ANL-5761
Reactors-Power

1

ARGONNE NATIONAL LABORATORY
P. O. Box 299
Lemont, Illinois

PRELIMINARY DESIGN REQUIREMENTS ARGONNE BOILING REACTOR (ARBOR) FACILITY

Revision I - July 15, 1957

by

L. W. Fromm, Project Manager

and

S. A. Bernsen
C. F. Bullinger
J. F. Matousek

Operated by The University of Chicago
under
Contract W-31-109-eng-38

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

2

TABLE OF CONTENTS

3

TABLE OF CONTENTS

4

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of N. Balai, W. S. Flinn, A. H. Heineman, R. A. Merck, D. R. Patterson, R. L. Ramp, and H. R. Zeithan in compiling this prospectus.

5

PRELIMINARY DESIGN REQUIREMENTS

ARGONNE BOILING REACTOR (ARBOR) FACILITY

Revision I

I. INTRODUCTION

ARBOR (ARgonne BOiling Reactor) is a highly flexible boiling reactor experimental facility to be built by Argonne National Laboratory* at the AEC National Reactor Testing Station (NRTS) at Arco, Idaho. This facility will provide the necessary physical plant for experiments designed to yield data on performance and operation for various light and heavy water, natural and forced circulation boiling reactor concepts over a wide range of temperature, pressure, and flow conditions. The system will be capable of simulating the particular types and ranges of parameters, controls and transients inherent in the direct, indirect, and dual cycle types of boiling reactor power plants. The gross power removal capacity in both steam and water loops has been chosen high enough to allow adequate nuclear simulation with high power density cores and to permit reasonable extrapolation to the ultimate large central station power plant. The reactor pressure vessel has been chosen as large as feasible within the realm of present technology for the desired design pressures in order to provide some useful information pertinent to boiling heavy water systems.

Descriptions of the functional requirements of the facility, together with preliminary concepts of methods for meeting them, are presented in this prospectus. The descriptions, as well as all drawings, specifications, and component designs, are preliminary only. They are presented to outline the scope of the project and to indicate the work to be accomplished by the Architect-Engineer and by the Laboratory. Specific areas of design responsibility for both the Architect-Engineer and the Laboratory are defined to as great a degree as is possible at this time. The information given shall in no way be construed as to relieve the Architect-Engineer from any responsibility in his design areas, including final equipment and piping layout. It must be realized that a considerable cooperative effort on the part of both the Architect-Engineer and the Laboratory will be required before the final design can be achieved.

Economic considerations have brought about a revision of some of the original concepts concerning the ARBOR Facility. These primarily are the substitution of water-cooled heat exchangers and steam condensers for the air-cooled type and possible construction of the plant in steps.

The design of the plant will be based on construction of the facility as an integrated unit under one contract. The necessary supplemental drawings will also be prepared for building the plant in steps.

*Operated by The University of Chicago under contract with the United States Atomic Energy Commission.

II. DESCRIPTION OF FACILITY

A. General

ARBOR, by nature of its purpose, represents somewhat of a departure from standard reactor plant design. Its physical description and requirements must be prefaced by a properly oriented design philosophy.

Construction and successful operation of this plant represents only a part of the program; the major goals will be reached only after several years of operation. It is expected that ARBOR will be capable of providing the information from which optimum design conditions and control systems can be determined for all the various boiling reactor types. For this reason a wide range of parametric variation has been designed into the system. It has been nominally sized for a heat removal capability of 200 mw (682.6×10^6 Btu/hr) at 600 psi; however, this capability can be reached over wide ranges of distribution of the reactor heat to the vapor and water phases. For certain specific sets of operating conditions, heat removal rates in excess of 400 mw can be realized. Under these conditions the water treatment system must function well above the design rate, which it can do for limited periods of time. Other features in the over-all experimental flexibility include:

(1) controllable forced circulation up to 36,000 gpm (provision for internal natural circulation within the pressure vessel when desired);

(2) operating pressure up to and slightly above 2000 psi;

(3) variable and selective control of significant operating parameters such as: steam flow, coolant flow, pressure, coolant temperature, and feed-water flow.

In order to accomplish this experimental flexibility at minimum cost and time, certain specific features are incorporated in the design philosophy. These are:

1. The plant is to be located at the National Reactor Testing Station to simplify the design requirements associated with the containment and size limitations inherent in reactor plants built in more populated areas. This location will also permit more operational flexibility than would be possible elsewhere, by virtue of the reduced consequences of reactor incidents.

2. The system is designed for operation using either H_2O or D_2O as the primary working fluid. All surfaces in contact with the primary fluid will possess acceptable characteristics of corrosion resistance. The austenitic stainless steels, some of the Type 400 series of stainless steels, or corrosion-resistant claddings are acceptable.

3. Even though operation with D_2O is planned, it is not necessary to demand the high integrity of pump seals, valve seals, joints, etc. which would be required for central station application. This results from the fact that only tests of limited duration are planned; if a reasonable amount of D_2O leakage should occur, the temporary operating loss can be tolerated.

4. The use of both high-temperature steam condensers and water coolers for power removal allows for variation of the reactor inlet temperature by proportioning the fraction of heat removal accomplished in each unit. The use of high-temperature condensers permits maximum heat removal with minimum size and cost.

5. A great deal of flexibility and capacity is provided by forced circulation pumps. The gross pumping capacity is approximately 36,000 gpm with 120 psi net developed head.

6. The vessel is large enough (9 ft ID) to provide very good coverage of light water cores and to approach reasonable D_2O configurations.

7. Local shielding of reactor and primary system is adequate to permit limited access to auxiliary systems during operation. However, plant operation will be conducted from a shielded control building located adjacent to the facility and designed to protect operating personnel from the results of nuclear or non-nuclear incidents.

8. Full use of simplified construction techniques consistent with climatic and radiation conditions are employed.

The plant layout, shown in Fig. 1, consists of the main reactor and equipment building flanked by steam condensers on one side and water coolers and control building on the other.

B. Structural

1. Main Building

a. High Bay Area

The following is a description of the Main Building, which consists of the High Bay Area; the Auxiliary Equipment Area; the Active Storage Area; and the Primary System Water Service Area.

The High Bay Area, shown in Figs. 4, 5, 6, 7 and 8, contains the reactor pit, the active equipment pit and the fuel storage pit. Sufficient head room is provided above the pits to permit the necessary installation and removal of fuel and equipment.

The High Bay Area is 40 ft wide by 85 ft long and has reinforced concrete load-bearing walls extending up to approximately 56 ft above grade. The upper portion of this building is built around the support structure for the 40-ton overhead bridge crane which serves the entire area. Siding and roofing are of insulated, corrugated aluminum or are asbestos cement panels.

Because of the 32-ft elevation of the reactor operating floor, a 2000-lb capacity man lift will be required adjacent to the auxiliary equipment area.

The 40-ton main bridge crane has the prime function of handling the reactor vessel top closure head, pumps, and other equipment in the active equipment pit. Precision controls are provided for all crane motions. A special 1-ton capacity, 18-ft span bridge crane is attached to the truss section of the roof to handle control rods, control rod drives, and fuel elements in the vicinity of the reactor pit and storage pit.

The reactor is located in a pit near the center of the main building. The pit floor is located $3\frac{1}{2}$ ft below grade. The pit is approximately 11 ft ID and 35 ft high. Ordinary concrete walls, 8 ft thick, encircle the pit and form the primary reactor shield. The inner face is lined with a water-cooled, 4-in. thick lead and steel cylinder. Cooling coils are also located in the floor of the pit. These coils protect the concrete from excessive heating from radiation and thermal effects. Thermocouple wells are located in the shield walls to provide assurance of safe temperature in the concrete. The bottom of the pit is water-tight and is connected to the active equipment pit through a 6-in. cast iron drain loop seal to prevent gas leakage between the two pit areas.

All piping passes through the reactor pit walls in insulated water-cooled steel sleeves. Bellows seals designed to accommodate both horizontal and vertical thermal expansion are provided on the outside faces to prevent out-leakage of activated air (due to argon-41) within the pit. A negative pressure of 1/2 in. of water will be maintained in the reactor pit by means of a 500-cfm blower which draws air downward past the sides of the vessel and discharges to a 100-ft high stack.

Provision is made for lead wires from thermocouples on the surface of the reactor pressure vessel to be brought through the reactor pit wall. Semi-gas-tight connections are required.

Eight nuclear instrument tubes are provided. Four horizontal tangential tubes penetrate the reactor pit walls at the level of the reactor core, and four vertical tubes extend from the main floor to a level below the core center.

Large, removable, concrete-filled shielding segments are arranged around the reactor vessel top cover flange shield assembly to complete the upper biological shield and are supported by the operating floor. They can also be moved about the operating floor to provide radiation shielding during the fuel element and control rod-handling operations. The segments are matched male and female sections, which are water cooled and weigh 12 to 15 tons each. Cooling water lines for the top shielding segments and for the vessel cover shielding are brought to flush-mounted floor boxes, from which connections are made to the shield pieces by means of armored hoses equipped with "quick disconnect" couplings.

The concept of shielding in the High Bay Area permits limited access during operation to the floor area above the active equipment pit. The area between the active equipment pit and the reactor operating floor will be known as the primary system water service area. The reactor operating floor at elevation 32 ft is 2 ft thick reinforced concrete designed for a loading of 2000 lb per sq ft. The 5-ft diameter stepped plugs in this floor are in line with the holes in the active equipment pit ceiling to facilitate removal of equipment. The walls of the primary system water service area are of reinforced concrete thick enough to support the upper portion of the building or to provide shielding as required. This area contains the following items:

a. Reactor Water Purification System
b. Deaeration System
c. Reactor Water Makeup Pump and Storage Tanks
d. Shield Cooling System
e. Miscellaneous Auxiliaries.

The active equipment pit is a shielded enclosure which surrounds the reactor pit on three sides. It contains the following items:

a. Forced Circulation Pumps
b. Reactor Feed-Water Pumps
c. Sump Pumps.

The ceiling of the pit is ordinary concrete, 4 ft thick, to allow limited access to the primary system water service area above. The outer walls of the pump cell also form the building walls and extend up to the 56-ft level. The lower floor of this pit is 22 ft 9 in. below grade. The ceiling of the cell forms the primary system water service area floor. Stepped plugs, 5 ft in diameter, in the ceiling provide openings for access to pumps and other equipment. Means for cooling the active equipment pit are provided in order to maintain reasonable temperatures in the area during reactor operation. A sump and sump pumps are provided in the pit to permit removal and proper disposal of any water which may accumulate in the pit as a result of leaks or accidental discharges.

The fuel storage pit (Fig. 5) is a water-filled well located in the High Bay Area adjacent to the Primary System Water Service Area. The walls and floor of the pit are constructed of ordinary concrete, 4 ft thick, to provide radiation shielding for any personnel adjacent to the pit. The pit is of sufficient size (approximately 12 ft x 16 ft) to accommodate two or more irradiated cores simultaneously and still provide a reasonable amount of work area. The pit is deep enough (approximately 23 ft) to permit a depth of water over the fuel materials sufficient to maintain tolerable radiation levels at the surface.

b. Auxiliary Equipment Area

The Auxiliary Equipment Area (Figs. 5 and 6) is located adjacent to the Primary System Water Service Area. It is enclosed by a rigid frame-type structure, 40 ft wide by 125 ft long, having a minimum clearance height of 13 ft. A cargo door is provided at one end. The floor is at the same level as that of the Primary System Water Service Area. This area will house the following items of equipment:

1. 1500-gpm Water Treatment Unit with Chemical Storage Space
2. Chemical Shutdown System (partly in High Bay Area)
3. Core Spray System
4. Emergency Power Diesel Generator
5. 1000-gal Treated Water Storage Tank
6. 1000-gal Cooling Water System Receiver
7. 1000-gpm Cooling Water Circulating Pump
8. Miscellaneous Non-Radioactive Auxiliaries
9. Secondary Feed-water Pumps
10. Auxiliary Steam Generator.

c. Active Storage Area

The Active Storage Area (Fig. 5) is located at the end of the building opposite the fuel storage pit. This area is a ground level room which houses the discharge storage tanks, waste retention tanks, transfer pumps, and auxiliaries. Access to this room is gained through a door in the primary system water service area in the Main Building. It will be covered with earth to provide necessary shielding.

2. Control Building

The control building (Fig. 5) is located as a wing adjacent to the Auxiliary Equipment Area of the Main Building. It consists of a reinforced concrete arch, windowless building with basement. The first floor level is approximately 9 in. above grade line, and the walls are approximately 24 in. thick. An approximate floor space of 20 ft by 50 ft is required for the control panels, and additional space is provided for a combination conference room - lunch room and for personnel lockers and sanitary facilities. The building is so designed that operating personnel may remain safely within it for 48 hr in the event of an incident which prohibits access to the other plant areas or to the outside surroundings.

The basement floor level is about 12 ft below grade and is connected to the Primary System Water Service Area in the Main Building by a service tunnel. The instrumentation and control cable ducts are hung on the walls of the tunnel for convenient access. A blast-resistant door closes off the control building basement from this tunnel.

3. Water Cooler and Steam Condenser Areas

a. Heat Exchanger Building

The water-cooled heat exchangers will be housed in a concrete building with floor line approximately at grade level. Earth will be heaped over the concrete slab roof and sides for additional radiation shielding (see Fig. 5).

b. Steam Condenser Building

The water-cooled steam condensers and de-aerating hotwell will be housed in a concrete wall building with sheet metal roof. The floor line of this building will be located at grade level with equipment supported on structural stands at the required elevations. Required shielding will be provided with concrete and earth (see Fig. 6).

C. Reactor

The reactor consists primarily of the heat-producing core assembly enclosed in a pressure vessel (Fig. 3). This vessel is located in the reactor pit in the High Bay Area of the Main Building, as previously described. The vessel is supported on six structural steel legs, 8 ft 10 in. long. The load of the vessel is transmitted to the support legs through a short skirt and lugs welded to the bottom head. The total operating weight, including water and core, is approximately 250 tons; the estimated shipping weight of the bare vessel shell is 150* tons. The top cover flange, consisting of a fabricated ring and semihemispherical dome, is removable to allow access to the core for changing fuel arrangements. The control rod drives are attached to thimbles penetrating this head. A water-cooled laminated steel radiation shield is fabricated around these thimbles. The weight of the top head and shield plug is approximately 37 tons.

The vessel is insulated with 4-1/2 in. of Type 430 stainless steel wool completely enclosed with No. 16 gauge stainless steel sheet attached to support rings welded to the shell.

The reactor vessel has a design pressure of 2600 psi at a design temperature of 695F. The inside diameter is 9 ft - 0 in. and the overall length is 44 ft - 11½ in., cold. Thermal expansion will increase this length to 45 ft - 1 in. at an operating temperature of 636F.

The vessel contains internal thermal shielding to protect the shell against excessive heating by radiation from the core. The thermal shield consists of a 1-in. thick, 1% boron-stainless steel inner cylinder, backed up by 1½ -in. and 2-in. thick stainless steel cylinders. A thermal

*Based upon ANL preliminary design of reactor vessel.

shock shield of stainless steel sheet is mounted immediatedly above the thermal shield to protect the upper vessel shell against sudden quenching as a consequence of emergency cooling of the core by spraying.

The reactor vessel will also contain an emergency core spray ring, feed-water distribution nozzles, and a conical forced-circulation inlet plenum chamber, the latter located in the lower head.

The reactor core is supported by the lower head and is attached to the inlet plenum chamber. It consists of the core support grid, control rod guide and shroud structure, and the fuel assemblies. The vessel can accommodate cores of various types and sizes up to an effective diameter of $5\frac{1}{2}$ ft.

D. Primary System

1. General

The function of the primary system is to remove the heat generated in the reactor core by means of direct steam and condensation and forced-circulation water cooling. Both of these processes will be carried out at high temperature to minimize the surface required for heat transfer. The primary system is designed to permit operation of the reactor within a range of pressures, powers, general parameters, and general operating conditions in such a manner that a maximum amount of cycle, system, and general operating flexibility may be obtained. This cycle and system flexibility is brought about by making the steam condensate circuit and forced-circulation water-cooling circuit independent of each other in such a way that they may be operated separately or concurrently. All heat exchangers in the primary system are of the water-cooled type.

For steps I and II (see Section III for meanings of steps I, II, and III) operation the reactor steam output will be discharged to atmosphere through a stack. For step III this heat will be dissipated through secondary steam which will discharge to the same stack. For step II, some primary steam and some secondary steam will be discharged.

The primary system is presently envisioned as consisting of the following major components:

a. Water-Cooled Heat Exchangers
   (1) Water Coolers
   (2) Steam Condensers

b. Forced-Circulation Pumps

c. Reactor Feed-Water Pump or Pumps

d. De-aerating-Hotwell

e. Connecting Piping and Valves .

The primary system is shown schematically in Fig. 9. This flow diagram represents the present concept of the system and should not be considered as final. A tentative arrangement of the equipment can be seen in Figs. 4, 5, 6, 7, and 8. The total water capacity of the reactor and primary system is about 80 tons. All components of the primary system, including piping and valves, that are in contact with primary system fluid will be constructed of materials such as Types 304, 316, or 347 stainless steel.

2. Forced-Circulation Water Coolers

These heat exchangers are of the conventional, evaporative condenser type with fixed tube sheets and bowed tubes. Secondary coolant will be allowed to boil on the shell side, which will be designed for operation at 600 psi.

The temperature difference between the primary fluid in the tube and the secondary fluid on the shell side will be maintained at less than 150F by controlling the pressure on the shell side. The units are basically designed in accordance with the ASME boiler code for a design pressure of 2500 psia and a design temperature of 690F on the tube or primary side; 800 psia design pressure and 550F design temperature on the shell or secondary side.

The coolers receive their flow from the forced-circulation pumps and remove heat from the water in specific amounts dictated by requirements of the particular simulated system being run. Heat removal is adjusted by flow-control valve operation and pressure regulation of the shell side coolant. The subcooled and metered water flow is returned to the reactor vessel inlet and through the reactor core. The reactor core discharges saturated water which mixes with the feed water in the downcomer section of the pressure vessel. This slightly subcooled mixture then goes to the forced-circulation pump inlet.

3. Steam Condensers

These heat exchangers are similar in design to the forced-circulation water coolers, except for head load and fluid flow specifications.

Saturated steam from the reactor vessel, which is metered by orifices (Fig. 9), passes through throttling valves and into the main steam condensers. In order to accommodate the wide ranges of pressures and flows, a parallel orificing and valving arrangement is contemplated. A significant feature of the steam circuit is that it is basically a two-pressure system. In order to minimize the influence of possible variations of condenser pressure upon the reactor, the steam is throttled so that the downstream pressure is approximately 50% of upstream pressure. Heat dissipation control of the condensers is primarily the same as that described for the forced-circulation water coolers. A "blind dutchman" by-pass across the throttling valves is provided if operation of the condenser at full system pressure is desired. The valved by-pass line going to the de-aerating-hotwell is used to supply the necessary steam for hotwell pressure control.

Condensate from the condensers goes to the de-aerating-hotwell, from which it is pumped back into the reactor vessel and mixed with the saturated water in the core discharge downcomer. This condensate is the source of subcooling for the forced circulation pumps.

4. Forced-Circulation Pumps

These pumps provide the driving head for forced-circulation operation. Both conventional shaft-sealed and totally enclosed pumps will be considered. In any case, electric motor drives will be used. Final selection will be based upon the leakage requirements of the system.

A final decision as to the number of pumps used has not as yet been made. This decision will depend upon the interrelationship of cost, layout, and flexibility of operation and control.

Figures 4, 7, and 8 show a tentative arrangement with the pumping duty equally divided among four pumps.

5. Reactor Feed-Water Pumps

The feed-water pump is used to return the condensate mixture from the de-aerating-hotwell tank to the reactor. As in the case of the forced-circulation pumps, conventional-type shaft sealing may be considered. An electric motor drive is to be used for this pumping also. Figures 4, 7, and 8 show the location of this pump. Two pumps may be used if the desired flexibility cannot be attained with one unit.

6. De-aerating-Hotwell

The de-aerating-hotwell receives the condensate discharge of the primary steam condensers and is located as shown in Figs. 6 and 8. The hotwell is heated and the temperature and pressure controlled by the condenser by-pass which discharges to the hotwell through a distributing header within the tank. The water level in the tank is maintained by the primary water make-up system which discharges to the hotwell.

15

A continuous bleed of about 60 lb/min is maintained from the steam dome of the de-aerating-hotwell to remove dissolved gases and dissociated hydrogen and oxygen from the primary system. The de-aerating-hotwell should be locatedas great a distance vertically from the reactor feed-water pump inlet as practical to make available a sufficient net positive suction head and to insure that the reactor core will always be under water. The de-aerating-hotwell is also to be kept sufficiently lower than the steam condensers to permit gravity drainage of the condensers into the tank.

7. <u>Piping</u>

Figures 4, 5, 6, 7 and 8 show a tentative layout of the piping system. All joints shall be welded except in the case of such items as orifices and other replaceable components.

The piping systems shall be so arranged in the plant layout so that each individual system may be isolated for hydrostatic testing, operational checkout, etc., upon completion of construction.

A serious effort shall be made to determine the feasibility of using centrifugally cast pipe in the fabrication of the primary system. Use of "pushouts" in large diameter pipes to eliminate tees; "three diameter" pipe bends as a substitute for forged elbows; and other schemes to reduce piping costs, are to be studied.

8. <u>Valves</u>

Figures 4, 5, 6, 7 and 8 show a tentative layout of the piping system, with size, type, and location of valves. It is desirable to have the piping arranged so that valve sizes are kept as small as feasible for economy and maximum piping flexibility.

The gate valves shown are for shut-off purposes. The globe-type valves are for throttling and general control purposes. Small by-pass valves are inserted for purposes of maintaining temperature of stand-by equipment.

The forced-circulation system by-pass valves are to be butterfly-type for reasons of low pressure drop and economy.

All high-pressure valves have welded ends.

9. <u>Steam Orifice</u>

Steam flow is measured by multi-orificing in parallel, as shown in Fig. 9, so that the entire range of steam flows and pressures can be covered.

A combination steam separator shut-down cooler of the conventional centrifugal-gravity type or of the fine mesh demister type is used in each steam line between the reactor and orifices to provide dry steam to the orifice. Care must be taken on the orifice or nozzle design so that moisture does not cause instability and/or a faulty signal.

10. Water Flow Measurements

The total forced-circulation water flow is measured by means of a venturi section located in the main reactor inlet line. Additional venturis are placed in the by-pass circuit and water cooler outlet lines to measure these flows.

E. Secondary Coolant System

General

The use of a pressurized shell, water-cooled heat exchanger and condenser system for disposal of reactor heat entails the incorporation of a secondary forced-feed cooling water system. Demineralized water at 70F from a 1500-gpm water treating system will be supplied to the shell side of the primary system water coolers and steam condensers by standard boiler feed pumps in response to a standard liquid level controller. The coolant will be allowed to boil for maximum heat absorption. Steam pressure will be maintained by temperature-controlled, back pressure regulators which discharge directly to the primary system steam disposal stack.

1. Pumps

A standard type carbon steel boiler feed pump capable of delivering approximately 800 gpm at 1600-ft TDH will be used. One pump is required for the water coolers and one pump for the steam condensers. These pumps are located in the Auxiliary Equipment Area.

2. Piping

A standard carbon steel piping system is satisfactory for all of the secondary system.

F. Auxiliary Systems

General

In addition to the primary system, certain auxiliary systems are needed for plant operation. These are the following:

1. Water supply
2. Primary water make-up
3. Reactor water clean-up
4. De-aeration
5. Emergency shut-down cooling
    a. Evaporative condenser
    b. Core spray system
6. Chemical shut-down
7. Pressure relief
8. Secondary cooling water treatment system
9. Shield cooling
10. Fuel storage pit cooling and clean-up
11. General purpose cooling water
12. Waste retention and discharge storage
13. Hydrostatic testing
14. Sampling

These systems are shown in Figs. 10, 11 and 12.

1. <u>Water Supply System</u>

The water supply system is divided into plant supply and domestic supply. Raw water is obtained from two deep well pumps located in the Auxiliary Equipment Area and is stored in a 100,000-gal tank, elevated 100 ft above grade and located adjacent to the Auxiliary Equipment Area, and in a 750-gal domestic supply tank located in the control building basement.

The well pumps can be actuated either by a level-sensitive switch system in the high tank or by a pressure-sensitive switch system in the domestic supply tank. The switch systems also actuate motor-operated stop valves in their respective supply lines to direct the pumped water to the desired storage facility.

Water from the inlet line to the high tank feeds through the water treatment system either to the heat exchanger secondary coolant feed-water pumps or to a 1000-gal capacity treated water storage tank for general plant use. The level in this tank is maintained by a pressure-actuated switch and air bleeder system of the conventional type, except that the switch actuates a motor-operated valve in the supply line from the water treatment system. Any possibility of back flow of water from the plant system to the domestic system is prevented by a series of check valves. These items are located in the Auxiliary Equipment Area.

The pressure-actuated switch and air bleeder system in the domestic supply tank maintain pressure in the tank between 60 and 80 psig. This water is distributed in the control building to sanitary facilities to serve the personal needs of

15 people and to supply an emergency shower located at the access door between the Primary System Water Service Area and the Auxiliary Equipment Area. The location of the domestic supply tank in the basement of the control building assures a supply of water for personnel detained within that building for any extended period of time because of a contaminating incident outside.

2. Primary Water Make-up System

The primary water make-up system is designed to replace the water removed either intentionally or accidentally from the primary system. It consists of a demineralizer, a primary water make-up tank and primary system make-up pumps. The first item will be located in the Auxiliary Equipment Area; the latter two will be located in the Primary System Water Service Area. The demineralizer is supplied from the treated water storage tank and discharges to the primary water make-up tank. This tank also acts as collector for the following:

a. After-condenser condensate
b. Recombiner condensate
c. Reactor vessel cover gasket leakage
d. Pump seal leakage
e. Control rod drive seal leakage.

3. Reactor Water Clean-up System

In order to maintain the high water purity required to minimize system contamination from radioactive corrosion products and to remove boric acid and other intentionally introduced additives, a primary water clean-up system is provided.

The primary water clean-up system consists of a regenerative heat exchanger, cooler, booster pumps, filter, and ion exchanger. These items are located in the Primary System Water Service Area. Approximately 25 gpm of circulating water is drawn off for continuous filtering and de-ionizing to maintain purity of the reactor water. A sufficient quantity of water to maintain the required temperature of the control rod thimbles is taken from this loop.

4. De-aeration System

The dissolved gases in the primary water make-up, as well as gases resulting from water dissociation during reactor operation, are removed from the primary system by a continuous flow of vapor and gases from top of the de-aerating-hotwell. The vapor and dissociation products are recovered by the de-aeration system, consisting of the after-condenser, the recombiner, and the dryer. These components are located in the steam condenser area.

The mixture of non-condensable gases and water vapor leaving the hotwell is throttled to the water-cooled after-condenser, which removes the major portion of the water vapor. The condensate returns to the primary water make-up tank. The remaining gases pass either to the stack during light water operation or to the recombiner during heavy water operation. The recombiner catalytically recombines the dissociated hydrogen and oxygen. This recombined water, probably in the vapor state, together with the other gases, passes through the dryer in which the remaining condensables are recovered and returned to the primary water make-up tank. Remaining gases then pass to the stack.

5. Emergency Shut-Down Cooling System

Since some heat generation from the core continues for a period of time after reactor shut-down, an emergency shut-down cooling system is utilized to prevent core or vessel damage resulting from accidental loss of either primary system fluid or primary system heat exchanger capacity.

Overheating and possible core melting because of the accidental loss of primary system fluid is prevented by the low-pressure core spray system. This system consists of the low-pressure boric acid tank located on the reactor operating floor upper level and the core spray ring located in the upper portion of the reactor vessel. Upon a suitable emergency signal boric acid solution is injected into the vessel through the spray ring and cools the full core area. Boric acid is added to the water as an additional safety precaution to maintain reactor subcriticality in the event of control rod or control system malfunction.

Over-pressurization, resulting in vessel or primary system damage, can occur if primary system heat exchanger capacity is accidentally lost. To prevent this damage, evaporative condensers, consisting of emergency cooling coils, are located in the steam dryers. These coils are fed with water from the high tank, and the steam generated by decay heat is condensed by the natural circulation of high tank water. The total condenser capacity is 24 mw.

6. Chemical Shut-Down System

Normal reactor shut-down is accomplished by means of neutron-absorbing control rods which can be rapidly injected into the core. In the event of malfunction of these rods, a chemical shut-down system is provided. This system consists of two high-pressure boric acid storage tanks located on the reactor operating floor and an air compressor located in the Auxiliary Equipment Area. These tanks contain a quantity of concentrated boric acid solution held under 3000 psi air pressure by means of the compressor. The system is properly valved so that the material is always available for injection, but cannot inadvertently leak into the reactor when not required. Solenoid valves are operated to inject the solution upon suitable signal.

7. Pressure-Relief System

In the event of malfunction of the normal heat removal mechanisms and failure of reactor shut-down mechanism and/or emergency shut-down coolers, a system of pressure relief is provided to protect the primary system. This system consists of two pilot-operated back pressure regulator valves and four relief valves, located on a manifold between the two reactor steam outlet lines.

The pilot-operated regulator valves are automatic, featuring adjustable set point and proportional band which may be adjusted from the control room. These valves will be set to operate, first, at 10 to 20% above the current reactor operating pressure. The relief valves are preset and only serve to protect the reactor system from exceeding the design pressure. The settings of the four valves are staggered at 50 psi intervals, with the first valve operating at 2400 psi and the fourth at 2550 psi.

During light water operation these valves will discharge to the stack. During heavy water operation an attempt will be made to prevent excessive loss of heavy water from the relief system. In this case the relief valves will discharge to the discharge-storage tanks where condensation and fluid recovery may occur in any heavy water which may be stored in these tanks. If necessary, an additional heat sink will be provided.

8. Shield Cooling System

Heat is generated in the floors, sidewalls and the shield walls of the top flange cover of the reactor pit as a consequence of the shielding process. These components are also heated by the hot reactor vessel. The removal of this combined heat is accomplished by circulating cooling water through coils imbedded in the aforementioned areas.

The system is composed of a heat exchanger, filter bank, two circulating pumps (one operating and one stand-by), and a surge drum which acts as a system supply. This equipment is located in the Primary System Water Service Area.

The floor coils are divided into six operating and six spare loops fed through a header and valve system and monitored for temperature, flow, and radioactivity. The sidewall coils are buried in the lead shielding cylinder surrounding the reactor vessel. There are 24 operating and 24 spare alternate coils fed through a header and valve system, also monitored. The steel and water shield surrounding the control rod drive thimbles on the top cover flange is fed through lines attached by quick disconnects located in floor boxes. The inner faces of the concrete shield segments surrounding this shield are cooled by internal coils fed in a similar manner.

9. Fuel Storage Pit Clean-Up and Cooling System

The shut-down heat production of stored irradiated fuel requires that the shielding water of the storage pit be cooled. Further, in order to prevent high activity in the water, it must be maintained at high purity. This is accomplished by the fuel storage pit clean-up and cooling system.

The storage pit is filled from the reactor water make-up ion exchanger. The water is drawn from the pit by a circulating pump and discharged through a filter, a heat exchanger, and a 15-gpm ion exchanger back into the pit. The overflow and drain lines go to the waste retention tanks. All equipment in this system is located in the Primary System Water Service Area.

10. General Purpose Cooling Water System

This system provides cooling water to the following components and systems:

a. Forced-circulation pumps
b. Reactor feed-water pumps
c. Reactor shield cooling system
d. Reactor water clean-up system
e. After-condenser
f. Storage pit clean-up system
g. Air compressor cooler.

It is composed of a receiving tank, an air-cooled heat exchanger, a circulating pump and a cooling tower for summer operation or as needed to maintain the desired heat removal from the system. The tank and pump are located in the Auxiliary Equipment Area; the heat exchanger and tower are located outside and adjacent to the building.

11. Waste Retention and Discharge Storage System

This system is used for the collection and/or storage of all reactor system fluids or contaminated liquids. It is located at ground level in the active storage area with access through the Primary System Water Service Area. Three coated steel discharge-storage tanks, three steel waste retention tanks, a waste retention tank transfer and drain pump and discharge-storage tank pump make up the system. All sump pumps and sources of contaminated waste will be connected to the retention tanks. The primary system will normally be connected to the discharge-storage tanks.

12. Hydrostatic Test System

Because a hydrostatic test of the reactor vessel top closure will be required each time it is assembled on the vessel, a permanent hydraulic test system is incorporated by running a line from the reactor make-up pumps to the primary system drain header, through which water may be delivered to any part of the primary system.

13. Sampling System

The sampling lines, shown at various points on the flow charts, are to be located as close to the source as possible to achieve minimum holdup.

G. Instrumentation and Control

1. General

The experimental nature of the ARBOR facility requires that extraordinary emphasis be placed on the instrumentation and control of the system. In addition to wide coverage of primary system steam flow, forced-circulation flow, temperatures and pressures, provision is made for special devices within the reactor to measure local flows and temperatures at various points in the core. Most of the measurements and control of both primary and auxiliary systems will be accomplished remotely from the control room. The following basic control systems are involved in the primary system operation:

a. Reactor (nuclear)
b. Reactor water level and feed-water flow
c. Water coolers
d. Condensers and hotwell
e. Turbine and bypass simulator .

In addition, several emergency and shut-down systems are provided for safety during abnormal operation. These are:

a. Reactor scram

    (1) Control rods
    (2) Chemical shut-down

b. Emergency shut-down cooling

    (1) Shut-down coolers
    (2) Core spray

c. Pressure relief.

These systems will be energized automatically and/or manually upon receipt of certain alarm signals indicating abnormal operating conditions.

There are a large number of control systems involved in the many plant auxiliaries; however, these components are of a standard nature. They concern such operations as water-level detection in storage tanks, and general purpose cooling water flow, temperature measurement, and regulation.

The most significant ARBOR control systems are described in the following paragraphs.

2. Reactor Control

The primary control of the reactor is accomplished by means of neutron-absorbing control rods, driven into or out of the reactor core by means of drives located at the top of the reactor vessel. The rod drives are operated from the control console. Rod controls are interlocked in a way that only the central control rod and one other rod may be removed from the core simultaneously. The speed of rod removal is limited in order to prevent too rapid an increase in reactor power. Provision is made to effect a rapid injection of all control rods into the reactor core (control rod scram), an action accomplished either manually or automatically upon receipt of certain abnormal system indications. During normal operation the control rods are operated either manually or automatically in response to various signals derived from the parameter control jack board (see Section G-7).

3. Reactor Water-Level Control

The water level in the reactor pressure vessel is controlled by a conventional three-element boiler feed-water control circuit.

The differential pressure water-level recorder produces a signal proportional to the error in water level (difference between the manually adjusted set point and the measured level). This error signal is added to another error signal proportional to the difference between total steam flow and feed-water flow; this combined error signal is used to adjust the position of the feed-water control valve.

The combined error signal may be expressed as:

$$e = K_1 (L_0 - L) + K_2 (S - W) \quad ,$$

where

K_1, K_2 = proportionality constants
L_0 = water level set point (manually adjusted)
L = measured water level
S = measured total steam flow
W = measured feed-water flow .

4. Water-Cooler Control

The objective of the water-cooler control system is to provide smooth continuous control of (a) the temperature difference between the reactor steam and the water entering the reactor from the forced circulation loop, and, independently, (b) the total flow of water in the forced circulation loop. A possible method of accomplishing this is described in order to provide some indication of system complexity. The Architect-Engineer is expected to review this and other possible methods in detail, consulting instrument manufacturers where necessary, and to propose in detail the final system to be employed.

Any required preset temperature differential (up to 150F) across the heat exchanger tube wall must be maintained, regardless of rate of flow through the units. This differential is maintained by a variable range-ratio controller which controls the back-pressure regulator in the secondary coolant steam-release outlet line. Pressure-sensing connections are installed in the inlet line of each water cooler and in the secondary coolant outlet ahead of the back-pressure regulator valve. In addition, the forced-circulation system is equipped with a venturi tube to sense total forced-circulation flow, several temperature-sensing elements to measure final mixed reactor inlet water temperature, and a number of by-pass lines containing flow venturis and flow-control valves.

All the water-cooler units are connected in parallel for concurrent operation. Each of the water coolers is equipped with temperature-sensing elements in the inlet and outlet lines connected so as to measure differential temperature across the unit, and a flow-measuring venturi and flow-control valve in the effluent line. A small valve in parallel with the flow-control valve permits a small flow of system water through the cooler to maintain temperature while the cooler is in stand-by condition.

Readings from flow venturis WF_1 in the individual cooler effluent lines may be read on a multi-selector flow indicator in the control room as a check on the position adjustment of the flow-control valves.

The total forced-circulation waterflow is controlled to the desired value by a series of water by-pass flow-control valves (W6), adjusted by a flow controller which reads total water flow, as sensed by the total forced-circulation venturi tube WF_4, and compares the readings with a set point. This set point, in turn, may be adjusted by other system variables (see Section G-7). The method for adjusting the by-pass valves (W6) must provide a flow control as linear as possible and must be such as to avoid surges as valves are brought on and off the line. Flow venturis WF_3 measure the flow in the individual by-pass lines.

Provision is made so that any or all of the cooler controls and valves may be operated manually whenever desired.

5. Condenser and Hotwell Control

The objective of the condenser control system is to provide automatic control of rate of steam condensation to match steam generation rate such that all steam entering the condensers is condensed, but that the condensate entering the hotwell is never subcooled by more than a given adjustable amount in the vicinity of 10F. Hotwell controls have as their objective the maintenance of desired hotwell saturation temperature and pressure, water level, and de-aeration bleed flow. Suggested methods of accomplishing these objectives are described in order to provide some indication of the complexity of the system. The Architect-Engineer is expected to review these and other possible methods in detail, consulting instrument manufacturers where necessary, and to propose in detail the final system to be employed.

Each of the steam condensers is equipped with temperature-sensing elements in the inlet and outlet lines, connected so as to measure differential temperature across the unit. It may be necessary to use thermopiles for these elements, since differential temperatures to be measured are 10F or less. Each condenser is also equipped with a motor-operated gate valve in the inlet and outlet line.

All steam condensers are connected in parallel for concurrent operation with the water coolers. Temperature, pressure, and water level will be controlled in a manner similar to that for the water coolers.

For proper simulation of power plant conditions, the hotwell tank must be maintained at saturated conditions. This is accomplished by by-passing a small amount of steam around the condensers through a small line directly into the hotwell. Flow through this line is controlled by a flow control valve, S9. The position of this valve is adjusted by an error signal, produced by a recorder-controller measuring hotwell pressure, which compares this pressure with a manually adjusted set point.

A constant bleed from the vapor space in the hotwell tank is maintained in order to assure removal of non-condensable gases. Bleed flow is controlled by means of a flow-orifice and flow-control valve in the bleed line.

Hotwell water level is controlled by means of a differential pressure liquid-level recorder-controller featuring adjustable set point and fixed proportional band. The controller adjusts the position of a flow-control valve in the line from the primary water make-up system. A set of adjustable high and low contacts on this recorder serve to actuate annunciators in the event of system malfunction.

6. Turbine and By-Pass Simulator Flow Control

The turbine-simulator and by-pass simulator flow-control valves are used to control reactor pressure or to simulate the turbine and by-pass control on a direct-cycle boiling reactor system. The positions of the four turbine-simulator flow-control valves are adjusted in response to constant or variable signals from the Jack Board (see Section G-7) in such a way that smooth continuous control of flow is obtained over the entire control range.

7. Parameter Control Jack Board

Although ARBOR is primarily an experimental facility, extensive use of automatic system control is necessary. Many of the primary variables will be controlled by one or more signals. Also, it will be necessary in some experiments to change the control point of these variables according to some simple linear or oscillatory function. In order to accomplish this, a Jack Board is provided. The signals from the required temperature, pressure, and flow measurements pass through suitable amplifiers and then to the Jack Board. At least three outlets for each signal are provided. The necessary recording controllers have their input and set point terminals at the board.

The following signals will require terminals at the Jack Board:

a. Reactor pressure
b. Total steam flow
c. Turbine-simulator steam flow
d. Turbine-simulator by-pass steam flow
e. Feed-water flow rate
f. Total circulating water flow rate
g. Circulating water reactor inlet subcooling
h. Central control rod position
i. Reactor neutron flux.

The Jack Board will also be equipped to send information to the controllers associated with the operation of the following:

a. Control rods
b. Turbine simulator and steam by-pass throttle valves
c. Water coolers
d. Forced-circulation flow and temperature-control systems.

27

Additionally, a number of mechanical or electronic circuits will be provided at the Jack Board to perform operations such as addition, subtraction, multiplication and division of the various input signals with each other or with selected constants. A function generator will also be located at the Jack Board to provide desired signals which vary with time or with one of the other input signals in order to impose desired variable control of selected parameters.

The Jack Board will permit experimentation with a large number of boiling reactor control systems and a large number of boiling reactor operating cycles by merely connecting the proper signals to the desired controllers and manually adjusting gain and set points.

III. DESIGN REQUIREMENTS

In the preceding description of the facility the discussion has been presented on the basis that the plant would be constructed in its entirety. However, because of the problems of fund availability it will probably be necessary to construct the plant in several steps, each of which would constitute an operating unit capable of fulfilling a portion of the flexibility requirements for the entire plant. The steps selected are as follows:

Step I - Direct-Cycle Forced and Natural Circulation

In this step the water coolers, steam condensers, secondary coolant equipment, steam separators, the hotwell and its auxiliaries, the reactor feed-water pump as described, the primary water make-up system, and the reactor water cleanup system are omitted. No heat removal from forced circulation water is possible, and the steam generated in the reactor is discharged directly to the stack through back pressure-regulating valves. The 1500-gpm water treatment plant and a less expensive feed-water pump are used to supply make-up water to the reactor.

Step II - Dual Cycle

The water coolers and necessary auxiliaries are added to permit heat removal from the forced circulation water.

Step III - Indirect Cycle and Heavy Water Operation

The steam condensers, hotwell and associated systems, reactor water cleanup and primary water make-up systems are added to convert the plant to its complete form as described.

The discussion of design requirements in this section will take into account the effort required for Steps I, II, and III. A more detailed statement as to the Architect-Engineer's duties regarding stepwise construction will be found in Section IV, Scope of Work and Division of Effort.

A. General

The Architect-Engineer shall prepare complete architectural and design drawings and specifications for the Main Building, control room, and Auxiliary Equipment Area buildings, condenser and water cooler areas, electrical substation, and appurtenant structures. This set of drawings will represent the plant as completed at the end of Step III. Additional drawings will be prepared to show alterations and deviations to facilitate construction of Steps I, II, and III.

The buildings must be of fireproof construction and designed in accordance with the provisions of the AEC Uniform Design Criteria and the Idaho Operations Office Engineering Standards. A minimum of architectural embellishment should be employed in the interest of economy.

B. Site Development

ARBOR will be constructed at the National Reactor Testing Station near Arco, Idaho, in a new area, designated Area 16. A map showing the exact location of the installation will be prepared by the Architect-Engineer after the final decision is made by the Laboratory and the AEC Idaho Operations Office (AEC-IDO).

Detailed contour maps of the area and information on soil and sub-soil conditions, weather conditions, etc., are available for study at the AEC Idaho Operations Office (AEC-IDO). A brief geological and meteorological description of the NRTS site is given in Appendix A. It will be the responsibility of the Architect-Engineer to secure exact data on soil conditions at the site by means of core drillings (in collaboration with AEC-IDO) if necessary, or other means, and to establish allowable bearing values for the soils encountered. The Architect-Engineer shall also prepare drawings and specifications for final grading, roads and walks, fences, security, buildings, outside lighting, and landscaping. All roads and walks may be gravel or equivalent construction.

The Architect-Engineer will prepare drawings and specifications for all site services, as follows:

1. Electric service will require the construction of a substation at the site and extension of the 13.8-kv service from a point designated by ANL to the substation. Transformers, switchgear and all necessary equipment are to be included to provide electric service to the facility for all electrical equipment and lighting.

2. Water supply will be provided by sinking 2 deep wells (approximately 600 ft) near the elevated storage tank.

3. All necessary drains, sewers, drainage shall be provided.

4. Fire protection services for mobile fire apparatus shall be provided in accordance with AEC-IDO requirements.

C. Structural

1. Main Building

a. High Bay Area

This section of the building is to be 40 ft wide by approximately 85 ft long. It will extend from 22 ft 9 in. below grade to 72 ft above grade (see Fig. 6).

(1) Free-Floor Loadings

The reactor operating floor, Primary System Water Service Area floor, and basement floor are to have a permissible uniform loading of 2000 lb/sq ft. The upper floors will have stepped access openings with concrete plugs to provide crane access to the forced-circulation pumps.

(2) Walls and Foundations

The reactor and shield will weigh approximately 1500 tons and occupy a space approximately 28 ft in diameter and 34 ft high. This structure will be attached to the building wall and supported on concrete columns, and will extend from grade to 32 ft above grade level as shown in Fig. 5. This shield must be constructed in two stages to facilitate plant construction in advance of delivery of the pressure vessel. A concrete cylinder, 26 ft ID by 28 ft OD, extending upward from the Primary Water Service Area floor to the reactor operating floor will permit construction and erection of the remaining portions of the building, equipment, and piping, independent of vessel delivery date. The cylinder forms will be fabricated from carbon steel plate with sleeves and inserts for penetration of the pipes, etc., required for attachment to the pressure vessel, and will remain permanently in place.

After the pressure vessel, piping, insulation, etc., are placed, the remainder of the shield interior will be installed. Beginning with the 1/2-in. thick by 11-ft ID carbon steel plate inner form, the necessary pipe sleeves will be placed over the pipes, with water jackets for cooling the concrete. The sleeves will be large enough to clear pipe insulation and permit expansion during operation. Bellows will connect the pipes to the sleeves at the outer face to seal off the reactor pit area.

Cooling coils as described in the auxiliary systems section (III-D-4, Item 19) will be attached to the outer periphery of the 11-ft diameter inner form. A 3-in. thick lead annulus will be built up opposite the straight portion of the reactor vessel around the cooling coils. This portion will be fabricated by pouring lead in successive layers within steel bands about 12 in. high by 1/4 in. thick.

The horizontal and vertical instrument hole thimbles are to be provided with facilities for draining, flushing with inert gas, or ventilating with air. Horizontal holes shall be pitched to drain back to the reactor face.

The concrete for the shield will be poured after all piping, sleeves, coils, etc., have been hydrostatically tested.

The floor between the Active Equipment Area and the Primary System Water Service Area shall be 4 ft thick for shielding pumps. The walls of the building from the basement up to the reactor operating floor will be 18 in. thick adjacent to the condenser area, 12 in. thick next to the active storage area, and 3 ft thick adjacent to the water cooler area. The 3-ft wall next to the water cooler area will extend to a height of 15 ft above grade level, after which it will be decreased to 12-in. thickness. The reactor operating floor shall be of sufficient thickness to accommodate structural requirements, but shall not be less than 2 ft.

(3) Access Openings

A swinging or sliding steel door providing a 6 by 7-ft opening between the Primary Water Service Area and the Auxiliary Equipment Area is required. A 4 by 7-ft blast-resistant, self-closing door between the lower level of the active equipment pit and the tunnel leading to the Control Building basement is also required. A 4 ft wide by 7 ft high opening between the Primary Water Service Area and Active Storage Area is required. An access ladder with a counterweighted steel trap door between the reactor operating floor at 32 ft elevation and the Primary System Water Service Area floor is required. This ladder shall be located on the Active Storage Area side of the reactor shield.

(4) Support for Handling Equipment

Rails for a 40-ton overhead bridge crane of approximately 37-ft span shall be provided and shall be designed to be supported on the concrete building walls. Rails for a one-ton overhead bridge crane of approximately 18-ft span shall be provided in the truss section of the roof.

(5) Elevator

A general purpose-type freight and passenger elevator shall be installed in the High Bay Area near the stairwell and adjacent to the Auxiliary Equipment Area. It shall serve all 5 floors and have a 3000-lb capacity, with operating speed of 100 fpm. Interior dimensions shall be approximately 5 ft 6 in. by 7 ft. Bi-parting doors are preferred. Self-service operation is required, with complete safety provisions, interlocks, warning lights, etc. The drive mechanisms shall not interfere with overhead crane operation.

32

(6) Upper Area

The upper 8-ft section of the High Bay Area side walls shall be of corrugated translucent green plastic siding over a steel frame. The rigid frame or truss-type roof structure shall support rails for the one-ton auxiliary crane in the center. Siding used on the end walls and roofing shall be of asbestos cement. Windows will not be required. Insulation for the end walls and roof of this portion of the High Bay Area is required to obtain suitable heat distribution and reduction of heat dissipated to an economical amount. A paneled-type insulation with rigid facing, suitable for painting, is required.

(7) Painting

All exposed concrete and other non-metallic surfaces of walls, floors, and ceilings shall be painted with "Liquid Tile" in accordance with recommendations of the manufacturer. Standard paint shall be used for metallic surfaces. Colors shall be specified by the Laboratory at a later date.

(8) Drains and Sumps

All equipment areas shall be drained to four sumps in the Active Equipment Area. Floors shall be sloped one inch in 12 ft toward the sumps. The reactor pit shall be connected to the active equipment area by means of a drain loop seal.

(9) Fuel Storage Pit

The fuel storage pit (Figs. 5 and 6) is a water-filled well located in the High Bay Area adjacent to the reactor. The walls and floor of the cell shall be constructed of ordinary concrete, 4 ft thick. The pit shall be 12 ft wide by 16 ft long by 23 ft deep. A drain sump, 8 in. in diameter by 1 ft deep, shall be provided in one corner of the pit. The floor of the pit shall have a uniform slope of one inch in 12 ft toward the drain sump.

All concrete joints shall be designed with water-tight seals (waterstops). All interior concrete surfaces of the pit shall have a steel trowelled finish and shall be painted with a light, reflective, water and radiation damage-resistant coating consisting of a glass fabric liner bonded with white "Liquid Tile."

b. Auxiliary Equipment Area

This section of the building (Figs. 5 and 6) will be 40 ft wide by 125 ft long. A standard construction, rigid frame design building, such as "Stran," is acceptable, with minimum clear height of 13 ft. Siding and roofing may be corrugated sheet aluminum or asbestos cement. Windows are not required.

One end of the building will connect to the High Bay Area adjacent to the fuel storage pit work area. The roof shall be suitably flashed into the high bay end wall.

(1) Free Floor Loadings

The ground floor shall be located at approximately nine inches above grade and be designed for uniform loading of 2000 lb/sq ft.

(2) Equipment Foundations

Suitable foundations for each item of equipment shall be provided to elevations as required for proper operation. The following items of equipment are located in this area:

(a) 1500-gpm Water Softener and/or Demineralizer Unit (with hardness indicator alarm on board)
(b) Regeneration Chemical Storage Space for 30-day operation.
(c) 300-kw Emergency Power Diesel Generator
(d) 1000-gal Treated Water Storage Tank
(e) 1500-lb/hr Steam Generator
(f) 1000-gpm Cooling Water System Receiver
(g) Chemical Shut-down System Boric Acid Tank
(h) Chemical Shut-down System Air Compressor
(i) Air Compressor for Tool Operation
(j) Fuel Oil Storage Tank
(k) Miscellaneous Auxiliary Components.

(3) Access Openings

"Rollup" type, 10 ft by 10 ft cargo doors are required at the end of the building opposite the High Bay Area, and a 3 ft by 7 ft entrance to the adjoining control room. The equipment in the area shall be so arranged that a truck may be backed into the building to receive components lowered by the High Bay Area overhead crane.

(4) Insulation

This building shall be insulated in the same manner as the upper portion of the High Bay Area.

(5) Painting

All exposed concrete and other non-metallic surfaces of walls, floors, and ceilings shall be painted with "Liquid Tile" in accordance with recommendations of the manufacturer. Standard paints shall be used for metallic surfaces. Colors shall be specified by the Laboratory at a later date.

c. Active Storage Area

The Active Storage Area is located at grade level and will be covered over with earth after completion. This room, approximately 40 ft by 60 ft by 12 ft high, will house three 8 ft diameter by 32 ft long coated steel discharge storage tanks and three 8 ft diameter by 24 ft long steel waste retention tanks, in addition to the drain piping and pumps. A 4 x 7-ft access opening, with steel fire-type door, to the Primary Water Service Area will be provided. All tanks and piping will be installed before forming and pouring the top slab. Drains from this area will connect to the pit in the Active Equipment Area. Painting will not be required. Only the three 24-ft long retention tanks will be installed for Steps I & II. Therefore, the far end of the building must be removable for future installation of discharge storage tanks.

2. Control Building

The Control Building will be located adjacent to the Auxiliary Equipment Area and connected to it by means of a short corridor. The Control Building, approximately 46 ft x 55 ft, will be of reinforced concrete blast-resistant arch-shape construction, 24 in. thick. A floor space approximately 20 ft by 50 ft will be required for placement of the control panels. Additional space, approximately 20 ft x 26 ft, for a combination conference-lunch room and for personnel requirements such as locker rooms, showers, toilets, etc., shall also be provided.

Access doors from the ground floor of the Control Building to the Auxiliary Equipment Area and to the exterior shall be weather stripped or otherwise designed to provide minimum air leakage. The Architect-Engineer shall study the advisability of using a blast-resistant door to the Auxiliary Equipment Area. A storm shelter-type extension, with doors, shall be provided outside the exterior access door to the building, in order to permit visitors to announce their presence via the public address system before they are admitted to the Control Building proper.

Interior accoustical properties shall be studied and, if sprayed-on insulation does not appear adequate, the possibility of installing a hung ceiling shall be investigated. Thermal insulation will not be required. Decisions regarding painting of this building will be made after the design has been completed.

The floor of the control room section will be asphalt tile laid on $2\frac{1}{2}$-in. thick mastic to permit running conduits across the top of rough concrete. Floors in locker room, toilets, showers, basement, shall be concrete painted with "Liquid Tile" as recommended by the manufacturer. Shower and locker room area walls shall be uninsulated but painted with "Liquid Tile" as recommended by the manufacturer. Colors shall be specified by the Laboratory at a later date.

The basement of the control building shall contain a water analysis laboratory, approximately 9 ft by 12 ft. The remainder of the basement shall be occupied by the necessary electrical switchgear for the plant. Suitable foundations shall be provided. The basement shall be connected to the Primary Water Service Area and Active Equipment Areas of the High Bay Area by a tunnel equipped with blast-resistant self-closing doors.

All exposed concrete surfaces of walls, floor and ceiling in the water analysis laboratory, and the floor of the basement proper, shall be painted with "Liquid Tile" according to the recommendations of the manufacturer. Walls and ceilings in the basement proper (other than in the water analysis laboratory) shall be unpainted. Standard paints shall be used for metallic surfaces and for piping and equipment. Colors shall be specified by the Laboratory at a later date.

3. Water Cooler and Condenser Areas

The building to house the water coolers will be required for Step II. A covered trench adjoining the High Bay Area of the main building will be required for housing the forced-circulation by-pass system for Step I. The roof may be covered with earth to provide required shielding. Subsequently in Step II the concrete building shall be added to house the water coolers which will be connected to the existing forced-circulation system. The end of the building opposite the exchanger tube sheet covers shall be removable for possible servicing requirements. Earth will be used for supplementary shielding.

Access to the water cooler and condenser areas shall be by doors to the exterior, provided with appropriate shielding labyrinths. The Architect-Engineer shall study the feasibility of providing shielded access openings between these areas and the Primary System Water Service Area in the Main Building.

Exposed concrete surfaces of walls, floors and ceilings of the water cooler and condenser areas shall be painted with "Liquid Tile" according to the recommendations of the manufacturer. Standard paints shall be used for other surfaces. Colors shall be specified by the Laboratory at a later date.

The steam condenser and de-aerating hotwell building will be constructed in Step III. This building will also be located at grade level with elevated supports for the equipment. A sheet metal roof will suffice for this building. Earth may be piled against the side walls to secure additional shielding if required.

D. Mechanical

1. General

The design requirements outlined for the mechanical components in the following discussion are predicated upon the following considerations:

a. Operational

The limited manpower available at the NRTS for operation and maintenance of the ARBOR facility establishes certain precepts which must be followed closely in all design considerations.

(1) Integrity of equipment is required with a minimum amount of developmental type units included. An exception on this point will be made for pump shaft seals. However, it is expected that this item will be thoroughly tested before acceptance.

(2) Ease of maintenance shall be designed into the plant in the form of accessibility of equipment, location of platforms, working space, and good employment of material handling equipment.

(3) Operating safety aspects must be carefully considered: by proper lighting; provisions for storage of tools and spare parts; hand-rails and stairs of adequate proportions; identification of valves, piping, and components, warning lights and horns, etc.

(4) In general terms, it should be possible to remove each piece of equipment from the plant in a radioactive condition. Although permanent handling facilities need not be provided, space must be available for installation of rigging equipment necessary to effect removal. All components on the reactor operating floor and in the active equipment area are to be serviced by the overhead crane. Water cooler and steam condenser buildings shall have removable ends so that equipment may be removed.

(5) Due to the problem of radiation and to the fact that a limited amount of time and manpower will be available for plant maintenance, the selection and arrangement of equipment shall be governed accordingly. Quality and integrity of operation of pumps, valves, heat exchangers, water treating equipment, etc., are most important.

(6) Where possible, equipment and accessories shall be commercial grade or as nearly so as practicable. Finishes and tolerances most certainly can be commercial grade, with inspection and cleaning held to a minimum over that normally required for power plant installations.

(7) A thorough study is required of all probable modes of operation to cover future pipe connections, instrumentation accommodations, equipment manipulation, sampling arrangements, etc.

b. Experimental

The following series of experiments will be performed for each of the various cores and for every significant modification to each of the cores (i.e., modifications involving variations in flux and/or power distribution, void coefficient, size, and orificing). Each individual experiment would involve adjustment of the required parameters to their desired values and measurement of the power level and/or system response as required. All other available information, such as that concerned with internal temperatures, pressures, flows, entrainment, carry-over, water decomposition, radiation levels, etc., if available, and if significant, would be obtained.

The experiments may be divided into three primary groups. The first group would be pursued in order to determine the characteristics of the reactor operating as a steady-state steam generator and the limits of its stability as affected by the pressure, coolant flow, and subcooling. The second group would involve investigation of the response of the reactor to the type of steam flow, water flow, and subcooling transients which will occur when the reactor is a part of a power-generation system. The third involves observation of the performance of the system when various types of control methods are employed to eliminate undesirable reactor response to variation in power demands.

Specifically, suggested experiments in the groups are:

(1) Steady-state operating characteristics (determination of power density vs. reactivity in steam voids up to limiting power density) for:

(a) Pressures of 600, 800, 1000, 1250, 1500, 2000 psi.
(b) Subcooling equivalent to non-boiling lengths approaching 0% and 100%, in 10% increments.
(c) Flows of 7500, 10,000, 15,000, 20,000, 27,500, 35,000 gpm for 4-ft diameter cores and including lower rates for cores of smaller diameter.

(2) Determination of the influence of the above parameters on the stability with:

(a) Variations in steam demand in a manner corresponding to that expected in a power plant, i.e., rates less than 2 to 3% per second.
(b) Turbine trip out with and without steam by-pass simulation.
(c) Variations in circulation velocity as might be required to control the reactor under steam demand fluctuations, i.e., 1 to 3% per second; and as might occur if one or more circulating pumps cuts in or out of the system.
(d) Variation of inlet subcooling in the range which is significant to control, and to possible feedwater flow incidents. Subcooling changes must be made to encompass the range of interest to both dual and indirect cycle modes of boiling reactor operation.

(3) Determination of the response of the system when operating under various integrated types of plant control. These systems will include those of the type designed for contemplated power plants, plus any other schemes, such as flow control, which may become evident through results of the experiments in 1 and 2 above.

It is expected that all control systems can be developed with suitable response from the data obtained in experiments 1 and 2 above.

The requirements of a clean system which are associated with a research reactor dictate the use of Type 304, 316 or 347 stainless steel in all components of the primary system for Step III and in most of the components for Steps I and II. However, the use of Type 405 stainless steel in the water coolers and steam condensers is permissible.

c. Construction in Steps

For Step I operation (direct cycle) the following equipment will be installed:

(1) Pressure Vessel
(2) Main Building
(3) Auxiliary Building
(4) Control Building
(5) Retention and Discharge Storage Tank Building
(6) 1500-gpm Water Supply and Treatment System
(7) Forced-Circulation System Minus Water Coolers

(8) Low Alloy Carbon Steel Steam Distribution System
(9) Carbon Steel Feedwater Pump
(10) Complete Electrical Distribution System
(11) Complete Instrumentation System
(12) Three Waste Retention Storage Tanks.

The primary system steam piping will be fabricated from low alloy carbon steel after connecting to stainless steel flanged joints in the steam lines downstream from the shut-down coolers. The turbine-simulator valve manifold and relief system are to be located near the base of the discharge stack, protected by a sheet metal building.

The carbon steel portion of the piping system is to be replaced with Type 304 stainless steel for Step III.

For Step II operation (dual cycle) the forced-circulation system water-cooled heat exchangers with piping and control valves are added.

For Step III operation (D_2O and indirect cycle) the following items will be added:

(1) Water-Cooled Steam Condensers
(2) De-aerating Hotwell
(3) Recombination System
(4) Reactor Water Cleanup System
(5) Stainless Steel Steam Distributing System
(6) Stainless Steel Feedwater Pump.

The items to be specified under mechanical requirements include:

(1) All components of the primary system, with exceptions as noted.
(2) All auxiliary systems.
(3) All components necessary for providing building services, heating, ventilating and air conditioning.
(4) Handling equipment.

Of these components the Laboratory will design and supply the reactor vessel.

Information relative to size, weight, the nature of the connections for the reactor vessel will be supplied by the Laboratory.

The remaining components will be designed by the Architect-Engineer in accordance with requirements set forth by the Laboratory. Extremely close cooperation will be necessary between the Architect-Engineer and the Laboratory, particularly with regard to this design work.

The following sections present the design requirements for the above systems and components. Detailed specifications are not given in every case. The items which the Laboratory will supply are included in order to give the Architect-Engineer a more comprehensive picture of the over-all plant.

2. Primary System

a. General

The primary system is composed of those components which contain the high-pressure, high-temperature reactor water, steam, and condensate, and which comprise the two closed loops involved in reactor heat removal. In order to achieve satisfactory corrosion resistance of all surfaces which contact primary system fluids water or steam, AISI Type 304, 316, or 347 stainless steel shall be used for such surfaces. (Carbon steel shall be used in the steam disposal system for Steps I and II.)

b. Reactor

The specifications for the reactor vessel are reproduced as Appendix B of this report. All reactor internals, as well as control rod drive mechanisms, will be designed and constructed by the Laboratory.

c. Water Coolers and Steam Condensers

Locations of the water coolers and steam condensers are shown in Figs. 5, 6, and 8. The water coolers are to be installed for Step II operation and the steam condensers for Step III.

The information secured to date by the Laboratory on the water-cooled heat exchangers is available for evaluation and aid in preparation of specifications.

ARBOR Water Cooled Heat Exchanger Requirements

I. Forced-Circulation Coolers

A. Fluid

1. Tube Side -- Primary system demineralized water
2. Shell Side -- Demineralized water

B. Operating Pressure (range)

1. Tube Side -- 600 psia to 2000 psia
2. Shell Side -- 90 psia to 600 psia

C. Operating Temperature (range)

1. Tube Side -- In 486°F; Out 360°F } MINIMUM
2. Shell Side -- In 70°F; Out 320°F }
3. Tube Side -- In 636°F; Out 516°F } MAXIMUM
4. Shell Side -- In 70°F; Out 486°F }

Note: Shell side coolant comes off as steam.

D. Material

1. Primary Side -- Type 405 Stainless Steel
(Channels may be Type 405 Stainless Steel clad)
2. Shell Side -- Carbon Steel

E. Tube Joints -- Rolled in and seal welded

F. Duty -- (total) 200 mw

G. Construction

1. Design Pressure -- Tube Side: 2500 psia
Shell Side: 800 psia
2. Design Temperature -- Tube Side: 690°F
Shell Side: 550°F

II. Steam Condensers

A. Fluid

1. Tube Side -- Saturated steam to condensate
2. Shell Side -- Demineralized water

B. Operating Pressure (range)

1. Tube Side -- 250 psia to 2000 psia
2. Shell Side -- 67 psia to 600 psia

C. Operating Temperature (range)

1. Tube Side -- In 400°F; Out 397°F } MINIMUM
2. Shell Side -- In 70°F; Out 300°F }
3. Tube Side -- In 636°F; Out 630°F } MAXIMUM
4. Shell Side -- In 70°F; Out 486°F }

Note: Shell side coolant comes off as steam.

D. Material -- Same as water coolers

E. Tube Joints -- Rolled in and seal welded

F. Duty -- (total) 150 mw

G. Construction -- Same as water coolers

d. Forced-Circulation and Reactor Feed-Water Pumps

The forced-circulation and reactor feed-water pumps will be designed and their elevations relative to the reactor vessel and de-aerating-hotwell specified by the Laboratory in collaboration with the pump manufacturer(s). The Architect-Engineer shall be responsible for design of the foundations, interconnecting piping, power supply, and control of units. The method of mounting the pumps must be studied very carefully to accommodate thrusts resulting from thermal expansion effects in the large diameter suction and discharge piping.

It will be necessary to investigate thoroughly the variation in feed-water pump requirements between Step II and Step III. Steps I and II operation may permit use of a standard carbon steel boiler feed pump, with a nickel-plated lining. Exact requirements for this unit can only be determined after a detailed evaluation of all operating conditions.

Tentative design requirements for the pumps are given for information in Appendix C of this report.

e. De-aerating-Hotwell

The de-aerating-hotwell is required for Step III. It consists of a horizontal cylindrical tank designed for 2500 psi at 695F, with approximately a 4000-gal water capacity. This vessel will be designed in accordance with standard de-aerator practice as far as possible and in accordance with the ASME Code for Unfired Pressure Vessels (Section VIII). The use of high-strength steels for construction of the hotwell shall be explored. A stainless steel liner is required.

The following nozzle connections are required on the hotwell tank:

Condensate from condensers.
Water column (top and bottom) for level and pressure instrumentation.
Steam injection (estimated at 40,000 lb/hr) for maintaining hotwell temperature.
Bleed to de-aeration system.
Water from primary water make-up system.
Reactor feed-water pump suction.
Return from feed-water pump back-pressure by-pass.
Drain.
Relief valve.

f. Piping and Valves

All system piping is to be built for a design pressure of 2500 psi and a design temperature of 695F. Although an ASA-B31 code design is preferred, certain exceptions to the code may be allowed in the interest of economy. For example, centrifugal castings and multi-layer pipe should be investigated.

All piping is to be arranged so that piping external to the building can be drained to prevent freezing under any possible condition. Piping should be insulated to accepted power plant standards and adequate protection of outdoor piping, piping insulation, and supporting structure must be provided for all weather conditions. Adequate venting of the piping system is also to be provided. Particular attention must be given to the condenser discharge piping and relief lines to prevent water-steam surging or hammer.

The system must be flexible enough to permit rather large temperature differences, since the experimental nature of the facility requires that there be greater and more frequent temperature fluctuations than would be found in a conventional, steadily operating process system or power plant. Examples of possible adverse piping conditions will be supplied to the Architect-Engineer by the Laboratory.

Reasonable care is to be given to the system during construction to insure cleanliness of the piping interior. Coating of butt welding joints with silicone grease to prevent burn-through will not be permitted. All primary internals are to be sufficiently clean before operation to result in water resistivity values of not less than 500,000 ohm-cm after sufficient time has elapsed to assure equilibrium in corrosion rates.

The various primary system valves are listed in Table I, together with their type of duty, design flow, desired pressure drop, and suggested type. This information is not to be considered firm, especially insofar as valve quantities (when two or more are suggested for a single duty) and sizes are concerned.

For Steps I and II the entire steam disposal system from the connecting flanges at the emergency shut-down coolers to the stack shall be fabricated from low alloy carbon steel. This will include the safety and relief valve system. All carbon steel must be replaced with Type 304 stainless steel for Step III.

Valves need not be of the sealed type. However, leakage must be kept to a nominal amount. Special attention must be given to those valves located outdoors so that adequate protection is provided against freeze-up. Separate vent and drain lines for each valve are to be provided if necessary to insure complete venting and draining of the valve along with its associated piping.

It must be emphasized that the interrelation of valves, pipe layout, and system instrumentation and control is a matter for joint effort between the Architect-Engineer and the Laboratory, so that the listing of valves in Table I must be considered tentative only.

All valves are to have a design pressure of 2500 psi and a design temperature of 695F. The type of operators to be used for motorized and control valves (electric or pneumatic) shall be studied by the Architect-Engineer and specifically recommended for each application. Hydraulic operators shall not be used. Electric operators are preferred for all outdoor installations, where feasible, because of the possibility of freeze-up of air lines in pneumatic systems. All pneumatic systems must be provided with air dryers.

A preliminary tabulation of primary system piping sizes and lengths is shown in Table II. Also included is a list of fittings. This information, based on the present system layout, anticipated flows, and a design velocity of 15 to 30 fps, is given only to aid the Architect-Engineer in estimating the extent of these items in the primary system.

g. Steam Separator -- Shutdown Coolers

Steam separator units will not be required for Steps I and II, and may not be for Step III. Therefore, only stainless steel-lined shutdown-coolers will be installed. The coolers (2) shall have a combined heat removal capacity of 24 mw using 100°F cooling water entering at a velocity of 4 to 6 fps. The coolers shall have Type 304 stainless steel cooling tubes and be located in the steam lines at sufficient elevation above the reactor level to prevent back flow up the water leg as a result of pressure drop in the steam line. If separators are required for Step III, specifications will be set forth at a later date.

h. Steam Disposal System

For Steps I and II operation, a once-through steam system is contemplated. Demineralized feed water at 70F will be introduced into the downcomer area and steam produced will be vented to atmosphere at rates up to about 620,000 lb/hr. For Steps I and II, primary system steam will be vented through a back pressure-regulating system by either of two methods. The most direct way is to blow the steam up through a vertical stack. In the event that this method is unsatisfactory the steam may be released through a submerged gridwork of tubes into a pond of water.

For Step II some secondary steam from the water coolers must also be dissipated in the same manner. In Step III all reactor heat will be dissipated by venting secondary steam.

Table I

DESCRIPTION OF VALVES - PRIMARY STEAM AND ASSOCIATED SECONDARY COOLING WATER SYSTEMS

Valve Desig.	No., Size & Type	Operator Data	Rating and Purpose
S_{1-1} thru S_{1-2}	Two Electrically Operated Gate, 10 in.	SMA-3-60 3.89 hp	Serve as steam separator isolation valves to direct flow through appropriate separators to maintain necessary separation velocities to cover reactor output total steam flows listed under valve grouping S_2; maximum pressure drop about 2 psi; depending on steam separation efficiencies over flow ranges listed under S_2, it may be possible to eliminate these S_1 valves; (not shown on flow chart).
S_{2-1} thru S_{2-4}	Four Pneumatically Operated Control, 4 in.	-	This valve grouping comprises the turbine-simulator valves and will pass flows listed below, and to control, individually and/or in combination, down to 10% of these flows while maintaining downstream pressure about 50% of upstream pressure:

lb/hr	Reactor Press. Sat,psi	Cond. Press. Sat,psi	Condensate Feed Water Rates, gpm
650,000	600	300	1,480
693,000	1,000	500	1,710
766,000	1,500	750	1,915
863,000	2,000	1,000	2,330

S_3	One Pneumatically Operated Control, 4 in.	-	This valve to pass up to 25% of reactor output total steam flow; used to maintain constant pressure in the reactor
S_{4-1} & S_{4-2}	Two Electrically Operated Gate, 12 in.	SMA-3-60 3.80 hp	These serve as inlet shut-off valves on steam condensers #1 and #2, respectively.
S_{5-1} & S_{5-2}	Two Electrically Operated Gate, 6 in.	SMA-1-15 0.97 hp	These serve as outlet shut-off valves on steam condensers #1 and #2, respectively.
S_{6-1} thru S_{6-2}	Two Electrically Operated Gate, 1 in.	SMA-OC-$7\frac{1}{2}$ 0.5 hp	Serve as equalizer; by-pass around valves S_4 to permit draining of condensate through the condenser and to maintain condensers in the operating warmed-up temperature range during stand-by condition.
S_7	One Electrically Operated Gate, 10 in.	SMA-3-60 3.89 hp	Serves as feedwater pump suction shut-off valve; pressure drop to be maximum of 1.5 psi at 3250 gpm and 625°F.
S_8	One Pneumatically Operated Control, 6 in. or 5 in.	-	Controls reactor feedwater flow rate down to 10% of condensate flow rates listed under S_2 above; valve characteristics to match reactor feedwater pump flow rate vs head characteristics.

46

Table I (Cont'd.)

Valve Desig.	No., Size & Type	Operator Data	Rating & Purpose
S_9	One Pneumatically Operated Control, 2 in.	-	Serves to pass up to a maximum of 40,000 lb/hr of steam to maintain saturated pressure conditions in the hotwell over conditions listed under S_2.
S_{10}	One Pneumatically Operated Control, 4 in.	-	Serves to by-pass pump flow back to hotwell, depending on reactor make-up requirement as controlled by valve S_8.
S_{11}	One Stop Check, Angle Type, 8 in.	SMA-3-60 3.89 hp	Passes pump discharge condensate flow rates listed under S_2 above; maximum pressure drop about 12 psi; to seat at maximum of 2 psi pressure differential.
S_{12-1} thru S_{12-5} &	Five Gate, 6 in.	Manually Operated Handwheel	These six S_{12} valves in combination with S_{15} serve function of routing feedwater through water cooler(s) for controlled subcooling requirements prior to delivery to reactor. S_{12-6} to handle flow rates shown under S_2 while S_{12-1} thru S_{12-5} to handle about half these flows.
S_{12-6}	One Gate, 8 in.	Manually Operated Handwheel	
S_{13}	One Electrically Operated, 2 in.	SMA-00-$7\frac{1}{2}$ 0.5 hp	Serves as sludge-handling condensate valve to drain contents of hotwell to retention tanks.
S_{14}	One Electrically Operated Gate, 6 in.	SMA-1-15 0.97 hp	Serves as shut-off valve between one of the forced circulation pump suction lines and the feedwater pump suction, which, when in the open position, will permit feedwater pump start-up circulation down the annulus surrounding the reactor core.
S_{15}	One Pneumatically Operated Control, 4 in.	-	This valve operates, in conjunction with the S_{12} valves and controls, subcooled water flow requirements to the reactor; to handle normally up to about half the flow rate listed under S_2.
SW_{1-1} & SW_{1-2}	Two Gate, 6 in.	Manually Operated Handwheel	Serves as cooling water pump suction shut-off valve; maximum flow rate 1200 gpm at 70° F; maximum pressure drop about 2 psi.
SW_2	One Check, 6 in.	None	Serves to check reverse flow through pump; maximum flow about 1200 gpm at 70° F; maximum pressure drop 5 psi.
SW_3	One Pneumatically Operated Control, 2 in.	-	Serves to by-pass pump flow back to suction side of pump if pressure builds up to predetermined value depending on control demands of valves SW_4.

47

Table I (Cont'd.)

Valve Desig.	No., Size & Type	Operator Data	Rating & Purpose
SW_{4-1} & SW_{4-2}	Two Pneumatically Operated Control, $2\frac{1}{2}$ in.	-	Serve to control shell-side water flow to steam condensers #1 and #2, respectively; maximum normal flow per valve about 450 gpm at 70° F; characteristics per valve to permit handling of up to 30% more and 80% less than normal flow.
SW_{5-1} & SW_{5-2}	Two Pneumatically Operated Control, 10 in.	-	Serve to release steam to atmospheric exhaust from steam condensers while maintaining preset saturated back pressures corresponding to those ranging from 300° F to 486° F shell-side temperatures; and discharging up to the steam volume equivalent of 540 gpm at 70° F water per condenser.
SW_{5-3} & SW_{5-4}	Two Electrically Operated Control, 12 in.	SMA-3-60 3.89 hp	Sizes shown are applicable to double-seated, V-ported valves; however, butterfly, plug, or other throttling-type valves in required number and sizes may be provided for each condenser to meet application requirements.
W_{1-1} thru W_{1-4}	Four Electrically Operated Gate, 14 in.	SMA-3-80 5.2 hp	Serve as pump suction shut-off valves, maximum flow rate of 9000 gpm each at 636° F, and 2000 psia; maximum pressure drop about 1 psi.
W_{2-1} thru W_{2-4}	Four Electrically Operated Gate, 12 in.	SMA-3-60 3.89 hp	Serve as pump discharge shut-off valves; maximum flow rate of 9000 gpm each at 636° F and 2125 psia; maximum pressure drop about 5 psi.
W_{3-1} thru W_{3-3}	Three Electrically Operated Gate, 10 in.	SMA-3-60 3.89 hp	Serve as inlet shut-off valves on water coolers #1, #2, and #3, respectively; each valve to pass up to 4, 167 gpm at 636° F and 2,125 psia; (12,500 gpm total flow); maximum pressure drop about 1 psi.
W_{4-1} thru W_{4-3}	Three Pneumatically Operated "Y" Pattern, 8 in.	-	Serve as water-cooler outlet line control valves passing water thru the three water coolers; normal flow per valve as listed under W_3 above; maximum pressure drop about 32 psi, while passing normal flow of 4,167 gpm at 486° F, with characteristics per valve to handle 50% of normal flow rates.
W_{5-1} thru W_{5-3}	Three Electrically Operated Gate, 1 in.	SMA-00-$7\frac{1}{2}$ 0.5 hp	Serve as by-pass around W_4 to provide a water flow circuit by which heated water may be circulated to keep coolers at operating temperatures during standby readiness condition.

48

Table I (Cont'd.)

Valve Desig.	No., Size & Type	Operator Data	Rating & Purpose
W_{6-1} thru W_{6-4}	Four Pneumatically Operated Butterfly, 10 in.	-	Serve as by-pass valves to control full pump capacity of 36,000 gpm at 636° F, and 2,125 psia, or to control normal 23,500 gpm flow of the 36,000 gpm while balance of 12,500 gpm is controlled via valves W_4 thru the water coolers; characteristics to be such that each valve can control down to 50% of normal flow of 5,880 gpm per valve; pressure drop per valve while passing 5,880 gpm at 486° F to be no greater than about 10 to 12 psi at about a 53° valve open position, with valve blade and shaft design to sustain up to 125 psi maximum differential while controlling at smaller flows approaching a 0° open blade position.
W_{7-1} thru W_{7-4}	Four Electrically Operated Gate, 1 in.	SMA-00-7½ 0.5 hp	Serve as by-pass around valves W_2 to provide a water flow circuit by which heated water may be circulated to keep pumps at near operating temperatures during standby condition.
WW_1	One Electrically Operated Gate, 6 in.	Manually Operated Handwheel	Serves as cooling water pump suction shut-off valve; maximum flow rate about 1,200 gpm at 70° F; maximum pressure drop about 4 psi.
WW_2	One Check, 6 in.	None	Serves to check reverse flow thru pump; maximum flow about 1,200 gpm at 70° F.
WW_3	One Pneumatically Operated Control, 2 in.	-	Serves to by-pass pump flow back to suction side of pump if pressure builds up to predetermined values depending on control demands of valve WW_4.
WW_{4-1} thru WW_{4-3}	Three Pneumatically Operated Control, 2½ in.	-	Serve to control shell-side water flow to water coolers #1, #2, and #3, respectively; maximum normal flow per valve about 480 gpm at 70° F; characteristics per valve to permit handling of 50% of normal flow.
WW_{5-1}, WW_{5-3} & WW_{5-5}	Three Pneumatically Operated Control, 8 in.	-	Serve to release steam to atmospheric exhaust from water coolers while maintaining preset saturated back pressures corresponding to those ranging from 320° F to 486° F shell-side temperatures, and discharging up to the steam volume equivalent of 400 gpm of 70° F water per cooler.
WW_{5-2}, WW_{5-4} & WW_{5-6}	Three, 12 in.	-	Sizes shown are applicable to double-seated valves; however, butterfly, plug , or other throttling-type valves in required number and sizes may be provided for each cooler to meet application requirements.

47

Table II

ESTIMATED PRIMARY SYSTEM PIPE AND FITTING REQUIREMENTS

Steam and Feedwater System							
Pipe (Centrifugal Cast)			Fittings				
Size (in.)	Weight (lb)	Length (ft)	Long Radius, 90° Ells	Tees	Caps	Reducers	Orifice Flanges
14	2,820	18			2		
12	13,600	105	one		2		1
10	15,500	168	sixteen 90°	2	2		
			one 10 x 8				
			one 45°				
8	2,200	37				five 8 x 4	1
6	2,100	60				five 6 x 4	5
4	1,120	70	eight 90°				
			four 45°				

Estimated weight of piping - 37,400 lb

one 12 in. strainer
one 12 in. blind dutchman*

Forced Circulation System							
Pipe (Centrifugal Cast)			Fittings				
Size (in.)	Weight (lb)	Length (ft)	Long Radius, 90° Ells	Tees	Caps	Reducers	Bends
30	19,400	27				one 30 x 18	
20	53,300	162			4	four 20 x 14	four 90° x 72 in. Rad.
18	19,550	76			5		
16	10,000	49	four			four 16 x 14	
14	200	13			1		
12	14,800	114				six 12 x 8	
10	8,000	87	twelve		1	three 10 x 8	three 90° x 60 in. Rad.
							three 180° x 60 in. Rad.
8	2,150	36					

Estimated weight of pipe and bends - 136,000 lbs.

3 pr. of 10 in. Orifice flanges
or
3 ea. of 10 in. Flow tubes
depending on step construction

*Blind dutchman shall be made up with orifice flanges and connected to DP cell for future use. Orifice will replace blind plate when required.

A glass-lined carbon steel stack, approximately 10 ft diameter by 125 ft high, will be located adjacent to the steam condenser area. The valve manifold shall be located at the base of the stack in a sheet metal building.

3. Secondary System

a. General

The secondary system will be incorporated in Step II with the installation of the forced-circulation water coolers. The secondary steam shall be piped around the main building to the back pressure-regulating manifold at the base of the stack.

b. Feed-Water Pumps

The carbon steel feed-water pumps will take suction from the water treatment system. The capacity of each pump shall be 800 gpm at approximately 1560-ft total developed head with 70°F water. At a discharge rate of 1200-gpm, approximately a 900-ft total developed head will be required.

One pump will be installed with the water coolers in Step II and one pump with the steam condensers for Step III. When both pumps are installed, the discharge piping shall be arranged for parallel operation.

A suitable by-pass system around the pumps is required to accommodate a wide variation in operating conditions.

c. Piping and Valves

Lines shall be sized for flow velocities of approximately 10 fps. Pipe and valves on the cold side of the system shall be straight carbon steel. The steam discharge piping and valves from the shell to the regulating manifold at the base of the stack shall be fabricated from suitable low alloy carbon steel such as 2-1/4% chromium-1% molybdenum alloy.

4. Auxiliary Systems

The auxiliary systems discussed in the following pages must be studied in detail by the Architect-Engineer. All the requirements stated herein are to be understood as suggestions only and are subject to review and alteration by the Architect-Engineer and the Laboratory.

Vents and drains must be provided at appropriate points in the system and are to be determined by the Architect-Engineer as the design progresses, and shown on the proper flow charts.

51

Numbers in parentheses preceding items of equipment refer to identifying numbers on the flow charts, Figs. 10 and 11. Step identifications indicate the first step in which this equipment is required.

a. Water Supply System (Step I)

(1) Deep Well Pumps (2)

Capacity - 600 gpm each
Depth - Approximately 600 feet, as required
Discharge - To Raw Water Storage High Tank and Domestic Storage Tank.
Location - Auxiliary Equipment Area
Motor - 440-v 3-phase, 60-cycle AC
Control - From High Tank Level and Domestic Storage Tank Pressure with local manual override.

(2) Raw Water Storage High Tank

Capacity - 100,000 gal
Type - Elevated with 100-ft head (insulated per normal practice).
Heating - Electrical for tank and riser to prevent freezing.
Location - Adjacent to Auxiliary Equipment Area
Material - Carbon Steel

(3) Water Treatment System

Capacity - 1500 gpm
Resistivity - 1 Megohm
Raw Water Hardness - Water analyses for two wells near the ARBOR site are given in Appendix A.
Type - Straight demineralization with automatic regeneration
Chemical Storage Capacity - 30 days
Location - Auxiliary Equipment Area
Electrical Components - 110-v, 1-phase, 60-cycle AC, if required.

(4) Treated Water Storage Tank

Capacity - 1000 gal
Tank Material - Carbon Steel, coated
Design Pressure - 75 psig
Design Temperature - 150F
Connections - as required (screwed or flanged)
Location - Auxiliary Equipment Area
Inspection - ASME Code Stamp required

Piping - Type 304 stainless steel or aluminum
Fittings - Aluminum or stainless steel flanged or screwed, as applicable
Valves - Aluminum or stainless steel flanged or screwed, as applicable

b. Auxiliary Cooling Water System (Step I)

(9) Auxiliary Cooling Water Receiving Tank

Capacity - 1000 gal
Material - Carbon Steel
Design Pressure - 25 psig
Design Temperature - 200F
Connections - As required (screwed or flanged)
Location - Auxiliary Equipment Area

(10) Auxiliary Cooling Water Circulating Pumps

Capacity - 1000 gpm each (This is an estimated capacity only. The exact requirements with reserve capacity shall be determined by the Architect-Engineer after a complete analysis of the system.)
Quantity - 2 (1 operating and 1 stand-by)
Discharge Head - Approximately 50 psig (determined by Architect-Engineer).
Material - Carbon Steel or Cast Iron
Connections - Flanged or screwed.
Location - Auxiliary Equipment Area
Motors - 440-v, 3-phase, 60-cycle AC.
Control - Manual start-up with automatic switch to stand-by on low discharge pressure.

(11) Auxiliary Cooling Water System Air-Cooled Heat Exchanger

Capacity - Approximately 3,000,000 Btu/hr. (This is an estimate. The exact requirements are to be determined by the Architect-Engineer after an analysis of the cooling water system. Design criteria may be established after all heat-removal capabilities of each heat exchanger, pump, storage pit, reactor shield, etc., are determined. The heat exchanger shall be designed to remove all process heat up to the point where the air temperature reaches 60F. When the air temperature goes above 60F supplemental cooling may be secured by a cooling tower to maintain the cooling water temperature entering the receiver tank at 85F.)

Design Pressure - 75 psig
Type - Fan-cooled, horizontal finned tube
Material - Carbon Steel, standard construction
Control - Louvers responsive to outlet water temperature
Fan Motors - 440-v, 3-phase, 60-cycle AC
Location - Adjacent to Auxiliary Equipment Area
Freeze-up Protection - Adequate provision must be made for prevention of coil freeze-up during wintertime shutdown. Normal decay heat removal will probably provide enough temperature to prevent freezing during time when reactor is not operating. However, provisions must be made for the time when no decay heat is being removed or when cooling water pumps are not operating
Inspection - ASME Code Stamp required.

(12) Cooling Tower

Capacity - Cooling tower size shall be determined by the Architect-Engineer after an analysis of the system requirements. The cooling tower is to be used as a supplement to the air-cooled heat exchanger when high ambient air temperatures prevent reduction of cooling water temperature to 85F.
Material - Wood and Carbon Steel
Location - Adjacent to Auxiliary Equipment Area
Freeze-up Protection - Provisions must be made for complete drainage during winter.
Piping - Schedule 40 carbon steel for all previously described equipment and to and from all heat exchangers, auxiliaries, etc., served by the system.
Fittings - Carbon steel, cast iron, or bronze: flanged or screwed, as applicable.
Valves - Carbon steel, cast iron, or bronze: flanged or screwed, as applicable.
Filters - The filters shall be of the Ful-flo type using cotton liners, sized for a maximum pressure drop of 3 psi after flow requirements are determined.

c. Shield Cooling System (Step I)

(17) Shield Cooling Circulating Pumps

Capacity - 50 gpm each

Quantity - 2 (1 operating and 1 stand-by)
Discharge Head - Approximately 25 psig (determined by Architect-Engineer).
Material - Steel or Cast Iron
Connections - Screwed
Location - Primary System Water Service Area
Motor - 440-v, 3-phase, 60-cycle AC.
Control - Manual

(18) <u>Shield - Cooling Heat Exchanger</u>

Heat-Removal Capacity - approximately 260,000 Btu/hr
Materials - Carbon Steel Shell - Admiralty Bronze Tubes
Connections - Screwed
Water Temperatures -
Shell Side - Cooling Water (softened)
Inlet - 85F
Outlet - 115F
Tube Side - Shield Cooling Water (softened and demineralized)
Inlet - 140F
Outlet - 125F
Design Pressure - 50 psig
Inspection - ASME Code Stamp required
Location - Primary System Water Service Area

(19) <u>Cooling Coil Arrangement</u> (vertical lead liner and pipe sleeves)

Number of coils - 24 operating and 24 spare: each coil approximately 18 in. high with tubes on 4-1/2-in. centers with spare coil tubes wound between operating coil tubes.
Coil Tubes - 1/2 in. OD x 16 ga AISI Type 304 stainless steel
Location of Coils - Imbedded in 3-in. lead shield around inside diameter of reactor pit, attached to steel inner shield form.
Valves - 1/4-in. I.P.S. carbon steel screwed globe on outlet of each coil.
Cooling Flow through each Coil - approximately 2 gpm
Flow Measurement - 3-gpm capacity rotameters located in each outlet line before entering return manifold; each rotameter may also serve matching spare coil.

Valve and Rotameter Location - Primary System Water Service Area

(20) Cooling Coil Arrangement (Reactor Pit Floor)

Number of Coils - 6 operating and 6 spare of the hairpin type: each coil to have tubes on 6-in. centers, with spare coils mounted between operating coils.

Coil Tubes - 1/2 in. OD x 16 ga. AISI Type 304 stainless steel

Location of Coils - Imbedded in concrete of reactor pit floor, not over 1 in. below surface.

Valves - 1/4-in. I.P.S. - Carbon steel screwed globe valves on outlet of each coil.

Cooling Flow through each Coil - approximately 2 gpm

Flow Measurement - 3-gpm capacity rotameters located in each outlet line before entering return manifold: each rotameter may also serve matching spare coil.

Valve and Rotameter Location - Primary System Water Service Area

(21) Cooling Arrangement - (reactor top cover shield)

Cooling Connections - 4(2 inlet and 2 outlet)

Valves - 3/4-in. I.P.S. carbon steel screwed globe valves on each inlet and outlet line at connection to manifold.

Connections - Armored hoses with quick disconnect shut-off-type couplings at shield and in operating floor so that no pipes project above floor line after hoses are disconnected.

Relief Valve - one required on one of discharge lines between shield and hose disconnect coupling; discharge pressure 50 psig.

Pipe Size - 3/4-in. Schedule 80 carbon steel pipe.

Cooling Flow - Approximately 5 gpm per connection

Flow Measurement - 5-gpm capacity rotameter location in each outlet line entering return manifold.

Valve and Rotameter Location - Primary System Water Service Area

(22) Cooling Arrangement - Top Shield Outer Segments

Cooling Connections - 8 (1 inlet and 1 outlet for each of 4 segments)

Coil Tubes - 1/2 in. OD x 16 ga. AISI Type 304 stainless steel.

Valves - 3/4-in. I.P.S. carbon steel screwed globe valves on inlet and outlet line at connection to manifold.
Connections - Armored hoses with quick disconnect shutoff-type couplings at segment and at operating floor so that no pipes project above floor line after hoses are disconnected.
Relief Valves - one required on outlet from each segment between segment and disconnect coupling; discharge pressure 50 psig.
Pipe Size - 3/4-in. Schedule 80 carbon steel pipe.
Cooling Flow - 3 gpm per segment.
Flow Measurement - 3-gpm capacity rotameter located in each outlet line before entering return manifold.
Valve and Rotameter Location - Primary System Water Service Area.

d. Storage Pit Cooling and Cleanup System (Step I)

(23) Storage Pit Cooling Heat Exchanger

Heat-Removal Capacity - Approximately 75,000 Btu/hr
Materials - Carbon Steel Shell - AISI Type 304 stainless steel tubes, tube sheets, and heads.
Connections - Screwed.
Water Temperature -
Shell Side - Cooling Water (softened)
Inlet - 85F
Outlet - 110F
Tube Side - Storage pit water (demineralized)
Inlet - 120F
Outlet - 95F
Design Pressure - 50 psig
Location - Primary System Water Service Area
Inspection - ASME Code Stamp required.

(24) Storage Pit Cleanup Circulating Pump

Capacity - 15 gpm
Discharge Head - Approximately 15 psig
Material - Carbon steel, glass or rubber-lined.
Connections - Screwed
Location - Primary System Water Service Area
Motor - 440-v, 3-phase, 60-cycle AC
Control - Manual
Design Pressure - 50 psig

57

(25) Storage Pit Cleanup Line Filter

Type - "Ful-Flo" type with cotton liners
Pressure Drop - 3 psi maximum at 15 gpm
Material - AISI Type 304 stainless steel
Connections - Screwed
Location - Primary System Water Service Area
Shielding - The filter casing is to be arranged for quick removal of liners and shielded with lead to provide a maximum surface level reading of 10 mr/hr.

(26) Storage Pit Cleanup Ion Exchanger

Type - Mixed Bed
Design Pressure - 50 psig
Capacity - 15 gpm demineralized water
Location - Primary System Water Service Area
Shielding - The ion exchangers are to be arranged for quick removal of resin cans and shielded with lead to provide a maximum surface level reading of 10 mr/hr.
Piping, Valves, Fittings - AISI Type 304 stainless steel, screwed.

(28) Flow Measurement

Rotameter - 15-gpm capacity
Material - AISI Type 304 or 316 stainless steel
Connections - Screwed or flanged
Location - Fuel Storage Pit Area of Primary System Water Service Area

e. Cooling Water to Pumps (Step I)

(29) Feed-water Pumps

Cooling Water Requirements - as required by pumps.

(30) Forced Circulation Pumps

Cooling Water Requirements - as required by pumps.
Piping Valves, Fittings - Carbon steel, screwed

f. Reactor Water Cleanup System (Step III)

(32) Reactor Water Cleanup Regenerative Heat Exchanger

Heat Exchange Capacity - Approximately 3,850,000 Btu/hr.

Design Pressure - 2500 psig at 670F (both sides).
Material -
  Shell - AISI Type 304 stainless steel (AISI Type 405 stainless steel possible alternate).
  Tubes, Tube Sheets, and Heads - AISI Type 304 stainless steel (AISI Type 405 stainless steel possible alternate).
Temperatures -
  Tube side - demineralized water
    Inlet - 630F
    Outlet - 310F
  Shell side - demineralized water
    Inlet - 110F
    Outlet - 430F
Connections - Welded
Construction - Rolled Tubes
Location - Primary System Water Service Area
Inspection - ASME Code Stamp required.

(33) Reactor Water Cleanup Cooler

Heat Removal Capacity - Approximately 2,000,000 Btu/hr
Design Pressure -
  Shell side - 150 psig
  Tube side - 2500 psig
Material -
  Shell - Carbon Steel
  Tube, Tube Sheets, and Heads - AISI Type 304 stainless steel
Temperatures -
  Tube Side - Demineralized water
    Inlet - 310F
    Outlet - 110F
  Shell side - Softened water
    Inlet - 85F
    Outlet - 160F
Connections - Flanged or welded as applicable
Construction - Welded-in tubes
Location - Primary System Water Service Area
Inspection - ASME Code Stamp required.

(34) Reactor Water Cleanup Filters

Type - "Ful-Flo" with cotton liners
Quantity - 2
Pressure Drop - 3 psi at 25 gpm
Material - AISI Type 304 stainless steel
Design Pressure - 2500 psig

Shielding - The filter casings are to be arranged for quick removal of liners by overhead crane and shielded with lead to provide a maximum surface level reading of 10 mr/hr.
Connections - Welded or flanged as applicable
Location - Primary System Water Service Area.

(35) Reactor Water Cleanup Ion Exchanger

Type - Mixed bed with cation bed preceding for preliminary scrubbing.
Design Pressure - 2500 psig
Capacity - 25 gpm demineralized water each.
Location - Active Equipment Area
Shielding - The ion exchangers are to be arranged for quick removal of resin cans by overhead crane and shielded with lead to provide a maximum surface level reading of 10 mr/hr.

(36) Reactor Cleanup Booster Pump

Capacity - 40 gpm
Quantity - 1
Discharge Head - approximately 50 psig
Material - AISI Type 304 stainless steel
Design Pressure of Casing - 2500 psig
Connections - flanged or welded
Motor - 440-v, 3-phase, 60-cycle AC
Control - Manual
Location - Active Equipment Area

Flow Measurement (Control Drive Thimble Cooling Water)

Rotameters (each thimble) - 1000 cc/min capacity
Design Pressure - 2500 psi
Design Temperature - 150F
Material - AISI Type 304 or 316 stainless steel. Packing must be radiation resistant. Materials other than asbestos or nylon must be specifically approved by the Laboratory.
Connections - flanged or welded
Location - Primary System Water Service Area

Flow Measurement (Control Drive Leakage)

Rotameters (each drive) - 1000 cc/mm capacity
Design Pressure - 100 psig
Design Temperature - 150F
Material - AISI Type 304 or 316 stainless steel. Packing must be radiation resistant. Materials

other than asbestos or nylon must be specifically approved by the Laboratory.
Connections - Flanged or screwed
Location - Primary System Water Service Area

Piping, Valves, Fittings

Material - Primary Side - AISI Type 304 stainless steel Schedule 160 welded. Secondary Side - carbon steel Schedule 40 screwed or flanged.
Design Pressure - 2500 psig at 670F

g. Primary Water Make-up System (Step III)

(38) Make-up Tank

Capacity - 500 gal
Material - AISI Type 304 stainless steel
Design Pressure - 50 psig at 200F
Connections - welded or screwed
Location - Primary System Water Service Area
Inspection - ASME Code Stamp required

(39) Primary Water Make-up Ion Exchanger

Type - Mixed bed
Design Pressure - 50 psig
Capacity - 15 gpm softened water
Location - Auxiliary Equipment Area

(40) Primary Water Make-up Pumps

Capacity - 17 to 20 gpm each
Quantity - 2 (1 operating and 1 stand-by)
Discharge Head - 4000 psi (positive displacement type).
Operating Temperature - 100F
Material - AISI Type 304 stainless steel
Connections - flanged or welded
Motor - 440-v, 3-phase, 60-cycle AC
Location - Primary System Water Service Area
Control - Manual

Piping, Valves, Fittings

Material - AISI Type 304 stainless steel welded
Design Pressure - 4000 psi at 200F on pump discharge side; 50 psig at 200F on pump suction side.

h. Core Spray System (Step I)

(42) Boric Acid Crystal Tank

Capacity - Approximately 250 gal
Material - AISI Type 304 stainless steel
Type - Special design drawing furnished by the Laboratory.
Location - Reactor operating floor upper level
Design Pressure - 50 psig
Inspection - ASME Code Stamp required

Special Valves

DC solenoid valves actuated by simultaneous low reactor pressure and water level signals (see Flow Chart, Fig. 12).

Piping, Valves and Fittings

Materials - Storage Tank to Boric Acid Tank - Carbon Steel, Schedule 40, screwed. Boric Acid Tank to Reactor - AISI Type 304 stainless steel, Schedule 40 between tank and first solenoid valves, schedule 160 between first valve and reactor.

i. Chemical Shutdown System

(45) Chemical Shutdown Boric Acid Tanks

Capacity - 900 gal each (2)
Contents - 900 gal (total in 2 tanks) concentrated boric acid solution.
Operating Pressure - 3000 psi
Design Pressure - 3600 psi
Design Temperature - 250F
Material - carbon steel with AISI Type 304 stainless steel liner.
Inspection - ASME Code Stamp required
Location - Auxiliary Equipment Area

(46) Compressor

Capacity - 1 cfm at 3000 psi
Material - Standard construction
Control - tank pressure between limits
Location - Auxiliary Equipment Area

(47) Special Valves

DC solenoid-operated valves connected into scram circuit of control system (see Flow Chart, Fig. 11).

Valves, Pipe, Fittings

AISI Type 304 stainless steel to meet design pressure requirements.

j. Vessel Closure Heating System

(49) Steam Generator

Capacity - 1500 lb/hr
Maximum Temperature - 825°
Maximum Pressure - 2000 psig
Heat Source - Fuel oil (medium grade)
Auxiliaries - Feed pump and controls
Material - Carbon steel (low alloy 4-6 chrome min.)
Location - Auxiliary Equipment Area

k. Vent and Drain Systems

Vent and drain requirements cannot be defined in detail until all equipment is designed and specified. In general it will be necessary to provide vents at all high points of the system run to appropriate collection points. Drains shall be provided from all low points of the system. All active drains will lead to the waste retention tanks. Active drains will include everything in the system except the effluent from the sanitary facilities in the control building. It shall be the duty of the Architect-Engineer to connect all vents and drains into their respective systems as the design progresses.

l. Domestic Water System

(50) Storage Tank

Capacity - 750 gal
Material - Aluminum or glass-lined carbon steel
Design Pressure - 125 psig
Design Temperature - 100F
Connections - Screwed
Location - Control Building Basement
Inspection - ASME Code Stamp required

Water Heater

Capacity - 80 gal
Type - Electrically heated, domestic
Location - Control Building Basement
Service - Personnel Showers, Lavatories, Laboratory Sink

Toilet Facilities

Number of Personnel - 15 males
Shower Stalls - 3
Drains - To Septic System

Emergency Shower

Location - Auxiliary Equipment Area near access door to Primary System Water Service Area
Drain - To Waste Retention Tanks

Drinking Fountain

Quantity - 1
Type - Electric Cooler
Location - Control Building Ground Floor

m. Waste Retention and Discharge Storage Tank System

(51) Waste Retention Tanks (Step 1)

Quantity - 3
Capacity - 9000 gal each
Approximate Size - 8 ft diameter by 24 ft long
Material - Carbon steel
Drain - Bottom of tank 4 in. I.P.S. flanged
Manhole - 20-in. diameter on head
Vent - Top (1/2 in. I.P.S. screwed)
Liquid Level Gauge - 6 ft high from bottom of tank (screwed connections)
Inlet - 3 in. flanged on top side
Design Pressure - 15 psig
Inspection - ASME Code Stamp required
Location - Active Storage Area

(52) Discharge Storage Tanks (Step III)

Quantity - 3
Capacity - 12,000 gal each
Approximate Size - 8 ft diameter by 32 ft long
Material - Coated steel
Drain and Inlet - 4 in. flanged on bottom
Manhole - 20-in. diameter on head
Vent - Top (1/2 in. I.P.S. screwed)
Liquid Level Gauge - (1 required only) 6 ft high from bottom of tank
Design Pressure - 15 psig
Inspection - ASME Code Stamp required
Location - Active Storage Area

(53) Waste Retention Tank Transfer Pump (Step I)

Capacity - 100 gpm
Discharge Head - 35 psig
Material - Bronze
Connections - Screwed
Motor - 440-v, 3-phase, 60-cycle AC
Location - Active Storage Area

(54) Pump Pit Sump Pump (Step I)

Quantity - 4
Capacity - 50 gpm
Material - Bronze
Type - Vertical - 5 ft extended shaft
Motor - 440-v, 3-phase, 60-cycle AC
Control - Float switch
Discharge - to Discharge Storage Tanks or to Retention Tanks by valve selection
Location - Active Equipment Pit

Piping, Valves, Fittings

Material - AISI Type 304 stainless steel where required, remainder carbon steel or bronze.
Design Pressure - As applicable.

(55) Discharge - Storage Tank Transfer Pump (Step III)

Capacity - 100 gpm
Discharge Head - 35 psig
Material - Aluminum or glass-lined carbon steel
Connections - screwed
Motor - 440-v, 3-phase, 60-cycle AC
Location - Active Storage Area

5. Building Services

a. Main Building

Heating - The Main Building shall be heated by means of oil-fired or electric heating units with forced air distribution. A minimum temperature of 50F shall be maintained in all areas of the Main Building during the most severe winter weather. Each heating unit shall be individually controlled by a thermostat located in the area served by the unit.

Ventilating - The upper portion of the High Bay Area and the Auxiliary Equipment Area shall be provided with sufficient ventilation to maintain a maximum temperature of 10F above the outside ambient temperature with the reactor operating in summer weather.

The reactor compartment shall be separately ventilated by a blower which draws air downward past the sides of the reactor vessel and discharges via the 100-ft high stack at a rate of approximately 500 cfm.

The active equipment pit shall be cooled by water cooling coils, air ventilation, or a combination of these in order to maintain the pit at a temperature not to exceed 120F with the reactor operating.

Fire Protection and Decontamination - The entire Main Building shall be equipped with a sprinkler system to afford protection against fire and to provide a means for initial decontamination of the building following accidental spread of contamination. The sprinkler system shall be manually controlled by separate valves for the High Bay Area, the Auxiliary Equipment Area, Primary System Water Service Area, and the active equipment pit, all located in the control room, and by individual manual valves located in the areas named. Fusible spray nozzles shall not be used.

An area fire alarm system shall be provided, as described in Section III-E-3. In addition, an automatic carbon dioxide fire extinguisher system shall be installed to protect the forced circulation and reactor feedwater pumps.

Compressed Air - A service air compressor having a minimum capacity of 30 cfm at 120 psig shall be located in the Auxiliary Equipment Area. The unit shall have a 100-cu ft receiving tank. Service lines for power tools and general use shall provide distribution to all parts of the main building. A 2-in. I.P.S. line shall extend to the vicinity of the reactor on the High Bay Area operating floor level to provide air for impact tool operation. No air lines from this compressor shall enter the Control Building, either at ground floor or basement level.

Emergency Shower - An emergency shower, to be used primarily for personnel decontamination, shall be located adjacent to the access door connecting the Primary System Water Service Area and the Auxiliary Equipment Area. The shower shall be supplied from the high raw water storage tank.

Drains - The active equipment pit shall be provided with sumps and sump pumps as specified in Section III-D-3. The Auxiliary Equipment Area shall be provided with floor drains, one of which shall be located below the emergency shower. These drains shall be connected to the waste retention tanks.

Fuel Storage Pit - The sump in the floor of the fuel storage pit shall be provided with a valved drain connecting to the waste retention tanks. An overflow drain pipe, not valved, shall also be connected. The overflow shall terminate in a vertical pipe with its upper end 4 in. below the reactor operating floor level, and shall extend downward within the pit at least 18 in. before passing out through the pit wall. A coupling shall be located 12 in. below the open end of the overflow pipe.

A clean water inlet, supplied from the treated water storage tank, shall enter the fuel storage pit at the top and shall terminate in a float-controlled valve whose discharge shall be located 18 in. below the reactor operating floor level. The float-controlled valve shall be adjustable to control the water level in the pit at any set point from 4 to 16 in. below the reactor operating floor level. The water inlet line shall also be equipped with a manual stop valve located in the Auxiliary Equipment Area.

The fuel storage pit shall be equipped with a clean-up system as specified in Section III-D-3. The intake to this system shall be located in the side of the pit 6 in. up from the pit floor and shall be protected from the entry of debris by a screen or other suitable arrangement. The discharge from the clean-up system shall enter the pit through the wall 18 in. below the reactor operating floor level.

b. Control Building

Heating, Ventilating, and Air Conditioning - The entire ground floor of the Control Building, as well as the laboratory room in the basement, shall be air conditioned. Equipment shall have sufficient cooling and heating capacity to maintain a maximum temperature of 80F with 35 per cent relative humidity at maximum summer outside ambient temperature, and a minimum temperature of 72F with 35 per cent relative humidity at minimum winter outside ambient temperature. Heating units shall be electric. Ventilation shall be provided in conjunction with the air-conditioning system sufficient to permit four changes of air per hour. The air inlet and outlet shall be equipped with CWS air filter units to protect against radioactive air entrance. Access doors shall be semi-gas-tight to permit pressurizing of building to 1/2 in. of water pressure against entrance of outside air, and the ventilating system shall be so designed.

The electrical equipment room in the basement of the Control Building shall be provided with sufficient ventilation (or air conditioning if necessary) to assure removal of all heat generated by the electrical equipment housed therein. Inlet air shall be obtained from, and discharge air shall be passed to, the same inlet and outlet facilities (CWS filter protected) as used by the ground floor air-conditioning and ventilation system.

Sanitary Facilities - Toilet, shower, and lavatory facilities for 15 males shall be provided on the ground floor of the Control Building, and lockers shall be provided for 30 people. A water cooler shall also be provided on the ground floor. Water for these facilities shall be supplied from the domestic storage tank, located in the Control Building basement. Drains from these facilities, as well as any floor drains provided on the ground floor of the Control Building, shall pass to a septic system. An 80-gal capacity electric domestic hot water heater shall be located in the basement.

In addition to the above, a shower and scrub sink shall be provided in the basement of the Control Building as close as is practical to the tunnel connecting to the main building; these facilities will be used for personnel decontamination. A stainless steel laboratory sink shall be provided in the basement laboratory room. Hot and cold water supply for these basement facilities shall come from the domestic storage tank and hot water heater, but drains from these as well as from floor drains in the basement shall pass to the main building sumps and thence to the retention tanks. A foot valve or other suitable device shall be placed in this drain line to prevent any back flow of contaminated water into the Control Building.

Provision shall be made for 15 persons to remain within the Control Building for a period of 48 hr in the event of an incident resulting in contamination of the surrounding area. A kitchen-type sink shall be installed in the lunch room on the basement floor of the control building, and provision shall be made for the installation of an electric cooking stove, a refrigerator, a food freezer, and cooking utensil storage cabinets. (The Laboratory shall provide this equipment.)

Compressed Air (Instrument) - An air compressor having a capacity of 15 cfm at 120 psig shall supply instrument air, if required. Filters and driers shall be furnished to provide positive protection from moisture, oil, and particulate matter. Driers shall be of the type utilizing silica gel as the drying medium. The system should include the equivalent of a Dollinger CPH-2 pre-filter, a Kemp drier with Vapoilsorid unit, and a Dollinger AAPH-15 post-filter unit. The entire compressor system shall be located in the basement in a sound reducing area.

6. Cranes

One overhead, top-running double-girder traveling crane for standby use in maintenance and repair of machinery and components, as well as for moving reactor top shielding and vessel cover, is required. The crane has a span of 37 ft 0 in. and has a full load capacity of 40 tons. The crane bridge shall be constructed of box girders or rolled beam shapes capped by suitable ASCE rails.

The crane hook shall be capable of approaching the crane rail on the water cooler area side of the High Bay Area within 3 ft, and shall be capable of approaching either end wall of the High Bay Area within 5 ft. The total lift of the crane shall be sufficient to permit the hook to approach the floor of the active equipment pit to within 4 ft.

With the hoisting motor of the crane operating at synchronous speed, the speed of vertical movement of the crane hook shall be 10 ft/min. The controller shall be full magnetic type, having not less than five speed points in hoisting and lowering. Smooth acceleration must be provided for all loads in both directions and lowering shall be accomplished without the use of a mechanical load brake.

Speed on the first lowering point shall not exceed 15% of synchronous speed of the hoist motor for lowering a hook load of 25% to 100% of rated load. Lowering speeds for all loads within the rated capacity shall be gradually increased by advancing the controller from "off" position towards "full on" lowering position. The speed change between lowering steps shall not exceed 35% synchronous speed at any given load up to 100% rated capacity. The last point lowering shall provide regenerative braking. The lowering speed shall not exceed 125% of the synchronous speed on any control point.

The primary alternating current shall be balanced in each of the three phases at all times. The primary alternating current shall not exceed 130% full load motor current in the hoisting direction and shall not exceed full load motor current in the lowering direction. The speed on the first hoisting point with no load on the hook shall not exceed 25% of the synchronous speed of the motor and shall not pass through the zero speed line with any load up to 125% of rated crane capacity. The hoisting speeds for all loads within the rated crane capacity shall be gradually increased by depressing the control pushbutton from the "off" position towards the "full on" hoisting position.

Mechanical brakes, spring set and electrically released, shall be provided on the hoist motor. A permanent pole alternator shall be connected to the magnetic eddy current load brake so that lowering speed in the event of simultaneous electric power and mechanical motor brake failure is limited to approximately 25 per cent of full load hoisting speed.

The speed of motion of the bridge and of the trolley shall be 30 ft/min for each motion, with the respective drive motors operating at synchronous speed. The controllers for these motions shall be full magnetic type, having not less than five speed points in either direction. Smooth acceleration must be provided for all loads in all directions. The speeds obtained in the five speed positions of the control pushbuttons shall have approximately the same relationship with each other, under all load conditions, as those obtained with the hoisting control.

Control of all motions of the crane shall be by pendant pushbuttons. Separate five-position pushbuttons for hoist raising, hoist lowering, trolley forward, trolley reverse, bridge forward, and bridge reverse, as well as power on and off buttons, shall be mounted in a pendant control box suspended by a chain from the crane trolley on the steam condenser area side of the crane hook. Suspension of the pendant control box from a separate monorail trolley would be preferable, if possible.

The 1-ton auxiliary monitor crane to be used for handling of fuel elements, control rods, etc., shall be specially designed for this purpose and purchased by the Laboratory for installation by the construction contractor.

All power for cranes shall be 440-v, 3-phase, 60-cycle AC. Electric power shall be fed to crane bridges, and from bridges to trolleys, by means of feedrails. Pendant cables and cable reels shall not be used for power feed.

E. Electrical

1. General

The design and construction of the electrical system for the ARBOR Facility shall embody and reflect the best practical and economical engineering design features. All equipment, apparatus, components devices, and materials to be incorporated in the design must conform in all respects to the standards of the American Standards Association, the American Institute of Electrical Engineers and the National Electrical Manufacturers Association. All wiring shall conform to the requirements of the National Electrical Code.

All conduits are to be run exposed along ceilings and walls where possible. Where conduits pass into the control room or electrical equipment room from other areas, a designated number of wires will be pulled and the conduit sealed, if required. All wire and conduit requirements are to be determined. The minimum wire size to be used throughout the plant, including thermocouple leads from junction boxes to instruments and shielded coaxial cables for nuclear instrumentation, shall be No. 14 gage.

All electrical components and wiring to be installed in the active equipment pit, Active Storage Area, Primary Water System Service Area, and water cooler and condenser areas shall have Class H radiation damage-resistant insulation or equivalent. All electrical components and wiring to be installed in the active equipment pit, the Primary Water System Service Area, and Active Storage Area shall be capable of operation at temperatures up to 150F.

Cables for the 13,800-v circuits must have a 15,000-v ungrounded neutral system voltage rating. Cables for 4160-v circuits must have a 5000-v rating.

Complete ground bus systems must be provided in each of the buildings for the convenient grounding of electrical equipment enclosures, motor frames, conduit systems, etc. Lightning protection for all buildings must be provided in accordance with U. S. Department of Commerce "Code for Protection Against Lightning" Handbook 46.

The quantities and sizes of the electric motors used in the plant will be determined from the requirements of the plant auxiliaries. All motors 1/2 horsepower and larger shall be 440-v, 3-phase, 60-cycle AC, except in the case of the large forced-circulation, reactor feed-water, and water cooler and condenser secondary feed-water pump motors, which will be 4160-v, 3-phase, 60-cycle AC as recommended by the pump manufacturers. Motors smaller than 1/2 horsepower may be either 110-v, 1-phase or 440-v, 3-phase, 60-cycle AC, as convenient. In general, motors are normal torque motors of the drip-proof types. Motors for outdoor service or for operation in moist atmospheres are of the totally enclosed, fan-cooled type. Drainage plugs are provided in the end shields of totally enclosed motors.

All motors shall be started across the line if possible. However, particular care is required in specifying starting equipment for motors of 800 horsepower and higher, to assure compatibility with main Site 16 substation equipment being provided at the EBR-II site. Coordination with the designers of this equipment is imperative. Reduced voltage starting and other special features may be necessary for these motors.

Circuit breakers and magnetic starters for all motors and components shall be located in the electrical equipment room in the basement of the Control Building, with the possible exception of those for the forced circulation and reactor feed-water, and water cooler and steam condenser secondary feed-water pump motors, where economic study by the Architect-Engineer may indicate more advantageous placement elsewhere. In addition, all components, except the main pump motors just mentioned, shall be provided with locally mounted disconnect switches for safety during maintenance work. These switches must be hp-rated, non-fusible safety switches with provisions for padlocking in both the open and closed positions, and must meet NEMA standards and Federal Specifications W-S-865 for Type A switches.

The position of operating handles, levers, etc., of all circuit breakers and disconnect switches must clearly indicate to the operator the position of the breaker or switch. Provision must be made for padlocking circuit breakers in either "Open" or "Test" positions. Disconnect switches must have provision for locking either open or closed.

Each magnetic starter shall be controlled by a pushbutton station in the control room. Control power for each magnetic starter for a motor shall be 110-v AC supplied by an individual unfused transformer connected to the load side of the circuit breaker for that motor. A green pilot light, marked "Power On" and located above the push-button station, shall indicate that the breaker is closed and the motor is ready to be started. An amber pilot light marked "Run" shall indicate when the motor has been started, and the green light shall be extinguished when the amber light is energized. All push-buttons operating motor starters shall be marked "Start" or "Stop." "Jog" or "Test" buttons, where needed, shall be so marked. Black buttons shall be used for start, jog, and test functions. Red buttons shall be used for stop.

Where motors operate valves, momentary contact push-buttons shall be used for control. Black buttons shall be used for opening and shall be marked "Open." Red buttons shall be used for closing and shall be marked "Close." For each valve, a green pilot light marked "Power On" shall be energized when power is available to operate the valves. A white pilot light marked "Open" shall indicate the fully open valve position, and a blue pilot light marked "Closed" shall indicate the fully closed position. These pilot lights shall receive their signals from limit switches mounted on the valve, which shall also have the function of interrupting power to the drive motor at the limits of travel. In cases where position indication throughout the range of the valve is required, a meter-type indicator shall be mounted above the pilot lights.

All relays used for interlocking and control circuits shall be 110-v AC, magnetically operated, constant duty. They shall have a minimum of four normally open and four normally closed contacts with electrically separate terminals for all contacts, such as Square D Type AG-40. Relays having more than these numbers of contacts (e.g., Square D Type AG-60) may be used where required. Where a group of relays are interrelated in function, they may be of the open type (e.g., Square D Type AO-40 or AO-60) and mounted in a common enclosure with full door access, adequately ventilated with dust-free air.

Clearly reading nameplates must be installed on all equipment and devices for explicit identification. Instruction nameplates must also be installed where specific instruction or precaution is essential.

2. Instrumentation and Controls

Control of the operation of the entire plant is to be centralized in a control room adjacent to the Auxiliary Equipment Area. Remote control of all valves, motors, and other controlled devices whose operation is part of daily plant routine must be possible from the control room. Metering and recording of all important plant and reactor quantities will be done in the control room as specified. All control power for reactor controls will be 110-v AC. Where constant voltage is required for electronic counter devices, control and/or instrumentation, electronically controlled voltage regulators with a fast time response shall be employed.

Pressure, temperature and flow controls are a part of the complete experimental reactor system, which includes control of the nuclear reactor. The system will be designed as set forth in this section to provide extreme flexibility in control parameters. The control circuits for related operations of equipment should be interlocked, insofar as possible, to prevent improper sequence of operation due to human error.

In general, control of steam flow, water flow, steam pressure, inlet subcooling, water level, condensate flow, etc., should be by electric motor-operated controllers (except where fast response requires air operation) mounted as close as possible to the device controlled. Signal and set point information will be telemetered from the instrument to the control room. Electrical transmission of signals shall be used in all cases except where there are specific reasons for employing other means. Where an instrument is directly connected to the primary system for measurements such as flow, etc., there must be no possibility for the instrument to contaminate the primary system with undesirable materials under any condition of operation, including any possible failures of the instrument.

The entire instrumentation and control system, with the exception of nuclear detection instrumentation and control rod drives and position indicators, shall be designed by the Architect-Engineer in close cooperation with instrument and instrumentation system manufacturers and with the Laboratory. Where control room space is required for Laboratory-supplied items, such as the devices excepted above, the Architect-Engineer shall provide such space as required and shall integrate these devices into the general control room arrangement.

It should be emphasized that the general control schemes indicated here are tentative and subject to change when more detailed design studies indicate that changes are desirable.

Control Room

The Control Room Area in the Control Building will be approximately 20 ft x 50 ft in size and shall have a centrally located control console containing the instrumentation and controls necessary for reactor start-up and operation. The three walls in view of the reactor operator when seated at the console will contain the various system recorders, indicators and controls together with the central annunciator and shut down panels.

Recorded indication from the system will be displayed on various strip and circular chart recorders as specified below. The panels should be of standard width, with instruments mounted for convenient reading. All recording instruments shall be equipped with large pointers or scale indicators readable at a distance, and shall be mounted to afford full view to the control console. It is desirable to have one company furnish all instruments insofar as possible in order to obtain a uniform appearance and to facilitate maintenance. Panels should be designed to enable complete internal wiring and dust sealing in the manufacturer's shop, and arrangements should be provided for interconnection to other panels and to reactor and system components without disturbing dust seals (via the electrical equipment room in the Control Building basement) by means of floor open raceways just behind the panels.

Control Console

The control console will be located approximately in the center of the control room. The exact size of console is subject to the control and indicating equipment selected. The console will be arranged so that a seated operator can reach all console controls and observe all indicators located on the wall panels ahead of and to the side of the console.

The console will contain the suitable controls to actuate and manually override any automatic systems associated with:

(1) Control Rods
(2) Steam Stop Valves, if installed
(3) Turbine-Simulator Steam Throttle Valves
(4) Steam By-pass Valves
(5) Reactor Feed-water Flow-Control Valve
(6) Water Cooler and Forced-Circulation By-pass Flow Control Valves
(7) Emergency Shut-down System, Control Rod Scrams, etc.

The following indicators will be located at the control console:

(1) Control Rod Position Indicators
(2) Galvanometer Scale indicating Ion Chamber Current Proportional to Reactor Power
(3) Reactor Period Meter
(4) One miniature, continuously indicating linear scale strip chart millivolt recorder connected to ionization chamber amplifiers.
(5) Reactor Pressure Indicator
(6) Flow Indicators for the following:
    - Turbine simulator steam flow
    - Total steam flow
    - Reactor feed-water flow
    - Total forced-circulation water flow
    - Forced-circulation by-pass flow
(7) Pilot lights indicating pumps operating, power on, etc., as specified later.

Parameter Control Jack Board

Since a great deal of cooperative study will be necessary to achieve the final design of the parameter control jack board, only the most general requirements may be specified here, and it must be emphasized that even these are subject to change.

As now visualized, the parameter control jack board must contain at a minimum the input, output, and signal mixing and adjustment facilities listed in Table III. All input signals from the various measuring devices and from signal mixers, proportioners and generators enter the jack board in the form of plug-ended cables which are retracted into the board when not in use, in the manner of the cables of a telephone switchboard. All output connections passing to controllers (for set point adjustment), control valve positioners, and signal mixers and proportioners shall appear on the board in the form of jacks into which the retractile plug cables may be inserted to set up desired control systems. All proportioning controls, signal generators, etc., directly connected with the jack board shall be mounted in the same panel section with the jack board and shall be internally wired and tested in the manufacturer's shop. All plug cables, jacks, controls, etc., shall be clearly identified by means of nameplates, engraved captions on the board itself, or other suitable devices. The number of plug cables or jacks representing each signal, as well as the number of each signal mixer and proportioner required, must be determined through study.

Table III

PARAMETER CONTROL JACKBOARD CONNECTIONS

Input Signals Proportional to	Signal Mixers and Proportioners*	Output Signals
Reactor pressure	$y = Kx$	Central control rod drive
Total steam flow	$y = x_1 + x_2$	Turbine-simulator flow control valves
Turbine simulator steam flow		
By-pass steam flow	$y = -x$	Steam by-pass flow control valve
Reactor feed-water flow	$y = x_1 x_2$	Water cooler flow control valve(s)
Forced-circulation water flow	$y = 1/x$	
Forced-circulation inlet sub-cooling	$y = f(s)$**	Forced-circulation by-pass flow control valves
Reactor power	$y = f(t)$***	
Central control rod position		

*Nomenclature: x, x_1, x_2 = input signals
y = output signal
K, K_1, K_2 = multiplier, dial controlled
t = time

**Obtained from curve tracing device where $y = f(x)$ may be any predetermined relationship between x and y.

***Obtained from signal generator capable of producing such signals as $y = K_1 \sin K_2 t$, $y = Kt$, etc.

75

System Control and Recorder Panels

a. General Description

The other necessary controls, indicators, and recorders not contained at the control console will be contained along the three wall faces in view of the console operator. The location of each component, except where specified, will be determined by the Laboratory at a time when more information relative to size, type and number of instruments is available.

b. Annunciators

A multi-point emergency shut-down annunciator, featuring mechanical reset, will be installed on the central portion of the control room wall panel. This annunciator shall provide interlock contacts of a fail-safe variety which may be used for emergency shut-down purposes.

A multi-point standard plant annunciator featuring electrical reset will be installed adjacent to the above unit. This may take the form of several annunciator cabinets, in order to provide sufficient stations conveniently, but all cabinets shall have common reset and audible alarm features as described below.

The annunciator panels will be elevated so they are in view of all points in the control room in front of the panels. They shall be so arranged that in the event of an abnormality, a horn sounds and a flashing light behind a translucent panel bearing the identification of the abnormality is energized. The operator's actuation of a reset button (separate for shut-down annunciator and plant annunciator) silences the horn and causes the hitherto flashing light to remain on continuously. When the abnormality is corrected, the light again flashes and a bell is heard. A second actuation of the reset button silences the bell and de-energizes the flashing light. The sound of the shut-down annunciator horn shall be louder and easily distinguishable from the plant annunciator horn. The annunciators shall be wired so that horn and bell are actuated for an abnormality regardless of other stations which are in the reset condition with lights on continuously.

c. Nuclear Data Recorders

The nuclear data recorders will be located adjacent to or below the annunciator panels. These will include:

(1) Three miniature, linear scale strip chart continuously indicating millivolt recorders for power-level trip circuits. The recorders will be equipped with high and low-level alarm contacts which can be set to desired levels for limited indication and shut-down annunciator operation. Test circuits must also be provided.

(2) One indicating millivoltmeter for reactor period indication. High and low alarm contacts will be provided as in (1) above. (Meter is to be located on control console.)

(3) Two continuously indicating strip chart millivolt recorders, one linear and one logarithmic, are to be provided for ionization chamber amplifiers.

(4) Means for recording control rod positions. A numerical printing type device should be considered.

d. Primary System

The various primary system signals to be indicated or recorded are listed below. The type of indication or record associated with the signal is noted; in the case where a signal is used for control, the controlled component is listed. Measurements associated with primary system steam flows and forced-circulation water flows and inlet subcooling require special care in the selection of the measuring device and recorder in order to assure highest attainable accuracy within the limits of practical design.

In several cases the controller output may be used for control of more than one function; these controllers will deliver their output to the Parameter Control Jack Board described above.

(1) Reactor Pressure - Reactor pressure will be measured at the top of the reactor water column and continuously recorded on a linear scale strip chart recorder. Reactor pressure will be used as a multiple control function and a signal will go to the Jack Board. The pressure recorder will have adjustable high and low alarm contacts which will be used for shut-down purposes and indicated on the shut-down annunciator.

(2) Reactor Temperature - Reactor temperature will be measured at a point on each of the steam lines close to the pressure vessel. This signal will be continuously indicated and will be used also to actuate adjustable high and low alarm contacts for shut-down annunciator operation.

(3) Reactor Water Level - Reactor water level will be measured by both differential pressure and float-type devices. Two float devices will be installed, one at the top and other at the bottom of a water column connected to and adjacent to the reactor vessel, which will actuate fixed high and low alarm contacts for shut-down annunciator actuation. The differential pressure, which will be measured by a differential pressure gage connected to the water column, will be continuously recorded on a 24-hr circular chart recorder with adjustable high and low alarm contacts

for the shut-down annunciator. The water level error, registered by the difference between the differential pressure measurement and a manually adjustable set point, will comprise one signal for use in controlling reactor feed-water flow rate. This signal will be combined with signals from the feed-water flow rate and the steam flow rate to position the feed-water control valve (see 4 and 13 below). In addition, a gage glass will be connected to the water column for direct visual observation of the reactor vessel water level by television camera relay to the control room.

(4) Flow through Steam Distribution Manifold - The simulated turbine steam flow will be measured by the four orifices upstream of the throttle valves. In addition, the flow-through orifices installed ahead of the steam by-pass simulator flow and the hotwell temperature control valves will be metered. The sum of these signals will be recorded on a multi-range linear scale strip chart recorder and will comprise the total steam flow. This flow signal will be used in the three-element feed-water flow control system.

In addition, the four turbine-simulator flow signals will go through a recording flow controller to the Jack Board for multiple control. Individual flows from each of the above orifices will be selectively monitored on a multi-point indicator.

(5) Steam By-pass Simulator Flow - The steam by-pass simulator flow will be measured by means of an orifice upstream of the throttle valve and the signal continuously recorded on a linear scale strip chart recording flow controller. Jack Board outlets for this signal will also be provided.

(6) Steam Condenser Temperature and Pressure Control - The differential temperature and pressure between the secondary coolant steam on the shell side and the primary system fluid on the tube side of the condenser inlet shall be controlled by a variable range recording pressure controller. This instrument will control the operation of the secondary coolant steam release valve. The plant annunciator will be actuated by individual readings at adjustable limits to indicate abnormal operating conditions.

Other methods of controlling condenser operation shall be investigated.

(7) Steam Condenser Liquid Level - Steam condenser secondary side water level will be measured by a differential pressure controller. This controller will operate the control valve in the secondary coolant feed-water pump discharge line. Liquid level will be read on a multi-point indicator.

(8) Condenser By-pass Steam Flow - The flow of steam through the hotwell by-pass will be measured and indicated in the control room on a multipoint flow indicator.

(9) Hotwell Pressure - Hotwell pressure will be measured and continuously recorded on a 24-hr circular chart proportional recorder-controller. This signal will control the position of the condenser by-pass steam flow control valve S9. The controller will have adjustable control point and band width, and high and low alarm contacts to actuate the plant annunciator.

(10) Hotwell Temperature - Hotwell temperature will be measured and indicated in the control room on a multi-point temperature indicator.

(11) Hotwell Level - Hotwell level will be measured by a differential pressure device and continuously recorded on a 24-hr circular chart proportional recorder-controller. The controller will have an adjustable set point and band width and will be used to control the make-up water flow control valve. High and low level alarm contacts will be provided to actuate the plant annunciator.

(12) Hotwell De-aeration Flow Rate - The rate of flow from the hotwell vent line will be continuously recorded on a 24-hr circular chart proportional recorder-controller, which will maintain desired flow by adjustment of flow control valve position. Adjustable set point and band width are required.

(13) Reactor Feed-water Flow Rate - The rate of feed-water flow will be measured by means of an orifice. This signal will be continuously recorded on a linear chart proportional recorder-controller. This signal, coupled with reactor water level and total steam flow, comprise the standard three-element feed-water control system.

(14) Reactor Feed-water Temperature - The reactor feed-water inlet temperature will be measured at a point on the feed-water line as close to the reactor vessel as possible. This signal will be indicated on a multi-point temperature indicator.

(15) Forced Circulation Water Outlet Subcooling - The differential between the reactor temperature (2 above) and the individual reactor coolant outlet lines (close to the vessel) will be measured and indicated on a multi-point differential temperature indicator.

(16) Forced Circulation Water Inlet Subcooling - The differential between the reactor temperature (2 above) and the reactor coolant inlet temperature will be continuously recorded on a linear scale strip chart recorder. This signal is for multi-purpose control and will go to the Jack Board.

(17) Water Cooler Liquid Level - Water cooler secondary side water level will be measured by a differential pressure controller. This controller will operate the control valve in the secondary coolant feedwater pump discharge line. Liquid level will be read on a multi-point indicator.

(18) Water Cooler Temperature and Pressure Control - The differential temperature and pressure between the secondary coolant steam on the shell side and the primary system water on the tube side of the water cooler inlet shall be controlled by a variable range recording pressure controller. This instrument will control operation of the secondary coolant steam release valve. The plant annunciator will be actuated by individual readings at adjustable limits to indicate abnormal operation conditions.

Other methods of controlling water cooler operation shall be investigated.

(19) Forced-Circulation Water Flow - The signal from the total forced-circulation flow tube (WF4) will be continuously recorded on a square root circular chart flow recorder controller. This recorder will be equipped with a low flow alarm contact for shut-down annunciator actuation. This total flow signal will also go to the Jack Board. This signal will control the forced circulation by-pass butterfly valve. Flows through the by-pass orifices and the individual heat exchanger flow orifices or venturi shall be individually read on a multi-point flow indicator and used to check the main flow tube.

e. Auxiliary Systems

In general the instrumentation and control of auxiliary systems will be as simple as possible. Selective indication in the control room of most signals will be required, but only a few will require continuous recording. In general, when a signal is listed in the following section only selective indication is required. In cases where control or high and low-limit alarm contacts are required, these functions are noted.

(1) Reactor Water Clean-up System (Step III)

(a) Temperatures at regenerative heat exchanger inlet and discharge points, both sides.
(b) Temperatures at discharge of cooler - high-temperature alarm contact to close valve in return line to reactor and actuate plant annunciator.
(c) Conductivity of water entering and leaving system.

(d) Flow through system - low alarm contact to actuate plant annunciator.

(e) Differential pressure across pre-filters - high contact for plant annunciator actuation.

(2) Control Rod Thimble Cooling

(a) Thimble temperatures (each thimble) - high-temperature contacts on each thimble for common plant annunciator actuation.

(b) Flows (each rod drive) - local reading only.

(c) Total flow.

(3) Control Drive Seal Leakage

Flows (each rod drive) - local reading only - high flow contacts on each drive for common plant annunciator actuation.

(4) Primary Water Make-up System (Step III)

(a) Make-up tank level - equipped with two sets of high and low contacts, one for operation of softened water admission valve, the other (at wider limits) for plant annunciator actuation.

(b) Make-up tank temperature - high-temperature contact for plant annunciator actuation.

(c) Make-up water flow - continuously recorded on 24-hr circular chart flow recorder.

(d) Make-up pump pressure - low pressure contact for plant annunciator actuation.

(5) Shield Cooling System

(a) Individual coolant loop flows - local reading only - low flow contact on each loop for common plant annunciator actuation.

(b) Total flow - low pressure contact for plant annunciator actuation.

(c) Common loop discharge temperature - high-temperature contact for plant annunciator actuation.

(d) Surge drum level - high and low-level contacts to actuate common plant annunciator.

(6) Fuel Storage Pit Cooling and Cleanup System

(a) Stprage pit temperature - high-temperature contact for plant annunciator actuation.

(b) Heat exchanger outlet temperature - high-temperature contact for plant annunciator actuation.

(7) Primary Make-up Ion Exchanger System (Step III)

Conductivity of ion exchanger discharge.

(8) De-aeration System (Step III)

(a) Flow - as mentioned above, de-aeration flow from the De-aerating-Hotwell will be measured by a 24-hr circular chart proportional recorder-controller which will maintain desired flow by automatic adjustment of the flow control valve position.
(b) Temperature of gas entering after-condenser.
(c) Temperature of gas leaving after-condenser.
(d) Temperature of condensate leaving after-condenser-high-temperature contact for plant annunciator actuation.
(e) Temperature of gas leaving recombiner.
(f) Other instrumentation as required for recombiner.

(9) Chemical Shut-down System

(a) Pressure - local indication only. Low pressure contact for plant annunciator actuation.
(b) Liquid Level - local indication only (gage glass).
Low-level contact for plant annunciator actuation.

(10) Core Spray System

Flow into reactor - no indication. A flow detector actuates plant annunciator when flow into reactor occurs.

(11) Emergency Cooling System

(a) Flow into coolers - no indication. A flow detector actuates a common plant annunciator when flow into either cooler occurs.
(b) Effluent steam temperature - high-temperature alarm detects water leakage into cooler and actuates plant annunciator.

(12) Auxiliary Cooling Water System

(a) Auxiliary cooling water effluent temperatures - high-temperature contacts on all secondary coolant effluent lines from heat exchangers, pumps, etc., to actuate common plant annunciator.

(b) Temperature leaving air-cooled heat exchanger or cooling tower-high-temperature contact to actuate plant annunciator.

(c) Circulating pump discharge header pressure - local indication only. Low-pressure contact for plant annunciator actuation and automatic switch-over to stand-by pump.

(13) <u>Water Supply System</u>

(a) Raw water storage high tank level - local limit switches control motorized valve to fill tank. Low-level contact actuates plant annunciator.

(b) Domestic storage tank level - local indication only (gage glass). Low-level contact actuates plant annunciator.

(14) <u>Waste Retention and Storage Tank Drain System</u>

(a) Waste retention tank level - local indication only. High-level contact to actuate plant annunciator. (Separate for each retention tank.)

(b) Discharge storage tank level - local indication only. High-level contact to actuate plant annunciator. (Common gage and contact for all three tanks.)

(c) Flow to discharge storage tanks - no indication. Flow detector to actuate plant annunciator upon flow into tanks.

f. <u>System Activity and Radiation Levels</u>

At selected points in the system, radiation levels will be measured. Some of these signals may be used to actuate the shut-down annunciator at present high levels. The remainder are for use in general plant radiation monitoring. All these measurements will be recorded on a multi-point linear scale strip chart recorder with a high-level contact to actuate the plant annunciator.

g. <u>Additional Indicators</u>

Additional pilot lights, indicators, alarms, etc., may be added as the detailed design of the plant develops.

3. Power and Lighting

Power for the ARBOR Facility shall be obtained from the main 13,800-v bus at the main Site 16 substation location, about 1/2 mile away. The total demand load for the facility is estimated to be 9000 kw. The Architect-Engineer shall include in his design the necessary 13,800-v power transmission line for two feeders, and shall design the local substation needed to transform and distribute this power at the ARBOR site.

An emergency power system shall be provided to supply sufficient power to critical components to permit orderly shut-down of the plant. This system shall consist of a diesel generator set equipped for automatic start-up in the event of simultaneous failure of both power feeders. The generator shall supply 440-v, 3-phase, 60-cycle AC to an emergency power circuit which is normally fed from the regular 440-v bus, and to which are connected the items listed below. The diesel generator shall be capable of carrying this load for a minimum of eight hours without attention.

1. Selected lights throughout the plant areas, sufficient to insure personnel safety.
2. All lighting in the Control Room
3. All instrumentation and motorized valves.
4. Instrument air compressor
5. Forced-circulation pump No. 1 (440-v emergency operation motor).
6. Cooling water circulating pump.
7. Shield cooling circulating pump.
8. Control room air conditioners
9. Food freezer, refrigerator, and cooking stove
10. Public address system.
11. Sump pumps.

Consideration must be given to the need for applying the emergency loads to the diesel generator in time-delayed steps rather than all at once, in order to prevent overload of the generator and/or the diesel engine starting motor.

A line diagram showing a suggested electrical distribution system for the ARBOR Facility is given in Fig. 13.

Lighting in the high bay and auxiliary equipment areas of the main building shall be provided by incandescent fixtures capable of producing a minimum of 30 ft-candles of illumination at all work surfaces. Duplex convenience outlets of the combination two- and three-pole type for 110-v service shall be spaced at about 10-ft centers around all work areas. Outlets providing 208-v and 440-v, 3-phase service shall be spaced to service approximately 1000 sq ft of floor area each.

Wall-mounted incandescent fixtures capable of operation at temperatures up to 150F shall be provided in the active equipment pit, Primary Water System Service Area, water cooler and condenser areas, and Active Storage Area to produce a minimum of 30 ft-candles of illumination at all work surfaces. Convenient outlets shall be provided for 110-v, 208-v, and 440-v service as specified for other areas of the Main Building.

Lighting in the Control Building shall be provided by incandescent fixtures sufficient to produce 50 ft-candles of illumination on the ground floor and in the basement laboratory room, and 30 ft-candles in other basement areas at all work surfaces.

On the ground floor of the Control Building, 110-v duplex combination two- and three-pole receptacles shall be provided at frequent intervals around the walls of the control room and on the fronts of the control panels. Separately wired 110-v outlets on separate circuits for the refrigerator and food freezer, and a 208-v receptacle for the electric cooking stove, shall be provided. Receptacles for 110-v service spaced on 4-ft centers, and two 208-v receptacles on opposite walls, shall be provided in the laboratory room. In other areas of the control building basement, 110-v, 208-v, and 440-v outlets shall be provided as specified for the areas in the Main Building.

Suitable exterior lights shall be provided for lighting the ARBOR site parking area, the walk between the parking area and the main entrance, and the main entrance proper, according to normal practice.

4. Communications

a. Public Address System - A public address system audible at any point in the High Bay, Auxiliary Equipment, and Active Storage Areas of the Main Building, the active equipment pit, all rooms in the Control Building, the water cooler and condenser areas, and outside the main entrance to the Control Building within the storm shelter extension, shall be provided. Microphones shall be provided in the High Bay Area on the operating floor, the Auxiliary Equipment Area, the active equipment pit, the Control Building basement, the control room, and outside the main entrance to the Control Building inside the storm shelter extension. Microphones shall have "press to talk" switches which shall also mute any speakers in the immediate vicinity of the microphone concerned to avoid feedback.

b. Internal Telephone System - An internal telephone system consisting of six independent circuits with jacks for all six circuits strategically located throughout the entire plant shall be provided. The system should be arranged so that it is possible to plug handsets into any two jacks in the plant corresponding to the same circuit and converse. Four of the circuits should be amplified, and two of the circuits should be sound-powered. No ringing devices will be necessary with this system.

c. Bell System Telephones - Four trunk lines shall enter the ARBOR site. Instruments having illuminated push-buttons for each of the four trunk lines plus a "hold" button shall be placed on the High Bay Area operating floor, the Auxiliary Equipment Area, the laboratory room in the Control Building basement, the control room, and near the main entrance. Only those instruments in the Control Building shall ring with incoming calls. The instrument in the control room shall be equipped with a microphone and loudspeaker arrangement to permit telephone operation without lifting the regular instrument receiver, if desired.

IV. SCOPE OF WORK AND DIVISION OF EFFORT

A. Laboratory Effort

In general, the Laboratory shall design and supply the ARBOR Facility components which are unusual with respect to normal industrial practice or which are particularly vital to reactor operation. These include:

1. All reactor components, including the reactor vessel shell, support, insulation, internal fittings, fuel elements, control rods, control rod drives, and top cover. The Laboratory has placed a contract for fabrication of the reactor vessel and will be responsible through a subcontract for transport and installation. Connection to the system piping will also be the Laboratory's responsibility.

2. Fuel handling equipment.

3. All coffins for the transference of radioactive materials.

4. Nuclear and radioactivity monitoring instrumentation. Information as to location and support requirements will be supplied by the Laboratory for incorporation into the proper Architect-Engineer drawings.

5. Research instrumentation (within the reactor vessel and related special apparatus outside). Structural and mechanical requirements, such as conduit locations, etc., will be supplied to the Architect-Engineer for incorporation into the proper drawings.

B. Architect-Engineer Effort

The Architect-Engineer shall execute the detailed design of all other portions of the ARBOR Facility not listed above as designed by the Laboratory, in accordance with design requirements established by the Laboratory, and shall prepare detailed specifications for said items. Within this area the Architect-Engineer shall perform the necessary design work with a minimum of guidance and supervision by the Laboratory. The following is a partial list of these items:

1. General

Site development (including roads, fences, walls, water supply systems, lighting, security buildings, electrical power supply, etc.).

2. Primary System

a. Water Coolers and Steam Condensers - Investigation of the most suitable method of heat disposal from the reactor system has been in progress at the Laboratory for a considerable length of time. Engineering estimates of various types of heat exchangers have been reviewed with respect to the preparation of suitable specifications. The accumulated information will be made available to the Architect-Engineer for completion of study and for preparation of the specifications for subsequent procurement by the Laboratory.

b. Forced-Circulation and Reactor Feed-Water Pumps. Considerable effort has been expended by the Laboratory to utilize shaft-sealed pumps for ARBOR Project. Due to operating conditions, these pumps must accommodate high suction pressures and under certain circumstances must operate with low NPSH.

Preliminary specifications have been prepared on the basis of information obtained in working with various prospective vendors. Final specifications shall be prepared for submission to prospective vendors as soon as all design requirements are firmly established. Delivery will be required by the winter of 1958.

c. All water coolers, steam condensers, pumps and foundations, pipe trenches, shielding walls, High Bay Area cells, Active Storage Area drain and retention tank supports and enclosure, etc.

d. Cranes, crane rails and support structures.

e. The piping systems, including the design and selection of assorted pumps, control valves, demineralization equipment, etc. Complete information on all phases of design of equipment, calculations of pipe stresses, methods of supporting and anchoring will be furnished to the Laboratory for approval.

Preliminary contacts have been made with prospective vendors of the various items of required equipment. The information obtained has been used in the preparation of conceptual layouts. This information will be released to the Architect-Engineer to enable him to commence immediately on detailed design work. It is intended that long-term delivery items, such as pipes, valves, fittings, pumps, etc., will be picked off and ordered by the Laboratory as soon as sufficient information is available. Likewise, a prefabrication pipe contract will be let by the Laboratory as soon as pipe details are completed. The Architect-Engineer shall provide personnel for joint inspection with the Laboratory of all items of purchased equipment.

3. Auxiliary Systems

All items described in the Auxiliary Systems Section III. D-4 will be designed and specified by the Architect-Engineer. Here again the components will be ordered in advance to expedite construction.

4. Power and Lighting

The Architect-Engineer will design the complete electrical system. The Laboratory will supply certain specific requirements for the design. It must be recognized that the electrical power distribution system, together with the various ratings, sizes of equipment, and load values, as covered here, are necessarily approximate and subject to change in the definitive design as the following pertinent points are established:

a. Exact location of the ARBOR Facility.

b. The final ratings of the various auxiliaries.

c. The loads to be carried by the emergency diesel-generator set.

d. The detailed and coordinated operating and control schemes for the various electrical and related components of the Facility.

5. Contracts and Field Supervision

The Architect-Engineer will prepare detailed drawings and specifications for all items, except those supplied by the Laboratory, to be used in preparation of proposals for bids. Field supervision and shop drawing review for all phases of all contracts, other than those executed solely by the Laboratory, will be supplied by the Architect-Engineer.

6. Preliminary Drawing List

The drawing list presented below is believed to be representative of the magnitude of the over-all project. Determination of the exact requirements is of course left to the Architect-Engineer.

Items marked with an asterisk* may be affected by Step I, II, III schedule of construction as discussed later.

ARBOR Drawing Requirements

Standard Size: 30 x 42 3/8 in. = 1 ft - 0 in. Scale

Structural and Architectural

1. Location and Grading Plan
2. Water Supply Plan
3. Excavation Plan and Elevation
4. Main Building Basement Framing Plan
5. Main Building First Floor Framing Plan

6. Main Building Operating Floor Framing Plan
7. Main Building Basement Reinforcing Plan
8. Main Building Operating Floor Reinforcing Plan
9. Reactor Foundation Plan and Details
10. Main Building Elevation A_1-A_1
11. Main Building Elevation A_2-A_2
12. Main Building Elevation A_3-A_3
13. Main Building Elevation B_1-B_1
14. Main Building Elevation B_2-B_2
15. Main Building Elevation B_3-B_3
16. Main Building Misc. Sections and Details
17. Main Building Misc. Sections and Details
18. Main Building Feed-Water Pump Foundation*
19. Main Building Foundation Sections
20. Main Building Monitor Structural Steel
21. Main Building Monitor Structural Steel
22. Main Building Monitor Structural Steel
23. Main Building Misc. Structural Steel Details
24. Main Building Misc. Structural Steel Details
25. Main Building Stair Details
26. Main Building Concrete Floor Plug Details
27. Active Storage Area Floor Framing Plan
28. Active Storage Area Roof Framing Plan
29. Active Storage Area Elevation A_1-A_1
30. Active Storage Area Elevation B_1-B_1
31. Auxiliary Building Floor Framing Plan
32. Auxiliary Building Roof Framing Plan
33. Auxiliary Building Elevation A_1-A_1
34. Auxiliary Building Elevation B_1-B_1
35. Control Building Basement Framing Plan
36. Control Building Main Floor Framing Plan
37. Control Building Roof Framing Plan
38. Control Building Basement Reinforcing Plan
39. Control Building Main Floor Reinforcing Plan
40. Control Building Roof Reinforcing Plan
41. Control Building Elevation A_1-A_1
42. Control Building Elevation A_2-A_2
43. Control Building Elevation A_3-A_3
44. Control Building Elevation B_1-B_1
45. Control Building Elevation B_2-B_2
46. Control Building Elevation B_3-B_3
47. Control Building Misc. Sections and Details
48. Control Building Misc. Sections and Details
49. Control Building Structural Steel Details
50. Control Building Structural Steel Details
51. Building Elevation - North*
52. Building Elevation - East*

90

53. Building Elevation - South*
54. Building Elevation - West*
55. Building Door Details
56. Building Door Details
57. Control Building Plumbing
58. Control Building Heating and Ventilating
59. Auxiliary Building Heating and Ventilating
60. Main Building Concrete Inserts
61. Main Building Concrete Inserts
62. Control Building Concrete Inserts
63. Reactor Biological Shield Details
64. Reactor Biological Shield Details
65. Cooling Tower Plan*
66. Cooling Tower Details*
67. Miscellaneous Outdoor Structures*
68. Concrete Shield Segment Details
69. Nuclear Instrument Hole and Well Details
70. Heat Exchanger Area Plan*
71. Heat Exchanger Area Elevation A-A*
72. Heat Exchanger Area Elevation B-B*
73. Condenser Area Plan*
74. Condenser Area Elevation A-A*
75. Condenser Area Elevation B-B*
76. Heat Exchanger Foundation Details*
77. Condenser Foundation Details*

Mechanical

1. Main Building - General Arrangement Plan - Basement*
2. Main Building - General Arrangement Plan - First Floor*
3. Main Building - General Arrangement Plan - Operating Floor
4. Main Building - General Arrangement Elevation A_1-A_1*
5. Main Building - General Arrangement Elevation A_2-A_2*
6. Main Building - General Arrangement Elevation A_3-A_3*
7. Main Building - General Arrangement Elevation B_1-B_1*
8. Main Building - General Arrangement Elevation B_2-B_2*
9. Main Building - General Arrangement Elevation B_3-B_3*
10. Active Storage Area - General Arrangement Plan*
11. Active Storage Area - General Arrangement Elevation A_1-A_1*
12. Active Storage Area - General Arrangement Elevation B_1-B_1*
13. Auxiliary Building - General Arrangement Plan*
14. Auxiliary Building - General Arrangement Elevation A_1-A_1*
15. Auxiliary Building - General Arrangement Elevation B_1-B_1*
16. Control Building - General Arrangement Basement Plan
17. Control Building - General Arrangement First Floor Plan
18. Control Building - General Arrangement Elevation A_1-A_1
19. Control Building - General Arrangement Elevation A_2-A_2
20. Control Building - General Arrangement Elevation B_1-B_1

63. Shutdown Cooling Piping Details
64. Main Building Vent and Drain Systems

Electrical

1. Conduits and Electrical Equipment - Main Building - Basement
2. Conduits and Electrical Equipment - Main Building - First Floor
3. Conduits and Electrical Equipment - Main Building - Operating Floor
4. Conduits and Electrical Equipment - Active Storage Area
5. Conduits and Electrical Equipment - Auxiliary Building
6. Conduits and Electrical Equipment - Auxiliary Building
7. Conduits and Electrical Equipment - Auxiliary Heat Exchanger Area
8. Conduits and Electrical Equipment - Water Cooler Area
9. Conduits and Electrical Equipment - Steam Condenser Area
10. Conduits and Electrical Equipment - Control Building Basement
11. Conduits and Electrical Equipment - Control Building Basement
12. Conduits and Electrical Equipment - Control Building Basement
13. Conduits and Electrical Equipment - Control Building Basement
14. Conduits and Electrical Equipment - Control Building First Floor
15. Conduits and Electrical Equipment - Control Building First Floor
16. Conduits and Electrical Equipment - Control Building First Floor
17. Electrical Equipment Details
18. Electrical Equipment Details
19. Pole Facility - EBR II to ARBOR
20. Electric Distribution Pole Details
21. Misc. Electric Installations
22. Lighting Main Building - Basement
23. Lighting Main Building - First Floor
24. Lighting - Main Building - Operating Floor
25. Lighting - Active Storage Area
26. Lighting - Auxiliary Building
27. Lighting - Control Building Basement
28. Lighting - Control Building First Floor
29. Lighting - Water Cooler Area*

30. Lighting - Steam Condenser Area*
31. Lighting - Misc. Exterior
32. Communications System
33. Single Line and Key Diagrams
34. Wiring Diagram 4160 Volt Switch Group
35. Wiring Diagram 4160 Volt Switch Group
36. Wiring Diagram 440 Volt Switch Group
37. Wiring Diagram 440 Volt Switch Group
38. Wiring Diagram 440 Volt Control Center
39. Wiring Diagram 440 Volt Control Center
40. Wiring Diagram 440 Volt Control Center
41. Wiring Diagram 440 Volt Control Center
42. Wiring Diagram 440 Volt Control Center
43. Thermocouple Wiring Diagram
44. Thermocouple Wiring Diagram
45. Thermocouple Wiring Diagram
46. Nuclear Control and Instrumentation Diagram
47. Elevations - Control Room Panels
48. Schematic Diagram - Rod Drive Control
49. Schematic Diagram - Steam System Instrumentation*
50. Schematic Diagram - Forced Circulation System Instrumentation*

7. Compliance with AEC Requirements on Preparation of Reports

It will be necessary for the Laboratory and the Architect-Engineer to collaborate in conforming to the AEC requirements, including Idaho Operations Office Engineering Standards, as regards engineering and construction standards, and the preparation of performance and accounting reports.

Particular attention is called to the necessity for preparation of Title I, II, and III reports. It should be quite evident that a large amount of the Title I work has been completed by the Laboratory. However, this information will have to be transferred to the Architect-Engineer's drawings. Due to the complexity of the ARBOR System the proposed concept must be developed in sufficient detail to present enough information for the preparation of a realistic cost estimate.

An outline of a typical Title I report required of the Architect-Engineer is presented below:

a. Summary - A brief description of various systems and arrangements studied, cost and operating comparisons, and recommendation by the Architect-Engineer.

b. Introduction - Brief history of Architect-Engineer's activity to date and discussion of future program with reference to Title II and Title III effort.

c. Plant Requirements
d. General Plant Description
e. Process Flow Description
f. Equipment Description
g. Structural Description
h. Electrical System Description
i. Instrumentation System Description
j. Cost Estimate
k. Design Evaluation, Conclusions, and Recommendations

8. Operating Manuals

The Architect-Engineer shall prepare and supply 50 copies of a plant operation and maintenance manual. Information pertaining to the reactor operation will be supplied by the Laboratory for integration into the final report.

C. Joint Laboratory and Architect-Engineer Effort

In general, the joint efforts of the Laboratory and Architect-Engineer shall be applied wherever the respective types of experience peculiar to the two organizations can be combined to accomplish the job in the most efficient manner. The Architect-Engineer shall execute the detailed design, with the Laboratory supplying a large portion of the necessary information.

It is emphasized that the instrumentation of the ARBOR Facility is rather complex. Most of the instrumentation must be viewed and designed as an integral system. As completion of the instrumentation design is approached, the Architect-Engineer will be required to prepare two types of diagrams covering the entire instrumentation system: (1) a type suitable for construction purposes; and (2) a type suitable to enable ready comprehension of the manner of system functioning, and to facilitate system repair and maintenance. These drawings, along with flow charts, shall be used for operator instruction also. In addition, the Architect-Engineer will be required to prepare comprehensive and detailed special diagrams, with suitable descriptions, of the safety instrumentation.

The following design items are included within the area of joint effort:

1. General over-all plant arrangement
2. Shielding

3. Process instrumentation
4. Control room design
5. Water cooler and steam condenser steam disposal system
6. Safety systems
7. Chemical shutdown
8. Ion exchange column shielding
9. Fuel storage pit design
10. Recombination system
11. Steam separator - emergency coolers

The above items of joint effort must be integrated with that of primary effort by the Architect-Engineer and incorporated on common drawings.

It is expected that instrument vendors will be consulted at an early stage for co-operation in design of the instrumentation and control system. Likewise, it is expected that a separate instrumentation contract will be let by the Laboratory and administered jointly by the Laboratory and Architect-Engineer.

As in the case of the Primary System design, the components for the various systems will be ordered by the Laboratory as information becomes available.

Due to unknown factors in the Recombination System, this unit will be fabricated and tested at the Laboratory under operating conditions. After testing, the unit will be disassembled and shipped to Idaho for installation in the ARBOR Facility.

It is almost impossible to define in complete detail the exact scope of work of each of the parties involved in a project such as the design of the ARBOR Facility. Therefore the requirements stated above and in the AEC Idaho Operations Office Engineering Standards constitute the most complete information available at this time. Any additional work which develops as the design progresses shall be handled by the Architect-Engineer at the direction of the Laboratory.

D. Schedule of Construction in Steps

As mentioned under Sect. III, DESIGN REQUIREMENTS, it will probably be necessary to construct the ARBOR facility in two parts. Since an accurate construction cost estimate on the facility will not be available until completion of the Title I report, it cannot be said at this time just how much of the plant can be built as a first part, and how much must be left. Consequently, the plant has been divided into three steps, each of which constitutes an operable facility providing a portion of the flexibility intended for the entire plant.

During the Title I Study, the Architect-Engineer is expected to consider the plant built both as a whole and in these three steps. It is intended that after completion of Title I work, the cost estimates for the three parts will be studied and a decision will be made as to whether Steps I and II can be combined to form the first construction part, with Step III following as the second part, or whether only Step I can be built initially, with Steps II and III following.

Subsequently, Title II construction drawings will be prepared in such a way that construction contract bids may be invited on the two alternates of (a) constructing only the first part and (b) constructing the entire plant, with the AEC retaining the option of switching from alternate (a) to alternate (b) by a given date, say, September 30, 1958. The latter provision will permit a change to construction of the full plant should the necessary additional funds become available in Fiscal Year 1959, without incurring the prohibitive expense normally associated with construction change orders. Study by the Laboratory has indicated that such a change could be made as late as September 30, 1958, without materially affecting the construction completion date.

The three steps to be considered during Title I work, together with the major equipment involved in each step, are delineated below:

Step I - Direct-Cycle Forced and Natural Circulation

(1) Pressure Vessel
(2) Main Building
(3) Auxiliary Building
(4) Control Building
(5) Retention and Discharge Storage Tank Building
(6) Water Supply and Treatment System
(7) Forced Circulation System minus Water Coolers
(8) Low Alloy Carbon Steel Steam Distribution System
(9) Carbon Steel Feed-water Pump
(10) Complete Electrical Distributing System
(11) Complete Instrumentation System
(12) Three Waste Retention Storage Tanks

Step II - Dual Cycle

(1) Forced Circulation Water Cooling System

Step III - Indirect Cycle and Heavy Water Operation

(1) Steam Condensers
(2) Stainless Steel Steam Distributing System

(3) Stainless Steel High Temperature Feed-water Pump
(4) Deaerating Hotwell
(5) Recombination System
(6) Reactor Water Cleanup System

78

APPENDIX A

GEOLOGICAL AND METEOROLOGICAL DESCRIPTION OF THE NRTS SITE

Although the Snake River plain gives a flat appearance, the topography is dune-like where the lava is mantled with soil. Many cinder buttes rise above the surrounding terrain. Where soil cover is absent the land surface is exceedingly rough. Soil is wind blown loess.

Except in the immediate vicinities of craters, pressure ridges and lava tubes, the basaltic lava rock which forms the central plain of the NRTS site, in general, affords stable foundations for heavy structures. Most of this rock has a high crushing strength and is nonplastic, although it is parted universally into blocks from a foot to several feet in size. Ordinary engineering techniques, coupled with test drillings to preclude the existence of lava tubes or other cavernous openings at shallow depth, should suffice to meet most foundation problems.

Excavation in the lava rock is, of course, more costly than in incoherent materials such as gravel. Although some parts are rough or craggy, most of the area is relatively smooth, so that sites for individual structures of a facility can be selected to minimize the volume of excavation required.

Surface wind flow in the vicinity of NRTS can be quite variable because of the surrounding mountainous territory. However, the prevailing winds are usually in the quadrant from southeast through southwest, 45 to 55 per cent of the time. The strongest winds are approximately 50 to 60 miles per hour. The average surface wind speed is 8 to 10 miles per hour with strongest winds occurring during the winter. The following frequency of surface wind speeds in the area can be expected:

0 to 3 miles/hr	10 to 20 per cent
4 to 15 miles/hr	60 to 70 per cent
16 to 31 miles/hr	10 to 20 per cent
32 to 47 miles/hr	1 to 2 per cent.

Other weather data for the Arco area are as follows:

Average Temperatures during months:

January	20° F
February	23° F
March	34° F
July	69° F
August	67° F
December	23° F

Temperature Range: -45 to 108° F
Degree Days: 6800
Days below 0° F: 10
Days below 32° F: 135
Days of Frost: 240
Frost penetration: 30 in.
Precipitation: 13 in./yr
Average Relative Humidity at noon:

January	65-70%
July	25-30%.

The following are analyses of water from two wells in the vicinity of the ARBOR site at NRTS:

	Site 10 USGS Well #2	Near Site 16 USGS Well 3A
Temp, °F	53.5	53
pH	7.7	8.2
Total Solids	186.0 ppm	188.0 ppm
Calcium	32 ppm	29 ppm
Magnesium	12 ppm	10 ppm
Iron	0.60 ppm	0.29 ppm
Silicate	32.0 ppm	36 ppm
Nitrate	1.6 ppm	2.3 ppm
Alkalinity		
(1) Carbonate	0 ppm	0 ppm
(2) Bicarbonate	149 ppm	146 ppm
Chloride	8.8 ppm	11 ppm
Sulfate	14 ppm	9.1 ppm
Fluoride	0.7 ppm	0.3 ppm
Hardness as $CaCO_3$	129 ppm	113 ppm
Sodium	8.9 ppm	15 ppm
Potassium	2.9 ppm	3.2 ppm
Boron	0.01 ppm	0.01 ppm
Dissolved Solids	183.0 ppm	186.0 ppm
Specific Conductance @ 25° C	282	276

100

APPENDIX B

REACTOR VESSEL SPECIFICATIONS (R-363400)
(Including Revision 1)

TABLE OF CONTENTS

APPENDIX B

I. INTRODUCTION

The equipment hereafter designated the ARBOR Reactor Vessel and Appurtenances is a pressure vessel with certain associated internal and external attachments required for use in the Argonne Boiling Reactor Facility to be constructed at the National Reactor Testing Station at Arco, Idaho. The vessel has an inside diameter of 9 ft 0 in. and is 44 ft 11½ in. high, including supports. A bolted spherically dished cover with a minimum clear opening 6 ft 6 in. in diameter is provided. Design conditions of pressure and temperature are 2600 psig and 695F, respectively.

The ARBOR Reactor Vessel and Appurtenances is a critical apparatus. Rules for safe construction are either completely lacking or are only now being formulated by the ASME Boiler Code Committee. As a consequence, evidence of excellence of engineering design, fabrication, materials, inspection and quality control during manufacture shall influence the selection of the Vendor by the Laboratory. All such claims of excellence shall be evaluated by the Laboratory in the form of plant and facility inspections prior to the letting of the supply subcontract. Unsubstantiated claims shall be sufficient to eliminate the Vendor from further consideration.

All machining, welding, assembly, and fitting operations, as well as the major portion of the component part fabrication operations, shall be carried out in the Vendor's own shops. The Vendor shall be responsible for the design of the ARBOR Reactor Vessel in accordance with the specifications as set forth herein. The conceptual drawings included outline the general over-all geometrical requirements and shall be followed wherever possible and practicable.

Delivery of the Reactor Vessel to the Idaho Site is required by November 1, 1959. It is acknowledged that material procurement is difficult at this time. The Laboratory will aid the Vendor with highest priorities. In order to expedite construction it is requested that the proposal be based upon employment of 3-shift per day operation as soon as practical.

The Vendor shall submit a production schedule with his proposal. This schedule shall include a manhour breakdown of the various phases of construction, including the number of manhours which may be worked weekly.

Generally, the design and fabrication of the ARBOR Reactor Vessel and Appurtenances shall follow the mandates of the 1956 revision (Addenda and case rulings) of Section I of the ASME Pressure Vessel Code, with certain exceptions and additional requirements as described later in this Specification.

The ARBOR Reactor Vessel may be fabricated by any of the following general methods:

(1) One piece forging.
(2) Welded forged sections.
(3) Formed and welded solid plate.
(4) Formed and welded "laminated" or "banded" plate construction - provided that the inner structural band or liner is at least $1\frac{1}{2}$ in. in thickness, not including cladding. (No cladding is required if inner band or liner is fabricated of Type 405 stainless steel.)
(5) Any combination of forgings and welded plate constructions.
(6) Centrifugal castings (for nozzle connections only).

If the ARBOR Reactor Vessel were fabricated in a conventional ASME Code construction, its shipping weight would exceed 200 tons. In order to reduce this weight, but still to retain a minimum factor of safety of 4.0, a material with an ultimate tensile strength in the range of 105,000 to 125,000 psi is necessary. Furthermore, the bolted closure design precludes the use of conventional ASME bolt steels. An alloy steel with a sustained ultimate tensile strength of at least 200,000 psi at 700F is mandatory. Additional requirements for these materials are detailed later in this Specification.

All of the ARBOR Reactor Vessel internal surfaces, with the exception of the 1% boron-stainless steel thermal shield and specified pipes and appurtenances, are to be clad with or fabricated from AISI Type 405 stainless steel.

II. SCOPE OF WORK

The Vendor shall design, fabricate, furnish and deliver f.o.b. siding at National Reactor Testing Station, Scoville, Idaho, consigned to Purchaser as designated, the following equipment:

One (1) ARBOR Reactor Vessel and its appurtenances, to include:

A. One (1) vessel shell, completely fabricated, consisting of a lower head, cylinder, and truncated conical upper flange, with all welded nozzles attached.

B. One (1) spherically dished cover, completely fabricated, drilled and faced for bolting, with control rod and instrument thimbles and specified shielding attached, and mounted in cover handling fixture.

C. Vessel internals consisting of:

1. One (1) lower grid support and inlet plenum, complete with connecting bolts.

2. Four (4) feedwater inlet downcomer pipes, completely fabricated, match-marked, and prepared for field installation.

3. One (1) core spray ring, completely fabricated but with spray nozzles not installed, prepared for field installation.

4. One (1) internal thermal shield, complete with connecting bolts. (Material for inner 1% boron-stainless steel shield cylinder to be supplied by the Laboratory.)

5. One (1) shock shield, complete with connecting bolts.

D. One (1) shell support structure, complete with connecting bolts.

E. Miscellaneous small parts consisting of:

1. One (1) complete set of closure bolt studs, match-marked with vessel.

2. One (1) complete set of body flange insert sleeves, match-marked with vessel.

3. One (1) complete set of closure bolt stud nuts, match-marked with closure bolt studs.

4. One (1) complete set of spherical washers for closure bolt studs, match-marked with studs.

5. One (1) complete set of closure gaskets.

6. One (1) set of six thread protectors for installation of cover on vessel.

7. One (1) complete set of spray nozzles for core spray ring.

8. All parts necessary for field installation of insulation, including insulation itself.

F. One (1) cover bolting template, match-drilled with the closure stud holes in the top cover, (shipping instructions for this item to be transmitted by the Laboratory at a later date).

G. Spare parts consisting of:

1. One (1) complete set of closure bolt studs.

2. One (1) complete set of body flange insert sleeves, match-marked with vessel.

3. One (1) complete set of closure bolt stud nuts, match-marked with spare closure bolt studs.

4. One (1) complete set of spherical washers for closure bolt studs, match-marked with vessel studs (Item E-1 above).

5. Twenty-four (24) complete sets of closure gaskets.

6. Six (6) spray nozzles for core spray ring.

All items are to be substantially as shown on the Laboratory drawings listed below and as hereinafter specified.

The Laboratory shall furnish the Vendor, on a loan basis, a template which has been match-drilled with the lower core grid plate as to mounting holes. The Vendor shall use this template to match-drill the mounting holes in the lower grid support ring. At a later date the Laboratory shall ship the lower core grid plate and core shell (fabricated by the Laboratory) to the Vendor for final fitting in the vessel. Any fabricating operation required to achieve the prescribed alignment shall be performed on the vessel internal attachments fabricated by the Vendor, and not on the lower core grid plate or core shell supplied by the Laboratory. Following the fitting operation, the Vendor shall ship the grid plate, core shell, and grid plate template according to instructions supplied by the Laboratory at a later date.

Prior to final fabrication of the upper ring forging, but concurrently with fabrication of non-affected parts of the vessel, the Vendor shall perform experiments to evaluate proposed gaskets and gasket surface configurations and shall construct the ARBOR Reactor Vessel according to the results of such evaluations. If a separate test facility is required, the Vendor shall consider the following methods:

a) Utilizing the lower head, upper ring forging, and top cover for construction of the test facility, and incorporating these components into the Reactor Vessel upon completion of the closure evaluation tests.

b) Fabricating a completely independent test facility from duplicate but unclad components, on a separate shop schedule.

Costs of such evaluation tests, including those for constructing either type of test facility, shall be separately quoted. Test gaskets for evaluation would be provided by the Laboratory under this arrangement.

III. DRAWINGS AND DESIGN CALCULATIONS

A. Laboratory Drawings

The following Argonne National Laboratory drawings are submitted as a conceptual design:

RE-5-18824-E General Arrangement ARBOR Reactor Vessel (Fig. 3)
RE-5-18825-D Upper Shell and Cover Arrangement for ARBOR Reactor Vessel
RE-5-18826-D Plan Section "E-E" and "F-F" ARBOR Reactor Vessel
RE-5-18827-D Lower Shell and Head Arrangement for ARBOR Reactor Vessel
RE-5-18828-D Plan Sections "B-B" and "C-C" ARBOR Reactor Vessel
RE-5-18829-D Support Legs ARBOR Reactor Vessel
RE-5-18830-D Insulation Arrangement ARBOR Reactor Vessel
RE-5-18831-C Shipping Skid Arrangement ARBOR Reactor Vessel
RE-5-18832-D Cover Hold Down Bolt Stud ARBOR Reactor Vessel
RE-4-18979-D Top Cover Handling Frame ARBOR Reactor Vessel

B. Vendor's Drawings and Design Calculations

1. The Vendor shall prepare and submit to the Laboratory for approval, eight (8) sets of drawings showing the general arrangement and detailed design and dimensions of the equipment described in II. Scope of Work, Items A through F inclusive, and such other detail drawings as may be required, including sectional and subassembly drawings showing the detailed construction of the items enumerated.

2. The Vendor shall likewise prepare and submit to the Laboratory five (5) copies of design and stress calculations for the items enumerated below as well as any other items which require such calculations for determination of size and method of joining to mating parts. Design requirements such as core weights, coolant flows, and heat generation rates shall be supplied by the Laboratory.

a. Shell
b. Flanged closure
c. Lower head
d. Welded joints
e. Nozzles and associated welds
f. Lower core support and inlet plenum
g. Vessel support

3. All drawings and stress calculations shall be sent to the Laboratory to the attention of L. W. Fromm, Manager, ARBOR Project.

4. The Vendor shall not begin manufacture of the ARBOR Reactor Vessel and Appurtenances until a written release for fabrication has been issued by the Laboratory, except at the Vendor's own risk. The release for fabrication will be issued only after approval of the Vendor's fabrication drawings and stress calculations by the Laboratory.

5. Where conflicts exist between the Laboratory and Vendor drawings, the conflicts shall be resolved in accordance with the ensuing General and Detailed Specifications.

6. After final approval of drawings the Vendor shall furnish the Laboratory with all prints desired.

7. The Vendor shall notify and obtain approval of a responsible representative of the Laboratory (to be designated) for any proposed shop changes in fabrication, prior to authorizing such changes. This notification and approval may be verbal. The Vendor shall follow up any such changes with revised drawings as soon as possible thereafter.

8. After shipment of the ARBOR Reactor Vessel and Appurtenances, the Vendor shall furnish the Laboratory with one (1) set of reproducible cloth tracings of the equipment as built.

IV. GENERAL SPECIFICATIONS

A. Materials

1. Structural Material for Vessel Shell and Cover

In order to reduce the weight and fabricability problems of the ARBOR Reactor Vessel and Cover, but still to retain a minimum factor of safety of 4.0, the use of a steel having an ultimate tensile strength of

105,000 to 125,000 psi is mandatory. The steel selected must develop its strength by simple heat treatments (normalizing and tempering are preferred) in order to minimize distortion of the finished product. In addition to the minimum tensile strength requirements, the steel shall possess the following properties:

a. Fine grain - 6 to 8 McQuaid-Ehn grain size.
b. Impact strength - 15 ft-lb minimum Charpy vee notch at -50F.
c. Ductility - 15% elongation, minimum.
d. Through hardenability in the maximum gross section.

The Bidder shall compile and submit to the Laboratory for evaluation complete data on the alloy steel proposed for use in fabricating the vessel shell and cover, including proof that the properties claimed are maintained throughout the maximum metal section proposed. These data shall include, but shall not be limited to, the following:

a. Chemistry
b. Identification (ASTM designation, trade name, or other)
c. Short-time tensile and yield strength as a function of time and temperature
d. Ductility and impact strength as functions of time and temperature
e. Stress-rupture (10,000-hr) data in the range 700 to 1000F
f. Creep (10,000-hr) data in the range 700 to 1000F
g. Heat treatment methods and effects
h. Hardenability
i. Miscellaneous significant data such as Young's modulus, thermal conductivity, coefficient of thermal expansion, notch sensitivity, etc.

2. Closure Bolt Studs

The bolted closure design precludes the use of conventional ASME bolting steels. An alloy steel with a sustained ultimate tensile strength of at least 200,000 psi at 700F is required. The tempering temperature for the stud alloy shall be at least 850F to preclude stress relaxation and softening at the service temperature. In addition to the minimum tensile strength requirements, the stud alloy shall possess the following properties:

a. Impact strength - 15 ft-lb minimum Charpy vee notch at + 10F as well as at 700F
b. Ductility - 10% elongation minimum at +10F; 25% reduction of area minimum at -50F
c. Through hardenability in the maximum gross section

The Bidder shall compile and submit to the Laboratory for evaluation complete data on the alloy steel proposed for use in fabricating the closure studs. These data shall include the same items listed above for vessel shell and cover structural materials, Section IV-A-1.

3. Cladding

The cladding material for the inside surfaces of the vessel shell, nozzles, and cover shall be stainless steel AISI Type 405. At least sixty-five (65) per cent of the cladding thickness adjacent to the exposed surface of the cladding shall correspond to the analysis of the cladding material in that the carbon content shall not exceed 0.08 per cent.

The Vendor shall propose to the Laboratory the method or methods to be used in applying cladding to the various parts, and shall provide experimental evidence of the excellence of the method.

4. Bolting Components

Alloys proposed by the Vendor for closure bolting components such as bolt stud nuts, flange insert sleeves, and spherical washers, as well as for connecting bolts, nuts, and inserts for vessel attachments, shall be compatible with each other and with mating parts without galling. Metallurgical evidence of such compatibility as well as high-temperature strength and ductility of proposed alloys shall be submitted by the Bidder to the Laboratory for evaluation.

5. Vessel Support Structure

The vessel support structure shall be fabricated from steel meeting ASME Code Specification SA-7 or approved equal, with the exception of top bearing plates, which shall be of ductile cast iron.

6. Insulation

Insulation shall be AISI Type 430 fine grade stainless steel wool, packed to a density of 5 lb/cu ft.

Sheet metal insulation covers, 1/8 in. thick or less, shall be formed from AISI Type 304 stainless steel. Insulation covers over 1/8 in. thick shall be formed of suitable carbon steel.

7. Hard Facing Deposits

Hard facing deposits shall be Stellite 6 and shall have a minimum finished thickness of 0.060 in. after all heat treatments and fabrication operations have been completed.

8. Weld Metal Deposits

Weld metal shall be deposited from electrodes specifically approved by the Laboratory for each type of joint.

B. Required Tests and Fabrication Records

1. Material Tests and Records

a. All tests on materials required by Section I - Power Boilers of the 1956 Edition (including addenda and interpretations) of the ASME Boiler and Pressure Vessel Code shall be applied to each plate or portion thereof, forging, or casting utilized in the fabrication of the ARBOR Reactor Vessel and Appurtenances. The results of all such tests shall be transmitted to the Laboratory and approved prior to incorporation of the materials covered into the vessel assembly.

b. Records of plate numbers, heat numbers, etc., together with copies of mill test reports, shall be transmitted to the Laboratory.

c. All heavy plate and forgings shall be radiographed (or tested non-destructively by other methods approved by the Laboratory) for internal defects, and the results shall be reviewed by the Laboratory. Defects in material so discovered can constitute cause for rejection by the Laboratory.

d. A permanent record of the location of all plates, forgings, etc., used shall be preserved and reported on the final certified as-built drawings.

2. Welds and Welding

a. All tests for welding (materials, process, operator qualifications, etc.) required by Section I of the 1956 Edition (including addenda and interpretations) of the ASME Boiler and Pressure Vessel Code shall be applied to the fabrication of the ARBOR Reactor Vessel and Appurtenances.

b. Six (6) copies of the qualification data on the welding process and operator qualification procedures for the different classes of work shall be submitted to the Laboratory for approval before starting on the assembly of the ARBOR Reactor Vessel.

c. Test welds of welded joints in gauges not less than that required in the construction of the ARBOR Reactor Vessel shall be prepared and submitted to the Laboratory for such tests as may be desired. The minimum number and types of welds required shall be determined by the Laboratory.

d. All welds exclusive of cladding attachment shall be completely radiographed. Class I double film radiographic techniques are required. All films shall be reviewed by the Laboratory. Welding flaws are to be corrected until further radiographs show that all such flaws have been eliminated.

3. Cladding Integrity

The bond integrity of all cladding shall be demonstrated by admitting nitrogen gas at 2000 psi between the base material and cladding sheet. The leakage of gas shall be detected by a liquid soap solution applied to the entire clad surface. At least one connection per sheet shall be installed for this test. The bond integrity test shall be executed after the vessel is completely fabricated and immediately prior to the shop hydrostatic test. The test shall be witnessed by a representative of the Laboratory. Flaws are to be corrected.

It is recommended that the Vendor execute a preliminary bond integrity test on flat clad plates prior to rolling or pressing applications in order to discover defective materials at an early date in the fabrication sequence.

4. Hydrostatic Strength and Leakage Test

The ARBOR Reactor Vessel shall be erected on its support structure in the Vendor's shop and the cover installed; the unit shall then be hydrostatically tested at a pressure not less than 3900 psig multiplied by the ratio of the allowable stress of the vessel structural material at the test temperature to the allowable stress at the design temperature (695F). The test shall be continued for a period of 24 hours. Water at a temperature no greater than 85F shall be used for this test. The test shall be witnessed by a representative of the Laboratory and by such persons as required for issuance of the ASME Code Certificate and Hartford Insurance Company Certificate of Inspection as called for elsewhere in this Specification.

No leakage of water at any point on the vessel other than at the bolted closure shall be permitted during the hydrostatic test. Any leaks discovered shall be corrected and the hydrostatic test repeated until satisfactory results are obtained.

Zero leakage shall be considered the goal for both the inner and outer gaskets of the bolted closure. No leakage of water through the outer gasket shall be tolerated in any case. Permissible leakage through the inner gasket during the hydrostatic test shall be governed by the best result obtained in the gasket and gasket surface configuration tests described in Section II. Responsibility for obtaining a closure on the Reactor Vessel equal to the best result achieved in the evaluation tests shall remain with the Vendor.

The quality of water used for the hydrostatic tests shall depend upon the condition of the vessel at the time of the test with respect to the existence of inaccessible areas for subsequent flushing and cleaning. If in the opinion of the Laboratory no such areas exist and there is assurance that all chlorides and other dissolved and entrained matter may easily be cleaned out subsequent to the test, ordinary tap water may be used.

5. Helium Leakage Test

The integrity of all pressure strength welds shall be demonstrated by a helium leakage test following the shop hydrostatic test. The entire surface of the Reactor Vessel, closure gasket excepted, shall be encased in a gas-tight plastic envelope, with all welds separately enclosed. With the pressure vessel filled with compressed air or nitrogen, containing at least 10% helium, at an initial pressure of 2000 psig, the collected helium leakage through any weld or through the enveloped plate surface shall not exceed 0.01 cc/hr of helium. All sources of leakage detected shall be repaired and the test repeated until satisfactory results are obtained.

The test shall be witnessed by a representative of the Laboratory.

For this test, the vessel may be filled with any bulk solid (not liquids) in order to reduce helium gas requirements, provided sufficient care is taken to prevent damage to vessel internal surfaces and attachments during placement and removal of such solids, and provided steps are taken to prevent overloading of the vessel support structure.

As an alternate to a pressurized helium leak test the Laboratory will entertain proposals for a vacuum leak test on the integrity of all welds.

The Vendor shall describe in detail the method he proposes to use in conducting both the pressurized and vacuum tests as well as a complete discussion of his past experience on similar operations.

The cost of each type of leakage test shall be quoted separately in the proposal for purposes of identification.

C. Cleanliness and Cleaning Procedures

1. Extreme care shall be taken to insure cleanliness of all internal surfaces of the ARBOR Reactor Vessel and Appurtenances during all stages of construction and assembly.

2. No shop marking inks containing halides shall be used in any of the fabrication processes on the ARBOR Reactor Vessel and

Appurtenances under any circumstance. All inks to be used shall be chemically analyzed prior to use to assure that this requirement is met.

3. All foreign matter such as scale, weld splatter, weld flux, oil, grease, etc., shall be cleaned by grit blasting, chipping, wire brushing, or detergent, as applicable. Any component part which will later become inaccessible for cleaning must be thoroughly cleaned prior to insertion. When grit blasting is used, only new, metal-free, previously unused grit may be used. When wire brushing is used, only new, previously unused, stainless steel wire brushes may be used. All methods of cleaning must be approved by the Laboratory.

4. Final cleaning of the vessel shall be accomplished after the shop hydrostatic and helium leakage tests.

5. After the final inspection by the Laboratory, the vessel shall be sealed off against entrance of contamination, using methods approved by the Laboratory.

D. Painting

1. After all openings into the interior of the vessel and cover have been sealed off, the exterior shall be thoroughly cleaned, and exposed carbon steel surfaces, including those on the vessel support structure, shall be painted with the required number of coats of 1000F heat-resistant aluminum paint.

E. Inspection

Because of the critical nature of the design and operation of the ARBOR Reactor Vessel, frequent inspection by the Laboratory during construction shall be mandatory. The Laboratory reserves the right to hold construction of any component pending receipt of satisfactory material test results as listed under B. - 1, Material Tests and Records, above. In addition, specific stages of construction at which inspection and approval by the Laboratory are required, are as follows:

1. Lower Head

a. Profile measurements of head after forming but prior to further fabrication, to assure the required geometry.
b. Review of quality after forming (depending upon method of fabrication) by suitable control procedures (radiography, etc.).
c. Layout of nozzle openings to assure correct location, prior to drilling.

d. Location of support lugs for thermal shield, core support, and external support.
e. Review of nozzles and nozzle openings after preparation for welding.
f. Final location of nozzles after welding.
g. Inspection of machined surfaces for dimensional accuracy, angularity, etc.

2. Cylindrical Shell

The cylindrical shell shall be inspected for dimensional accuracy and concentricity in accordance with ASME Code requirements.

3. Upper Conical Section

a. Dimensional check of piece prior to machining.
b. Metallurgical proof of hardenability, strength, and ductility at the midpoint of the section are mandatory prior to machining.
c. Dimensional check of the finish machined section and nozzle layout prior to drilling.
d. Review of nozzles and nozzle openings after preparation for welding.
e. Final location of nozzles after welding.
f. Gasket surfaces and bolting insert holes prior to attachment of conical section to cylindrical shell.
g. Additional approvals dependant on Vendor's proposed construction method.

4. Finished Vessel Shell

a. Check of entire vessel for dimensional accuracy before stress relieving and heat treating.
b. Check after heat treatment.
c. After erection on support structure and after hydrostatic test, check on trial fitting of core support structure, inlet plenum, thermal and shock shields, insulation covers, etc.
d. Final inspection of all components after cleaning prior to sealing for shipment.
e. Inspection of components mounted on carrier for shipment.

F. Shipping

1. The Vendor shall notify the Laboratory of the scheduled shipping date for the ARBOR Reactor Vessel and Appurtenances, the selected shipping route, expected date and time of arrival at destination, etc., prior to shipment.

2. The Vendor shall shore, brace, and otherwise secure and protect all components to prevent damage during shipment. All items listed separately above under Section II, Scope of Work, shall be shipped separately.

3. Methods of protecting the pressure vessel and components during shipment shall be worked out in advance of shipment of the Vendor and approved by the Laboratory.

4. The vessel diameter and nozzle extensions as shown on the conceptual drawings are approaching shipping clearance limits. A statement that the vessel may be safely transported to its destination from the Vendor's plant shall be included when his proposal is submitted.

G. Erection

In the event that a bid for Erection has been submitted and accepted by the Laboratory, the Vendor shall also be designated the Erection Contractor and as such shall perform the additional work described in this section.

The Erection Contractor shall be responsible for transfer of the vessel from the rail siding to the site. He shall provide field supervision and a crew for erection on the foundation in the Main Building. The method of erection has a direct bearing on over-all construction plans and is to be worked out between the Erection Contractor, the Architect-Engineer, and the Laboratory.

The Erection Contractor shall also be responsible for connecting all piping to the vessel nozzles, field insulation, and installation of the reactor vessel internals fabricated and fitted by the Vendor. He shall also conduct a hydrostatic test after the vessel piping is extended to the first block valve in each line, before the biological shield concrete is poured. This test is, of course, in addition to the shop hydrostatic test.

The Erection Contractor shall not be responsible for correction of leaks in piping, components, or welds not fabricated under his supervision unless such leaks are the result of the Erection Contractor's operations.

The Erection Contractor shall schedule the erection work as directed by the Laboratory, in cooperation with the General Construction Contractor, in such a way as to cause minimum possible delay in the progress of the overall project.

This phase of the work is to be considered as an addendum to the vessel cost, and separated in the proposal.

H. Instruction Books

1. The Vendor shall prepare a comprehensive and illustrated instruction book describing the fabrication of the ARBOR Reactor Vessel and Appurtenances without reference to any other extraneous material. The subject matter of the instruction book shall include:

a. A detailed, complete, and self-explanatory pictorial representation of the finished ARBOR Reactor Vessel and Appurtenances.
b. The design and operating criteria.
c. The complete set of design and stress calculations.
d. A reproduction of the General and Detailed Specifications for the Design of the ARBOR Reactor Vessel and Appurtenances.
e. Materials of construction incorporated and their location.
f. Details of all material, weld, and procedure tests.
g. Details and results of hydrostatic tests.
h. Reproductions of all mill test reports.
i. Reproductions of the ASME and Insurance certificates required by the ASME Boiler and Pressure Vessel Code.
j. A list of spare parts.

2. Ten copies of the Instruction Book shall be sent to the Laboratory for its use.

I. Correspondence

Correspondence originated by the Vendor shall be distributed as follows:

1. Five (5) copies to

Argonne National Laboratory
P.O. Box 299
Lemont, Illinois
Attention: L.W. Fromm

2. Copies to the ARBOR Project Architect-Engineer, as later specified by the Laboratory.

V. DETAILED SPECIFICATIONS

A. Vessel Shell and Cover

1. Codes and Certificates Required

a. The design and fabrication of the ARBOR Reactor Vessel shall meet all requirements of the 1956 Edition (including addenda and interpretations) of the ASME Boiler and Pressure Vessel Code, Section I - Power Boilers, insofar as the Code is applicable to nuclear pressure vessels. Specific exceptions from the requirements of the Code shall include the following:

(1) No safety valves shall be attached to the vessel proper.
(2) Provisions for inspection handholes and manholes shall be omitted.
(3) Provisions for regular periodic inspections of interior and exterior surfaces and welds shall be omitted.
(4) Materials other than those listed in the Code for shell and bolting shall be permitted. Allowable stresses shall be taken as one-fourth the ultimate tensile strength of the material at the design temperature.

b. The Vendor shall provide the Laboratory with:

(1) An ASME Code Certificate.
(2) A Hartford Insurance Company Certificate of Inspection.

2. Operating and Design Conditions

Maximum Operating Pressure	2000 psig
Maximum Operating Temperature	636F
Design Pressure	2600 psig
Design Temperature	695F
Minimum Hydrostatic Test Pressure	$3900 \text{ psig} \times \frac{\text{stress at 100F}}{\text{stress at 700F}}$
Maximum Collapsing Pressure	15 psi
Minimum Allowable Heating and Cooling Rate	50°F per hour

3. General Dimensions

Inside Diameter	9 ft 0 in.
Straight Shell Length	19 ft 4-1/2 in.
Over-all Height including Support	44 ft 11-1/2 in.
Minimum Base Metal Wall Thickness (Design stress 26,250 psi assumed)	6 in.
Nominal Thickness of Cladding	0.375 in.
Guaranteed Minimum Thickness of Cladding	0.188 in.
Total Shell Thickness	6-3/8 in.
ID of Closure (at minimum diameter)	6 ft 6 in.

4. Geometrical Form

The form of the pressure vessel shell shall be a cylinder with an internal diameter of 9 ft 0 in., and with a straight section approximately 19 ft $1\frac{1}{2}$ in. in length.

The lower head shall be a full semi-hemispherical head of 4 ft - 6 in. radius with a finished flange length of 3 in. The thickness of the lower head shall not be less than the cylindrical section of the vessel to which it is attached. The head may be of welded segment construction.

The upper section of the vessel shall be a truncated cone modified to receive the closure bolting and gasketing.

Closure of the upper vessel opening shall be achieved by bolting a spherically dished cover, with instrument and control rod thimbles and radiation shielding attached, to the vessel flange. A method of sealing the top cover to the shell has not been defined for obvious reasons. However, due to the necessity for frequent removal of the cover, it will not be feasible to use a seal welded closure. Therefore practical applications of using gaskets or hollow tube "O" rings must be investigated.

The gasket surface of the upper cone section of the vessel shall be finished to 16 microinches after all welding and heat treating operations have been completed. A total indicated runout (T.I.R.) of 0.002 in. in both radial and circumferential planes is required for successful gasket performance.

The gasket surfaces of the top cover shall be inlaid Stellite #6, finished to a minimum thickness of 0.060 in. with surface finish of 16 microinches and a total indicated runout of 0.002 in. across the radial and circumferential planes. These faces are to be finished after all welding and heat treating operations. Leakage between the cover and vessel flange shall be prevented by the use of a double gasket arrangement incorporating bleeder ports between the inner and outer gaskets.

5. External Vessel Attachments and Perforations of the Vessel Shell and Top Cover

The external attachments to the pressure vessel shall be fabricated from the same material as that at the point of attachment in order to eliminate transition welds (except as noted below). They shall include:

a. A conical support skirt with six (6) fabricated lugs attached to the lower head.

b. Four (4) lifting lugs attached to the upper cone for:

(1) Handling of vessel during fabrication, assembly, and erection.

(2) Attachment to sway braces in final installation.

c. Four (4) lifting lugs attached to the cover for handling during shipment and operation.

d. A structural steel saddle and skid arrangement to facilitate shipment and movement to erection point. This equipment will be removed at the time of erection.

e. Vessel shell thermocouple attachment blocks welded at designated points.

f. The pressure vessel shall be perforated for the attachment, by fusion welding, of various connections into the interior of the vessel. The finished length of the connection (nozzles) shall be 12 in. as measured from the exterior surface of the pressure vessel except as otherwise shown on the Laboratory drawings. (Shipping considerations may dictate a revision of these dimensions.) Sufficient extra length shall be provided for sealing openings for shop hydrostatic tests and pneumatic tests performed. All nozzles shall be safe ended for field welding connections after shop tests.

A list of connections follows:

One (1) mark N1 30 in. OD x 25 in. ID forced-circulation inlet elbow and nozzle with thermal sleeve in lower head.
Four (4) mark N2 20-in. OD forced-circulation outlet nozzles in lower head.
One (1) mark N3 2-in. liquid level nozzle in lower head.
One (1) mark N4 4-in. shutdown cooling nozzle in lower head.
One (1) mark N5 2-in. reactor vessel blowdown nozzle in lower head.

Two (2) mark N6 10-in. steam outlet nozzles in upper vessel cone.

Four (4) mark N7 8-in. feed-water inlet nozzles in upper vessel cone.

One (1) mark N8 2-in. liquid level nozzle in upper vessel cone.

One (1) mark N9 $2\frac{1}{2}$-in. poison injection nozzle in upper vessel cone.

Nine (9) mark N10 3.750-in. bore, heavy wall control rod drive thimbles in top cover.

Two (2) mark N11 1-in. gasket bleed-off connections in upper vessel cone.

Four (4) mark N12 4-in. instrument thimbles with special 8-in. reducing flanges in top cover.

Two (2) mark N13 3-in. thermal shield cooling nozzles in lower head.

All thimbles in top closure will have threaded type flanges to facilitate assembly of radiation shield, insulation, etc. The Vendor shall supply all necessary blind flanges, gaskets, bolts, etc., for testing and shipping.

Except as noted on drawings, all nozzles shall be fabricated from dual metal centrifugally cast of laminated type Schedule 160 pipe of the same materials as the cover. The internal and external intersections of nozzles and vessel walls are to be ground to smooth radius curves for elimination of stress concentrations, etc. All nozzle pipe and tubing shall be hydrostatically tested at 4500 psi before selection for fabrication; certificates of inspection for each piece shall be submitted to the Laboratory. All welds are to be X-rayed and films submitted to the Laboratory for inspection.

6. Internal Vessel Attachments

The internal attachments to the reactor vessel shall include:

a. One machined shoulder in the upper flange forging for support of radiation shielding plate, control rod guide spider, etc.

b. Six (6) Type 405 stainless steel thermal shield support lugs welded directly to the lower head cladding metal.

c. Six (6) Type 405 stainless steel core support lugs welded directly to the lower head cladding metal.

d. One (1) $2\frac{1}{2}$-in. Type 304 stainless steel Schedule 20 poison distribution ring supported near the top of the shock shield. This ring shall be perforated for a uniform spray coverage of the core with 15 gpm of cooling water. Type 304 stainless steel full cone spray nozzles shall develop the required coverage at a minimum pressure drop of 10 psi for all reactor pressures between zero (0) psig and twenty-five (25) psig. The ring shall be set up in the Vendor's plant and demonstrated for approval by the Laboratory. A uniform distribution of water over a 72-in. diameter area 120 in. below the spray ring is mandatory. It shall then be trial fitted in the vessel before shipping. The final connection shall be field welded by the Laboratory or by the Erection Contractor.

e. Four (4) oval-shaped feedwater downcomers fabricated from six (6)-in. Schedule 10 Type 304 stainless steel pipe (to clear a 79-in. diameter circle) are to be attached to the 4 8-in. feedwater inlet nozzles with thermal sleeves.

Distributor pipes are to be provided on the lower ends of the downcomers. Preliminary fitup of the downcomer pipes is to be made in the shop and approved before shipment. Final installation shall be made in the field by the Laboratory or by the Erection Contractor.

7. Tolerances

In general all dimensions are to be fractional with the exception of gasket and bearing surfaces where noted. The 0.002-in. radial and circumferential total indicated runout (T.I.R.) of the gasket surfaces along with the 16-microinch surface finish are required for successful gasket performance. A similar surface finish, with a 0.008-in. radial and circumferential total indicated runout is required for the seating surface of the lower grid support ring.

Dimensional tolerances have been made as large as possible in order to secure a workable vessel at least cost.

Angular tolerances are ± 0 degree 6 minutes.

The control rod nozzles are to be located within 1/16 in. of indicated dimensions in plan view and are to be parallel to the vertical axis of the vessel within ± 0 degree 6 minutes. Control rod thimble flange faces are to be perpendicular to the thimble axis within ± 0 degree 6 minutes.

The plane of the seating surface of the lower grid support ring is to be perpendicular to the vertical axis of the vessel within ± 0 degree 6 minutes. The center of the lower core grid plate (supplied by the Laboratory), when installed and bolted to the lower grid support ring, shall lie within 1/16 in. of the vessel vertical axis, and the grid plate horizontal axes shall be displaced no more than 0 degree 6 minutes from the vessel horizontal axes.

Except as noted, the vessel shell is to be constructed to ASME Code tolerances with the exception of the shell inside diameter, which shall be 9 ft 0 in. ± 1/2 in. This tolerance should be attainable without resort to machining the inside of the shell, unless the method of vessel fabrication would normally require such machining regardless of tolerance. The additional cost, if any, of achieving the ±1/2-in. tolerance rather than normal ASME Code tolerance, is to be quoted separately as an extra.

B. Internal Lower Grid Support Structure and Inlet Plenum

1. The lower grid support structure shall consist of a Type 405 stainless steel ring bolted to the six (6) 405 stainless steel legs which are welded to the support lugs in the lower head. The ring shall have a Stellite No. 6 inlaid seating surface of 0.060-in. minimum final thickness after finishing to 16 microinches as shown on Dwg. RE-5-18828-D. The total indicated runout of the seating surface, both radially and circumferentially, shall not exceed 0.008 in. The eight (8) bolting holes for attachment of the Laboratory fabricated lower core grid plate and core shell shall be match-drilled from a template furnished on a loan basis by the Laboratory. The top faces of the legs shall be faced off square within ± 0° 6' of the vertical axis of the shell to receive the bolting ring. The inlet plenum attaches to the inlet nozzle and inside diameter of the bolting ring. The entire lower grid support structure and inlet plenum, together with the lower core grid plate and core shell fabricated and shipped to the Vendor by the Laboratory, shall be trial fitted and tack welded in place for inspection and approval by a Laboratory representative before joining the lower head to the cylinder shell. Any fabrication operations required to achieve the prescribed alignment (plane of grid plate perpendicular to vessel vertical axis within ± 0 degree 6 minutes; center of grid plate within 1/16 in. of vessel vertical axis; horizontal angular displacement of grid plate axes no greater than ± 0 degree 6 minutes from vessel horizontal axes) shall be performed on parts fabricated by the Vendor, not on items supplied by the Laboratory. Final assembly of the bolting ring to the support legs and welding of the plenum shall be in the field by the Laboratory or by the Erection Contractor. Shims may be used between the ring and legs if necessary, provided they are firmly secured.

2. Surfaces of the bolting ring (other than the seating surface), support legs, plenum, etc., shall be machine finished to 100 microinches or better, as noted.

3. Bolts - Type 405 stainless steel, or specifically approved alternates.

4. Welding electrodes - Type 405 lime-coated stainless steel (0.08 maximum carbon) or approved equal.

C. Internal Thermal Shield

1. The Thermal Shield shall consist of three (3) concentric cylinders mounted on the six (6) support lugs. The inner cylinder shall be 8 ft 0 in. ID with a wall thickness of 1 in. and a length of 15 ft 6 in. It shall be fabricated from 1% boron-stainless steel plate into six (6) segments bolted together with stainless steel shoulder bolts. A sectional stiffener plate ring shall be welded to the upper end of the segment for supporting the shock shield.

The inner cylinder shall be supplied by the Laboratory in a rough machined form. The Vendor shall finish machine the cylinder and provide all necessary connecting bolting. The Vendor shall notify the Laboratory of the required date for delivery of the rough machined thermal shield inner cylinder parts to the Vendor's shop.

2. The intermediate cylinder shall be 8 ft 3 in. ID with a wall thickness of $1\frac{1}{2}$ in. and a length of 15 ft 6 in. It shall be made up of six (6) segments bolted together with stainless steel shoulder bolts and fabricated from Type 405 stainless steel plate. The connecting bolts and lugs shall have a maximum height of 1/2 in. to serve as spacers with adjoining cylinders. Buttons 1/2 in. high on 12-in. centers shall be provided on both sides of the plates to act as spacers between individual shield cylinders.

3. The outer cylinder shall be 8 ft 7 in. ID with a wall thickness of 2 in. and a length of 15 ft 6 in. It shall be made up of six (6) segments bolted together with stainless steel shoulder bolts and fabricated from Type 405 stainless steel plate. The connecting bolts and lugs shall have a maximum height of 1/2 in. to serve as spacers. Buttons 1/2 in. high on 12-in. centers shall be provided on the outside of the plates to act as spacers against the vessel wall.

4. The thermal shield shall be trial fitted in the Reactor Vessel in the Vendor's shop. Out-of-round tolerances for the thermal shield shall be no greater than that for the ARBOR Reactor Vessel itself. The location of the shield parts shall be match-marked on the support lugs for re-assembly and fastening in the field by the Laboratory or by the Erection Contractor.

5. All surfaces of the shock shield are to be grit blasted after final disassembly for shipment. All mill scale, weld splatter, weld flux, etc., shall be removed by grinding before grit blasting. Only fresh unused non-metallic grit may be used.

D. Shock Shield

1. The shock shield is a cylinder installed in the upper portion of the Reactor Vessel to protect the vessel shell against thermal stresses induced in the hot walls by the accidental or intentional introduction of low temperature cooling water.

2. The shock shield shall be installed concentrically with the walls of the vessel shell and supported from the inner thermal shield cylinder by bolting. Suitable spacers shall be incorporated in the design of the shock shield to maintain concentricity with the vessel.

3. The shock shield shall be fabricated from 3/16-in. thick AISI Type 405 stainless steel sheet in six (6) segments which shall be bolted together. Louvers shall be provided in the lower portion of the shock shield to permit free passage of steam and reactor water into and out of the annular space between the vessel wall and the shock shield, but to prevent spraying of cold water from the core spray ring directly on the vessel walls.

4. The shock shield shall be trial fitted to the thermal shield within the vessel in the Vendor's shop. The location of shock shield parts shall be match-marked to the thermal shield for reassembly and fastening in the field by the Laboratory or by the Erection Contractor.

E. Shell Support Structure

1. The Shell Support Structure shall be fabricated from rolled structural shapes or welded plates with bearing plates on each end to form six (6) 8 ft 10-in. long columns. The top plate shall have a ductile iron bearing plate mechanically attached to provide a sliding surface for the mating vessel support lugs. Column bracing lugs will be provided for attachment to the biological shield. The unit loading is estimated at 220 psi. The columns shall be designed to withstand the impact of dropping the 35-ton top cover and handling fixture upon the vessel from a distance of 20 in.

F. Miscellaneous Small Parts

1. Bolt Studs, Nuts, Body Flange Inserts and Spherical Washers

Bolt studs shall be inserted into mating conical threaded body flange inserts to provide a means of quickly removing and replacing bolting without galling of threaded joints. Bolt studs, nuts, and body flange inserts shall be fabricated from high-strength alloy materials which are ductile at atmospheric and at service temperatures (notched Izod impact 15 ft-lb minimum). The factor of safety at service temperatures shall not be below 4.0. Spherical washers shall be compatible (non-galling) with mating sections and with the nut and flange alloys. Experimental data on proposed alloys is mandatory, and all such alloys shall be approved by the Laboratory.

2. Gaskets

Final selection of gasket type and material shall be agreed upon between the Vendor and the Laboratory, subject to review of operating experience and tests in process.

3. Thread Protectors

The thread protectors are applied to the bolt stud ends for removal and replacement of the top cover. These threaded sleeves may be made from SAE-1045 carbon steel and "blued" for corrosion resistance. Six (6) thread protectors are required.

4. Spray Nozzles

The full cone spray type nozzles shall be fabricated from Type 304 stainless steel and shall develop the required coverage discussed in Section V-A-6-d.

G. Spare Parts

All spare parts are to be furnished to the same specifications as the original parts.

H. Cover Bolting Template

The Vendor shall prepare a mild steel template of sufficient thickness to resist warpage and to retain dimensional stability, to be used for locating and drilling the bolting holes in future top covers fabricated for the ARBOR Reactor Vessel. Bolting holes in the top cover and in the template shall be simultaneously drilled. The template shall carry the "W-X-Y-Z" axis marks and shall be used for locating bolting holes in the upper vessel flange.

The template is to be shipped per instructions of the Laboratory at a later date.

I. Wrenches and Bolt Stud Removal Equipment

The Vendor shall transmit requirements for wrenches and bolt stud removal equipment to the Laboratory simultaneously with the submission of final design drawings for construction approval.

J. Insulation

The Vendor shall supply 5-in. thick Type 430 stainless steel fine grade wool in rolls for field insulation of the vessel shell and nozzles. This steel wool will be compressed to a thickness of $4\frac{1}{2}$ in. (maximum density 5 lb/cu ft) and secured in place by Type 430 stainless steel chicken wire until covered by the No. 16 gauge Type 304 stainless steel sheet covers. The $4\frac{1}{2}$ x 3 x 1/4-in. carbon steel ring angles and sheet metal are to be trial fitted in the shop and then removed for shipment. Field installation of insulation shall be by the Laboratory or by the Erection Contractor.

K. Cover Handling Fixture

The Vendor shall check the conceptual design of the Cover Handling Frame shown on drawing RE-4-18979-D for all stresses, deflections, connections, and general method of construction, and make any required changes. The frame is to be designed to take the impact bending load occasioned by dropping the cover from a height of 20 in.

The frame jack screws will be used primarily for raising and lowering the cover for 3 in. from the gasket face to assure uniform gasket compression.

The lifting lug opening must be checked for accommodation of the 40-ton crane hook. The frame shall be painted with aluminum paint before shipment.

APPENDIX C

TENTATIVE DESIGN REQUIREMENTS FOR WATER COOLERS AND STEAM CONDENSERS

The water coolers shall be designed to dissipate a minimum total heat load of 200,000 kw (6.8 x 10^8 Btu/hr) with a total primary water flow rate of 12,500 gpm at an inlet temperature of 486F. The units shall have a design pressure of 2500 psi at a temperature of 695F and shall operate satisfactorily at 2000 psi pressure with an inlet temperature of 636F. Pressure drop through the units (headers and coils) shall not exceed 5 psi at 12,500 gpm total flow. The coolers shall be capable of safe operation with a 400F maximum water temperature drop from inlet to discharge.

The steam condensers shall be designed to dissipate a minimum total heat load of 150,000 kw (4.1 x 10^8 Btu/hr) with a total primary steam flow rate of 612,000 lb/hr at an inlet temperature of 410F at a pressure of 250 psig. The units shall have a design pressure of 2500 psi at a temperature of 695F, and shall operate satisfactorily at 2000 psi pressure with an inlet temperature of 636F. Pressure drop through the units (headers and coils) shall not exceed 15 psi at 612,000 lb/hr (250 psig) total flow.

Both coolers and condensers shall be completely leak tight, and must be capable of outdoor operation at any ambient temperature between -40 and +110F. Proper provision must be made for complete venting and draining of both coils and headers. AISI Type 405 stainless steel shall be used for all surfaces exposed to primary water or steam.

SECTION I

GENERAL PUMP SPECIFICATIONS

I. Operating Conditions

A.	Design Pressure	2500 psig
B.	Design Temperature	695F
C.	Fluid	Demineralized Water
D.	Operating Pressures	See Applicable Specs.
E.	Operating Temperatures	See Applicable Specs.
F.	Normal pH Value	7.0
G.	Warming, Starting and Priming	

The Vendor shall state the minimum quantity and duration of circulation required for immediate safe starting of each pump when supplied with water of the operating temperature and pressure at the pump suction.

H. Safe Minimum Delivery and By-pass

The Vendor shall state the minimum output at which each pump will operate without overheating. This is the amount of water to be by-passed to the vessel from which suction is taken.

The Vendor shall furnish with each pump a suitable orifice, or modulating flow control valve, to by-pass without objectionable noise or vibration the safe minimum quantity of water so as to protect the pump in case of reduced or shutoff discharge. This by-pass will open intermittently under manual or automatic control.

I. Shaft Seal Water

The maximum quantity and pressure of primary system water required for seal balancing and leak-off makeup if any, shall be stated by the Vendor. Any plant cooling water requirements for the primary seal cooling water heat exchanger, to be furnished by the Vendor, as well as any jacket cooling, shall be specified.

II. Materials and Fabrication Methods

The Contractor shall include in his proposal specifications for all materials to be used and recommended by him for the condition of service outlined in this specification. Where materials differ from standard specifications, alloy contents shall be clearly stated. Where heat treatment is involved, Brinell Hardness Number (BHN) shall be specified.

The pump surfaces in contact with the system water must be resistant to corrosion by demineralized water having a specific resistance of at least 500,000 ohm-cm with total solids content of less than 5 ppm and a pH of 6 to 8. Nuclear irradiation may cause the water to carry approximately 10 cc/liter of entrained or dissolved oxygen. Temperatures of the water pumped will vary from 300F to 640F. Therefore the use of Type 405 or the 300 series stainless steels will be required. Use of dual metal casings are approved where applicable.

All pump castings shall be made by the electric furnace process to ASTM-E-71 Class II Specifications with radiographic inspection of welded and highly stressed areas as specified by the Laboratory. The radiograph procedure shall conform to the ASTM-E-94 specification. Chemical composition of the castings shall conform to Table I of ASTM-A-351-52T specifications. Mechanical properties of the castings shall conform to Table II of ASTM-A-351-52T specifications.

Castings shall be of uniform quality and condition, clean and free from blowholes, porosity, hard spots, shrinkage, defects, cracks or other injurious defects.

The lot or heat number (indicating the date of casting) shall be stamped or cast on each casting unless a suitable method of identification by heats or lots satisfactory to the Laboratory is provided. Castings shall also be marked with the pattern or mark number (all raised letters).

Material shall be stamped only if it is annealed in process after stamping. If stamping is used, the die stamped identification marks shall consist of heat number only and shall be placed on a cast pad located at a point of minimum stress on the casting.

Internal chills and chaplets shall not be used except by specific authorization. When either chaplets or internal chills that remain a permanent part of the casting are used they shall be of a composition conforming to that specified for the casting in which they are employed.

The preparation of the surfaces other than those in contact with the operating fluid shall be by mechanical means as necessary to remove all sand, scale, fins, excessive rough spots, padding, etc., and to provide a surface finish suitable for dye penetrant or fluorescent inspection.

All machining shall conform to normal standards of good workmanship. Dimensions and tolerances to be maintained as shown on drawings. Failure by Vendors to maintain tolerances as shown on the drawings may be cause for rejection without cost to the Laboratory.

All final machined surfaces shall have a finish of 125 microinches except where better finish is required. Rough machined surfaces shall have a finish of 250 microinches or better and be suitable for fluid penetrant examination. An oil base lubricant and/or cooling fluid may be employed during machining operations, providing the fluid does not contaminate internal surfaces (joints and crevices included) which are inaccessible to cleaning. In those cases where machining must be performed on items containing crevices or complex internal parts only pure water may be employed as a lubricant. Ordinary potable tap water will be considered as meeting this requirement.

All passages not machinable but accessible for hand finishing will be finished to 250 microinches or better. Grinding and polishing shall be performed with previously unused aluminum oxide or silicon carbide, rubber or resin bonded grinding wheels, carbide burrs, or carbide files. In wire brushing stainless steel parts, new stainless steel wire brushes are required.

Inaccessible surfaces may be grit blasted with new unused aluminum oxide or silicon carbide grit of 140 or 120 mesh, respectively, to obtain a finish better than 400 microinches (RMS).

Blasting equipment shall be cleaned thoroughly of all previously used blasting materials.

After grit blasting, both the surfaces blasted and those adjacent to them shall be acid cleaned and then cleaned with a nylon brush and tap water.

All other surfaces shall have a finish suitable for dye-penetrant or fluorescent inspection.

During hand finishing, parts should be positioned so that there is a minimum of dust and abrasive falling into passages. Nozzles should be positioned downward to permit free passage for as much residue as possible.

III. Design Features

A. Shaft Seals

Shaft sealed-type pumps are preferred, although canned rotor-totally sealed pumps will be considered. Vendors are to provide a detailed description of the shaft seal proposed for each pump with the proposal. In addition, the Vendor shall exhibit a full scale operating seal for the diameter of the pump shaft proposed for each pump. Atmospheric pressure seal leakage must be less than 750 cc/min for each pump and must be collected for return to the system. Methods of sealing which incorporate the use of auxiliary seal water circulating systems will be considered. Contamination of collected leakage with external water, water vapor, oil, or oil vapor must be prevented.

Seals must demonstrate a life of at least 500 hr when an exact duplicate of the pump seals is tested under conditions duplicating operating temperatures, pressures, shaft sizes, and rotating speeds.

The seal safety and leakage collecting devices shall provide at least one throttle bushing of a minimum of one shaft diameter long between the seal and reactor fluid and shall provide at least two throttle bushings with bleedoffs between mechanical seal and the atmosphere. Throttle bushings must be shouldered to prevent blowout.

Provisions shall be made to control and drain away all seal leakage, in case of seal catastrophe, through the regular seal leakoff line. Leakage under these conditions should not exceed 25 gpm per pump at full temperature and operating pressure of the system. The pump must continue to operate under conditions of complete seal failure in order to allow time for detection of the seal leakage.

Vendor shall state the leakage rate through the throttle bushing and seal for a new seal and for a seal after 500 hr of operation.

Cooling jackets shall be installed surrounding the seals so that water temperature adjacent to the seal face in the seal compartment shall be maintained below 200F. The Purchaser shall furnish a supply of low pressure cooling water for seal and bearing housing cooling, the temperature of which shall not exceed 95F.

At the conclusion of the shop performance tests the seals shall be thoroughly inspected, and wearing faces shall be replaced with new parts when reassembled.

Because of the pioneering nature of the application of shaft seals on pumps operating at high suction pressures it is realized that the pump Vendors will have a logical interest in the operating performance of these pumps. Therefore, in the event of seal operating difficulties during the first year, it is expected that the Vendor will be anxious to provide direct, concrete assistance in solving any problems. The Vendor may inspect the pumps at conveniently arranged times when the reactor is not operating.

B. Casing

The casing shall be designed to withstand continuously the maximum pressure which can be developed by the pump. Adequate provision shall be made in the design to permit proper expansion without distortion or binding and for all other effects due to the temperature and characteristics of the water being pumped. The casing joints shall be provided with dowels or keys for accurate reassembly.

The pump shall be provided with adequate drain and vent valves.

C. Shaft and Impeller

The shaft shall be of adequate size and strength to withstand safely and continuously all stresses resulting from the weight to be supported, and from starting (including across-the-line motor starting), operating, and temperature conditions to which it will be subjected. The critical speed of the shaft shall be such as to provide a liberal margin of safety between such speed and the range of operating speeds of the pump.

The complete rotor shall be provided with a suitable hydraulic balancing device or equivalent arrangement to supplement the thrust bearing described below. Adequate provision shall be made to prevent distortion, binding, excessive leakage or thrust due to either direct or differential expansion of the rotor parts.

Although minimum specified physical NPSH is available, there will normally be enough subcooling present at both system pump suction inlets to provide good operating characteristics. However, all pumps must be designed to operate under temporary cavitating conditions.

The impellers for the first stage shall be designed to minimize required NPSH. All impellers shall be carefully machined and polished. Each impeller shall be statically and dynamically balanced before assembly on the shaft.

Diffusers, channel rings, and stage pieces, if used, shall be of chrome steel of not less than 12% chrome content. All water passages shall be carefully machined and polished.

Wearing rings shall be suitably heat treated to provide adequate difference in hardness and to prevent galling between running parts. They shall be secured in such a manner as to prevent turning. Bidder shall state in proposal the diametral clearance between wearing rings or surfaces.

Any shaft sleeves used shall be of a suitable heat treated or hard-faced material, and arranged so that they will not turn on the shaft.

Such sleeves shall be attached to the shaft in such a manner as to minimize distortion, eccentricity, or stress caused by differential expansion of shaft and sleeve in service. The shaft sleeves shall be polished.

Shafts shall be of forged alloy steel, accurately machined and ground.

The complete rotor of the feed-water pump shall be statically and dynamically balanced.

D. Instrumentation

The Vendor shall provide connections for the following instrumentation:

1. Lubricating oil level indicator for each different oil sump in the pump and motor.

2. Bearing temperature thermocouple wells on the pump, motor, fluid drive, etc.

3. Seal leakoff flow.

4. Thermocouple wells to measure water temperature adjacent to the seal faces.

5. Overspeed warning indicator for control room indication, where applicable.

IV. Cleaning

Cleaning procedures at various stages of fabrication and inspection shall be as follows:

A. Cleaning prior to inspection in the green: Castings shall be well cleaned with heads and gates removed for inspection in such a manner as not to impair the contour of the casting. This shall be followed by such cutting or grinding as necessary to complete the removal of the heads or gates to the satisfaction of the inspector.

B. Cleaning after annealing: Before final inspection castings shall be thoroughly cleaned and all sand and scale removed by mechanical means. Surfaces in contact with the primary fluid shall be degreased in fresh acetone or detergent. Parts containing crevices or joints shall be degreased only with acetone.

C. Prior to assembly, individual parts shall be cleaned as follows:

1. Remove heavy dirt by scrubbing with a stiff bristle brush, soap, and water.

2. Rinse thoroughly in tap water.

3. Immediately after (2), rinse thoroughly in fresh commercial distilled or demineralized water, followed by methyl alcohol or acetone. Assembly shall be done with gloves.

V. Inspection and Testing

In order to minimize the number of inspection trips, all pump components shall be prepared simultaneously for each inspection step.

Hydrostatic leak testing, whenever possible, shall be accomplished on rough or semi-final machined parts. This will provide for any necessary corrective welding to be done before final machining.

The part to be tested shall be subjected to a hydrostatic pressure of at least $1\frac{1}{2}$ times the maximum allowable working pressure as determined in accordance with Section VIII, ASME Boiler and Pressure Vessel Code.

Rough or semi-final machined parts may be tested with ordinary potable tap water. When it is necessary to test a finish machined part, filtered tap water may be used.

The test water shall be at room temperature. The pressure in the tested part shall be brought to its required value; after which the source of pressure must be disconnected. All air pockets must be eliminated.

The unit shall withstand the test pressure for a period of two hours without any weeping, leakage or drop in pressure greater than that expected because of surrounding temperature changes.

Castings shall be repaired by the foundry to meet Class II specification requirements. Three copies of a record drawing of the repair locations with X-ray films shall be approved by the Laboratory and pump Vendor.

The manufacturer shall check the completeness of removal of a defect by the following methods:

Defect revealed by Hydrostatic Leak Test: A combination of visual, fluid penetrant and radiographic examinations as necessary to remove the defect to sound metal.

Defect revealed by Fluid Penetrant Test or Visual Examination: The completeness of the removal shall be determined by the fluid penetrant test. Fluid penetrant shall not contain any halogens.

Defect revealed by Radiographic Examination: The completeness of removal of a defect shall be determined by a combination of visual fluid penetrant and radiographic examination.

Weld repairs when made shall be examined at the manufacturer's expense by radiographic inspection and fluid penetrant tests.

Performance Tests

The pumps shall be shop tested by the Vendor in accordance with the procedures of the Test Code of the Standards of the Hydraulic Institute. Due notification shall be given the Laboratory so that his inspector may be present. Filtered tap water may be used for tests. Pumps shall be completely disassembled, inspected, cleaned, and reassembled after tests, in a clean area.

A certificate of shop test of the pumps shall be furnished the Laboratory, whether or not his inspector was present at the test, and the pumps shall not be shipped until the Laboratory has approved the pump characteristics and the test results.

After installation, the pumps will be thoroughly tested by the Laboratory to verify the performance under actual operating conditions. The pumps shall meet all requirements of these specifications and all the Vendor's guarantees prior to acceptance by the Laboratory.

The pumps are required to be smooth running and free from vibration. The pumps shall also operate free from cavitation, providing the Vendor's requirements for minimum NPSH are met.

VI. Protection for Shipment

Each pump shall be finished all over to give a smooth and finished appearance. The exterior surfaces shall be cleaned thoroughly and painted with a prime coat of Dupont "Dulux" Metal Protective Primer or approved equal. Final painting and the application of insulation will be done by the Laboratory.

A nameplate shall be attached to the pump so that it is visible after insulation.

Each unit of equipment and unassembled part shall be marked suitably to facilitate identification and installation.

Before shipment all inlets and outlets shall be blanked off or plugged and all exterior carbon steel bare machined surfaces shall be coated with a suitable anti-rust compound.

All pumps are to be completely bagged in polyethylene and crated for shipment in boxes suitable for outside desert storage. The crates must be constructed so that bags are not broken during shipment.

The Vendor shall furnish special maintenance tools. Tools shall be new and of first class quality. Tools shall be shipped to the job in separate containers clearly marked with the name of the equipment for which they are intended. Bidder shall furnish a price list of tools he proposes to furnish.

A complete list of recommended spare parts and their prices shall be submitted with the proposal.

SECTION II

SPECIFICATIONS FOR REACTOR FEED-WATER PUMP ARBOR FACILITY

ARGONNE NATIONAL LABORATORY

1. Scope of Work

Vendor shall furnish and deliver f.o.b. siding, Scoville, Idaho, the following:

One (1) motor-driven reactor feed-water pump complete with appurtenances, including motor drive and variable speed fluid drive (if required) as hereinafter specified.

2. Drawings (Vendor's)

After notification of award, Contractor shall submit to the Laboratory for approval:

A. Six (6) sets of drawings showing the general arrangement and principal dimensions of equipment, including cross section of pump taken along center line of shaft, and such detail drawings, loading and anchor bolt requirements, etc., as may be required by the Laboratory.

B. Six (6) sets of certified copies of manufacturer's outline dimension prints of motor giving size of terminal boxes, etc.

Vendor shall furnish head-capacity and horsepower curves based on actual shop tests of pumps for the Laboratory's records.

3. Operating Conditions and Capacities

The feed-water pump will be required to perform over a wide range of operating conditions. The NPSH available is 55 ft. Suction pressures may vary from 250 psi to 1800 psi at near saturation temperatures. Some representative conditions are given below:

137

Capacity (gpm)	Developed Head (ft)	Specific Gravity	Suction Pressure (psi)	Suction Temperature (° F)
1440	1130	0.860	250	400
1730	386	0.806	540	475
1770	1630	0.812	500	467
1800	1940	0.800	600	486
1850	415	0.786	680	499
1980	2460	0.775	750	510
2030	516	0.756	900	531
2160	2940	0.756	900	531
2200	3710	0.763	850	524
2240	540	0.731	1100	556
2540	726	0.699	1350	582
2920	930	0.675	1600	604
3240	1310	0.649	1800	621

Obviously all of the above conditions cannot be achieved with a standard design boiler feed pump. However, the employment of a variable speed drive will help to bring performance to within throttling range of the feed-water flow control valve. Pump curves shall be supplied with the proposal showing the pump speeds and amount of throttling required to reach intermediate conditions.

Pump shall operate satisfactorily between shut-off pressure and full load. Pump characteristic shall be such that the head will continue to increase with decreasing capacity until a maximum pressure is reached at zero capacity. The head at zero capacity shall not exceed approximately 120% of the head at rated capacity for full speed of rotation.

4. Pump Design and Construction

Pump should be of the horizontal, centrifugal, barrel-type, direct-connected to motor and fluid drive, if used, by approved flexible couplings, and shall conform in general to requirements listed below. However, other arrangements will be considered.

Pump Support

The pump will be located as shown on the accompanying Drawings RE-6-24030-A and RE-6-24031-A. Pump foundation requirements shall accompany the proposal.

Suitable base plates shall be provided for pump and driver, arranged to catch oil and water drips and furnished with a rim for retaining these drips. The base plates shall be designed so as to drain readily through tapped connections provided in one or both ends. Holes shall also be provided in the base plates so that grout may be applied between the plates and foundation.

Bearings

Sleeve bearings shall be employed for the pump shaft and shall have liberal bearing surfaces with horizontally split boxes. Effective sealing devices shall be provided on all bearings for prevention of oil, grease or water leakage.

A suitable thrust bearing shall be provided to locate the shaft longitudinally and to compensate for end thrust under any condition of operation.

Lubrication

An adequate and positive system of lubrication shall be provided for, and common to, all bearings of both pump and driver. The Seller shall provide an adequate cooler for the lubricating oil, an oil reservoir with level indicator, and a suitable oil pump, positively driven from the main pump shaft and primed at all times to insure immediate delivery of oil when the main pump is started.

An auxiliary oil pump driven by a 440-v, 3-phase, 60-cycle AC, totally enclosed fan-cooled motor shall be provided and mounted on the main bed plate. This auxiliary pump shall build up sufficient oil pressure to permit safe starting of the feed pump and motor driver and shall be suitable for continuous operation of the pump and motor equipment.

Mercoid pressure switches for operation on 250-v DC shall be provided to perform the following functions:

A. Starting stand-by auxiliary oil pump on low lubricating oil pressure.

B. Stopping stand-by auxiliary oil pump on high lubricating oil pressure.

C. Sounding alarm to Control Room when auxiliary oil pump starts on low lubricating oil pressure.

139

Suction and Discharge Connections

The 12-in. suction and 10-in. pump discharge nozzles shall be provided with beveled ends for welding, as approved, for Purchaser's piping connections. Top connections are required. Nozzle shall be provided on pump discharge for re-circulating connection.

Insulation

Pumps shall be fitted with a suitable heavy steel lagging, lined with sufficient thickness of high quality insulating material. Lagging shall be made in sections for easy removal and replacement.

5. Variable Speed Fluid Drive

Pump shall be furnished complete with a variable speed fluid drive unit, which shall be mounted on a substantial welded steel bed plate together with the pump and motor.

The fluid drive shall be of the fully enclosed type with four (4) radial sleeve bearings and two (2) Kinsbury thrust bearings, gear driven gear type oil pump and control shaft for connection to Purchaser's feed-water control equipment.

Twin oil coolers shall be built into the oil reservoir base of the fluid drive and all external oil piping shall be of steel pipe with steel fittings and welded joints. Flanges, where necessarily used for dismantling, shall be of forged steel of the welding neck or slip-on type. Oil cooler shall be designed for maximum oil temperature of 180F, with 85F inlet water temperature and for a maximum water operating pressure of 75 psi.

The fluid drive shall be provided with a gauge board for mounting in control room, containing one (1) oil pressure gauge and two (2) oil temperature gauges, one for each group of bearings. Electrical transmission of signals from the fluid drive unit to the gauge board shall be used.

Fluid drive shall have suitable heavy, one-piece steel, flexible coupling guards, mounted on brackets at each end of unit to enclose input and output shaft flexible couplings.

Speed Indicator Equipment

Pump shall be equipped with an electrical speed measuring device and a speed indicator for mounting on Purchaser's Control Room board (remote).

Speed-measuring device shall be furnished mounted and connected to the boiler feed pump shaft. Belts or couplings, if used, shall be provided with suitable guards to protect them from the weather during shipment. Speed-measuring device shall be totally enclosed and shall have suitable conduit opening. Device shall be Weston Electric Instrument Corporation's Model 758 Type WAC Magneto or equivalent.

Speed indicator shall have scale range of zero to the maximum rpm expected of the pump and shall be of the rectangular type, approximately 4 in. square arranged for flush mounting on a steel panel 1/4 in. thick. Indicator shall be Weston Electric Instrument Corporation's Model #741 or equivalent to match and line up with other instruments to be provided by Purchaser for control board.

6. Motor

Motor shall have the following characteristics:

Type	Horizontal, single speed, squirrel cage induction.
Voltage	4160-v, 3-phase, 60-cycle AC
Horsepower Rating	Not less than maximum brake horsepower required by the driven apparatus.
Frame	Drip proof. End shields on coupling end shall be split on motors of NEMA 504 frame size or larger.
Bearings	Sleeve bearings. Bearing on coupling end shall be split on motors of NEMA 504 frame size or larger.
Class of Insulation	Class H radiation resistant
Temperature Rise	40C
Ambient Temperature	60C
Locked Rotor (starting) Torque	75% full load torque
Breakdown Torque	Not less than 190% of full load torque
Locked Rotor Current	Not more than 700% of rated full load current.

141

Control and External Wiring	Furnished and installed by Purchaser. Each motor shall be furnished with a conduit box for 4000-v Motor.
Standards	In accordance with ASA-C-50.

7. Performance Tests

Tests shall be made as follows on the completed, assembled full size pump at normal operating speeds:

a. Conditions - 150F maximum temperature clean water

b. Suction Pressure - Nominal (above minimum NPSH requirements of the pump). Minimum NPSH requirements shall be determined during these tests.

c. The test shall consist of taking the following measurements:

(1) Bearing temperatures
(2) Seal face temperature
(3) Seal leakage rate
(4) Head, capacity and input hp at 0%, 20%, 50%, 75%, 90%, 100%, 120% of design capacity (corrected for temperature).

d. After the above readings are taken, the pump shall be run at design head for two (2) hours. The following measurements will be made at 10 min. intervals:

(1) Head and capacity
(2) Bearing temperatures
(3) Seal face temperature
(4) Seal leakage rate
(5) Input horsepower.

e. After completion of the above test series, the following test series will be made: Conditions: 15 hr at each of the 13 operating conditions listed under Item 3, Section II (Operating Conditions and Capacities). The following measurements shall be made at 1-hr intervals, with cycling at 1-hr intervals.

(1) Head and capacity
(2) RPM
(3) Input horsepower
(4) Bearing temperatures
(5) Seal face temperature
(6) Seal leakage rate
(7) Operating log will be kept and curves prepared

f. The Laboratory's representatives shall witness all tests.

SECTION III

SPECIFICATIONS FOR FORCED CIRCULATION PUMPS ARBOR FACILITY

ARGONNE NATIONAL LABORATORY

1. Scope of Work

Vendor shall furnish and deliver f.o.b. siding, Scoville, Idaho, the following:

Item II - Three (3) Vertical, Motor-Driven Forced-Circulation Pumps including Motor Drive and Appurtenances as hereinafter specified.

Item III - One (1) Vertical, Motor-Driven Forced-Circulation Pump identical to the above three except that a 440-v, 60-cycle, 3-phase AC motor shall be mounted on the main shaft in addition to the main driver. This motor is required to circulate approximately 1000 gpm at 40 psi for emergency cooling. The 440-v motor will operate from the emergency diesel-generator circuit. Alternate methods of securing this flow will be considered.

2. Drawings (Vendor's)

After notification of award, Vendor shall submit to the Laboratory for approval:

A. Six (6) sets of drawings showing the general arrangement and principal dimensions of equipment, including cross section of pump taken along center line of shaft, and such detail drawings, loading and anchor bolt requirements, etc., as may be required by the Laboratory.

B. Six (6) sets of certified copies of manufacturer's outline dimension prints of motors giving size of terminal boxes, etc.

Vendor shall furnish head-capacity and horsepower curves based on actual shop tests of pumps for the Laboratory's records.

3. Operating Conditions and Capacities

Suction Pressure	varies from 600 psi at 486F to 2000 psi at 636F
NPSH available	30 ft - 45 ft
Specific Gravity	varies from 0.801 at 486F to 0.625 at 636F
Discharge Head	348 ft at 486F
Total Capacity	36,000 gpm
No. of Pumps (9,000 gpm each)	4

Pumps shall operate satisfactorily between shut-off pressure and full load. Furthermore, the pumps shall operate satisfactorily in parallel without hunting or other disturbance at all loads down to 30 per cent of rated capacity. Pump characteristics shall be such that the head will continue to increase with decreasing capacity until a maximum pressure not to exceed approximately 120 per cent of the head at the rated capacity, is reached at zero capacity. Stepwise control of the flow will be achieved by bringing on additional pumps as required. The four pumps operating in parallel shall be designed to give uniform increases of flow rate over the entire range of capacity requirements.

A systems capacity vs head curve to show the total head requirements at all flows is enclosed to aid in final evaluation of pump characteristics (Graph No. 1).

Necessary pump characteristic curves shall be submitted by the bidder for determination of throttling required across control valves.

4. Pump Design and Construction

The pumps shall perform satisfactorily under all the conditions listed above under Item 3. The pump motor shall be sized to deliver 348 ft TDH at 486F. Although the pumps will operate on 60F water at startup, the flow will be throttled to prevent motor overloading.

All designs shall conform to the criteria of the ASME Unfired Pressure Vessel Code.

The pumps will be vertical shaft units with the motors mounted above and connected to the pumps by a flexible coupling. The pumps will have counter-clockwise rotation when viewed from the motor end. Single suction pumps will be required for the above application.

Discharge nozzle will be 12-in. Schedule 160 pipe size (approx.) prepared for welding. Suction nozzle will be 16-in. Schedule 160 pipe size (approx.) prepared for welding. Exact I.D. of nozzle bores will be supplied by the Purchaser when contract is placed. The weld preparation will be in accordance with the ASA B31.1-1955, Code for Pressure Piping.

Because of thermal expansion problems, support of the pumps on the piping or by three-point suspension hangers is required. Swaying will be prevented by guides or sway braces. Bidder shall define method of support proposed and illustrate in detail with a drawing.

The pumps shall be designed to operate with 45 ft NPSH and be capable of operation with 30 ft NPSH for short periods of time. The pump must pass through this transient without severe damage or discontinuance of pumping. Continuous operation at 30 ft NPSH would be highly preferable, if economically attainable, since a 45-ft NPSH requires deeper building excavations.

Ball-type thrust bearings shall be used with a self-contained lubrication system. Due to the high level of radioactivity in the pump area it will be necessary to change oil frequently. Easily accessible oil drain and fill connections are required. Effective sealing devices shall be provided on all shafts for the prevention of contamination of primary system fluid with cooling water or oil.

Pump and motor cooling water requirements shall be stated in the data summary.

The pumps shall be designed so the complete motor and rotating element can be removed from the casing without disturbing the piping and by removing only the casing pressure joint bolts and the hangers and sway braces. The motor need not be separated from the rotating element during this removal operation. Designs shall be such that an absolute minimum number of bolts must be loosened or removed during removal of the rotating element and motor.

5. Lubrication

Auxiliary lubricating requirements shall be described by the Bidder.

6. Insulation

Method of insulating with Type 430 stainless steel wool shall be prescribed by the Bidder, but furnished and applied by the Laboratory.

7. Motor

145

Motor shall have the following characteristics.

Type	Vertical, ball bearing, single-speed, squirrel cage induction.
Voltage	4160 v, 3-phase, 60-cycle A.C.
Horsepower Rating	Not less than maximum brake horsepower required by the driven apparatus.
Frame	Drip proof
Insulation	Class H radiation resistant
Temperature Rise	40C
Ambient Temperature	60C
Locked Rotor (starting) Torque	75 per cent full load
Breakdown Torque	Not less than 190 per cent of full load torque
Locked Rotor Current	Not more than 700 per cent of rated full load current
Control and External Wiring	Furnished and installed by Purchaser. Each motor shall be furnished with a conduit box for 4000-v motor.
Standards	In accordance with ASA-C-50

8. Performance Tests

Complete tests shall be made as follows on all completed, assembled full size pumps at normal operating speeds.

a. Conditions - 150F maximum temperature clean water

b. Suction Pressure - Nominal (above minimum NPSH requirements of the pump)
Minimum NPSH requirements for each pump shall be determined during the tests.

c. The test shall consist of taking the following measurements:

(1) Bearing temperatures
(2) Seal face temperature
(3) Seal leakage rate
(4) Head, capacity and input HP at 0 per cent, 20 per cent, 50 per cent, 75 per cent, 90 per cent, 100 per cent, 120 per cent of design capacity (corrected for temperature)

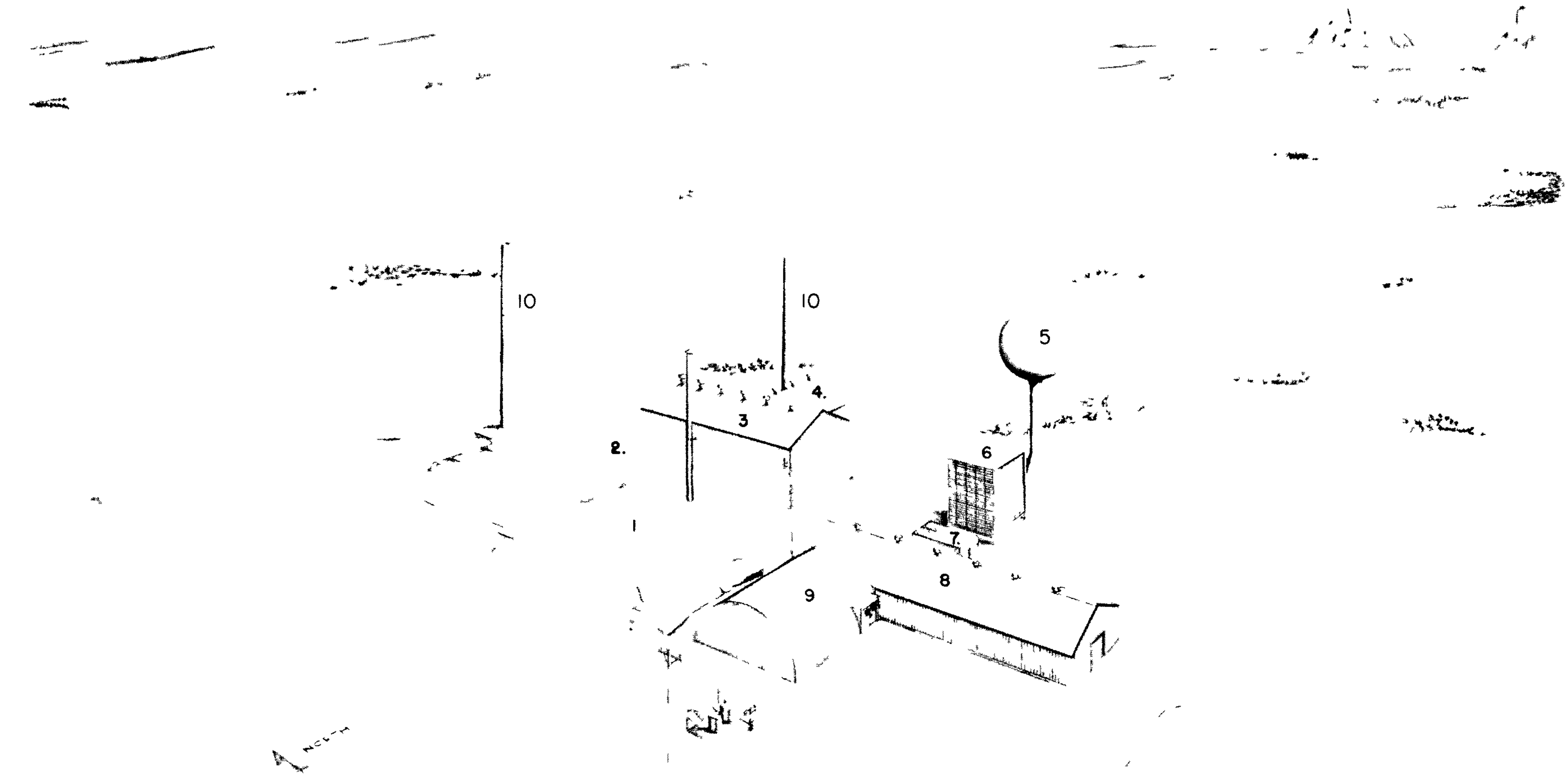
d. After the above tests are run, a test series shall be made at the following conditions of suction temperature and pressure:

(1) 486F ± 10F - 600 psia
(2) 545F ± 10F - 1000 psia
(3) 596F ± 10F - 1500 psia
(4) 636F ± 10F - 2000 psia

Each pump shall run for 75 hr at each of the four temperatures listed above, at design head with cycling every two hours during the test. The following measurements shall be made at two-hour intervals.

(1) Head and capacity
(2) Bearing temperature
(3) Seal face temperatures
(4) Seal leakage rate
(5) Input horsepower
(6) Operating log will be kept and curves prepared

e. The Laboratory's representatives shall witness all tests.



LEGEND

1 WATER COOLERS
2 ACTIVE STORAGE AREA
3 REACTOR BUILDING
4 STEAM CONDENSERS
5 HIGH TANK WATER STORAGE
6 COOLING TOWER
7 AUXILIARY HEAT EXCHANGER
8 AUXILIARY EQUIPMENT AREA
9 CONTROL ROOM
10 STEAM EXHAUST STACK

FIG 1
PLANT PERSPECTIVE

RE-8-18403 D

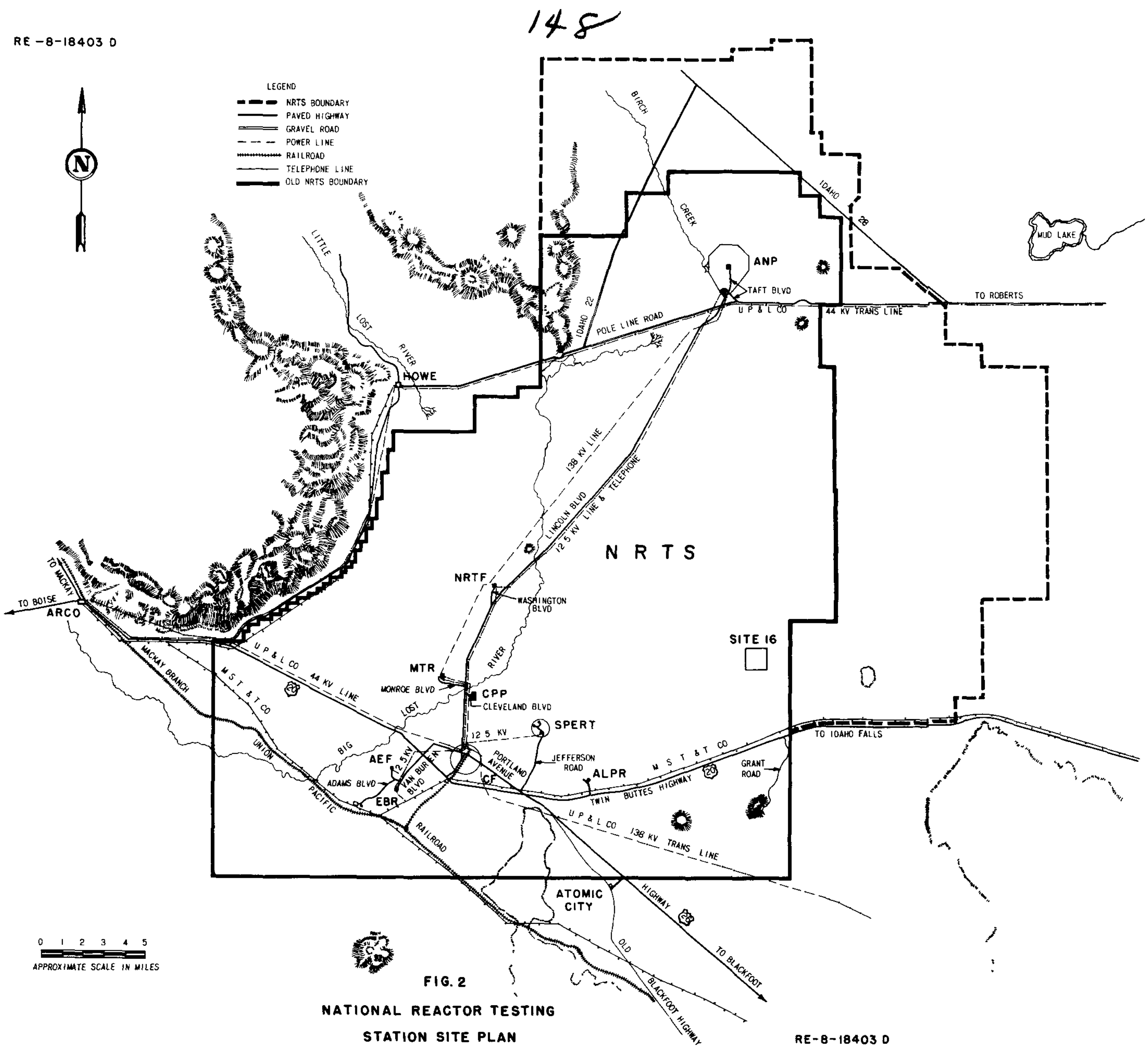
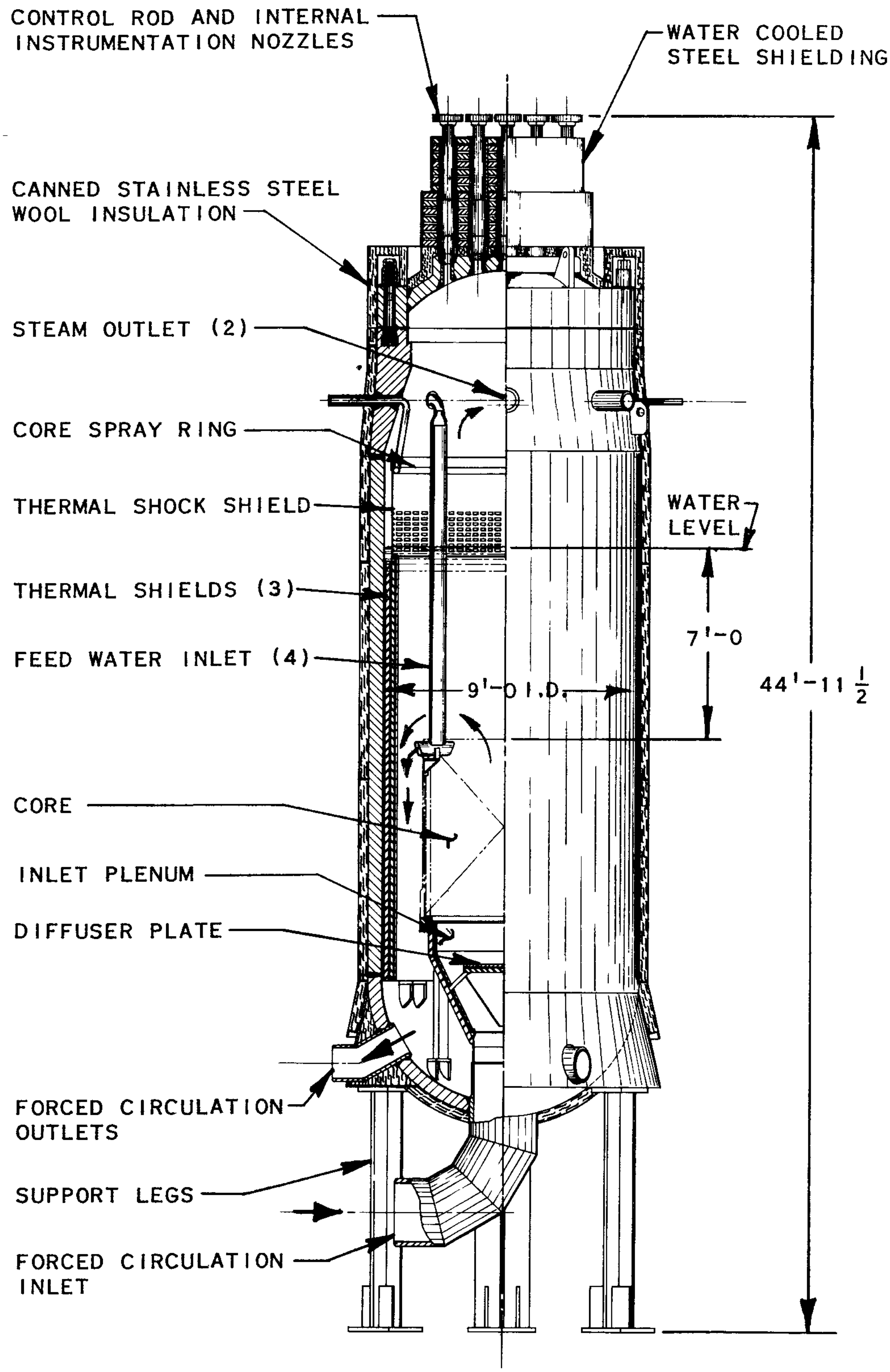


FIG. 2

NATIONAL REACTOR TESTING STATION SITE PLAN

RE-8-18403 D

149



ESTIMATED OPERATING WEIGHT = 490,000 lbs

FIG. 3
REACTOR VESSEL

RE-6-19151-A
C.BULLINGER:L.B.,11-7-56

150

151

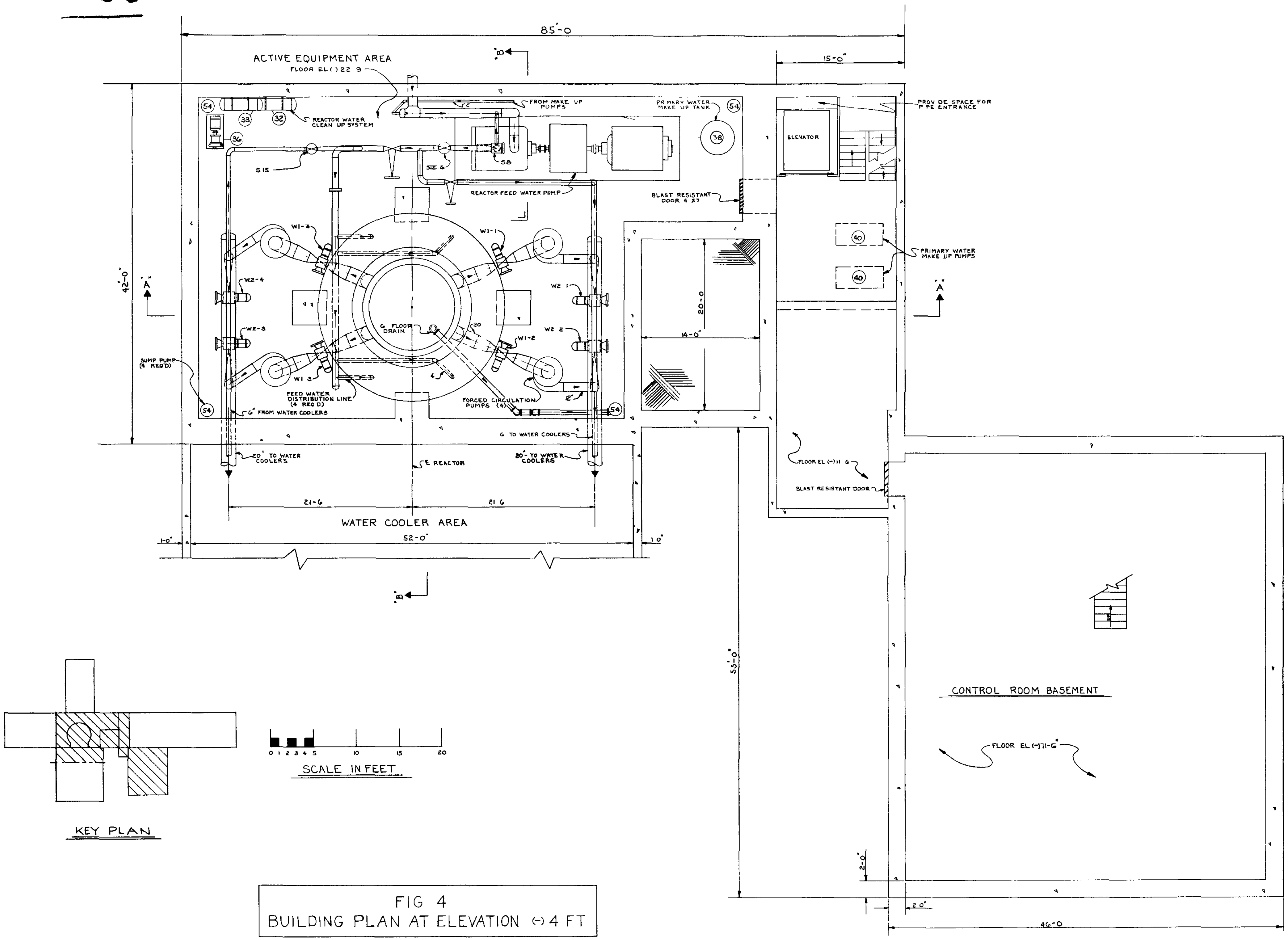


FIG 4
BUILDING PLAN AT ELEVATION (-) 4 FT

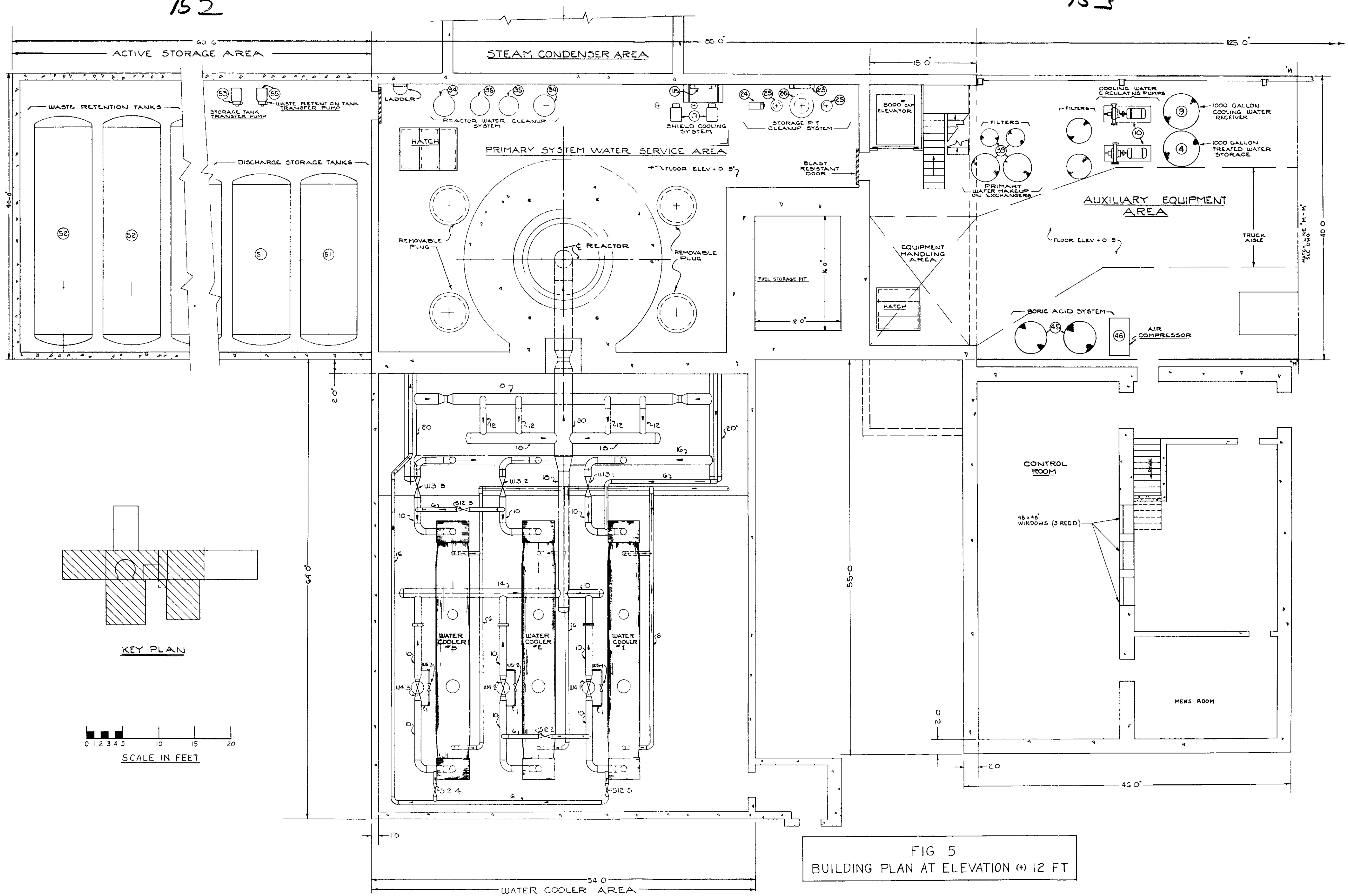


FIG 5
BUILDING PLAN AT ELEVATION (+) 12 FT

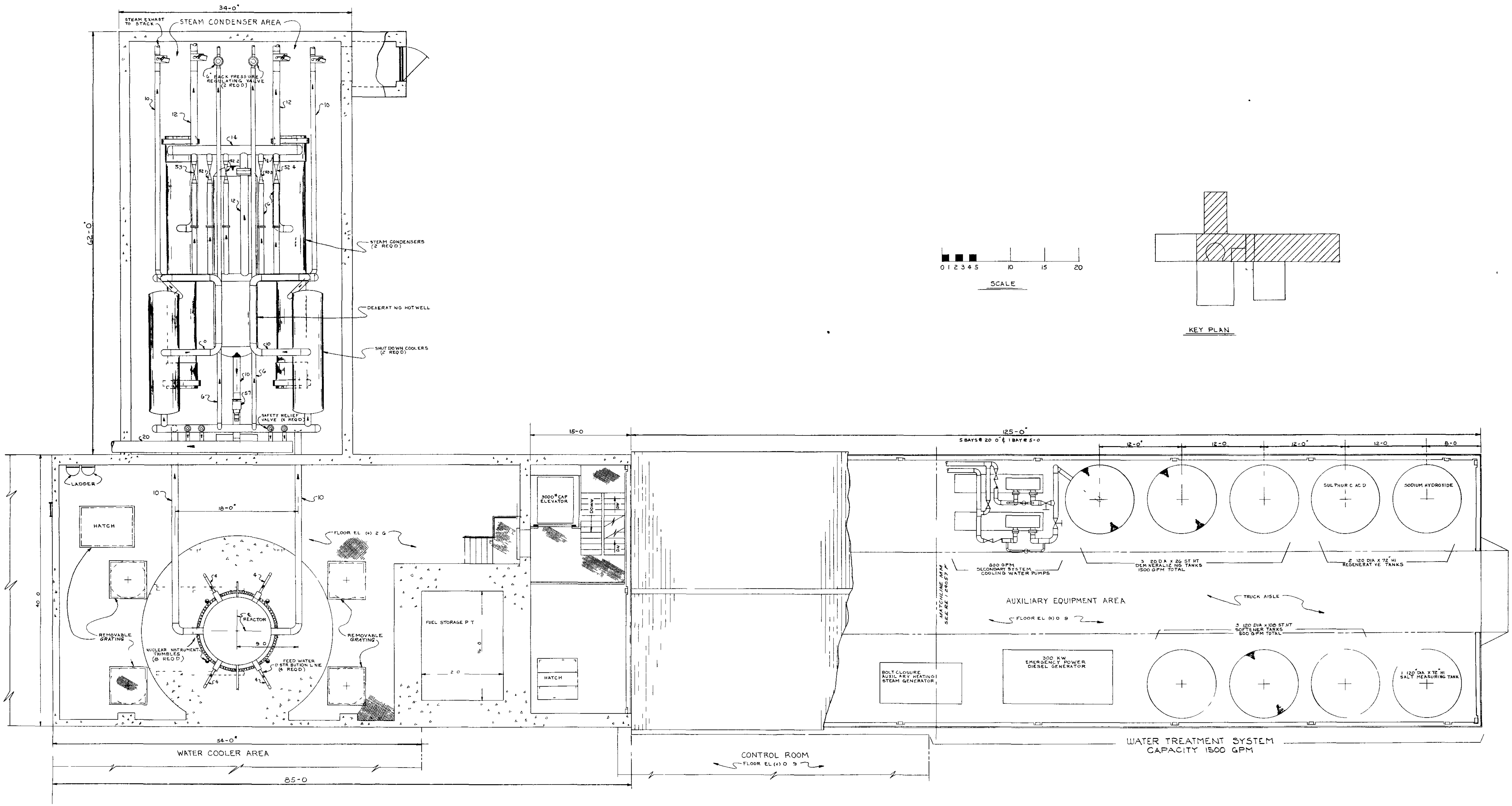


FIG 6
BUILDING PLAN AT ELEV (+) 30 FT

156

157

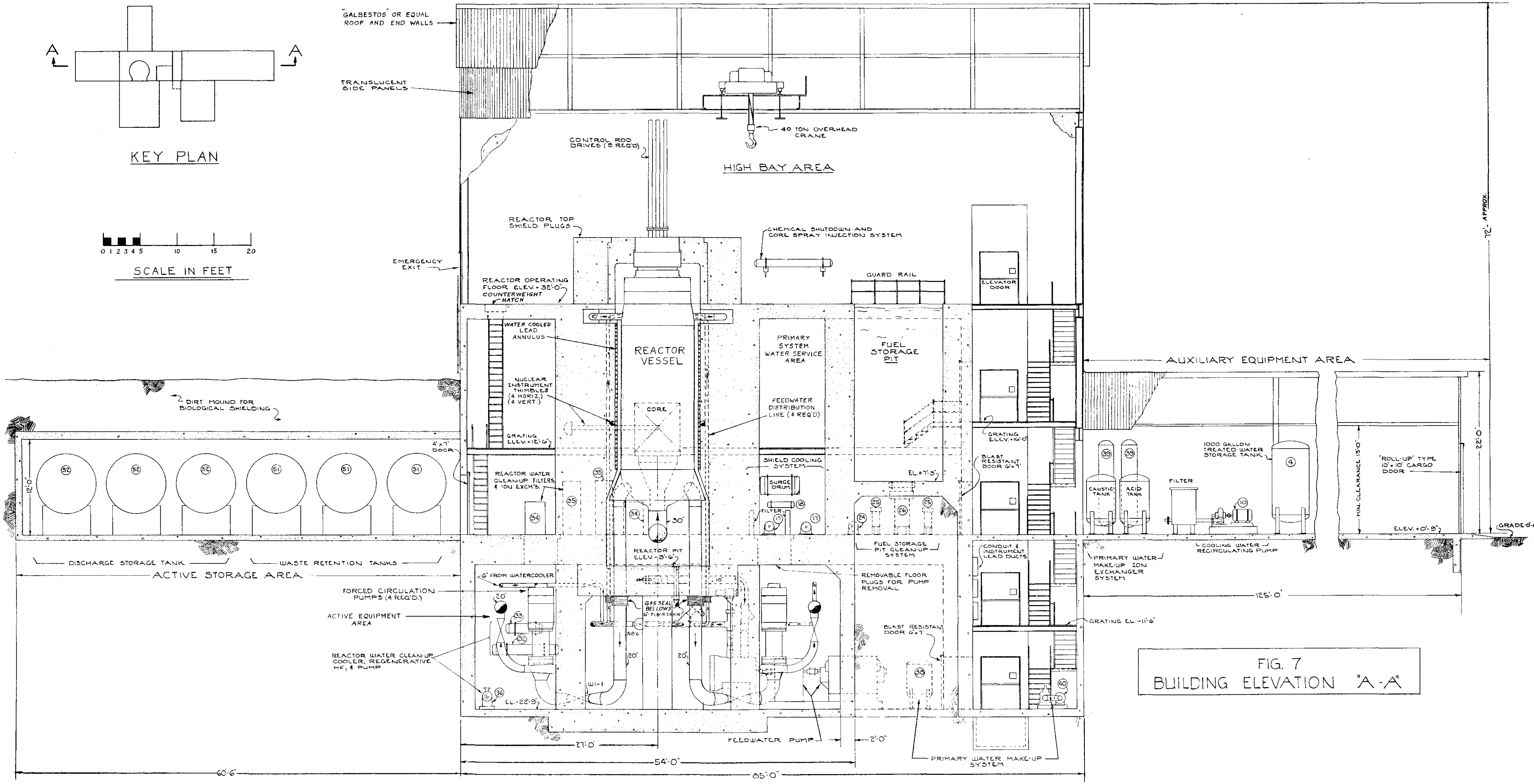


FIG. 7
BUILDING ELEVATION "A-A"

158

159

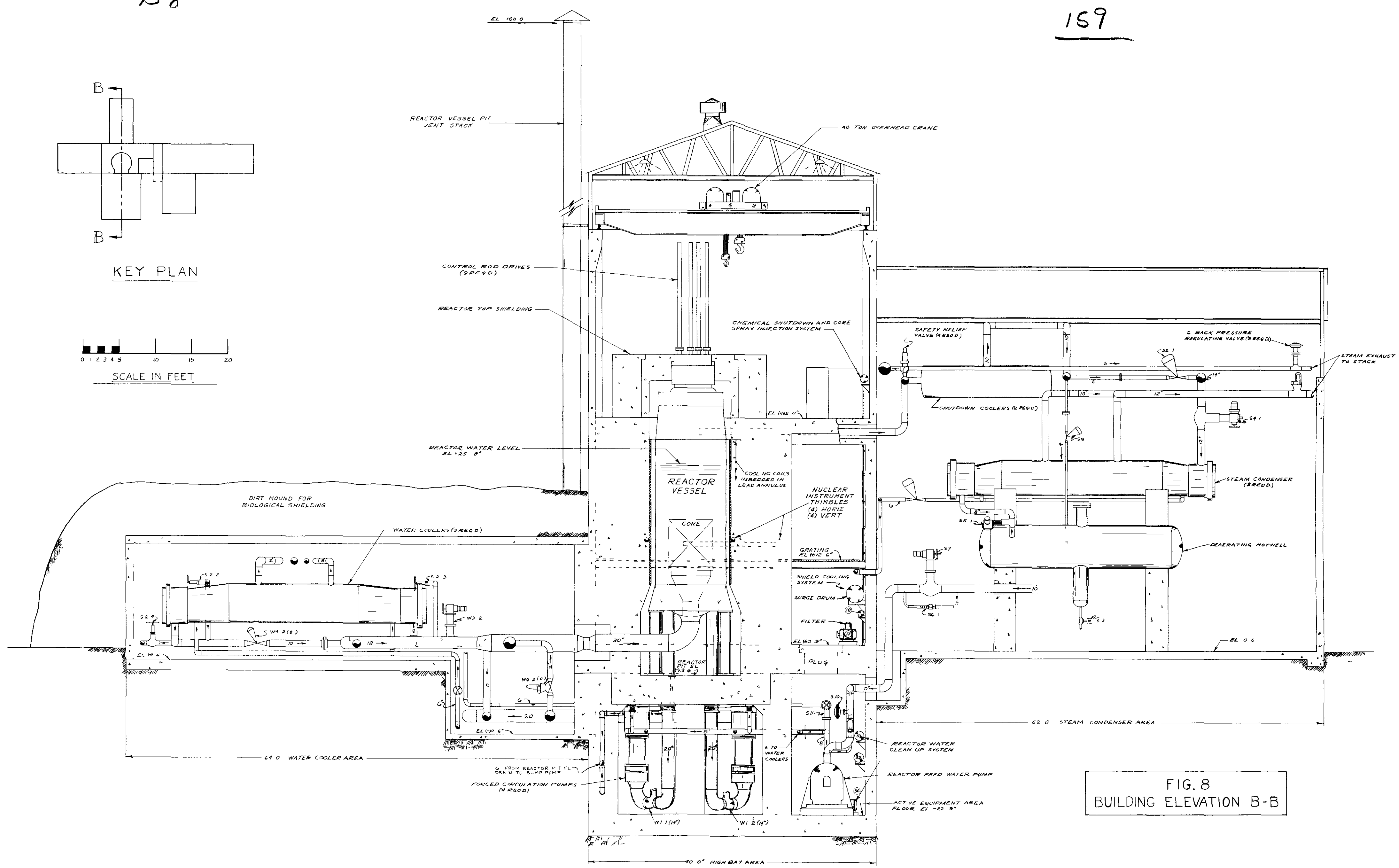


FIG. 8
BUILDING ELEVATION B-B

160

161

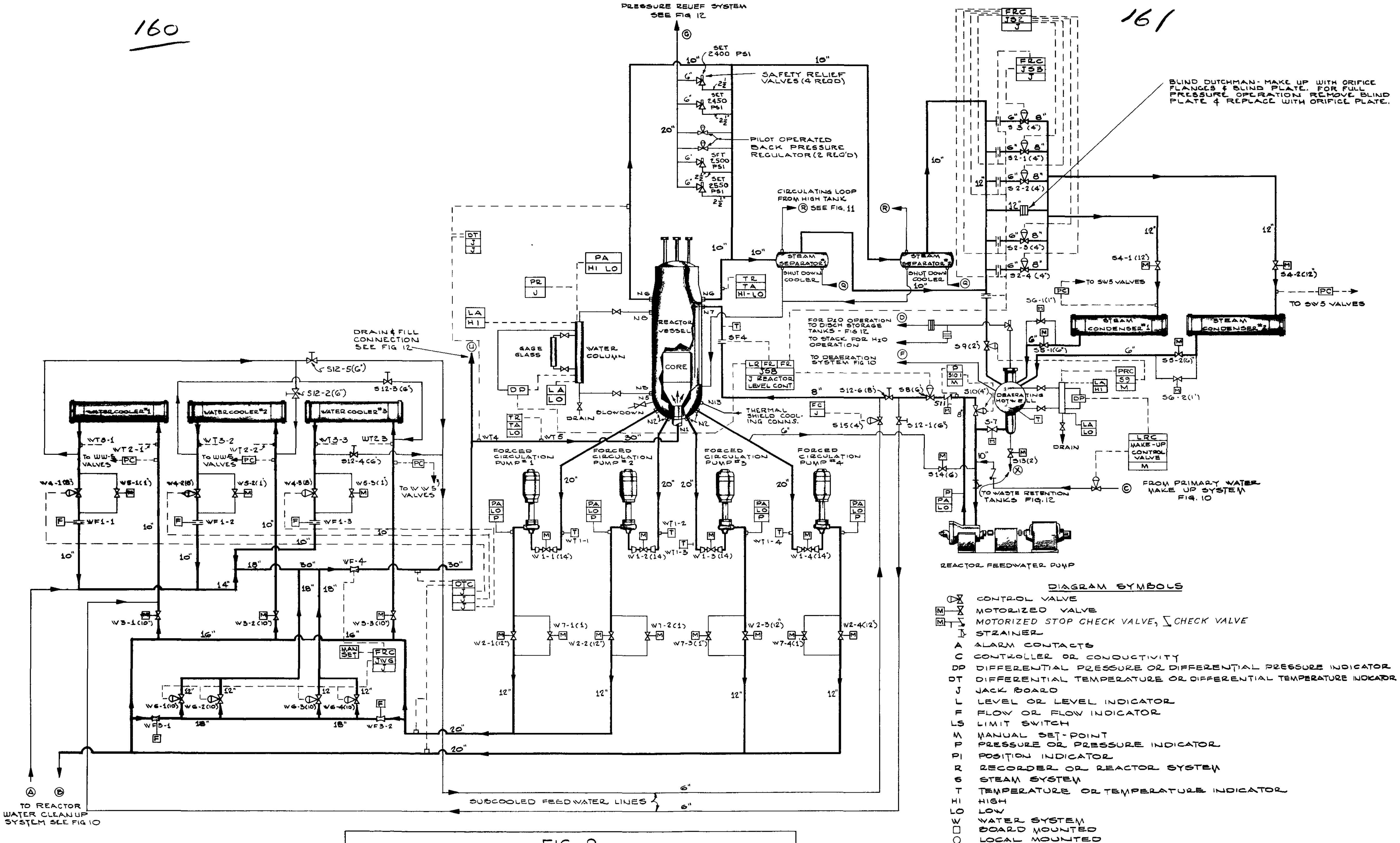


FIG 9
PRIMARY SYSTEM FLOW CHART

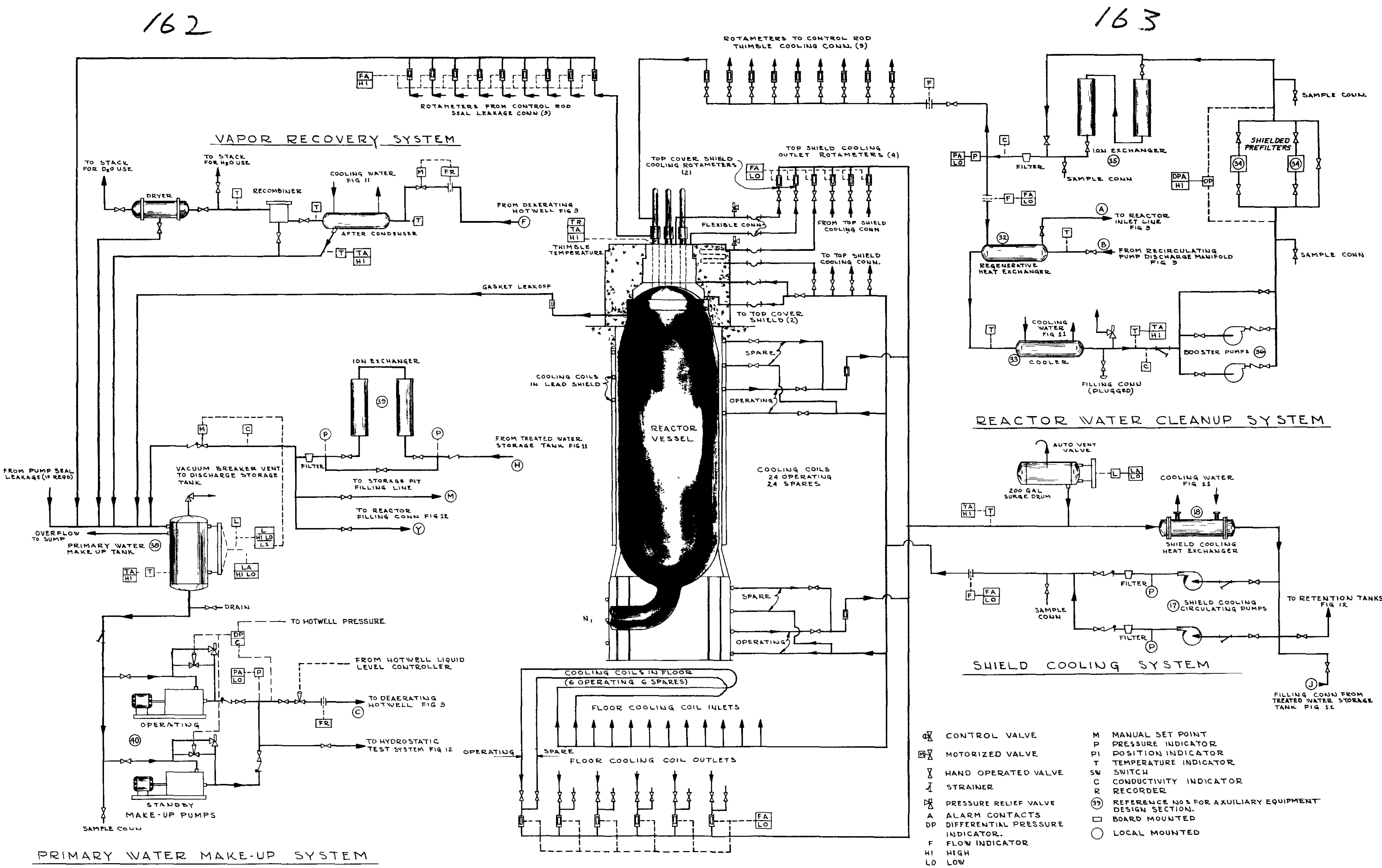


FIG. 10
AUXILIARY SYSTEM FLOW CHART NO. 1

164

165

DIAGRAM SYMBOLS

(symbol)	MOTORIZED VALVE
(symbol)	PRESSURE RELIEF VALVE
(symbol)	CONTROL VALVE
(symbol)	STRAINER
A	ALARM
DP	DIFFERENTIAL PRESSURE
F	FLOW INDICATOR
HI	HIGH
L	LEVEL INDICATOR
C	CONTROLLER
LO	LOW
LS	LIMIT SWITCH
M	MANUAL SET POINT
P	PRESSURE
T	TEMPERATURE INDICATOR
(23)	REFERENCE NOS FOR AUXILIARY EQUIPMENT DESIGN SECTION
□	BOARD MOUNTED
○	LOCAL MOUNTED

NOTE "A, B & C"

SOLENOID OPERATED VALVES "A" & "B" IN SERIES "A" & "B" ENERGIZE TO OPEN C ENERGIZES TO CLOSE. VALVES CAPABLE OF BEING MANUALLY OR AUTOMATICALLY TRIPPED FROM CONTROL ROOM

NOTE "D, E & F"

D.C. SOLENOID VALVES D & E IN SERIES ENERGIZED TO OPEN ON SIMULTANEOUS LOW REACTOR PRESSURE AND LOW REACTOR LEVEL SOLENOID VALVE "F" ENERGIZED TO CLOSE

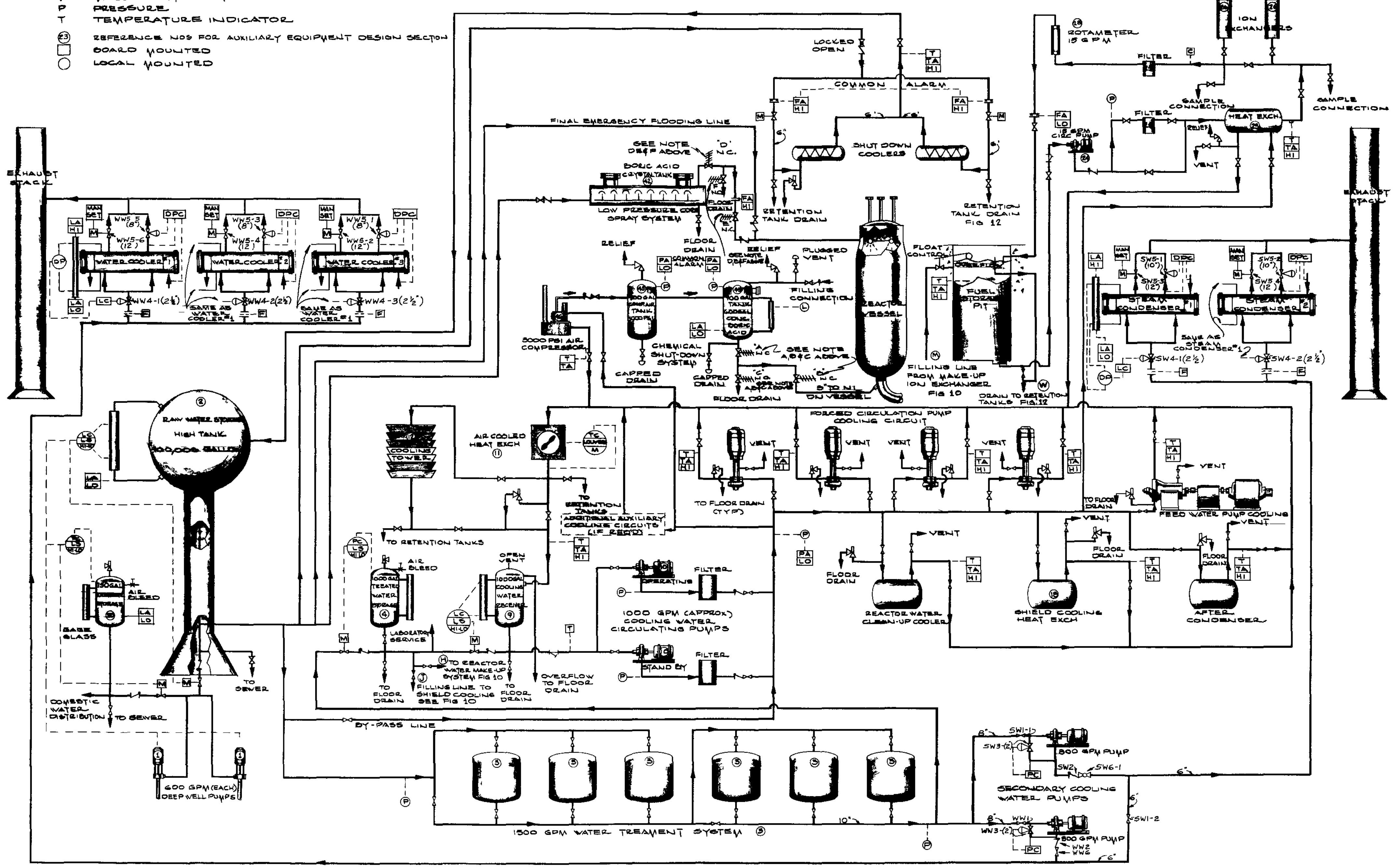


FIG 11
AUXILIARY SYSTEM FLOW CHART #2

166

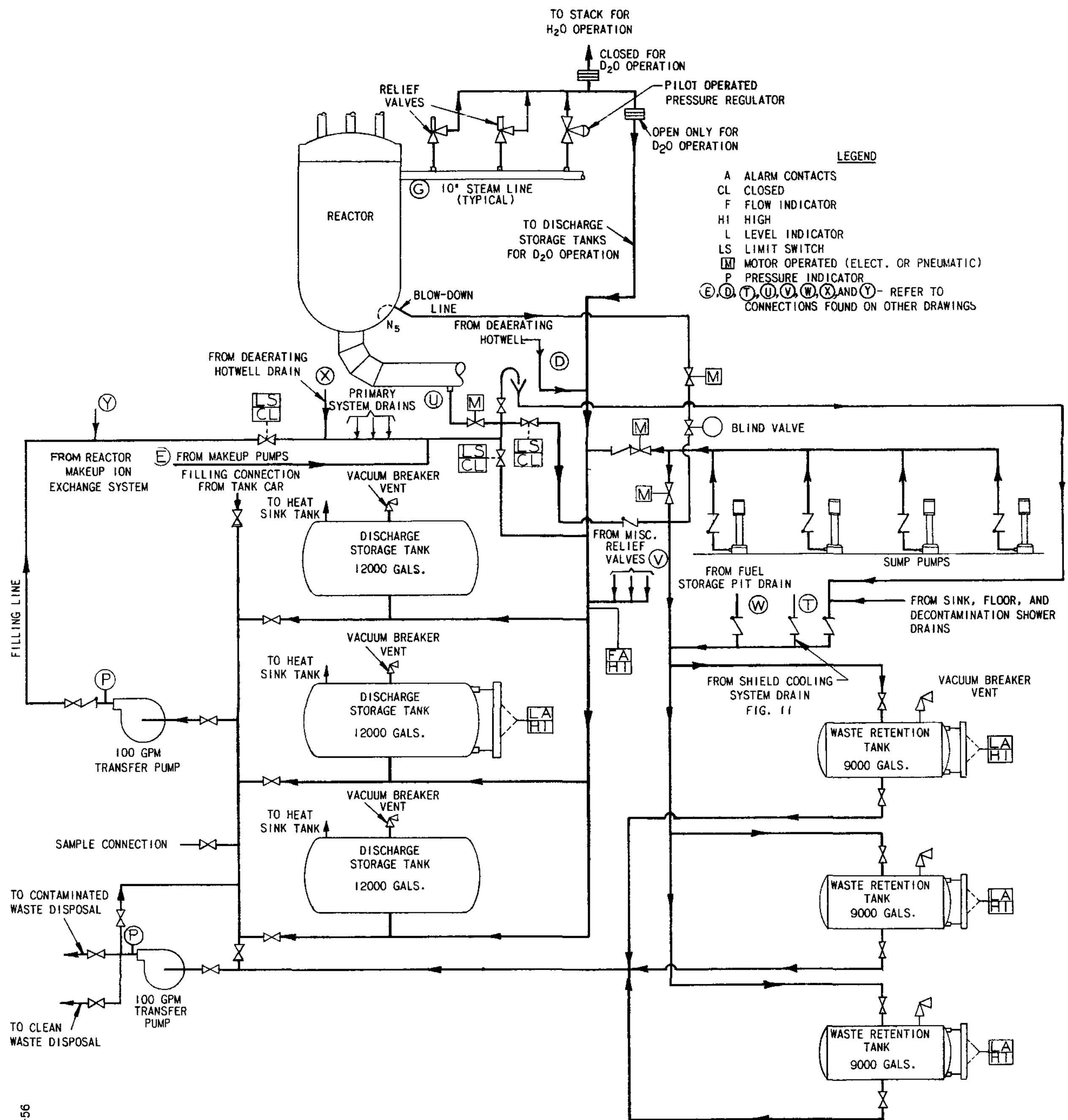


FIG. 12
WASTE RETENTION AND STORAGE TANK DRAIN SYSTEM FLOW CHART

167

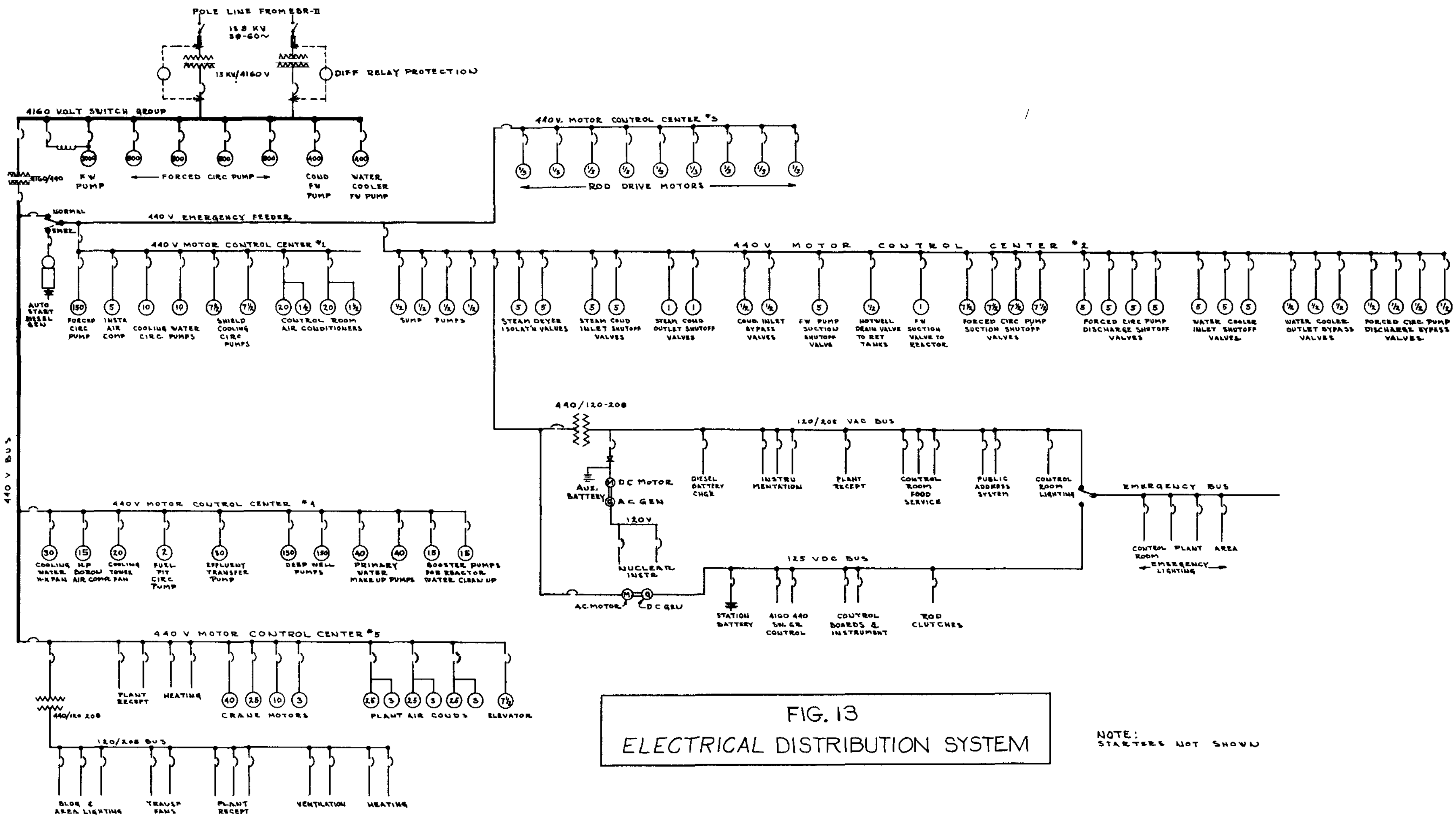


FIG. 13
ELECTRICAL DISTRIBUTION SYSTEM

NOTE:
STARTERS NOT SHOWN