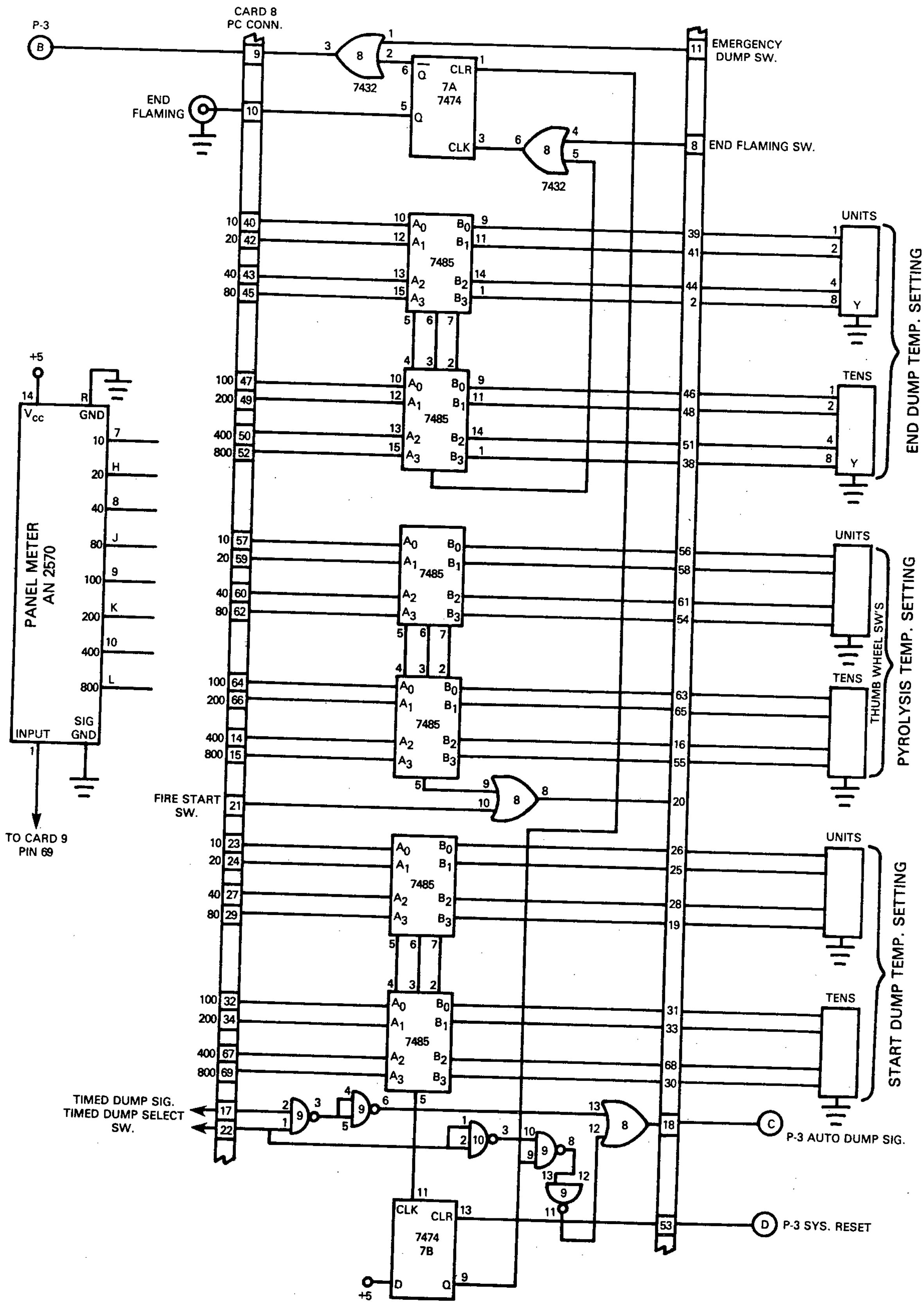


Fig. C9 — Temperature control

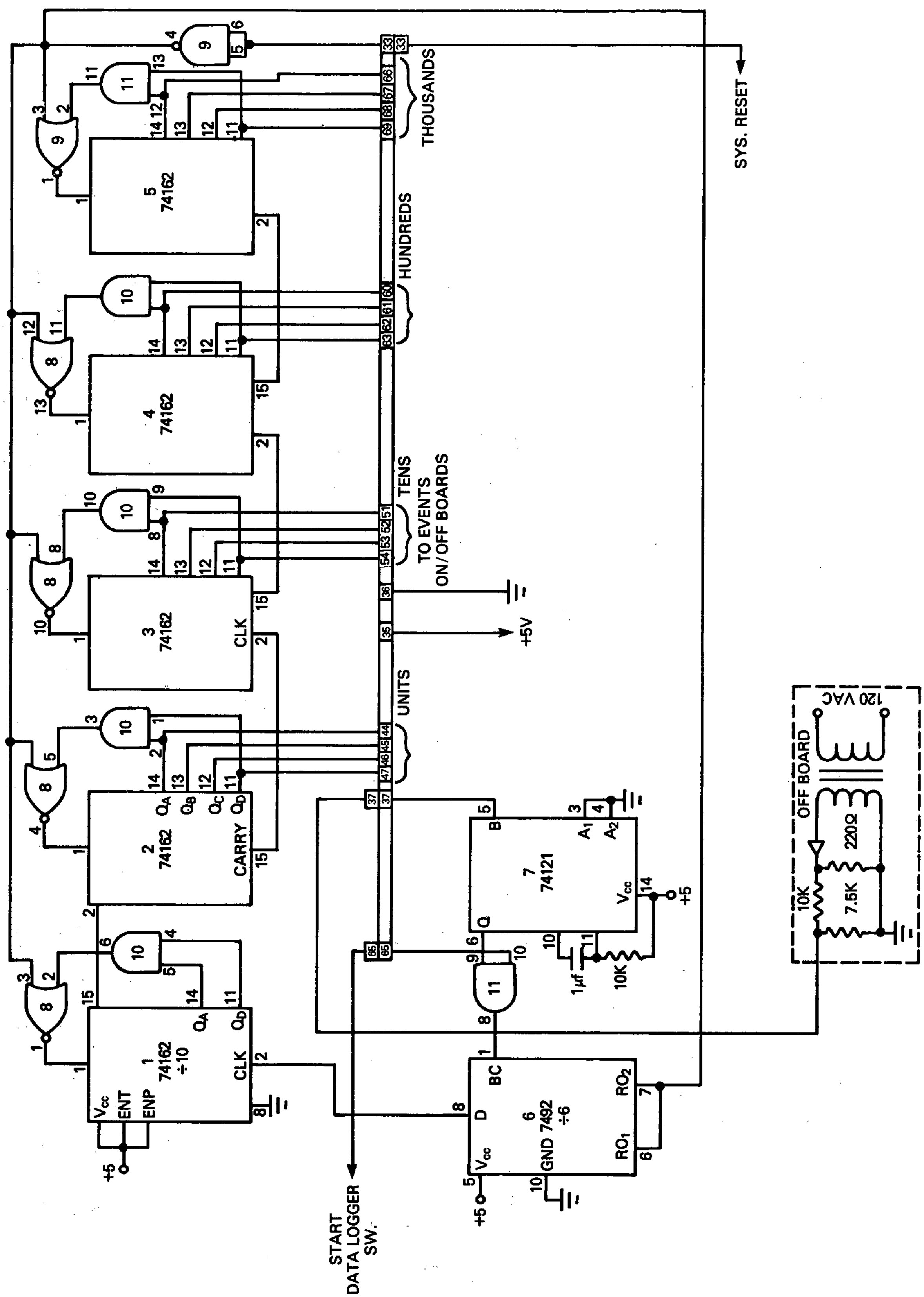


Fig. C10 — Clock card 7

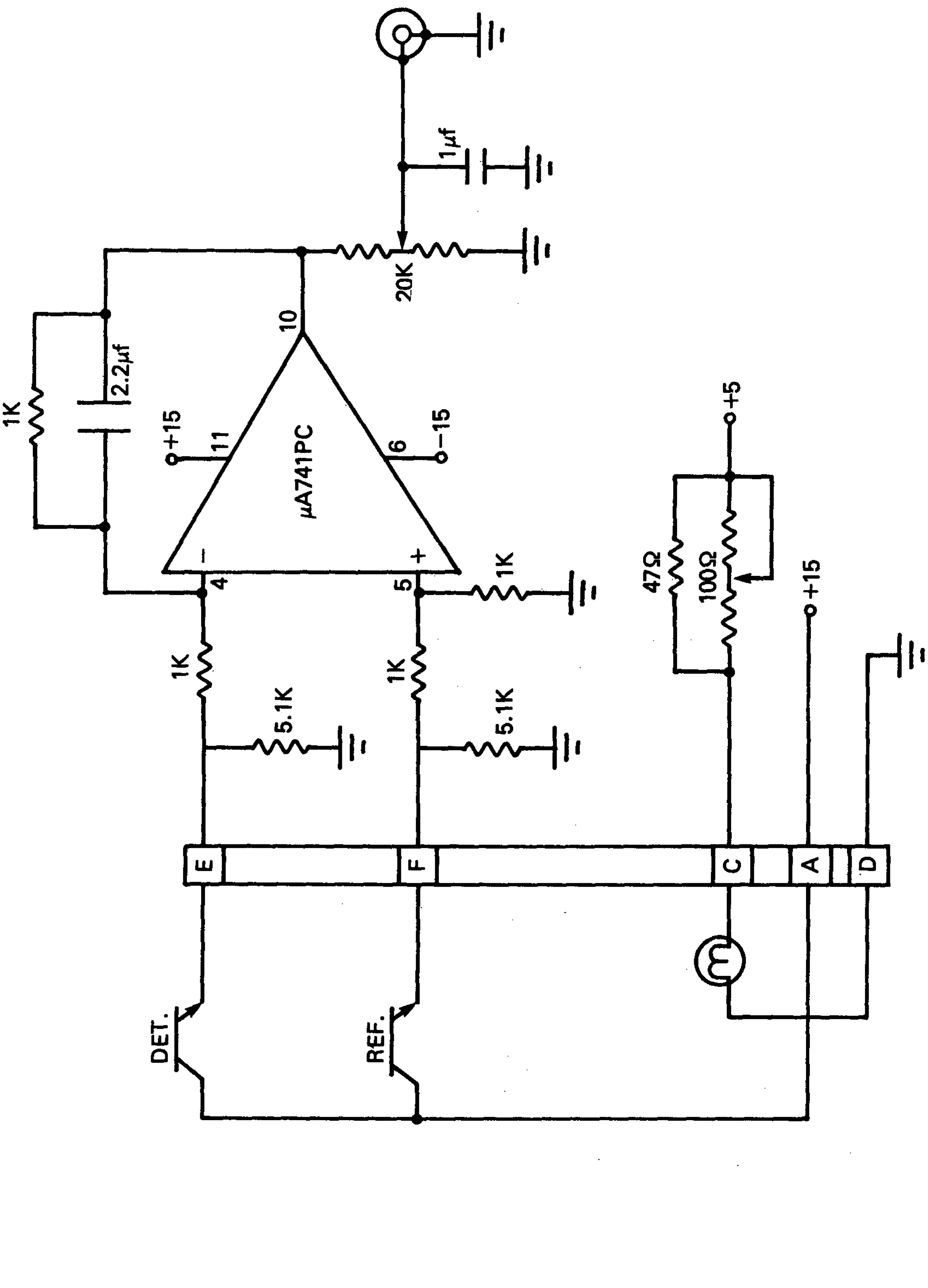


Fig. C11 — Obscuration detector

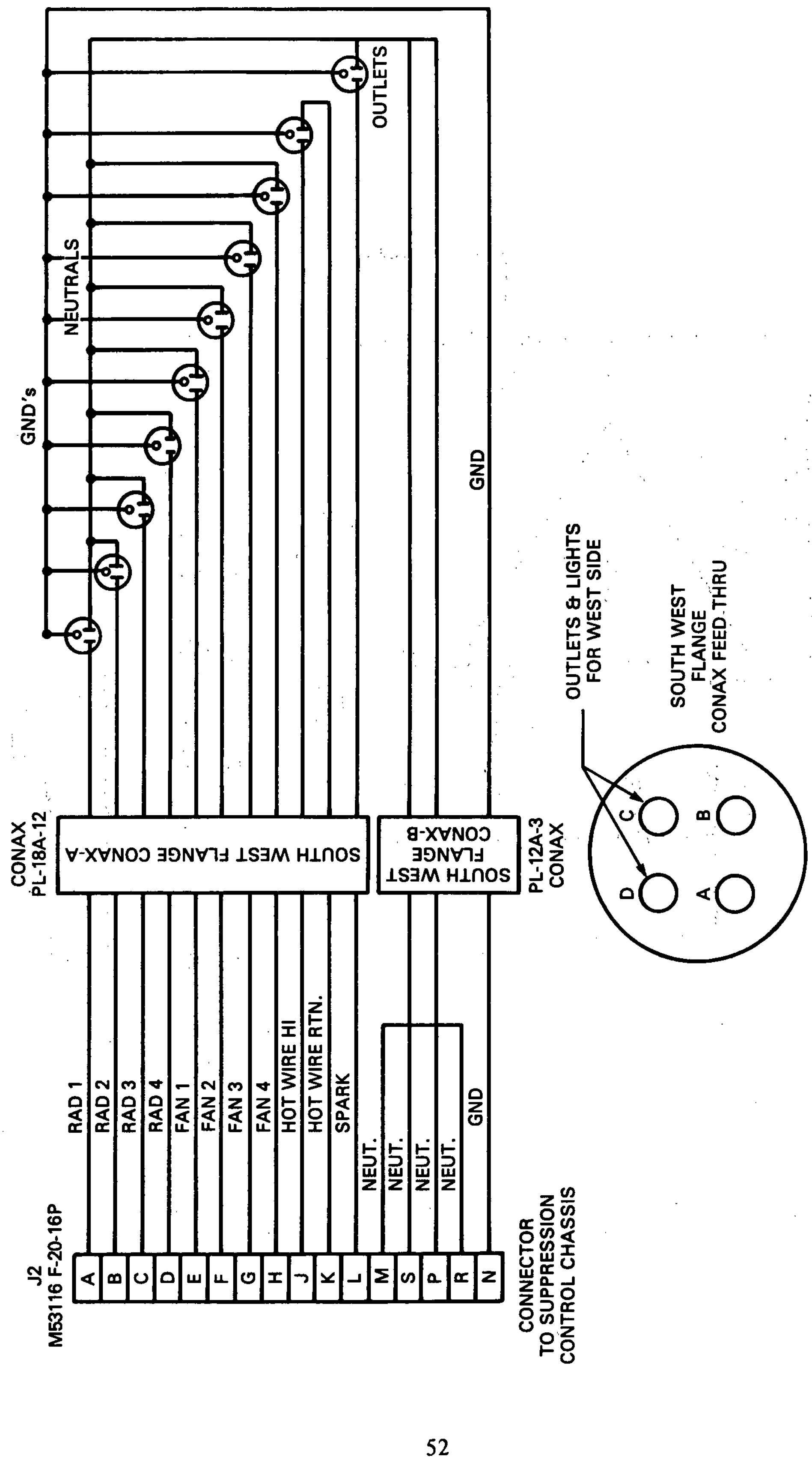


Fig. C12 — Controlled chamber outlets

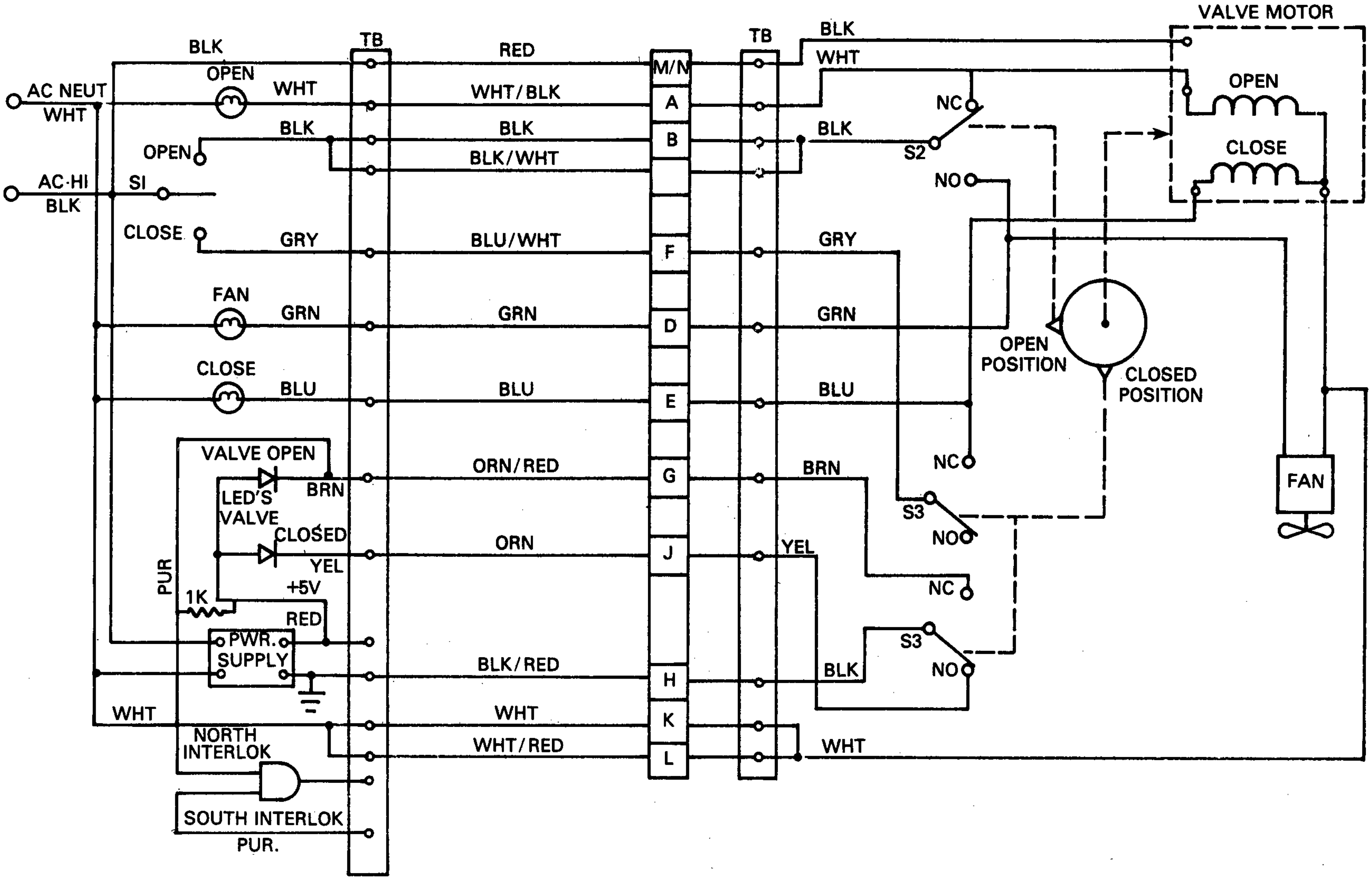


Fig. C13 — Motor driven exhaust valve typical for north and south valves

Appendix D
GAS SUPPLY AND CONTROL SYSTEM

The control system provides means to both manually and automatically initiate and terminate events, that is controlling nitrogen dump valves, and other events described elsewhere in this report. These events are selected under panel headings; "Manual select," "Timed Select," and "Temp. Cont. Events." In addition, there are interlocks to inhibit functions for safety purposes and dump termination at a predetermined chamber pressure to avoid overpressure as well as to provide operator selection of some predetermined termination pressure. In addition, nitrogen dumping may be initiated by a high-temperature sensing circuit and terminated by low temperature (Temp. Cont. Events) from chamber fires. After an experiment the chamber pressure may be restored to atmospheric pressure by using the "Relief Valve" and vented by using north and south vent valves and the ventilation fans.

Transducer analog signals are conditioned via amplifiers, level detectors, etc. to exercise the control logic in addition to operator front panel controls. The operator may at any time abort any event. The Abort/Reset switch, Arm/Disarm switch or opening the AC Valve Power circuit breaker will stop nitrogen dumping but has no effect on other events. In the event autodump fails, the operator can initiate a dump using Emergency Dump, but only providing that interlocks are set and the chamber is not above a preset chamber pressure (autopressure termination point). When the mode control switch on the Nitrogen Pressurization Control panel is changed the system will automatically reset. This will inhibit the new mode from initiating a dump and requires the operator to manually reset the system again before a new dump mode can be used.

NITROGEN PRESSURIZATION AND FIRE SUPPRESSION CONTROLS

Procedure

1. Before turning on the control system be sure the Arm switch is set to Disarm position and the AC Valve Power switch is off.

2. Dumping by chamber pressure is always active no matter what mode of dumping is used. This makes possible automatic dumping at a predetermined pressure resulting from a fire within the chamber and autotermination of the dump to avoid chamber overpressure. It is, however, possible to set the "Dump On" and "Dump Off" potentiometers to levels which give wide limits should it be required. For the above reasons the step will be to follow the procedure "Using Chamber Pressure for Dumping" in this appendix.

3. Set Mode Control switch located on Nitrogen Pressurization Control panel to required mode of dumping (Temp., Time, or Manual). Use Manual mode also if dumping will be controlled by chamber pressure.

4. If temperature mode is selected, the thumbwheel switches should now be set for the sensed high-temperature point to initiate dumping and the low-temperature point to terminate the dump. These switches are under the "Temp. Cont. Events" headings. For a timed dump, set the Timed On thumbwheel switches to the number of seconds from zero time at which dumping is to take place and the Timed Off switches to seconds of time at which dumping is to terminate. This zero time is the instant of depressing "Start Data Loggers" push button switch. Under the Timed Select heading depress the Dump switch.

5. Fans, Radiant Heaters, Spark, and Hot Wire may be timed or manually operated. If timed operation is used, depress the appropriate push button switch under Timed Select and then set the Timed On and Timed Off switches in seconds as required. If manual operation is used, be certain that the same device is not selected under a timed switch.

6. Now arm the system by using the Arm/Disarm switch at the left-hand corner of the Nitrogen Pressurization Control panel. Next depress the Abort/Reset push button switch and turn on the AC Valve Power switch, then select the cylinders (north 1-4, south 1-4) to dump. When ready to start the experiment, depress the Start Data Loggers switch. At the selected start time, high-temperature setting, or settings for dumping via chamber pressure dumping will take place and terminate at the selected start/stop, high/low temperature setting or Dump On/Dump Off level.

7. **When data collection is complete, depress the Start Data Loggers push button switch again. This will halt the magnetic tape units and terminate data logger scanning. Next depress the Output Enable switch on the Doric Digitrend data loggers. This will automatically place a file gap on the magnetic tape and inhibit further data collection.**

8. As a safety precaution the Arm/Disarm switch should now be set to the Disarm position (down) and the AC Valve Power breaker switch should now be turned off.

USING CHAMBER PRESSURE FOR DUMPING

Chamber pressure may be used to initiate or terminate a dump depending on the setting of the pressure level potentiometers. It is therefore imperative that this level be known prior to any use of the gas discharge system. The level may be established using the digital pressure meter and potentiometers on the panel located between the Suppression Control Unit and the N_2 Pressurization Unit.

To ensure that the following procedure will be accurate, the pressure transducers should be zeroed and spanned at this time. Refer to Appendix E for this procedure.

Before attempting to use *any* system controls, make certain that valve power is *OFF*. This switch is located on the lower right-hand corner of the N_2 Pressurization Control unit and should be in the down position for off. This practice—turning off valve power—will be used whenever any system controls are used. Next set the N_2 Pressurization Control unit Arm/Disarm switch to Disarm or down position, then move switch to Arm position. Press the Abort/Reset push button switch located to the right of the Arm/Disarm switch to light the LED above it. Now select at least one of the north or south N_2 cylinders numbers 1 through 4 by depressing the lensed push button switch to illuminate it.

Using the meter and potentiometers on the panel mentioned above, set the "Dump On" and "Dump Off" potentiometers to their full counterclockwise position. Then set the panel switch to Cal Source and adjust the "Cal Source PSIA Adj" potentiometer directly above this switch to read on "Chamber/Cal PSIA" meter the desired chamber dump pressure. Now slowly turn "Set for Dump On" potentiometer clockwise until the "Dump" LED lamp comes on.

Using the "Cal Source" potentiometer, now set for the chamber pressure at which the dump is to terminate, then slowly turn "Set for Dump Off" potentiometer clockwise until the "Dump" LED just goes out. To check that the on and off pressure points are correct, turn the "Cal Source" potentiometer counterclockwise to a pressure as indicated by the digital panel meter that is at least 6.89 kPa (1 psia) below the dump on point. Now press the "Abort/Reset" push button switch once to reset (LED goes out) and again to set (LED goes on), and then while observing the dump lamp and the "Chamber/Cal PSIA" meter very slowly turn the "Cal Source" potentiometer clockwise to note the coincidence of the dump lamp coming on and the correct pressure. Continue clockwise rotation after dump on to the point where the dump lamp just goes out. If the dump lamp came on and then off at the desired pressures lock the potentiometers at these settings, otherwise repeat to establish the correct pressure on/off points.

The next very important step is to be sure to set the switch to "*Dump Source*" position, otherwise when a run is in progress no dump will occur. In any event, it is still possible to manually initiate a dump by using the "N_2 Dump" push button switch to the right of the Abort/Reset switch and to terminate a dump by depressing the "Abort/Reset" switch. Should it be required to use chamber pressure to initiate a dump but not to terminate, then set the "Dump on" potentiometer as described above and the "Dump Off" to its full counterclockwise position. If only termination of a dump is required, then set the "Dump Off" potentiometer as above and the "Dump Off" potentiometer to its full counterclockwise position.

One may, if desired, check the chamber pressure transducer by using bottle air pressure to dynamically check the system although this is not strictly necessary. To do so first be sure the air supply bottle regulator is set for no more than 103 kPa (15 psi) gauge pressure. Then (see Fig. 11, Panel I), using valve controls on the uppermost panel of the "Gas Control Rack" first turn full clockwise the "Air Pressure" needle valve then open "Open to Cal" toggle valve. Next close "North Chamber Pressure" and "South Chamber Pressure" toggle valves. Now having set "Arm/Disarm" and "Abort/Reset" switches as above, slowly open the "Air Pressure" needle valve so as to bring up the pressure slowly. Observe the 0-2 atm Heise gauge and dump lamp. The dump lamp should come on at the desired pressure as read from the Heise gauge. This may be repeated by opening the north and south chamber valves mentioned above which will return the system to atmospheric pressure. Now press "Abort/Reset" to reset, then again to set, and open these two valves and observe again the rise in pressure and lighting of the dump lamp. After being satisfied that the dump on point is correct, return the toggle valves to "Open to Run" for chamber pressure valves and close "Open to Cal" valve.

Appendix E
TRANSDUCER AND GAS ANALYZER CALIBRATION

Gas Analyzer Calibration

This procedure must be carried out before any experimental runs to ensure proper operation of analyzers and in particular that they respond accurately to calibration gases.

First, ensure that calibration gas pressures (N_2, CO/CO_2, and air) at the bottles located outside and at the south end of T502 are not more than 68.2 kPa (10 psig) as read from the bottle regulator gauges. At the "Gas Control Rack" (Fig. 11, Panels II, III, and IV) determine the north and south analyzer pressures (Panel II) with the north and south sampling pumps on and drawing gas from the chamber. This is ensured by setting the right-hand ball valves on the north and south loop panels to "Sample Gas" position. Check the analyzer flowmeters (Panels III and IV) for the correct flows. The south (north) loop flowmeters should be reading NO_x, 0.75; CO, 0.75; CO_2, 0.75; and O_2, 0.20. The pressures in the analyzers as determined by the digital readout on Panel II should be balanced by adjusting the pressure regulator in the back of the cabinet. Once this adjustment is made, the north and south analyzer systems must be calibrated separately. Complete the procedure for the north (south) analyzers before continuing the calibration for the other analyzers. In addition, once this point has been reached in the calibration procedure, the flows should not be adjusted on either loop system.

The right-hand ball valve for the loop being calibrated should now be set in the "Cal Gas" position. Open first the "N_2" (Fig. 11, Panel III) ball valve for the zero-standard gas. Adjust the calibration gas metering valve so that the analyzer pressure is the same as it was when sampling from the chamber. It may be required now to adjust the outside N_2 gas bottle regulator to obtain adequate flows. Next set the lower data logger to single point and to the channel for the instrument to be zeroed (see text, Table 2 for this channel number). For the oxygen analyzers the zero potentiometer is located under the front panel door. On the CO and CO_2 analyzers this potentiometer is at the upper right-hand corner. Now set each instrument for zero by observing the data logger read out.

To span each instrument close the N_2 panel valve and open the required up-scale span gas. Adjust as before the calibration gas-metering valve for proper flow using the span gas. Again it may be necessary to adjust the bottle regulator for adequate flows. Now use the gain control potentiometers on the analyzer front panel (under door on O_2 analyzer) to set for the percent of full scale (0 to 100%). These percentages are marked on each instrument, e.g., 40.8% of full scale on the CO_2 analyzer. This reading will be read as 40.8 mV on the data logger read out. To be sure that the gain settings have not altered the zero settings, the process should be repeated.

After completing the analyzer calibration, return the right-hand ball valve to "Sample Gas" positions and all the "Calibration Gases" ball valves to the horizontal positions. Next be sure to shut off the bottle regulator valves. The analyzers are now ready for use.

Transducer Calibration

There are eight pressure transducers that must be zeroed and spanned. These units are located at the Gas Sampling Console (Panel II) as seen in Fig. 10. Each panel meter is labeled according to its function, i.e., North Chamber, South Chamber, etc. Note that from each panel meter a bold black line runs to the zero and span holes. These holes allow insertion of a thin-bladed screw driver (at least an 8-in. shaft) to adjust the transducer set screws.

First turn on the vacuum pumps. The switch and pump are located in the rear cabinet to the right of the Gas Sampling Console. On the panel above Panel II the two rightmost ball valves are to be set to Transducer Reference and Pump for spanning the units and during experimental runs. To zero the transducers the second from the right valve is set to the vent position. With this valve in the vent position each transducer will be zeroed by observing the Data Logger output for that particular transducer. The channel number for each transducer may be found by using Table 2 (Data Logger Channel Assignments). Next span each transducer for the prevailing atmospheric pressure by observing the Data Logger readouts as before.

Appendix F
COMPUTER PROGRAMS FOR DATA COLLECTION AND MANIPULATION

A. Program to collect the data with 2313 A/D Converter

```
&ADFN  T=00003 IS ON CR00017 USING 00059 BLKS R=0000

FTN4
      PROGRAM ADFN
C
C                 FINAL VERSION 820726
C ******* NOTE******   TO LOAD THIS PROGRAM USE THE TRANSFER FILE LADFN
C   %ADA MUST BE LOADED ALSO.
C THIS PROGRAM USES THE 2313 A/D CONVERTER TO COLLECT 13 CHANNELS OF DATA.
C THEY ARE::
C                CHANNEL NO.                DATA
C                -----------                ----
C                    00                 TC OVER FIRE
C                    02                 TC OVER FIRE
C                    04                 PRESSURE NORTH
C                    06                 TC #2 SOUTH
C                    08                 TC #2 NORTH
C                    10                 TC #7 NORTH
C                    12                 TC #7 SOUTH
C                    14                 CO  SOUTH
C                    16                 CO2  SOUTH
C                    18                 O2  SOUTH
C                    20                 RADIOMETER B TREE
C                    22                 OBSCURATION SO(WEST)
C                    24                 OBSCURATION NO(EAST)
C
C THE PROGRAM CONVERTS THE FOUR TC READINGS(#2 SO,#2 NO,#7 NO,#7 SO)
C INTO DEGREES CELSIUS AND PLOTS THE FOUR TEMPERATURES ON THE GRAPHICS
C TRANSLATOR, 2648 TERMINAL SCREEN, 7245B PRINTER/PLOTTER, OR THE 9872B
C PLOTTER. THE PLOT IS MADE IN REAL TIME, WITH THE PLOT STARTING OVER
C AGAIN EVERY TWO MINUTES.
C
C THIS PROGRAM ALSO CONVERTS THE PRESSURE READING TO ATMOSPHERES,CONVERTS
C THE CO, CO2 AND O2 READINGS INTO PERCENTAGES, AND PRINTS THESE VALUES
C ON THE 2648 TERMINAL SCREEN IN REAL TIME, AS WELL AS THE TWO TC READINGS
C FOR OVER THE FIRE IN VOLTS, IN THE ORDER OF CHANNEL NOS, 00,02,04,14
C 16,18.
C
C THIS PROGRAM ALSO STORES ALL THE CHANNEL NO. VALUES(AFTER THE VARIOUS
C CONVERSIONS) ON A MAG TAPE IN REAL TIME.
C
C THIS PROGRAM WAS CREATED FROM PROGRAM ADF(FILE NAME &2313) AND PROGRAM
C LPLOT(FILE NAME &LPLOT). FOR EXPLANATIONS OF THE VARIOUS CALLS, PLEASE
C REFER TO THESE TWO PROGRAMS.
C
C THIS PROGRAM REQUIRES AS INPUT: THE NUMBER OF CHANNELS AND THEIR NUMBERS,
C WHICH PLOTTER TO PLOT ON, AXES LABELS AND A TITLE FOR THE PLOT, AND MAX
C AND MIN VALUES FOR THE X AND Y AXES.
C
C *************************NOTE*****************************************
C  AT THIS TIME, THE OPTION TO READ IN WHICH PLOTTER TO USE HAS BEEN
C  COMMENTED OUT OF THE PROGRAM, AND THE PROGRAM IS SET UP TO PLOT ON
C  THE 1350A GRAPHICS TRANSLATOR.
```

```
C
C  ALSO, THIS PROGRAM IS AN INFINITE LOOP. TO STOP THIS PROGRAM, HIT ANY
C  KEY SEVERAL TIMES UNTIL A PROMPT IS ISSUED, AND TYPE OF,ADFT,1. WHEN
C  THE PROGRAM HAS ABORTED, TYPE CN,8,EO TO PUT AND END OF FILE MARKER
C  ON THE MAGNETIC TAPE.
C
C ***********************************************************************
C  DECLARATION OF VARIABLES
         INTEGER IQBUF(200),LNGTH,LBF(16),IBUFR(384)
         INTEGER IRTN,LNGTH,DA,IC,IX,IPER,MULT,IAUX
         INTEGER IOPTN,IP,MD,N,ID,FLAG,FLAG1,IDD
         INTEGER NBF,ICA,GCODE,LU(5),MM
         INTEGER ION,LAST,ISLOT,LBFS
         INTEGER IOBUF(100),IGCB(192)
         INTEGER IAX(15),IAY(15),IHED(20),ITIME(6),IYEAR
         DIMENSION X(100),Y1(100),Y2(100),Y3(100),Y4(100),JCHAR(4)
         REAL VOLTS(100),FTIME,TTIME
C
C  INITIALIZATION OF VARIABLES
C
         DATA IOBUF/100*0/
         DATA ITITL/25*0/,IBUFR/384*0/,IQBUF/200*0/
         DATA VOLTS/100*0./
         DATA JCHAR/1H+,1HO,1H*,1H#/
C
C  ASSIGN INPUT OUTPUT DEVICES
C                   LU=INTERACTIVE TERMINAL
C                   DA=LU LOCATION OF A/D CONVERTER(2313)
C
         CALL RMPAR(LU)
C
C  SET CONSTANTS AND INITIALIZE COUNTERS
C                   LNGTH=NUMBER OF SCANS OF DATA
         LNGTH=200
         FLAG1=0
C
C  NUMBER OF CHANNELS BEING RECORDED AND THEIR NUMBERS
C
         WRITE(LU,540)
         READ(LU,*) NBF,(LBF(I),I=1,NBF)
C
C  ESTABLISH PLOTTING DEVICE
C
C        WRITE(LU,10)
C10      FORMAT(" OUTPUT ON GRAPHICS TERMINAL          TYPE 0",/,
C    1          "      ON 9872 PLOTTER                 TYPE 1",/,
C    1          "      ON 7245B PRINTER/PLOTTER        TYPE 2",/,
C    1          "      ON 1350A GRAPHICS TRANSLATOR TYPE 3")
C        READ(LU,*)ILUG
C
C  DEFINE LU AND ID NUMBERS OF PLOTTERS AND GRAPHICS TERMINAL
C
C        LUG=7
C        IF(ILUG.EQ.1)LUG=11
C        IF(ILUG.EQ.2)LUG=13
C        IF(ILUG.EQ.3)LUG=12
C        ID=1
C        IF(LUG.EQ.11)ID=2
C        IF(LUG.EQ.13)ID=3
C        IF(LUG.EQ.12)ID=4
C  TO CENTER CHARACTER SET HALF WIDTH AND HALF HEIGHT
C  DEPENDING ON IF USING PLOTTER OR CRT
         HW=0.5
         HH=0.5
```

```
C         IF(ID.EQ.1)GOTO 20
C         HW=0.333
C         HH=0.25
C   OBTAIN AXIS LABELS AND TITLE FOR PLOT
 20       WRITE(LU,175)
 175      FORMAT(" ENTER X-LABEL,Y-LABEL & TITLE ON 3 SEPARATE LINES")
          READ(LU,180) IAX,IAY,IHED
 180      FORMAT(15A2/,15A2/,20A2)
C
C    ENTER MINIMUM AND MAXIMUM VALUES FOR THE Y-AXIS
C
          WRITE(LU,200)
 200      FORMAT(" ENTER YMIN,YMAX")
          READ(LU,*) YMIN,YMAX
C
C    INITIALIZE PLOTTER
C
          FLAG=0
C **NOTE** THE NEXT TWO LINES MUST BE TAKEN OUT TO PUT THE OPTION OF
C            CHOSING WHICH PLOTTER IS USED BACK INTO THE PROGRAM.
C
          LUG=12
          ID=4
 400      CALL PLOTR(IGCB,ID,1,LUG)
          CALL SETAR(IGCB,1.0)
          CALL VIEWP(IGCB,0.,135.,0.,100.)
          CALL WINDW(IGCB,0.,150.,0.,100.)
          CALL CSIZE(IGCB,2.)
          CALL FXD(IGCB,0)
          CALL PEN(IGCB,1)
C
C  WRITE AXES LABELS AND TITLE
C
          CALL MOVE(IGCB,55.,1.)
          CALL LABEL(IGCB)
          WRITE(LUG,240) IAX
 240      FORMAT(15A2)
          CALL LABEL(IGCB)
          CALL MOVE(IGCB,3.,30.)
          CALL LDIR(IGCB,+1.57)
          CALL LABEL(IGCB)
          WRITE(LUG,240) IAY
          CALL MOVE(IGCB,40.,80.)
          CALL LDIR(IGCB,0.)
          CALL LABEL(IGCB)
          WRITE(LUG,250) IHED
 250      FORMAT(20A2)
C
C DRAW X AND Y AXES
C
          XTIC=10
          YTIC=20
C THE X-AXIS SHOWS REAL TIME, 120 SECONDS PER SCREEN
          XMIN=0 + 120*FLAG
          XMAX=120 + 120*FLAG
          CALL LINAX(1,XMIN,XMAX,XTIC,LUG,IGCB)
          CALL LINAX(2,YMIN,YMAX,YTIC,LUG,IGCB)
          CALL VIEWP(IGCB,17.,120.,10.,80.)
          CALL WINDW(IGCB,XMIN,XMAX,YMIN,YMAX)
          IF(FLAG.NE.0)GOTO 40
C
C ESTABLISH A CLASS NUMBER
C
```

```
      ICLAS=0
 40   WRITE(LU,239)
 239  FORMAT("BEFORE FIRST EXEC CALL")
      CALL EXEC(20,0,I,0,IPRM1,IPRM2,ICLAS)
      WRITE(LU,241)
 241  FORMAT("AFTER FIRST EXEC CALL")
      J=0
C
C WRITE ON TERMINAL SCREEN THE CHANNEL NUMBERS
C
      WRITE(LU,560) (LBF(I),I=1,3),(LBF(I),I=8,10)
C
C SCHEDULE THE PROGRAM WITH THE 2313 CALLS
C
 186  K=0
 183  CALL EXEC(9,5HADA  ,ICLAS)
C
C RETRIEVE DATA FROM 2313 PROGRAM
C
      CALL EXEC(21,ICLAS,IBUFR,200)
C
C OBTAIN THE TIME THE DATA WAS COLLECTED
      CALL EXEC(11,ITIME,IYEAR)
C
C OBTAIN A STARTING TIME FOR REFERENCE
      IF((FLAG1.EQ.0).AND.(K.EQ.0))
     +     FTIME=FLOAT(ITIME(4)*3600 + ITIME(3)*60 + ITIME(2))
      FLAG1=1
C CONVERT THE TIME INTO SECONDS
      TTIME=FLOAT(ITIME(4)*3600 + ITIME(3)*60 + ITIME(2))
C
            MM=0
C
C
      K=K+1
C
C AFTER RETRIEVE DATA, READ CHANNELS 1 THROUGH 13 , AND PUT THEM IN
C ARRAY VOLTS(I)
C
              DO 111 I=1,NBF
                VOLTS(I)=FLOAT(IAND(IBUFR(I),177760B))*.0003125
                VOLTS(I)=VOLTS(I)/12.5
 111          CONTINUE
C
C CONVERT THE VOLTAGES INTO PERCENTAGES, AND ATM, AND DEGREES
C
              CALL PANDT(VOLTS)
C
C WRITE TO TERMINAL SCREEN AND MAG TAPE
               WRITE(LU,572) (VOLTS(I),I=1,3),(VOLTS(I),I=8,10)
               WRITE(8,573) ITIME(4),ITIME(3),ITIME(2),(VOLTS(I),I=1,NBF)
C
C
C SCHEDULE THE 2313 PROGRAM 15 TIMES
C
      IF(K.LE.15) GOTO 183
C
C PLOT THE DATA
C
C PLOTS FOR DIFFERENT THERMOCOUPLE VALUES ON THE GRAPHICS TRANSLATOR
C
      J=J+1
            X(J)=TTIME - FTIME
            IF(X(J) .LT. XMIN) X(J)=XMIN
            Y1(J)=VOLTS(4)
```

```
                Y2(J)=VOLTS(5)
                Y3(J)=VOLTS(6)
                Y4(J)=VOLTS(7)
                CALL LINE(IGCB,MM)
                IF(J.EQ.1)GOTO 300
                CALL MOVE(IGCB,X(J-1),Y1(J-1))
                CALL DRAW(IGCB,X(J),Y1(J))
  300           CALL MOVE(IGCB,X(J),Y1(J))
                CALL CPLOT(IGCB,-HW,-HH,-2)
                CALL LABEL(IGCB)
                WRITE(LUG,310) JCHAR(1)
  310           FORMAT(1A1)
                IF(J.EQ.1)GOTO 301
                CALL MOVE(IGCB,X(J-1),Y2(J-1))
                CALL DRAW(IGCB,X(J),Y2(J))
  301           CALL MOVE(IGCB,X(J),Y2(J))
                CALL CPLOT(IGCB,-HW,-HH,-2)
                CALL LABEL(IGCB)
                WRITE(LUG,310) JCHAR(2)
                IF(J.EQ.1)GOTO 302
                CALL MOVE(IGCB,X(J-1),Y3(J-1))
                CALL DRAW(IGCB,X(J),Y3(J))
  302           CALL MOVE(IGCB,X(J),Y3(J))
                CALL CPLOT(IGCB,-HW,-HH,-2)
                CALL LABEL(IGCB)
                WRITE(LUG,310) JCHAR(3)
                IF(J.EQ.1)GOTO 303
                CALL MOVE(IGCB,X(J-1),Y4(J-1))
                CALL DRAW(IGCB,X(J),Y4(J))
  303           CALL MOVE(IGCB,X(J),Y4(J))
                CALL CPLOT(IGCB,-HW,-HH,-2)
                CALL LABEL(IGCB)
                WRITE(LUG,310) JCHAR(4)
C
C START A NEW SCREEN EVERY TWO MINUTES, ALLOWING 5 SECONDS TO
C REDRAW THE AXES.
            IF(X(J) .LT. XMAX-5.) GOTO 186
            FLAG=FLAG+1
            CALL PLOTR(IGCB,ID,0)
            IF(FLAG.NE.0) GOTO 400
  999                   STOP
C
C  WRITE FORMAT STATEMENTS
C
  540  FORMAT("ENTER THE NUMBER OF CHANNELS AND THEIR NUMBERS",/,
     +         "--ON THE SAME LINE SEPARATED BY COMMAS",/,
     +  ,      "--THE FIRST NUMBER INPUTED MUST BE THE # OF CHANNELS")
  560  FORMAT(6(I6,5X))
  572  FORMAT(6(1X,F10.7))
  573  FORMAT(3(I2),16(F10.7,1X))
C
C  READ FORMAT STATEMENTS
C
  820  FORMAT(F10.7)
  830  FORMAT(I4)
  840  FORMAT(I2)
  850  FORMAT(25A2)
C
C
                        END
            SUBROUTINE LINAX(IAXIS,AMIN,AMAX,TIC,LUG,IGCB), FROM T. O'NEAL 81012:
C LINEAR AXIS DRAWING ROUTINE
C
C IAXIS - 1=X-AXIS , 2=Y-AXIS
```

```
C AMIN  - MINIMUM VALUE OF AXIS
C AMAX  - MAXIMUM VALUE OF AXIS
C TIC   - NUMBER OF TICK MARKS ALONG AXIS
C LUG   - LOGICAL UNIT NUMBER FOR GRAPHICS OUTPUT
C
        INTEGER IGCB(192)
C SET AXIS LEGTH IN WORLD COORDINATE SYSTEM(WCS)
        IF(IAXIS.EQ.1) ALEN=114.
        IF(IAXIS.EQ.2) ALEN=70
C DEFINE ORIGIN
        X0=26.
        Y0=10.
        TICM=AMIN
        CALL MOVE(IGCB,X0,Y0)
        CALL CSIZE(IGCB,3.)
        IF(IAXIS.EQ.2) GOTO 100
C
C DRAW X AXIS
C
        CALL DRAW(IGCB,ALEN+X0,Y0)
C LABEL X ORIGIN
        CALL MOVE(IGCB,X0,Y0)
        CALL MOVEI(IGCB,-12.,-4.5)
        CALL LABEL(IGCB)
        WRITE(LUG,30)TICM
 30     FORMAT(F8.0)
C DRAW X TICK MARKS
        DO 50 K=1,TIC
        TICK=ALEN*(FLOAT(K)/TIC)
        CALL MOVE(IGCB,TICK+X0,Y0)
        CALL DRAW(IGCB,TICK+X0,Y0-2.0)
C LABEL X TICK MARKS
        TICM=TICM+((AMAX-AMIN)/TIC)
        CALL MOVE(IGCB,TICK+X0,Y0)
        CALL MOVEI(IGCB,-12.,-4.5)
        CALL LABEL(IGCB)
        WRITE(LUG,30)TICM
 50     CONTINUE
        GOTO 200
C
C DRAW Y AXIS
C
100     CALL DRAW(IGCB,X0,ALEN+Y0)
C LABEL Y ORIGIN
        CALL MOVE(IGCB,X0,Y0)
        CALL MOVEI(IGCB,-17.,-0.8)
        CALL LABEL(IGCB)
        WRITE(LUG,40)TICM
 40     FORMAT(F8.2)
C DRAW Y TICK MARKS
        DO 150 K=1,TIC
        TICK=ALEN*(FLOAT(K)/TIC)
C LABEL Y TICK MARKS
        TICM=TICM+((AMAX-AMIN)/TIC)
        CALL MOVE(IGCB,X0,TICK+Y0)
        CALL DRAW(IGCB,X0-2.5,TICK+Y0)
        CALL MOVEI(IGCB,-17.,-0.8)
        CALL LABEL(IGCB)
        WRITE(LUG,40)TICM
150     CONTINUE
200     CALL PENUP(IGCB)
        RETURN
        END
```

```
C
C THIS SUBROUTINE CONVERTS THE VOLTS VALUES FOR CARBON MONOXIDE,
C CARBON DIOXIDE, AND OXYGEN INTO A PERCENTAGE.
C IT CONVERTS THE FOUR THERMOCOUPLE READINGS(TC#2 SO, TC#2 NO, TC#6 NO, &
C TC#6 SO) INTO TEMPERATURE IN DEGREES CENTIGRADE.
C IT CONVERTS THE PRESSURE READING INTO ATMOSPHERES.
C
      REAL VOLTS(100)
C
C CONVERT THE CO,CO2,O2 READINGS INTO PERCENTAGE
C
      VOLTS(8)=VOLTS(8)/.35
      VOLTS(9)=VOLTS(9)/.02
      VOLTS(10)=VOLTS(10)/.0039
C
C CONVERT FOUR TC READINGS TC#2 SO, TC#2 NO, TC#6 NO, TC#6 SO, TO
C DEGREES CENTIGRADE
C
     DO 10 I=4,7
        VOLTS(I)=VOLTS(I)-.0004
        VOLTS(I)=VOLTS(I)*1000.0
        COR=0.0
        IF(VOLTS(I).GT.1.44) COR=.01
        IF(VOLTS(I).GT.2.18) COR=.03
        IF(VOLTS(I).GT.2.80) COR=.05
        IF(VOLTS(I).GT.3.30) COR=.07
        IF(VOLTS(I).GT.3.76) COR=.09
        IF(VOLTS(I).GT.4.26) COR=.11
        IF(VOLTS(I).GT.4.96) COR=.13
        IF(VOLTS(I).GT.9.54) COR=.15
        IF(VOLTS(I).GT.10.52) COR=.17
        IF(VOLTS(I).GT.11.34) COR=.19
        IF(VOLTS(I).GT.11.96) COR=.21
        IF(VOLTS(I).GT.12.58) COR=.23
        IF(VOLTS(I).GT.13.12) COR=.25
        IF(VOLTS(I).GT.13.62) COR=.27
        IF(VOLTS(I).GT.14.04) COR=.29
        IF(VOLTS(I).GT.14.50) COR=.31
        IF(VOLTS(I).GT.14.92) COR=.33
        IF(VOLTS(I).GT.15.34) COR=.35
        IF(VOLTS(I).GT.15.76) COR=.37
        IF(VOLTS(I).GT.16.14) COR=.39
C
C  MAKE MILLIVOLT CORRECTION
C
        VOLTS(I)=VOLTS(I)-COR
C
C  CALCULATE MILLIVOLT TO CENTIGRADE CONVERSION
C
        VOLTS(I)=VOLTS(I)*25.0
C
 10   CONTINUE
C
C ADD OFFSET TO TEMPERATURE CALCULATED ACCORDING TO THE TEMPERATURE
C READINGS ON THE DATA LOGGERS AT THE START OF THE RUN
C **NOTE** THESE VALUES SHOULD BE CHANGED AT THE START OF EVERY RUN.
C
        VOLTS(4)=VOLTS(4) + 20.6
        VOLTS(5)=VOLTS(5) + 18.9
        VOLTS(6)=VOLTS(6) + 19.6
        VOLTS(7)=VOLTS(7) + 20.9
C
C CONVERT THE PRESSURE READING TO ATMOSPHERES
C
```

```
      VOLTS(3)=VOLTS(3)/.14692
C
      RETURN
      END
```

B. Program to redisplay the data on various graphics mediums and a tabular display of data

```
&ADA    T=00003 IS ON CR00017 USING 00009 BLKS R=0000

FTN4
      PROGRAM ADA
C THIS PROGRAM COLLECTS DATA FROM THE 2313 A/D CONVERTER
C IS SCHEDULED THROUGH CLASS I/O BY THE PROGRAM ADFN
      INTEGER IQBUF(200),LNGTH,LBF(16),IBUFR(384)
      INTEGER IRTN,LNGTH,DA,IC,IX,IPER,MULT,IAUX
      INTEGER IOPTN,IP,MD,N,ID,FLAG,IDD
      INTEGER NBF,ICA,GCODE,LU(5),MM
      INTEGER ION,LAST,ISLOT,LBFS
      INTEGER IOBUF(100),IGCB(192)
      INTEGER IAX(15),IAY(15),IHED(20)
      DIMENSION X(100),Y1(100),Y2(100),Y3(100),Y4(100),JCHAR(4)
      REAL VOLTS(100)
      DATA IOBUF/100*0/
      DATA ITITL/25*0/,IBUFR/384*0/,IQBUF/200*0/
      DATA VOLTS/100*0./
      DATA JCHAR/1H+,1HO,1H*,1H#/
      CALL RMPAR(LU)
      ICLAS=LU(1)
      DA=20
      LNGTH=200
      CALL B2313(IQBUF,LNGTH)
      CALL S2313(DA,IRTN)
C     IF(IRTN.LT.0) GOTO 1000
      ION=-1
      ICA=140B
      LAST=230B
      CALL A2313(DA,IRTN,ION,ICA,LAST)
C     IF(IRTN.LT.0) GOTO 1003
      ICA=200B
      ION=-1
      GCODE=7
      CALL A2313(DA,IRTN,ION,ICA,GCODE)
C     IF(IRTN.LT.0) GOTO 1005
      IC=0
      IX=0
      IPER=100
      MULT=3
      IAUX=0
      CALL P2313(DA,IRTN,IC,IX,IPER,MULT,IAUX)
C  DO R2313 CALL
      IP=0
      MD=2
      ISLOT=4
      LBF(1)=00
      LBFS=IOR(ISLOT*32,LBF(1))
      NBF=13
      ID=-1
      MM=1
C
C
C
       CALL R2313  (DA,IRTN,IP,MD,LBFS,NBF,IBUFR,ID)
C     IF(IRTN.LT.0) GOTO 1040
      ILEN=200
      CALL EXEC(20,0,IBUFR,ILEN,IPRM1,IPRM2,ICLAS)
C
C000  WRITE(10,650) IRTN
```

```
C1003 WRITE(10,653) IRTN
C1005 WRITE(10,655) IRTN
C1010 WRITE(10,660) IRTN
C1040 WRITE(10,690) IRTN
  650 FORMAT("IRTN ERROR IN 2313 SUBSYSTEM NORMALIZE CALL=",I3)
  653 FORMAT("IRTN ERROR IN 2313 SUBSYSTEM LAD CALL=",I3)
  655 FORMAT("IRTN ERROR IN 2313 LLMPX GAIN SETTING=",I3)
  660 FORMAT("IRTN ERROR IN 2313 PACER CALL=",I3)
  690 FORMAT("IRTN ERROR IN 2313 DATA COLLECTION=",I3)
  700 FORMAT(I3)
      END
```

```
&ADPRT T=00003 IS ON CR00017 USING 00008 BLKS R=0000

FTN4,L
       PROGRAM ADPRT
C
C          PROGRAM CREATED BY TINA WHITE
C                  FINAL VERSION 820714
C THIS IS JUST A SHORT PROGRAM TO PRINT OUT THE DATA
C COLLECTED ONTO MAGNETIC TAPE BY THE 2313(PROGRAM ADFN)
C IT PRINTS UP TO EIGHT CHANNELS AT A TIME
C **********THE MAGNETIC TAPE MUST BE ON LU 8**************
C
       INTEGER LU(5),ICH(16),CHAN(16),NCHAN,ITITL(25),NBF
       INTEGER ICHWD,ISTAT,ITIME(3)
       REAL    VOLTS(16),HOLD(16)
       DATA    VOLTS,HOLD/16*0./,ICHWD/10B/
C
       CALL RMPAR(LU)
       WRITE(LU,100)
  100  FORMAT(" INPUT NO. OF CHANNELS RECORDED ON THE MAG TAPE")
       READ(LU,*) NBF
       WRITE(LU,110)
  110  FORMAT(" INPUT THE NO. OF CHANNELS TO PRINT AND THEIR NUMBERS",/,
     +        "     --ON THE SAME LINE SEPARATED BY COMMAS")
       READ(LU,*) NCHAN,(CHAN(I),I=1,NCHAN)
C
C CONVERT THE CHANNEL NUMBERS TO ARRAY INDICES
C
       DO 10 I=1,NCHAN
         ICH(I)=CHAN(I)/2 + 1
   10  CONTINUE
C
       WRITE(LU,120)
  120  FORMAT(" INPUT A TITLE FOR THIS PRINTING")
       READ(LU,200) ITITL
  200  FORMAT(25A2)
C
       WRITE(10,130) ITITL,(CHAN(I),I=1,NCHAN)
  130  FORMAT(45X,25A2,////,55X,"CHANNEL NUMBERS",/,132("*"),
     +        //,3X,"TIME",10X,8("***",I2,"***",6X))
       WRITE(10,131)
  131  FORMAT(/,132("*"),/)
  500  READ(8,220) (ITIME(I),I=1,3),(VOLTS(I),I=1,NBF)
  220  FORMAT(3(I2),16(F10.7,1X))
C
C OBTAIN ONLY THE DESIRED DATA FROM THE VOLTS ARRAY
```

```
C
      DO 20 I=1,NCHAN
        L= ICH(I)
        HOLD(I)=VOLTS(L)
 20   CONTINUE
      WRITE(10,140) (ITIME(I),I=1,3),(HOLD(I),I=1,NCHAN)
140   FORMAT(1X,I2,":",I2,":",I2,2X,8(4X,F10.7))
C CHECK THE STATUS OF THE MAGNETIC TAPE
      CALL EXEC(13,ICNWD,ISTAT)
      ISTAT=IAND(ISTAT,40200B)
      IF(ISTAT.NE.0) GOTO 999
      GOTO 500
999   STOP
      END
```

&ADPL1 T=00003 IS ON CR00017 USING 00033 BLKS R=0000

```
FTN4,L
      PROGRAM ADPL1
C
C           PROGRAM CREATED BY TINA WHITE
C                FINAL VERSION 820727
C
C  **NOTE**
C     THERE ARE TWO VERSIONS OF THIS PROGRAM. THE OTHER IS IN THE FILE
C     &ADPL2.  THIS VERSION IS USED TO REPLOT 2313 DATA ON THE 1350A
C     GRAPHICS TRANSLATOR ONLY   PROGRAM ADPL2 IS USED TO PLOT ON THE
C     OTHER HP-IB PLOTTERS. TO LOAD THIS PROGRAM USE THE TRANSFER FILE
C     LADPL1.
C THIS PROGRAM TAKES THE DATA COLLECTED BY PROGRAM ADFT ON
C MAGNETIC TAPE AND PLOTS IT.  IT PLOTS ONE POINT FOR EVERY
C TWENTY SCANS, JUST AS IT WAS PLOTTED DURING THE RUN.
C IT CAN PLOT UP TO SIX LINES ONE ONE PLOT, WITH FIFTY POINTS
C PER PLOT.  YOU CAN MAKE AS MANY CONSECUTIVE PLOTS AS NEEDED.
C SEE A CURRENT LISTING OF PROGRAM ADFT FOR CHANNEL NUMBERS.
C
C THIS PROGRAM IS NOT LIMITED TO PLOTTING ONLY THE THERMOCOUPLE
C TEMPERATURES.  BY INPUTING THE RIGHT RANGE FOR THE Y-AXIS, THE
C OTHER CHANNELS CAN ALSO BE PLOTTED.
C
C
C DECLARATION OF VARIABLES
C
      INTEGER IGCB(192),LU(5),IAX(15),IAY(15),IHED(20)
      INTEGER CHAN(6),NCHAN,NBF,CH,MM,NUM,ITIME(3),FLAG
      REAL TTIME,FTIME
      DIMENSION VOLTS(100),X(100),HOLD(6),JCHAR(6)
C
C INITIALIZATION OF VARIABLES
C
      DATA VOLTS/100*0./,FLAG/0/
      DATA JCHAR/1H+,1HO,1H*,1H#,1HX,1H$/
      CALL RMPAR(LU)
      WRITE(LU,1000)
1000  FORMAT("*********NOTE********",/,
     +         "THIS PROGRAM SHOULD BE USED TO REPLOT THE 2313 DATA"
     +      ,/,"ON THE 1350A GRAPHICS TRANSLATOR ONLY.  TO PLOT ON ANY"
     +      ,/,"OTHER DEVICE USE PROGRAM ADPL2 (FILE &ADPL2)")
      WRITE(LU,100)
```

```
 100    FORMAT("ENTER THE TOTAL NUMBER OF CHANNELS ON THE MAG TAPE")
        READ(LU,*)NBF
        WRITE(LU,101)
 101    FORMAT("ENTER THE NUMBER OF CHANNELS TO PLOT AND THEIR"
     1          " NUMBERS",/,"SAME LINE SEPARATED BY COMMAS")
        READ(LU,200) NCHAN,(CHAN(I),I=1,NCHAN)
 200    FORMAT(I2)
C
C CONVERT CHANNELS NUMBERS TO ARRAY INDICES
        DO 10 I=1,NCHAN
           CHAN(I)=CHAN(I)/2 + 1
  10    CONTINUE
C
C NOTE--THE NEXT FEW LINES HAVE BEEN COMMENTED OUT, SINCE THIS
C        PROGRAM ONLY PLOTS ON THE 1350A GRAPHICS TRANSLATOR
C       WRITE(LU,102)
C102    FORMAT(" OUTPUT ON GRAPHICS TERMINAL          TYPE 0",/,
C    1          "        ON 9872 PLOTTER              TYPE 1",/,
C    1          "        ON 7245B PRINTER/PLOTTER     TYPE 2",/,
C    1          "        ON 1350A GRAPHICS TRANSLATOR TYPE 3")
C       READ(LU,*) ILUG
C
        ILUG=3
C DEFINE LU AND ID NUMBERS OF PLOTTERS AND GRAPHICS TERMINAL
C
        LUG=7
        IF(ILUG.EQ.1)LUG=11
        IF(ILUG.EQ.2)LUG=13
        IF(ILUG.EQ.3)LUG=12
        ID=1
        IF(LUG.EQ.11)ID=2
        IF(LUG.EQ.13)ID=3
        IF(LUG.EQ.12)ID=4
C TO CENTER CHARACTER SET HALF WIDTH AND HALF HEIGHT
C DEPENDING ON IF USING PLOTTER OR CRT
        HW=0.5
        HH=0.5
        IF(ID.EQ.1)GOTO 20
        HW=0.333
        HH=0.25
C OBTAIN AXIS LABELS AND TITLE FOR PLOT
C
  20    WRITE(LU,103)
 103    FORMAT("ENTER X-LABEL,Y-LABEL,AND TITLE ON 3 SEPARATE LINES")
        READ(LU,201) IAX,IAY,IHED
 201    FORMAT(15A2/,15A2/,20A2)
C
C ENTER MINIMUM AND MAXIMUM VALUES FOR THE Y-AXIS
C
        WRITE(LU,104)
 104    FORMAT("ENTER YMIN AND YMAX (SAME LINE,COMMA INBETWEEN)")
        READ(LU,*) YMIN,YMAX
C
C ENTER THE NUMBER OF TIMES PLOT IS TO BE MADE
C ONE PLOT COVERS TWO MINUTES
C
        WRITE(LU,105)
 105    FORMAT("ENTER THE NUMBER OF PLOTS TO BE MADE",/,
     1          "ONE PLOT COVERS TWO MINUTES")
        READ(LU,*) NUM
C
C INITIALIZE PLOTTER
C
        DO 60 N=1,NUM
```

```
      CALL PLOTR(IGCB,ID,1,LUG)
      CALL SETAR(IGCB,1.0)
      CALL VIEWP(IGCB,0.,135.,0.,100.)
      CALL WINDW(IGCB,0.,150.,0.,100.)
      CALL CSIZE(IGCB,3.)
      CALL FXD(IGCB,0)
      CALL PEN(IGCB,1)
C
C WRITE AXES LABELS AND TITLE
C
      CALL MOVE(IGCB,55.,1.)
      CALL LABEL(IGCB)
      WRITE(LUG,106) IAX
 106  FORMAT(15A2)
      CALL MOVE(IGCB,3.,30.)
      CALL LDIR(IGCB,+1.57)
      CALL LABEL(IGCB)
      WRITE(LUG,106) IAY
      CALL MOVE(IGCB,40.,90.)
      CALL LDIR(IGCB,0.)
      CALL LABEL(IGCB)
      WRITE(LUG,107) IHED
 107  FORMAT(20A2)
C
C DRAW X AND Y AXES
C
      XTIC=10
      YTIC=20
      XMIN=0 + 120*(N-1)
      XMAX=120*N
      CALL LINAX(1,XMIN,XMAX,XTIC,LUG,IGCB)
      CALL LINAX(2,YMIN,YMAX,YTIC,LUG,IGCB)
      CALL VIEWP(IGCB,17.,120.,10.,80.)
      CALL WINDW(IGCB,XMIN,XMAX,YMIN,YMAX)
C
C READ 15 SCANS OF DATA THEN PLOT A POINT
C
      MM=0
      J=0
      CALL LINE(IGCB,MM)
 50   J=J+1
        DO 30 K=1,20
          READ(8,202) (VOLTS(I),I=1,NBF)
 202      FORMAT(16(F10.7,1X))
C OBTAIN STARTING TIME IN SECONDS FOR REFERENCE
          IF(FLAG.EQ.0 .AND. K.EQ.1)
     +      FTIME=FLOAT(ITIME(1)*3600 + ITIME(2)*60 + ITIME(3))
          FLAG=1
C CONVERT THE TIME TO SECONDS
          TTIME=FLOAT(ITIME(1)*3600 + ITIME(2)*60 + ITIME(3))
 30     CONTINUE
C
        X(J)=TTIME-FTIME
        DO 40 L=1,NCHAN
          CH=CHAN(L)
          IF(J.EQ.1)GOTO 300
          CALL MOVE(IGCB,X(J-1),HOLD(L))
          CALL DRAW(IGCB,X(J),VOLTS(CH))
 300      CALL MOVE(IGCB,X(J),VOLTS(CH))
          CALL CPLOT(IGCB,-HW,-HH,-2)
          CALL LABEL(IGCB)
          WRITE(LUG,108) JCHAR(L)
 108      FORMAT(1A1)
          CALL MOVE(IGCB,X(J),VOLTS(CH))
```

```
                 HOLD(L)=VOLTS(CH)
   40         CONTINUE
C
        IF(X(J).LT.XMAX-5) GOTO 50
        CALL PLOTR(IGCB,ID,0)
        IF(LUG.NE.11) GOTO 60
        IF(N.EQ.NUM) GOTO 60
        WRITE(LU,55)
   55   FORMAT("CHANGE THE PAPER ON THE 9872 PLOTTER",/,
     1         "ENTER 1 WHEN READY")
        READ(LU,*)IRDY
   60   CONTINUE
C
  999   STOP
        END
        SUBROUTINE LINAX(IAXIS,AMIN,AMAX,TIC,LUG,IGCB), FROM T. O'NEAL
C LINEAR AXIS DRAWING ROUTINE
C IAXIS - 1 = X-AXIS, 2 = Y-AXIS
C AMIN  - MINIMUM VALUE OF AXIS
C AMAX  - MAXIMUM VALUE OF AXIS
C TIC   - NUMBER OF TICK MARKS ALONG AXIS
C LUG   - LOGICAL UNIT NUMBER FOR GRAPHICS OUTPUT
C
        INTEGER IGCB(192)
C
C SET AXIS LENGTH IN WORLD COORDINATE SYSTEM(WCS)
C
        IF(IAXIS.EQ.1) ALEN=114.
        IF(IAXIS.EQ.2) ALEN=70.
C DEFINE ORIGIN
        X0=26.
        Y0=10.
        TICM=AMIN
        CALL MOVE(IGCB,X0,Y0)
        CALL CSIZE(IGCB,3.)
        IF(IAXIS.EQ.2) GOTO 300
C
C DRAW X AXIS
C
        CALL DRAW(IGCB,ALEN+X0,Y0)
        CALL MOVE(IGCB,X0,Y0)
        CALL MOVEI(IGCB,-12.,-4.5)
        CALL LABEL(IGCB)
        WRITE(LUG,100) TICM
  100   FORMAT(F8.0)
C
C DRAW X TICK MARKS AND LABEL THEM
        DO 10 K=1,TIC
           TICK=ALEN*(FLOAT(K)/TIC)
           CALL MOVE(IGCB,TICK+X0,Y0)
           CALL DRAW(IGCB,TICK+X0,Y0-2.0)
           TICM=TICM+((AMAX-AMIN)/TIC)
           CALL MOVE(IGCB,TICK+X0,Y0)
           CALL MOVEI(IGCB,-12.,-4.5)
           CALL LABEL(IGCB)
           WRITE(LUG,100) TICM
   10   CONTINUE
           GOTO 350
C
C DRAW Y AXIS
C
  300   CALL DRAW(IGCB,X0,ALEN+Y0)
        CALL MOVE(IGCB,X0,Y0)
        CALL MOVEI(IGCB,-17.,-0.8)
```

```
      CALL LABEL(IGCB)
      WRITE(LUG,200) TICM
  200 FORMAT(F8.2)
C
C DRAW Y TICK MARKS AND LABEL THEM
      DO 20 K=1,TIC
         TICK=ALEN*(FLOAT(K)/TIC)
         TICM=TICM+((AMAX-AMIN)/TIC)
         CALL MOVE(IGCB,XO,TICK+YO)
         CALL DRAW(IGCB,XO-2.5,TICK+YO)
         CALL MOVEI(IGCB,-17.,-0.8)
         CALL LABEL(IGCB)
         WRITE(LUG,200) TICM
   20 CONTINUE
  350 CALL PENUP(IGCB)
      RETURN
      END
```

&ADPL2 T=00003 IS ON CR00017 USING 00031 BLKS R=0000

```
FTN4,L
      PROGRAM ADPL2
C
C         PROGRAM CREATED BY TINA WHITE
C                FINAL VERSION 820726
C
C **NOTE**
C   THERE ARE TWO VERSIONS OF THIS PROGRAM.  THIS VERSION IS USED TO
C   REPLOT THE 2313 DATA ON THE HP-IB PLOTTERS EXCEPT THE 1350A GRAPHICS
C   TRANSLATOR.  THE OTHER VERSION, IN FILE &ADPL1, IS USED TO REPLOT
C   ON THE 1350A GRAPHICS TRANSLATOR
C
C THIS PROGRAM TAKES THE DATA COLLECTED BY PROGRAM ADFN ON
C MAGNETIC TAPE AND PLOTS IT.  IT PLOTS ONE POINT FOR EVERY
C FIFTEEN SCANS, JUST AS IT WAS PLOTTED DURING THE RUN.
C IT CAN PLOT UP TO SIX LINES ONE ONE PLOT, WITH ONE PLOT FOR EVERY
C TWO MINUTES.  YOU CAN MAKE AS MANY CONSECUTIVE PLOTS AS NEEDED.
C SEE A CURRENT LISTING OF PROGRAM ADFN FOR CHANNEL NUMBERS.
C
C THIS PROGRAM IS NOT LIMITED TO PLOTTING ONLY THE THERMOCOUPLE
C TEMPERATURES  BY INPUTING THE RIGHT RANGE FOR THE Y-AXIS, THE
C OTHER CHANNELS CAN ALSO BE PLOTTED.
C
C
C DECLARATION OF VARIABLES
C
      INTEGER IGCB(192),LU(5),IAX(15),IAY(15),IHED(20)
      INTEGER CHAN(6),NCHAN,NBF,CH,MM,NUM,ITIME(3),FLAG
      REAL FTIME,TTIME
      DIMENSION VOLTS(100),X(100),HOLD(6),JCHAR(6)
C
C INITIALIZATION OF VARIABLES
C
      DATA VOLTS/100*0./,FLAG/0/
      DATA JCHAR/1H+,1HO,1H*,1H#,1HX,1H$/
      CALL RMPAR(LU)
      WRITE(LU,100)
  100 FORMAT("ENTER THE TOTAL NUMBER OF CHANNELS ON THE MAG TAPE")
      READ(LU,*)NBF
      WRITE(LU,101)
```

```
  101    FORMAT("ENTER THE NUMBER OF CHANNELS TO PLOT AND THEIR"
     1          " NUMBERS",/,"--ON THE SAME LINE SEPARATED BY COMMAS")
         READ(LU,*) NCHAN,(CHAN(I),I=1,NCHAN)
C
         DO 10 I=1,NCHAN
            CHAN(I)=CHAN(I)/2 + 1
   10    CONTINUE
C
         WRITE(LU,102)
  102    FORMAT(" OUTPUT ON GRAPHICS TERMINAL           TYPE 0",/,
     1          "        ON 9872 PLOTTER                TYPE 1",/,
     1          "        ON 7245B PRINTER/PLOTTER       TYPE 2",/,
     1          "        ON 1350A GRAPHICS TRANSLATOR TYPE 3")
         READ(LU,*) ILUG
C
C DEFINE LU AND ID NUMBERS OF PLOTTERS AND GRAPHICS TERMINAL
C
         LUG=7
         IF(ILUG.EQ.1)LUG=11
         IF(ILUG.EQ.2)LUG=13
         IF(ILUG.EQ.3)LUG=12
         ID=1
         IF(LUG.EQ.11)ID=2
         IF(LUG.EQ.13)ID=3
         IF(LUG.EQ.12)ID=4
C TO CENTER CHARACTER SET HALF WIDTH AND HALF HEIGHT
C DEPENDING ON IF USING PLOTTER OR CRT
         HW=0.5
         HH=0.5
         IF(ID.EQ.1)GOTO 20
         HW=0.333
         HH=0.25
C OBTAIN AXIS LABELS AND TITLE FOR PLOT
C
   20    WRITE(LU,103)
  103    FORMAT("ENTER X-LABEL,Y-LABEL,AND TITLE ON 3 SEPARATE LINES")
         READ(LU,201) IAX,IAY,IHED
  201    FORMAT(15A2/,15A2/,20A2)
C
C ENTER MINIMUM AND MAXIMUM VALUES FOR THE Y-AXIS
C
         WRITE(LU,104)
  104    FORMAT("ENTER YMIN AND YMAX (SAME LINE,COMMA INBETWEEN)")
         READ(LU,*) YMIN,YMAX
C
C ENTER THE NUMBER OF TIMES PLOT IS TO BE MADE
C ONE PLOT COVERS TWO MINUTES
C
         WRITE(LU,105)
  105    FORMAT("ENTER THE NUMBER OF PLOTS TO BE MADE",/,
     1          "THERE ARE TWO MINUTES TO A PLOT")
         READ(LU,*) NUM
C
C INITIALIZE PLOTTER
C
         DO 60 N=1,NUM
         CALL PLOTR(IGCB,ID,1,LUG)
         CALL SETAR(IGCB,2.0)
         CALL VIEWP(IGCB,0.,135.,0.,100.)
         CALL WINDW(IGCB,0.,150.,0.,100.)
         CALL CSIZE(IGCB,3.)
         CALL FXD(IGCB,0)
         CALL PEN(IGCB,1)
C
```

```
C WRITE AXES LABELS AND TITLE
C
      CALL MOVE(IGCB,55.,1.)
      CALL LABEL(IGCB)
      WRITE(LUG,106) IAX
 106  FORMAT(15A2)
      CALL MOVE(IGCB,3.,30.)
      CALL LDIR(IGCB,+1.57)
      CALL LABEL(IGCB)
      WRITE(LUG,106) IAY
      CALL MOVE(IGCB,40.,80.)
      CALL LDIR(IGCB,0.)
      CALL LABEL(IGCB)
      WRITE(LUG,107) IHED
 107  FORMAT(20A2)
C
C DRAW X AND Y AXES
C
      XTIC=10
      YTIC=20
      XMIN=0 + 120*(N-1)
      XMAX=120*N
      CALL LINAX(1,XMIN,XMAX,XTIC,LUG,IGCB)
      CALL LINAX(2,YMIN,YMAX,YTIC,LUG,IGCB)
      CALL VIEWP(IGCB,17.,120.,10.,80.)
      CALL WINDW(IGCB,XMIN,XMAX,YMIN,YMAX)
      CALL CSIZE(IGCB,2.)
C
C READ 15 SCANS OF DATA THEN PLOT A POINT
C
      J=0
      MM=0
      CALL LINE(IGCB,MM)
 50   J=J+1
         DO 30 K=1,15
            READ(8,202) (ITIME(I),I=1,3),(VOLTS(I),I=1,NBF)
 202        FORMAT(3(I2),16(F10.7,1X))
C OBTAIN THE STARTING TIME FOR REFERENCE
            IF(FLAG.EQ.0 .AND. K.EQ.1)
     +           FTIME=FLOAT(ITIME(1)*3600 + ITIME(2)*60 + ITIME(3))
            FLAG=1
C CONVERT THE TIME READING TO SECONDS
            TTIME=FLOAT(ITIME(1)*3600 + ITIME(2)*60 + ITIME(3))
 30      CONTINUE
C
         X(J)=TTIME-FTIME
         IF(X(J).LT.XMIN) X(J)=XMIN
         DO 40 L=1,NCHAN
            CH=CHAN(L)
            IF(J.EQ.1)GOTO 300
            CALL MOVE(IGCB,X(J-1),HOLD(L))
            CALL DRAW(IGCB,X(J),VOLTS(CH))
 300        CALL MOVE(IGCB,X(J),VOLTS(CH))
            CALL CPLOT(IGCB,-HW,-HH,-2)
            CALL LABEL(IGCB)
            WRITE(LUG,108) JCHAR(L)
 108        FORMAT(1A1)
            CALL MOVE(IGCB,X(J),VOLTS(CH))
            HOLD(L)=VOLTS(CH)
 40      CONTINUE
C
      IF(X(J).LT.XMAX) GOTO 50
      CALL PLOTR(IGCB,ID,0)
      IF(LUG.NE.11) GOTO 60
```

```
            IF(N.EQ.NUM) GOTO 60
            WRITE(LU,55)
   55       FORMAT("CHANGE THE PAPER ON THE 9872 PLOTTER",/,
      1           "ENTER 1 WHEN READY")
            READ(LU,*)IRDY
   60       CONTINUE
C
  999       STOP
            END
            SUBROUTINE LINAX(IAXIS,AMIN,AMAX,TIC,LUG,IGCB), FROM T. O'NEAL
C LINEAR AXIS DRAWING ROUTINE
C IAXIS - 1 = X-AXIS, 2 = Y-AXIS
C AMIN  - MINIMUM VALUE OF AXIS
C AMAX  - MAXIMUM VALUE OF AXIS
C TIC   - NUMBER OF TICK MARKS ALONG AXIS
C LUG   - LOGICAL UNIT NUMBER FOR GRAPHICS OUTPUT
C
            INTEGER IGCB(192)
C
C SET AXIS LENGTH IN WORLD COORDINATE SYSTEM(WCS)
C
            IF(IAXIS.EQ.1) ALEN=114.
            IF(IAXIS.EQ.2) ALEN=70.
C DEFINE ORIGIN
            X0=19.
            Y0=10.
            TICM=AMIN
            CALL MOVE(IGCB,X0,Y0)
            CALL CSIZE(IGCB,2.)
            IF(IAXIS.EQ.2) GOTO 300
C
C DRAW X AXIS
C
            CALL DRAW(IGCB,ALEN+X0,Y0)
            CALL MOVE(IGCB,X0,Y0)
            CALL MOVEI(IGCB,-12.,-4.5)
            CALL LABEL(IGCB)
            WRITE(LUG,100) TICM
  100       FORMAT(F8.0)
C
C DRAW X TICK MARKS AND LABEL THEM
            DO 10 K=1,TIC
               TICK=ALEN*(FLOAT(K)/TIC)
               CALL MOVE(IGCB,TICK+X0,Y0)
               CALL DRAW(IGCB,TICK+X0,Y0-2.0)
               TICM=TICM+((AMAX-AMIN)/TIC)
               CALL MOVE(IGCB,TICK+X0,Y0)
               CALL MOVEI(IGCB,-12.,-4.5)
               CALL LABEL(IGCB)
               WRITE(LUG,100) TICM
   10       CONTINUE
               GOTO 350
C
C DRAW Y AXIS
C
  300       CALL DRAW(IGCB,X0,ALEN+Y0)
            CALL MOVE(IGCB,X0,Y0)
            CALL MOVEI(IGCB,-17.,-0.8)
            CALL LABEL(IGCB)
            WRITE(LUG,200) TICM
  200       FORMAT(F8.2)
C
C DRAW Y TICK MARKS AND LABEL THEM
            DO 20 K=1,TIC
```

```
            TICK=ALEN*(FLOAT(K)/TIC)
            TICM=TICM+((AMAX-AMIN)/TIC)
            CALL MOVE(IGCB,X0,TICK+Y0)
            CALL DRAW(IGCB,X0-2.5,TICK+Y0)
            CALL MOVEI(IGCB,-17.,-0.8)
            CALL LABEL(IGCB)
            WRITE(LUG,200) TICM
   20     CONTINUE
  350     CALL PENUP(IGCB)
          RETURN
          END
```