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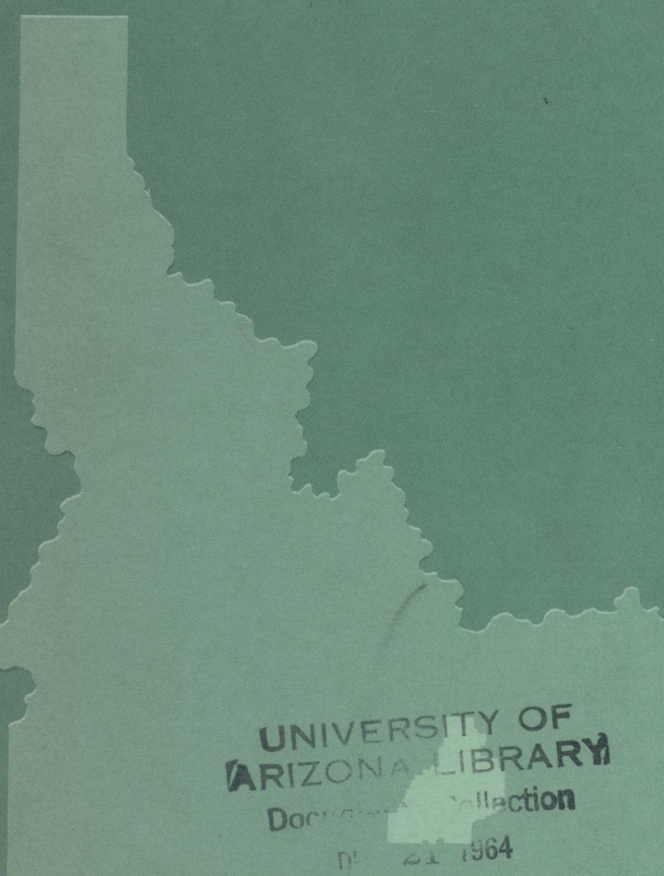
FUNDAMENTALS IN THE OPERATION OF NUCLEAR TEST REACTORS

VOL. 3 ENGINEERING TEST REACTOR DESIGN AND OPERATION



PHILLIPS
PETROLEUM
COMPANY

ATOMIC ENERGY DIVISION

NATIONAL REACTOR TESTING STATION
US ATOMIC ENERGY COMMISSION

FUNDAMENTALS IN THE OPERATION OF NUCLEAR TEST REACTORS

This manual and course of study have been prepared under the direction of the MTR-ETR Operations Training and Qualifications Committee appointed by R. L. Doan, Manager, Atomic Energy Division, Phillips Petroleum Company:

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PHILLIPS
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Atomic Energy Division
Contract AT(10-1)-205
Idaho Operations Office
U. S. ATOMIC ENERGY COMMISSION

VOLUME 3

ENGINEERING TEST REACTOR DESIGN AND OPERATION

VOLUME 3

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CHAPTER I

ENGINEERING DESCRIPTION OF THE ENGINEERING TEST REACTOR

A. PHILOSOPHY AND DESIGN SUMMARY

The Engineering Test Reactor (ETR) was designed to perform engineering tests on fuel elements and components of nuclear plants. In order that these tests be made under conditions simulating the actual proposed application, certain requirements had to be met. These are as follows: one, the reactor would have to generate very high thermal and fast flux in the core holes; two, provision had to be made in the core (high flux zone) for test facilities ranging in size from 3 x 3 x 36 inches to 9 x 9 x 36 inches; three, a reasonably uniform flux from top to bottom of core had to be maintained; and four, the reactor would be designed to contain closed loop-type facilities for circulating any coolant fluid.

The above conditions led to a reactor design quite different from that of the Materials Testing Reactor (MTR). The foremost differences are that all experimental facilities in the ETR are vertical and are placed inside the reactor vessel. The reactor control rod drives are mounted below the reactor bottom head where they are least affected by the experimental facilities. The latter is dependent on the first, since it was anticipated that the upper vessel area would be too congested with experimental facility tubes, hangers, etc, to permit the use of control drives extending downward from the top head.

The vessel top was established near floor level because of the large clear height needed to remove experiment trains and facility tubes. The depth of the vessel, position of the core, size of the biological shield, etc, was set by allowable radiation level and biological considerations.

The building size was determined by the number of experimental facilities and the instrumentation and equipment spaces required for each.

B. DESIGN PARAMETERS AND DATA

Table 1

Reactor Core and Reflector

Operating power, MW		175
Fuel assembly array		10 x 10
Core lattice spacing east-west, north-south		3.040 in.
Fuel assemblies in core	Design Jan. 1963	49 52
Aluminum reflector lattice spacing		3.035 in.
Black rods in core		4
Gray rods in core	Design Jan. 1963	12 12 [a]
Beryllium reflector geometry		
Inside dimensions (in.)		30.4 x 30.4
Thickness (in.)		4-1/2
Height (in.)		37-1/2
Regulating rods in reflector	Design	2 [a]
Major experimental facilities in core		9
Major experimental facilities in reflector		8
Core filler pieces (corner filler pieces)		4

[a] No. 10 and No. 13 gray rods are being used as regulating rods as of January, 1963.

Table 2

Fuel Assemblies

Number in core	Design Jan. 1963	49 52
Active core length		36 in.
Length of assembly		54-1/16 in.
Size of assembly (approx)		3 x 3 in.
Fuel plates per assembly		19
Thickness of fuel plate		0.050 in.
Length of fuel plate		37 in.
Spacing between fuel plates		from 0.119 in. in outer channels to 0.105 in. in inner channels

Table 3

Control Rods

Number of black poison rods (safety)		4
Number of grey poison rods (shim)		12
Number of fuel plates per rod	Design Jan. 1963	14 16
Black poison material	Design	304 stainless steel enriched with boron
	Jan. 1963	347 stainless steel sprayed with cadmium, then with 302 or 316 stainless steel

Table 3

Control Rods (Cont.)

Grey rod material	Type "A" nickel with 0.2 percent cobalt maximum impurity

Table 4

Reactor Physics

Power density of reactor core		494 kW/liter
Average specific power		76,000 kW/kg U
Core life before refueling	Design Jan. 1963	3500 MWd 4500 MWd (approx)
Core average diameter, equivalent		32 in.
Core height		36 in.
Volume of core		21,600 cu in.
U-235 content of new core	Design	14 kg (approx)
	Jan. 1963	23.7 kg (approx)
U-235 content at end of cycle	Design	10.5 kg (approx)
	Jan. 1963	18.0 kg ((approx)
Metal-to-water ratio		0.67
Thermal (nv 2200 meters/sec) flux, average in fuel elements over cycle	Design	3.3×10^{14} nv
	Jan. 1963	1.6×10^{14} nv

Table 4

Reactor Physics (Cont.)

Fast flux, average over cycle above thermal	Design	1.5×10^{15} nv
	Jan. 1963	5×10^{14} nv
Poison content, natural boron		120 g
Vertical max/avg power ratio in fuel		1.4
Horizontal max/avg power ratio in fuel		1.7
Core max/avg power ratio in fuel		2.4
Initial excess reactivity		10 percent
Control rod worth		
Black, total	Design	14.4 percent
	Jan. 1963	7 percent
Grey, each	Design	1 percent
	Jan. 1963	0.4 to 3 percent
Regulating rod, each	Design	0.5 percent

Table 5

Reactor Heat Transfer

Pressure at reactor tank inlet		200 psig
Core pressure drop	Design	40 psig
	Jan. 1963	43 psig
Coolant inlet temperature at reactor		110°F
Coolant outlet temperature	Design	138°F
	Jan. 1963	133°F

Table 5

Reactor Heat Transfer (Cont.)

Number of flow passes through reactor		1
Average velocity in core passages		32 fps
Total coolant flow	Design	44,400 gpm
	Jan. 1963	51,000 gpm
Flow in fuel assemblies		29,700 gpm
Flow in control rods		6100 gpm
Flow in reflector		13,200 gpm
Leakage		2000 gpm
Heat transfer area (core)		
Start of cycle		1336 ft^2
End of cycle		1464 ft^2
Average heat flux in fuel elements		453,000 Btu/hr-ft^2
Maximum heat flux (hot-spot factor 2.5)	Design	1,150,000 Btu/hr-ft^2
	Jan. 1963	1,350,000 Btu/hr-ft^2
Burnout heat flux		4.6×10^6 Btu/hr-ft^2
Maximum allowable fuel element surface temperature	Design	280°F
	Jan. 1963	400°F

Table 6

Reactor Vessel

Total height of vessel	35 ft 8 in.

Table 6

Reactor Vessel (Cont.)

Inside diameter-upper cylinder wall		11 ft 5 in.
Inside diameter-lower cylinder wall		7 ft 7 in.
Material		Stainless clad carbon steel and stainless steel
Thickness-upper cylinder wall		2-1/4 in.
Thickness-lower cylinder wall		1 in.
Opening in ellipsoidal top head		4 ft 6-7/8 in.
Opening in bottom head		5 ft 5 in. diam
Thickness-bottom head		8-1/2 in.
Thickness-top flange		4-1/2 in.
Thickness-GEEL top flange		7 in.
Size of water inlet pipe		36 in.
Elevation-water inlet pipe		90 ft 9 in.
Size of water outlet pipe		36 in.
Elevation of water outlet pipe		83 ft 4 in.
Diameter of discharge chute		15 in.
Nozzles	12 in. angular	4
	12 in. horizontal	9

Table 6

Reactor Vessel (Cont.)

Nozzles	8 in. angular	7
	8 in. horizontal	3

C. GENERAL DESCRIPTION OF FACILITY

The ETR facility is a complete nuclear engineering test facility located south of and adjacent to the MTR. As such, it includes its own compressor building, heat exchanger or process water building, electrical building, and office building. The above are independently functioning buildings built with common dividing walls. The functions or design of the auxiliary buildings are not covered in this section which is confined to a description of the salient design features of the reactor, reactor structure, canal, reactor building, and handling facilities.

The reactor is light-water cooled and moderated and has a thermal rating of 175 MW. It is housed in a gastight building 112 by 136 feet, extending 58 feet above and 38 feet below grade. The reactor vessel consists of the multidiameter vessel proper, removable elliptical dome with flat top flange, flat bottom head, a discharge chute, inlet water flow distributor, experimental hanger supports, experimental access nozzles, and the process water inlet and outlet line connections. The vessel serves the functions of containing the reactor core and of providing radiation space and facilities to accommodate the in-pile tubes to be used for nuclear radiation experiments. Facilities also are provided for control rods, instrumentation, shielding of the vessel walls, directing coolant flow through the core, and support of all internal structure. The stainless clad carbon steel and stainless steel reactor vessel design pressures and temperatures are 250 psig and 200°F. Operating pressures and temperatures are 200 psig at 110°F inlet and 150 psig at 133.5°F outlet.

The vessel internals consist of the inner tank, the internal thermal shields, reactor core, core support structure and the experiment upper support ring. The core support structure consists of six structural supports extending from the reactor bottom head up to and including the support plate and reactor grid plate. This structure supports the reactor core, beryllium reflector and aluminum reflector, serves as a guide for the experimental in-pile tubes and control rods, and transmits the pressure drop load across the core to the reactor bottom head.

The reactor core is a square configuration of 52 fuel elements, 12 shim control rods, 4 safety control rods, 4 corner filler pieces, and 9 experimental facilities and is approximately 30.4 inches square.

The beryllium reflector is a 4-1/2 inch thick layer of beryllium extending completely around the core. The two originally designed regulating rods were contained in holes on opposite sides in the beryllium reflector. Space also is provided in the beryllium for additional capsule-type experiments. The aluminum reflector pieces extend from the beryllium reflector out to the inner tank walls. Provision is made for eight experimental facilities in the aluminum reflector. Each aluminum reflector element is built with a hollow interior providing for additional irradiation space of the capsule type.

The reactor vessel is enclosed and supported by a high density concrete biological shield extending from the first floor to the basement ceiling. This shield is 8 feet thick at the core centerline. The 25-foot outside diameter of the shield is covered with a 3/4-inch steel plate.

The subpile room is located directly below the reactor bottom head. Walls of the subpile room also are high density concrete, and transmit the biological shield load to the reactor foundations extending down to bedrock. The subpile room is the area in which experimental in-pile tubes connect with the experimental piping, and this piping is routed to the experimental cubicles via access holes in the subpile room walls. Control rod, regulating rod, and chamber drives extend through the subpile room downward into the rod access room located directly below. The rod access room is located below basement floor level, and is the area in which the control rod, regulating rod, and chamber drives are physically located and serviced.

The canal is "T" shaped. The portion immediately west of the reactor is known as the working canal, and the north and south extensions are known as the storage canal. Fuel elements, control rod sections, and certain experimental equipment can be discharged directly to the working canal via the reactor discharge chute. The working canal also provides storage for reactor handling tools and contains the canal saw which is used to remove end boxes from fuel elements or to saw other materials, including experimental equipment, to lengths suitable for further handling, shipments, etc. The storage canal is used for storage of hot fuel, hot control fuel, miscellaneous experimental equipment, reactor equipment, baskets, slugs, canal bulkheads, and other items. Large casks for shipment of reactor fuel or experimental equipment also are placed in this canal for loading and/or unloading. Canal walls and bottom are constructed of ordinary concrete, and are several feet thick to provide the necessary shielding for personnel working in the console and basement areas.

Material handling facilities include a 30/5-ton bridge crane, a 2-ton bridge crane, the 1-1/2-ton GEEL bridge crane, a freight elevator, a passenger elevator, two hatchways, and associated equipment. Individual experiments use various types of handling facilities which due to their specialized nature, are not discussed.

For purposes of orientation and quick reference, several key reactor and reactor building elevations are listed in tabular form below. (All elevations may be converted to sea level datum by adding 4828.26 feet.)

Table 7

Reactor and Building Elevations

1.	First floor	96 ft 6 in.
2.	Console floor	74 ft 0 in.
3.	Basement floor	58 ft 3 in.
4.	Canal parapet	99 ft 10-1/2 in.
5.	Canal water level (average)	98 ft 10-1/2 in
6.	Canal floor	78 ft 10-11/16 in.
7.	Reactor vessel top flange	99 ft 11-3/8 in.
8.	Top of discharge chute	87 ft 11-7/16 in.
9.	Top of inner tank	87 ft 3-1/4 in.
10.	Top of control rod guide tube	84 ft 8-13/16 in.
11.	Top of core filler piece and corner filler piece	81 ft 8-3/4 in.
12.	Top of beryllium reflector	81 ft 7-7/8 in.
13.	Top of aluminum reflector	81 ft 7-3/4 in.
14.	Top of fuel element fuel plates	81 ft 7-1/2 in.
15.	Centerline of active lattice	80 ft 1 in.
16.	Top of grid plate	78 ft 3-15/16 in.
17.	Top of support plate	73 ft 4-15/16 in.
18.	Bottom of reactor vessel bottom head	68 ft 10-3/8 in.

D. REACTOR BUILDING

The reactor building is 136 feet in the east-west direction and 112 feet in the north-south direction. It extends 58 feet above the grade and 38 feet below grade to the basement floor. The walls, floors, and columns below grade are of reinforced concrete construction. The walls above grade are insulated metal-sandwich panel siding with the interior surface sealed and taped to make the structure gastight. The roof construction consists of steel decking on purlins with applied foam glass insulation and built-up roofing. The panel walls, roof, and crane structure are supported on a steel superstructure of columns and trusses. The steel columns rest on the reinforced concrete columns which extend to bedrock from the first floor level.

The high bay area above the first floor has a clear height of 47 feet to the bottom of the roof truss structure. The first floor is at elevation 96 feet 6 inches, the same floor elevation as the MTR. The first floor is designed for three intensities of loading. That part of the first floor between column centerlines E 24 to E 25 from the north truck door to and including the pipe tunnel, the eastward extension of the pipe tunnel, and remaining floor area north to the edge of the stair well enclosure is rated at 1000 psf. The central floor area in the vicinity of the reactor is limited to 750 psf. This area extends 22 feet south, 29 feet 2 inches west, 27 feet north, and 27 feet 6 inches east of the reactor centerline (except where this area overlaps the 1000 psf area described above). The balance of the first floor area is limited to 350 psf. The bounds of these floor areas are painted on the floor for quick reference. The first floor slabs are 10 inches thick except for the 1000 psf area which is 12 inches thick. The centerline of the reactor is located approximately 61 feet west of the reactor building east wall and 47 feet south of the north wall. The working canal extends westward from the reactor structure, and the process water pipe tunnel extends eastward from the reactor structure under the first floor.

The T shaped canal consists of two sections. The working canal (stem of the T) is 37 feet long and 8 feet wide tapering to a 2-foot 8-inch width at the reactor. The storage canal is 60 feet long and 12 feet wide. Except for the well beneath the reactor discharge chute, the water depth is 20 feet with a 1-foot freeboard. Two removable bulkheads for the working canal permit the various sections of the canal to be drained individually. The canal floor is rated at 200 psf live load plus the water load. (See Figure 1.)

The console floor, elevation 74 feet, serves the dual purpose of a shielding roof for the experimental cubicles at basement level and a working level for experimental consoles and equipment. The walls of the pipe tunnel, the biological shield, and the canal walls extending from the first floor to the console floor divide the console area into two halves connected only at the west end by a 9-foot 6-inch wide corridor. The entire console floor is rated at 350 psf. That part of the floor directly over the basement cubicle area is constructed of three-foot thick ordinary concrete; the balance of the floor is one-foot thick. Electrical ducts are laid in 9-inch thick nonload-bearing concrete fill over the floor proper.

A 30- x 80-foot concrete balcony has been added on the south side of the console area in order to obtain additional floor space for experimental instrumentation and control equipment. This balcony is served by two stairways to the console floor as well as by the south circular stairway which penetrates it. The balcony is designed for a live load of 200 psf.

The basement floor is at elevation 58 feet 3 inches. It rests on a compact fill and is designed for a 900 psf load.

Personnel access between floors is by means of two circular stairways located north and south of the working canal, an enclosed stairwell in the southeast corner of the reactor building, and a second stair well and passenger elevator in the north-east corner of the reactor building.

Equipment access between floors is by a 10 x 14 foot, 10-ton capacity freight elevator located near the north truck door in the northeast corner of the reactor building or by two hatchways north and southeast from the reactor centerline. The north hatchway is 8 x 10 feet through the console floor and the east hatchway is 10 x 10 feet. The openings through the first floor are one foot larger each way to permit the console floor hatches to be removed through the first floor hatchways.

Various small access holes are provided both in the first and the console floor for experimental use.

The area directly under the reactor is known as the subpile room. It is separated from the basement area by a four-foot thick high density concrete circular wall. This room is 20 feet in diameter. The floor elevation is 58 feet 3 inches, the same as the basement floor. The walls of the subpile room act as shielding, and also as a support for the reactor and biological shield. Access is by means of a shielding door opening to the basement on the east side. Thirty-eight holes through the wall provide for penetration of experimental piping, instrument leads, etc.

The control rod access room is located directly below the subpile room and has a floor elevation of 44 feet 9 inches. This room is reached by a stairway extending westward from basement floor level. As the name implies, it houses and provides access to the control rod, regulating rod, and chamber drive mechanisms.

E. REACTOR AND REACTOR STRUCTURE

The following sections contain a more detailed description of the reactor components and the reactor structure.

In order to provide the reader with key information regarding the reactor and reactor structure, certain basic figures containing key information are included at the end of this chapter. For convenience, these figures are listed below:

Figure 1 Reactor building first floor layout

Figure 2 Reactor structure vertical cross section

Figure 3 Reactor structure top plan with vessel head removed

Figure 4 Grid plate

Figure 5 Lattice and reflector horizontal cross section above core

Figure 6 Fuel assembly

Figure 7 Control rod assembly

Figure 8 Control rod guide tube

Figure 9 Control rod drive assembly isometric

It should be understood by the reader that the above figures show only basic features in most instances. Figures are not to be construed as engineering drawings. The applicable key engineering drawings are referred to after each general topic heading.

Most engineering details dealing with the ETR are included on drawings prepared by Kaiser Engineers and by Phillips Petroleum Company. Kaiser drawing numbers are as follows: ETR-5528-MTR-642-M-672 where ETR refers to ETR; 5528 is the Kaiser job number assigned to ETR construction; MTR-642 identifies the location of the work included on a particular drawing as to building number; M indicates that this particular drawing is a mechanical drawing; and 672 is the file or identification number assigned to that individual drawing. Phillips Petroleum Company drawings are generally identified by a drawing number as ETR-E-1320 where ETR identifies the project as being concerned with ETR work; E denotes a particular physical size of drawing; and 1320 constitutes the file or identification number assigned to that drawing.

All drawings, other than Kaiser and Phillips drawings, which are referred to in the following material will designate the firm which prepared the drawing as well as the key drawing numbers.

1. Reactor Pressure Vessel (See O.G. Kelley drawing 55-4694-1; Figure 2 and Figure 3)

The pressure vessel was designed to serve the following functions: one, contain demineralized cooling water at 250 psig; two, contain the core, inner tank, internal thermal shields, and core support structure; three, support and locate the various experimental facilities; four, provide space for remote handling of fuel elements, A-pieces, capsule experiments, etc; five, direct coolant flow through core; and six, provide for control rods and instrumentation.

The pressure vessel was designed and constructed to the requirements of the ASME Boiler and Pressure Vessel Code whenever applicable. Areas that could not be designed by the code, such as the transition sections and the flat bottom head, were given a stress analysis based on the simultaneous application of the maximum combined loadings due to pressure, static loads, and shock loads.

The vessel is constructed of stainless clad carbon steel and stainless steel. Carbon steel is SA-212 Grade B, and stainless steel is AISI 304 ELC.

The over-all height of the multi-diameter vessel is approximately 35 feet 8 inches. The upper cylinder wall is 11 feet 5 inches inside diameter and 2-1/4 inches thick. The transition between the upper and lower cylindrical shells is an ellipsoidal section. The lower cylinder wall is 7 feet 7 inches inside diameter and is one inch thick, except where it connects to the ellipsoidal transition piece extending downward from the upper cylinder wall. This top section is one inch thick at its attachment to the lower cylinder wall, and tapers to a thickness of 3-7/8 inches at its point of attachment to the ellipsoidal transition section. The top of this ring is machined and serves as a mount for the inner tank. An ellipsoidal head with a 5-foot 5-inch inside diameter flanged opening is attached to the bottom of the lower cylinder wall. This head tapers from one inch thick up to three inches thick, and the reactor vessel bottom head seals the 5-foot 5-inch diameter opening.

The reactor vessel top closure is an ellipsoidal head 2-1/4 inches thick with a 4-1/2 inch thick removable top flange which seals the 4 foot 6-7/8 inch inside diameter top opening. The original top flange had no experimental penetrations. A second top flange has been supplied which is 7 inches thick and has the top head penetrations required for the GEEL experiments. The additional thickness on this flange is required for hole reinforcement. A viewing port has been added to this flange to permit viewing reactor internals, in-pile tubes, lead experiments, etc, under actual operating conditions.

The reactor vessel bottom head is a flat, circular, stainless steel plate 8-1/2 inches thick. This head supports the reactor core and is equipped with holes to accommodate experiment facility tubes and control, regulating, and control chamber drive rods.

Twenty-three nozzles are located around the upper cylinder wall above first floor level to accommodate experimental piping, leads, and instrumentation.

A discharge chute, 15-inch inside diameter, is located in the upper transition section on the west side and connects with the working canal. The chute has a water cover of approximately 11 feet with the vessel top closure off and 15 feet with only the top flange removed. The discharge chute is sealed with an elliptical cover during reactor operation.

The flow distributor is integral with the vessel and is located at the lower end of the upper cylinder wall of the vessel. It functions to reduce turbulence within the vessel by directing the coolant flow upward around the periphery of the vessel toward the elliptical top head. A flow splitter at the inlet distributes the water equally into each leg of the flow distributor, and the water enters the reactor vessel proper through four openings in the top of the flow distributor. The distributor is fabricated of AISI 304 ELC stainless steel.

Fifteen support hangers are located around the inside surface of the flow distributor to position and hold experimental facilities. Each hanger has a 2-inch diameter keyhole slot 26 inches deep. One-inch diameter holes also are provided in lugs at the hanger sides 23 inches below the top of the hanger. The latter serves to anchor the lateral bracing on the experimental facility tubes.

Additional support for experimental facilities is furnished by a support ring located near the top of the reactor vessel top flange. This support ring also is AISI 304 ELC stainless steel. The support ring is 8-1/2 inches deep, 5-3/4 inches thick with an inside diameter of 10 feet 5 inches. It is notched at the west side to provide a 12-inch radial vertical clear area above the discharge chute. Twenty-two holes are distributed around the support ring to attach additional experimental hanger arms.

The pressure vessel is supported at the transition from the larger to the smaller diameter on support sections mounted on the concrete biological shield. Self-lubricated bronze alloy expansion plates allow for diametral thermal expansion. Guides at the transition section and also at the bottom head prevent rotation and/or vertical misalignment. The reactor load from the expansion plates is distributed to the concrete structure by a 1-1/4-inch thick steel bed plate.

Two 4-inch drain lines connect into the vessel with nozzles 10 and 88 inches below the reactor vessel top flange. These lines are located in the northwest quadrant of the reactor vessel.

The coolant inlet and outlet pipes are 36-inch diameter pipes located on the east side of the reactor vessel at approximate elevations of 90 feet 9 inches and 83 feet 4 inches, respectively.

2. Thermal Shields (see Figure 2)

The thermal shields protect the pressure vessel walls and the concrete biological shield from excessive thermal stresses.

(a) Internal Thermal Shield (see O. G. Kelley drawing 55-4694-7)

Four internal thermal shields protect the vessel walls. They are made of AISI 304 ELC stainless steel in the form of concentric cylindrical shells. They are 57 inches long and are 3/4, 7/8, 1-1/8, and 1-5/8 inches thick respectively, beginning with the innermost shield. The water spaces are: 1 inch between the thermal shields; 4-1/2 inches between shell and inner tank; and 2 inches between shell and vessel wall.

The thermal shields are supported by three brackets attached to the lower cylindrical vessel wall.

(b) External Thermal Shield (see drawing ETR-5528-MTR-642-M-34)

An external thermal shield is embedded in the concrete biological shield. It is formed of lead 3-1/2 inches thick and has stainless steel cooling coils. Primary coolant circulating through these coils keeps the inside surface of the concrete below 120°F which is well below the point of dehydration for concrete.

3. Inner Tank (see O. G. Kelley drawing 55-4694-5 and Figure 2)

The inner tank has the following functions: one, to direct coolant flow downward through the core to the bottom of the vessel and upward through the internal thermal shields; two, to support the control rod guide tube support frame and latches; and three, to support lead experiment brackets.

The inner tank is fabricated of AISI 304 ELC stainless steel. It is composed of an upper flange, a one-inch thick conical transition section, and a five-foot 2-1/4-inch inside diameter shell approximately seven feet long. The upper 22 inches of the shell is one inch thick and the remainder is 1/2 inch thick. The lower 10 inches is machined internally for clearance around the grid plate. Four brackets 90 degrees apart in the one-inch thick cylindrical section form the supporting structure for the control rod guide tube upper support frame. Several 1/2-inch tapped holes are provided around the periphery of the inner tank upper flange and are primarily used to support and hold leads from small lead experiments.

4. Core Support Structure (see O. G. Kelley drawing 55-4694-1 and Figure 2)

The reactor core, beryllium reflector, and aluminum reflector pieces are supported and located on the grid plate. The grid plate is supported by six structural columns which transmit the static and dynamic loads to the bottom head of the pressure vessel.

(a) Grid Plate (see Figure 4)

The grid plate is 9-1/2 inches thick and 62.21 inches in diameter and is machined from a stainless steel forging. It is a precision retaining and locating device for all core components. Since the grid plate forms the reference point for location of all core components and, in fact, all reactor and experimental components, a high degree of precision was necessary in machining and installing this key component. The locating holes machined in the grid plate in combination with the locating pads common to all core and reflector components determine the ultimate vertical and lateral positioning of all core components, as well as nominal water flow channels existing between these components. Extreme care should be exercised in all handling operations involving the grid plate, fuel elements, experimental equipment, aluminum reflector pieces, etc, in order to protect the surface finishes and sizing of all reactor operating components.

Adapters are provided for the experimental facility positions with penetrations for fuel element and aluminum reflector pieces.

(b) Core Support Columns (see O. G. Kelley drawing 55-4694-1)

The grid plate is supported by six 5- x 18-1/2-inch AISI 304 ELC stainless steel I-beam columns 8 feet long. Approximately four feet above the bottom head, the six columns are bolted to the lower support plate. They are further restrained from excessive lateral movement by means of extensions to the thermal shield supports.

(c) Lower Support Plate (see drawing ETR-5528-MTR-642-M-722)

The 2-inch thick, 52-1/2-inch diameter support plate is machined from AISI 304 ELC stainless steel. It contains perforations for the experimental facility tubes, control rods, regulating rods, and ion and fission chambers, and serves as a guide for the above facilities. In the case of the experimental facility tubes, it furnishes lower end support for reentrant-type experiments that do not penetrate the bottom head. Besides the above, the lower support plate functions as a mid-point support for the core support columns.

5. Reactor Core and Reflectors (see Figure 5)

The following subsections contain descriptions of reactor core components, the beryllium reflector, and aluminum reflector components. The reactor control rod assembly, the regulating rod assembly, and the core and reflector experimental facilities are not discussed in this section even though parts of these items are physically located in the core and/or reflector. The above components are covered in the following sections.

For identification purposes, all removable core and reflector positions are labeled by a system of rectangular coordinates based on an approximate 3- x 3-inch grid spacing, except that the corner aluminum reflector pieces are slightly offset and that the 4-1/2-inch thick beryllium reflector slabs are considered to fall on the coordinate row. Basically, this system of coordinates is set up in the following manner: beginning at the extreme west row in the aluminum reflector, rows are identified as A, B, C, etc, proceeding in an easterly direction. Also, beginning at the extreme north row in the aluminum reflector, rows are identified as 1, 2, 3, etc, proceeding in a southerly direction; thus, each position is identified by means of its east-west and north-south coordinate as F10, G13, etc. Odd-shaped aluminum reflector pieces located around the periphery of the inner tank are not readily removable and are not identified by this system of coordinates.

In the beryllium reflector, facility holes are generally designated by their location with respect to the nearest coordinate position as B05, BH15, etc, where "B" stands for beryllium and "05" is the location of that particular hole.

(a) Designation for Large Experimental Facilities

(1) All 6 x 6 facilities are designated by the coordinate of the southeast 3 x 3 grid increment as C66J13 or R66M3 where "C" stands for core, 66 indicates a 6 x 6 facility, J13 is the coordinate of the southeast 3 x 3 increment of that

particular facility, and "R" stands for aluminum reflector.

(2) The 9 x 9 facility is designated by the center-east 3 x 3 grid increment as C99M7.

(3) The 6 x 9 facility is designated by the center-east 3 x 3 grid increment as C69G7.

(4) All 3 x 3 experimental facilities naturally fall on regular grid increments.

(b) Fuel Element (see drawing ETR-E-1380 and Figure 6)

The fuel elements are flat-plate, aluminum - boron - uranium assemblies containing nineteen 0.050-inch thick, 37-inch long fuel plates which are positioned and held by two aluminum side plates. The assembly is 54-1/16 inches long and consists of an adapter or lower end box, fuel section, and a handle. Boron is used in these assemblies as a burnable poison. This is added to the aluminum-uranium alloy core to reduce the amount of reactivity that must be controlled over the reactor operating cycle, thereby allowing more fuel to be loaded into the reactor, and also to provide a more uniform flux distribution in the core over a given cycle.

The end box has two locating surfaces, a conical surface at the upper end and a cylindrical surface at the lower end. In addition, a small locating dowel is positioned on a flat surface in one corner near the upper end of the end box and extends downward parallel to the longitudinal centerline of the adapter. This dowel mates with either of two 180 degrees opposed, locating holes in the grid plate, thus controlling the west-east orientation of the fuel plates in the core. The element is thus positioned both laterally, vertically, and radially when inserted in the grid plate. The end box has a 1-3/4-inch diameter hollow interior to allow water flow to pass through the fuel element and grid plate.

The original ETR fuel assemblies used in the ETR were all brazed and welded assemblies, ie, the fuel section was fabricated by brazing the fuel plates to the side plates, and the lower adapter and lifting handle were then welded to the fuel section. (See drawing ETR-5528-MTR-642-M-761.) However, early ETR operating experience proved that these elements did not operate reliably at maximum power, and that the brazed flat plates had a tendency to buckle under full flow. Mechanically assembled fuel sections are now being used in the ETR. These sections are fabricated by pinning the fuel plates and side plates together or by roll-swaging the fuel plates into the side plates. Fuel plates also are fabricated in such a manner that they are stronger and flatter than the brazed fuel plates.

The fuel plates in the fuel section are mechanically assembled between two side plates. They are arranged to form a variable channel element with the three outer channels being wider than the twelve inner channels. The variable channels serve to overcome flow restriction in the outer plates due to the fuel element end box, and thus provide for a smaller pressure differential between channels for a more even channel flow and for more even heat transfer across the element. Edge distances (distance from outer fuel plates to edge of the side plate) also are controlled in order to provide the correct flow channels between the outside fuel plates of adjacent elements. The side plates have two-inch long spacing pads on both outer surfaces at the upper end. The pads provide a 3.035-inch square dimension at the upper end which is just 0.005 inch less than the space between the elements in the assembled core. The remaining area between pads and end box is 3.000 inches square. Hence, an element, after being withdrawn two inches during removal, is relatively free.

The handle is a 1/2-inch diameter rod welded into extensions to the side plates. The weld on this rod is for positioning only and can be broken under excessive load. For this reason, a handling tool with a wide surface (not a simple hook tool) should be used to remove fuel elements.

(c) Beryllium Reflector (see drawing ETR-5528-MTR-642-M-771)

The beryllium reflector consists of four rectangular slab assemblies arranged in a square array around the reactor core. The reflector is 4-1/2 inches thick, 37-1/2 inches high, and 30.400 inches square to the locating pads on the inner surface of the reflector. Each side is built up from four beryllium pieces 9-3/4 inches high, the four pieces being doweled together. The four sides are firmly held together at the ends by a full length tie bar at each corner.

Besides its normal function as a reflector, the beryllium serves three other purposes: one, it contains the outer rows of fuel elements, reducing the effect of vibration on these elements by providing a solid wall of high damping ability; two, it separates the coolant flowing past the fuel elements from that past the aluminum pieces preventing a crossflow that would be otherwise caused by the pressure difference between flow channels; and three, it contains positions for the two regulating rods plus several small holes to be used for slug and capsule irradiations.

The beryllium is relieved 0.050 inch on the inside surfaces to maintain proper coolant flow channels around the outside of the outer rows of fuel assemblies. Cooling also is obtained from 408-1/4-inch holes drilled from top to bottom through the reflector. A plenum chamber between the beryllium and the grid plate distributes this flow to 388-3/8-inch holes through the grid plate.

Thirty 1.312-inch diameter holes from top to bottom are provided for basket assemblies, and two 2.030-inch holes are provided for regulating rods.

(d) Aluminum Reflector (see drawing ETR-5528-MTR-642-M-772)

The aluminum reflector pieces surround the beryllium reflector and extend from the reflector to the inner tank wall.

The removable reflector piece is 49-11/16 inches long, not including the lifting pin. The lower 9-15/16 inches is an end box similar to that of the fuel elements. The upper two inches is 3.015 inches square, the remainder being relieved 0.020 inch on each side.

Since the spacing between centers of the aluminum pieces is 3.035 inches, the water flow between elements is negligible. Cooling is therefore obtained by means of a 1.553 inch diameter hole in the center of each element which is restricted by an aluminum plug. The aluminum plugs are removable to provide space for experiments.

Outside of the 3- x 3-inch reflector pieces are aluminum filler pieces shaped to fit in the space left between the reflector pieces and the inner tank wall. The filler pieces are irregularly shaped pieces 40-3/8 inches long. Besides interlocking, they are doweled to the grid plate at the bottom and to a stainless steel ring assembly at the top.

6. Reactor Controls

The ETR reactor safety control and regulating functions are accomplished by the use of sixteen control rods, two of which are used as regulating rods. The control rods are distributed within the core.

Four of the control rods (safety rods) are known as black poison rods and are used for start-up and shutdown only. In their lowest position, these four rods were designed to overcome reactivity of 14.4 percent. The other twelve control rods are known as grey poison rods and are used not only for start-up and shutdown, but also as power level "coarse" controls during reactor operation. The nickel material of the grey rods was chosen so that its macroscopic absorption cross section is approximately the same as that of the fuel elements. In this way, a minimum distortion of the thermal flux distribution in the core is obtained. In their lowest position, the twelve grey rods were designed to overcome an excess reactivity of 12 percent.

The two regulating rods were designed to overcome 0.5 percent excess reactivity. However, when the regulating rods were put into use, it was found that they would overcome less than 0.1 percent excess reactivity and that reactor control was difficult. To remedy this, No. 10 and No. 13 grey control rods have been put into operation as regulating rods. The regulating rod tends to level out the power level established by the grey rods so that an essentially smooth power curve is generated by a reactor incorporating control rods and regulating rods. Only one regulating rod is used at any given time during operation of the ETR.

(a) Control Rod Assemblies (see drawings ETR-5528-MTR-642-M-741, ETR-E-1257, ETR-E-1390, ETR-D-1393, ETR-E-1724, ETR-E-1725; Figures 7 and 8)

The control rod assembly (from top to bottom) consists of individual poison, fuel, and shock sections attached end-to-end and inserted in guide tubes which extend from the reactor bottom head up through the support plate and grid plate to a point approximately three feet above the top of the core. The lower end of the shock tube mates with the control rod drive. Poison and fuel section cooling is accomplished by passage of primary coolant through the opening at the top of the rod, thence, downward past the poison and fuel plate sections, and finally out of the tube through slots placed in the shock section at a point approximately three feet below the grid plate. Thus, the hydraulic load is always downward.

The design of the poison section of the grey and black rods is essentially the same. They are made of plates, 7/32 inch thick arranged to form a 2-1/2-inch square. The black rod poison material is 347-type stainless steel sprayed with cadmium which is in turn sprayed with 302 or 316 stainless steel. The grey rod material is type "A" nickel with 0.2 percent cobalt maximum. The grey rods also have two 1/8-inch thick by 24-7/32-inch long absorbers of the same material added to the interior.

The 16-plate fuel section of the control rods is similar to that of a standard fuel element except for the smaller cross section.

The shock section is the lowest part of the moving rod assembly. It consists of a 2-1/2-inch square aluminum tube and an attached stainless steel shock tube. Slots are cut in the square tube which match the slots in the guide tube and provide an exit for the primary coolant flow.

The removable portions of the control rods are joined together by means of a mechanical spring latch system.

The control rod assembly operates inside of guide tubes and is approximately centered in the tubes by means of rollers mounted in the poison and shock sections. The roller system allows free motion of the movable sections within the guide tube, prevents rubbing, and acts as a guide during the scram motion. The system consists of a series of roller bearing groups with each group containing four rollers in an approximately horizontal plane. Two adjacent rollers are fixed while the other two rollers in the same set are spring mounted. Thus, limited freedom of motion in two planes is available, and this freedom makes allowances for irregularities and misalignments in the guide tube. The rollers are made of solid 304 stainless steel. A hardened stainless steel pin through the roller completes the assembly.

The latching arrangement consists of spring latches which engage rectangular cutouts machined in the top and bottom adapters of the control rod fuel section. The spring latches are mounted at the bottom of the poison section and at the top of the shock section and are protected against damage by two hardened stainless steel guards located on either side of the latch itself.

Latching is accomplished by snapping the spring latch into the machined cutouts in the fuel section. A spring latch control rod handling tool, incorporating a square cross section and toggle link actuated lifting lugs, has been provided for handling both the fuel and poison sections. When handling the fuel section or poison section, the handling tool which is provided should always be used since it may be necessary to push downward on the fuel section to effect the latching action. Use of the wrong tool may result in physical damage to the fuel plates or even to the top of the poison section.

Unlatching of the rod sections is accomplished by raising the entire control rod assembly in the guide tube until the desired point of disconnect is above the top of the guide tube, rotating the handling tool clockwise, which rotates the latch spring into the corners of the fuel section and allows the balance of the control rod assembly beneath the disconnect point to fall back into the guide tube.

The shock section is handled with a hook tool.

(b) Guide Tube (see drawing ETR-5528-MTR-642-M-750, and Figure 8)

The guide tube is an aluminum alloy drawn tube 3 inches square and approximately 15 feet long which surrounds the moving portion of the control rod. Lateral support for the tube is obtained from several locations. These are the socket in the bottom head, the support plate, the grid plate, and the upper frame. Since these are approximately equally spaced, adequate alignment, vibration damping, and structural support is available through the length of the rod. The guide tube has slots machined in its top and bottom portions to equalize water flow through the poison section and to provide water flow outlet beneath the grid plate.

(c) Control Rod Drive Assemblies (see drawing ETR-5528-MTR-642-M-673, and Figure 9)

The 16 ETR control rod assemblies are driven from beneath the reactor by individual control rod drive assemblies. The control rod drive assembly housing is sealed to the reactor bottom head by a flanged connection utilizing a spiral-type stainless steel and asbestos gasket. The upper end of this housing, which includes the shock absorber section, is open and extends up into the reactor bottom head. The control rod drive assembly housing extends from the reactor bottom head down through the mounting plate between the subpile room and the rod access room. The housing is guided and sealed on the bottom side of the mounting plate by means of a bolted flange connection with "O" ring seals. The drive tube, which drives the control rod assembly up or down in the reactor proper, operates through a sliding seal packing inside of the watertight housing. The rod drive assembly drive motors also are mounted on the bottom side of the mounting plate. The balance of the control rod drive assembly extends down into the rod access room and includes the helical lead screw, magnet and magnet release mechanism, snubber, and other components.

The control rod drive assembly drive mechanism consists of the drive motor, gear reduction unit, lead screw with drive tube extension, and the magnet and magnet release mechanism including the ball coupling. For a normal reactor start-up, the control rod assembly rests on a helical spring in the bottom of the control rod drive shock absorber section. (The helical spring replaced a Belleville spring stack used on the original installation.) A ball-type coupling attaches the control rod assembly to the drive rod assembly, and the scram magnet exerts an upward force through an actuating rod sufficient to hold the ball coupling engaged as the control rod assembly is driven up or down.

The drive mechanism is driven by a 1750 rpm, three phase induction motor. This motor type was selected because of its good speed regulation characteristics which match the safety requirements limiting control rod withdrawal rates. The motors are directly coupled to the 22:1 gear reduction unit which consists of a horizontal worm that drives a worm gear mounted on the control rod axis. The worm gear, which is internally threaded, drives the Acme thread lead screw. This lead screw has five threads per inch. The 22:1 gear reduction rate effected through the gear reduction unit results in a lineal speed of approximately 16 inches/minute over the total drive mechanism stroke of 38 inches.

Release operation of the scram magnet results from interruption of electrical power to the scram magnet. The mechanism is electrically fail-safe, since loss of power shuts down the reactor by releasing the control rod assembly allowing it to fall to such a position that the poison section is in the active lattice.

While the control rod is coupled to the drive tube extension of the lead screw, the coupling balls are held in position by an actuating plunger attached to the top end of the drive tube extension. The scram magnet exerts sufficient upward force to hold the plunger in the coupled position. This magnetic force is opposed by the scram actuating spring, such that the cam moves axially downward upon interruption of power to the electromagnet. This downward cam motion allows the coupling balls to move inward and uncouples the control rod. A metal bellows seal located near the top of the drive tube extension permits the required axial cam motion while preventing leakage of reactor water.

Upon release, the control rod falls under the action of gravity and/or reactor differential pressure until it contacts the hydraulic shock absorber mounted to the bottom head and is brought to a stop on the helical compression spring.

Resetting the scram release mechanism is accomplished by drawing the lead screw downward to the lower limit of its travel. This action causes reset pins in the release mechanism to strike the reset stop, compressing the release spring and causing the scram magnet and its armature to close. Since the control element also is at its lower-most position as a result of its fall into the shock absorber section, the coupling balls engage the control rod, and the drive tube is again coupled to the control rod.

(d) Control Chamber Functions and Locations (see drawings ETR-5528-MTR-642-M-599, ETR-E 1477, and ETR-E-1520)

The following section is a brief description of the function, history, and location of the control chambers in the ETR. For a more detailed report of the above, see IDO-16566.

These chambers are the log N Period, Fission, Neutron Level Safety, Servo Control, and the N-16 Activity Monitor. The functions of the above chambers are briefly as follows:

Log N Period: to give power and period indication and period protection from 1 x 10^{-4} to 300 percent power.

Fission: to give power indication from source strength approximately 1 x 10^{-7} to 100 percent.

Neutron Level Safety: to indicate power from 1 x 10^{-1} to 150 percent to provide an electronic scram in case the power reaches an unsafe level. When the reactor power is below three percent of full power, the electronic scram level is at 15 percent. Control points at 105, 110, and 120 percent initiate a power setback other than an electronic scram. The level chambers are adjusted at 100 percent power to make level recorder match power recorder.

Servo Control: to automatically control power at any preset point from 1 to 100 percent. (Below 1 percent, power must be controlled manually.) This automatic control is accomplished by controlling the regulating rods. No. 10 and No. 13 control rods are used as regulating rods. A servo control system is provided for each rod.

N-16 Activity Monitor: to monitor N-16 gamma radiation in the primary coolant system and automatically reduce power when indicated. Two separate identical N-16 systems are used.

Most of the control chamber locations have been revised from those of the original design to solve problems that became evident during the initial phases of the ETR start-up. In the case of the log N and fission chambers which were originally installed in thimbles in the reactor vessel below the grid plate and were driven from beneath the reactor, the ratio of neutron flux to gamma flux was insufficient for proper operation of the chambers. The level, servo, and thermopiles were originally installed in horizontal holes in the concrete biological shield approximately one foot above the reactor midplane. These have been modified primarily because insufficient neutron flux was available to operate these instruments.

A temporary solution to the log N, fission, level, and servo problems was found by installing dry tubes in the reactor from above through various vessel nozzles. These tubes were installed with the chamber end either in or immediately above the aluminum reflector. In some cases, a dry tube was used at different times for more than one purpose. However, as the reactor became filled with experimental facilities, it was necessary to find some other location for the chambers. No satisfactory solution was found for the flux problem in the case of the boron thermopiles, and these were replaced by five small fission chambers which drive a common linear amplifier. These have been replaced by a second N-16 system.

The log count rate fission chambers are presently installed in the bottom head thimbles originally designed for the log N compensated ion chambers. These thimbles were used in place of the fission chamber thimbles because the larger diameter accommodated a more sensitive fission chamber which is larger than the original chamber.

The log N chambers are now located in new horizontal chamber holes in the concrete biological shield on the core midplane. These are located on radial lines directly south and 29 degrees west of north. These locations have a lower flux field, but an increased ratio of neutron flux to gamma flux.

The Neutron Level Safety, the servo-system, and fission chambers which replaced the boron thermopiles are presently installed in the original horizontal chamber holes in the biological shield. These holes are located one foot above the core midplane. Three neutron level safety chambers are installed in the reactor structure. Two are located on the south side of the reactor in the B-2 hole 40 degrees east and the B-4 hole 25 degrees west of the north-south centerline. The third neutron level safety chamber is located on the north side in the B-6 hole 15-1/2 degrees west of the north-south centerline.

Two servo-system chambers are used to control the two regulating rods. One of these is in the B-3 hole on the south side, 21 degrees east of the north-south centerline and the other in the B-1 hole on the north side, 43-1/2 degrees east of the north-south centerline. The five fission chambers which replaced the boron thermopiles were located in the C-9 and C-4 holes on the south side of the reactor and the C-1, C-2, and C-5 holes on the north side.

The N-16 Activity Monitor is an RCL Remote Monitron. It was originally installed in a hole drilled part way through the pipe tunnel walls but did not function properly in this location because the gamma flux was much less than anticipated.

Two chambers are now located in the pipe tunnel.

They are shielded with a 1/4-inch thick lead shield to reduce the gamma field from 50 to about 10 r/hr.

7. Experimental Facilities (see Figure 5)

Seventeen openings are provided in the ETR grid plate for major experimental facilities, nine openings in the core and eight openings in the aluminum reflector. The openings in the core consist of one 9- x 9-inch, one 6- x 9-inch, three 6- x 6-inch, and four 3- x 3-inch openings. The openings in the reflector consist of two 6- x 6-inch and six 3- x 3-inch openings.

Penetrations through the pressure vessel shell via the horizontal and angular nozzles and through the bottom head permit external connection of coolant and service facilities. They also provide access for experimental and operational instrumentation leads.

Some penetrations in the bottom head are offset (doglegged) from the penetration in the grid plate due to the close proximity to reactor controls in the central area of the bottom head and below. The two innermost 3- x 3-inch facilities do not penetrate the bottom head for the same reason and are intended to be reentrant-type loop facilities with the lower end of the in-pile tube terminating above the support plate.

Each experimental penetration through the bottom head is furnished with a seal plug which is installed in the bottom head whenever experiments with bottom head penetrations are removed from the reactor. Seal removal plugs also are provided for each of the five sizes of bottom head penetration. These are used for servicing or changing the bottom head seals. (See drawings ETR-5528-MTR-642-M-612 and ETR-E-1302.)

The bull nose end of the seal plugs has been revised by the elimination of the counterweights and the pocket at the top of the major diameter of the plug. This was done for the following reasons: one, the pocket acted as a dirt collector; two, the counterweights which were designed to latch in a countersunk recess at the top of the bottom head would sometimes latch and, due to friction or other causes, sometimes stay unlatched; three, visual inspection to determine whether latching had taken place was not possible; and four, it was determined that the retaining ring at the bottom of the plug was sufficient to hold the plug in place during reactor operation.

Space for other small experimental facilities is provided by thirty 1.312-inch diameter holes in the beryllium and by a 1.553-inch diameter hole in each of the aluminum 3- x 3-inch reflector pieces. Many of the single hole aluminum reflector pieces have been replaced by four hole reflector pieces (R-4X pieces) which are sized to accept "X" baskets.

Experiment piping leaving the vessel through the 8- and 12-inch nozzles above the first floor returns to the subpile room through twelve 12-inch schedule-40 carbon steel pipes imbedded vertically in the biological shield. The top penetration of these pipes is furnished with a 1/4-inch cover plate.

Two 8-inch in-tank facility tubes extend from the subpile room up through the biological shield to the inside of the upper part of the vessel and permit through installation without top penetration. The top flanges of these facility tubes are about five feet below the top flange of the vessel.

Experiment instrumentation brought out of the vessel nozzles is run through the biological shield to the console floor area through twenty-seven 6-inch stainless steel pipe ducts. The flanged openings on the console floor are near the ceiling five feet below the first floor level.

8. Shielding (see Figure 2)

The shielding for the ETR is based on tolerance values specified in the National Bureau of Standards Handbook 52: "Maximum Permissible Amount of Radioisotopes in the Human Body and Maximum Permissible Concentration in Air and Water".

Portland concrete used as shielding has a minimum density of 2.35 g/cc. Magnetite concrete has a minimum density of 3.5 g/cc.

The concrete biological shield is the shielding surrounding the reactor vessel. At the reactor midplane, the thickness is 8 feet of magnetite concrete. This thickness is uniform around the reactor and extends from the subpile room ceiling to the first floor level with the exception of the regions penetrated by the canal and primary coolant pipes. On the canal side, the concrete thickness is 2-1/2 feet; in the region penetrated by the primary coolant pipes, the thickness is 5-1/2 feet.

At the console floor level, five-inch thick steel slabs are attached to the outside surface of the vertical pipes embedded in the biological shield to make up for the decreased concrete shield thickness and also to provide for radiation from active experiments such as those using sodium coolants.

The top head shielding consists of one to three feet of magnetite concrete encased in steel. This shielding is made in sections to permit handling with the 30-ton crane. Shields were poured in place to minimize gaps between sections and were dowelled so that the sections could be removed and replaced in the same relation to each other. Top head shielding should always be stored over the pipe tunnel on the east side of the reactor to prevent exceeding floor loading limits.

The subpile room is located directly below the reactor bottom head. Walls of the subpile room also are magnetite concrete, and transmit the biological shield load to the reactor foundation extending down to bedrock. The canopy ceiling and walls of the rod access room which extend above the floor of the subpile room each have 12 inches of magnetite concrete encased in steel to permit access to control rod drive rod assemblies and other equipment within a short time interval after shutdown.

The canal walls and floor are Portland concrete. The walls of the canal are 6 feet thick to a point about 12 feet above the console floor and taper to 2 feet thick at the first floor level. The east wall of the storage canal is 7 feet thick to permit placement of fuel element storage racks adjacent to that wall.

Gamma radiation is attenuated to the basement area by the 7 feet of concrete in the canal floor.

The primary coolant pipes are enclosed in a rectangular tunnel of magnetite concrete. The walls and ceiling are 4 feet thick and the floor is 5-1/2 feet thick.

F. HANDLING FACILITIES

Miscellaneous items of equipment for handling, working with, or storing reactor and experimental equipment are described in the following sections.

1. Overhead Cranes

Three independent crane facilities are installed in the ETR Reactor Building, a 30/5-ton crane, a 2-ton crane, and a 1-1/2-ton crane. Both the 30/5-ton crane and the 2-ton crane have been modified after the original installation to give better control, to provide a greater safety factor for load bearing components, and to accommodate the NR casks.

The 30/5-ton crane modifications consisted of replacing the trolley, changing the bridge drive from ac to dc, adding a mechanical load brake, and revising the crane hoist to include two 15-ton hooks as well as the 30-ton hook.

The changes to the trolley hoist hooks were necessary because of the NR cask requirements. This cask extends up through a three-foot diameter hole in the trolley at the high point of its lift, and is held by two 15-ton load blocks on either side of the cask. The wire ropes to these load blocks reeve onto two integrally mounted drums. The drum size has been increased to eliminate overlap of the wire rope. A 30-ton lifting beam, used in conjunction with the 15-ton load blocks, permits the use of a 30-ton hook centrally mounted between the load blocks. A dolly has been provided for the 30-ton lifting beam for use in storage and hookup.

The hoist and trolley motors are equipped with springset, electrically-released, automatic brakes. These brakes are always set when their respective motors are not energized and are released when their motors are energized. The crane bridge has a foot-operated hydraulic brake with a parking attachment. The original hoist had an "EDDY CURRENT" brake attached to the motor for controlling the hoist speed, but had no mechanical load brake. This feature was added to the new hoist to provide precise control of all loads while being lowered and to hold a load stationary in the event of a power failure, even with the electric brake inoperative.

The main hoist, trolley, and bridge drives are operated by three dc generators driven by an ac motor and have five speeds from minimum to maximum. In addition, the low speed range is continuously variable from about 1 to 20 percent of maximum. The maximum speeds are: trolley, 50 feet per minute; bridge, 100 feet per minute; and 30-ton hoist, 10 feet per minute. The 5-ton hoist is mounted on the 30-ton trolley and is operable in steps up to 23 feet per minute. The auxiliary hoist which still operates on ac supply cannot be continuously operated in any but the highest speed position without burning out the resistors. Reduced speed operation of the 5-ton hoist is therefore limited to 15 seconds in any 60 second period. Maximum height of the 30-ton hook and the 5-ton hook above the first floor is 32 feet.

The 2-ton crane operates over the central area of the reactor building with a coverage 17 feet 7-1/2 inches north, 9 feet 3-1/4 inches south, 50 feet east, and 68 feet west of the reactor centerlines. It is mounted above the 30-ton crane with a clearance of approximately four inches when the 2-ton hook is in its highest position. The bridge speed is 110 feet per minute, and the trolley speed is 75 feet per minute. The 2-ton hoist has three speed position; low speed, 4 to 6 feet per minute; medium speed, 14 feet per minute; and high speed, 34 feet per minute.

The 2-ton hoist originally had a splitring wound-rotor motor. This was changed to a two speed motor with a magnetic clutch and gear reducer assembly to obtain the third speed. This arrangement was adopted in order to provide constant (reduced) speed independent of load.

The 1-1/2-ton crane is special equipment installed for the GEEP facility. It is a top-riding bridge crane mounted above the 2-ton crane. It serves a limited area over the reactor extending 3 feet north and south, 13 feet east, and 4-1/2 feet west from reactor centerlines. Bridge speed is 8.4 feet per minute, trolley speed is 9.8 feet per minute, and hoist speeds are 15 to 30 feet per minute. The maximum hook height above the first floor is 50 feet 6 inches.

2. Freight Elevator

The freight elevator in the ETR is hydraulically operated and has a 20,000 lb capacity, exclusive of the weight of the car and plunger. The platform is 10 feet wide by 14 feet long. The elevator speed is 30 feet per minute with capacity load in the "UP" direction and 40 feet per minute with capacity load in the "DOWN" direction. The power unit and associated control equipment are located in a machine room adjacent to the hoistway on the basement floor. The power unit is a positive displacement pump connected to a three-phase induction motor mounted on a common bedplate.

3. Refueling Platform (see drawing ETR-5528-MTR-642-M-36)

The refueling platform is a rotating-type platform with an eccentric working slot to provide vertical access to any area in the reactor. The platform mounts on the top flange of the reactor vessel. The mounting ring is carbon steel faced on the bottom side with aluminum pads to prevent damage to the vessel flange top surface.

The rotating portion of the platform is an aluminum frame covered with a 1/4-inch tread plate. It rolls on and is positioned by steel rollers. The eccentric working slot is two feet wide and about eight feet long. A 60-inch diameter central opening clears experimental equipment projecting above the vessel top and permits rotation when this equipment is in place. Two removable segments of 1/4-inch tread plate cover the part outside of the slot when rotation is not required. Two cam clamp assemblies mounted on the steel ring lock the platform in any position.

4. Canal Working Platform (see drawing ETR-E-1029)

The canal working platform is permanently attached to the east end of the canal parapet and permits access to the working area of the canal immediately over the reactor transfer tube. The platform is constructed in two sections on either side of the canal with an open working area between the sections. Each section is served with a stairway from the first floor level. The railings extending over the canal are removable to allow passage of long experimental casks between the reactor and the canal.

5. Canal Bridge (see drawing ETR-5528-MTR-642-M-26)

The canal bridge translates in the north-south direction over the storage canal. It is constructed of aluminum with a total weight of approximately 1100 lbs. The floor area is four feet wide by 15 feet long and is fabricated from 3/16-inch thick tread plate. Two ladders at either end extend to the floor area. The ladder on the east side is hinged in order to clear the working canal parapet. The bridge is manually operated from the top of the platform. A handwheel at waist height at the center of the north side transmits motion with a 3.8:1 mechanical advantage through a bevel gear train to a roller chain sprocket drive and thence to a drive shaft connected to two of the four rubber-tired wheels which ride on the parapet top. The platform is guided by rollers on the inside of the parapet wall. Hardwood blocks mounted on the guide roller assemblies act as bumpers and prevent over-travel.

6. Reactor Transfer Tube (see drawing ETR-5528-MTR-642-M-851)

This mechanism consists of a transfer tube, mounting brackets, hydraulic cylinder and controls.

The transfer tube is located in the working canal under the discharge chute and is used for transferring components between the reactor vessel and the canal. The transfer tube is a 6-inch inside diameter aluminum pipe 8 feet 7-1/2 inches long with a flared top. Four 1-inch diameter pins across the tube 6 feet 3 inches from the bottom end position the fuel elements in the upper end of the transfer tube. The transfer tube is hinged at the bottom end. It is rotated in an arc of about 20 degrees about its base by a hydraulic cylinder mounted on the canal floor. This cylinder moves the top of the transfer tube from a position aligned with the discharge chute which is under the reactor structure to a position in the canal accessible from the canal working platform. The transfer tube, mounting brackets, and cylinder are all removable from above. The hydraulic controls are located on the north side of the canal working platform above. Thus, an operator can see the transfer tube while operating the controls. The controls consists of a manual globe valve in the line to each end of the cylinder and a four-way three-position manual control valve. The globe valves control the speed of operation and should be adjusted to provide a 10-second minimum stroke for the unloaded transfer tube. This system operates on 40 psig demineralized water.

7. Element Storage (see drawing ETR-5528-MTR-642-M-825)

The fuel element storage racks consist of 36 compartments, each 3-7/8 inch square in a structural frame constructed of aluminum. Between each compartment and around the perimeter is a 40 mil sheet of cadmium. The cadmium is sealed in an aluminum sandwich to prevent interaction with the water in the canal. The bottom of the compartments is an open grating which restrains the fuel elements but permits water circulation and, therefore, convection cooling. This grating is held off the floor by four legs extending 6 inches below. The top flange of the rack has a slot and lifting pin on two opposite sides to fit the lifting bail.

8. Transfer Cask (see drawing ETR-5528-MTR-642-M-855)

The fuel element transfer cask is designed for use as a shield in transporting cut fuel elements from the ETR Reactor Building to the MTR Gamma Building or the Chemical Processing Plant. Up to eight fuel elements may be moved at one time, dependent on the cooling period out of the reactor. The inside dimensions are 15 inches in diameter by 40 inches high. The lead thickness is approximately 11 inches. The outside diameter is 38 inches, and the over-all height is 5 feet 10-3/4 inches. The weight of this cask is approximately 24,800 lbs. The bottom end of the cask is rectangular with shoulders on two opposite sides to fit the straddle carriers. The lead is encased inside and out with stainless steel clad carbon steel or solid stainless steel plate. At the lower end, the inside shape is changed to an 11-inch square clear area to conform to the shape of the transfer basket. In the transfer operation, the fuel elements are lowered into the cask and are placed in the transfer basket which acts as a support or divider. The transfer basket is removable and resembles the fuel storage racks in many respects, including the cadmium lining around all eight positions. The cask lifting arms are designed similar to those on the MTR cask. Hardware on the lead filled cover also is the same as that on the MTR cask.

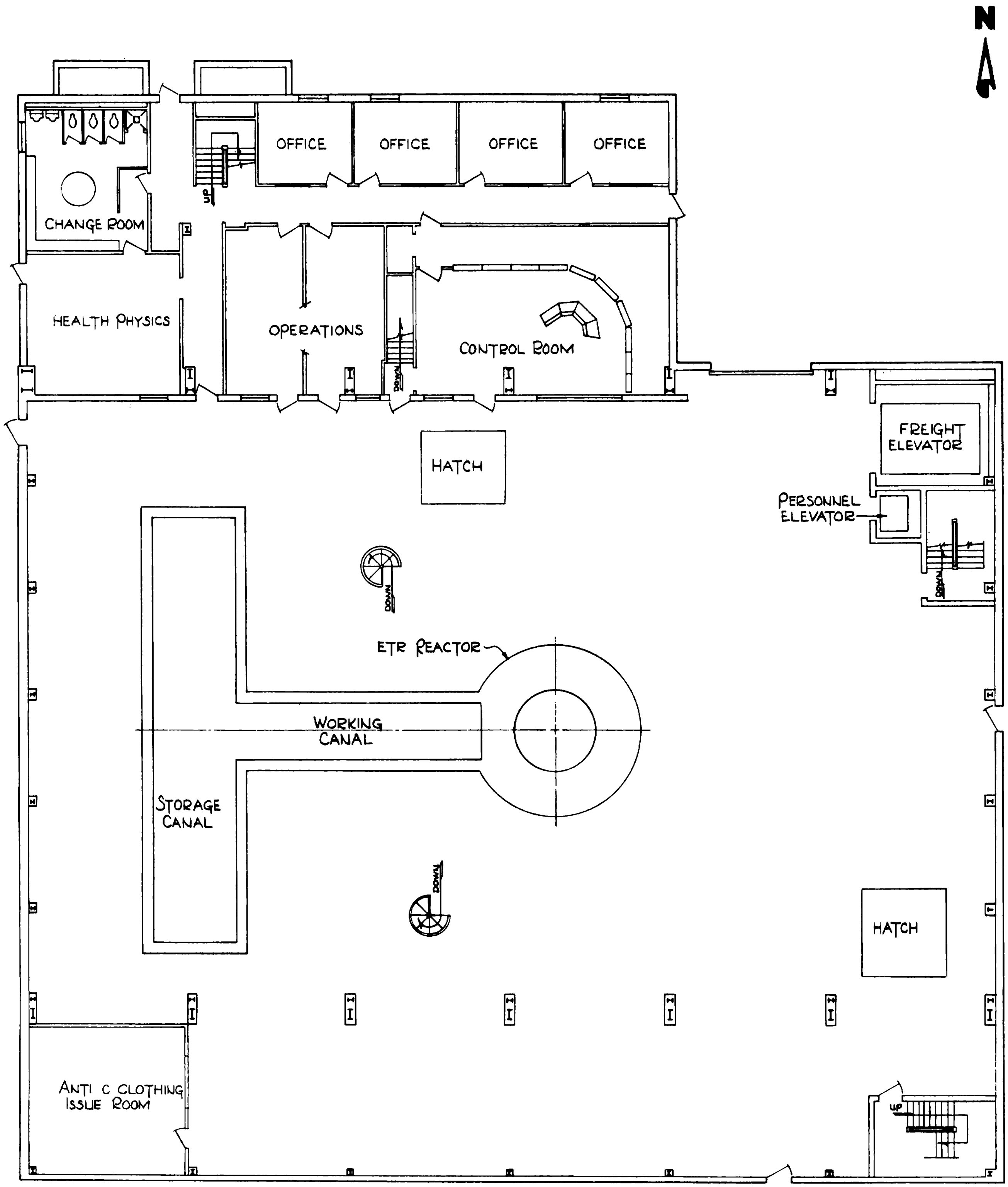

Fig. 1 Reactor building first floor layout.

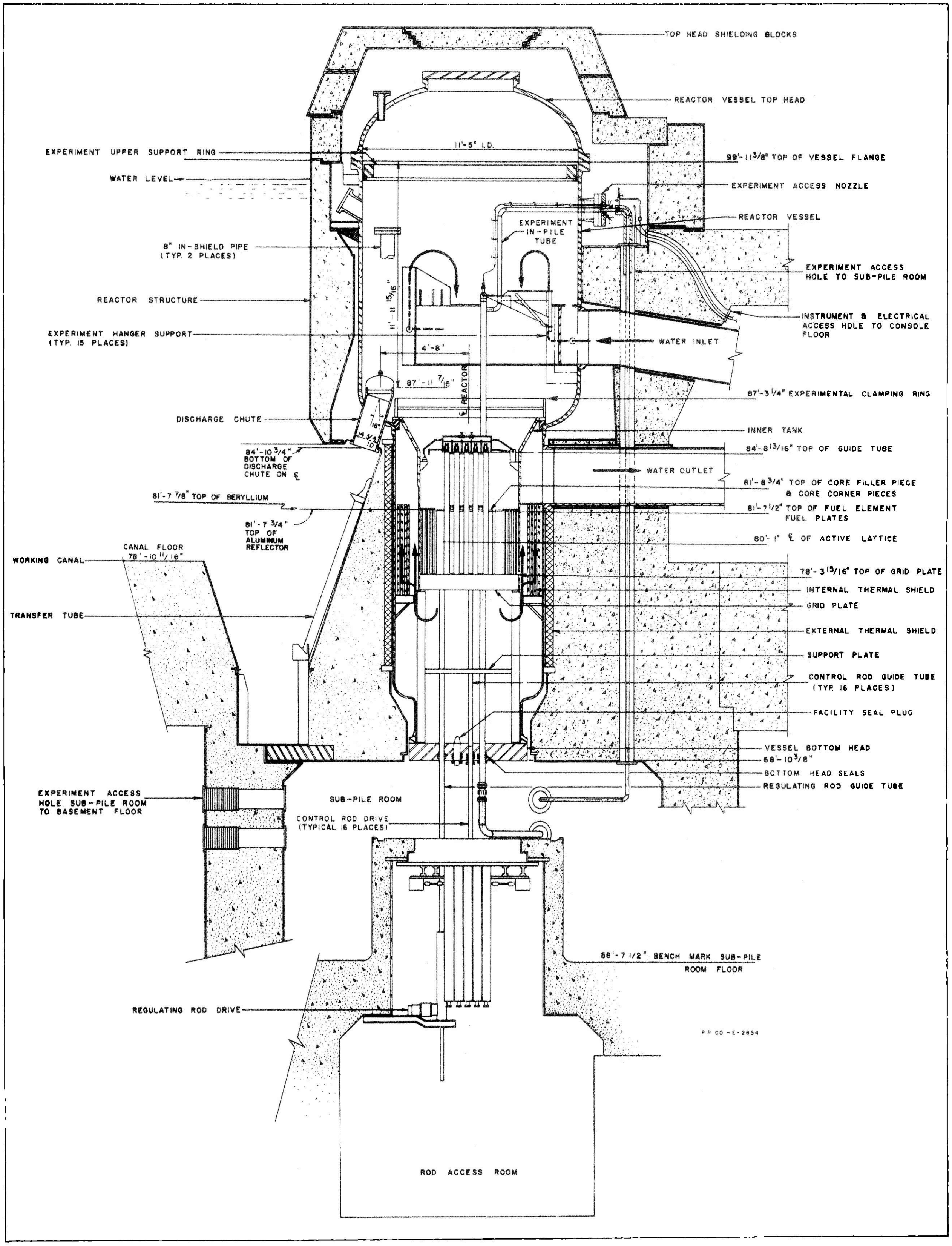

Fig. 2 ETR structure vertical cross section.

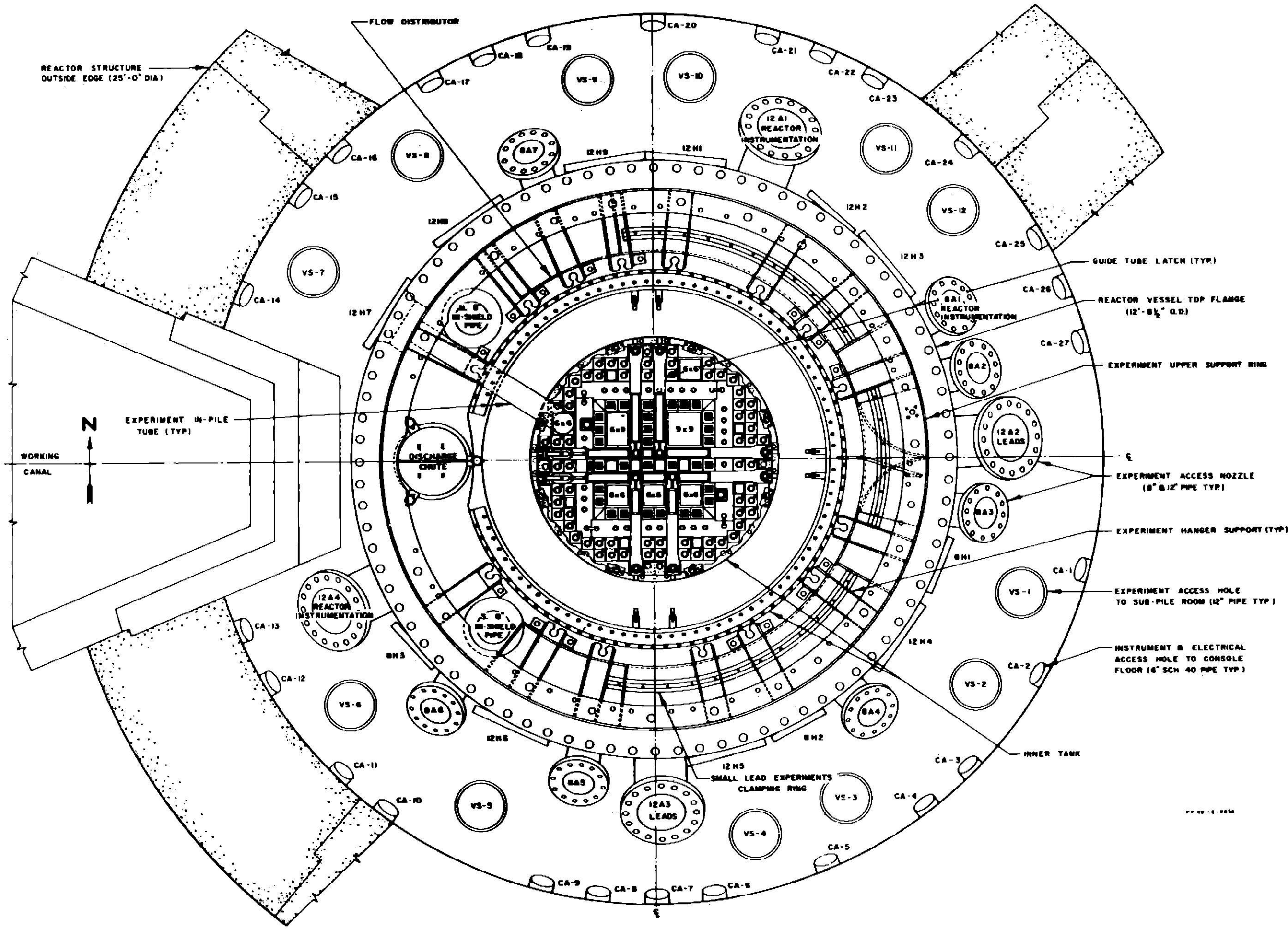

Fig. 3 ETR structure top plan with vessel head removed.

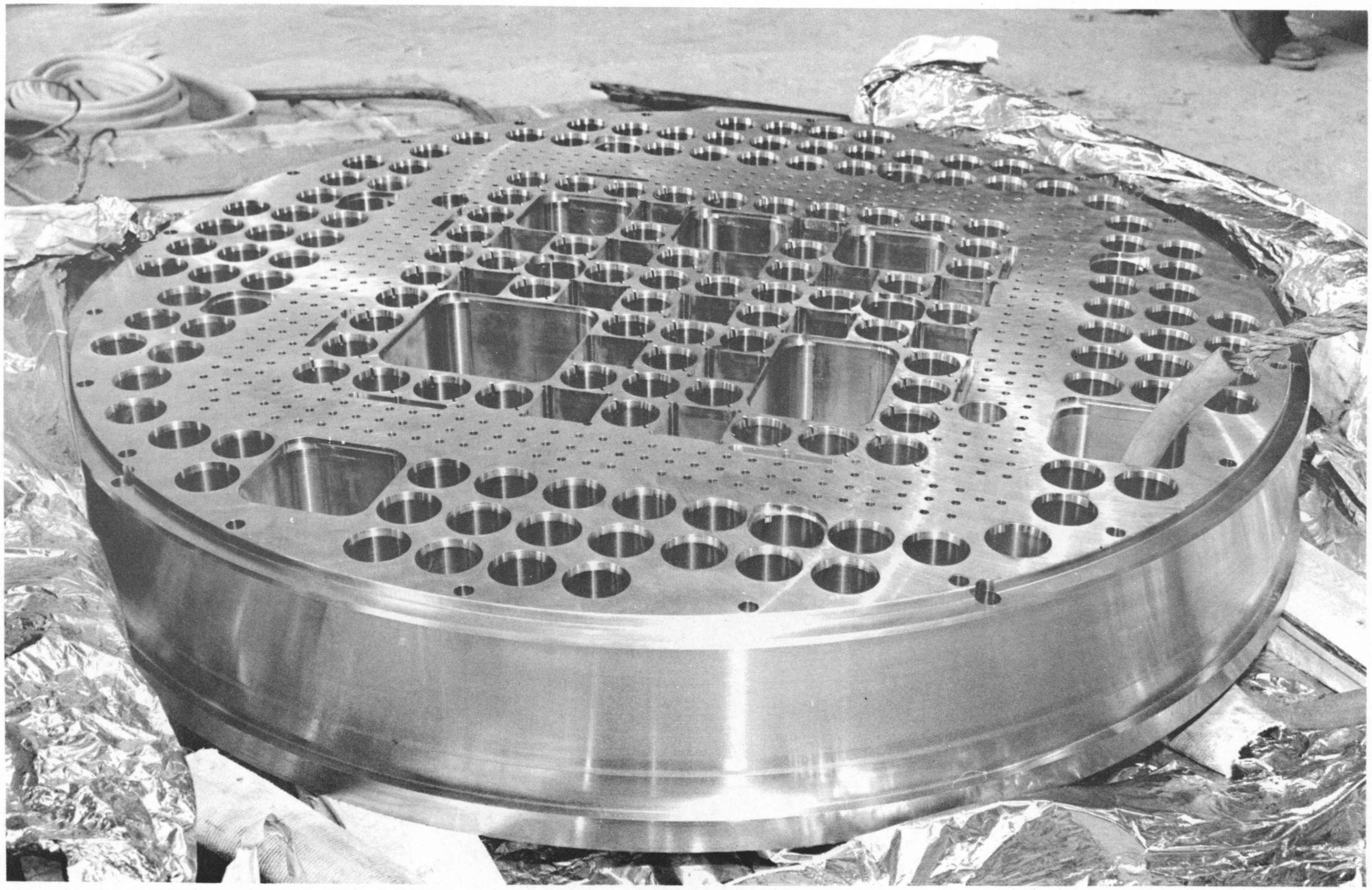

Fig. 4 ETR grid plate.

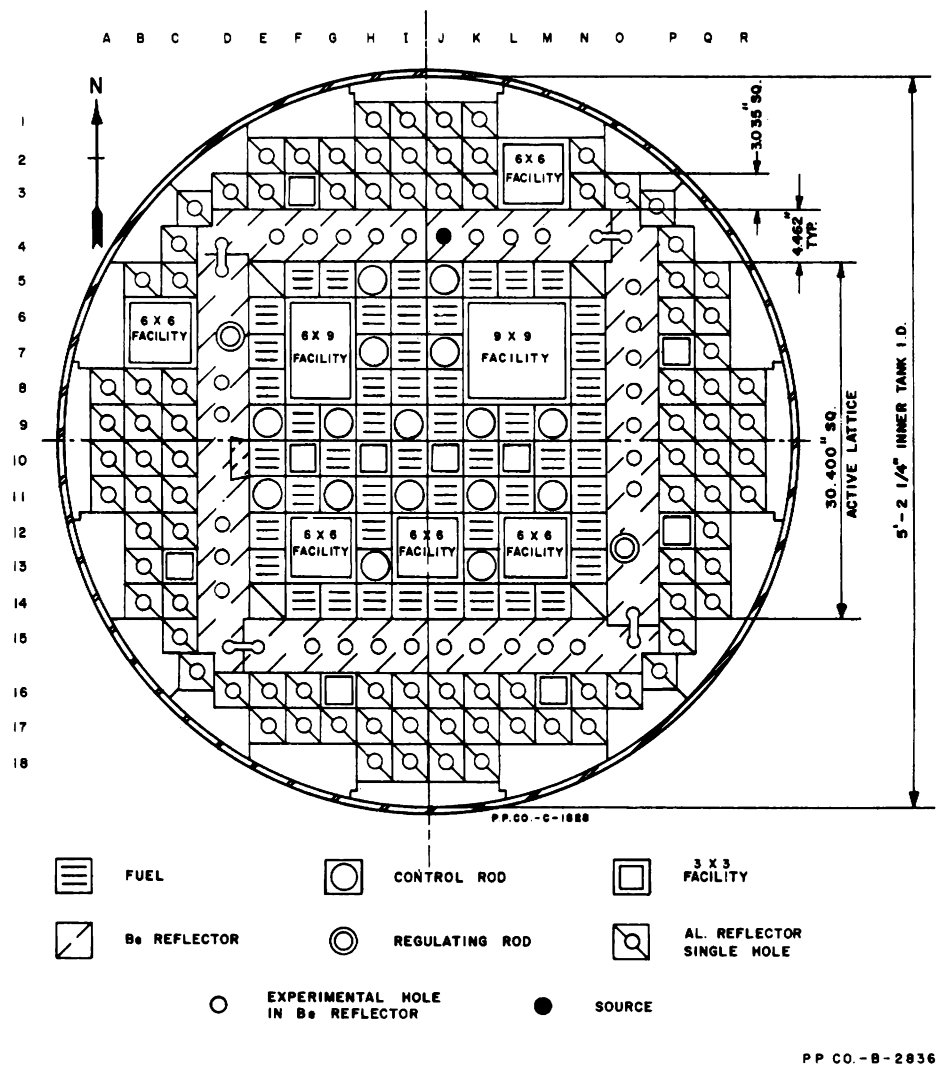

Fig. 5 ETR lattice and reflector horizontal cross section above core.

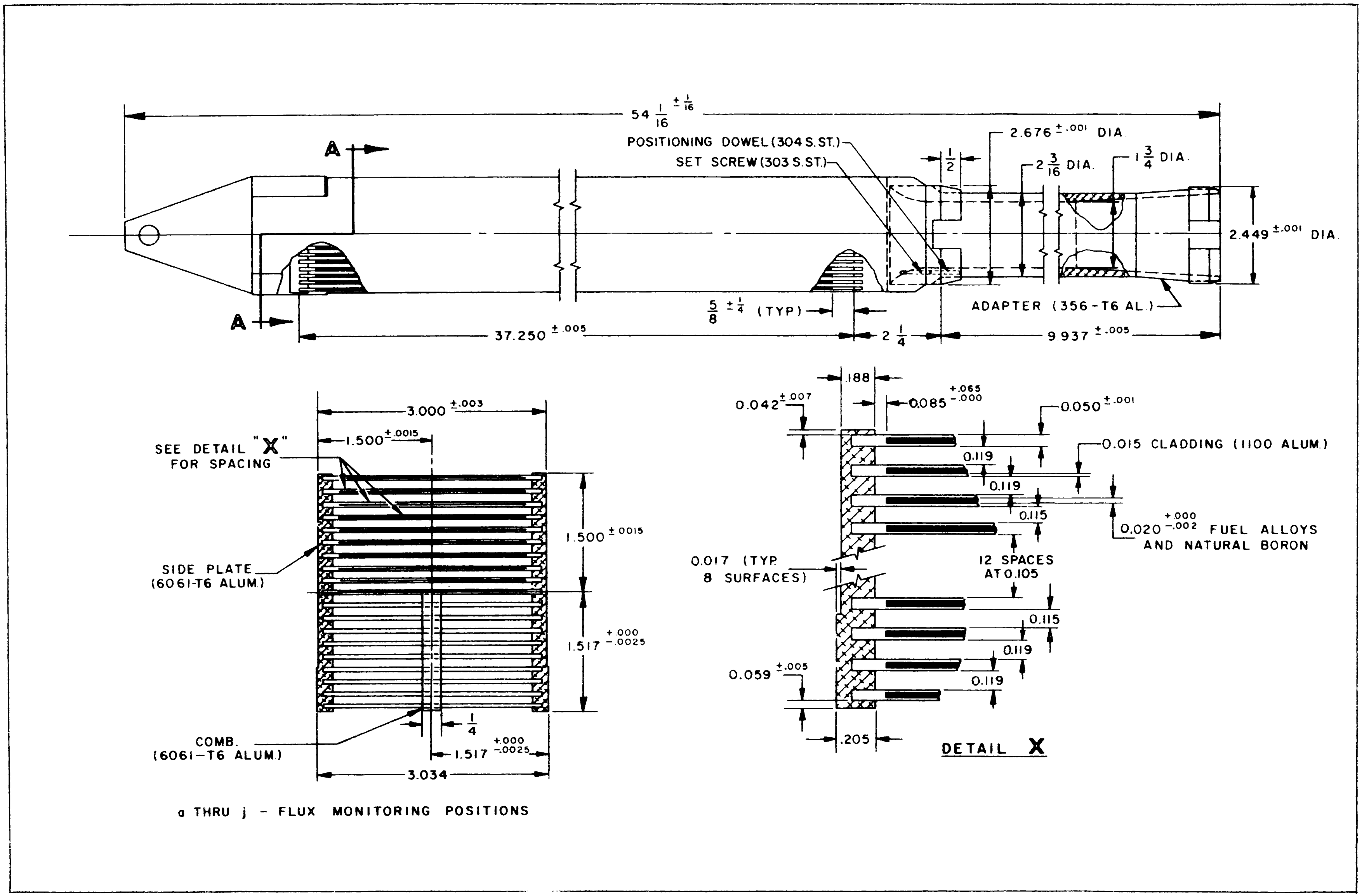

Fig. 6 ETR fuel assembly.

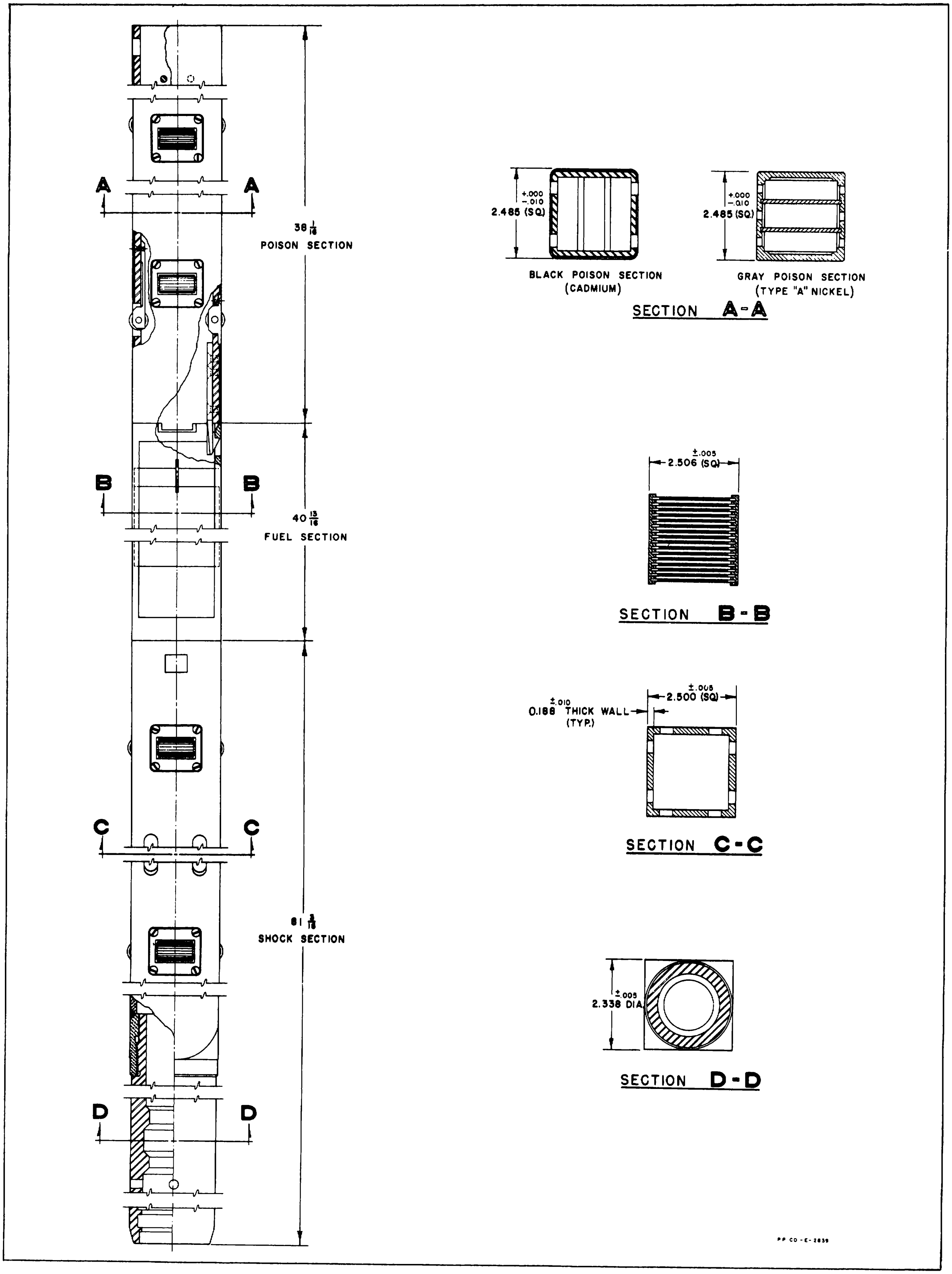

Fig. 7 ETR control rod assembly.

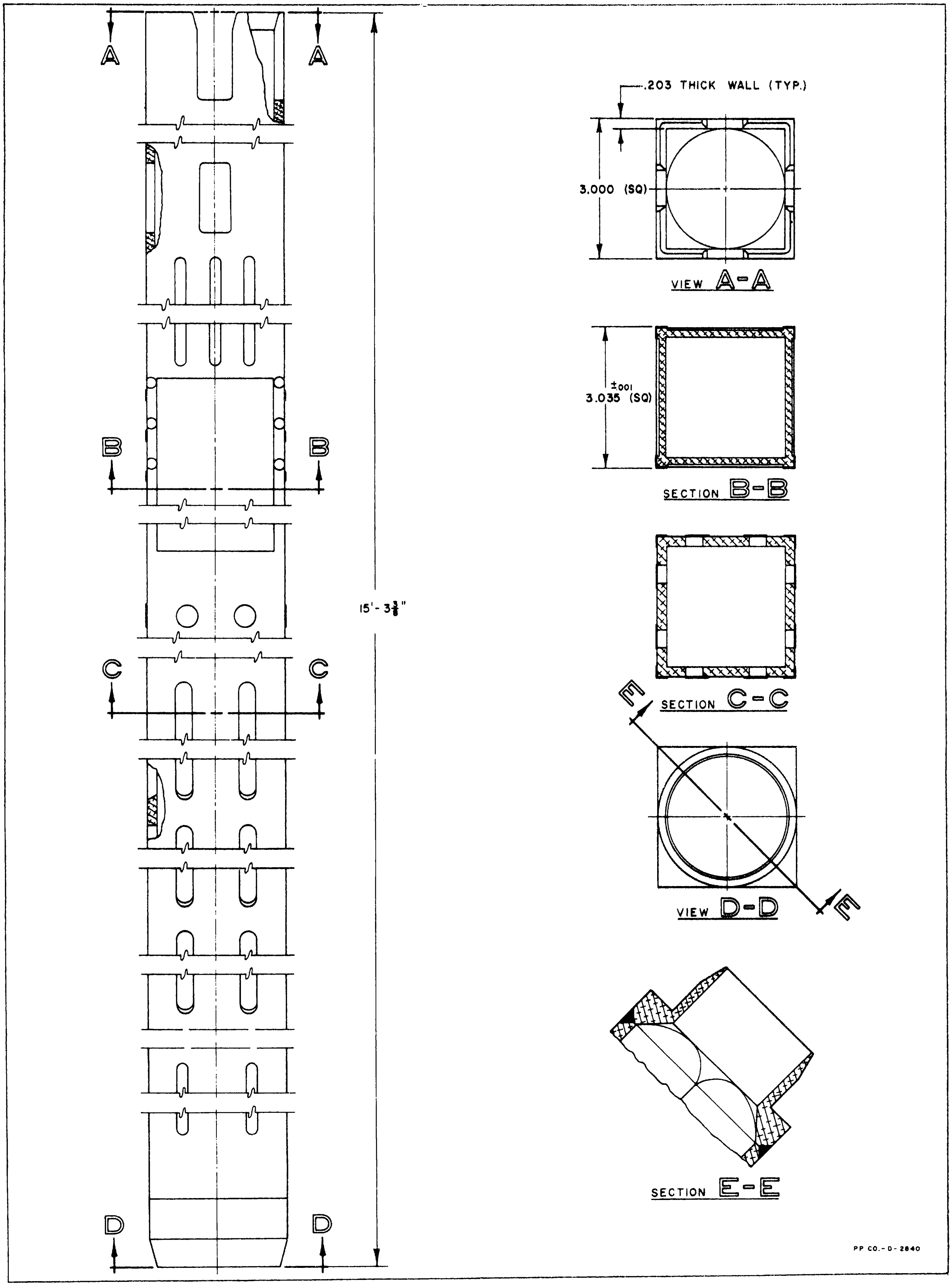

Fig. 8 ETR control rod guide tube.

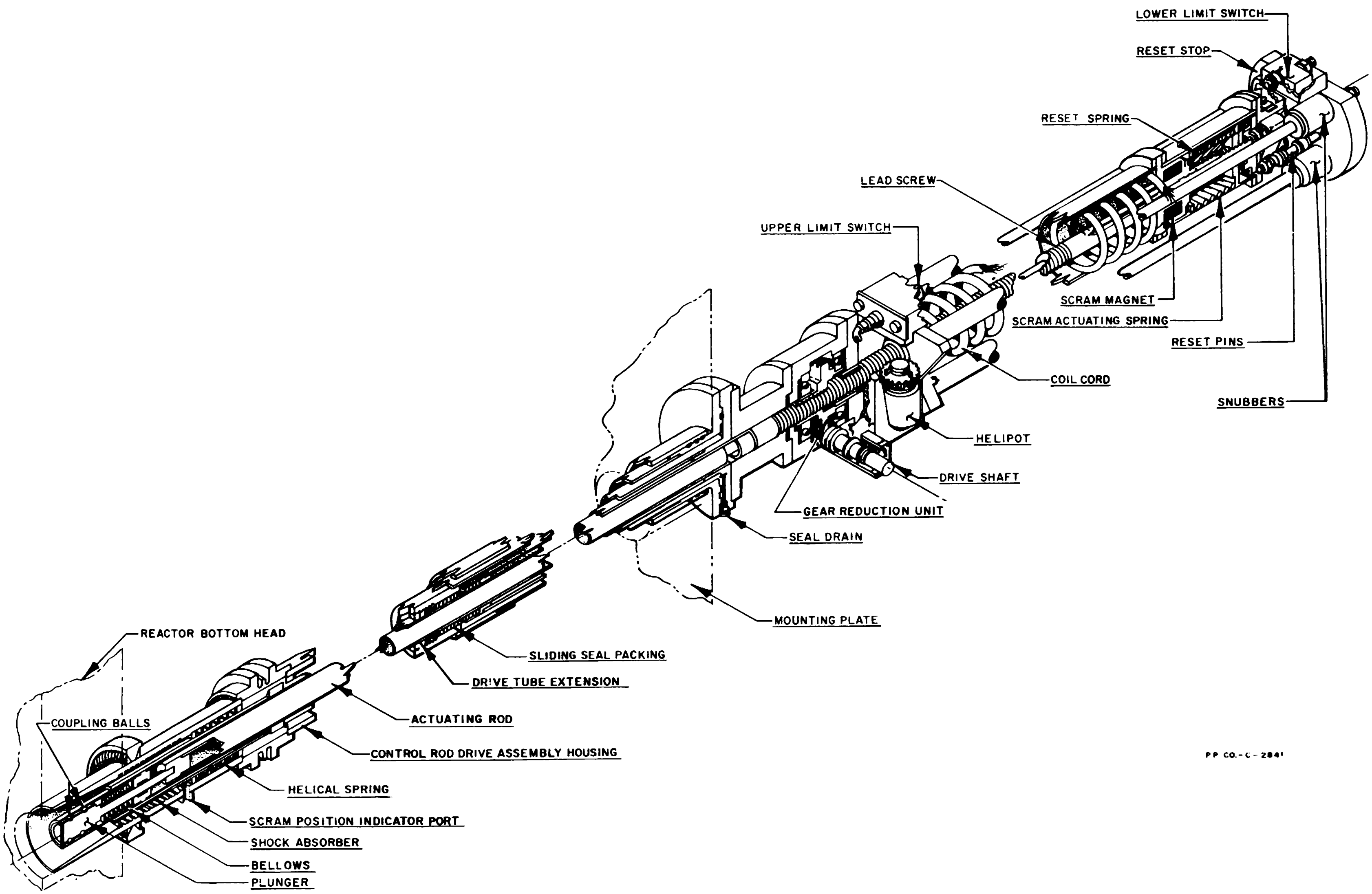

Fig. 9 ETR control rod drive assembly pictorial.

CHAPTER II

THE FUNDAMENTALS OF ENGINEERING TEST REACTOR OPERATION

The Engineering Test Reactor was designed and constructed to satisfy a need for additional high flux material testing space and to meet the more demanding requirements of complex advanced loop experiments. The reactor has 17 vertical holes of various sizes in the core and reflector that can accommodate irradiation facilities the full length of the 36-inch active lattice. In addition to the large experimental facilities, holes approximately 1-1/4 inches in diameter and 36 inches long are available in the beryllium and aluminum reflectors for capsule irradiations and lead-type experiments. At the design power of 175 MW, the maximum above thermal flux is 2.5×10^{15} n/cm^2 sec and the maximum thermal flux is 8×10^{14} n/cm^2 sec.

Light demineralized water serves as both moderator and coolant for the reactor. The nuclear fission process generates heat that must be removed in a safe and efficient manner. At a primary coolant flow rate of 50,000 gpm, the circulating water rises in temperature approximately 25 degrees, from 110 to 135°F, while passing through the reactor core. This heat is transferred to the secondary coolant system through 12 shell and tube heat exchangers. The secondary coolant system circulates approximately 632,000 gal of treated water at a rate up to 38,000 gpm through the heat exchangers and a nine cell redwood cooling tower that dissipates the reactor heat to atmosphere. The primary coolant is circulated by four 800 hp pumps that produce a 43 psig differential pressure across the reactor core and a water velocity of 32 feet per second through the fuel elements.

Electrical power is provided by two incoming 13.8 kV power lines from the MTR substation. These two lines directly supply two 4000 hp Clark compressors and transformers that feed a 4160 volt commercial bus system. Additional transformers provide 480,220 and 110 volt power. A diesel generator system receives power from the 4160 volt diesel power system comprising a 1000 kW White Superior diesel generator and a 1040 kW Enterprise diesel generator. Either the Enterprise or the White diesel is run continuously to supply power to a portion of the load in the event of a commercial power failure. An additional 480 volt failure-free system is provided through a battery bank motor generator system. Regulated or constant frequency 480 volt power is supplied to the reactor control and instrument systems by another motor generator system.

The engineered experimental loops that have been installed have more than doubled the original plant cost. These experiments consist of: one, high pressure water circulating loops of varying complexity, from a two canned rotor pump system to a six canned rotor pump installation; two, a recirculating gas cooled loop; three, single pass air cooled loops; four, a totally enclosed liquid metal cooled experiment; and five, lead-type experiments. All of the experiments must be fully integrated into the reactor plant and must receive a thorough shakedown before the experiment can test a fueled sample. There are several plant facilities available to the experiments. These include high pressure experimental air, a utility coolant system, and a high pressure demineralized water coolant system, as well as the normal plant facilities such as instrument air, electrical power, and demineralized water.

High pressure experimental air is supplied to the air cooled loops by two 15 lb/sec Clark air compressors. Filtered air is available at any pressure from 50 to 300 psig and can be heated to 1200°F by a combination of one to three eight-million Btu/hr, oil fired, air heaters.

A utility coolant system and a high pressure demineralized water system are provided to handle specific reactor and experimental cooling requirements. The utility cooling water system consists of four 2000 gpm vertical turbine pumps to supply cooling water for the Clark compressors, the Enterprise and White diesels, a 10 MW experimental heat exchanger, emergency cooling for the primary coolant system, and two carbon steel basement loops for experimental use. The high pressure demineralized water loop consists of two pressurizing pumps, two circulating pumps, a 10 MW experimental heat exchanger, and a basement 10-inch stainless steel experimental loop. The HDW system circulates water at a rate up to 2000 gpm at 200 psig to satisfy a portion of the experimental cooling load.

A reactor cycle has been designated as a six week period consisting of one to two weeks of shutdown with the balance of the time devoted to maintaining the reactor as close to 175 MW as the experiments will permit. The shutdown times are fixed and the dates distributed to interested parties to allow the experimenters to properly schedule their irradiation. Due to the multitude of experiments, the varied experimental operating parameters, and individual experimenters' requests, a reactor cycle may be extended or shortened. A cycle begins with a reactor shutdown. A shutdown time is selected to allow sufficient time to degas and flush the primary coolant system with fresh demineralized water, and remove the reactor dome before reactor shutdown work is to start. A minimum two-hour degassing period has proved necessary to prevent the release of radioactive gases into the reactor building when the reactor dome is removed.

A shutdown period is a time of great potential hazard. When large in-tank experimental tubes are installed and removed, such installations require careful planning and exacting workmanship to construct high pressure piping into the reactor tank. Each shutdown usually involves the removal of one or more experiments from the vertical in-tank loops. Such a removal involves Maintenance and Operations personnel and large casks that are placed on top of the reactor shielding. Each removal requires a written procedure that must be followed to prevent damage to the experiment and tube or overexposure of personnel. During shutdown, repairs and alterations are made to experimental and plant facilities to improve the overall safety of operation. Shutdown work may consist of over 100 work orders. Each work order must be scheduled and each system or item of equipment must be in a safe condition before any work can be started. When a piece of equipment is to be worked on, electrical breakers must be open, and breakers, pushbuttons, valves, etc, must be tagged whenever any latent danger exists. Shutdown work in the reactor tank is generally performed by Operations personnel. Tank work consists of refueling of the core and shim rods, discharge and insertion of experimental capsules, leads, pieces, and the transfer of items within the reactor. All reactor tank work must be logged, and any movement within the tank of any item must be recorded. Considerable damage to the reactor and experiments could result from placing an experiment or piece in the wrong position, so each item should be identified where possible. At the conclusion of a shutdown, a final tank inventory is taken by measuring each position. During shutdown, the usual reactor and experimental annunciator alarm systems are not always valid, so extreme caution must be exercised to prevent the running of pumps without cooling, the energizing of surge tank heaters without adequate water level, or any other manipulation that will cause equipment failure. Here again, proper logging and tag-out procedures will minimize the hazards. After each work order has been completed, the equipment should be checked in a prescribed manner and then returned to its normal operation condition of flow, temperature, and pressure to avoid a last minute rush and to uncover any equipment deficiencies.

The reactor, reactor facilities, and experiments are provided with safety circuitry to minimize the hazards from equipment failure and operational errors. Each parameter is provided with a setpoint that determines the condition where an alarm, reactor power reduction, or other action will occur. Experiment setpoints are rechecked at regular intervals and whenever experimental parameters are changed. The reactor nuclear setpoints are checked each cycle, and the reactor process setpoints are checked at less frequent intervals. The experimental circuitry is fed into the reactor circuitry through "W" switches. When the reactor is at power, "W" switches should not be opened without special permission.

When the shutdown work is completed, the reactor dome is bolted in place, the primary system is filled and pressurized, and normal flow is started. Start-up check sheets are completed on the primary coolant system, the reactor control system, and all associated facilities. With the completion of start-up check sheets and when flow and pressure have been established on each experiment, the reactor may be taken to power. A reactor start-up is usually an orderly process, but offers certain dangers due to the lack of sensitivity of instruments at extreme low power levels. The four black safety control rods are withdrawn first, then the grey rods are withdrawn according to a prescribed rod program. The rod withdrawal program is designed to prevent flux peaking in the reactor core and possible experiment overheating. At each power level, all experiments must be checked for any off-normal points and for any potential dangers. The approach to full power must be slow and cautious to prevent any high experiment sample temperatures. Also, at high power levels, the secondary coolant system cannot absorb rapid temperature changes.

The optimum power run would be to reach full power four to six hours after start-up and maintain full power until the core is depleted or until the end of the cycle. There are a great many things that can cause reactor down time, so an optimum run seldom occurs. Experimental and plant failures such as heat exchanger leaks, thermocouple failure, instrument failure, and breakdowns of plant equipment can occur. Operational mistakes such as closing an incorrect breaker or switch, opening or closing the wrong valves, or failing to recognize a malfunction before it causes trouble also can cause reactor down time. Each equipment failure or operational mistake requires an upgrade in that particular piece of equipment, a change in operational procedure, or an increase in training to prevent a similar occurrence.

A nuclear test reactor designed to test nuclear fuel samples at extreme conditions presents certain perils not associated with a plant of more conventional objectives. Certain calculated risks must be accepted to conduct a full experimental program. However, all risks must be minimized and backups provided to prevent incidents. Test reactors provide a small margin for error, and a minor situation can rapidly deteriorate to cause an incident; therefore, an operating philosophy must be developed whereby safety of personnel and plant is of paramount importance. Incidents, reactor shutdowns, and serious equipment failures can be minimized and often prevented by a well-trained and alert operating force. Vibrations, odd noises, and any unknown situation should be immediately investigated and reported to the proper persons. Recording instruments and detection devices usually indicate when conditions are changing so action can be taken before real trouble develops. The operating force should be familiar with plant standard practice regulations, as well as the current experiment operating instructions. To prevent operational errors, incidents, and misunderstandings, the line of command should be used, where possible, to pass information and instructions. When performing any non-routine job involving irradiated material or plant and experimental equipment, the job must be carefully planned and executed to avoid personnel and equipment hazards.

The overall objectives of test reactor operation are somewhat mixed. A large yearly MWd record is some measure of operating efficiency, but this could easily be reached with capsule irradiations and no irradiation in engineered loops. Complying with all customers' requests and accepting all last minute changes would result in a low irradiation output. To fully utilize the experimental facilities, a working program level has been established in which all effort is directed toward a maximum power output consistent with safe operating practice and total sponsor requirements.

CHAPTER III

REACTOR CONTROL COMPONENTS

A. GENERAL

The control system is to provide smooth and continuous operation under all circumstances and provide adequate safety devices which will prevent core or experiment damage in the event of a component failure or accident. Control of the reactor is accomplished by sensing instruments and amplifiers which raise the signal to a usable level and by control mechanisms which respond to this signal or to the operator's request.

B. REACTOR CONTROL COMPONENTS

1. Control Rods

Control rods provide the means of coarse reactor control. Each shim rod consists of a poison, ie, neutron absorbing section, a fuel section containing 184 grams of enriched U-235, and a shock section. The three sections are mechanically latched together and connected to a drive mechanism below the reactor. The connection of the control rod to the drive mechanism is by a mechanical linkage and is held by an electromagnet clutch. The control rods are driven by a 1/3 hp motor through a worm drive mechanism. The shim rods may be moved at the operator's request, either up or down, and may be dropped by shutting off the current to the electromagnet clutch.

The 16 control rods consist of 4 black rods and 12 grey rods. The black rod poison sections are fabricated of 347 stainless steel sprayed with cadmium, then with 302 or 316 stainless steel and are, therefore, excellent neutron absorbers. These control rods are considered safety rods, and control circuitry does not permit the reactor to approach power without these being totally withdrawn, ie, fuel section in the core, poison out. The grey control rod poison sections are fabricated of nickel stainless steel, and the neutron absorbing qualities of these shim rods are generally less than the black shim rods. The grey rods are withdrawn to bring the reactor to criticality, raise power, and replace fuel as it is being consumed.

The positions of the individual rods are indicated at the reactor console by an ac voltmeter connected across a variable resistor, with the sliding contact connected mechanically to the rod drive (see Figure 10). The voltage shown on the meter, which is calibrated in inches, is proportional to rod height.

Each shim rod drive mechanism is equipped with microswitches at its upper and lower limits of travel. When actuated, the switches shut off power to the shim rod motors and turn on their respective lights adjacent to the shim rod position indicators at the reactor console.

The current for each magnet clutch is supplied by two magnet amplifiers in parallel. If one amplifier fails, the other automatically takes over the full load. The clutch is equipped with a microswitch that is closed when the armature is pressed against the magnet. Should the armature fall away from the magnet, ie, by shutting off the current, the microswitch opens and through the action of a relay, initiates a rundown of the drive mechanism and turns on the "CLUTCH" light at the reactor console, showing the clutch disengaged.

A proximity switch, known as the "SEAT" switch, is actuated when the shim rod is at its lower limit or "seated". It should be noted that this is independent of the position of the drive mechanism. A light at the reactor console is turned on when the "SEAT" switch is actuated.

2. Servo System (see Figures 11 and 12)

The servo mechanism is used to automatically control reactor power between

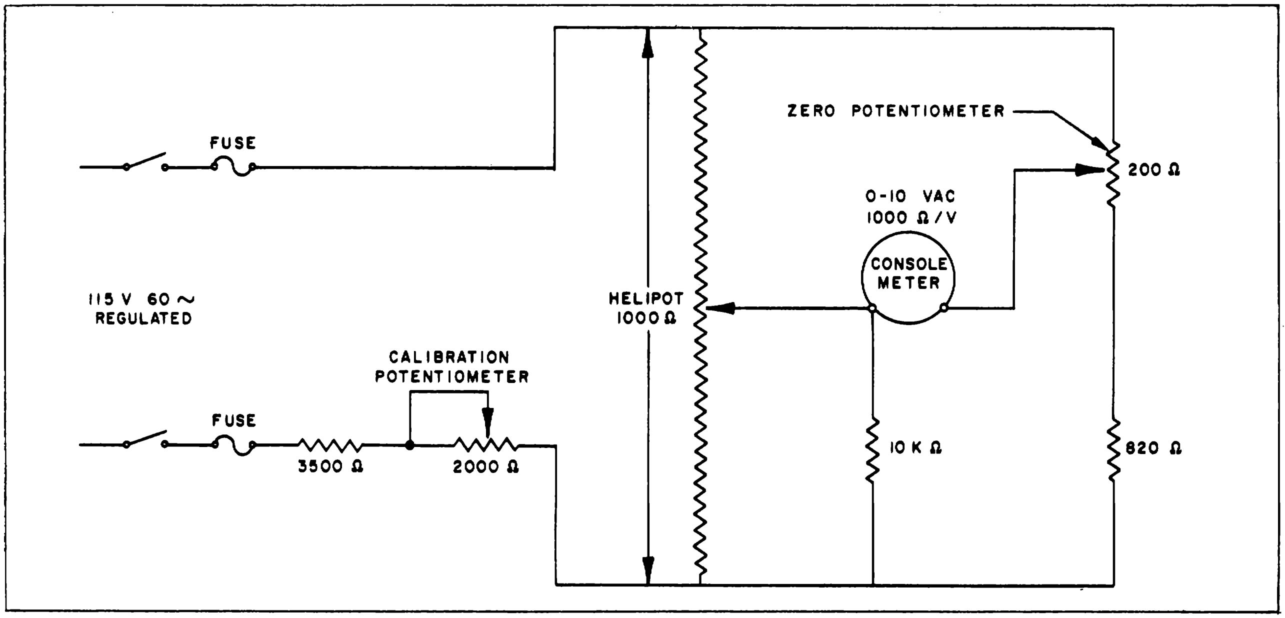

Fig. 10 Shim rod position indication.

N_L and N_F, ie, 1 and 100 percent of full power. The operator brings the reactor to the desired power level by means of a motor operated rheostat or MOR. If the neutron flux level, as seen by an ion chamber, differs from that of the MOR setpoint, the system will adjust the reactor power by moving the regulating rod, a neutron absorber, in or out of the pile as necessary. At the present time, the two original regulating rod systems are not in use. They have been replaced by No. 10 and No. 13 control rods that have been modified to serve as regulating rods.

The ion chambers used for the servo systems are parallel circular plate (PCP) type located in the biological shield (see Figure 13). The active section of a PCP chamber consists of a set of graphite discs, each of which is coated on both sides with B^{10}. This arrangement increases the exposed surface area to neutrons. Alpha particles are emitted by the B^{10} (n,α) Li^7 reaction when the discs are bombarded by neutrons. These alpha particles, in turn, ionize the gas in the chamber to produce an ion current proportional to the neutron flux at the chamber.

The ion chamber in the servo system may be compared to a variable resistor with the resistance varying inversely with the magnitude of the neutron flux in which the chamber is located. Ions produced in the chamber by the neutron flux appear as electrical current. With a constant voltage applied, a current inversely proportional to the resistance or directly proportional to the flux will flow through the chamber.

Considering the circuit in Figure 14, the voltage at point "A" will depend on the values of R_1, R_2, and the battery voltage. If R_1 is increased, the voltage at "A" will decrease. If R_2 is increased, the voltage at "A" will also increase. The ion chamber may be represented by R_1, and the MOR by R_2. A flux increase, ie, resistance decrease, at the chamber would cause the voltage at "A" to go more positive, which would signal the regulating rod to insert and bring the reactor flux and the voltage at "A" back to the original level. By varying R_2, the MOR, it is possible to select the flux level desired, and the servo system will move the regulating rod to bring the system back to balance. In other words, if R_2 is decreased, the chamber resistance must also decrease to hold the voltage at point "A" constant.

The motor operated rheostats are step logarithmic rheostats with 500 steps

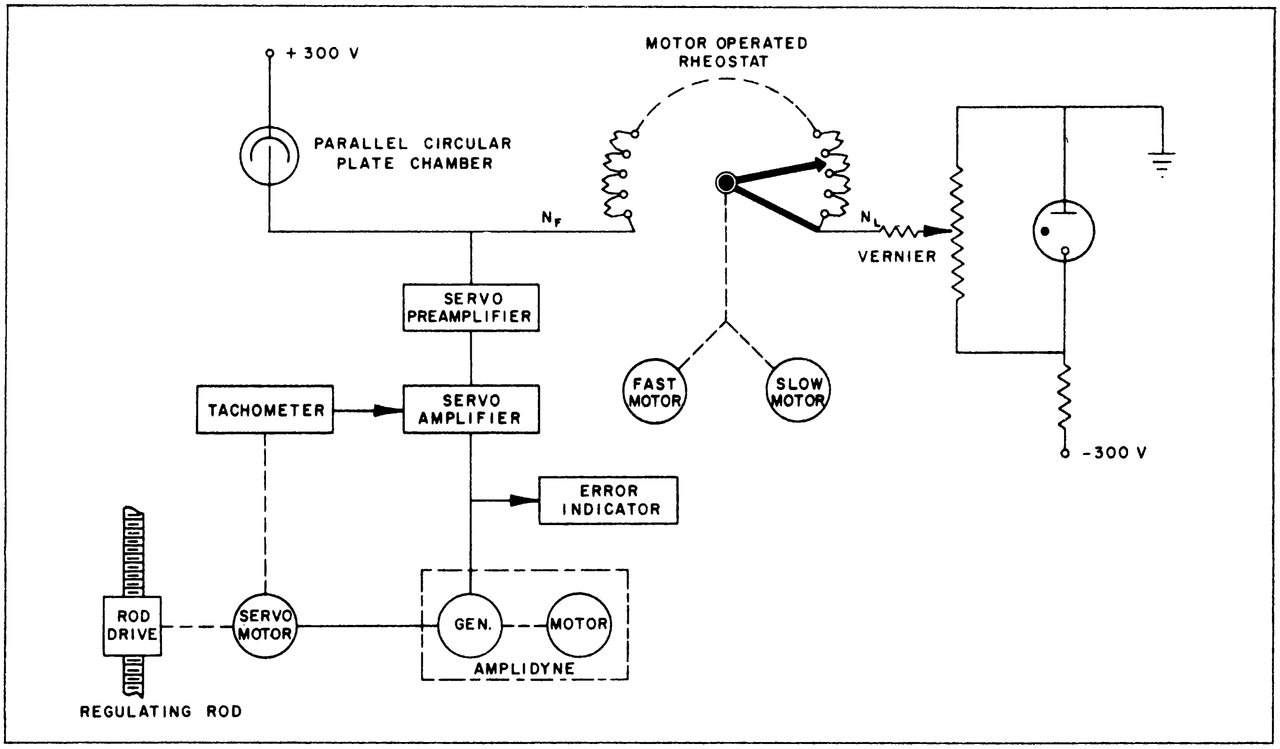

Fig. 11 MTR type regulating rod servo control.

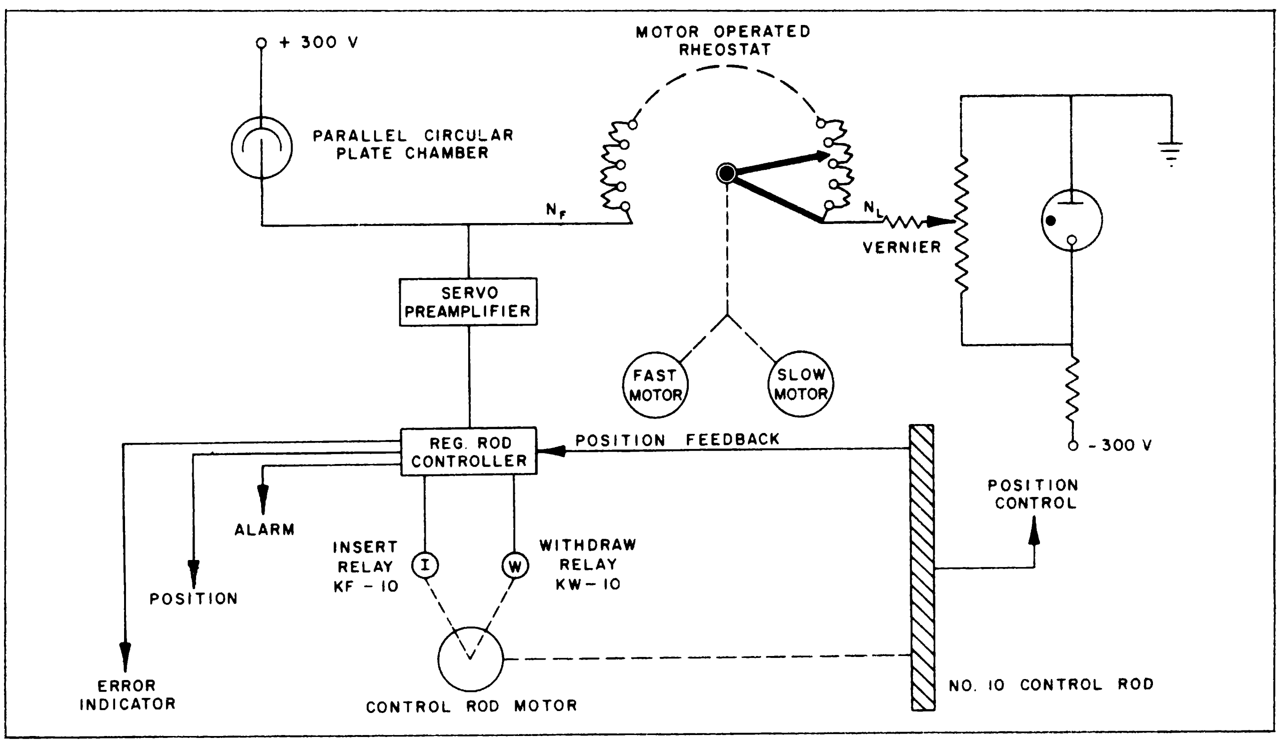

Fig. 12 Regulating rod servo control.

from 50 megohms at N_L to 0.5 megohms at N_F. The MOR is controlled from the reactor console and may be raised or lowered by one of two speeds. Fast speed from limit to limit is 90 seconds, slow speed is 480 seconds. A selsyn indicator

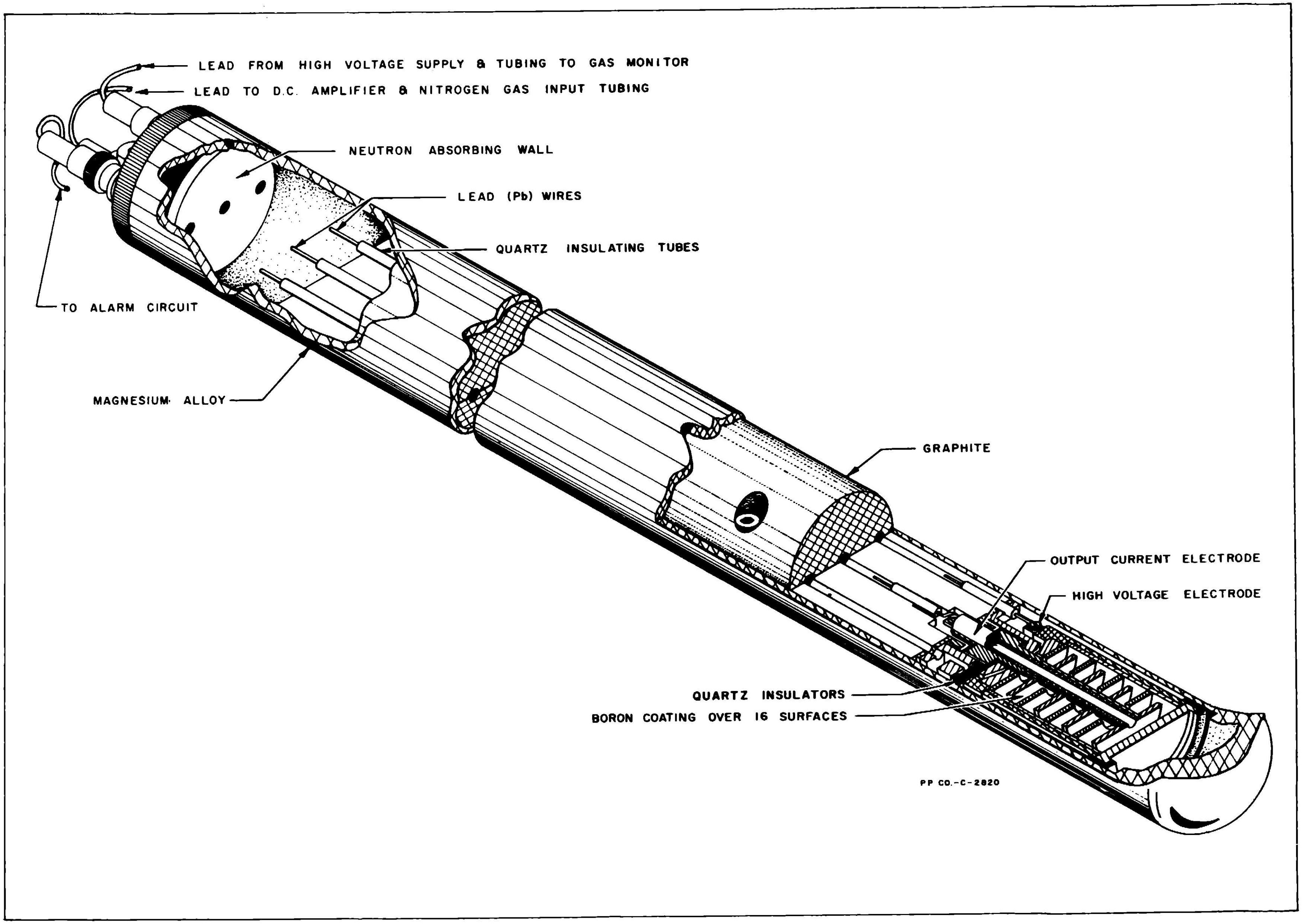

Fig. 13 PCP chamber.

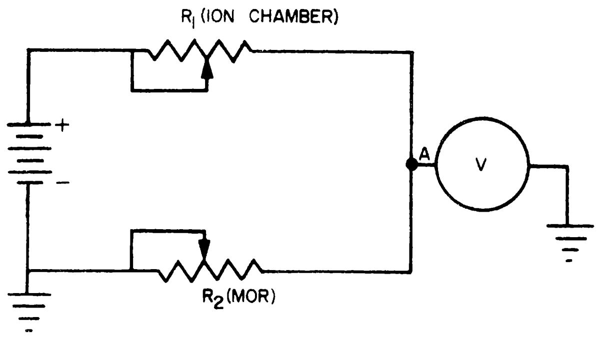

Fig. 14 Simplified diagram of servo system.

located in the control room gives visible indication of the position of the MOR.

The level vernier is a 5000 ohm potentiometer across which a portion of the negative reference voltage is applied. Its function is to change the reference voltage to the MOR, and thus provide fine control of the reactor power setpoint.

The servo preamplifiers are connected to a reference point between the servo ion chamber and the MOR. The voltage signal at this point is then amplified and transmitted to the servo control amplifier.

The original servo system used the regulating rod positions located in the northwest and southeast portion of the beryllium reflector. These are no longer in use due to their inadequate amount of control.

In the original servo system, the signal from the preamplifier is fed to the servo amplifier which provides the field current for the amplidyne generator. With a balanced signal from the ion chamber and MOR, the amplifier emits two equal currents to the opposing field coils of the amplidyne generator, and there is no generator output. When the amplifier currents differ, caused by unbalance between the MOR and ion chamber, the field of the amplidyne generator is varied, causing the output of the generator to vary. The amplidyne output is fed to the regulating rod motor which moves the regulating rod in the direction required to rebalance the system.

A tachometer generator with output proportional to the regulating rod velocity is connected to the regulating rod motor. The output of the tachometer is opposite in sign to the input of the servo amplifier. It is fed into the input of the servo amplifier to produce servo system stability.

The present servo systems utilize the No. 10 and No. 13 control rods as regulating rods. They differ from the original systems in that a position adjusting control amplifier is used in place of the servo amplifier and amplidyne. The signal from the preamplifier is fed into the control amplifier which then moves the No. 10 or No. 13 rod in or out by relay action depending on the signal from the preamplfier.

The position of the regulating rod is indicated at the reactor console by a dc voltmeter calibrated in inches. Feedback for system stability is provided through an RC circuit from the dc position indication circuit.

The regulating rod, which utilizes the upper portion of No. 10 or 13 control rod, is provided with limit switches at 36 inches, 29 inches, 26 inches, 25 inches, and 24 inches. The 36-inch and 24-inch positions stop the rod drive motor. The 29-inch switch prevents the withdrawal of other shim rods. The 26-inch switch drives in the preferred rod, and the 25-inch switch inserts the other 15 shim rods.

During shutdown, a strong negative signal comes from the preamplifier and results in saturation of the output tube of the servo controller. To overcome this, a contact has been placed in the ground leg of a converter coil in the controller. At "SAG", this contact closes, energizing the converter, giving a "Servo Demand" annunciator until the reactor approaches servo control. If the "Servo Demand" annunciator fails to alarm at "SAG", it will indicate a malfunction in the servo system.

3. Instrument Centers (see Figure 15)

The actual control of reactor power is accomplished in the reactor control room. Located on the ground floor, it contains the reactor console and control instruments.

The console is located in the east end of the room and is arranged in an arc, giving the operator easy access to the controls. The various control and information devices are mounted on five panels. The left panel contains 12 dials which show the vertical position of the individual grey rods, No. 5 through 16. Four lights show the extreme limits of the shim rod drive, seating of the shim rod, and condition of the magnetic clutch. Directly under each set of lights is a multi-position switch for controlling individual rods and lights to indicate which action is being exercised. This panel also contains a 16-position selector switch for individual withdrawal of any shim rod.

The left center panel contains two dc voltmeters indicating regulating rod position, the switch for selecting the regulating rod to be used, and the MOR switch and vernier for controlling reactor set-point.

The center panel contains the deviation galvanometer and its associated controls, the fission chamber positioning switches and indicating lights. At the lower left end of the panel is the low speed switch for insertion or withdrawal of individual shim rods. On the lower right is a switch for intermittent or high speed withdrawal of either part or all of the black control rods or the grey control rods.

The right center panel holds switches for manual reductions of power, the scram and scram reset, and rundown. It also holds the "RAISE-SCRAM-COCK" switch and switches for closing the building ventilators and shutting down the building supply fans should air activity reach a high level. Two red lights from the scram relays and a servo error dial indicating the output signal of the servo preamp are located on this panel.

The right panel contains indicator dials, switches, and lights, identical to those for the greys, for the four black shim rods. This panel also contains the reactor key switch, start and run buttons, procedure panel, and communication system controls.

On the console desk apron are the acknowledge and reset buttons for the annunciator panel, telephone, sound power phone, and microphone.

The control room instrument panels contain most of the indicating and recording instruments necessary for operation of the reactor. The reactor operator is guided by information from these instruments, so they are arranged according to their importance. Directly ahead of the console are the nuclear recorders and the power recorder. To the left of these are the primary system recorders, and to the extreme left are the stack activity and radiation recorders. Above the recorders and directly ahead of the console are two annunciator panels which inform the operator that an abnormal condition exists or that certain control mechanisms have been energized.

Important operating parameters are interlocked to the reactor safety circuitry by recorders. Directly below these recorders are test blocks which are used as a quick disconnect of the safety interlock.

Located to the right of the console are "W" switches which interlock certain experiment operating parameters to the reactor control circuitry. Directly above these is an annunciator panel which warns the operator in the event of an abnormal operating condition in any of the individual experiments.

The instrument room is located on the mezzanine floor of the reactor building, beneath the control room. This room

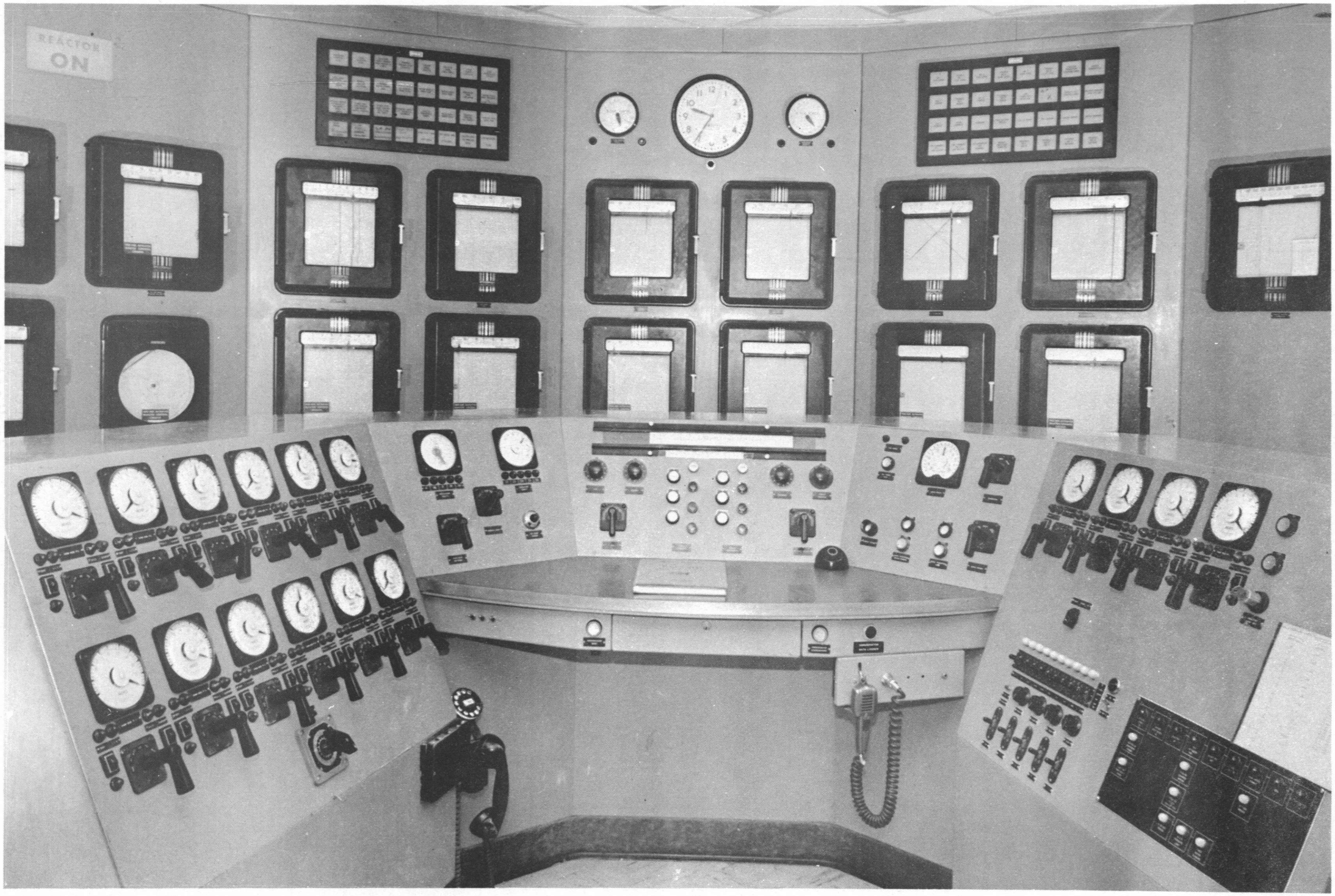

Fig. 15 ETR console.

contains the major amplifiers, circuit relays, instrument power distribution, and motor power distribution. The restart, period, safety level, sigma, magnet, and servo amplifiers, plus magnet current and trouble monitors are arranged in cabinets for easy access.

The rod access room, located below the subpile room contains all control rod drives, motors, magnetic clutches, control rod limit and clutch switches, and position transmitters. The fission chamber drives and motors also are located here. The A-1 preamplifiers which transmit the fission chamber signals to the restart amplifiers are located on the rod access wall. The control rod seat switches are located in the sub-pile room, immediately below the reactor.

Two instrument cubicles, located on the north and south side of the reactor on the console floor, contain amplifiers for incoming signals from the log N, neutron level, and servo chambers. They also contain the MOR's and the Servo preamplifiers.

4. Nuclear Instruments

The nuclear instrument system is composed of several separate systems. These systems, with the exception of the nitrogen 16 recorder, respond to the neutron flux of the reactor. This system, as a whole, monitors, controls, and records the reactor power.

(a) Restart Channels (Count Rate Meters)

The function of the restart channels is to provide information on the neutron flux during shutdown and rate of change of the neutron flux between 10^{-9} N_F and N_F. Each of the two identical systems consists of a movable fission chamber, a preamplifier, a high gain pulse amplifier, a count rate amplifier, and a count rate recorder.

The fission chambers are ionization chambers coated with U-235 which will fission on interaction with neutrons. This will cause ionization within the chamber and produce detectable pulses of ion current in a low flux field. The fission chambers are located in bottom head thimbles originally designed for the log N chambers. To extend the range of the instruments, they are equipped with motor drives and move through a distance of five feet. The pulses from the chamber are large, and by proper biasing of the amplifier, they can be counted separately. The chamber sensitivity is 70 counts per second in a flux of 100 neutrons per cm^2 per second.

The preamplifiers are the stage amplifiers designed to amplify the 50 microvolt signal from the chamber and transmit it to the pulse amplifier.

The pulse amplifiers, located in the instrument cubicles, consist of a differentiating circuit, an amplifier, and a pulse height selector. Their functions are to build up the pulses to an amplitude sufficient to be detected and used by a count rate meter and to aid in discrimination between true fission pulses and background ionization caused by other radiation.

The count rate amplifiers in the instrument room receive pulses from their respective pulse amplifiers and convert them to voltages proportional to the logarithm of the count rate. This information is then transmitted to a meter on the face of the amplifier and the restart recorder in the control room.

(b) Log N and Period System

This instrumentation monitors from 10^{-6} N_F to $3N_F$, and the reactor period from negative 30 to positive 3 seconds. Its purpose is to give visual indication of the increasing reactor power during the iterim between criticality and appreciable power levels.

The log N recorder indicates the percent power, and the period recorder indicates the rate of change of power in seconds of reactor period. The entire system is duplicated as a safety measure. Each channel is composed of: a compensated ion chamber; its power supply; a logarithmic amplifier; a logarithmic recorder; a reactor period amplifier; a sigma amplifier; a period recorder; and some auxiliary contacts which limit reactor operations to safe levels and periods.

The compensated ion chambers are designed to give reliable measurement of neutron flux over a wide range in the presence of intense gamma radiation. This is accomplished by having the equivalent of two chambers, one sensitive to neutrons and gammas, and the other sensitive to gammas alone. The outputs are connected in opposition so that the net result is a signal indicative of neutrons only. Their output current ranges from 10^{-10} amps at low levels to 10^{-4} amps in a flux of 10^{10} n/cm^2/sec. These chambers are located in horizontal chamber holes in the concrete biological shield (see Figure 16).

Power supplies for the compensated ion chambers are located in the instrument cubicles. They supply a negative 0 to 350 volts (adjustable) and a positive 600 volts to their chambers. A relay which opens at 1/2 normal positive voltage operates a control room annunciator to warn of power supply failure.

The log N amplifiers, also located in the instrument cubicles, are direct coupled amplifiers with logarithmic characteristics. They receive signals from the compensated ion chambers and convert them into voltages proportional to the logarithmic of the neutron flux. The signal is sent to the log N recorders and also is differentiated to produce a signal that indicates the time rate of change, or period, of the neutron flux at the chamber. This signal is then sent to the period recorder.

The log N recorders, located on the reactor control panel, record on a six decade strip chart the percent flux level of the reactor. Through their auxiliary switches, they are primary instruments in governing operation of the reactor between 10^{-6} N_F and full power.

Each period amplifier, located in the amplifier cabinet, receives its signal from its log N amplifier. It differentiates and amplifies this signal and transmits it to the sigma amplifiers to provide the one-second period scram. The interconnection of these units is shown in Figure 17.

The reactor period recorders indicate and record the period of the reactor. This is the time it takes for the reactor power to increase by a factor of e. It is also the time rate of change of the log N recorders. For example, when the log N recorders are not moving, the period is infinite. Auxiliary switches in these recorders play an important part in reactor operation.

(c) The Neutron Level System

This system consists of components responsible for transmitting level fast scram signals to the magnet amplifiers and indicating and recording the relative power between 0.1 and 150 percent power. It includes three channels of neutron level monitoring, each composed of a parallel circular plate chamber, a sigma amplifier, a sigma preamp, and a level recorder. These also are shown on Figure 17.

The ionization chambers are located in reactor holes B2, B4, and B6. These chambers, coated with boron 10 to make them neutron sensitive, have an output of about 5 x 10^{-5} amperes at the operating flux of 10^{10} n/cm^2/sec. They have a response time of 5 to 10 milliseconds to core flux changes and are used because of this fast response.

The preamps receive signals from the chambers and transmit them to the sigma amplifiers. Each preamp has two input resistors, one greater than the other by a factor of 10. The higher resistor, used below 3 NL, causes the system to assume a higher power level and make the

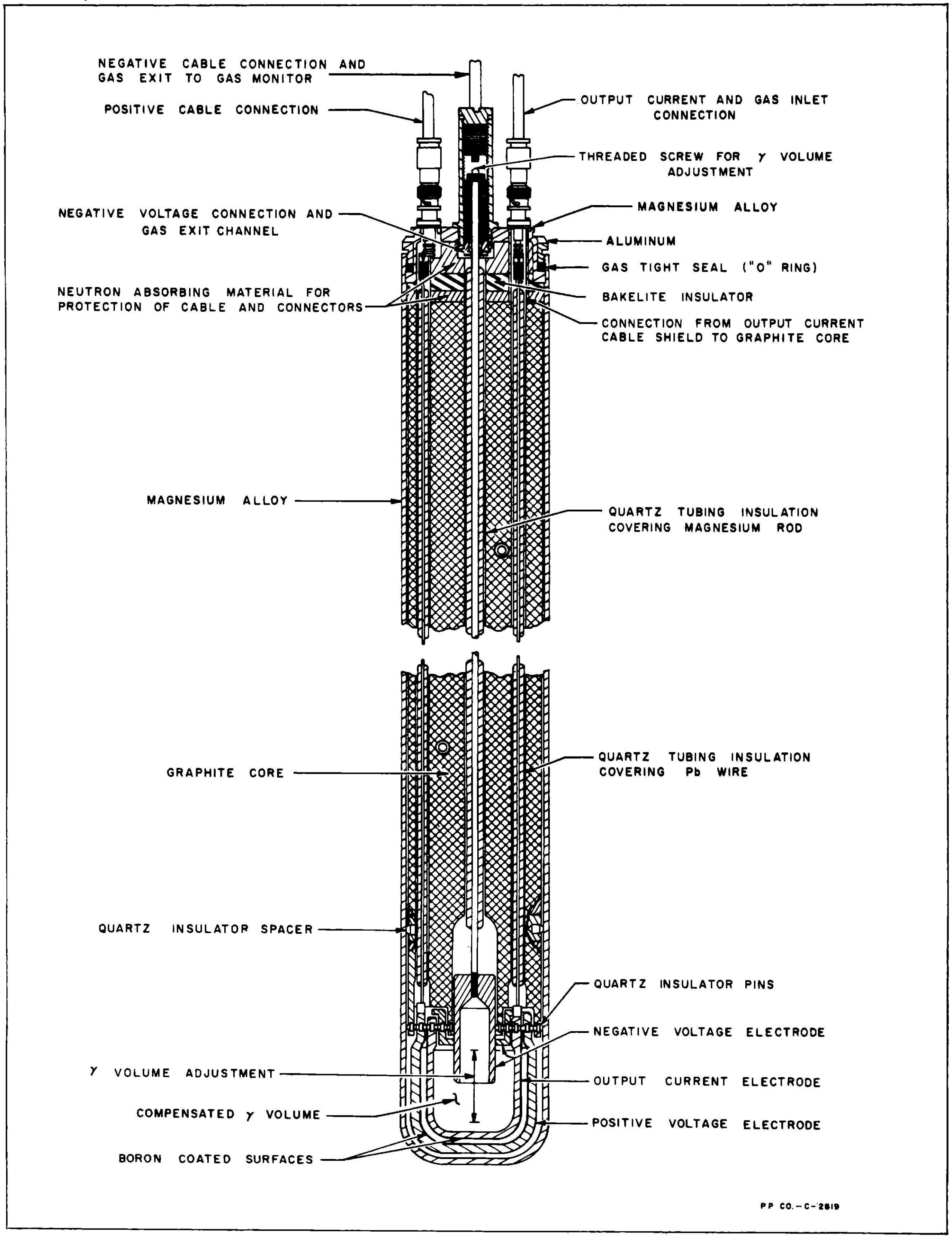

Fig. 16 CIC chamber.

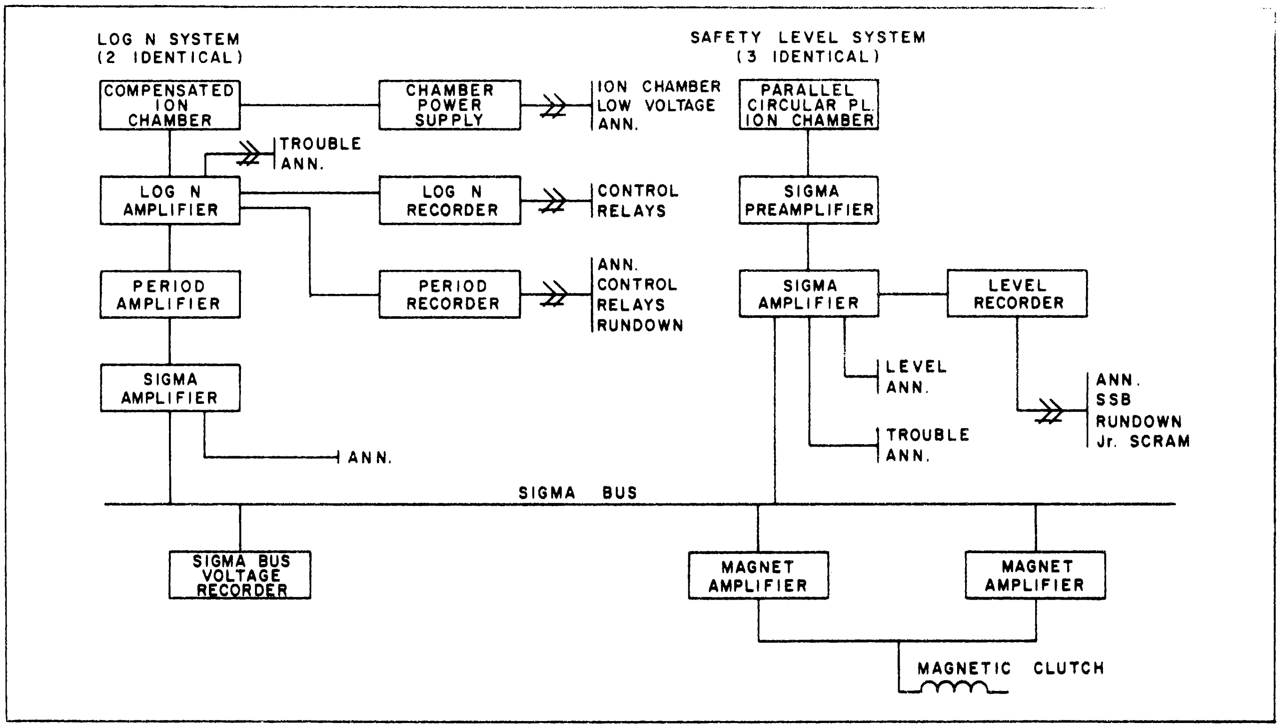

Fig. 17 Electronic scram system and control instrumentation.

electronic scram more readily available during start-up of the reactor. These resistors are automatically switched at 3 N_L by relay action.

The sigma amplifiers, located in the amplifier cabinet, supply a signal to the magnet amplifiers via the sigma bus, thus controlling the magnet current. The electronic or fast scram is obtained by reducing the magnet current with a high or low signal to the sigma bus from any one of the five sigma amplifiers. Thus, a short period or a high neutron level will produce an electronic scram.

The sigma bus is the carefully constructed shielded circuit in the amplifier cabinet which connects the output of all sigma amplifiers to the input of all magnet amplifiers. It is connected to the sigma amplifiers in such a way that it assumes only the highest voltage from the outputs of these amplifiers. Thus, only one controls, but it is always the highest one.

The neutron level recorders, located on the panel in the control room, record on a strip chart the neutron level transmitted by their respective sigma amplifiers. These recorders have auxiliary switches which cause an alarm at 1.05 N_F, a slow setback at 1.1 N_F, a rundown at 1.1 N_F, and scram at 1.2 N_F.

The sigma amplifier trouble relays form a unit in the amplifier cabinet. This unit receives trouble and scram signals from relays in the sigma amplifiers and transmits them to the proper control room annunciator.

(d) N^{16} Radiation

The N^{16} system is not actually a nuclear instrument, but it is used as a measure of reactor power; therefore, it is included in this group.

N^{16} is formed in the reactor during operation by the reaction $O^{16} + n \rightarrow N^{16} + p$. The N^{16} system is designed to measure the gamma activity from the $N^{16} \rightarrow O^{16} + \beta + \gamma$ decay. This system consists of an ion chamber and preamp unit, amplifier and recorder.

The ion chamber-preamp unit is located in the pipe tunnel. Its primary purpose is to produce a signal proportional to the gamma intensity which is proportional to the reactor power, to amplify the signal to a usable level, and transmit it to the N^{16} amplifier located in the amplifier cabinet.

The N^{16} amplifier receives the signal from the preamp, further amplifies it, and transmits the information to a meter on the face of the amplifier, directly calibrated in mr/hr. Three ranges are available, 0 to 25, 0 to 125, and 0 to 750 mr/hr, by means of a "LOW-MED-HIGH" switch also located on the face of the amplifier. This instrument is designed to be "fail-safe". Should any of the internal components fail, a relay will drop out and an alarm light on the front of the amplifier will come on.

The N^{16} recorders, located in the reactor control panel, receive their signal from the N^{16} amplifiers. They are calibrated in percent power. Auxiliary switches on the recorder cause power reductions if the recorder and amplifier are on the high range at 1.1 N_F and 1.2N_F. It should be noted here that the meter on the N^{16} amplifier is calibrated in mr/hr while the N^{16} recorder is calibrated in percent power. Because the operating range of the N^{16} system is limited, the chamber must be heavily shielded. The signal to the recorder then contains a multiplier to compensate for the shielding. The recorder reading is set up at full power to read directly in percent of reactor power.

5. Primary System Instruments

(a) Power Calculator (see Figure 18)

One of the fundamental measurements of power is the amount of heat generated in the reactor.

The water power system consists of a flow indicating transmitter, Dynatherm bridge and temperature bulbs, power calculator unit, master power supply, and power recorder.

The master power supply comprises a dc power supply and a 1000 cycle ac supply. The dc supply is of common design, and supplies the proper dc and filament voltage to the 1000 cycle ac supply. The ac supply generates a stable 1000 cycle signal by means of a tuning fork oscillator. The oscillator signal is amplified to the 36 volts required by the calculating system.

The flow indicating transmitter, FT 4-5, measures and indicates the differential pressure across a bank of pitot tubes, mounted on a Gentile ring. FT 4-5 transmits a voltage, E_f, proportional to the flow. This voltage is applied to an electrical adder network which changes the range of the voltage. This new voltage, V_f, is sent to the isolation amplifier. The isolation amplifier is an impedance matching network that sends the signal to the flow recorder and also to the Dynatherm bridge through a coupling transformer.

The Dynatherm resistance bulbs are sensitive resistive elements designed to exhibit a resistance that varies with the temperature. One set of bulbs arranged in quadrants is located on the inlet header, and one set of bulbs arranged in quadrants is located in the outlet header. There are spare bulbs on both the inlet and outlet headers. The resistance bulbs are cable connected to the calculator unit and wired within the unit to form the Dynatherm bridge. The output voltage, E_p, from the Dynatherm bridge is then a result of the flow and the differential temperature across the reactor, or E_p is proportional to the apparent power. This resultant voltage is fed into the power calculator which applies two correction factors, friction flow and thermal shield flow. Figure 18 shows this mathematical relationship. This corrected signal is then used to position the power recorder located in the instrument panel in the reactor control room.

The power calculator unit contains a flow standard and a temperature dif-

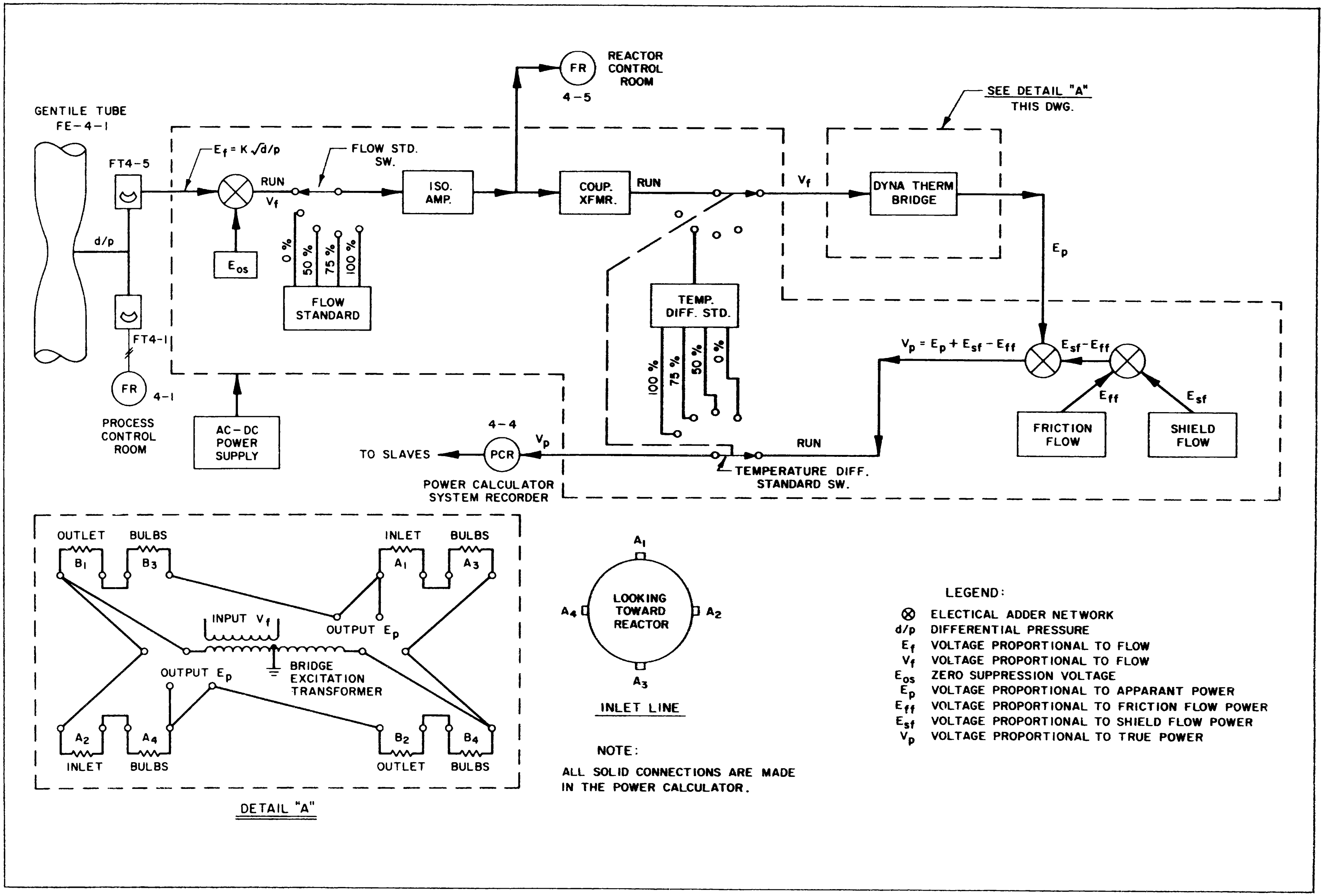

Fig. 18 Power calculator block diagram.

ferential standard. These standards may be substituted for the flow transmitter and/or the Dynatherm bridge to check out or calibrate the system.

Auxiliary switches on the power recorder are arranged so that in the event the power level is too high, contacts in the recorder will close, energizing relays in the reactor safety circuitry.

The power recorder also has provisions for operating five slave recorders, one of which is on the control room panel.

(b) Reactor Coolant Flow

The primary coolant flow through the reactor is an important operating parameter, and precise measurement is imperative. The flow is sensed by a bank of eight pitot tubes mounted on a Gentile ring located in the inlet coolant line. The delta pressure output is converted to an electrical signal and is transmitted to both the primary flow recorder and power calculator system.

The recorder is calibrated to read true flow in gpm. It is also equipped with auxiliary contacts which energize relays in the safety circuitry.

(c) Reactor Inlet and Outlet Coolant Temperature

This system senses the temperature at the reactor inlet and outlet by means of two Dynatherm resistance bulbs identical to those used in the power calculator system. The output of each bulb is connected to a recorder to give actual indication of the temperature of the primary coolant as it enters the reactor and as it is discharged.

The recorder is equipped with auxiliary contacts which energize relays in the safety circuitry in the event of excessive high temperature.

(d) Reactor Delta Temperature

The difference between inlet and outlet coolant temperature is monitored and recorded. The signal is derived from the average of two Dynatherm bulbs at the reactor inlet, and two at the reactor outlet. The output signal of each is fed to a bridge circuit and the resultant current is recorded in degrees Fahrenheit. The recorder is equipped with auxiliary contacts which close on abnormally high delta temperature and energize relays in the reactor safety circuitry.

(e) Reactor Inlet and Outlet Pressure

The reactor inlet and outlet pressure signals are derived from pressure taps at the inlet and outlet coolant lines. The output signals are fed to strain gauges which convert the pressure signals to a proportional electrical signal. The strain gauge consists, essentially, of a wire in which the resistance varies with a strain placed on it by pressure; ie, as the pressure is increased, the resistance also increases. The output signals from the strain gauges are then recorded directly in psig. This recorder also is equipped with auxiliary contacts to protect the reactor against abnormally low inlet or outlet pressures.

(f) Reactor Delta Pressure

The pressure drop across the reactor core is monitored by a system similar to the reactor inlet and outlet pressure. The pressure taps for this system are located in the lower reactor drain line and in the bottom head. The input pressure signals are fed to the strain gauge in opposition, and the output electrical signal is then the difference between the two. This signal is recorded directly in psig. The recorder is equipped with contacts which protect the reactor in the event of either abnormally high or low delta pressure.

In addition, two fast response electronic instruments monitor the reactor pressure drop. Transducers are connected to the reactor tank pressure taps. The transducers provide a positive dc voltage signal that is proportional to the reactor tank delta pressure. This signal and a negative bias (pressure input bias) are added at the input of a summing amplifier. When the delta pressure signal is normal and the pressure input is properly adjusted, the amplifier output signal is zero. If the delta pressure signal deviates from normal, the amplifier output is proportional to the deviation. Two transistorized trigger circuits are tripped when the amplifier output reaches adjustable preset levels to produce an alarm or a reactor scram and scram alarm on high or low delta pressure.

6. Radiation Instruments

The radiation monitoring instruments at the ETR fill a variety of purposes. Some are important in reactor operation while other provide Health Physics protection. The radiation instruments provide audible and visual alarms if levels rise abnormally high, and corrective action is then taken.

(a) Fission Break

A rupture of any of the fuel elements or fuel bearing experiments in the reactor could result in serious contamination of the primary coolant system. The fission break monitor is provided to detect such ruptures before any quantity of radioactive material has been released to the coolant system.

The fission break monitor provides facilities for continuously determining the fission product concentration in a sample of primary water. The sample water, after passing through a flow orifice and a flow control valve equipped with control and indicating equipment, is routed through a filter, cation exchange, and anion exchange columns. It is then discharged to the drain. By use of the ion exchange columns, the fission products are separated and iodine-135 is concentrated in the anion column, which is monitored by this system. The system consists of a scintillation detector, power supply, pulse preamp, pulse amplifier, rate amplifier, and recorder.

In this system, pulses from the scintillation detector are transmitted through the preamp to the pulse amplifier, both of which are needed to amplify the pulses to a sufficient amplitude to drive the count rate meter. Both the preamp and the amplifier are similar to the ones used in the restart channels. The count rate meters differ, however, in that the restart channel rate meter has a logarithmic response, and the rate meter in this system has a linear response. It is capable of handling up to 2,000,000 counts/min and can be read directly from the meter on the count rate amplifier or from the recorder in the reactor control room.

The recorder is located on the reactor control panel and receives its signal directly from the count rate amplifier. The scale on the recorder reads from 0 to 50 cps, but may be ranged to read 5, 25, 50, 250, or 500 cps at full scale. Auxiliary switches on the recorder give a control room annunciator at 40 cps.

The entire system, with the exception of the recorder, is located on the console floor.

(b) The Stack Gas and Particulate Monitors

The stack gas and particulate activity system is used to monitor and indicate both particulate and gaseous activity in the reactor and experimental exhaust.

For collecting the particulate matter, a continuous air sampler is used which collects the radioactive matter on a continuous strip of filter paper. The filter is then moved past the detecting head.

After the removal of particulate from the air stream, the sample is routed to a gas chamber. The gas chamber consists of a six-inch diameter by six-inch long cavity within a lead shield. The detecting head is centered in this cavity.

Each system consists of a scintillation detecting head, preamp, amplifier, count rate meter, and recorder. Each system is identical to the one used to monitor primary water fission products. Both systems are located in the cubicle at the base of the exhaust stack with the exception of the recorders, which are on the reactor control panel. Each recorder has an auxiliary switch that operates its respective control room annunciator.

Two trouble alarms are incorporated in the system, one if the air flow through the flow rater is too high or too low, the other for failure of the filter tape drive, or if the paper is torn. These alarms do not actuate a control room annunciator, but merely turn on indicating lights on the front of the instrument.

The signals are recorded separately in the reactor control room. Each recorder is equipped with 0 to 50 cps scale and a contact to alarm at 40 cps. They may be ranged to give a reading 5, 25, 50, 250, and 500 cps, 1 x and 100 x of any of the preceding ranges.

7. Data Reduction System

The data system located in the reactor control room of the ETR is provided primarily for the experimenters. The data system has the ability to handle 300 points or different parameters.. The parameters that can be handled include pressures, flows, type J & K thermocouples, and strain gauge tranducers.

The data systems consist of 15 banks of points with 20 points in each bank. The value of any variable can be indicated on a lighted digital display. This is accomplished by selecting the point and pushing the point select button. The value of the point will be redigitized every three seconds.

At preselected intervals, the digital clock will automatically call for the variables to be printed out on the five typewriters. The values will be in the usual units of measurement. The operator can select how frequently the automatic log cycle will occur. There is a demand log button on front of the data system panel. This will cause variables to be typed out on five typewriters whenever the operator wishes additonal logs.

Associated with each bank of points is an alarm pinboard. On this pinboard, high or low limits are set for the variable. If the variable is on the correct side of its setpoint during a log cycle, it will be printed out on the typewriter in black; if not, in red.

The second major function of the data system is alarm scanning. The operator can set the frequency of scanning. Between log cycles, the system will automatically scan all inputs and compare each to its individual setpoints. Off-normal points will be indicated by a light under its respective number on the annunciator light bank. The off-normal horn will sound when a variable is first found off-normal. The variable will be typed out in red on the off-normal typewriter. If the variable should return to normal, it will be typed out in black on the off-normal typewriter.

Scanning takes place at a rate of 8 points per second. Point selection for digital display and logging cycles takes precedence over scanning cycles.

CHAPTER IV

REACTOR CONTROL CIRCUITS

A. CONTROL PHILOSOPHY

The control circuitry provides a link between the operator, control instrumentation, and the controlling mechanisms. In addition, it assures that the reactor is operated safely during all stages of operation.

Normal operating power of the reactor is a factor of approximately 10^{10} above that of shutdown. It is, therefore, not conceivable that one instrument could possibly operate over the range from start-up to full power. At start-up, only the restart channels provide indication of the rate change in neutron flux; therefore, the circuitry requires that these instruments be in range, and the respective fission chambers must not be moving before control rod withdrawal is permitted. At start-up, the black control rods must be withdrawn to their upper limits before the grey control rods may be withdrawn. This assures that an adequate amount of poison is available to shut down the reactor, if necessary. Withdrawal of control rods is not permitted between start-up and 10^{-5} N_F if the reactor period is less than 30 seconds. At this level, the instrumentation is more reliable, and the reactor is through the crucial start-up stage. The mode of operation changes at this time, high speed withdrawal is permitted, and a minimum period of seven seconds is allowed.

The control circuitry allows power to be raised safely and automatically to N_F from N_L and, in addition, protects the reactor against excessively high power level if the operating level is overshot.

These limitations and requirements, and the circuitry used to accomplish them, are described in detail. Drawings X-ID-700-6-1 through 13 will be referred to throughout the description.

B. POWER REDUCTIONS

Several systems are available to reduce reactor power, each differing in speed and extent. Figures 19 and 20 are plots of the change in neutron flux with time after initiation of the various power reductions. The power reductions, with exception of the jr. scram and electronic scram, may be initiated manually at the reactor console. Also, many of the experiment consoles are provided with means to manually initiate reactor power reductions.

Power reductions are initiated automatically by a variety of mechanisms with the majority of these stemming from the experiment instrumentation. Power reductions are provided to prevent abnormal operating parameters which could endanger the reactor or any auxiliary equipment. The severity of the power reduction varies with the severity of the condition. A check list of the automatic reactor power reductions is shown in Figure 21. These are initiated by contacts within the recorders and associated with transmitters which close at a given setting and energize the respective relay in the safety circuitry. In addition, important operating parameters of the experiments are connected to the reactor safety circuitry and are capable of initiating power reductions automatically. The power reductions are described below in order from the least severe to the ultimate shutdown.

1. Slow Setback

This is an automatic or manual lowering of the MOR setpoint on slow speed. A slow setback will reduce the reactor power from N_F to N_L in 480 seconds; however, the operator will have to make manual control rod adjustment to maintain the regulating rod in range. A slow setback is initiated when relay K71 is energized.

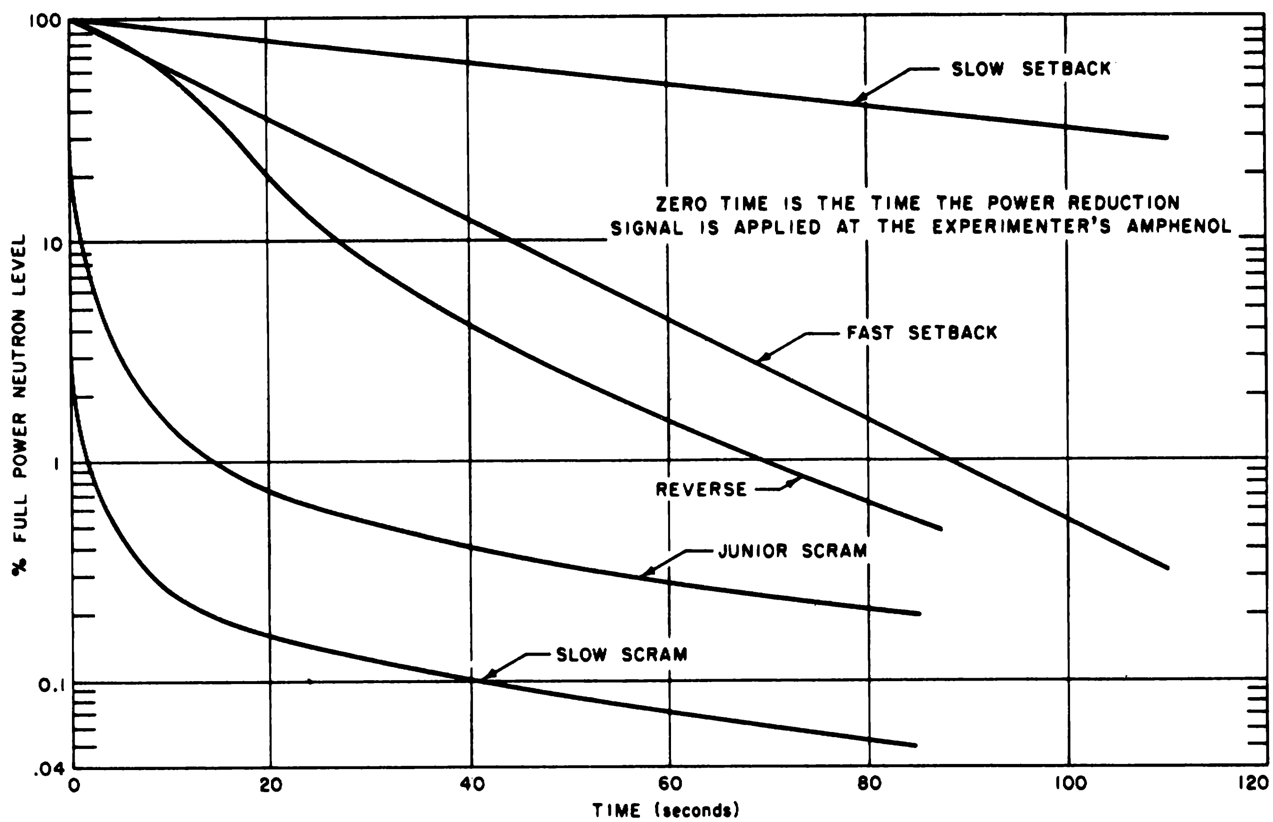

Fig. 19 Approximate neutron flux decay for automatic ETR power reductions.

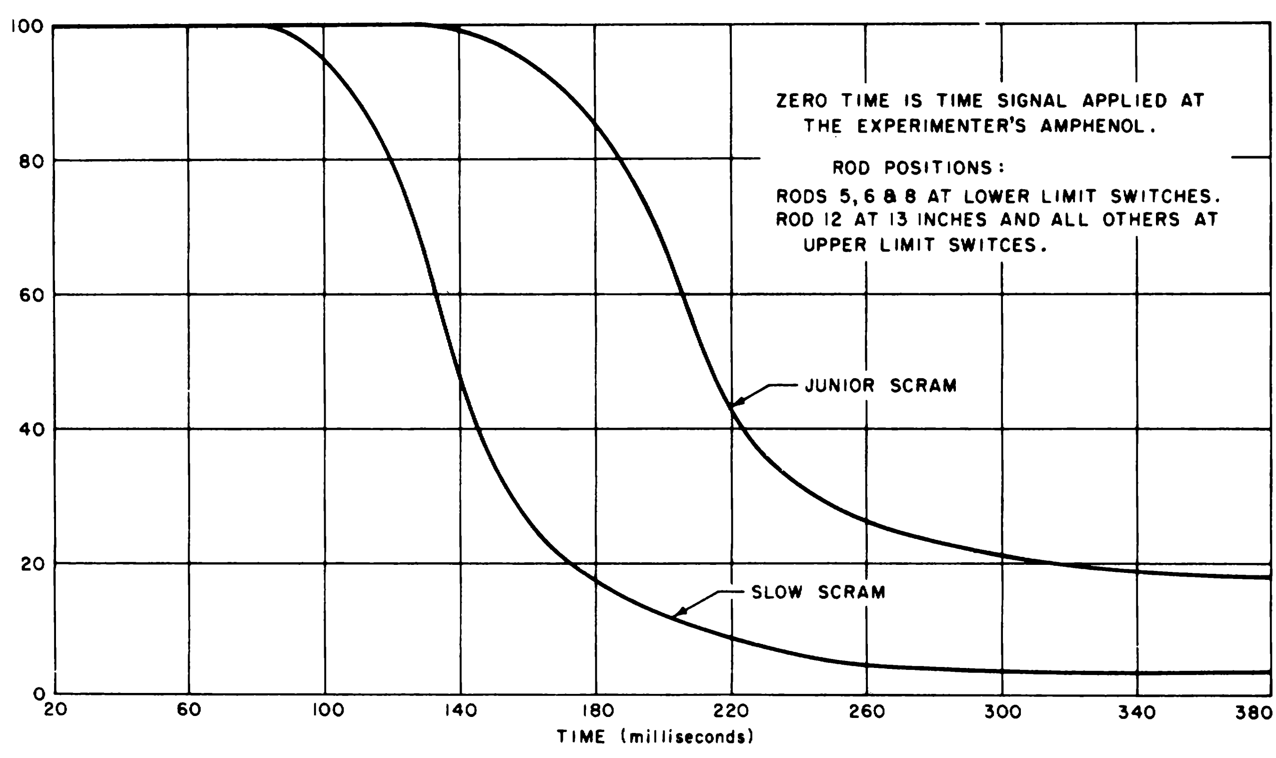

Fig. 20 Approximate neutron flux decay vs time, ETR slow scram and jr. scram.

AUTOMATIC POWER REDUCTION		FAST SCRAM	SLOW SCRAM	JR. SCRAM	RUN-DOWN	FAST SET BACK	SLOW SET BACK
Neutron Level	1.5 N_F	X					
Neutron Level	1.2 N_F		X				
Neutron Level	1.1 N_F				X		
Neutron Level	1.1 N_F						X
Neutron Level Between SAG & 3 N_L			X				
Neutron Level 3 N_L in Start					X		
Period 1 sec.		X					
5 sec. Period in Manual					X		
N^{16} Activity	1.2 N_F				X		
N^{16} Activity	1.1 N_F						X
Reactor Power	1.15 N_F		X				
Reactor Power	1.1 N_F				X		
Reactor Power	1.05 N_F						X
Outlet H_2O Pressure	120 psi		X				
Outlet H_2O Pressure	130 psi				X		
Delta T	1.2 N_F		X				
Delta T	1.15 N_F				X		
Delta T	1.1 N_F						X
H_2O Flow	0.9 N_F		X				
H_2O Flow	0.9 N_F				X		
H_2O Flow	0.95 N_F						X
Under Voltage	95% 4160 V		X				
Under Frequency	-2 cycle		X				
Inlet & Outlet H_2O Temp.	1.2 N_F			X			
Inlet & Outlet H_2O Temp.	1.1 N_F				X		
Flow Delta P - 4 psi, + 5 psi			X				
Low & High Surge Tank	10'' - 20''						X

	CHART DRIVE	PEN SPEED SEC.	BURN OUT	INPUT	
Level	4''-40''	12	DS	PCP	Level - Fast scram signal in case of
Log N	4''-40''	12	US	CIC	high power & records power from 0.1
Period	4''-40''	2	DS	CIC	N_L to 150 % N_F.
N^{16}	4''-40''	2	DS	Ion Chamber	Period & Log N - Monitor pile power
CRM	4''-40''		US	Fiss Chamber	from 10^{-6} N_F to 3 N_F & transmit
					period scram to sigma bus.
					CRM - Startup to power range

Fig. 21 Automatic reactor power reductions.

2. Fast Setback

A fast setback is an automatic or manual lowering of the MOR on fast speed and will reduce the reactor power from N_F to N_L in 90 seconds. A fast setback is initiated when relay K72 is energized.

3. Rundown

A rundown consists of an automatic or manual motor driven insertion of all control rods not at the lower limit. It is initiated when K25 is energized and will return all shim rods to their lower limits, unless the abnormal condition causing the rundown clears, deenergizing K25. It should be noted that on recovery from a rundown, at least three black control rods must again be withdrawn to their upper limits before the grey shim rods can be withdrawn. A rundown will not drive in the grey control rod that is being used as a regulating rod.

4. Jr. Scram

Each control rod is equipped with a test block in the magnetic clutch circuitry and is connected in parallel with a contact from the jr. scram relay K60. The test blocks are used to select any one or more desired shim rods to drop in the event of a jr. scram. The individual test block contacts are closed if the cover is in place and open if the cover is removed. If a jr. scram is initiated, contacts K60-1 through K60-16 will open. This will produce an open circuit to the magnetic clutches of the shim rods which have their test block covers removed and, consequently, cause a jr. scram.

5. Full Scram

A full scram is initiated by the action of relays K171 and K53. These relays are paralleled, but the contacts in the magnetic clutch circuitry are in series, and the energizing of either relay will open contacts in the magnetic clutch circuitry. The ac power to the magnet amplifiers is thus stopped, dropping all 16 control rods.

6. Electronic Scram

An electronic scram may be produced by any one of three level ion chambers or either of two log N chambers and will cause one or more control rods to drop. This scram is sometime called a "fast scram" because it is produced purely by electronic means involving no relays. It is designed to protect the reactor against extremely short reactor periods and high reactor power levels. The electronic scram is accomplished by feeding the output signal of the period and neutron level amplifiers into the magnet amplifiers via the sigma bus. An increase in the sigma bus voltage will produce a proportionate decrease in the current output of the magnet amplifiers. Magnet amplifier outputs are adjusted such that the current will be insufficient to hold a control rod at either a one-second period or 150 percent N_F.

C. CONTROL ROD MOVEMENT

1. Start-up Requirements

Because the control rods provide the main source of control of the reactor, the circuitry involved is quite complicated. A great number of requirements must be satisfied in order to withdraw the control rods and bring the reactor to power. These requirements will be described in a manner similar to actual start-up of the reactor.

If the voltage required for the control circuitry is normal; relays KV1, KV2, and KV3 are energized; contacts KV1-1, KV2-1, and KV3-1 will be closed. This will energize KP1, informing the technician at the console by a green light on the procedure panel that control power is available. Contact KP1-4 closes simultaneously and allows the reactor to be started. The reactor is then started by unlocking the key switch, S-8, pushing the start button, S-9, and, providing that at least one period test block, one restart test block, and one log N test block are in place, relay K2 will energize and close contacts K2-1, K2-2, and K2-3.

When contact K2-1 closes, K82 is energized and the start-up warning horn is sounded. Ten seconds later, T1 energizes, opening T1-1 and closing T1-2. T1-1 drops out K82 which silences the horn. T1-2 picks up KP2 which energizes the "REACTOR ON" lights at the reactor console and throughout the building.

Contact K2-2 seals around the start button and the test blocks initially required.

Contact K2-3 energizes and, providing the motor operated rheostats are at opposite limits and the trip relay, K4, is energized, the control rods may be withdrawn.

Two methods of control rod withdrawal are available at this time, either group intermittent or individual withdrawal of the black rods. In order to withdraw the black control rods on group intermittent, the motor timer, IT, must be running, the withdraw trip permit, K4, must be energized, and the intermittent withdraw switch, S6-4, must be closed.

The motor timer, IT, closes IT-A 1/5 of a second of every five seconds, energizing K5. If the above conditions are satisfied, the black shim rods will be withdrawn to their ULS in approximately 22 minutes. Should the motor timer fail while withdrawing in intermittent and either IT-B or IT-C remain closed, the timer failure protection relay, T2, prevents continuous withdrawal of the shim rods. The relay will energize in two seconds if either IT-B or IT-C remains closed. T2-2 will then open and drop out K5.

A white light is provided on the procedure panel at the console to inform the engineer of the position of the motor timer contacts. K174 picks up when either IT-B or IT-C closes. K174-1 closes, and K174-3 opens which momentarily shuts off the light at the console by dropping out KP3. If IT-B or IT-C remains closed and T2 is energized, T2-1/TDO will open and T2-1/TDC will close in two seconds. This will energize KP3, and the light at the procedure panel will remain on continuously. The engineer is then informed that withdrawal has ceased.

To withdraw shim rods individually on low speed, the low speed withdrawal switch, S2-2, is closed. If the withdraw trip, K4, is energized, the selected rod will withdraw to its ULS.

The withdraw trip, K4, is designed to protect the reactor against short periods and to assure an indication of the neutron count rate from initial start-up to 10^{-5} N_F. Three requirements in this circuitry must be satisfied in order to withdraw the control rods in start. K74-1 (fission chamber not moving) must be closed, as the count rate indication is not valid while the chamber is moving. K61-4 (restart recorders in range) must be closed. If the recorder pen is at either of the extreme ends of the scale, there is no valid indication of the neutron count rate. K64-1 (greater than 30-second period) must be closed. During the interim between start-up and criticality, the restart recorders are the only indication of reactor power, and a period of less than 30 seconds could be dangerous. If the above contacts are closed and the withdrawal switches are in the neutral position, K4 (trip withdrawal permit) will be energized and close K4-1, K4-2, and K4-7. K4-1 and K4-2 permit control rod withdrawal. K4-7 seals around S2-1 and S6-3. If intermittent withdrawal is used, S6-3 and S6-4 will open, but K4 will remain energized and withdrawal is permitted, unless either K74-1, K61-4, or K64-1 opens. If any of the above contacts opens, K4 will drop out, and K4-1 and K4-2 will open. When the condition causing the withdraw trip returns to normal, control rod withdrawal will not be resumed because K4 will remain de-energized. The withdrawal switch being used must be returned to the neutral position and the withdrawal procedure again initiated. This provides automatic protection and insures that the operator knows exactly which step of the procedure he must select. When the reactor reaches "SAG", ie, 10^{-5} N_F, the information from the instruments is more reliable and the above requirements are no longer necessary. K7-2 closes at this point and seals around K74-1, K61-4, and K64-1. Above "SAG", only a period of less than seven seconds will prevent rod withdrawal. When this occurs, K63-1 will open, which drops out the withdrawal portion of the control circuitry. Once the reactor power is above "SAG", K7-3 closes, and continuous withdrawal of more than one shim at a time is permitted. This is known as high speed withdrawal through S6-2. Also, at this point, the run button, S-10, is pushed, and if both fission chambers are at their outer position, K3 is energized. This opens the motor timer circuit and will allow the run auxiliary circuit to be energized if the selected regulating rod is in its operating range.

2. Control Rod Circuitry

In order to withdraw the control rods in start, the preceding requirements must be satisfied and, in addition, relay K9 (withdraw permit) must be energized if servo operation is to be used. This will be discussed under Servo Operation.

The black rods control the greatest part of the reactivity of the reactor; therefore, it is imperative that all four of these rods be withdrawn to their upper limits before the reactor reaches criticality. This will assure, if necessary, a safe shutdown of the reactor. Once the reactor is above "SAG" where the instrumentation is more reliable, only three black rods are required by the circuitry to be at their upper limits.

If the black control rods are fully withdrawn, their respective upper limit relays will be de-energized and contacts K17-7, K27-7, K37-7, and K47-7 will be closed. K50 will then be energized and K50-1 and K50-2 will be closed. This permits the grey control rods to withdraw. If the reactor achieves criticality before the black rods are fully withdrawn, the control circuitry will scram the reactor at "SAG". This is accomplished through K7-8, K50-8, and K54-4. The reactor will also scram if a black rod is dropped during start-up and the reactor power is above "SAG" and below 3 N_L. When the reactor power reaches $3N_L$, K54-1 closes, and K54 is energized. K54-4 opens and the black rod upper limit scram is eliminated. Also, grey rods may be withdrawn if one black control rod is dropped because K170-1 and K170-2 bypass K50-1 and K50-2. If more than one black rod is dropped, grey rod withdrawal is no longer permitted because both K50 and K170 will be de-energized, opening their respective contacts in the grey rod withdrawal circuitry.

3. Individual Control Rod Movement

KW1 through KW16 are the individual control rod withdrawal relays and, when energized, allow the shim rod motors to operate. Several types of withdrawals can be selected, and individual requirements must be satisfied for each method. General requirements are that a control rod cannot be withdraw if it is being inserted, and, in addition, either K50 or K170 must be energized to withdraw grey rods. Withdrawal of control rods is prevented by K25 if a rundown is in progress. Also, KF1-6 through KF16-6 open when a rundown is initiated, preventing control rod withdrawal. In the start regime, control rods may be withdrawn on group intermittent or individually on low speed. The regulating rod selector switch, S4, must either be in manual, which closes S4-23, or if the servo system is to be used, K9 must be energized, which closes K9-1. Additional requirements are that the clutch must be engaged and the individual control rod switch on either normal or preferred. If low speed withdrawal is used, the shim rod to be withdrawn is selected with S3 and the low speed switch, S2, closed. The inching circuit, K51, which places a resistor in each phase of the shim rod motor, must be energized. If intermittent or high speed is used, the selection is made with S6. The respective withdrawal relays are energized by contacts from K5.

If it is necessary to raise the control rod drive only, leaving the control rod in its seat, the "RAISE-SCRAM-COCK-

SCRAM" switch is placed in "RAISE-SCRAM" position which closes S5-1. When S5 is off normal position, the current to the magnets is cut off. Then the control rod switches of the drives to be raised are placed in the "RAISE" position which closes S21-5 through S36-5, and, provided the control rod remains seated, the control rod drive will withdraw to its upper limit.

Relays KF1 through KF16, when energized, supply power to the respective control rod motors for insertion. The individual control rods may be inserted manually by either of two methods. The control rod to be inserted is preferred, and the low switch is placed on "INSERT" which closes S2-5. Providing the inching circuit is energized, the rod will insert until it is seated or the lower limit is reached. One or more control rods may be inserted manually by placing the individual control switches on "INSERT". This method bypasses the inching circuit, and the rod will insert to its lower limit in a shorter period of time. If a scram is initiated, or a clutch magnet fails, the respective clutch relays are de-energized, and the rods fall to their seats. Contact No. 6 from the respective clutch relay closes, and if the rod control switch is in any position but "OFF" or "RAISE", the rod drive will insert until the clutch is reengaged or to its lower limit. On the initiation of a rundown, K25 is energized. K25-1 through K25-16 close and energize the respective insert relays. The control rods then insert until the lower limit is reached or the condition causing the rundown de-energizes K25. The control rod being used as a regulating rod will not insert on a rundown if its selector switch is left in "BLOCK".

D. SERVO OPERATION

The motor operated rheostat circuitry is identical for both servo systems; therefore, the No. 2 system will be described. At start-up, the regulating rod selector switch, S4, is placed on rod No. 2. This act causes No. 2 MOR, through K7-6 and S4-7, to drive to its lower limit. No. 1 MOR, through S4-10 and S4-11, drives to its upper limit. The preceding condition then assures that the reactor will enter automatic control at N_L, and if regulating rods must be switched during operation, No. 1 MOR may be lowered into servo. If the above conditions are established, contacts K21-1 and K22-1 are closed. KP4 is then energized; however, the regulating rod selector switch, S4, must be returned to manual, which bypasses K9 before shim rod withdrawal is permitted.

Before the MOR setpoint can be raised, it is necessary to have the run auxiliary relay, K-8, picked up. To pick up K-8, the run relay must be energized and the reactor must be on greater than a 30-second period. When the servo is selected, run auxiliary is picked up when the regulating rod comes into service.

When the reactor power reaches N_L, the regulating rod inserts to control the power level. The reactor power is then raised by placing the MOR control switch, S7, in either "SLOW" or "FAST RAISE". The "SLOW RAISE" position closes S7-6 and energizes KM7. The "FAST RAISE" position closes S7-4 and energizes KM8. The No. 2 MOR is prevented from being raised, if a slow or fast setback is in progress, by K70-4. Also, these power reductions energize the respective MOR relays, KM2 or KM4, thus further preventing a MOR raise by opening KM4-5.

The MOR setpoint may be lowered manually by placing the MOR control switch, S7, in either "FAST" or "SLOW LOWER". The "SLOW LOWER" position closes S7-2 and energizes KM4. The "FAST LOWER" position closes S7-1 and energizes KM2. The selected MOR cannot be raised until the reactor power is above "SAG". If the reactor power drops below "SAG", the selected MOR will automatically drive to its lower limit by the closing of K7-6. A fast setback closes contact K72-1 and energizes KM2 and opens KM2-5. The fast setback which reduces power more rapidly than a slow setback will therefore override the slow setback.

The two regulating rods using No. 10 and No. 13 control rods and their associated circuitry are very similar. Therefore, the No. 2 regulating rod system using No. 10 control rod will be discussed as typical for both.

When No. 2 servo system is selected, No. 10 control rod is used for servo operation. The circuitry for No. 10 rod allows it to be used as a normal control rod if manual control is exercised or if No. 1 regulating rod is used for servo control. In order to withdraw the control rods, K9 (withdraw permit) must be energized. If No. 2 regulating rod is selected at start-up, K9 will be de-energized because No. 10 rod is not at its upper limit and K107-5 will be open. Therefore, on start-up the selector switch must be positioned in manual to withdraw the initial rods. When No. 10 rod is withdrawn to its upper limit, No. 2 regulating rod is selected, and K9 is energized through S4-5, K42-4, and K107-5. At "SAG", the run button is pushed which energized K3, providing the fission chambers are at their outer limit, and K3-7 closes, bypassing the upper limit No. 2 regulating rod (K107-5) requirement, and K9 remains energized when the reactor enters servo control.

When No. 2 regulating rod is selected, S4-22 closes and energizes KE-2. KE-2 controls the signal to the servo error indicator; however, it will not perform until the reactor power is above "SAG" and No. 10 rod is positioned in "BLOCK", which will energize relay RY4. When No. 10 shim rod control switch is positioned in "BLOCK", this closes S30-6 and energizes K41 through contacts K108-3 and K107-3. K41-1 closes and seals around K107-3. K41 will then remain energized when the reactor enters servo control and K107-3 opens. K41-2 closes when K41 is energized and, in turn, energizes K105. This assures the inching circuit for No. 10 shim rod is energized at all times during servo operation, either through K51-5 or K51-6. K41-3 closes and allows the regulating rod limit switch relays to be energized. This will be discussed later. When the reactor power reaches "SAG", K40 is energized. K40-1 closes and seals around K107-2 so that K40 will remain energized when the reactor enters servo control. K40-3 closes, thus preparing the reactor for servo control by supplying power to RY1-1 and RY2-1. RY1 and RY2 are relays controlled by the position adjusting control amplifier and are energized when an adjustment in power is required. For example, as the reactor power reaches N_L, RY2-1 will close and the regulating rod will insert until the power is level. If the reactor power decreases, RY1-1 closes and the regulating rod withdraws until the power is reestablished.

Both regulating rods control a large amount of reactivity, and continued withdrawal would cause a short period. Therefore, when a 30-second period is reached, K64-6 opens and stops withdrawal until the period is greater than 30 seconds. If further adjustment is needed, the regulating rod will again withdraw.

The regulating rod is equipped with limit switches on the drive mechanism. These switches perform functions which extend the automatic control and are closed as the regulating rod inserts. LS42 closes when the regulating rod inserts past 29 inches. K42 is energized and opens K42-4 which de-energizes K9. Withdrawal of control rods, which could cause the regulating rod to insert further, is then not permitted until the regulating rod is above 29 inches. LS43 closes at 26 inches and through the action of K43 and K24, inserts the preferred control rod. This will decrease the reactor power, and the regulating rod will withdraw. When the regulating rod is above 29 inches, K42-6 opens, and the preferred insertion ceases. LS44 closes when the regulating rod inserts past 25 inches and K44 is energized and closes K44-4 which energizes K25. This action initiates a rundown, and it will persist until the regulating rod is driven out past the 29 inch limit which opens LS42, and, in turn, K42-6 opens.

K25 is then de-energized and the rundown ceases. LS45 will close when the regulating rod inserts past 24 inches. The reactor is then out of servo control because K45 is energized and K45-4 is open. It should be noted that since the regulating rod is below 25 inches, K25 is energized. To stop the rundown, the regulating rod selector must be placed in manual which will de-energize K41 and K41-3 will open. K44 is then de-energized and K25 is, in turn, de-energized.

The reactor is then returned to servo control by positioning No. 10 rod control switch in "NORMAL" or "PREFERRED", and withdrawing the rod to the upper limit. The control switch is then placed in "BLOCK", and No. 2 regulating rod is selected. The MOR may now be lowered until the regulating rod is in range, and normal servo operation then proceeds.

In the event of a scram during operation, it may be necessary to return to power rapidly, and high speed withdrawal may be used if the reactor power does not drop below "SAG". If No. 10 rod control switch is left in "BLOCK", it will withdraw with the black shim rods through S30-8, K41-6, and K40-6. The reactor can then be returned to power, using servo control, in minimum time. If the control switch on No. 10 rod is placed in "NORMAL" or "PREFERRED", No. 10 control rod must be withdrawn through S30-1, after the black shim rods have been withdrawn.

If a reactor rundown is received during operation, K40-2 will prevent No. 10 control rod from being driven in when No. 2 servo is being used.

CHAPTER V

REACTOR CONSOLE MANIPULATION

A. PRIOR TO START-UP

Before the reactor is started up for normal operation, all auxiliary systems and experimental loops must be operating at normal conditions. A start-up check list is provided to assure that the conditions necessary for start-up have been completed. A start-up preparation for the reactor then proceeds. The fission chambers are withdrawn slightly and the restarts watched for a count rate drop to assure these systems are operating properly. The fission chambers are then returned to their original positions.

Both the black and the grey rods are given a full scram and an electronic scram from approximately two inches. This assures that the rods are operating properly and all rods are capable of releasing in the event of a scram.

Additional requirements are that all instrumentation be operating properly and that the required test blocks are in place. The experimental "W" switches must be closed to assure their safety circuits are interlocked to the safety circuitry of the reactor. The MOR to be used for servo operation must be at N_L, the other at N_F. When the check list is completed, all interested persons are notified and a final check is made to assure that all equipment is operating properly. The reactor is then prepared for start-up.

B. START-UP

When the necessary requirements for starting the reactor have been fulfilled, the "Key" switch is turned on and the start button is pushed. After the 10-second start-up warning horn stops, the withdrawal of the black control rods can proceed. These rods, while in the "START" regime, may be withdrawn individually on low speed or may be withdrawn as a group on intermittent speed.

The reactor engineer must constantly watch the restart channels for a visual indication of the rate of change of neutron flux. When the black controls rods are at their upper limits, withdrawal of the grey rods on low speed in a predetermined order proceeds. The count rate is watched closely, and when the recorder pen continues to increase after withdrawal has stopped, the reactor is considered critical. At this time, the restart channels will be three to four decades above the starting level, and the log N and period recorders will start to show a power increase. Extreme caution must be exercised during the preceding step because the instrumentation is not too reliable, and rapid withdrawal could cause a short reactor period. When the log N and period recorders begin to indicate, the withdrawal permit will be lost when a period of 30 seconds or less is attained. When the log N recorders reach 10^{-5} N_F, the run button is pushed, the motor timer stops, and intermittent withdrawal is lost. The control rods may now be withdrawn on either high or low speed with minimum periods of seven seconds. It should be emphasized that during normal start-up, the seven-second period limit should not be used as a basis for safe operation.

The control switch for the control rod to be used as a regulating rod should be turned to "BLOCK", and the servo system for that rod should be selected when the control rod reaches its upper limit switch.

When the reactor power has reached approximately 10^{-3} N_F, the neutron safety level will begin to record and should be observed along with the log N and period recorders.

The levels begin indicating at this power level to give the engineers additional information of the condition of the reactor and to introduce an added safety factor during start-up. When the log N recorders reach 3 N_L, the levels will indicate 30 N_L. At this power level, a series resistor is dropped out of the level input signal, and the neutron level recorders shift down scale a factor of ten to record actual power.

C. POWER OPERATION

1. Servo Control

Considerable operating experience is required to change power in servo operation and, in some instances, to maintain servo operation. Normally, as the reactor power nears N_L, the servo error meter will begin to move in the positive direction, and when the signal is large enough, the regulating rod will be driven in to level the reactor power. The regulating rod preamplifier is adjusted so that the regulating rod will begin to control the reactor between N_L and 3 N_L with the MOR at N_L.

Once the regulating rod is in range, power will be raised in steps, the level and frequency being determined by the shift supervisor. Raising the MOR will cause the regulating rod to withdraw, thus raising the reactor power. The reactor engineer must then manually withdraw the selected control rod, which will cause the regulating rod to insert. The MOR may then be raised again. The final power in each step is determined by the water power recorder. However, due to a significant time lag in the power calculator system, the desired power is calculated from the neutron safety levels, and this value is approached with care. The system is then allowed to stabilize, and minor adjustments in power, if necessary, are made with the vernier.

When the reactor power is above N_L, the N^{16} and ΔT recorders also become useful, and their signals are used as an additional measure of power.

2. Manual Control

If manual control is to be exercised in power operation, the undivided attention of the reactor engineer operating the reactor is required. In this case, power is raised simply by withdrawing the selected control rod until the desired period is reached. The reactor power will then continue to rise until the control rod is inserted to level the power. When operating at a particular power, constant adjustment of the control rod is necessary because the power will tend to drift. Any change in the inlet temperature of the primary coolant will upset the power, and xenon poisoning will further this deviation. Power must be returned to the desired level by careful adjustment of the control rod.

D. OPERATION WITH POWER REDUCTIONS

The actions taken following a power reduction vary with the type of reduction received. Generally, power will be recovered as quickly as possible, but recovery will be governed by the condition causing the power reduction, and in no case will the reactor be returned to power with an unsafe operating parameter.

The reactor power should not be raised after a power reduction or during normal start-up without the Shift Supervisor, Shift Foreman, or Senior Reactor Engineer present in the control room.

An abnormal condition causing a power reduction may or may not clear immediately. Corrective action should be taken as soon as possible so that power may be reestablished. When the power reduction clears, a check is made, not only with the person in charge of the equipment which caused the reduction, but also with all other persons operating auxiliary or experimental equipment, to assure that all equipment is ready for the reactor to return to power.

The methods used to recover power, following a reduction, are described in order from the least to the most severe.

1. Slow Setback

A slow setback lowers the MOR, thus causing the regulating rod to insert. The engineer must manually insert the preferred control rod at a rate necessary to maintain the regulating rod in range. When the slow setback clears, the reactor will then be ready to return to power in servo operation. If the slow setback does not clear, the reactor power will be reduced to N_L in 480 seconds, and corrective action must be taken to clear the condition before the power may again be raised. If the reactor is operating in manual control with the power above 3 N_L and a slow setback is initiated, it will be converted to a rundown. The rundown will continue until the condition clears, or 3 N_L is reached.

2. Fast Setback

The action a fast setback produces is identical to that of a slow setback but the MOR will be lowered from N_F to N_L in 90 seconds as compared to 480 seconds for a slow setback. To control a fast setback the engineer may have to manually insert more than one control rod to maintain the regulating rod in range. A fast setback also is converted to a rundown above 3 N_L in manual control.

3. Rundown

A rundown will insert all control rods except the selected regulating rods until the condition is corrected and cleared, or until all control rods are at their lower limits. The method used to recover power is dependent upon the duration of the rundown. A rundown lasting more than 70 seconds will reduce the power to N_L. The MOR should then be lowered to approximately 50 percent of the value before the rundown is initiated. This action will prevent the reactor from returning to servo operation at N_F. If the MOR was not lowered, the power when returned would probably be excessive due to lag in the system and the flux shift in the core. It should be noted that in the event a rundown occurs, the regulating rod will withdraw to maintain the reactor power, but its effect compared to 15 other control rods inserting will be small. The regulating rod will continue to withdraw until it is cocked, and is then prepared for return to servo operation. Once the rundown clears, the black rods may be withdrawn on high speed. The grey rods, which were at their ULS before the rundown occurred, may be withdrawn on high speed, and additional control rods needed to recover power are withdrawn individually. The period recorders should be watched until the power is above N_L, and then attention is divided between the period, neutron levels, and other instrumentation. If the rundown reduces the power severely, xenon poisoning will affect the recovery of power. This will be discussed under full scram recovery. If the rundown reduces the power only slightly, the MOR should be lowered a proportional amount and the power recovered as described above.

4. Jr. Scram

The jr. scram is designed to reduce the reactor power quickly, but allow it to be returned promptly. A jr. scram will release two previously selected control rods, one black and one grey. After an initial jr. scram occurs, the engineer must lower the MOR approximately 50 percent, and if the jr. scram has cleared, additional grey rods may then be withdrawn to recover power. Before bringing the reactor to any power after a jr. scram, two additional black control rods should be selected for jr. scram. The reactor is thus protected should a second jr. scram occur before the control rods selected for the first jr. scram can be returned to their upper limit. When power has been reestablished to the point that xenon is overriden, and the reactor is again in servo control, it is necessary to return the jr. scram control rods to their upper limits by inserting the additional grey rods used to recover power. The additional control rods selected for the second jr.

scram protection may then be returned to normal.

If the jr. scram does not clear immediately, the two drive mechanisms will return to their lower limits and reengage their respective clutches. These rods will be withdrawn first, and additional grey rods withdrawn as needed.

5. Electronic Scram

An electronic or fast scram will release one or more control rods. The number dropped is dependent upon the rate the reactor power is increasing and the current setting for the individual control rod magnets. If both black and grey control rods are dropped, the black rods are withdrawn first on high speed, and then additional grey rods are withdrawn as needed. The MOR should again be lowered before withdrawal proceeds.

6. Full Scram

A full or relay scram releases all 16 control rods, including the control rod being used as a regulating rod. If the reactor has operated at full power long enough for poison equilibrium conditions to be reached, it is necessary to reestablish power as quickly as possible so the xenon-135 is overriden. If all control rods are withdrawn to their upper limits and xenon override power level has not been reached, then the reactor must be refueled or xenon-135 allowed to decay. In the event a full scram occurs, the MOR is lowered, and the control switch for the regulating rod is left in "BLOCK" position. It will then be withdrawn with the black control rods on high speed. This prepares the reactor for servo operation, and additional time is not consumed by withdrawing the black control rods and then the servo control rod. The xenon concentration will begin increasing when the scram occurs; it is therefore necessary to withdraw additional grey control rods to bring the reactor critical and recover power. When the reactor power is above N_L, the neutron levels and periods must be watched closely. As the power increases to the level that xenon is overriden, the additional control rods required to recover must be inserted as the xenon-135 is consumed. The power level will be maintained in servo control at a level where xenon is consumed until the control rods are essentially returned to their original positions. The reactor power will then be returned in steps to N_F, and normal operation will be resumed.

E. OPERATION UNDER ABNORMAL CONDITIONS

Under any abnormal condition, the reactor operator must quickly decide for himself what action he must take to prevent damage to the reactor and yet avoid unnecessary shutdown time. The following section covers a few of the possible situations with recommended procedures for each.

1. Annunciators

The annunciators tell the operator of most abnormal conditions that can occur. For this section, the annunciators can be arranged in three groups: one, those announcing automatic power reductions; two, those that require immediate attention to prevent a power reduction; and three, those announcing situations requiring correction, but not immediately affecting reactor operation.

The first group is self-explanatory. The actions required from the operator by signals from one of these are to analyze the cause, to correct the trouble, and to return the reactor to its proper operation level as soon as possible. Annunciators in this group will usually be accompanied by or preceded by annunciators from the second group.

The second group would include water inlet temperature and water outlet temperature. An annunciator from either of these should be accompanied by an increase in the reading of the other and would indicate a need for more cooling of the process water. If this cannot be obtained, reactor power must be lowered. Annunciators from water power, water flow, or differential temperature are self-explanatory and will require immediate correction to prevent an automatic power reduction. A rod holding magnet current High or Low annunciator should be brought to the attention of the responsible person immediately as it may indicate an impending rod drop. Experiment annunciators may be included here, as they may be announcing conditions at the experiment which, if not immediately corrected, would result in a reactor power reduction.

Annunciators in the third group tell of conditions that should be investigated as soon as possible, or called to the attention of responsible personnel, but that cannot immediately affect reactor operation. Included in this group are all monitron and CAM annunciators, instrument trouble, gland seal leaks, and control rod seal leaks.

2. Sticking of Control Rods

Sticking of a regulating rod would be shown by a drift in power that the regulating rod did not compensate for, also, by a servo demand annunciator and indication on the console meter. This could be checked by selecting and preferring the same rod; then inserting and withdrawing this shim rod should cause the regulating rod to withdraw and insert to compensate for shim rod movement. The operator should switch to the other servo system if the rod cannot be freed easily. Repair may then be made at the next shutdown. Sticking of a control rod will be shown when the operator tries to move it. A stuck shim rod may be assumed if the rod withdrawal indicating light comes on when attempting to withdraw a rod, but no reaction is observed on the regulating rod relays (the regulating rod should insert to compensate for shim rod withdrawal), no power increase is observed on any reactor power monitoring instruments, and the shim rod position indicator does not move. If a shim rod is sticking and cannot be freed, and if it is not near its upper limit switch, the reactor will probably have to be shut down while the trouble is being repaired because the stuck rod will produce a shading effect as the other rods are withdrawn.

3. Dropping of a Control Rod

A control rod may drop due to failure of a magnet amplifier, action of a sigma amplifier, a failing magnet, or a malfunction of the shim rod holding mechanism (balls not properly reset). The regulating rod will cock and power will drop rapidly. On the failure of a rod magnet, additional grey rods may be withdrawn to recover power. An attempt will be made to repair the magnet while normal operation proceeds. If the magnet is not readily repairable, a mechanical latching mechanism may be used on one rod under certain conditions. If a mechanical latch is used, the control rod will not release in subsequent scrams.

4. Instrument Failure

Any instrument that fails or shows erratic operation should be removed from the control circuit by pulling its corresponding test block after it is certain the instrument is giving false readings. It can then be repaired without affecting reactor operation.

NOTE

Removal of both log N test blocks will give the MOR a fast lower and also will produce an electronic scram, if the reactor is at power, from a 3 N_L shift on the neutron levels. Removal of the main flow and the ΔT test blocks at the same time will result in a full scram.

Any instrument not equipped with a test block cannot materially affect the operation of the reactor and may be ignored until it is repaired. In any case, the instrument should be repaired as soon as possible.

F. SHUTDOWN

Normal shutdowns are scheduled by the Operations Branch for reactor refueling, system maintenance, and experiment removal or insertion. In addition to the required shutdown work, preventive maintenance is performed, and the various safety circuits are checked to assure that they will respond at the proper abnormal condition.

Unscheduled shutdowns may be required due to a number of reasons. The reactor may require refueling, either from inability to recover from a power reduction, or because all excess fuel may have been consumed. Experiments or auxiliary equipment may develop trouble that requires shutdown for repair. In any event, shutdowns will be completed as expeditiously as possible and the reactor will be returned to power.

G. LOW POWER OPERATION

Short term, low power operation is used frequently. These runs are generally made to aid in the determination of the flux pattern in the reactor core, but runs may be made for calibration or other purposes.

In flux determinations, a number of wires or strips of a specified material are placed at different locations in the reactor core. A short term, low power run is then made, and the activated flux wires are removed and counted. The flux, at any position in the core, can be determined and extrapolated for the full power value.

Normal primary system operating pressure and flow conditions are not necessary for this type of operation. Therefore, it is not required that the top dome be placed on the reactor, and it is usually left off for convenience. Under these conditions, the primary flow is set at 2000 gpm, which is supplied by an emergency pump. If the flow from this emergency pump should drop below 1800 gpm, the reactor will be scrammed. Since normal flow and pressure are not available, the control rod drop time is longer than during operating conditions. Also, the current required to keep the magnet engaged is less than that required during normal operating conditions. To insure a minimum drop time during shutdown conditions, the magnet current is reset to a maximum of 60 milliamps, as compared to 125 milliamps maximum for normal conditions.

The reactor safety circuitry from experimental and auxiliary equipment, excluding the 1800 gpm emergency flow scram, is not energized until the reactor reaches 3 N_L on the log N recorders. However, though the experiments do not have to be at operating conditions for low power runs, they should have loop flow and other conditions specified by the Project Engineer.

CHAPTER VI

REACTOR TANK OPERATIONS

A. DESCRIPTION OF REACTOR COMPONENTS

1. Control Rods

The sixteen ETR control rods are made up of four components; the guide tube, poison section, fuel section, and shock section. These are arranged with the fuel section latched between the shock section and the poison section inside the guide tube.

(a) Guide Tube

The guide tube is an aluminum alloy drawn tube three inches square and approximately 15 feet long, which surrounds the moving portions of the control rod. The guide tube is supported by the bottom head, the support plate, the grid plate, and the guide tube support arms. It is provided with slots above and below the core for cooling water flow.

(b) Poison Sections

The poison sections are constructed of plates 7/32 inch thick and arranged to form a 2-1/2-inch square approximately 42 inches long. It is provided with four rollers at the top and four rollers at the bottom to allow free movement within the guide tube. The poison sections are latched to the top of the fuel sections by a spring latch. Latching is accomplished by snapping the spring latch into the machined cutouts in the fuel section. The poison sections are inserted and removed by the use of the spring latch control rod handling tool. The tool has a square cross section and toggle link actuated lifting lugs. There are four black poison rods and twelve grey poison rods used in the ETR. The plates of the black sections are made of 347 stainless steel sprayed with cadmium, which is in turn sprayed with 302 or 316 stainless steel for the final covering. The grey material is type "A" nickel low in cobalt.

(c) Fuel Section

The fuel section of the control rod is similar to the standard fuel element. However, it has only 16 reduced width fuel plates instead of 19. With the same plate loading concentration, these elements contain about 46 percent as much fuel as the standard fuel elements.

The fuel section has rectangular cutouts machined in the top and bottom of the section which receive the spring latches of the poison and shock sections. The spring latch control rod handling tool is used to remove the fuel sections.

(d) Shock Section

The shock section is the lowest part of the moving control rod assembly. It consists of a 2-1/2-inch square aluminum tube attached to a stainless steel shock tube. Two spring latches are attached to the upper end of the square tube for latching to the fuel section. The control rod drive engages inside the shock tube and serves to position the control rod. The shock section is provided with rollers to keep it free in the guide tube.

(e) Control Rod Drive

The 16 ETR control rods are actuated from beneath by individual control rod drives. These mechanically-driven devices are situated in the control rod access room, and their actuating elements penetrate the bottom head of the reactor pressure vessel.

The drive consists of a motor, gear train, rotating nut, lead screw, magnet release, and a drive tube. The magnet release and drive tube are coupled to the lead screw and move with the lead screw. A ball-type coupling attaches the control rod shock section to the drive tube. The coupling is actuated with a magnet and is latched to the control rod when the magnet is energized. A scram or dropping of the control rods is accomplished by removing the magnet power which allows the control rod shock section to fall down over the drive tube. There is a shock absorber at the top of the control rod drive that is attached to the bottom head. This serves to cushion the fall of the control rod during a scram.

2. Fuel Elements

The fuel elements for the ETR are flat plate, MTR-type assemblies. Each element contains nineteen 0.050 inch thick, 2.774 inch wide, 37 inch long fuel plates. They are positioned into sideplates and fitted with a lifting bail and an end box to form a fuel element 3 inches square and about 54 inches long.

3. Core Filler Piece

The core filler piece is a solid aluminum piece with the same dimensions as a fuel element. It has twenty-eight 1/4-inch cooling holes running vertically in the piece. It is used for filling spaces not containing experiments or fuel elements in the reactor core.

4. Aluminum Reflector and 4-X Pieces

The aluminum reflector pieces surround the beryllium reflector. These are 3 inches square by 37.5 inches long with a 1.553-inch diameter hole drilled lengthwise through its center. This hole is used to contain experiments. It may be filled with a solid aluminum plug when not in use. The 4-X experimental piece has approximately the dimensions of the aluminum reflector piece. It has four 1.312-inch holes for experiment insertion. There are two types of 4-X pieces, one for use in the core and one for use in the reflector. The main difference in these pieces is the spacing pads at the top of the piece. The core piece provides more space for cooling water flow. The core 4-X pieces are designated by C-4X and the reflector pieces by R-4X.

These pieces have lifting pins attached to the top of the piece to facilitate moving them.

5. Baskets, Liners, and Flow Restrictors

To facilitate the handling of experimental capsules and slugs, aluminum baskets are provided. These are generally constructed of aluminum tubing and are about 37 inches long. They are fitted with a slightly larger diameter top with two holes for handling the baskets with a tool. There is an aluminum spider in the bottom of the basket to hold the slugs and to allow coolant to flow out the bottom.

The X-basket, which is the most commonly used, has an outside diameter of 1.29 inches and is used for capsules with a maximum diameter of 1.125 inches.

The B-basket, which is used in the beryllium, has an outside diameter of 1.20 inches and is used for capsules with a maximum diameter of 1.0 inch.

The SB-basket is used for smaller slugs with a diameter up to 0.625 inch. It has an outside diameter of 0.875 inch and is provided with four spacing rings with a diameter of 1.20 inches.

The diameter of the hole in the aluminum reflector piece is 1.55 inches so a liner is needed for use with an X-basket. The liner is about 40 inches long with a 1.5-inch outside diameter and a 1.33-inch inside diameter. It has a cross pin near the bottom to space the X-basket properly.

When an experimental hole is not in use, it is necessary to insert a flow restrictor to prevent excessive loss of cooling water. A solid aluminum flow restrictor approximately the size of an

X-basket is used to replace the X-basket, and there is a solid aluminum plug for the aluminum reflector pieces. Also, short pieces of aluminum rod and flow restrictor cans are used in the baskets as flow restrictors.

B. SAFETY IN-TANK OPERATIONS

1. Bottom Head Penetration Work

During penetration work on the bottom head for insertion and removal of experimental tubes and shim rod and regulating rod drives, extreme care should be used to prevent loss of reactor water. Whenever bottom head penetrations work is being done, the discharge chute cover should be off to provide an additional reservoir of water. In the event a major leak should occur in the bottom head, immediate steps should be taken to keep water over the reactor core. This can be done by adding demineralized water into the primary system, or fire water with a fire hose, or through the emergency fire line into the primary water system.

2. Movement of Radioactive Materials

When radioactive materials are being transferred to the canal, moved within the reactor, or removed from the reactor in any way, there should be constant Health Physics monitoring. Care should be taken while discharging fuel elements to the canal that they are lifted only high enough to clear the discharge chute. When a job is to be done that could result in exposure to personnel, it should be thoroughly planned and monitored.

3. Reactivity Consideration

Whenever any work is done in the reactor that could cause an increase in reactivity, the count rate meter should be diligently observed. There is a slave count rate meter for use at the reactor top. This should be on and the alarm setpoint set or the count rate meters in the control room watched. Shim rods should be refueled before the rest of the core. Only one rod should be changed out at a time.

4. Entry into the Reactor Tank

Whenever it is necessary for a man to enter the reactor tank to do shutdown work there must be an HP present at all times. The man will be required to wear protective equipment such an anti-C clothing, respirator, boots, etc. It is required that a safety line be attached securely to the man.

5. Operations Surveillance of Work in the Reactor

Any work done in or over the reactor tank must be with attendance of responsible operations personnel designated by the Shift Supervisor. This is to insure that safety precautions are used so no damage is done to the reactor or other equipment and that the workers obey safety and HP rules. Care should be taken to see that nothing is dropped into the reactor tank or that articles dropped are retrieved.

C. PREPARING THE REACTOR FOR SHUTDOWN WORK

1. Flush

When the reactor is shut down, it is necessary to flush the system with clean demineralized water to reduce the radioactivity and contamination of the water in the tank. The reactor is usually flushed for one hour at a rate of 1000 gpm for a total flush of 60,000 gal.

2. Remove Shielding

It is necessary to remove the concrete shielding rings from the reactor to gain access to the reactor top dome. This is done with the ETR 30-ton crane.

3. Lower Tank Water Level

The water in the reactor vessel must be lowered below the top vessel flange before the top dome is removed. A four-inch upper drain line is provided for this purpose. A plug valve in this line is operated by an extension handle at the NW corner of the reactor shielding. While lowering the tank level, it is necessary to vent air into the reactor from a vent valve on the top head. The level of the reactor building warm sump tank should be watched so it does not overflow.

4. Remove Top Dome

To remove the reactor top head, it is necessary to unbolt it from the reactor tank. If there is experimental piping penetrating the top dome, it should be stripped and the gland seal packings in the top dome should be loosened. The 30-ton crane is then centered over the reactor and the dome slowly lifted. Care should be taken to see that the experimental piping is not damaged by the cables or top dome. An HP should be present when the top is removed to check for air activity and radiation.

After the top dome is removed, it is necessary to remove and store the rubber "O" ring that seals the top flange. The working platform is then placed over the reactor.

5. Guide Tube Support Arms

The guide tube support arms must be lifted up to gain access to the reactor core. The four short north and south arms are released from the long arms by unscrewing the locking studs with the long wrench tool. They are then tilted up to a near vertical position, generally with a hook tool, and latched to the inner tank wall by lifting the latch dogs and dropping them into holes in the arms. The long support arms are released by pulling on a latch ring on the west end of the arms with a hook tool. They are then lifted up and latched similarly to the short arms.

6. Discharge Chute Cover

Before removing the discharge chute cover, it is necessary to have the water level in the reactor tank and the canal equal. When the reactor tank level is at the upper drain and the canal level at the overflow height, the levels will be correct. The discharge chute hold-down lugs are then loosened with the same wrench tool used for the guide tube support arms. The cover is then removed from the reactor to storage with the 2-ton crane, using a large hook tool.

D. TOOLS USED IN TANK WORK

1. Description of Tools Generally Used

The tools used are generally of two groups: the fixed tools, and tools with interchangeable heads and handles. Tools vary in strength, length, weight, and size for different job requirements.

The finger tool is used for picking up small objects. They are made in various lengths from 3 feet or 4 feet up to 20 feet or longer. It consists of a tubular rod with a plunger running the full length of the tool. By inserting the plunger, two fingers at the bottom of the tool open. By releasing the plunger, the fingers will close on an object.

The Vorhies tool is a positive locking hook tool used for handling experiments with a hole or eye for lifting. The tool is closed by operating a plunger from the top of the tool.

The inventory tool is a pipe with a calibrated plunger inside. By lowering the plunger into a hole in the core, a depth measurement can be made.

The most versatile tools used consist of handles of various lengths with screw-on-type heads.

The crows foot head consists of two horizontal fingers with a separation between them. It is designed to slip under a ball-type lifting pin on the aluminum reflector pieces and the 4-X pieces.

The C-hook or fuel element tool is designed in the shape of a "C" and has various sizes, both in width of mouth and length.

The hook tool head is a stainless steel rod bent into a hook. It is useful in many tank operations.

2. Description of Kaiser Tools and Others

Originally, Kaiser Engineers designed a complete set of tools for all operations in the reactor tank. However, many of these have given way to lighter and more adaptable tools. Several of the Kaiser tools have interchangeable units so one handle may be used for different purposes. These tools are still used on special jobs.

Another tool that finds use in tank operations is the wrench tool, which consists of a heavy tube with a special socket at the end. It is used to unlatch the guide tube support arms and the discharge chute cover. A large shepherd-type hook is used with the 2-ton crane for removal of the discharge chute cover.

E. TANK OPERATION

1. Record Keeping

Whenever any reactor component or experiment is moved within the reactor or transferred from the reactor, accurate records must be kept. Generally, a shutdown schedule or a transfer sheet is used for record keeping. If the pieces are stored in the tank temporarily and there is no schedule to indicate their position, an accurate location map should be made and marked.

When transferring components between the reactor and the canal, they should be identified in both places. If an experiment or a fuel element is placed in the wrong position, considerable damage could result.

2. Control Rod Change-Out

(a) Removal of Control Rod Assembly

To remove the control rod, it is necessary to raise the control rod drive on "RAISE-SCRAM" a few inches to release the coupling balls from the shock tube.

To remove the control rod poison section, the spring latch control rod handling tool is used. The tool is lowered into the top of the guide tube until the square cross section of the tool matches up with the upper adapter of the poison section.

The tool must be oriented so that the toggle link actuated lugs on the tool are in an east-west position. The lugs must be retracted manually until the tool is in the proper position. The plunger is then released and the lugs, which are spring loaded, will engage the rectangular cutouts in the poison section. The poison section is unlatched from the fuel section simply by raising the entire control rod assembly until the poison section is above the top of the guide tube and rotating the handling tool clockwise. This rotates the latch springs of the poison section into the corners of the fuel section and allows the fuel section and the shock section to fall back into the guide tube.

The control fuel section is removed in the same manner as the poison section. The latch springs of the shock section are positioned in the corners of the fuel section, allowing the shock section to fall back into the guide tube.

The shock section is removed from the guide tube using a shock removal tool.

The guide tube may be removed by lifting it with hook tools or with the Kaiser guide tube tool. Lift clear of the beryllium slab, move close to the discharge chute, then raise and lower through the chute to the canal. The discharge unloader and the canal pit grates must be removed before discharging. It is necessary to have radiation monitoring when any of the control rod sections or the guide tubes are moved.

The guide tube is replaced using the same tools. It is lowered into position until it is seated on the bottom head.

To replace the shock section, it is again necessary to raise the control rod drive a few inches. The shock section can then be lowered into position with a hook tool. The shock section must be oriented with its spring latches in the east-west direction.

To insert the control rod fuel element, the spring latch control rod handling tool is used. The fuel section is attached to the tool and then lowered into position. The fuel plates should be oriented in the east-west direction. The spring latch control rod handling tool should always be used since it may be necessary to push downward on the fuel section to effect the latching action. The use of the tool will protect the fuel from physical damage that could result from the use of an improper tool. The lugs on the tool are then retracted and the tool removed.

The poison section is inserted with the spring latches in the east-west direction. The spring latch control rod handling tool also is used in this operation to prevent damage to the poison section spring latches that could result from dropping. The two center plates visible on the top of the poison sections will line up with the fuel plates on the grey rods only. The bars visible on the top of the black poison section will be running in the north-south direction with the spring latches on the east and west sides. (See Figure 7 ETR Control Rod Assembly, page 29).

The latching of the rod should then be checked by running the control rod down to its lower limit. This resets the balls, and couples the drive to the shock section. If the rod is properly latched it cannot be lifted with a tool.

(b) Removal of Control Rod Drive

In order to perform maintenance work on a control rod drive, it must be removed from the bottom head and, generally, from the rod access room.

As a preliminary step in the removal of a control rod drive, the control rod and the guide tube must be removed. After removal of the control rod, the drive should be lowered to its lower limit so nothing protrudes above the bottom head. The hole in the bottom head above the rod drive is then plugged, using the Kaiser M-889 plugging tool. The head of the tool must be tilted vertically and made to penetrate the grid plate and the support plate diagonally through the guide tube holes. The head of the tool is then set in plugging position and plugged in the bottom head with a twisting motion.

The electrical breakers to the rod drive to be removed and to any adjacent drives must be opened and tagged. The electrical connections to the rod drive are then removed, the motor uncoupled, and the seat switch removed. The shock section of the drive is then unbolted from the bottom head and the drive removed carefully, checking for excessive water leakage. After the rod drive has been replaced, the plugging tool is removed by tilting the head vertically and going through the guide tube penetrations diagonally. The tool should be lifted with the rope tackle rather than the crane to prevent tool or core damage.

3. Fuel Element and Filler Piece Changes

A C-hook tool is used to transfer the fuel elements and the filler pieces. These are latched onto the lifting bail and the piece may be lifted and moved to the discharge chute. Care must be taken so the fuel element is not raised any higher than necessary because of radiation. The fuel element plates are oriented east and west while in the core. The core filler piece bail must be placed east and west in the core.

4. Reflector and Experimental Piece Changes

The aluminum reflector and experimental pieces are provided with a lifting pin with a small knob on the end. A crows foot tool is used to latch onto the lifting pin. The pieces are then lifted and transferred like the fuel elements. The experimental 4-X pieces have one top corner milled down. This is usually oriented to the northeast.

5. Basket Removal and Insertion

The experimental baskets may be moved by using a hook tool, although a positive latching tool similar to the Vorhies tool is generally used. Care must be taken not to drop or damage baskets containing experiments. When moving capsules or small objects in the reactor, it is desirable to have all the positions filled to prevent loss through the grid plate.

6. Flux Wire Insertion

Occasionally, it is necessary to insert or remove flux wires from the reactor. A hook tool, Vorhies tool, or a finger tool may be used for this job, although the latter two are usually preferred. The tool used depends somewhat on the type of flux wire holder used and the position.

7. Lead Experiment Insertion

A lead experiment is generally a capsule-type experiment with instrumentation leads for connection outside the reactor. These leads are encased in an aluminum or stainless steel tube that is attached to the capsule. The leads are brought out of the access nozzles at the top of the reactor tank section. The water level is lowered to below the nozzles and the nozzle flange removed. The lead tubes are made in two sections joined by an in-tank connector. The upper and lower sections are positioned in the reactor and the in-tank connector made up. After the experiment is in position, it is then clamped to the tank wall with remotely operated clamps. A special flange is then placed over the lead tube and is sealed against loss of reactor water. The lead connections can then be made up and the experiment pressure-tested. Many of the lead experiments have special insertion instructions that will be issued before the insertion.

8. Insertion of Experimental Tubes

There are 15 bottom head penetrations provided for experimental in-pile tubes. There will be specific insertion procedures for each experiment that is installed, but the general procedures for insertion will be similar.

To prepare for experiment insertion, the reflector or core pieces from the experimental position are removed. The grid adapter piece is then lifted using one or two Kaiser grid adapter tools or regular hook tools and discharged to the canal. For the insertion of some tubes, it may be necessary to remove pieces and control rods adjoining the facility.

A hydraulic jack is then placed under the bottom head seal plug and the seal plug retaining ring removed. A seal plug adapter piece is attached to the lower end of the experimental tube to mate with the top of the seal plug. The experimental tube is then carefully lowered into the reactor vessel, through the grid plate and the support plate until the adapter piece is mated with the seal plug. With constant communication between the reactor top and the subpile room, the seal plug is then jacked up slightly to be sure the plug and the adapter are together. The seal plug and the experimental tube are then lowered, stopping often to check that the tube and the seal plug are still in contact. This is continued until the experimental tube is through the bottom head.

The in-pile tube is then positioned and attached to supports inside the reactor tank. The piping in the subpile room and the reactor tank may now be welded to the in-pile tube.

F. PREPARING REACTOR TANK FOR START-UP

1. Tank Inventory

When the reactor shutdown work is completed, an inventory is taken of all reactor positions containing experiments. The purpose of this is to check the shutdown work to make sure that all experiments are in their correct position and that no capsules have been lost or misplaced.

The inventory tool is lowered onto the basket or hole and the inner plunger rod is lowered onto the capsules. The reading is then taken, recorded, and checked against master loading sheets.

2. Cleanup and Inspection

After tank work is completed, the tank should be visually inspected for any irregularities. The tank should be checked to see that all positions are full, and that all pieces and experiments are properly seated, and inspected for any foreign matter and tools or parts of tools that may have been dropped into the tank. All irregularities should be corrected.

3. Guide Tube Support Arms

The guide tube support arms should be lowered into place and latched. The long arms are lowered first. The latching pin on the west end of the arms should be latched. The short arms are then lowered onto the long arms and latched into place with the wrench tool.

4. Discharge Chute Cover

The discharge chute cover is put in position. Before lowering into the tank, the "O" rings should be checked to see if they are in satisfactory condition, and that the latching dogs are swung out so they will not bind on the discharge chute. The cover is then lowered onto the discharge chute, making sure that the "O" rings are not damaged. The cover is checked to see that it is in the chute straight. The cover is then latched in place by turning and tightening the latches with the wrench tool.

5. Top Dome

A Pre-Dome Check List is completed in preparation for placing the top dome on the reactor. Before the top dome is placed on the reactor tank it is necessary to remove the working platform and place the reactor "O" ring in place. The dome is then lowered into place taking care that the experimental tubes are not damaged and that the dome is centered properly before setting it on the reactor. The top dome is then bolted down.

6. Fill and Leak Check

When the top is bolted down and the experimental tube packings are made up, the tank is ready to be filled. The upper reactor drain line should be closed and a hose with quick disconnect fitting placed on the vent valve on the top dome and bled to the canal. The reactor tank is then filled with demineralized water through the primary system until water is obtained from the vent line. The vent is then closed and the reactor pressured to approximately 180 lb. The top dome seal and all packing and flange seals should then be checked for water leaks. If any leaks are found, they should be corrected.

7. Shielding

Before the reactor can go to power, the concrete shielding rings must be placed around the reactor top. After this is done, thermocouple and pressure leads to experiments penetrating the top dome should be made up.

CHAPTER VII

PRIMARY COOLING

A. GENERAL DESCRIPTION

The heat removal system of the reactor consists of a primary cooling system, which absorbs the reactor fission heat and rejects it to a secondary cooling system, which, in turn, dumps the heat to the atmosphere through cooling towers. Light water is the coolant used in both systems; the primary coolant in the reactor also is the moderator. Both cooling systems are closed loops: a primary loop consisting of demineralized water which is exposed to the atmosphere only in the degassing tank, and a secondary cooling system which is in contact with the atmosphere at the cooling towers. These two systems are separated by the tubes in the primary heat exchangers, the latter designed to prevent leakage between the primary and secondary cooling systems. Activity in the primary and secondary cooling water is continuously monitored.

Before reactor start-up, the primary loop is filled with demineralized water from the existing MTR demineralized water storage tanks. Two 1000 gpm pumps (Reactor Flush Pumps) take suction from the demineralized water storage tanks and supply the water to the primary loop, through a manual valving arrangement, at the upstream side of two heat exchanger banks. The valve in the connecting line to the surge tank is open, and air will be trapped in the surge tank. After the system is completely filled with water at atmospheric pressure, the pressurizer pump is started, followed by the primary pumps. The pressurizer pump raises the system pressure, causing the pressure controller to open the back-pressure valve. This allows water to pass into the degassing tank and stabilizes the system pressure. The air trapped in the surge tank at the start-up will be compressed, and sufficient additional air is added to lower the water level in the tank to the normal positon after normal pressure is reached. The water that this air displaces will be removed through the back-pressure valve to the degassing tank.

In the main circuit, 50,000 gpm of water is pumped by the primary pumps to manifold through the reactor vessel. Passing through the heat exchangers, the water returns to the suction of the primary pumps. A bypass flow control valve, actuated by the pressure differential across the reactor, regulates the flow through the vessel to maintain 32 feet per second through the core. During normal operation, the water will enter the reactor vessel at 110°F and leave at 135°F. The inlet temperature will be controlled at 110°F by the secondary cooling system.

The material of construction of the primary coolant system, including the heat exchanger tubes, is stainless steel, with the exception of the pump casings and some of the valves which are cast steel.

B. MAJOR FUNCTIONS OF THE PRIMARY SYSTEM

1. Flow (see Figure 22)

The primary system supplies approximately 50,000 gpm of light demineralized water to the reactor vessel. This water passes through the reactor core at a velocity of approximately 32 feet per second and removes the heat that is generated in the reactor core. The main flow loop is a closed circulating loop which consists of the following components.

Four large centrifugal pumps driven by 800 hp motors are used to circulate the water. Each pump discharges approximately 15,000 gpm of water into a 24-inch line. These lines run to a common 36-inch inlet header which carries the

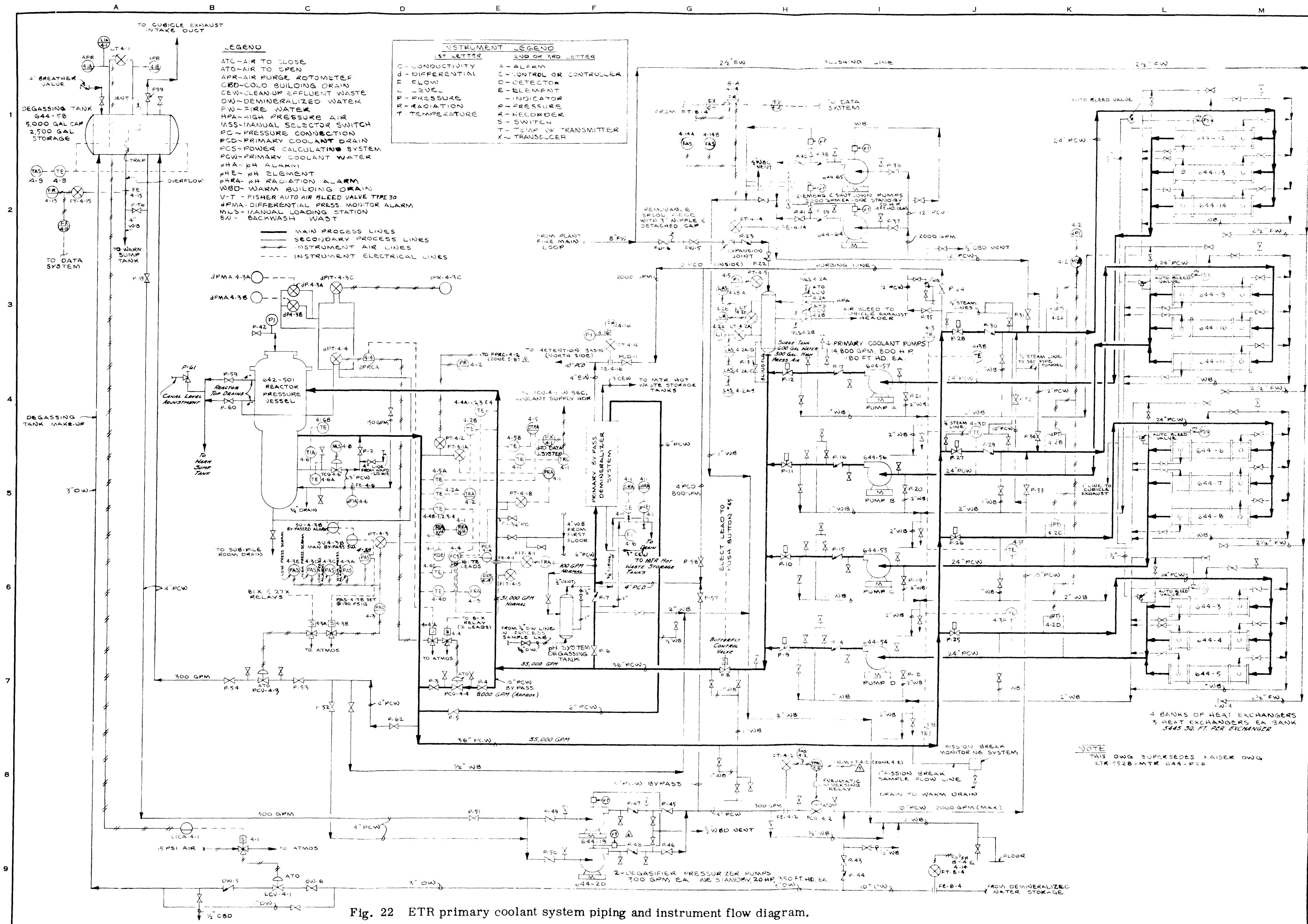

Fig. 22 ETR primary coolant system piping and instrument flow diagram.

water to the reactor vessel. The water leaves the reactor vessel through a common 36-inch outlet header that carries the water to the heat exchangers. Just upstream of the heat exchangers, the water splits into four individual systems. In each system, a 24-inch line carries the water through a heat exchanger bank and to the suction of a primary pump. Thus, the closed loop is completed. There is a motor operated block valve, called limitorque valve, located on the suction and discharge side of each primary pump. These eight vales are operated in the full open position during normal operation of the primary system. There is also a check valve located on the discharge side of each primary pump.

The flow to the reactor vessel is measured by a Gentile tube located in the reactor inlet header. (See Figure 23.) This flow is located downstream of all major bypass lines between the inlet and outlet header so that it is primarily measuring the flow that actually passes through the reactor vessel. The flow that goes to the reactor is controlled by two valves. The first is a motor operated butterfly valve that is used as a throttling valve. This valve is never closed farther than 45 degrees from its full open position. The position of the butterfly valve is set by an operator from a pushbutton station. Throttling the butterfly valve increases the pressure drop across the valve. This, in turn, increases the head and decreases the flow delivered by the primary pumps. The second valve is a control valve located in a 10-inch line that connects between the inlet and outlet headers. The valve is called the bypass valve since any flow passing through this valve bypasses the reactor vessel and the Gentile tube. A differential pressure controller monitors the pressure drop across the reactor core and automatically positions the bypass valve to maintain the desired differential pressure across the reactor core. Since the 10-inch bypass valve is relatively small, the butterfly valve is used to make a coarse setting on the flow to the reactor vessel. In this way, it is possible to keep the bypass valve within its control range at all times.

2. Pressure

The pressurizing requirements of the primary system are based upon a temperature of 110°F and a pressure of 200 psig at the discharge of the primary coolant pumps. The system pressure is controlled by adding a constant amount of water from the degassing tank to the primary system and removing a varying amount of water from the primary system to the degassing tank. The degassing tank is equipped with an overflow line and a demineralized water makeup line containing a level control valve. Thus, the level in the degassing tank remains nearly constant even though the amount of water entering and leaving the tank is not necessarily constant.

Water flows from the degassing tank to the suction side of two pressurizing pumps. In normal operation, one of these pumps is in operation and the other is on standby. The discharge pressure from the pressurizing pump is sufficient to drive the water through a flow control system into the primary system. The water enters the suction side of the primary pumps where the pressure is approximately 142 psig during normal operation. A flow control valve on the discharge of the pressurizing pump automatically maintains a constant flow rate of 300 gpm to the primary system. There is a high pressure override feature in the flow control system to prevent excessive pressures in the primary loop. A pressure controller located on the reactor oulet header is set to override the flow signal and close the flow control valve at a pressure of 165 psig.

The pressurizing system just described normally provides a constant flow of water into the primary system. This, then, makes it possible to control the pressure in the primary system by controlling the amount of water that is removed from the primary system to the degassing tank. This is accomplished by the back-pressure control valve. A pres-

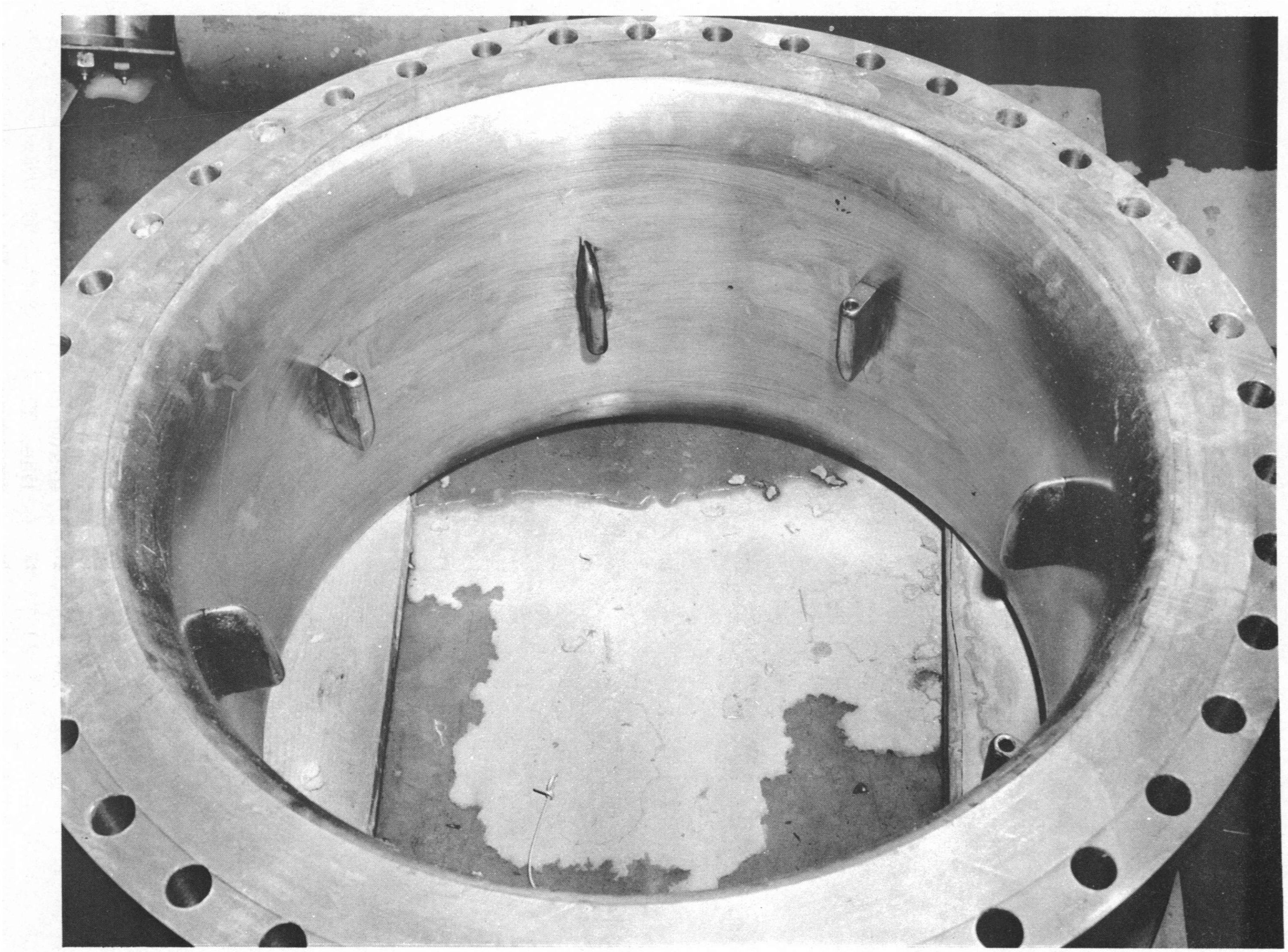

Fig. 23 ETR gentile flow tube.

sure controller monitors the reactor inlet pressure and automatically positions the back-pressure control valve to maintain a pressure of 200 psig at this point.

3. Temperature

The primary water system is designed to operate at a reactor inlet temperature of 110°F under normal reactor conditions of 175 MW and 50,000 gpm flow and an outlet temperature from the reactor of 135°F. The primary system transfers the reactor heat to a secondary water system through twelve shell-and-tube heat exchangers. There are four banks of three heat exchangers, each in parallel, each bank being stacked in a vertical plane. The exchangers use a shell-and-tube counter-flow arrangement with the primary water flowing through the tubes. The units have fixed double tube sheets and are of a straight through, one pass design (see Figure 24).

The reactor inlet water temperature is controlled by varying the rate of heat transfer to the secondary system. This is accomplished by varying the flow rate and temperature of the secondary water system. Therefore, the temperature control system consists of a controller which receives a temperature signal from the primary water system at the inlet to the reactor. The controller then positions a flow control valve in the secondary system to achieve the desired primary temperature.

4. Degassing

A 5000 gal degassing tank is located on the roof of the heat exchanger building to remove dissolved gases. Primary coolant water flows through the tank at atmospheric pressure at a maximum flow of 300 gpm. Fission gases are removed and an explosive mixture of hydrogen and oxygen is prevented by passing air, at atmospheric pressure, over the water surface of the tank and venting the mixture to the cubicle exhaust system.

The original calculations made on H_2 and O_2 gas production indicate that the equilibrium between production and recombination will be reached at a gas concentration much lower than the minimum value necessary to cause bubble formation in any part of the system. It was predicted that the equilibrium gas concentration under actual operating conditions would be approximately 5 cc/liter. Actual measurements found the gas concentration to be 40-50 cc/liter which is still well below minimum solubility of 166 cc/liter at the primary pump inlet.

The quantity of gas that can be removed by this equipment is directly proportional to the gas concentration in the primary cooling water. At the predicted concentration, approximately 0.2 scfm would be removed. In addition to removing water decomposition products, the degassing device also will perform the following functions: (a) remove hydrogen resulting from corrosion of fuel elements and structural material; (b) remove carbon dioxide formed by oxidation of any trace of organic material in the system; and (c) remove the noble fission gases, such as krypton and xenon, which will result from a fission break.

At a flow rate of 300 gpm, it will be possible to reduce the concentration of the noble fission gases in the primary coolant system at about the same rate as the demineralizer will remove ionic fission products. At this flow, it is anticipated that the hydrogen off-gas rate will be 0.2 scfm which is more than adequate to remove any hydrogen resulting from corrosion. Since the solubility of air and hydrogen will be lower in the degassing tank than anywhere else in the system, the possibility of gas bubble formation in the core or any other part of the primary loop will be eliminated.

During normal operation, approximately 300 gpm of primary coolant is withdrawn continuously from the reactor outlet line. This flow is bled through the back-pressure valve to the degassing tank. The automatic flow control valve downstream of the pressurizer pumps maintains a constant outflow of 300 gpm from the degassing tank. Water level in the degassing

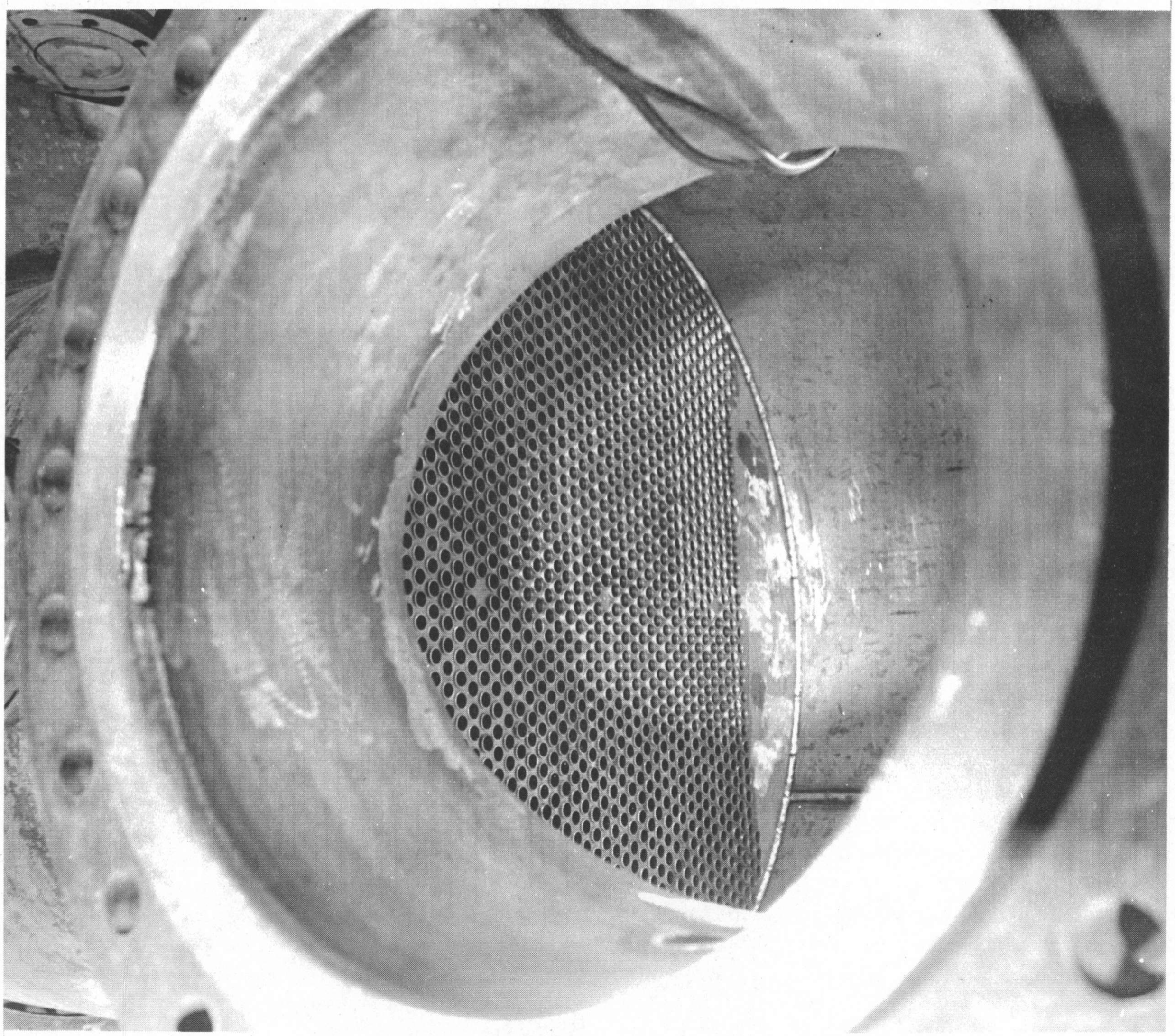

Fig. 24 Primary heat exchanger showing end of tube bundle.

tank is automatically maintained through a level-controlled demineralized water makeup line and an overflow line.

5. Bypass Demineralizer (see Figure 25)

In order to maintain the required high purity of the primary water, a bypass demineralizer system consisting of two anion beds and two cation beds has been installed.

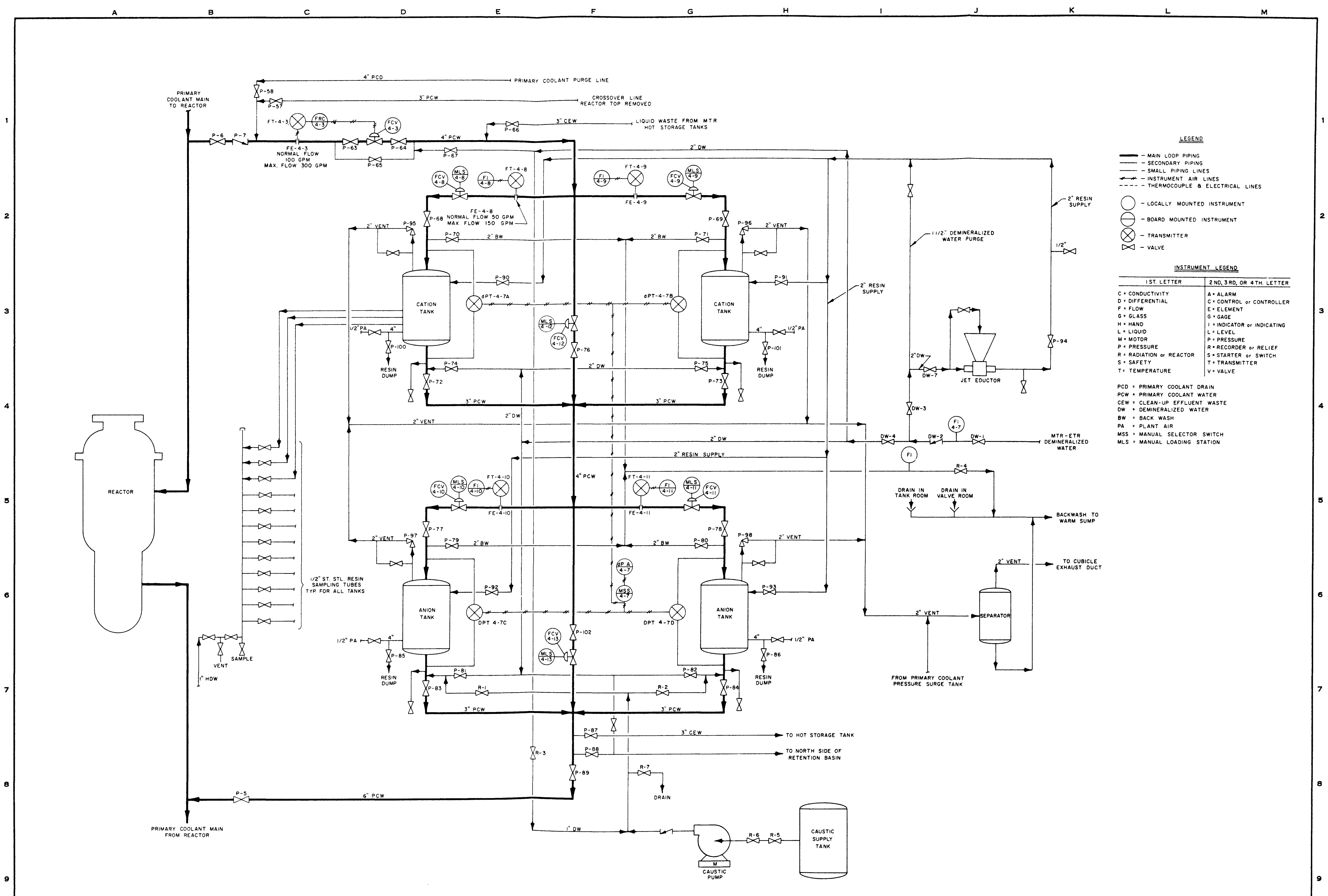

Fig. 25 ETR primary coolant bypass demineralizer piping and instrument diagram.

It will maintain the primary water to maximum ionic impurities of 1/2 ppm corresponding to 1,000,000 ohm-cm by demineralizing a bypass flow of 100 gpm. It also will be capable for short term operation at 300 gpm for fission product removal.

The bypass flow through the demineralizer is controlled by an automatic flow control valve in the inlet line to the demineralizer. The valve receives a signal from a flow meter through a recorder-controller having an adjustable setting. During the reactor shutdown, up to 300 gpm can be passed through the bypass demineralizer by the pressurizer pump when the water is too radioactive to remove the cover of the reactor, or too radioactive to be discharged to the retention basin. During that time, the primary water is recirculated in the primary loop at a rate of 2000 gpm by the emergency and shutdown pumps. (These pumps are described below.)

The system was designed for non-regenerative operation, but has been modified to provide for the regeneration of the anion beds. Spent resin is slurried into a disposable casket. The fresh supply of resin is fed into the tanks with demineralized water. This water is drained to the warm sump tank or the retention basin.

The pH is controlled by bypassing part of the fluid around the anion or the cation tanks.

The system is designed for flexibility so that each tank may be completely or partially bypassed. This is accomplished by diaphragm-operated control valves located on the pipe leading to each tank inlet controlled by remote manual stations mounted on the process water control panel. Flow indicators for each tank also will be located on the panel adjacent to the manual control stations.

A connection is provided at the inlet to the tanks for pumping hot waste from the MTR hot waste tank through the demineralizer system before it goes to the retention basin. This may be done at the rate of 100 gpm.

6. Emergency Flow

Several emergency situations may arise that involve the loss of normal flow in the primary system. In these cases, the reactor is automatically shut down. It is necessary, however, to maintain some flow through the reactor core to remove fission product decay heat, and thus prevent nucleate boiling in the core. This essential flow is supplied by the "Emergency and Shutdown Pumps".

The two primary emergency pumps receive their power from the diesel generator bus. One of the pumps runs continuously during reactor operation. The standby pump is set to start immediately upon failure of the running pump. Approximately 2000 gpm of primary water is supplied to the suction side of the emergency pumps from the 36-inch reactor outlet header just upstream of the heat exchangers. The emergency pumps then return this water to the primary system at two points. The water can reenter the main loop on the inlet line to either the "A" or "B" banks of the heat exchangers. Normally, it enters at both places. There are check valves on the inlet lines to "A" and "B" heat exchanger banks which are located between the points where the emergency flow leaves and reenters the main loop. These check valves close on loss of main flow. Thus, the flow from the emergency pumps must circulate through the reactor vessel in order to return to the suction side of the emergency pumps. There also are check valves located on the discharge side of each emergency pump which prevents the flow from bypassing back through the standby pump. An orifice located on the discharge side of the emergency pumps indicates the emergency flow rate on a flow recorder.

7. Activity Monitoring

Two radiation systems continually monitor the water in the primary system. These are the N^{16} measuring system and the fission break monitoring system.

Some of the O^{16} in the primary cooling water is converted to N^{16} by the absorption of a neutron as the water passes through the reactor core. The amount of N^{16} formed is a function of the neutron flux in the reactor. N^{16} has a half life of seven seconds and emits a hard gamma ray as it decays. The intensity of the gamma radiation in the primary system is measured at the outlet header just downstream of the reactor. The amount of gamma radiation is proportional to the amount of N^{16} and, thus, to the neutron flux; therefore, this instrument system is used to indicate reactor power level.

The purpose of the fission break monitor is to detect fuel element failure by the presence of fission products in the primary cooling water. Water is drawn continuously from the primary outlet header. The sample passes through a pressure regulator, a flow meter, and a glass wool filter. The sample then passes through a cation resin bed for the absorption of all major radioactive corrosion materials. This leaves only the materials normally associated with a fuel element leakage, viz, iodine and bromine, to be collected in an anion resin bed. The anion bed is continuously monitored by a gamma scintillation detector. The intensity of the gamma radiation is proportional to the iodine in the primary water, and indicates the presence and severity of a fission break.

8. Primary System Surge Tank

The primary surge tank has a capacity of 900 gal. The tank is connected to the primary system by an eight-inch line with a block valve. The block valve is open during normal operation of the primary system. The tank is normally half full of water. The remaining half of the surge tank is occupied by air compressed to the primary system pressure at the discharge side of the primary pumps. The level in the tank is controlled by bleeding high pressure air in or out of the tank through valves controlled from a remote manual loading station.

The air cushion in the surge tank serves to smooth out any pressure surges in the system. Also, at times when the reactor power decreases rapidly, the temperature of the primary water decreases rapidly. This, in turn, reduces the volume of the water in the main primary loop. The water in the surge tank, with the compressed air as a driving force, serves to fill the void volume in the primary system and keep the main loop liquid full.

C. REACTOR VESSEL CONSIDERATIONS

1. Tank Level Controls

The reactor top dome is in place, and the reactor vessel is liquid full at all times during normal operation of the primary system. During periods of shutdown, however, the reactor top dome is removed, and it is often necessary to adjust the water level within the reactor vessel. The level of the water in the reactor vessel can be adjusted by drainage from the vessel to the warm sump tank through the two taps on the side of the vessel. The upper drain tap is positioned for a level to accommodate normal shutdown tank work and the lower drain tap is positioned for changing experimental equipment. The level in the reactor vessel must be dropped before the dome can be removed, so air is admitted through a vent valve on the top cap. An important safety aspect of the drain lines is the fact that the water cannot be drained below the reactor core by use of these two lines. The level of the lower drain tap still provides several feet of water shielding above the reactor core.

The primary coolant inlet and outlet lines are the only other two major lines that penetrate the reactor vessel. Here again these lines enter and leave the reactor vessel at a point above the reactor core. This allows for some water shielding above the core even in the event of a major break in one of these two lines.

2. Flow Distributor

The inlet 36-inch primary coolant line penetrates the reactor vessel and discharges its water into a flow distributor located inside the reactor tank. This flow distributor directs the flow of the primary coolant water into the vessel so that turbulence at the core inlet and hydraulic loads on the internal reactor components are minimized. The distributor is rectangular in cross section and extends along the circumference of the vessel wall beyond the vessel center. A flow splitter at the inlet distributes the water equally into each line. Along the distributor, several openings allow the water to flow into the reactor. The remainder is directed upward by the curved sections at the distributor exits.

3. Thermal Shields

The thermal shields protect the reactor vessel walls and the concrete biological shield from excessive thermal stresses. There are two sets of thermal shields, one internal and one external. The three sources of heat considered were direct gamma radiation from the core, gamma radiation from capture of thermal neutrons, and the slowing down of fast neutrons.

The internal thermal shield is constructed of four concentric stainless steel shells with a one-inch space for water flow between each shell. The concentric shells vary in thickness and their size was determined from flow distribution, pressure drops, and attendant heat transfer conditions, as well as radiation attenuation. The reactor primary coolant is a medium which transports the heat removed from the internal thermal shield. This internal thermal shield is located in the reactor vessel outside of the inner tank; the latter forms a wall around the reflector and also acts as a baffle for the exit of the primary water which must pass between the shells of the internal thermal shield before leaving the reactor vessel to enter the primary coolant outlet header.

The external thermal shield is a cylinder located between the pressure vessel and the concrete biological shield to reduce the incident energy radiation on the concrete and thereby reduce thermal stresses to a tolerable level. The 3-1/2-inch thick lead shield has stainless steel cooling coils embedded in it and utilizes primary coolant flow to remove the heat absorbed by the shield. The cooling water for the coils is tapped from the reactor inlet cooling water line and returned to the outlet line. The temperature of the cooling water leaving the cooling coils in the shield as well as the ambient temperature outside the biological shield are both checked on a temperature indicator located in the process control room. The flow of the coolant through the coils can be controlled with a control valve which is remotely operated from a manual loading station in the process control room. To meet the design conditions of the biological shield, the coolant temperature at the thermal shield outlet should never exceed 125°F and the ambient temperature outside the biological shield should never drop below 70°F.

4. Top and Bottom Head Experiment Penetrations

There are several experiments that actually penetrate through the top and bottom heads of the reactor vessel. Two separate sets of packing are used to seal these penetrations against the internal pressure of the primary cooling water. In additon, a source of high pressure demineralized water is supplied to the penetrations at a pressure of approximately 250 psig. This water enters through a lantern ring which is located between the two sets of packing; thus, it is this clean demineralized water that is forced through the upper or lower packing if either of these two packings should develop a leak. There is no flow rate of this seal water except where a leak has developed. Therefore, the seal water flow rate to each experiment penetration is monitored periodically to determine the condition of the packing.

5. Control Rod Leak Detection System

The control rod drive mechanism for the reactor penetrates the bottom head of the reactor vessel. Two sets of packing are again used to seal against the high pressure primary coolant water inside the reactor vessel. The lantern ring, located between the upper and lower sets of packing, has a connecting line to the warm drain system. Thus, any water that leaks past the upper packing is drained off at the lantern ring to the warm drain system, and the lower packing does not have to seal against any appreciable pressure. Water leakage from each control rod drive passes through a rotameter before it discharges into the drain system; therefore, any water leakage through the upper packing is monitored before it goes to the drain. The amount of leakage shown on the rotameters indicates the condition of the control rod drive packing.

D. ABNORMAL CONDITIONS

1. Electrical Power Failure

The primary system has several safety features designed to protect the reactor during a commerical power failure. The two major results of a commercial power failure are:

(a) The reactor is scrammed from electrical relays.

(b) The main primary cooling water pumps lose power and coast to a stop.

The following auxiliary actions also take place:

(1) The operating emergency pump continues to run since it is on diesel generator power. This pump circulates approximately 2000 gpm of water through the primary system. The function of the primary emergency pumps has been discussed previously.

(2) There is a three-way solenoid valve in the instrument air line to the bypass flow control valve that actuates on power failure. This solenoid bleeds all the air pressure from the valve diaphragm and closes the valve. This action insures that all of the 2000 gpm emergency flow goes through the reactor vessel.

(3) A three-way solenoid valve in the instrument air line to the back-pressure control valve actuates on power failure. The solenoid bleeds all the air pressure from the valve diaphragm and closes the valve. This action immediately stops the flow of water from the primary system to the degassing tank.

2. Loss of Flow

This case refers to loss of one or more of the main primary pumps without an electrical power failure. The reactor is scrammed from two fast response electronic differential pressure systems across the reactor. There is a second three-way solenoid valve in the instrument air line to the bypass flow control valve. A microswitch in the reactor differential pressure controller actuates this solenoid when the reactor differential pressure drops several psig below its normal value. This solenoid bleeds the air pressure from the diaphragm of the valve and closes the valve. This insures that all the primary flow from the remaining main pumps and/or the emergency pump goes through the reactor vessel.

3. Loss of Pressure

A second three-way solenoid valve is in the instrument air line to the back-pressure control valve. A pressure switch on the pressure controller actuates this solenoid when the pressure in the primary system drops to 190 psig. This solenoid causes fast action closing of the back-pressure control valve. If the loss of pressure continues, the reactor is shut down.

4. Major Break in the Primary System

There is a connecting line with two manual block valves between the fire water main and the primary system. This line could be used to add large quantities of water to the primary system in the event of a major break in the primary system.

E. DISCUSSION OF IMPORTANT OPERATING PROCEDURES

1. Normal Shutdown Procedures

The purpose of this procedure is to prepare the primary system for a system flush and the removal of the reactor vessel top dome. Three major things must be done: the main primary flow must be shut off without interfering with the 2000 gpm emergency flow; the primary system surge tank must be isolated from the primary system; and the degassing tank must be isolated from the primary system.

The primary pumps must be shut down without losing the emergency flow and without allowing the discharge check valves to slam closed. The check valves are allowed to close smoothly by first closing the motor-operated block valve in the discharge of each primary pump. A primary pump may be shut down as soon as its discharge valve is fully closed. The emergency cooling water flows through both pumps "A" and "B"; therefore, continuous emergency flow is insured by the fact that the discharge valves in the discharge lines of both "A" and "B" pumps are not closed at the same time.

The primary system surge tank is isolated before the primary system is completely depressurized to prevent losing the water level in the surge tank. In this way, the surge tank remains at near normal operating conditions and is ready for service when the primary system is again repressured.

The degassing tank is located at an elevation which is higher than the top of the reactor vessel. This tank also is open to the atmosphere; therefore, the degassing tank must be isolated from the primary system to prevent water from running from the degassing tank into the reactor vessel at the time that the reactor top dome is removed.

2. The Flush Procedure

The contaminated water in the primary system is replaced with clean demineralized water after the primary system has been shut down, but before the reactor top dome is removed. The purpose of this flush is to reduce the radiation levels for shutdown work in the reactor vessel. The clean demineralized water from the MTR storage tank is brought into the primary system, and the contaminated water is discharged from the primary system through a drain line to the MTR retention basin. The two check valves on the inlet side "A" and "B" heat exchanger banks insure that the clean water passes through the entire primary system forcing the contaminated water out the drain line ahead of it.

3. Normal Start-up Procedure

The start-up procedure is essentially the reverse of the shutdown procedure described above. After the top dome is in place, the primary system is filled with demineralized water and thoroughly vented at all high spots in the system to remove all air possible. The degassing tank is not opened into the primary system until the system is liquid full and vented. The surge tank is not opened into the primary system until the pressure in the primary system is approximately equal to the pressure in the isolated surge tank. Each primary pump is started against a closed discharge valve. This is done to prevent overloading the primary pump motors during the initial starting of the pumps.

CHAPTER VIII

SECONDARY COOLING SYSTEM AND WATER TREATMENT

A. GENERAL DESCRIPTION

The secondary coolant system is designed to remove heat from the demineralized primary coolant water through the primary heat exchangers. The secondary coolant water is, in turn, passed over a cooling tower where the temperature is reduced to within a few degrees of wet-bulb temperature by evaporation. From the cooling tower coldwell, the secondary water is pumped through vertical turbine pumps to the shell side of the primary heat exchangers, thus completing the secondary coolant loop. The volume of water in the secondary loop, including the stored water in the cooling tower basin, is 632,000 gal. The quantity of water lost by evaporation or wind drift amounts to three percent of the total flow. The makeup raw water is supplied from deep well turbine pumps located in the MTR area. The water treating equipment for the secondary coolant system consists of a chlorinator, an acid injection pump for pH control, and a chemical corrosion inhibitor unit with the necessary piping and instruments to properly measure and control water treatment.

B. MAJOR FUNCTION OF THE SECONDARY SYSTEM

1. Heat Removal (see Figure 26)

The purpose of the secondary system is to remove heat from the primary cooling system and dissipate this heat to the atmosphere. The primary heat exchangers and the cooling tower are the components designed to achieve this transfer of heat.

Twelve shell and tube-type heat exchangers are used to transfer the heat from the primary cooling system to the secondary cooling system. There are four banks of three heat exchangers, each in parallel. The primary water flows in a single pass through the tube side. The secondary water flows in a single pass through the shell side. During normal operation, the secondary system removes 175 MW of heat from the primary system. The temperature of the secondary water entering the heat exchangers and the temperature of the secondary water leaving each bank of heat exchangers is monitored by resistance bulbs. These temperatures are recorded in the process control room. The differential pressure across the secondary side of each bank of heat exchangers also is measured and recorded in the process control room.

The secondary water is circulated from the heat exchangers to the cooling tower. A large wooden header delivers the water to a distribution system at the top of the cooling tower. The cooling tower is divided into nine bays, any one of which may be isolated from the water distribution system. Each cooling bay has a counterflow induced draft fan with a capacity of 542,000 cfm. The cooling tower fans have four 10-foot stainless steel variable pitch blades and are driven by 60 hp motors. The motors are coupled to the fans through an 11:1 spiral bevel-gear reducer. The pitch on the blades is adjustable from 9 to 16.5 degrees. All fans but two have one speed forward and one reverse speed. The other two fans have two speeds forward and reverse. It is often necessary to reverse one or more fans during cold weather to prevent ice formation in the cooling tower. The fans are controlled from remote push-button stations in the process control room. The water is discharged through spray nozzles at the top of the tower and falls down through a network of redwood slats. The fans draw air from openings at the base of the tower

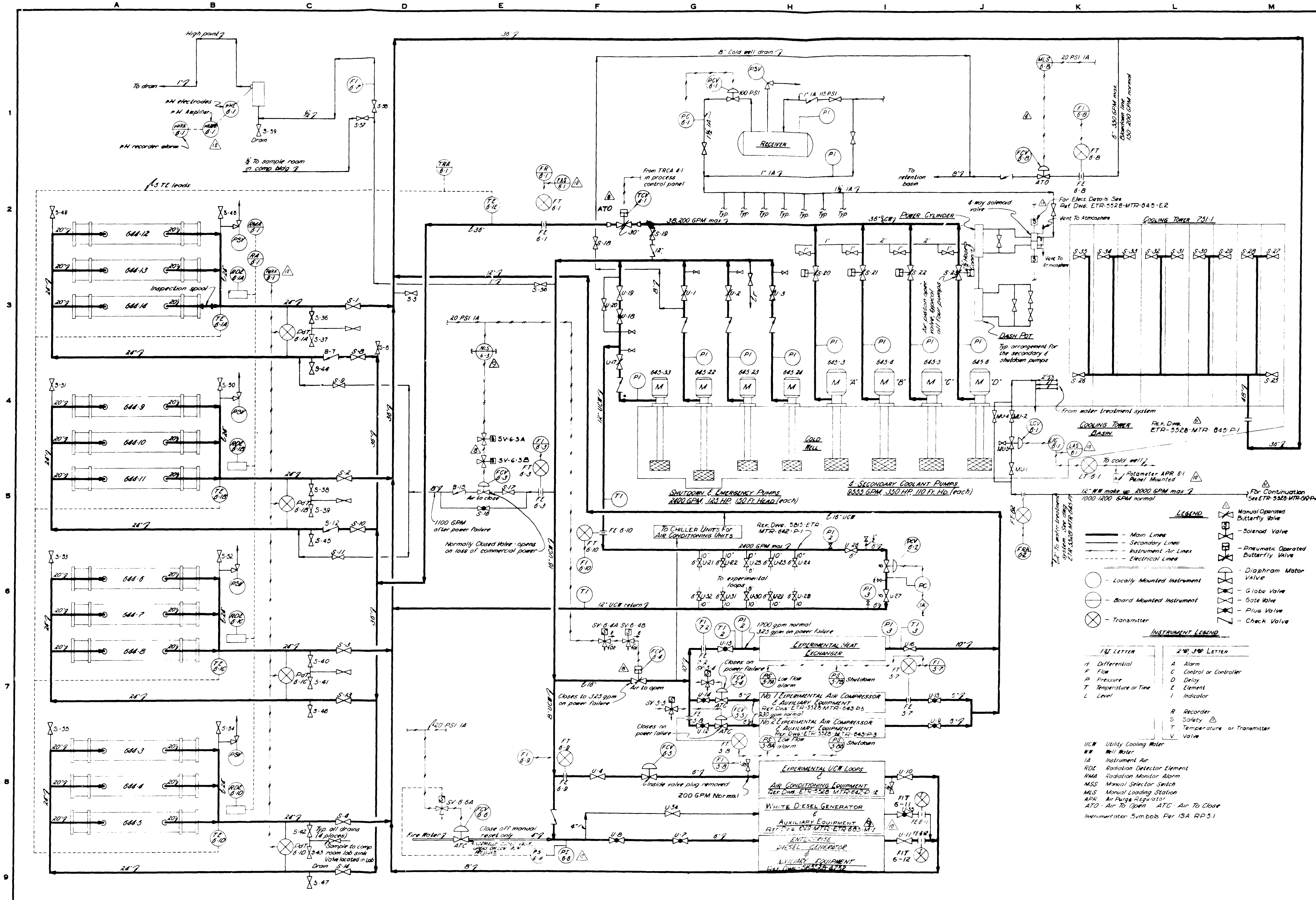

Fig. 26 ETR secondary coolant system piping and instrument diagram.

and discharge it out the top. In this way, the cooling tower dissipates the 175 MW of heat to the atmosphere.

2. Flow

The flow of secondary water is circulated through the secondary system by four pumps connected in parallel. They are two-stage vertical turbine-type pumps rated at 9500 gpm each and are driven by 350 hp motors. Water is pumped from a coldwell underneath the pumps. The water flows into a common header to the four banks of heat exchangers and through another common return header to the cooling tower. After passing over the tower and into the tower basin, the water returns to the coldwell by gravity flow.

An air operated block valve is in the discharge line from each secondary pump. Instrument air pressure is supplied to a power cylinder on the valve through a four-way solenoid valve. The solenoid is energized and the block valve is opened when the corresponding secondary pump is started. The solenoid closes the block valves when the secondary pump stops for any reason. If the block valve does not open when the pump is started, the pump is shut down again after several seconds by the action of a timer.

The flow in the secondary system is controlled by a butterfly temperature control valve. The flow of secondary water is varied to regulate the amount of heat which is transferred from the primary system. A temperature sensing element measures the temperature of the primary cooling water near the reactor inlet. This temperature signal goes to a temperature controller, which in turn positions the flow control valve in the secondary system to achieve the desired primary temperature.

3. Temperature

It was shown in the previous section that the temperature of the primary cooling water directly regulates the secondary cooling water flow rate; however, the basic function that is being controlled is the amount of heat that is removed from the primary system. The rate of heat transfer depends on both the flow and temperature of the secondary cooling water. Therefore, the secondary flow rate can be indirectly regulated by varying the temperature of the secondary system. This allows the operator in the process control room to keep the secondary flow control valve within its operating range by regulating the temperature of the secondary water.

The temperature of the secondary water is controlled through the cooling tower. The cooling that can be achieved from the tower depends on the outside air temperature, the atmospheric condition, the amount of air pulled through the tower, and the water flow rate. Of these, it is the volume of air which is varied to regulate the temperature of the secondary water. Thus, the operator selects the number of cooling tower fans to be run in the forward direction to maintain a satisfactory secondary temperature.

4. Emergency Flow

A secondary emergency flow can be supplied to the secondary side of "A" and "B" heat exchanger banks from the utility cooling water system. The utility cooling water is pumped from the coldwell to serve various cooling functions around the plant by four vertical turbine pumps. The utility cooling water returns over the cooling tower through the same common header utilized by the secondary cooling water.

The utility cooling water discharge header is connected to the secondary water inlet headers to "A" and "B" heat exchangers. An air operated valve, a check valve, and a flow orifice is in the connecting line. The flow rate of the utility water entering the secondary system is shown on a flow indicator in the process control room. The air operated valve is normally closed and may be operated from a manual loading station in the process control room. Loss of commercial power will de-energize the solenoids in the air line to the flow control valve, venting the control air from the diaphram, which will open the valve. Check valves are in the secondary inlet lines to "A" and "B" heat exchangers located just up-stream of the point where the utility cooling water enters. These valves close on loss of the main secondary flow and force the emergency utility water through the heat exchangers before it returns to the cooling tower.

5. Radiation Detection

The radiation level of the secondary water is monitored at the outlet line from each heat exchanger bank. A radiation measuring element is mounted next to each of the four return lines. The four radiation signals are recorded on the multi-point recorder in the process control room. An audible alarm sounds when any one of the signals indicates that a small amount of radiation is present.

The purpose of this radiation detection system is to give a fast indication of any leak between the primary and secondary systems. The most probable place for such a leak to occur would be through the failure of a heat exchanger tube. The radiation element that first shows an increase would indicate which heat exchanger bank contained the break. Radioactive contamination in the secondary system would escape in the cooling tower and spread over the surrounding area; therefore, it is important that no appreciable amount of contamination is allowed to enter the secondary cooling water.

6. Cooling Tower Blowdown

During normal operation, a regulated amount of secondary water is purged to the retention basins through the blowdown line. This water purge passes through a flow orifice, an air operated blowdown control valve, and a check valve. The flow is indicated on a flow indicator in the process control room. The blowdown control valve is positioned from a manual loading station in the process control room.

The evaporation of the secondary water in the cooling tower removes water from the system, but does not remove the solids and chemicals with the water; therefore, the evaporation process continuously increases the concentration of solid materials in the secondary water. An equilibrium concentration of total solids is established by purging some of the high solid concentration water from the secondary system and replacing it and the evaporation losses with low solid concentration water from the wells at MTR. The amount of makeup water added is regulated by a control valve positioned by a coldwell liquid level controller. The control of total solids in the secondary water is discussed in detail under "Water Treatment".

C. ABNORMAL CONDITIONS

1. Electrical Power Failure

Several emergency provisions are in the secondary system to insure sufficient cooling for the primary cooling water at the time of a commercial power failure. All four of the secondary cooling water pumps shut down on a commercial power failure. Two of the four UCW pumps are on diesel power. Normal running conditions are having the two diesel generator pumps and one commerical pump on the line. On a commercial power failure this will insure cooling water flow to various areas.

The tie-over that supplies utility cooling water to the secondary side of "A" and "B" heat exchanger was discussed under paragraph B-4. The emergency flow control valve is normally controlled from a manual loading station. There are two three-way solenoid valves in the air line to the emergency flow control valve which are de-energized immediately on a commercial power failure. The solenoids bleed the air from the diaphragm of the emergency flow control valve and allow approximately 1000 gpm of utility cooling water to enter the secondary system.

D. WATER TREATMENT

1. General

It would be inefficient and expensive to purge any more chemicals to the drain system than is necessary, yet chemical and hardness ion concentrations can get too high due to evaporation. Optimum operating conditions for the secondary system occur when the chemicals and hardness ions are about seven times more concentrated in the secondary water than in the raw makeup water. This is called "seven concentrations" and is controlled by regulating the rate of blowdown from the secondary system. An operator determines the concentration of total hardness ions and of calcium ions in the secondary water every four hours. The blowdown rate is regulated to keep values approximately seven times higher than the corresponding values in the raw makeup water. Since the raw water comes from wells, the hardness remains essentially constant and is analyzed once per month. The total hardness ions are maintained between 1030 to 1470 ppm and the calcium ions below 370 ppm in the secondary system.

2. Acid System

The acid system consists of a concentrated acid tank and an acid pump. Concentrated sulphuric acid is pumped to the concentrated acid tank from the MTR area. The tank has a sight glass for level indication and high level alarm to prevent overflowing the tank. A controlled amount of acid is pumped from the concentrated acid tank to the coldwell by a proportioning pump. The pump is a positive displacement-type pump, and the length of the stroke determines the amount of acid delivered. This particular pump has a special air cylinder which allows a pneumatic signal to change the length of the pump stroke. This air signal is controlled from a manual loading station in the process control room.

Acid is added to the coldwell to control the secondary water pH between 6.0 and 6.3. This pH range gives protection against the formation of sludges. A high pH will promote a type of corrosion attack which is localized in the form of pitting rather than spread over the metal surface. Low values of pH increase the danger of trace corrosion of copper and redeposition of copper on the steel piping and heat exchangers. The specified pH range also is desirable from the standpoint of protecting the cooling tower wood against delignification.

A continuous sample of water is taken from the secondary system and passed through an on-stream pH cell. The pH of the secondary water, as measured by this instrument, is recorded on a pH recorder in the process control room.

3. Dianodic System

Dianodic is the trade name for a chemical mixture containing phosphate and chromate ions. This chemical is added to the secondary system to inhibit the deposits and pitting caused by raw water in contact with metal pipes. The phosphate causes any scaling to come loose, and the chromate forms a protective film over the clean metallic surface. The phosphate also helps to control pH.

The Dianodic system consists of two mixing tanks and a Dianodic injection pump. Dianodic is delivered in a solid form in heavy cardboard barrels. The solid Dianodic is dissolved in water in the mixing tank. A barrel of Dianodic is added to the mixing tank which has been partially filled with water. After the mixing has been completed the tank is filled with water. On the tank, there is an electric mixer which is used to stir the solution until all the Dianodic is dissolved. The concentrated Dianodic solution is pumped from the mixing tank to the raw water makeup line just before it discharges into the coldwell. A chemical proportioning pump is used to inject the Dianodic solution into the secondary system. This pump was originally designed to mix separate solutions of chromate and phosphate in the proper proportions. Since the Dianodic solution contains both the chromate and phosphate ions, the pump is used to inject the one solution into the secondary system at a rate set by the operator. The operator determines the Dianodic concentration in the secondary water every four hours and adds sufficient Dianodic to maintain this concentration between 11 and 14 ppm.

4. Chlorine System

Chlorine gas is injected into the secondary system to kill and inhibit the growth of living organisms, such as moss and algae, on the cooling tower and in the pipes. The chlorine is injected into the secondary system three times a week during normal operations. Enough chlorine is added to reach a concentration of one ppm in the secondary system.

Chlorine gas is delivered to the ETR in gas cylinders. The cylinders are connected to the chlorine injection system. A commercial unit, called a chlorinator, is used to measure and control the rate at which the chlorine gas is added to the secondary system. The gas flows from the cylinders through the chlorinator and into the raw water makeup line just before it discharges into the coldwell. An operator periodically samples the secondary water and determines the amount of chlorine in the water during the time that chlorine is injected into the system. Chlorine is added only when the secondary water is circulating and when raw water is flowing into the coldwell. This insures that gas will be carried into the coldwell and that the concentration of chlorine gas will not become too high in the coldwell.

The chlorine gas cylinders and the chlorinator are contained in a separate room in the pump house. This room is equipped with an exhaust fan which draws air from the pump house, passes it through the chlorine room, and discharges it to the atmosphere. This is done to prevent any harmful concentration of chlorine from accumulating in the chlorine room. Any person entering the chlorine room is required to wear a special chlorine absorbing mask or use an air line respirator.

E. WATER ANALYSIS

1. Dianodic Concentration

The Dianodic concentration test is based on the oxidizing property of hexavalent chromium that will free iodine from potassium iodide. This free iodine causes a dark yellow to brown color. Sodium thiosulfate is then titrated in to absorb the iodine. In order to tell exactly when the iodine is gone, starch is added near the end turning the solution blue. When the blue disappears, the iodine is gone and the amount of sodium thiosulfate ($Na_2S_2O_3$) used measures the Dianodic chromate present. The normal range is 11 to 14 ppm.

(a) Secure a 50 ml sample of secondary water.

(b) Add 5 ml of 50 percent H_2SO_4.

(c) Add 10 ml of 5 percent potassium iodide solution. Stir well and allow to stand for 2 minutes. Solution turns dark yellow to brown due to free iodine.

(d) Titrate the prepared sample with N/100 sodium thiosulfate ($Na_2S_2O_3$) until the dark yellow color of iodine is almost gone.

(e) Add one ml of stabilized starch solution. The sample should turn dark blue.

(f) Continue titrating with sodium thiosulfate until the disappearance of the blue color.

(g) From the graph available, determine the ppm of Dianodic present from the number of ml of sodium thiosulfate used for the titration.

2. Total Hardness

The test is based on the measure of calcium and magnesium indicated by an organic dye (hardness indicator with hardness buffer). When titrated with the sequestering, or separating agent (hardness titrating solution), the color changes from red to blue. The end point is sharp and rapid so should be approached slowly. The final discharge of the reddish tinge is considered the end point.

(a) Obtain a 25 ml sample and dilute to 50 ml.

(b) Transfer to a clean casserole.

(c) Add one level measure (0.2) of Hardness Buffer Reagent and stir until dissolved.

(d) Add one level measure of Hardness Indicator and stir. If hardness is present, the sample will turn red.

(e) Add hardness titrating solution slowly from burette with continued stirring.

(f) When approaching the end point, the sample will show a blue coloration, but a definite reddish tinge will still be observed. Continue adding titrating solution drop by drop until the final discharge of the reddish tinge. Be careful not to overshoot.

(g) Using a 25 ml sample, multiply the ml of titrating solution used by 40 to obtain ppm total hardness as $CaCO_3$.

NOTE

If total hardness is above 400 ppm, as it is in the secondary system, use a 10 ml sample and multiply by 100 to obtain ppm $CaCO_3$.

3. Calcium Hardness

This test confirms the concentration of Ca^{++} ions which contribute to the total hardness of the secondary water. Too high a concentration is not good as hardness ($CaCO_3$) will begin to precipitate out on the pipes and in the heat exchangers.

The test is based on measuring just the calcium ions by the color change of an organic dye (calcium indicator). When calcium is present, the dye is pink. The sample is then titrated with a separating agent called hardness titrating solution which removes the calcium from the sample. When the Ca^{++} ions are removed, the dye turns orchid-purple. Always add one additional drop to be sure no further color change will take place.

(a) Measure a 25 ml sample and transfer it to a casserole.

(b) Add 25 ml demineralized water to bring the volume to 50.

(c) Add 2 ml of 1N sodium hydroxide (NaOH) and stir.

(d) Add one level scoop (0.2 g) of calcium indicator and stir until dissolved. If calcium is present, the sample will turn salmon-pink.

(e) Slowly add hardness titrating solution from the burette with continued stirring until a purple tinge is observed.

(f) Continue drop by drop until one drop does not produce any further color change. The end point should be an orchid-purple color.

(g) Multiply the ml of titrating solution used by 16 to obtain ppm calcium.

NOTE

If calcium is above 110 ppm, use a 10 ml sample and multiply by 40.

4. Chloride

This test for the chloride ion should not be confused with the free or residual chlorine test. It is useful in determining the cycles of concentration in the secondary system, just as the total hardness test does. Since the secondary water is evaporated until normal, chemicals are seven times as concentrated as raw water, and secondary chloride should be about seven times its raw water concentration. The control range is 75 to 105 ppm.

The test is based on the titration of water containing the chloride ion with a standard silver nitrate solution using potassium chromate as an indicator. The chloride ion is precipitated by the silver nitrate as white silver chloride. As soon as the chloride is completely precipitated, additional silver nitrate will cause a red color due to the formation of red silver chromate. The first permanent reddish tinge is taken as the end point.

(a) Draw 50 ml of water to be tested and transfer it to a clean casserole.

(b) Add four to five drops of phenolphthalein. If sample turns red, add just enough N/50 sulfuric acid to discharge the color. If sample remains clear, do not add the acid.

(c) Add five drops of potassium chromate indicator and stir. The solution should turn bright yellow.

(d) Slowly add silver nitrate solution from the burette with continued stirring until the first permanent reddish tinge appears. Do not overshoot to brick red.

(e) Using a 50 ml sample, the chloride in ppm is equal to the ml of silver nitrate employed minus 0.2 ml, multiplied by 20. The 0.2 is subtracted, as this amount of silver nitrate is required to produce the endpoint in distilled water.

(f) Record the chloride as ppm Cl on the log sheet.

5. Residual Chlorine Test

The test detects yellow-orange orthotolidine hypochlorite because it is the hypochlorite form of chlorine that has the most potent disinfecting properties. If a high chlorine concentration is maintained, the organisms develop a resistance; therefore, chlorine should be added to the system three times per week, instead of continually. The normal rate is about 100 lb/24 hrs until the residual test indicates a chlorine concentration of about one ppm. Small amounts test yellow. Large amounts test orange. The color is determined by comparing with a standard in a comparator.

(a) Secure two samples of test water in the sample glasses of the comparator. One will be used as the standard.

(b) Add about 0.5 ml of Orthotolidine Reagent to one of the cells. A yellow color will appear if chlorine is present. Where Dianodic is present, the yellow will darken.

(c) Place the samples into the color comparator with the standard on the left. Rotate the comparator disk until the samples appear identical in color.

(d) Read the comparator and record as ppm chlorine.

NOTE

The sample should be checked at the cooling tower as quickly as possible after orthotolidine is added, as misleading darkening can occur. Do not conduct the test in direct sunlight, as it can cause the test color to fade.

F. GENERAL DESCRIPTION OF IMPORTANT PROCEDURES

1. Draining the System

Several times during each year, it is necessary to drain the secondary piping and/or the cooling tower for cleaning or repairs. The cooling tower and the remainder of the secondary system each have their own provisions for draining. The piping and heat exchangers are drained by use of the blowdown valve and four drain lines located at low points of the piping in the secondary pipe pit.

The cooling tower basin is divided into two sections, each of which may be drained individually. A drain line drains water from a concrete flume located at the tower basin. Small gates control the entry of water from either section of the basin into the drain flume. The coldwell is at a lower elevation than the cooling tower basin; therefore, a separate system is used to drain the coldwell. A crossover line with a manual block valve connects the discharge of one utility cooling water pump with the blowdown drain line. After the tower basin is drained, this utility pump can be used to pump the water from the coldwell into the drain system.

2. Filling the System

The raw water makeup line enters the coldwell through the pump house main floor. The coldwell and the cooling tower basins are filled to their normal levels by admitting raw water to the systems through the makeup line. A utility cooling water pump or a secondary water pump can be used to fill the coolant water piping, the heat exchangers, and the cooling tower basin. The coldwell level control valve adds water to maintain the level in the coldwell. In this way, water is pumped into the secondary piping until it is liquid full.

3. Start-up of the System

The actual start-up of the secondary system is not very complicated since it involves only the starting of the secondary pumps and the cooling tower fans. The pumps are located in the pump house near the cooling tower, while the pushbutton stations for the pumps are located in the process control room; therefore, an operator should be present in the pump house when the pumps are started to see that they are operating satisfactorily. Each cooling tower fan is turned through at least one revolution by hand before starting. This is done to insure that there is sufficient clearance between the fan and the fan housing to prevent any contact and possible damage to the fan.

CHAPTER IX

UTILITY COOLING WATER SYSTEM

A. INTRODUCTION (see Figure 27)

The utility cooling water system at the ETR is designed to supply secondary water to plant and experimental facilities for heat removal, and to return the water to the secondary system. Plant facilities include the A and B heat exchangers (during shutdown), the Clark compressors, the Enterprise and White diesel heat exchangers, and the office building air conditioning units. Experimental facilities include the HDW experimental heat exchanger, and individual loop utilities not directly exposed to contamination.

The UCW system utilizes secondary water from the ETR pump house coldwell. UCW flow is supplied by one or more of the four 125 hp pumps which take suction from the coldwell. The water passes through the UCW lines and is returned to the 36-inch secondary coolant return header to the cooling tower.

Raw water, delivered by the MTR deep well pumps, is chemically treated with inhibitor to reduce scaling and corrosion. Sulfuric acid is added to control alkalinity, and chlorine is injected to prevent the buildup of slime and algae. These additions are included in the make-up water as it enters the pump house coldwell.

The original ETR design included only three UCW pumps: 645-22, 645-23, and 645-24. The pumps were designated secondary emergency and shutdown pumps and, during a commercial power outage, supplied coolant to the secondary side of A and B heat exchangers to remove the reactor after-heat. At the time of the power failure, an emergency standby diesel generator unit would automatically start and pick up critical plant loads in a timed sequence, one of which was a UCW pump. Also, UCW flow was automatically blocked to all facilities except the A and B heat exchangers and the (Enterprise) emergency diesel.

The need for a noninterrupted source of utility cooling water to certain experimental loops and the inadequacy of the original system required an expansion of the UCW system. A new 12-inch loop was installed on the south and west sides of the ETR basement; the coldwell was enlarged; and a new UCW pump, 645-33, was installed, west of and in line with the original pumps, to supply the 12-inch loop.

B. EMERGENCY USE

Paralleling the expansion of the UCW system, the electrical system was expanded by the addition of a White diesel generator. Pump 33 is connected to the 480 V operations commercial power bus fed from the 4160 V "D" bus. Pump 22 is supplied with commercial power from unit 6A of MCC5A. Pumps 23 and 24 are supplied with diesel generator power through units 7A and 8A of MCC5A. During normal reactor operation the two diesel generator pumps and one of the commercial pumps are operated.

The flow to the secondary side of A and B heat exchangers is controlled by FCV-6-3 through a tie line from the discharge header of the UCW system. The tie line branches to divide the flow between A and B heat exchangers and each branch line connects to the main inlet line of the heat exchanger. The flow then follows the normal path of secondary water through the heat exchangers and returns to the cooling tower.

The flow control valve, FCV-6-3, is an air to close valve connected to the instrument air line. Two solenoid valves, SV-6-3A and SV-6-3B are in series on the instrument air line. The solenoids are

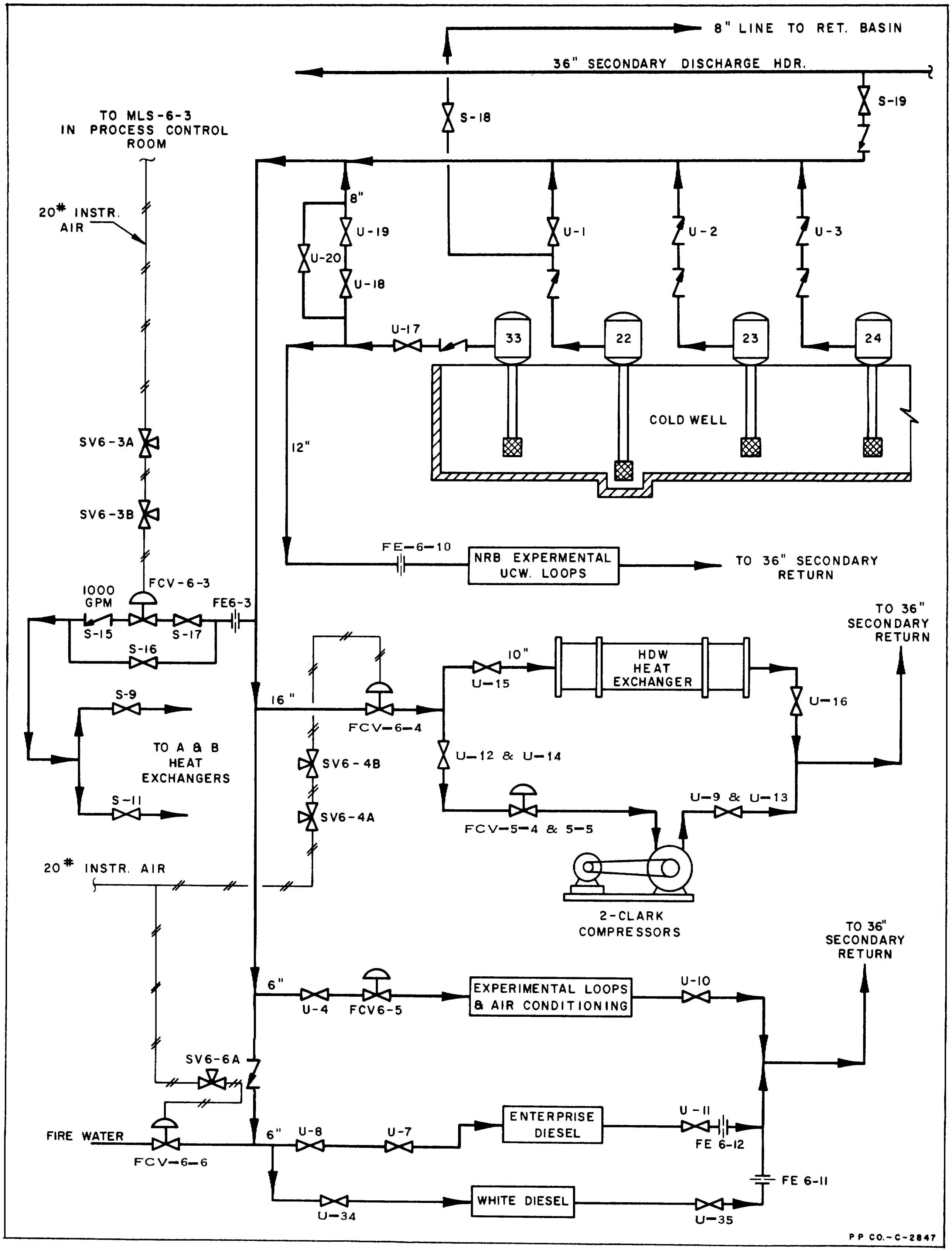

Fig. 27 ETR utility cooling water system.

energized by commercial power and keep 20 lb instrument air on the diaphragm of FCV-6-3 which holds it closed. If a commercial power failure should occur the solenoid valves will dump the air from FCV-6-3 and supply UCW cooling water to A and B heat exchangers. One heat exchanger can be selected to receive this emergency flow by means of manual block valves on the individual branch lines. However, normal operation requires that both be valved in for emergency flow from the UCW pumps.

C. NORMAL USE

1. Coolant to HDW Heat Exchanger and Clark Compressors

Normally, the emergency flow control valve, FCV-6-3, is closed and the UCW is pumped into the plant where it supplies three different systems. The first supplies water to the compressor building, entering from the north side in a 16-inch pipe, through the foundation, under the grating, and then splitting to feed water to the HDW heat exchanger and to the two Clark compressors with individual lines to each. The high pressure demineralized water is used as a secondary coolant to remove heat from certain experimental facilities. UCW is used in the secondary side of the 10 MW heat exchanger located in the compressor building that removes the heat picked up by the HDW. In the secondary pipe tunnel, located to the south of the heat exchanger building, the 16-inch line to the compressor building leaves the main UCW header. This line contains a flow control valve, FCV-6-4, which is an air operated valve with two solenoids on the air line that will actuate at the time of commercial power failure to bleed the air from the diaphragm of FCV-6-4 and permit it to close to a stop, which permits a flow of 325 gpm until power is restored.

2. Coolant to the Diesel Generators

The second loop on the UCW supplies the cooling water to the Enterprise and White diesel heat exchangers. The Enterprise and White diesel generator system is included as part of the plant split-bus power system and one diesel is run continuously throughout a reactor cycle. Cooling water is required whenever a diesel is running and is used in the secondary side of heat exchangers cooling the jacket water and the lube oil.

An emergency fire water line is provided for diesel cooling if UCW cooling water is lost. A flow control valve FCV-6-6 in the fire water line will open on low UCW pressure to supply fire water to the diesel. A check valve in the UCW supply line insures that the emergency fire water will go to the diesel.

3. Coolant to Experimental Facilities

The third part of the original UCW system is a 6-inch loop that furnishes coolant for the experimental facilities in the basement of the reactor building. The inlet line enters the reactor building at the southeast corner of the console floor and drops down to the basement ceiling elevation where the 6-inch supply and return loops are located. Cooling water from the supply loop passes through the experimental utilities and enters the return loop. The return line parallels the inlet line in the reactor building, but enters the secondary system return line to the cooling tower in the secondary pipe tunnel. On the north side of the basement and connected to the UCW loop is a 1-1/2-inch system which supplies UCW to the heating and ventilating rooms beneath the office building. The original design called for the basement loop to supply approximately 670 gpm, but the demands of the experimenters soon made this inadequate. The estimated use of the UCW by the experimenters soon exceeded 1800 gpm and led to the enlargment of the system to satisfy the anticipated demand.

4. 12-Inch Experimental Loop

The expansion of the UCW system included additional coldwell space, a fourth UCW pump, and a new UCW loop on the south and west sides of the basement.

In the basement, a 12-inch overhead line supplies UCW to the south and west side experimental facilities, the supply line terminating to the west of the WAPD C-7 cubicle at a pressure regulating valve, PCV-6-2, located in the U-bend of the line. The return line commences on the downstream side of PCV. A fourth pump of identical size and design as the three existing UCW pumps was installed and connected to the 12-inch experimenters' loop. In order to achieve more flexibility in the system and allow the existing pumps to supply the 12-inch loop, if necessary, a tie was installed between the discharge of the new pump and the discharge header of the existing UCW system, with manual block valves installed for flow control. Under normal operating conditions, these block valves are left open, and either system can supply water to the other in case of a mechanical failure of the pumps. In order to regulate the pressure in the 12-inch loop as the load varies, a pressure regulating valve, PCV-6-2, located in the basement at the transition between supply line and return line, maintains a back pressure of around 70 psig at a flow of 2400 gpm on the supply side.

D. EQUIPMENT

1. Pumps

The four UCW pumps are housed in the secondary pump house, building No. 645, and are a mutli-stage, vertical turbine type pump manufactured by the Fairbanks Morse Company, each with a capacity of 2400 gpm. Each is directly driven by a 125 hp, three-phase, 440 V electric motor. Pumps No. 23 and 24 are supplied with diesel-generator power from motor control center 5A in the secondary pump house. Pump No. 22 is supplied with commercial power from MCC5A. Pump No. 33 is supplied with commercial power through unit 16d in the 480 V switchgear located in the electrical building.

2. Valving

On the discharge line from each of the four UCW pumps is a check valve and a manually operated butterfly valve. The discharge butterfly valves on all the pumps are normally kept in the open position as long as one or more pumps are operating. If no UCW pumps are operating it is necessary to start the initial pump with the discharge valve closed. When the pump is at rated speed the discharge valve is opened.

In addition to pumping UCW through the various loops, one of the pumps, No. 22, is used to pump out the cold well whenever it is necessary to do so for cleaning or maintenance. The suction line on No. 22 pump extends downward 18-inches lower than the other pumps and goes into a sump to drain the cold well. This water is pumped directly to the south end of the MTR retention basin.

A 16-inch tie line provided with a manual block valve, S-19, and a check valve exists between the secondary discharge header and the UCW discharge header. The block valve normally remains open so water may be supplied from the secondary header to the UCW system in the unlikely event that all the UCW pumps are inoperative.

E. OPERATION

1. Normal

(a) FCV-6-3 and FCV-6-4

The valves in the cross-tie between No. 33 discharge and the header, U-18 and U-19, are normally open. FCV-6-3, the flow control valve on the emergency line to A and B heat exchangers, is normally closed. FCV-6-4, the flow control valve to the HDW heat exchangers and the Clark compressors, is wide open and permits the flow of 1700 gpm to the heat exchanger and around 900 gpm each to the compressors. Seldom are both compressors required to be in operation at the same time, and a reduced flow of

2600 gpm is sufficient through this part of the system.

(b) 6-inch Experimenters' Loop, FCV-6-5 and 12-inch Experimenters' Loop

The 6-inch basement experimenters' loop at present uses very little water, and the flow is approximately 100 gpm. The solenoids for FCV-6-5 have been removed, and the flow through the loop is constant. The 12-inch basement experimenters' loop maintains a normal flow of around 2400 gpm at 72 psig.

2. Emergency

(a) FCV-6-3

When a commercial power outage occurs, all of the secondary pumps will stop, resulting in the loss of secondary flow to the primary heat exchangers. FCV-6-3, the control valve for the emergency secondary coolant supply, will open immediately on a commercial power outage and will remain open until power is restored. Approximately 1000 gpm is supplied to the secondary side of A and B heat exchangers.

(b) FCV-6-4 and Others

FCV-6-4, controlling the UCW flow to the compressor building, during a commercial power outage immediately closes down to a stop and the flow is reduced to 325 gpm, all of which goes to the HDW heat exchanger and the process control room air conditioning unit. The air positioned flow control valves to the two Clark compressors, FCV-5-4 and FCV-5-5, close completely. FCV-6-5, the flow control valve for the 6-inch experimenters' loop, has been deactivated and is always open, so the small flow through this loop is unchanged as is the UCW flow to the Enterprise and White diesels.

3. Return to Normal Conditions

Upon restoration of commercial power, FCV-6-3 will close, shutting off the emergency cooling to the secondary side of the main heat exchanger, and FCV-6-4 will open to restore 1000 gpm flow to the secondary side of the HDW heat exchanger. The valves to the two Clark compressors will reopen to reestablish flow prior to restarting a compressor.

If FCV-6-6, emergency water to the Enterprise and White diesels, has tripped it must be reset when normal UCW pressure is established.

Any UCW pumps that stop during the power outage must be restarted after power is restored.

CHAPTER X

CANAL OPERATIONS

A. DESCRIPTION OF CANAL AND EQUIPMENT

The canal is T-shaped and consists of two sections, the working canal which is 37 feet long and 8 feet wide, which connects with the reactor vessel, and the 60-foot long and 12-foot wide storage section. Except for the well underneath the reactor discharge chute, the water depth is 20 feet throughout which gives a one-foot freeboard. The storage canal is spanned by a movable bridge on rollers traveling the length of the storage section. The working canal can be isolated from the storage section by the insertion of a bulkhead at the junction. Also, a portion of the working canal near the reactor can be isolated by means of a second bulkhead.

The working canal provides sufficient working room for the removal of experiments from the reactor tank to the canal. In order to remove experimental equipment of lengths up to 15-1/2 feet, a well is located in the canal floor below the normal position of the unloading mechanism. Fuel elements and experimental sections are transferred from the reactor into the working canal through the discharge chute in the reactor vessel transition piece. This is accomplished by lowering the fuel element into a transfer tube located in the canal under the discharge chute. The transfer tube, which is hydraulically operated, is pivoted to permit an operator to secure the element by a hook tool from the canal. The operator then "walks" the element to the storage racks.

An underwater saw is located on the south wall of the working canal to cut off fuel element end-boxes and to cut in-pile piping into disposable lengths. Also by the south canal wall is a capsule reloading tray, flux wire storage grid, and a Kollmorgan underwater periscope used for capsule inspection.

Along the bottom of the canal are the S and T grids, each made up of a 9- by 7-inch grid of 4-inch aluminum piping for storage of capsule experiments and one or two trash cans for storage of low level radioactive scrap for later removal to the burial grounds.

The storage canal has additional storage space for irradiated fuel slugs, experimental equipment, fuel elements, and reactor core components. The north half of the storage canal has been designated for storage of nonfueled components in the P and R grids and storage of fuel assemblies in cadmium-lined storage grids A, B, C, D, E, F, G, and X, Y, Z. The X, Y, and Z grids are short grids for the storage of cut fuel elements and control elements. Numbered and lettered stainless steel buckets have been provided for irradiated capsule storage. Spent fuel elements are stored in the 36-hole, cadmium-lined storage grids to "cool" before being cut and shipped to either the Gamma Facility or Chemical Processing Plant. The south half of the canal storage area will be used for storing long in-pile loop experimental samples. Other bulky items such as canal bulkheads are stored here.

B. SHIPPING

All irradiated capsules, experiments, and depleted fuel elements are transferred from the canal in shielded containers. The experimenters provide their own casks to ship capsules and experiments. The cask is lifted with the 30-ton crane, lowered into the canal, and loaded with the experiment. After loading, the cask is raised out of the water under HP surveillance, wiped dry, and checked for radioactive contamination. Casks shipped via commercial transportation must have a surface contamination less than 200 disintegrations/min and radiation of less than 200 mr/hr at contact.

Standard fuel assemblies and control assemblies discharged from the reactor are stored in the canal for a minimum period of one month prior to shipment to the Idaho Chemical Processing Plant. Elements are transferred eight at a time to ICPP. A water addition funnel and vents have been added to the element transfer cask so that cooling water can be maintained in the cask in the event of a carrier breakdown.

Standard fuel assemblies are shipped to the Gamma Facility a day or two after being discharged from the reactor. Due to the excessive heat generated by these elements, the assemblies are shipped a few at a time. A curve is available in the ETR SPM that indicates the fractional allowable cask heat load from an element from a given reactor core position. Of course, the number of elements that can be shipped increases each day after the reactor has been shut down.

C. CANAL PIPING

The canal is supplied with demineralized water from the MTR storage tanks. For "quickfill", a 4-inch stainless steel pipe is used with the water entering the working canal north wall at the 12-foot water level. For canal purging, a 3-inch stainless steel pipe is provided. The purge is supplied at two locations in the storage canal and two locations in the working canal. The rate of purge is controlled by a manual valve at each location, adjustable from 0-100 gpm per valve and operated from the first floor along the canal parapet wall. Normally the purge system will operate at a fraction of its capacity which will be sufficient to keep the activity in the canal to a permissible level under normal operating conditions. The rate of purge is determined by the amount of radioactivity from spent fuel elements and experiments and should be sufficient to maintain the canal water temperature below 90°F.

The original adjustable overflows with 3-inch pipe connections were found useless and were removed, and fixed level overflows were installed. Each overflow has a capacity of about 120 gpm, and drains into a 6-inch canal drain terminating in the 5000 gal "warm" sump tank. In addition to the overflow, there are three drain sumps containing 6-inch valves in the canal floor; one is located in the storage canal and one within each bulkhead compartment in the working canal. The drain line in the storage canal is embedded in the canal footing and runs to a riser in the north section of the storage canal. To this riser are connected all the canal overflows and the first floor gutter drains adjacent to the canal parapet wall. The 6-inch drain riser from the plug valve in the working canal is embedded in the north canal footing and runs under the working canal and terminates in the 5000 gal warm sump tank. Connected to this riser are the two reactor top drains and the canal level adjustment valve located 42 inches below the top of the parapet. The level adjustment valve is used to lower the canal water when it is desired to have the reactor discharge chute cover off and work on lead experiments with open flanges on access nozzles. Before the reactor discharge chute cover is removed, the levels of the reactor tank and the canal should be equal. If need should arise to raise the reactor tank level during the time the discharge chute is off, it should be filled through the canal instead of through the reactor tank so that the canal will not be filled with the more contaminated water of the reactor.

D. CANAL CLEANING TOOL

The canal bottom can be cleaned by a manually operated, portable, suction-type cleaning tool which is connected to suction connections in the canal wall. Four 2-inch suction lines are centrally located in the canal, each line terminating 6 inches below the normal water level. Each connection has couplings for quick connection to the flexible hose of the cleaning tool and is equipped with an exposed shutoff valve at the outside of the canal parapet. The flow cleaning lines join into a common line which discharges to the 5000 gal warm sump tank. The canal cleaning tool is fabricated from 1.5-inch aluminum tubing, of which the upper portion serves as a handling tool and the lower portion as the suction line.

E. CANAL UNDERWATER SAW

The canal underwater saw table is made in three sections with a total length of 21 feet and is 3 feet wide. There is a "V" grove the entire length of the table for clamping pieces to be sawed.

The underwater saw table, located 6 feet above the canal floor, is fastened to the south canal wall by clamps. This makes it possible to remove sections of the table without disturbing the saw. The saw may be removed by disconnecting the crank cam and removing the top connrod bearing cap. The saw frame can then be lifted out.

The underwater saw blade hydraulic feed piston and clamps for holding materials to be cut are operated by demineralized water. The feed piston has tubing connected to both ends to force the blade into or withdraw it from materials. The saw is powered with a 3/4 hp, 220/440 volt, three-phase ac motor through a gear reducer giving the saw forty 6-inch strokes per minute.

All controls are mounted on a control panel facing out from the canal parapet. The controls consist of the motor "ON-OFF" switch, feed control, two individual clamping controls, feed pressure regulator, return stroke exhaust pressure regulator, and gauges for line pressure, saw feed cylinder back pressure, and feed pressure. The feed control has three positions: feed, retract, and rapid traverse.

The fuel element or experiment piece to be cut is clamped in the "V" portion of the underwater table. The saw motor is turned on and the saw feed traverse switched to "FEED" position. The saw blade pressure regulator is set at desired pressure for material being cut.

F. CANAL SHIELDING DESIGN

The planned 20 foot water depth in the canal will allow 15-1/2 feet of water above the active section of fuel elements stored in the canal and will reduce the radiation above the canal to 1/35 tolerance if 65 fuel elements are placed in the canal 2.5 hrs after shutdown.

There would be about three feet of water between a group of 65 spent elements and the canal wall if a single row of storage racks were placed midway between the canal walls. In order to reduce the radial gamma radiation to 1/10 tolerance, the lower sections of the canal wall are six feet of ordinary concrete. The upper section is tapered to about two feet.

In the region of spent element storage, the walls are seven feet thick. Space limitations make it necessary to place storage racks of irradiated fuel elements against the canal walls. The fuel elements in the canal will have 1-1/2 feet of water below the active sections. The water, in addition to the seven feet of ordinary concrete in the canal floor, will attenuate gamma radiation to 1/30 tolerance below the canal floor.

The region between the pressure vessel and the canal water contains sufficient shielding material to attenuate radiation from the core to tolerance levels in regions around the top of the canal. The only real danger of radiation from the canal shielding is in dropping a hot fuel element into the canal pit.

With the grating in place and four feet of water shielding, in addition to 8-1/2 inches of steel between the pit and the sub-pile room, a dropped element would create a calculated radiation field of 350 mr/hr. Such an event would cause a warning alarm to be sounded in the sub-pile room which would evacuate personnel from the area until the element is retrieved. If it becomes necessary to handle radioactive material in this area with the gratings removed (usually long items being discharged) the sub-pile room will be evacuated and the door locked until the gratings are restored to their proper position.

1. Canal pH Control

The canal water is sampled once per shift in four different locations and pH readings are recorded on the reactor building data sheet. The amount of nitric acid added, if any, for pH control also is recorded and initialed by the reactor service operator.

The canal pH is controlled between 5.5 and 6.5 by acid addition. Usually, 100 ml of nitric acid will change the canal pH from 6.55 to 5.9 pH. This addition will last for a week with a normal purge of 20 gpm. In reviewing old canal pH records, the pH normally climbs about 0.10 pH per day. The canal is equipped with a small electrical mixer to mix the acid in the canal.

One danger of which the canal operator should be aware is the possibility of flooding the basement if canal purge is left on and all power to the building is off for electrical bus changes. Water will back up the warm catch tank vent system into the rod access room.

G. CANAL RECORDS

The experimental program depends upon accurate records. Every object leaving the reactor is logged in the ETR Canal Transfer Records. Each capsule in an experiment is listed separately, and all movements are recorded. As the experimental program gains momentum, the need for additional storage grids and accurate bookkeeping becomes more important. Originally, the flux monitors were stored on aluminum wires and hung on the working canal south parapet. Lately a flux monitor grid marked "W" has been added.

Occasionally, the hydraulic flow in the X-baskets will cause the experimental capsules to cut the X-basket in two pieces. This creates a difficult task of removing the capsules, spacers, and X-basket pieces from the reactor core. The capsules are then identified in the canal and stored for rebasketing.

An irradiated capsule or experiment cannot be removed from the canal without a signed ID-109 form or capsule removal form "Removal of Capsules from MTR-ETR Canal". The ID-109 form is made up in quadruplicate, and distribution is as marked on the ID-109 form. The Removal of Capsules from MTR-ETR Canal form is made up in triplicate.

The "Canal Transfer Record" form is the original working paper for the canal records and has to be accurate. Every piece coming from the reactor is identified, and reactor location is logged in with canal storage location. The canal transfer records are posted and recorded on canal inventory sheets which show at a glance the current storage grid inventory.

At first glance the canal transfer records seem to have more location transfer spaces than necessary. Taking a fuel element as a representative canal operation, the element is first stored in a storage grid, later transferred to the saw table for cutting, then transferred to a cut fuel storage grid, and finally shipped to the Gamma Facility or Chemical Processing Plant. Each movement must be properly logged.

Extreme care must be taken in handling fuel elements as they can easily be damaged. Fuel elements have a tendency to float when transferred through the water with any speed, which presents an additional radiation hazard. Health Physics surveillance is necessary whenever any object is removed from the canal whether or not it is in a cask.

CHAPTER XI

THE ETR ELECTRICAL SYSTEM

A. ETR GENERAL PLAN

1. NRTS Power

The power for the National Reactor Testing Station is furnished under contract with the Idaho Power Company and the Utah Power Company. These two companies are part of the Northwest Power Pool. Power is transmitted via Goshen to the Scoville substation. From Scoville, a loop system is used to furnish power to the site substations, including the TRA substations. From the Scoville (Central Facilities) substation, the loop extends to ICPP, TRA, NRF, TAN, ETR-2, and SPERT substations and then returns to Scoville.

A separate transmission line from American Falls to the TRA substation is contemplated, which would make the power supply essentially failure-free.

The ETR receives power on two incoming lines from the TRA substation. The ETR electrical system buildings and transformer yards include the TRA substation, the electrical building 648, the cable vault, the ETR transformer yard, and the White diesel building.

The power for the ATR is supplied in parallel to the ETR power supply. The connection is made on the 13.8 kV side of the transformers on incoming lines "A" and "B".

2. ETR History

The ETR was originally designed with four power systems: commercial or normal power; emergency power; failure-free power; and regulated power. Due to increased power demands on the failure-free system, it was necessary to purchase and install an additional White diesel generator unit. The emergency system was converted to utilize the standby emergency diesel unit as an additional operating diesel generator. The White diesel or the Enterprise diesel generator is in operation continuously, to supply power to the "E" bus.

Motor generator set No. 1, the original failure-free unit before the expansion of the electrical system, supplies one primary emergency pump and part of the experimenters' load. Other loads, including the second primary emergency pump, are supplied from the operating diesel. Uninterrupted power is thus supplied to such critical items as the primary emergency pump, some experimenters' loop pumps, and instrumentation. Continuous flow and instrumentation is provided for experimenters' loops which contain critical samples. The four systems now used, viz, normal, diesel generator power system, motor generator power system, and regulated power system, will be discussed in this manual.

B. THE 132 KV SYSTEM

1. ETR Incoming Power

Power is furnished for ETR distribution on two parallel lines tied into the 132 kV three-phase transmission line from the Scoville substation. The parallel lines enter the TRA transformer yard and pass through two horn gap switches to two 15,000 kVA 132/13.8 kV oil-filled transformers. These transformers are designed for tap changing under load to maintain a desired voltage level at the ETR (see Figure 28). Fans have been installed on these transformers to enable them to assume the load of the ATR.

Two 13.8 kV feeders connect the secondaries of the 15,000 kVA transformers to the 13.8 kV switch gear in the ETR electrical building. These feeders have been installed in two separate duct

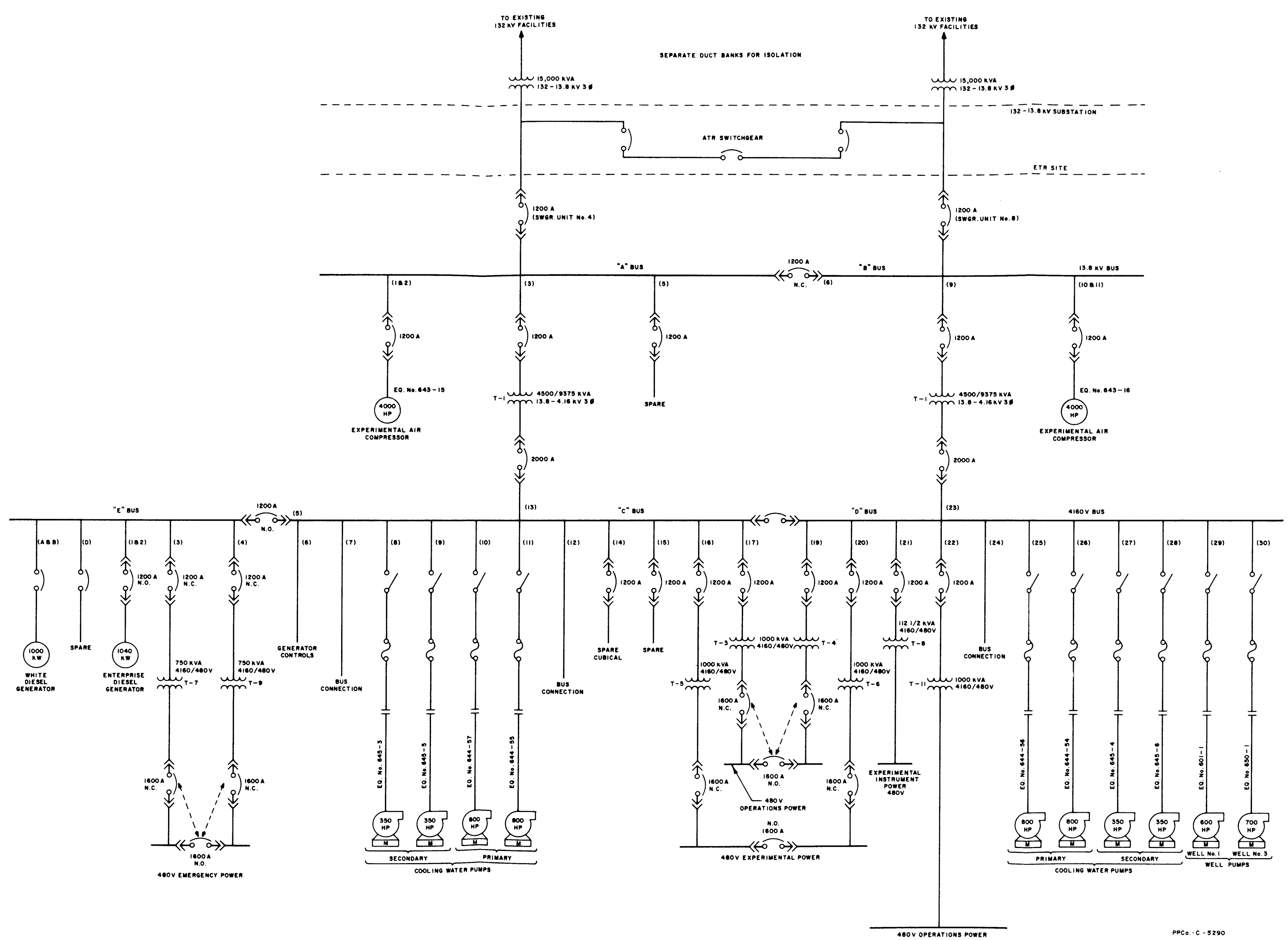

Fig. 28 ETR high voltage one line diagram.

lines, so that damge to one line will cause no interruption of power, since the remaining feeder will safely carry the entire load. The feeders are designated incoming line A, which furnishes power through the 13.8 kV breaker in unit 4, and incoming line B, which furnishes power through the 13.8 kV breaker in unit 8 of the 13.8 kV switchgear panel.

C. THE 13.8 KV SYSTEM

1. Incoming Lines

In building 648, the ETR electrical building, the 13.8 kV switchgear panel is located in the center of the west end. Incoming lines to "A" and "B" breakers are located in units 4 and 8, respectively, of this panel.

There are remotely operated close and trip relays for closing and opening the main incoming 13.8 kV line breakers in units 4 and 8 and bus tie in unit 6. These relays are operated from the TRA substation, or from the Scoville substation Supervisory Control Board. The permissive control switches located in units 4 and 8 will trip the incoming line breaker and prevent the breaker from being closed remotely. The A-B bus tie-breaker also is closed remotely.

The circuit breaker is composed of two parts, the breaker and the operating mechanism. They are rated at 1200 amps, have an interrupting rating of 25,000 amps and a momentary rating of 40,000 amps. They are electrically operated by a 125-volt dc control bus energized by the battery bank No. 1. When the breaker is closed, the red light on the panel will be on; when open, the green light on the panel will be on. When the white light is out, it indicates that the auxiliary relay (86) has tripped.

2. Metering

Each incoming line is metered with a voltmeter, ammeter, and wattmeter. The voltmeter reads the line voltage 1-2, 2-3, and 3-1. The voltmeter switch also has an "OFF" position. The ammeter switch has no "OFF" position and is turned to the position desired to read the line current in amperes. The wattmeter reads power in MW. The watthour demand meter for total power to ETR is located in the TRA substation.

3. Protective Relays

Sufficient protective relays are installed to open the incoming line breakers "A" or "B" whenever trouble develops. These protective relays have targets which remain down to indicate which relays were responsible for the breaker operation. (The protective relays duplicated on each incoming line are described below.)

(a) The time-delay directional overpower relay (67) will trip the main incoming line breaker. If this relay operates and opens the incoming line breaker, it will reset; but, the target will remain down until it is reset, indicating that this relay was responsible for the breaker operation.

(b) The three time over-current relays (51) will trip the main incoming line breaker. Relays automatically reset, but targets must be manually reset.

(c) The three over-voltage relays (59) trip the main incoming line breakers. Relays reset, but targets remain down until manually reset.

(d) Three directional over-current relays (67) and one directional over-current relay (67-G) will similarly trip the incoming line breaker.

(e) The under-frequency relay (81) on each 13.8 kV incoming line is set to trip at 58 cycles and operates two auxiliary relays. Auxiliary relays for line A are 81X-1A and 81X-1B, and for line B, 81X-2A and 81X-2B. The 1A and 2A relay trips the experimental air compressor on that incoming line and all operating primary pumps. The respective

4160 V feeder breaker also is opened (unit 13 or 23). The 1B or 2B relay scrams the reactor and closes valves PCV4-3 and PCV4-4. When either of the (81) relays operates, the target in the relay must be reset and the 81X relays must be manually reset. The under-frequency relays are located on the incoming 13.8 kV feeders, units 4 and 8.

(f) The auxiliary dual unit at the east end of the 13.8 kV panel contains the four directional over-current relays for each incoming line, as well as six under-voltage relays for the incoming lines of the 480 V switchgear.

4. Clark Compressor Switchgear

The 13.8 kV bus in this switchgear panel supplies two 4000 hp motors on the high-pressure experimental air compressors in the compressor building. The circuit breakers for the compressor motors are near each end of the bus in units 2 and 10, so that compressor No. 1 is normally supplied from line A and compressor No. 2 from line B.

Units 2 and 10 each have the following meters and relays.

(a) An ammeter for reading phase currents and a wattmeter reading the power in kilowatts.

(b) Three phase-current balance relays (46) which will trip the auxiliary lockout relay on phase unbalance.

(c) Three motor differential relays (87) which also will trip the auxiliary lockout relay.

(d) One time over-current relay (45/50/83) which will trip the auxiliary lockout relay.

(e) One residual over-current relay which will trip the auxiliary lockout relay if the line currents become unbalanced.

(f) One lockout relay (86) which will trip the compressor breaker. The breaker cannot be closed until the lockout relay has been reset.

Compressor No. 1 auxiliaries are located in unit 1, and compressor No. 2 auxiliaries are located in unit 11. The auxiliaries for each compressor include the following:

(a) One phase sequence and under-voltage relay (47) which will open the closing circuit on reverse phase, open phase, or under-voltage, and will trip the breaker on under-voltage.

(b) One thermal relay (26) which will trip the lockout relay. Open door of the unit to reset.

(c) One IRT temperature relay (49) which will operate an auxiliary relay, 49X, that will annunciate a high winding temperature. The annunciator sounds at the compressor building local panel and in the process water control room main panel. This relay is set on the temperature pickup adjustment dial target. Relay must be reset at the switchgear.

(d) Series contacts on the motor field contactor and the motor field contactor auxiliary relay (TDO) will trip the breaker on loss of field excitation.

(e) A recording kilovoltmeter, a dc ammeter, and voltmeter for the compressor motor exciter current and voltage.

(f) The exciter field rheostat.

(g) There is a recording watthour demand meter for each compressor, one in unit 5 and one in unit 6.

A normally closed tie breaker (A-B) in unit 6 of the 13.8 kV switchgear panel is utilized whenever it is necessary to open one of the incoming line breakers. Either line will carry the entire ETR load.

5. 13.8 kV Feeders to 4160 V Bus

Two feeders, with circuit breakers in units 3 and 9 of the 13.8 kV panel, supply power to the two 7500 kVA, 13.8/4.16 kV transformers. Each transformer is capable of delivering the total load to the 4160 volt bus. The transformers have tap changers, but must be de-energized before changing taps. These permit the 4160 voltage to be raised or lowered, depending upon whether the voltage is too low or too high.

The 13.8 kV feeders for transformers No. 1 and 2 have the following protective devices on each feeder:

(a) Two time over-current relays with instantaneous elements (50/51) which will trip the breaker on line over-current.

(b) Time over-current relay (51N) which will trip the breaker on large unbalances between phases, and a time over-current relay (51G) which will operate the auxiliary lockout relay.

(c) Three current percentage differential relays which will operate the auxiliary lockout relays.

(d) One lockout relay which will trip the breaker and open the closing circuit. This relay must be reset before the breaker can be closed.

(e) One desensitizing relay (87X), which is time delay opening and instantaneous closing. This relay is operated by the combination of either the loss of potential on the 13.8 kV potential bus or the opening of the feeder breaker in the 13.8 kV switchgear and either the loss of potential on the 4160 V bus or opening of the feeder breaker in the 4160 switchgear. Operation of the relay closes contacts, completing a resistive shunt across the trip coils of the (87) relays, thus preventing the inrush current to the transformers from operating the (87) relays.

D. 4.16 KV SYSTEM

1. The 4160 V Bus

The 4160 V system includes three busses: the "C", "D", and "E" busses. Transformer No. 1 in the ETR transformer yard feeds the 4160 V bus "C" through the line breaker in unit 13 of the 4160 V switchgear panel.

Transformer No. 2 feeds the 4160 V bus "D" through the line breaker in unit 23 of the 4160 V switchgear panel. The diesel generators feed the "E" bus directly with no transformer.

The 4160 V switchgear is the metal-enclosed type with drawout air breakers and current limiting starters. As before, the red light indicates the breaker is closed, the green light indicates the breaker is open. A white light out indicates the auxiliary relay has been tripped. A yellow light on indicates the breaker was operated by relay action. A yellow light out indicates the breaker was tripped with the permissive control switch.

Bus "E" ties into bus "C" through the normally open 24 CE tie-breaker. "E" bus is fed power from one of the diesel generator systems. Normal operation will require either the Enterprise diesel or the White diesel on the line to feed bus "E". (See Figure 29, ETR power distribution diagram.)

2. Metering

Each of the incoming lines to the 4160 V bus is metered as follows: an ammeter for reading line currents, a voltmeter for reading line voltage, a wattmeter which reads real power, and a varmeter which reads reactive power.

3. Protective Relays

The incoming 4160 V feeders in units 13 and 23 each have the following:

(a) Two time over-current relays (51) which will trip the incoming breaker on line over-current after operation. The target must be reset.

(b) One time over-current relay (51N) which will trip the incoming line breaker

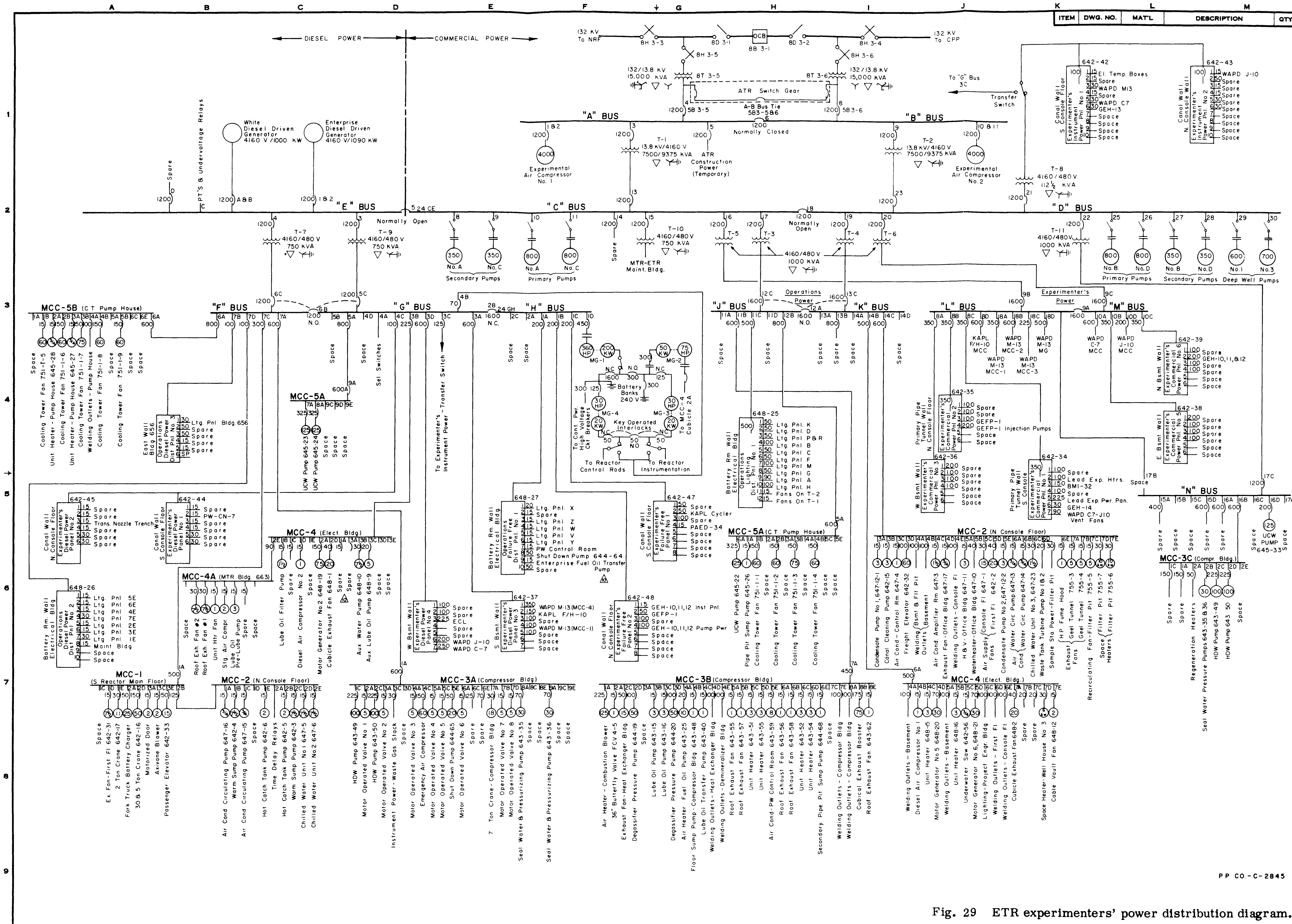

Fig. 29 ETR experimenters' power distribution diagram.

on large unbalances between phases.

(c) A contact on the 86T auxiliary lockout relay located in unit 3 or 9 of the 13.8 kV switchgear will trip the breaker. Another contact on the same relay will open the closing circuit. This will isolate the 13.8/4.16 kV transformer on the corresponding line.

(d) The under-voltage relay (27) in unit 13 operates two auxiliary relays, 27X-1A and 27X-1B. The under-voltage relay (27) in unit 23, operates 27X-2A and 27X-2B. On each line, the auxiliary relay 1A or 2A are spares. The auxiliary relays 27X-1B or 2B, one on each incoming line, scram the reactor and close valves PCV4-3 and PCV4-4.

(e) An interlock is provided that will prevent closing the 24 CE tie-breaker if the breaker on the incoming feeder in unit 13 and the CD tie-breaker are open at the same time.

The CD tie-breaker, located in unit 18 between "C" and "D" busses, is normally open. This breaker would be utilized if one of the incoming lines required maintenance.

4. Loads - Busses "C" and "D"

Bus "C" carries primary pumps A (644-57) and C (644-55), secondary pumps A (645-3) and C (645-5), as well as feeders to the 4160/480 V transformers T-3, T-5, and T-10. Refer to the high voltage one-line diagram, units 8 through 17, inclusive. Bus "D" carries primary pumps B (644-56) and D (644-54), secondary pumps B (645-4) and D (645-6), deep well pumps No. 1 and No. 3, and transformers T-4, T-6, T-8, and T-11. These include units 19 through 30.

Each 4160 V feeder for transformers T-3, T-4, T-5, T-6, T-8, T-10, and T-11 is protected with time over-current relays and also has a line current ammeter and a wattmeter. Unit 21, containing the feeder and breaker for T-8, and unit 15 containing the feeder and breaker for T-10 do not include wattmeters.

Each primary pump motor has a line current ammeter, located in the electrical building, as well as a dc ammeter and dc voltmeter reading field current and voltage. Also, each primary pump motor has the following protective relays:

(a) A thermal overload relay which trips on overload. Reset by pressing reset button.

(b) The squirrel cage protective relay (SCR) trips if the motor is operated on the squirrel cage winding long enough to overheat the winding. Reset by pushing reset button.

(c) The ground fault relay and auxiliary relay opens the control circuit and drops out the contactor on short circuit or an open line. Target must be manually reset.

(d) The field application relay (FR) and the auxiliary relay (FRX) apply the field when the motor has reached the required speed and the exciter voltage is high enough to pull the motor into step.

(e) The power factor field removal relay (PFR) removes the dc field when the machine pulls out of step and stops the motor.

The exciter field rheostat will vary the exciter field current which will vary the motor field voltage. When the pump is operating at full capacity, the rheostat should be adjusted so that the motor line current will be a minimum. At this exciter voltage, the motor will be operating at 100 percent power factor.

The main contactor on each breaker is remotely operated from a "START-STOP" switch in the process control room.

Each secondary pump motor switchgear unit in the 4160 V panel in the electrical building has a line current ammeter, as well as the following protective devices: a ground fault relay, a thermal overload relay, and a disconnect switch which operates the same as those on a primary pump. The main contactor is remotely operated from the process control room.

The deep well pumps have a line ammeter, a ground fault relay, a thermal overload relay, and a disconnect switch.

5. Diesel Generator Power Distribution - 4160 V "E" Bus

The 4160 V "E" bus is normally supplied power by either the Enterprise or the White diesel generator. As mentioned previously, the "E" bus may be fed by commercial power through the "CE" tie-breaker in case both diesels are inoperable. All of the control equipment for the 4160 V diesel power supply and distribution are contained in the following 4160 V switchgear panels: Units 1, 2, 3, 4, 5, 6, 7, A, B, C, and D.

Unit 1 contains the following Enterprise diesel generator equipment:

(a) A dc ammeter which indicates the generator field current.

(b) A dc voltmeter which indicates the generator field voltage.

(c) A Watthour demand meter which indicates demand in kilowatts and energy in kilowatt hours.

(d) A field rheostat which is used to adjust the field excitation on the generator.

(e) Three percentage differential relays (87) which operate the lockout relay on generator phase unbalance.

(f) A power directional relay (67P) which will open the main generator breaker (52G) when excessive power flows into the generator.

(g) An instantaneous voltage relay (83) prevents closing the feeder breaker on low generator voltage.

Unit 2 contains the following Enterprise diesel generator equipment:

(a) The main breaker is contained in this unit, but is closed from unit 7 where a synchroscope and a control switch are provided.

(b) An ammeter with accompanying selector switch which indicates the generator output current in each of the phases.

(c) A varmeter which indicates reactive power in kilovars.

(d) Three overcurrent relays with voltage restraint (51G) which operate the lockout relay (86G) on time overcurrent.

(e) Two overcurrent relays (50/51) with inverse time characteristics will operate the lockout relay (86G) on overcurrent.

(f) One time overcurrent relay (51N) operates the lockout relay (86G) on time overcurrent.

(g) The lockout relay (86G) will trip the generator main breaker (52G) and must be turned to the reset position before the breaker can be closed.

(h) The permissive switch will trip the generator main breaker (52G) and must be reset to the "NORM" position before the breaker can be closed. This switch is provided with a red (closed) and a green (open) indicating light.

Units 3 and 4 contain the following "E" bus equipment:

(a) The 4160 V feeders for the 750 kVA transformers T-9 and T-7, respectively. These transformers, T-9 and T-7, furnish diesel generator power from the "E" bus to the 480 V "F" and "G" busses, respectively. The "H" bus also is fed by the "G" bus through the 24GH tie-breaker.

(b) Each unit has a line ammeter, with an accompanying selector switch.

(c) Each unit has a wattmeter.

(d) Each unit has a two position, trip and close, breaker control selector switch, with red, green, and amber (auxiliary relay trip) indicating lights.

(e) Each unit has two time overcurrent relays with instantaneous elements (50/51) which will trip the breaker on overcurrent.

(f) Each unit has one time overcurrent relay (51N) which will trip the breaker on large phase unbalances.

Unit 5 contains commercial diesel generator power bus tie-breaker (24 CE) and the following associated equipment:

(a) A permissive control switch that may be used to manually trip the breaker. This switch must be reset before the breaker can be closed.

(b) A contact on the 24CE breaker will scram the reactor any time the tie-breaker (24CE) is closed. This contact is in parallel with the 81X, 27X, and 27EX contacts which will scram the reactor on underfrequency and undervoltage on the commercial feeders and on undervoltage on the "E" diesel bus.

Unit 6 contains the synchronizing equipment and control switches for the 24 CE tie-breaker and the 24GH tie-breaker. It also contains the Enterprise diesel generator automatic synchronizing relays. The equipment in unit six is described below:

(a) A synchronizing relay (25) with associated equipment, including the speed matching relay, automatically synchronizes the Enterprise diesel speed, if it is operating and on the line, with the "C" bus and will close the 24CE tie-breaker. The same automatic synchronizing equipment is used for adjusting the speed of MG-1 to synchronize across the 24GH tie-breaker.

(b) Four synchronizing auxiliary relays (52Z) for use with the associated synchronizing equipment. These relays, among other functions, remove the synchronizing equipment from the circuit after the synchronizing has taken place and the associated tie-breaker has been closed.

(c) A speed matching relay (15) which controls the governor of the Enterprise diesel and MG-1 while the automatic synchronizing is taking place.

(d) A frequency relay (81) which prevents the operation of the synchronizing equipment until the generator, in the case of the "E" bus, or the motor of MG-1 in the case of the "H" bus, is at synchronizing speed.

(e) A voltage relay (27) which requires full ac control voltage for synchronization.

(f) A synchronism check relay (25A) which works in conjunction with the synchronizing relay (25).

(g) A two position "OFF" and "ON", "24GH auto Sync MG-1 to Line" switch which must be actuated to automatically synchronize the "G" bus with MG set No. 1 and close the GH tie-breaker.

(h) A control selector switch (43A) with "AUTO" and "MAN" positions for use in synchronizing.

(i) A synchronizing selector switch with "4160 V", "OFF", and "480 V" positions.

(j) An automatic synchronizing switch (43T) with "4160 V" and "480 V" positions. This switch has a spring return to the "480 V" position.

(k) A governor control switch (65) with "RAISE" and "LOWER" positions. This control switch is for the Enterprise diesel only.

(l) A voltage adjusting rheostat for the fine adjustment of the excitation on the Enterprise diesel generator. This operates in conjunction with the field rheostat located in unit No. 1.

(m) A two position "TRIP" - "CLOSE" generator field breaker control switch (41CS) with red, green and amber indicating lights.

(n) A two position "TRIP" - "CLOSE", "CE" bus tie-breaker control switch (24CE) with red, green, and amber indicating lights.

(o) A two position "TRIP" - "CLOSE", "GH" bus tie-breaker control switch (24 GH) with red, green, and amber indicating lights.

(p) A voltmeter with associated selector switch which indicates the phase voltage from the Enterprise diesel.

(q) A frequency meter which indicates the frequency from the Enterprise diesel.

(r) A wattmeter which indicates the power from the Enterprise diesel.

(s) A synchroscope which indicates the synchronism of the selected system.

Unit 7 contains the synchroscope and the control switch for the Enterprise diesel generator main breaker (52G). This breaker can be manually closed only. The governor speed control switch is in unit 6. After the speed of the diesel has been adjusted and the synchroscope in unit 7 indicates synchronization the control switch in unit 7 can be used to safely close the breaker. A reactor scram is initiated when this breaker is opened unless the reactor control room "W" switch No. 32 is in the "OFF" position.

Unit A contains the White diesel generator field breaker and the following associated equipment.

(a) A dc ammeter which indicates the generator field current.

(b) A dc voltmeter which indicates the generator field voltage.

(c) A two position "TRIP" and "CLOSE" generator field breaker control switch (41CS) with red, green, and amber indicating lights.

(d) A lockout relay (86G) will trip the generator main breaker (52G). The lockout relay must be reset before the main breaker can be closed. A white indicating light is lit when the lockout is released.

(e) Three percentage differential relays (87) which will operate the lockout relay (86G) on a generator phase unbalance.

(f) A synchronism check relay (24). This relay prevents closing the generator main breaker (52G) when the generator and the "E" bus frequencies are out of phase.

(g) A reverse power relay (67P) is provided which will open the generator main breaker (52G) on reverse power across the main breaker from the "E" bus into the White diesel generator.

(h) A field rheostat for adjusting the diesel generator field excitation.

(i) Fine adjustment knob for field excitation.

Unit B contains the White diesel generator breaker (52G) and the following associated equipment:

(a) A two position "TRIP" and "CLOSED" main breaker control switch with red, green, and amber indicating lights.

(b) A two position "RAISE" and "LOWER" governor control switch.

(c) A two position "ON" and "OFF" synchroscope control switch.

(d) An ac ammeter which indicates the generator output current. This meter is equipped with a selector switch for selecting any one of the phases.

(e) An ac voltmeter that indicates the generator output voltage in kilovolts on the phase selected by an associated selector switch.

(f) A varmeter which indicates the reactive power in kilovars.

(g) A wattmeter which indicates the power in megawatts.

(h) A frequency meter which reads the frequency in cycles per second.

(i) A synchroscope with slow and fast indication.

(j) Three overcurrent relays with voltage restraint (51G) which will operate the lockout relay (86G) on time overcurrent.

(k) One time overcurrent relay (51N) which will operate the lockout relay (86G) on time overcurrent.

The main breaker must be closed manually. After the diesel speed has been adjusted with the governor speed control switch, and the synchroscope indicates synchronization, the main breaker can be safely closed. A reactor scram is initiated when the breaker is opened providing the reactor control room "W" switch No. 24 is in the "ON" position.

Unit C contains the following equipment:

(a) Two voltage relays (27E) which actuate two auxiliary relays (27EX) on low "E" bus voltage.

(b) Two auxiliary voltage relays (27 EX) which actuate the following: Reactor scram, open the "GH" tie-breaker and a reactor control room alarm. As mentioned above, these relays are actuated by the 27E relays.

(c) A 27 dc relay in the rear of unit C will give a control room alarm on loss of power or fuses to the auxiliary voltage relays (27EX).

(d) A voltmeter with associated selector switch which indicates the voltage on the "E" bus.

(e) Three spare phase directional overcurrent relays.

(f) A spare potential transformer.

Unit D contains a spare feeder breaker with associated equipment.

6. Synchroscopes

The synchroscope indicates the phase difference between two busses fed from different power supplies (such as commercial and diesel) or between two machines.

The words FAST and SLOW on the scale indicate that the frequency of the incoming machine is respectively higher or lower than that of bus or running machine. Clockwise rotation of the pointer signifies that the incoming machine is operating faster than the running machine; counterclockwise rotation indicates that the incoming machine is operating slower than the running machine.

Synchronism is indicated when the difference in the phase angle is zero and the instrument pointer is over the index at the top of the scale (12 o'clock position). If the pointer oscillates at a fixed position or if the pointer oscillates and simultaneously rotates at an irregular velocity, the phase difference still exists. The needle should rotate clockwise past the index with a smooth and continuous movement.

E. THE 480 V SYSTEM

1. 480 V Distribution

The 480 V distribution system supplies commercial and diesel generator power to the plant and experimental loads. Transformers T-3, T-4, and T-11 supply operations commercial power to "J" bus, "K" bus, and "N" bus, respectively. Transformers T-5, T-6, and T-8 supply experimenters commercial power to "L" bus, "M" bus and to the experimenters instrument power panels 1 and 2, respectively. In the event of a commercial power failure a transfer switch on the secondary side of T-8 will operate to supply diesel generator power from the "G" bus to this portion of the experimenters load.

The 480 V feeder breakers to "J" and "K" bus from T-3 and T-4 are located in units 12C and 13C, respectively. These feeders are equipped with undervoltage relays (27) located in the dx panel of the 13.8 kV switchgear, which will open the feeder breakers in units 12C and 13C. A tie-breaker (24JK) located in 12A will automatically close if one of the incoming feeder breakers opens, provided the pistol grip switch (unit 4A) is in the automatic position.

Two 750 kVA transformers, T-7 and T-9, with feeders from the "E" bus furnish busses "F", "G", and "H" with diesel generator power during normal operations. When a diesel generator power outage occurs, the 24GH tie-breaker will open and MG-1 powered by battery bank No. 1 will invert and furnish power to the "H" bus.

The 480 V feeders from T-7 and T-9, to busses "F" and "G", respectively, are equipped with undervoltage relays (27), located in dx panel of the 13.8 switchgear, which will open the feeder breakers in units 6C and 5C. When either of these breakers open they are interlocked with the tie-breaker (24FG) to automatically close the tie-breaker and transfer the load to the other feeder if the pistol grip switch (unit 4A) is in the automatic position.

In general, 480 V power is furnished from the feeders to the 480 V busses in the switchgear panel and then to various motor control centers throughout the plant. With exception of motor control center No. 1 which is supplied with diesel generator power only, the motor control centers are supplied with both commerical and diesel generator power. Other units in the 480 V switchgear supply power directly to various pieces of experimental equipment. Critical items which are usually backed up by a duplicate pump, etc, are split so that one pump is supplied with diesel generator power and the other is supplied with commerical power. Therefore, a power failure of either source of power may result in shutting down the operating pump, but the standby pump will be picked up by the backup power system. In addition (referring to the distribution diagram, Figure 29) one emergency and shutdown pump is supplied from the operations failure-free power distribution panel, circuit 9. This panel is supplied from the failure-free bus "H" through unit 1A of the 480 V switchgear panel. The other pump, connected to MCC 3A, is supplied by a 480 V feeder from unit 7A.

2. Motor Control Centers

Motor control centers are located throughout the plant for 480 V distribution. Each center is labeled with a number and the individual units are labeled to indicate what the breaker controls. Each unit with contactors and starters has indicating lights. A red light indicates the contactor or starter is closed; a green light indicates the circuit is energized and the contactor or starter is open. When the lights are out, the motor control center is de-energized. Each motor control center can be de-energized with the panel main breaker or by opening the feeder breakers in the 480 V switchgear panel. The motor control center panels contain both commerical power circuits and diesel generator power circuits.

Motor Control Center No. 1 is supplied with diesel generator power and is located on the south side of the main reactor floor.

Motor Control Center No. 2, located on the north console floor, supplies both commercial and diesel generator power.

Motor Control Center No. 3 is located above the process control room. MCC-3A is supplied with diesel generator power. MCC-3B and MCC-3C are supplied with commercial power.

Motor Control Center No. 4 is located in the electrical building and is supplied with both commercial and diesel generator power.

Motor Control Center No. 5 is located in the Secondary Pump House. MCC-5A is supplied with both commercial and diesel generator power. MCC-5B is supplied with diesel generator power only.

3. Lighting

Power for lighting is furnished from commercial, diesel generator and failure-free lighting distribution panels, energized from the 480 V switchgear panel. They are located at the east end of the electrical building. In general, each breaker in a lighting distribution panel furnishes power for one 480/240/120 V, single-phase transformer and lighting panel.

The commercial lighting distribution panel is a 480 V, three-phase panel energized by closing the breaker in 11C of the 480 V switchgear, "J" bus.

There are two diesel generator lighting distribution panels. The panel fed from unit 7d, 480 V switchgear panel, is the old emergency system panel. The panel schedule should be checked before opening any of these breakers as they furnish power for solenoids and other important equipment.

The failure-free lighting distribution panel is fed from unit 1a of the 480 V switchgear panel. The branch breakers should never be opened while the reactor is operating, and during shutdown they can be opened only during an emergency. The panel schedule shows the equipment fed from this distribution panel.

4. Communications and Alarm Systems

The entire ETR area is served by the commercial telephone system. A code call chime, lights, and horn system are installed.

The intercommunication network consists of six intercommunication systems: "A", "B", "D" and "E" circuits; the supervisor's intercom circuit; and a paging system, "P", circuit.

The "A" system provides two-way communication between the reactor control room and remote stations located on the three floors of the reactor building, the electrical building, the process control room, the health physics office, and the instrument repair shop. Either the control room or remote stations may originate calls, and two or more remote stations may communicate with each other through grouping controls at the console. The master controlling station is built into the reactor control room console.

The "B" system is designed to provide communication between the reactor control console and three remote stations located on the first floor, in the sub-pile room, and in the control rod access room. Any remote station can be used as a master station, capable of monitoring the other two, and also communicating with them as a group. The reactor control console is a second master station.

The "D" system provides sound-powered telephone stations throughout the plant, and includes the reactor control room stations. This system provides communication where remote calibration or control is involved. The "E" system provides sound-powered stations for experimenters' use. The experimental facilities sound-powered telephone system connects the reactor control room and experimental areas.

The supervisor's intercommunication circuit provides the supervisor with direct communication to the reactor control room.

The paging system, "P", provides a network of loudspeakers for paging coverage of all floors of the reactor building, the process control room, the office building corridors, change room, and rest rooms.

The fire alarm and sprinkler overflow alarm systems are connected to the corresponding alarm circuits which will sound single-stroke coding-type gongs and a coding fire alarm horn. All ETR and MTR gongs and horns sound the code of any box operated in either area.

The watchman reporting system in the MTR area has been expanded to provide adequate coverage of the ETR area.

The reactor warning horns are provided for each floor in the reactor building to sound continuously for 10 seconds prior to reactor start-up. The warning lights, internally illuminated signs engraved "REACTOR ON", are placed around all floors of the reactor building, in the reactor room, process room, and the demineralizer control room in MTR Building 608.

The evacuation siren system has been extended to cover the ETR area. Also, an evacuation alert alarm is connected between the MTR and ETR control rooms. The ETR evacuation siren is activated by a switch in the ETR reactor control room. Evacuation sound-powered phones connect the MTR-ETR shift supervisors' offices, the reactor control rooms for both plants, and the steam plant.

F. THE REGULATED POWER SYSTEM

1. Motor Generator Sets (see Figure 30)

The regulated power system consists of an ac-dc induction motor-generator set, MG set No. 2; one dc-ac motor-generator set, MG set No. 3; a 258-volt storage battery bank No. 2, as well as the necessary switchgear for its operation. The regulated power system provides power to the reactor instrumentation.

MG set No. 2 is a two-piece unit; direct-coupled, open-type, rigidly constructed and mounted on a common welded steel base plate. The motor is an induction type designed for 440-volt, three-phase, 60-cycle power, and is rated 75 hp. The dc generator will deliver 50 kW at 250 volts. It is a two wire dc generator receiving its excitation from the 240-volt dc bus.

MG set No. 3 is a two-piece unit with shaft exciter; direct-coupled, open-type, rigidly constructed, and mounted on a common welded base plate. The 30-hp motor is designed for operation on 240 volt dc power. This motor will operate over a voltage range from 258 to 207 volts. This range includes operation when the battery bank is fully charged to emergency conditions, when the battery bank is discharged. The generator will deliver 20 kW at 480 volts, three-phase, 60-cycle terminal voltage at 0.8 power factor.

The storage battery bank for the regulated power system consists of the 120-cell battery bank No. 2. The bank is able to deliver a constant load of 50 kW for at least 25 minutes to a minimum of 207 volts at the battery terminals.

2. Operation

Under normal operating conditions, MG set No. 2 will be operated from the

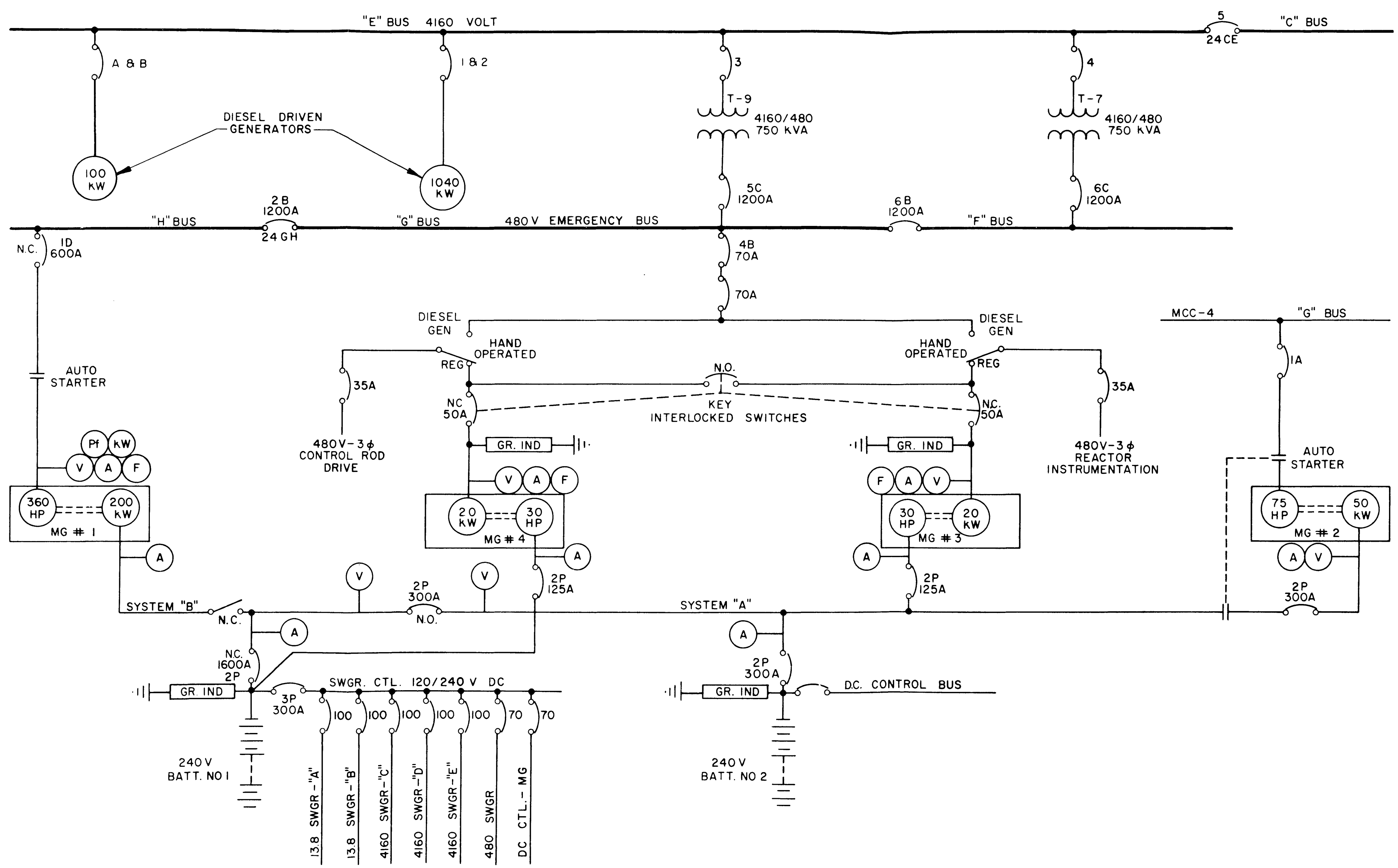

Fig. 30 ETR regulated power schematic.

480 V diesel generator bus "G" and will be furnishing dc power to MG set No. 3. MG set No. 2 will simultaneously float the storage battery bank No. 2 at 258 volts. MG set No. 2 is provided with adequate voltage regulators to maintain a constant 258 dc volts at the battery terminals at all times that the battery banks are floating, except during an equalizing charge.

The alternator of MG set No. 3 will normally supply its own load and will operate at approximately 50 percent of its full rated capacity. Either MG set No. 3 or No. 4 is capable of supplying enough power for both MG set loads in case one MG set should fail. There are hand-operated and key-interlocked transfer switehes to transfer loads to one MG set if required, but will prevent the MG sets from being operated in parallel.

The power from MG set No. 3 should be constant, even during a diesel generator power failure. If MG set No. 2 should stop, it would be automatically disconnected from the storage battery bank to prevent it from being motorized. MG set No. 3 will continue to operate from the storage battery bank and supply uninterrupted power to the reactor instrumentation. After diesel generator power is restored to MCC-4, the timing relay closes, which supplies power to MG set No. 2. The MG set will start automatically and will again supply dc power to operate MG set No. 3, as well as recharge battery bank No. 2 and then float it on the line.

An equalizing charge will be applied to the storage battery banks periodically. This will, however, only be done while the reactor is shut down. Before placing battery bank No. 2 on an equalizing charge, MG set No. 3 must be shut down and any reactor instrumentation power will be obtained from the diesel generator power supply by closing a manually-operated knife switch. Suitable controls are provided by which the dc voltage delivered by MG set No. 2 will be readjusted to 280 volts for an equalizing charge of not less than 10 amps continuously. The equalizing charge control relay is interlocked so that an equalizing charge cannot be started while MG No. 3 is in operation. MG No. 3 cannot be started while an equalizing charge is taking place. The equalizing charge relay also is connected to the control of MG set No. 2 to automatically drop out the equalizing charge relay and reduce its terminal voltage to 258 volts at any time the normal power fails during the equalizing charge. (See Figure 30, Regulated power schematic.)

G. THE MOTOR GENERATOR OR FAILURE-FREE POWER SYSTEM

The motor generator or failure-free power system supplies power to the "H" bus loads and to the reactor controls during a diesel generator power outage. The "H" bus supplies power to one of the primary emergency and shutdown pumps which supplies a continuous cooling water flow through the reactor tank. Certain experimental loop instrumentation and circulating pumps also are supplied with failure-free power from this bus. During normal operation, the "H" bus and MG No. 1 are supplied by diesel generator power. MG No. 1 is, in turn, supplying dc power to float storage battery bank No. 1 at 258 volts, as well as to power MG No. 4. MG No. 4, directly connected to battery bank No. 1 line, supplies reactor control power.

The MG power system consists of one inverter motor-generator set, MG No. 1; one dc-ac motor-generator set, MG No. 4; a 258-volt storage battery bank No. 1; and associated switchgear for system operation.

MG set No. 1 is a two-piece unit with a shaft-mounted exciter, direct-coupled, open-type, rigidly constructed, and mounted on a common steel base plate. The ac synchronous machine operates on 480 V, three-phase, 60-cycle power and is rated at 300 hp when operating as a motor, and 250 kW when operating as an alternator. The dc machine operates on 240

V and is rated at 360 hp when run as a motor, and 200 kW when run as a generator.

MG No. 4, identical to MG No. 3 described in previous paragraphs, supplies uninterrupted power to the reactor controls and is connected directly to battery bank No. 1.

Storage battery bank No. 1 consists of a 120-cell battery bank with a normal voltage of 258 volts and has a capacity to supply 285 kW for approximately 20 minutes to a minimum of 207 volts at the battery terminals. As mentioned in a previous paragraph, the battery bank will occasionally be placed on equalizing charge. MG No. 4 must be shut down and the manually-operated knife switch closed to supply the reactor controls with power from the "G" bus. There is no protective interlock on MG No. 4 at present, and it must be manually stopped before starting an equalizing charge on battery bank No. 1. The equalizing charge will be automatically interrupted should the 24 GH tie-breaker open due to a diesel generator power outage. MG No. 1 will supply an equalizing charge of 280 V and not less than 25 amps to battery bank No. 1.

The dc generator on MG set No. 1 has a thermal overload relay, which will open the main generator breaker to the battery bank if the generator output is excessive. An overspeed trip also is provided for the protection of the machine. If any of the breakers between battery bank No. 1 and the "H" bus should open an annunciator will sound in the reactor control room.

H. THE DIESEL GENERATOR POWER SYSTEM

1. Purpose

The diesel generator power system is supplied power by two diesel generator units, a White and an Enterprise. The diesel generator units supply power directly to the "E" bus. One feeder from the "E" bus, through transformer T-9, supplies the 480 V "G" and "H" busses and the other feeder, through transformer T-7, supplies the 480 V "F" bus.

With the increased experimental and plant loads it was necessary to modify and expand the electrical system. The system was expanded to incorporate a split bus philosophy, a commerical bus and a diesel generator bus. With this system it is possible to supply critical loads with both commercial and diesel generator power. These two power sources are completely independent of one another and only at times of shutdown or maintenance of both diesels at one time will they be tied together by closing the 24CE tie-breaker.

One of the diesels will normally be running at all times. In addition, during a diesel generator power outage, a small portion of the diesel generator power system, the "H" bus, is supplied by a battery bank through a motor generator set which makes this bus virtually failure-free.

2. The Enterprise Diesel Generator

The Enterprise diesel generator unit is composed of a 1525 hp diesel engine, a direct-coupled generator, 1300 kVA at 0.8 power factor, and the auxiliary equipment. When the Enterprise diesel is operating, the generator supplies power to the "E" bus through the generator breaker 52G. The breaker located in unit 2 is manually controlled from unit 7 of the 4160 V switchgear panel where a synchroscope is provided.

The power output of the diesel generator can be read on the wattmeter in unit 6 in kilowatts. The total diesel generator load can be determined by totaling the kilowatts of the wattmeter readings on the primaries of the 4160/480 V feeders, units 3 and 4.

The diesel is started by air released from the diesel air receiver by a solenoid valve actuated by a manual start button. This solenoid is de-energized when the diesel is operating at 50 percent of its normal voltage. Flows, temperatures, and pressure are indicated on the diesel panel. A multi-point recorder provides monitoring of the discharge gas temperature from each cylinder, the stack gas, cylinder exit water, jacket water, and lube oil temperatures. Annunciator horns sound and a local annunciator light shows whenever an off-normal condition exists. One horn is located above the diesel control panel and another is located in the reactor building main floor low bay area just south of the canal. An annunciator will also sound in the reactor control room when an alarm sounds at the Enterprise panel if the Enterprise "W" switch is on. "Silence", "Reset", and "Test" buttons are provided for the annunciator system.

The fuel oil system is supplied from the main storage tanks located in the MTR area. The oil is fed to a 1500-gal underground tank by the electrical building. Control of the oil level in the tank is accomplished by means of limit switches. The low limit switch will open a solenoid valve on the supply line and turn on the transfer pump. The high limit switch will close the solenoid valve and shut off the pump. Fuel oil is metered as it enters the underground tank. The oil is gravity fed from a start-up tank to the engine mounted pump for priming purposes. The main pump, rated at 4 gpm and 50 psig, supplies oil from the underground tank to the diesel with excess oil being returned to the tank. There is an oil strainer on the main pump outlet, as well as a pressure alarm. There is also a standby pump in the system which is not engine mounted. This pump is controlled from the diesel control panel.

The lube oil for the engine is supplied from a 275-gal reservoir. The lube oil pump, which is engine mounted, transfers the lube oil from the reservoir through the heat exchanger and into the engine. The lube oil is returned from the engine to the reservoir. The system also has a standby pump which is activated by low pressure in the lube oil system.

The jacket water system is a closed system with a surge tank floating on the line. The surge tank is kept filled by means of a float valve on the supply line to the tank. The supply is a 3/4-inch potable water line. The main pump is engine mounted and has an output of 300 gpm. Flow from the pump goes through the jacket and is split into two streams. One stream of 30 gpm passes through the air supercharger and from there back to the pump suction. The other stream of 270 gpm provides jacket cooling and then passes through a heat exchanger and back to the pump suction. A standby pump is activated by high water temperature. The R4 relay is energized at 180°F by TS-3. A contact on the R4 relay closes to start the standby auxiliary pump.

The diesel heat exchangers utilize a utility cooling water flow of 400 gpm at 60 psig and approximately 80°F. A flow of 200 gpm passes through the lube oil heat exchanger and 200 gpm passes through the air intake intercooler and back to the UCW main line. The combined stream at 400 gpm then flows through the jacket water heat exchanger and back to the return header.

The generator has a rated capacity of 1040 kW at 600 rpm, 0.8 power factor and 4160 volts. The exciter is belt driven from the generator shaft and is rated 15 kW at 1750 rpm, 250 volts.

3. The White Diesel Generator

The White diesel generator unit is composed of a 1423 hp diesel engine and a direct-coupled 1250 kVA at 0.8 power factor generator. When the White diesel is operating it supplies power to the "E" bus through the diesel generator main breaker, 52G. The main breaker is located in unit B. The breaker control switch and synchroscope also are located in this unit.

The power output of the diesel is read on a wattmeter in unit B. The total generator load can be obtained by totaling the kilowatts on the wattmeter readings on the primaries of the 4160/480 V feeders in units 3 and 4.

The diesel is started by air released when the air starting pull rod is pulled. When the engine is firing on all cylinders, the air starting pull rod should be released. This will automatically shut off the starting air. Pressures and temperatures are indicated on the diesel panel and at various locations on the diesel auxiliary piping. The panel is equipped with a trouble horn and lights. The horn will sound and the light will be lit above the item that caused the alarm. When this alarm sounds, an alarm also will be sounded at the west end of the reactor building low bay. An annunciator also will sound in the reactor control room if the reactor control room "W" switch No. 24 is on.

The fuel oil supply system for the White is common to that described for the Enterprise. The engine mounted pump supplies oil from the underground tank to the diesel with the excess oil being returned to the tank. There is an oil filter on the outlet of the diesel oil pump. The pump also is equipped with a high pressure relief valve.

The lube oil for the engine is supplied from a 225 gal reservoir. The auxiliary lube oil pump is started and lube oil is circulated thirty minutes prior to starting the diesel engine. The auxiliary pump is stopped automatically when the engine is started and the engine mounted pump assumes the flow. The engine mounted pump then takes over and circulates the lube oil from the lube oil sump tank through the filter, through a temperature control valve set at approximately 160°F, through the heat exchanger, through the engine, and finally back to the lube oil sump tank. The auxiliary pump automatically starts when the diesel engine is shut down. It performs a thirty minute post cooling cycle before timing out and shutting down.

The jacket water system is a closed system with a 65 gallon surge tank floating on the line. The jacket water is circulated by an engine mounted pump with an output of approximately 320 gpm. Flow from the pump goes through the engine jacket. A small side stream also goes to the turbocharger. The water is then collected on the outlet of the jacket and the turbocharger and goes from these to a 3-way temperature control valve, to the jacket water cooler, and then back to the suction of the pump. The surge tank floats on the line at the outlet of the jacket. The surge tank level is maintained by an automatic liquid level control system, supplied by a 1/2 inch service water line. Make-up water is supplied to the jacket water system from the surge tank on the suction side of the pump. The temperature of the jacket water from the engine and from the turbocharger is controlled between 155 and 170°F.

UCW is used for the cooling of the air intake cooler, the lube oil cooler, and the jacket water cooler. The UCW is supplied at a temperature of from 70 to 80°F. A part of this supply goes through the intake air heat exchanger to control the air temperature within the limits of 80 to 110°F. The UCW then goes to the lube oil cooler where it controls the lube oil temperature between 135 and 150°C. The UCW goes directly from the lube oil cooler to the jacket water cooler where the jacket water temperature is controlled between 155 and 170°F. The UCW then returns to the UCW system at a temperature of between 80 to 110°F.

The generator has a rated capacity of 1000 kW at 360 rpm, 0.8 power factor and 4160 volts. The exciter is belt driven and is rated at 13 kW at 1750 rpm, 125 volts.

4. Power Outages

The "C" and "D" busses are supplied by commerical power. The "E" bus is supplied power by one of the diesel generator systems. The 24CE tie-breaker will normally be open. Any time the 24CE tie-breaker is closed or either power system fails, a reactor scram will result.

A power failure on either system will not affect the operation of the other. Critical items throughout the plant are supplied by both power systems, to insure a continuous supply of power to these items.

The 24GH tie-breaker should not open unless one of the following conditions exist:

(a) Underfrequency on the "G" bus.

(b) Undervoltage on the "E" bus.

(c) The breaker in unit 5C is opened.

The return to normal conditions and synchronizing procedures are posted on the 4160 V panel 5 and will be kept up to date.

The 24CE tie-breaker will normally be open. At any time the CE tie-breaker is closed, the reactor will be scrammed.

CHAPTER XII

EXPERIMENTAL AIR SYSTEM

A. GENERAL DESCRIPTION

1. Purpose of System

Large quantities of experimental air are required by various experiments conducted at the ETR facility. This air must be essentially hydrocarbon free. The air will have a minimum amount of dust in order to reduce the filter load of radioactive particles in the experimental air disposal system subsequent to passing through the reactor. In addition to air cleanliness, precise temperature, pressure, and flow control must be maintained.

Experimental air is supplied by two Clark compressors and is heated by one or more of three Thermal Research Corporation air heaters.

2. System Specifications

The over-all specifications for the experimental air system are as follows: (1) provide air for experimental purposes at 50 to 320 psig, with a variable flow rate of 1 to 30 lb/sec; (2) provide heated air between the temperature ranges of 500 to 1200°F at the heater outlet, with a flow rate of 1 to 24 lb/sec; (3) provide a backup supply of experimental air for MTR at 300 psig and a flow rate of 6 lb/sec; (4) provide, in the event of commercial power failure, an emergency system that will furnish air at 1 lb/sec flow rate and 6 psig.

3. Outline of Flow

Suction air for the two experimental air compressors is supplied from a filtered air plenum in the intake air building (655). Air entering the building, which is equipped with the necessary rain louvers in the north, east, and west walls, passes through a laminated cellulose filter into the air plenum and through three 36-inch pipes to a chamber underneath the change room in the compressor building (643). Each compressor has its respective suction pipe from this chamber. Compressor No. 1 has a 44-inch diameter suction pipe, and compressor No. 2 has a 36-inch diameter suction pipe. Both of these suction pipes are sloped to drains located to eliminate accumulated condensate.

The filter in the intake building provides removal of airborne dust particles and is designed to insure adequate filtering even at the low air velocities which may be required by lower capacity facilities. The filter serves the dual purpose of protecting the compressor system from excessive wear due to larger dirt and grit particles, and also will reduce the dust loading of the finer-pored pipe line filters downstream of the oil absorption beds.

From the high pressure experimental air compressors, the combined flows, totaling 30 lb/sec at 300 psig, enter two receivers in parallel each with a volume of 427 ft^3. This volume is required to furnish an immediate emergency air supply in case of an unexpected shutdown of the compressors. The two high pressure air receivers are carbon steel vessels equipped with a pressure relief valve set at 330 psig. Fine capacity and pressure control will be maintained at the receivers through an automatic pressure controller.

A bleed valve is connected to the inlet manifold of the receivers to allow running adjustments to be made on the capacity and pressure control during machine start-up. This valve also will serve in testing the compressors without using the balance of the experimental air system.

Also coming off the inlet manifold is a 6-inch line to the MTR. This line permits usage of ETR air by MTR or the reverse. Air from the ETR is taken off downstream of the filters, passes through a block valve, and through an automatic valve to the MTR. Air from the MTR passes through the automatic valve, then through a block valve and into the inlet manifold. The automatic valve closes, isolating the two systems, if pressure on the line drops to 240 psig.

The ETR experimental air system discharge manifold from the receivers connects to parallel lines, each of which has an oil vapor absorption filter with a capacity of 15 lb/sec of air at 300 psig. The filter vessels are filled with activated alumina designed to remove all detectable quantities of oil vapor and droplets from the experimental air stream. The particular equipment is Kemp Manufacturing Company's unit PF-48, each containing 1000 lbs of absorbent and each with an oil vapor holding capacity of 85 lbs.

The basic Kemp design was modified somewhat in order to meet special ETR problems. A 14 lb flanged nozzle is located near the bottom of the bed in order to facilitate media changing when it becomes spent. Heated plant air is purged through the vessel to remove the moisture from the absorption bed.

On both beds, the purge air is heated before entering the bed. This is accomplished by a heat exchanger on the line using electrical heaters.

In operation, the absorption medium will gradually become saturated with oil, and when occasional checks indicate the bed is practically spent, a fresh charge will be added to the filter. The filters conform to the following performance characteristics:

(a) Remove 99 percent particulate matter 5 microns and larger.

(b) Remove all detectable hydrocarbon in either mist or vapor form, which has a molecular weight of 100 or larger.

In series with each of the absorption filters. are two high efficiency pipe line filters. This equipment consists of pressure vessels containing filter banks of a fine-pore media. The two-fold purpose of this equipment is: (1) to catch any pellets splitting off from the oil absorption bed; and (2) to remove most of the remaining dust in the air stream. A large particle carried by a high velocity stream into one of the experiments would have bullet-like destructiveness. In addition, it is advantageous to remove as much fine dust as possible at this point in order to prolong the use of the radioactive stack gas filters, and thereby keep the filter changes to a minimum. The specific equipment is an American Air Filter type "G" pipe line filter containing Airmat Deep-Bed filter frames. The filter frames are contained in a 350 psig pressure vessel approximately 3 feet in diameter.

The air passes through three layers of an extremely fine-pored media which removes 99 percent by weight of the particulate matter 5 microns and larger. This filter will have sufficient dust-holding capacity to allow filter runs of three months or more.

As there is an absorption vessel and a pipe line filter in each parallel line, one line can be isolated for maintenance while the other supplies the experimental air systems.

After the pipe line filters, the air streams are combined and pass through three oil-fired air heaters (equipment No. 643-25 through 643-27) in parallel. Requirements of these heaters are based on a system to heat 24 lb/sec of air from 100°F, at a pressure of 300 psig, to 1200°F.

At the discharge of each heater, a ring-joint high temperature angle block valve is provided in order to facilitate removal of any one heater while operating the other two. These separate heater discharges combine into a single header. From the header, individual lines pass through control valve stations, and thus to the experimental loops in the reactor proper. A line from the discharge header to an exhaust silencer through the building roof facilitates testing the heaters without using the experimental systems.

A line between the receivers and the test line through the roof permits full loading of the compressors when demand is less than full load conditions. The line contains a flow orifice and control valves.

Air from the emergency compressor is piped into each experimental loop through an automatic emergency coolant valve.

A flow diagram of the experimental air system showing valving and instrumentation is shown in Figure 31.

B. CLARK COMPRESSORS

1. Description (See Figure 32)

(a) Manufacture and Specifications

The two Clark Brothers Company compressors are identical machines in all respects. They are 4000 hp, synchronous motor driven, model CBA-8 compressors.

The compressor is a three stage reciprocating, eight cylinder, balanced horizontally opposed type. The sizes of opposed cylinders are dynamically compensated by using different materials in the pistons in order to allow perfect balance of the machine. As an example, the large cylinders are made of aluminum, while cast iron or steel pistons are used for the opposing smaller cylinder.

Cylinders are numbered starting from the front of the machine and counting toward the motor. Odd numbers are on the left and even on the right. A layout of the compressors is shown in Figure 33.

Each compressor is constructed of a heavy-duty, one-piece casting and is equipped with removable covers to provide access to internal running parts. The cylinders are all high tensile strength, close grained cast iron, and are completely water jacketed for cooling.

The air compression heat is removed by intercoolers and an aftercooler on the compressor.

The intercoolers (four per unit) are of U-type construction with cooling water flowing in and out U-tube bundles on either end. Air discharged from the compressor cylinders flows around the bundles. Intercoolers between the first and second stage cylinders have been manifolded. (See ETR-E-1071 and ETR-E-1072.) This manifolding allows the compressor to run at low flow rate without popping the safety pop valves and without having to change the original loading sequence, thereby providing better control.

The aftercooler on each compressor is of the same type construction as the intercoolers, with the exception that there is only one U-tube bundle, and it is located on the air inlet end of the aftercooler.

A separator removes moisture from the cooled air leaving the aftercooler. The moisture is then removed from the separator by a trap drain system.

The main crank shaft is 14 inches in diameter and is of heat-treated forged steel with precision ground journals and crank throws. The shaft extends through the drive motor and is supported on that end by an outboard bearing. The connecting rods are of forged steel and of four bolt constructions. The crossheads are of box type construction and are adjustable at both the top and the bottom without removing the crosshead from the frame.

Each compressor is provided with a 4000 hp synchronous motor with an individual motor generator set to supply the field excitation. The motors conform to the applicable standards and requirements of AIEE and NEMA. The motors are General Electric type TSF synchronous

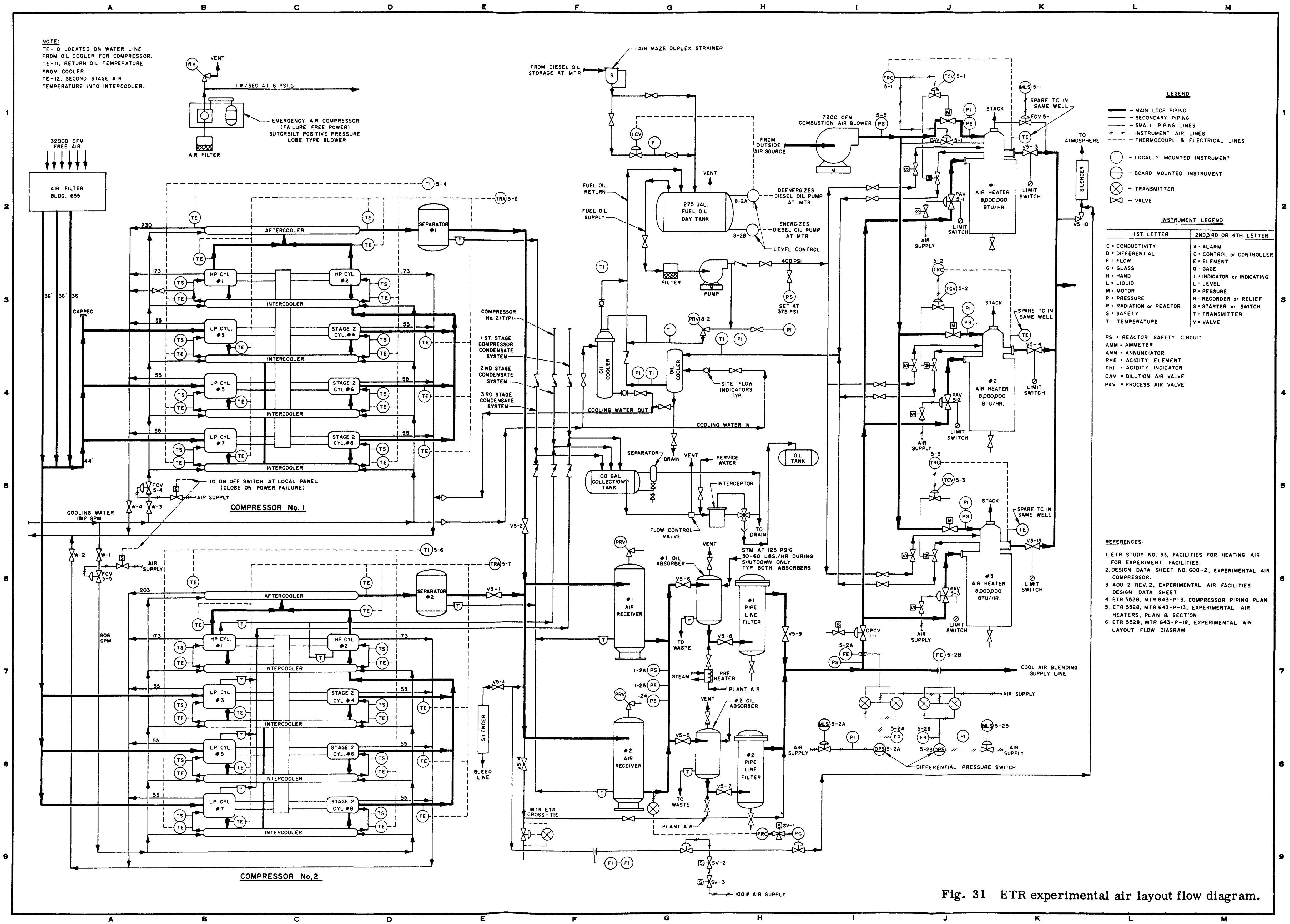

Fig. 31 ETR experimental air layout flow diagram.

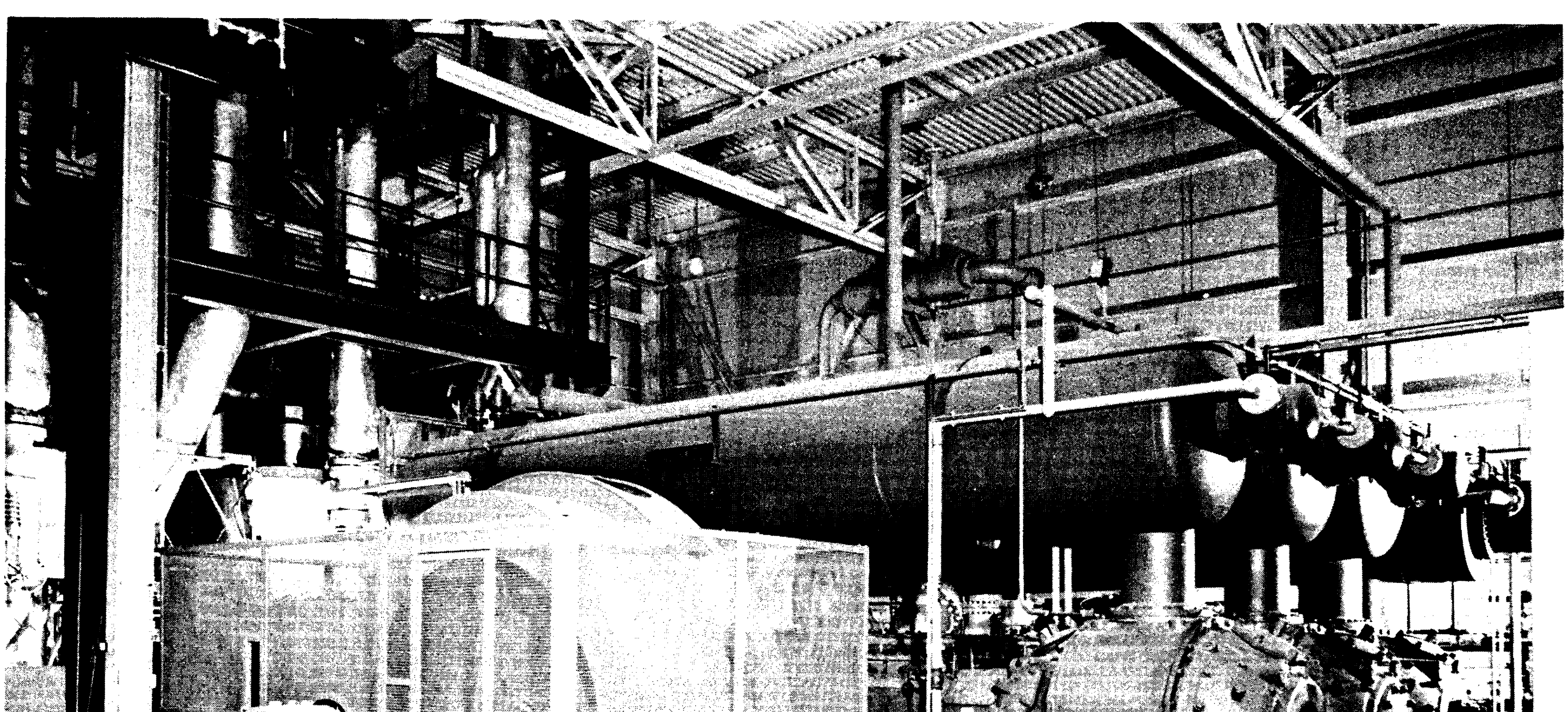

Fig. 32 ETR Clark compressor.

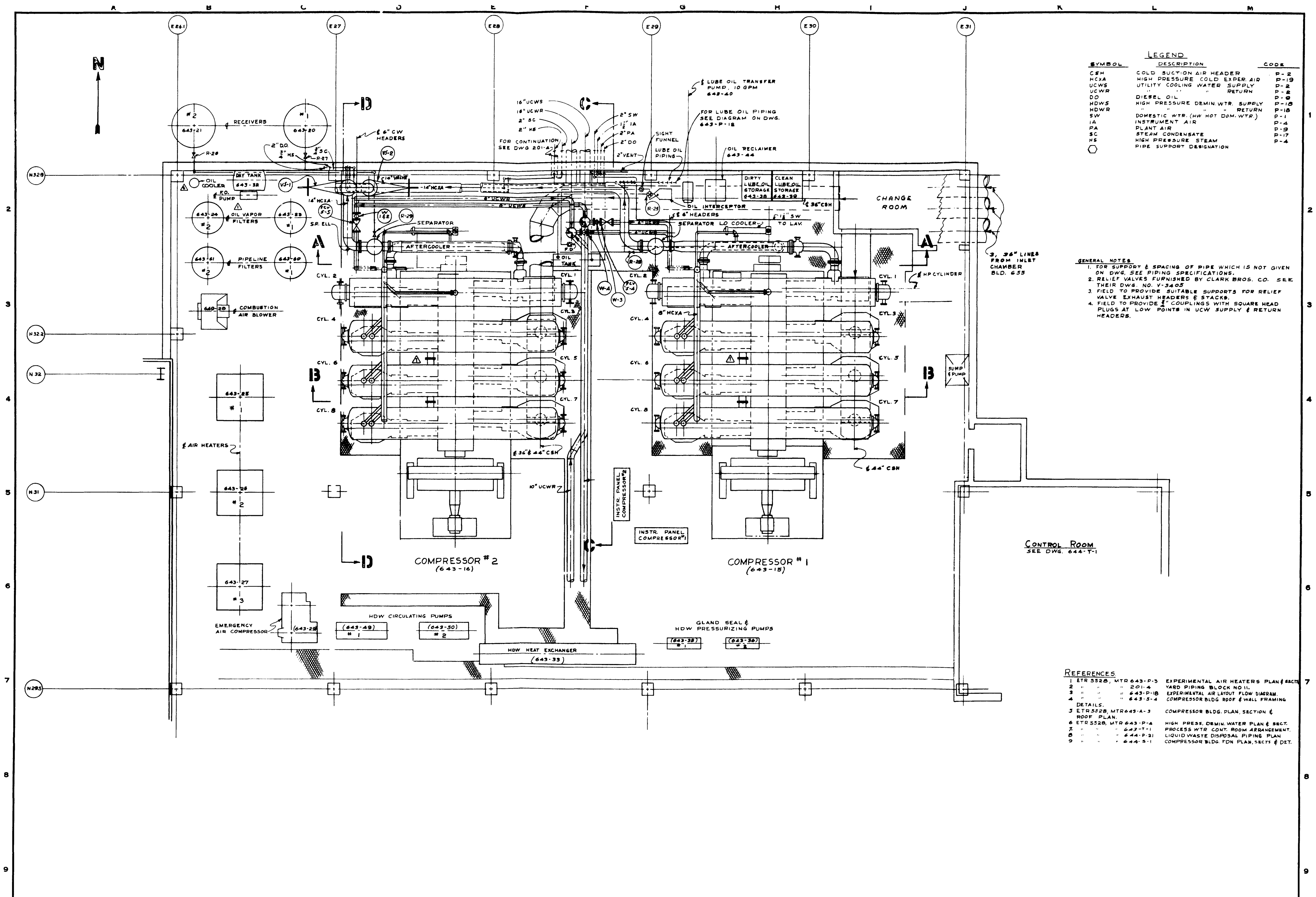

Fig. 33 ETR experimental air facility compressor piping plan.

motors. Name plate data for motors are as follows:

HP	4,000
RPM	300
PF	1.0
Type	TSF
Volts	13,200 volts
kVA	3,090
Amp Arm	135 amps
Amp Field	70 amps
Exc Volts	250 volts
Phase	3
Frequency	60 cycles

MG set excitors are located in the electrical building (648). Start-stop controls for the excitor and the synchronous motor are located at the local compressor control panel. An emergency stop station is located at the main control panel in the process water control room. Electrical equipment for excitors and motors is located in units 1, 2, 10, and 11 of the 13.8 switchgear. These units house the lockout relay reset switch (86), breaker permissive switch (68), excitor field rheostat, ammeters, wattmeters, and relays for electrical protection of the compressors. Units 1 and 2 are associated with compressor 643-15 (No. 1), and 10 and 11 with compressor 643-16 (No. 2). Units 4d and 5d of MCC 4 in the electrical building house the breakers for the MG set excitors and also contain an "AUTO-OFF-MANUAL" control switch for each excitor.

Each compressor is designed for a discharge pressure of 300 psig, 15 lb/sec air at a pressure range of 50 to 300 psig. Each machine conforms to the following design and performance characteristics:

(1) Suction Conditions

Pressure	12.2 psig absolute corresponding to 4933 ft elevation
Temperature	-20 to 100°F
Flow	Maximum flow 15 lbs/sec air

(2) High Pressure Discharge Conditions

Pressure	Maximum discharge pressure will be 320 psig. Minimum pressure will be 50 psig.
Temperature	100°F
Flow	Maximum flow 15 lbs/sec air at pressure range of 50 to 320 psig.

(3) Other Conditions

Cooling Water Temperature	82°F at 90 psig
Electric Power Characteristics	13,800 volts, three-phase 60 cycle

(4) Control Requirements

(a) Capacity control: the operator can manually adjust the capacity of the high pressure discharge of the compressors in 13 steps with about 1.3 lbs/sec increments through the compressor operating range.

(b) Pressure control: control is achieved by a pressure controller which utilizes the signal from a pressure sensing element on the receivers exit manifold to actuate a series of adjustable and fixed pilot valves which, in turn, activate the suction valves and pockets on the compressor cylinders. The control on the compressors is such that pressure variation at any set point is plus or minus 3 psig. The flow rates shall be variable from 0 to 15 lbs/sec with one flow rate to be about 1.5 lbs/sec while discharging at 300 psig. The compression will discharge into the receivers, maintaining the selected pressure to a tolerance of plus or minus 3 psig.

(c) Air Flow

Air from the intake air building is drawn in through inlet pipes to either of the two compressors. The first stage cylinders (3, 5, and 7) draw the air up from the inlet, compress it slightly, and discharge it up to the intercoolers. The first stage cylinder discharges directly to its second stage cylinder through an intercooler. All three first to second stage intercoolers have been manifolded to maintain the same pressure on all three. The air passes through the intercooler, and most of the heat of compression is removed. The intercoolers discharge to the second stage cylinders (4, 6, and 8) where it undergoes an intermediate compression.

The three second stage cylinders discharge down into a common discharge bottle. Air flows through the discharge bottle up to an intercooler for compression heat removal. From this final intercooler, air is drawn down to the third stage cylinders for final compression.

The third stage cylinders discharge down to a common header which discharges into an aftercooler. In the aftercooler the final compression heat is removed, and the air temperature is lowered to about 100°F. From the aftercooler, air passes through a separator for removal of large slugs of liquid and into a 14-inch line to the receivers. Air moves from the receivers to the experimental users.

Air discharge temperatures from the cylinders are monitored by thermocouples which record on a multipoint recorder in the main control panel.

(d) Lubricant and Trap System

The main lubricant of the compressor is supplied by a shaft-driven oil pump. The pump draws oil from the 425 gal capacity crankcase and forces it through a filter and the oil cooler. Cooled oil then flows back to the oil header. Lubrication of bearings, brushings, etc, is accomplished from the oil header. Thermocouples are mounted on the lube oil lines to and from the crankcase, and a thermocouple, measuring the temperature of the lube oil returning to the crankcase, is connected to an indicator on the local panel. An oil temperature switch is on the discharge side of the lube oil pump which causes an alarm if oil temperature exceeds 180°F; normal temperature is 120 to 130°F.

An auxiliary lube oil pump is used in conjunction with the main lube oil pump. This pump is controlled from the local panel. The auxiliary pump serves two purposes. First, the pump is turned on before a compressor starts up for force lubrication of the various parts. The auxiliary pump pressure is regulated at about 23 psig. When the main pump comes on, its output is about 50 psig, and a pressure switch, set at about 25 psig, causes the auxiliary pump to stop. In the event pressure drops to 30 psig, the same pressure switch will restart the auxiliary pump. The second purpose is for the auxiliary pump to serve as a backup in case of main pump failure. This pressure switch is called the high oil pressure switch. This system uses a hydrocarbon based oil.

A separate system is used for cylinder and pressure packing lubrication. Lube oil is supplied to these points by means of McCord lubricators mounted on the north end of the compressors. The lubricators are of force feed type and are chain driven from the crankshaft. When the compressor is down, lubricators may be manually operated either by working individual plungers up and down or by rotating a ratchet handle on the lubricator shaft extension. This lubricator svstem uses a silicone base lubricant called Cellulube. Consumption of lubricant for this system is about five quarts per 24 hours of operation.

Due to the lubricant usage and condensation of moisture in the air it is necessary to use a rather elaborate trap system on the compressor to handle the condensate buildup. Traps are connected to the intercoolers, separators, and receivers. These traps automatically discharge accumulated moisture to a catch tank on the north wall of the compressor building. Traps have a bypass provision in the event of their malfunction. Also, the discharge side of the intercooler and the separator have sight glasses to provide immediate observation of any liquid buildup.

The cross arm enclosures each have a line to carry off any unreasonable liquid buildup. These lines are connected to a holdup tank under the grating. Flow to the tank is by gravity. Liquid is pumped out of the tank when it is full.

(e) Water Flow

Compressor cooling is accomplished by use of utility cooling water at a rate of 900 gpm. Water is drawn from the 16-inch utility cooling water header by a 6-inch header and returned by a 6-inch header to the 16-inch utility cooling water return. A block valve is on both the supply and return. On the 6-inch supply line, there is an air operated block valve in additon to the manual block valve. This valve is controlled electrically from the local compressor panel by means of a solenoid valve on the air supply. This solenoid valve on the air supply closes the water valve in the event of a commercial power outage.

The cooling water splits into two streams for each compressor; one supplying the cylinders and intercoolers, the other supplying the aftercooler and oil cooler. Flow passes from the header through an intercooler, and then into the cylinder directly below that intercooler and into the return line. The water is warmed in the intercoolers and this prevents thermal shocking of the cylinders. The other flow path from the header is through the aftercooler and then through the oil cooler and to the return line. A flow control valve, located downstream of the aftercooler and controlled by the outlet water temperature regulates the flow through the aftercooler. Thermocouples, measuring the outlet water temperatures from each intercooler are connected to a multipoint indicator on the local panel. Thermometers are mounted on the intercooler inlet and the cylinder outlet lines. Similarly, thermocouples measuring the outlet water temperatures from the aftercooler and from the oil cooler are connected to an indicator on the local panel. Thermometers are provided to observe the inlet temperatures for these two components.

The cooling water has an air vent system. Lines are connected from a header to various high points in the cooling water system. Air is vented out the lines to the header and a trap on the header vents off the air.

2. Control

(a) Philosophy of Control

As the compressor is a constant speed machine, a method must be used to vary the amount of output air according to the demand on the compressors.

The method used on the Clark Compressor is the "Automatic Suction Unloader System". This control method uses a pneumatic suction valve unloader and a controller which operates them.

A simplified drawing of a cylinder and valving can be seen in Figure 34, and should be referred to during the following explanation.

The cylinder works in the following manner. When pressure within the cylinder is lower than the pressure in the inlet header, the suction valves open and air flows into the cylinder until pressure is equalized. When pressure is equal, the suction valve closes.

When the suction valve closes, the compression cycle begins. Compression

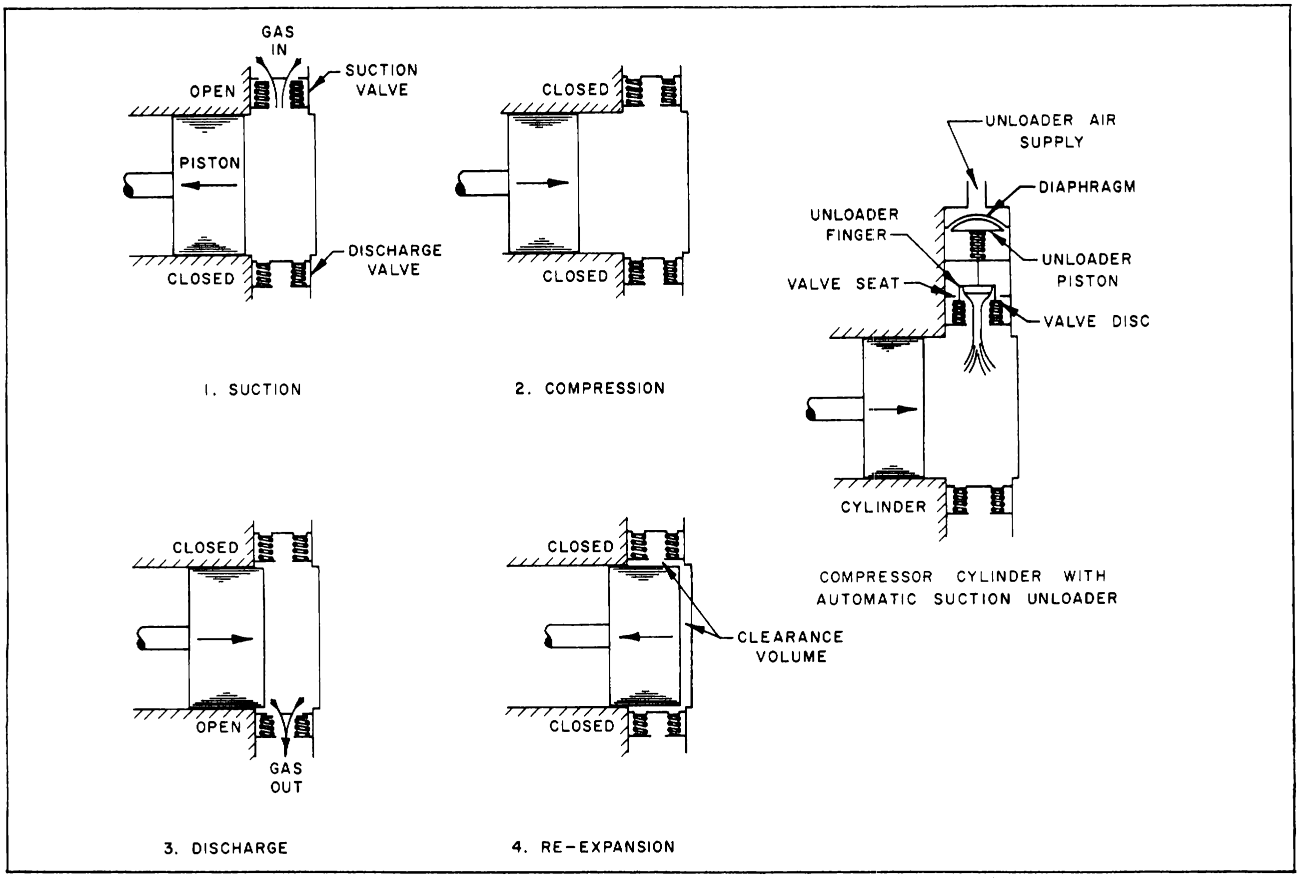

Fig. 34 Sequence of events and automatic suction unloader.

continues until pressure within the cylinder is equal to the pressure on the discharge side. With the pressures equal, the discharge valve opens and air flows to the discharge side. Discharge flow continues as the piston moves forward and decreases the volume of the cylinder until the end of the stroke. As the piston starts the return stroke, the cylinder pressure drops and the discharge valve closes. This ends the discharge portion of the cycle.

As the return stroke continues, the air which occupied the clearance volume re-expands, and pressure decreases from the discharge pressure. During this re-expansion stroke, both suction and discharge valves are closed, as pressure in the cylinder is less than discharge but greater than suction.

The valve operation is the same for single or double acting cylinders. With a double acting cylinder, each end operates as described previously, with re-expansion and suction occurring on one end while compression and discharge occur in the other.

Automatic suction unloaders are used to eliminate the compression and discharge portions of the cycle. Their function is to hold the suction valves open and permit air flow in either direction through the valve.

Referring to Figure 34, the workings of the automatic suction unloader can be followed. The unloader finger holds the suction valve off the seat and air goes into the cylinder on the suction stroke. However, at the end of the suction stroke, the disk does not seat, so compression cannot take place. Instead, the gas is forced back into the suction line until the piston reverses and starts in the opposite direction, at which time gas is again drawn into the cylinder. This cycle is repeated until the air demand is great enough to require the additional output of the cylinder. When the additional demand is made, the controller causes the pressure on the unloader diaphragm to release and allow the valve to function in the normal manner.

Controller demand is originated by a signal from the air receivers based on pressure at the receivers. The varying of receiver pressure causes compressor loading and unloading. This loading and unloading will be discussed later.

(b) Control Panels

Three control panels are associated with the Clark Compressors. Two are local panels, one for each compressor, and one is the main panel, located in the process water control room. Normal starting and stopping of compressors is done at the local panels while control is accomplished at the main panel.

Each of the local panels are identical and contain the following items:

(1) Control for air operated utility cooling water valve.

(2) Motor-excitor, start-stop station.

(3) Auxiliary lube oil start-stop station.

(4) Synchronous motor start-stop station.

(5) Pressure gauges for discharge pressure of each first stage cylinder, each second stage cylinder, and combined third stage cylinders.

(6) DC voltmeter and ammeter for the excitor.

(7) Power factor meter for the synchronous motor.

(8) AC voltmeter and ammeter, with selector switches for the synchronous motor.

(9) Red lights, to indicate stage loading; light comes on when stage is loaded.

(10) Nineteen pressure gauges to indicate loading of cylinder and pockets; 40 psig indicates unloaded and 0 psig indicates load.

(11) 12-point temperature indicator for the following points:

(a) Outlet temperature of cooling water for each intercooler on each end (8 points).

(b) Aftercooler water outlet temperature.

(c) Discharge water temperature from the oil cooler.

(d) Discharge oil temperature from the oil cooler.

(e) Second stage air temperature from the oil cooler.

(12) Running time meter

(13) A timer with three indicating lights. Purpose of timer is to permit automatic load switching of compressor when running a reduced load (50 percent or less).

(14) Alarm panel which annunciates in the event of a trouble condition. The following troubles give alarms at the local panels:

(a) Discharge air temperature for each cylinder. A thermocouple is installed in the discharge line from each cylinder and goes to a recorder in the process control room. The alarm signal is initiated from the recorder.

(b) Water temperature from any intercooler. A Fenwall temperature switch is installed in each water outlet line from the intercoolers. The switch is activated on high temperature giving the alarm.

(c) Water temperature from aftercooler. This alarm is activated in the same manner as the intercooler alarm.

(d) High motor winding temperature. This alarm is activated by the high temperature relay located at the 13.8 switchgear.

(e) Alarm at main panel. In the event any alarm is activated at the main panel, the alarm at the local panel is activated.

(15) A pistol grip switch with an "OFF" and nine positions. This switch is for manually loading the compressor by means of the solenoid valves in the signal lines. The timer is incorporated in this switch.

The main control panel is used primarily for the control of compressor output. As mentioned previously, it is located in the process water control room. The panel houses the following items:

(a) Emergency stop button for each compressor.

(b) dc ammeter, dc voltmeter, power factor meter, ac ammeter with selector switch, and ac voltmeter with selector switch for each compressor.

(c) Nine pressure gauges for indicating stage loading.

(d) Twelve switches marked "AUTO-UNLOAD" for control of loading steps.

(e) Receiver pressure gauge.

(f) Control pressure range selector switch. This is a three-position switch with the three ranges being 40-140, 132-230, and 220-320.

(g) Automatic - Manual control selector switch. This switch is housed in the same unit as the manual control signal pressure gauge and pressure regulator.

(h) Two 12-point recorders, one for each compressor, showing temperature of air discharge from each cylinder and aftercooler.

(i) Pressure controller with 0 to 100 scale.

(j) Flow indicator for compressor loading line.

(k) Controller for compressor loading line valves.

(l) Alarm panel with silence button. Trouble annuncaitors for both compressors and heaters are indicated on the panel. Troubles indicated are as follows:

(1) High bearing temperature for compressor bearings A, B, C, D, E, F, G, H, and J. These alarms are activated by Penn temperature switches mounted on the north end of the compressor. Bearings are numbered from north to south.

(2) High outboard bearing temperature. This alarm is activated by a Penn temperature switch located in the pit for the compressor motor.

(3) Low lube oil pressure. This alarm is activated by a Penn pressure switch on the north end of the compressor

(4) High motor winding temperature. This alarm is activated in the same manner as the alarm on the local panel.

(5) High oil temperature. This alarm is activated by a Penn temperature switch located on the north end of the compressor.

(6) High auxiliary oil pressure. This alarm is activated by a Penn pressure switch located on the north end of the compressor.

(7) High air discharge temperature from aftercooler. This alarm is

activated from the temperature recorder in the same manner as the cylinder discharge temperatures on the local panels.

(8) Trouble at local panel. This alarm is activated by any alarm at the local panel.

(9) Low experimental air 5-2A. This alarm is activated by low air flow.

(10) Low experimental air 5-2 B. This alarm is activated by low air flow.

(11) Low receiver pressure.

(12) Loss of heater flame.

(13) High oil day tank level.

(14) Low oil day tank level.

(c) Pilot Valves

Control of the compressor output is achieved by using receiver pressure as the controlled element. Control of the various steps of loading are maintained by use of air relays or pilot valves. These pilot valves receive a signal from the pressure sensing element and transmit the signal to other pilots, which activate the suction valves on the compressor cylinders.

The pilot valves are the heart of the whole control system. Operation of these valves is described in the following paragraphs.

Pilot valves are of two types, the fixed and the adjustable type. Figure 35 illustrates a cutaway section of both types. The adjustable pilot valve has five connections: (1) the bottom inlet into which controller output air is connected; (2) the "S" port into which a constant pressure of 40 psig is supplied; (3) the "B" port which is left open to the atmosphere; (4) the "A" port into which a constant pressure of 40 psig is supplied; and (5) the "C" port which is the outlet for 40 psig air to the fixed pilot. The 40 psig air is maintained by a pressure regulator to the "A" and "S" ports.

The adjustable valve functions in the following manner. With no pressure on the bottom connection, the 40 psig air from "S" port bleeds around the plunger and out the small opening in the bottom of the valve body. The spring above the plunger forces it to the down position, and ports "B" and "C" are connected, venting off

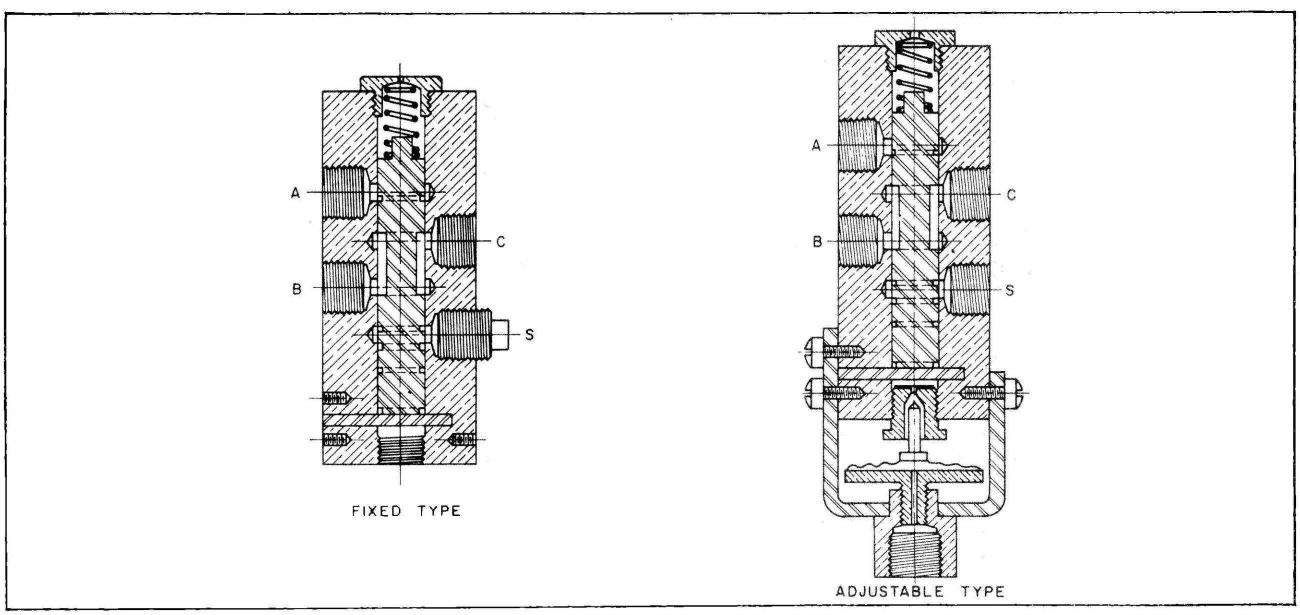

Fig. 35 Compressor pilot valve.

the line on "C" port. "A" port is closed off by the position of plunger. When pressure is applied to the bottom connection, the diaphragm expands, forcing the pin to close off the small opening in the bottom of the valve body. Air from "S" port forces the plunger into the up position against the spring. This connects "A" and "C" ports, allowing 40 psig air into the line connected to "C" port.

The fixed pilot valve is of exactly the same connection as the adjustable type except the diaphragm, nozzle caps, push pin, and bracket are missing. The bottom connection receives air from the "C" port of the adjustable pilot valve. The "A" port is supplied with a constant supply of 40 psig air. The "C" port is the outlet supplying 40 psig air to the desired location. The "B" port is left open to the atmosphere, and the "S" port is permanently plugged. Action of the plunger and connection of ports is the same as for the adjustable pilot valve.

(d) Automatic Control (see Figure 36)

As previously mentioned, control of the compressor output is accomplished by means of loading and unloading the various cylinders. This may be done by either a manual or automatic means of control. A basic consideration for the control system is that a control signal pressure of 40 psig is required to unload and 0 psig required to load.

The controller receives its signal from the receivers by one of the three transmitters. The output signal from the controller, which varies between 0 and 30 psig passes through the automatic-manual control valve and then through a header to 12 adjustable pilots. These pilots are set for 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, and 26 psig. The adjustable pilots are physically located in the main control panel in a row in the center portion of the panel, and the fixed pilots are on the south end. Assuming the compressor is fully loaded and starts to unload, the controller output rises to 4 psig and the first pilot is activated. The pilot plunger is moved to the upper position and ports "A" and "C" are connected. 40 psig air passes from "A" to "C" and through the three-way auto-unload valve (which is in the "AUTO" position) to the "B" port of the first fixed pilot valve. Five fixed pilots are mounted on the inside left end of the main control panel. These pilots will be referred to as the pocket pilots. The bottom port of the first pocket pilot is connected to the "C" port of the 6 psig adjustable pilot. As the controller output is only 4 psig, this pilot is not activated and "C" port is connected to "B" port and therefore vented. As a result of this, the first pocket pilot is not activated and the "C" port at the first pocket pilot is connected to "B" port which has 40 psig air. By the same mechanism as the first pocket pilot, the other four are deactivated and "B" and "C" ports connected; therefore, the 40 psig air at "B" port on the first pocket pilot flows to "C" port on the fifth pocket pilot. The air then passes through two parallel solenoid valves. Nine pressure gauges, upstream of the solenoids, indicate the compressor step loading.

The parallel solenoids are a part of a safety device to prevent the starting of a compressor with the cylinders in a loaded condition. One solenoid supplies control air to specific cylinder mounted pilots on compressor No. 1, while the other solenoid supplies the corresponding pilot on compressor No. 2. One side of the three way solenoid valve is piped with 40 psig on the normally open ports. One side of the solenoid is piped with the signal from the controller on normally closed ports, and one side of the solenoid is piped to the cylinder pilots or pocket pilots. In the deenergized condition, 40 psig air comes from the normally open port through the common port to the cylinder pilot. In the deenergized condition, the normally closed port is closed. The solenoids are energized by the synchronous speed relay on the compressor motor. When energized, the normally open port closes and the normally closed port opens, allowing flow through the common port to the cylinder pilot. In this manner, any time a compressor

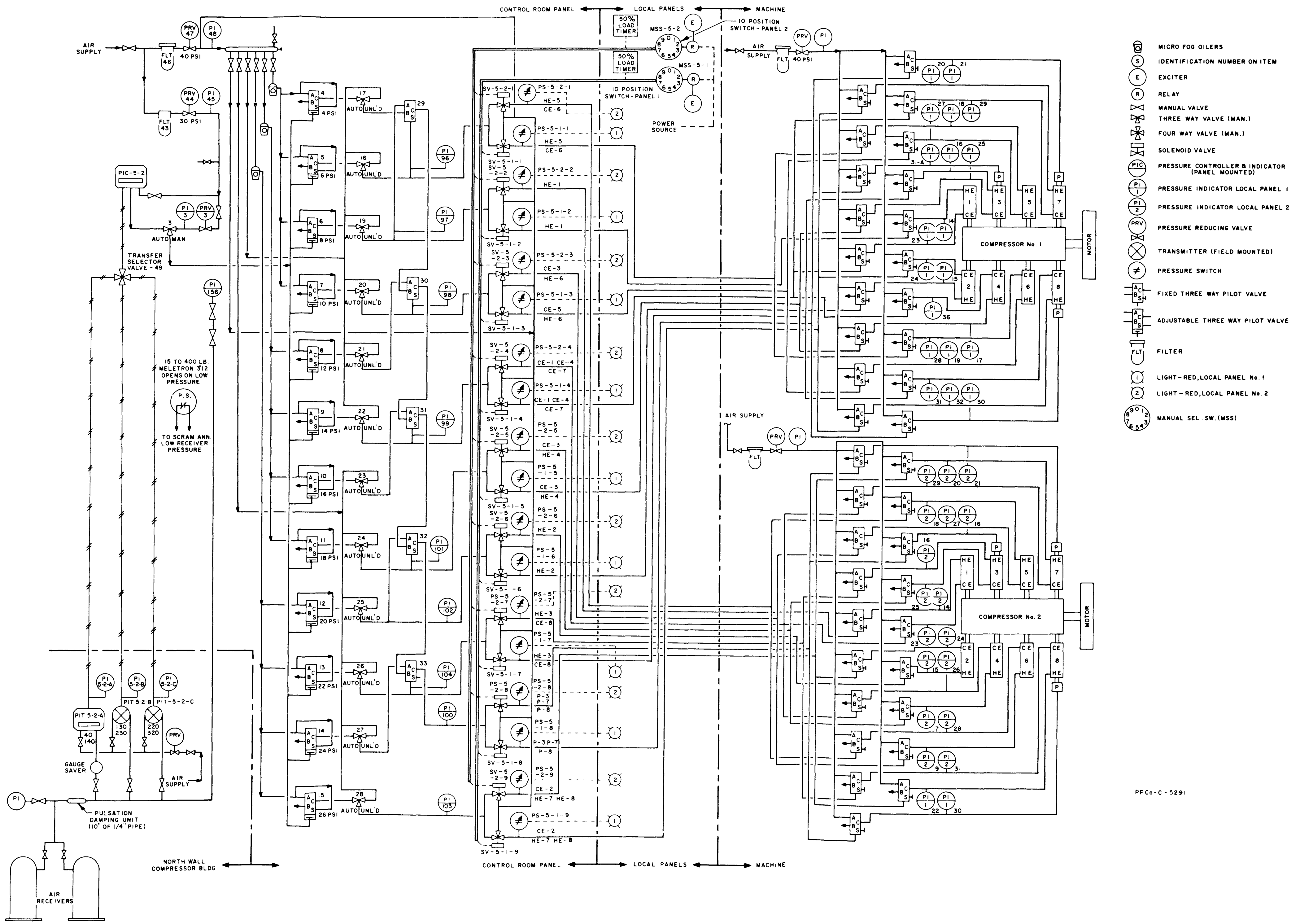

Fig. 36 ETR experimental air compressor schematic piping and control diagram.

motor is not up to synchronous speed, its cylinders will be unloaded by virtue of the 40 psig air on them from the solenoid. The solenoids also are controlled by the 10-position switches at the local panels. These switches deenergize the solenoids in the "OFF" position, preventing loading, and energize them to cause loading as shown on Table 8. When using the switch for loading, the pockets will not come in and out at various loads as they do under automatic control, since their solenoid is not energized until No. 8 position is reached on the switch.

Table 8

Loading Steps

Switch Position	Solenoid	Action
OFF		Compressor unloaded
1	SV-1-9 and 2-9	Loads HE-7, CE-2, HE-8
2	SV-1-7 and 2-7	Loads HE-3, CE-8
3	SV1-6 and 2-6	Loads HE-2
4	SV1-5 and 2-5	Loads HE-4, CE-3
5	SV1-4 and 2-4	Loads CE-7, CE-4, CE-1
6	SV1-3 and 2-3	Loads HE-6, CE-5
7	SV1-2 and 2-2	Loads HE-1
8	SV1-8 and 2-8	Closes Pocket
9	SV1-1 and 2-1	Loads HE-5, CE-6

NOTE

SV1 solenoids for Compressor No. 1

SV2 solenoids for Compressor No. 2

Air pressure is applied from the solenoid valves to the bottom port of the fixed pilots on pockets 3, 7, and 8 on the compressor. With pressure on the bottom of the fixed pilot ports, "A" and "C" are connected, and the 40 psig air on "A" passes to "C" and causes the suction valves on pockets 3, 7, and 8 to unload.

A Melitron pressure switch receives a pneumatic signal from downstream of the solenoid valve. This switch activates the red load indicating light at the local panel when pressure drops to the compressor pilot.

A pressure gauge on the line between the pilot and suction valve is mounted on the panel. This is one of the 19 stage loading indication gauges.

If the compressor requires additional unloading, the controller output will increase to 6 psig, thereby activated the 6 psig adjustable pilot, and placing 40 psig air at "C" port. From "C", air passes through the solenoids to the pilots on HE-5 and CE-6, causing these cylinders to unload. A tee in the line goes to the bottom of the first pocket pilot which would make "A" and "C" ports connected to the "C" port of the 8 psig adjustable pilot which is not activated; therefore, "C" port is vented through "B" port. The "B" and "C" ports of the last four pocket pilots are connected. By this means, "A" port of the first pocket pilot (which is vented) is connected to the pilots on the pockets 3, 7, and 8, and they are loaded.

Unloading sequence for the remaining cylinders will follow about the same general line and can be followed on Figure 36. Table 9 gives the unloading steps and cylinders affected.

Manual control is similar to automatic control with the exception that when the "AUTOMATIC-MANUAL" switch is in "MANUAL", the controller is isolated. The signal to the adjustable pilots is controlled by a regulator on an air line tied into the control pressure header by the "AUTOMATIC-MANUAL" switch. Pressure of the control signal in

Table 9

Unloading Steps

Controller Output Signal	Load Step	Action
0		Compressor completely loaded
4	1	Pockets 3, 7, and 8 unloaded
6	2	CE-6, HE-5 unloaded; pockets 3, 7, and 8 loaded
8	3	HE-1 unloaded; pockets 3, 7, and 8 unloaded
10	4	HE-6, CE-5 unloaded; pockets 3, 7, and 8 loaded
12	5	Pockets 3, 7, and 8 unloaded
14	6	CE-7, CE-4, and CE-1 unloaded; pockets 3, 7, and 8 loaded
16	7	Pockets 3, 7, and 8 unloaded
18	8	CE-3, HE-4 unloaded; pockets 3, 7, and 8 loaded
20	9	HE-2 unloaded; pockets 3, 7, and 8 unloaded
22	10	CE-8, HE-3 unloaded, pockets 3, 7, and 8 loaded
24	11	Pockets 3, 7, and 8 unloaded
26	12	HE-7, CE-2, HE-8 unloaded
30		Compressor completely unloaded

"MANUAL" can be read on the pressure gauge directly below the controller.

The 12 "AUTO-UNLOAD" switches can be used to directly unload any of the 12 steps. The "AUTO-UNLOAD" switch is a three-port type with one port being common to the cylinder pilot and/or the pocket pilot. The second port is tied to the adjustable pilot, and the third is tied to the 40 psig air. In the "AUTO" position, the first and second ports are tied and in the "UNLOAD" position the first and third ports are tied, causing the 40 psig air to be placed on the cylinder pilots, causing them to unload. Table 8 gives the loading steps.

3. Safeties

(a) Electrical Safeties

Several safeties are incorporated into the electrical system of the compressors. This is necessary to protect the machine, as well as to avoid accidents that could be disastrous.

The electrical safeties are as follows: (1) low frequency on incoming power lines causes compressors to stop, (2) low voltage to the compressor causes it to unload and stop, (3) high motor winding temperature indicates an alarm.

(b) Mechanical Safeties

Many mechanical safeties are incorporated into the compressors in addition to the electrical safeties. The majority of these safeties have been mentioned in the previous sections, but for the sake of clearness, mechanical safeties are listed as follows:

(1) Pop valves on receivers to prevent pressure buildup.

(2) Pop valves on intercoolers and aftercoolers to prevent pressure buildup.

(3) Thermocouples on discharge air from cylinders and aftercooler.

(4) Temperature switches on water from intercoolers and aftercoolers.

(5) Temperature switches for compressor bearings and outboard bearings.

(6) High and low lube oil pressure switches.

(7) Low auxiliary lube oil pressure switches.

(8) High oil temperature switches.

(9) Low UCW flow switches.

Pressure and temperature and flow switches all cause a panel alarm. In addition, the low auxiliary lube oil pressure switch will cause the compressor to shut down. The compressor is shut down also if a low UCW flow and a high discharge air temperature occur at the same time.

4. Starting and Stopping

Starting and stopping of the compressor will be covered only briefly. For detailed instructions, the operating manual should be consulted.

(a) Starting

As the 4000 hp engine represents a rather large electrical load, the power dispatcher should be notified before starting so he may adjust the site load, if necessary.

Cooling water flow should be established and valving checked to insure a flow path for the air. The auxiliary lube oil pump should be started. Also, the McCord lubricators should be cranked through at least 12 complete cycles to insure lubrication of cylinder walls and pressure packing. Control system should be set up for proper control. The compressor should then be barred over one revolution to insure that there is no obstruction to movement. The electrical system can then be energized and the compressor started.

(b) Stopping

Stopping of the compressor is a relatively simple operation. The machine should be unloaded and then the electrical system tripped out. Water should be cut off immediately. The auxiliary lube oil pump should be allowed to run about 30 minutes. As an added safety measure the main breaker should be jacked open.

C. EMERGENCY COMPRESSOR

1. Description

(a) Purpose

In the event of a commercial power outage or main compressor failure it is desirable to have an auxiliary source of compressed air. This air is provided by the emergency (Sutorbilt) compressor.

Under normal conditions the compressor is not operating, but with a power outage or compressor failure it is automatically started. Power is supplied from the diesel generator electrical system. The emergency compressor is started by a low pressure switch receiving a signal from the air receivers.

(b) Manufacture and Specifications

The emergency compressor is a positive displacement blower, Sutorbilt Corp., serial No. 133V. It is their 12 x 13 size, belt driven by a 60 hp Allis Chalmers motor. Design and performance characteristics are as follows:

Capacity	1 lb/sec air
Outlet Pressure	6 psig
Outlet Temperature	110°F maximum
Suction Pressure	12.2 psi absolute corresponding to 4933 ft elevation
Electric Power	440 volts, 3-phase 60-cycle
Driven Horsepower	60 hp

(c) System Flow

Air is drawn through an intake filter at the compressor and discharges into a header. A vent line goes through the building roof. This line contains a pressure-regulating-type valve that opens and vents off excess pressure in the event of a pressure buildup on the discharge side of the compressor. Three other lines from the header go to experimental users. These lines contain valves which automatically open in the event of low air on the experimental side of the valve.

D. EXPERIMENTAL AIR HEATERS

1. Description

(a) Manufacture and Specifications

Three experimental air heaters are provided to heat the experimental air. These three heaters are manifolded off the heater, as shown in Figure 37. Two of these heaters are identical and the third has a dilution air feature to allow for a lower outlet temperature. These heaters are type DF heat exchangers and were designed and constructed in the shops of Thermal Research and Engineering Corporation in Conshohocken, Pennsylvania and contain as an integral part a thermal high velocity burner for distillate fuel oil.

Since these units are heat exchangers, there is no contact between the products of combustion and the air being heated. The air being heated (hereafter referred to as process air) is carried on the inside of two passes of stainless steel tubes. The air passes first through the coiled outer pass and secondly through the straight tube or inner pass. The products of combustion coming from the combustion chamber section of the burner pass first around the outside of the straight tubes and then make a 180 degree turn and come up around the outside of the coiled tubes.

The unit is assembled in four basic parts; namely, the inner pass, the separating baffle, the outer pass, and the outer shell. The inner pass and outer pass (the outer pass being the coiled pass) are connected at the bottom of the heat exchanger through a single flange with a special high-temperature gasket located between the two connecting flanges. This flange must be unbolted to separate the inner and outer passes. This entire assembly, with the separating refractory baffle located between the two passes, is hung from the frame inside of the outer shell of the heat exchanger. It is, therefore, allowed to expand in a downward direction to allow for thermal expansion. No movement is noted on the outside since this movement takes place entirely within the confines of the outer shell of the heat exchanger.

The inlet and outlet connections for the process air out are located 180 degrees apart with the exhaust or stack connection located halfway between.

The normal construction consists of the inner or straight tubes of type-309 stainless steel and the outer or coiled tubes of type 304 stainless steel. The shell around the separating baffle is type 310 stainless steel and the balance of the unit including headers and manifolds is type 316 stainless steel. The inlet manifold is mild steel. The entire outer shell is kept insulated with 1-1/2 inches of Johns-Manville Super-X under 1-1/2 inches Magnesite insulating block. The wrapping of insulation is covered with aluminum sheathing. The upper portion is insulated with insulating block, then cemented over and covered with a final coat of aluminum paint.

The high velocity burner included with the type DF heat exchanger is mounted at the very top of the center line on the heat exchanger, and fires downward into the chamber containing the inner pass or straight refractory baffle. This refractory baffle is a castable refractory, and is cast directly into the stainless steel containment shell. It can only be replaced by withdrawing the entire tube bundle as-

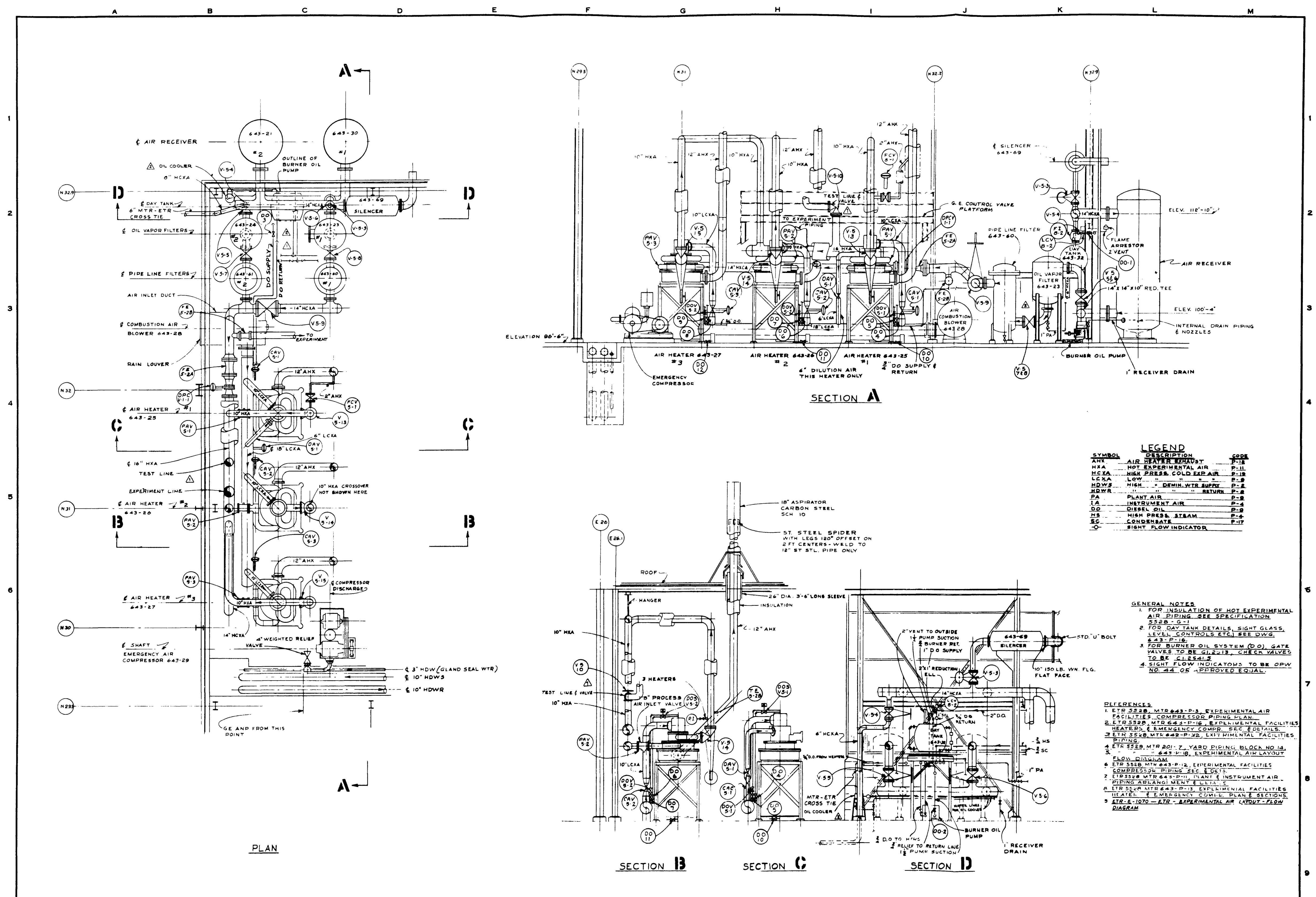

Fig. 37 ETR experimental air facility heater and emergency compressor plan and section.

semblies from the outer shell and then separating the inner and outer passes.

The high heat release rate of the burner used with this heat exchanger makes possible the small physical size. Combustion is about 90 percent completed in the refractory lined combustion section of the burner. This is also a castable refractory and is not to be confused with the refractory lined separating baffle previously mentioned. The combustion chamber is sized to completely fill the hole at the top of the inner pass bundle. On unit No. 1, a dilution air system is incorporated where cold combustion air is allowed to come in around the combustion chamber section of the burner for tempering the flame and providing a wide temperature range. Therefore, the outside diameter of the combustion chamber on the heat exchanger with dilution air is approximately 1-1/2 to 2 inches smaller than the outside diameter of the combustion chamber section of the burner used in the other two heat exchangers. The combustion chamber is longer on the unit with dilution air since the main mounting flange of the burner must be moved up to allow for the dilution air manifold insertion between the top of the heat exchanger and the connecting flange of the burner.

The products of combustion which exit from the high velocity burner are at a temperature over 3000°F, although these may be diluted down to lower temperatures when dilution air systems are used. At high fire, the combustion temperature is considerably higher than the metals can tolerate. Therefore, when operating a heat exchanger of this type, process air must be passing through the unit prior to firing the burner. Protection has been provided the units by incorporating an excess temperature cutout thermocouple which is in contact with a high temperature tube.

When starting the air heaters, the burner must be fired with the controller in its low fire position. When the burner is at high fire, a terrific quantity of combustible mixture can be injected into the confined chamber of the heat exchanger.

Heat is transferred in a heat exchanger of this sort basically by two forms: forced convection heat transfer, and radiation heat transfer. Since the burner has a clear flame, the heat in this case is being transferred primarily by forced convection. Some radiation is provided by the separating refractory baffle getting hot after the unit has been operating for awhile, but this is a small percentage of the heat being transferred. As soon as the burner is ignited and products of combustion at high temperatures start flowing through the heat exchanger, the process air is being heated since the thermal inertia of the system is small. This is the basic reason for the very rapid response characteristics of this heat exchanger which allow wide changes in loads to be obtained in very short periods of time. Therefore, as soon as the burner is fired and process air is flowing through the heat exchanger, the process air temperature recorder and the tube pyrometer will start to rise. This heat is being transferred to the air and the operator should immediately insure that the desired temperature is not being exceeded. If the set-point of the temperature controller is properly adjusted, then the burner valving should automatically position the burner output to provide the desired outlet temperature. Subsequently, the entire modulation of the heat exchanger should be automatic in that the operator need only set the air flow through the unit at the desired amount and set the temperature controller to give him the desired temperature.

Over-all specifications for the heaters are as follows:

(1) Handle air flows from a minimum of 1 lb/sec to a maximum of 24 lbs/sec.

(2) Heat 100°F inlet air to a minimum of 500 and a maximum of 1200°F.

(3) Maximum pressure drop at 24 lbs/sec flow, 300 psig pressure and 1200°F outlet temperature will not exceed 4 psig.

(4) Minimum pressure at heater outlet will be 50 psig and maximum pressure will be 300 psig.

(5) Operation is to be possible at any combination of the above conditions.

(6) Control of temperature is such that temperature is maintained within tolerance of plus or minus 5°F.

(7) Heatup time required for maximum operating conditions does not exceed 30 minutes.

Single heaters conform to the following:

(1) Each heater is capable of an output of 8,000,000 Btu/hr.

(2) Each heater is capable of handling a maximum flow of 8 lbs/sec.

(3) A minimum flow of 1 lb/sec at 500°F can be obtained by use of the dilution air feature (on No. 1 heater) and the blow-off valve (FCV 5-1) between the outlet and exhaust stack on No. 1 heater.

(4) Each heater is provided with individual firing circuit and temperature control instrumentation.

(b) Flows

The various flow systems described in the following sections may be followed in Figure 31 and 37.

(1) Process Air: The process air is supplied by the compressors to the experimental users through any combination of the three heaters. Air to the heaters is supplied by a 14-inch header from the receivers. The inlet valve to each heater is an open-shut electrically controlled, pneumatic operated, 8-inch, gas tight gate valve. Air passes through the heater and is heated in the manner previously described. Leaving the heater, the air passes through a 10-inch manually-operated angle block valve. The 10-inch outlet line from each heater makes a loop up and over the heater and ties into a 16-inch hot experimental air line. Three experiment lines originate at the 16-inch hot air header, plus a test line to a roof silencer. The test line is to allow firing of the heaters for test purposes without passing air through the experiments.

(2) Combustion Air: As the heaters are oil fired units, it is necessary to supply air to support combustion. This is accomplished by the combustion air system.

Air is supplied by a Spencer Turbine Co., model 25125-H blower rated at 7200 scfm at 29 oz, and powered by a 125 hp General Electric Motor.

Outside air is drawn in by the blower and discharged into the 18-inch combustion air header. For each heater, there is a 10-inch line supplying combustion air. Each line contains a combustion air valve which is controlled by a pneumatic signal from the temperature controller. This valve controls combustion air flow to the heater combustion chamber. The combustion air valve also is linked to the fuel oil control valve. Products of combustion are exhausted through a 12-inch line which passes through the roof of the building.

It has been previously mentioned that No. 1 heater has a dilution air feature. This dilution air is combustion air supplied by a 6-inch line from the combustion air header. This line also contains a control valve which is controlled by a pneumatic signal from the temperature controller. The flow from the 6-inch line is into the combustion chamber. From this point, flow is the same as normal combustion air.

(3) Fuel Oil: The heaters are fired with diesel oil supplied from two storage tanks located in the MTR utility area. The

diesel oil is pumped to a 275-gallon day tank located outside of the compressor building on the north side. Tank level is maintained by an automatic fill system. At low level the solenoid valve in the fill line opens, and the transfer pumps start. When high level is reached the solenoid valve closes and the pump stops. Before entering the day tank, oil passes through a strainer and an integrator.

Oil is pumped out of the tank through a filter by the burner oil pump. Oil is discharged from the pump at 400 psig to a 3/4-inch supply header. This pressure control is by means of a preset pressure regulating valve. Oil bypassed by the valve passes through a cooler and is returned to the day tank.

At each heater, the supply goes through a block valve, strainer, and solenoid valve before reaching the burner. Excess oil that is not consumed flows through a control valve, block valve, and into the return header to the day tank. Before reaching the day tank, the unburned oil passes through a cooler to maintain the temperature below the flash point of the diesel fuel.

2. Control

(a) Philosophy of Control

The controlled variable for the heaters is the outlet temperature of the process air. The temperature is controlled by the rate of firing the burner. This rate of fire is dependent on the amount of combustion air and diesel oil supplied to the burner and is controlled by an air signal from the temperature controller. (Refer to Figure 31.)

A thermocouple in the outlet line transmits an electrical signal to the temperature recorder controller. The recorder controller records the temperature of the outlet, as well as transmitting an air signal to the temperature control valve. This control valve is connected to the combustion air valve and return oil valve by means of a mechanical linkage, as can be seen on the linkage chart. (Refer to Figure 5, Experimental Air Operating Manual.)

(b) Control Panel

The control panel for the heater is located in the process water control room. All control of the heaters is from this panel.

Items mounted on this panel are listed below:

(1) For over-all system operation "ON-OFF" panel power switch with indicator light.

(2) Start-stop station for combustion air blower with indicating light.

(3) Start-stop station for burner oil pumps with indicating light.

(4) Pre-purge button with indicating light.

(5) Flow meter for process air. This meter has two pens, one indicating flow to heater, and the other flow bypassing heaters.

(6) A procedure indicating board, which indicates by lights the condition of the heater control circuits. This allows the operator to detect troubles in starting or operating the heaters.

For each heater there is identical equipment in the panel. This equipment is listed below:

(1) Temperature recorder controller for the outlet air temperature.

(2) Open-close control switch with indicating light for inlet process air valve.

(3) Burner "ON" indicator light. Light is on when oil solenoid valve to burner is open.

(4) Heater tube pyrometer. Pyrometer reads heater tube temperature by

means of a thermocouple, and in the event of excess tube temperature, shuts down the heater.

(5) Voltmeter to indicate flame stability at the burner.

(6) Burner start station. This station includes "ON-OFF" switch to energize firing circuit, pushbutton to energize ignition transformer, and oil solenoid and indicating light for ignition transformer.

(7) Indicating light for satisfying of firing circuit.

(c) Control Valves

There are several control valves in heater system which are used to control variables and the output of the system.

The temperature control valve is controlled by an air signal from the temperature recorder controller. As the signal from the controller increases, the movement of the valve is increased. A mechanical linkage from the temperature control valve causes movement of the combustion air valve. An electric pneumatic relay is tied to the temperature control valve. The purpose of this relay is to cause the valve to move to a choke position at the initial lighting of the heater. This choke condition causes maximum oil and minimum air, and is activated by depressing the burner start button.

The combustion air valve controls the flow of combustion air to the burner. This valve is operated by the temperature control valve through mechanical linkage. The valve opens for higher rate of fire. In the case of the choke condition for initial ignition, the valve is forced to a closed position.

The burner oil-return oil valve controls the amount of oil used by the burner. This valve is connected by mechanical linkage to the combustion air valve. As the valve in the return line closes, more oil is forced through the burner.

The dilution air valve on heater No. 1 allows the heater to operate at low temperatures and flows. The valve is controlled by a pneumatic signal from the temperature recorder controller, operable only on low signal from controller. It is fully closed at usual low fire signal. The purpose of the valve is to allow additional combustion air to enter combustion chamber for low temperature operation.

The burner oil solenoid valve could be considered an "ON-OFF" control valve. The solenoid valve opens and allows oil flow when burner is ignited and closes when heater is shut down or when a safety calls for shutdown.

3. Safeties

As high temperatures are developed by the oil fired heaters, it is necessary to have rather extensive safeties on the system. These safeties are divided into three categories: firing, operating, and shutdown.

(a) Firing

A great many conditions must be met to achieve a firing condition on the heaters. Most conditions are checked by either a pressure switch or microswitch, and in some cases, a time delay relay serves as a safety. These safeties are described below:

(1) A process air pressure switch and a flow switch insures existence of process air before burner can be fired.

(2) A combustion air pressure switch insures existence of combustion air before burner can be fired.

(3) The pre-purge time delay relay causes an 8-minute pre-purge of the combustion chamber by combustion air before firing.

(4) An oil pressure switch insures proper oil pressure before firing.

(5) The low-fire start proving switch forces control to be in low-fire position before firing.

(6) The valve position sensing micro-switches are located on inlet and outlet process air valves.

(b) Operating

Operational safeties shut down the heater in the event of an unsafe condition by causing the oil solenoid valve to close, thus stopping oil flow to the burner.

These safeties are listed below:

(1) Process air pressure switch and process air flow switch.

(2) Combustion air pressure switch.

(3) Oil pressure switch.

(4) Valve position sensing micro-switches.

(5) Excess tube temperature pyrometer. Shuts down burner in the event of high tube temperature.

(6) Flame failure safeguard which scans combustion chamber and shuts down burner in the event flame goes out.

(c) Shutdown

When a heater is shut down, the following two safeties are involved:

(1) Post-purge time delay relay forces a 4-minute purge of the combustion chamber by combustion air before the blower stops. This is to sweep the chamber clear of combustion products.

(2) Panel voltmeter. This instrument indicates flame stability and should be observed in the case of heater shutdown. In the event of a burner oil solenoid valve leak or failure, it would indicate presence of a flame.

4. Starting and Stopping

(a) Starting

Starting a heater is relatively simple; however, certain conditions must be met before a heater can be fired. These conditions are as follows:

(1) Power and control voltage must be present at the combustion air blower, high pressure fuel pump, and control panel.

(2) Process air should be flowing through the heat exchanger or heat exchangers to be started. (Experimental compressor checked out and operating.)

(3) Pneumatic control air pressure should be present to all pneumatic instruments.

Before a start can be made, proper combustion air pressure and fuel pressure must be present at the burner. The fuel pump also is started by a "START-STOP" station on the panel. It is advisable to keep block valves on the diesel oil to and from each heater closed when the heater is not running to prevent oil from leaking through the solenoid valves and accumulating within the combustion chamber.

The pre-purge can now be started. This causes an 8-minute purge by combustion air to take place. The air purge insures that the products of combustion are swept from the combustion chamber. An amber indicating light on the control panel comes on while the pre-purge is taking place.

After the pre-purge, the bleed valve on the bottom of the heater should be opened to check for the presence of diesel oil. The combustion air valve should be opened at least part way before opening the bleed valve. If oil is detected, the heater should not be fired, and another should be selected.

When the above conditions are complete, the switches which are marked "HEAT EXCH No. 1, 2, or 3" can be turned on. The switch will not start the burner, but merely places the flame failure control relay in a condition to allow the burner to be started.

The burner used in the heat exchanger must be at a low output setting for proper ignition to occur. Therefore, the low-fire start proving switch has been utilized. The switch prevents a start attempt from being made unless the combustion air pressure at the head of the burner is less than 3 inch water column. The combustion air pressure to the burner is lowered to this value by the manual control valve on the lower right hand side of the temperature controller. The selector switch on the left hand side must be in the "MANUAL" position to do this.

All conditions are now correct for lighting a heat exchanger burner. This is performed by merely depressing the burner "START" button and holding this button in until flame has been properly proven. A proper flame condition will not be actually visible from the panel, so a flame stability indication in the form of a dc voltmeter has been utilized. If a steady voltage of about 75 volts exists, proper flame conditions can be assumed to exist, and the button is then released. The time for obtaining stable flame conditions will be approximately 10 to 15 seconds. When the start button is depressed, two indicator lights will come on: a red light immediately above the button, and an amber light on the panel marked "BURNER ON". This amber light is in parallel with the fuel solenoid valve, and whenever the valve is open, this amber light is on. When flame has been proved, the red indicator light will go out, and the "START" button may be released. The amber light will remain on, and the solenoid remains open due to the flame failure scanner sighting a flame. If it is not sighting a flame, or, if for any reason the flame is extinguished during an operation, the solenoid valve will automatically be closed and this amber indicator light marked "BURNER ON" will automatically go out.

(b) Stopping

To shut down a heater the air discharge temperature should be lowered at a rate of 200°F per 15 minutes until low fire condition is reached. The burner may then be turned off. To turn a burner off, turn the switch marked "HEAT EXCH No. 1, 2, or 3", as required, to the "OFF" position. This shuts the fuel solenoid valve causing the amber indicating light to go out. The combustion blower should be left on to allow a purging of the combustion side of the heat exchanger to take place. This purge is automatic and will continue for approximately 4 minutes following the depressing of the blower "STOP" button.

After a heat exchanger has been turned off, the pump and blower can be turned off, assuming that no other heat exchanger is operating. If other heaters are operating, the blower and pump should be left on, and the diesel oil block valve to the shutdown heater should be closed.

CHAPTER XIII

THE HIGH PRESSURE DEMINERALIZED WATER SYSTEM

A. FUNCTION OF SYSTEM

1. Pressurizing System (See Figure 38)

The pressurizing system is designed to supply: one, 60 gpm of water at 250 psig to the reactor gland seal rotameter rack to prevent leakage of contaminated coolant from the reactor vessel; two, 11 gpm of water at 205 psig to the gland seals of the primary coolant pumps, degassifier and pressurizing pumps, and the emergency and shutdown pumps to prevent leakage of primary coolant water; and three, 10 gpm of makeup water to the experimental cooling loop and to pressurize the system to 130 psig at the circulating pump suction.

2. Purge System

The purge system is designed to supply 2 gpm of water at 25 psig to the ion and fission chamber housings. The purpose of this system is to fill the housing for shielding and to cool the chambers.

3. Experimental Cooling Loop

The heat removal system or the experimental cooling loop is designed to provide 1850 gpm of water at 130°F and 200 psig to the basement experiments, and to return the water with a maximum temperature of 170°F and a pressure of 130 psig. Design capacity of the experimental heat exchanger is 10,150 kW. The heat will be transferred through the heat exchanger to the utility cooling water loop for heat removal by the cooling tower.

B. COMPONENTS AND DESCRIPTION OF THE SYSTEM

1. Supply System

The demineralized water for the system is supplied by a 3-inch line from the 10-inch demineralized water header from the ETR-MTR makeup demineralizer unit (equipment No. 608.1). (See drawing ETR-5528-MTR-608-P-4.)

The 3-inch supply line enters the east side of the compressor building 643 and goes to a Fisher pressure reducing valve, PRV-7-1, located east of the experimental heat exchanger. PRV-7-1 reduces the demineralized water pressure to between 50 and 60 psig, supplying constant pressure demineralized water to the suction side of the gland seal and pressurizing pumps.

2. Pressurizing System

The gland seal and pressurizing pumps (643-35 and 643-36) provide the mechanism for pressurizing the system. Normally, one pump will run on diesel generator power with the remaining pump in a standby condition. Both pumps are supplied with diesel generator and commercial power and the standby pump will come on if the operating pump stops. Both pumps may be run if the load requires it. If both pumps are run simultaneously, 643-35 pump will operate on diesel generator power and pump 643-36 will operate on commercial power.

The two pumps will provide a flow of 11 to 120 gpm at a pressure of 250 psig. Both pumps are provided with orificed bypasses which will allow them to float on the line without overheating.

The pressure from the pumps is controlled by PCV-7-4, a Fisher pneumatic valve, which is operated from a manual loading station, MLS-7-4, located in the process control room. The pressure on the system is transmitted to the process control room by PT-7-4, a Republic pressure transmitter, where it can be read

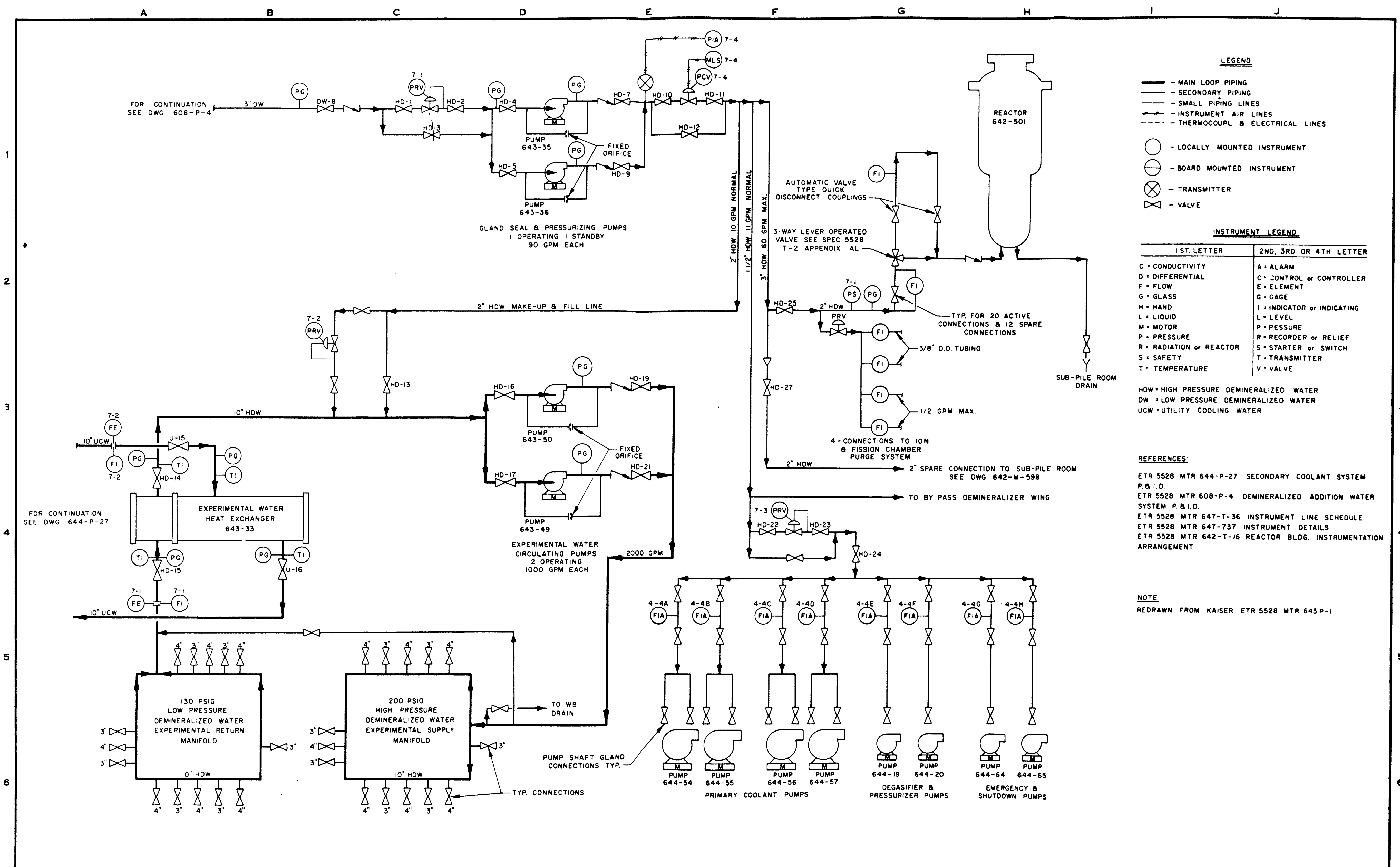

Fig. 38 ETR high pressure demineralized water piping and instrument diagram.

on PI-7-4, a Foxboro circular indicator. This pressure is normally around 250 psig.

From PT-7-4, the high pressure water is divided into the following three separate systems.

(a) The Pump Gland Seal System

This system consists of a 1-1/2-inch line which feeds PRV-7-3, a Fisher pneumatic valve that controls the water pressure at approximately 205 psig. The water then flows through the individual rotameters, designated as FI-A through H, on the gland seal rotameter rack where the flow is measured and indicated. Each rotameter is for one specific pump and will actuate an alarm in the process control room on a low flow condition. From the rotameter rack the water goes to the pump gland seals. The pumps that this system supplies are the primary coolant pumps, the degassifier and pressurizing pumps, and the emergency and shutdown pumps.

(b) The Facility Gland Seal and Chamber Purge System

The facility gland seal system is located on the south console floor. This system is supplied by a 2-inch line directly from PCV-7-4 which supplies the pressure on the lantern rings around facility penetrations through the reactor top and bottom heads. Pressure in the system is maintained above vessel pressure to prevent leakage of contaminated coolant from the vessel. There are 20 gland seals pressurized by the system. The normal flow, if any, to the 20 seals is through one rotameter on the supply header, range 0.4 to 5.8 gpm, with a high flow alarm at 2.5 gpm. The water then goes to the 20 seals through 20 three-way valves. If the total flow is excessive, provisions are provided to isolate each line and measure the flow by a rack mounted rotameter with a range of 0.05 to 0.08 cc/min. Four spare rotameters are furnished to cover flows up to 0.65 gpm. Quick disconnects are provided on each gland seal line and on a flexible hose attached to the rotameter to facilitate scanning the seals for leaks.

A pressure indicator and pressure alarm switch set at 230 psig are mounted on the rack to sense the demineralized water supply pressure. The normal pressure will be 250 psig and the mercoid pressure switch will actuate an alarm in the reactor control room on loss of adequate pressure. Drain legs from the gland seal lantern rings are provided to allow the operators to purge the system. The system is capable of delivering 50 gpm to the 20 seals. However, a flow of 1 gpm to any one seal would be considered excessive. Under normal conditions, there should be little or no flow through the seals.

The fission and ion chamber purge system will supply a normal total flow of 2 gpm of demineralized water at 25 psig to two fission chamber and two ion chamber housings. The housings are pipe risers that extend through the bottom head of the reactor to a position close to the grid plate. The purpose of this system is to fill the housing for shielding and to cool the chambers. Fisher-Porter rotameters are provided for measuring the flow to the housings. These have a flow alarm contact that will actuate an annunciator in the reactor control room when the flow is below 0.4 gpm. Normal flow is 0.5 gpm. To protect the possible collapse of the chambers from overpressure, there is a pressure relief valve set to relieve at about 30 psig. There is also a mercoid pressure switch that will alarm on low supply pressure at 20 psig in the reactor control room. The water supply for the system is taken from the 250 psig reactor facility gland seal header through a pressure reducing valve. Drain lines from the housings are located in the subpile room and a 10 psig back pressure should be maintained. This can be accomplished by throttling the valves on these lines, if necessary. An air purge line extends from the top of the housing to the rod access room. These valves are necessary to fill the system and to keep it free from air.

(c) The Experimental Cooling Loop

The experimental cooling loop receives its supply from a 2-inch line that tees off from the 3-inch header downstream of PCV-7-4 and goes to PCV-7-2, a Fisher pneumatic valve that controls the supply pressure of the high pressure demineralized water to the experimental cooling loop.

This pressure is controlled at approximately 130 psig to the suction side of the experimental water circulating pumps (643-49 and 643-50). An orifice bypass is installed across each pump to allow the pumps to float on the line with variations of demand by the users. These pumps operate in a similar manner as described previously for the seal water and pressurizing pumps with diesel generator and commercial power supplied to both pumps. The circulating pumps will circulate up to a maximum of 2000 gpm, but at present, normal-flow is approximately 1350 gpm. This flow is indicated on FI-7-1, an MH mercury manometer-type mechanical flow meter. The discharge pressure of the circulating pumps is approximately 200 psig, or a ΔP of around 70 psig. The supply header temperature of the loop should be 130°F and the return header temperature up to 170°F. The maximum that the system is designed to handle at present is 10,150 kW which will be transferred through the experimental heat exchanger (643-33) to the utility cooling water loop for heat removal by the cooling tower (751). The needs of this system will vary as the experiments are added and discontinued in the reactor.

CHAPTER XIV

ETR HEATING, VENTILATING, AND AIR CONDITIONING SYSTEM

The heating, ventilating, and air conditioning systems for the ETR are best described as 17 separate systems plus a chilled water system which provides service to the reactor control room, amplifier room, sub-pile room, and rod access room.

The heating and ventilating systems for the reactor building first floor, reactor building console floor, office building, amplifier room, and reactor control room are primarily controlled from a Minneapolis-Honeywell Supervisory Data Center located in the heating and ventilating rooms in the ETR office building. The temperature setpoints for each area are controlled from the data center, as well as the position of the air control dampers of each system. Also located at the data center is a precision temperature indicator that indicates the temperature at various points in each system as well as in the area being served.

A. REACTOR BUILDING FIRST FLOOR SYSTEM

This system is designed to circulate first floor air four times per hour and maintain an area temperature of 65°F. Two of these hourly air changes shall be from fresh outside air and two by recirculation. This circulation is effected by means of one supply air fan with a capacity of 48,000 cfm and one exhaust fan with a capacity of 24,000 cfm.

Air flows are determined by the position of the dampers controlling the outside air, return air, mixed air, and supply air. The positions of the dampers are controlled from the Supervisory Data Center. The face and bypass damper positions are pneumatically modulated and operate in opposite directions to regulate the volume of mixed air passing through the steam coils.

A vertical bank of three steam coils, each controlled by a pneumatically operated "ON-OFF" temperature control valve provides means of heating the air that is not bypassed to the fan intake. Maintenance of the desired atmospheric pressure in the first floor area is dependent upon balance between supply and exhaust air volumes.

B. REACTOR BUILDING CONSOLE FLOOR AND BASEMENT AREA SYSTEM

This system is designed to heat and ventilate the console floor and basement areas of the reactor building. The system will maintain an air change rate equal to six times the total cubicle area per hour. To maintain this rate, the cubicle exhaust fans will exhaust approximately 16,000 cfm to the waste gas stack, while the console floor supply fan is recirculating 19,100 cfm and supplying 15,100 cfm of fresh air. The total exhaust exceeds the total fresh supply and maintains a slightly negative pressure in the basement and cubicle areas (see Figure 39).

Total air flows are determined by the open position stops on damper motors controlling the outside air, return air, and exhaust air. The face and bypass damper positions are pneumatically modulated and operating in opposite direction, to regulate the volume of mixed air bypassing the steam coils to assist in maintaining the area setpoint temperature.

A vertical bank of two steam coils, each controlled by a pneumatically operated "ON-OFF" temperature control valve, provides means of heating the air that is not bypassed to the fan intake.

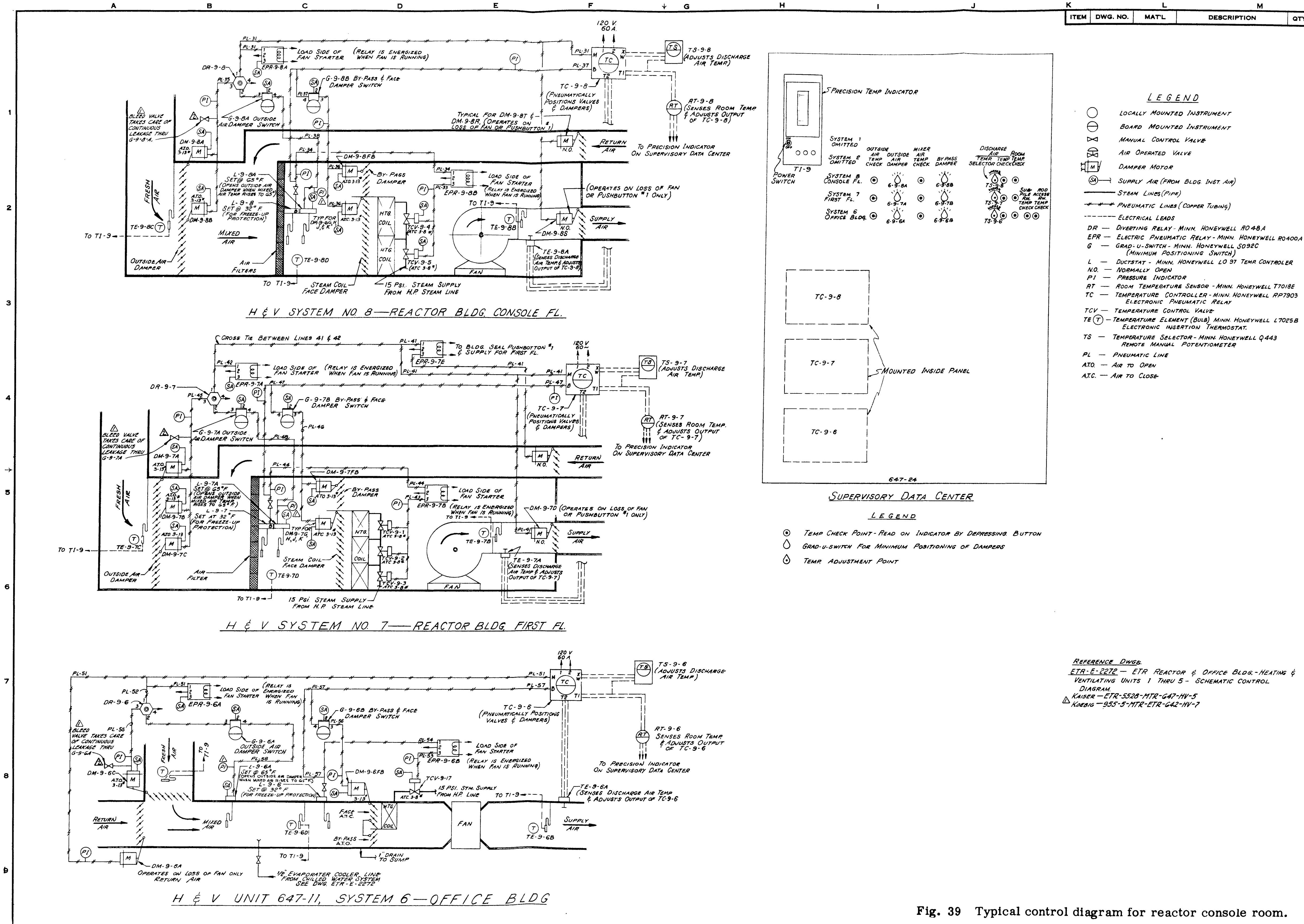

Fig. 39 Typical control diagram for reactor console room.

The exhaust air flow route is from the console floor through rectangular openings along the perimeter of the basement ceiling, to the cubicles, and then drawn into the cubicle exhaust duct by the cubicle exhaust fans (see paragraph Q) and expelled to the waste gas stack via a continuation duct.

C. OFFICE BUILDING SYSTEM

This system is designed to maintain six changes of air per hour for the office section of building 647; two of these changes shall be fresh air. It also maintains office temperature at 70°F. In addition, twelve changes of air are provided per hour for the change room, toilets, and Health Physics room.

The system includes a supply air fan rated at 5160 cfm, and an exhaust fan rated at 3000 cfm. An additional fan in the Health Physics room exhausts air to the main exhaust duct served by the building exhaust fan. Return air at the rate of 2470 cfm is taken to the unit mixing box for recirculation. Distribution and flow to the various offices and building areas are shown on drawing 647-HV-2.

Total air flows are determined by the position of the outside and return air dampers that are controlled from the supervisory data center. The face and bypass damper positions are pneumatically modulated and operate in opposite directions to regulate the volume of mixed air passing through a single unit steam coil. The area temperature setpoint is controlled from the data center.

D. AMPLIFIER AND INSTRUMENT REPAIR ROOM SYSTEM

The heating, ventilating, and air conditioning unit for this system is basically the same as for the office system but includes a three row cooling coil for circulation of chilled water (see Figure 40).

The supply air fan will furnish a total of 3560 cfm to the system area; 1000 cfm shall be routed to the instrument repair room; 2560 cfm to the amplifier room; 2180 cfm is returned to the unit mixing box from the amplifier room; and 820 cfm from the instrument room, and the balance of the total supply, 560 cfm, will be leaked to surrounding areas. This leak rate requires fresh air makeup to the mixing box at the same rate.

Total air flows are determined by the position of the outside air and return air dampers. The face and bypass dampers are pneumatically modulated, operating in opposite directions to regulate the volume of air passing through the steam and cooling water coils.

Temperature control during the heating cycle is maintained from the data center by positioning the dampers and controlling the temperature setpoint. During cooling operation, the same air rates will apply, but chilled water from the chiller units will be circulating through the air conditioning unit cooling coil. Temperature regulation is effected by a three-way valve regulating chilled water flow through the cooling coil from the chillers and recirculation through the coil bypassing return to the chillers. The temperature of the chilled water supply and return lines may be monitored at the data center.

E. REACTOR CONTROL ROOM SYSTEM

This system is designed to provide a total air supply to the control room of 2760 cfm, to be diffused equally through three ceiling diffusers.

Return air to the unit mixing box is at the rate of 2460 cfm. Air is leaked to the office building corridor at the rate of 300 cfm. Fresh air makeup in the mixing box is also 300 cfm.

The action of the control room temperature control is identical to that of the amplifier room.

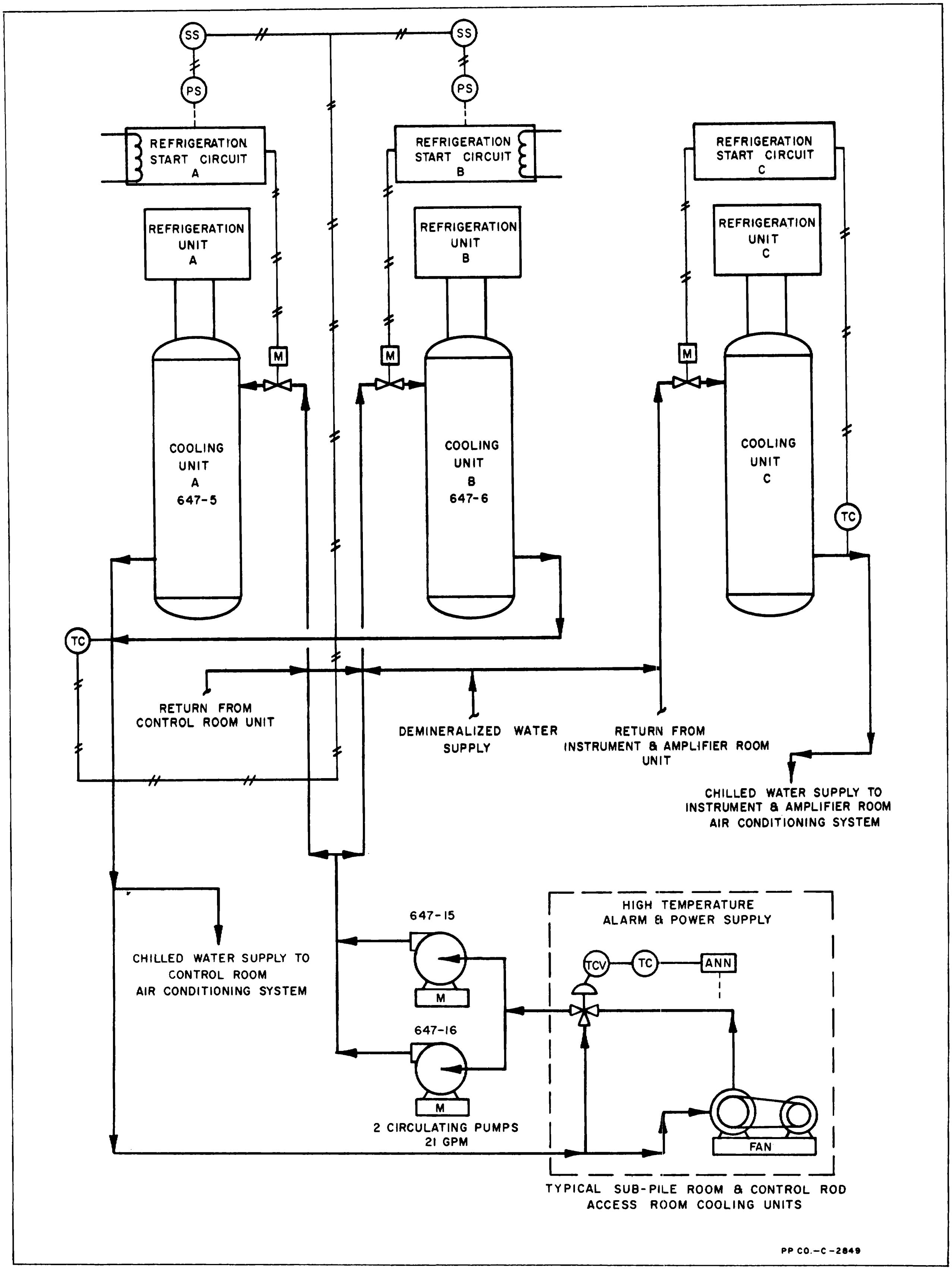

Fig. 40 Cooling coil water and water chiller controls typical of one system.

F. SUB-PILE ROOM SYSTEM

This system is designed to cool the subpile room to a maximum of 105°F. This is accomplished by supplying chilled water from the chiller units to each of two Spotaire cooling units. The rate of chilled water flow through each unit coil is 11 gpm, entering at 45°F and leaving at 50°F. Each unit is equipped with a direct drive, multiblade centrifugal type fan.

Temperature regulation will be effected by three-way TCV-9-13 regulating chilled water flow through the cooling coil from the chillers, or bypassing return to the chillers to maintain the area setpoint temperature of 105°F from thermostat T-9-3 located between the cooling units. Thermostats T-9-3 and -4 activate a common high temperature relay. The signal from this relay is sent to the reactor control room. The temperature of the sub-pile room may be monitored at the Supervisory Data Center.

A connecting duct to the cubicle exhaust loop in the basement area exhausts air from the room. Normal air supply to this room is by leakage only, and room pressure shall be negative in relation to the main basement area.

G. CONTROL ROD ACCESS ROOM SYSTEM

This system is identical to the sub-pile room system except for lower cooling unit capacities and a lower chilled water flow rate to each chiller of 5.0 gpm. Temperature regulation will be effected by a three-way TCV-9-14 and thermostat T-9-4. The temperature of the rod access room may be monitored at the Supervisory Data Center.

H. CHILLED WATER SYSTEM

The chilled water system serves the reactor control room, the amplifier room, the sub-pile room, and the rod access room cooling coils with 45 to 50°F chilled water. The heat from the chillers is removed by utility cooling water at approximately 70°F. In the event the utility cooling water is cut off to the chillers, a tie-in from the building fire water system will supply cooling water.

The system includes three package-type dry expansion water chillers, each consisting of compressor and motor, chiller, condenser, refrigerant piping, expansion valve, solenoid valve, controls, and cutoff switches.

In addition, external to the chiller units, are two system pumps and individual recirculation pumps in the control room and amplifier room circulation systems.

Each chiller is equipped with a high-low pressure contact. Normally, during maximum load, 35 gpm will be pumped through each chiller. As the room loads decrease, the quantity of water returning from the room coils and entering the chiller will decrease due to the three-way valves in the control room and amplifier room loops. As the chilled water flow decreases through the chillers, the refrigerant suction pressure will decrease approaching cutoff point.

A temperature controller actuated by an immersion bulb in the main chilled water supply line will stop the chillers when the water temperature falls below 44°F to prevent freeze-up.

The chillers will shut down when the suction pressure to the compressor is below the setpoint and when the discharge pressure is above the setpoint. The chillers will restart automatically when the suction pressure is normal, but the pressure switch must be reset after a high-pressure cutout. Temperature controller TC-9-5 will restart the stopped compressor when the chilled water leaving the operating compressor rises to 53°F.

A 1/2-inch valved bypass line is provided around RCV-9-1 and RCV-9-2 to keep some water flowing to the idle chiller at all times to prevent possible freezing. The chilled water flow to the rod access and sub-pile rooms cooling units will remain constant because the three-way valves in these loops will cause the chilled water to bypass the coils in amounts varying with cooling demands. The chillers circuitry permits only one unit to operate on emergency power during normal power failure and are interlocked to permit start-up of the standby if the unit in operation fails.

I. WATER PROCESS CONTROL ROOM SYSTEM - Building No. 643

This system is served by a packaged air conditioning unit complete with refrigerant compressor and motor, water cooled condenser, Freon, fan and fan motor, heating and cooling coils, filters, water regulating valve, drip pan, and regulating controls.

The unit is designed to supply 2000 cfm through one duct outlet to the room and maintain summer temperature of 80°F with 51 percent maximum relative humidity and winter temperature of 70°F. The fresh air and return air rates are manually regulated by the setting of a damper quadrant on the mixing box. Heating control is maintained by TCV-9-10 in the heating coil steam supply line actuated by a room thermostat, T-9-10, is located on the east wall of the room.

J. COMPRESSOR BUILDING SYSTEM - Building No. 643

This system is designed to maintain two fresh air changes per hour. Fresh air intake is through four roof-mounted evaporative coolers connected to the four unit heaters by ducts and mixing boxes. Fresh air and return air rates are regulated by the manual setting of the mixing box damper. Used air is exhausted through five powered roof ventilators, each having a capacity of 10,500 cfm. These fans may be individually operated as required. Associated louvers are motor driven and interlocked with related fan circuits. Winter heating is regulated by temperature control valves in the steam supply line to each unit heater coil, each actuated by its related thermostat. Each system has a low-temperature override control of its related temperature control valve by the Ductstats (L-9-9a, 9b, 9c, 9d). Summer cooling and ventilation is effected by evaporative cooling of intake air, full use of the powered roof ventilators, and by opening the adjustable wall louvers on the north side of the building.

K. HEAT EXCHANGER BUILDING SYSTEM - Building No. 644

The heat exchanger bay section of building No. 644 is heated by two horizontal propeller-type unit heaters. The steam supply to the heating coils is by manually operated steam valves. The fan motor is "ON-OFF" controlled by a space thermostat mounted on the south wall.

The system for the demineralizer valve room is heated by one horizontal propeller-type unit heater. The steam supply to the heating coil is a manually operated steam valve. The fan motor is "ON-OFF" controlled by a space thermostat. The tank room is heated to 50°F by one steam-heated converter. An electrically operated valve in the steam supply line is controlled by a temperature controller mounted on the north wall of the valve room. The related temperature bulb is mounted on the south wall of the tank room. The connecting capillary is sleeved through the wall.

L. COOLING TOWER PUMP HOUSE - Building No. 645

The pump house is heated by two industrial unit heaters. Each unit fan is started and stopped by means of a push-button. Steam supply to each unit coil is regulated by an electric modulating-type valve which is controlled by a graduate acting room thermostat. Summer ventilation may be effected by opening manually operated roof and wall louvers. The chlorine room of Building No. 645 is exhausted by means of an exhaust fan taking suction from the floor level.

M. ELECTRICAL BUILDING SYSTEM - Building No. 648

Winter heating of the main floor is maintained by two industrial-type unit heaters equipped with mixing boxes. Steam supply to the unit heater coils is regulated by control valves in the related supply lines, each controlled by its related thermostat. Fresh air intake shall be equal to the total cfm exhausted from the battery rooms and force vented from the cable vault. A floor-mounted fan on the first floor level removes air from the first floor area, at a maximum rate of 6000 cfm, and force ventilates the cable vault area through a connecting duct. Venting is effected through a vent duct rising to the roof at the west end of the building. Air is exhausted from the battery rooms at the rate of 1980 cfm by means of a roof-mounted, powered ventilator.

Summer cooling of the areas is effected by adjusting the mixing box damper to route intake air from the evaporative coolers through the unit heaters. Additional ventilation may be obtained by manually opening the gravity vents in the ceiling.

N. EXPERIMENTAL AIR FILTER PIT AND TUNNEL - Building No. 755

Tunnel cooling and ventilation is accomplished by taking air through an evaporative cooler, rated at 8000 cfm, located at ground level at the reactor building end of the tunnel, and exhausting tunnel air through either one of two tunnel exhaust fans rated at 7500 cfm. A second evaporative cooler, rated at 6000 cfm, mounted on the roof of the filter pit admits air for cooling the filter pit area.

This system also includes a recirculation fan and mixing box with an associated motor operated damper and two electric unit heaters controlled by individual thermostats. The damper motor has a separate thermostat control. The recirculation fan operates only in the winter to prevent filter pit temperature from falling below 50°F. The modulating thermostat actuating a damper motor opens and closes the outside air intake damper in the mixing box to provide the necessary mixing of the outside and recirculated air to prevent freezing air from entering the room.

O. WASTE GAS STACK ROOM - Building No. 753

This system includes only an electric space heater and controlling "ON-OFF" thermostat set at 50°F, and a current relay.

P. WHITE DIESEL BUILDING

The White diesel building is heated by a horizontal propeller-type unit heater. The steam supply to the heating coil is regulated by two pneumatically operated steam valves. The fan motor is "AUTO-ON" controlled by a space thermostat located on the west wall of the building. The fan circulates 3000 cfm (2000 cfm outside air and 1000 cfm return air). Also there are two roof fans and a wall louver for temperature control.

Q. CUBICLE EXHAUST SYSTEM

The cubicle exhaust system is a continuation of the basement heating and ventilating system. The air flow route is from the console floor through rectangular openings along the perimeter of the basement ceiling to the experimental cubicles, and then into the cubical exhaust duct. Two 20 hp cubicle exhaust fans, each rated at 7200 cfm, discharge to the suction side of a booster fan. In the reactor building are three exhaust ducts located at the working canal, storage canal, and reactor top. These ducts come through the main floor. Located in this duct on the console floor is an Axivane fan, rated at 3900 cfm and driven by a 2 hp motor, which discharges into the suction side of the cubicle exhaust fans.

The booster fan, rated at 25,000 cfm, driven by a 75 hp motor is in a room located on top of the heat exchanger building and discharges to the waste gas stack via a continuation duct. Located in the same room as the booster fan is an exhaust fan, rated at 5000 cfm and driven by a 15 hp motor. This fan draws air from the heat exchanger building and discharges it to the suction side of the booster fan.

R. BUILDING SEAL OPERATION

Two "Building Seal Pushbuttons", No. 1 and No. 2, are located on the reactor control console in the reactor control room. These pushbuttons are interlocked with dampers and fan motors for the reactor building to permit sealing the building and purging the building of contaminated air when conditions require this function. The "Building Seal Pushbuttons" close dampers and shutdown fans as follows:

Pushbutton No. 1

1. Console Supply Fan
2. First Floor Exhaust Fan and Building Seal Damper
3. First Floor Return Air Damper
4. Console Floor Return Air Damper
5. Console Floor Supply Air Damper
6. Console Floor Outside Air Damper

Pushbutton No. 2

1. First Floor Supply Fan
2. Cubicle Exhaust Fans and Building Seal Damper
3. First Floor Supply Damper
4. First Floor Outside Air Damper
5. Cubicle Exhaust Dampers

CHAPTER XV

ETR FIRE PROTECTION

A. DESCRIPTION

The ETR fire water loop is a continuation of the MTR facilities. The pumping units are located in the raw water pump house. The distribution system will provide water to fire hydrants strategically located in the yard area to protect all building (see Figure 41).

It also provides emergency cooling water to the ETR reactor in the event of a major primary cooling system failure.

1. Reactor Building Protection

The ETR main building has four types of fire extinguishing equipment available at strategic locations. These are the portable CO_2, dry chemical, and water extinguishers, and the standard fire hoses that are supplied from the plant fire water system. The locations of the portable extinguishers are marked by wall placards which are readily identified by their diagonal red and white stripes. On this placard will be a smaller metal sign giving information as to the use of the extinguisher. The fire hose stations are found in the southeast and northwest corners of each floor and are marked by a red area on wall and floor immediately adjacent to the hose location.

(a) Main Floor Area

The main floor of the ETR contains eight portable CO_2 extinguishers in addition to the two hose stations.

(b) Console Floor

The console floor and balcony contains eight CO_2 extinguishers in addition to the two hose stations.

(c) Basement Floor

The basement floor contains one CO_2 and three dry chemical extinguishers. There are also the usual two hose stations.

(d) Office Area

The office building contains two hose stations, one located in the hallway on the first floor, and the other in the hallway on the second floor. Each floor contains two water extinguishers. The Health Physics office, reactor control room, chiller room, fan room, and amplifier room each contain one CO_2 extinguisher.

(e) Experimental Loop Protection

Because of the nature of some of the experimental loops, it is necessary to have additional fire protection.

Two Dowtherm cubicles have fixed pipe automatic dry chemical fire extinguishing systems. The system consists of nozzles which are fed through permanently installed piping from a dry chemical unit. Should a fire occur, the rapid rate of temperature rise will automatically actuate the dry chemical unit and will flood the entire cubicle with dry chemical. The system can be manually tripped, if necessary, by devices located at the dry chemical unit.

For experiments containing liquid metals, there is for use a portable unit containing metal "X" type extinguishers, protective clothing, shielding, and other equipment.

2. Compressor Building Protection

The ETR compressor building, in addition to the usual combustible material, has the hazard of three oil fired heaters, associated pump, and piping located in the building. To protect against this

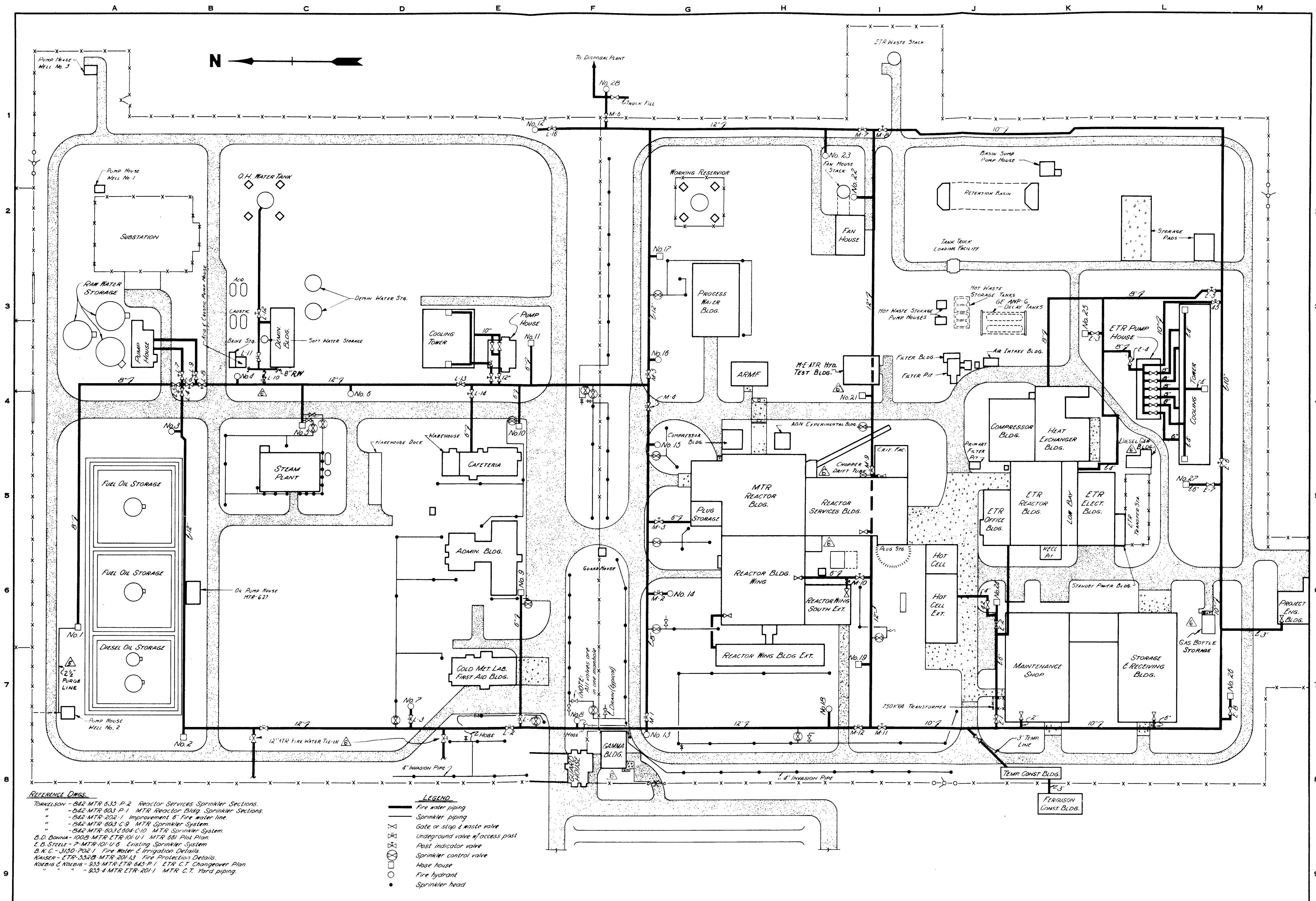

Fig. 41 MTR-ETR area fire system.

hazard, a hose station with adapter and 12 cans of foam are located by the large door at the east end of the building. Because of the high voltage electrical equipment in the area, extreme caution should be used in spreading foam in the event of fire. In addition, there are three CO_2 extinguishers and three dry chemical extinguishers located at strategic locations throughout the building.

3. Electrical Building and White Diesel Building Protection

The White diesel building is equipped with two dry chemical extinguishers. Two dry chemical and three CO_2 extinguishers are located in the electrical building, one of the latter being located in the electrical building cable room.

4. Cooling Tower and Pump House Protection

The fire protection system for the ETR cooling tower is a deluge-type system. A 10-inch line comes around the cooling tower, through the floor into the ETR pump house, and into a header in the pump house. From the header, the water splits into six risers. Five of the risers supply deluge water to sprinkler heads in the nine cooling tower bays. The other riser supplies water to the three hose stations on the cooling tower top deck. Each of the six risers has a hydraulically operated valve. The five deluge valves are tripped by a solenoid valve actuated by heat sensing devices throughout the cooling tower. The heat sensing devices, set at 140°F, trip the solenoid valves and deluge the cooling tower bay from which the signal was received. The header valve for the hose stations is tripped by a pneumatic signal when any one of the three hose valves on the cooling tower top is opened. The deluge valves may be tripped manually from the cooling tower pump house. When the deluge valves are actuated either manually or automatically, an alarm is sent to the fire station through the ADT system. The piping between the deluge valves and the cooling tower is kept dry when not in use to prevent freezing in the winter. The old 8-inch deluge system line is tied in upstream of the present header, and the 8-inch valve is left open for added fire protection.

5. Heat Exchanger Building

The principal fire hazard that can be associated with the heat exchanger building would be a fire originating on the roof. The only fire protection in this building is a hose station located in the southeast part of the building. Due to the location, as well as radiation and contamination problems, it is improbable that this station will ever be used for fire protection.

6. ETR Outside Area Protection

As mentioned earlier, the ETR fire protection system is a continuation of existing MTR facilities and circles the entire area. Tied into this existing 10-inch line are other 6-inch, 8-inch, and 10-inch lines which go to various buildings and hose-house hydrants. Three hose houses are in the ETR area at the following locations: east of the heat exchanger building; west of the cooling tower; and at the northeast corner of the maintenance building. The hose-house contains 200 to 300 feet of 2-1/2-inch hose, connectors, and nozzles for each size. An additional hose-house and fire hydrant is located at the southwest corner of the main loop for protection of the temporary buildings located in that area.

The water pressure on the fire main system has a static pressure of 80 psi. The electric driven fire pump maintains this 80 lb pressure with a certain time delay on pressure drops. If the pressure drops to about 65 psi the emergency gasoline fire pumps start and boost the pressure to about 125 psi. The fire water system is being revised to increase the capacity of the system.

7. ADT Fire Alarm System

The ADT (American District Telegraph) system at ETR can be activated by telephone or by pulling an alarm box. By dialing 2211, a direct line to CF fire station, the fire can be reported. The CF fire station will call the MTR steam plant and the operator at the MTR can transmit an audible fire alarm to the MTR-ETR area. Each alarm box has a particular code which is stamped on the box; also attached to the box is a fire code. To activate the system, the box lever must be pulled one or more times. This will audibly alarm the fire gongs at MTR and ETR; the alarm code will give the location of the alarm box which was pulled. The alarm cuts a tape code at the CF fire station, giving the area and alarm box which was activated. It also transmits a code to the steam plant at MTR on what is termed the "universal transmitter".

CHAPTER XVI

GENERAL PLANT UTILITIES

A. BUILDING EFFLUENT CONTROL

Three general classes of liquid wastes are discharged from the ETR. These are cold effluents, warm effluents, and hot effluents.

1. Cold Effluents (see Figure 42)

Cold effluents are those which are considered as never containing radioactivity; for example, cooling tower purge, steam boiler blowdown, etc.

Such effluents as cooling tower purge or wastes and overflow from raw water demineralizer contain no activity and are pumped to the south end of the east MTR retention basin for flow measurement before disposal to the MTR leaching bed.

2. Warm Effluents

Warm effluents are those which normally have a small amount of radioactivity such that the material is within the allowable tolerance for leaching into the soil or can be brought economically within this tolerance by diluting or by holding for short-term decay of radioactivity. Material falling within this class includes reactor primary water following normal operation, canal drain water, access tunnel drains, pipe tunnel drains, etc.

These effluents will enter collector piping leading directly to a 5000 gal "warm" sump tank beneath the basement floor of the reactor building. The lowest source, the sump in the control rod access tunnel, will require a pump; the remaining drains will flow by gravity to the 5000 gal "warm" sump tank.

The 5000 gal warm sump tank has two sump pumps rated at 200 gpm at 110 foot head. These pumps can be manually operated; however, they are normally automatically operated by remote level indicating devices. Either pump can be selected to start first with the second pump starting at a higher tank level. Discharge piping is 4-inch stainless steel through a horizontal swing check and a basement floor operated plug valve. Discharges of these two pumps connect to a common 4-inch header which penetrates the sump tank exterior wall, rises to within 5 feet 0 inches of finished grade, and terminates at the north end of the MTR retention basin. A spare connection is provided on both "hot" and "warm" tank discharges, accessible 5 feet 0 inches below grade and 3 feet 0 inches from the north wall of the office building. At this point, the "warm" sump tank discharge has a transition to mechanical joint cast iron and remains so until its termination. The warm effluents also may be pumped directly to any of the four MTR hot waste storage tanks.

3. Hot Effluents

Hot effluents are those which are above the radioactivity tolerance for disposal as defined for warm effluents, or which frequently contain long-life radioactivity of an amount making it uneconomical to reduce to leaching tolerance by diluting and holding for short-term decay. The principal source of this class of effluent includes experimental loop-flushing liquids and possible radioactive liquids used in the loops.

Hot effluents will be on a separate collection system draining into a 500 gal hot sump tank. This tank will act as a sump from which hot wastes can be pumped to the MTR 10,000 gal hot-waste storage tanks. No provision will be made for sampling or neutralizing hot wastes in the 500 gal sump tank.

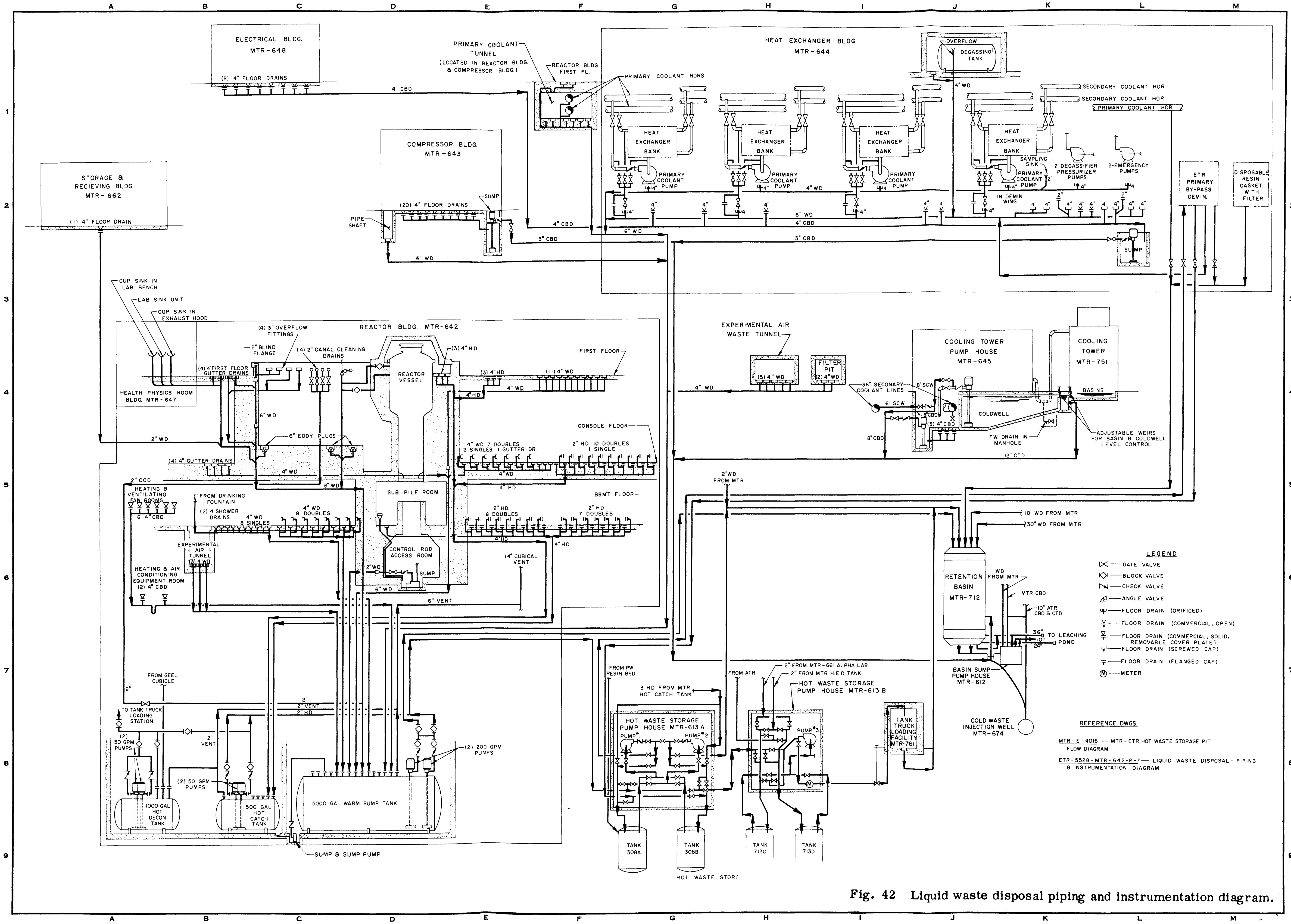

Fig. 42 Liquid waste disposal piping and instrumentation diagram.

The 500 gal hot sump tank located in the tank area under the basement floor along the north wall has two sump pumps rated at 50 gpm at 75 foot head. These pumps can be remote manually operated; however, they are normally automatically operated by remote level indicating devices. Normal operation requires only one pump with the other as a backup that starts at a higher tank level. Discharge piping is 2-inch stainless steel through a horizontal swing check and a basement floor operated plug valve. The discharges of these two pumps connect to a common 2-inch header which ties into a 4-inch line and serves as an emergency discharge from the 5000 gal warm sump tank. This 4-inch stainless steel line penetrates the sump tank exterior wall, rises to within 5 feet 0 inches of grade, and terminates at the MTR Hot Waste Storage.

A tank truck loading facility is located near the MTR Hot Waste Storage pit so that hot wastes can be pumped to a tank truck for disposal at the Chemical Processing Plant.

Both the warm sump and the hot sump tanks are tied into the cubical exhaust system. This maintains a negative pressure on the tanks for the removal of gasses. This also maintains a negative pressure on the warm and hot drains throughout the building to prevent the escape of air activity when a drain cap is off.

4. Reactor Building Drain Lines (Exclusive of Sanitary Drains)

The following warm and hot drains are provided in the ETR building.

(a) First Floor - Six hot drains, eleven warm drains

A gutter with a checker grate cover and four gutter drains are provided on the floor around the canal. Warm and hot drains have twin connections whenever adjacent to a building column. The first floor is sloped toward the gutter for a distance of 6 feet. The total slope is 1/2 inch. A small curb is provided around the annular space adjacent to the reactor to prevent water from the first floor from running down to the console floor. Three of the hot drains are located in the reactor nozzle trench.

(b) Console Floor - Eleven hot drains, nine warm drains

A gutter with a checker grate cover and four gutter drains are provided around the canal. Warm and hot drains have twin connections whenever adjacent to the biological shield or a column.

(c) Basement Floor - Fifteen hot drains, sixteen warm drains

The basement floor has a line of hot drains and warm drains adjacent to the sub-pile room and another pair of lines near the exterior wall of the cubicle area. All drains in the basement floor have twin connections. The twin connections include one connection for a semi-permanent pipe connection from experiments and one for collecting water from the floor. Flush mounted caps are provided to close inlets when not in use. Each type is plainly marked for ready identification. Warm drains are provided for the Health Physics room. The pipe tunnel and safety showers are connected into the warm drainage system.

5. Liquid Waste Tolerances

The system reduces the probability of above tolerance liquid wastes being discharged into the leaching bed and provides sufficient flexibility for choosing between disposal of low-level active wastes by dilution to tolerance or by concentration and subsequent burial.

The maximum allowable concentration for soluble waste material that might find its way to the water table is three times the drinking water tolerance, on a yearly average. At any given time, up to six times, the drinking water tolerance can be used at the discretion of the operator so long as the yearly average does not exceed three times the drinking water tolerance. To discard material greater than six times the drinking water tolerance, special permission will be required from the Idaho Operations Office, USAEC.

Since it takes approximately 190 days for subsurface water from the ETR site to reach the boundaries of NRTS, it is assumed that the tolerance will be based on activities extrapolated to 190 days after addition to the leaching bed.

Drinking water tolerance for mixed, unidentified fission products is taken to be 1 x 10^{-7} microcurie per milliliter. For waste in which all the radioisotopes have been identified, the drinking water tolerance will be determined from the maximum permissible amounts of radioisotopes contained in Table 3 of Handbook 52, U. S. Department of Commerce, National Bureau of Standards, using the method described in Appendix 1 of that document.

B. PLANT AND INSTRUMENT AIR SYSTEM

The ETR instrument and plant air is received from the MTR-ETR plant and instrument air compressors and auxiliary equipment. This equipment is located in the MTR steam plant. The air distribution system is by underground carbon steel pipe. Air to the ETR is brought to the north side of the compressor building, 643, to the east side of the heat exchanger building, 644, to the south side of the electrical building, 648, and to the east side of the cooling tower pump house building, 645.

The pressure of the ETR plant air system is at 125 psig, while the instrument air system is at 110 psig.

The ETR instrument air system has a total of 46 service outlets, while the ETR plant air system has a total of 78 service outlets.

C. HIGH PRESSURE STEAM SYSTEM

The high pressure steam for the ETR is generated in the MTR steam plant.

The steam is carried to the ETR in 4-inch carbon steel insulated pipe, in conduit along with the return condensate line. The steam is delivered to the north side of the office building, 645, the north side of the compressor building, 643, the east side of the pipe pit in the heat exchanger building, 644, the south side of the electrical building, 648, and the east side of the cooling tower pump house, 645. The lines are sloped to drain and are trapped at all low points.

The ETR steam distribution system provides space heating to the following: reactor bay, basement floor, console floor, office bay, electrical and White diesel buildings, cooling tower and pump house. Tank heating is provided to the demineralized water storage, the diesel oil storage, and the acid storage tanks. Steam also is provided to experimental loops for water preparation systems.

The total continuous ETR steam demand is 6560 lb/hr.

D. DOMESTIC WATER SYSTEM

Domestic water is a blend of soft water with raw water.

The domestic water for the ETR is supplied by the MTR soft water treating unit. The ETR domestic system is connected to the MTR system by 3-inch carbon steel piping. Water is delivered to the north side of the office building, 645, the north side of the compressor building, 643, and the south side of the electrical building, 648.

The pressure of the domestic water distribution system is 80 psig.

Water is supplied to the ETR domestic system at a maximum demand rate of 230 gpm.

APPENDIX

GLOSSARY OF USEFUL TERMS

Persons new to the nuclear field encounter many terms which are seldom used elsewhere. In order to assist Trainees in getting acquainted with these terms, a few of the more common ones have been assembled here. As experience is gained and more study is made, it will be realized these are not rigorous definitions, but only helpful guides in terms used in daily work at the MTR and ETR.

A. REACTOR TERMS

1. Fast Neutrons

Those neutrons produced that have not been slowed down. They have energies above 1 MeV and may range as high as 15 MeV.

2. Intermediate or Resonance Neutrons

Those neutrons which have been slowed down to an energy range between 1 eV and 1 MeV. In this energy region many materials show absorption resonances to neutrons.

3. Slow Neutrons

Those neutrons that have been slowed down below 1 eV in energy.

4. Thermal Neutrons

Those neutrons which have been slowed down to "thermal" energy; ie, 60°F. This is approximately 0.03 eV where the probability is as great that on the next collision they will gain energy as well as lose energy.

5. Delayed Neutrons

Those neutrons that are emitted as a result of the fission, but are delayed about 1/2 second to 1 minute. They constitute about 0.75 percent of all neutrons from a fission. The remaining 99.25 percent are prompt and are emitted at the moment of fission.

6. Pile

This term originated from the original reactor which consisted of a graphite pile with uranium interspersed through it.

7. Core

The section of the reactor which is the active fuel section.

8. Lattice

The section which contains the fuel elements and shim rods.

9. Reflector

A material which tends to reflect the neutrons back into the active core, and thus increases the reactor efficiency.

10. Moderation

The reduction in neutron velocity by elastic collision.

11. Moderator

A material used for moderation. This material should be of small atomic weight and have a low neutron absorption cross section.

12. K_{eff}

This symbol is known as the multiplication factor and is the number of neutrons at the end of a neutron generation compared to each neutron there was at the beginning of the generation. As a matter of interest, when $K_{eff} = 1$ the reactor is critical. A K_{eff} of 1.0001 would mean the reactor is in the neighborhood of a 60 second period. A K_{eff} of 1.0075 would mean the reactor is on a stable period of 1 second. A K_{eff} of 1.01 would mean the reactor is on a stable period of about 0.02 second.

13. K_{ex}

$K_{ex} = K_{eff} - 1$. Sometimes it also is known as $\triangle K$.

14. Reactivity (also called $\triangle K/K$)

A measure of the difference between the existing multiplication factor and what is necessary to be critical; ie, K = 1. It may be positive or negative depending on whether the pile is supercritical or subcritical. It is a measure of the potential to raise power and indicates how long operations may proceed before being overcome by poison. If $\triangle K/K$ is negative, it is impossible to reach criticality or raise power. When $K_{eff} = 1, \triangle K/K = 0$. ($\triangle K/K = K_{eff}-1/K_{eff} = 1-1/1=0$.)

15. $\triangle K/K/sec$

This ratio will establish the speed with which it is possible to raise or lower the reactor power.

16. Critical

The state at which the multiplication factor (K_{eff}) is 1. This means that the pile will sustain itself at that power.

17. Subcritical

The state at which K_{eff} is less than 1; ie, power is being lowered.

18. Supercritical

The state where the multiplication factor (K_{eff}) is between 1.0000 and 1.0075; ie, power is being raised. Technically the reactor is super delayed-critical as it is critical on delayed neutrons.

19. Prompt Critical

The state at which K_{eff} is greater than 1.0075. In this state, the delayed neutrons are no longer necessary to a sustaining reaction and prompt neutrons keep the power rising. In the MTR, "prompt-critical" corresponds to a period of just under one second. In general, a super prompt-critical reactor is on a dangerously short period.

20. Reverse Reactivity

A phenomenon associated with the depleted shim rods. The cadmium poison becomes plated with transmuted cadmium atoms which tend to reflect instead of absorb neutrons. Inserting one of these rods tends to increase power; hence, they are unsafe and must be detected and removed.

21. Temperature Coefficient of Reactivity

The change in reactivity that results from a temperature change of 1°F. A negative coefficient at the MTR and ETR results from heating of the pile causing its parts to increase in size due to thermal expansion. This, in turn, lowers neutron efficiency due to increased leakage, poorer reflection, and greater uranium atom spacing. The net result is a drop in reactivity. A negative reactivity coefficient is desirable because a runaway pile will tend to shut itself down.

22. Flux

The concentration of neutrons/cm^3 times the velocity in cm/sec; $\emptyset = nv$. n = no. of neutrons/cm^3; v = Velocity in cm/sec. (Thermal neutron velocity ≈ 220,000 cm/sec.) Total irradiation then becomes nvt where t is time in seconds.

23. Pile Period T

The time required for the pile flux to increase by a factor of e (2.71). It is also inversely proportional to the time rate of change of the logarithm of the flux; ie, $1/T = d(\ln\emptyset)/dt$. This is the inverse of the slope of log N recorder tracing. The flatter the slope, the shorter the period. As a matter of interest, the relationship between the period and reactor power is given by $P = P_o e^{t/T}$ where P = power, P_o = initial power, t = time, and T = period. Power is proportional to the flux; therefore, let $P/P_o = \emptyset$, then $\emptyset = e^{t/T}$; $\ln\emptyset = t/T$; differentiating we get $d(\ln\emptyset)/dt = 1/T$.

24. Scattering

A collision in which there is transfer of energy from one particle to another.

25. Elastic Scattering

A billiard ball type of collision in which kinetic energy is transferred to the target nucleus. Both momentum and kinetic energy are conserved. Elastic scattering moderates neutrons.

26. Inelastic Scattering

A collision in which some of the kinetic energy of the projectile is converted into internal energy of the target nucleus. This energy becomes evident as a gamma ray. Only momentum is conserved in this reaction.

27. Cross Section (σ)

The probability for an event such as a collision or absorption to occur. Its units are in square centimeters. For convenience, cross sections are written in terms of "barns". 1 barn (b) $\equiv 10^{-24}$ cm^2.

28. Scattering Cross Section (σ_s)

The probability for the projectile neutron to be scattered when passed through a given substance.

29. Absorption Cross Section (σ_a)

The probability for the neutron projectile to be absorbed by the substance.

30. Activation Cross Section (σ_{act})

The probability the collision will result in the target atom becoming radioactive.

31. Fission Cross Section (σ_f)

The probability that when the neutron is absorbed by the target, the target atom will fission.

32. Foils

Flux measuring devices, generally composed of thin metal. They are used to determine flux in desired locations of the Reactor by their activation. Neutron bombardment causes them to become radioactive, yet their small size does not cause a flux depression in the area.

33. Cerenkov Radiation

The blue glow visible around intensely radioactive sources. It is visible in the reactor tank around used fuel elements and around highly active experiments.

The blue light (it is always blue) is generated like this: high energy gammas, by Compton recoil, release shell electrons from water atoms. If the electrons are given energy greater than 0.26 MeV, they have a velocity exceeding the speed of light in the water. As they speed through the water, they generate an electromagnetic vibration analogous to a shock wave in air or a ship's bow wave in water. This is the blue glow, and it shows no spectral lines characteristic of any element. The generating electrons quickly lose their energy to other shell electrons of the water.

Cerenkov radiation can be generated in any transparent substance by charge particles of any kind, providing they are moving faster than the speed of light in that substance. In air, the blue glow will appear when generating electrons have energies above 21 MeV.

34. Radiation

Energy being released from an atom. Four types of radiation are: alpha (α), beta (β), gamma (γ), and neutron (n).

35. Alpha (α)

A high energy helium nucleus (He^{++})

36. Beta (β)

A high energy electron (e^-)

37. Gamma (γ)

A high energy electromagnetic ray emitted from a nucleus. X-rays are similar, except they are emitted from outer electron shells.

38. Neutron (n)

A neutral particle. It may be considered to be composed of a proton and electron combined. Having no charge, they are unaffected by electrical or magnetic fields.

39. Isotope

Elements which retain their chemical characteristics, but have different atomic weights.

40. Radioactive Isotopes

Isotopes which are giving off radiation in order to obtain a stable state.

41. Curie

1 Curie = 3.7×10^{10} disintegrations/sec. (8.7×10^{-4} grams of Co-60 = 1 Curie.)

42. Electron Volt

An electron volt (eV) is a unit of energy equal to the energy possessed by an electron that has moved through a potential rise of one volt. (eV = 10^{-19} watt = 1.6×10^{-12} ergs = 1.07×10^{-9} amu = 1.5188×10^{-22} Btu = 3.8276×10^{-20} calories.)

43. Contamination

Radioactive material on or in a non-radioactive substance. Generally, only surface contamination is encountered, and ordinary cleaning with soap and water will remove it.

44. Poison

An element with a high neutron absorption cross section is known as a poison. It takes neutrons out of the pile and may be used to control or smother a reactive pile.

45. Fission Products

When a uranium atom fissions, the elements which are produced are known as fission products.

46. Xenon (Zē. non)

A fission product from uranium. It has a very high absorption cross sectio for neutrons, 3.2 million barns.

47. Barytes Concrete

Barytes concrete has a high density; thus, it is a good radiation shield. The gravel and sand which is used is called barite, which is approximately 93 percent $BaSO_4$. Barite is common barium ore.

48. Shim Rod

Large manual control rod. Used to go critical and to scram. To shim reactivity for day-to-day operation.

49. MOR

A motor-operated rheostat which is part of the automatic control system. This rheostat can be set for a given resistance and balanced against an ion chamber resistance located in the Reactor. When they balance, the regulating rod will maintain power at a given point.

50. Regulating Rod

Small poison rod connected with the MOR and servo-mechanical system for automatic control.

51. PCP

Parallel circular plate ion chambers used for the three neutron level recorders and two servo systems because of their fast response.

52. Compensated Ion Chamber

Another form of ion chamber wherein the gamma radiation is compensated to show only neutron effects. The log N recorders receive their signals from this type.

53. Fission Chamber

A chamber where a coating of U-235 exists, and fission takes place proportional to the number of neutrons present. It is used for signal for a count-rate meter because of its extreme sensitivity.

54. ΔP

The water pressure drop across the reactor.

55. ΔT

The temperature rise of the process water while passing through the reactor.

56. Upper Grid

The removable section of the MTR core which holds the tops of the fuel elements in place and provides an alignment for the shim rods.

57. Rabbit Canal

The small shallow canal located on the west side of the MTR reactor in the basement. Rabbit facilities are located here which provide access to the lattice for short term irradiations. The small capsules used to carry the experimental material are called rabbits. The canal is necessary for radiation shielding.

58. D Piece

Beryllium piece which plugs the top of the MTR discharge chute.

59. Lead Plug

Set below the D piece in the bottom plug and is necessary to cut down the radiation in the sub-pile room.

60. Scram

Releasing one or more (usually all) of the shim rods so the poison section falls into the core, thus killing the pile.

61. Jr. Scram

A smaller number of rods (usually two) dropping into the core.

62. Reverse

An automatic insertion of all rods.

63. Fast Setback

Automatic rundown on MOR to N_L in 88 seconds.

64. Slow Setback

Automatic rundown on MOR to N_L in 465 seconds (7 minutes 45 seconds).

65. Preferred Insert (MTR)

If the regulating rod falls below the 7-inch light, the rod that is preferred will insert automatically until the regulating rod has returned to the 11-inch light (26-inch and 29-inch at ETR).

66. Semaphores

The cable arms from the instrument cubicles to the MTR top plug. Switches associated with these arms prevent start-up unless the arms are in the proper position.

67. Pile Suction

The vacuum drawn on the MTR pile by large blowers. They cause air to be drawn through the pile for cooling. It is discharged up the stack.

68. Monitor Room

The MTR basement room which contains fuel element monitoring instruments. Fuel elements are monitored for pressure drop, heat output, and radioactivity dissemination. The Reactor Service Operator (RSO) attends this facility.

69. Selsyns

A self-synchronous motor system which is often used to transmit position measurement to a remote station. If one motor (transmitter) moves, the other motor (receiver) immediately moves the same amount. The only connection between them is electrical.

B. EXPERIMENT TERMS

1. Block Valve

These valves are used to block flow completely and are generally hand operated. They may be gate or globe construction. A general rule in valve operation is never force a valve to its full-open position. Open it fully, then close it one-half turn. Never force a valve closed with a wrench, as it damages the seat.

2. Throttle Valve

Throttle valves control flow in systems and sometimes are used for reducing system pressures. They may be butterfly, needle, or globe construction. Never throttle with a gate valve.

3. Check Valves

This type of valve allows flow in only one direction. It closes on reversal of flow.

4. Air-Operated Valve

These are valves which are actuated by placing air pressure on a diaphragm which operates the stem. When the air pressure is varied, the valve opening will vary.

5. Pressure Reducing Valve (PRV)

These valves reduce system pressures by throttling the flow. Energy, hence pressure, is lost in the throttling turbulence. They are often self-regulating and can be set to hold a given pressure.

6. Demineralized Water

Water which has had all of the dissolved minerals removed. The impurities are less than 1 ppm.

7. Process Water

Demineralized water which is used to cool the reactor core.

8. Potable Water

Water for human consumption. It has been softened about 50 percent and treated with chlorine.

9. Raw Water

The water which comes straight from the well.

10. pH

The pH of water refers to the hydrogen ion concentration of the water and is an index to the acid or alkaline nature of the water. A pH of 7 is neutral and means a hydrogen ion concentration of 7 and a hydroxyl concentration of 7, or a total of 14. A pH of 8 means a hydroxyl ion concentration of 8 and a hydrogen ion concentration of 6. The higher the hydroxyl ion concentration, the higher the pH and the more alkaline the water. pH's may vary from 0 to 14.

11. Conductivity

A measure of the ability of a substance to conduct electricity. This is indicative of the purity of water, hence is useful in detecting changing loop conditions.

12. Commercial Power

Power which is purchased from commercial sources.

13. Failure-Free Power

Battery supplied motor-generators provide continuous power for a limited time when commercial power is not available.

14. Emergency Power (MTR)

Power which is provided by the emergency diesel generator, which is located in the steam plant. The diesel starts when commercial voltage drops below a preset value.

15. Amplidyne

A motor-generator set especially designed to act as a mechanical amplifier for dc electricity. A high power output may be generated by a small dc signal.

16. MG Set

Short for motor-generators. They are used to provide a constant, smooth, failure-free power supply. At this plant, there is an ac motor driving a dc generator, which drives a dc motor, which in turn drives an ac generator. This ac current is free of fluctuations normally found in commercial power. Batteries can supply the last two units so that current continues to flow without interruption on loss of primary power.

17. Frequency Generator

A motor-generator used to generate a controlled frequency power. When this drives a pump, it determines the speed of the pump, thus can control loop flow.

18. In-pile Thimble

This is the section of the experimental loop which is in the reactor. It contains an experimental test specimen.

19. Out-of-Pile Thimble

This is a section of the loop containing an identical specimen to that in the in-pile thimble. The specimen is subject to identical conditions with the one in the reactor, except that it receives no neutron bombardment. Comparison of the two shows the effect of neutrons on the test material.

20. Heat Exchanger

A unit designed to transfer heat from one system to another without mixing the systems. On the loops, it is used to extract excess heat gained by the water passing over a loop fuel element in the reactor.

21. Purification System

A system incorporated into the loop to maintain the water as pure as desired. It accomplishes this by use of ion exchangers to extract the free ions and crud filters to remove large free particles.

22. Ion Exchanger

A column of resin which extracts free ions from water. Special synthetic resins show a special affinity for cations; others for anions. Eventually they become saturated and may then be regenerated or disposed of.

23. Makeup System

Due to leakage and removal of samples from loops, it is necessary to make up the loss. This system adds pure water by means of a high pressure positive displacement pump.

24. Surge Tank

A tank in the experimental loop system where water may be heated to produce the required loop pressure. It also provides the space necessary for the variation of water volume due to increase in temperature.

25. Catch Tank

A temporary storage tank into which loop water can be drained in case it becomes highly radioactive and cannot be pumped to the MTR drain.

26. Amphenol Plug

A multipronged plug incorporated into the reactor "W" switch circuit which provided a quick convenient means of connecting the experiments into the reactor safety circuitry.

27. "W" Switch

A multicontact switch in the reactor safety circuits from an experiment. It is a convenient method of preventing signals from being transmitted to the reactor controls when testing safety responses at an experiment. These switches should never be opened without approval of Operation, Safeguards, and Project Engineering.

28. Test Block

A plug-in switch whereby selected safety functions of an instrument can be removed from the reactor circuitry. It performs the same function as a "W" switch, except only portions of the circuitry are invalidated.

29. Dowtherm

An organic liquid which has excellent heat transfer characteristics. It has such a pungent odor that harmful concentrations do not normally develop before they are detected. Its flash point is 210°F, so presents a fire hazard in cooling the high temperature loops.

30. Experimental Cooling Loop (ECL)

This facility provides a source of coolant for pumps and heat exchangers of the experimental loops. It contains process water and returns it to the process water system. It also is called the 4-inch cooling line.

31. XLE

This is a small compressor which can supply air for air cooled experiments. The XLE receiver also can be supplied by the Clark Compressor.

32. Clark Compressor

Large air compressors for experimental cooling. There are two 4000 hp compressors at ETR and a 1500 hp compressor at MTR.

33. Pressure Controller

An instrument that automatically controls the heaters on the surge tank. It automatically shuts off the heaters or turns them on, as the pressure rises or falls below the setpoint.

34. Temperature Controller

An instrument that controls the temperature of the water in the loop just before it enters the in-pile thimble. It accomplishes this by automatic operation of the loop heaters.

C. INSTRUMENT AND ELECTRICAL TERMS

1. D/P Cell

An instrument that will measure a differential pressure and transmit an amplified air signal proportional to the original D/P. The term D/P cell is a Foxboro Instrument Company trade name, but it is often applied to other differential pressure instruments.

2. Meletron

A trade name of the Barksdale Valve

Company given to a pressure switch. It is sensitive to pressure by the use of a diaphragm or bourdon tube which in turn actuates a microswitch at some predetermined setpoint.

3. Mercoid

A trade name of the Mercoid Instrument Company, usually used in reference to a bourdon tube which actuates a mercury bottle switch. The combination may have a range from 0 to 10,000 psig.

4. Flow-Rator

A trade name of the Fisher-Porter Company, although the term is usually applied to any make of a rotameter. This instrument works on the principle of a variable area between the tube and a contained float. As the flow increases, the float is pushed higher, opening a larger bypass area. The height of this float tells the amount of flow.

5. Flow Orifice

An orifice or small opening that is placed in a process flow line to create a pressure drop across it. This pressure drop can be used to calculate the flow.

6. Flow Venturi

A horn-shaped restriction in a fluid flow line with taps monitoring the pressure at the upstream at the narrow neck. The pressure taps are used to measure the differential pressure across the device, and thus the flow through it can be calculated by using known formula.

7. V/A Cell

A trade name of the Fisher-Porter Company. It is a variable area flowmeter which is used under high pressures and, usually, small flows. The flow is indicated by a gauge which is actuated by magnetic-mechanical connection to the bobber.

8. Potentiometer

The word actually means a type of voltage measuring circuit, but it is often used in the instrument field to designate a type of instrument that can be used to measure the emf developed by a thermocouple. The circuit also is referred to as "null-balance" because the potentiometer develops an emf that exactly counterbalances the emf of a thermocouple. Thermocouple temperature is determined by properly calibrating a voltage scale to read in degrees.

9. Pyrovane

A trade name of the Minneapolis-Honeywell Company. The term is generally used to designate a temperature measuring and controlling instrument. It is based on a D'Arsonval meter deflected by a current flow caused by the emf of a thermocouple.

10. Resistance Bulb

A device used to sense a temperature. The resistance of the bulb varies with the temperature and, by knowing this relationship, an unknown temperature can be determined.

11. TE Box

The name is used around the MTR to designate a terminal box for the thermocouple leads. The thermocouples from an experiment are terminated at a male plug, and a matching female plug is wired to an instrument. Switching of thermocouples is quickly and easily accomplished by the use of the TE Box.

12. Thermo-Bulb

A temperature measuring element which detects a temperature using a thermal filled system. This can mean a gas fill vapor pressure, mercury fill or other liquid fills. A change in temperature causes expansion of the fill which then is detected at a sensing element of some type.

13. Thermocouple

A device made up of two dissimilar metals fused together at one end. When this junction is heated, a voltage is produced proportional to the temperature. There are standard types of thermocouples that are employed to measure temperature emf's. Common types are: Iron-Constantan, Copper-Constantan, Chromel-Alumel, and Platinum-Platinum rhodium.

14. Microswitch

A trade name of the Minneapolis-Honeywell Company, Microswitch Division. This is an electrical switch that is operated by a very small movement of the actuator. They can be purchased in about any size, shape, or electrical rating.

15. Reactrol

A transformer-type device that uses a saturable core reactor as the control unit. It is an electrical method of controlling large current flows by means of a small input signal and can be thought of as a control valve for electricity.

16. Relay

A device used for switching electrical circuits. Generally, it is composed of three systems: (1) an actuating coil; (2) circuits with normally closed contacts; and (3) circuits with normally open contacts. The actuating coil draws a contact bar up when energized and opens normally closed (NC) contacts and closes normally open (NO) contacts. When actuating current is cut off, the actuating bar drops down and returns the contacts to their NORMAL condition.

17. Solenoid

An electrical coil which creates a magnetic field which in turn can be utilized to operate a switch, valve or lever. Solenoids are generally used where remote operation of a unit is required.

18. Time Delay Mechanism

A device that causes a delay between an initial signal and a resulting operation. They can be adjusted from seconds up to minutes of delay.

19. Pressure Transmitter

An instrument that is capable of detecting a pressure and transmitting an amplified signal proportional to the pressure to some distant point. The standard pneumatic signal is 3 to 15 psig. An electrical telemetering system may be used and the signal may be whatever is desired.

20. Controller Recorder Indicators (CRI or IRC)

An indicating and recording instrument which also can control a process. Control may be exercised automatically or manually as desired.

21. Indicator Controller

An instrument which controls a condition and indicates its present condition, but does not record this information.

22. Indicator

A gauge which only indicates a condition; ie, it does not record it.

23. Recorder Indicator

An instrument which records data on a chart and indicates the condition as it is recorded.

CONVERSION FACTORS

Multiply	By	To Obtain
1. Angstrom units (Å)	1×10^{-8}	centimeters
2. Atomic mass units (amu)	1.6599×10^{-24}	grams
3. Barns (b)	1×10^{-24}	square centimeters
4. British thermal units (Btu)	251.8	calories
5. British thermal units	6.584×10^{21}	electron-volts
6. British thermal units	3.9292×10^{-4}	horsepower-hours
7. British thermal units	2.931×10^{-4}	kilowatt-hours
8. British thermal units	1.2208×10^{-8}	megawatt-days
9. British thermal units	8.16×10^{13}	neutrons produced by U-235 fission
10. British thermal units	3.29×10^{13}	fissions (at 200 MeV/fission)
11. Btu/hour	0.29293	watts
12. Btu/(lb)(°F)	1.0	calories/(g)(°C)
13. Btu/second	1054.8	watts
14. Calories (cal)	2.6126×10^{19}	electron-volts
15. Calories	2.6126×10^{13}	MeV
16. Centimeters (cm)	0.3937	inches
17. Cubic centimeters (cc or cm^3)	0.061023	cubic inches
18. Cubic feet (cu ft or ft^3)	28317	cubic centimeters
19. Cubic feet	1728	cubic inches
20. Cubic feet	7.4805	gallons
21. Cubic feet	28.316	liters
22. Days	1440	minutes
23. Days	86400	seconds
24. Degrees Centigrade (°C) + 273.16	1	Centigrade degrees absolute

CONVERSION FACTORS (continued)

Multiply	By	To Obtain
25. Degrees Centigrade + 17.78	1.8	degrees Fahrenheit
26. Degrees Fahrenheit (°F) + 459.72	1	Fahrenheit degrees absolute
27. Degrees Fahrenheit -32	5/9	degrees Centigrade
28. Ergs (erg)	9.4805×10^{-11}	Btu
29. Ergs	6.2419×10^{11}	electron-volts
30. Gallons, U.S.	3.78533	liters
31. Gallons/minute (gal)	0.0022280	ft^3/second
32. Horsepower (hp)	0.70697	Btu/second
33. Horsepower-hours	3.107×10^{-5}	megawatt-days
34. Inches (in.)	2.540	centimeters
35. Inches	25400	microns
36. Inches	1000	mils
37. Joules (J)	9.478 x 10-4	Btu
38. Kilometers (km)	3280.8	feet
39. Kilowatts (kW)	3413.0	Btu/hour
40. Kilowatts	56.884	Btu/minute
41. Kilowatts	0.94807	Btu/second
42. Kilowatt-hours (kWh)	41.667×10^{-6}	megawatt-days
43. Kilowatt-hours	2.2472×10^{19}	MeV
44. Liters (liter or l)	0.26418	gallons
45. Megawatt-days (MWd)	8.189×10^{7}	Btu
46. Megawatt-days	24×10^{3}	kilowatt-hours
47. Megawatt-days	5.3916×10^{23}	MeV

CONVERSION FACTORS (continued)

Multiply	By	To Obtain
48. Megawatt-days	1.052	grams U-235 fissioned (at 200 MeV/fission)
49. Megawatt-days	2.696×10^{21}	atoms U-235 fissioned (at 200 MeV/fission)
50. Megawatt-days	6.69×10^{21}	neutrons produced by U-235 fission (at 200 MeV/fission)
51. Meters (m)	3.2808	feet
52. Microns (μ)	1×10^{-6}	meters
53. Ounces, avoirdupois (oz)	28.350	grams
54. Pounds, avoirdupois (lb)	453.59	grams
55. Radians	57.296	degrees
56. Rest energy of electron (= mc^2)	0.5110	MeV
57. Roentgens (r)	1	esu of ions/cm^3 of standard air
58. Roentgens	2.082×10^9	ion pair/cm^3 of standard air
59. Roentgens	1.610×10^{12}	ion pairs/gram of air
60. Roentgens	6.77×10^4	MeV absorbed/cm3 standard air
61. Roentgens	5.24×10^7	MeV absorbed/gram air
62. Roentgens (r)	83.8	ergs absorbed/gram air
63. Roentgens equivalent physical (rep)	93	ergs/gram absorbed by soft animal tissue
64. Rads (rad)	100	ergs/gram absorbed by any given material
65. Square centimeters	1×10^{24}	barns
66. Watts (W)	3.4137	Btu/hour
67. Watts	3.121×10^{10}	fissions/second
68. Watts	1	Joules/second

CONVERSION FACTORS (continued)

Multiply	By	To Obtain
69. Watt-second	6.2419×10^{12}	MeV
70. Years (yr)	365.24	days
71. Years	8765.8	hours
72. Years	3.1557×10^{7}	seconds

PHILLIPS
PETROLEUM
COMPANY

OMIC ENERGY DIVISION