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DESCRIPTION OF THE THERMAL HYDRAULICS LABORATORY AT HANFORD

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J. M. Batch and K. G. Toyoda

PURPOSE

The purpose of this report is to provide a brief written description of the facilities existing at Hanford for research and development in the fields of heat transfer and hydraulics.

INTRODUCTION

Within the Hanford Laboratories Operation a large laboratory exists for research and development in the fields of heat transfer and hydraulics. The laboratory is operated by the Thermal Hydraulics Operation to supply experimental information in support of the programs concerned with the development of reactor engineering technology at Hanford.

The research and development programs in progress are concerned principally with the heat transfer from nuclear fuel elements to water as a coolant. Specific fields of study include heat transfer during boiling, boiling burnout, hydraulic stability, heat transfer during transient conditions of flow and heat generation, coolant mixing, two-phase pressure drop, and discharge rates under critical flow conditions.

Many of the experiments are performed at typical reactor conditions of pressure, flow, and temperature, and with test sections fabricated to actual fuel element dimensions. Where heat transfer is involved, heat generation within the test sections is provided by resistance heating with high amperage, direct current electricity.

Although most of the work performed in the laboratory is in direct support of the various Hanford reactors, many of the programs are of general interest, and the experimental results have wide applications. Since there is considerable interest in the laboratory and in the results of many of the programs, the following descriptions of the facilities for heat transfer and hydraulic experimentation are provided.

GENERAL DESCRIPTION OF THE LABORATORY

The Thermal Hydraulics Laboratory occupies a floor space of approximately 11,900 square feet. The layout is shown in Figure 1. The laboratory has three major apparatuses or divisions. These are:

1. High Pressure Heat Transfer Apparatus
2. Low Pressure Heat Transfer Apparatus
3. Hydraulics Laboratory

Additional facilities for experimentation or for support in the operation of the major apparatuses include a silicon rectifier, direct current power supply; a motor generator, direct current power supply; an Organics Heat Transfer Apparatus, an electrical analog, a data reducing and calibration facility, and assembly and storage areas.

The High Pressure Heat Transfer Apparatus is an electrically heated facility designed for 2500 psig at 650°F. The maximum flow rate is 250 gpm. Experiments can be performed with test sections in either horizontal or vertical positions. To date, experimentation has been concerned mainly with subcooled and boiling burnout for fuel element models of solid rods (flow in annulus), for multi-rod configuration, and for externally and internally cooled configurations.

The Low Pressure Heat Transfer Apparatus is an electrically heated facility suitable for operation at 985 psig and 300°F at the inlet and 360 psig and 450°F at the outlet to the test section. Maximum circulating flow rate is approximately 100 gpm. The apparatus is used for support of existing reactors. Studies made on this apparatus include transient characteristics of pressure, flow, and temperature following sudden reductions of coolant; steady state pressure-flow characteristics of solid and internally and externally cooled fuel element assemblies; and flow mixing in cluster fuel element models.

A graphical illustration showing the major equipment, piping, and power connections of the two electrically-heated apparatuses is presented in Figure 2.

The Hydraulics Apparatus is designed to supply water to various test assemblies at 750 psig at 400°F. The Hydraulics Laboratory is confined to isothermal and/or adiabatic studies of pressure-flow characteristics. The test section includes actual Hanford flow configurations from front to rear header. Other test assemblies which comprise part of the Hydraulics Laboratory include a vertical test section and a critical discharge study test assembly.

The power supplies to provide direct current for simulation of nuclear heat generation in the heat transfer apparatuses are three motor generators and a silicon rectifier assembly. The nominal rating of the M-G set is 1125 KW (50 V at 22,500 amps) while the silicon rectifiers are capable of producing 2700 KW (85 V at 32,000 amps) continuously and 3840 KW (120 V at 32,000 amps) on a duty cycle. Either power supply may be connected to the bus system of either the High Pressure or the Low Pressure Heat Transfer Apparatus bus system, and both facilities may be operated simultaneously.

ORGANIZATION AND OPERATION

The Thermal Hydraulics Operation's principal responsibility is to provide heat transfer and fluid flow information of value for the design and operation of the Hanford reactors. The major group effort is concerned with obtaining experimental data from the several facilities, and with analyses leading to practical application of these data for reactor operation. In general the results are used to establish reactor operating limits and to provide information necessary for reactor hazards analysis.

The engineers in the group both run the laboratory apparatus and analyze the results. A working team is formed for each program to plan the experiments, design and fabricate appropriate test sections, prepare detailed test specifications, perform the experiments, analyze the results, and write the final reports. Most of the engineers serve on more than one team. For example, since one man has prime responsibility for operation and maintenance of each major experimental apparatus, that man serves on all teams running programs involving that particular apparatus. Engineering technicians assist in operating and maintaining the laboratory equipment.

The laboratory operation is supported by a maintenance force assigned specifically to the Thermal Hydraulics Operation to assist in maintaining the various equipment. This force includes a foreman, fitters, electricians, instrument technicians, and a welder. Additionaly, machinists, millwrights, and other craft personnel are readily available from the central maintenance organization.

The current experimental operation is such that all of the facilities may operate simultaneously. Each apparatus is operated on an individual basis with the intent of obtaining maximum operating efficiency on each equipment. The work schedule is normally on an eight hour day, five days a week basis, although double shift operating schedules are often utilized when running the High Pressure Heat Transfer Apparatus.

EQUIPMENT DETAILS

1. High Pressure Heat Transfer Apparatus

a. General

The High Pressure Heat Transfer Apparatus is a recirculating facility designed for steady state heat transfer experiments to investigate subcooled and boiling burnout, single and two-phase pressure drop, and other related studies. The primary circulating facility is rated for 2500 psig at 650°F. The deionized water coolant can be circulated at a maximum flow rate of 250 gpm. A simplified schematic flow diagram of the facility is shown in Figure 3.

b. Primary Pump, Piping, and Heat Exchangers

The facility piping is comprised of 2" to 4" Type 347 stainless steel pipes. The water circulation pump is a Byron Jackson mechanical seal pump, 2 x 4 - four stage special double case, rated for 250 gpm at 1450 TDH, and is driven by a 200 HP motor. The pump discharge flow is heated with four in-line electrical preheaters having a total capacity of 500 KW. The controls of the heaters consist of one 100 KW step, two 75 KW steps, three 33 1/3 KW steps, and one 150 KW variable and stepless control. The electrical preheaters are used to raise the loop water temperature to compensate for the cold system pressurizing injection water and to provide a control of the water temperature entering the test section.

The normal procedure for pumping is to provide 250 gpm of flow from the pump regardless of the test section flow rate requirements. Water in excess of that required for the test section is by-passed. This procedure is followed to establish a more stable operating system from flow and water temperature standpoints. Air operated flow control valves are provided in both the piping to the test section and in the by-pass line to control the respective flow rates.

The flow rate is measured with two types of meters - an electronic Cox turbine meter and a differential producing, venturi type meter. Several ranges of each type are available to assure the maximum accuracy.

Water from the test section and the by-pass line is combined and then water cooled in a Sentry Equipment Company shell-and-tube heat exchanger having a heat removal capacity of 15,000,000 Btu/hr. The heat exchanger is operated with constant cooling water flow rate; the primary fluid to the heat exchanger is regulated with a temperature-controlled, three-way valve so that a constant loop water temperature may be maintained during steady state operation.

The present facility is designed for steady state operation. Additions of equipment to permit transient type experimentation will be completed during 1960. This facility includes a high pressure (5000psig) air storage system to maintain a controlled pressure up to 2000 psig in a 1000 gallon water storage tank. A quick acting valve assembly (less than 50 milliseconds full stroke) will change the source of water circulation through the test section from the recirculating pump to the water storage tank. This system is necessary to permit transient type experimentation on the existing tight recirculating facility to assure equipment integrity, and to provide an adequate supply of water during a transient period. The system further provides the flexibility of permitting water at any pressure and at any temperature to be introduced to the test section. A line diagram showing the basic piping and equipment for the transient system is shown in Figure 4.

c. Test Sections

The test sections may be either horizontal or vertical in orientation. The length of these test sections may vary from 3 feet to 35 feet in the horizontal assembly and from 3 feet to 20 feet in the vertical assembly. The configuration of the fuel element model may vary with typical models being a single rod, several rods in a cluster, and tube-and-tube type. The present maximum housing or process tube size is 3.25" ID. However, larger sizes may be accommodated by changes in the electrical power connections. Sizes and configurations of the test sections are limited only by the electrical resistivity characteristics of metals which must match the power supply output and by the design requirements of cooling water and electrical connections in complicated assemblies.

A typical test section of a cluster element is shown in Figure 5.

d. System Pressurization and Water Treatment

Water used as the coolant is demineralized water obtained from steam condensate and treated in an Illco-Way anion-cation water treating equipment. Water with a resistivity greater than 500,000 ohms is used to assure electrical insulation between the heat generating test section and other piping components. Approximately 2 per cent of the recirculating water is continually bled from the system and deionized to maintain the water quality.

The loop is pressurized to the required operating pressure by a bleed and inject method in conjunction with the water treatment procedure. The water to be treated is bled from the suction side piping of the recirculation pump and cooled to less than 100°F in a shell-and-tube heat exchanger. The rate of water bleed off is controlled through a high pressure drop valve. This water is then circulated to the storage tank.

Water from the tank is circulated to a vacuum de-aerator and to the water treatment towers at a maximum rate of 5 gpm. When required, chemical addition for pH control is made at this point. The water is then injected into the loop through the seal of the primary loop circulating pump with an American-Marsh positive displacement pump.

e. Control Panel and Instrumentation

The control panel for the High Pressure Heat Transfer Apparatus is located in front of the test section (Figure 1). Instruments include recorders for the test section and system water temperatures, cooling water temperature recorder-controllers, system pressure recorder-controller, manometers, water treatment control, alarm system for high temperatures in the pump and heaters, low air pressure, etc.

Partial views of the control panel are shown in Figures 6 and 7. A listing of the more important instruments is given in Table I of the Appendix.

f. Temperature Monitoring

The basic thermocouples are chromel-alumel for the test rod temperature and iron-constantan for the water. A permanent extension lead wire system of 80 I/C couples and 120 C/A couples is installed between the test section areas and the panel board. Each end terminates in a quick-disconnect jack panel or console so that any pick up point can be connected to measure temperature on any appropriate recorder on the control panel by simple changes.

Temperatures are measured throughout the system for indications of potential troubles and for general control. These include the pump suction and discharge water, pump heat exchanger outlet water, preheater inlet and outlet water, preheater shell, flow control valve inlet and outlet water, flow meter inlet circulating loop, heat exchanger inlet and outlet. Since these temperatures are not critical to data analysis within the test section, readings are normally made on a 20-point recorder or on indicators. For such temperatures as preheater shell and pump heat exchangers which affect equipment safety, the readouts are also connected to the annunciator system.

Other water temperature readings critical for data analysis or for temperature control, such as inlet and outlet water temperatures of the test section, are monitored on single-pen recorders. The inlet water temperature is used to control the variable-and-continuous electric preheater; a separate inlet water temperature measurement and a pump suction temperature are used to regulate the heat exchanger three-way valve by a pneumatic controlling temperature recorder-controller and Indexit recorder. Where more accurate readings are required, a 48-point, push button, extended range potentiometer may be used during operation.

Techniques for measuring heater rod temperature vary with the configuration of the test assembly. Normally 1/16" or 3/64" OD sheathed thermocouples with magnesium oxide insulation are imbedded in or attached to the heater surface. Temperatures are recorded on two-pen, continuous record recorders, or on single-pen recorders having a 25-point manual and automatic stepping switch arrangement. All recorders have a full-scale response of less than one second so that sudden and rapid changes in heater temperatures can be detected before damage to the test section can occur.

g. Pressure Measurement

Several key pressure measurements in the system are continuously monitored with 0 to 2500 psi Heise or 0 to 3000 psi Helicoid gauges, or with a four-point extended range pressure recorder which uses SR4 Baldwin strain gauges as the sensing element. These pressures include inlets and outlets to the pump and to the test section. System pressure is automatically controlled by use of a strain gauge pressure transducer and an extended-range pressure recorder-controller sensing the tube outlet pressure, and which in turn controls the system bleed valve pressure drop.

Pressure drop data of test sections are obtained by indicators set up in a manifold of 60" mercury manometers and Barton torque tube differential indicators of 0 to 10, 0 to 25, and 0 to 50 psi ranges.

h. Flow Measurement

Flow measurements are made with calibrated venturi type elements or Cox turbine flowmeters. Differential pressures of the venturis are measured with a high pressure, 60 inch mercury manometer. For higher flows giving differential readings larger than 60" of mercury, four Barton Torque Tube pressure indicators having the ranges of 0 to 10, 0 to 25, 0 to 50, and 0 to 100 psi are used in a manifold system.

Four Cox turbine flowmeters having ranges from 2 to 75 and 5 to 300 gpm are used to supplement the flow measurements. The electrical signals from these flowmeters are visually displayed on digital indicators.

2. Low Pressure Heat Transfer Apparatus

a. General

The Low Pressure Heat Transfer Apparatus is a facility designed principally for the studies concerned with existing Hanford reactors. The operating characteristics of the facility permit certain transient-type as well as steady state experimentation to be performed.

The apparatus is normally a recirculating facility utilizing steam condensate to prevent scale deposit on the fuel element model in tests resulting in high heating surface temperature. The apparatus is designed for operation up to 985 psig at 300°F at the inlet side of the test section and for 360 psig at 450°F on the discharge side.

b. Circulating System

A simplified schematic flow diagram is shown in Figure 8. The piping is basically 2" and 4" type 304 stainless steel.

Flow is circulated by one of two Byron Jackson pumps. The pumps have the following characteristics:

No. 1 - 500 psig developed head at 35 gpm, 12-stage vertical 300 psig maximum suction pressure, 300°F maximum temperature

No. 2 - 700 psig developed head at 70 gpm, 14-stage vertical, 300 psig maximum suction pressure, 300°F maximum temperature

Water from the smaller B.J. pump No. 1 may be heated to 300°F by a Pfaudler shell and tube steam heater. The flow to the test section is manually controlled with several globe valves of different sizes in parallel. Each line contains a Potter turbine flowmeter in sizes from 3/4" to 2". Piping to the test section may be interchanged so that the supply will enter the test section as a single feed or as two feeds. The latter is to accommodate a fuel element model simulating an internally and externally cooled configuration. For this flow geometry, additional flow control valves and flowmeters are installed in each line to permit flow adjustment and flow monitor independently to each flow channel.

The heated coolant leaving the electrically heated test assembly, which may be all liquid or mostly steam, is cooled by two Schutte-Koerting steam condensers located immediately downstream of the test section. Cooling water for this purpose is provided by a by-pass around the test section of part of the water discharged from the recirculating pump. The pressure of the steam or water leaving the condenser is manually regulated to produce a desired pressure at the outlet of the test section. Water is then cooled in two shell-and-tube heat exchangers to a nominal 70°F.

The extent of pressurization required on the Low Pressure Heat Transfer Apparatus is to assure that the pump suction pressure is high enough to prevent cavitation in the pumps. The pressurization is accomplished by air loading of a pressure tank floating on line. Normal minimum pressure required is 5 psig.

c. Test Sections

The principal test section is a model of the fuel elements used in the existing Hanford reactors installed in a standard or actual process tube lined with electrical resisting phenolic resin. The lining is necessary to prevent electrical leakage from the resistance-heated test element to the housing tube. The electrical connection from bus to test section is shown in Figure 9.

Immediately downstream of the heated portion is a "dummy section", a reactor nozzle, outlet fittings, and header arrangement to simulate the reactor flow configuration as closely as possible.

An additional short test section is located parallel to the above reactor prototype. This test section is used for basic studies of heat transfer and boiling heat transfer mechanism, of flow mixing or channeling in cluster elements, stratification of vapor phase, etc. The housing tube may be metal or glass to permit visual observations or high speed filming. A typical glass tube assembly is shown in Figure 10.

d. Control Panel and Instrumentation

The control panel location is next to the process equipment and test section, and is indicated in Figure 1. Instrumentation includes Heise gauges, 6-point temperature recorders, single pen recorders, 2-pen pressure recorders, and steam preheater recorder-controller.

Partial views of the Low Pressure Heat Transfer Apparatus are shown in Figures 11 and 12. The latter shows also the high speed recording equipment used to obtain transient data. (The high speed recorders are described in Section 5C.) A listing of the more important instruments is given in Table II of the Appendix.

e. Temperature Measurement

The temperature measurement system is basically iron-constantan for both the water and test rod measurements. Quick disconnect plugs terminate either end of the permanent extension lead wire system to permit selection of any temperature recording on any one point on any recorder. Leads may be connected simultaneously to the recorders or to a circular 30-point selection temperature indicator during operation.

Basic heater rod thermocouples are 1/16" or 1/8" OD sheathed thermocouples imbedded in grooves slotted in the outer surface of the test rod. The hot junctions may be electrically insulated with cement.

f. Pressure Measurement

The pressure measurement is made by seven Heise gauges. The gauges range from 0 to 100 and 0 to 1200 psig. Any point to be measured may be directly indicated or be manifolded to any of the gauges. Provisions for recording up to six pressures on circular charts are also available.

Four pressure indicators are also available for manifolding delta pressure readings. Ranges of these indicators are 0 to 50, 0 to 100, 0 to 250, and 0 to 400 psi.

g. Flow Measurement

Flow is measured with one of five Potter turbine flowmeters ranging in size from 3/4 to 2". Flow range is from 2 to 12 gpm for the smallest and 5 to 125 gpm for the largest Potter. Readout is obtained on milliammeters.

3. Hydraulics Laboratory

a. General

The Hydraulics Laboratory is a facility designed to study pressure-flow characteristics of existing Hanford reactor process tube flow geometries. Additions have been made to broaden the scope to include studies in vertical test sections and in equipment suitable for study of non-heating, two-phase pressure drop and critical discharge flow phenomena from orifices, nozzles, and pipes. All test apparatuses utilize the same pumping, water heater, and flow measuring equipment. Water employed is the standard Hanford reactor process water.

b. Process Piping

The Hydraulics equipment is a single-pass system, made up of basically 3" and 4" pipelines. Materials are Type 304 stainless steel at the inlet and carbon steel on the outlet system. Design rating is 750 psi at 400°F. A flow diagram is shown in Figure 13.

Process water is stored in a 3300 gallon head tank located on the mezzanine above the laboratory area and "floats" on the suction side of the pump. A level controller assures adequate supply of water in the tank at all times. The pumping station consists of three pumps. These are a Bingham 4-stage horizontal centrifugal pump, 500 gpm at 1387 feet head, 250 hp motor; and two Ingersoll Rand, five stage vertical pumps with 100 gpm at 1155 feet head, 60 hp motor. Water pumped by any of the three pumps is passed through a flow metering system of Potter and Fischer Porter turbine type primary elements. Flow control is performed by manual adjustment of remote loading stations. The water may be steam heated in a Ross U-tube heat exchanger up to a nominal temperature of 350°F. By proper valving the water can be supplied to one of the desired test sections.

After passing through the test section, all water is dumped to the sewer with quenching, if required.

c. Test Sections

Test assemblies, prototypical from front to rear header of the several different types of Hanford reactors, are used for determining pressure-flow characteristics. Actual reactor fuel elements are employed. All tests are made under isothermal or adiabatic conditions. Where test interest in directed at the fittings, the fuel elements may be omitted, and the process tube serves as the connecting pipe.

A vertical test section, with metal or plastic housing, is also available for hydraulic studies. Principal geometry simulates the Plutonium Recycle Test Reactor process tube although other configurations may be easily installed for testing.

The third test apparatus is designed for two-phase pressure drop measurements or for study of critical discharge rates from pipes, nozzles, and orifices. The latter is fitted with a momentum chamber to provide force data valuable for determining slip ratios in steam-water mixtures.

d. Control Panel and Instrumentation

The control panel location and general equipment layout is shown in Figure 1. The control panel is shown in Figure 14. Several Heise pressure gauges, U-tube manometers, Barton torque tube differential pressure indicators, a 12-point temperature recorder, and Potter electronic flow readout are used to obtain data. The pressure indicating instruments are manifolded so that pressure at any point or pressure drop between any two points may be readily obtained.

A list of the more important instruments is presented in Table III of the Appendix.

Temperature readings in the various test sections and pipings are obtained by use of iron-constantan thermocouples. Readout is obtained on the temperature recorder. Weston dial thermometers are also used in locations near the flow control valves to aid operators in setting test conditions.

Flow meters are calibrated by the weight method. The weigh tank capacity is 2000 lb. The timer used in connection with the weigh tank gives .1 second readings. At the present time, this assembly is used to calibrate the flow meters of all the major apparatuses.

4. Direct Current Power Supply

a. General

Two sources of power supply are available to provide the resistance heat direct current to the High Pressure Heat Transfer Apparatus and the Low Pressure Heat Transfer Apparatus fuel element models. These consist of three integrated motor-generator sets and a silicon rectifier system. The locations of this equipment are shown in Figure 1. Bus duct systems with eleven 1/2" x 6" copper bars in parallel supply the power from the sources to an intertie area located adjacent to both of the electrically-heated apparatuses. The intertie is such that either power supply may be connected to either the high or the low pressure test section, and both facilities may operate simultaneously. Figure 2 shows the general connection scheme.

b. Motor-Generators

The motor-generators consist of a double-ended machine and a single machine manufactured by Electric Products. Each is capable of producing 7500 amperes of direct current at 50 volts or a combined total of 22,500 amperes at 50 volts. The double-ended machine is driven by a 1250 hp, 512 rpm, 2300 volt synchronous motor. The single machine drive is a 700 hp, 512 rpm, 3200 volt synchronous motor. The generator controls are intertied such that one, two, or all three machines may be operated as a unit.

A portable control console may be located at either end of the motor-generator switchgear depending upon the test apparatus utilized. All control and power data indicators and recorders are mounted on this portable console. However, provisions for remote programmed power control and "stop" exist at each of the test apparatus control areas. Figures 15 and 16 show the generators and control equipment for this power supply.

c. Silicon Rectifiers

The silicon rectifier system was supplied by the General Electric Company. All equipment is designed for indoor use. The rating of this system is 2700 KW at 85 volts and 32,000 amps on a continuous basis. The equipment has overload capacities of 3840 KW at 120 volts and 32,000 amps on a one-half hour on, one hour off duty cycle or 48,000 amperes for one minute. The system consists of:

1. 13.8 kv AC circuit breaker
2. DC controlled saturable reactor
3. Two rectifier transformers for 13.8 kv, 3 phase, 60 cycle operation
4. Two 16,000 amp silicon rectifier cabinets
5. Amplidyne for DC control of the saturable reactor

The control panel is located between the High Pressure Heat Transfer Apparatus and the Low Pressure Heat Transfer Apparatus control areas. The panel is complete with controls, indicators, and power recorders. Remote programmed power changes can be performed. Emergency stop buttons are located at either control area. Figures 17, 18, 19, and 20 show the rectifier system and control panel.

5. Miscellaneous Support Equipment

a. Organic Heat Transfer Apparatus

The Organic Heat Transfer Apparatus is designed to obtain basic heat transfer and fouling data for organic coolants. Efforts on this apparatus have been limited to preliminary information on Monoisopropylbiphenyl. The resistance heating principle is employed using a single-phase A.C. power supply. Test section sizes are 1/4" to 3/8" OD tubing, approximately 12 inches long. Basic design rating is 100 psig at 800°F, with a maximum flow rate of 10 gpm.

b. Analog Computer

An analog computer having a grid net work of 12 by 24 points, supports analysis of steady state heat transfer problems. Resistance to heat flow is simulated by setting an appropriate electrical resistance between each grid point. Electrical current input to each grid point simulated heat generation, and temperatures are found from the voltages throughout the grid network. This computer is of special value for problems where the geometry is such that analytical solutions are not practical.

c. Calibration and Special Support Equipment

The support of the laboratory operation requires numerous specialized equipment to produce and obtain accurate data. Supporting devices include special equipment for calibrating, troubleshooting, recording, and analyzing data. Some of these items are:

1. Oscillographic recorder, Heiland Visicorder Model 1012, mirror galvanometer type, direct print, 36 channels. Chart speed may be varied in steps from .1 to 160 inches/sec. Recording width is 11 3/8". Carrier and DC amplifiers used with the recorder give frequency response capabilities of better than 1000 cycles per second.

2. Oscillographic recorders (2 units), Offner Type M Dynograph, six channels, chart speeds up to 250 mm/sec. Recording width 7 centimeters each channel, frequency response DC to ± 10% at 70 cps. Input signal may be DC, reluctance type, strain gage, or carrier.

3. Pressure transducers, differential and absolute measurements, ranges ± 1 psid to ± 1000 psid, and 0 to 100 to 0 to 3000 psia.

4. X-Y recorders, Moseley Autograf Model 2S complete with curve follower attachment for programmed control of motor-generator and rectifier power supply systems, response one second full scale, range 0 to 7.5 mv to 0 to 150 volts.

5. Semi-automatic data reducer, Benson Lehner Oscar Model J, for analyzing and reading continuous strip chart and oscillographic records, complete with electrotypewriter and key punch adaptor.

6. High speed camera, Wollensak "Fastax" Model WF-2, 16 mm film, speeds up to 18,000 frames per second. Equipment complete with high intensity,

short duration stroboscopic light source capable of producing high intensity light flashes of less than 2 x 10^{-6} seconds duration up to 6000 flashes per second.

7. Mueller Bridge, Rubicon Model 1551, range 0 to 141.110 ohms, for use with National Bureau of Standards calibrated and certified platinum resistance temperature element.

8. Kelvin Bridge, Gray Instrument No. E-3272, range .5 microhms to 22.2 ohms, sensitivity one microampere.

9. High Precision potentiometer, Rubicon 2780, Type B with electrostatically shielded case, range 0 to 16 millivolts to 0 to 1.6 volts, limit of error at low range, 1 microvolt or .015%.

10. Oscilloscope, Textronic Model 545, cathode ray, wide range, fast rise unit.

6. Supporting Services

a. Assembly Area

Machine, welding, instrument, electrical, and fitter shops are located within the laboratory building for joint usage with other experimental components. Additional to these shops, special areas are designated to perform specialized craft work in support of test section assembly. Adjacent to the High Pressure Heat Transfer Apparatus is a welding area with a special aligning lathe to assemble the test sections and pipe components. A hoist is available to transport the heavier test sections to the test apparatus. Thermocouple makeup and installation is performed in this area for heavier fuel element models. A separate thermocouple makeup area for smaller test sections is provided next to the rectifier power supply.

b. Storage Areas

Storage facilities for completed test sections are provided in either of two assembly areas. Components such as pipes, fittings, and valves which require long procurement time are maintained on hand in a separate storage building or in the plant warehouses. Total storage space retained by the Thermal Hydraulics Operation is approximately 4,000 square feet. Accurate inventories of all stored items are maintained to assure sufficient supply of critical items for operational continuity.

c. Water

Water requirements for equipment operation include raw and reactor process water. Both types of water are available in the laboratory area at pressures of up to 50 psig.

d. Steam

Steam is available in the building from the plant boiler at 225 psig in a 4" line. Steam is required to provide condensate in both of the electrically-heated apparatuses and for heating of process water in the Hydraulics Laboratory and the Low Pressure Heat Transfer Apparatus steam preheaters.

e. Air

Instrument and control air, which must be oil free and dry, is available at 100 psig from a 10 hp non-lubricated compressor and a dryer system. Air for general purposes is supplied from a larger building compressor at 100 psig.

f. AC Power

The primary electrical power is available at 13.8 KV. The rectifier power supply utilizes this supply directly. Transformers for 13.8 KV/2300 V, 13.8KV/440 V, 2300 V/440 V step downs to provide generator, pump, electric preheater, and other power requirements are located outside of the laboratory building.

LABORATORY OPERATION

1. Personnel

a. High Pressure Heat Transfer Apparatus

The operation, maintenance, and routine modification of the High Pressure Heat Transfer Apparatus is delegated to a responsible engineer. No operation is conducted without his presence or authority. He is assisted by a technician to carry out the specified responsibilities. During operation, further assistance may be provided by other engineers interested in the test and by other technicians as required.

b. Low Pressure Heat Transfer Apparatus

The operation of the Low Pressure Heat Transfer Apparatus is conducted in the same manner as the High Pressure Heat Transfer Apparatus.

c. Hydraulics Laboratory

The responsibility for the operation, maintenance, and modification of the Hydraulics Laboratory is delegated to a specific engineer. The equipment may be operated by a technician but under supervision and direction of the responsible engineer.

d. Maintenance

The routine maintenance and minor modifications to existing facilities are performed by craft personnel. The craft personnel number ten plus a foreman and include a welder, fitters, instrument technicians, and electricians. These personnel are assigned to support the operation of the Thermal Hydraulics Laboratory specifically. Other craft personnel such as machinists and millwrights are assigned to other components in the laboratory building, but are available to the Thermal Hydraulics Operation for performing work.

Program priorities are established by the Supervisor, Thermal Hydraulics Operation. Based on these priorities, craft services are scheduled with the craft foreman by the Thermal Hydraulics Operation maintenance co-ordinator.

2. Operating Schedules

The prime responsibility of the Thermal Hydraulics Operation is to the support of Hanford reactor operation. All work concerned with continuity of reactor operation is therefore of the highest priority.

The normal schedule for equipment operation is based on a 40-hour, 5-day week. Because of the relatively long start up and shut down time required for the high pressure apparatus, double shifts may be used on occassion to increase operating time. Other facilities may also operate on a two-shift basis where the need for data warrants.

3. Safety

Safety is given a high degree of attention since many of the experiments involve water at high pressures and temperatures and in many cases, high electrical currents. Job hazard breakdowns are written and reviewed with personnel at intervals. All experiments which deviate from established practices are discussed thoroughly with operating personnel. Test section areas are barricaded during operation, while operating areas are chained off to prevent unauthorized entries. Safety glasses are required and furnished in the laboratory building.

Piping and vessels are designed, fabricated, tested, and inspected in conformance to applicable codes. All safety valves and pressure vessels are routinely inspected by procedures and at frequencies recommended by the Third Party Inspector.

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Table I

PANEL INSTRUMENTATION
HIGH PRESSURE HEAT TRANSFER APPARATUS

Measurement	Quantity	Description
Temperature	3	Recorder, L&N Micromax, 0 to 1500°F C/A calibration, single pen record, heater temperature
Temperature	2	Recorder, Westronics D-11, 0 to 2500°F C/A calibration, 2 pen record, heater temperature
Temperature	2	Recorder, L&N Speedomax, Model G, 0 to 700°F I/C calibration, single pen record, water temperature
Temperature	1	Recorder, L&N Speedomax Model G, 0 to 600°F, I/C and 0 to 100°F delta, 2 pen record, water and water temperature rise
Temperature	1	Recorder-controller, General Electric Model HF, 0 to 700°F I/C calibration, electric preheater control
Temperature	2	Recorder-controller, Brown Model Y 152, 0 to 700°F, water temperature
Temperature	1	Recorder, Bristol 20 PG, 0 to 700°F, 20 point, water temperature
Temperature	1	Indicator, precision, Brown Model SC 156 X, 0 to 75 mv, water and heater temperature
Temperature	1	Recorder, Brown, SY 153, 2 pen record 0 to 2500°F, C/A calibration, heater temperature
Pressure	1	Recorder, Brown Y 153, 4 point, extended range to 2500 psig, for Baldwin SR 4 strain gauge transducers
Pressure	1	Recorder-controller, Brown Y 152, extended range to 2500 psig, for Baldwin SR 4 strain gauge transducers
Pressure	3	Indicator, Heise, 16" dial, 0 to 2500 psig
Pressure	3	Indicator, Helicoid, 8" dial, 0 to 3000 psig
Pressure	4	Indicator, differential, Barton 227, 0 to 10 psid
Pressure	4	Indicator, differential, Barton 227, 0 to 25 psid
Pressure	4	Indicator, differential, Barton 227, 0 to 50 psid
Pressure	1	Indicator, differential, Barton 227, 0 to 100 psid

Table I
Panel Instrumentation, High Pressure Heat Transfer Apparatus

Measurement	Quantity	Description
Pressure	4	Manometer, 0 to 60"
Flow	4	Indicator, Cox Type 6R, digital, up to 300 gpm, for use with Cox turbine flowmeters
Flow	1	Recorder-controller, Brown Y 152P, 0 to 150 gpm, for use with Potter turbine flowmeters
pH	1	Recorder-controller, Brown 152R
pH	1	Indicator, Beckman Model W, 2 to 12

Table II

PANEL INSTRUMENTATION
LOW PRESSURE HEAT TRANSFER APPARATUS

Measurement	Quantity	Description
Temperature	3	Recorder, Brown Y 153, 6 point, 0 to 600°F and 0 to 1200°F, I/C calibration
Temperature	1	Recorder, Brown Y 153, 6 point 0 to 800°F, I/C calibration
Temperature	1	Indicator, Brown Y 156, 0 to 600°F and 0 to 1200°F
Temperature	1	Recorder, Brown Y 153, two pen record, 0 to 1500°F, I/C calibration
Pressure	3	Recorder, Brown Y 702C, two pen, 0 to 500 psig
Pressure	2	Indicator, Heise, 16" dial, 0 to 1200 psig
Pressure	3	Indicator, Heise, 12" dial, 0 to 700 psig
Pressure	2	Indicator, Heise, 12" dial, 0 to 500 psig
Pressure	1	Indicator, Heise, 8" dial, 0 to 100 psig
Pressure	1	Indicator, differential, Barton 227, 0 to 50 psid
Pressure	1	Indicator, differential, Barton 227, 0 to 100 psid
Pressure	1	Indicator, differential, Barton 227, 0 to 250 psid
Pressure	1	Indicator, differential, Barton 227, 0 to 400 psid
Flow	2	Indicator and converter for Potter turbine meter, up to 125 gpm

Table III

PANEL INSTRUMENTATION
HYDRAULICS LABORATORY

Measurement	Quantity	Description
Temperature	1	Recorder, Bristol 12 PG, 12 point, 0 to 300°C I/C
Pressure	1	Indicator, Heise, 12", 0 to 100 psig
Pressure	1	Indicator, Heise, 12", 0 to 300 psig
Pressure	1	Indicator, Heise, 12", 0 to 500 psig
Pressure	1	Indicator, Heise, 12", 0 to 600 psig
Pressure	1	Indicator, Heise, 12", 0 to 700 psig
Pressure	2	Indicator, differential, Barton Model 227, 0 to 10 psid
Pressure	2	Indicator, differential, Barton Model 227, 0 to 500 psid
Pressure	2	Indicator, differential, Barton Model 227, 0 to 100 psid
Pressure	2	Indicator, differential, Barton Model 227, 0 to 150 psid
Pressure	2	Indicator, differential, Barton Model 227, 0 to 400 psid
Flow	1	Indicator and converter for turbine flowmeters, range to 200 gpm

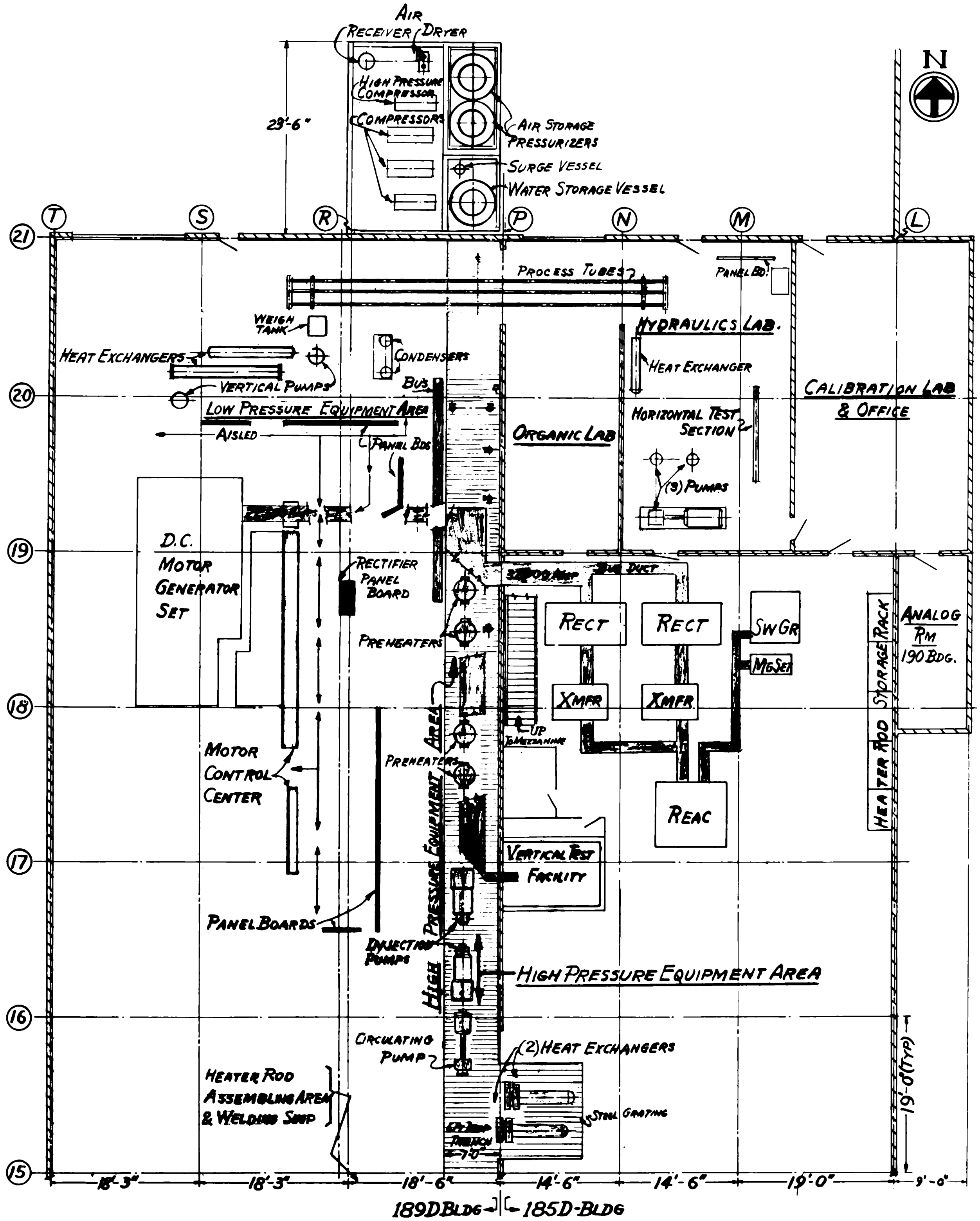


Figure 1

FLOOR LAYOUT - THERMAL HYDRAULICS LABORATORY

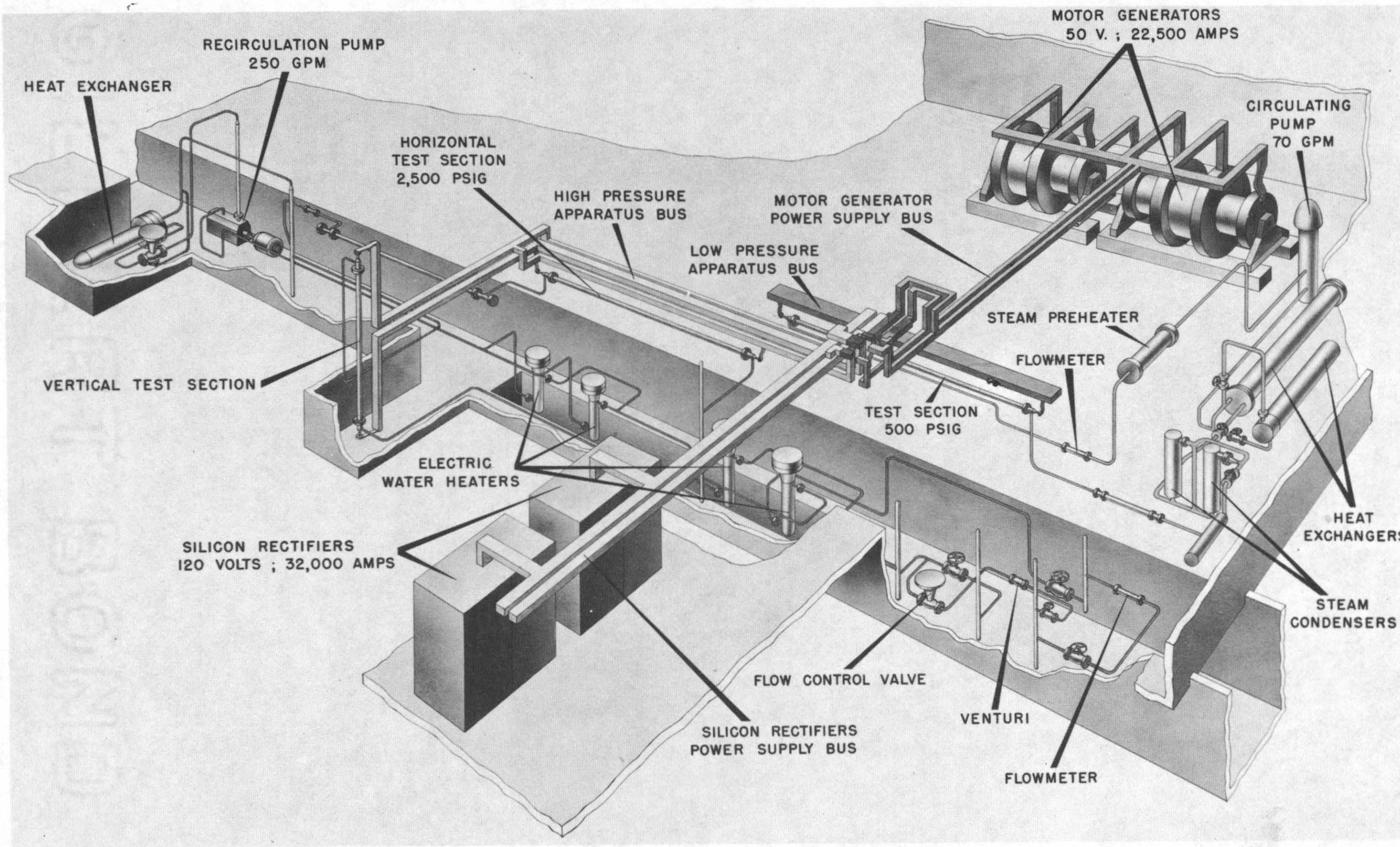


Figure 2

THERMAL HYDRAULICS LABORATORY
HEAT TRANSFER FACILITIES

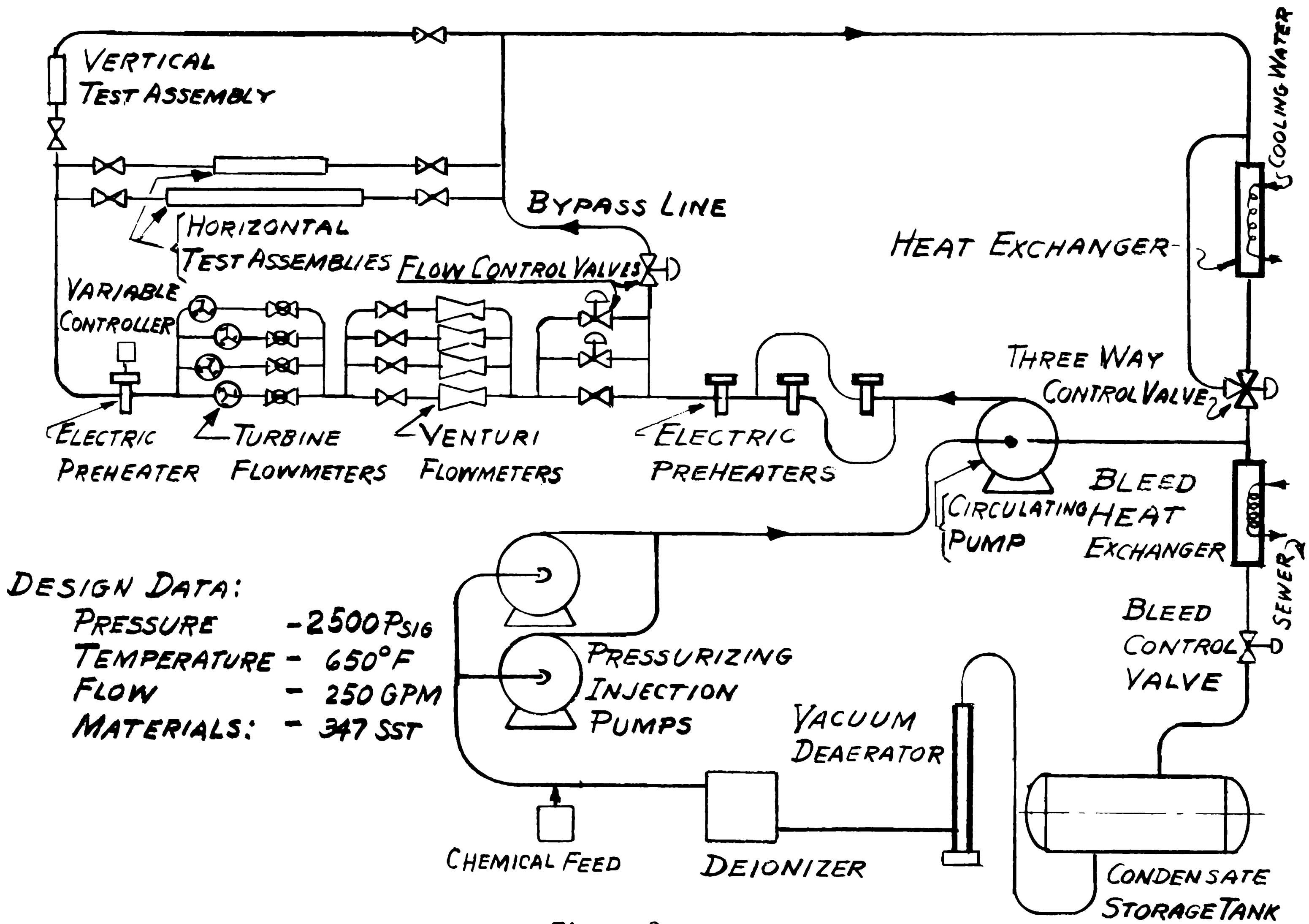


Figure 3

FLOW DIAGRAM OF
HIGH PRESSURE HEAT TRANSFER APPARATUS

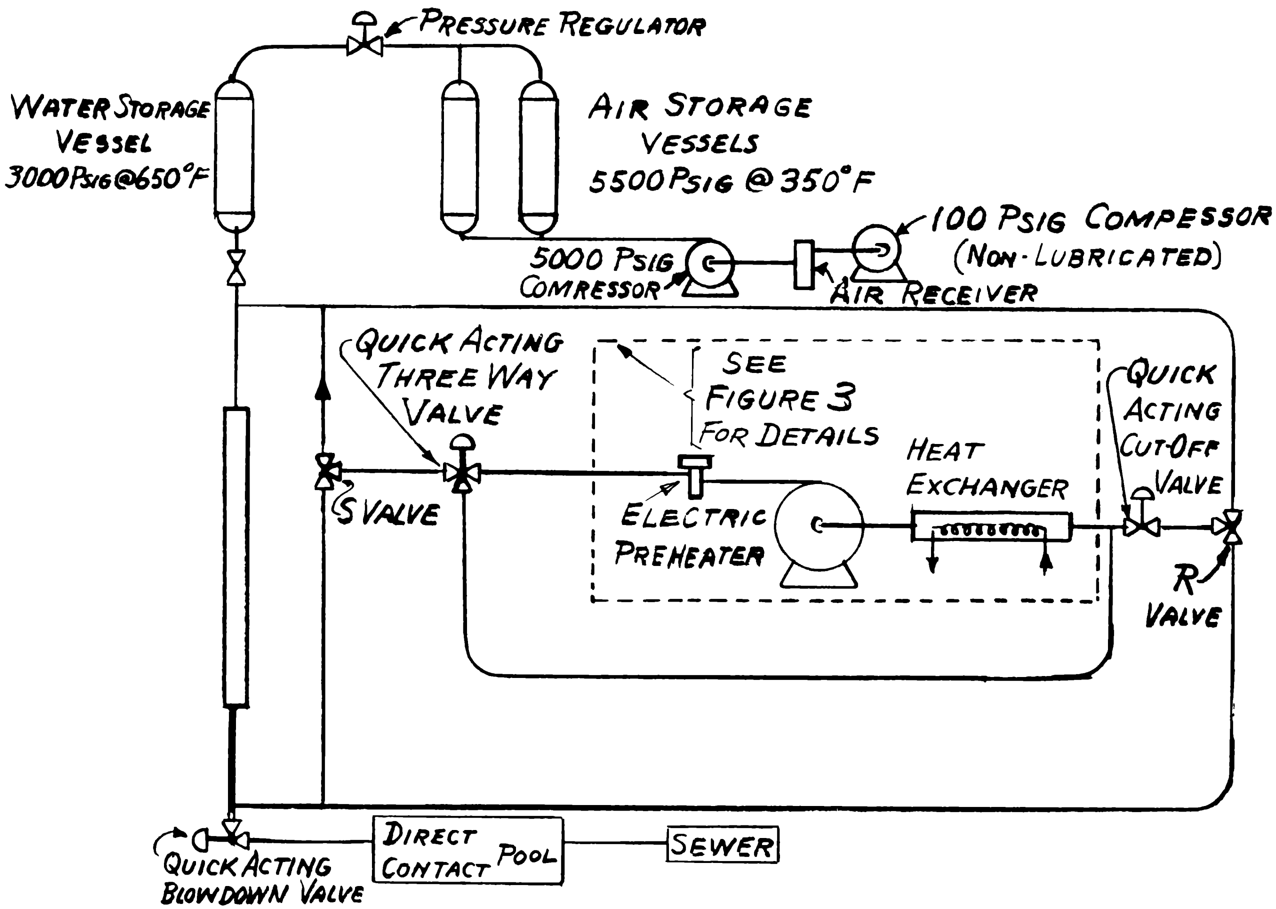
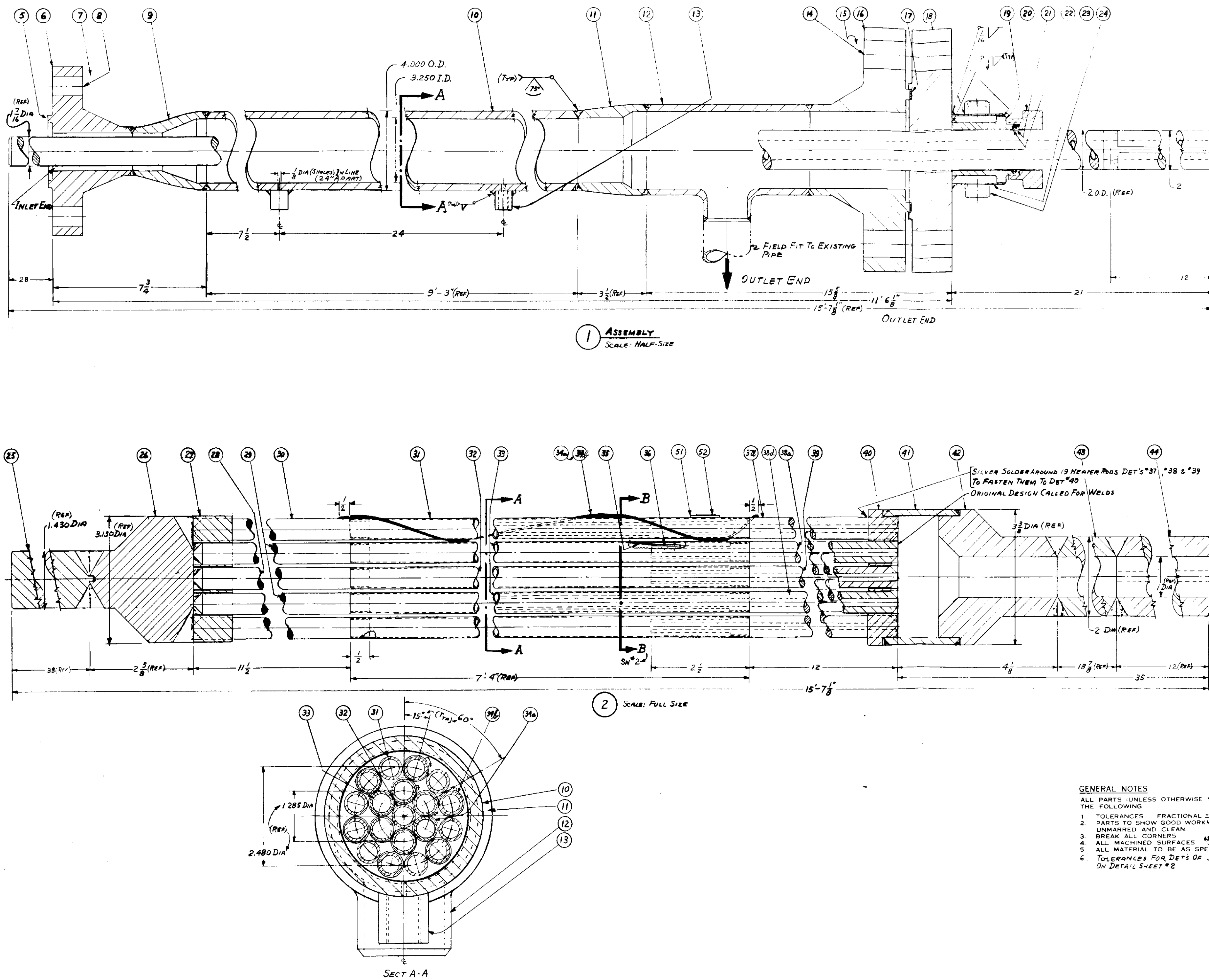


Figure 4

FLOW DIAGRAM OF
HIGH PRESSURE HEAT TRANSFER APPARATUS TRANSIENT SYSTEM



QTY.	PT NO.	DESCRIPTION	DET SH No.	MATERIAL	HAPO STORES STOCK No.
	1	ASSEMBLY (PROCESS TUBE)	1		
	2	SUB-ASSEMBLY (INTERNAL)	1	SUB-ASSY'S 2&3 SHOW ALL DET'S	ALL DET'S NOT SHOWN ON #2
	3	SUB-ASSEMBLY (THERMOCOUPLES INSTALLED ... 189-D LAB)	3	↓	ALL DET'S NOT SHOWN ON #3
	4	SUB-ASSEMBLY (ADD'L ... MODIFICATIONS MADE IN 189D, NOT ON B/M)	3		
1	5	2" GASKET (RING) LARGE GROOVE 1500#	—	FLEXITALIC	33-2885-225
1	6	2" FLG WELD NECK 1500# LARGE TONGUE BORE 2" I.D.	—	SST 347	50-2450-186
16	7	7/8" HEX NUTS 11NC	—	ALLOY STL	42-3820-200
8	8	7/8" BOLT (STUDS) 11NC 6" LONG	—	↓	42-1020-718
1	9	3 1/2 x 2 REDUCER DBLE EXTRA STRONG (WELD)	2	SST 347	LADISH OR EQ
1	10	PROCESS TUBE 4.000" O.D. 3.250" I.D. x 9'-3" LONG	—	SST 347	189D-LAB
1	11	4 x 3 1/2 REDUCER DBLE EXTRA STRONG (WELD)	2	SST 347	LADISH OR EQ
1	12	4 x 4 x 2 TEE SCH 80 (CUT 2" I.D. TO 2.067 DIA)	—	SST 347	↓
5	13	1/4" HALF COUPLING (PRESSURE TAPS)	3	SST 347	189-D LAB
8	14	1 1/4 BOLT (STUDS) 7UNC 9" LONG	—	ALLOY STL	42-1020-821
16	15	1 1/4 HEX NUTS 7UNC	—	↓	42-3822-226
1	16	4" FLG WELD NECK 1500# LARGE TONGUE	—	SST 347	LADISH OR EQ
1	17	4" GASKET	—	FLEXITALIC	
1	18	4" FLG BLIND 1500# LARGE GROOVE BORE 2.125 DIA	—	SST 347	
1	19	BODY (ON ASSEMBLY WELD DET #19 TO FLG DET #18, THEN WELD DET #23 TO DET #18 & TO DET #19; THEN WELD DET #24 TO #23)	2		
1	20	CAP 4" DIA x 2" LONG	↓	TOOL STL AISI S...	46-8196-325
1	21	"O" RING 2 3/8 OD x 3/16 W LINEAR 1820-32	—	GEN SERV COMP	33-6900-032
2	22	RINGS 2 3/8" OD x 2" ID x 1/16" THK	—	TEFLON SHT	33-8185-200
1	23	COOLING JACKET 16 GA	2	SST 304L	47-2760-011
2	24	1/2 COUPLINGS (CUT IN HALF, FIT TO DET #23) SE	—	SST 347	50-1225-170
1	25	CONDUCTOR INLET	2	LEADED COPPER	189D-LAB
1	26	CONNECTOR I			
1	27	↓ II (TO 19 HTR RODS)			
1	28	HEATER ROD			
6	29				
12	30	↓	↓	↓	
12	31	TUBE O.D. = .564, I.D. = .446 x 7'-4" LONG	3	INCONEL	
1	32	O.D. = .564, I.D. = .468 x 7'-4" LONG			
6	33	↓ O.D. = .564, I.D. = .463 x 7'-4" LONG	↓	↓	
AS REQ	34	WIRE .072 DIA = 13 B&S GAGE & .062 DIA	—	ANNEALED	
28	35	SPRING	2	INCONEL	↓
114	36	0" SCR RD HD 80NF 2A x 1/8 LONG	—	BRASS	42-5120-100
12	37	HEATER TUBE OUTLET #37 & #38 2 1/2 LONG	2	LEADED COPPER	189D LAB
6	38	#38 & #39 2 1/2 LONG			
1	39	↓			
1	40	CONNECTOR III (TO 19 HTR TUBE OUTLETS)		↓	
1	41	SLEEVE (MADE UP FROM COPPER SHEET, BENT TO REQ DIA & WELDED)		COPPER SHT	
1	42	CONNECTOR IV		LEADED COPPER	
1	43	V (O.D. = 2", I.D. = 1", 30° CHAMF EACH END)	↓		
1	44	↓ VI	2		
2	45	RIB 3/32" WIDE x 1/16" HIGH x 9 1/2 LONG	3		
2	46	x 1/8"			
2	47	↓ x 5/32"	↓	↓	↓
1	48	BRACKET	3	STL (MILD)	46-8090-170
16	49	THERMOCOUPLES (WATER)		30 GA CHROMEL AL. IN ... SST	189D LAB
44	50	↓ (TUBE)	↓	30 GA CHROMEL ALUMEL WITH ...	
54	51	CLIP FOR INSULATOR 3/4 LONG (BENT & SPOT WELD TO TUBES)		INCONEL "X" .025" THK	
54	52	INSULATOR PIN 1/2 LONG x 1/16 DIA		ALITE	↓

GENERAL NOTES

ALL PARTS (UNLESS OTHERWISE NOTED) SHALL CONFORM TO THE FOLLOWING

1. TOLERANCES FRACTIONAL $\pm \frac{1}{64}$" DECIMAL $\pm .005$" ANGULAR $\pm 0°30'$
2. PARTS TO SHOW GOOD WORKMANSHIP, FREE FROM BURRS, UNMARRED AND CLEAN.
3. BREAK ALL CORNERS
4. ALL MACHINED SURFACES 63 (ASA B46.1 - 1955)
5. ALL MATERIAL TO BE AS SPECIFIED, OR EQUAL QUALITY
6. TOLERANCES FOR DET'S OF SUB-ASSEMBLY #2 AS NOTED ON DETAIL SHEET #2

FIGURE 5
THO MODEL OF
PRTR MARK I FUEL ELEMENT & PROCESS TUBE
(Original Full Size Model)
ASSEMBLY & SUBASSEMBLY

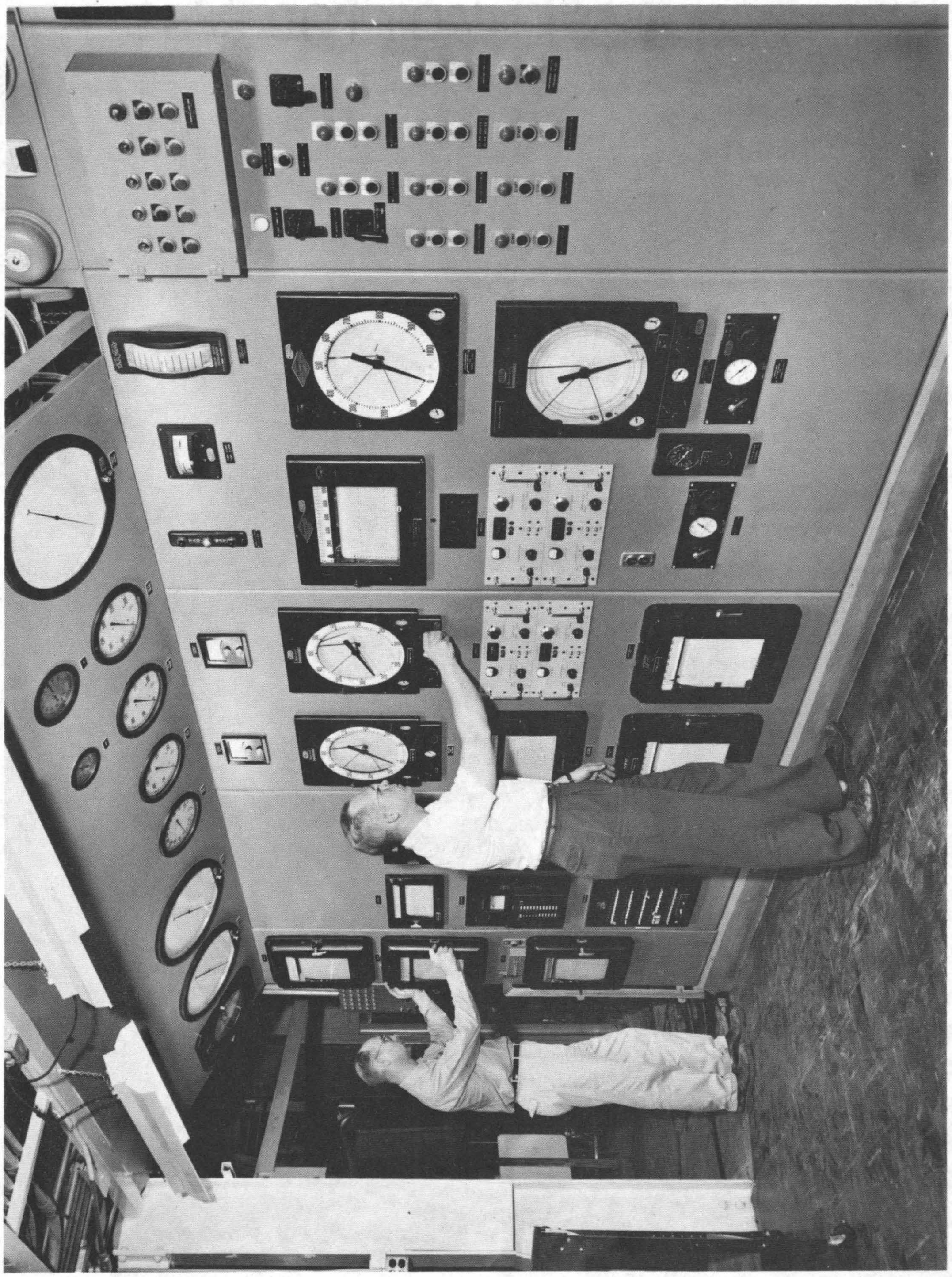


Figure 6

PANEL BOARD
HIGH PRESSURE HEAT TRANSFER APPARATUS

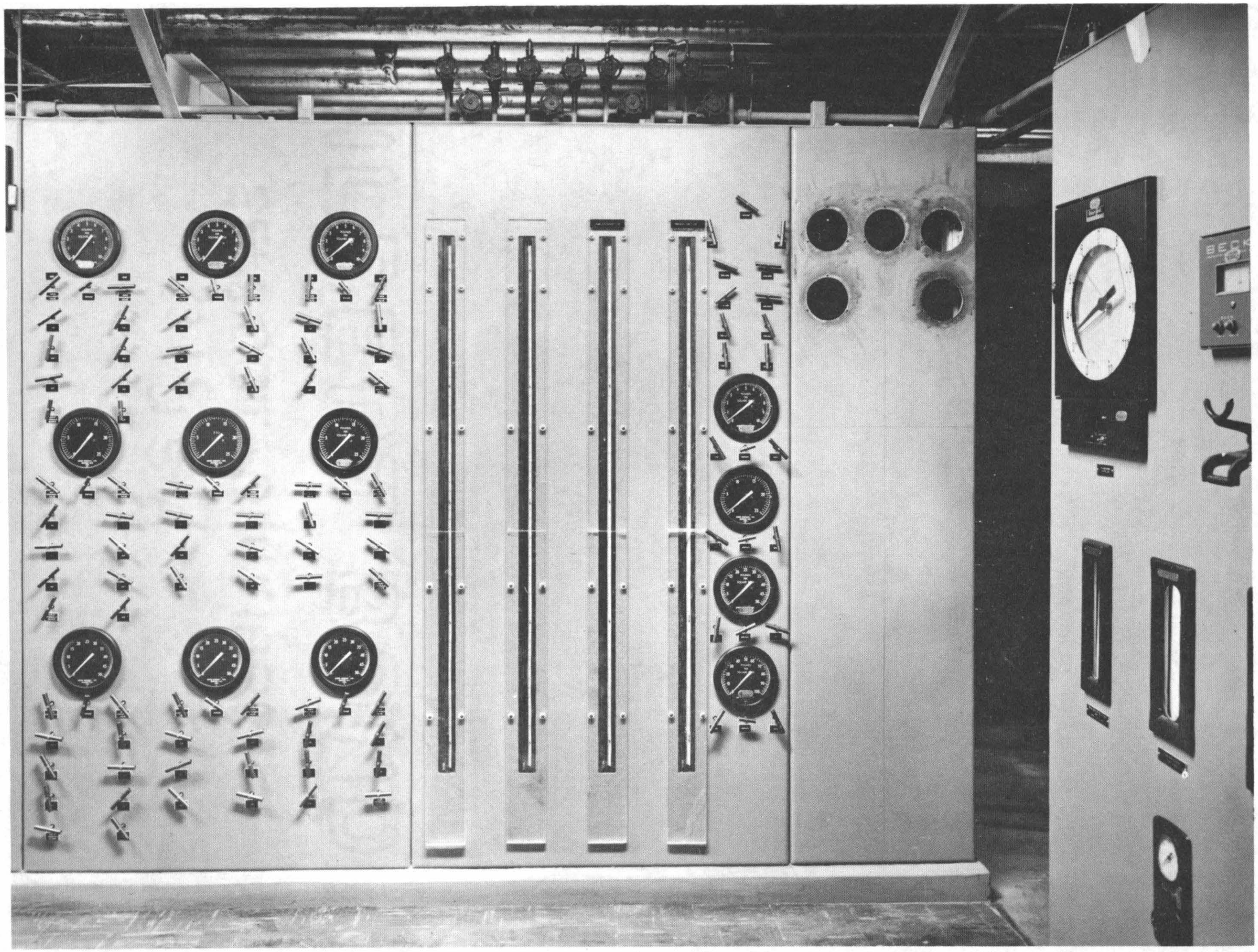


Figure 7

PANEL BOARD
HIGH PRESSURE HEAT TRANSFER APPARATUS

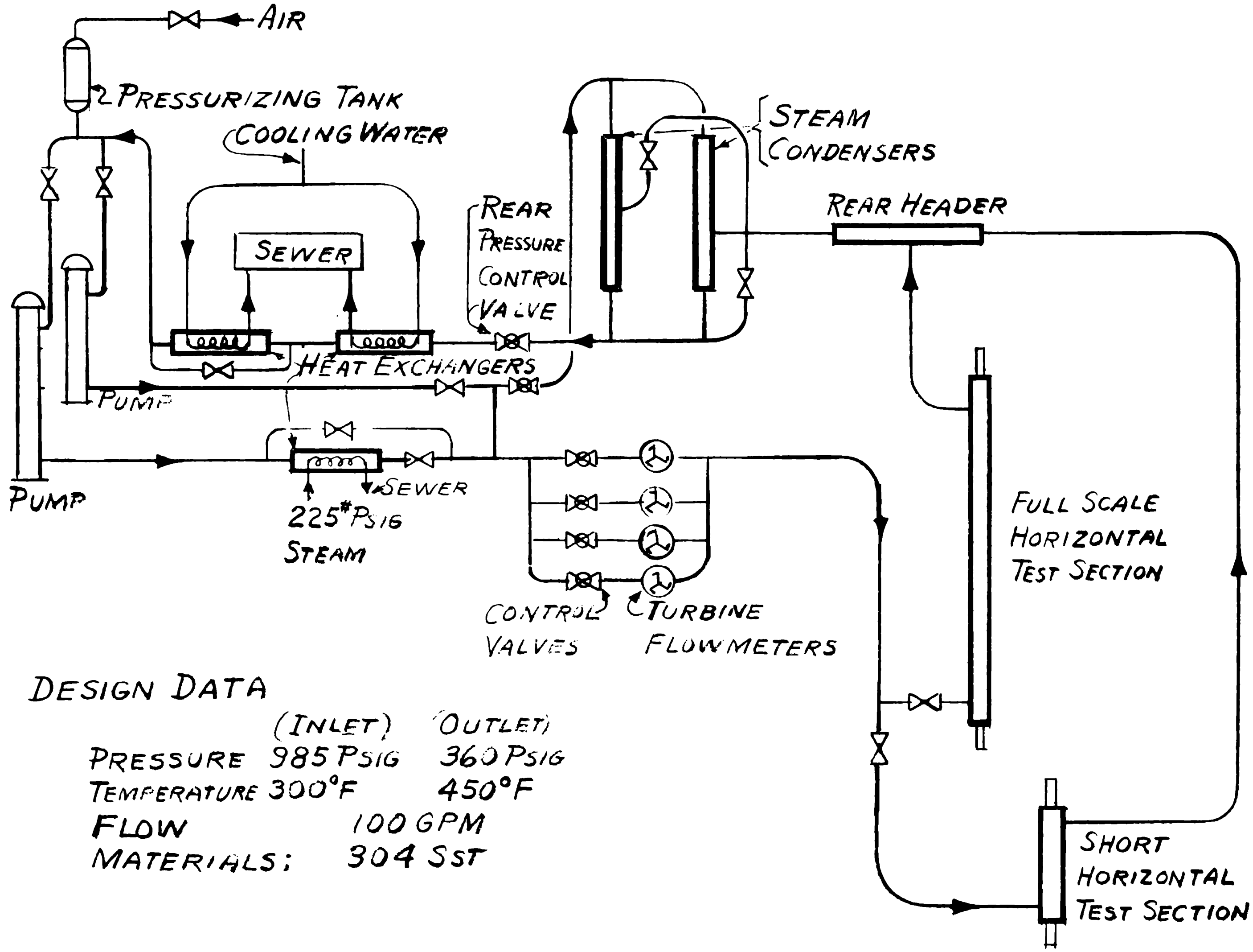


Figure 8

FLOW DIAGRAM OF
LOW PRESSURE HEAT TRANSFER APPARATUS

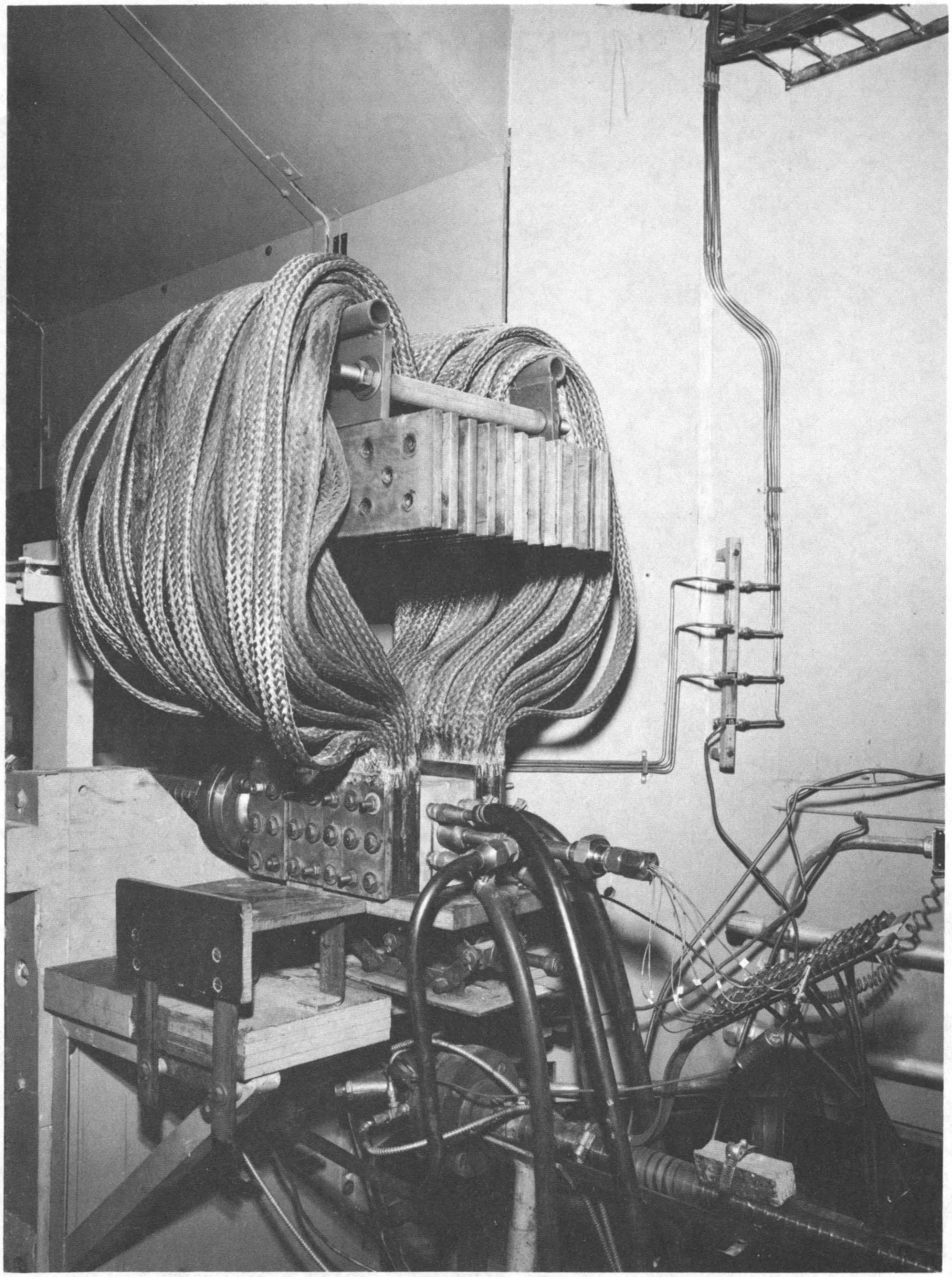


Figure 9

TYPICAL ELECTRICAL CONNECTION
END VIEW

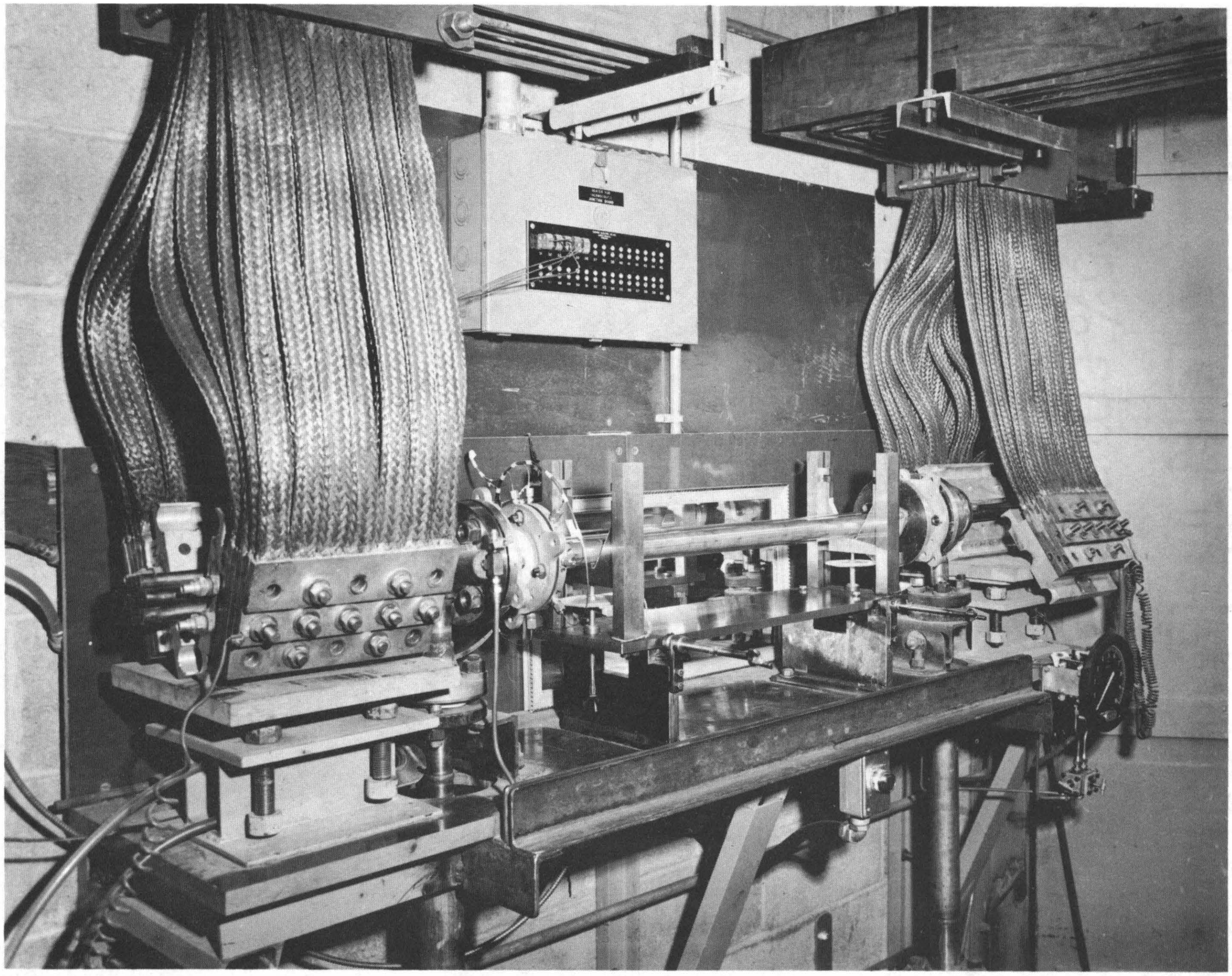


Figure 10

GLASS TUBE ASSEMBLY

UNCLASSIFIED

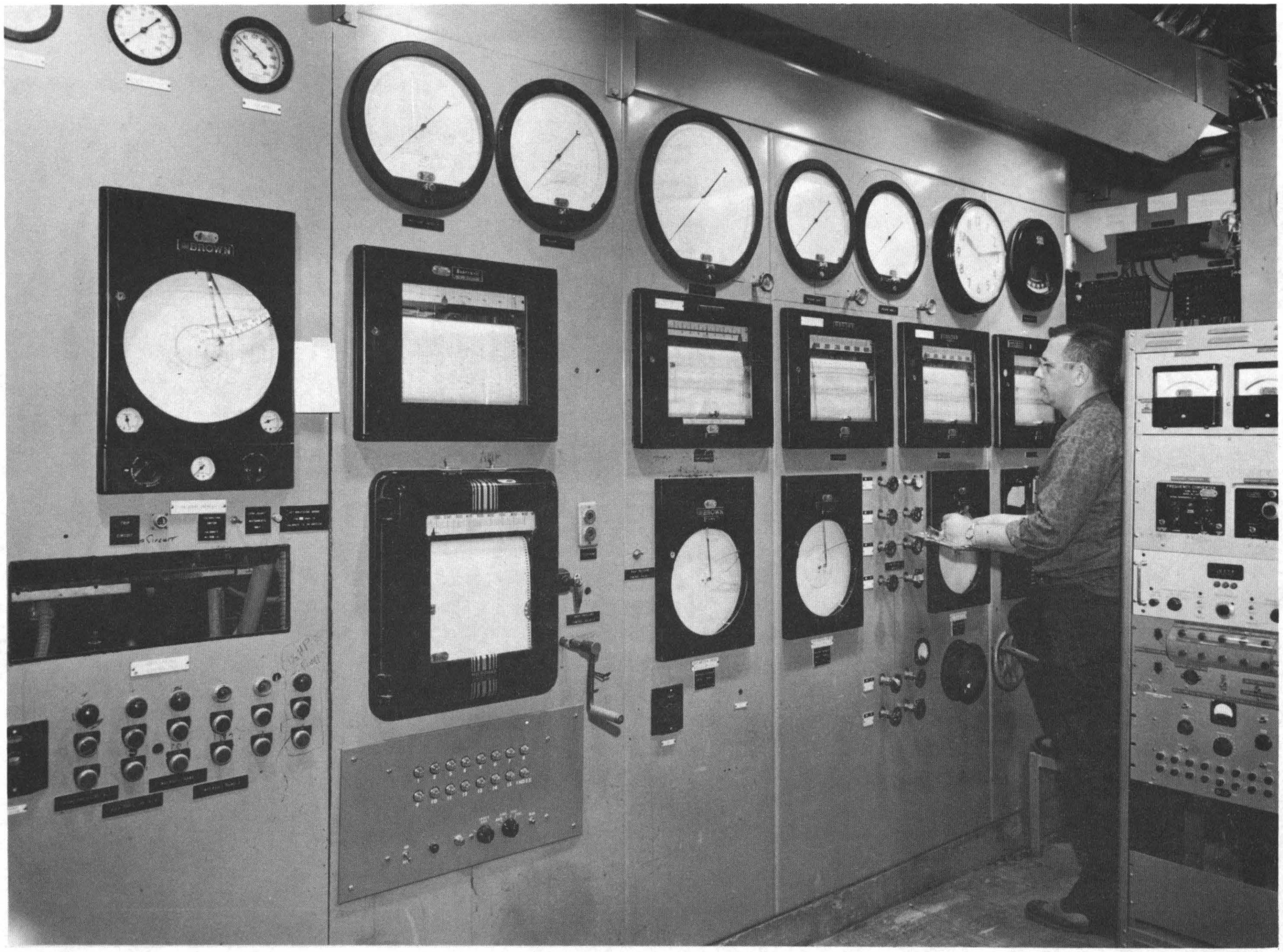


Figure 11

PANEL BOARD
LOW PRESSURE HEAT TRANSFER APPARATUS

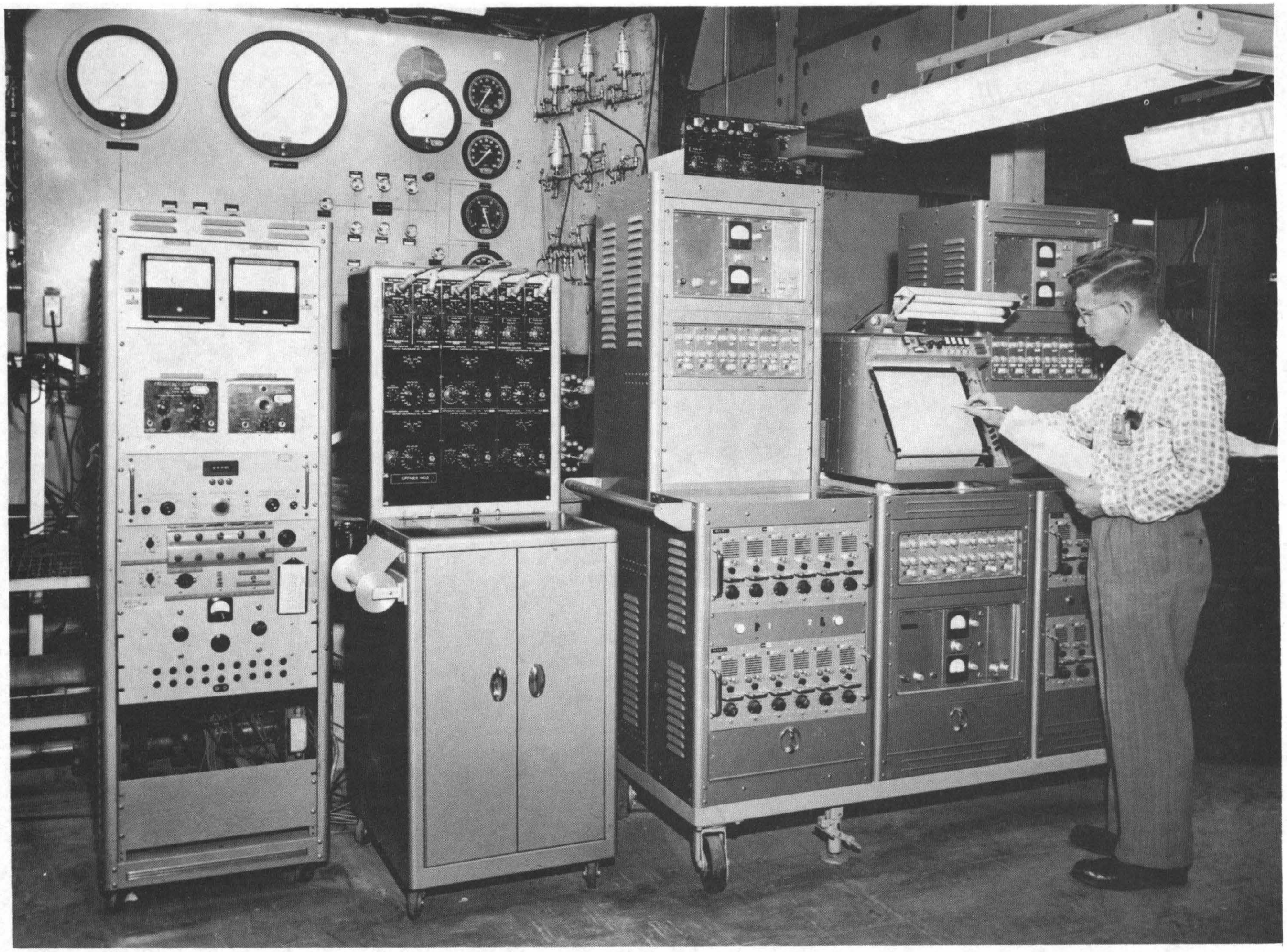


Figure 12

PANEL BOARD AND HIGH SPEED RECORDING EQUIPMENT
LOW PRESSURE HEAT TRANSFER APPARATUS

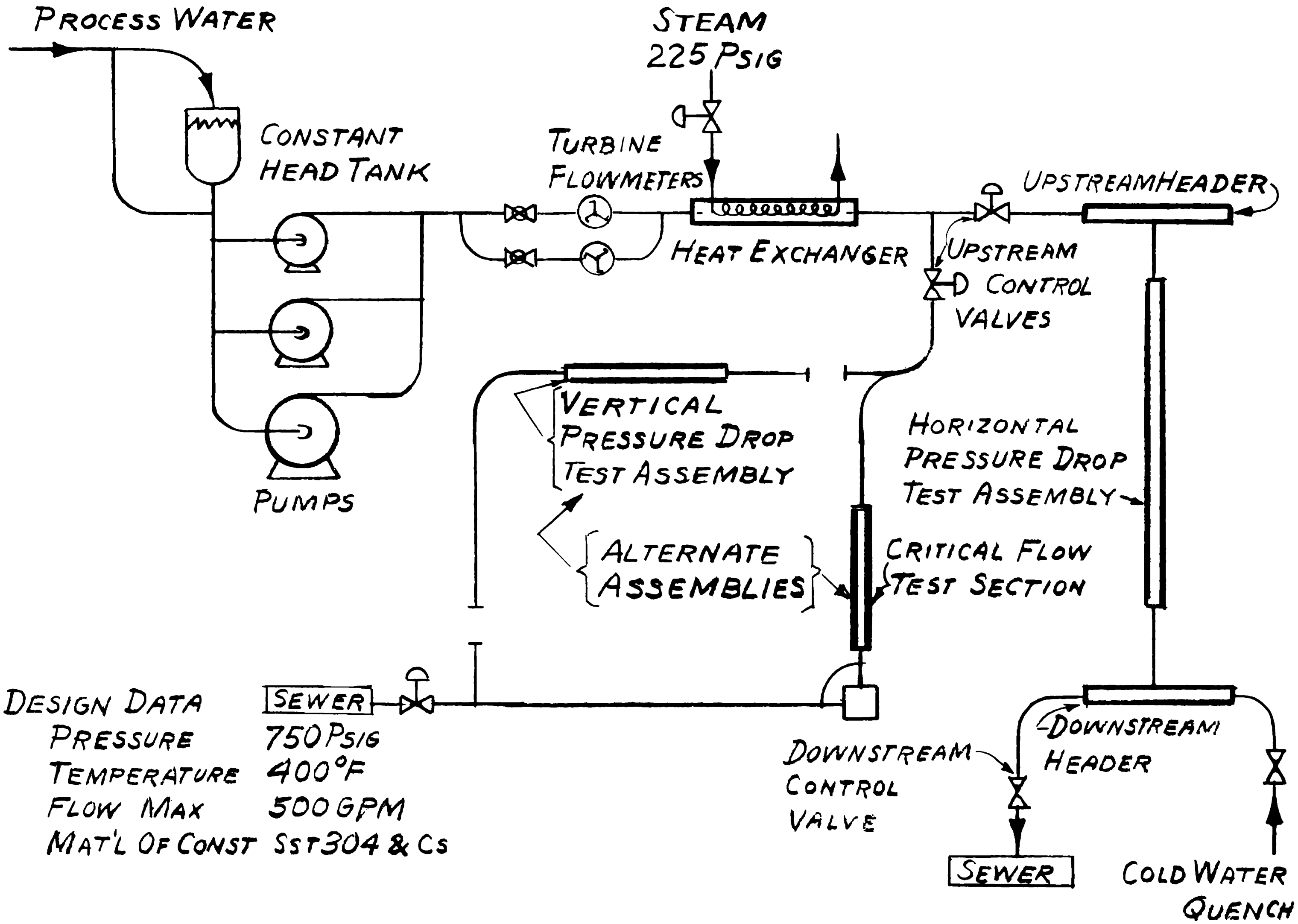


Figure 13

FLOW DIAGRAM OF HYDRAULICS LABORATORY

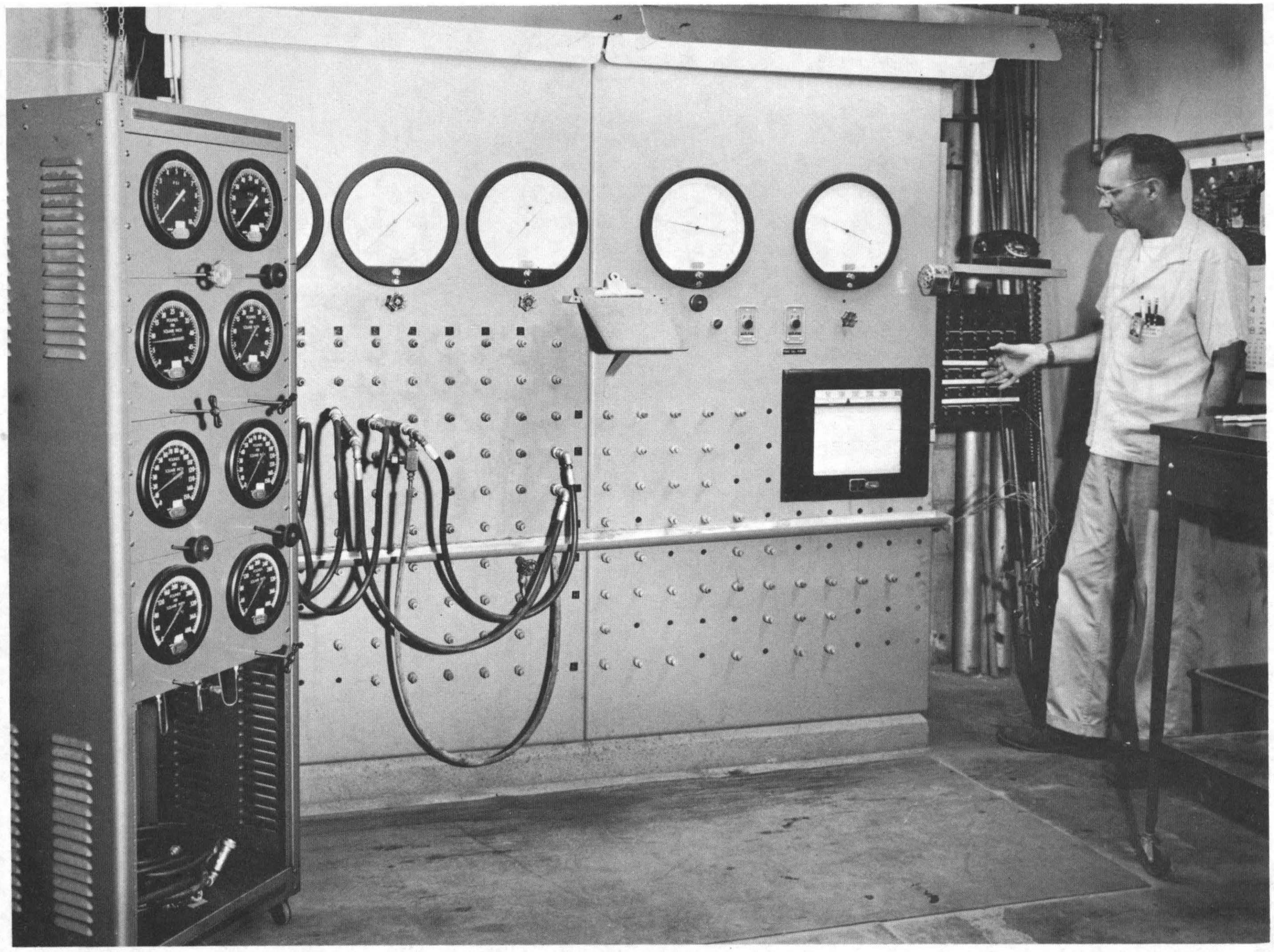


Figure 14

PANEL BOARD
HYDRAULICS LABORATORY

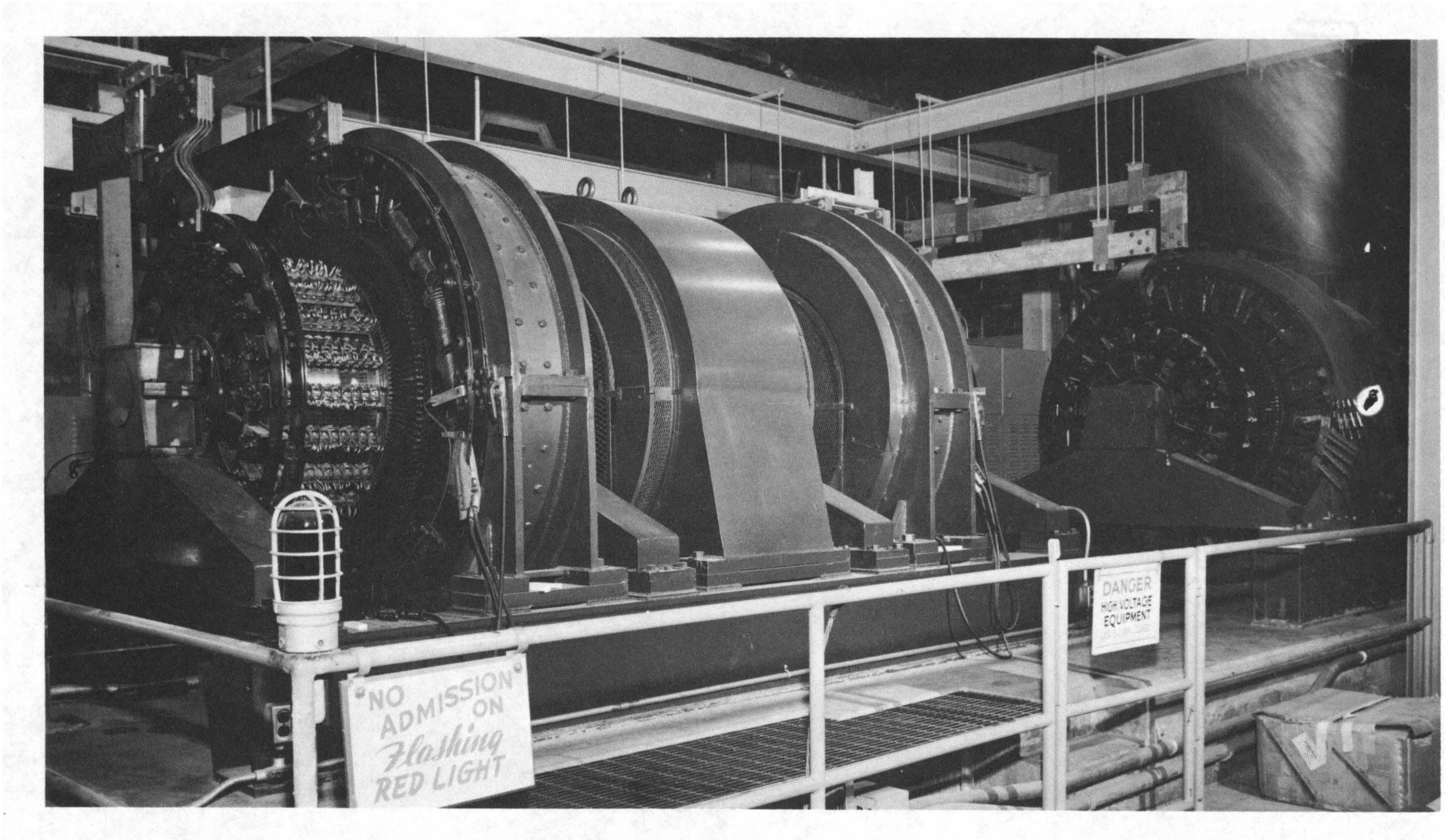


Figure 15

MOTOR GENERATOR SET

Figure 16

MOTOR GENERATOR CONTROL
CONSOLE AND SWITCHGEAR

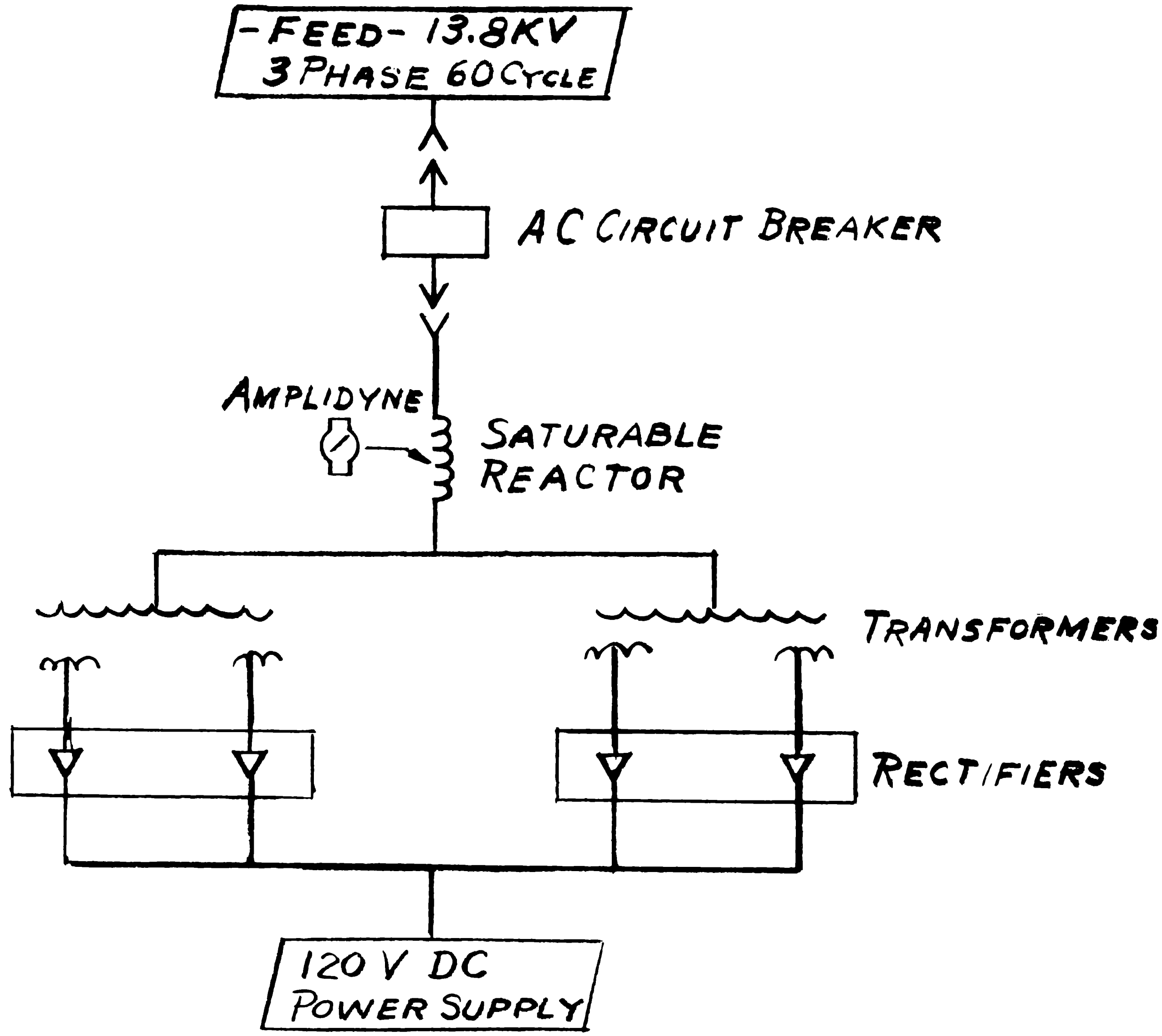


Figure 17

ONE LINE DIAGRAM
RECTIFIER POWER SUPPLY

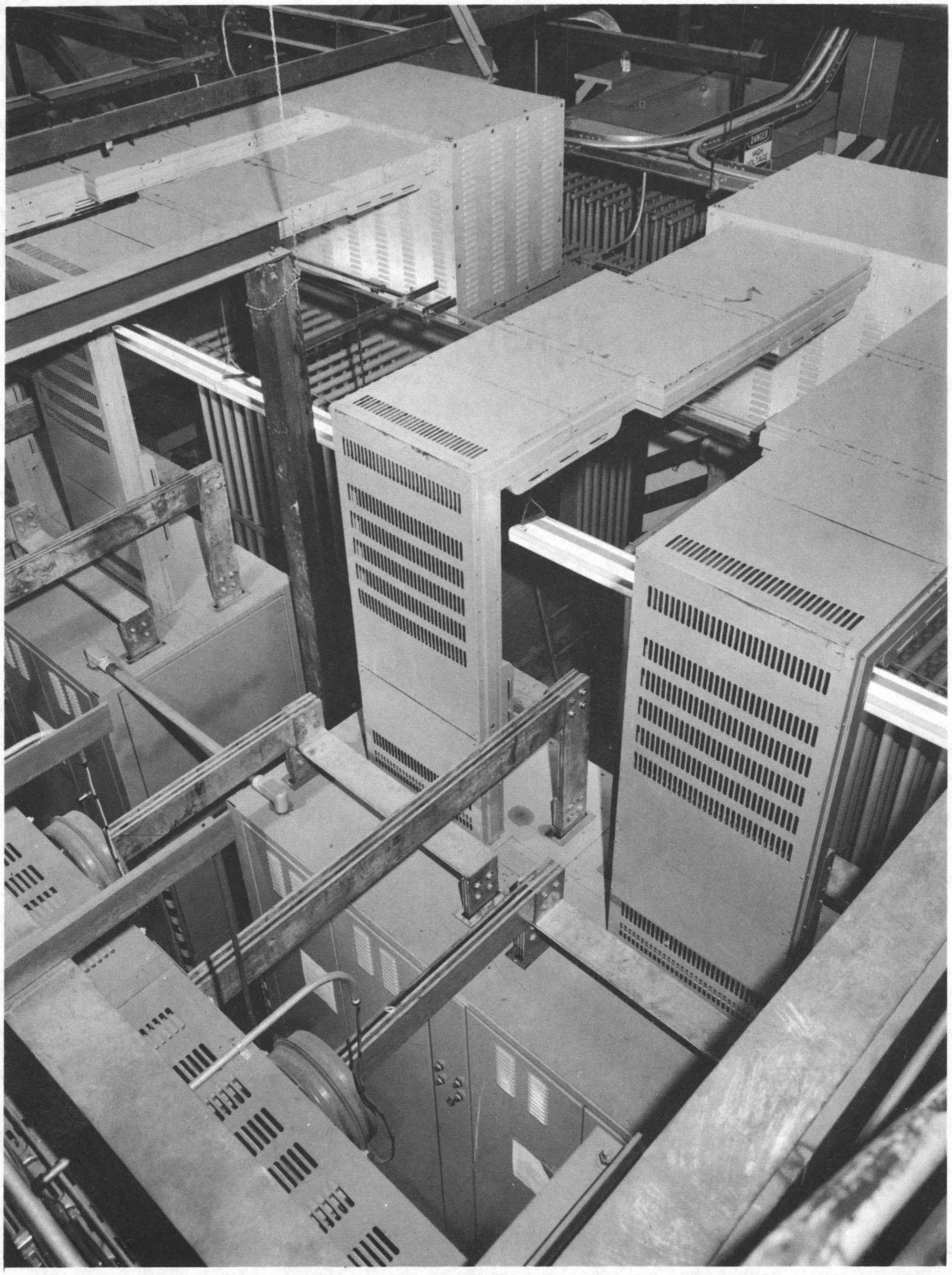


Figure 18

RECTIFIER SYSTEM

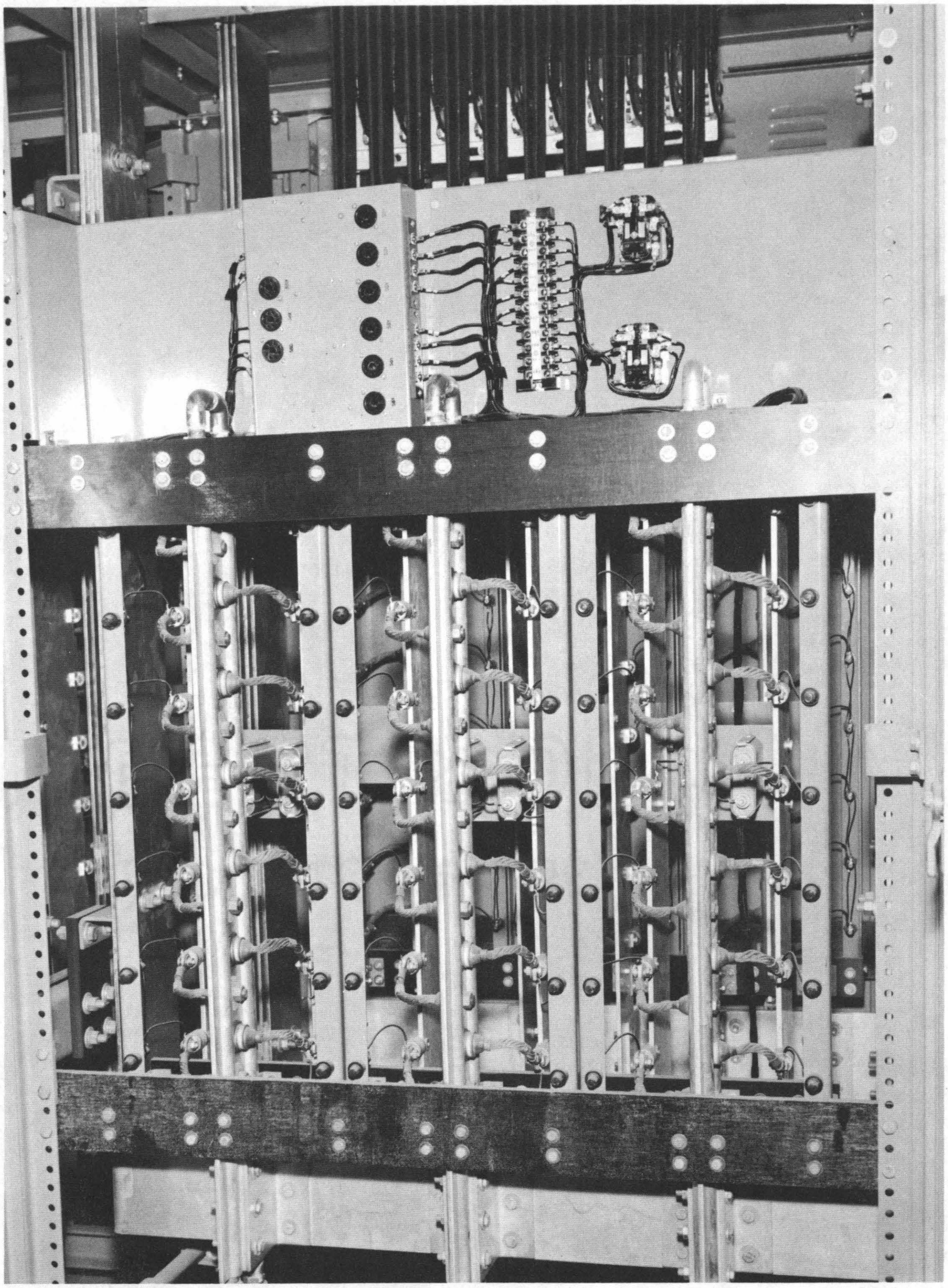


Figure 19

PARTIAL VIEW - SILICON RECTIFIER CABINET
SHOWING FUSE MONITOR PANEL, WATER-COOLED BUS, AND RECTIFIER ELEMENTS

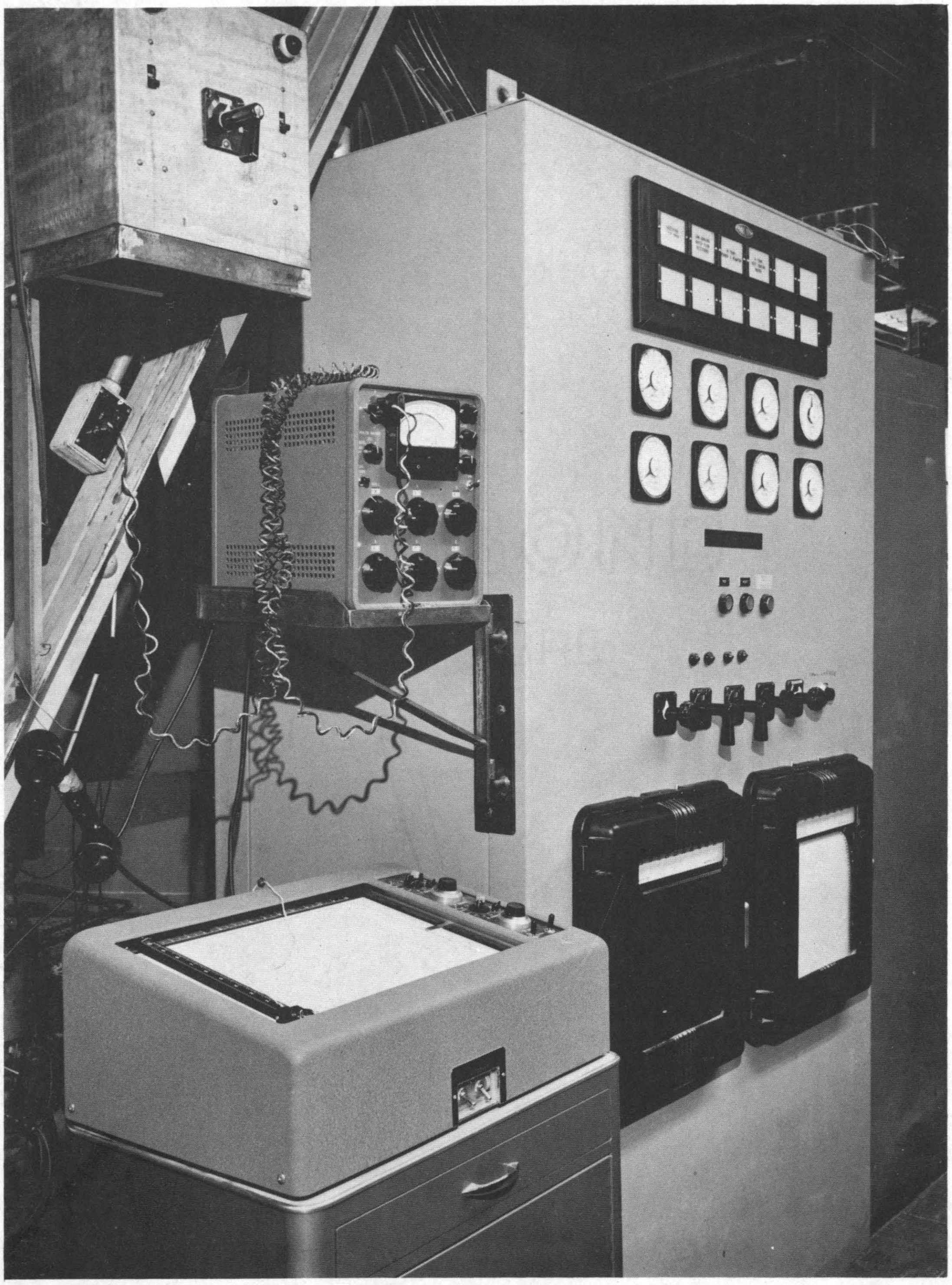


Figure 20

RECTIFIER CONTROL PANEL AND
PROGRAM INPUT UNIT