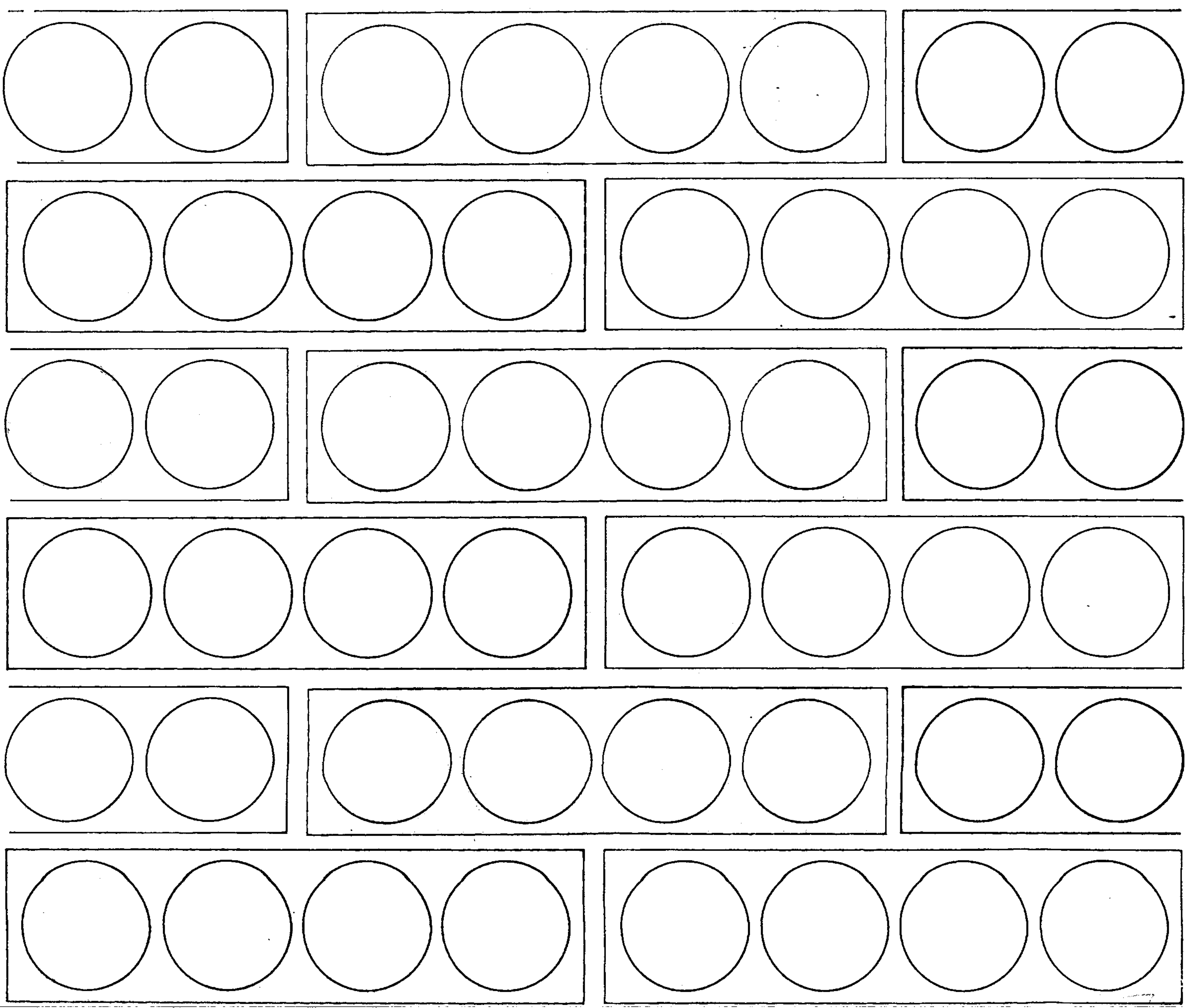
pickering generating station

design-description



PICKERING GENERATING STATION

Hydro Electric Power Commission of Ontario
Atomic Energy of Canada Limited Power Projects
1969

DESIGN DESCRIPTION

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

PICKERING GENERATING STATION

DESIGN DESCRIPTION

1. SUMMARY DESCRIPTION OF STATION

A brief description of the Pickering Generating Station is provided in this section as an introduction to the more complete technical description found in the sections following.

The Pickering Generating Station is located in the County of Ontario on the north shore of Lake Ontario, approximately 20 miles east of downtown Toronto and 13 miles west of Oshawa, in the Province of Ontario, as shown in Figure 1-1.

The site upon which the Pickering Generating Station is being erected is owned by the Hydro-Electric Power Commission of Ontario, who will own and operate the station when it is completed.

Responsibility for management of the project, for the general station design and for detailed design of the conventional parts of the station, and for on-site construction will be assumed by Ontario Hydro. Atomic Energy of Canada Limited (Power Projects, Sheridan Park) has been retained by Ontario Hydro to design the nuclear reactor, associated equipment and services and the integrated control systems for the entire station. The station is designed to operate as a base load plant.

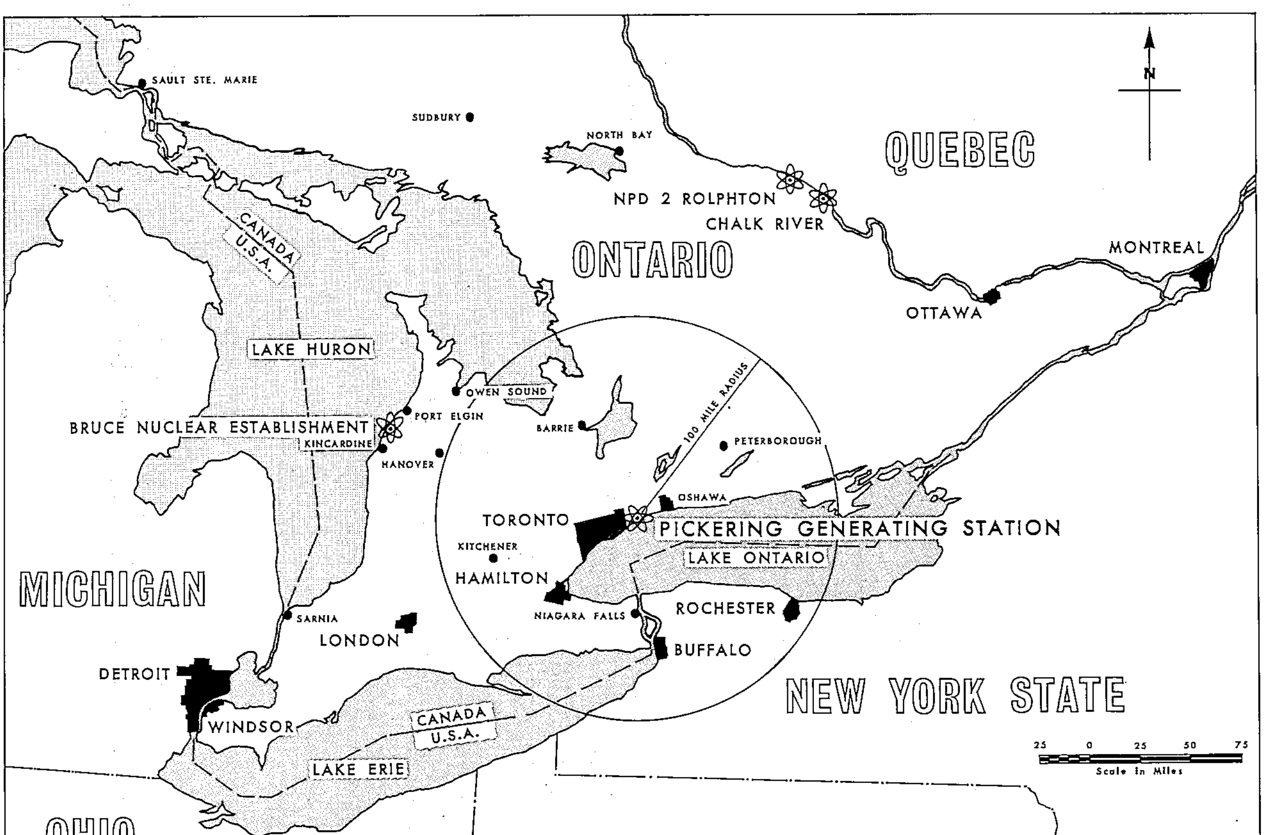
The station described in this report comprises four nuclear reactors, four turbine-generators and associated equipment, services and facilities arranged as shown in Figures 1-2A and B. The Station is arranged in such a manner that an additional four units may be added so as to form a symmetrical arrangement about the common service area and Administration Building.

The scheduled in-service dates of the four units comprising the station are as follows:

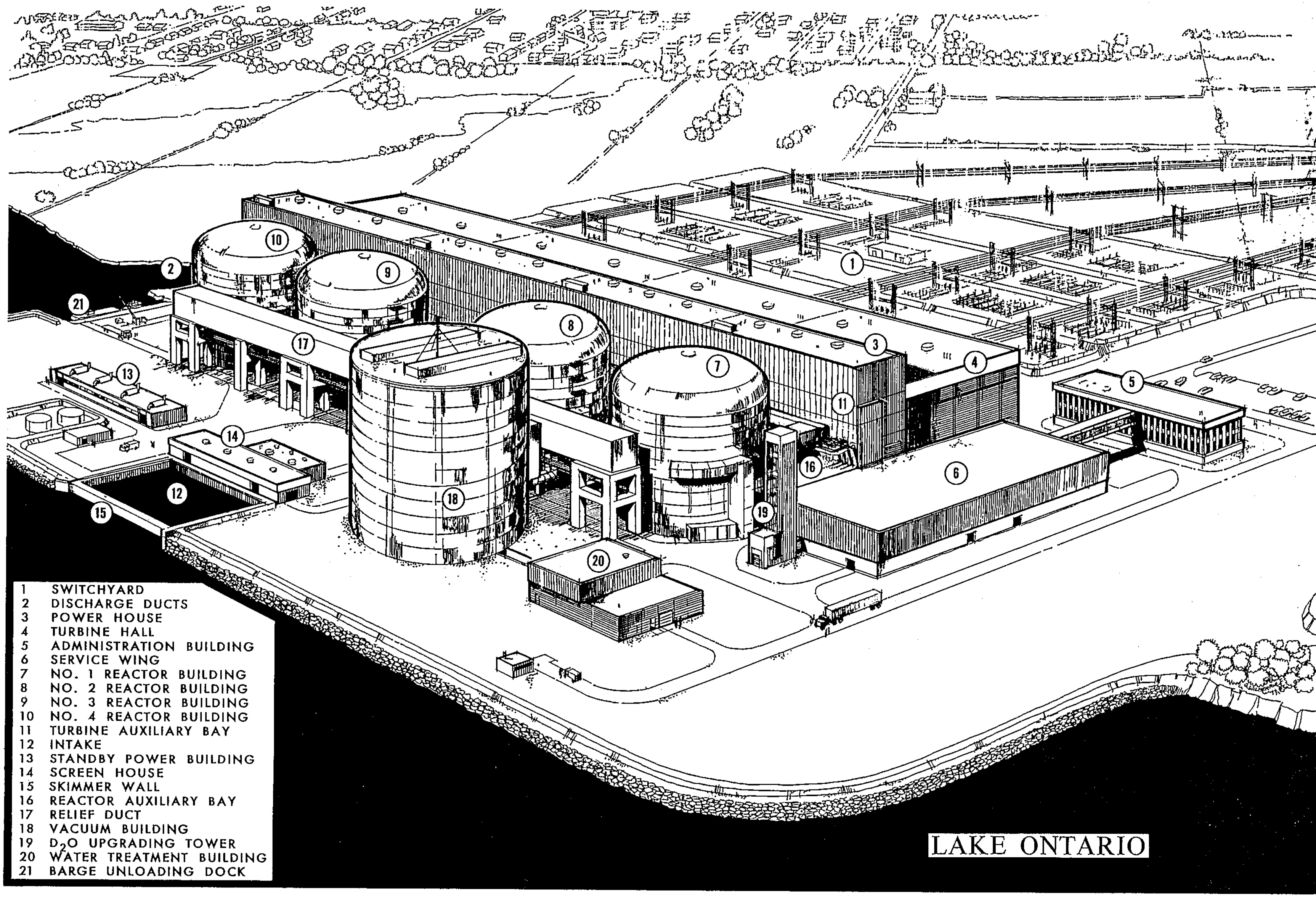
Unit 1,	Sep. 1971
Unit 2,	Mar. 1972
Unit 3,	Oct. 1972
Unit 4,	Oct. 1973

The design net electrical output of each unit is 508 megawatts at 90 percent power factor, yielding a total station net output of 2032 megawatts. Power will be produced at 24,000 volts and delivered at 230 Kilovolts and 60 cycles per second to the Southern Ontario grid of Ontario Hydro.

Each unit comprises a power source capable of operating independently of the other units but using certain common

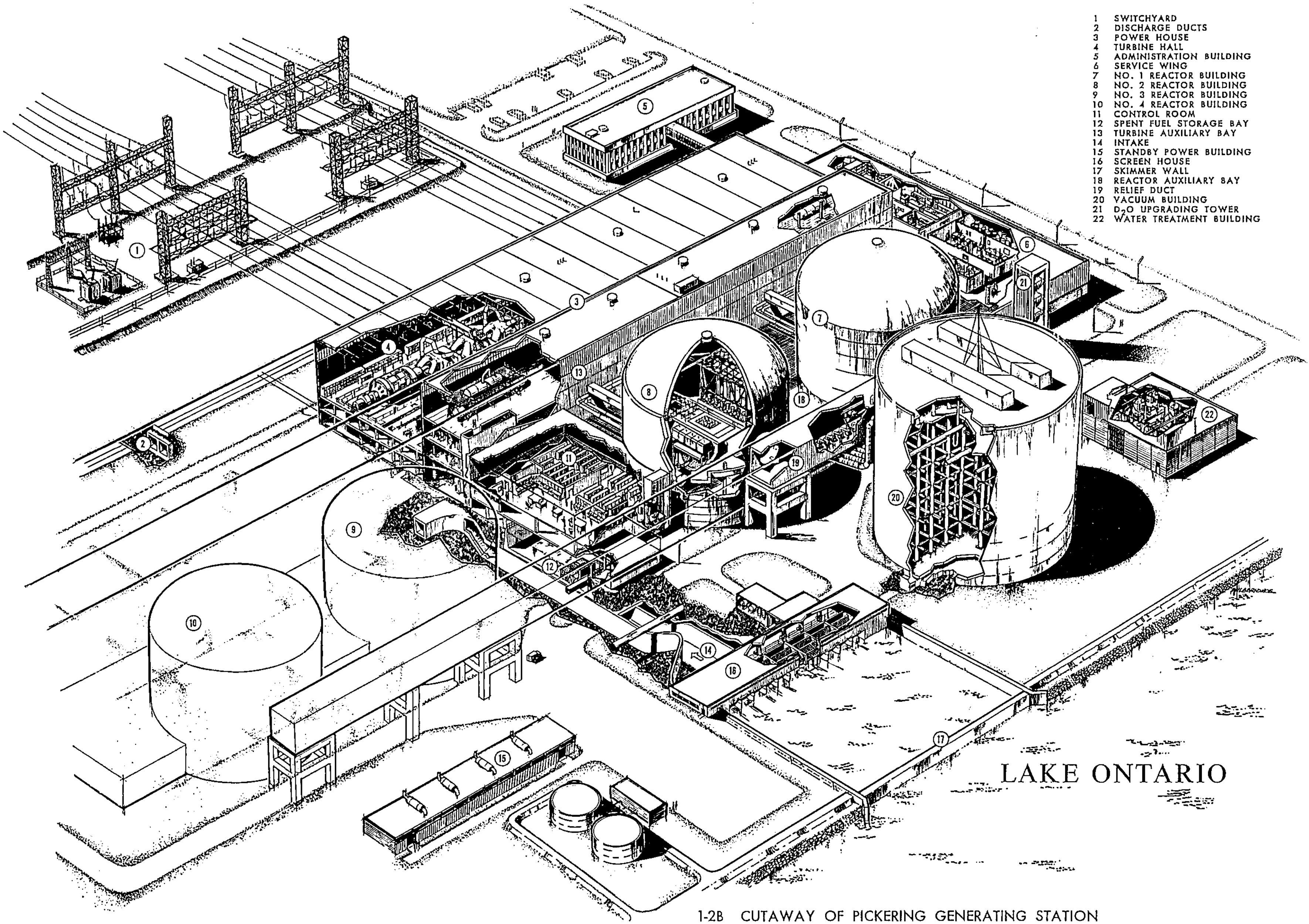


1—1 GENERAL LOCATION



1-2A PICKERING GENERATING STATION

44.20000-14
1968



1-2B CUTAWAY OF PICKERING GENERATING STATION services. The power generating equipment of each unit is a conventional steam-driven turbine generator: the associated heat source is a heavy-water moderated, pressurized heavy-water cooled, natural uranium dioxide fuelled, horizontal pressure tube reactor. The heat in the heavy-water coolant of each reactor is transferred through twelve tube-in-shell heat exchanger boilers to a conventional steam circuit which serves one turbine-generator. A simplified flow diagram for one unit is shown as Figure 1-3.

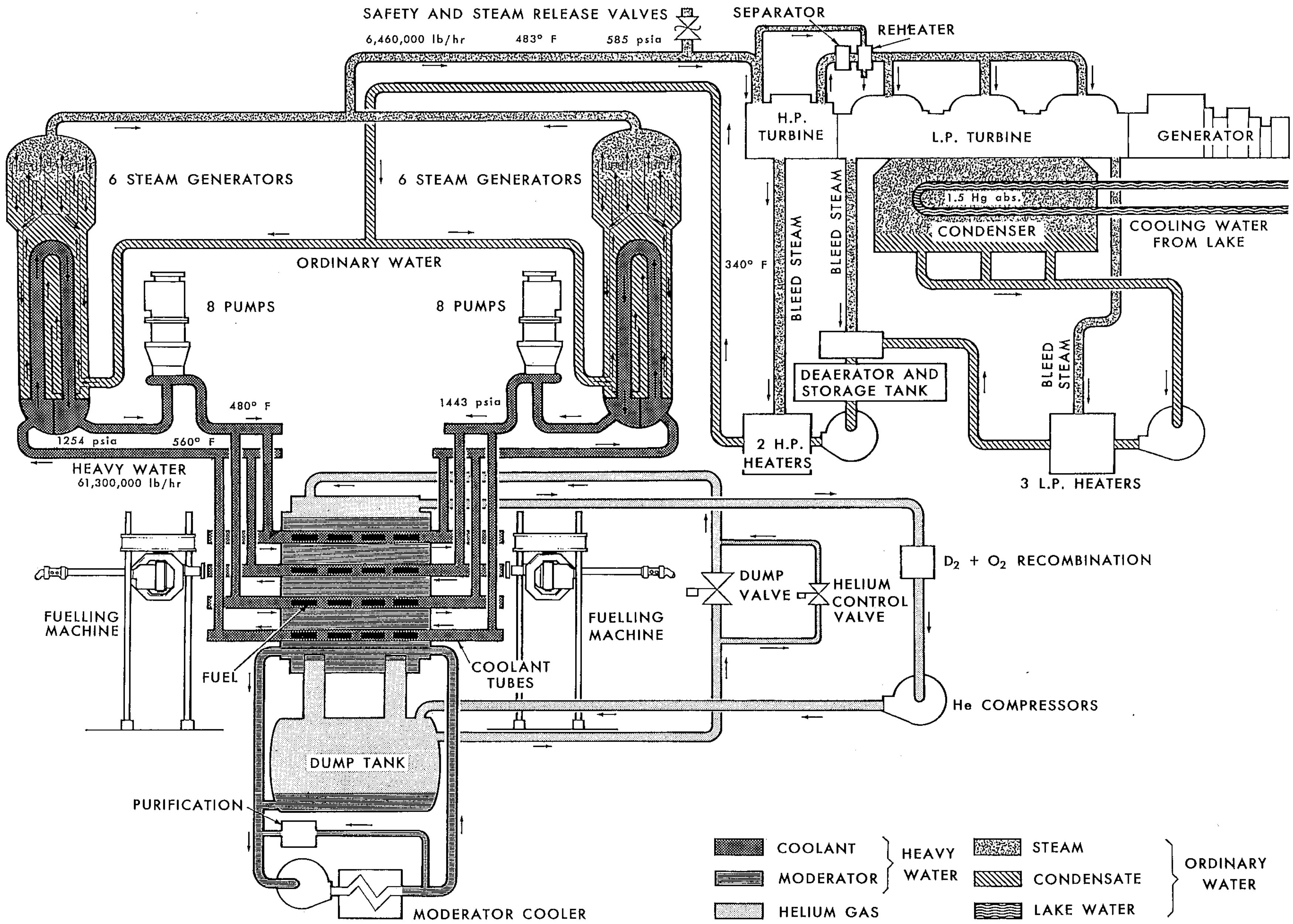
Each reactor, together with its associated boilers and closely related auxiliary equipment and systems, is located in a separate 140 foot internal diameter, reinforced-concrete Reactor Building. Associated with each group of four Reactor Buildings, and connected to them by a large duct, is a Vacuum Building, which is maintained at an absolute pressure of two inches of mercury. The combined volumes of the Vacuum Building, the relief duct and any one Reactor Building constitute an "emergency containment system" which is designed to contain all radioactive effluents which might result from a reactor system failure.

A two-storey Reactor Auxiliary Bay, which serves the four-unit station, is connected to and wraps around the northerly half of the perimeter of each Reactor Building. This building contains reactor auxiliaries and secondary circuits of low radioactivity level, new fuel storage, a spent fuel storage bay, and the plant control centre. A two-storey Service Wing is located at the easterly end of the Reactor Auxiliary Bay, i.e. centrally in the ultimate eight-unit station arrangement. It is connected to both the Reactor Auxiliary Bay and the Powerhouse and contains maintenance shops, change rooms, decontamination centre, station laboratories and the production control centre for the entire station.

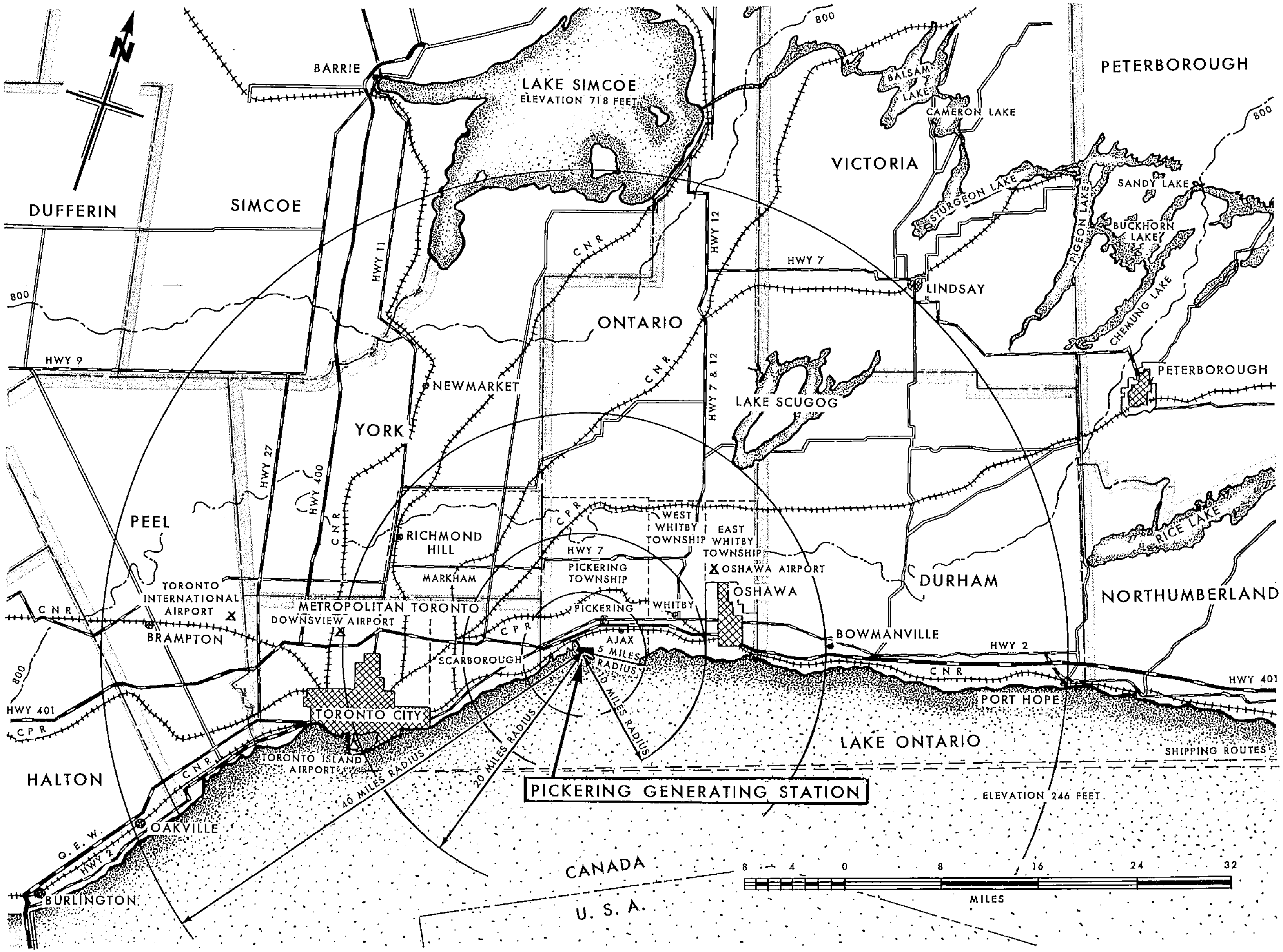
The four turbine-generators are arranged in line in the turbine hall of a steel frame powerhouse which runs the length of and adjoins the Reactor Auxiliary Bay. The Powerhouse also contains the circulating and service water pumps, in addition to the conventional steam and electrical power equipment.

A separate building adjacent to the Service Wing on the lake side contains the water treatment plant. Also located in a separate building on the lake side of the station are the standby generators which supply station electrical service power when the normal power supply is not available.

A separate Administration Building provides: office and administration facilities, personnel entrance to the station via an elevated passageway, telephone and public address equipment rooms, and a cafeteria.



1-3 SIMPLIFIED STATION FLOW DIAGRAM



2—1 PICKERING GENERATING STATION - 40 MILE RADIUS

44.10000—17
REV. 1, 1969

2. SITING AND ENVIRONMENTAL DATA

2.1 SITE LOCATION

The Pickering Generating Station is located on a 500 acre site in the Township of Pickering in Ontario County on the north shore of Lake Ontario about 20 miles ENE of downtown Toronto and 13 miles WSW of Oshawa, at latitude 43°49N and longitude 79°04W. In addition to the land area, the immediately adjacent water lots to the extent of 174 acres in Lake Ontario form part of the site. The site is adjacent to the community of Fairport on the east side of Frenchman Bay. The nearest incorporated village is Pickering, 3 miles north, and the nearest town is Ajax, 3-1/2 miles north east. The general location of the site is shown in Figure 2-1.

An aerial view of the 500 acre site and vicinity is shown in Figure 2-3. Superimposed on this aerial view are: a plan view of the four unit station, Ontario Hydro's property line and a line 3000 feet from the centre of all reactors of a projected eight unit station. Ontario Hydro also owns a 300 foot wide transmission line right-of-way south from Cherrywood Transformer Station. This right-of-way widens out to 1300 feet at the site boundary.

2.2 TOPOGRAPHY

The general topography of the reference site and the surrounding area is indicated in Figures 2-1 and 2-2 which are adapted from maps published by the Department of Defence, Army Survey Establishment and from surveys carried out by Ontario Hydro. Figure 2-3 is an aerial photograph of the area surrounding the site, with the outline of the station buildings superimposed.

The north shore of Lake Ontario runs generally WSW to ENE, but the site is on the west side of a promontory so that the site shoreline runs from WNW to ESE. The site boundary runs inland to a maximum of 7/8 of a mile from the shoreline.

The eastern part of the property rises to 275 foot elevation in the vicinity of a large drumlin. At the front of this part there is a fairly steep bluff rising to 30 feet above and 15 to 20 feet back from a sandy beach. The western part of the property is of lower elevation, becoming virtually swamp at the western extremity with an elevation of less than 5 feet above the nominal lake level of 245 feet. The area surrounding the plant structures is graded to an elevation of 253.5 feet above sea level. The waterfront area has been extended beyond the original shore line by the use of fill from elsewhere on the site.

The water in the lake in the immediate area of the site is less than 20 feet deep out to about 2000 feet from the shore line and 60 feet deep about 1-1/2 miles off shore.

The ground inland from the site is generally flat, with the 300 foot contour being about 2 miles away. The 500 foot contour corresponding approximately to the prehistoric Lake Iroquois shore line is within 4 miles to the northwest but runs about 5 or 6 miles back from the present lakefront from north of the site to beyond Oshawa. Further north the Oak Ridges moraine ridge rises to over 1000 feet above sea level on a line 10 to 15 miles inland and roughly parallel to the lakeshore. Beyond this watershed the general elevation of the Trent River basin is about 800 feet and consists of a predominantly clay plain with scattered lakes and drumlins.

The nearest point of land across Lake Ontario is about 35 miles SSE from the site. It is close to the town of Wilson, New York, U.S.A., and 12 miles east of the Niagara River. The distance to the international mid-lake boundary is 20 miles and it is 13-1/2 miles to the main shipping lanes to and from Toronto.

There are no major rivers or lakes other than Lake Ontario and Lake Scugog (20 miles north east) within 40 miles of the site. The lakeshore plain has numerous small rivers and creeks running south from the high moraine ridge 10 to 15 miles inland. Of these the nearest on the west are the Rouge, entering Lake Ontario 2-1/2 miles from the site, Petticoat Creek at a distance of 2 miles and several very small streams emptying into Frenchman Bay or the swampland adjoining the site. On the east there is Duffin Creek at a distance of 2 miles and an unnamed creek east of Ajax at 4 miles distance.

2.3 ACCESS

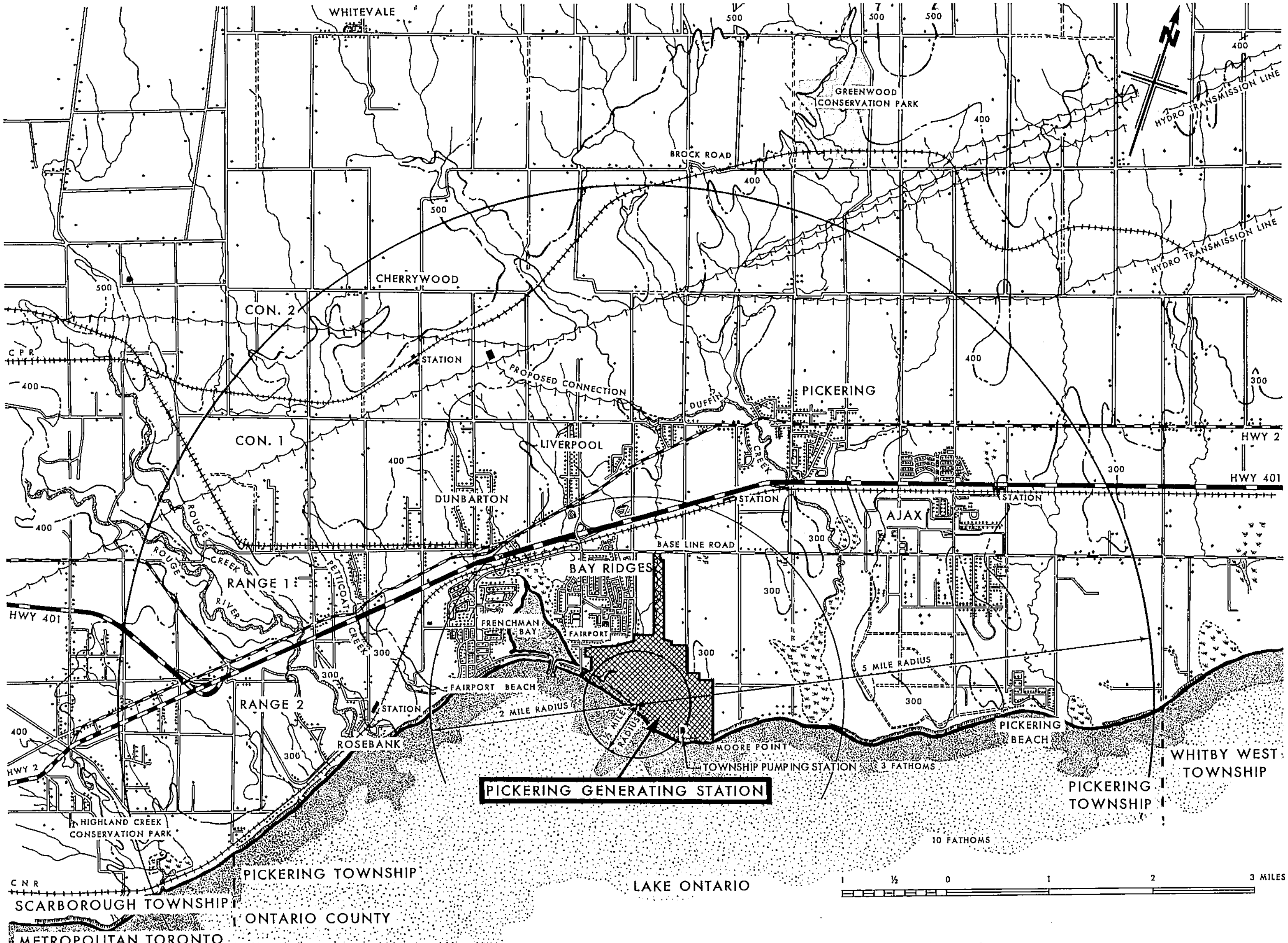
From the Liverpool Road interchange on the MacDonald-Cartier Freeway (Highway 401) the distance by road is 1-3/4 miles to the site boundary. In addition to this approach from the north west, passing near the recently developed residential community of Bay Ridges, access on township roads is available from the north connecting with the Pickering and Whitby interchanges on Highway 401 and with Highway 2 further north and north east. The CNR main line runs within 1-1/2 miles of the site with siding facilities at Pickering Station, 2-1/4 miles north of the site. The nearest small port is Port Whitby, 7 miles east of the site, but major shipments would require the use of Toronto harbour. A dock is being constructed on the east bank of the cooling water outfall excavation to facilitate unloading the major reactor components which will be shipped by barge. The nearest airport is 13 miles away in North Oshawa but scheduled flights do not take place from any airfield closer than Toronto International Airport at Malton, 30 miles to the west.

The right-of-way for the transmission line to the main Ontario Hydro System runs 3-1/2 miles north west to the present Cherrywood S.S.

The site boundary will be fenced to ensure exclusion of the general public from the station.

2.4 POPULATION

The site is within the region of Southern Ontario where



2—2 PICKERING GENERATING STATION — 5 MILE RADIUS

44.10000—5

2-3 STATION LAYOUT AND BOUNDARIES ON PICKERING TOWNSHIP AERIAL MOSAIC

44-10000-24
REV. 1, 1968

TABLE 2.4—1

PROJECTED 1986 POPULATIONS WITHIN 28 MILES OF PICKERING SITE

Miles Radius	SW (shoreline)	W	NW	N	NE	E (shoreline)	Total Within Radius
0 to 4	500	3,000	10,000	6,000	11,500	600	31,600
to 8	41,500	100,000	18,000	20,000	26,000	720	206,220
to 12	109,500	233,500	28,700	28,600	91,300	6,820	498,720
to 16	262,500	447,700	41,950	32,800	140,180	13,660	938,790
to 20	477,500	672,300	51,420	35,500	154,130	16,180	1,407,030
to 24	675,500	985,780	71,420	47,470	165,130	33,700	1,979,000
to 28	827,500	1,237,370	104,390	49,730	170,330	34,720	2,424,040

NOTE: These figures could be increased in some areas by 8% to 10% if the rate of immigration typical of the 1960-65 period continues.

TABLE 2.4—2

POPULATION CLOSE TO SITE ESTIMATED FOR 1965

Miles Radius	SW	W	NW	N	NE	E	Total Within Radius
1	----	75	900	10	15	5	1,005
1-1/2	----	155	6,900	25	50	170	7,300
2	----	955	*7,200	125	65	175	8,460
2-1/2	----	1,175	7,900	305	75	180	9,635
3	15	1,295	8,050	1,055	150	180	10,745
3-1/2	40	1,455	8,240	**2,405	3,780	195	16,115
4	100	1,645	8,440	2,635	***9,165	395	22,380
4-1/2	200	1,995	8,690	2,905	9,565	405	23,760
5	325	2,395	8,965	3,185	9,840	430	25,140

NOTE * : Bay Ridges development population approximately 6000 within 1-1/2 to 1-3/4 miles NW.

NOTE ** : Pickering Village population approximately 1800 within 2-1/2 to 3-1/2 miles N.

NOTE ***: Town of Ajax population approximately 8600 within 3 to 4 miles NE.

continued urbanization and population growth is occurring at present and is expected to continue in the foreseeable future. This growth occurs around the existing urban centres and along the main traffic routes. Because of the expected growth, considerations of population distribution have included information from projections for the year 1986, prepared by the Ontario Department of Economics and Development, in addition to normal census data. The projected population is expected to exceed three and a quarter million within 40 miles radius of the site at that time.

Three-quarters of the projected population will be in the direction of Metropolitan Toronto. The remainder will be chiefly in Oshawa and vicinity and along both sides of the MacDonald-Cartier Freeway to 7 or 8 miles inland from the lakeshore in Pickering and Whitby Townships in Ontario County and Darlington Township in Durham County.

The predicted 1986 density for the Township of Scarborough is about 8.5 persons per acre which is more than twice the present figure. For the remainder of Metropolitan Toronto an average of up to 15 persons per acre can be expected owing to the high intensity of land use and development. Rural areas vary from .05 to 1 person per acre. The generally suburban area within 5 miles of the station may be expected to have an average density up to 2 persons per acre by 1986.

Table 2.4-1 shows the accumulated population totals projected to the year 1986 in each of the landward 45° sectors at intervals of 4 miles radius out to 28 miles. This includes the whole of the present area of Metropolitan Toronto and the major urban centres of Newmarket (24 miles), Whitby (8 miles), Oshawa (13 miles), and Bowmanville (20 miles).

In the neighbourhood of the site considerable development is underway and expected, both of housing subdivisions and industry. Table 2.4-2 shows estimated 1965 population totals out to 5 miles from the site. Present area density figures were augmented by specific cases as far as possible in preparation of the estimates. A typical example is the new development of Bay Ridges in the northern part of lots 21 and 22 Range I where more than 1000 single family houses have been built within 1-1/2 miles of the site.

Although the space taken by highways, industry and other non-residential uses is considerable, other areas like Bay Ridges with densities up to 15 persons per acre are already planned north of the MacDonald-Cartier Freeway in the neighbourhood of the village of Pickering (3 miles north), east of the site towards Duffin Creek mouth (1-1/2 miles) and at Fairport Beach to the west of the site across Frenchman Bay (1-1/2 miles). These could eventually mean a considerable increase in the figures of Table 2.4-2, except for the north west sector, which is more or less saturated (as of 1965) unless zoning changes are made by the Township. An estimate of 12,000 for the 1986 total within 2-1/2 miles would probably be realistic.

Because of the nature of land use, both present and future, in the general area, no significant seasonal variation of population is expected. The vacation facilities of the lakeshore are primarily for local use.

2.5 LAND USE

The land locally was originally used for mixed farming but the proximity of urban areas has led to emphasis on dairying, tree fruit farming and particularly vegetable growing in recent years. The agricultural production of Ontario County remains about 3 percent of the total provincial output of most important products in line with the fraction of the provincial acreage under cultivation. In Pickering and Whitby Townships increasing urbanization is leading to the conversion of farm land to residential, commercial and industrial use.

The area to the west, including Metropolitan Toronto, consists to a large degree of urban or suburban development for 40 miles along the lakeshore and up to 10 miles inland. The only other important local urban areas outside Metropolitan Toronto are Ajax, Whitby and Oshawa. Oshawa is already a substantial industrial area. The industrial part of Ajax, 3 miles NE of the site, is expected to expand southward towards the lake and the intervening area from the site to Duffin Creek within Pickering Township is primarily intended for industrial development. To the north of the MacDonald-Cartier Freeway farming is the predominant land use, gradually giving way to vacation and summer cottage areas from about 15 miles inland. To the east beyond Oshawa and into Durham County the lakeshore plain is principally farmland with some vacation areas but no substantial organized recreational areas exist at present (1967).

A preliminary survey shows no mining or resource industries within 30 or 40 miles with the exception of a few widely scattered sand or gravel pits lying between the 400 and 500 foot contours.

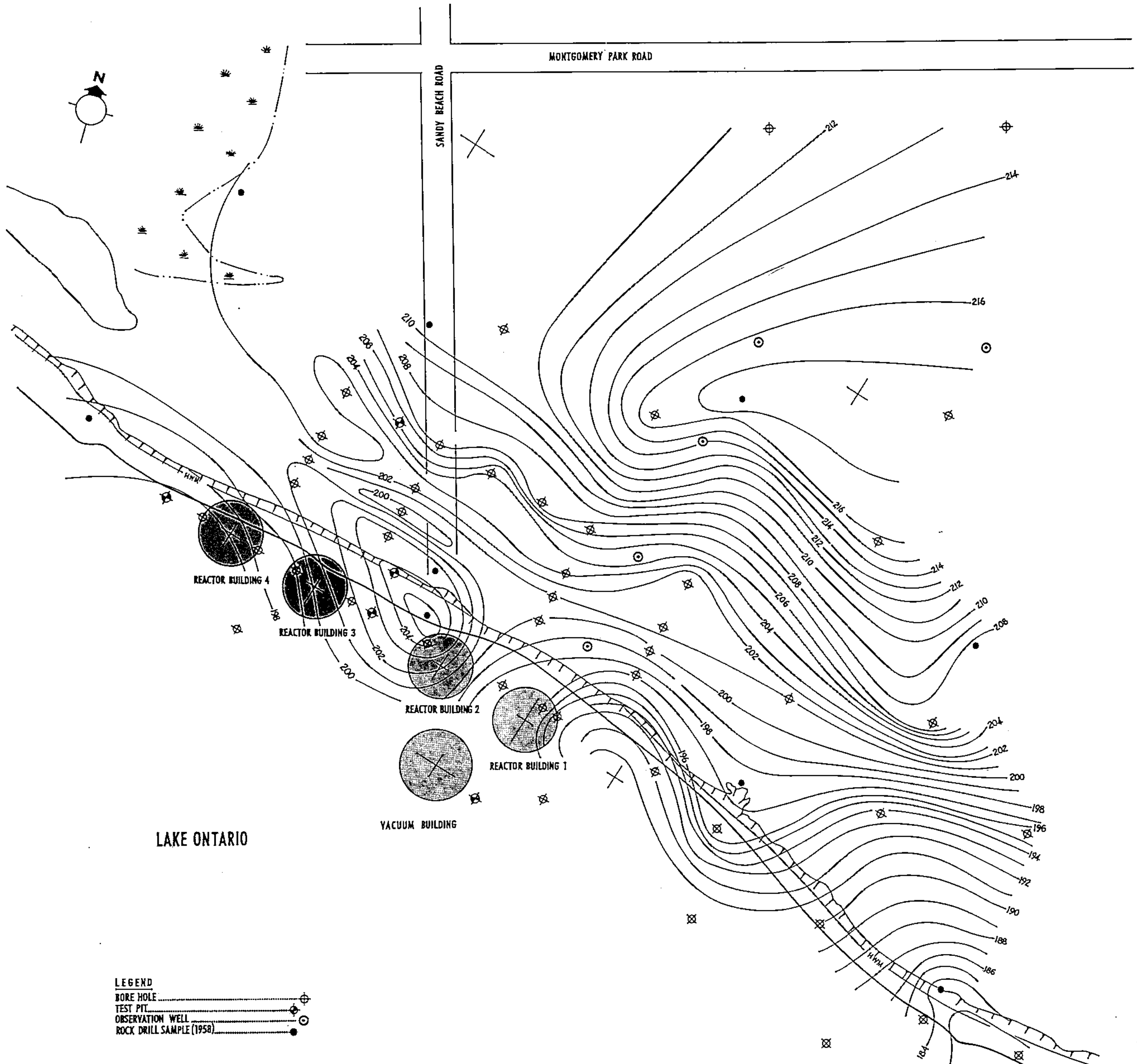
2.6 SITE GEOLOGY

A preliminary geological site survey was carried out in 1958 by Ontario Hydro Research Division and the report of this survey of the "Dunbarton" site is on file in Hydro and Power Projects.

A further more detailed survey was carried out in early 1965 and a number of interim reports have been prepared which are also on file.

Major excavations have been made down to bedrock for the water intake structure and to elevation 220 for the Powerhouse. Piles have been driven for the Reactor Buildings and turbine-generator foundations.

The results of these surveys, excavations and pile driving show that the depth to the shale bedrock under the site varies between 40 and 50 feet below lake level. A plan of rock contours based mainly on information from the recent



2-4 ROCK CONTOUR MAP

survey is given in Figure 2-4 and shows that the bedrock rises with increasing distance inland.

The overlying deposits on the bedrock throughout the local area are glacial tills. There is a dense granular formation in the lower 15 to 25 feet, covered by a softer till up to the surface layer. This consists of several feet of sand at the beach changing inland to a fairly stiff upper layer of weathered till with an appreciable clay content. Excavation of this till down to bedrock, has shown it to be highly impervious. Little or no water inleakage into the excavations has occurred.

No difficulties have been experienced in driving piles to bedrock. From the tests on the properties of the soil and investigations carried out using test pits, it is considered that no unusual conditions need be expected and sound foundations can be obtained for the plant structures using a system of piles to bedrock to support major structures.

2.7 SEISMOLOGY

According to the classification given in the National Building Code of Canada, the Pickering Township area is in earthquake Zone I. This is defined as one in which minor damage only may occur and it applies to the entire area of southwestern Ontario.

2.8 HYDROLOGY

From the nature of the land and rock strata it would appear that movement of ground water in the proposed site area will be generally towards the lake as indicated by the plot of rock contours shown in Figure 2-4.

2.9 WATER SUPPLIES AND SEWAGE WORKS

Major domestic and industrial water supplies in the area are taken from Lake Ontario and there are a number of intakes for both purposes at points from Toronto through to Bowmanville, with additional installations planned as the need arises. The data shown in Table 2.9-1 was obtained from Pickering Township officials and the Resources Commission for water intakes within ten miles of the Pickering site. The eastern section of the water supply plan obtained from the Metropolitan Toronto Planning Board is shown in Figure 2-5. Information received from the Ontario Water Resources Commission shows that apart from the Toronto installations the intakes existing are all shallow, i.e. 20 to 30 feet deep running out 2000 to 3000 feet. It is expected, however, that a planned new intake for Oshawa (in the vicinity of Gold Point, 10 miles east of the site), and a possible additional Toronto Metro intake at Highland Creek, 5 miles west of the site, would be deep run and therefore farther out.

The nearest intake at present in use is the J.S. Scott lake water pumping station operated by Pickering Township. The plant buildings are on the west side of Brock Road at the lakefront approximately 2400 feet from Reactor Building No. 1.

The pumping station supplies the Bay Ridges area, and the system extends past the northern end of Frenchman Bay to the Dover Shores area, reaching Fairport Beach.

The J.S. Scott station dates from 1962 and has a peak capacity of about 1,250,000 gallons per day. The maximum daily usage is about 1,000,000 gallons and the present average is about 270,000 gallons. The storage tank at the station has a capacity of 400,000 gallons. Intake pumping is automatically controlled so that, depending on usage and settings, intake may be stopped for periods of up to 24 hours.

The station draws from a 30 inch diameter intake pipe at 25 foot depth running 1800 feet southeast into the lake. The water taken is subjected, as a routine, to alum flocculation treatment and rapid sand filtration before reaching the station storage tank where it is chlorinated and subsequently pumped as required by system demand. Facilities exist for other treatments, such as line addition to adjust acidity, but these are not used at present.

The village of Pickering is served by the Ajax municipal system which has its lake water intake about 3 miles east of the proposed site.

The sewage disposal plant for the Bay Ridges area is located about 2000 feet west of the site.

Individual domestic water supplies, particularly for cottages and in rural areas, continue to be taken from wells at present but eventually piped water will be extended throughout the built-up areas in the southern part of the township.

2.10 LAKE WATER

2.10.1 Currents

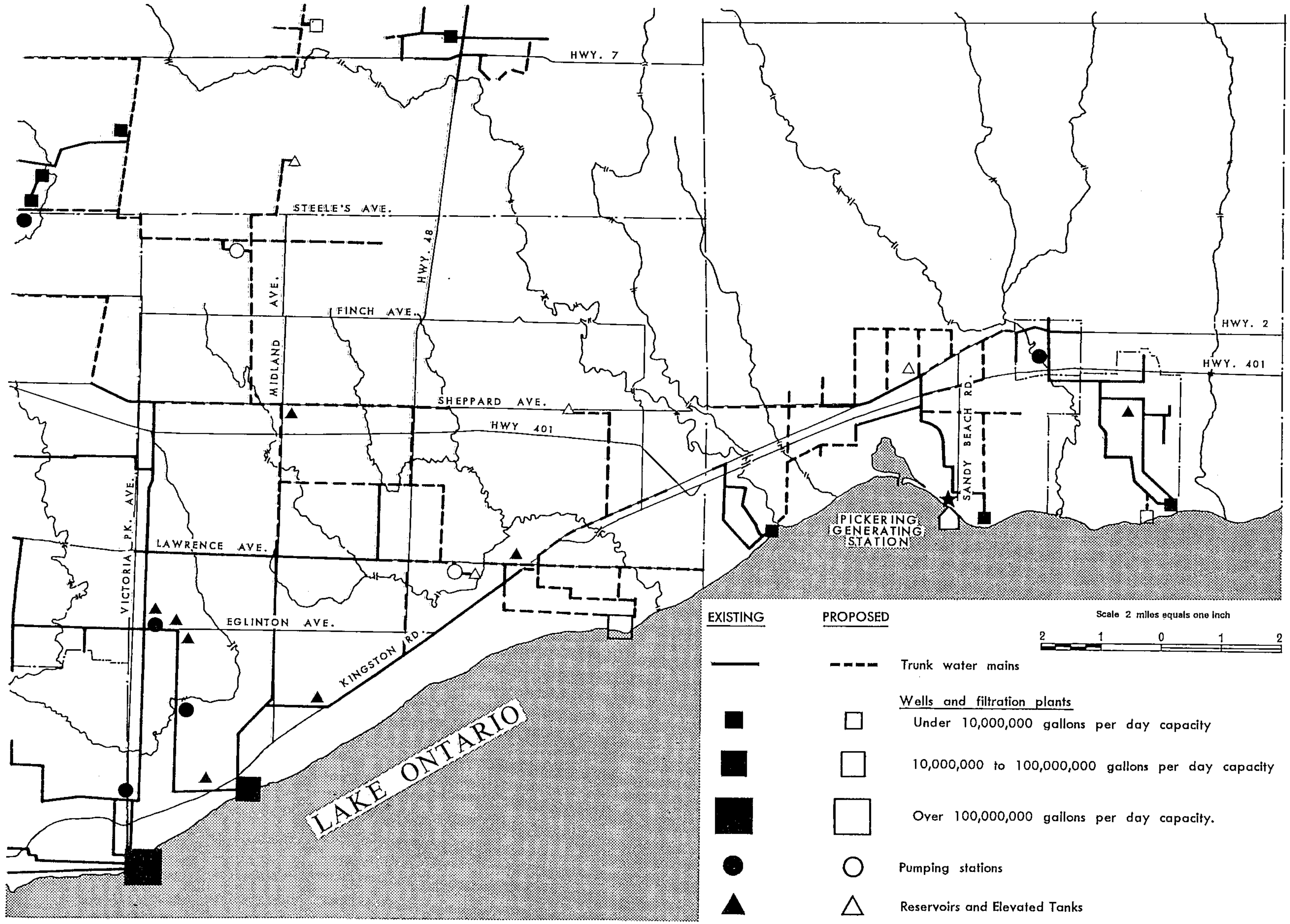
The lake currents in this part of Lake Ontario set mainly to the west but are not very strong (i.e. probably less than 0.3 knots as a rule). The effect of the prevailing westerly winds can be considerable on the surface water (Reference 1).

2.10.2 Levels

The approximate maximum and minimum monthly mean lake levels at the site are taken as 249.3 feet and 242.75 feet respectively. Atmospheric pressure differentials and wind action along the length of the lake can build up seiches causing the lake level to vary more widely than the mean levels indicate. "Variations in level of several feet lasting for periods of several hours are common on all the lakes" (Reference 1).

2.10.3 Temperatures

The lake water temperatures are not shown in detail but monthly means for the area offshore of the site are as follows: (Reference 2).



2-5 WATER SUPPLY PLAN

44,10000—23
REV. 1 1967

TABLE 2.9–1

WATER INTAKES WITHIN TEN MILES OF PICKERING

Plant Name	Distance From Pickering (miles)	Date Installed	Intake Depth (ft.)	Distance Intake From Shore-line (ft.)	Peak Capacity (Gal. per Day)	Storage Capacity (Gal.)	Treatment
Scarborough (Kennedy Rd.)	13W	----	25	3000	24×10^6	----	Full treatment — Interconnected with Metro system.
John-Manville (Port Union)	4W	1946	22	2200 (20" pipe)	4.5×10^6	----	Settle and return.
West Rouge	2-3/4W	1954	18	On Shore	5×10^5	250000	Pee gravel filtration, chlorination.
J.S. Scott (Pickering Twp)	1/2E	1962	25	1800 (30" pipe)	1.25×10^6	400000	Full treatment (Re Vbl. 1)
Wm. A. Pamish (Ajax Municipal Harwood St.)	3E	1959	23	1970 (32" pipe)	15×10^6	10^6	Settling and sand filtration, chlorination. (No connections to adjacent municipalities)
O.I.L. (disused)	3.5E	1943	12	538	1.5×10^6	----	Pumps removed.
Whitby (Municipal Puc)	7.5E	1965	29	2900 (36" pipe)	18×10^6	750,000 filtered	Revolving screen filter with chlorination, flocculation and chemical treatment as required. (No connections to adjacent municipalities).
						250000 raw —	Industrial use.

April	37°F	July	64°F	October	57°F
May	42°F	August	68°F	November	43°F
June	55°F	September	64°F	December	34°F

These values are based on ship condenser water inlet temperature, i.e. from 10 to 15 feet deep. Municipal water intakes which are 20 feet or more deeper usually have temperatures a few degrees lower.

Larger short term variations may be expected to occur due to wind induced movements of the thermocline and changes up to 20°F in one hour have been recorded.

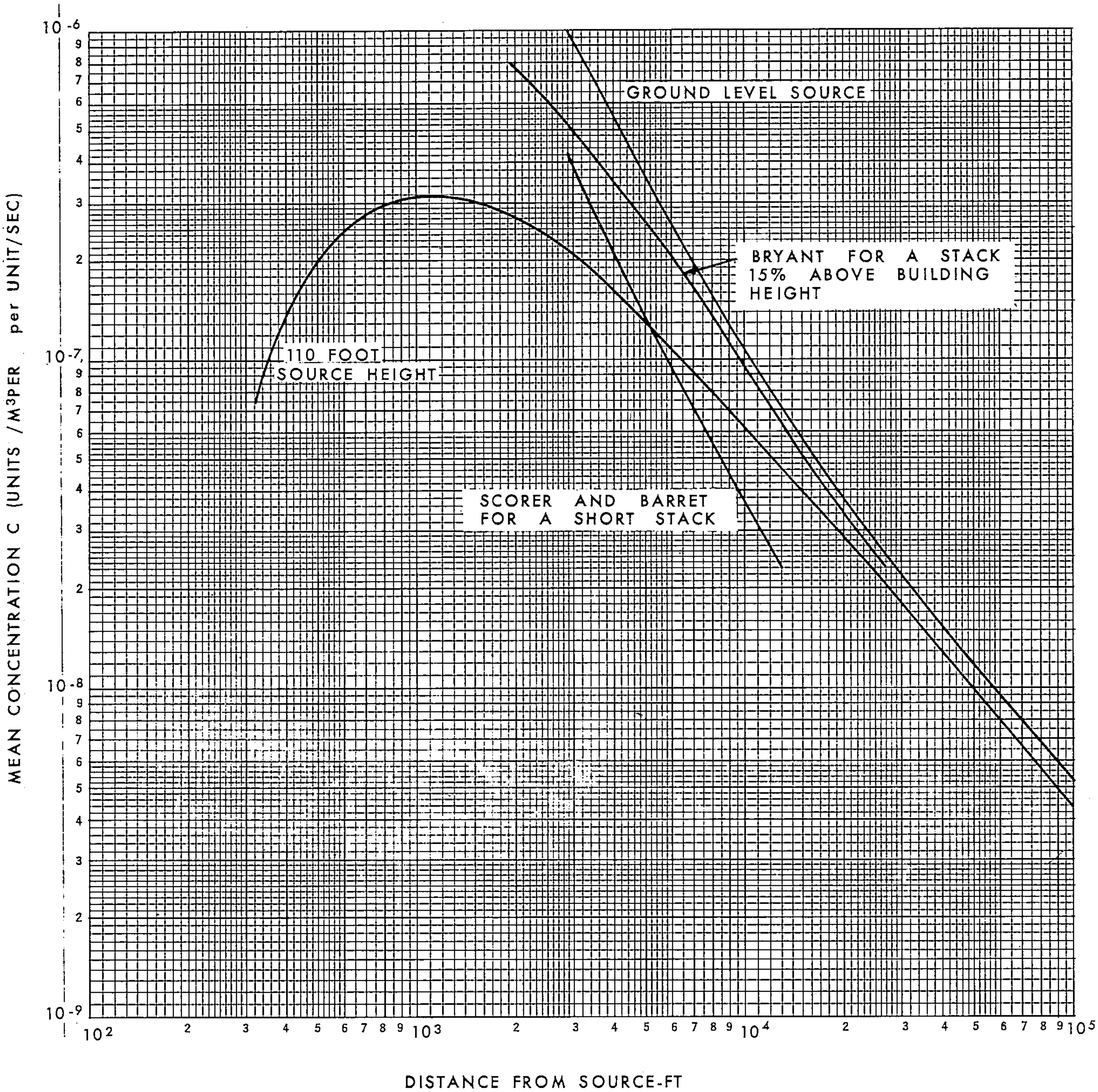
2.10.4 OTHER USES

In addition to providing water supplies the lake water is used for sewage disposal, recreational swimming and boating and sport fishing throughout the area. There is very little commercial fishing.

2.10.5 WATER ANALYSIS

An analysis of water, taken from Lake Ontario at a sampling point opposite the intake of the Pickering Generating Station in November 1965, is presented below:

Colour	Colourless
Odour	Odourless
Turbidity	105
pH Factor	8.2
Bicarbonate (HCO_3)	153 ppm
Chloride (CL)	33 ppm
Sulphate (So_4)	32 ppm
Calcium (ca)	47 ppm
Magnesium (mg)	9.6 ppm
Sodium (na)	12.8 ppm
Potassium (k)	2.2 ppm
Total Hardness as $CaCO_3$	158 ppm
Calcium Hardness $CaCO_3$	118 ppm
Magnesium Hardness $MgCO_3$	40 ppm
Dissolved Solids at 105 C	250 ppm



2–6 MEAN CONCENTRATION OVER 180° ARC FOR CONTINUOUS RELEASE (PASQUILL D)

44.01010—7

Dissolved Solids at 600 C	156 ppm
Suspended Matter	316 lb/million U.S. gallons

2.11 METEOROLOGY

2.11.1 Building Design Data

A set of recommended values of design weather data for the area in line with the National Building Code has been obtained and is on file. The values are as follows:

1.	Winter design temp: 2-1/2%	-1°F
2.	Winter design temp: 1%	-4°F
3.	Annual degree-days below 65°F	7100
4.	Maximum 15 min. rainfall	1.1 ins.
5.	Maximum one day rainfall	4 ins.
6.	Annual total precipitation	32 ins.
7.	Snow load, horizontal roof	34 lbs/ft^2
8.	Wind load	21 lbs/ft^2

2.11.2 Wind

Wind observation data from Toronto Island (Reference 3) has been used as a first approximation for the Pickering station site, which is 20 miles northeast along the lakeshore. The annual wind rose shows that the greatest onshore wind frequency is 17 percent. The Island data is considered more appropriate than that of the Toronto International Airport at Malton which is well inland. Some data collected for winds at a height of 200 feet in connection with air pollution studies at the R.L. Hearn Station have been examined, but the depth of record is too small to allow a complete comparison.

2.11.3 Diffusion

2.11.3.1 Normal Operation

The continuous release of activity from the Pickering plant is expected to be sufficiently small (Ref. Section 9, Volume 1 of this Report) that there will be no effect on the surrounding population. However, for evaluation of the effect of any postulated continuous release of activity from the station the frequency of different atmospheric conditions in the vicinity of the site is required. When data are available they will be used in evaluating the effect of continuous releases during normal operation. In the meantime the Pasquill D category of atmospheric conditions is being used for ground release and for release from the planned ventilation system exhausts which will be located on the building structure at a height of 110 feet. The concentration at various distances from the Reactor Buildings is shown in Figure 2-6.

The relative concentration of activity at the plant boundary between a ground level release and that from a stack 110 feet high is shown in Figure 2-6. The difference at a distance of 3,000 feet is about a factor of 4 in relative concentration. The relative concentration for releases from a stack only slightly higher than adjacent buildings would be expected to fall between these curves. There are many diffusion formulae for short stacks some of which are summarized by P.J. Barry (Reference 4). The concentration at and beyond the 3,000 foot boundary using the formula developed by Scorer and Barrett (Reference 5), and suggested by P.J. Barry as being representative, is also shown on Figure 2-6. The mean concentration at a distance of 3,000 feet is between that for a ground level release and that for a stack release at 110 feet, but drops below that for the 110 foot stack at 5,000 feet.

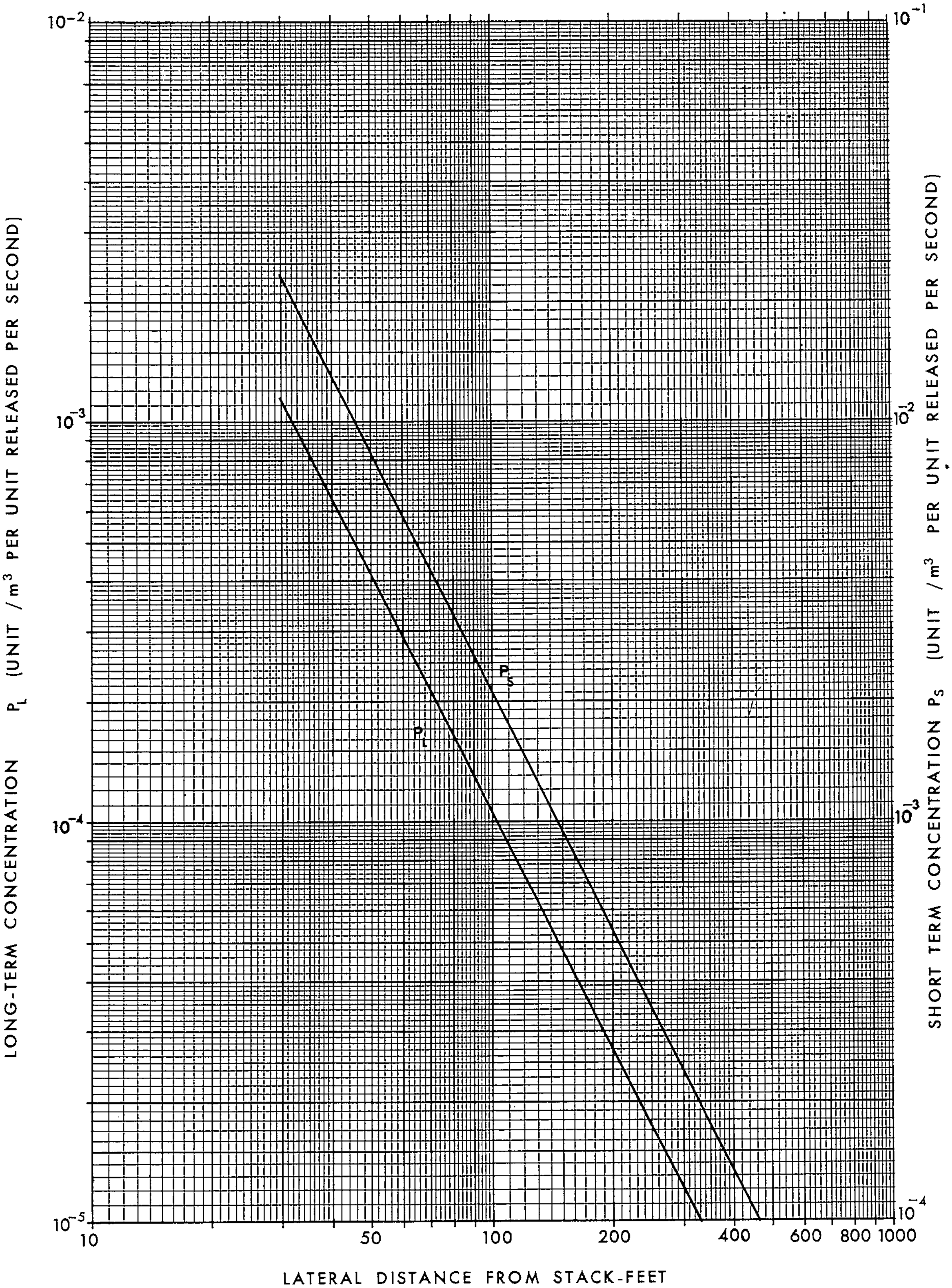
The dispersion of gaseous effluents from short stacks is also discussed by P.M. Bryant (Reference 6). Since the other two curves shown in Figure 2-6 are based on work by Bryant for a ground level release and for a release from a 110 foot high stack, the mean concentration at all distances from a stack 15% higher than the adjacent building is shown to fall between these two curves as expected. Using the mean concentration from this curve at 3,000 feet it is seen that the permissible releases given in Table 9.6-1 would be reduced by a factor of two. This would not be significant since the expected releases are much below the permissible values.

Under bad conditions the dilution at the ground near the point of discharge may be very poor for short periods (Reference 4). In particular, looping action of the plume from the discharge, which can occur in light wind with unstable conditions, while not a concern beyond the plant boundary, may bring occasional strong concentrations to the ground in the immediate site area. Similarly, the local conditions which might accompany a low inversion with very light winds can cause high concentrations of discharged gases which may persist for some hours within the plant area.

However, the continuous release of activity from the Pickering plant is expected to be sufficiently small that there should be no effect on the surrounding population even if it were considered a ground level release. The permissible release rates for a number of radioactive isotopes are given in Table 9.6-1. The estimated equilibrium activities in a Reactor Building are given in Table 9.6-2. Since all the areas expected to contain any significant activity are on closed circuit ventilation, only a very small fraction of the equilibrium activity would be expected to be discharged per day as the result of leakage into and removal from the closed circuit ventilation areas. The amount of leakage into an inaccessible area at a slightly lower pressure than the adjoining accessible area will depend on the tightness of the barrier between the two areas. All these areas are physically separated by walls or floors and all doors and penetrations between these areas will be sealed to prevent leakage. A small fraction of the equilibrium activity shown in Table 9.6-2 being released per day would be orders of magnitude below the permissible average release rates shown in Table 9.6-1.

2.11.3.2 Relative Concentrations in the Immediate Vicinity of the Plant

The behaviour of waste gases after discharge from a



2–7 SHORT AND LONG TERM CONCENTRATIONS FOR RELEASES ENTRAINED IN BUILDING WAKE

44.01010–11

short stack in the vicinity of buildings is dependent on the size and shape of the buildings and the air flow in the neighbourhood of these obstacles. A "cavity" is produced downstream and immediately behind the buildings which is surrounded by the "wake" which extends a considerable distance downstream. The stack release may become entrained in the building wake which will produce the maximum ground level concentrations. The concentration in the wake will vary depending on the distance from the stack and is generally taken to be proportional to the inverse of the square of the distance from the source (Reference 4). Short and long term concentrations are presented by Bryant (Reference 6) for releases entrained in the wake of buildings as shown in Figure 2-7. Using these data and the location of discharge ducts at the south side of the Powerhouse wall, the maximum short-term concentration at ground level would be about 10^{-3} units per cubic meter per unit of activity released per second. The long term concentration would be about 4×10^{-5} units per cubic meter per unit of activity released per second.

The most critical short-term period for workers on the ground in the vicinity of the plant would appear to be during a purge of the boiler room. The only significant activity in the boiler room would be tritium. The equilibrium activity in the boiler room is shown to be 150 curies in Table 9.6-2 of the Safety Report. The maximum purge rate is 10,000 cfm and the boiler room volume is 1.1×10^6 cubic feet. The maximum rate of discharge of the contained activity would be:

$$\frac{150}{1.1 \times 10^6} \times \frac{10{,}000}{60} = 2.28 \times 10^{-2} \text{ curies per second}$$

The short term concentration in the wake of the buildings may reach a maximum of:

$$2.28 \times 10^{-2} \times 10^{-3} = 2.28 \times 10^{-5} \text{ curies/m}^3$$

This is about 100 times the maximum permissible concentration in respirable air for continuous exposure. Since a purge of the boiler room is expected to be a very infrequent occurrence, and since the purge rate and time could be controlled, and since monitors would indicate an unacceptable level of activity, and since the workers would not be present for more than eight hours during the above conditions, it is considered acceptable.

The long term concentration in the wake of the buildings should be much below the maximum permissible concentration in respirable air for continuous exposure. The continuous release rate from the plant would be orders of magnitude below that during a purge. If the continuous release is taken at 10^{-3} of that during a purge the long term concentration of tritium in the wake of the buildings would be:

$$2.28 \times 10^{-5} \times 4 \times 10^{-5} = 8.5 \times 10^{-10} \text{ curies/m}^3$$
$$(\text{cf. permissible } 10^{-7} \text{ curies/m}^3)$$

It is the opinion of the designers that a high stack is unnecessary to protect the public, the construction forces or plant personnel. Design effort is being made to limit the activity release to levels which will be of no concern to anyone in the vicinity. The monitoring and radiation hazards control requirements within the plant are designed to detect high concentrations of activity in the plant area and to enable suitable precautions to be taken.

2.11.3.3 Accident Conditions

For the evaluation of the effect on the public of postulated accidental releases from the plant, the Pasquill method has been used with an assumed atmospheric condition described as Pasquill F. This category F condition is the lowest dispersion range for known atmospheric conditions. The maximum concentration of activity at various distances from the Reactor Buildings is shown in Figure 2.1-1, Volume 2 — Accident Analysis, of the Safety Report.

2.12 REFERENCES

Reference 1 — "Climatology and Weather Services on the St. Lawrence Seaway and the Great Lakes", U.S. Department of Commerce - Weather Bureau, Technical Paper No. 35-1959.

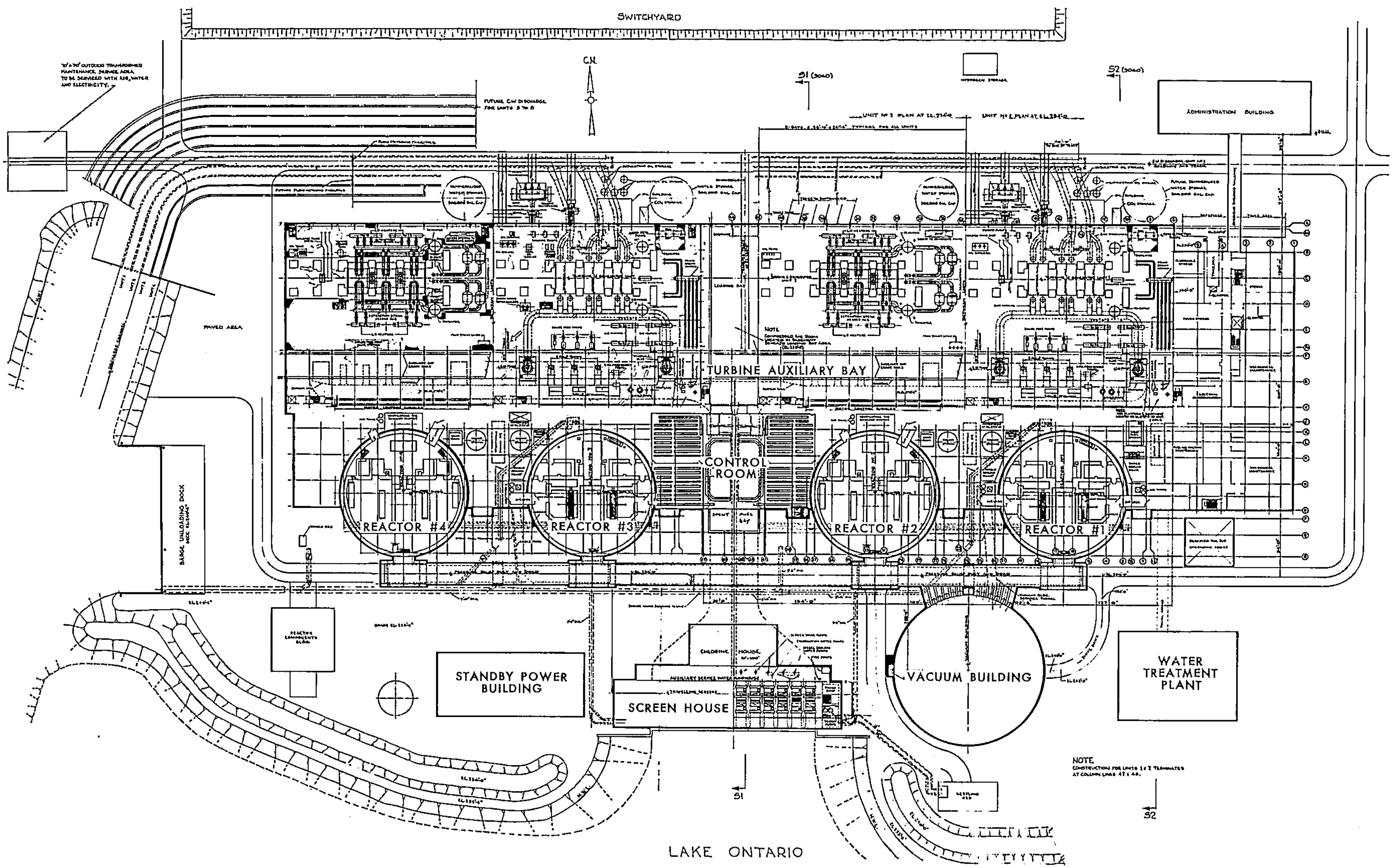
Reference 2 — "Surface Temperature of the Great Lakes", F. Graham Miller Jr., Fishery Research Board of Canada 9 (7) 1952.

Reference 3 — "The Climate of Toronto", L. Shenfield, D.F.A. Slater — June 1960 (Published by the Meteorological Branch, Department of Transport) CIR3352 TEC 327.

Reference 4 — "Estimation of Downwind Concentration of Airborne Effluents Discharged in the Neighbourhood of Buildings", P.J. Barry — Atomic Energy of Canada Limited, AECL-2043, July 1964.

Reference 5 — "Gaseous Pollution from Chimneys", R.S. Scorer, C.F. Barrett — Int. Journal of Air and Water Pollution, Volume 6 pp. 49-63 (1962).

Reference 6 — "Methods of Estimation of Dispersion of Windborne Material and Data to Assist in Their Application", P.M. Bryant, A HSB (RP) R42, UKAEA 1964.



3–1 STATION GENERAL ARRANGEMENT - PLAN (LOWER PART)

44.20100—4
REV. 1, 1968

3. BUILDINGS AND CONTAINMENT

3.1 GENERAL LAYOUT

The site plans for the Pickering Generating Station are based on an ultimate eight-unit layout. Each unit will consist of a single reactor housed in a reinforced concrete Reactor Building, a single turbo-generator housed in a Powerhouse, together with associated ancillary equipment and structures. The buildings, structures and systems described in this Section provide housing, containment and other facilities for the first four units. The arrangement is shown in Figures 3—1, 3—2 and 3—3.

The site grade is 253.5 feet (GSC datum) and the ground floor elevation of all buildings is 254 feet. All major buildings and structures of the station, except for the main area of the Powerhouse and the cooling water intake structure, are built on piles which have been driven to bedrock. The main area of the Powerhouse has been excavated to a dense layer at about elevation 220 feet, and the cooling water intake structure has been excavated to bedrock. Test piles have been successfully driven at the site at typical locations and have been tested at 200 percent of design load.

The following parameters have been taken into account in determining the design of the buildings and structures at the site:

(i) Earthquake forces, — calculated in accordance with the provisions of the National Building Code of Canada.

(ii) Wind velocity, — calculated in accordance with the provisions of the National Building Code of Canada.

(iii) Snow load on a horizontal surface.

The main group of buildings forming the four-unit station consists of the four Reactor Buildings, the Vacuum Building, the Powerhouse which includes the Turbine Hall and Turbine Auxiliary Bay running the full length of the station, the Reactor Auxiliary Bay which is attached to the south side of the Powerhouse, and the Service Wing and the Administration Building at the eastern end. A single intake channel, screen house and gravity feed intake duct for condenser cooling water and process water serves all four units. The intake duct is built on rock between Reactor Buildings No. 2 and No. 3. The cooling water intake duct divides into two separate ducts at the Turbine Auxiliary Bay, one running to the east for units 1 and 2 and a second to the west for units 3 and 4. The condenser cooling water pumps and process water pumps will be located in these ducts which run the length of the Turbine Auxiliary Bay. The condenser cooling water will be discharged into covered ducts immediately north of the Powerhouse and returned to the lake at the western end of the four-unit layout.

A spent fuel bay, which is designed for storage of fuel from four units, is located at and below grade level directly above the intake duct. The control centre is located on the second floor of the Reactor Auxiliary Bay, directly above the spent fuel bay. This location is central to the four-unit station, and the facilities are capable of providing control for four reactors and associated power generating and other equipment.

The Reactor Buildings are set more than half their diameter into the south wall of the Reactor Auxiliary Bay. Access to all accessible (during operation) areas in the Reactor Buildings is through airlocks within the Reactor Auxiliary Bay. Personnel access to the boiler room during shutdown is through a covered manway which leads from the Turbine Auxiliary Bay to the Reactor Building. It is fitted with an airlock at the connection to the Reactor Building. An additional secondary or emergency route is provided by a similar airlock approximately opposite the first and connected by a covered manway to the Reactor Auxiliary Bay south side stairs.

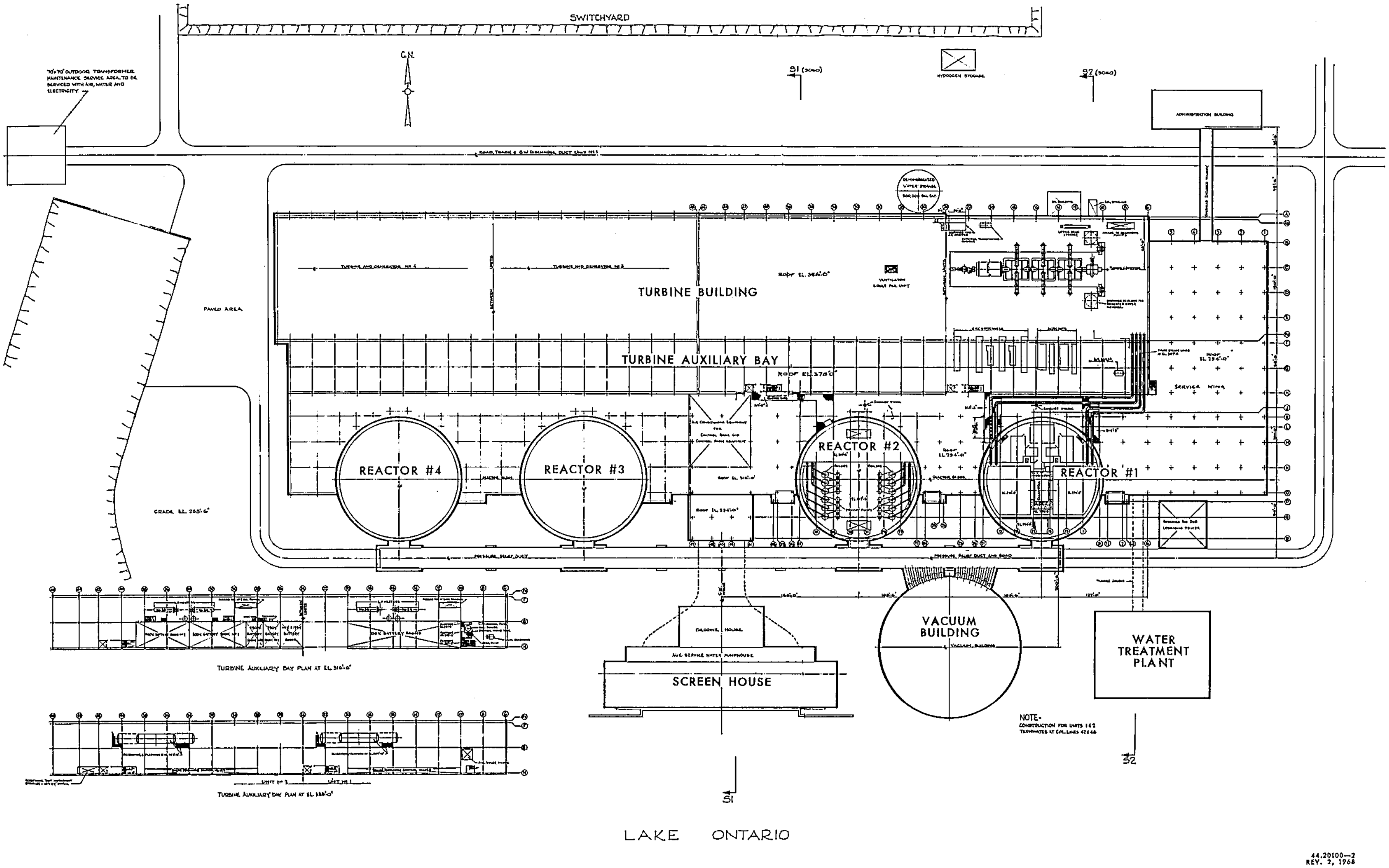
The separate Vacuum Building which forms part of the containment system is connected to each Reactor Building by a large pressure relief duct located, at the level of the boiler room, on the south side of each Reactor Building. The Vacuum Building provides reserve volume for containment of any high energy fluids released within the Reactor Buildings.

The service Wing, which is attached to and serves the Powerhouse and the Reactor Auxiliary Bay, contains stores, laboratories and workshops both for active and uncontaminated operations. It is situated at the east end of the four-unit station, which would give it a central location in an ultimate eight-unit station. The size of the Service Wing and its layout are planned to be adequate to handle the work load from such a station. The main passageways of the Reactor Auxiliary Bay provide clear access on both floors between the Service Wing and the Reactor Buildings, and it is intended as a general practice that equipment will be brought to the Service Wing for any decontamination and shop work.

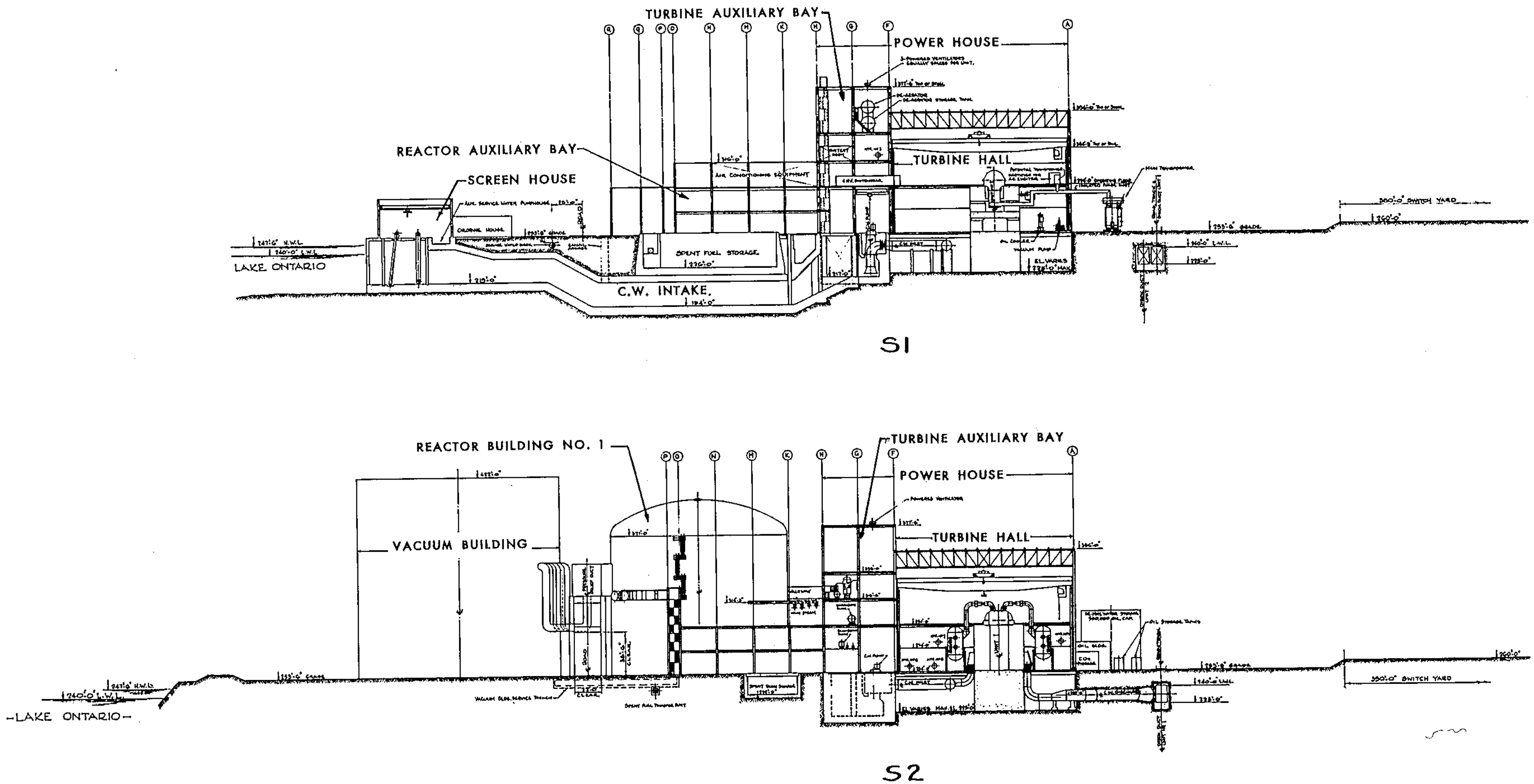
Below the central part of the Service Wing there is a basement which will contain the waste management facilities, including hold-up and dilution tanks. The location has been selected so that the excavation for the Powerhouse and Service Wing basement is continuous.

The station Water Treatment Building is located to the south of the Service Wing. It is designed to house the equipment required to handle the load for a four-unit station, but can be extended to accommodate the equipment requirement of an eight-unit station. The Water Treatment Building is connected to the Turbine Hall basement by a service tunnel which runs beneath the Service Wing. A branch of the tunnel serves a D_2O upgrading tower which is located between the Service Wing and the Water Treatment Building.

The combustion turbines which supply emergency power to the station are located in individual housings south of Reactor Buildings No. 3 and No. 4.



3–2 STATION GENERAL ARRANGEMENT - PLAN (UPPER PART)



3—3 STATION GENERAL ARRANGEMENT - ELEVATION

44.20100—5
1967

The station Administration Building is connected by a bridge to the upper floor of the Service Wing. This bridge constitutes the main entry and exit route for station personnel to all work areas and will contain the final monitoring point. The Guardhouse is located at the west end of the Administration Building beside the main gate to control the entrance of personnel and vehicular traffic to the station building area.

The 230 kV switchyard is located on the north side of the station in a convenient location for connection to transmission lines. Provision is made for an eventual 500 kV switchyard north of the units planned for the east side of the central service area.

3.2 REACTOR BUILDING

3.2.1 General

The Reactor Building serves to support and enclose the reactor and directly associated equipment, to shield personnel from radiation occurring during operation or shutdown and, in conjunction with the Vacuum Building and pressure relief duct, to contain activity which might be released in any accidents involving failure of system components. Figures 3—4, 3—5 and 3—6 show the main features of the Reactor Building and the locations of the principal items of equipment.

Systems specifically contained in the Reactor Building, in addition to the reactor itself, together with its fuel loading and discharge equipment, include the entire primary heat transport and moderator systems together with their associated auxiliary systems.

The Reactor Building is designed as part of the containment system to prevent the escape of activity in the event of any postulated accident to the reactor. The design criteria are based on simultaneous maximum accident loads, normal gravity loads and snow loads, combined with either wind or earthquake forces. The design internal pressures are +6 psig and —8.5 psig.

3.2.2 Type of Construction

The requirement to contain a maximum pressure after accident of 6 psig and to provide shielding led, as previously in the case of Douglas Point, to the selection of a cylindrical reinforced concrete building. The Pickering Reactor Building has an elliptical concrete dome instead of a hemispherical steel dome as is used at Douglas Point.

Leading dimensions of the building are as follows:

Internal diameter	140 feet 0 inches
Wall thickness	4 feet 0 inches
Height of cylindrical portion (grade to springline)	117 feet 0 inches
Dome rise to crown	35 feet 9 inches
Thickness — at crown	1 foot 6 inches
— at springline	2 feet 0 inches

The glacial till overburden does not provide a suitable foundation for large buildings. The Reactor Building is therefore supported on a system of about 750 steel piles which are driven to rock at about 40 feet below grade. The piles are capped by a circular reinforced concrete slab which is 5 feet thick and extends 4 feet radially beyond the perimeter wall. This slab serves as a base upon which the internal building structures and the external wall are constructed.

3.2.3 Access

Entry into the Reactor Building is permitted only through airlocks so that the containment system integrity may be maintained unimpaired. These airlocks are provided in pairs at each of three levels in order to provide two exits from each separate region of the building where work may be carried on. This arrangement has also been chosen to reduce to a practical minimum the distance from any point in the building to an exit. The airlocks can be operated automatically or manually. They will thus be available under all conditions and personnel will be able to escape in an emergency.

The airlocks are described in Section 3.2.6, and the general philosophy of access control in Section 9.

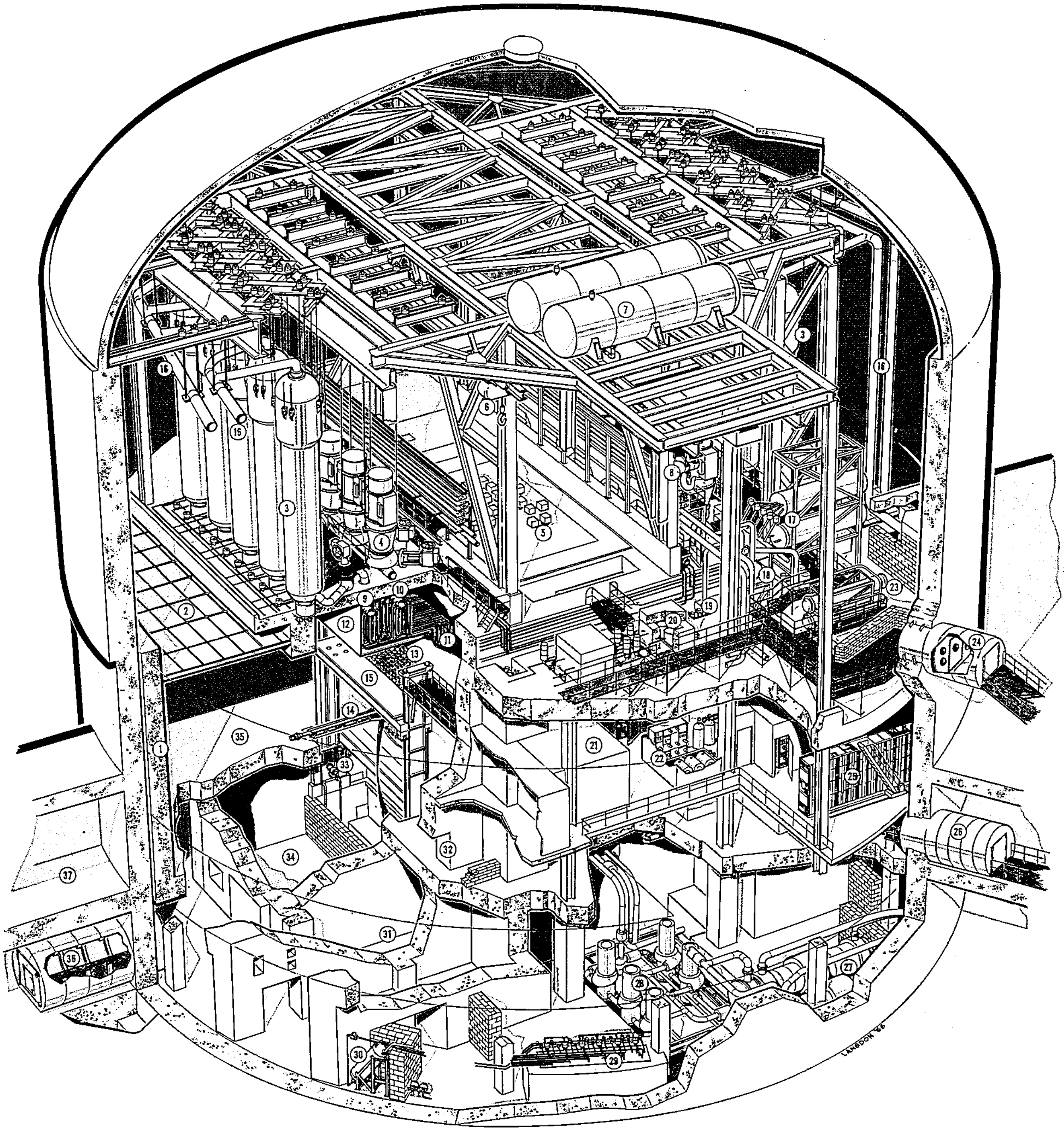
3.2.4 Leak Tightness

The Reactor Buildings are constructed in the same manner as at Douglas Point. The concrete perimeter wall is placed in a sequence of "main" and "filler" blocks so as to reduce shrinkage to a practical minimum. Concrete temperature during placement is controlled by regulating the mixing water temperature.

Waterstops are used at construction joints with polysulphide rubber compound filler at the inner surface edges of the joints. Suitably designed embedments and transition pieces are used at penetrations of the containment; for example, welded bellows are used where differential movement may occur and embedded collars on pipes and sleeves to extend possible leakage paths in concrete.

When a particular Reactor Building has been completed together with the related portion of the pressure relief duct a proof pressure test and leakage test will be carried out as part of the construction and commissioning procedures. In order to isolate the Reactor Buildings and portions of the duct, embedments, which facilitate attachment of barriers, are incorporated in the concrete.

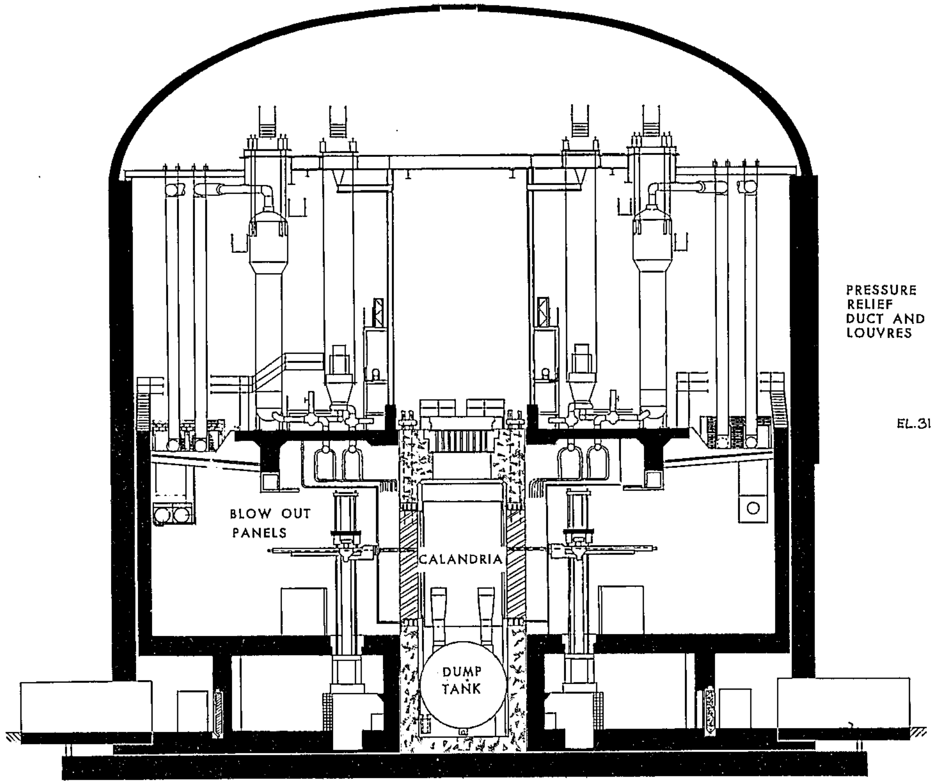
The target leakage rate for these tests is 1%±0.5% per 6 psi hour. The bases of this target figure are: the allowed release in the event of the worst dual failure accident (loss of control, loss of protection); a reduction by a factor of 10 of available fission products due to proportional separation with the fraction of coolant which flashes, plate-out and wash-out, and due to the effects of time delay in release and distribution of fission products in the containment



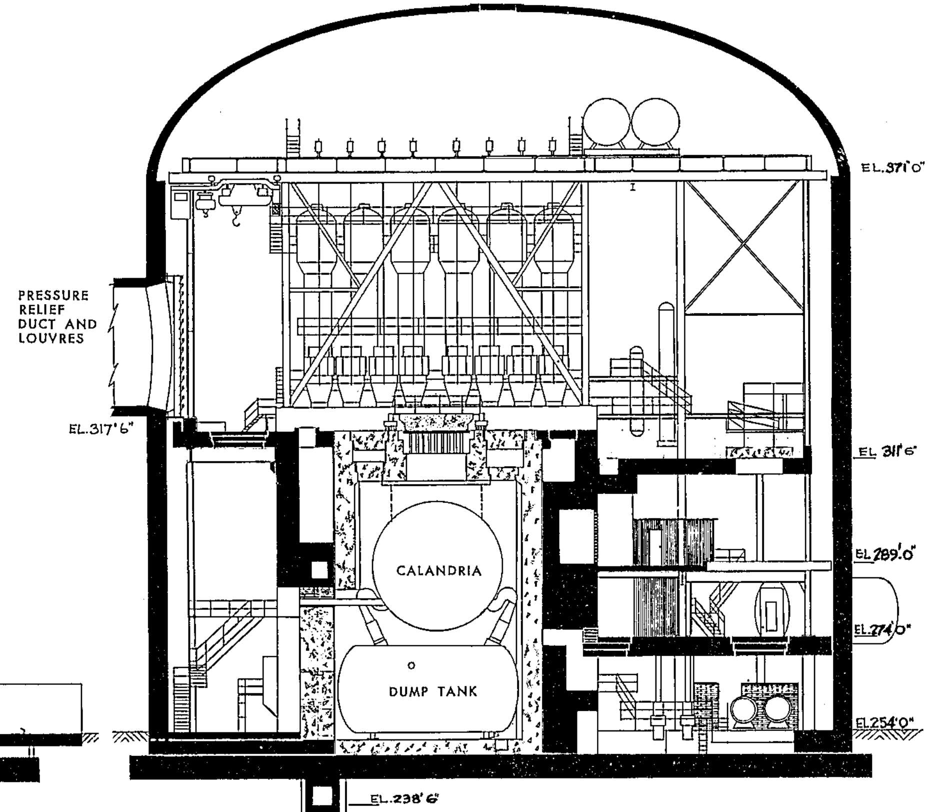
1 PRESSURE WALL
2 BLOWOUT PANELS
3 STEAM GENERATORS
4 PRIMARY HEAT TRANSPORT PUMPS
5 CONTROL AND SHUT-OFF RODS
6 PUMP MONORAIL
7 FEED WATER RESERVE TANKS
8 BOILER ROOM CRANE
9 PRIMARY HEAT TRANSPORT REACTOR OUTLET HEADER
10 PRIMARY HEAT TRANSPORT REACTOR INLET HEADER
11 FEEDER PIPES
12 FEEDER INSULATION CABINET
13 REACTOR END FITTINGS
14 FUELLING MACHINE HEAD
15 FUELLING MACHINE BRIDGE
16 MAIN STEAM SUPPLY PIPES
17 SURGE COOLER AND RECEIVERS
18 STANDBY COOLER
19 PIPE CHASE
20 PRIMARY SYSTEM FILTERS
21 CONTROL EQUIPMENT ROOM
22 CALANDRIA ZONE CONTROL EQUIPMENT
23 BLEED CONDENSER AND COOLER
24 BOILER ROOM AIRLOCK
25 REACTOR CONTROL DISTRIBUTION FRAME
26 MAIN EQUIPMENT AIRLOCK
27 MODERATOR HEAT EXCHANGERS
28 MODERATOR PUMPS
29 MODERATOR AND PRIMARY ION EXCHANGE COLUMNS
30 SPENT RESIN DRYING TANK
31 FUELLING MACHINE AUXILIARIES ROOM EAST
32 FUELLING MACHINE VAULT DOORWAY
33 FUEL TRANSFER PORT
34 FUELLING MACHINE SERVICE ROOM EAST
35 FUELLING MACHINE VAULT EAST
36 FUELLING MACHINE AIRLOCK
37 REACTOR AUXILIARIES BAY

3-4 CUTAWAY VIEW OF REACTOR BUILDING LOOKING SOUTH-WEST

44.21000-17



LOOKING NORTH



LOOKING WEST

3–5 REACTOR BUILDING - ELEVATION

44.21000—18
REV. 2, 1968

enclosure; and a margin of 2.7 over the calculated allowed release to account for deterioration of the containment leak tightness with time.

3.2.5 Internal Arrangement

The interior of the Reactor Building is divided by a massive concrete structure of walls and floors which is independent of the external wall and dome. This structure creates certain shielded areas which can be entered safely while the reactor is operating, and other areas which may be occupied if required while the reactor is shut down, depending on the nature of the contained equipment. A system of steel platforms, walkways, ladders and stairs provides access to equipment which cannot be reached directly from the concrete floors. The general arrangement of these walkways is shown on Figures 3—7 and 3—8.

The calandria vault, which is described more fully in Section 4, forms an independent box-like structure of heavy concrete and contains the calandria and the dump tank. It is centred 13 feet south of the building centreline and is set on the foundation slab at elevation 249 feet. Circular openings are made in the east and west walls of the vault to allow for the reactor end shields and the bottom half of the south wall is omitted to allow component installation. The top of the vault concrete is at the boiler room floor elevation 317 feet 6 inches.

Directly north and south of the calandria vault, running east and west across the full width of the Reactor Building and extending from the grade floor at elevation 254 feet to the boiler room floor at elevation 317 feet 6 inches are the north and south cross walls. These walls are 4 feet 6 inches thick because of shielding considerations. They are also major structural components. The bottom centre portion of the south cross wall, which consists of cast in place heavy concrete blocks, is the calandria vault access closure.

South of the south cross wall is an accessible area which extends from the grade floor to the underside of the boiler room floor at elevation 317 feet 6 inches and from the south cross wall to the perimeter wall. In this area shielded guide tubes facilitate the loading of cobalt rods from the reactor control units at the 317 feet 6 inches level into flasks on the 254 foot floor. A platform at elevation 278 feet serves the reactor ion chambers.

Between the north and south cross walls above elevation 274 feet are the east and west fuelling machine vaults which are separated by the calandria vault. Thick concrete floors at 274 feet provide shielding of the grade floor from the reactor end shield faces as well as forming structural elements. Access to either fuelling machine vault is normally through an airlock and a shielding-sealing door assembly in the north cross wall. An alternative, less convenient, entrance is provided from the boiler room above, through the south end of the blowout panel area to a platform around the feeder cabinets. A ladder at the north end and a stairway at the south end connect this platform to the 274 foot level.

Located immediately below the fuelling machine vaults are the fuelling machine service rooms. Each fuelling machine vault is connected to the service room below by a slot in the floor of the vault. The fuelling machines are suspended from the underside of a bridge which closes this slot when the machine is withdrawn or lowered. The bridge provides shielding and sealing of the floor slot so that the service room may be entered when the reactor is in operation. The fuelling machines reside in the service room when not in use.

Access to either fuelling machine service room is through a shielding-sealing door from an accessible passage running north to south between the service room wall and the perimeter wall. A light metal door is fitted to provide an atmosphere separation when the main door is open. The service room wall also incorporates a shielding window to allow inspection of the lowered fuelling machine from the accessible area.

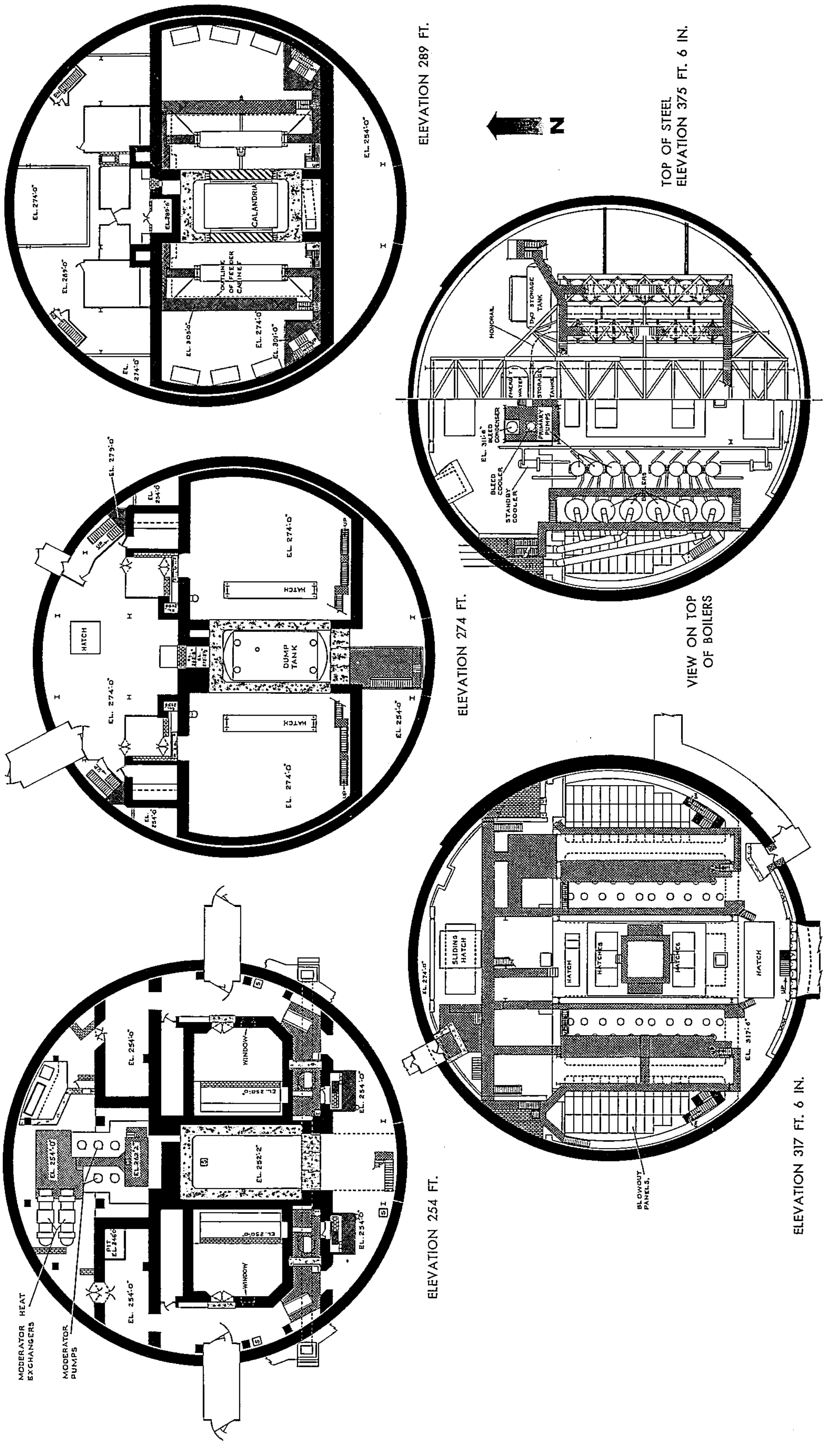
Fuelling machines may be removed from the service rooms, across the accessible passages and through the equipment airlocks leading onto the Reactor Auxiliary Bay grade level floor, where they can be wheeled to the maintenance area in the Service Wing.

Adjacent to the fuelling machine service rooms to the north are rooms containing auxiliary equipment and controls for the fuelling machines. To the south of the fuelling machine service rooms are rooms containing the fuel handling equipment, in which new fuel enters the fuelling system and spent fuel is transferred into the spent fuel duct. The spent fuel duct runs under the Reactor Building to the spent fuel bay, which is located between Reactor Buildings No.2 and No.3.

North of the north cross wall at grade level are the moderator room, moderator ion exchange room, and two auxiliaries rooms. The moderator room is inaccessible during operation. The moderator ion exchange room has been made accessible during operation by the placement of shielding walls to prevent direct radiation from the moderator system. There is a common atmosphere in the moderator room and ion exchange room. The two auxiliaries rooms contain fuelling machine pressurizing pumps, fuelling machine hydraulic units, moderator addition equipment, and the heavy water collection pit and equipment. These rooms are accessible during operation.

The floor at elevation 274 feet north of the north cross wall is served by two airlocks in the perimeter wall and constitutes a large accessible assembly area. Two shielded rooms on this floor contain primary heat transport system filters and ion exchange columns.

Above the 274 foot floor is a mezzanine at elevation 289 feet which is accessible from the airlocks at the 274 foot level by enclosed stairways. The ventilation drying equipment and the reactor control distribution frames are located on the mezzanine. Five enclosed areas for ventilation control take up the remainder of the space.



3-6 REACTOR BUILDING PLAN

These are: two areas for instrumentation containing D_2O, one for moderator dump valves, one for reactor zone control equipment which contains hydrogen, and one for heavy water collection equipment, helium compressors and heavy water recombination units.

The boiler room floor which forms the top of the internal concrete structure extends over the entire building area at elevation 317 feet 6 inches except for the portion north of the north cross wall which is 6 feet lower and contains primary circuit auxiliary equipment.

Above the boiler room floor is a structural steel framework which supports a thirty-ton crane, the boilers and primary system pumps. The crane is centered on and runs along the north-south centreline of the Reactor Building in a bay which is 30 feet wide from east to west. An 11 foot by 28 foot hatch in the south part of the boiler room floor allows the crane to work the full height of the building on the south side. In the north part of the boiler room floor an 11 foot by 26 foot opening is covered by a hatch, part of which is motorized for quick opening. The boiler room crane can operate conveniently between the 274 foot floor and the boiler room floor on the north side by opening this motorized portion. Crane access is also provided to the moderator room below the 274 foot floor by an 11 foot by 26 foot hatch. Above the boiler room floor there is a system of monorails on the overhead steelwork to facilitate moving components of equipment to the main crane.

A circular opening, 25 feet in diameter, leads from the south of the Reactor Building to the vacuum containment system. This opening is louvered in order to allow gases to pass only outward from the Reactor Building. The containment system is described in Section 3.6.

Throughout the building special provision has been made to allow the equalization of pressures in case of energy releasing incidents so that the containment shell will be subjected to a nearly uniform internal pressure, and unbalanced pressures on internal structural components will not be severe. These provisions include the pressure walls at the east and west extremities of the fuelling machine vaults, blowout panels in the fuelling machine vault roof (boiler room floor) which provide atmospheric separation during normal conditions but will blow off under specified values of differential pressure, slots closed with light rupture panels at the circumference of the boiler room floor north and south, and floor openings east and west in the north segment floors at elevations 289 and 274 feet. Collapsible plastic sheet barriers or louvers will be used elsewhere as required to limit pressure differentials across structural components.

3.2.6 Air Locks

The main Reactor Building airlocks, which form part of the containment system, are fitted with double inflatable seals at the inner and outer doors to give a high degree of leak tightness. There are three equipment airlocks: two at elevation 254 feet having doors 8 feet by 8 feet designed to allow removal of the fuelling machines from the Reactor Building, and one at the north west side of the floor at elevation 274 feet having doors 8 feet by 10 feet high which will allow passage of the fuelling machine bridge mechanism components, moderator heat exchangers, and a large shielding flask for removal of reactivity control elements. In each equipment airlock door a smaller man-size door is included for the convenience of personnel. An additional airlock for personnel only is located on the north east side of the 274 foot floor.

Two additional airlocks are located in the Reactor Building, giving access for personnel to the boiler room (during shutdown only). One of these airlocks, located on the north side of the Reactor Building, is connected by an elevated covered manway to an elevator and stairway in the Turbine Auxiliary Bay. The other airlock on the south side is connected by a manway to the stairway rising above the Reactor Auxiliary Bay roof. This south-eastern airlock is considered primarily as an emergency escape route. Both airlocks are protected from direct radiation from the boilers by shielding walls.

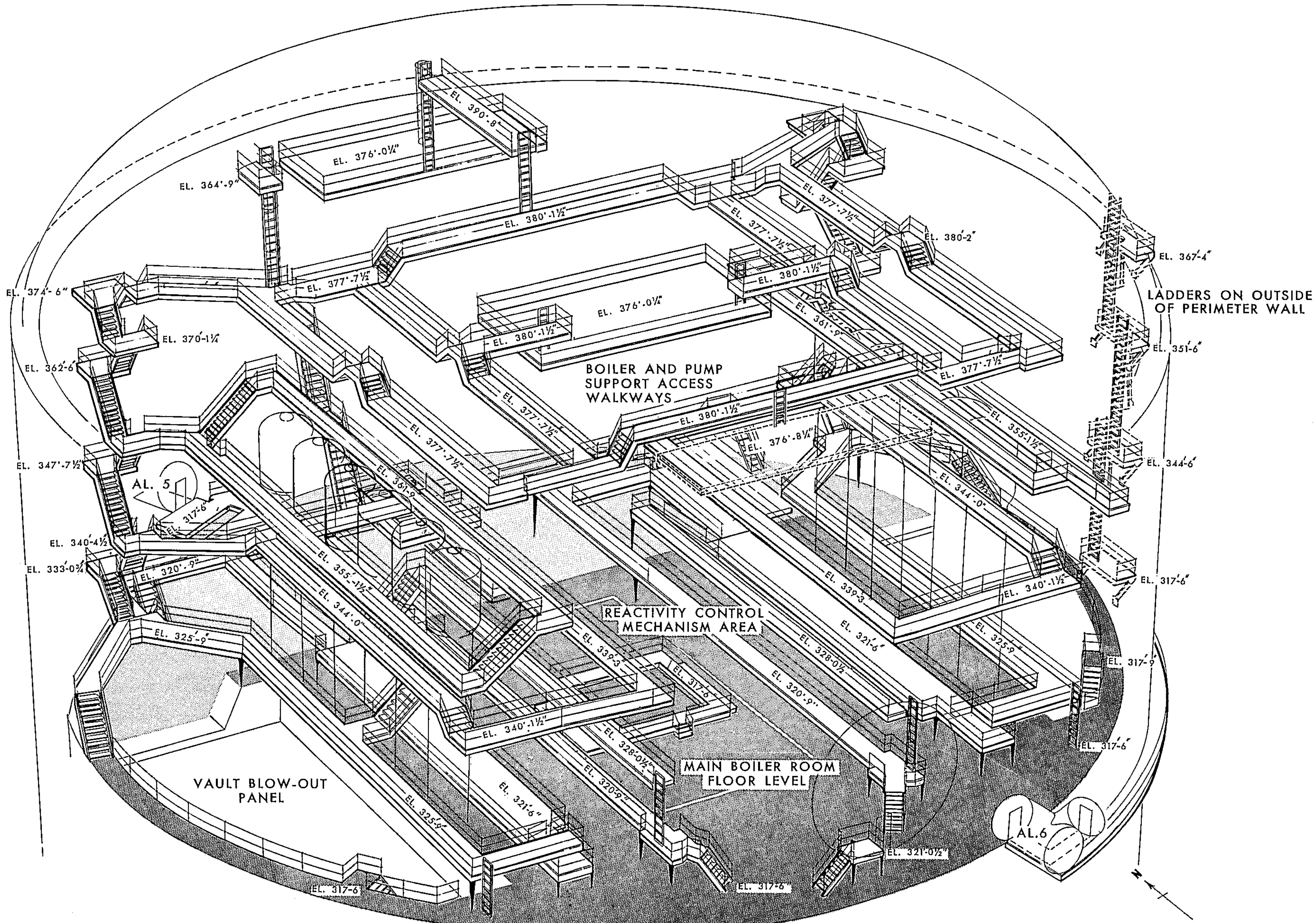
All personnel doors in equipment airlocks and all doors in personnel airlocks open outward from the Reactor Building and are pneumatically operated in an interlocking sequence. This provides for pushbutton initiation of pressure equalization, unsealing, unbolting and opening followed by automatic closing, bolting and sealing and reset of equalizing valve. This sequence, which can be carried out manually in the event of power or air failure, is interlocked from end to end in each airlock. The operation of the interlock system for personnel doors will also govern the action of those equipment doors in which they are mounted.

In the case of the four airlocks which provide access to the accessible areas in each Reactor Building (elevations 254 and 274 feet), the seals on the personnel doors will normally be uninflated. In the event of high building pressure or activity these seals would be inflated automatically on the same signal which closes the Reactor Building ventilation dampers and trips the reactor (see table 7.5—1). Due to the interlocking arrangement of the doors at least one set of seals would operate even if an airlock were in use at the time of such an incident.

The seals on all doors in the airlocks into the boiler room will normally be inflated and will isolate the boiler room atmosphere from the outside atmosphere at all times.

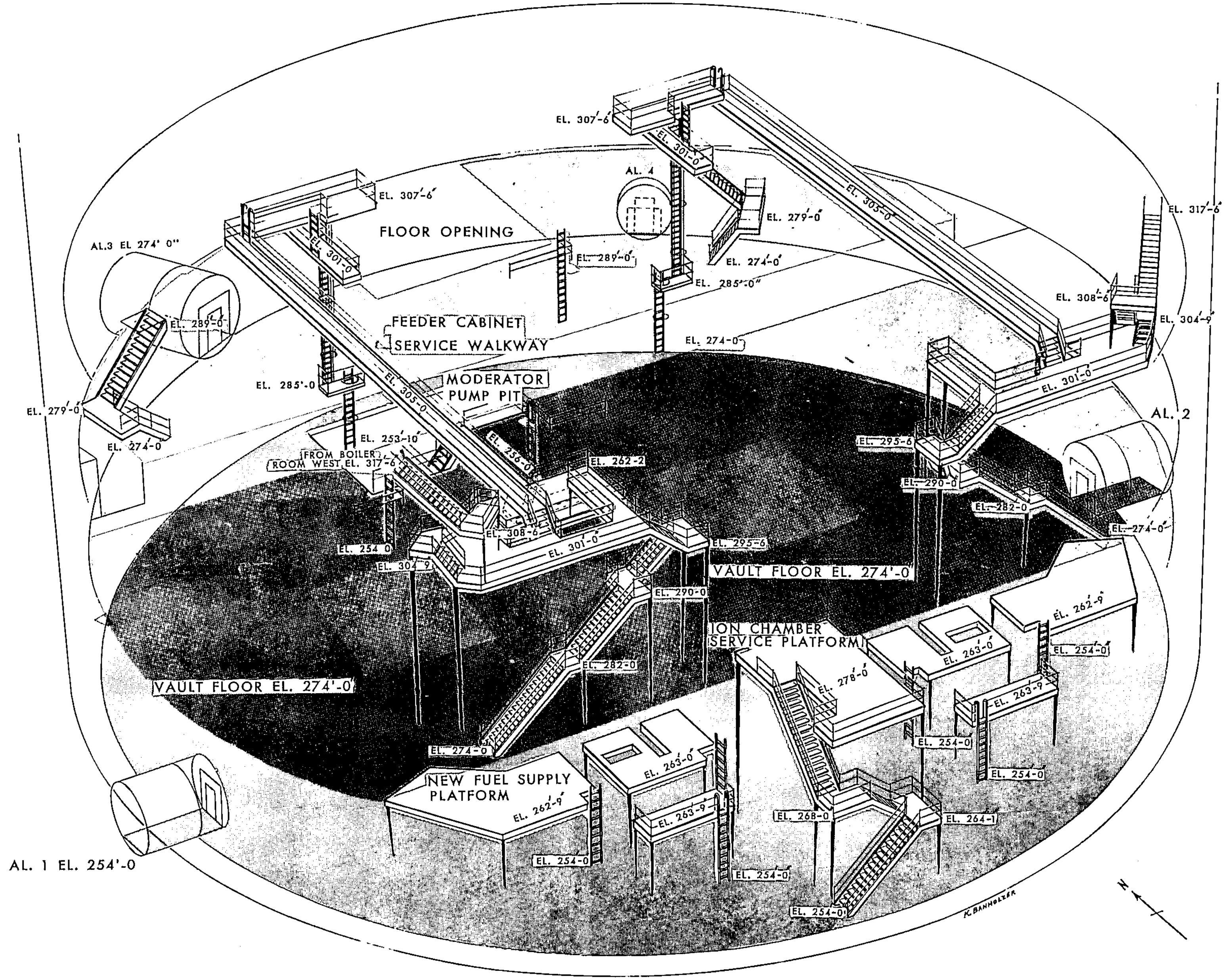
3.2.7 Differences in Reactor Buildings

The four Reactor Buildings are almost identical. The differences between the buildings are minor, and concern the location of a few penetrations through the perimeter wall, the handing of airlocks, and the location of additional shielding concrete on the exterior surface of the perimeter wall. The additional shielding is one foot thick, and is applied to the east side of Reactor Buildings No.1 and No.3



3–7 STAIRWAYS AND WALKWAYS ABOVE EL. 311'6"

44.21253—1
REV. 1, 1968



3–8 STAIRWAYS AND WALKWAYS BELOW EL. 311'-6"

44.21253—2
REV. 1, 1968

and to the west side of Reactor Building No.2 at the boiler room level to augment the shielding of personnel outside the Reactor Building from the boilers.

Differences exist in the handing of the equipment and personnel airlocks at elevation 274 feet for units 2 and 4 because of the necessary relationship between the equipment airlocks and the large centrally placed hatch and hoist arrangements in the Reactor Auxiliary Bay at this level. In addition, for Reactor Building No.2 the manway connecting the stairway to the southeast personnel airlock at boiler room level also connects to the access airlock for the pressure relief duct as described in Section 3.6.3.

3.3 REACTOR AUXILIARY BAY

3.3.1 General

The Reactor Auxiliary Bay runs the full length of the Powerhouse (1,000 feet) and covers the area between the Turbine Auxiliary Bay and the Reactor Buildings as far as 16 feet beyond (south of) the common centreline of the latter.

To keep the size of the Reactor Buildings and the need for entry of personnel to a minimum, reactor auxiliary systems which do not contain highly radioactive fluids and which, therefore, do not require the containment and shielding provided by the Reactor Building, are located in the Reactor Auxiliary Bay.

3.3.2 Building Arrangement

The Reactor Auxiliary Bay is a conventional two-storey steel frame building fitted around the northern halves of the four Reactor Buildings. The ground floor is a 15 inch thick reinforced concrete slab at grade level. The floor slab and all major structures are supported on a system of steel piles and concrete floor beams. The second floor and roof consist of a 7—1/2 inch thick reinforced concrete slab resting on a steel frame structure with the columns bearing on reinforced concrete pile caps.

The spent fuel storage bay is located in the Reactor Auxiliary Bay at the ground floor level between Reactor Buildings Nos. 2 and 3. This location makes it central in the four-unit station as indicated in Figure 3—1. A detailed description of the fuel bay is given in Section 3.3.3. The four-unit circulating water intake passes directly under the spent fuel bay in two closed ducts. These reinforced concrete ducts are built on bedrock and support the fuel bay above.

The space on the second floor of the Reactor Auxiliary Bay, directly above the spent fuel storage bay, is occupied by the (four-unit) station control centre, including the control room, the control equipment room, and the shift and work assignment offices. A description of the layout of the control centre is given in Section 7.

The stairs at the south wall of the Reactor Auxiliary Bay, which have the dual purpose of serving the Reactor Buildings and the Reactor Auxiliary Bay itself, are extended above the roof at the east side of each Reactor Building to allow access to the south side of the Reactor Building boiler room floor through external walkways. The walkway for Reactor Building No.2 connects also to an access airlock in the pressure relief duct.

Vertical access on the north side is provided by stairways and elevators in the Turbine Auxiliary Bay. These stairs also rise to the level of the boiler room floors in the Reactor Buildings, thereby giving access to the north side of these floors via change rooms and external covered manways (bridges).

Main steam pipes and relief valves run above the Reactor Auxiliary Bay roof on a system of supporting steel work.

The spent fuel storage bay cooling and purification equipment area is located at the ground floor level adjacent to the storage bay. The shield cooling equipment areas are adjacent to the east and west sides of the Reactor Buildings. Helium storage tanks, one for each Reactor Building, are located in the area between the Reactor Buildings and extend through the second floor. Clear passageways, which form a main aisle down the full length of the building, with branches to the Reactor Building airlocks, are provided to allow fuelling machines to be moved out of the Reactor Buildings to the fuelling machine maintenance areas in the Service Wing. Apart from the control centre, the second floor is mainly occupied by the ventilation equipment for the Reactor Buildings and the Reactor Auxiliary Bay. On the north side between Reactor Buildings No.1 and No.2 and between No.3 and No.4 is a clear floor area with hatch openings. These hatches are fitted with 25 ton monorail hoists.

The second floor of the Reactor Auxiliary Bay also houses the heavy water cleanup and evaporation equipment for the D_2O upgrading tower located just clear of the south wall of the Service Wing.

Cable runs in general will be hung from the roof; the steam and feedwater piping, which run from the Reactor Buildings to the Turbine Building, are supported by a steel frame about 35 feet above roof level. This steel frame also supports the platform and laydown area, plus part of the walkways, which give access to the personnel airlocks at elevation 317 feet 6 inches.

Below grade inside the Reactor Auxiliary Bay, there are spent resin storage pits, one for each Reactor Building. After installation of the spent resin tanks the pits will be covered with 2 feet 6 inch thick heavy concrete slabs to provide shielding. No access should be required after construction.

A tunnel between the Reactor Auxiliary Bay and the Vacuum Building provides a passageway for personnel between the two buildings, and carries services from the Reactor Auxiliary Bay to the Vacuum Building. The tunnel is situated immediately to the west of Reactor Building No.1 and runs in a southerly direction from the Reactor Auxiliary Bay to the basement of the Vacuum Building. Services accommodated consist of power and instrument cables, and process piping.

Over the control room the roof of the Reactor Auxiliary Bay supports an extensive penthouse for the control room ventilation and air conditioning equipment. A portion of this penthouse is also used for the enclosure of cable runs.

3.3.3 Spent Fuel Bay

The spent fuel storage bay area is separated from the main area of the Reactor Auxiliary Bay by partition walls. A portion of the storage bay enclosure extends 54 feet south of the south wall of the Reactor Auxiliary Bay.

The bay water containment system consists of a concrete bay liner installed within the main structural concrete of the spent fuel bay and separated from it by an air gap, as shown in Figure 3—9. The concrete liner has 14 inch thick steel reinforced walls and a 12 inch thick steel reinforced floor. The inside face of the concrete liner is painted with white epoxy paint and the exterior (back fill) face of the structural concrete is coated with asphalt waterproofing. The double wall arrangement is designed to prevent bay water leaking through any possible defects in the concrete to the surrounding ground water. The concrete liner and epoxy coated surface are the prime barriers against leakage and all pour and construction joints are to be fitted with metal water stops. Any leakage through the concrete liner will be trapped by the air gap and drained to the bottom of the wall where it will be conveyed by 3 inch diameter drain pipes to one of five fuel bay manholes. The manholes, each collecting drainage from a particular area of the storage bay, are fitted with submersible pumps discharging into a common header leading to the bay water cleanup equipment. From the cleanup equipment any leakage water will be recirculated to the bay. The storage bay is divided into four containment areas each working entirely separate from the others, as shown in Figure 3—9.

Watertight gates are fitted to the division walls between the inspection bays and the southerly extension of the storage area. The main storage area can be separated from its southerly extension by the installation of stop logs. If it should prove necessary, the inspection bays and the two storage sections can be isolated and drained. Draining the inspection bays or the small southern section of the storage bay would not be a major problem since the volume is relatively small and no spent fuel normally resides in these areas. Emptying water from the main bay area would be a major operation. All stored fuel would have to be removed and the stop logs installed. The bay water could then be pumped to the waste management area and discharged to the lake under control. With the main area empty and with the inspection bays and southerly extension flooded the station could remain in operation for several weeks. This would be accomplished by using the southerly extension as temporary fuel storage. Floor drains, which are normally closed are fitted to each bay area leading into one or more of the bay manholes. All five containment manholes are fitted with a small submersible pump and provision has been made to allow installation of an additional pump if required. With two manhole pumps running the southerly extension could be emptied in approximately 8 hours and the water recirculated to the bay through the cleanup equipment.

All embedded parts leading through the structural concrete have been designed to prevent leakage and the major fittings have also been designed to allow a second sealing system to be attached if leaks develop at these points. The multi-layer epoxy coat, selected to be resistant to radioactivity, is expected to provide a leaktight, easily cleaned surface for the design life of the plant. Radiation tests are being conducted on epoxy coated surfaces. The water stops in the concrete liner will be steel and the water stops in the structural concrete will be placed on the wall centreline.

All metal parts immersed in the bay water will be stainless steel.

It is intended that the spent fuel transfer flasks shall rest on removable shock absorbing platforms at the bottom of the bay to avoid the possibility of damaging the epoxy paint lining.

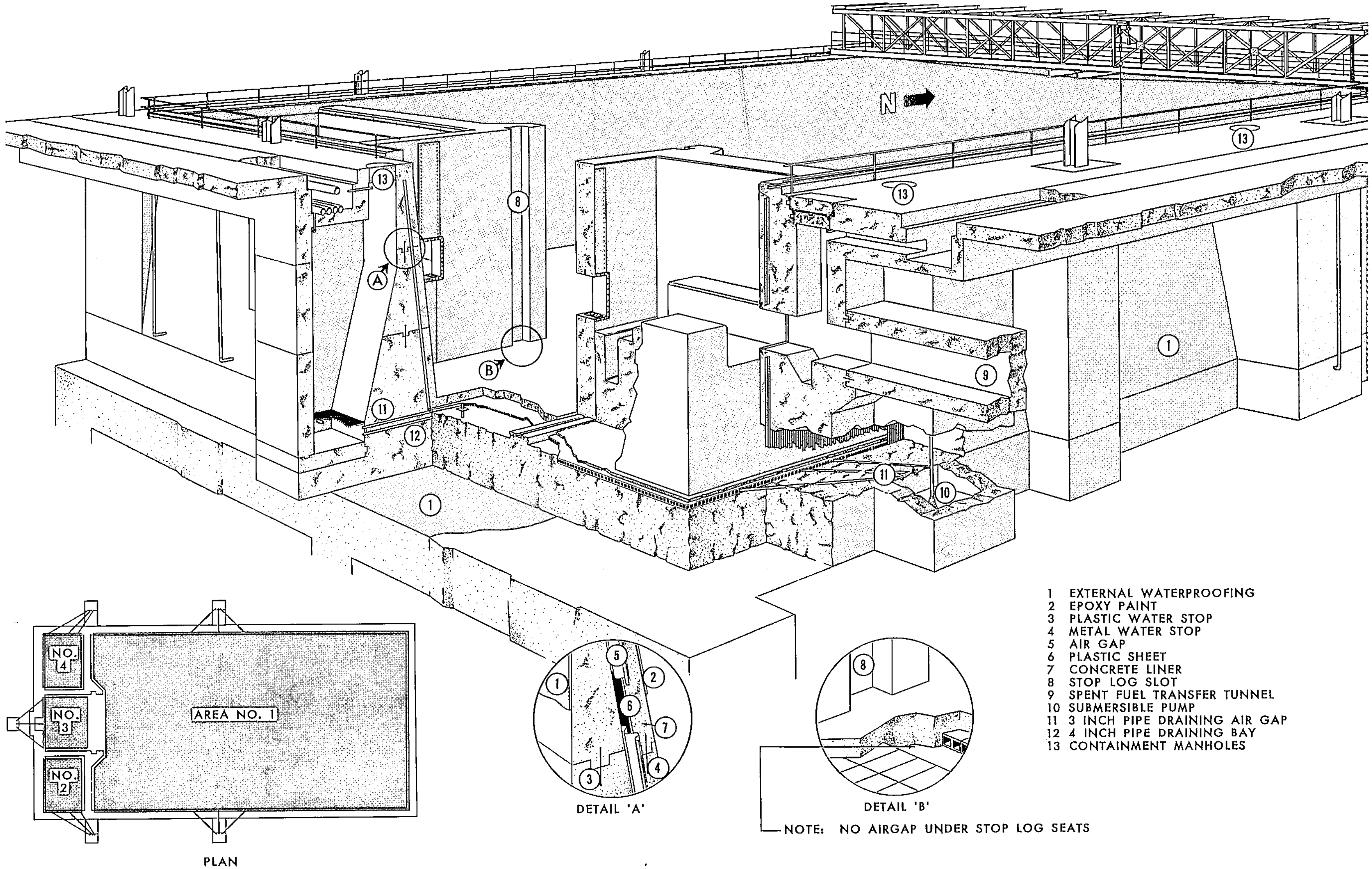
Spent fuel will be loaded into the transfer flask by the fuel handling gantry and the flask lifted from the bay onto road transport by a hoist with a 62 ton lifting capacity. The portion of the bay building which projects south of the wall of the auxiliary bay has doors in both the east and west walls to allow passage of road vehicles.

Straight concrete ducts (internal dimension 4 feet by 4 feet) run from the Reactor Buildings to the storage bay at an elevation 15 feet 6 inches below grade. These ducts house the spent fuel transfer lines. Access to the ducts is provided at both the east and west sides of the Reactor Buildings and at the east and west sides of the storage bay via manholes. The water in the spent fuel transfer lines flows into the inspection bays. Any leakage within the concrete ducts will be drained to a storage bay containment manhole, pumped to the bay water cleanup equipment and recirculated to the storage bay.

The area enclosed by the partition walls around the fuel bay will be held at a slightly negative pressure to that in the surrounding Reactor Auxiliary Bay, which will supply the ventilation flow. The system is designed to discharge into the discharge duct of No.2 unit on the south side of the Powerhouse.

3.4 POWERHOUSE

The Powerhouse consists of a turbine hall and a turbine auxiliary bay. The turbine generators are arranged in a line down the turbine hall which runs the length of the station. A loading bay is located centrally in the length of the



3–9 SPENT FUEL STORAGE BAY CONTAINMENT SYSTEMS

44.21500–2
REV. 1, 1968

turbine hall. The auxiliary bay houses the condenser circulating water and process water pumps, switch gear, deaerator, and other auxiliary equipment.

The Powerhouse is supported on reinforced concrete pads placed on a dense layer at about elevation 220 feet. The building is not supported on piles. However, the turbine-generator foundation block is supported on steel pipes driven to bedrock from elevation 220 feet. The Powerhouse is a conventional steel frame structure approximately 1,000 feet long, including the loading bay, 210 feet wide and rises to 124 feet above grade as shown in Figures 3—1 to 3—3.

3.5 SERVICING AND UPGRADING FACILITIES

3.5.1 Service Wing

The Service Wing provides space and facilities for the repair, overhaul and maintenance of large and small parts. It is a two storey structure with basement, laid out to serve an eight unit station, and is attached to both the Powerhouse and the Reactor Auxiliary Bay at the east end of the four unit station, as shown in Figures 3—1, 3—2 and 3—3.

The basement accommodates the waste disposal facilities. It is excavated to an elevation of 217 feet, is 60 feet long, the full width of the Service Wing, and is served by a freight elevator and stairs.

The first floor of the Service Wing, which is at an elevation of 254 feet, provides areas for the repair of fuelling machines, the overhaul of contaminated equipment, the decontamination of large parts and the maintenance of clean units. These areas are to the south of a corridor that spans the width of the Wing from east to west. On the north side of the corridor, areas are provided for the decontamination of small parts, the building maintenance workshops, the machine shop and the main stores and unloading dock. Access to these areas, as well as to the Turbine Auxiliary Bay, is from a central corridor which extends from the east-west corridor to the receiving area lobby at the northern end of the Wing.

The second floor of the Service Wing is at an elevation of 274 feet, with access to its various areas being from two main corridors which span the width of the Wing from east to west, and the length of the Wing from the north end to the east-west corridor, in an arrangement similar to that for the first floor. Areas to the south of the east-west corridor provide for the decontamination of plastic and rubber goods, and for the Service Wing ventilation equipment. The north-eastern area of the floor accommodates the control equipment workshops, the chemical and radiation safety laboratories and offices, and the production engineering administration offices. The cotton goods laundry and the personnel cleanup and change areas are located to the west of the central north-south corridor.

The monitoring and cleaning facilities of the Service Wing constitute the main transition points between the zoned and unzoned work areas of the station. The last monitor passed on leaving the station is located at the bridge which joins the upper lobby of the Service Wing to the Administration Building. The zoning of work areas to facilitate Service Wing operations is described in Section 9.

3.5.2 D_2O Upgrading Tower

The D_2O Upgrading Tower is a steel framed structure with aluminum siding, and comprises a 120 feet high tower and two-storey building. The tower portion of the structure houses a rectifying column, and the building portion contains associated process equipment as well as a small storage and service area with truck entrance.

An enclosed walkway at grade level provides access to the D_2O Upgrading Tower from the southern end of the Service Wing. Services for the upgrading facility are fed through a branch of the tunnel which runs under the Service Wing linking the basement of the Turbine Hall to the Water Treatment Building.

3.6 NEGATIVE PRESSURE CONTAINMENT SYSTEM

3.6.1 General

The principal involved in negative pressure containment is that within a very short time interval (less than 30 seconds) after any accident resulting in overpressure in a Reactor Building the pressure within the containment boundary would be below that of the surrounding atmosphere. Thus, after the initial transient no outward leakage would take place.

The containment system consists of the Reactor Buildings, the Vacuum Building, and the relief duct and vacuum ducts of the pressure relief system. The arrangement of the structures is shown on Figures 3—1 to 3—3.

The Vacuum Building consists of a reinforced concrete structure as described in Section 3.6.2. It contains a water spray system (see Section 3.6.2.7) which provides a dousing spray of water through the atmosphere of the building to cool the air or condense any steam present.

The pressure relief system (described in Section 3.6.3) consists of ductwork which interconnects the Reactor Buildings and the Vacuum Building, and 12 pressure relief valves which isolate the atmosphere of the Reactor Buildings from that of the Vacuum Building during normal operating conditions.

During normal operation of the station the Vacuum Building will be maintained at a pressure of approximately 1.0 psia, including the vapour pressure of the water in the building. The Reactor Buildings will normally be operated at a slightly negative pressure, of the order of one inch of water, as determined by the ventilation system. In the event of any accident in a Reactor Building which causes the pressure to rise to a positive pressure of 1.0 psig, the pressure relief valves in the pressure relief system will open to relieve the pressure through the ducts to the Vacuum Building. Following this operation, all pressure relief valves will remain fully open until the pressure in the Reactor Building falls below 1.0 psig; at that pressure all but two valves will close by gravity. The remaining two of the twelve pressure relief valves will be automatically controlled to maintain the Reactor Building pressure in the range of 0 to −0.5 psig.

The criteria for the structural design are based on the forces arising from the operation of the system combined with gravity loads, snow loads, and either wind loads or earthquake forces.

3.6.1.1 Design Parameters

The maximum single incident which the pressure relief system is designed to accommodate is a sudden piping failure equivalent to complete severance of a reactor inlet header. The discharge rate for this accident, shown in Section 3.3, Figure 3.3–1 of Volume II of the Pickering Safety Report, will result in almost complete loss of coolant from one half of the reactor in 12 seconds. The estimated peak pressure in the Reactor Building would be 1.6 psig with all 12 pressure relief valves operating, and 2.37 psig with 9 valves open.

In the case of "dual" failures all the coolant from both heat transport loops is released in about 24 seconds to the Reactor Building, as shown in Figure 4.2–4 of Volume II. In this case the calculated maximum pressure in the Reactor Building is 3.17 psig with 9 valves open. The pressure relief system was settled at an early stage in design, with redundancy to allow for valve failure and for possible added energy to the coolant from the fuel and piping.

In the event of the maximum accident, the Reactor Building pressure will rise at a rate of about 2 psi/sec. When the pressure at the pressure relief valves reaches the valve actuation pressure of 1 psi, the Reactor Building pressure will be between 3 and 4 psig (6 psig maximum), depending on which Reactor Building is affected. The rate of relief will exceed the discharge rate, and the Reactor Building pressure will return to atmospheric pressure within 30 seconds of the start of the accident. For less severe accidents the transient pressure rise in the Reactor Building and the time of the positive pressure transient would be correspondingly less. At pressures below 1.0 psig, three of the pressure relief valves can be opened by remote-manual control. The number of psi seconds above atmospheric is about 54 for the design case with 9 valves open.

The Vacuum Building is sized at 2.9 x 10^6 cubic feet free volume so that it can contain all the air which could be purged from a Reactor Building and the pressure relief duct in the event of any accident, plus an allowance for increase in air temperature and about 10^6 cubic feet of volume for steam. The building will be capable of containing all the steam produced by the discharge of the entire primary coolant, without the need for a dousing spray (although this would come on automatically at 6.2 psia).

The Vacuum Building and pressure relief system are designed to collectively contain all the energy which could be released inside a Reactor Building following any postulated accident to the reactor or heat transport system. The energy that can be absorbed within the Vacuum Building, including the stored water therein, is in excess of all the energy in the primary system (liquid, and stored in the fuel and the piping) and in the secondary system (liquid, steam and stored in the piping) and that which would be generated by the reactor for one half hour following a reactor shutdown. This energy is approximately 500 x 10^6 Btu (see Volume II for details of energy sources).

The normal operating pressure in the Vacuum Building is expected to be about 1 psia. The effect on containment capability of increasing the Vacuum Building pressure is shown in Appendix C of Volume II of the Safety Report. Based on this analysis the maximum allowed Vacuum Building pressure for sustained operation is 5 psia. With this Vacuum Building pressure the maximum accident can be accommodated without exceeding design conditions. For short periods totalling not more than one week per year the Reactor Safety Advisory Committee has allowed continued operation with the Vacuum Building unavailable providing two or more Reactor Buildings are coupled in the containment envelope.

3.6.2 Vacuum Building

The Vacuum Building is a reinforced-concrete structure with a cylindrical external (perimeter) wall (shell) enclosing an internal space frame. The frame supports the roof and the emergency water storage tank. A basement is provided to allow access to the underside of the floor slab for maintenance. The basement will be utilized for housing the Vacuum Building equipment including the vacuum pumps, electrical and instrumentation equipment, and the water recirculation and recovery system.

Entry into the Vacuum Building will be allowed only when the building is out of service. Two openings will be provided in the floor slab and will be sized for personnel access and equipment passage. Two hatches are planned in the roof slab for access to the water tank. An additional access to the tank is available via a ladder from the building floor. A ramp is provided to the basement for vehicle and personnel access; a personnel emergency exit is also provided. Services to the basement will be routed through a tunnel connected to the Reactor Auxiliary Bay.

Air permeability tests for concrete indicate that the total maximum leakage into the building under service conditions will be less than 100 cubic feet per minute of atmospheric air. This has been taken as the design leakage rate for the building. Greater leakage rates than the design target will not affect the containment capability of the system. However, high in-leakage must be continuously pumped out and is an economic factor.

The general arrangement and layout for the Vacuum Building is shown on Figures 3—10 and 3—11. A cutaway view of the arrangement is shown in Figure 3—12.

3.6.2.1 Foundation

The Vacuum Building is supported by about 1,000 steel pipes of 50 feet length bearing directly on the underlying bedrock. The capacity of each pile is 100 tons. A 5 feet thick working slab serves as common pile cap. The top of the slab is at elevation 242 feet and serves as basement floor. Loads from the internal structural columns and from the building floor slab are transferred to the working slab through piers 7 x 7 feet in cross-section and 10 feet high. The perimeter wall is supported by the pile cap through a foundation wall about 5 feet thick and 10 feet high. The peripheral column piers will be cast monolithically with the foundation wall.

3.6.2.2 Perimeter Wall (Shell)

The perimeter wall (cylindrical shell) has an inside diameter of 165 feet and an internal height of 166.5 feet (from finished floor to underside of roof slab).

The 36 inch thick shell is designed for an external radial pressure of 14.7 psi. In addition to the uniform external pressure any local differential pressures caused by the discharge of air and steam into the building will be taken into account. The forces at the vacuum ducts penetrations due to the momentum of incoming gases will be kept to a tolerable minimum by the use of a force-balance arrangement at the discharge end of each duct.

At the base of the shell radial deflections will be restrained by the foundation wall and the floor slab; the top of the shell will be free to deflect radially. For elastic stability the shell was analysed as a cylindrical vessel, with one end supported and the other end free, subjected to external pressure.

A synthetic rubber seal and joint (referred to as roof/wall joint and seal) will connect the perimeter wall to the roof slab. This seal will allow relative movements between the roof and the wall for different loading conditions.

The wall will be constructed by the slip-form method (or movable forms). A complete ring of forms 4 feet high is constructed with working platforms attached. The concrete is poured continuously while the forms are being moved upward by a jacking arrangement at the rate of about 9 inches per hour. This method will eliminate all construction joints and thus will provide better leak-tightness. It will take about 11 days to construct the entire wall.

3.6.2.3 Internal Structure

The function of the internal structure is to support the roof, the emergency water tank and the floor slab. It comprises a building space frame of seven storeys. The column lines run in the east-west and north-south direction and are spaced at 21 feet and 3 inches except for the peripheral columns which are arranged in a manner to suit the circular enclosure.

The columns will be circular (spirally reinforced) with an overall diameter of 4 feet. The column tie beams, spaced at 23 feet, 6 inches, are 2 feet wide by 4 feet deep. The grid of girders supporting the roof slab and the water tank will be normally 6 feet by 3 feet except in the area of the vacuum chambers on the roof where some girders will be increased in depth to resist high shears.

3.6.2.4 Roof

The roof of the Vacuum Building is a 24 inch thick two-way reinforced slab. The roof loads are transmitted to the building columns by a grid of concrete girders. The slab is designed for a uniformly distributed load of 14.7 psi.

3.6.2.5 Floor

The floor is a 24 inch flat slab with upstand shear panels at the columns. The downward forces are carried by the foundation piers, while the net upward forces will be transmitted to the columns through the shear panels. The outer edge of the slab is supported on the foundation wall.

The slab will be subject to two sets of load combinations. The first condition includes an upward uniformly distributed load of 14.7 psi less the weight of the slab. The second set of load combinations will include 525,000 cubic feet of water distributed over the entire floor area plus any other gravity loads that could be present while the floor is flooded. For the latter loading condition the pressure in the building is assumed to be 14.7 psia.

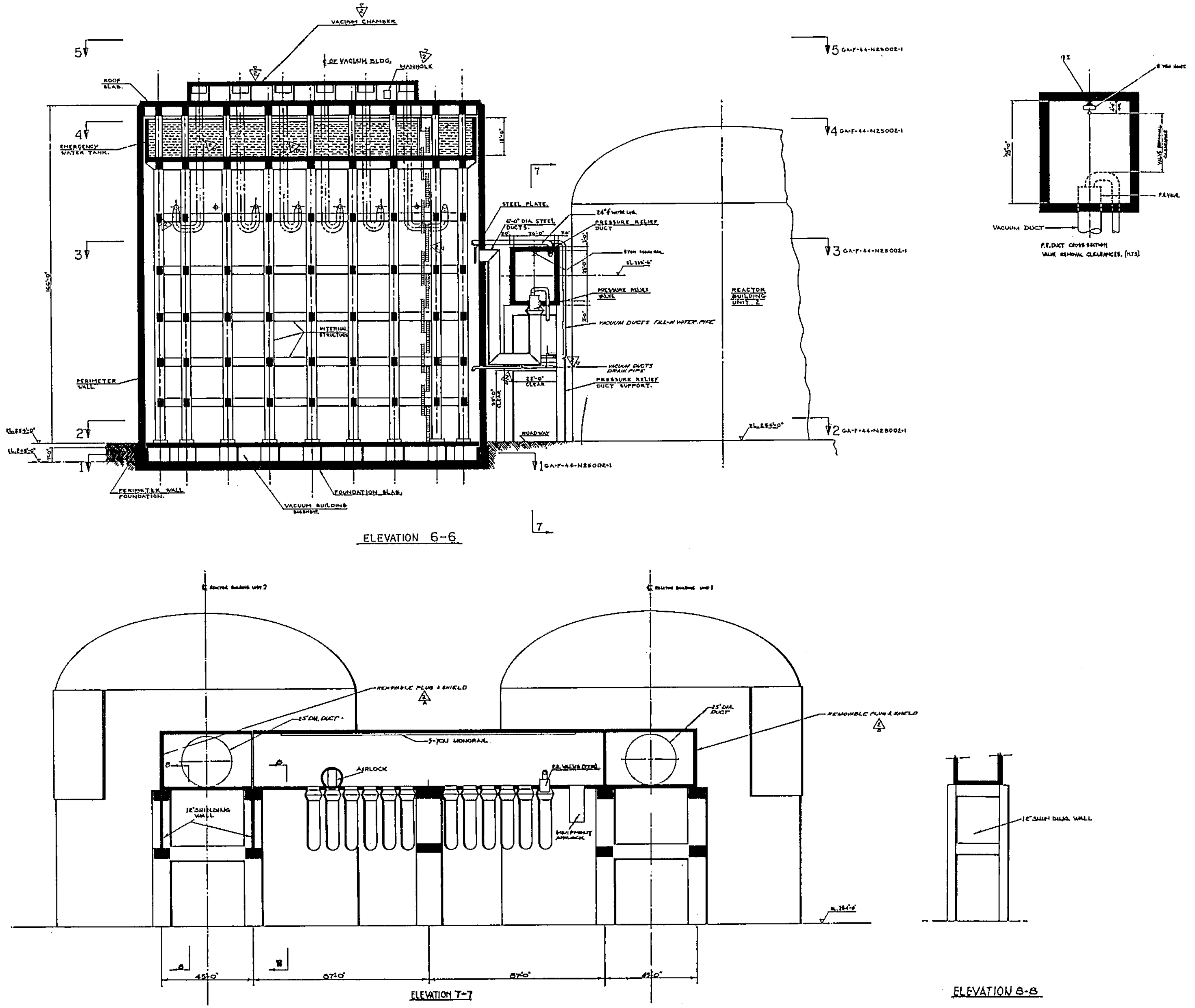
The finished floor is at elevation 254 feet.

3.6.2.6 Emergency Water Storage Tank

The water storage tank will supply emergency water to the Reactor Buildings and will provide water for the dousing spray in the Vacuum Building.

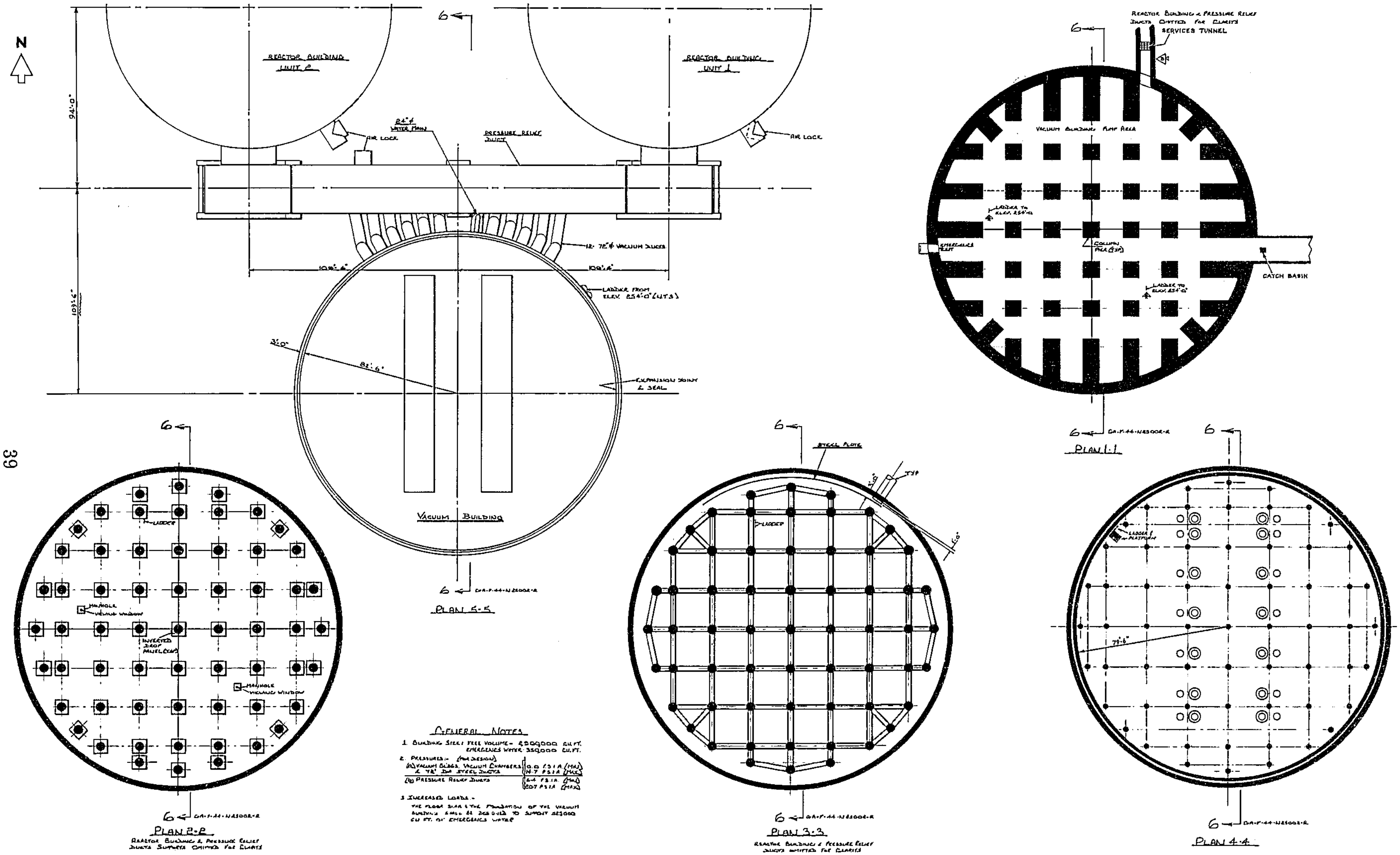
The tank is located directly underneath the roof girders. It is a cylindrical container open to the building atmosphere. Its internal dimensions are 153 feet 3 inches in diameter and 19 feet 7 inches in height. The tank has a net capacity of 350,000 cubic feet. Both the vertical wall and the floor of the tank are of reinforced concrete and are 18 and 21 inches thick respectively. The tank is supported by the internal frame through a grid of girders.

The tank will be filled by the high pressure service water pumps. The rate of fill is 14,000 gallons per minute. After an accident or for any other reason if the water is discharged to the floor of the building, the tank will be immediately filled halfway by the service water pumps.



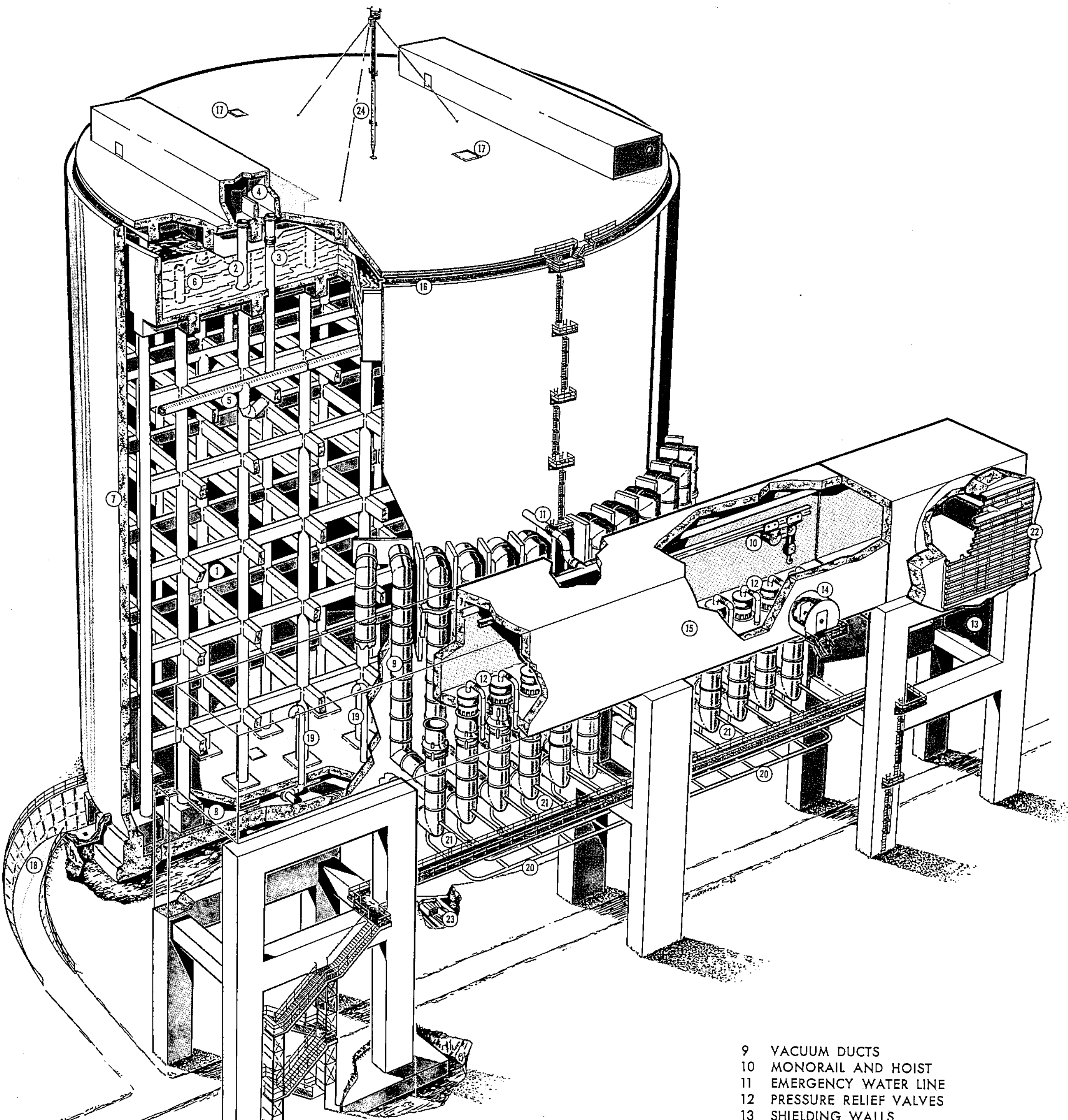
3–10 VACUUM BUILDING - ELEVATION

44.25000–7
REV. 2, 1968



3—11 VACUUM BUILDING PLAN

44.25000—8
REV. 1, 1967



1 VACUUM BUILDING INTERNALS
2 PRESSURE ACTUATED WATER DISPLACEMENT SYSTEM INLET HEADER
3 PRESSURE ACTUATED WATER DISPLACEMENT SYSTEM OUTLET HEADER
4 VACUUM CHAMBER
5 DISTRIBUTION AND SPRAY HEADER
6 EMERGENCY WATER STORAGE TANK
7 PERIMETER WALL
8 BASEMENT
9 VACUUM DUCTS
10 MONORAIL AND HOIST
11 EMERGENCY WATER LINE
12 PRESSURE RELIEF VALVES
13 SHIELDING WALLS
14 PERSONNEL AIRLOCK
15 PRESSURE RELIEF DUCT
16 ROOF/WALL SEAL
17 WATER TANK ACCESS HATCH
18 BASEMENT ACCESS RAMP
19 VACUUM PUMP SUCTION HEADER
20 VACUUM DUCT DRAIN PIPE
21 VACUUM DUCT FILL PIPE
22 REACTOR BUILDING PRESSURE RELIEF LOUVRES
23 SERVICES TUNNEL
24 WEATHER MAST

3-12 VACUUM BUILDING AND RELIEF DUCT

This immediate refilling of the tank accounts for the loading condition called for in the preceding section where an amount of water equivalent to 150% of the tank capacity was considered to be distributed on the floor.

During normal operating conditions of the station the water in the tank will be recirculated by the water recirculating and recovery pumps located in the basement of the building.

3.6.2.7 Water Spray System

The function of the water spray system is to condense any steam discharged into the Vacuum Building and thus prevent the pressure from rising beyond that resulting from the air purged from a Reactor Building. The water spray discharged by the system will also cool the air in the building and thus suppress the pressure caused by temperature rise.

The spray system includes the water storage tank; the pressure actuated water displacement system (2 vacuum chambers, 14 inlet or supply headers, and 14 outlet or discharge headers); and the distribution and spray headers.

Figure 3-13 illustrates the spray system. Vacuum (1.0 psia) is maintained in the top chamber at all times. A rise of pressure inside the Vacuum Building above 6.2 psia will cause water to spill into the discharge header which feeds the distribution and spray headers.

The rate of flow of spray water is proportional to the amount by which the pressure in the building exceeds the dousing initiation pressure; also to the depth of the water in the tank. The spray system is designed to cope with an energy release rate of 5 x 10^6 Btu per second which is based on the most severe accident to the heat transport system. To remove energy at a rate of 5 x 10^6 Btu/sec a flow rate from the spray system of 85,000 pounds of water per second is required at a removal rate of 60 Btu/lb. Fully effective dousing will be established within 10 seconds after a pressure of 6.2 psia in the Vacuum Building has been reached, assuming the building pressure continues to rise during this time interval. No significant area in the building will be left unsprayed. The arrangement of spray headers is shown in Figure 3-14.

The vacuum chambers located in the roof are isolated from the Vacuum Building by water seals. The inside pressure of the chambers will be maintained at 1.0 psia at all times by separate vacuum pumps. The chambers are 12 feet wide and 8 feet high and each of the two chambers is about 110 feet long. The chambers are constructed of concrete. A weir box, sized for depth of crest of 3 feet for maximum discharge, is provided for each set of supply and discharge headers. Entry into the chambers through openings in the chamber walls will be allowed only when the Vacuum Building is out of service.

The inlet headers are 42 inch diameter reinforced fibreglas pipes suspended from a flange on the roof slab into the tank. The bottom end of each header is 18 inches above the bottom of the tank. It is expanded to form a cone 4 feet in diameter to minimize entrance losses.

The outlet headers are 36 inch diameter flanged fibreglas pipes placed opposite the inlet headers. The bottom portion of each header is "U" shaped to provide a water trap which isolates the building from the chambers. To assure a seal at all times the recirculating system will continuously discharge a small quantity of water into the water traps.

The distribution and spray headers have dual function: they distribute the water over the entire building area and discharge it in the building atmosphere in the form of fine (1/4 inch droplet) spray. The headers are 30 inch diameter fibreglas pipes with the top portion of the shell perforated. These headers are located below the tank supporting girders, as shown on Figure 3-10.

3.6.2.8 Vacuum Building Equipment

The equipment to pump down the Vacuum Building pressure and to maintain this vacuum, and the equipment to circulate and chlorinate the water in the elevated storage tank is located in the Vacuum Building basement.

3.6.2.8.1 Main Vacuum Pumps

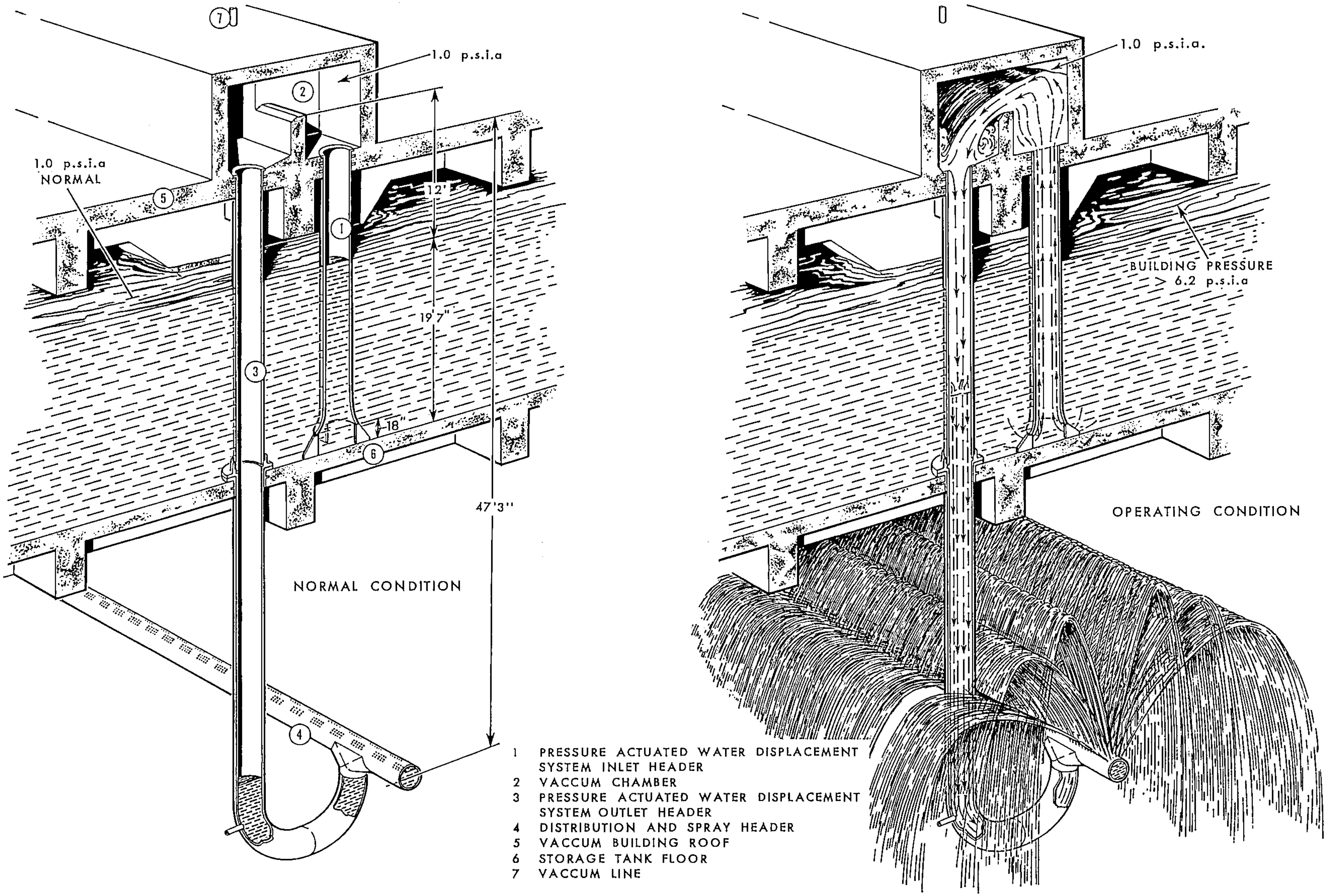
The design conditions within the Vacuum Building are: two inches of mercury absolute pressure including vapour pressure at a temperature of 75°F. The saturated vapour pressure at 75°F is 0.87 inches of Hg. The pump down time from atmospheric pressure to 2 inches Hg has been selected at 24 hours. A total pumping capacity of 6300 cfm is required to pump down the 3 x 10^6 cubic foot volume in 24 hours.

The continuous inleakage of air to the building has been taken at 100 scfm for design purposes. At the above design conditions a steady pumping rate of 3000 cfm would be required, of which more than half would be vapour. For most of the year the temperature within the Vacuum Building will be 60°F or less and the required pumping rate to remove 100 scfm air inleakage would be considerably below the 3000 cfm since the vapour would constitute a smaller fraction of the 2 inch absolute pressure.

To meet the above requirements three vacuum pumps of 2100 cfm capacity have been selected. For the pump-down all three pumps operate in parallel. To remove the steady inleakage one pump is expected to be adequate, but a second will operate on an intermittent basis when required.

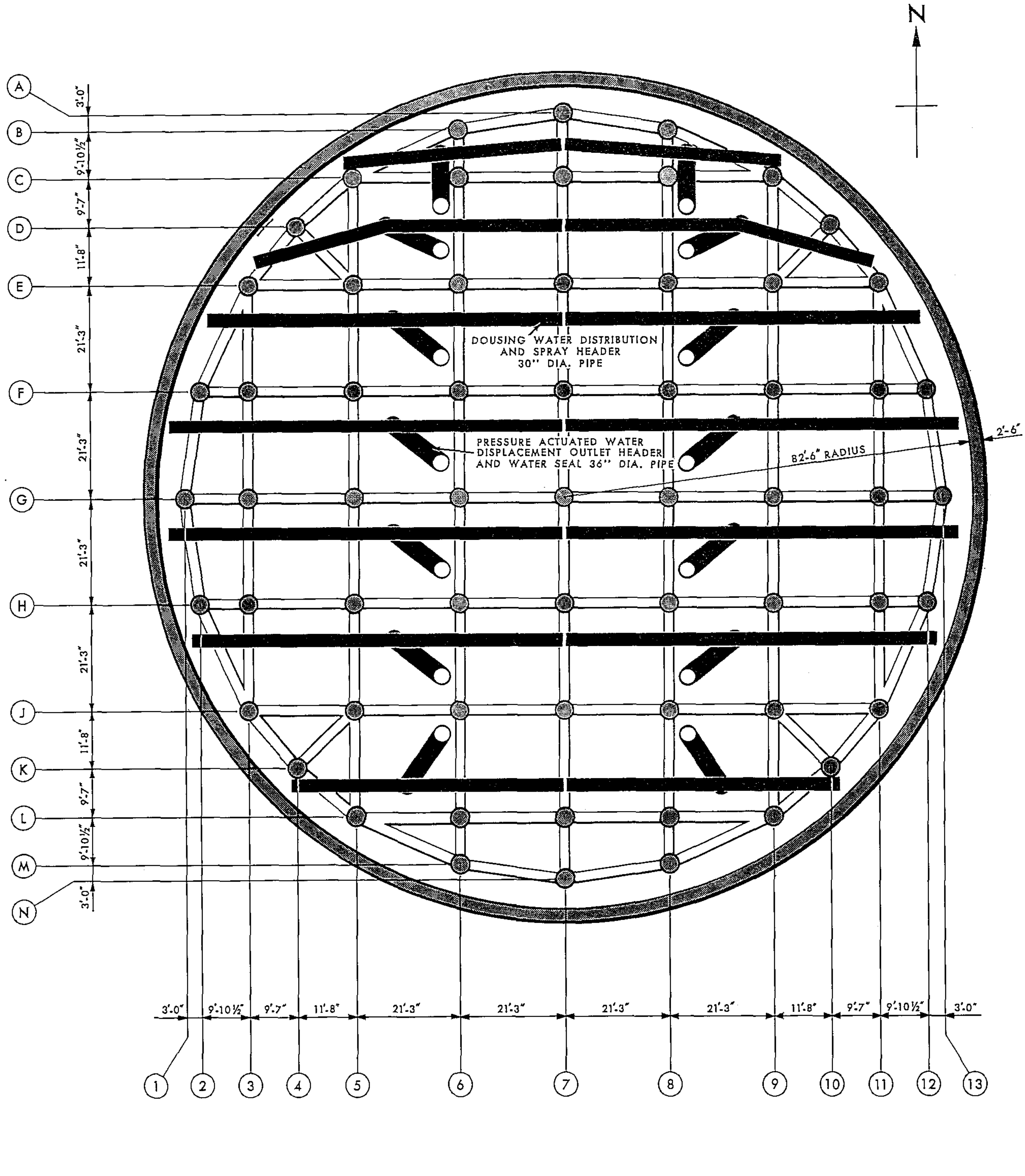
3.6.2.8.2 Vacuum Chamber Pumps

The pressure in the vacuum chambers on the top of the Vacuum Building will be maintained at an absolute pressure of two inches of mercury or less under all circumstances. A separate small pumping system is supplied, consisting of two 100 cfm capacity pumps, one to operate and one as standby. To eliminate a possibility of a false dousing signal



3-13 VACUUM BUILDING SPRAY SYSTEM

44-34316-1
REV. 2 1968



3-14 LAYOUT OF DOUSING WATER
DISTRIBUTION AND SPRAY HEADERS

44.25000-9 REV. 1
1967

during the initial pump down, the piping system will be arranged so that the main pumps can be connected to both the main building and the vacuum chambers. Following pump-down of the building the upper vacuum chamber will be changed over to be connected to the small vacuum pumps.

3.6.2.8.3 Vacuum Pump Operation

The vacuum pumps will be controlled to maintain the pressure in the building and upper chamber at 2 inches (nominal) of mercury. The pump discharge will be monitored and normally discharged directly to atmosphere. In the event that radioactivity is detected in the pump discharges, the pumps will be automatically shut down. The discharge from the small pumps should not become contaminated since the upper chambers are isolated from the main building. Provision will be made to manually connect the vacuum pump discharge to the filter system (iodine and absolute) located in the inlet to the No. 1 unit discharge duct.

3.6.2.8.4 Storage Water Recirculation and Recovery Systems

A system will be provided to continuously circulate and chlorinate about 200 Igpm from the elevated storage tank in the Vacuum Building. Most of this water would be returned to the storage tank after being chlorinated. A small flow, estimated at 10 Igpm, would be directed to the spray system headers to ensure a continuous supply of water to the water traps. This 10 Igpm will be discharged from the headers through a small overflow port in each header to separate pipes leading to the circulating pump suction. A sight glass is installed in each overflow line to permit checking that there is flow.

The same pumping system will be used to recover water from the Vacuum Building floor in the event of an accident which causes the pressure actuated water displacement system to operate. Connections and valves will be provided to allow this displaced water to be pumped back to the elevated tank or to the lake depending on its temperature and contained radioactivity. Monitors will be provided on the pump discharge which will prevent discharge to the lake if there is unacceptable radioactivity in the water as the result of an accident. If the pressure actuated water displacement system discharges all the water in the storage tank through the sprays, one half of the normal stored water will be immediately restored in the top of the Vacuum Building from the high pressure process water system at a rate of about 14,000 Igpm. One half of the water on the floor (unless it is unacceptably hot) would be pumped back to the elevated storage tank at a rate of 200 Igpm. The remainder would be pumped to the lake providing it contained no activity.

3.6.3 Pressure Relief System

The pressure relief system interconnects the Vacuum Building and the Reactor Buildings. The system consists of the pressure relief louvers; the pressure relief duct; the pressure relief valves; and the vacuum ducts.

3.6.3.1 Louvers

The pressure relief louvers are designed to allow only outward flow from a Reactor Building. Inward flow will shut the louvers and thus check any discharge resulting from overpressure in another Reactor Building.

The louvers are located on the inside face of the Reactor Building wall over the opening for the pressure relief duct. They cover an area of 28 x 28 feet and comprise a series of check gates mounted on a steel frame. The gates are approximately 48 inches long, 16 inches wide and are fabricated from 1/4 inch carbon steel plate. The main members of the frame are 24 inch deep steel beams spanning vertically and spaced at 3 feet 6 inches. The beams are supported on anchors embedded in the Reactor Building wall. The beam connections are designed to allow for movement resulting from differential thermal expansion.

The supporting frame and the gates will be designed for a differential pressure of 6.0 psi. The gates will be normally in the closed position and will tend to return to that position by gravity. An arrangement will be provided to allow for locking the louvers in the open position.

3.6.3.2 Pressure Relief Duct

The pressure relief duct serves all four Reactor Buildings. It is an elevated, rectangular reinforced concrete structure running east-west about midway between the Vacuum Building and the Reactor Buildings, and is supported by concrete frames set on steel piles (the maximum spacing of the support frames is 87 feet). The centreline of the duct is at the boiler room level, 82 feet above site grade. The internal width and height of the duct are 20 feet and 25 feet respectively, the thickness of the vertical wall and roof is 2 feet, and the floor slab is 2–1/2 feet thick. Provision has been made for temporary installation of an isolating diaphragm and concrete shielding within the duct between Reactor Buildings No.2 and No.3, so as to permit operation of Reactor Buildings No.1 and No.2 in advance of completion of Reactor Buildings No.3 and No.4.

The pressure relief duct is connected to the Vacuum Building via the vacuum ducts (see Section 3.6.3.3), and to each Reactor Building via an 8 foot long cylindrical reinforced concrete branch connection having an internal diameter of 25 feet and a wall thickness of 2 feet. One end of each branch connection is cast monolithically with the Reactor Building wall. A special joint is provided at the relief duct which is designed to transfer forces resulting from internal overpressures to the Reactor Building wall while allowing for differential settlement between the relief duct and the Reactor Building.

For entry into the main duct a personnel airlock is provided on the north wall in the vicinity of the pressure relief valves. This personnel airlock is connected to the manway serving Reactor Building No.2 southeast boiler room personnel airlock. An equipment airlock to allow for the removal of the pressure relief valves is suspended from the floor of the duct 11 feet to the east of the valve nearest Reactor Building No.1. A door in the louvers allows access to the ducts from a Reactor Building when the reactor in that building is shut down.

The atmosphere in the duct is the same as that of the boiler rooms. The inside face of the duct walls may be painted where required to limit drying of the concrete and thus eliminate excessive shrinkage in the concrete.

The pressure relief duct is designed for a net external pressure of 8.5 psi and a net internal pressure of 6.0 psi. The duct will be subject to the same pressure and leakage testing as required for the Reactor Buildings.

3.6.3.3 Vacuum Ducts

Twelve 6 feet diameter vacuum ducts connect the Vacuum Building to the pressure relief duct. The vacuum ducts are suspended from the pressure relief duct, and are welded to steel receptacles in its floor (the receptacles house pressure relief valves, and form extensions of the vacuum ducts). The vacuum ducts provide more than the required flow area for pressure relief; with only nine ducts available the system will limit the positive pressure transients within 30 seconds time interval for any accident. This redundancy allows for three valves out of service.

The shape of the ducts is dictated by the requirement that the ducts should provide an alternative method of isolating the two pressure zones (Vacuum Building and Reactor Buildings) in case of failure of any pressure relief valve. This will be achieved by flooding the lower "U" shaped part of the ducts. The water column thus provided will be adequate to counterbalance the maximum calculated pressure differential. The emergency water tank will supply the water for flooding the ducts by gravity flow.

The ducts will discharge horizontally into the Vacuum Building. To minimize unbalanced horizontal momentum and pressure forces a force-balance arrangement is provided at the end of each duct.

The ducts are fabricated from 3/8 inch carbon steel plate. Ring stiffeners are attached at 6 feet intervals. An expansion joint at the valve end of the duct allows $\pm$ 1-1/2 inches horizontal movement in all directions. The ducts are suspended at this end by four hanger rods. At the Vacuum Building horizontal forces are carried directly by the wall; vertical loads are transferred to the wall by stiffening ribs cast monolithically with the wall.

The ducts are designed for a net external radial pressure of 14.7 psi. Loads imposed by flooding and high velocity gases are also taken into consideration. The two lower bends in each duct are supported laterally to limit any induced vibration during discharge to the Vacuum Building.

3.6.3.4 Pressure Relief Valves

3.6.3.4.1 General

Twelve pressure relief valves in parallel are installed in steel receptacles between the vacuum ducts and the pressure relief duct. These valves isolate the atmosphere of the Reactor Buildings from that of the Vacuum Building during normal operating conditions. If there is a rise in pressure in the Reactor Building in excess of .5 psi, the valves will open and relieve the excess pressure to the Vacuum Building. If the pressure does not reach .5 psi, one, two or three of the valves may be opened by remote control. After an initial pressure excursion, one, two or three valves are automatically controlled to maintain a Reactor Building pressure between atmospheric and 1/2 psi below atmospheric. It is required that the valves provide sufficient relief so that the Reactor Building pressure does not exceed 6 psig for any credible incident. The non-functioning of three valves will not prevent the system controlling the maximum building pressure to 6 psig. Three valves are automatically controlled. The non-functioning of two valves will not prevent subsequent control of building pressure between atmospheric and minus 1/2 psi.

The valves are a gravity actuated piston type, designed for maximum dependability and for negligible friction between the moving piston and the cylinder. They are removable as units for servicing.

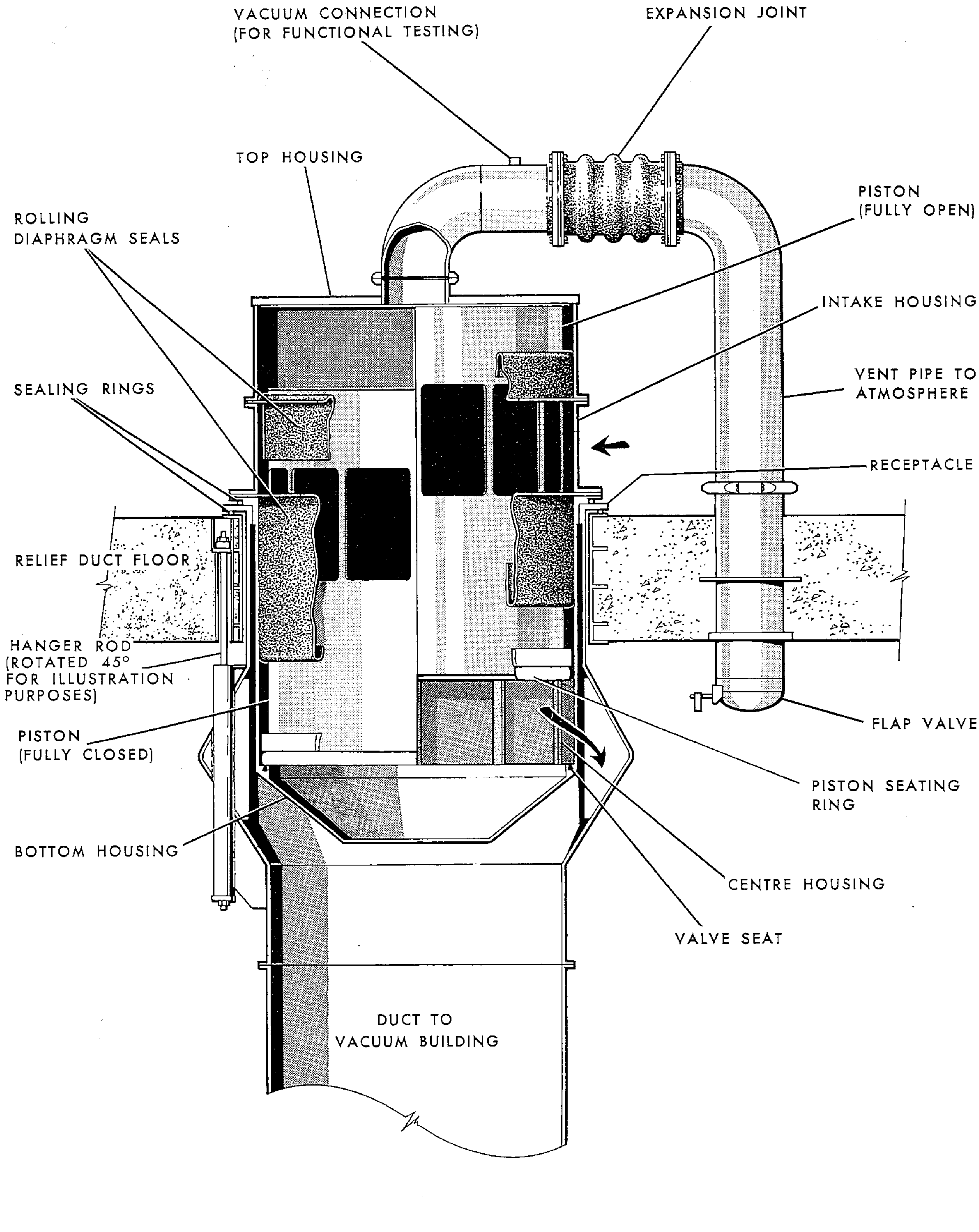
3.6.3.4.2 Structural Detail

The pressure relief valve is illustrated in Figure 3—15. It is approximately 6 feet in diameter and is constructed primarily of mild steel. The valve consists of a housing forming a vertical cylinder in which a piston moves up and down. Two rolling diaphragms serve to prevent leakage past the piston with minimum friction. The housing has ports connecting its upper portion to the pressure relief duct and its lower portion to one of the twelve vacuum ducts leading to the Vacuum Building.

The piston has ports which align fully with the upper ports in the housing when the valve is open and are long enough to partially align with the same ports when the valve is closed. The bottom of the piston contains a ring which seats the piston onto a rubber seal ring in the valve housing.

Each valve assembly is located separately in one of twelve steel receptacles in the floor of the pressure relief duct. Each receptacle is welded to a vacuum duct, forming an extension of it, and is sealed to the floor of the pressure relief duct by a rubber seal fastened between flanges.

The space above the piston is vented to atmosphere through a pipe assembly which penetrates the pressure relief duct floor. The outside terminations of these pipes are closed by flap valves. When a pressure relief valve is



3-15 PRESSURE RELIEF VALVE TO VACUUM BUILDING

44-25200-4
REV 2, 1968

removed for servicing, its flap valve can be locked shut so that the pressure relief duct is not open to atmosphere. All of the vent pipes have a connection to a vacuum system for test operation.

3.6.3.4.3 Operation

When, as a result of an overpressure accident in a Reactor Building, the pressure in the pressure relief duct has risen to about .5 psig, it will exert sufficient force on the underside of the valve pistons to overcome the weight of each piston, and of the effect of the pressure imbalance across the lower diaphragms. The air above the pistons compresses sufficiently to cause the flap valves to open. The pistons will lift 21 inches to the fully open position (if the pressure excursion has been relatively large) and the upper and lower ports in the housings will be completely exposed. The pistons will remain in this position until the pressure in the relief duct falls below 1 psig. Normally all but one piston will then close by gravity. The piston which does not close is partially opened intermittently by the application of a controlled vacuum to the vent pipe.

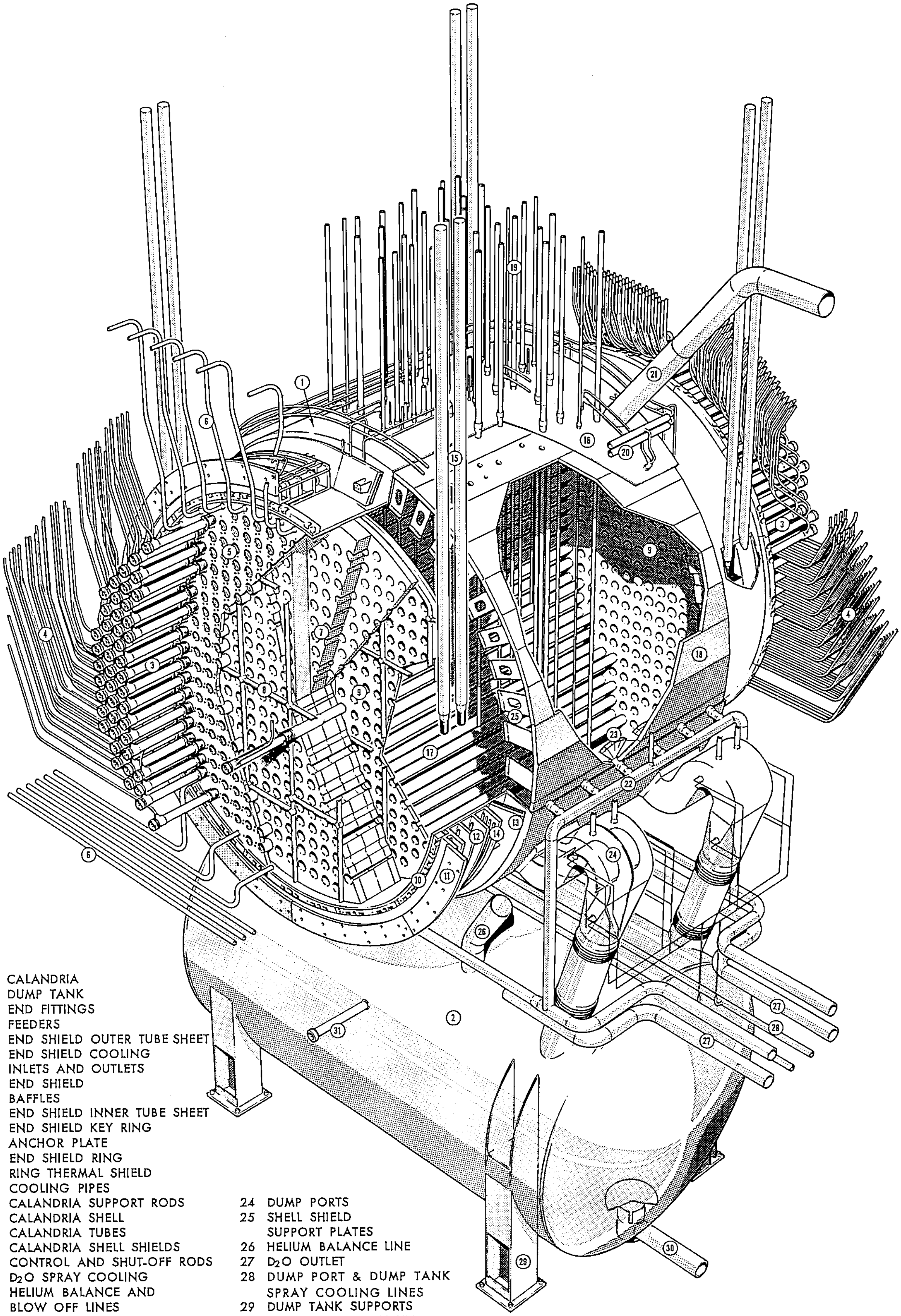
The vacuum connection which is provided on all pressure relief valve vent pipes enables the opening of the relief valves for functional testing without the necessity of pressurizing the relief duct. During such an operation the related vacuum duct will be closed by a water lock (as described in Section 3.6.3.3) and the flap valve in the vent duct will be locked shut. Vacuum operation can also be used to open valves under manual control. This permits venting the Reactor Building atmosphere under accident conditions that do not raise the pressure to over .5 psig.

3.6.3.4.4 Containment

Care has been taken to ensure that leakage to atmosphere is eliminated. When a valve is removed for service, the flap valve on the end of the vent duct can be positively closed so that relief duct sealing is maintained.

The rolling diaphragm seal normally prevents relief duct atmosphere from entering the vent pipe. The choice of a rolling diaphragm enables a non-rubbing seal to be made between the moving piston and the stationary housing, for greater reliability.

Gaskets prevent leakage in connecting paths to the Vacuum Building. As this building is designed to form part of the containment under accident conditions, leaks to it are considered of secondary importance.



1 CALANDRIA
2 DUMP TANK
3 END FITTINGS
4 FEEDERS
5 END SHIELD OUTER TUBE SHEET
6 END SHIELD COOLING INLETS AND OUTLETS
7 END SHIELD
8 BAFFLES
9 END SHIELD INNER TUBE SHEET
10 END SHIELD KEY RING
11 ANCHOR PLATE
12 END SHIELD RING
13 RING THERMAL SHIELD
14 COOLING PIPES
15 CALANDRIA SUPPORT RODS
16 CALANDRIA SHELL
17 CALANDRIA TUBES
18 CALANDRIA SHELL SHIELDS
19 CONTROL AND SHUT-OFF RODS
20 D_2O SPRAY COOLING
21 HELIUM BALANCE AND BLOW OFF LINES
22 D_2O INLET MANIFOLD
23 D_2O INLET NOZZELS
24 DUMP PORTS
25 SHELL SHIELD SUPPORT PLATES
26 HELIUM BALANCE LINE
27 D_2O OUTLET
28 DUMP PORT & DUMP TANK SPRAY COOLING LINES
29 DUMP TANK SUPPORTS
30 DUMP TANK DRAIN LINE
31 REHEARSAL FACILITY

4.2—1 REACTOR ASSEMBLY

4. REACTOR BOILER AND AUXILIARIES

4.1 GENERAL

The steam raising equipment for the Pickering Generating Station consists of the reactor and associated primary heat transport system, boilers and auxiliary systems and equipment. The general location and arrangement of the equipment is shown in Figures 3-4 to 3-6. The station simplified flow diagram, Figure 1-3, shows schematically the method of transporting the heat from the reactor to the boilers.

4.1.1 Station Heat Balance

The calculated heat balance for the station and the production of heat in various parts of the reactor are shown in Table 4.1-1.

4.1.2 General Description of Steam Raising Plant

Most of the main equipment which constitutes the steam raising plant is now being manufactured. Detailed design work is proceeding on the system auxiliaries and on piping layouts and design. A general description of the equipment and systems is given directly below.

The reactor is a heavy water moderated, pressurized heavy water cooled, natural uranium dioxide fuelled, horizontal coolant tube reactor. Figure 4.2-1 shows the general arrangement of the major components. These are: the calandria with integral end shields and peripheral internal thermal shields, the dump tank with connections to the calandria, the helium cover gas system, and the coolant tube assemblies and connected feeder piping. The coolant tubes, in which the fuel resides, are located within 390 calandria tubes and are supported in sliding bearings at the end shields of the calandria.

The calandria tubes are separated from the coolant tubes by a sealed annulus containing dry nitrogen. Heavy water which fills the calandria serves as moderator, reflector and coolant for the peripheral thermal shields. Helium fills the pipes connected to the top of the calandria and occupies space above the heavy water if the water level is below full calandria.

Below the calandria and connected to it by four moderator discharge ports is the cylindrical dump tank. The goose-neck shaped discharge ports provide for a gas-liquid interface between helium in the dump tank and moderator in the calandria. During operation the helium in the dump tank is held at a pressure in excess of that in the top of the calandria by an amount equal to the height of heavy water above the gas-liquid interface. When the helium pressure above the moderator in the calandria and that in the dump tank is made equal by interconnection the moderator is "dumped" by gravity into the dump tank.

The heat produced in the fuel by fission is removed by heavy water in the primary heat transport system. This system consists essentially of two identical loops in series, one at each end of the reactor. Each loop includes 195 outlet feeder lines, an outlet header, six boilers (two parallel banks of three), a pump suction header, eight pumps (two parallel banks of four), a reactor inlet header and 195 inlet feeder lines. The reactor inlet and outlet headers and the pump suction header are each made up of two equal sections arranged physically in line (but hydraulically in parallel). The reactor outlet header sections are joined by a smaller diameter pipe in which there is a valve. This valve will be normally closed at one end of the reactor only. This division reduces the axial thermal expansion of the headers relative to the reactor, and reduces the loss of coolant which would result from a gross failure in the primary system. The primary coolant is circulated in opposite directions in adjacent channels in the reactor. The volumes of heavy water in the primary and moderator systems are shown in Table 4.1-2.

Shielding from direct radiation from the reactor is provided by heavy concrete (ilmenite aggregate) forming the calandria vault and by the steel and water end shields of the calandria. The large opening in the south wall of the calandria vault, which exists to permit entry of the major reactor components, is filled by heavy concrete. The internal thermal shields in the calandria reduce the intensity of radiation reaching the walls of the calandria vault. Heat produced in the concrete is removed by one layer of cooling coils embedded in the concrete. Cooling water in a closed circuit is circulated through the coils.

Fuel for the reactor is in the form of bundles, 19.5 inches long. Each bundle consists of 28 hermetically sealed elements containing compacted and sintered pellets of UO_2. The elements are of identical dimensions to those used at Douglas Point. The elements are attached mechanically at their end to form a cylinder 4.03 inches in diameter with a small space being maintained between each element by spacers attached to the element cladding.

Loading of new fuel into the reactor and removing spent fuel is carried out "on power" by two co-ordinated fuelling machines controlled from the station control centre. One machine is located at each end of the reactor on the underside of a bridge. These machines operate through a semi-automatic program of homing onto a reactor fuel channel, making a pressure tight connection, removing sealing and shield plugs, inserting or removing fuel, and reclosing the channel.

New fuel is introduced by hand to a magazine which transfers it to the fuelling machines. Spent fuel is discharged from the fuelling machine to a spent fuel transfer mechanism which in turn transfers it by a conveyor to permanent underwater storage in the spent fuel storage bay in the Reactor Auxiliary Bay.

4.2 REACTOR DESIGN AND CONSTRUCTION

TABLE 4.1—1

STATION HEAT BALANCE

(all values in megawatts)

Heat produced in fuel channels		1655.01
Heat loss from fuel channels	2.6	
Net heat output from fuel channels		1652.41
Heat loss from primary circuit outside reactor	3.11	
Pumping energy appearing in primary circuit	12.0	
Net heat supplied by primary circuit		1661.30
Heat produced in moderator	82.0	
Heat produced in calandria tubes	2.5	
Heat produced in rest of calandria structure	2.4*	
Heat produced in dump tank	0.1	
Heat transferred from fuel channels to moderator	2.6	
Total heat normally appearing in moderator circuit		89.6
Maximum heat produced in adjuster rods	0.3*	
Maximum heat produced in absorber units	1.5**	
Extra heat in moderator due to 28 mk of boron	**	
Heat produced in thermal shields	0.1	
Heat produced in end shields	1.0	
Heat produced in concrete shield	0.4	
Total heat produced in shields		1.5
Total heat from reactor fuel (1652.41 + 89.6 + 1.5)		1743.51
Heat transferred to secondary circuit	1661.30	
Heat losses in secondary circuit outside turbine cycle	0.6	
Net heat input to turbine cycle		1660.70
Turbine cycle efficiency	32.5%	
Generator output		540
Heat removed by condenser cooling water	1120.7	
Station power requirements	32	
Net station output		508
Overall station efficiency ($\frac{505}{1743.5}$ x 100)	29.1%	

* The 2.4 value includes the 0.3 value

** Does not enter into the heat balance

TABLE 4.1—2

VOLUMES IN HEAVY WATER SYSTEMS

Moderator System	
Moderator volume in filled calandria	8,536 ft^3
Moderator volume in calandria at minimum critical level (200 cms below calandria centreline)	2,383 ft^3
Dump Tank volume (gross)	9,130 ft^3
Dump Tank volume, to level of 16-inch helium pipe	8,940 ft^3
Total usable dump tank volume below dump ports, including connections between calandria and dump tank	9,340 ft^3
Volume of moderator in full calandria above dump ports	6,820 ft^3
Volume of moderator system external to calandria and dump tank	572 ft^3
Total volume of heavy water in moderator system, with no reserve in dump tank	9,068 ft^3
Primary Heat Transport System	
Volume of main circuit	4,600 ft^3
Volume of standby circuit	152 ft^3
Volume of auxiliary circuits (at normal level in bleed condenser)	652 ft^3
Total Volume	5,404 ft^3
Volume of storage tank (at normal level)	250 ft^3
Total heavy water required to fill system (including 250 ft^3 in storage tank) at operating conditions	315,400 lb.
Total heavy water required to fill system (including 250 ft^3 in storage tank) at 130°F	386,900 lb.

4.2.1 Calandria

The calandria is a horizontal single-walled austenitic stainless steel cylindrical vessel which provides containment for the heavy water moderator and reflector. It has internal peripheral thermal shell shields of 4-1/2 inch thick austenitic stainless steel slabs which are positioned close to the cylinder wall of the vessel. At each end and integral with the calandria shell are combination thermal-biological shields. These end shields provide support for the calandria shell and for the calandria tubes which are rolled into the inner tube sheets of each end shield.

The 390 Zircaloy-2 calandria tubes are spaced on an 11-1/4 inch square lattice. At each end, the vessel is stepped down in diameter to provide an internal corner cutout. The complete calandria is supported at the ends by eight support rods. Facilities to dump the moderator are provided through four rectangular dump ports, which form syphon-shaped ducts connected to the dump tank. These ducts act as water traps, and are located near the bottom of the vessel. A helium balance line, 16 inches in diameter, connects to the top of the vessel through one of two 18-inch diameter pressure relief ducts. Each 18-inch duct has a branch with a rupture disc at its end to act as a pressure-relief, in the unlikely event of an overpressure condition in the calandria shell, resulting from a burst coolant tube and calandria tube.

All the reactivity control mechanisms penetrate the reactor from the top of the calandria. Typical details of the calandria are shown in Figure 4.2-1.

The calandria shell and dump ports are fabricated from austenitic stainless steel type 304L (ASTM A—240). The details of construction and the design stresses are generally in accordance with the requirements of Section III of the ASME Boiler and Pressure Vessel Code for a Class A vessel, although because of its function it is registered as a Class C vessel.

All shell main welds are of the full-penetration type and are subjected to radiographic and/or ultrasonic inspection. The approximate dimensions and metal thickness of the calandria are summarized in Table 4.2-1.

The details of the joint by which the calandria tubes are attached to the tube sheets are shown in Figure 4.2-4. The joint uses a "landed" sleeve insert in compression to give a strong, leak-tight joint with a relatively thin calandria tube.

The calandria tube thickness has been kept to a minimum for the sake of neutron economy, but has a design factor of safety of at least 2.2 against plastic deformation (buckling) due to external pressure, based on a maximum external pressure differential of 22.4 psi which acts on the bottom row of the calandria tubes at the instant of opening the helium balance valves (to initiate dumping).

The step at each end of the calandria provides an annular section of the shell which can deflect to allow for the differential thermal expansion of the Zircaloy-2 calandria tubes and the stainless steel shell of the vessel. The dimensions of the step were selected to achieve the optimum reduction in heavy water in the low-flux regions of the reactor, and to maintain an adequate minimum radial clearance from the calandria tubes at the ends of the calandria shell.

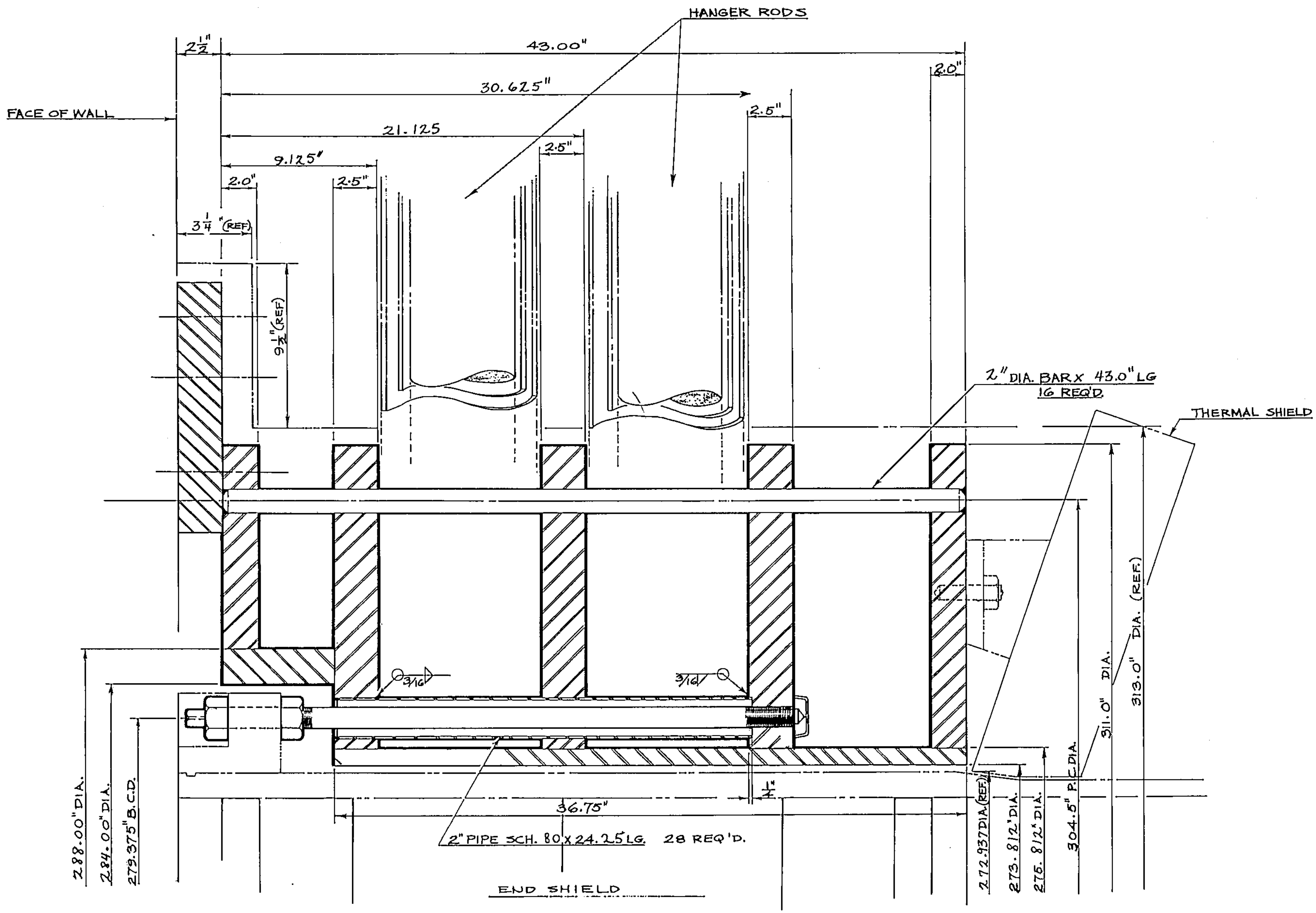
TABLE 4.2-1

DIMENSIONS AND METAL THICKNESS OF CALANDRIA

Outside diameter of shell (nominal)	26 ft 6-1/2 in.
Overall length	27 ft 1 in.
Corner step - reduction in reflector	1 ft 11-3/4 in. radial x 1 ft 7 in. axial
Main shell plate metal thickness	1 in.
Annulus plate metal thickness	1 in.
Calandria tube diameter	5.150 in. I Dia
Dump Ports - at calandria shell	40 in. x 24 in.
Inner Tubesheet thickness	2-3/4 in.
Subshell thickness (where attached to annular plate)	1 in.
Circumferential Plate thickness (over end shields)	2 in.
Outer Tubesheet thickness	2-1/4 in.
Approximate weight (exclusive of fuel and moderator)	665 tons

The arrangement of a discharge or dump port is shown in Figure 4.2-1. The interface between the moderator in the calandria and the helium in the dump tank occurs in the dump ports. The dump ports are rectangular ducts where they fit onto the calandria main shell in its lower quadrants. Before entering the dump tank they change to circular sections to allow for the incorporation of an expansion joint. The circular portion is 30 inches in diameter, while the rectangular portion starts as 24 inch x 40 inch and then contracts to 18 inch x 40 inch before changing to the circular shape.

The two moderator inlet manifolds, which are located on either side of the calandria just below the middle, supply two sets of six upturned nozzles feeding cool moderator into the reflector region between the reactor core and the shell shield slabs. The shape and direction of the nozzles prevent direct impingement of the incoming flow on the calandria tubes. The mixing action of the incoming flows causes the moderator to flow downward between the



4.2—2 ARRANGMENT AND TYPICAL DETAILS OF END SHIELD AND END SHIELD RING calandria tubes resulting in nearly uniform temperatures throughout.

Four moderator outlets are located at the bottom of the calandria.

Both during reactor operation and during shutdown periods the shell shields and all internal exposed metal of the reactor, including pressure relief nozzles, dump ports, calandria tubes, and control rods are subject to heating due to radiation. To prevent overheating of parts not in continuous contact with the moderator, the calandria is fitted with 25 spray nozzle clusters at its top. These provide a drenching spray throughout the entire interior of the calandria. The sprays operate continuously so as to cool continuously any part not covered by moderator at any time.

The spray nozzles are arranged in two systems, each system having its own separate external piping fed from the moderator pumping system. Either system operating alone is designed to provide complete spray coverage. The necessary flow to avoid overheating of D_2O in the annular space between the shell shields and the shell is maintained by convection or by a flow of D_2O via grooves in the back of the upper shield slabs according to the moderator level.

4.2.2 Calandria End Shields

The two end shields are located at either end of the calandria shell and are integral with it. Each end shield consists of four layers of steel slabs, totalling 2 feet 11-1/2 inches in thickness, plus the inner and outer austenitic stainless steel tube sheets, of 5 inch combined thickness, plus two 2-1/2 inch thick layers of cooling water adjacent to the tube sheets. The circumferential plate is of austenitic stainless steel 2 inches thick. The overall diameter of an end shield, including the circumferential plate, is 22 feet 9 inches.

The end shields are penetrated by 390 horizontal passages for reactor fuel channel end fittings and are fitted with austenitic stainless steel lattice tubes which surround, support and guide the end fittings and are welded into the tube sheets at either end.

The end shield assemblies form a part of the calandria vault enclosure and provide shielding to reduce the radiation reaching the fuelling machine vaults to a level which permits occupancy during shutdown. They are an integral part of the calandria structure and the whole weight of fuel, moderator, calandria and end shields is carried by four pairs of support rods, two pairs attached to each end shield. Each end shield assembly is located centrally within an end shield ring which is grouted into the calandria vault wall. A nominal clearance of 7/16 inch exists between the end shield and the end shield ring. Figures 4.2-1 and 4.2-2 illustrate the general arrangement and typical details of an end shield and an end shield ring.

Each end shield assembly contains ten slabs of steel, making a core 22 feet 5 inches in diameter and 2 feet 11-1/2 inches thick. The material used for the slabs is carbon steel in general conformance with ASTM A—201, Grade A, firebox quality or ASTM A—243 Class C for forgings. Two upper 12 inch semi-circular sections are each in one piece and carry the weight of the calandria end shield assembly to the support rods. The various shielding slabs are sandwiched together without welding, and are held together as an assembly by keys and bolts. The circumferential plates are shrunk onto the machined shielding slabs and welded to the tube sheets. The circumferential plates are 2 inches thick and, like the tube sheets and lattice tubes, are type 304L austenitic stainless steel. The inner tube sheet is 2-3/4 inches thick and the outer tube sheet is 2-1/4 inches thick. The 390 holes in the end shield slabs around the stepped lattice tubes are 8-9/16 inches in diameter toward the inner end and 9-3/16 inches in diameter toward the outer end and provide 3/8 inch wide annular cooling passages which interconnect the water spaces at either end. Baffles within each water space provide a six-channel multipass cooling flow arrangement with cooling water entering at six points at the bottom of the shield and leaving at the top. The cooling passages are generously sized to preclude the possibility of internal fouling. The end shield assemblies are weldments, weighing approximately 245 tons apiece. They are Class C vessels constructed generally to the standards of Class A, Section III of the ASME Boiler and Pressure Vessel code. The shields operate at a pressure of 24 psig.

The operating temperature of the steel in the end shields is approximately 160°F.

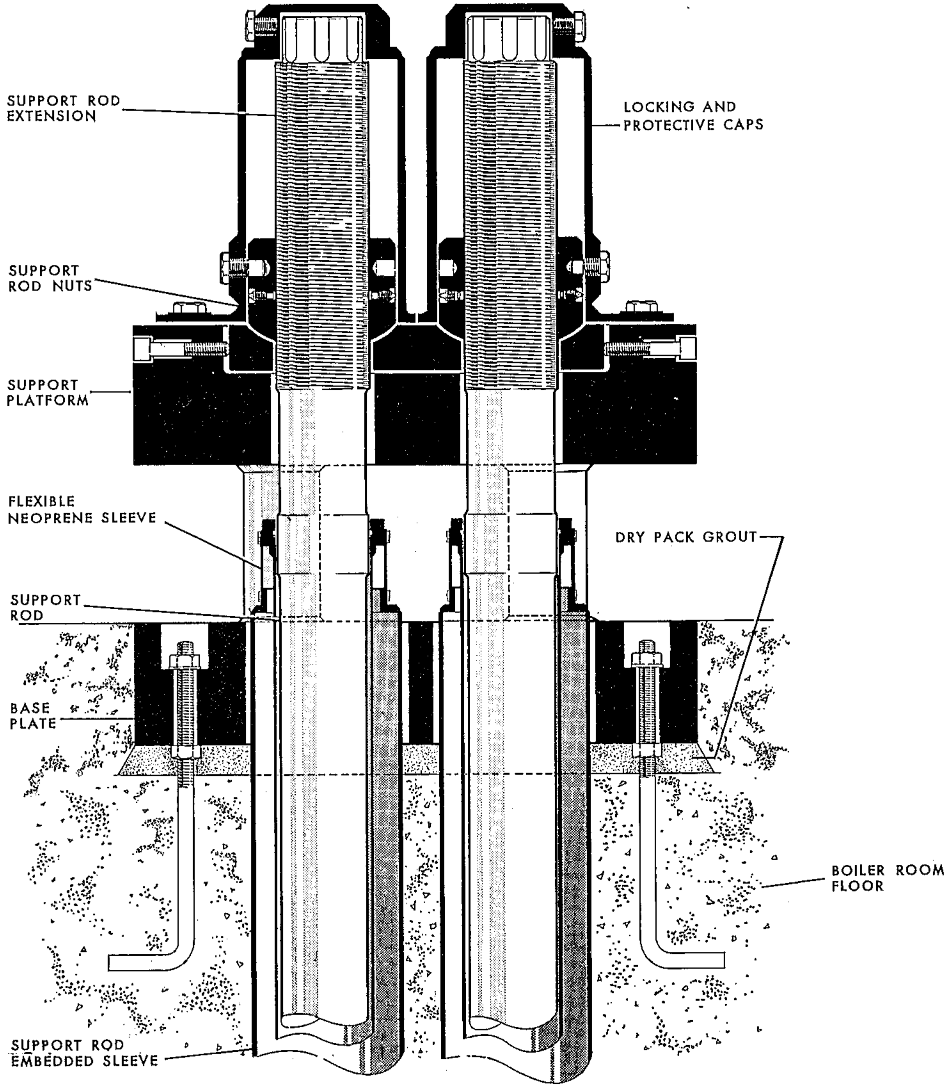
The nuclear heat generated in the slabs is removed by a closed water circuit which also removes heat from the end fittings and tube sheets. Approximately 1600 kW of heat appears at each end shield.

The design temperature of the water entering the end shields is 150°F and the outlet temperature is 157°F. The velocity and flow have been selected to keep temperature differences throughout the end shields small. External adjustments of the individual inlet coolant flows provide for proper distribution of the coolant within the end shields.

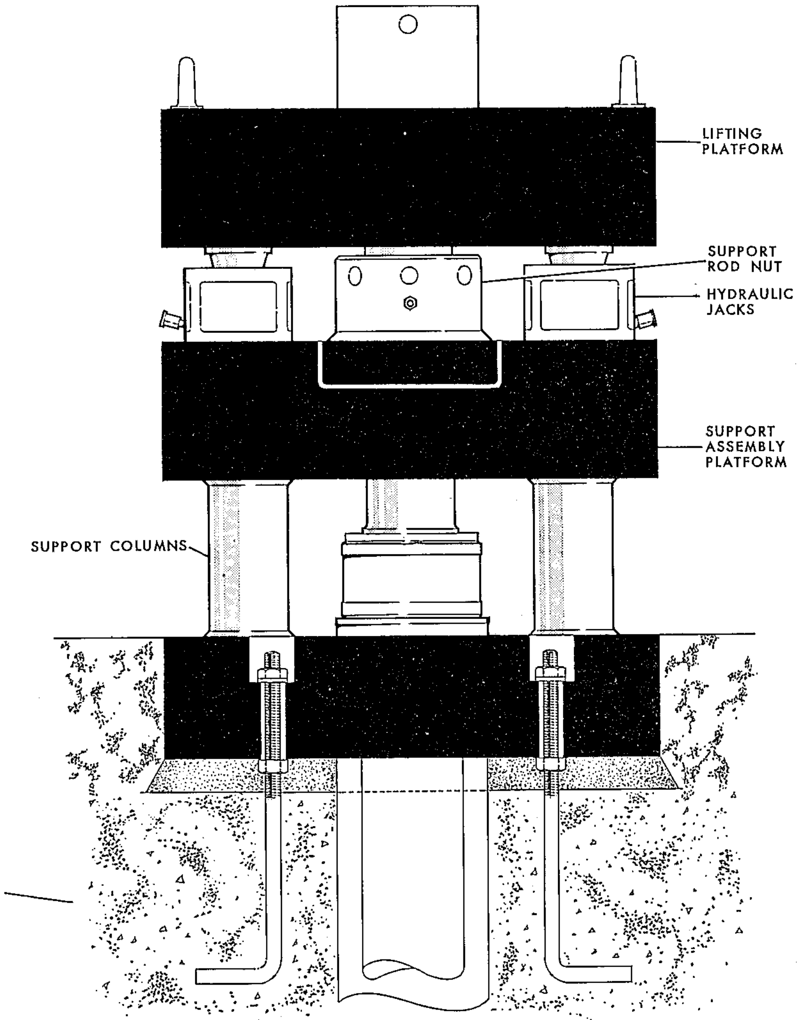
4.2.3 Calandria Support and Alignment

The calandria with its integral end shields, which are located at the two ends of the calandria, is supported by four pairs of 5-5/8 inch diameter by 28-1/2 feet long carbon steel rods, screwed into carbon steel inserts, which in turn are screwed into the upper halves of the central slabs of the end shields. Keys between the slabs transfer the load to the two supported slabs in each end shield assembly.

Since the calandria shell and end shields form an integral assembly, alignment between the calandria end shields is not a problem. Because the support rods are normally quite cool, water cooling is not necessary, and relative movement



ARRANGEMENT OF CALANDRIA SUPPORT ASSEMBLIES



ASSEMBLY OF LIFTING PLATFORM TO SUPPORT RODS FOR VERTICAL ADJUSTMENT OF CALANDRIA POSITION.

4.2—3

between the end shields and end shield rings will be small.

The support rods are designed so that the stress level results in a small (approximately 0.020 inch) vertical movement of the calandria between its full and dumped condition.

The rods are supported from assemblies located on top of the calandria vault structure. Vertical positioning of the calandria is achieved by unseating the support rod nuts and adjusting them to the required setting. The unseating operation is performed by assembling a lifting platform to the rod extensions and actuating hydraulic jacks positioned between this platform and the support assembly platform. Details are shown in Figure 4.2-3.

Tie rods and keys between the end shield ring and the end shields align and restrain movement of the whole calandria. The rods at the east end restrain axial movement, so that the calandria is free to expand axially at the west end. Keys at the top and bottom restrain lateral movement of the calandria at both ends, but allow radial expansion.

4.2.4 End Shield Rings

The two carbon steel end shield rings are grouted into circular openings in the calandria vault walls. Each ring comprises a cylindrical shell, on the outside of which five annular flanges are spaced and welded circumferentially. The addition of stiffener bars attached to each flange provides a rigid structure.

The end shield rings serve three main purposes. They provide (a) increased radiation shielding in high flux regions, (b) structures to which the end shields are keyed, thus restraining the calandria assembly in the required position, and (c) accurate openings to contain the end shields and accommodate radial and axial expansion of the calandria.

Provision is made to prevent neutron streaming through the annular gap between the end shields and rings. Piping is installed within the ring structures to remove heat generated by the immergent heat current, caused by radiation from the calandria and heat transmitted from the end shields, end fittings and feeder pipes.

The pressures in the two fuelling machine vaults may differ by a maximum value of 3.6 psi at the time of a major loss-of-coolant accident, which will subject the calandria end shield assembly to a substantial axial load in either direction. Axial movement of the assembly relative to the end shield rings is restrained by tie rods, which secure the east end shield to its corresponding ring. Additional keys also restrain any horizontal side movements of the end shields within the rings while still permitting them to move vertically at both ends.

4.2.5 End Shield Ring Thermal Shield

The arrangement of the calandria shell shield would not prevent the end shield ring and adjoining concrete from being subjected to excessive heat flux of up to 800 mW/cm^2 intensity. Since ilmenite concrete with one row of cooling pipes can tolerate only a maximum heat flux of 45 mW/cm^2 a thermal shield is provided to attenuate this flux.

The ring thermal shields consist of 2-1/2% and 3-1/2% nickel steel water cooled structures with internal cooling channels. These structures are situated in the space between the calandria and the vault end walls. To facilitate manufacture, each thermal shield is assembled from eight flat sided segments, tilted towards the calandria and supported from the end shield rings.

The heat flux is attenuated to less than 80 mW/cm^2 at the end shield ring. This heat is removed by the cooling pipes embedded in the end shield ring.

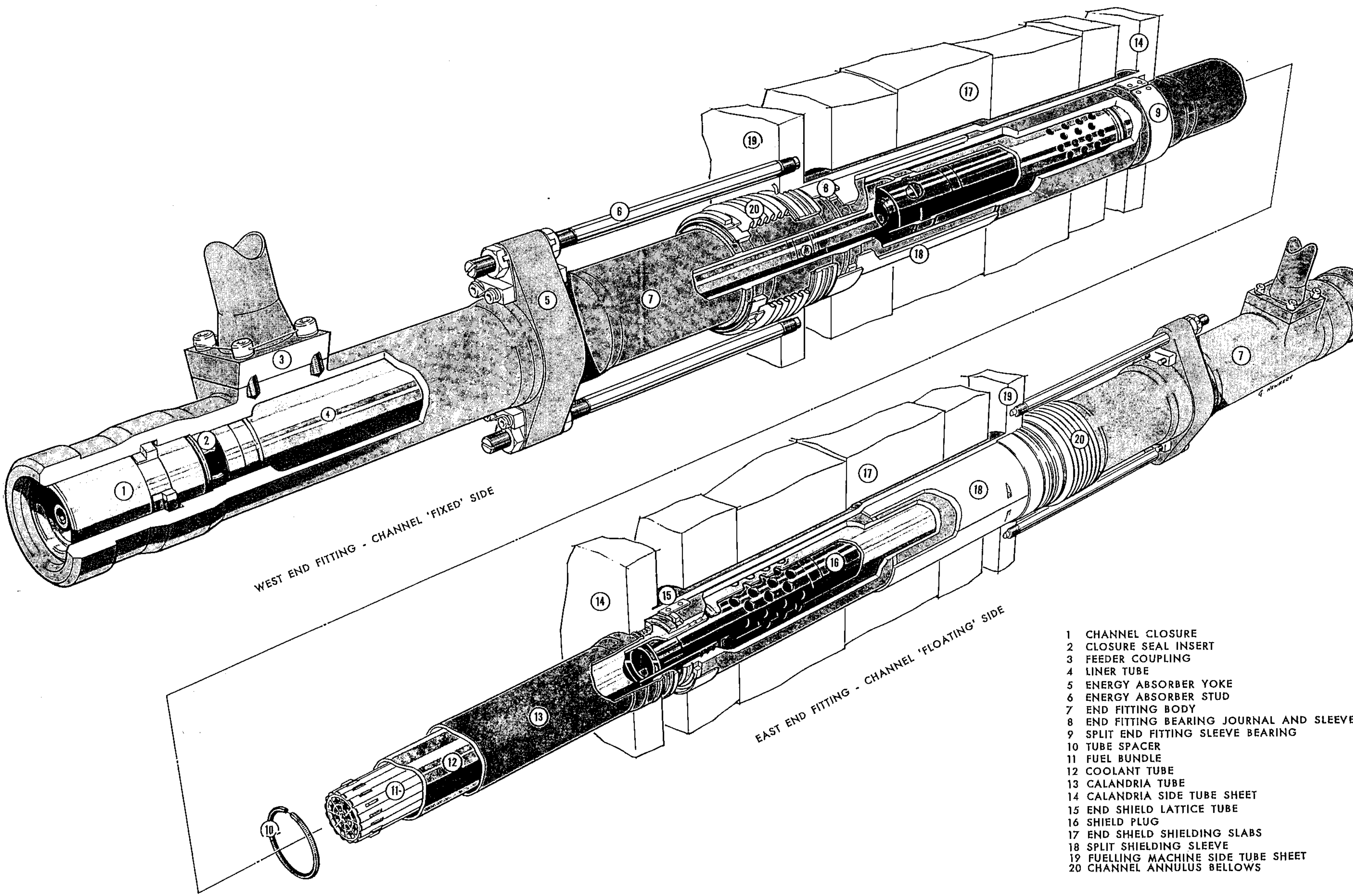
4.2.6 Dump Tank

The dump tank, shown in Figure 4.2-1, is a horizontal cylindrical austenitic stainless steel vessel with dished heads. It is 38 feet 4 inches long and 18 feet 3 inches in diameter. The wall thickness of the cylindrical tank body is 5/8 inch while that of the dished heads is 7/8 inch. It is located in the calandria vault directly below the calandria and its longitudinal axis is at 90° to that of the calandria. It is connected to the calandria by four dump ports attached to its upper two quadrants, at either end of the tank, through expansion joints. The expansion joints allow for vertical and lateral movement of the calandria relative to the dump tank.

The capacity of the dump tank was determined by a consideration of the results of a failure of the primary system such that one half of the primary coolant would be added to the heavy water in the moderator system. This situation could arise, for example, through discharge of the primary coolant inside the calandria. The capacity of the dump tank and the connecting dump ports is sufficiently large that the level of the moderator in a dumped calandria would be just below the minimum level for criticality, even with the addition of one-half of the primary coolant to the moderator system.

The minimum moderator level for criticality is estimated to be less than 200 cms below calandria mid elevation for the absence of xenon load, cool primary coolant, most reactive and cool fuel, cool clean moderator, no adjuster rod load, and none of the shut-off rods in the core. A review of the condition relating to this is given in Appendix 1 to this report. Actual component volumes are given in Table 4.1-2.

The wall thickness selected was based on structural considerations, since factors of shielding areas adjacent to the dump tank are not significant. The dump tank normally operates nearly empty of liquid and contains helium at a pressure of approximately 25 psia. It has been designed in accordance with the rules for construction as laid down in Section III of the ASME Boiler and Pressure Vessel Code,



4.2–4 COOLANT ASSEMBLY FITTING MOUNTED IN END SHIELD

44.31100–4
REV. 1, 1968

and by these rules is a Class C vessel.

Protection against overpressure of the tank is provided by pressure relief valves located outside the vault on helium piping connected to the tank.

The dump tank is supported from the floor by four flexible legs to accommodate thermal movements. The calandria is fixed at the east end, and in order to minimize relative movement between the calandria and the dump tank, the two legs on the east side will only deflect axially. The other two legs are free to deflect in any direction.

The dump tank has connections for the supply of spray cooling, with duplicated feed pipes, and for transfer of heavy water and helium to the moderator circuit and helium system. A sump located at one end of the tank, at the bottom, ends in the D_2O drain connection. This sump allows for the necessary rate of water removal from the tank without helium entrainment during pump-up. A sleeve passes horizontally through the dump tank and parallel to the reactor coolant channels. It serves as a rehearsal facility for testing out the fuelling machine without using a reactor fuel channel. The helium balance connection is a 16 inch diameter pipe welded to the top of the tank.

4.2.7 Coolant Assemblies

The primary function of the 390 coolant assemblies is to house the reactor fuel and to direct the flow of primary coolant past it to remove the nuclear heat. Each coolant assembly consists of a zirconium alloy coolant tube to which is attached at each end a ferritic stainless steel end fitting. The zirconium alloy coolant tube provides a low neutron capture containment structure for the primary coolant within the reactor core, while the end fittings provide entry and exit connections both to the primary system and to the reactor fuelling system. A sectional view of the coolant assembly, mounted in an end shield, is shown in Figure 4.2-4.

The coolant tubes have the following parameters:

	Unit 1 & 2	Unit 3 & 4
Internal diameter (minimum)	4.07 in	4.07 in
Minimum wall thickness	0.1965 in.	0.160 in.*
Length, approx. (trimmed for installation)	20 ft 8 in.	20 ft 8 in.
Material	Cold drawn Zircaloy-2 autoclaved at 750°F	Zirconium 2.5% Niobium cold drawn, stress relieved at 750°F

** The minimum wall thickness allowed in approximately 100 low flow channels is 0.155 inch.*

Zirconium 2-1/2% Niobium is preferable to Zircaloy for coolant tubes because of higher strength and superior creep properties even at higher stresses. It is not used for Units 1 and 2 because there was insufficient manufacturing experience and inadequate data on corrosion properties at the time the order was placed for the tube material.

Although the coolant tubes do not come under the Nuclear Vessel Code Section III, they will be designed to meet conditions equivalent to a Section III Class A vessel.

The design stress for the Zircaloy-2 coolant tube material for Units 1 and 2 is the same as that approved by the Department of Labour for Douglas Point, as shown in Figure 4.2-5. The particular design point on this curve which sets the pressure tube thickness is based on an analysis of pressure and temperature along the length of the pressure tube for the most severe operating conditions. The design point occurs at about 0.8 of the tube length from the inlet end. The particular design conditions at this point are 16,110 psi at 562°F.

The design stress for cold worked Zirconium 2-1/2% Niobium for Units 3 and 4 has been conservatively selected at 20,000 psi based on in-flux creep data.

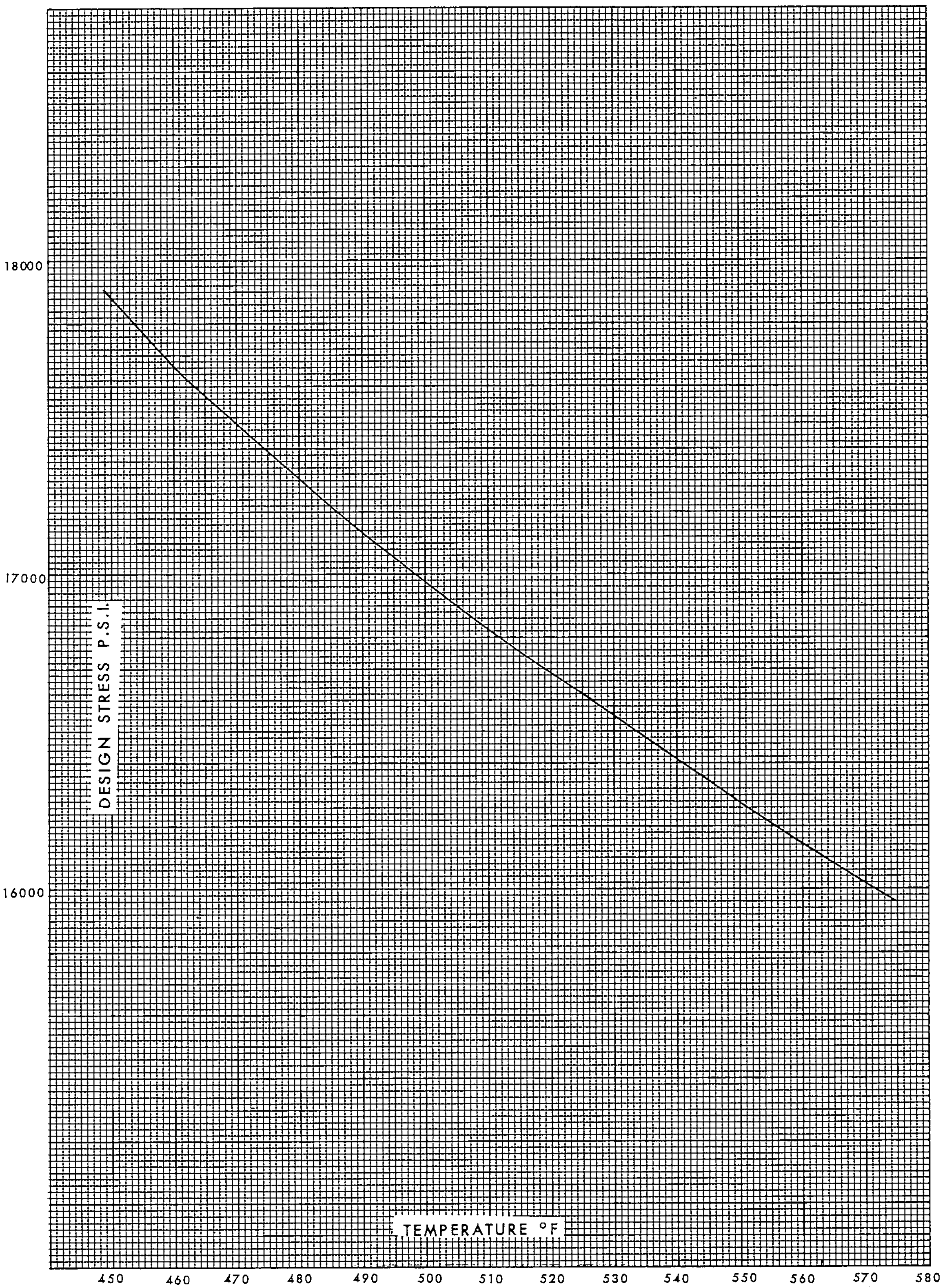
Test Temperature 572°F	Zircaloy—2	C.W. Zr:Nb
Ultimate tensile strength Specified minimum	48,000 psi	63,000 psi
0.2% Yield Strength Specified minimum	39,000 psi	47,000 psi
Permissible design stress	16,000 psi	21,000 psi

The inlet and outlet end fittings are identical and are fabricated from ferritic type 410 stainless steel extrusions which conform generally to ASTM A-336 Grade F6. The material is further limited in the silicon content to meet the more restrictive requirements of Type 403 material, and minimum hardness and impact properties are specified. The fittings are approximately 6-1/2 inches external diameter by 8 feet 4 inches long. The coolant tubes are rolled into the end fittings with a three groove joint. Development tests have demonstrated that this joint has a pullout strength at operating temperature and pressure which exceeds the minimum ultimate strength of the Zircaloy-2 coolant tubes. The tests have also shown such joints to be leak tight after repeated thermal and mechanical loading cycles involving the pressure and the bending stresses pertinent to the application.

The end fittings are designed to provide the following:

(a) Transition joints between the coolant tubes and the primary circuit piping.

(b) Support for the Coolant tubes and their contents.



4.2—5 DESIGN STRESS FOR ZIRCALOY-2
(TAKEN FROM DOUGLAS POINT)

44-31110-1

(c) Suitable configuration to make a pressure tight connection with the fuelling machines and to allow insertion and removal of fuel during operation of the primary coolant system.

(d) Shielding for the penetrations through the reactor end shield to permit access to the fuelling machine vaults and the face of the end shields, at shutdown, for servicing.

(e) Sealing for the annulus between the coolant and calandria tubes to maintain a protective atmosphere within.

The features of the end fittings which satisfy the above requirements can be seen in Figure 4.2-4. A feeder connection flange on each end fitting provides for attachment to a primary coolant feeder pipe with a metal gasket. This joint is accessible for remaking from the fuelling machine area, if required. Internally, the end fittings contain a liner tube extending from near the outboard end to a point adjacent to, but not in contact with, the end of the coolant tube. The liner tube forms the inner wall of an annular coolant channel joined to the feeder connection. Radial holes in the liner tube permit the coolant to enter or leave the coolant channel beyond the end of the string of fuel.

A stop prevents the end fitting from blowing out of the lattice in the event of a tube fracture or failure of the expanded joint.

Annulus sealing is provided by an Inconel bellows attached to the end fitting and to the end shield tube sheet. The bellows also resists rotation of the end fitting by feeder pipe moments, and thereby keeps torsional stresses in the coolant tubes very low.

A type 410 stainless steel shield plug 39 inches long resides in the liner tube. It is located axially by retractable jaws which seat in a groove in the liner tube. The forward or inner end of the shield plug, which overlaps the coolant entry or exit radial holes in the liner tube, contains a fuel support plate. The flow through the channels furthest from the reactor centre is trimmed by using smaller diameter feeders.

A removable channel closure is located at the outboard end of each end fitting. These closures are held in place by retractable jaws. The closure is fitted with a seal disc which provides containment of the primary system coolant. The design and support of the seal disc is such that the primary system pressure increases the unit loading at the seal surface, thus improving the seal. The sealing contact is soft nickel plate on the face of the seal disc, bearing against a replaceable hardened seat of custom 455 stainless steel in the end fitting.

The end fitting bodies are mounted in the lattice tubes of the end shields. The passage between each end fitting and the lattice tube is stepped to prevent radiation streaming. Each end fitting is supported at the inner and outer end of the end shield lattice tube on a non-lubricated metal to metal bearing. These bearings provide alignment and positioning for the end fitting and permit end movement. All coolant assemblies are held stationary with respect to the end shield by adjustable positioners at the "fixed" (west) end. The positioners can withstand the axial thrust of a blown seal plug or a ruptured coolant tube. At the east or "floating" end, energy absorbers are designed to catch and hold the end fitting in the end shield in the event of a failure of the coolant tube, its expanded joint, or an end fitting.

4.3 REACTOR ENCLOSURE

4.3.1 Calandria Vault

The calandria vault, as shown in Figure 4.3-1, is of rectangular shape with inside dimensions of 19 feet 6 inches wide, 35 feet 2 inches long and 54 feet 10 inches high. It provides an enclosure, the radiation shielding and support for the calandria vessel and dump tank. The entire structure is of heavy concrete (north and south walls 4 feet 6 inches thick, east and west walls 3 feet 9-1/2 inches thick, and roof 10 feet 6 inches thick) with a nominal density of 210 lbs/ft^3 using an ilmenite ore aggregate. In order to allow independent vertical movement (from thermal expansion and shrinkage) the vault is built completely separate from all adjacent structures. Contact with the surrounding ordinary structural concrete is limited to points at the edge of the boiler room floor. These contact areas are located at the top corners of the vault and provide lateral support in the east-west direction (19 feet 6 inch dimension) during unbalanced emergency pressure loading and earthquake conditions.

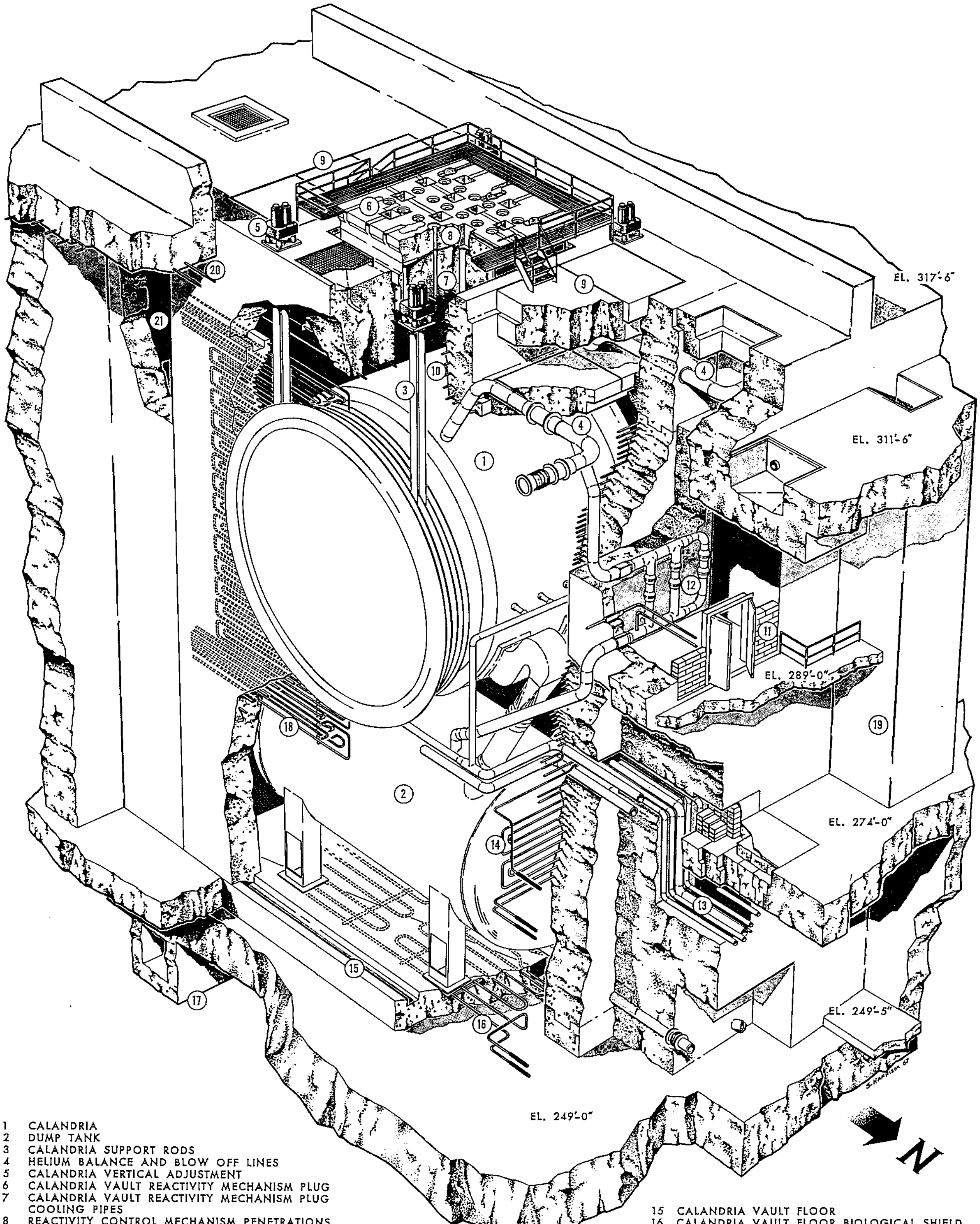
Embedded into the east and west walls of the vault, i.e. between the reactor and the east and west fuelling machine vaults, are the end shield rings which receive and locate the end shields.

Two 18 inch calandria overpressure blowoff lines pass through carbon steel sleeves embedded into the north wall of the vault and leading into the top of a vertical pipe shaft. One line then leads to the upper north-east corner of the west fuelling machine vault and the other to the upper north-west corner of the east fuelling machine vault. Sealing and locking of the embedded sleeves into the heavy concrete is achieved by using suitably positioned steel flanges seal welded to the sleeve outside diameter and embedded into the concrete to form a labyrinth type seal, backed up with an epoxy grout filled pocket placed between the concrete and the sleeve. Access to the vertical shaft is via a hatch beam at the boiler room floor level.

Sealing of the annular space between the embedded sleeve inside diameter and the blowoff pipe outside diameter is with a metal bellows seal suitably welded into place.

Adjacent to the north wall of the vault is an ordinary structural concrete wall 11 feet 9-1/2 inches thick into which is cast:

(1) A valve chest (floor elevation 289 feet 6 inches) to contain the helium balance valves;



1 CALANDRIA
2 DUMP TANK
3 CALANDRIA SUPPORT RODS
4 HELIUM BALANCE AND BLOW OFF LINES
5 CALANDRIA VERTICAL ADJUSTMENT
6 CALANDRIA VAULT REACTIVITY MECHANISM PLUG
7 CALANDRIA VAULT REACTIVITY MECHANISM PLUG COOLING PIPES
8 REACTIVITY CONTROL MECHANISM PENETRATIONS
9 CALANDRIA VAULT HATCHES
10 CALANDRIA VAULT ROOF BIOLOGICAL SHIELD COOLING
11 HEAVY CONCRETE BLOCK WALL
12 HELIUM VALVE CHAMBER
13 CALANDRIA VAULT PIPING
14 NORTH WALL BIOLOGICAL SHIELD COOLING
15 CALANDRIA VAULT FLOOR
16 CALANDRIA VAULT FLOOR BIOLOGICAL SHIELD COOLING
17 SPENT FUEL TRANSFER DUCT
18 EAST WALL BIOLOGICAL SHIELD COOLING
19 PIPE CHASE
20 FUELLING MACHINE VAULT COOLING
21 CALANDRIA VAULT BOILER ROOM INTER SPACE

4.3-1 CALANDRIA VAULT

44.21300-5
1967

(2) a pipe labyrinth (floor elevation 262 feet 8 inches) at outside face and rising to elevation 272 feet 2-1/2 inches at inside face of vault; and

(3) a vertical pipe shaft joining boiler room floor (elevation 317 feet 6 inches) to the moderator room floor (elevation 249 feet).

A 16 inch diameter helium pipe from the top of the dump tank passes through an embedded sleeve in the north heavy concrete wall of the calandria vault into the vertical pipe shaft, thence through a sleeve embedded in the ordinary concrete wall and into the helium valve chest where it is welded into the helium balance valve assembly. Again, the vault atmosphere is contained by a metal bellows seal welded between the 16 inch pipe and the sleeve embedded and sealed into the heavy concrete wall. In order to complete the helium balance line circuit, a 16 inch pipe is connected between the helium balance valves and that portion of the east side blowoff line passing through the vertical pipe shaft. Connecting the helium line to the blowoff line avoids the necessity of having an extra penetration and seal to the vault.

Except for the dump tank drain, other piping, such as moderator circuits, spray lines and drain lines, passes from the vault to the moderator room via the pipe labyrinth; all pipes are suitably sealed with metal bellows and organic seals in order to contain the vault atmosphere. The dump tank drain passes through an embedded sleeve at the bottom of the north wall. Shielding of all penetrations into the north wall of the vault is provided by a minimum of 4 feet 6 inches of ordinary concrete.

To allow component access into the vault the entire bottom half of the vault south wall is temporarily omitted, giving a clear entry of 19 feet 6 inches wide by 31 feet 10 inches high during construction. This opening is closed by poured "in situ" shielding which consists of unreinforced heavy concrete blocks. Ion chambers to sense reactor flux are positioned in a suitable manner through this shielding.

Above the shielding and embedded into the south wall is a blow-in-blow-out panel having an area of 12-1/4 ft^2, which connects the calandria vault interior with the boiler room. This panel is designed in such a way that in the event of any loss-of-coolant accident in the Reactor Building the vault external pressure differential is limited to 1/2 psi. This panel also limits the vault internal pressure differential to the design figure of 1/2 psi in the event of an accidental Vacuum Building connection to the Reactor Building.

The calandria vault roof incorporates two steel lined hatches and hatch beams. The outermost hatch beams provide emergency access to the vault.

The reactivity mechanisms are supported by and pass through a heavy concrete and steel plug located at the centre of the vault roof. The bottom of this plug is cooled by a network of pipe coils in the same manner as the rest of the calandria vault internal surfaces. The top and bottom of this plug consists of steel plate, which permits accurate positioning of the plug, and consequently, the reactivity mechanisms.

4.3.2 Biological Shield Cooling System

The calandria vault concrete walls, floor and roof, including the hatch beams, the heavy concrete and steel plug and the fuelling machine vault wall and ceiling behind and above the feeder insulation cabinet, are cooled by a network of 1-1/4 inch schedule 80 pipe coils. Such cooling is necessary to limit the maximum concrete temperature to 130°F and to minimize thermal movement of the vault concrete.

The pipe location from the inner faces of the vaults and the spacing are such as to provide the heat dissipation required. Pipes in the walls and ceiling are run in a parallel pair arrangement wherever possible so as to minimize the consequences of a possible flow stoppage in one pipe circuit. Also vertical loops which might tend to produce air pockets and consequent hot spots are avoided.

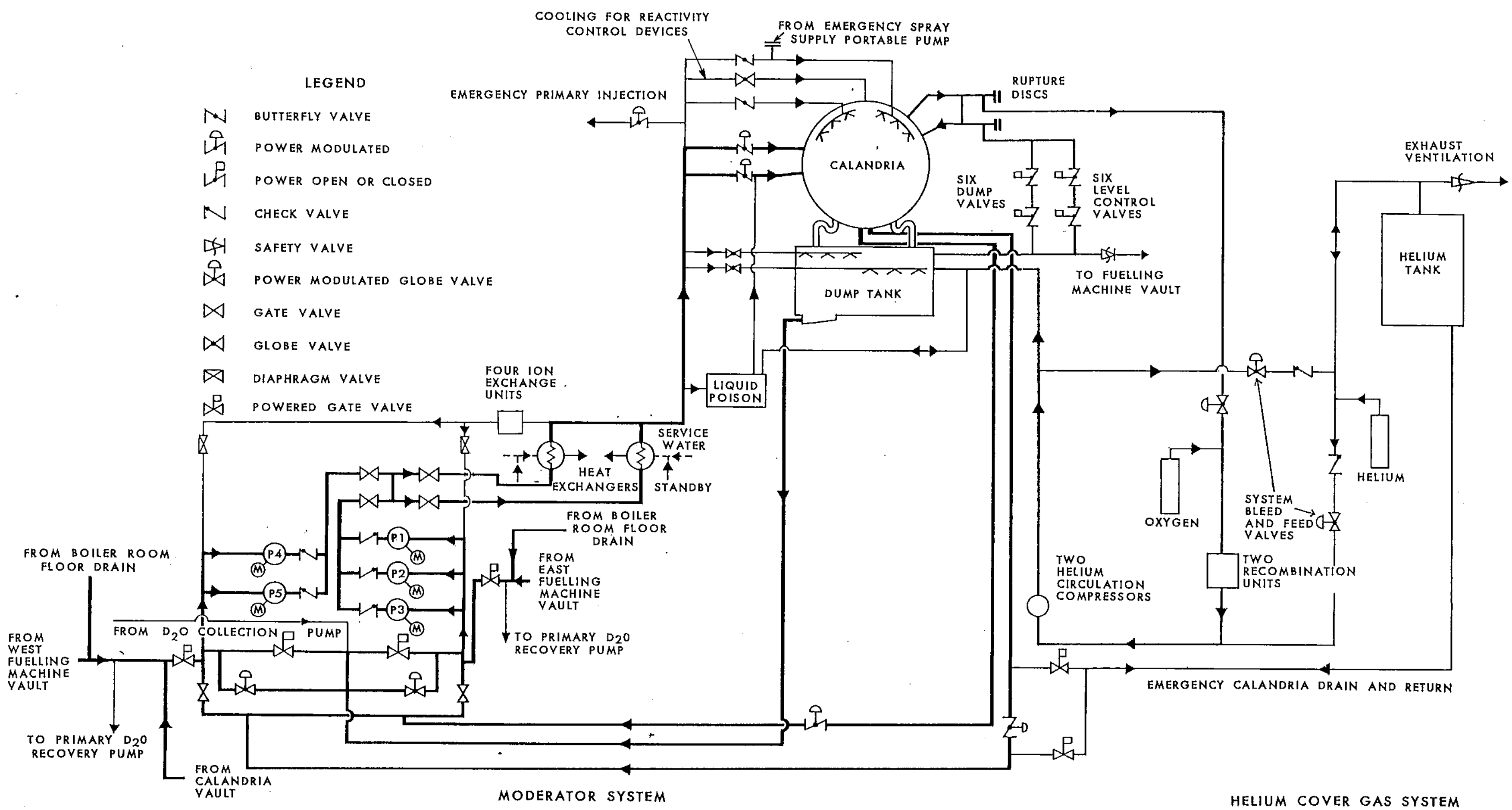
The cooling water inlet and outlet temperatures will be approximately 85°F and 91°F respectively, and the flow velocity will be approximately 1 foot/second.

4.3.3 Fuelling Machine Vault Vapour Barrier

The fuelling machine vault floor, walls and ceilings, other than areas occupied by the blowout panels, the end shields, and that area above and behind the feeder insulation cabinet, are covered with an epoxy coating system to prevent vapour and atmosphere transfer from or to the vault. Special care is taken with penetrations to ensure a leak-tight vault. The concrete surfaces of the fuelling machine service rooms, below each fuelling machine vault, are also covered with an epoxy coating system. The fuelling machine vault wall and ceiling above and behind the feeder insulation cabinet is lined with carbon steel sheet. At the ceiling the liner is fastened to the concrete by embedded strap anchors. At the wall, the liner is fastened to the concrete with a flexible support stud system and is welded to the end shield via a stainless steel transition ring. The outer periphery of the wall is joined back to the ceiling liner and to the concrete wall by means of a flexible seal. The flexible stud system and flexible seal referred to above will permit relative movement of the liner resulting from temperature changes and movement of the calandria. The flexible seal will be located in a relatively accessible position.

4.3.4 Feeder and Header Insulation Cabinet

The reactor headers, feeder pipes and all but the outer ends of the reactor end fittings are enclosed in an insulated cabinet which is hung from inserts located in the ceiling of each fuelling machine vault. All openings and penetrations of the cabinet are sealed. Pressure relief panels are provided to cater for internal or external pressure rises due to steam leaks, etc., and will equalize the cabinet internal and



4.4—1 MODERATOR AND HELIUM COVER GAS SYSTEMS SCHEMATIC

44.32000—3
REV. 4, 1968

external pressure.

The cabinet consists of a structural aluminum framework which is covered with aluminum panels. The panels are removable to provide access for any required inspection or maintenance of feeder piping. Both the frame and panel inside surfaces are insulated with glass fibre so as to minimize (a) the heat loss from the headers and feeders, (b) the heat load on the fuelling machine vault cooling system, and (c) the thermal stresses set up in the framework and panels.

4.4 MODERATOR AND COVER GAS SYSTEM

4.4.1 Requirements of the System

During full power operation of the reactor there is an input of approximately 92 megawatts of heat energy to the moderator. Some of this is formed within the moderator and containing structure and some comes from the coolant channels. In addition, impurities are formed in the moderator and some dissociation of the D_2O takes place due to the high radiation field.

The moderator system serves to cool and condition the heavy water moderator and to control its level in the calandria. The system also supplies cooling flows to the calandria and dump tank sprays. Heavy water in the system can be used under emergency conditions as a supply for other systems.

Forming an integral part of the moderator system is a cover gas system which uses helium to provide an inert atmosphere over the liquid in the vessels, to act as a purge gas, and to provide support pressure for the moderator in the calandria.

The moderator and cover gas systems are designed to perform the following functions:

(i) Control of level of moderator in the calandria.

(ii) Rapid gravity dump of moderator into the dump tank.

(iii) Circulation and cooling of the moderator.

(iv) Supply of heavy water to cooling circuits for the interior of the calandria and attached piping, discharge ports, the dump tank, and some reactivity controlling mechanisms.

(v) Recombination of dissociated D_2 and O_2 caused by irradiation of the moderator.

(vi) Addition of liquid poison to the moderator.

(vii) Purification of moderator through ion exchange beds.

(viii) Emergency transfer of heavy water to the primary heat transport system. In addition, leakage collection and sampling of moderator water is provided.

4.4.2 Description of the System and Its Operation

4.4.2.1 General

The moderator and cover gas system consists of a number of interrelated sub-systems. These are:

(i) Moderator circulation and heat removal circuit.

(ii) Associated spray cooling systems.

(iii) Helium circuit.

(iv) Liquid poison system.

(v) Moderator purification system.

(vi) Emergency transfer system.

(vii) Leakage collection and D_2O recovery.

The first three of the above are so closely interrelated that, although the systems are described separately in the following sections, their operation is treated together.

Equipment for the moderator and related systems is located in the north area mainly at grade level. Major items in the moderator circulation circuit are located immediately adjacent to the calandria vault in the central part of the area. The moderator ion exchange beds are located east of the main equipment.

A simplified flow sheet for the system is shown in Figure 4.4-1.

With few exceptions, the tanks, equipment valves and piping in the moderator and cover gas system are made of austenitic stainless steel. All piping in the system conforms to the ASA Code for Pressure Piping. Modulating control valves at the suction and discharge side of the system pumps are stainless steel butterfly valves, with manual gate valves used for isolation. These valves have double stem packing with interspace bleed-off. Rubber diaphragm type valves with stainless steel bodies are generally used throughout the system.

Power operated valves in the system use air-driven diaphragm or piston operators, and the dump valves use air cylinders. For each valve a choice of "fail-to-open" position or vice versa, Class III or IV power, duplication of pilot solenoids, etc. is considered. Valves which have air supplied to their operators under normal conditions are fitted with dual air pilots. The connections are such that if the solenoid coil on either pilot valve should burn out, the valve would still operate properly from the other pilot. All valves may be serviced without stopping spray flow. Freeze plugs are used to isolate valves where other means are not available. Permanent drain connections to the D_2O collection system are provided to drain either half of the pump inlet loop after isolation valves are shut.

4.4.2.2 Moderator Circulation and Heat Removal Circuit

The main moderator circulation system consists of five pumps, two heat exchangers, and necessary valves and piping. It is shown by heavy lines in Figure 4.4-1. The dual outlets from the calandria feed a horizontal horseshoe-shaped pump suction header. A single outlet from the dump tank is also connected to the pump suction header. Cooled heavy water is fed by dual lines to the main calandria inlet.

The five circulation pumps are vertically-mounted centrifugal pumps, each having a rated flow of 3000 Igpm at a developed head of approximately 105 psi. All parts of the pumps which contact the heavy water are stainless steel. The pumps have rotating shaft seals backed up by an interseal cavity with drain-off, and a labyrinth bushing. The driving motors are 250 hp, 4000 volt, 3-phase motors directly connected to the pump impeller shaft. All five pump motors are connected to the Class III electrical power system. Three pumps will operate in the event of loss of Class IV power. In the period between loss of Class IV power and starting of the standby combustion engines which supply Class III power, the moderator pumps would stop circulating the moderator. The reactor would trip on loss of Class IV power and be shut down by insertion of the shutoff rods. The moderator would remain in the calandria and would prevent the structure becoming overheated. If the moderator was dumped for some reason, the temperature of the calandria structure would begin to rise. Providing the combustion engines start within a few minutes no damage to the calandria would result.

There is a check valve in the outlet lines from each pump to prevent back flow through a stopped pump. The east and west bank of pumps, on separate headers, may be isolated for servicing with manual gate valves located at the inlet and outlet of the headers.

The two heat exchangers are horizontally mounted U-tube heat exchangers, manufactured and tested in accordance with Section III Class C of the Nuclear Vessel Code. The moderator passes through 1/2 inch O. Dia by 0.058 inch wall tubes made of 70% Cu: 30% Ni. The heat exchangers are cooled by process water. In the event of loss of normal process water supply, an emergency process water pump may be started which would provide sufficient process water to cool the moderator with the reactor shut down (i.e. approximately 5 percent of normal flow).

4.4.2.3 Associated Cooling Systems

Cooling water for the various spray and other cooling circuits associated with the calandria and dump tank is supplied from the outlet side of the heat exchangers in the moderator main circuit. Duplicate cooling systems are provided. The arrangement is shown in Figure 4.4-1. The cooling systems include sprays for the dump tank, the calandria and attached piping, and the dump ports.

4.4.2.4 Helium Circuit

4.4.2.4.1 General

The helium circuit consists of two helium compressors together with a circulating and purge system, recombination units and a large storage tank. The helium system includes the piping and valving used for maintaining, controlling, and removing the helium pressure differential which supports the moderator in the calandria. The circuit is shown in Figure 4.4-1.

The helium compressors draw a purging flow of helium at approximately atmospheric pressure from the top of the calandria, through a recombination unit, and compress it to approximately 25 psia. The compressed helium enters the dump tank through connections to each of the four external dump ports which connect the calandria to the dump tank. During normal operation when the moderator is in the calandria, the helium provides a purging flow through the dump tank and leaves by way of the 16 inch diameter helium balance line. A return path to the top of the calandria is provided through control valves which bypass the multiple sets of 12 inch helium dump valves in the helium balance line. The helium enters the top of the calandria through one of two 18 inch helium balance lines, circulates as a purging flow above the moderator or is bypassed to the other helium balance line if the calandria is completely full, and is then drawn off by the helium compressors through a connection to the latter helium balance line.

The 12 inch dump valves are bypassed by a set of four 4 inch and two 1 inch diameter control valves. During the early stages of pump-up, all six moderator level regulating valves are closed. At some calandria level above 70%, the two 1-inch valves will be opened in order to permit fine control of the D_2O level in the calandria. These valves are controlled by the reactor regulating system (DCC).

The purpose of the purging flow is to remove dissociated D_2 and O_2, which result from irradiation of the D_2O, from the system at a rate to maintain the D_2 concentration at a safe level. A purge flow of helium of 50 cfm is believed to be adequate. The recombination unit (two 100% units on alternate duty), through which the purging flow passes, recombines the purged D_2 and O_2 gases to form D_2O. The recombiners are catalytic units containing 1/8 inch diameter pellets of palladium-alumina compressed powder. These units along with the helium compressors are located on the 289 foot floor in Room 307.

The friction losses in the helium recirculation circuit are relatively small, so the pressure differential which must be developed by the helium compressing arrangement is only slightly greater than the approximately 10 psi which corresponds to the head of heavy water in the full calandria. Except under maintenance conditions the dump tank is maintained at 25 psia. Under normal full power conditions, with full calandria, the pressure above the moderator in the calandria is at or slightly above atmospheric.

To maintain the helium pressure in the dump tank at 25 psia under conditions of varying amounts of D_2O in the dump tank requires a varying quantity of helium in the circulating system. This is provided for by valved connections from the inlet and discharge sides of the helium compressors to the helium storage tank, which acts as a helium reservoir. The helium storage tank is a 10,000 ft^3 carbon steel vessel lined with epoxy paint. It is maintained at a pressure of approximately 17 psia. The valves which connect to the storage tank are operated by the controller which controls dump tank pressure, providing a helium feed or bleed when necessary.

Helium is added to the storage tank, when required, from high pressure cylinders. The operation is manual.

Provision is made for the installation of two small diaphragm compressors, which will each compress a 1.5 cfm flow of helium to about 25 psig for level measurement. The D_2O levels in the calandria, the dump ports, and the dump tank are determined by sensing the pressure at appropriate points in the vessels. For each sensor, helium is fed through a restriction and then through a tube to the selected place in the vessel where it bubbles into the liquid. The helium back-pressure at the inlet to the tube is equal to the pressure in the liquid at the level where the bubbles emerge. The helium back-pressures are measured by differential pressure instruments.

The supply of helium for the level measurement flows will be determined after the rate of helium out-leakage from the cover gas system has been established. If the leak rate from the system is greater than the flow required for liquid level measurements, the supply will be from helium bottles. If the leak rate is less, then the supply will be taken from the main helium circuit by the two small diaphragm compressors noted above, one operating and one on standby.

Alarms are provided for:

- Low flow to recombination units
- High temperature in recombination units
- Build up of condensate on closed dump valves
- Low pressure in helium bubbler tank, oxygen addition station, and high and low pressure in the helium tank.

4.4.2.4.2 Helium Dump and Balance Piping

A 16 inch diameter helium pipe connects the dump tank through a valving system to the top of the calandria. At the calandria end, the connection is to the side of the westerly 18 inch diameter relief thimble on the top of the vessel. The helium balance pipe and its valving system provide for rapid equalization of pressure between the helium in the dump tank and the helium above the moderator in the calandria. Pressure separation between the helium in these two vessels is normally maintained by closed dump valves in the piping. The dump valves are mounted in three parallel 12 inch lines which connect upper and lower sections of the helium balance piping. Each of the three lines contains two 12 inch butterfly valves in series. All six helium dump valves open on reactor trip if the shutoff rods fail to shut down the reactor. Operation of any two of the three sets of 12 inch valves provides a reduced dump rate. Each of the three reactor protective channels controls a dump valve in two of the three parallel paths. Opening any two sets of the dump valves suffices to cause the moderator level to fall even when the helium is being pumped at the full pump-up rate.

The system of 12 inch helium dump valves is bypassed by a set of four 4 inch and two 1 inch diameter control valves. These control valves are arranged in three parallel lines with two valves in series in each line. These valves form part of the duplicated reactor control system. When the reactor is operating normally, with constant moderator level, all the helium pumped by the helium circulation system passes through the control valves.

The helium storage tank is protected against overpressure by a safety relief valve which blows to the ventilation exhaust duct, and it is protected against vacuum by a connection to the building atmosphere through a vacuum relief valve so that air is drawn in if the pressure of the helium in the tank drops below atmospheric.

4.4.2.5 Operation of the Main Systems

4.4.2.5.1 General

Control of the moderator system is from the station control room. Individual switches are provided there for the pumps and for most of the powered valves of the on-off type. The modulated valves are controlled by automatic controllers which have a manual operating facility. Where appropriate, pump and valve switches have an "auto" position in addition to the "on" and "off" or "open" and "closed" positions. If the controlled equipment operates normally, the switches and controllers are in the "auto" position, and operation of the system is entirely automatic. By use of the switches manual control of most of the valves and pumps is possible, and this applies to the helium spill valves which control the moderator level in the calandria.

Under automatic operation of the moderator system, four different conditions exist and different valve positions apply for each. The four conditions which are described are (a) operation with full (normal) level of the moderator in the calandria, (b) operation with low moderator level, (c) pump-up, and (d) the dumped condition.

4.4.2.5.2 Normal Operation

Under normal full power conditions the calandria is full of moderator, with the level at 100 percent of full tank. A cooling flow of about 8900 Igpm enters the calandria by the main inlet and 2060 by the (submerged) spray nozzles in the top of the vessel. A further 380 Igpm supplies cooling spray to the dump tank and dump ports. Normally there is no spill over the dump ports and all the heavy water entering the calandria leaves by the dual moderator outlet pipes. The flow from the calandria feeds both portions of the pump suction header. The cooling spray flow in the dump tank is removed from the sump on the tank and returns to the pumps through the smaller pump suction line shown on Figure 4.4-1. The flow control valves in the lines which take the moderator from the calandria to the pumps are modulated by a signal indicating dump port level. The valve opening is increased if the dump port level is high and is decreased if the dump port level is low.

At full power, the heat input to the moderator circuit is normally about 91.1 megawatts. The breakdown of the heat input is given in Table 4.1-1. The heat exchangers in the system are rated at 46 MW each with the cooling water at 68°F, and allowing for some fouling on the lake water side. The rated conditions are for heavy water entering at 150°F and leaving at about 110°F. Some limitations are imposed on the permitted moderator temperatures by stresses and thermal displacement in the calandria structure. The nominal limits are 155°F for the maximum moderator outlet temperature and 70°F for the minimum moderator inlet temperature to the calandria. The moderator temperature in the calandria is held to a set value by a controller which adjusts the inlet valves on the service water which cools the heat exchangers.

The main moderator flow enters the calandria near mid height through upturned nozzles which direct the flow in an upward direction. The mixing action of this incoming flow causes the moderator to have an essentially uniform temperature equal to that of outflow.

The reactor will be designed to operate under various conditions of reactivity and power, with the critical level of the moderator ranging from below half to full tank, but this mode of operation would not be expected except under unusual conditions. If the reactor is operated with the moderator level significantly below full tank it is necessary to reduce reactor power somewhat below the design value to avoid overheating some channels in the distorted flux distribution. Normally, at full power the reactivity is adjusted by refuelling and by adjustment of the level of the zone flux control absorbers so that the calandria runs full of moderator.

At full height, the flow conditions in the calandria are as described above for the normal full calandria operation. The actual level of the moderator is as determined by the reactor control system, with an upper limit imposed by a level controller whose set point can be selected by the station operator in the upper ranges of full tank.

The helium spill valves are set under the direction of the reactor regulating system and the level controller so that whichever requires the lower level adjusts the helium pressure differential to be just adequate to hold the required moderator height in the calandria. When a reactivity increase is required the helium spill valves close somewhat so that the pressure differential is raised slightly; and conversely. Raising the helium pressure differential acts to depress the level of the heavy water at the free surface in the dump ports, displacing some heavy water into the calandria proper. (Raising the helium differential suddenly and appreciably would cause the interface in the dump ports to move until helium bubbled up through the moderator). The level of the interface in the dump ports is sensed, and controlled as follows: if the level is displaced downward, the modulated valve which regulates the flow of the heavy water effluent line from the calandria is moved to a more closed position, so that some heavy water passes from the dump tank to the moderator circulation system until the level in the dump port is restored; and conversely. The overall result, then, of increasing the helium pressure is to increase the amount of heavy water introduced and held up in the calandria. In addition to being subject to the reactor regulating system and the limit imposed by the moderator level controller, the moderator level is limited by one further condition. Level switches sense objectionably low water level in the dump tank, and open the helium spill valves to return moderator to the dump tank.

In the normal operating condition four pumps operate and one is a standby. The standby pump is started manually. Each pump is fitted with a vibration switch which will alarm if it experiences excess vibration.

Alarms are provided for:

- Low flow;

i) each of the two calandria spray supplies,

ii) each of the two supplies for the dump tank, dump port spray,

iii) to the adjuster rods and shutoff rods.

- Temperature;

i) high temperature in the calandria effluent,

ii) low temperature of the calandria supply.

- Level;

i) high and low level in the dump tank,

ii) dump tank full and minimum critical level exceeded,

iii) high level in the calandria,

iv) high or low level in the dump port,

v) high and low level in the fuelling machine and calandria vault drain.

- Pressure;

i) high or low pressure at the pump suction,

ii) high or low pressure in the helium storage tank,

iii) high and low pressure in the dump tank.

No reactor trips are associated with the moderator system.

4.4.2.5.3 Low Level Operation

When the moderator level in the calandria is low the reactor power is limited. The valves leading from the calandria to the pump suction are under control as for normal operation. The valve on the line leading to the main calandria inlet is controlled, as under normal operating conditions, to maintain the flow of the calandria spray supply. If the moderator heavy water spills over the dump ports, the valves in the lines to the circulating pumps are automatically opened.

4.4.2.5.4 Pump-up

With both helium compressors operating at maximum capacity, pump-up of the moderator from the dump tank to full calandria takes about 42 minutes. Pump-up may be done with any combination of pumps up to five.

If moderator dump occurs either due to failure of the shutoff rods to shut down the reactor at the required rate, or due to malfunction of a component of the dump system, a poison out may occur. It will be necessary to raise the moderator level to 50 percent full calandria before the shutoff rods can be raised.

During the pump-up, there is a flow of helium between the helium tank and the moderator helium system. This is a result of the action of the system which controls the pressure of the helium in the dump tank. During the pump-up, for every cubic foot of heavy water transferred from the dump tank to the calandria a cubic foot of helium at 25 psia is added to the dump tank to hold the pressure constant.

The amount of helium which is removed from the calandria as the cubic foot of water is added to it must be such that the helium pressure falls by the amount necessary to hold up the extra height of water. During the earlier stages of pump-up when the calandria is less than half full, more helium must be removed from the calandria than is required in the dump tank, and during the filling of the top half of the calandria less helium is removed from the calandria than is required in the dump tank. The discrepancy is made up by helium passing to the storage tank during the early part of the pump-up and returning to the system during the later stages. The valves on the helium feed and bleed system which are operated from the pressure controller are relatively small.

4.4.2.5.5 Tripped (Dumped) Condition

When a reactor trip signal occurs the shutoff rods will be released into the core and the helium dump valves will remain closed, providing the reactor power decreases at a rate in excess of a preset minimum rate. If the reactor power does not decrease at the minimum rate, dumping of the moderator is initiated.

The volume of the dump tank and connected storage will permit shutting down the reactor in any accidental circumstance. (For specification of dump tank size see Appendix 1). The usable volume will store all of the moderator system heavy water and half of the primary system water. If primary system water spills into the calandria to the extent that it exceeds the minimum critical level (see Section 4.2.6) it will be passed through a 4 inch bypass to the helium tank.

4.4.2.6 Liquid Poison System

The liquid poison system, shown in simplified form on Figure 4.4-2, injects controlled quantities of boric acid into the moderator circuit on demand from the reactor control system. The boron concentration in the moderator is adjusted so that the calandria is full when the reactor is operating at full power. After equilibrium fuelling has been achieved in the reactor, and following lengthy shutdowns, boron is required in the moderator only for periods of a few hours.

The boric acid supply is held as a solution in a 15 ft^3 capacity tank located in the north accessible area on the 274 foot floor. Helium is used as a cover gas over the solution in the tank. The tank holds enough boron for 2-1/2 "charges", where a charge is the amount required to compensate for complete loss of equilibrium xenon (28.5 mk). Boric acid, in the anhydrous form, is added to the supply tank when necessary through a 4-inch ball valve located on top of the tank. A connection to the D_20 sampling system, including a line and a valve which bypasses the sample station, is provided.

A small pump is used to introduce the concentrated solution into the moderator circuit. The flow of poison is controlled by a needle valve and a powered valve in the line from the supply tank.

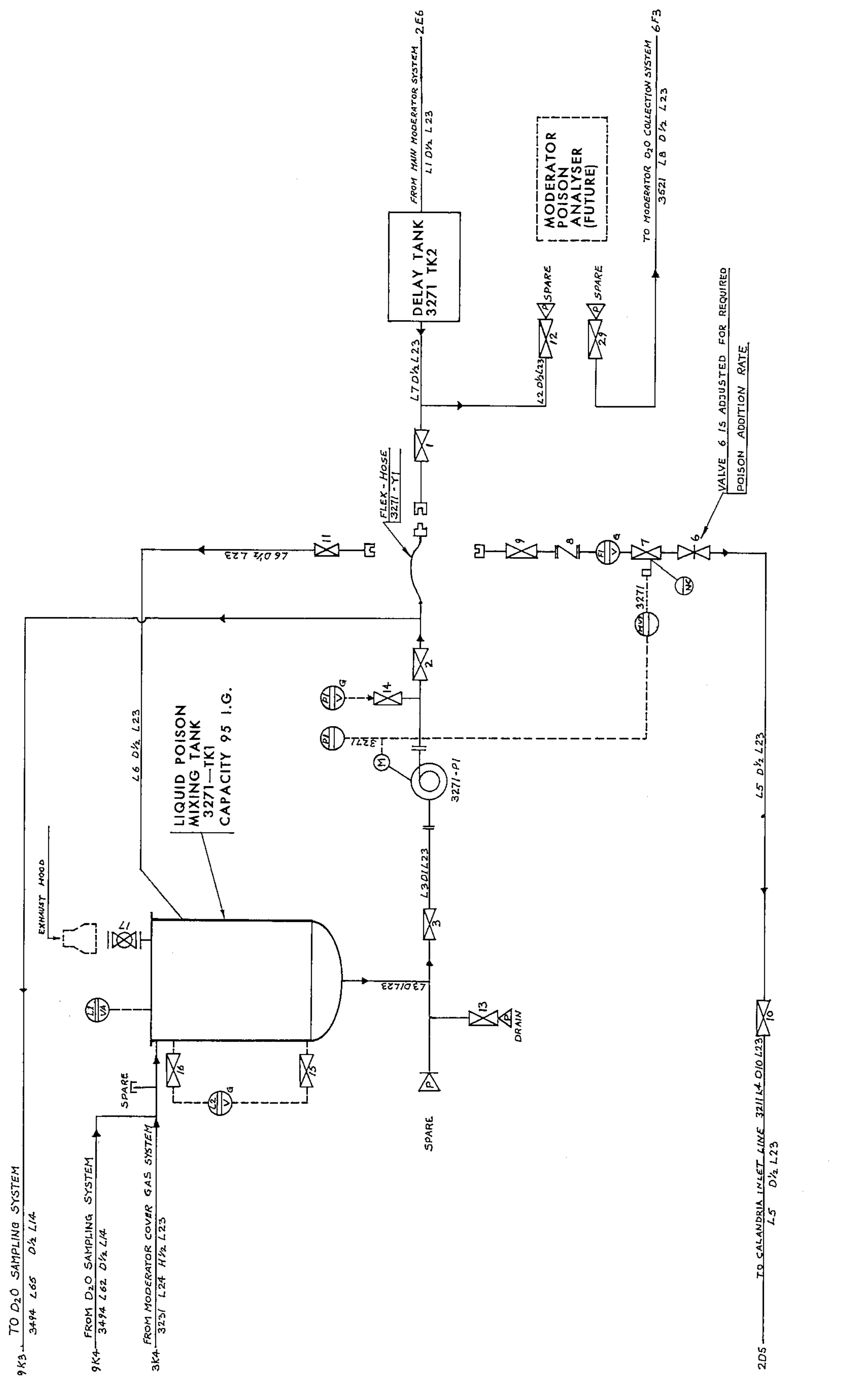
The concentration of boron in the system is measured manually.

Boric acid is a weak acid. The borate ion, $D_2 BO_3$, is removed from the moderator by the strong base ion exchange resin XE-78.

Alarms are provided for low and high levels in the liquid poison tank.

4.4.2.7 Purification Circuit

The moderator purification, resin transfer, drying and storage arrangement is shown in Figure 4.4-3. The ion exchange units remove boric acid and impurities from the moderator system. Four beds are provided, and the valving arrangement is such that any number of them can be connected to operate in parallel. The total flow to the ion



4.4—2 LIQUID POISON SYSTEM FLOW SHEET

44.30000-12
REV.2,1968

exchange beds is measured and can be adjusted to any desired safe value. Valves for valving-in beds are manually operated in the purification room. Each bed has a 7 ft^3 resin capacity, with a height of 30 inches. The resin is held on stainless steel dutch weave screens.

The principal use of the beds is to remove boric acid put in by the liquid poison system. When equilibrium fuelling pertains, boron introduced for xenon load compensation after long shutdowns must be completely removed for normal operation, with a removal time constant of about 10 hours. This corresponds to a cleanup flow of about 100 Igpm. All four ion exchange units are filled with a mixed resin bed consisting of approximately 90% anion for boric acid removal and 10% cation for removal of other ions. The equilibrium which boron establishes with available resin is such that during the later stages of purification, when the boron concentration in the moderator is low, boron would be eluted from a bed which had been in prolonged contact with moderator of higher boron content such as pertains at the start of cleanup. To avoid this, the different beds are used in sequence, one bed used during periods of highest boron concentration in the moderator, followed by another bed to take the concentration down somewhat further, and then by a third and possibly the fourth to complete the job. Fresh beds are used for the final purification. When a bed is unsuitable for a particular concentration range it is advanced up the sequence to work on the next higher range. The resin from the bed used for highest concentrations is replaced when it is no longer usable, and this bed then becomes the finishing bed.

To replace the resin in a bed, the bed is valved off from the normal purification circuit and connected to a resin drying tank. The resin is flushed out from the bed to the drying tank. The flushing D_2O passes out through screens in the tank and back to the moderator system.

A single drying tank services the four moderator circuit ion exchange units. When the resin has been transferred, the water is removed from the drying tank and the resin is heated by hot tubes in the resin space. The tubes are heated by heavy water which is heated by immersion heaters in an attached vessel. Dried resin is blown out of the drying tank with compressed air and transferred to one of the spent resin storage tanks in the vault below ground in the auxiliary bay. The transfer is effected without air discharge from the storage tank by utilizing the capacity of the tank and allowing some pressure build up. When the resin has settled in the storage tank, the pressure in the tank above atmospheric is relieved slowly, permitting the excess contained air to escape through a local filter to the ventilation exhaust duct. Two resin storage tanks are provided, each fitted with valves so it can be used independently of the other. Each tank has a volume of about 2300 ft^3, and a design pressure of 70 psig.

If the resin drying system is being used to dry a batch of resin when an ion exchange column requires a fresh charge, the spent resin may be transferred to a 21 cubic foot service tank. The resin can subsequently be transferred to the drying tank. Provisions are being made for de-deuterating spent resin batches in the service tank if this should become necessary.

Fresh resin is added to an empty ion exchange column from a resin addition station outside of the north wall of the Reactor Building at elevation 274 feet. Resin fill lines from each ion exchange bed extend up through the 274 foot floor to the addition station. The hopper is valved to the appropriate fill line and a hose from a heavy water supply in the area is connected to the hopper tank to flush the resin into the ion exchange column.

Prior to the addition of fresh resin to the ion exchange column, the resin must be deuterated to avoid downgrading the moderator heavy water. Deuteration is the replacement of the H^+ and/or OH^- ions in the resin with D^+ and/or OD^- ions and is accomplished by first adding light water to the resin in a hopper to form a resin and water slurry and then displacing the light water with a slow upward flow of the heavy water through the resin bed.

The deuteration facility which is common to the four Pickering units is located in the north east area of the Reactor Auxiliary Bay elevation 274 feet adjacent to reactor unit 1, and is shown on flowsheet, Figure 4.4.-3.

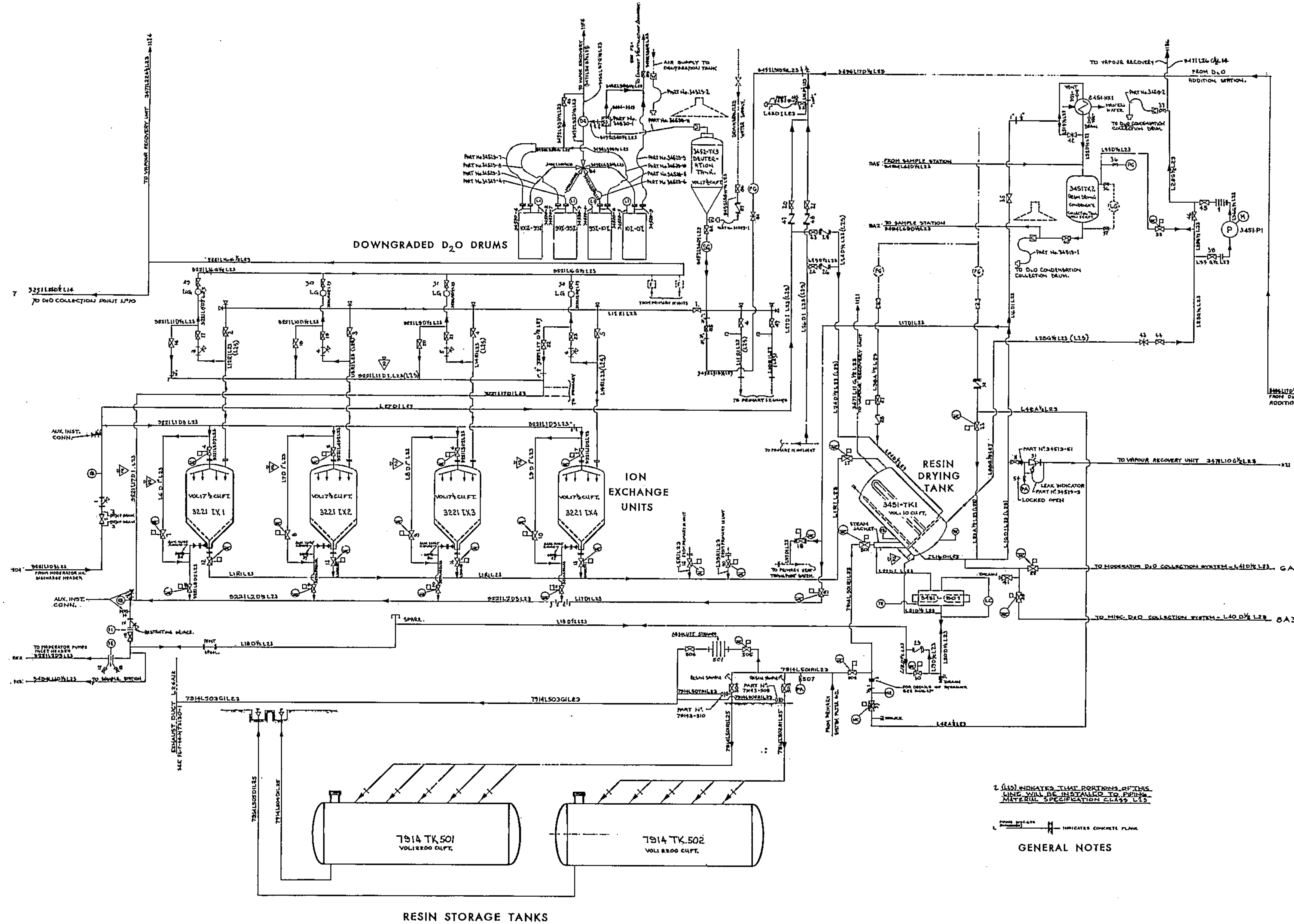
Conductivity is measured in the line which returns purified D_2O from the ion exchange units to the moderator pump inlet header. High conductivity is alarmed.

4.4.2.8 Connections for Emergency Use of Heavy Water

The heavy water from the moderator system can be used to supply heavy water for emergency injection of coolant to the primary heat transport system after it has depressurized. The heavy water is conducted through a 10 inch carbon steel pipe to a distribution system on the 311 foot floor. The connection to the moderator system is shown in Figure 4.4.-1.

The emergency supply is directed to the primary heat transport system at each end of the reactor. The control of the emergency injection is described elsewhere in this report. An emergency connection is provided on the 10 inch emergency transfer line. This connection leads from a capped end on the outside of the Reactor Building through a check valve to the transfer line. It provides a possible route to introduce ordinary water from fire hydrants or from a mobile pump into the (depressurized) primary system or indirectly into the moderator system.

Large drain connections are provided in the floor of each fuelling machine service room and in the boiler room. These connections serve to recover heavy water from major breaks in the primary system in the vaults and boiler room. The floor connections are piped through pairs of valves in series to the ends of the moderator pump suction header. The calandria vault also has a drain connection piped through a pair of valves to the moderator pumps. The interspace between the valves on all these heavy water recovery lines is



4.4-3 PURIFICATION CIRCUIT FLOW SHEET

44-30000—13

connected to a collection system so any leakage through the valves under ordinary conditions can be recovered and analyzed.

4.4.2.9 Auxiliary Systems Related to the Moderator System

4.4.2.9.1 Moderator Heavy Water Collection System

Provision has been made for collecting heavy water from various points in the moderator and associated systems. The points include the seals of the moderator pumps and the interpacking space in valves with double stem packing. Equipment can also be drained into this system for maintenance.

The system, Figure 4.4-4, includes a tank located in a pit which receives gravity drainage from the various leakage collection points. An air atmosphere in the tank is vented to the west fuelling machine vault dryer to recover the heavy water from the air.

A pump located in the pit returns the collected water to either the moderator suction header or the downgraded drum fill station after the water has been sampled for isotopic purity.

4.4.2.9.2 Miscellaneous Uses of the D_2O Collection System

In cases where equipment requires draining prior to dismantling for repairs, the isolation valves to that piece of equipment are closed and a flexible hose is connected to the equipment drain valve and the other end of the hose is connected to the nearest of the fifteen collection points. By venting the equipment, the hold-up can be drained to the D_2O collection tank.

Where large quantities of D_2O must be stored, such as for moderator heat exchanger repairs, the liquid may be drained to the D_2O collection tank and then pumped to the drum fill station into heavy water drums. On completion of the repairs the D_2O may be returned to the moderator system via the D_2O addition system.

4.4.2.9.3 Heavy Water Addition

The D_2O addition and transfer circuit is shown in Figure 4.4-5.

A moderator D_2O drum addition station is provided to add heavy water to the main moderator system. The heavy water is added from drums to the moderator D_2O collection tank. The heavy water is pumped from the tank to the moderator east or west pump suction header.

4.4.2.9.4 Heavy Water Transfer

The D_2O transfer circuit, which consists of valves and piping, is located along the east wall of room R-105. Piping interconnections are provided among the following systems:

(a) Moderator system — evaporative cleanup system — upgrading system

(b) Primary Heat Transport system - evaporative cleanup system - upgrading system

(c) Miscellaneous D_2O collection system - PHT system

The more probable transfer operations are listed below:

(1) PHT system upgrading system PHT system

(2) PHT system evaporation cleanup system PHT system

(3) Moderator system upgrading system moderator system

(4) Moderator system evaporation cleanup system moderator system

(5) Moderator D_2O addition station Moderator D_2O collection system moderator system

(6) Moderator D_2O collection system moderator system

(7) Miscellaneous D_2O collection system PHT system

The D_2O addition and transfer system valves are all manually operated since the circuit is accessible, and because these valves will be operated very infrequently during normal reactor operations.

A second portable scale has been provided for weighing D_2O drums during the initial fill of the moderator and primary heat transport systems. This second scale shall be used for the commissioning of all Pickering units.

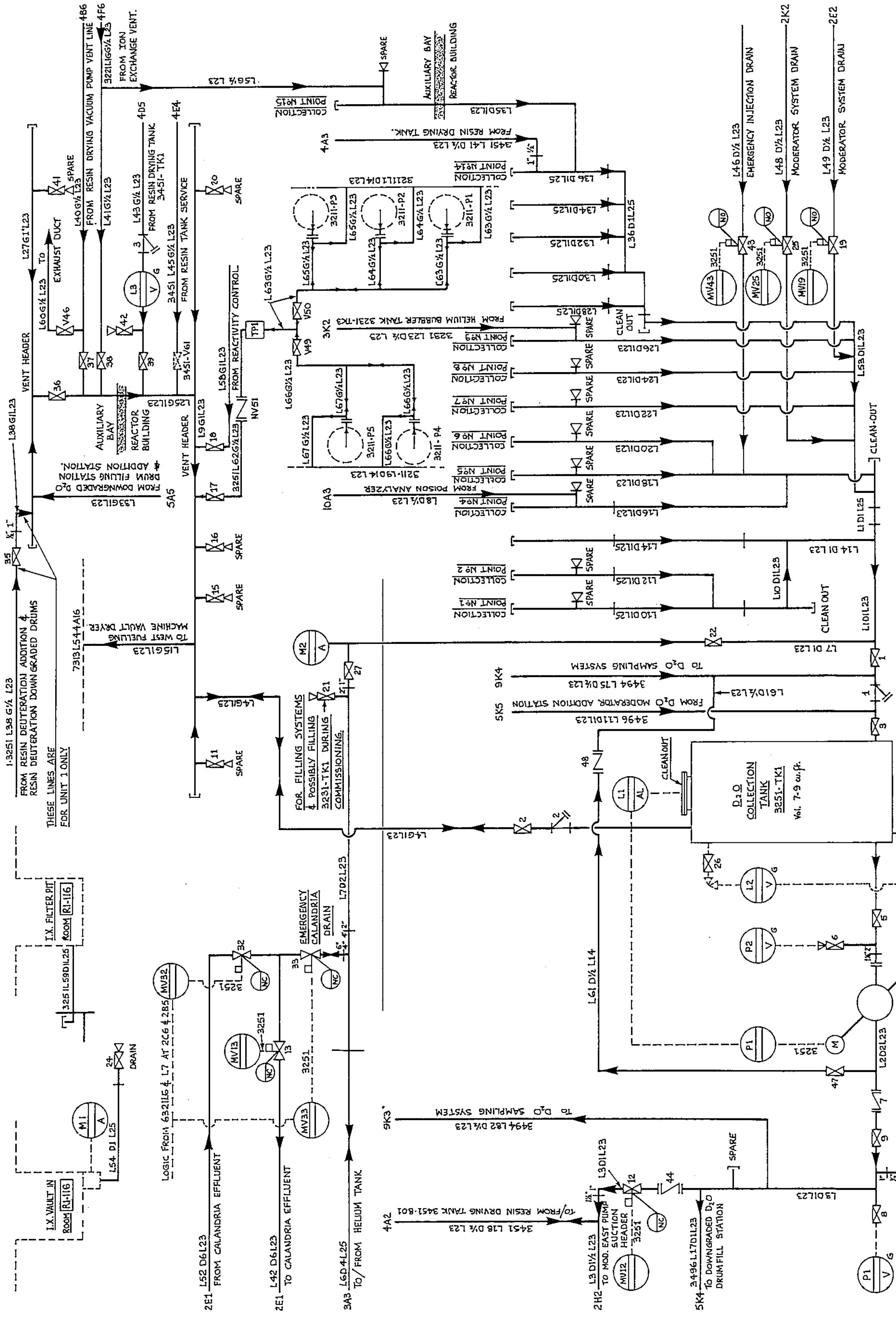
Independent drum fill stations have been provided for the moderator D_2O collection system, miscellaneous D_2O collection system, primary D_2O collection system, fuelling machine vault air dryer, boiler room air dryer, moderator room air dryer, and the building liquid recovery system, to collect downgraded or chemically degraded heavy water. These drums will be transported to the upgrading or evaporative cleanup systems for upgrading or purification on a batch process.

Connections have been added to the helium tank for the addition and storage of heavy water during the commissioning period. Spare connections have also been provided on the transfer system for the same purpose.

4.4.2.9.5 Evaporation Clean-up and Upgrading Systems

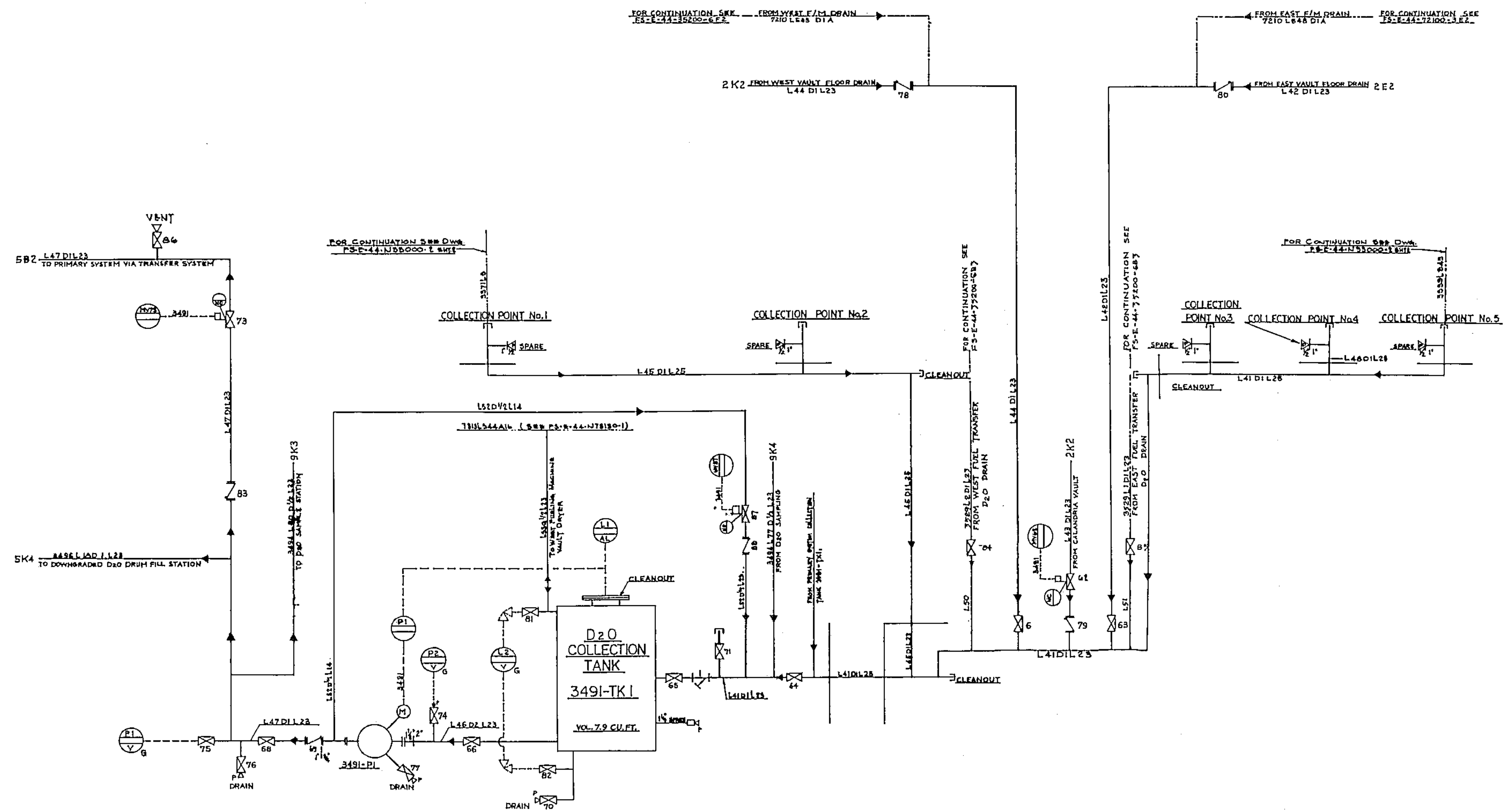
The evaporation cleanup system processes heavy water which is chemically impure and the upgrading system processes heavy water which has been downgraded isotopically.

4.5 HEAT TRANSPORT AND STEAM-WATER SYSTEMS



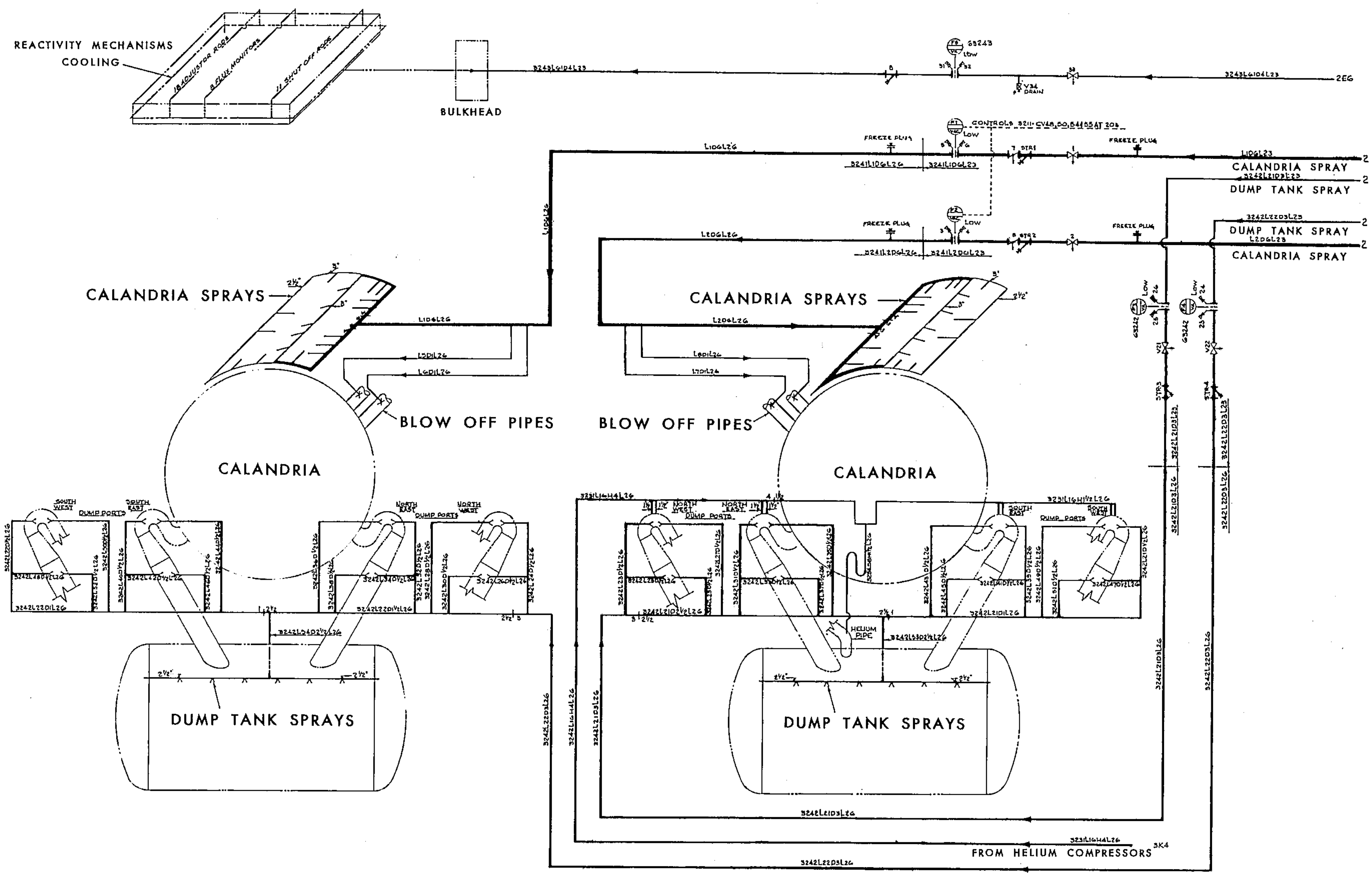
4.4—4A MODERATOR D_2O COLLECTION SYSTEM MAIN FLOW SHEET

44.30000-14
REV. 2, 1968



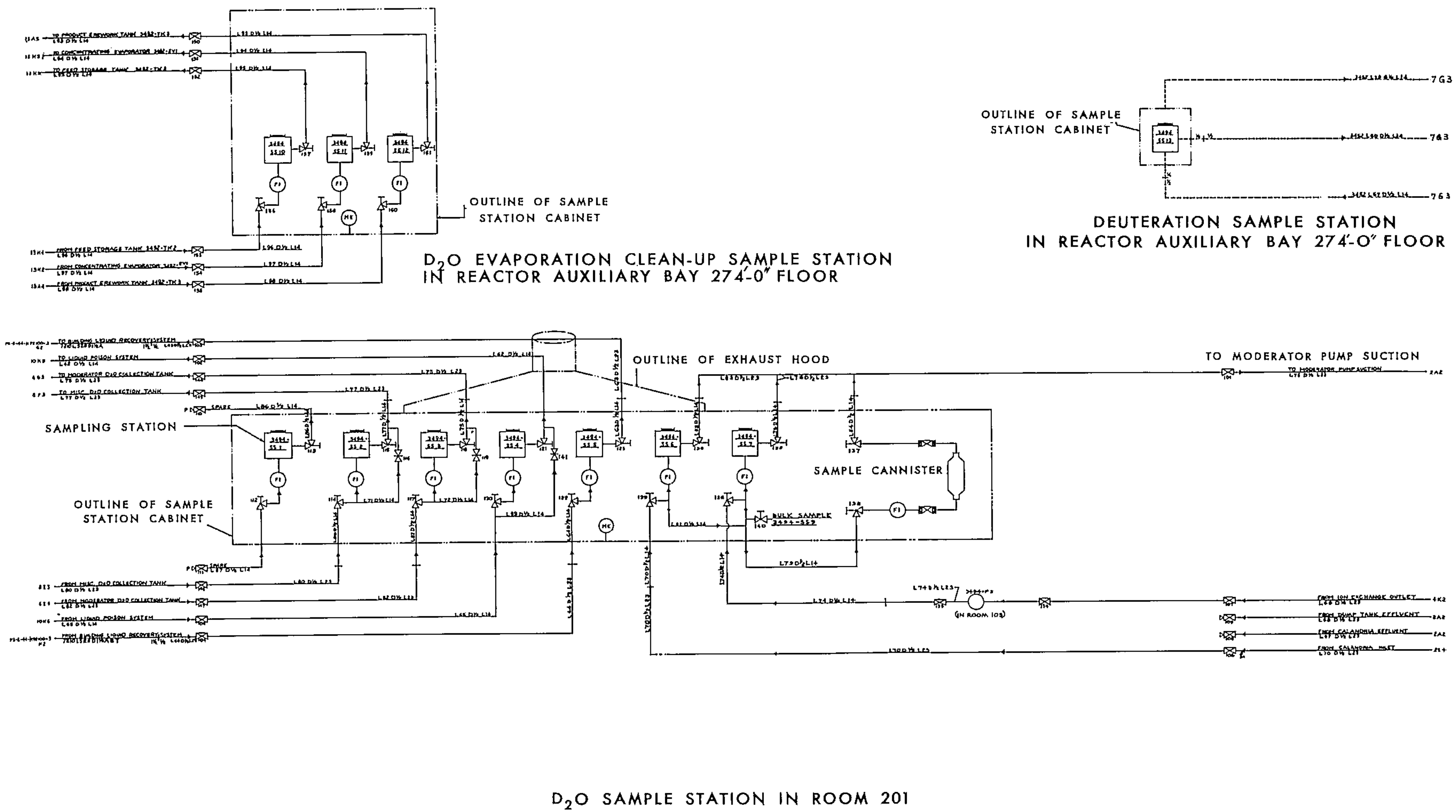
4.4-4B MISCELLANEOUS D_2O COLLECTION MAIN FLOW SHEET

44.30000-15
REV. 1, 1968



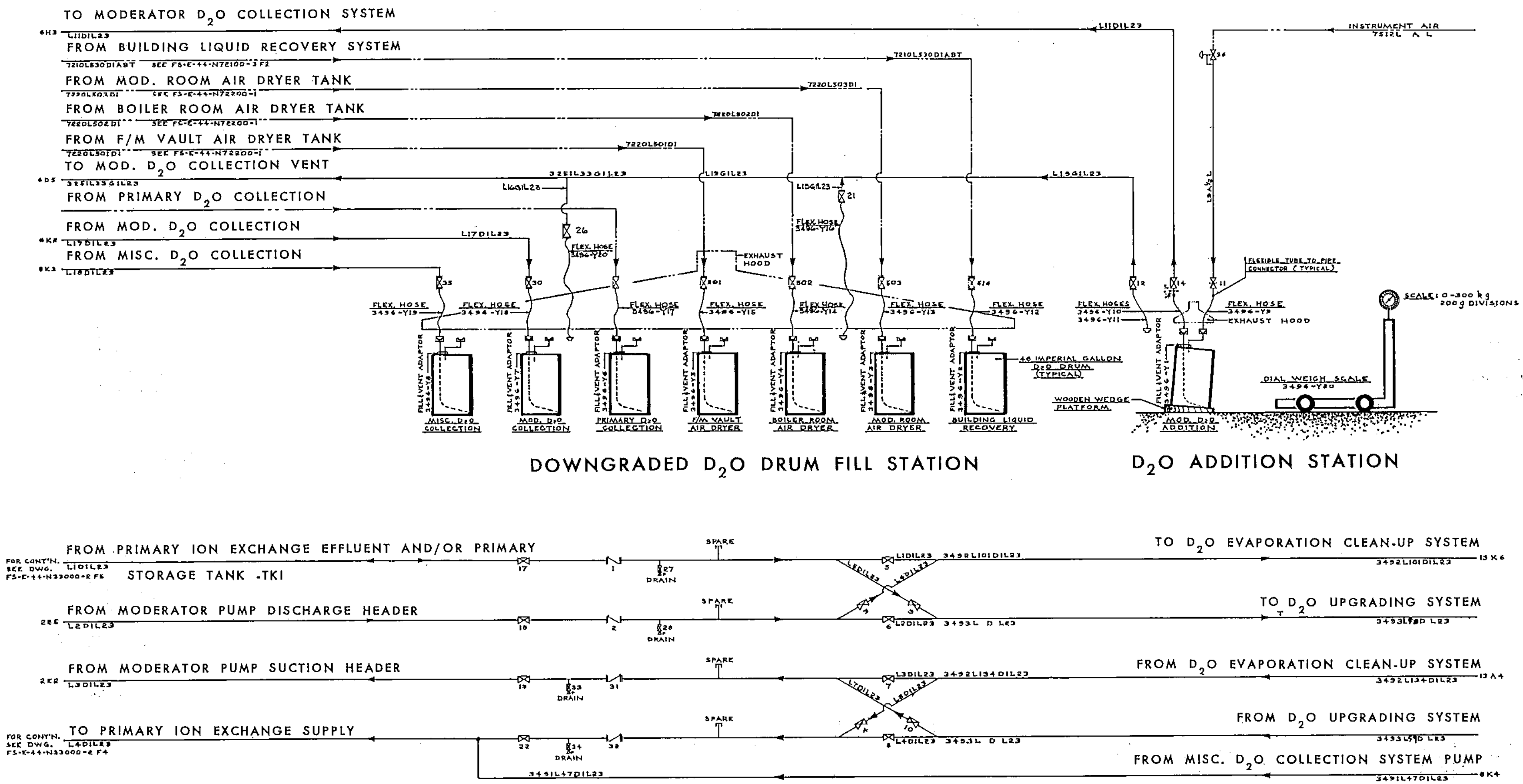
4.4—4C MODERATOR SYSTEM SPRAY COOLING

44.30000.20
1967



4.4—4D MODERATOR SYSTEM D_2O SAMPLING STATIONS

44.30000.19
1967



4.4—5 HEAVY WATER ADDITION AND TRANSFER FLOW SHEET

44.30000-16
REV. 2, 1968

4.5.1 General

The pressurized heavy water cooling system for the reactor is called the (primary) heat transport system. This section describes the heat transport system and the closely associated steam water systems, commonly referred to as the secondary system.

The heat transport system transports the heat from the fuel in the reactor to tube-in-shell heat exchangers where it generates steam in a secondary system. Pressurized heavy water is the primary coolant. The heat transport system includes a standby cooling system to remove decay heat from the fuel following a unit cooldown and a system to supply high pressure heavy water to the fuelling machines.

The complete steam-water system includes the boilers and related auxiliaries, steam transfer piping and valves, the turbine and condenser, the reheat system and the feedwater system. The portion of this secondary system within the Powerhouse is described in Section 6. The remainder, which is described in this section because its operation is closely related to that of the heat transport system, includes the boilers, the feedwater distribution system to the boilers, and the relief and steam discharge valves on the steam mains.

A simplified flowsheet of the heat transport system is shown in Figure 4.5-1. The complete flowsheet for the system is Drawing No. FS-E-44-N33000-1 and -2. The principal data concerning the heat transport system are given in Table 4.5.-1.

The arrangement of the heat transport equipment in the boiler room is shown in Figures 4.5-2A and 2B.

The pipe used in the heat transport system for the main coolant circuit and for most of the auxiliaries is carbon steel equivalent to ASTM A-106 Grade B. The piping system will be welded and will comply with requirements of Section III of the ASME Boiler and Pressure Vessel Code (the Nuclear Pressure Vessel Code), the ASA B31.1 Code for Pressure Piping and, where applicable, Section VIII of the ASME Boiler and Pressure Vessel Code.

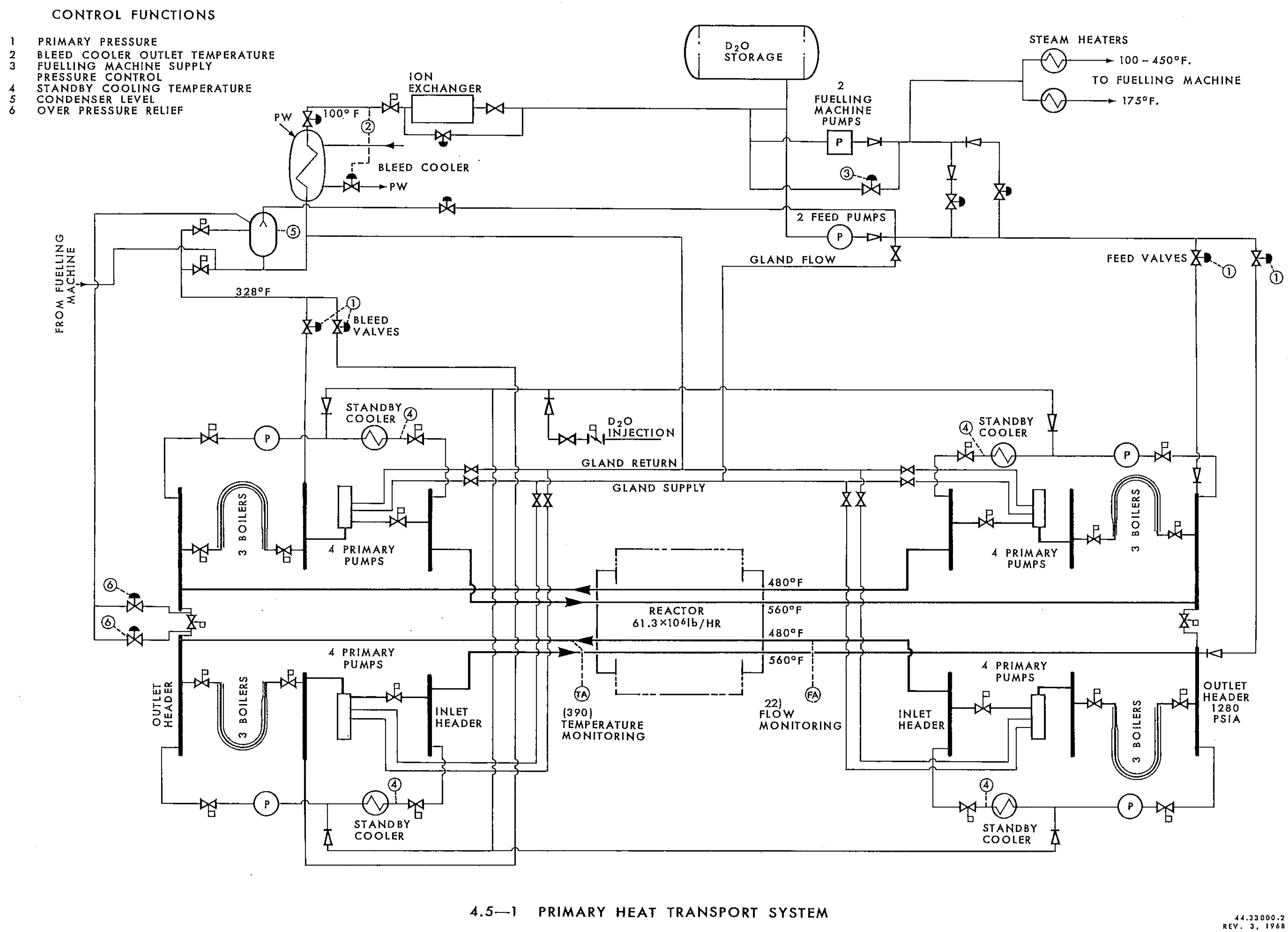
Materials other than carbon steel in the heat transport system include: zirconium alloy coolant tubes, martensitic stainless steel reactor end fittings, high alloy steel in pumps, Monel tubing in the boilers and coolers, and stainless steel in the fuelling machine supply circuits.

All parts of the main and auxiliary systems will be constructed to helium-tight standards. The large pumps have shaft seals of a type designed to collect seal leakage. Large size primary system valves are of the lantern-gland type with interseal drains; the small size manual and motorized valves are of the bellows sealed type.

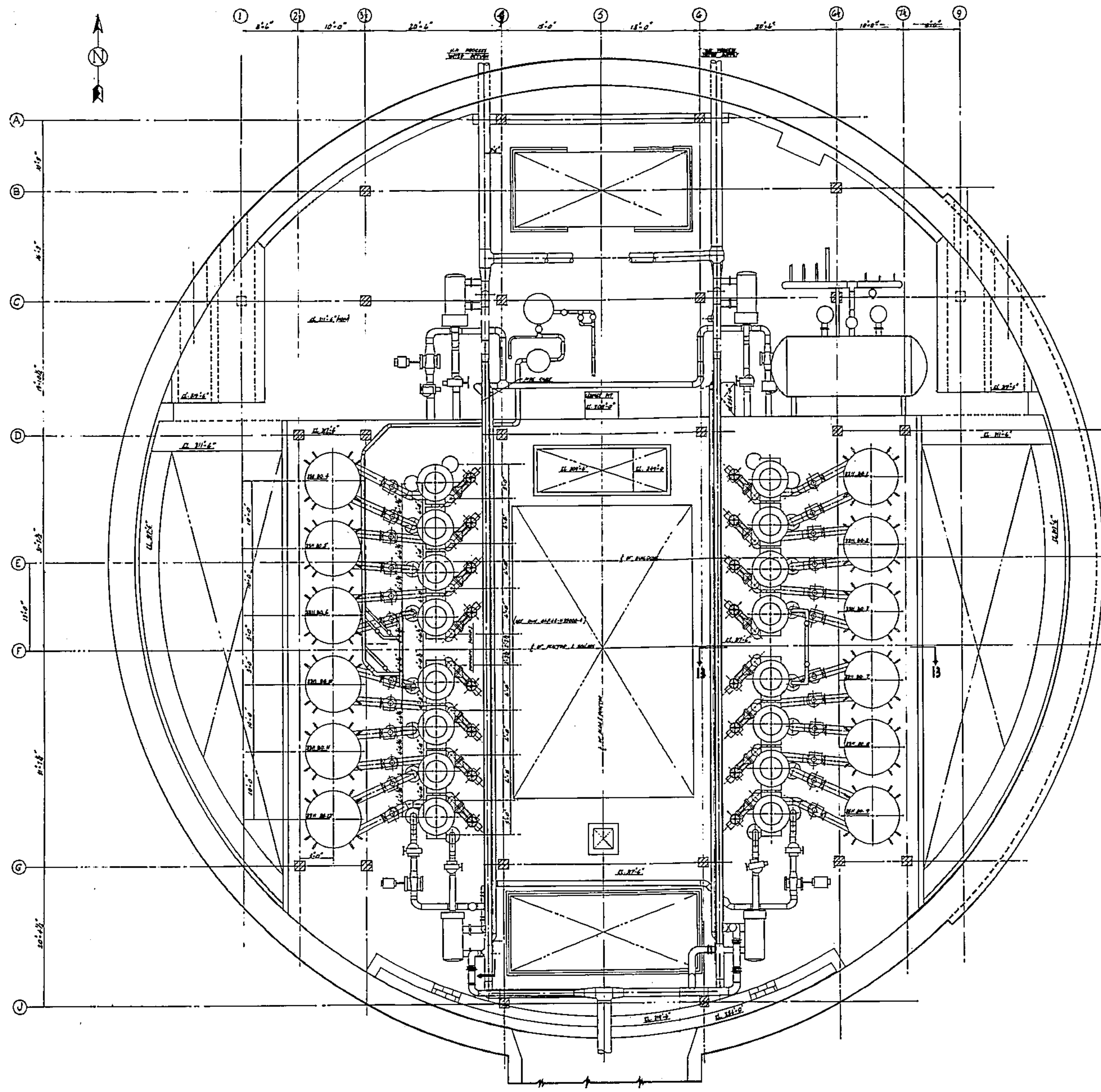
TABLE 4.5-1

HEAT TRANSPORT SYSTEM DATA
(Full load conditions unless otherwise stated)

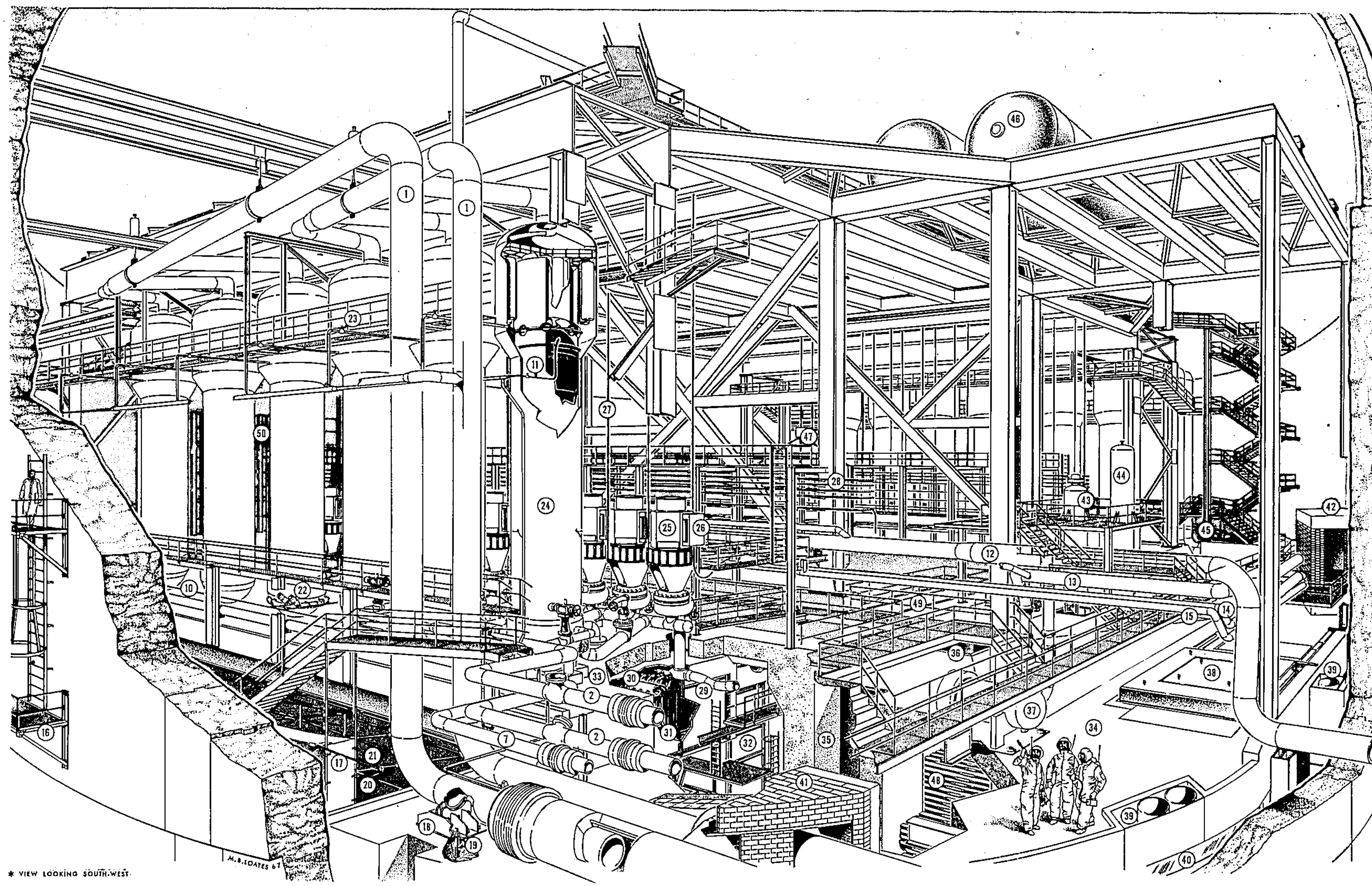
General	
Coolant	Heavy water (pressurized)
Volume of System - Main circuit	4600 ft^3
- Standby cooling and auxiliary circuits	804 ft^3
- Storage tank	(at normal level) 250 ft^3
Total D_2O in System	Approx. 158 tons
Coolant pH	10 approx.
Main Circuit	
Coolant Flow Rate (total)	61.335 x 10^6 lb/hr
Reactor Inlet Temperature	480°F (249.5°C)
Reactor Outlet Temperature	560°F (293.4°C)
Mean Pressure, Outlet Headers	1280 psia
Mean D_2O Temperature	515°F (268.7°C)
Mean D_2O Density	52.91 lb/ft^3 (0.847 gm/cc)
D_2O Temperature at Low Power	510°F approx. throughout
Design Pressure (ex. coolant tubes)	1600 psig at 570°F
Piping Material	Carbon steel
Boilers	
Arrangement	Four groups of three: one exchanger & drum per boiler
Tube Material	Monel
Total Steam Output	6.459 x 10^6 lb/hr
Feedwater Inlet Temperature	340°F (171°C)
Min. Temp. Diff. between D_2O & H_2O	9.0°F
Steam Pressure at Drum	578.6 psig (593.3 psia)
Steam Temperature at Drum	485°F
Steam Quality at Drum Outlet	99.78%
Steam Pressure at Low Power	744.3 psia (510°F)
Design Pressure - Shell Side	780 psig
- Tube Side	1450 psig
Design Temperature - Shell Side	517.5°F
- Tube Side	571°F (299°C)
Main Pumps	
Quantity	16 (12 operating; 4 on standby)
Arrangement	4 pumps for each group of boilers



4.5—1 PRIMARY HEAT TRANSPORT SYSTEM



4.5-2A PRIMARY HEAT TRANSPORT IN BOILER ROOM



1 MAIN STEAM LINE
2 BOILER FEEDWATER
7 REHEATER DRAINS RETURN
10 BOILER TUBE SHEET BLOWOFF LINE
11 REHEATER DRAIN ISOLATING VALVE
12 HIGH PRESSURE SERVICE WATER SUPPLY
13 HIGH PRESSURE SERVICE WATER RETURN
14 RECIRCULATED SERVICE WATER SUPPLY
15 RECIRCULATED SERVICE WATER RETURN
16 PERIMETER PLATFORM
17 ROPE CLOSURE SEAL
18 MAIN STEAM LINE ANCHOR BRACKET
19 ANCHOR BOLT
20 TIE
21 NEOPRENE RUBBER BLOWOUT PANELS
22 BOILER BLOWOFF LINE MOTORIZED VALVES
23 BOILER TOPWELL BLOWOFF LINE
24 BOILERS (EAST BANK)
25 PUMPS (EAST BANK)
26 MOTOR COOLERS
27 PUMP HANGERS
28 CABLE TRAYS
29 REACTOR INLET HEADER
30 REACTOR OUTLET HEADER
31 FEEDERS
32 INSULATION CABINET
33 317'6" FLOOR ELEVATION
34 311'6" FLOOR ELEVATION
35 PIPE CHASE
36 LEAK PIT
37 STANDBY COOLING HEAT EXCHANGER
38 MOBILE HATCHWAY
39 VENTILATION PIPE LINES
40 PLASTIC CLOSURE SEAL
41 REMOVABLE HEAVY CONCRETE BLOCKS
42 AIRLOCK FROM SERVICE BUILDING
43 BLEED CONDENSER
44 BLEED COOLING HEAT EXCHANGER
45 STAIRCASE TO BOILER WALKWAYS
46 EMERGENCY COOLING STORAGE TANKS
47 ION CHAMBER MOUNT
48 HELIUM VALVE CHAMBER ROOM
49 HELIUM BALANCE AND BLOWOFF LINE HATCHWAY
50 REACTOR BUILDING PRESSURE RELIEF LOUVERS

4.5—2B HEAT TRANSPORT IN BOILER ROOM

44.33000—1
REV. 1, 1968

Type	Centrifugal, double volute, single discharge
Rated Flow	10,100 Igpm each
Total Head	480 ft
Drive Motors, electrical load	1.17 MWe each (at 480°F)

TABLE 4.5-2

PRINCIPAL FEATURES OF HEAT TRANSPORT SYSTEM

a) Continuous circulation of coolant.

b) Pump flywheels to avoid a sudden drop in coolant flow in the event of loss of power to the pumps.

c) Considerable thermal circulation of coolant through the reactor following loss of pumping power.

d) Pattern of coolant flow rates through coolant tubes compatible with pattern of heat production across the reactor, to yield a common increase in coolant temperature in all channels.

e) Controlled pressure at the reactor outlet headers.

f) Overpressure relief.

g) Addition of coolant to and removal from the system.

h) Control of dissolved gas in coolant.

i) Purification and pH control of coolant.

j) A shutdown cooling system for the reactor which is independent of the boilers.

k) Provision for supply of high pressure heavy water to the fuelling machines.

l) Capability of receiving emergency injection of heavy water after depressurizing of primary circuit.

m) Fully automatic control of all main and auxiliary systems other than some service systems.

n) The provision of standby units of equipment to give reserve capacity where warranted.

o) Accessibility of all components during shutdown and accessibility of some during operation.

p) Collection of D_2O leakage from potential leak points in the system.

q) Capability of recovering moderate heavy water leakage from the system to the fuelling machine vault or boiler room and injecting it without depressurizing the primary system.

4.5.2 Heat Transport System

4.5.2.1 General

A description of the coolant assemblies which form part of the heat transport system hardware is given in Section 4.2. The fuel channels are fed through individual feeder pipes from headers at each end of the reactor. Similar pipes transfer the coolant from the channels to reactor outlet headers at each end. There are 195 inlet feeder pipes and 195 outlet feeder pipes at each end of the reactor. The feeders and headers at each end of the reactor are housed in their respective fuelling machine vaults. The arrangement is illustrated in Figure 4.5-3.

To give a coolant flow through each coolant assembly appropriate to its heat output, the feeder pipes are designed with various flow resistances so that the proper channel flow is created. The feeder pipes range in size from 1.506 inches to 2.920 inches inside diameter and from about 20 feet to 60 feet in length. The feeders are designed for a pressure of 1600 psig and are made from carbon steel material complying in general with specification ASTM A-106 Grade B.

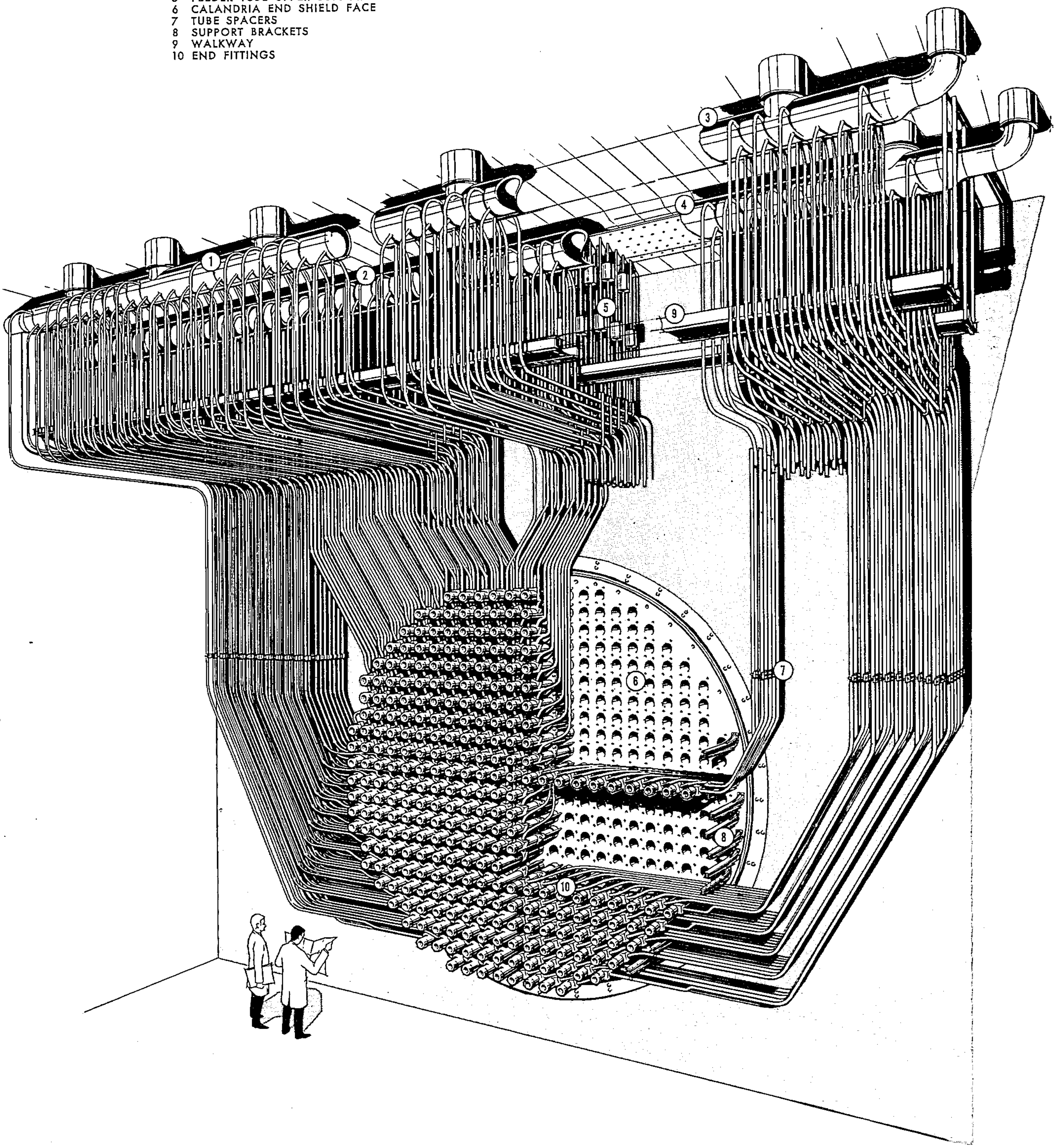
The feeders are arranged in banks with up to 10 feeders in a bank. Each feeder is connected at its upper end by welding to a header pipe, with a maximum of five feeders at any section. At the lower end, each feeder is connected to the channel end fitting by a bolted connection using a Grayloc seal. The feeder pipes will be supported by hangers so that little of their weight is taken on the reactor end fittings or the headers.

Flow is monitored in twenty-two selected channels. In the inlet feeder to these channels flow measuring venturi are inserted in the straight lengths of the pipe run near the headers. All outlet feeders will be fitted with dual temperature detectors. These are located at the end shield faces near each coupling. This location allows maintenance and, if necessary, shielding of maintenance personnel.

There are four inlet and four outlet header sections per reactor, each approximately 20 feet long, manufactured from 16-inch outside diameter Schedule 160 pipe. Four pump suction header sections are mounted in the boiler room at the ends of the reactor. Each header is manufactured from 14 inch schedule 100 pipe and is approximately 23 feet long. Each pair of reactor outlet header sections is connected by a 4 inch diameter pipe in which there are two isolating valves.

The headers are made of carbon steel to ASTM A-106 Grade B ultrasonically inspected and will conform to the requirements of the ASME Nuclear Pressure Vessel Code. The connections to the headers for attachment of feeders will be made using nozzles of the proper size to match the feeder. 14 inch Schedule 100 nozzles on the headers, will be provided for connection to the boilers and to the pump discharge piping. One end of each header section is reduced to 10 inch Schedule 100 to connect to the standby cooling system piping. On each of the two reactor outlet header sections on the east side of the reactor a 2 inch connection

1 REACTOR OUTLET HEADER
2 REACTOR INLET HEADER
3 REACTOR OUTLET HEADER
4 REACTOR INLET HEADER
5 FEEDER TUBE UPPER SUPPORTS
6 CALANDRIA END SHIELD FACE
7 TUBE SPACERS
8 SUPPORT BRACKETS
9 WALKWAY
10 END FITTINGS



4.5—3 FEEDER TUBE ARRANGEMENT

44-33126-4
1968

is provided for the primary coolant pressurizing system. The headers are supported by the connecting piping, the pump connections and inlet feeders in the case of the inlet headers, and the boiler connections and outlet feeders in the case of the outlet headers. The feeders and reactor headers are in the fuelling machine vault and are enclosed in an insulated cabinet described in Section 4.2.

Each reactor outlet header section is connected to three boilers in parallel. The connecting pipe is 14 inch Schedule 100. Each of the three pipes is fitted with a motorized isolating valve. The heavy water discharge pipes from the boilers are also 14 inch Schedule 100, and are connected through similar valves to the pump suction headers.

Four heat transport pumps are mounted in parallel on each pump suction header section with their discharges connected through motorized stop valves to the reactor inlet headers. Motorized valves have been specified in preference to the check valves used at Douglas Point to prevent back flow through a stopped pump and also to permit some back flow through the pumps in the event of a major piping failure at or near a pump suction header.

Each of the twelve boilers consists of an integral tube-in-shell heat exchanger and steam separator. The overall height of the units is 46 feet 7 inches including the steam outlet nozzle and bottom support. The steam separating head is the largest diametral section of the unit and is 8 feet 2 inches in diameter. The heavy water portion of each boiler consists of a 14 inch inlet and outlet connection to the channel cover, a Monel clad steel tube sheet 11 inches thick, and 2600, 0.5 inch outside diameter Monel tubes about 59 feet long (0.049 inch wall thickness).

The 16 heat transport pumps are centrifugal, vertically mounted single stage units, rated at 10,100 Igpm at 480 feet head. Each pump is provided with two mechanical seals. They are equipped with flywheels to provide pumping power during reactor rundown following loss of electrical power. An illustration of a heat transport pump is presented in Figure 4.5-7.

4.5.2.2 Pressurizing and Pressure Control System

The heat transport system is kept in a pressurized liquid state by control valves which feed or bleed heavy water to or from the system. The pressure which is controlled is the mean of the pressures in the reactor outlet headers. The nominal operating pressure set point is 1280 psia. The compressibility of the water in the system is such that, at operating conditions, the net addition of one cubic foot of heavy water to the main coolant circuit raises the pressure by about 17 psi. This compressibility allows adequate time for feed and bleed valves to adjust and to maintain the system pressure within an acceptable range, i.e. between low and high pressure reactor trip settings of 1200 and 1384.6 psia. The control band and other important action set points are shown in Figure 4.5-4.

Under steady state conditions, about 14 Igpm of water at 100°F is fed into the circuit and an equivalent mass of 480°F water is bled from it. This normal feed is made up of 12 Igpm in-flow entering from the main pump glands, and 1 Igpm entering each half of the reactor through the feed connections to the east reactor outlet headers. These small flows are maintained in the feed lines to avoid thermal shock which would occur in starting cold feed flow in a stagnant line; a stagnant line would be hot at the connection to the header.

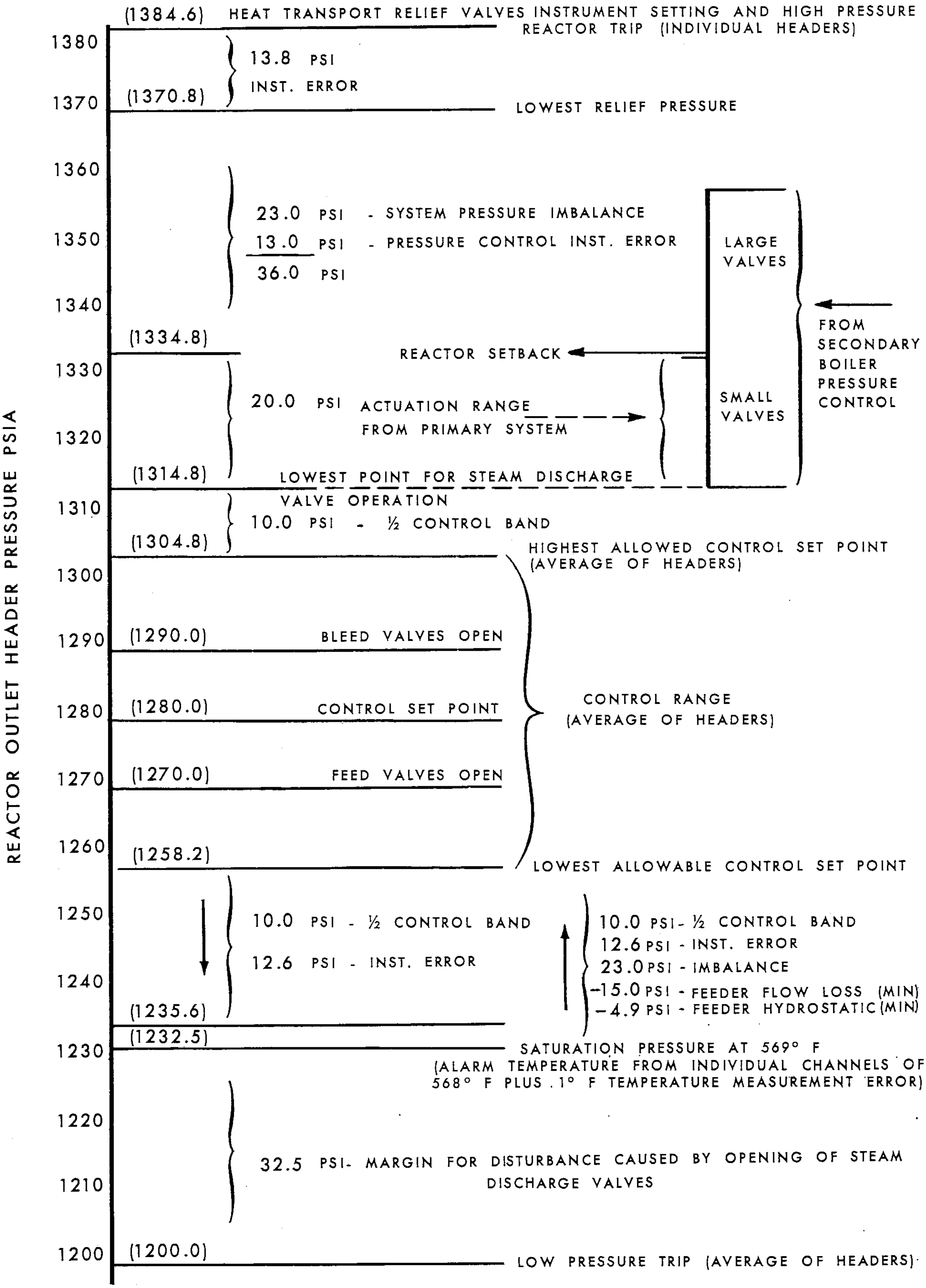
The pressurizing feed flow for the system is provided by two multi-stage vertical centrifugal pumps, each rated at 270 Igpm at 1420 psi nominal head. These pressurizing pumps are installed in parallel, with one pump normally operating and the other available as standby. The pumps are powered by Class III power.

The pressurizing pumps draw heavy water from the low pressure heavy water storage system, which in turn is replenished by the cooled bleed ejected from the pressurized heat transport circuit. Under normal operating conditions 24 Igpm is supplied to the primary circulating pump glands, with approximately 12 Igpm entering the primary circuit, while the remaining 12 Igpm returns through the bleed cooling system to the pressurizing pump suction. The normal steady flows are shown in Figure 4.5-5. The net input to the system is 14 Igpm (cold D_2O) which is the equilibrium bleed flow.

If net cooling and consequent shrinkage in the main circuit takes place, a demand will exist for an increase in the feed flow. The characteristics of the pressurizing pumps, the system, and the feed valves are such that a nominal net make-up of about 243 Igpm can be achieved (including the inflow from pump glands), with the bleed cut off and the main system pressure at or slightly below its pressure control point, and no fuelling machine demand. The fuelling machine could be demanding about 40 Igpm. This is adequate make-up for most transient conditions which the reactor will encounter during operation.

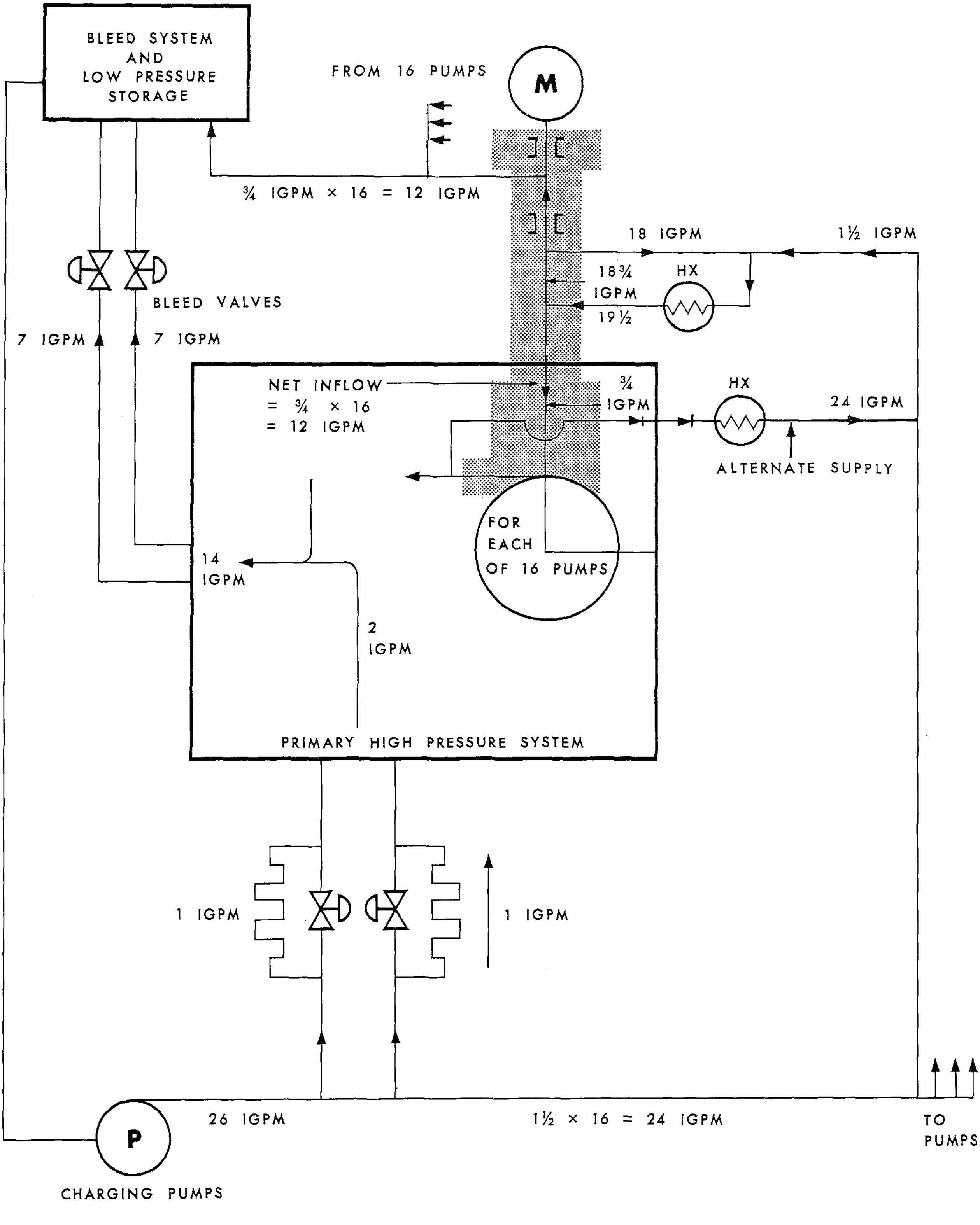
If net heating and consequent swelling in the main circuit takes place, the bleed valves will adjust their opening to increase the bleed and lower the pressure. Flow through the bleed valves is flashing flow at sonic velocity, hence the bleed flow is mainly determined by the opening of the bleed valves. The valves when fully opened are sized to pass a mass flow equivalent to 344 cold Igpm. This is adequate to cover any swell in the primary circuit which can occur with the reactor under normal conditions. The maximum swell occurs when the system warms up at the maximum controlled rate of 5°F/minute, and is equivalent to 152 cold Igpm. The bleed valve must release this plus the 12 Igpm from gland inflow, plus 2 Igpm from feed connection inflows plus an additional flow estimated at 40 Igpm which is put into the main circuit by the fuelling machines during certain stages in the refuelling operation.

The heat transport circuit feed and bleed valves are all provided in duplicate, with independent control systems. Thus, if any one of the valves or its control system were to



4.5—4 HEAT TRANSPORT SYSTEM PRESSURE CONTROL

44.33000-5
1968



4.5-5 HEAT TRANSPORT FEED SYSTEM EQUILIBRIUM FLOW BALANCE

44.33300-1
REV. 1, 1968

malfunction, the reactor would still be able to operate properly and shut down if necessary without a reactor trip. Thus, for example, there are two feed valves to the primary circuit; one to each half. Each valve will pass about 155 Igpm when fully open. If one valve should fail open (with its mate closed attempting to compensate for normal operation) then the maximum flow passing into the system would be still well within the bleed system capability for removal. Conversely, the amount passing through the failed open valves would be adequate for the normal shrinkage requirements of the primary circuit.

The two pressurizing pumps are located in the northeast corner of the boiler room with their bases on the depressed section of the floor at elevation 311 feet 6 inches.

4.5.2.3 Bleed and Gland Cooling

The bleed from the primary system enters the bleed valves at 480°F under normal operating conditions, slightly higher under hot shutdown conditions. The bleed flow flashes in passing through the valves to a considerably lower pressure and saturation temperature on the outlet side. Normally the flashed bleed is about 310°F.

This two phase hot bleed must be condensed, then cooled by a heat exchanger before being passed to the purification system or to the low pressure storage system. The condensing at normal loads is accomplished by a flow of cool heavy water through spray nozzles with the outflow of condensed hot liquid controlled by the liquid level. The condenser will act as a degasser when the vertical reflux condenser is used in lieu of the sprays. A cold zone for degassing is provided. The cooling water for the spray nozzles and the reflux condenser is provided by the main pressurizing pumps.

The condenser pressure must be sufficient to drive the bleed through the bleed cooler and the purification circuit. After condensing, the hot bleed is passed through a single stage bleed cooler.

In addition to the main bleed flow and the gland return flow, the return flow from the fuel handling equipment is directed to the inlet of the bleed cooler. This flow is variable in both quantity and temperature, but will be smaller than the maximum bleed flow rate. The nominal rating of the bleed cooler is 57×10^6 Btu/hr.

The bleed cooler is of conventional shell and tube design with removable U-tube bundles and bolted heads to allow cleaning and maintenance. The heavy water passes through the tubes. The tubes will be welded to the tubesheet. The tube side design conditions are 1250 psig at 480°F. Shell side design conditions are 150 psig at 350°F. Recirculating service water at 85°F will be provided for cooling.

4.5.2.4 Feed to Fuelling Machines

Heavy water for the cooling, heating and operation of the fuelling machines is supplied by two high pressure pumps, designated fuelling machine pumps. The pumps are triplex piston type with a rated capacity of 50 Igpm each at 2400 psi. Each pump is adequate to supply the flow required for the fuelling system, hence only one normally operates, the other serving as standby. The motors are connected to the Class III power system bus.

The fuelling machine pumps draw from the same low pressure heavy water storage system as do the pressurizing pumps. Their suction is placed to take first advantage of the purified and cooled heavy water returning from the bleed cooler.

The fuelling machine requires water at two separately controlled temperatures. Heat exchangers are provided to obtain the temperatures required. The heat source for the heat exchangers is ordinary water steam from the boilers.

A bypass line is provided from the pressurizing pump outlet, for occasions when the fuelling machines are not connected to the reactor and the high head of the fuelling machine pumps is not required. This bypass line has check valves to prevent the higher pressures of the fuelling machine pumps from affecting the pressurizing pumps during normal operation.

Under conditions of failure of both pressurizing pumps a second bypass line may be used to provide a flow of up to 100 Igpm to the pressurizing pump header to provide flow to the gland injection circuit of the main primary circuit pumps and pressurizing flow to the primary heat transport system.

The fuelling machine pumps will be located in the moderator auxiliary rooms at elevation 254 feet, and thus will be accessible during operation.

4.5.2.5 Standby Cooling Equipment

Removal of reactor heat is best performed by the main boilers, and so long as feedwater is supplied cooling can only fail due to a serious failure of the pressure boundary. Also, for all system cooldown operations, the boilers can be used to bring the coolant temperature down to about 350°F. Below 350°F, and for holding the heat transport circuit cold enough to perform maintenance, a standby cooling system is provided.

At each header group of the reactor a pump and cooler is connected between the reactor outlet header and the reactor inlet header. There are thus four standby cooling circuits. The system is designed for 1600 psig and the connections and piping are 10 inch Schedule 100. Each standby cooling pump is a horizontal centrifugal unit rated at 3000 Igpm at about 60 foot head. The standby cooling heat exchangers are of conventional shell-and-tube design with U-tube bundles and bolted heads. The shells will be removable for cleaning and maintenance. Tubes are welded to the tubesheets. The tube side design conditions are 1600 psig at 510°F. The shell side design conditions are 150 psig at 350°F. Each exchanger will use 3750 Igpm of service water at 68°F (maximum). The heat exchangers are designed to withstand rapid temperature transients.

When all four pumps and standby coolers are operating the cooling is adequate to keep the primary circuit below 130°F after a shutdown time of a few hours. If any pump should fail a reduced flow would be maintained through the standby circuit. The temperature of the primary circuit would rise to a level uncomfortably hot for maintenance, but not to a hazardous level. The standby pumps are connected to the Class III power buses.

Each standby cooling circuit is normally isolated from the main primary cooling circuit. The standby circuits are full of low pressure, room temperature heavy water. On first cooling down of the plant, the temperature of the primary system is first reduced by blowing steam from the secondary side of the boilers. This is continued until the primary circuit is down to 350°F. A valving system is provided for passing a small heating flow through the isolated standby circuits during this initial period from about 500°F to 350°F. The standby cooling pumps are started to provide recirculation flow in the standby circuits. Thus the standby circuits are pressurized and brought up to about the same temperature as the primary system by the time the primary circuit temperature drops to 350°F.

At this temperature the isolating valves to the standby cooling system may be opened. The primary coolant pumps must be stopped for the standby system to work, but they will not do so until a standby flow path is assured by opening of the valves. Finally, the standby system brings the temperature down to the desired level.

Each standby cooler can remove 6.5 MW (thermal) during the period it is holding the system at 130°F. The cooler size is sufficient to remove the heat equivalent to 22 MW rejected initially to each standby cooling system at 300°F.

It is physically possible to start the standby cooling circuits with the primary system at 500°F, but the thermal shock and stresses which would result thereby are objectionably high and hence the number of such cycles should be kept very small.

When the standby cooling system is in operation it is permissible to have any or all of the boiler heat exchangers empty. Also, when the temperature is low enough, the pressure at any header can be held by manual control at atmospheric pressure by controlling the quantity of heavy water in the system. This will permit maintenance on any point of the system above the headers without interfering with the operation of the standby cooling system.

4.5.2.6 Overpressure Relief

In the event of certain compound failures in the pressure control system or during certain transients which could result from fault conditions in other systems, the pressure in the primary system could rise above the upper limit of the control range (1304.8 psia).

The first action which would occur if the pressure at the reactor outlet header exceeds 1314.8 psia is that a small steam discharge valve would open to lower the steam side pressure and reflect a reduced average temperature into the heat transport system. If the heat transport system pressure continued to rise the steam discharge rate would increase by opening of additional discharge valves. This is a powerful control and would cope with all known transient conditions, such as loss of a heat transport circulation pump, or sudden closure of a turbine stop valve.

If the heat transport pressure continued to rise to 1334.8 psia a reactor power set back would be initiated. This would be expected to cause a reduction in system pressure. However, if the pressure continued to rise to 1384.6 psia, four instrumented relief valves on the heat transport system would open and discharge hot heavy water to the bleed condenser. The condenser has been sized to accommodate the condition of sudden closure of the turbine stop valves from a depressed operation condition and failure of all steam discharge valves to operate. Its free volume is about 130 cubic feet and it is designed for saturation pressure at maximum heat transport system temperature.

Also, if the heat transport system pressure reaches 1384.6 psia, a reactor high pressure trip will occur.

4.5.2.7 Purification and Gas Control

Two separate identical sets of filters are provided for the primary systems so that one set may be valved out while the other is operating. These filters are located in shielded rooms on the 274 foot level. Filters are provided in: the heat transport system bleed circuit, the fuelling machine water supply circuit, and the circulating pump gland supply system. The filters are 10 and 25 micron, replaceable cartridges. Filters are also provided in a line connecting the reactor inlet and outlet headers enabling on-line cleanup of the main circuit if this is found to be necessary.

A portion of the heavy water effluent from the bleed cooler is passed through ion exchangers for purification. Two ion exchange columns are provided in each shielded room on the 274 foot level. The maximum flow through two ion exchangers in parallel is 100 Igpm, equal to the rating of both fuelling machine pumps. If the ion exchange resin in one pair of columns is expended or the beds become plugged the flow can be manually transferred to the alternate pair of ion exchange columns in the other shielded room. The ion exchange columns and enclosure are designed for easy removal and permanent storage as solid waste.

Degassing of the heat transport system will be accomplished within the bleed condenser prior to ion exchange as required. The gas control system collects and discharges vapour, oxygen, fission product and other off-gases to the leakage collection tank and thence to the boiler room air-dryers. The heavy water coolant is kept very low in oxygen by running under slightly reducing conditions with a few cm^3/litre of excess deuterium in the coolant. Since excess deuterium is considered detrimental to zirconium, the actual concentration of deuterium will be kept as low as proves feasible for good system chemistry.

4.5.2.8 Heavy Water Storage and Gas Cover

A storage tank capable of holding 1400 cubic feet of heavy water is provided at the northeast end of the boiler room floor. The tank has been sized to contain all the water expanded from the primary system in raising the temperature from 70°F to operating conditions, plus some space for cover gas. The atmosphere within the tank will be helium and the operating pressure will vary from a slight vacuum to 10 psig.

4.5.3 Emergency Coolant Injection and Recovery

4.5.3.1 Injection System

Provision is made to pump heavy water from the moderator system, using the moderator pumps, into the heat transport system so that in the event of loss of primary coolant of a major magnitude cooling of the fuel can be maintained or restored.

For small leaks in the heat transport system the normal make-up system provides water to keep the system full. The emergency injection system is provided to prevent fuel overheating following a loss of coolant accident.

The emergency injection required to prevent fuel failures following the worst postulated loss of primary coolant failure is 3500 Igpm. The moderator pumps will provide at least 4000 Igpm injection at 15 psig at the injection point. A detailed account of emergency injection requirements following several postulated accidents is given in Volume II of this Report.

The Pickering heat transport system has two loops. The emergency injection system is arranged with connections from the moderator system to each standby cooling circuit (four connections) between the main isolation valves of the standby circuit. On an indication of low pressure (100 psia) in the heat transport system the valves in the emergency injection system from the moderator system to the reactor heat transport inlet headers in the loop with the low pressure open automatically. These valves require about 15 seconds to open fully. The moderator circulating pumps will fill the emergency injection piping with moderator water in less than 15 seconds after the valves are open and provide a pressure of approximately 30 psia at the check valve adjacent to the injection point. When the pressure in the heat transport system falls below the available injection pressure the check valves will open, allowing the injection flow to start.

In the event that it is known from the instrumentation provided that failure has occurred in a reactor inlet header, the emergency injection water may be redirected by the operator by remote manual operation of the standby system isolation valves.

In Douglas Point the emergency injection system operates automatically and automatically selects the injection points by detection of differences in pressure between the inlet and outlet reactor headers. In Pickering the emergency injection takes place automatically into the appropriate reactor inlet headers and requires manual redirection to other headers. The reasons for this automatic injection - manual redirection arrangement are:

(1) For all accidents except large failures at or near a reactor inlet header, the best injection points are both reactor inlet headers in that heat transport system loop. If pipe or component failures occur anywhere in the boiler room or if any of the reactor outlet piping or channels fail, emergency injection into the reactor inlet headers after depressurization would provide emergency coolant water at the entrance to each inlet feeder pipe and thus to each reactor channel.

(2) With the Pickering heat transport system valve arrangement, the fuel is adequately cooled by the discharging coolant during any loss of coolant accident for a certain period of time. Emergency injection is only required after the system is essentially depleted of coolant. Even for the maximum accident, no fuel would be expected to fail if the cooling were interrupted for approximately 100 seconds.

(3) Alternative injection points and instrumentation to detect the correct injection points and initiate injection at Douglas Point are intended to prevent injection into a failed header. Although we consider pipe failure areas equal to the cross-sectional area of a reactor header, failure of the headers is improbable. The headers have a larger margin of safety against failure due to overpressure than other components in the circuits and are more robust than the connections to the header.

(4) If a pump outlet pipe failed at the reactor inlet header, it may result in a large hole in the top part of the header. Coolant would be discharged out of this hole from the reactor channels flowing in reverse and from the pump and boiler side. Injection of water into both reactor inlet headers of that heat transport system loop after the system became depressurized would provide coolant to all the fuel channels. Injection into both inlet and outlet headers at the opposite end of the heat transport system loop from the failure would, of course, provide more prompt cooling on one half of the fuel but would require knowledge of the failure location.

(5) If an inlet feeder pipe (or pipes) fails, some of the injected water would be wasted. However, unless a large number of inlet feeders fail, the loss of injected water would not be significant. The fuel in the failed channels would be cooled by reverse flow through the normal outlet end.

(6) For a system which is required to operate reliably in the event of a very improbable accident it is the designer's opinion that the minimum of complexity should be a major consideration. Automatic injection into reactor inlet headers on detection of low heat transport system pressure involves the minimum of complexity.

(7) The system can be fully tested with the exception of actual operation of the check valve.

4.5.3.2 D_2O Recovery Systems

If a break occurs in the heat transport system in the fuelling machine vaults, about one-third of the escaping water will initially flash to steam and be carried to the Vacuum Building. The remaining two-thirds of the discharge will remain as water and would be expected to collect in the vault. Subsequent coolant discharge would be progressively less volatile and eventually would be discharged as warm water. A drainage system consisting of sloping floors and open drains will provide a path for the water to flow by gravity to the sumps in the fuelling machine service rooms. A 12 inch connection from this sump to the moderator pumps will provide a return path for the discharged water through the moderator pumps and coolers back into the primary system via the emergency injection points. A connection from the 12 inch line to a low NPSH pump of 400 Igpm capacity will provide a return path to the pressurizing pump suction for a moderate leak in the primary system.

If the primary system break occurs in the boiler room the unflashed water would be expected to collect on the boiler room floor. A system of sloping floors and drains will conduct this water by gravity to the sump in the fuelling machine service rooms.

4.5.4 Steam-Water System (Secondary System)

4.5.4.1 General

The portions of the secondary system outside the Powerhouse are: the feedwater lines, the reheater drains lines, the boilers, the blowoff and drain system, the steam lines, and the safety relief valves and steam discharge valves on the steam main.

The steam from the boilers will be conducted to the 28 inch steam mains (4) inside the Reactor Building by 20 inch connecting pipes.

Under full power conditions the steam leaves the steam separators at 593.3 psia (485°F). An allowance of 8 psi is made for pressure drop from the boiler steam separators to the turbine throttle valves. Under reactor shutdown conditions the steam conditions are 744.3 psia (510°F). The safety valves on the steam lines will be set to cover a range of pressure from 780 psig to 803.4 psig.

Safety valves and steam discharge valves will be located on each of the four 28 inch steam mains where they pass outdoors between the Reactor Building and the Powerhouse. There will be several safety relief valves on each steam main with a total discharge capacity in excess of full power steam flow, and several steam discharge valves also capable of discharging full power steam flow. The use of the steam discharge valves to control secondary system pressure is discussed in Section 7 of this Report. Under hot shutdown conditions when the reactor power is less than 5 percent of normal, or during minor transients in the heat transport system, the discharge from the steam discharge valves is directed to the forebay where the steam is condensed. Under abnormal transient conditions, a part of the steam may be discharged to the atmosphere.

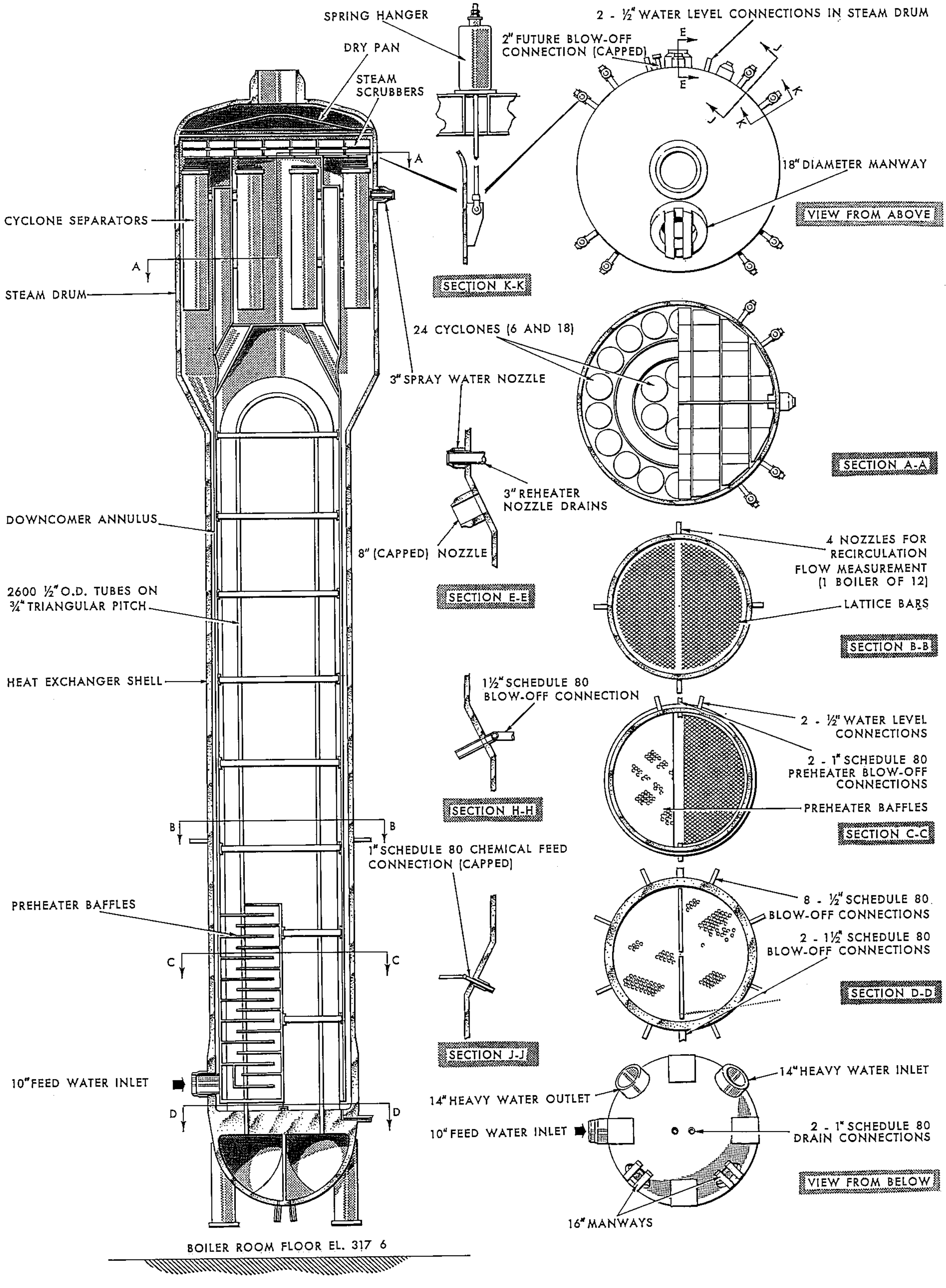
4.5.4.2 Boilers

Sectional views of the boilers are shown in Figures 4.5-6A and 4.5-6B. Boiler data are listed in Table 4.5-3.

Each of the 12 boilers consists of a single integral U-tube-in-shell heat exchanger and steam separator head, feed water and blowdown connections and headers. Recirculation takes place inside the 5 feet 5 inch internal diameter shell in an annulus provided between the shell and the Monel boiler tubes. Each boiler will be suspended from structural steel beams and columns by spring supports and will also receive support from four pedestals under each boiler at the boiler room floor level.

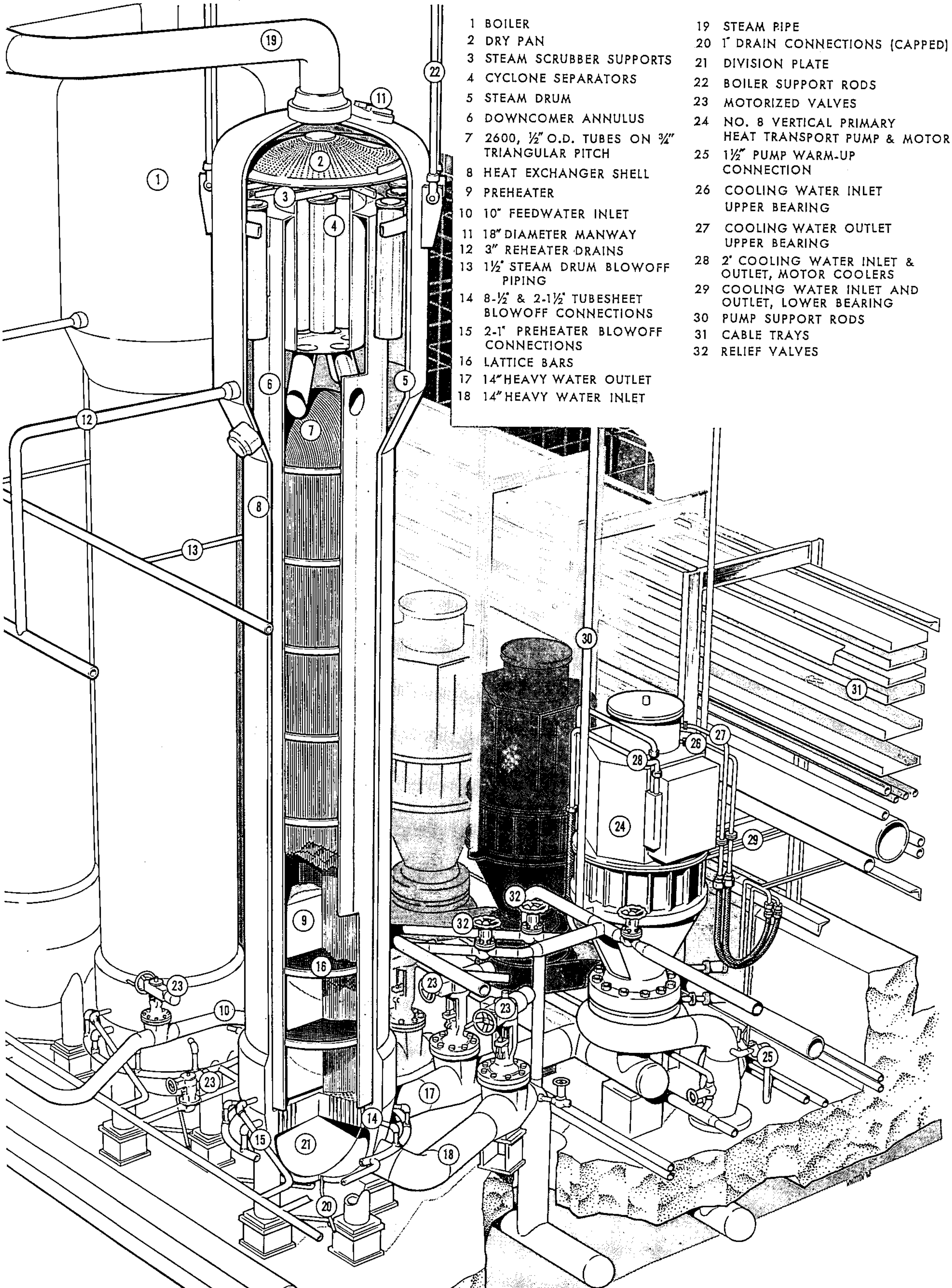
The steam separating head of each boiler is connected to the steam main by 20 inch connecting pipes with no intervening valves. The 28 inch steam main from each group of three boilers proceeds separately to the Powerhouse where the four mains enter a common crossover section before entering the governor and stop valves, and the turbine steam chest, in that order.

The section through the boilers, Figures 4.5-6A and 4.5-6B, shows the feedwater connections where the 340°F feedwater enters a preheater section of the boilers. Baffles are provided to prevent unacceptable thermal stresses in the tube sheet at the preheater. After passing through the preheater the feedwater enters the main section of the boiler at the saturation temperature and joins the recirculation water from the steam separating head in producing steam. Steam mixed with water enters the separating head of the boiler. Water recirculates through the downcoming annulus inside the shell at a mass rate in excess of eight times the rate of steam formation. The steam separators in the boiler head separate the water and steam to give a steam quality of 99.8 percent.



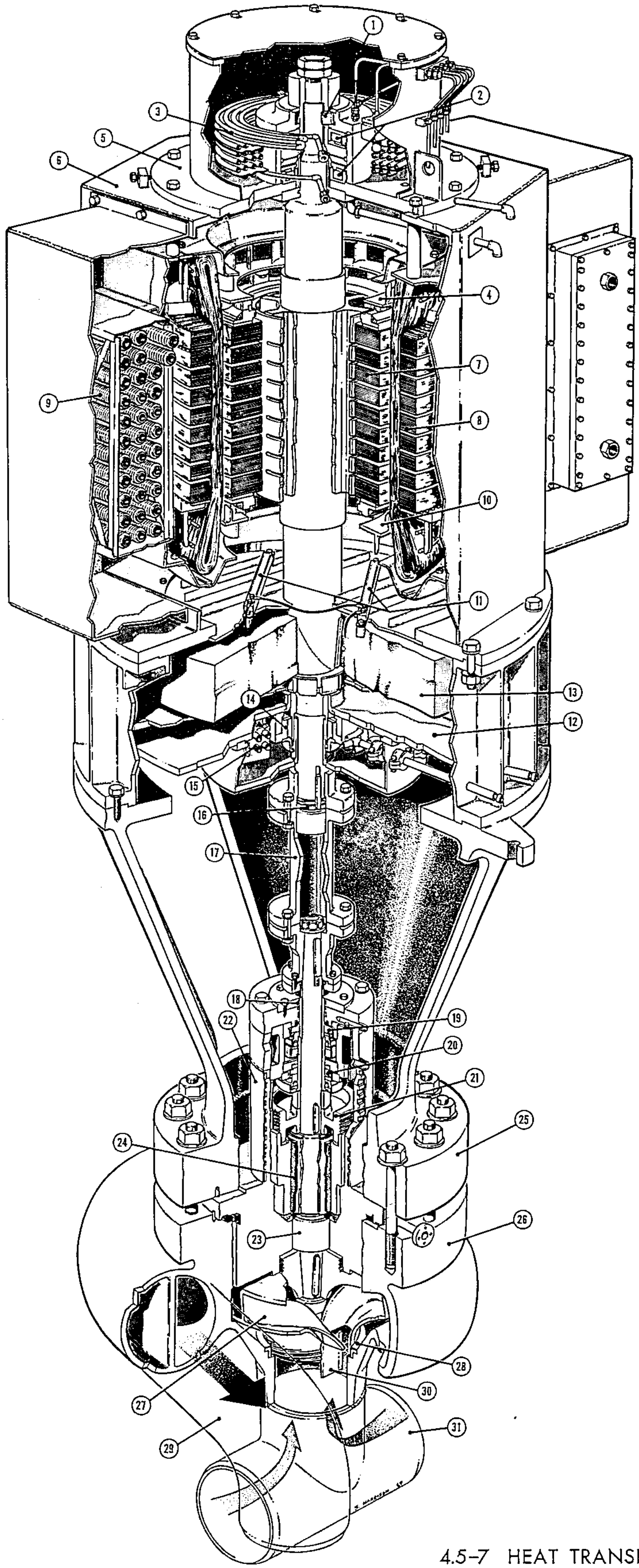
4.5—6A BOILER SECTION

44.3311 0-3
REV. 1, 1968



4.5—6B PRIMARY SYSTEM BOILERS & PUMPS

44.33110-1
1968



1 UPPER GUIDE BEARING
2 THRUST BEARING
3 BEARING COOLING COILS
4 AIR CIRCULATION FAN
5 UPPER BEARING BRACKET
6 MOTOR FRAME
7 ROTOR
8 STATOR
9 STATOR COOLERS
10 AIR CIRCULATION
11 SPACE HEATERS
12 LOWER BEARING BRACKET
13 FLYWHEEL
14 LOWER GUIDE BEARING
15 BEARING COOLING COILS
16 THRUST DISC
17 SPACE COUPLING
18 VAPOUR CONTAINMENT SEAL
19 SECONDARY MECHANICAL SEAL
20 PRIMARY MECHANICAL SEAL
21 RECIRCULATION IMPELLER
22 PUMP COVER
23 THROTTLE BUSHING
24 PUMP BEARING
25 MOTOR STAND
26 PUMP CASE
27 PUMP IMPELLER
28 CASE WEAR RING
29 PUMP DISCHARGE ELBOW
30 ANTI-ROTATION VANE
31 SUCTION TEE

4.5-7 HEAT TRANSPORT PUMP

44.33122—1
REV. 1, 1969

Four feedwater headers enter the Reactor Building above the boiler room floor level (317 feet). Each feedwater header connects to three boilers with intervening isolating valves. Each feedwater header also has a check valve within the boiler room to prevent loss of feedwater in the event of failure of the feedwater header outside the boiler room.

TABLE 4.5-3

BOILER DATA

Performance	
Total number of boilers	12
Steam output	6,459,387 lb/hr
Steam pressure	593.3 psia
Steam temperature	485°F
Feedwater flow	5,969,862 lb/hr
Feedwater temperature	340°F
Reheater drains return flow	489,525 lb/hr
Reheater drains temperature	483°F
Heavy water flow	58,579,000 lb/hr
Heavy water inlet temperature	560°F
Heavy water outlet temperature	480°F
Heavy water pressure at boiler inlet	1270 psig
Heavy water pressure at boiler outlet	1248 psig
Recirculation ratio (minimum)	8.0
Moisture in steam wt %	0.20
Physical	
Height (overall including steam head)	46 ft 7 in.
Diameter — heat exchanger	5 ft 8-1/4 in. O. Dia
— steam separating head	8 ft 2-3/8 in. O. Dia
Thickness of tube sheet	11.125 in.
Number of tubes per boiler	2600
Diameter of tubes	0.50 in. O. Dia
Wall thickness of tubes	0.049 in.
Total length of heat transfer tubing per boiler	152,800 ft
Total length of heat transfer tubing per boiler - boiling	132,554 ft
Total length of heat transfer tubing per boiler - preheating	20,246 ft
Dry weight	185,000 lb

Blowoff connections to each boiler are provided to allow boiler blowoff during normal operation without upsetting the behaviour of the heat transport system. Blowoff is used principally to remove solids and dirty water from the boilers.

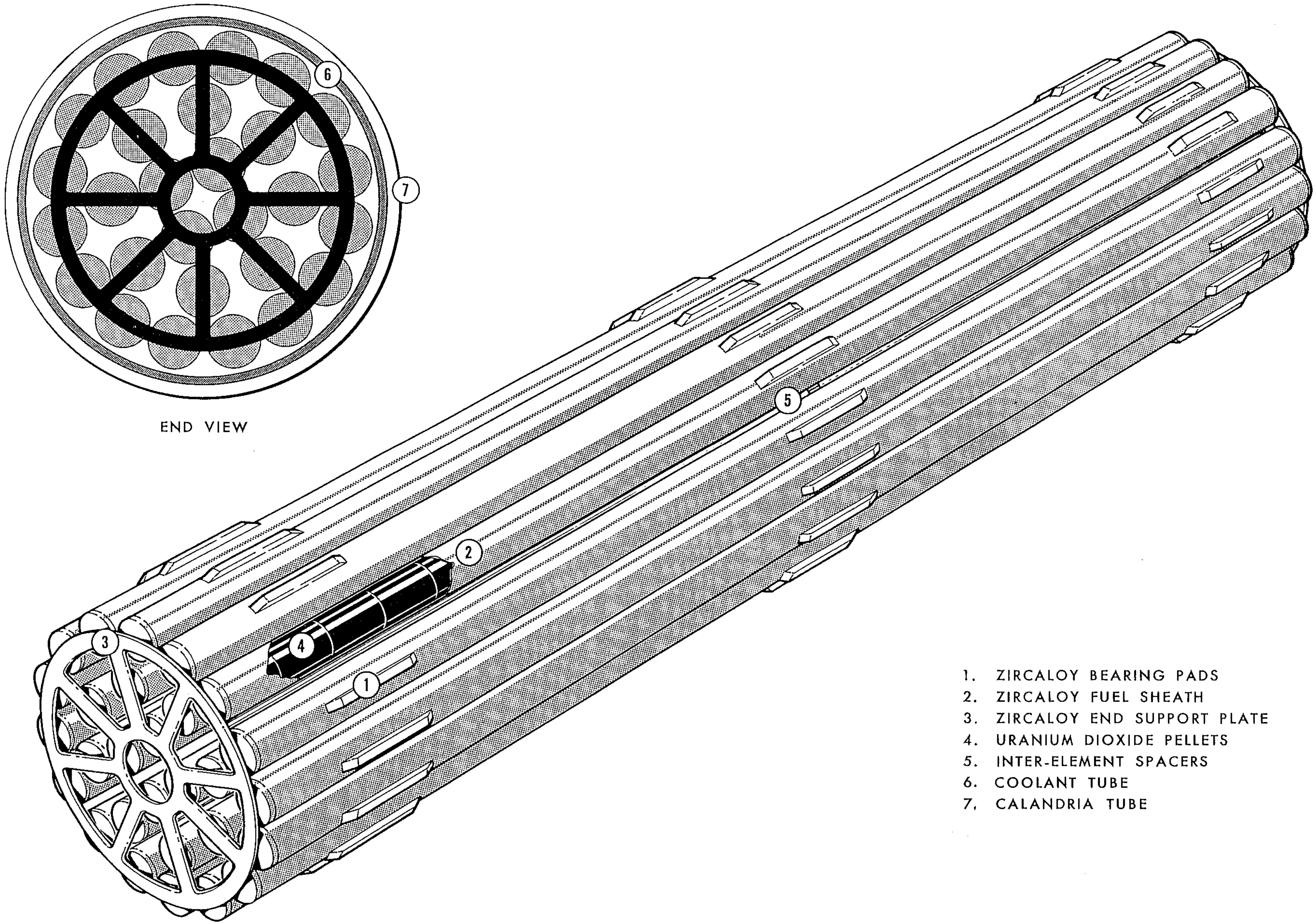
4.5.4.3 Boiler Water Systems

Feedwater to the boilers will be regulated by control valves on the four feedwater headers in the Powerhouse. Two separate feed mains each supply two sets of three boilers independently. The normal feedwater temperature is 340°F but will drop to about 250°F at low power operation due to reduction in feed heating. A connection to supply live steam from the main steam supply to heat the feedwater will be provided to ensure that the feedwater does not drop below the minimum acceptable temperature to the boilers of 240°F.

In the event of a reactor trip and fast cooldown, the water in the boilers would be depleted when the boiler temperature reached 350°F (the temperature at which the primary standby cooling system is designed to operate). A small reliable supply of feedwater is required to ensure that adequate water remains in the boiler under these transient conditions and also during normal reactor shutdown conditions to remove afterglow energy. A small (2% of normal) feed pump will be supplied, connected to the Class III electrical power system.

Provision is being made for a "poison prevent" system to allow reactor operation for one hour at 70 percent of full power in the event of loss of electrical load to the station. This system consists of a supply of demineralized water (4 million pounds per reactor) and connections to the deaerator from the steam main to supply steam to heat this water to the minimum acceptable to the boilers (240°F). These connections and the deaerator surface area will be designed to provide heat to 70 per cent of normal feedwater flow to raise its temperature from 40°F to 240°F.

To cover the remote contingency of loss of all feedwater supply or a break in a feedwater pipe outside the Reactor Building, a 17,000 Imp. gallon elevated supply of water is located in each Reactor Building. This supply can only be connected to the boilers when they are at low pressure and could be used after they have blown dry and depressurized. The 17,000 Imp. gallon supply would provide shutdown reactor cooling for about 2 hours.



5.2—1 28 ELEMENT FUEL BUNDLE

21.37500.1
1968

5.1 GENERAL

The general principles on which the designs of the reactor fuel and the fuel handling equipment and systems are based are similar to those adopted for the Douglas Point Nuclear Power Station. These in turn are in some aspects similar to, or are developments from those used in the design of the fuel and fuel handling equipment for the NPD—2 station at Rolphton.

The fuel consists of uranium dioxide in the natural isotopic proportions, in the form of fuel bundles. The bundles are made up of "elements" in the same general configuration as the Douglas Point fuel, although the diameter of the bundles is greater. The elements (in the first charge) have the same dimensions as the Douglas Point fuel, but the bundle assembly details are different.

The approach to fuel handling and refuelling differs in details from that followed at Douglas Point. This is dictated to a large degree by the physical size of the station, successful development of various components of the Douglas Point station and a desire to simplify the conceptual approach in certain areas of the fuelling system. The principles of on-power, once-through refuelling and permanent underwater storing of spent fuel in a bay outside the Reactor Building are retained. All fuel handling operations within the Reactor Building are controlled by automatic sequencing from the station control room; optional manual overrides are provided, however, so that the station operator can vary the sequences to meet unusual conditions.

Basically the fuel handling, transfer and storage systems consist of the following three interrelated components and mechanisms:

(i) Two fuelling machines

(ii) Fuel transfer system

(iii) Spent fuel storage and inspection bays.

5.2 REACTOR FUEL

5.2.1 General

The fuel assemblies are bundles of cylindrical elements made up of compacted and sintered natural UO_2 pellets in Zircaloy sheaths. The first charge is designed and fabricated to make the maximum use of technology developed in the production of fuel for NPD and Douglas Point. However, the design and fabrication methods for the fuel are expected to change somewhat during the life of the plant as experience is gained and advances are made in fabricating lower cost fuel.

Two fuel designs were given preliminary consideration for the first charge of the Pickering reactor. These are: (i) 28-element bundles with the element length and diameter identical to those used in the 19-element Douglas Point fuel, and (ii) 22-element design with graded diameter elements and the same overall length (i.e. 19.5 inches). The development of the 28 element fuel was given priority for the first charge. The reactor is also capable of operating efficiently with 22 element fuel operating at a maximum $\lambda d\theta$ of 48 watts per centimeter. The remainder of this fuel description will be concerned only with the 28 element bundle design for the first charge.

5.2.2 Fuel Duty

The fuel bundle is introduced into the reactor coolant tubes by remotely operated fuelling machines, which in combination with hydraulic drag forces can exert a maximum compressive load on a bundle of 1800 pounds. In normal use, the bundles reside in a low power position first, and then advance to higher power positions in a number of moves at intervals by sliding along the coolant tube. Each fuel bundle will pass the maximum power position about half-way through its life. After that, the power will decrease with subsequent moves until it is ejected by the fuelling machine.

The fuel will experience a maximum of six moves or as few as three moves in passing through the core depending on the number of bundles fuelled at one time. The selected number of moves will be the optimum based on the consideration of factors such as, coolant tube wear, fuel burnup and the required number of refuelling operations. The on-power refuelling operation moves the fuel past the point of residence and returns it to its new residence position during a period of a few minutes. The incoming fuel will, therefore, experience a higher heat rating during refuelling than during subsequent residence, up to the mid-way residence position.

5.2.3 Bundle Design

The twenty-eight fuel elements are held together in a bundle, at the ends, by end-plates and are separated by spacers attached to the sheaths near the mid-plane of the bundle as shown in Figure 5.2-1. Forced sub-channel coolant mixing is considered unnecessary.

Inter-element spacers are of the skewed split-spacer type. One-half of the spacer is attached to each of the neighbouring elements such that the half-spacers contact each other at a skewed angle to reduce any tendency to "lock" because of vibration. The design of the split spacers is such that the minimum inter-element spacing at the spacer location after maximum anticipated fretting wear will be not less than 0.040 inch.*

A bearing pad is provided at or near the mid-length of each element of the outer row to prevent the fuel sheaths

* *"Conceptual Design and Interium Performance Specification - 500 MWe Reactor Fuel", Power Projects Specification NP—E—385.*

TABLE 5.2–1

REACTOR COOLANT CHANNEL SPECIFICATIONS AND NOMINAL FUEL DIMENSIONS (28–ELEMENT FUEL)

Channel Specifications

Coolant tube I.D. (cold, unpressurized)	$4.070 ^{+.018}_{-.000}$ in.
Core length (between calandria tube sheets)	19 ft. 6 in. (594 cm)
Maximum channel power (normal)	5.125 MW
No. of coolant tubes in core	390
Lattice pitch	11.25 in. (28.6 cm)
No. of fuel bundles in core	4,680
No. of fuel bundles in channel	12

Nominal Fuel Dimensions

Length of bundle	19.5 in. (49.5 cm)
O.D. of bundle (over bearing pads)	4.030 in. (10.2 cm)
Weight of bundle	54.5 lbs (23.7 kgm)
Sheath O.D.	0.598 in. (1.52 cm)
Sheath thickness	0.016 in. (0.041 cm)
Inter-element spacing (minimum)	0.050 in. (0.127 cm)
UO_2 diameter	0.564 in. (1.433 cm)
Coolant tube cross-sectional area	13.010 in^2 (83.9 cm^2)
Fuel bundle cross-sectional area (including sheath)	7.864 in^2 (50.7 cm^2)
Coolant flow area	5.146 in^2 (33.2 cm^2)
UO_2 area (mid plane)	7.020 in^2 (45.29 cm^2)

Maximum Heat Rates and Power Distribution

Neutron flux depression — maximum to average in bundle at irradiation at 2.0 n/kb	1.29
No. of elements in outer ring	16
No. of elements in intermediate ring	8
No. of elements in centre ring	4
Maximum $\lambda d\theta$ — outer ring	41.8 W/cm
Maximum $\lambda d\theta$ — intermediate ring	33.4 W/cm
Maximum $\lambda d\theta$ — centre ring	29.4 W/cm
Maximum linear power outer ring	8.41 kW/cm
Maximum linear power intermediate ring	3.36 kW/cm
Maximum linear power centre ring	1.48 kW/cm
Total maximum linear power	13.25 kW/cm
Total maximum linear power corrected for material at bundle ends	12.85 kW/cm
Specific fission power — average	18.8 W/gm_u
Specific fission power — maximum	32.2 W/gm_u
Maximum surface heat flux (nominal)	350,000 $Btu/ft^2.hr$ (112 W/cm^2)

Operating Conditions

Estimated pressure drop — 12 bundle string	80 psi
Maximum UO_2 temperature	3,632°F (2000°C)
Maximum sheath temperature (outside)	579°F (304°C)
Coolant temperature inlet	480°F (249°C)
Coolant temperature outlet	560°F (293°C)
Coolant pressure, inlet to fuel	1,385 psia
Coolant pressure, outlet from fuel	1,300 psia
Maximum coolant velocity at outlet of maximum rated channel	29.3 ft/sec (896 cm/sec)
Maximum axial force on bundles during refuelling	1,800 lbs.
Distance bundle moved over Zircaloy and stainless steel in passing through reactor	160 ft.

Fuel Charge and Residence Time

Total weight of UO_2 in core	232,000 lbs UO_2 (116 tons)
equivalent	92.3 $tonne_u$
Average fuel residence time	14,000 hours
Minimum fuel residence time	11,600 hours
Maximum fuel residence time	21,000 hours
Average NO. of bundles loaded per day at 80% load factor	9
Estimated burnup	8,000 MWd/te

from touching the coolant tube. An approximate full-scale cross-section of the fuel and coolant tube is shown in Figure 5.2-2. A summary of the fuel design data and operating conditions is given in Table 5.2-1.

It has been decided to use Zircaloy-4 as the sheathing material for the Pickering fuel instead of Zircaloy-2 which was used exclusively for the Douglas Point fuel and for most of the NPD fuel. The choice of sheathing material was based on in-pile and out-pile tests and the cost and availability of Zircaloy-4. Table 5.2-3 gives a comparison of some of the relevant properties of these two materials.

The fuel elements are identical with those of the Douglas Point fuel, with the exception of sheath attachments which are different. They are fabricated by the same methods. The bundle assembly methods are the same as for the Douglas Point fuel, but it is possible that some minor modification will be required because the diameter of the end plate relative to the pitch diameter of the outer element is smaller than for the Douglas Point fuel. The increased depth of the gap between contacting bundles is required to allow greater contact with the fuelling machine sensor-pusher than is possible in the Douglas Point system.

Bearing pads and spacers are attached to the sheath by a beryllium-zircaloy bond. Satisfactory joints have been made and irradiated in NRU and NPD.

5.2.4 Distribution of Heat Generation in the Bundle

The flux distribution in a newly loaded 28 element bundle has been experimentally determined and reported by CRNL.* The calculated values of $\lambda d\theta$ and linear power of the three rings of elements and flux distribution through the bundle based on these experimental data are shown in Table 5.2-2 and Figure 5.2-3. The measured flux distribution corresponds to a maximum-to-average flux ratio of 1.26 as compared to 1.28 for the 3.25 inch Douglas Point 19-element bundle. It is estimated that at a burnup of 2 neutrons per kilobarn the maximum-to-average flux ratio in the 28 element bundle will be approximately 1.29.

5.2.5 Sheath and Coolant Temperatures

The sub-channel coolant flow areas, coolant velocities and heat input are shown in Table 5.2-2. The measured sub-channel mixing flow in 19-element fuel with no wire wraps was approximately 0.2 lbs/ft second. The sub-channel temperatures in the 28-element design with a cosine heat flux shape along the channel length are shown in Figure 5.2-4. A sub-channel mixing flow of 0.2 lbs/ft second is assumed.

The maximum external sheath temperature in the maximum rated channel is also shown in Figure 5.2-4. It will be noted that the maximum sheath temperature may exceed the coolant saturation temperature by about 5°F. Nucleate boiling would begin on the sheath surface at about 10°F above the coolant saturation temperature, based on the correlation of Jens and Lottes.*

** CRNL Progress Report, January 1 to March 31, 1965, PR-RRD-41.*

TABLE 5.2—2

SUB—CHANNEL COOLANT FLOW AREAS, COOLANT VELOCITIES AND POWER

28-Element, 594 cm (19 ft. 6 in.) channel, 10.34 cm (4.07 in.) Pressure Tube

Sub-Channel Number	Coolant Area cm^2	Coolant Velocity cm/sec	Linear Heat Rate W/cm
1	0.224	754.1	89.42
2	2.474	932.4	841.06
3	1.690	878.1	655.88
4	0.311	591.0	237.62
5	0.822	715.7	294.93

Total heat produced = 4.99 MW

Total mass flow = 22.2 kg/sec

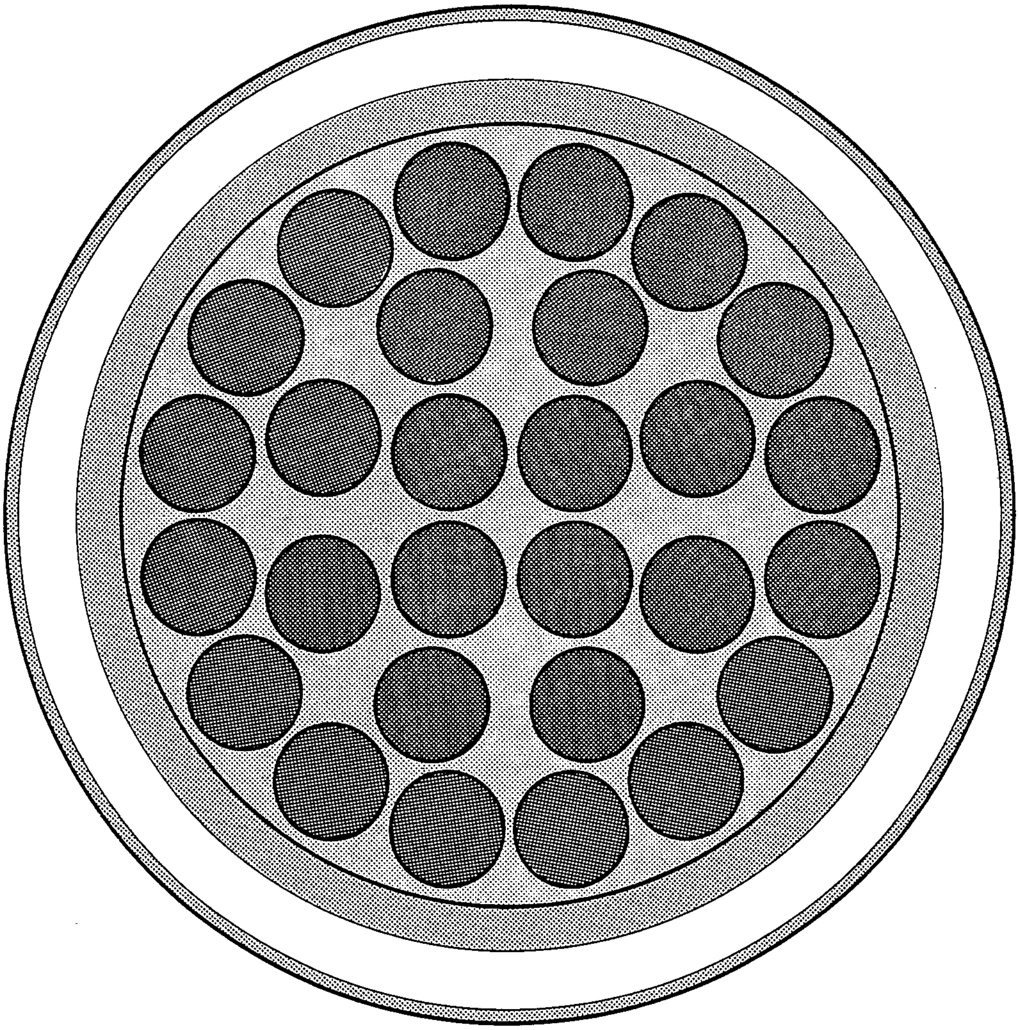
= 1.76×10^5 lb/hr

ΔT_{av} = 44.45°C = 80°F

5.2.6 Element Bowing

Differential thermal expansion at the shoulder of the pellet dish between the high and low temperature sides of the outer elements may produce bowing of the fuel element if there is no axial clearance between pellets at full power. Since the flux depression in the 28-element bundle is approximately the same as that in the Douglas Point 3.25 inch 19-element bundle, bowing in the former is expected to be not greater than 0.055 inch as estimated for the 19-element bundle. This bowing would be elastic unless the axial stress in the sheath is high. In the event that the axial sheath stress is at the yield point the bowing may be

** Jens, W.H. and P.A. Lottes, ANL-4627 (1951)*

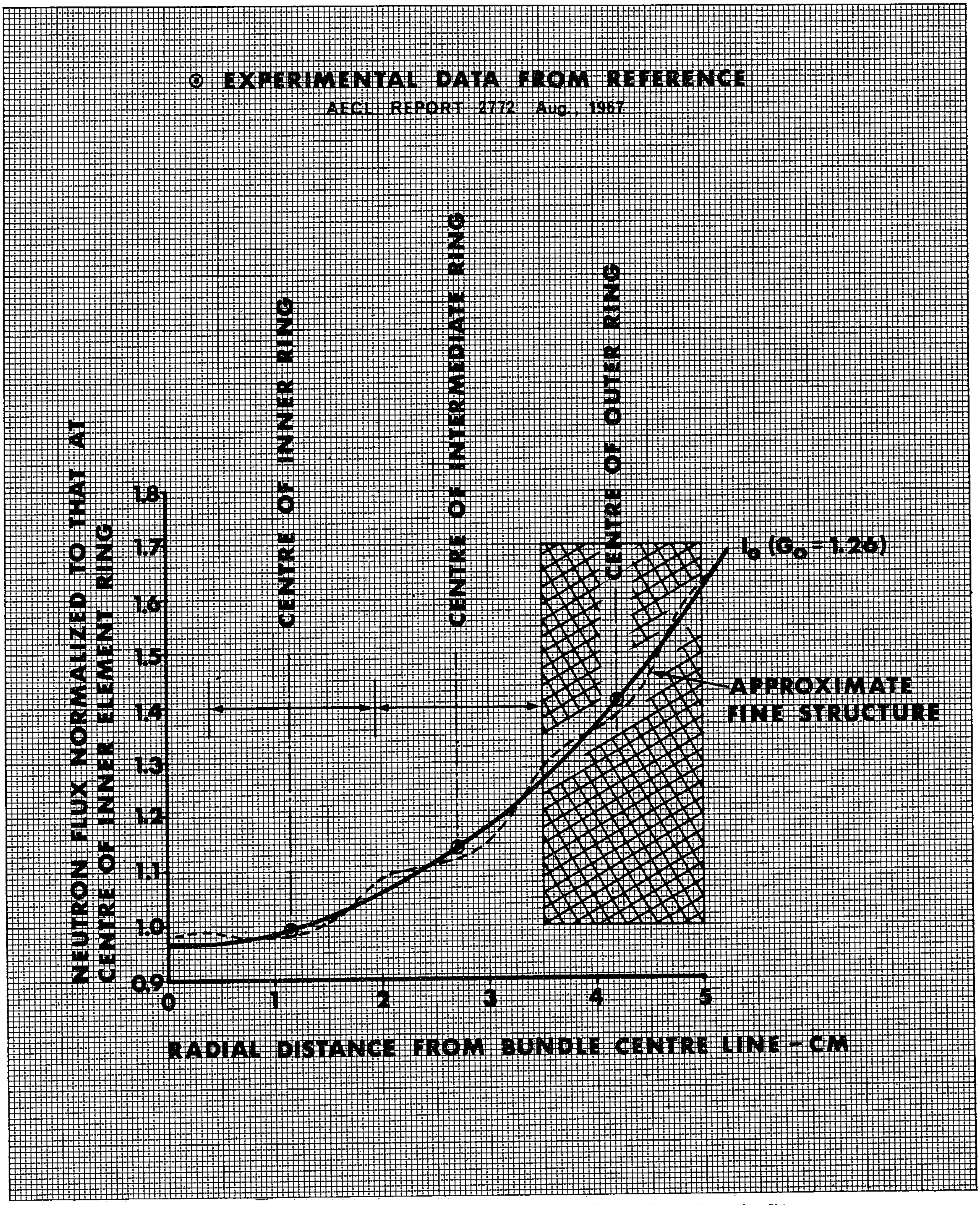


28 ELEMENT BUNDLE

FULL SCALE CROSS SECTION
OF FUEL AND COOLANT TUBE

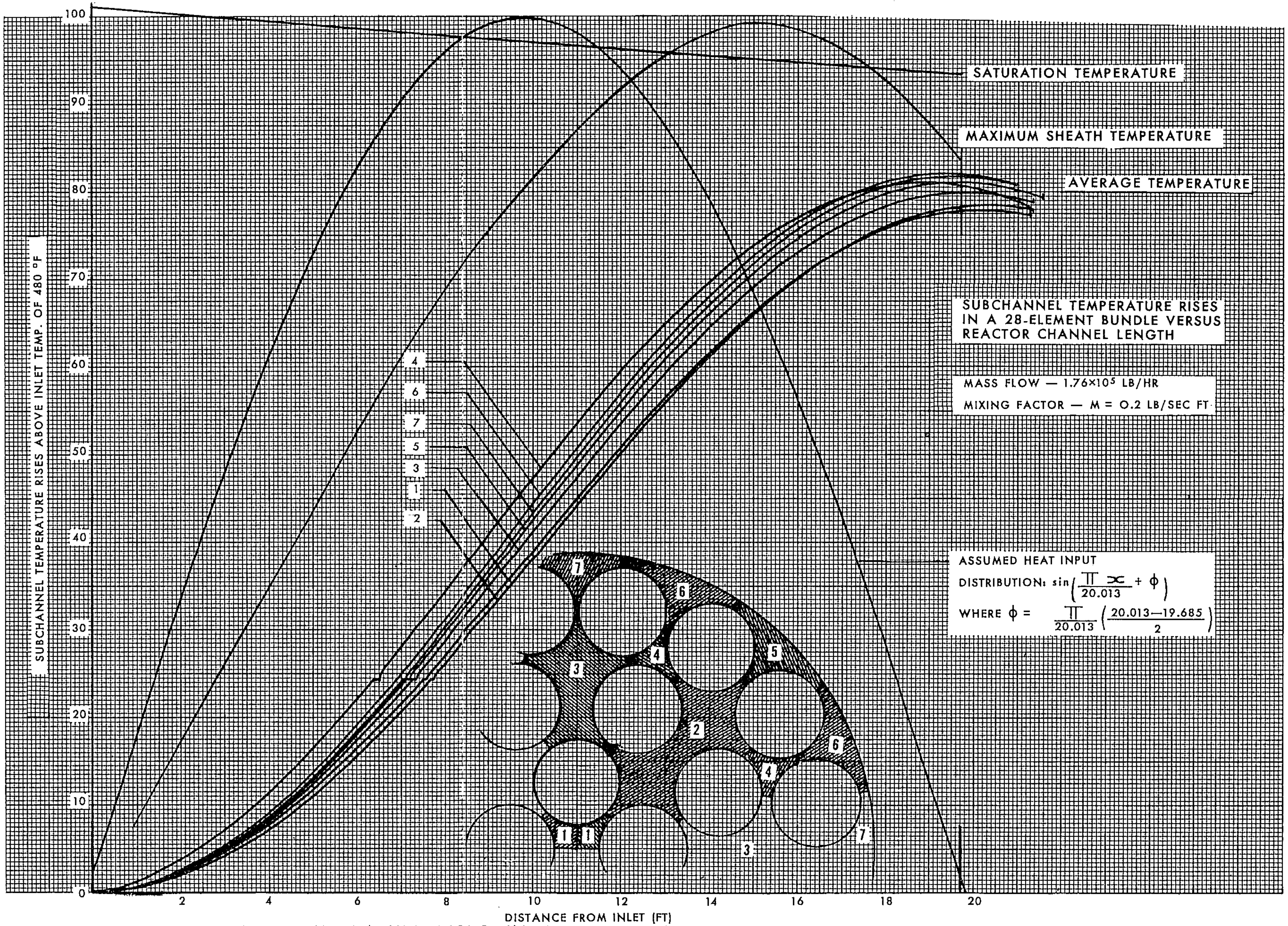
5.2—2 CROSS SECTION OF FUEL AND COOLANT TUBE

44.37500-3
REV. 1, 1968



5.2—3 FLUX DISTRIBUTION THROUGH OUTER FUEL ELEMENT OF 28-ELEMENT BUNDLE

44.37000—12
REV. 1, 1968



5.2—4 SUBCHANNEL TEMPERATURE RISES IN A 28 ELEMENT BUNDLE VERSUS REACTOR CHANNEL LENGTH

44,37500—4
1968

permanent.

Bowing of an outside element at maximum fuel rating would be in excess of the diametrical clearance between the central bearing pads and the coolant tube. It would appear that the fuel element may bow sufficiently that the central bearing pad will touch the coolant tube and be restrained from further bowing by a relatively small lateral force between the bearing pad and coolant tube. This conclusion is in accord with the results of the NPD-2 Prototype Fuel Moving Experiment in the U-2 loop (Experiment NRU-913) where the force required to move the fuel string increased by about 25 pounds between zero power and full power. The power ratings in this moving test were generally less than $\lambda d\theta = 40$ W/cm. However, one 7-element bundle (1.0 inch diameter element) operated at an $\lambda d\theta$ of 53 W/cm toward the end of the experiment.

TABLE 5.2—3

ZIRCALOYS

Element	Zircaloy—2	Zircaloy—4
Sn	1.20 – 1.70	1.20 – 1.70
Fe	0.07 – 0.20	0.18 – 0.24
Cr	0.05 – 0.15	0.07 – 0.13
Ni	0.03 – 0.08	0.007maximum

Sum of Fe, Ni and Cr in Zr-2 must range between 0.18 and 0.38.

Sum of Fe and Cr in Zr-4 must be 0.28 minimum.

Neutron Absorption Cross Section

Approximately the same, but Zr—2 slightly smaller.

Corrosion

Water at 300°C — Approximately the same — 0.03 mdd* for the post-transition rate.

Steam at 400°C — Approximately the same — 1 mdd for the post-transition rate.

Hydrogen Pickup

In water up to 360°C — Zr-4 better than Zr-2.

* *milligrams per decimeter^2 per day.*

5.2.7 Loads on Bearing Pads

The submerged bundle weight of the 3.25 inch Douglas Point fuel (33.5 pounds) may be carried by 2, 3 or 4 bearing pad contacts at each end of the bundle. A review of the data reported indicates the total area of contact with the tube is about 0.15 in^2 and the average bearing pressure on these contact points is 250 lb/in^2. The Douglas Point spiral bearing pads, ground to the coolant tube diameter, have not produced fret marks on the coolant tube or excessive wear during flow or wear tests performed on this fuel. The development of bearing pads with 3 or 4 times as great a bearing area is in progress.

The submerged bundle weight of the 4.07 inch fuel for the Pickering reactor (51.5 pounds) is spread over the same angular sector of the bundle as the Douglas Point fuel and is therefore carried by from 3 to 5 contact points at each end of the bundle. A bearing pad is also required at or near the outside element mid-point to prevent the fuel sheath touching the pressure tube. Taking these factors into account the bearing load per contact is about the same as that in the Douglas Point fuel.

5.2.8 Fuel and Coolant Tube Vibration and Fretting

The design velocity of the coolant within the coolant channel is limited to 30 feet per second because of concern about fuel element vibration, inter-element fretting and fretting between coolant tubes and fuel bearing pads. Flow tests have been performed on Douglas Point size split spacer fuel at maximum velocity (27.2 feet per second) for a period of about 6000 hours. During these tests no fret marks on the coolant tube surface have been observed using bearing pads formed to the tube radius. A maximum decrease in inter-element spacing of .005 inch due to fretting wear of matching spacers was observed after this period.

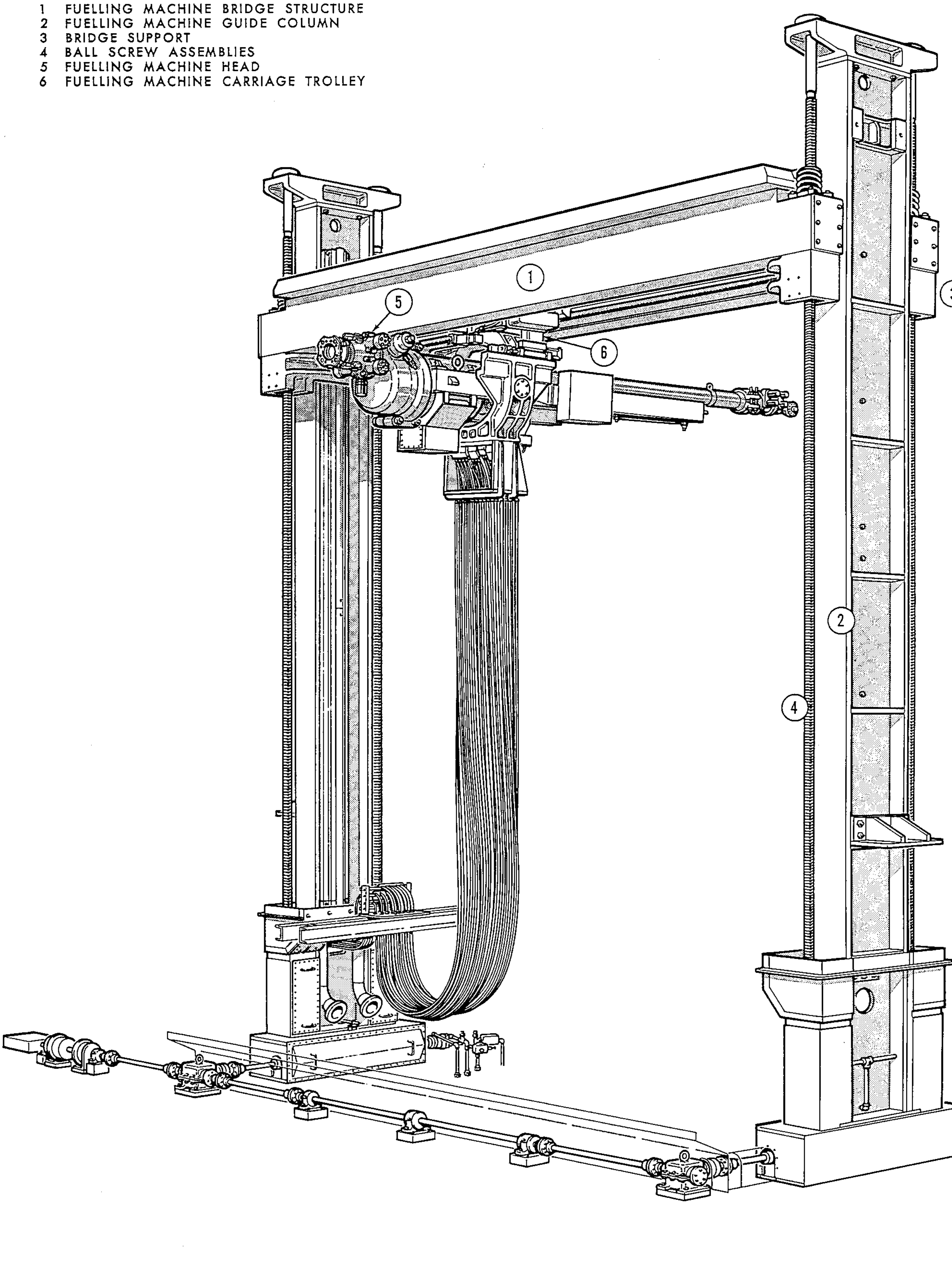
The 4 inch diameter system using 28 element fuel will have approximately the same maximum coolant velocity as the Douglas Point fuel. Since the fuel elements are identical in geometry and inertia to those tested for Douglas Point, vibration and fretting difficulties are not expected. Flow tests have been performed on Pickering fuel for 5,000 hours and no fret marks have been observed on the coolant tube.

5.2.9 Irradiation Experience

Four irradiation tests of split spacer bundles have been carried out in Chalk River loops. One of these included 28-element split spacer bundles of the Pickering design and was satisfactorily irradiated for 80 effective full power days when the test was terminated. The other tests were with 19-element bundles with welded and beryllium brazed spacers and bearing pads. The brazed spacer performed satisfactorily at these irradiations for exposures up to 288 full power days at an average outer element $\lambda d\theta$ power rating of 43 W/cm.

A total of sixty-five split spacer bundles have been loaded into the NPD reactor during normal refuelling. Three of these have been discharged and though damaged by the reactor fuel latches, were found to have performed satisfactorily in those features pertinent to the 28-element bundle.

1 FUELLING MACHINE BRIDGE STRUCTURE
2 FUELLING MACHINE GUIDE COLUMN
3 BRIDGE SUPPORT
4 BALL SCREW ASSEMBLIES
5 FUELLING MACHINE HEAD
6 FUELLING MACHINE CARRIAGE TROLLEY



5.3-1 EAST FUELLING MACHINE

44.35300-6
1968

Twelve split spacer bundles, fabricated by the methods to be used for the 28 element bundle, are being included in the Douglas Point first charge for irradiation at power and coolant flow conditions comparable to the Pickering maximum rated channel. Some of these bundles will be examined for spacer fretting damage and other performance characteristics associated with the beryllium braze method of attaching spacers and wear pads.

5.3 FUELLING MACHINES

5.3.1 General

The fuelling operation for the Pickering station is carried out by the co-ordinated actions of two fuelling machines, each serving one end of the reactor. Each fuelling machine as shown in Figure 5.3-1 consists of:

1. Head
2. Carriage
3. Bridge
4. Fluid and Electric supply

The fuelling machine head is hung from the carriage which runs in a horizontal direction on the underside of the bridge, providing the "X" motion requirement for lateral positioning of the head. The bridge structure travels vertically up or down on two fixed guide columns, supplying the "Y" motion requirement for the vertical positioning. The bridge structure in the down position serves the additional function of both shielding and sealing, which allows access to the fuelling machine service room below each fuelling machine vault floor. A rehearsal tube is located below the reactor with end fittings in each service area. All operations of the fuelling machine may be practiced on these end fittings. The hoses and cables form a catenary passing directly from the north wall of the fuelling machine service area to either the head or the carriage.

5.3.2 Fuelling Machine Head

In principle the head concept of the Douglas Point machines has been retained. The general arrangement of the fuelling machine head is shown in Figures 5.3-2A, -2B, -2C and -2D.

The outside diameter of the magazine housing has been maintained the same as Douglas Point in order to use the same size two-piece Grayloc clamp and seal ring. The magazine housing and end cover are designed as forgings which take the form of a cylindrical pressure vessel with flat heads. A twelve position rotatable magazine is located concentrically inside the magazine housing and is indexed by a Ferguson roller gear drive the same as Douglas Point. The twelve magazine positions provide for five fuel stations (holding two bundles each), two channel closures, two shield plugs, one snout plug, one ram adaptor and one guide sleeve. The guide sleeve is handled by the rams using a special guide sleeve tool which is stored behind the guide sleeve in the same magazine position.

The snout assembly, snout emergency lock, snout plug and fuel separators are similar to Douglas Point.

A mechanical "B" ram and latch ram and a water hydraulic "C" ram are used which perform the same functions as Douglas Point. The "B" ram stroke is shorter than the "C" ram stroke. The "B" ram is designed to go into the coolant channel only far enough to handle the shield plug.

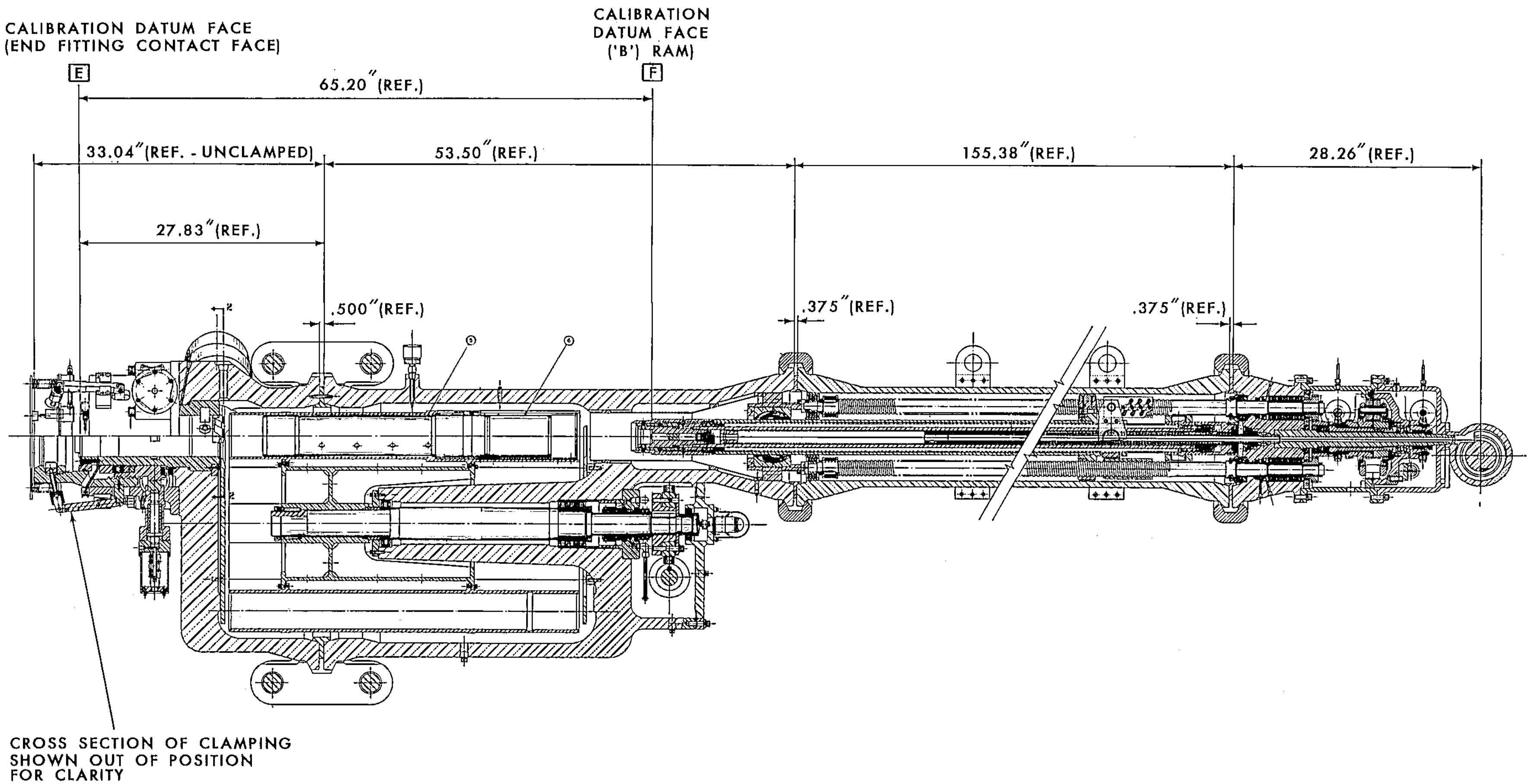
The cylindrical ram housing has concentric Grayloc hubs of the same size at both ends. The ram housing encloses a concentric arrangement of ram tubes surrounded by a concentric arrangement of four water lubricated ball screws. The two ball screws on the vertical centreline drive the "B" ram by means of two ball nuts in a vertical crosshead attached to the back end of the plain cylindrical "B" ram tube. The two ball screws on the horizontal centreline drive the latch ram tube by means of two ball nuts in a horizontal crosshead attached to the back end of the latch ram tube. The latch ram tube extends rearward through the back end of the "B" ram tube and acts as the cylinder for the "C" ram which has a longer stroke than the "B" ram.

A closure is attached to the back of the ram housing by means of a Grayloc clamp and seal ring. This closure is penetrated by and provides a mounting for the four ball screws. Self energized hydrostatic face seals are used to seal in the water environment where the ball screws penetrate the closure. The ball screws are mounted in the closure using conventional oil lubricated angular contact bearings. An oil lubricated gear case is attached to and extends rearward from the closure and contains the bearings and gears for the "B" ram and latch ram drives.

All four ball screws are driven at the same speed by the "B" ram oil hydraulic motor through a worm drive. Latch ram motion is superimposed on the "B" ram motion by means of a double planetary gear system driven by a second oil hydraulic motor through a worm drive. Both worm drives have double end worms so that one end of each is available for manual turning. "B" ram and latch ram position sensing is done by means of potentiometers geared to the respective worm shafts.

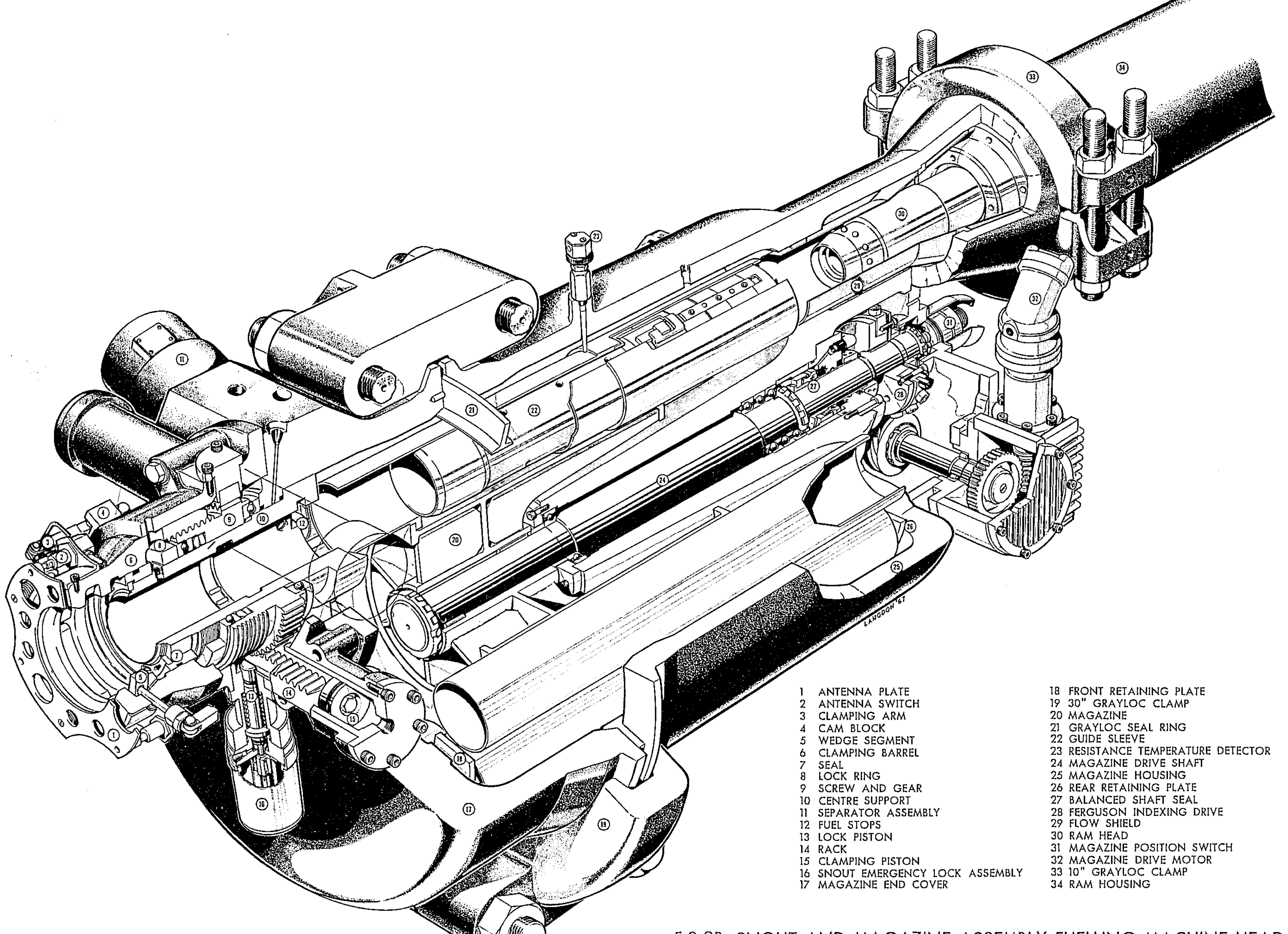
A shaft mounted in the centre of the ram housing end closure extends rearward through the gear case providing a fixed spindle mounting for the gears. A hole through the centre of this extension provides a water passage and channel for the tape used to sense the position of the "C" ram. The tape reel and spring motor are in water, enclosed in a housing which is attached to the back of the gear case. Rotary motion of the tape reel and motor shaft is transmitted through a hermetically sealed rotary seal to gearing and the "C" ram potentiometers in an oil filled, pressure compensated chamber of the housing.

The complete ram assembly including rams, drives and housing are attached as a unit by means of a Grayloc clamp



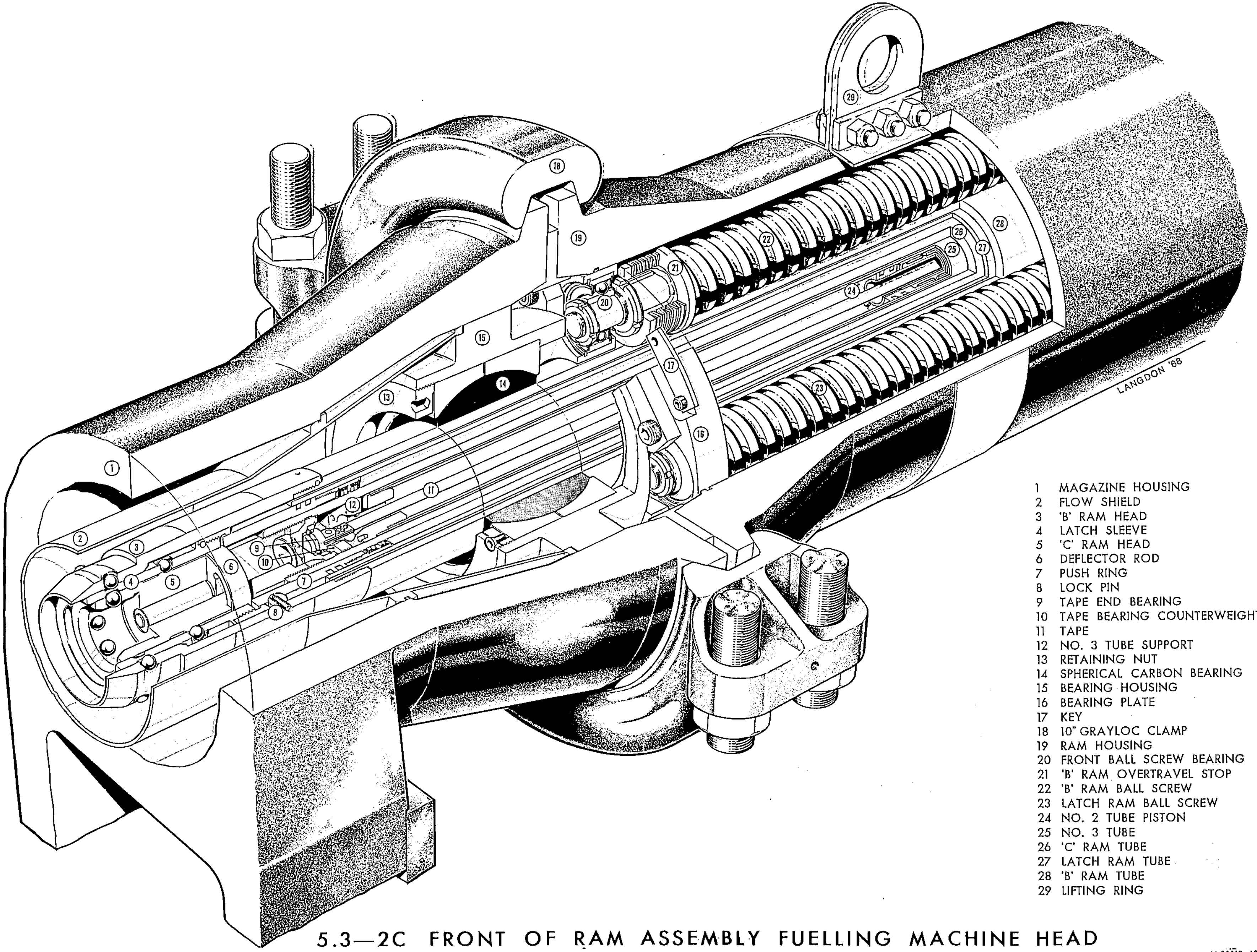
5.3—2A FUELLING MACHINE HEAD

44.35310—7
REV. 1, 1968

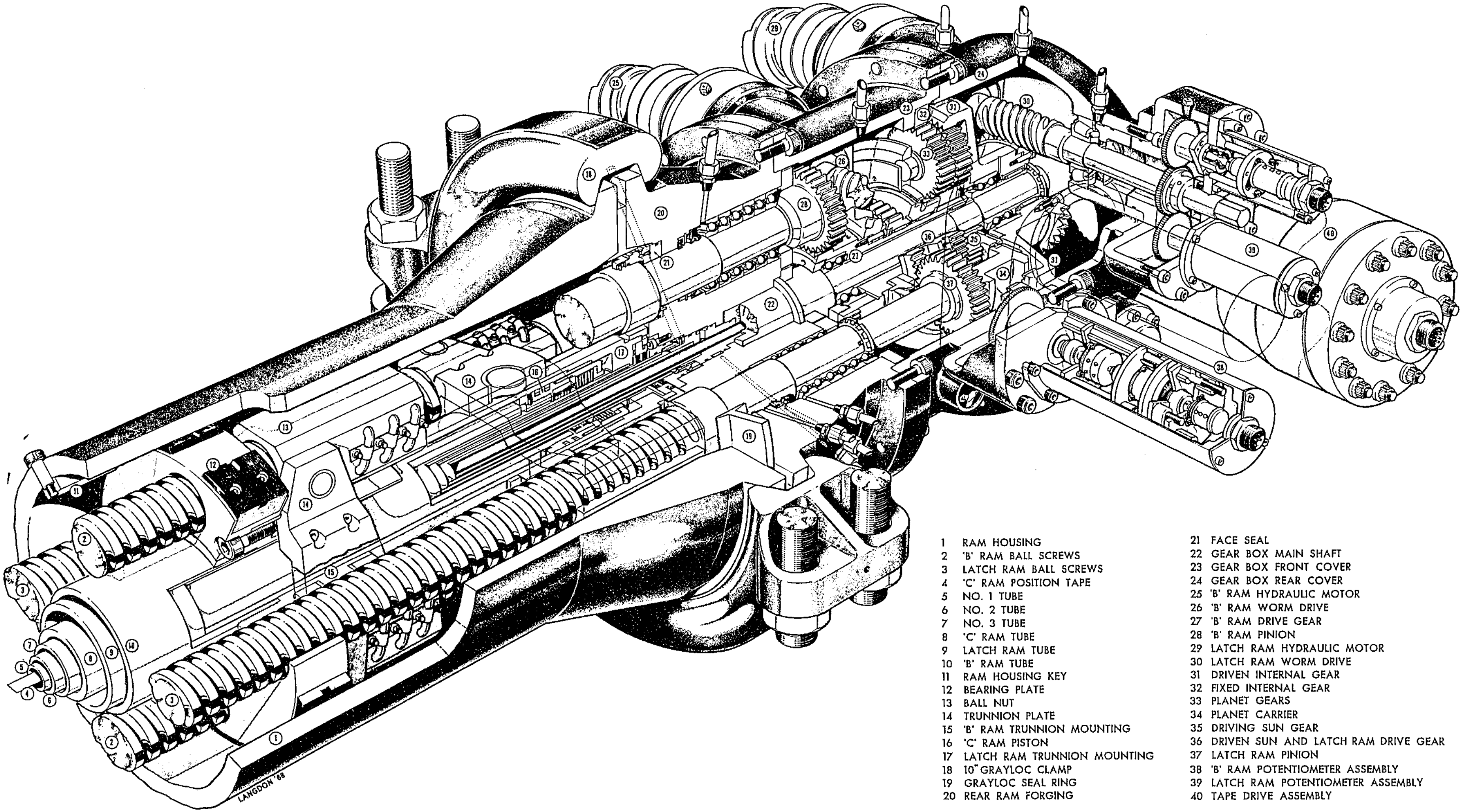


1 ANTENNA PLATE
2 ANTENNA SWITCH
3 CLAMPING ARM
4 CAM BLOCK
5 WEDGE SEGMENT
6 CLAMPING BARREL
7 SEAL
8 LOCK RING
9 SCREW AND GEAR
10 CENTRE SUPPORT
11 SEPARATOR ASSEMBLY
12 FUEL STOPS
13 LOCK PISTON
14 RACK
15 CLAMPING PISTON
16 SNOUT EMERGENCY LOCK ASSEMBLY
17 MAGAZINE END COVER
18 FRONT RETAINING PLATE
19 30" GRAYLOC CLAMP
20 MAGAZINE
21 GRAYLOC SEAL RING
22 GUIDE SLEEVE
23 RESISTANCE TEMPERATURE DETECTOR
24 MAGAZINE DRIVE SHAFT
25 MAGAZINE HOUSING
26 REAR RETAINING PLATE
27 BALANCED SHAFT SEAL
28 FERGUSON INDEXING DRIVE
29 FLOW SHIELD
30 RAM HEAD
31 MAGAZINE POSITION SWITCH
32 MAGAZINE DRIVE MOTOR
33 10" GRAYLOC CLAMP
34 RAM HOUSING

5.3-2B SNOUT AND MAGAZINE ASSEMBLY FUELLING MACHINE HEAD
PICKERING GENERATING STATION



5.3—2C FRONT OF RAM ASSEMBLY FUELLING MACHINE HEAD



1 RAM HOUSING
2 'B' RAM BALL SCREWS
3 LATCH RAM BALL SCREWS
4 'C' RAM POSITION TAPE
5 NO. 1 TUBE
6 NO. 2 TUBE
7 NO. 3 TUBE
8 'C' RAM TUBE
9 LATCH RAM TUBE
10 'B' RAM TUBE
11 RAM HOUSING KEY
12 BEARING PLATE
13 BALL NUT
14 TRUNNION PLATE
15 'B' RAM TRUNNION MOUNTING
16 'C' RAM PISTON
17 LATCH RAM TRUNNION MOUNTING
18 10" GRAYLOC CLAMP
19 GRAYLOC SEAL RING
20 REAR RAM FORGING
21 FACE SEAL
22 GEAR BOX MAIN SHAFT
23 GEAR BOX FRONT COVER
24 GEAR BOX REAR COVER
25 'B' RAM HYDRAULIC MOTOR
26 'B' RAM WORM DRIVE
27 'B' RAM DRIVE GEAR
28 'B' RAM PINION
29 LATCH RAM HYDRAULIC MOTOR
30 LATCH RAM WORM DRIVE
31 DRIVEN INTERNAL GEAR
32 FIXED INTERNAL GEAR
33 PLANET GEARS
34 PLANET CARRIER
35 DRIVING SUN GEAR
36 DRIVEN SUN AND LATCH RAM DRIVE GEAR
37 LATCH RAM PINION
38 'B' RAM POTENTIOMETER ASSEMBLY
39 LATCH RAM POTENTIOMETER ASSEMBLY
40 TAPE DRIVE ASSEMBLY

5.3-2D FUELLING MACHINE HEAD REAR OF RAM ASSEMBLY,
PICKERING GENERATING STATION

TABLE 5.3-1

FUELLING MACHINE HEAD OPERATING SYSTEMS

SYSTEM	OPERATOR	ACTUATOR	SENSING DEVICE
Ram 'B'	Oil Hydraulic Motor	Ball Screw Drive	Potentiometers
Ram 'C'	D_2O Pressure	Telescopic Pressure Cylinder	Potentiometers
Latch 'L'	Oil Hydraulic Motor	Ball Screw Drive	Potentiometers
Magazine	Oil Hydraulic Motor	Ferguson Indexing Drive	Rotary Switch & Potentiometers
Guide Sleeve	Ram 'B'		Ram 'B' Potentiometers
SEPARATOR			
— Feeler	D_2O Pressure	Hydraulic Cylinder	L.V.D.T's
— Side Stops & Latch	D_2O Pressure Solenoid Coil	Hydraulic Cylinder Solenoid Armature	Reed Switches Reed Switches
— Retractor	D_2O Pressure	Hydraulic Cylinder	L.V.D.T's
Snout Clamps & Lock	Oil Pressure D_2O Pressure	Hydraulic Cylinders Racks & Pinions Hydraulic Cylinder	Reed Switches
MAGAZINE			
— Temperature	Pneumatic Positioner	Control Valves	R.T.D's
— Pressure	Pneumatic Positioner	Control Valves	Pressure Transmitters
HYDRAULIC POWER SUPPLIES			
— Oil System	Electric Motors	Pumps	Pressure Switch & Level Switch
— D_2O System	Electric Motors	Reciprocating Pumps	

TABLE 5.3-2

FUELLING MACHINE BRIDGE AND CARRIAGE OPERATING SYSTEMS

SYSTEM	OPERATOR	ACTUATOR	SENSING DEVICE
Trolley 'X'	Oil Hydraulic Motor	Rack & Pinion	Potentiometers
X-Tilt	Trolley 'X' Drive		Linear Potentiometers
Gimbal 'Z'	Oil Pressure	Hydraulic Cylinder	Reed Switches & Potentiometers
Gimbal Swing	Oil Pressure	Rotary Hydraulic Cylinder	Limit Switch
Bridge 'Y'	Hydraulic Motors	Ball Screw Drive	Potentiometers & Speed Switch
Y-Tilt	Oil Hydraulic Motor	Screw Drive Self-locking	Linear Potentiometer
BRIDGE SEALING			
Bulb Seal		Load Energized	

and seal ring to the back of the magazine housing.

The fuelling machine head drives, actuators and sensing devices are listed in Table 5.3-1.

5.3.3 Fuelling Machine Carriage

The carriage comprises two main components: the trolley (see Figure 5.3-3), and the head support cradle.

The fuelling machine head is suspended in the head support cradle on a horizontal axis. The head can pivot on this axis against a preloaded spring levelling device. The total movement is restricted to ± 3/8 inch measured at the face of the fuelling machine snout. The head support cradle in turn is supported from the upper gimbal of the trolley on a pair of horizontal ball ways which allows the axial motion ("Z" motion) of the head to be achieved. The gimbal is carried from the trolley on a vertical axis about which the head can rotate through an angle of 90°. At either extreme of rotation the head is allowed to pivot about the vertical axis against a preloaded spring centralizing device. The total movement similar to that of the levelling arrangement is restricted to ± 3/8 inch measured at the face of the fuelling machine snout. The trollery from which the gimbal is supported provides the lateral positioning as well as the horizontal and vertical alignment of the head with any of the reactor end fittings. In order to home on to an end fitting the head is driven in a direction normal to the reactor face on the "Z" motion travel. Both the end fittings and the snout are tapered to facilitate homing on and to be self-centering. As the axial homing takes place the head will tilt within the limits described above. This tilt is sensed and fed back for correction in the "X" and "Y" position of the head.

The "X" motion travel of the carriage is achieved by a rack and pinion arrangement through a directly coupled low speed hydraulic drive. This is a two speed device of 36 and 6 inches per minute. The driving force is restricted to the maximum permissible end fitting load in the event of a limit control failure.

The low speed "Y" drive is accomplished on two jacks, with the total travel restricted to the homing requirements, i.e. ± 3/8 inch. The jacks are self-locking to prevent load overhauling.

5.3.4 Fuelling Machine Bridge

The fuelling machine bridge comprises three main components:

1) Guide Columns (Figure 5.3-4A)
2) Bridge Structure
3) Vertical Drive (Figure 5.3-4B)

Each guide column consists of the main structural column, two 4 inch diameter ball screws, the ball screw support structure, bridge support, and the lower sealed drive housing. The bridge support travels the overall height of the column on the ball screws and is guided by the vertical roundway track fixed to the column. The screws and supporting bearings are sized for a maximum operating load of 37,000 pounds and a static load under accident conditions of 96,000 pounds. The supporting ball screw nut is trunnion mounted in the bridge support with provision for run out in the event of a control failure at the lower end of travel. Energy absorption is provided for in both the upper and lower extremes of travel.

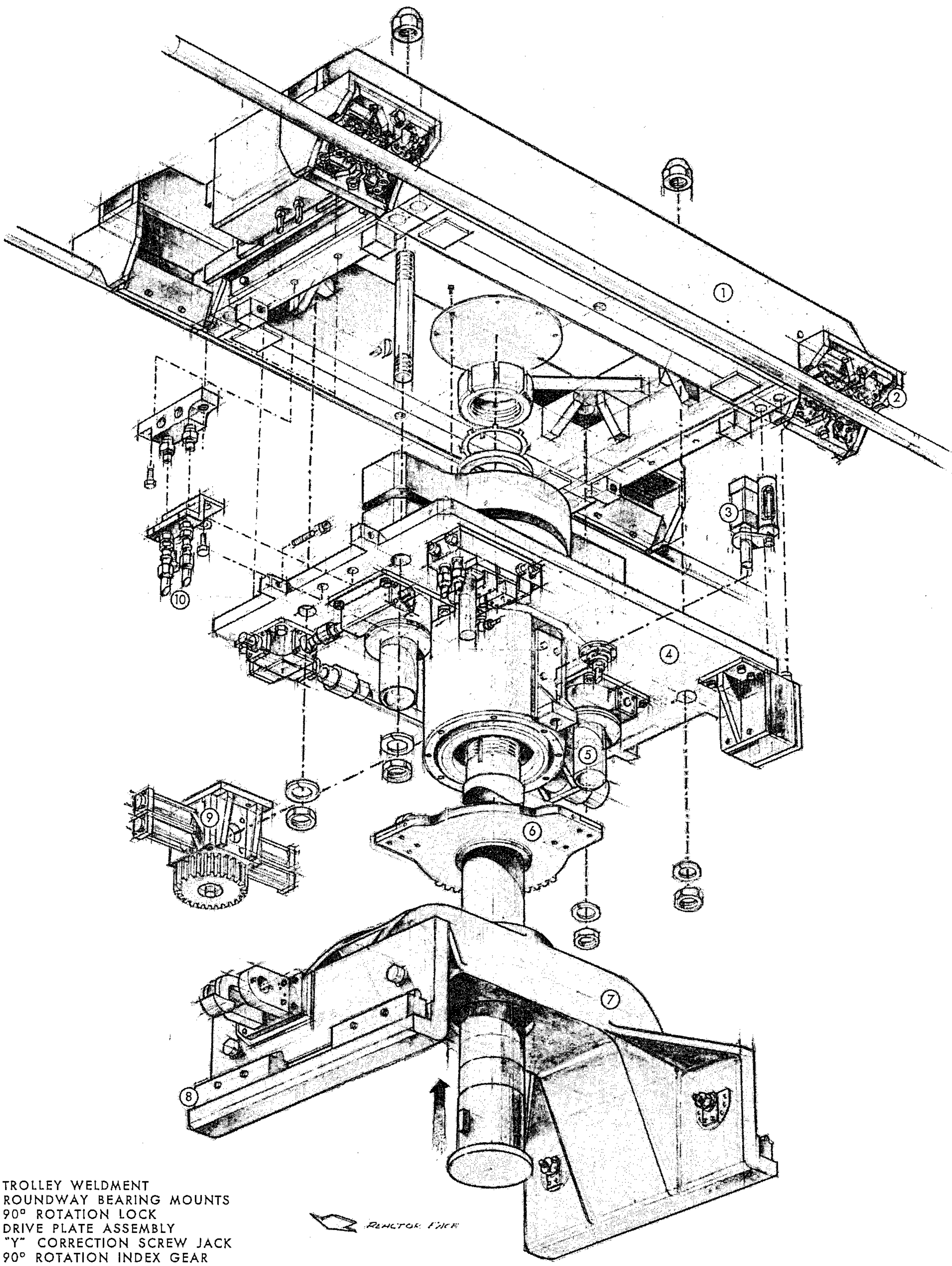
The bridge structure is an all welded construction consisting of two box members laterally braced with a four inch deep framework on the top. The enclosed framework forms a number of pockets which will be concrete filled for shielding purposes. In addition the bridge structure supports a six inch steel shielding slab. The bridge is supported on the bridge supports which are carried on the guide columns. It is rigidly fixed to one support and is free to move lengthwise on rollers at the other, compensating for thermal growth during reactor operation. The bridge provides motion for the fuelling machine head in the vertical direction by its travel over the length of the ball screws. Two tracks on the lower inside face of the bridge structure carry the carriage for head positioning in the horizontal direction.

The vertical drive for the bridge consists of a hydraulic motor close coupled through worm gear reduction units to the base of each column. Each column drive is mechanically tied to the other by cross shafting, providing the necessary synchronization and reliability. An extension of the cross shafting is carried into the auxiliaries area for mechanical braking and to provide for position readout of the bridge. Because of the large masses involved and the high efficiency of the ball screws two brakes are provided to prevent creep of overhauling loads during operation. One brake being an integrated requirement in the position control for holding purposes while the second is separated from the control and interlocked with the "Z" motion to ensure "no drift" while the head is locked onto a reactor end fitting. As a further safeguard counterbalance valves are provided on both motors so that a positive torque is required to drive the bridges down.

The hydraulic drives operate at two speeds of 720 and 120 rpm, which through the reduction units provides a linear translation of 36 and 6 inches per minute at the ball screws. Each motor is sized to support the load individually in case of hydraulic, motor or shaft failure.

5.3.5 Fuelling Machine Supply Hoses and Cables

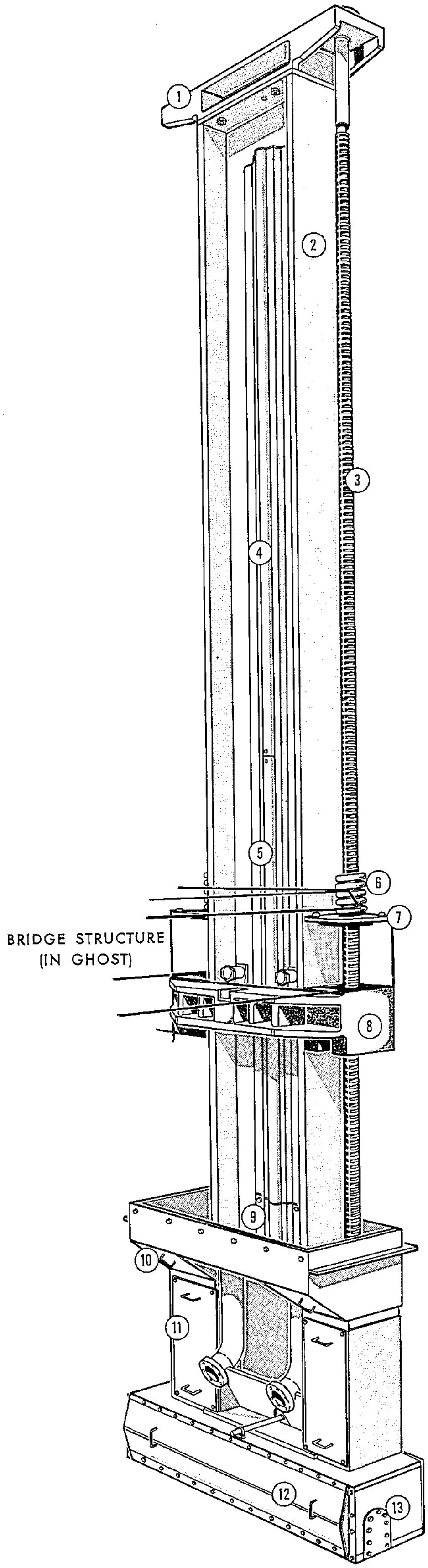
It is the intention to run all hoses and cables required for head operation directly from the north wall of the fuelling machine service area to the underside of the head support cradle. In a similar manner the requirements for the carriage will be carried directly from the north wall facility. This system entails the minimum length of hoses and number of fittings with the corresponding lower pressure drop. In addition, this arrangement allows the head to be readily separated from the carriage while maintaining continuous

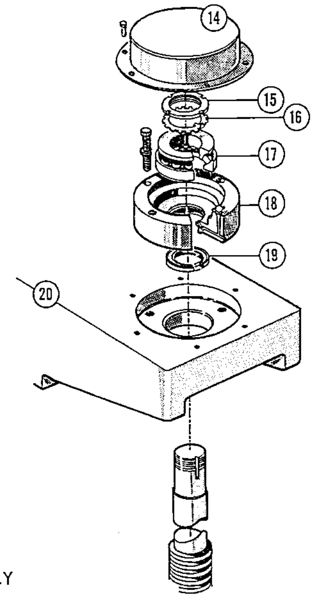


1 TROLLEY WELDMENT
2 ROUNDWAY BEARING MOUNTS
3 90° ROTATION LOCK
4 DRIVE PLATE ASSEMBLY
5 "Y" CORRECTION SCREW JACK
6 90° ROTATION INDEX GEAR
7 UPPER GIMBAL
8 "Z" MOTION BALL CARTRIDGE
9 90° ROTATION ACTUATOR
10 HYDRAULIC REMOTE DISCONNECT COUPLINGS

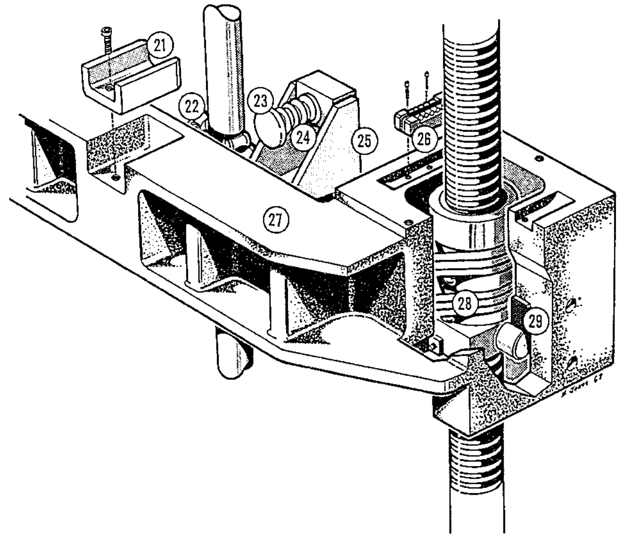
5.3-3 FUELLING MACHINE CARRIAGE TROLLEY (WEST)

44.35321-1
1967



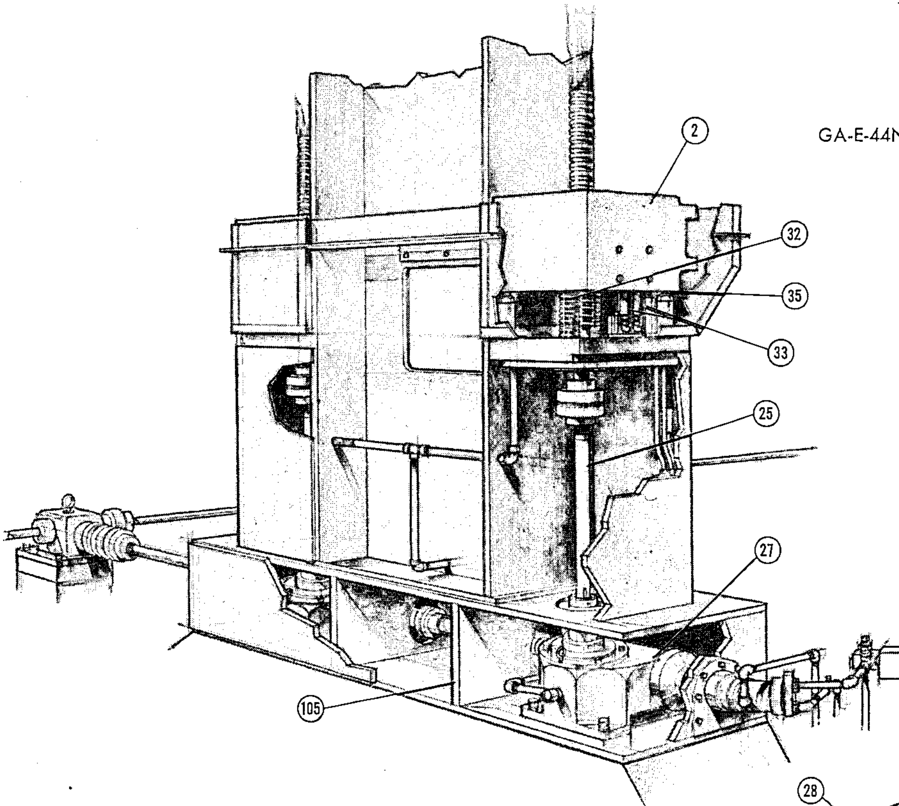


1 BALL SCREW SUPPORT
2 COLUMN WELDMENT
3 BALL SCREW ASSEMBLY
4 ROUNDWAY UPPER
5 ROUNDWAY LOWER
6 COIL SPRING
7 SPRING SUPPORT PLATE
8 BRIDGE SUPPORT ÁSSEMBLY
9 LOWER ROUNDWAY PAD
10 UPPER COVER PLATE
11 LOWER COVER PLATE
12 BASE FRONT COVER
13 BASE SIDE COVER
14 TOP BEARING COVER
15 BEARING LOCKNUT
16 BEARING LOCKWASHER
17 THRUST BEARING
18 TOP BEARING SEAT
19 OIL SEAL
20 BALL SCREW SUPPORT
21 BRIDGE KEY GUIDE
22 ROUNDWAY BEARING (THOMSON)
23 COLLAR
24 COIL SPRING
25 BRACKET
26 TYCHOWAY BEARING
27 BRIDGE SUPPORT
28 BALL SCREW NUT
29 TRUNNION BUSHING



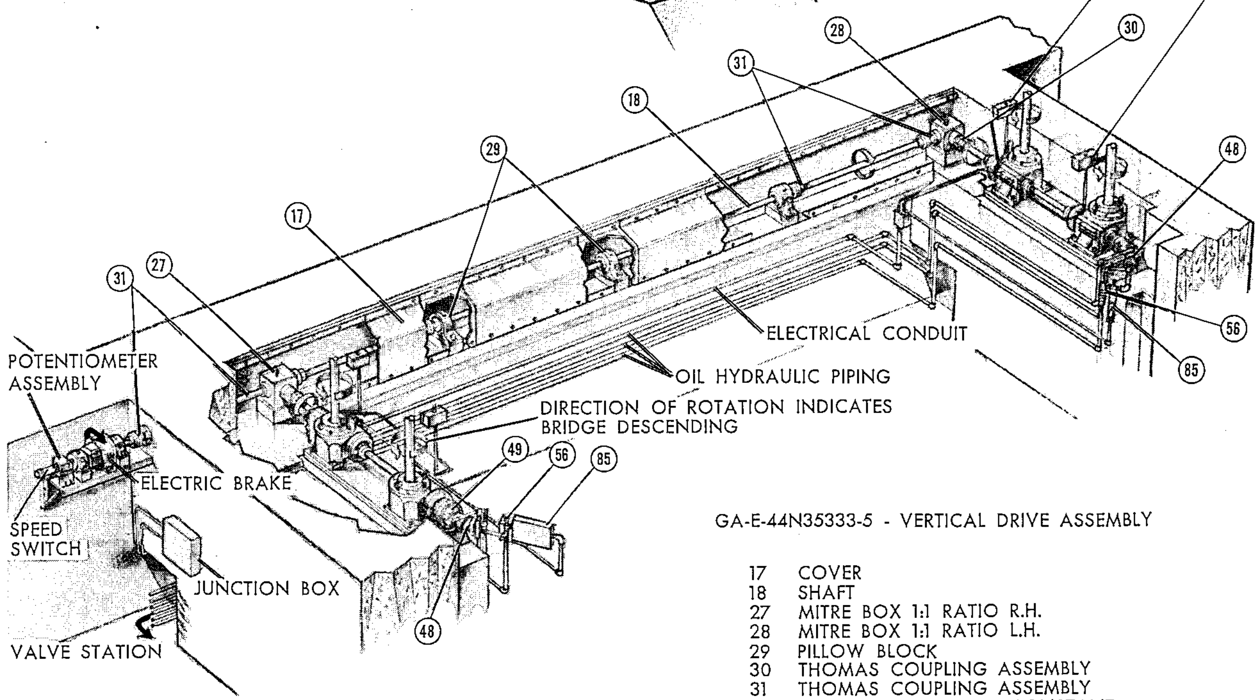
5.3-4A SOUTH GUIDE COLUMN

44-33300-4 REV. 1
1967



GA-E-44N35331-4 - NORTH GUIDE COLUMN

2 BRIDGE SUPPORT ASSEMBLY
25 SPLINED DRIVE SHAFT
27 SPEED REDUCER 20:1 RATIO
32 DASHPOT
33 PROXIMITY LIMIT SWITCHES
35 MODIFIED SET SCREW (MECHANICAL STOP)
105 THOMAS SHAFT COUPLING



GA-E-44N35333-5 - VERTICAL DRIVE ASSEMBLY

17 COVER
18 SHAFT
27 MITRE BOX 1:1 RATIO R.H.
28 MITRE BOX 1:1 RATIO L.H.
29 PILLOW BLOCK
30 THOMAS COUPLING ASSEMBLY
31 THOMAS COUPLING ASSEMBLY
48 HYDRAULIC MOTOR - CONSTANT DISPLACEMENT TYPE (720 RPM)
49 THOMAS COUPLING
56 COUNTER BALANCE VALVE
85 PRESSURE SWITCH

5.3-4B WEST FUELLING MACHINE BRIDGE - VERTICAL DRIVE ASSEMBLY

44.35300-5
1967

cooling. This arrangement will also have the minimum load effect on the "X" positioning due to catenary weight.

5.3.6 Fuelling Machine Control Systems

5.3.6.1 General

The central part of the control systems for the fuelling machine is a general purpose digital computer. The computer will process the feedback signals from the various control systems and the command signals to these systems. With the exception of the ram "C" force and the magazine pressure and temperature controls, the systems are all of the trip-and-lock type of positioning control.

The fuelling process is a step-by-step operation. A pre-determined order of successive fuelling machine operation steps is called a program. The programs are combined in different ways to form the sequences in which the fuelling machine operates.

The following basic operation modes of the fuelling controls can be distinguished:

(1) RUN — fully automatic through a sequence, protected by interlocks at each step.

(2) STEP — similar to (1) but requiring a manual command to proceed after each step.

(3) SEMI-AUTOMATIC — manual commands inserted through computer keyboard printer, including auto-positioning.

This keyboard printer prints out the command and then the operator gives function START from computer panel.

(4) MANUAL CENTRAL — commands from switches on fuel handling control panels in control centre; minimum interlocking provided by logic external to computer, simple functions only; e.g. advance-stop-retract, open-stop-close, etc. (= "jogging" controls).

(5) MANUAL LOCAL — commands as (4) but from switches on field panels in Reactor Building and in the spent fuel storage area.

Operation modes (1), (2) and (3) utilize the digital computer, while modes (4) and (5) do not. The operation and control of the fuelling machines is performed by a combination of D_2O hydraulic systems, oil hydraulic systems and electrical systems.

5.3.6.2 Heavy Water Systems

The D_2O will be supplied by the primary heat transport main pressurizing pumps at 1400 psi when the fuelling machines are at low pressure. When high pressure at the magazine is selected a pressure of 2400 psi will be supplied by two fuelling machine pumps. Each pump will have sufficient capacity to supply both fuelling machines. Water temperature from the pumps will be 100°F nominally, the necessary temperature rises being obtained in one heat exchanger for the 175°F supply and another for the variable supply to each machine. A schematic diagram of the D_2O systems is shown in Figure 5.3-6A.

The D_2O system is required to:

(1) maintain the fuelling machine magazine at temperature and pressure conditions suitable for operation on the reactor, on the fuel transfer port, and for parking;

(2) supply cooling flow to seals on the ram and magazine drives;

(3) supply flow to operate the ram "C" and the separator actuators at controlled speeds and forces; and

(4) provide a method of detecting leakage from closure plugs.

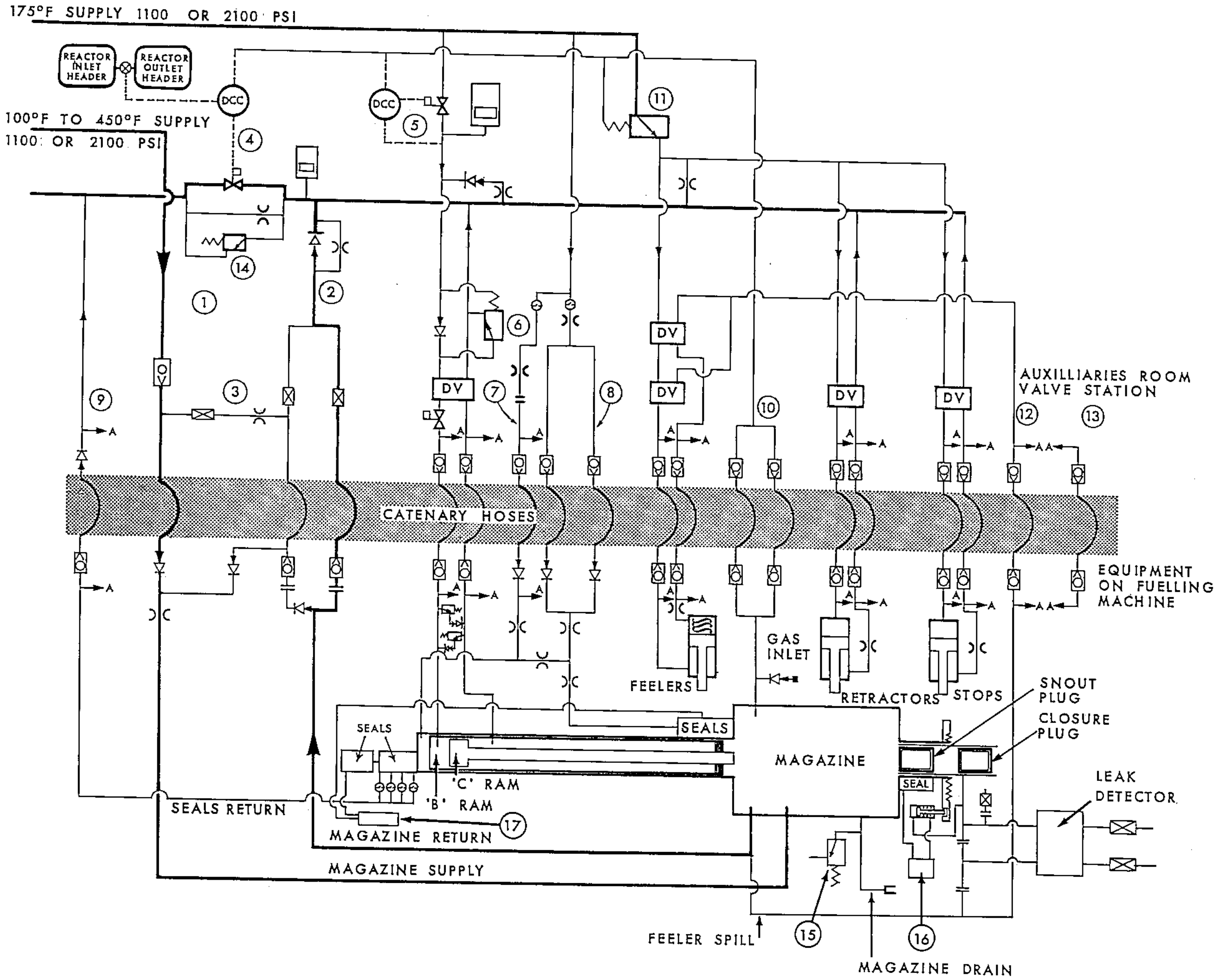
The magazine temperature is normally held at 175 to 200°F for operation at the fuel transfer port. Before the machine is clamped to a reactor end fitting the temperature in the magazine is raised to about 300°F by increasing the temperature and the flow of the magazine supply. This is done to reduce the thermal stresses in the end fitting and the snout of the machine.

When the machine is "parked", the magazine pressure is controlled at 500 psia by throttling the flow in the return line to the primary system.

When the machine has clamped to a reactor end fitting, "high pressure" is selected and the magazine is then controlled, again by throttling the return flow, at a pre-determined differential pressure above that of the reactor inlet or outlet header, dependent on the end fitting in use. When the snout and closure plugs have been removed the differential pressure cannot be maintained and the control valve in the return line closes. The "on reactor" pressure control then takes over. This controls the pressure differential across a check valve in the magazine return line, maintaining this at a level such that there is no flow in the magazine return line, while providing a path for the return flows from the actuators.

The pressure control systems are similar to the Douglas Point design; the temperature controls differ in that the heat exchanger output temperature is controlled by governing the steam flow. At Douglas Point two supplies at constant temperatures are mixed in variable proportions.

A constant flow at 175°F is provided to cool the seals on ram "B", latch and magazine drives. This flow is increased to fill the volume behind ram "B" when it advances at high speed.



LEGEND

- FLOW SWITCH
- SHUT OFF VALVE
- ACCUMULATOR
- FLOW RESTRICTION
- DIRECTIONAL VALVE =
- EXCESS FLOW VALVE
- CHECK VALVE
- PRESSURE RELIEF VALVE
- PRESSURE REDUCING VALVE CONTROLS PRESSURE AT B RELATIVE TO A
- MOTORIZED CONTROL VALVE
- TWO-WAY VALVE =
- DIGITAL COMPUTER CONTROL
- ALTERNATE EMERGENCY CONNECTIONS

1 MAGAZINE SUPPLY
2 MAGAZINE RETURN
3 EMERGENCY MAGAZINE SUPPLY-BURST HOSE
4 MAGAZINE PRESSURE CONTROL
5 'C' RAM PRESSURE CONTROL
6 'B' RAM OVERHAUL RELIEF
7 'B' RAM FILL
8 SEALS SUPPLY
9 SEALS RETURN
10 MAGAZINE PRESSURE SENSE
11 SEPARATORS PRESSURE CONTROL
12 FEELER SPILL
13 SEPARATORS AND 'C' RAM EMERGENCY LINE
14 PRESSURE RELIEF
15 PRESSURE RELIEF
16 D_2O COLLECTION RESERVOIR
17 D_2O COLLECTION RESERVOIR

5.3—6A SIMPLIFIED FUELLING MACHINE D_2O SYSTEM

44.63536—1
REV. 2, 1968

Ram "C" and the separator actuators have unbalanced piston areas into the magazine. To control the forces they exert the supply to them is controlled at a set differential above magazine pressure. They use the same 175°F supply as the seals. Four forces are required of ram "C" in plug operations and pushing fuel. A pressure indicating controller with 4 set points positions a modulating control valve to achieve the desired forces. An "overhauling relief valve" and a speed control valve allow the ram to provide a controlled resistance to a column of fuel bundles as it retracts before them.

The separators are combined feeler, stop and retractor assemblies, installed in duplicate on each head to sense the gap between fuel bundles and to separate shield plugs and bundles which are to enter the machine from those which are to be left in the channel, the operating force is set by a pressure reducing valve referenced to the magazine pressure sensing line. Each mechanism is operated by a 4-way 2-position directional solenoid valve, as is ram "C".

Each feeler circuit has a second directional valve in the actuator line to shut off the supply and connect both sides of the feelers to the "feeler spill" line, which is connected directly to the magazine. This allows the feelers to "float" under a light spring load when riding on fuel bundles to sense the gap between them.

The present intention is to use the Douglas Point design leak detector, although this has not yet been proven. After the closure plug and snout plugs have been replaced, pressure in the magazine and snout cavity are reduced. The snout cavity is then isolated by closing the magazine to snout valve and leakage across the closure plug is measured in terms of change in volume of water in the cavity. This deflects a sensitive bellows in the leak detector and bellows movement is sensed by a linear variable differential transformer.

Relief valves are provided on the head and across the pressure control valves; excess flow valves or check valves are provided to cater for hose failure. The magazine return line is duplicated and back-up is provided for the magazine supply, which will be switched in automatically. One emergency line is provided which, in case of failure of any actuator line hose, will be valved in manually. This involves manual valves on the head and in the auxiliaries room.

5.3.6.3 Oil Hydraulic Systems

The oil systems are shown schematically in Figure 5.3-6B.

5.3.6.3.1 Bridge and Carriage Systems

The oil supply for the bridge "Y" motion passes through valves selecting high or low speed to a 3-position valve which selects the direction of motion. There is no direct mechanical counter-weighting of the bridge structure. Reaction against gravitational forces is supplied from drive reaction torque through the gear sets and ball screws. There is an overall efficiency of approximately 76% so that the bridge would overhaul if allowed to run freely. This is one reason for the choice of hydraulic motors instead of electric as these are sufficiently small to allow a separate motor to be installed at the base of each ball screw, the two drive shafts being connected by an inter-connecting shaft. In case of failure of the one motor, this can be isolated by a manual valve, and the second motor can operate the bridge at low speed. In addition, counterbalance valves are located on the descent exhaust side of the oil motors to protect against failure of the oil supply lines in the floor of the service room. These are set to provide counterbalance of the weight of the bridge structure, plus deceleration equivalent to ascent motion gravity deceleration. When the bridge has been stopped it will be held in place by an electro-mechanical brake.

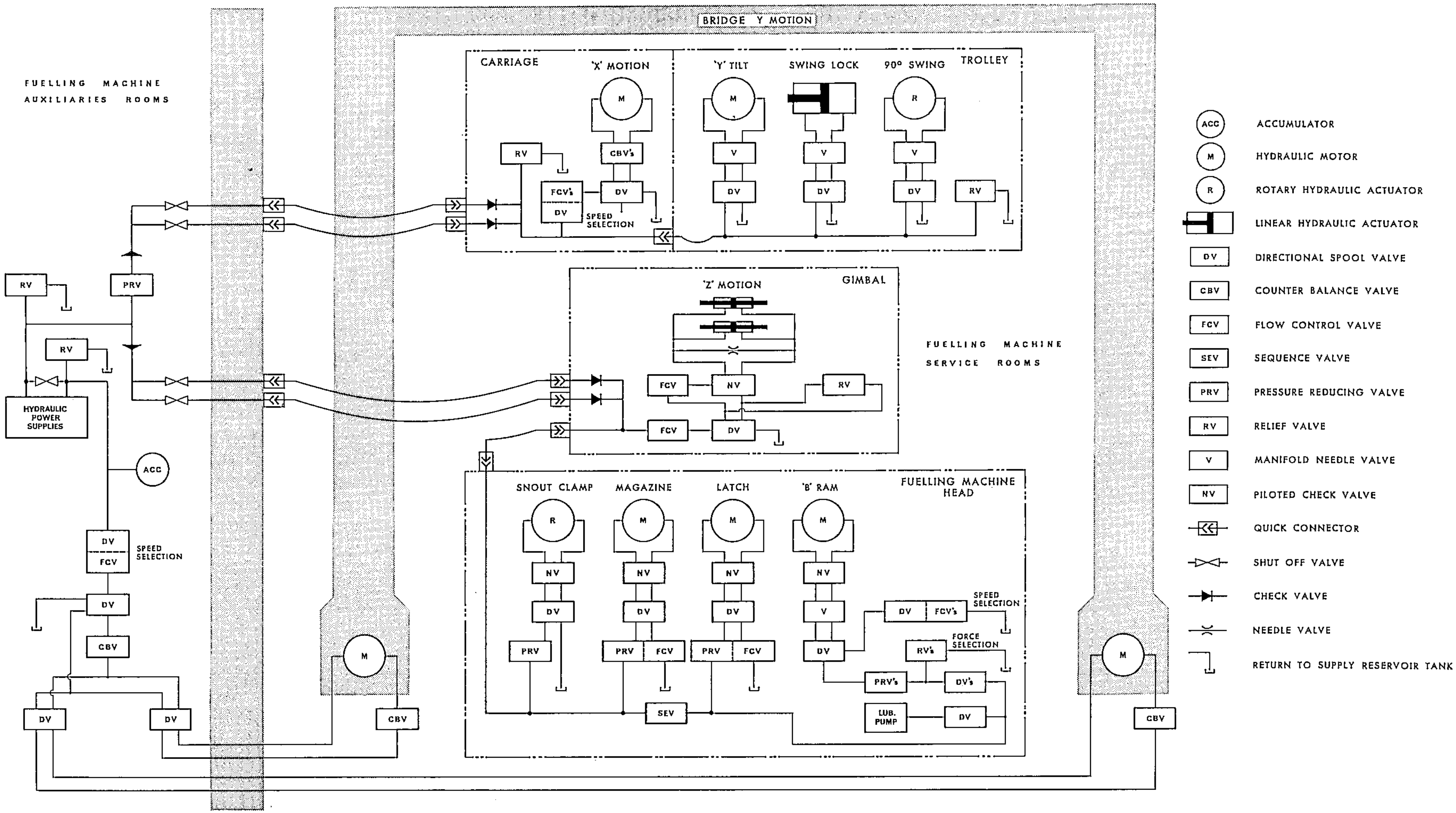
The "X" motion drive, although much smaller than the "Y" motion, is similar to it, in that two speed operation is provided by meter-in flow control and counterbalance valves are provided to control the rate of deceleration and counter the gravity loading from the catenaries. A most important requirement for the "X" motion is that the force be limited to prevent excessive bending moments in the fuelling machine suspension structure.

The "Y" tilt drive is a separate unit with a limited range so that in the event of malfunction of the tilt drive the end fitting will not be overstressed. The bridge is not required to move during locking on a channel, so the bridge motor is hydraulically locked once the initial course positioning of the bridge and carriage have been completed. The tilt control is by a directional valve and a manually adjustable flow control valve for speed control. Since the drive is less than 16% efficient no other form of braking is contemplated.

5.3.6.3.2 Head Actuators

Except for a few minor changes the oil hydraulics on the head for the Pickering machines are the same as those at Douglas Point. These circuits are shown on Figure 5.3-6B. All the head actuators contain pilot-operated check valves to lock them hydraulically when not being driven. To allow for emergency operation in case of failure of the supply pressure to the actuator, quick disconnect fittings are provided between the directional valve and the actuator. Additional disconnect fittings are provided directly across the actuators for differential pressure measurements. "B" ram has 5 forces, tentatively set at 6,000, 4,000, 2,000, 300 and 100 pounds. The two highest forces are required for plug operation, the 2,000 and 300 pound forces for pushing fuel against and with the flow, and the 100 pound force for operation of the guide sleeve mechanism. An attempt is to be made to modify this mechanism to accept 300 pound and eliminate the last force. Where possible the drives will be equipped with square ended shaft projections opposite the oil motors to allow the drive to be operated by a remote manipulator in case of failure of the oil system.

The latch, magazine, snout plug, and "Z" motion drives



5.3–6B SIMPLIFIED FUELLING MACHINE OIL HYDRAULIC SYSTEMS

44.63535–2
REV. 1, 1967

are very similar to those on the Douglas Point machines. Pilot-operated check valves have been added to the snout plug cylinders as an additional safeguard against accidental unlocking.

There are separate oil hydraulic supplies for each machine, with separate pumps for the bridge and head and carriage systems. The pumps will be interconnected through a manual valve normally isolating them to provide backup. The large pump for the bridge is a variable volume unit which may be stroked down to approximately 20% capacity to supply the head and carriage systems, while the double pump used for these will be capable of operating the bridge at low speed. The bridge pump will be set to supply approximately 30 USgpm at 1225 psi and will require a 30 horsepower motor. The fuelling machine double pump set will be the same as that used at Douglas Point. The high pressure pump can deliver 231 cubic inches per minute at 2,000 psig. It will operate continuously to pressurize the snout clamp. The high flow, low pressure pump will come into effect when either the "Y" tilt motion, magazine or "B" ram fast speed is selected. It will be set to unload at 700 psig, the delivery rate being approximately 1140 cubic inches per minute. A 7-1/2 horsepower motor drives these two pumps.

5.3.6.4 Electrical System

The majority of the logic for the control systems will be included in one of the station general purpose digital computers. This computer will process the feedback signals from the various transmitters and put out the command signals to the different systems. A block diagram illustrating the control arrangement is shown in Figure 5.3-6C. Fuelling machine operation is a step-by-step process. Pre-determined sequences of successive machine steps are stored in computer programs. Sequences are defined as follows:

T1 Load new fuel into fuelling machine at fuel transfer port.

T2 Load new fuel and unload spent fuel at the fuel transfer port.

T3 Unload used fuel at the fuel transfer port.

R1 Load fuel from east machine into the reactor at the inlet end of a coolant channel and unload fuel from the reactor into the west machine at the outlet end of a coolant channel.

R2 Load fuel from west machine at inlet end and unload fuel into east machine at outlet end.

Additional sequences to enable the fuelling machine to load fuel against the flow and also to shuffle fuel by changing the relative positions of fuel bundles in a channel will also be provided. The information required to program the computer will be prepared in flow charts. Subroutines will be compiled to interpret the flow chart in the computer.

5.3.6.5 Location of Control Equipment

The physical arrangement of the controls differs from Douglas Point notably in the introduction of the computer to replace the special purpose logic and the use of local motor control centres in the Reactor Auxiliary Bay and power relay racks in the Reactor Building, as shown in Figure 5.3-6C.

The latter changes have been introduced to reduce the distance over which the power cables must be run with consequent voltage drop. Operation will normally be fully automatic from the fuelling console located in the central control room. Semi-automatic operations will be from the computer console. This is adjacent to the fuelling console. Signals from these panels will go to the computer, the control racks in the control centre, the motor control centres in the Reactor Auxiliary Bay, the relay racks in the areas RI-110 and 111, to the equipment in rooms RI-104, RI-105, RI-112 and RI-113, and to the devices on the fuelling machines. Mobile local panels will be provided for manual operations of the machines during maintenance as at Douglas Point. These will be mounted on a dolly which can be taken into the auxiliaries or service rooms or used in areas RI-110 and 111.

The power supplies for the oil systems and those for the heavy water systems will be located in rooms RI-104 and RI-105. The auxiliaries rooms will contain the heavy water heat exchangers and the oil and water valves, except for those which will be mounted on the machines.

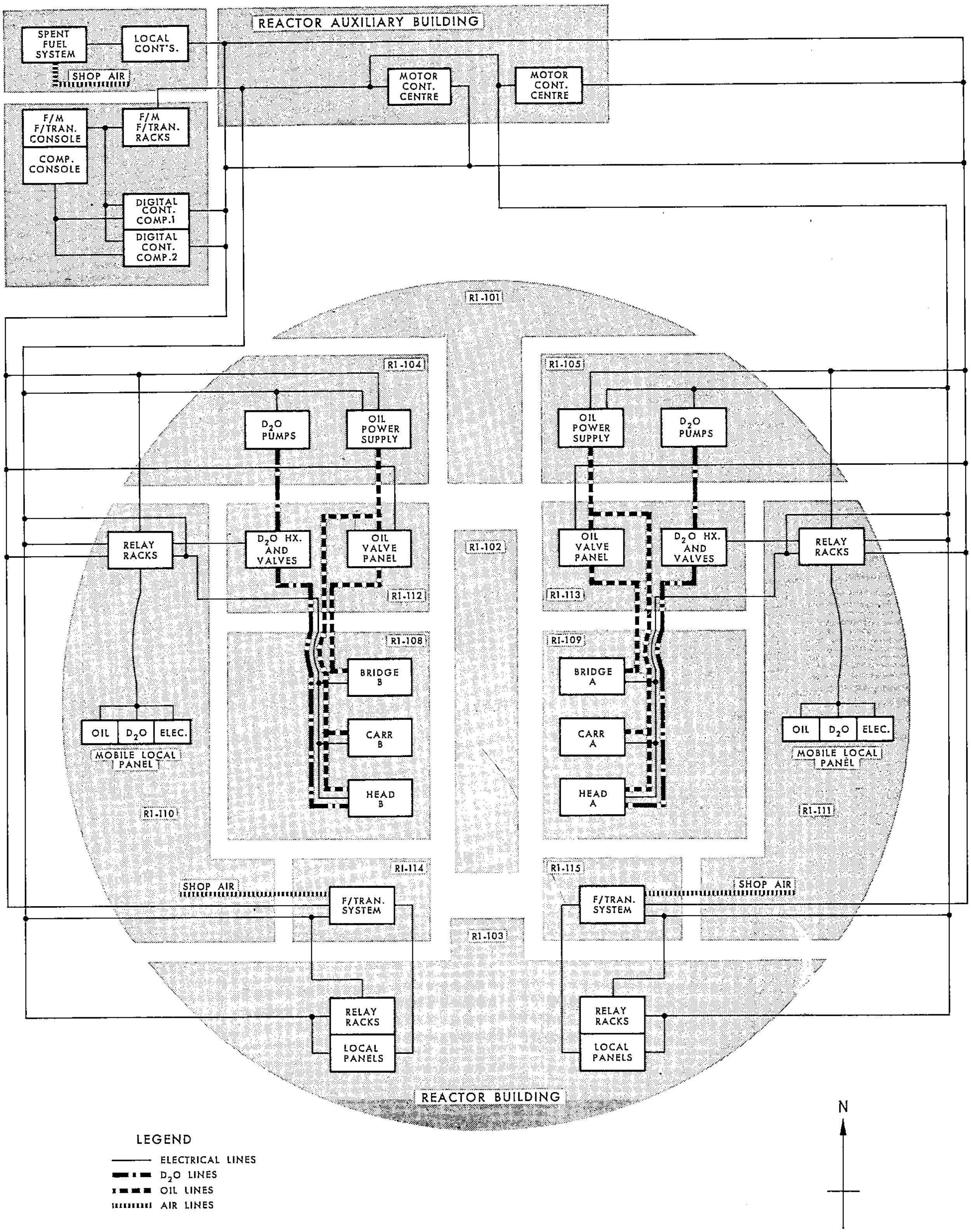
5.3.6.6 Control Centre Panels

The control centre panels will be divided into 4 groups, automatic and manual controls for the east fuelling machine, for the west fuelling machine, for the east and west fuel transfer systems and the keyboard and manual-auto switches on the computer console.

The automatic section of each fuelling machine control will include switches for the selection of the magazine channel to be used for fuel, and switches for selecting mode and sequence. The sequence switch will be used to determine whether the machine is to be used alone, with the other fuelling machine, or with the fuel transfer system in the automatic and semi-automatic modes.

The automatic section of the fuel transfer and spent fuel panels will also include switches for the selection of sequence and mode.

The manual sections of each panel will include switches and indicating lights for each device, enabling this to be operated in each direction applicable and indicating that the appropriate position has been reached or the operation completed. For each device with a feedback position control system, a position indicator covering the full range with an accuracy of 1% will be provided. For those motions requiring greater accuracy than this, a common precision



5.3-6C FUEL HANDLING CONTROLS LOCATION DIAGRAM

44.63500-2
1967

meter and a motion selector switch will be provided, possibly with a manual balancing arrangement, enabling these positions to be determined with an accuracy of 1 part in 5,000. These will include the "X" and "Y" carriage motions, the ram "B" and "C" motions and possibly the latch and "Z" drives. As one of the requirements of the design is that manual operations be independent of the computer, these measurements will be external to the computer. Each system will have a manual-auto switch which will override the mode control switch.

For the pressure and temperature controls there will be a manual set point station for each loop enabling the operator to switch from automatic to manual independently of the mode control switch and providing continuous indication of valve position.

The computer printer will be available to print out a complete record of operations since the start of the sequence in progress, either on demand or automatically in case of an alarm.

A simulator will be located in the control centre with the computer. It will consist of a set of switches simulating feedback signals from switches on the field devices and manually operated analog units to simulate position feedback transducers and pressure and temperature transmitters, and a plug-board enabling the simulator devices to be patched into the system in various arrangements.

The computer is considered a highly reliable unit, but to increase reliability even further key information will be stored in both computers. This will include memory information on the condition of each magazine station, the position of the plugs and of the fuel adaptor, and the step in the sequence which is in progress. Position feedback transducers on the rams, latch and magazine, as well as pressure and temperature transmitters on the fuelling machine heads will be duplicated.

Those parts of the feedback control loops handled by the computer will be included in both machines, with cross checking between the two.

Two 100% supplies of each type will be provided with arrangements for connecting the alternative supply rapidly at the control centre racks. In the case of oil supplies to the carriage, interconnection between the two pump outputs with appropriate remotely operated valves will be provided.

Indication will be provided independently of the computer, with sufficient accuracy to enable any operation to be performed manually. Rugged devices with high signal levels are required and reliability is a prime consideration. Where a short linear motion, that is, of the order of 5 inch or less, is being measured, linear variable differential transformers have been chosen as the simplest and most reliable units. Where the accuracy requirement is of the order of 1 part in 5,000, a coarse and fine pair of potentiometers is specified. Potentiometers have a sliding contact but a high degree of reliability can be expected and these probably provide the simplest overall system. As a backup a brush type DECITRAK encoder system is being installed on a ram assembly at Sheridan Park.

5.4 FUEL TRANSFER

5.4.1 New Fuel Handling

5.4.1.1 General

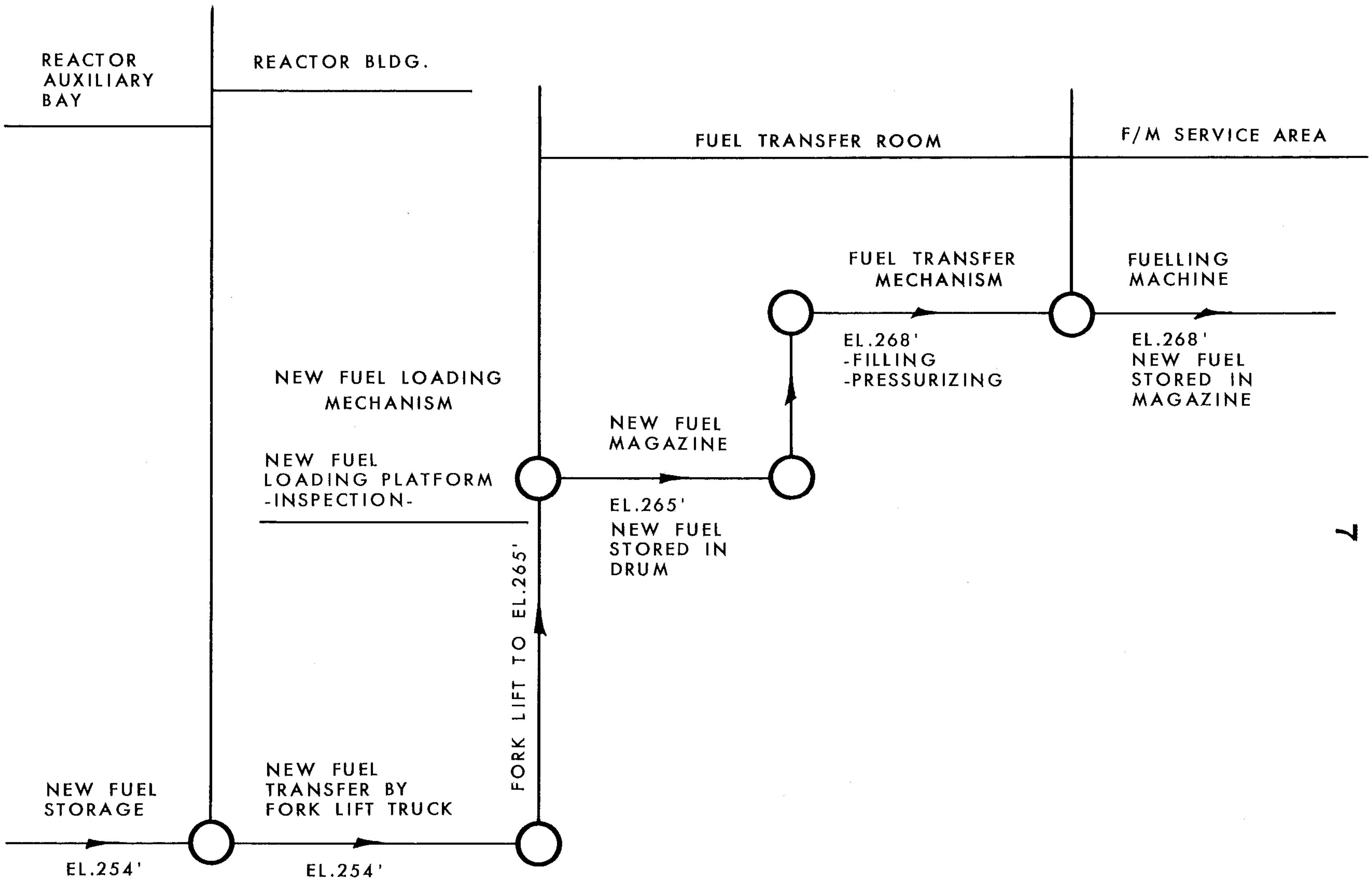
The new fuel transfer system is illustrated in Figures 5.4-1 and 5.4-2.

Packages holding 36 fuel bundles are moved by fork lift truck from new fuel storage to the Reactor Building. Inside the building the packages are deposited on turntables at elevation 262 feet 9 inches, located in passageways R110 and R111. Each turntable can hold two fuel packages. The turntable positions the fuel bundles directly under a manually assisted pneumatic hoist, which carries them to the new fuel loading mechanism. The hoist is fitted with a fuel handling tool which permits rotation of the fuel bundle for inspection.

After inspection and identification by number, the fuel bundle is lowered into the trough of the new fuel loading mechanism. The trough is in line with the port through which new fuel is introduced into the system. The port is normally closed by a shielding gate which is locked in the port, and which is unlocked to permit removal only when the radiation level in the fuel transfer room is sufficiently low. The loading trough will accommodate two fuel bundles end to end. Placing two fuel bundles in the trough establishes a permissive which, in conjunction with other permissives from the shielding gate and new fuel magazine, allows the operator to energize the ram which pushes fuel from the trough, through the port and into the new fuel magazine. The load ram is chain driven by a pneumatic motor having speed control. The stroke of the ram is such as to locate the fuel bundles centrally in a magazine channel to a tolerance of $\pm$ 1/4 inch.

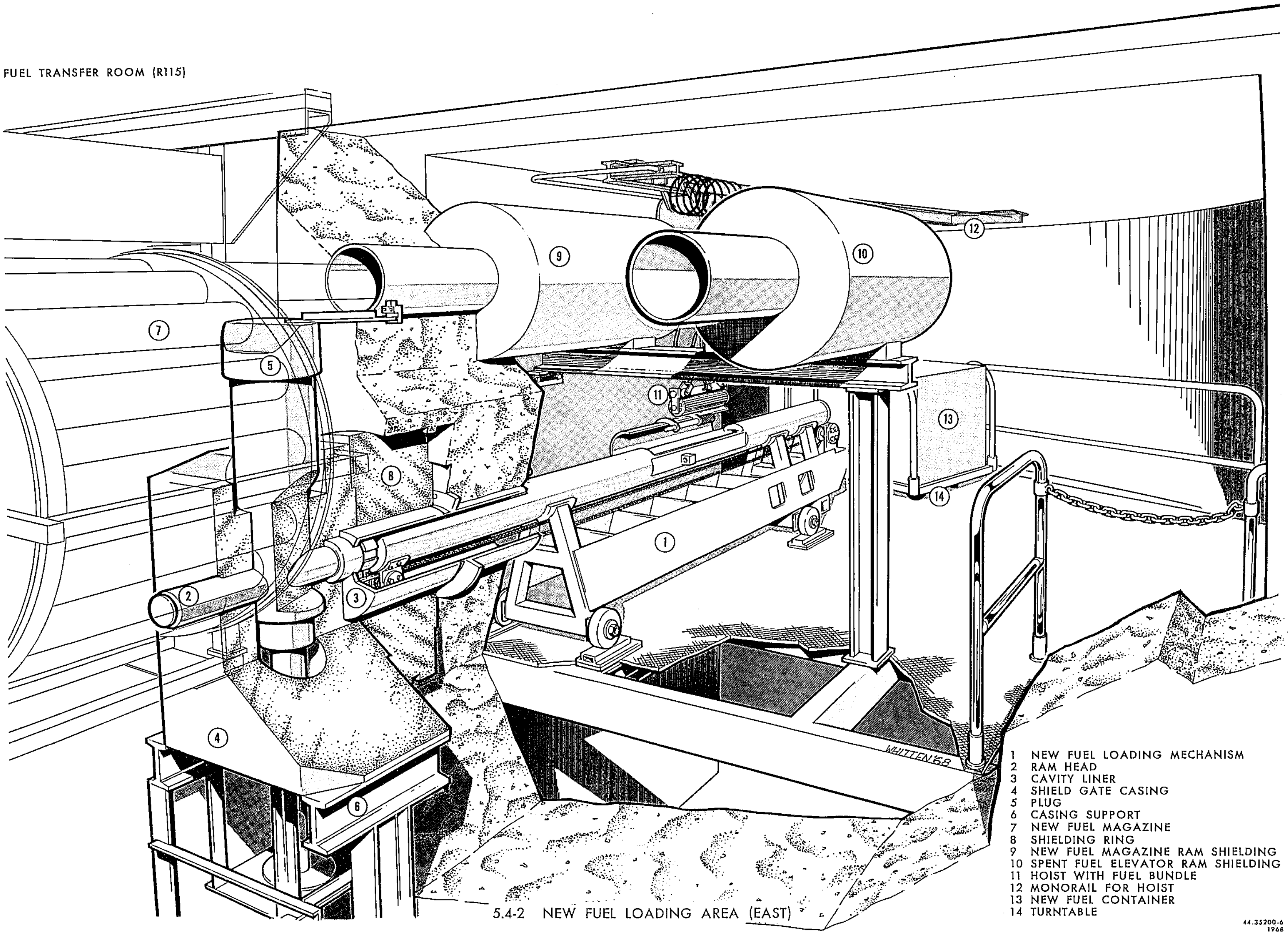
5.4.1.2 New Fuel Magazine

The new fuel magazine has a rotor containing 16 two-bundle fuel channels giving a capacity of 32 fuel bundles. Since there are two new fuel magazines per reactor, the total new fuel storage in the system is 64 bundles per reactor or approximately one week's fuel supply. The magazine is rotated three channels at a time by a single station Ferguson indexing drive unit which is coupled to the magazine by a gear train. The gears are a 192 tooth 8 Dp internal gear on the magazine and a 36 tooth 8 Dp pinion on the drive output shaft giving a reduction ratio of 3:16. Thus as the Ferguson drive output shaft rotates 360°, the magazine is rotated 67-1/2° or 3 channels. Indexing is initiated by the operator under local manual control when loading the magazine. Torque requirements of the magazine are unidirectional. Thus backlash in the gear train will not disturb the accuracy of the indexing

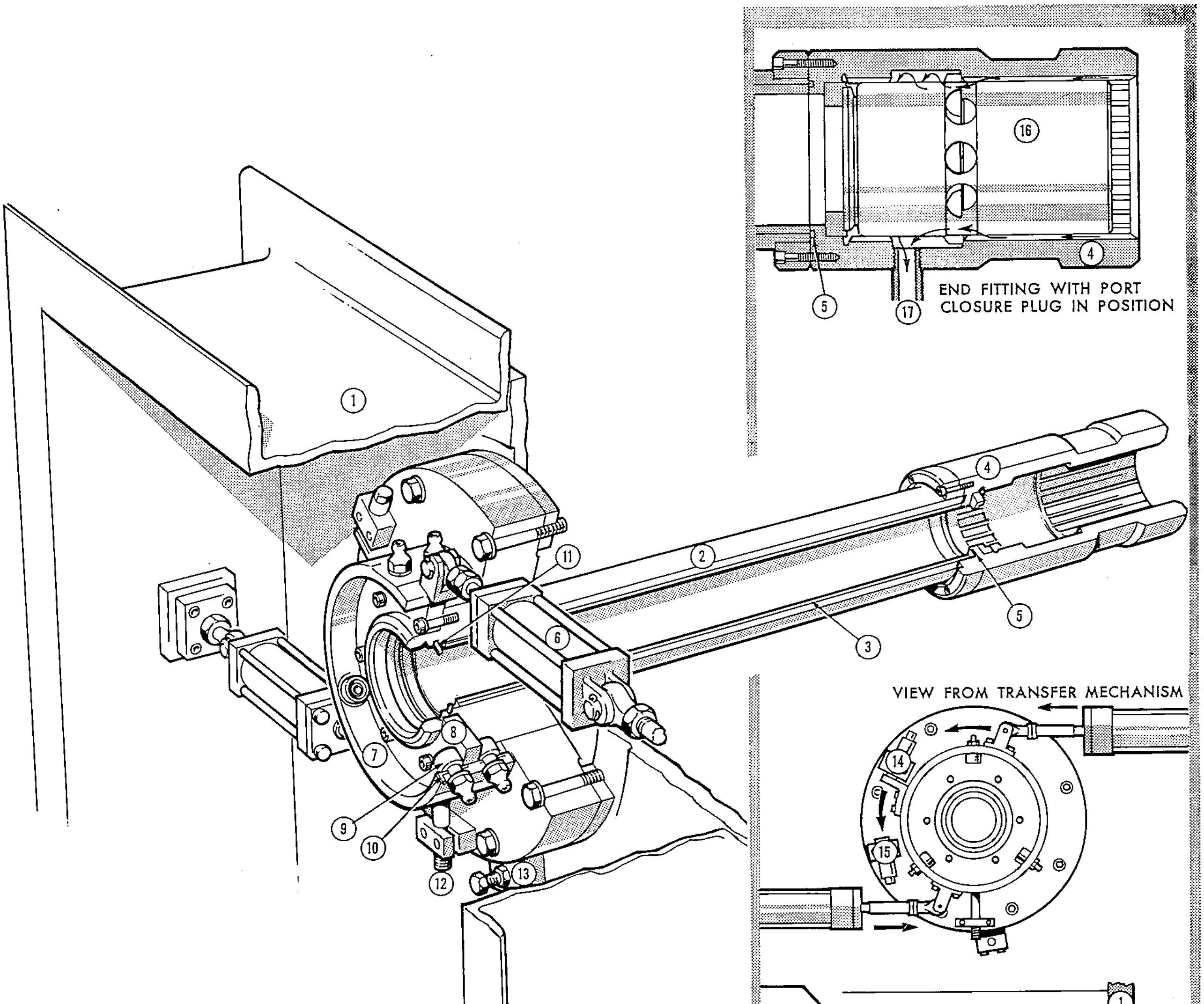


5.4-1 NEW FUEL TRANSFER SYSTEM

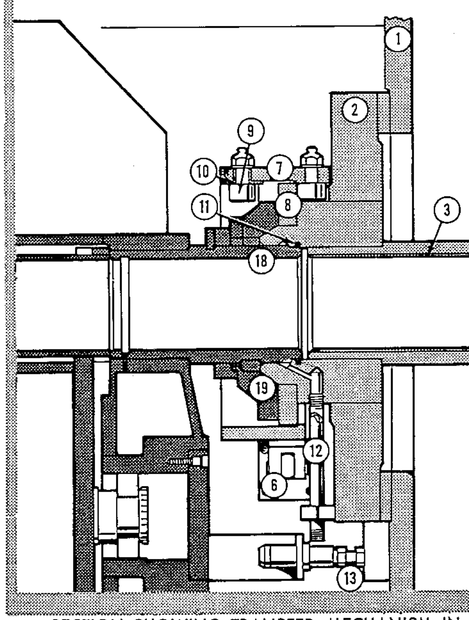
44.35200-3
REV. 1 1967



5.4-2 NEW FUEL LOADING AREA (EAST)



1 EMBEDDED FRAME
2 PORT MOUNTING HEAD
3 TUBE LINER
4 END FITTING-CONNECTION TO FUELLING MACHINE
5 METALLIC SEAL
6 LOCKING CYLINDERS
7 LOCK RING
8 LATCH PLATE
9 ROLLERS
10 ECCENTRIC BUSH FOR ROLLER ADJUSTMENT
11 TRANSFER MECHANISM SNOUT SEAL
12 DRAIN TO LEAKAGE DETECTOR
13 SWITCH STOP-TRANSFER MECHANISM SNOUT EXTENDED
14 LIMIT SWITCH-SNOUT UNLOCKED
15 LIMIT SWITCH-SNOUT LOCKED
16 PORT CLOSURE PLUG
17 D_2O RETURN FROM FUELLING MACHINE
18 TRANSFER MECHANISM-SNOUT
19 SELF ALIGNING FLANGE-T/M SNOUT



SECTION SHOWING TRANSFER MECHANISM IN POSITION FOR LOADING

5.4—3 TRANSFER PORT FUEL TRANSFER SYSTEM

44.35220.1
1967

operation. However, backlash will be minimized by providing adjustment in mounting the Ferguson unit so that clearance between gear teeth can be controlled. The purpose in rotating the magazine three channels at a time is to reduce the unbalanced torque from the rather large value which would result if each channel were loaded successively.

The magazine is arranged so that when the channel at the bottom is in line with the new fuel port to receive two fuel bundles from the inspection area, the channel at the top is in position to discharge two fuel bundles into the transfer mechanism. With the shielding gate removed, the new fuel port is open into a chamber of the magazine. However, the transfer room is held at a slight negative pressure so that there will be an airflow through the port into the transfer room from the new fuel loading area.

The ram which pushes fuel from the new fuel magazine into the transfer mechanism is a pneumatic cylinder with hydraulic speed control. The stroke of the cylinder is such as to push two fuel bundles from the new fuel magazine and locate them centrally within the magazine to a tolerance of $\pm 1/4$ inch.

5.4.1.3 Transfer Mechanism

Transfer of new fuel from the new fuel magazine to the reactor fuelling machine is accomplished by the transfer mechanism. This device accepts fuel from the new fuel magazine, swings it through 90° and pushes it through the transfer tube in the wall of the fuelling machine vault and into the fuelling machine magazine. The transfer mechanism has a rotary magazine containing six two-bundle channels. The magazine is rotated one channel at a time by a Ferguson indexing drive equipped with a Direct Power unit and electric motor.

Design conditions for transfer mechanism shell and heads:

Internal pressure — 175 psig
Temperature — 300°F

To receive a load of new fuel the transfer mechanism positions itself at the new fuel magazine and advances on its fine motion to engage the guide ring on the loader. This fine motion is provided by ball-way assemblies and two air cylinders mounted on the transfer mechanism. Two fuel bundles are pushed from the new fuel magazine into the top channel of the transfer mechanism by the pneumatic ram on the loader. The magazines in the new fuel magazine and in the transfer mechanism both index to the next position and the fuel transfer operation is repeated until the transfer magazine has received a full fuelling machine load of fuel (usually 10 bundles — maximum 12 bundles).

The transfer mechanism withdraws on its fine motion until its snout clears the guide ring on the new fuel magazine. It then is rotated through 90° by a pneumatic rotary actuator to line up with the transfer tube into the fuelling machine service area. The device then advances on its fine motion toward the tube and enters the locking ring.

5.4.1.4 Transfer Port

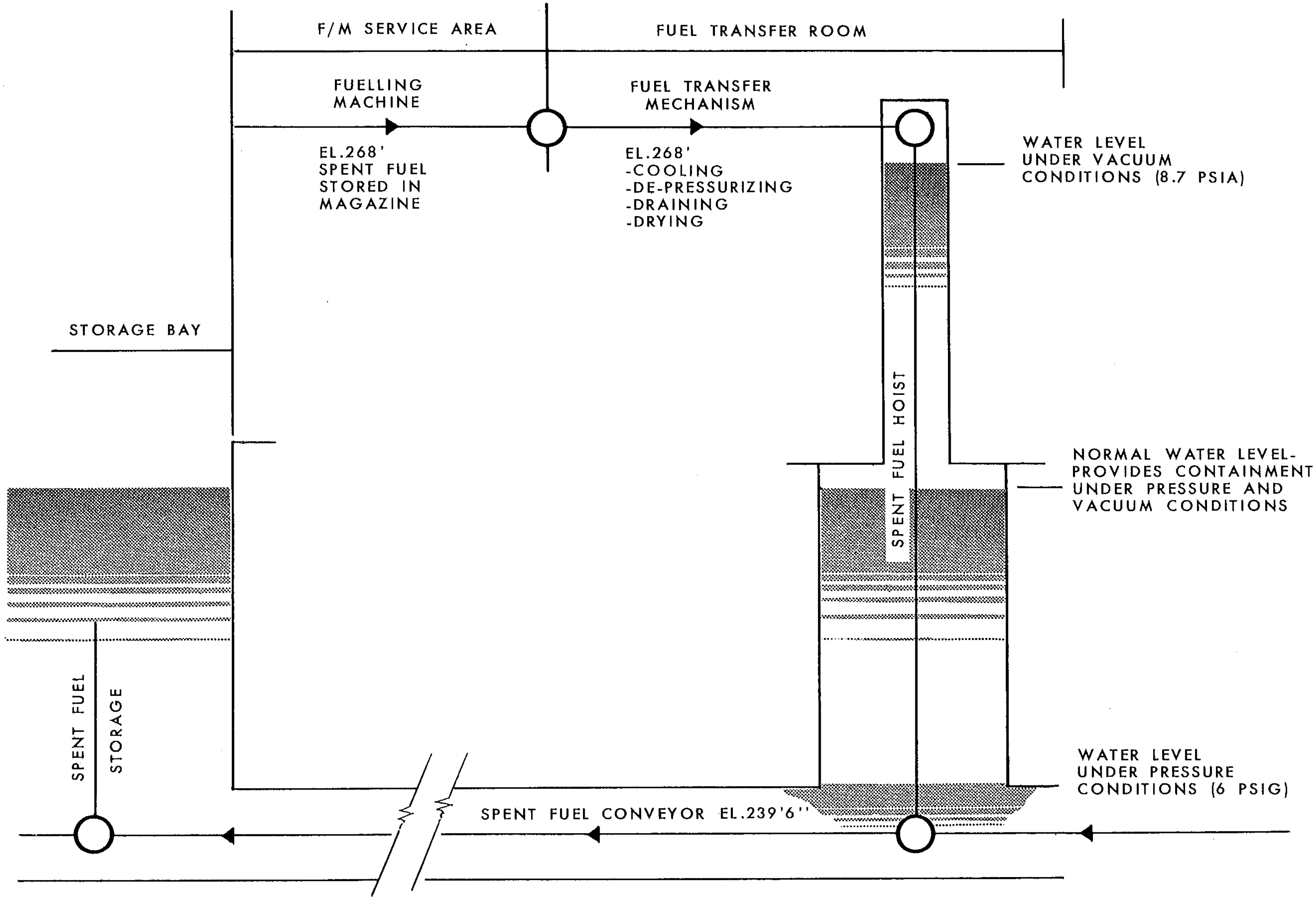
The general arrangement of the transfer port is shown in Figure 5.4-3. The transfer tube penetrates the wall of the fuelling machine service area and provides a port for the inter-change of fuel between the transfer mechanism and the fuelling machine. When not passing fuel the tube is plugged by a channel closure. The transfer room end of the tube has an 'O' ring seal and a locking ring for coupling to the transfer mechanism. The 'O' ring seals radially around the circumference of the transfer mechanism's snout. The locking ring clamps against a self-aligning flange on the snout. Thus a small amount of angular misalignment can be tolerated when coupling the transfer mechanism to the transfer tube. When the snout enters the locking ring and the seal, the ring is rotated by a pair of air cylinders and the transfer mechanism is locked to the transfer tube.

The fuelling machine end of the transfer tube has an end fitting similar to the reactor end fittings which will accept a channel closure plug, and to which the fuelling machine can couple. The channel closure plug is removed by the fuelling machine only when the transfer mechanism and fuelling machine are ready to interchange fuel and when pressure across the plug is balanced.

5.4.2 Interchange of Fuel Between Transfer Mechanism and Fuelling Machine

The transfer mechanism is vented and allowed to fill with D_2O. When full, the system which circulates D_2O coolant through the transfer mechanism is pressurized to approximately 130 psig. The fuelling machine removes its snout plug which reduces the pressure inside the fuelling machine to approximately 130 psig, at which time the closure plug in the transfer tube is removed by the fuelling machine. A flow of heavy water at a rate of 20 Igpm is maintained through the transfer mechanism to the heat exchangers. This flow cools the spent fuel in the transfer mechanism.

The fuelling machine magazine contains a full load of spent fuel. The transfer mechanism contains sufficient new fuel bundles in channels 2 to 6 to satisfy the requirements of the fuelling machine. Channel No. 1 of the transfer mechanism is empty. Channel 6 is at the top position which is a requirement when moving the transfer mechanism to and from the transfer tube. The magazine of the transfer mechanism indexes two steps to bring channel 1 to the top position in line with the fuel transfer tube. There is an index position between each pair of channels to permit draining of the fuel channel before it is brought in line with the snout. The fuelling machine prepares to discharge spent fuel and pushes two bundles into channel 1 of the transfer mechanism. The magazine of the transfer mechanism indexes to bring channel 2 to the top position in line with the snout. Two bundles of new fuel are pushed from this channel into the fuelling machine by the transfer



5.4—4 SPENT FUEL TRANSFER SYSTEM

44.35200-4'
REV. 1 1967

mechanism ram. The magazine of the fuelling machine is indexed to the next fuel channel. The operation continues until all the new fuel is in the fuelling machine and all the spent fuel is in the transfer mechanism. The magazine of the transfer mechanism is indexed to bring channel 6 to the top position which is a requirement for lowering the water level and moving from the transfer tube. The fuelling machine inserts the closure plug in the transfer tube and installs its snout plug. D_2O which is trapped between the closure plug and the snout plug is drained off through the fuelling machine snout drain. The fuelling machine is then uncoupled from the transfer tube to service the reactor.

5.4.3 Spent Fuel Handling

The spent fuel transfer system is illustrated in Figures 5.4-4 and 5.4-5.

5.4.3.1 Transfer Mechanism

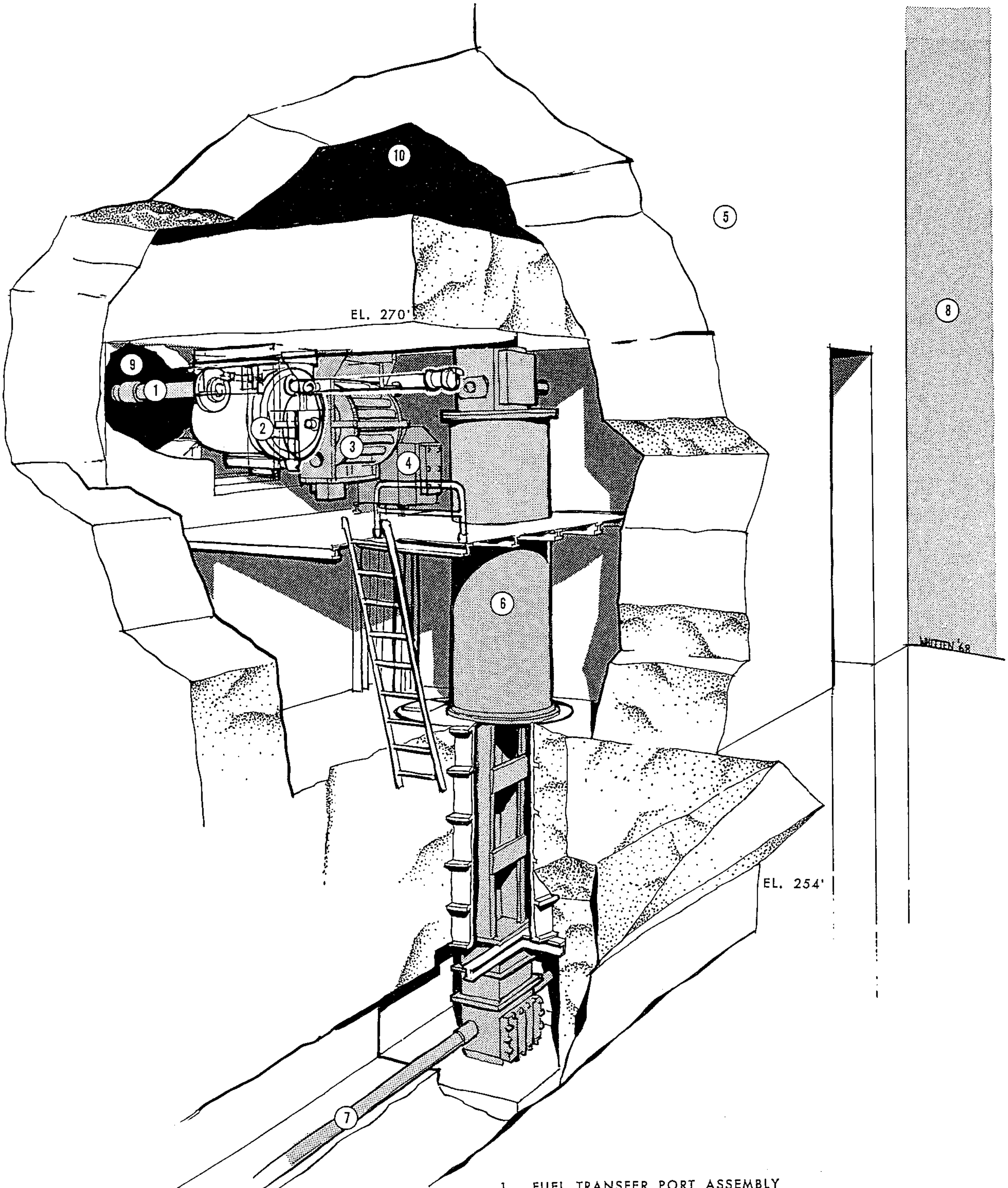
The transfer mechanism, which now contains a full fuelling machine load of spent fuel, has been indexed to bring its empty channel 6 to the top position. It remains coupled to the transfer tube while its temperature is reduced to about 130°F by the circulation of cooled D_2O, which is supplied directly to the mechanism from the heat exchangers. When the 130°F temperature has been reached, the water level is lowered below the snout by opening the drain valve and vent valve, and is maintained at this level by a weir at the rear end of the housing. The drain valve is closed and the transfer mechanism remains vented to the D_2O tank at atmospheric pressure. The circulation of D_2O is continued to remove the heat being released by the spent fuel. Incoming D_2O is fed into the front end of the transfer mechanism at the bottom. Heated D_2O rises and spills over the weir at the rear end, which controls the water level and is returned to the heat exchangers by the circulating pump.

When the water level in the transfer mechanism has been lowered below the snout, the locking ring on the transfer tube is rotated by its pair of air cylinders to uncouple the transfer mechanism from the tube. The transfer mechanism retracts on its fine motion a distance of about 4 inches so that its snout clears the transfer tube locking ring. The fine motion is provided by mounting the housing of the transfer mechanism on rails and driving it through its 4 inch stroke by a pair of air cylinders. One rail is a hardened steel shaft on which the housing is mounted by a pair of linear ball bushings. The other rail is a closed cam track along which runs a single self-aligning wheel which supports the other side of the housing. When its snout is clear of the locking ring, the transfer mechanism rotates through 90° and moves on its main traversing rails a distance of 48 inches into position at the elevator. For its rotary motion the transfer mechanism is suspended from a circular track which is carried on a series of cam followers. Rotation is provided by a pneumatic rotary actuator. The main traversing motion is accomplished by suspending the carriage of the transfer mechanism from a pair of rails mounted on the ceiling of the fuel transfer room, and driving it through its 48 inch stroke by an air cylinder equipped with speed controls. One rail is hardened steel roundway along which the carriage of the transfer mechanism is guided by a pair of linear ball bushings. The other rail is a closed camtrack along which run the self-aligning wheels of the carriage.

When at the elevator, the transfer mechanism advances on its fine motion to enter the locking ring of the elevator and locks thereon. While moving to the elevator, the transfer mechanism has its empty channel (No. 6) at the top position. Now that it is locked on the elevator and the elevator carriage is at its top position, the magazine of the transfer mechanism indexes to bring a channel containing spent fuel out of the water but not in line with the snout. A time delay is introduced into the fuel transfer operation at this point to ensure complete drainage of the channel and the evaporation of D_2O adhering to the fuel. At present no provision is being made to reclaim the D_2O vapour which escapes from the snout of the transfer mechanism while coupled to the elevator. After the time delay, the magazine moves to the top position and the fuel is pushed into the elevator by the transfer magazine ram. This operation does not require the full ram stroke. Thus the ram stalls when the fuel comes against the end stop in the elevator. During the transfer of spent fuel to the elevator, D_2O is circulated through the transfer mechanism to remove heat released by fuel remaining in the magazine. The D_2O level is maintained below the snout opening by the weir and circulating pump.

The magazine is a rotary type with six channels equally spaced on a pitch circle diameter of 18 inches. The hub of the magazine is an enclosed cylinder which reduces the D_2O hold-up and provides buoyancy to reduce the load on the bearings. The magazine is carried on a pair of ITI 11796 size 308 deep groove ball bearings made of 400C stainless steel. Each bearing has a radial load capacity of 600 lbs. when operating in a D_2O environment. The magazine is driven through a 6:1 reduction gear train consisting of a 180 tooth 22.50" Pd 8 Dp internal ring gear mounted on the magazine and a 30 tooth 3.75" Pd pinion on the output shaft of the Ferguson indexing drive unit. The purpose of the gear train in the magazine drive is to facilitate removal of the drive and shaft seal for servicing without having to dismantle the magazine as would be the case with a direct coupled drive. It also reduces the torque requirements of the drive and permits the use of a single station indexing unit. The indexing drive is mounted so that the centre to centre distance of the pinion and ring gear can be adjusted by rotating an eccentric bushing to reduce backlash to acceptable limits.

The ram on the transfer mechanism is a two stage telescoping screw device driven by an air motor through a speed reducer and having a stroke of 103-1/4 inches. It consists of an inner and an outer Acme screw assembly which is enclosed within a pair of splined telescoping tubes, the entire assembly being housed in a 5 inch diameter tube about 5 feet long. As the ram extends the overhanging weight is supported by the ram head as it passes through the tubes of the transfer mechanism, the transfer tube and



1 FUEL TRANSFER PORT ASSEMBLY
2 FUEL TRANSFER MECHANISM
3 NEW FUEL MAGAZINE ASSEMBLY
4 SHIELD GATE ASSEMBLY
5 SOUTH CROSS WALL
6 ELEVATOR
7 SPENT FUEL CONVEYOR TUBE
8 REACTOR BUILDING WALL
9 FUELLING MACHINE SERVICE ROOM
10 FUELLING MACHINE VAULT

5.4-5 VIEW LOOKING EAST
FUEL TRANSFER ROOM (EAST)

44.35200-5
1968

fuelling machine snout. Power is applied to the inner screw by an air motor operated speed reducer. The input shaft is sealed by a double Quad-Ring seal with leak-off groove and drain connection. The ram assembly is flanged connected to the housing of the transfer mechanism and can be removed as a complete unit by unbolting the flange. The ram internals are exposed to the D_2O environment of the transfer mechanism and hence are lubricated by this medium. The ram strokes between mechanical stops which are adjustable to give a stroke variation of $\pm 1/2$ inch from the nominal 103-1/4 inch stroke. The stops are accessible for adjustment by removing the ram head. The ram has a two-speed drive. The low speed is used at the ends of the stroke when entering the mechanical stops and when the ram head is approaching the fuel. The low speed is used also a few inches before the ram stalls when pushing fuel into the elevator.

5.4.3.2 Elevator

The elevator, reference Figure 5.4-6, interconnects the transfer mechanism in the fuel transfer room with the conveyor in the spent fuel duct. The elevator has the following functions:

(a) Lowers spent fuel, two bundles at a time, from transfer mechanism to conveyor and deposits fuel on conveyor.

(b) Returns fuel from conveyor to transfer mechanism if necessary.

(c) Brings fuel can from conveyor to transfer mechanism if necessary.

(d) Provides pressure containment for the Reactor Building by means of an hydraulic seal between Reactor Building and storage bay.

The elevator consists of a carriage which moves vertically between two fixed positions, one at the top of its travel where it is in alignment with the snout of the transfer mechanism, and the other at the bottom of its travel where it meshes with the saddles on the conveyor. The carriage will accommodate two fuel bundles and has four fingers, two per bundle, which are cantilevered from a pair of guide wheels running in vertical tracks at each end of the carriage. The fingers support the fuel on their end bearing pads when lying end to end in the carriage. The carriage is raised and lowered by a pair of chains driven by an air motor through a speed reducer and sprockets. Accurate positioning of the carriage is obtained by running it against fixed stops at the ends of its travel and stalling the drive. When the carriage is in its top position to receive fuel from the transfer mechanism, a set of pivotted saddles swings into place to fill up the gaps between the carriage fingers, and to provide a relatively continuous surface over which the fuel slides when entering the elevator. Before the fuel is lowered on the elevator the pivotted saddles swing clear of the path of the elevator carriage.

In the event that the elevator carriage stops between its two end positions, a cooling water spray system can be operated to prevent overheating of the spent fuel bundles.

The elevator comprises four basic sections:

(1) The drive section at the top of the elevator which contains the air motor drive, the snout lock for coupling to the transfer mechanism, the pivotted saddles which support fuel as it is pushed into the elevator together with its pneumatic operator, the retractable end stop against which fuel is pushed by the transfer mechanism ram, the pneumatic fuel return ram, and the water spray header.

(2) The water containment section extending downward from the drive unit to the floorplate over the transfer shaft. This section has a watertight housing, which is sealed where it joins the floorplate, and contains tracks for the elevator carriage.

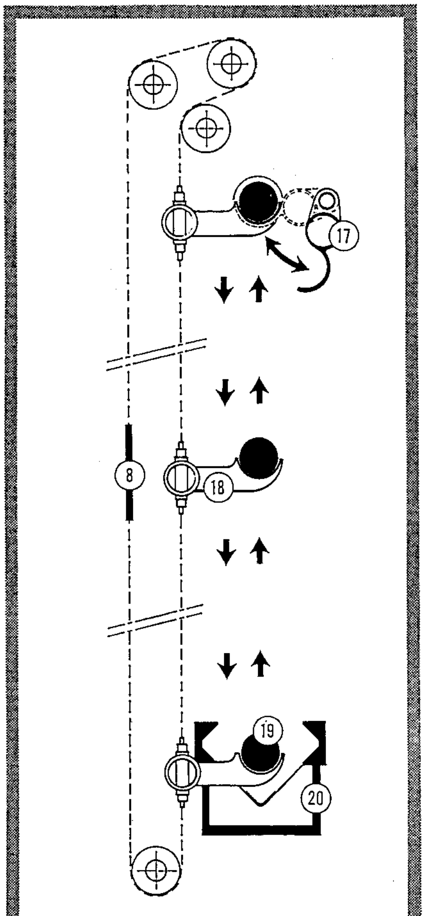
It is designed to withstand the hydraulic pressure of water which would rise inside this section if the Reactor Building was inadvertently depressurized, and an external pressure of 6 psi if the Reactor Building became pressurized.

(3) The transfer shaft section, which passes vertically through the concrete foundations from the floor of the transfer room to the spent fuel duct, completes the pressure containment of the Reactor Building. It is normally full of light water and contains tracks for the elevator carriage.

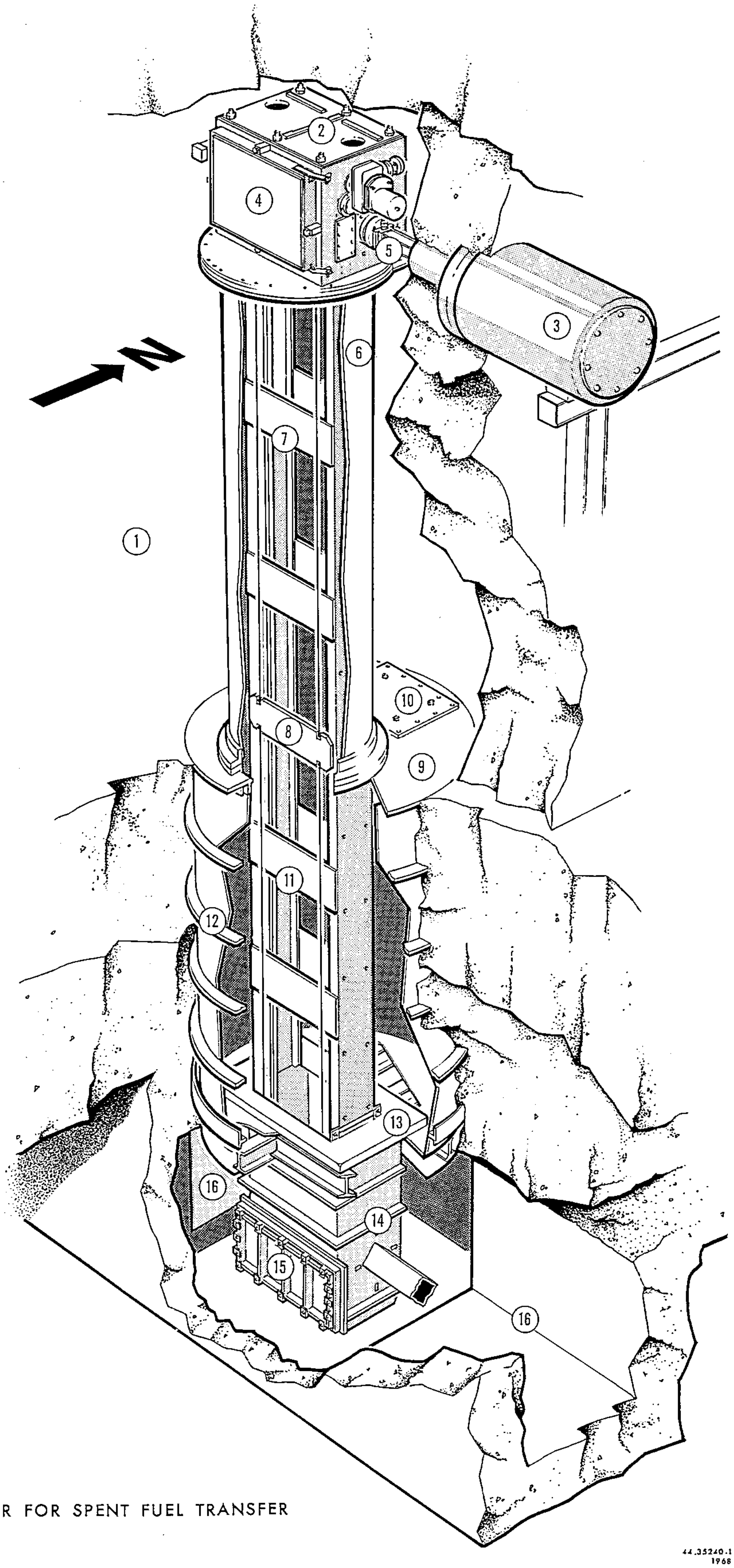
(4) The tail section is at the bottom end of the elevator in the spent fuel duct. It provides water containment between the transfer shaft and the conveyor tube. It contains the chain return sprockets for the elevator drive, the retractable stop for the conveyor, and its pneumatic operator, tracks for the conveyor cart and the elevator carriage.

5.4.3.3 Conveyor

The conveyor consists of an 8-wheeled cart running on the inside of an 8 inch square stainless steel tube laid in the spent fuel duct between the Reactor Buildings and the inspection bay. The cart is pulled through the tube by a plastic covered stainless steel cable. The drive is of the traction type, powered by an air motor. It is located at the inspection bay end of the system. The conveyor serves two reactors and hence four elevators. Thus there are five stations at which the cart must be accurately positioned, one at the inspection bay, and two in each Reactor Building. The accurate positioning at each station is assured by running the cart against adjustable mechanical stops and stalling the drive. The stops at the end stations are permanent; those of the intermediate stations are retractable and operated by air cylinders.



SPENT FUEL CONVEYOR



1 TRANSFER ROOM
2 TOP HOUSING ASSEMBLY
3 RAM SHIELDING ASSEMBLY
4 ACCESS DOOR
5 FUEL STOP AND RETURN RAM
6 COLUMN
7 UPPER GUIDEWAY ASSEMBLY
8 COUNTERWEIGHT PLATE
9 FLOORPLATE
10 ACCESS COVER
11 LOWER GUIDEWAY ASSEMBLY
12 TRANSFER SHAFT EMBEDDED PART
13 BOTTOM HOUSING COVER SEAL
14 BOTTOM HOUSING
15 ACCESS DOOR
16 SPENT FUEL TUNNEL
17 GUIDE TROUGH ASSEMBLY
18 ELEVATOR CARRIAGE
19 FUEL BUNDLE
20 CONVEYOR CART SUPPORT HOUSING

5.4-6 ELEVATOR FOR SPENT FUEL TRANSFER

44.35240-1
1968

The conveyor cart is an open topped saddle of sufficient length to accommodate two fuel bundles lying end to end. It has four slots milled through one side in line with the end pads on the fuel bundles. These slots permit the fuel support fingers on the carriages of the elevators to pass through the cart. Thus, the fuel bundles which are carried on the fingers of the elevator carriage are left behind on the conveyor cart as the fingers pass through.

5.4.3.4 Conveyor Unloader

The conveyor unloader terminates the conveyor at the inspection bay end. Its function is to remove fuel bundles from the conveyor cart and deposit them in a storage container positioned on the storage loader.

The conveyor unloader has two light water hydraulic cylinders; the smaller one is connected to a linkage which removes the end plate from the conveyor cart and lowers the larger cylinder into its operating position; the larger cylinder pushes the two fuel bundles from the conveyor cart into the cavity in the storage container.

With the fuel bundles in the storage container and the large cylinder retracted, the small cylinder is reversed to replace the end plate in the conveyor cart and to lift the large ram so that the conveyor cart can be moved to an elevator.

5.4.3.5 Storage Loader

The storage loader is located adjacent to the conveyor unloader in the inspection bay. Its purpose is to receive empty storage containers in the storage bay area, bring them to the conveyor unloader, index the cavities in the storage container with the discharge port of the conveyor unloader, and return full storage containers to the storage bay area.

The basket loader has five light water hydraulic cylinders; four for indexing the storage container and one for moving the storage container between the inspection and storage bays through the large port in the dividing wall.

The gantry crane over the storage bay places empty storage containers on the storage loader and removes the full ones for stacking in the storage bay.

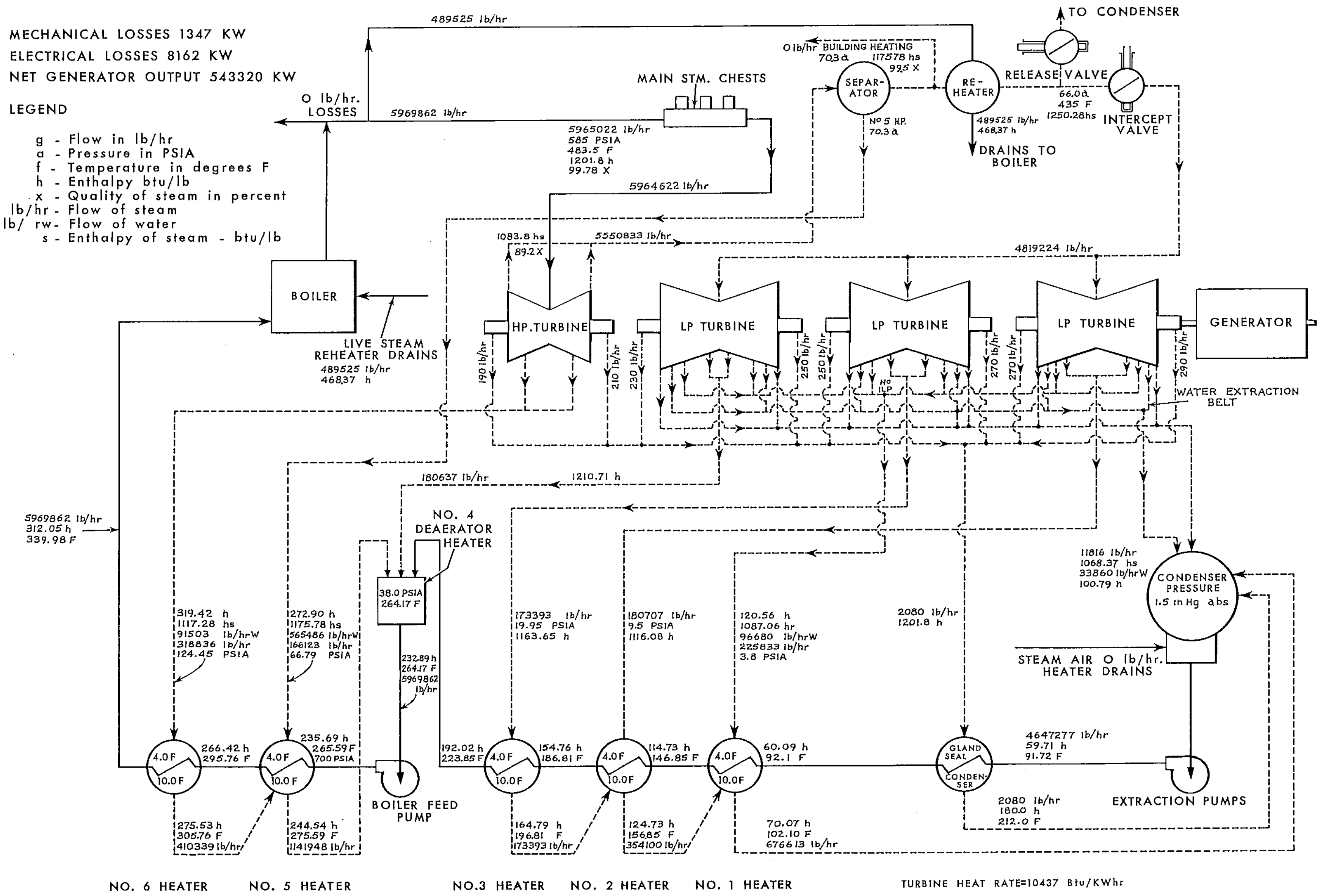
5.5 FUEL TRANSFER CONTROLS

The fuel transfer controls include electrical controls and instrumentation for the equipment and systems described in Section 5.4.

The main part of the logic is provided by the station digital computer. The modes of operation are the same as those described for the fuelling machine in Section 5.3.6.1.

Sequences involving the fuelling machine and fuel transfer system are mentioned in Section 5.3.6.4. Sequences will also be provided to (1) load the transfer mechanism with new fuel, (2) transfer used fuel from the transfer mechanism to the storage area, and (3) transfer fuel from the storage area to the transfer mechanism.

The location of the main control areas is shown in Figure 5.3-6C, and the panels in the control centre are discussed in Section 5.3.6.6. Local panels for manual operation will be provided outside the fuel transfer room and in the spent fuel storage area.



6—1 TURBO GENERATOR HEAT BALANCE

44.64100—1

6. TURBINE GENERATOR SYSTEM

6.1 GENERAL

The Turbine Generator System comprises four turbine generator units and associated condensing and feedwater systems. Each turbine generator system is fully independent, operating in conjunction with its own nuclear reactor. The turbine generator units are single shaft machines with a speed of 1800 rpm and a nominal gross output of 540 MW. The steam conditions at full load are 585 psia, 483.5°F at the high pressure turbine throttle valves with live steam reheat of the high pressure turbine exhaust to 435°F. The corresponding steam consumptions are:

5,970,000 lb/hr to the high pressure cylinder

490,000 lb/hr live steam to the steam reheater.

A simplified full load heat balance is shown in Figure 6-1.

6.2 TURBINE

The turbine is a tandem compound unit direct coupled to the generator. It comprises one double flow high pressure cylinder followed by external moisture separators, live steam reheaters and three low pressure cylinders. Two external main steam chests are provided, one on each side of the high pressure cylinder, each containing two emergency stop valves and two governing valves. The high pressure turbine exhausts to four one-stage steam and water separators in parallel which are in series with two live-steam reheaters in parallel. Six intercept valves and six release valves are located in six steam lines carrying reheated steam to the three low-pressure turbines. The intercept valves close upon loss of load to limit the speed rise of the machine, and the release valves open to discharge entrained steam in the high pressure turbine, separators and reheaters to the condenser.

The inlet steam to the high pressure turbine is dry and saturated and as it expands through the turbine the water content increases. At the high pressure turbine exhaust the steam and water pass through a centrifugal type separator where 95% of the water is removed. The water is extracted to a feed heater and the steam passes to a tube type reheater where it is reheated by main steam from the nuclear boilers. The steam to be reheated passes across the outside of the tubes and the reheating steam passes through the tubes.

The reheating steam is condensed to water in the reheaters and is pumped back to the boilers by two 100% capacity reheater drain pumps. The reheated steam passes to the low pressure turbines from where it exhausts into the condenser.

Extraction openings are located on the turbine casings to provide steam extraction to six stages of feedwater heating. In addition large quantities of water in the steam are also removed at these points from turbine zones operating in the wet steam region to reduce the possibility of water erosion on turbine casings and blades.

The turbine start-up from turning gear to synchronization is programmed into the unit computer. This program includes monitoring turbine conditions such as bearing vibration and eccentricity with corrective action being taken if permissive limits are exceeded.

The turbine is fitted with normal overspeed and trip protection which includes an overspeed limiting device to close emergency trip and intercept valves upon opening of the generator breaker. When the sudden loss of load occurs this prevents excessive speed rise by tripping of the turbine emergency stop valves.

The turbine generator load control is of the reactor following type, the electrical load on the generator being regulated from the reactor pressure controller. Steam pressure from the nuclear boiler to the high pressure turbine is adjusted by the unit control computers so that pressure is adjusted for the particular reactor output needed to meet turbine generator electrical load. This pressure varies between 765 psia at no load to 585 psia at full load.

6.3 FEEDHEATING SYSTEM

Six stages of feedwater heating are provided, three horizontal low pressure heaters, one deaerating heater, and two horizontal high pressure heaters. Each low pressure and high pressure heater consists of twin shells and are the closed tube type.

Three 50% duty condensate pumps take condensate from the condenser hotwell and pump it through the three low pressure heaters to the deaerating heater. The deaerating heater provides suction to three 50% duty constant speed electrically driven foiler feed pumps which supply feedwater through the two high pressure feedheaters to the nuclear boiler.

Feedheater drains from No. 6 feedheater shells are cascaded to No. 5 feedheater and each shell of No. 5 feedheater has two 100% duty drain pumps discharging to the deaerating heater. No. 5 heater also receives the drains from the steam separator. Drains from the low pressure heaters are cascaded to the next lower heater and No. 1 heater drains to the condenser. Suitable drain bypass lines and controls are fitted to handle feedwater drains during start-up and low load operation.

In addition to the main boiler feed and condensate pumps, one auxiliary boiler feed pump and one auxiliary condensate pump are installed to provide feedwater for reactor cool down. These pumps are rated at 4% of the capacity of the main pumps.

6.4 REACTOR POISON PREVENT SYSTEM

Provision is being made for a system to maintain reactor power at 70% to prevent the reactor from poisoning out following a turbine generator trip.

The design of this system is based on poison override of 45 minutes plus a poison prevent period of 60 minutes with the reactor at 70% of full power. One 500,000 gallon tank per unit will supply demineralized water via the condenser hotwell and condensate pumps to the deaerator. It will be heated to the minimum feedwater temperature required by the boiler (240°F) by live steam from the boilers. The heated water will be delivered to the boiler by the boiler feed pumps. The steam not required to heat the incoming demineralized feedwater will be discharged to atmosphere through the steam discharge valves.

The normal feedwater make-up to the feed system will also be provided from the 500,000 gallon demineralized water tank.

6.5 CONDENSING SYSTEM

The 280,000 sq.ft. surface condenser is in three transverse spring mounted shells welded to the turbine exhaust chamber necks. It contains 27,000 1-inch diameter, 40 feet tubes and requires 313,000 gallons per minute of lake water to condense the turbine exhaust steam. The water increases in temperature 18°F as it passes through the condenser, after which it is discharged back into the lake.

The water is provided by two low head single stage circulating water pumps located in a pumphouse adjacent to the turbine generator building.

Condenser vacuum is maintained by three rotary type mechanical vacuum pumps with normal operation requiring one pump, and two pumps for standby and evacuation duty during start-up.

6.6 GENERATOR

The generator is rated at 686,000 kVA at 45 psi hydrogen pressure, 24,000 volts, 3 phase, 60 cycle. The stator windings comprise hollow copper conductors through which cooling water at low pressure is circulated and the generator rotor is hydrogen cooled. The generator cooling water is kept at a controlled conductivity in a closed system; the system includes water to water heat exchangers to carry away heat associated with stator electrical losses.

The excitation system is a rectified ac system using magnetic amplifiers, the main exciter and the pilot exciter being driven directly from the generator shaft.

7. CONTROL AND INSTRUMENTATION

7.1 GENERAL

The instrumentation and control systems for the Pickering Station are for the most part based on designs and techniques evolved during the design of the Douglas Point Plant. Maximum use will be made of instrumentation methods which are believed to be superior in reliability and safety.

The basic control and protection philosophy for the Pickering reactors is essentially the same as that used at Douglas Point. A multiple channel regulating system is separated to the maximum extent from a triplicated protective system which will be tested during operation. The maximum rate of increase in reactivity is limited to the traditional value of 0.33 mk per second by physical limitations of systems and components.

The main differences between Douglas Point and Pickering affecting the control and instrumentation systems are associated with the size of the reactor, the need for a longer poison-override time, and the multiple unit construction schedule. The larger reactor increases the tendency for the neutron flux to deviate from its intended distribution as a result of minor local disturbances. To suppress this tendency the flux is measured and controlled in a number of zones in the core. To reduce the possibility of reactor poison-outs occurring due to minor faults, reactivity is held up in cobalt absorbers to override xenon poison for 45 minutes following a reactor trip from equilibrium full power operation.

The control centre has been planned for four units. At least two of these units will be under construction at the same time. While the first unit is loaded with fuel, reaches the critical stages, and is subsequently producing power, the second unit will be under construction and in commissioning stages. The second unit is physically located between the first unit and the control centre. Special care in design and construction will be taken to ensure that no disturbance or interference can take place with the control and protective system of reactors in the critical state. The addition of units three and four will increase the concentration of activity in the vicinity of the control centre. The control centre has been arranged so that controls and control equipment for each system occupy one quadrant of the 20,000 sq.ft. centre, thus providing physical separation of the control equipment and connections for each unit. Within the control room it is anticipated that a temporary barrier between the control area of units one and two and three and four will be required during construction.

7.2 OVERALL PLANT CONTROL

Viewed as a whole, the control system compels the plant to work in the intended manner despite uncertainty and variability of parameters in its components and despite failures and mishaps up to some degree of severity, beyond which the control system shuts the plant down with the maximum safety and minimum damage.

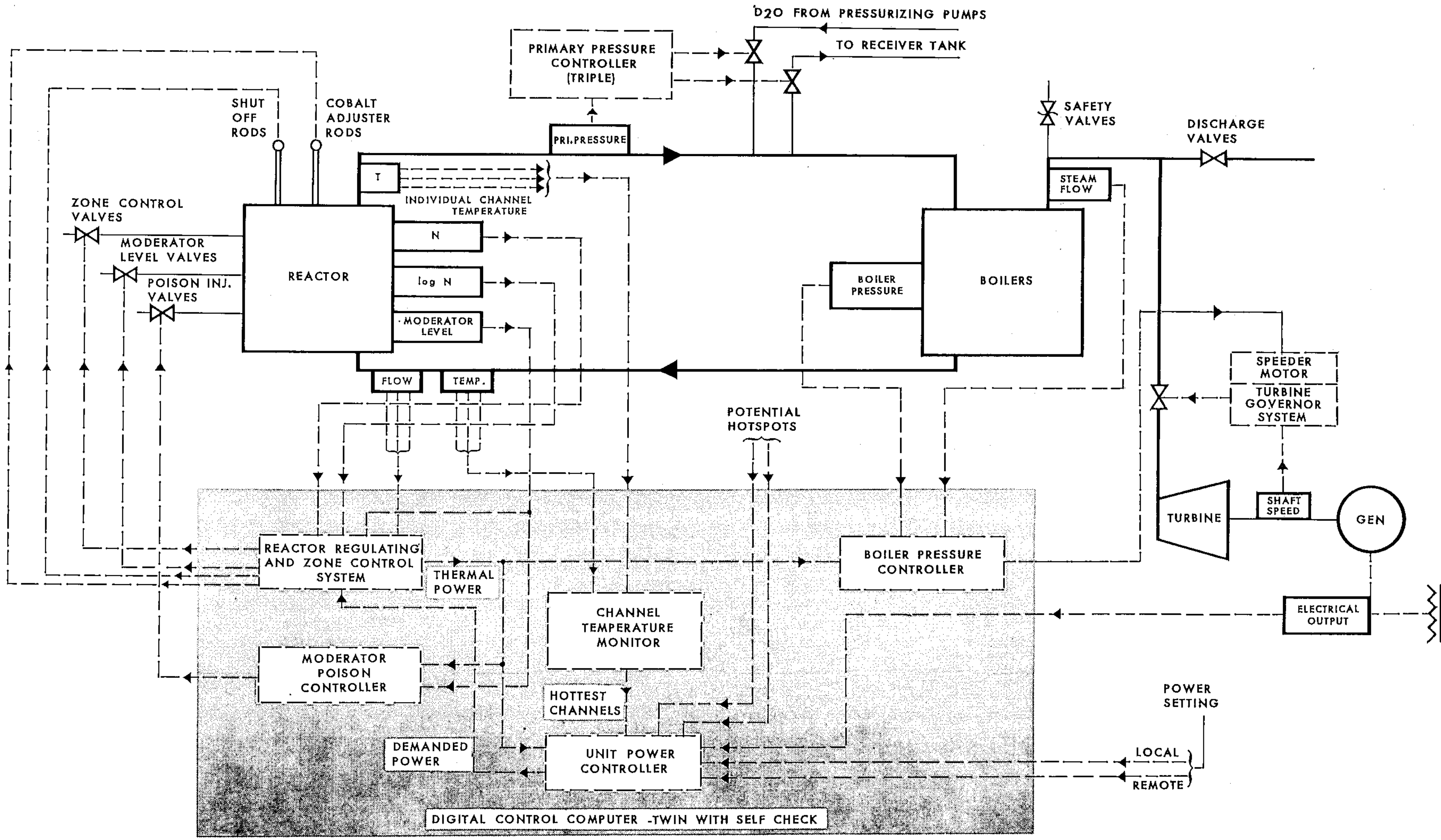
The overall block diagram of the control system, which is similar to that for Douglas Point, is shown in Figure 7.2-1. For the short term, the outflow of electricity is adjusted in relation to the reactor power to maintain the boiler pressure at its correct value. At a slower rate, the reactor power is itself adjusted so that the consequent electric outflow is either a maximum or is as otherwise desired.

If a change in power level of the plant is required after a period of steady operation at significant power levels, the new desired power level would be set by the operator on the plant power controller. This controller automatically adjusts the reactivity in the reactor by a controlled change of level of neutron absorbers in the core. The change in reactivity in the core results in a change of reactor power output which is measured as a change in coolant temperature rise in the coolant flowing through the reactor at a constant rate. The change in reactor power level is felt in the boiler within a few seconds by the change in temperature of primary coolant entering the boiler. The steam production in the boiler automatically changes to correspond to the new power level. The turbine governor valves are made to alter their position to maintain the boiler pressure at a predetermined setting corresponding to power level. The boiler pressure and thus temperature is made to rise with a decrease in power level and vice-versa to reduce the variation in mean temperature and volume of the primary reactor coolant as the plant power varies.

Exactly the same sequence of events takes place in the Douglas Point unit if a change of setting is made on the power demand servo. In Douglas Point the rate of change of power level is controlled by an analogue device. In Pickering it is planned to use electronic digital computers to control and check all the regulating mechanisms or systems which affect the reactivity of the reactor. Two computers will be used for each 500 MWe unit, the second computer providing a complete back up for important control functions performed by the first computer.

7.3 THE CONTROL COMPUTERS

The most important change of emphasis from Douglas Point is in the more extensive use of electronic digital computers as controlling devices. It has been appreciated for many years now that a computer can in principal carry out all types of control tasks, and there has been a rapid development of technology in this field, accompanied by a rapid increase in the computing capability which can be obtained for a given price and a given standard of reliability. Important experience in the design and programming of a control computer has been obtained in the Douglas Point project, and since the computer has been operating with many simulated and some real inputs since the fall of 1964, some operational experience had already



7.2—1 CONTROL SYSTEM BLOCK DIAGRAM

44.66000-1
REV. 3, 1968

been accumulated before the plant as a whole began to operate, illustrating a unique practical advantage. In the light of this experience the computer is now regarded as the proper basic device for carrying out complicated control functions provided that the total scale of activity is sufficient to justify the large minimum cost of a computer complex of suitable performance and reliability. For nuclear generating units of 500 MWe output in the conditions of the Pickering project, this criterion is met, despite the fact that two computers must be used for the most important control functions to meet reliability requirements. Compared with alternative techniques of automatic control, the use of computers;

i) Simplifies and rationalizes engineering and drafting of instrumentation and control systems

ii) Speeds up procurement and construction

iii) Permits more complete solutions of control problems

iv) Facilitates commissioning and subsequent corrections and improvements of systems.

The distribution of principal functions between the computers with the estimated number of inputs and outputs involved is shown in Figure 7.3-1.

The arrangement of the computers with their peripheral equipment is shown in Figure 7.3-2. Cross connections between the computers are kept at a minimum and precautions are taken at all stages to ensure that trouble in one computer cannot cause consequential trouble in the other.

The computers are of IBM type 1800, each with 16,000 word core memory and a drum memory equipped initially for 128,000 words and capable of expansion to 256,000 words. Information is transferred from the drum to the core at the rate of 70,000 words per second separately from the main computer operation. Typical times for operations by the computer using information in the core memory are as follows:

Add or subtract	4.25 micro secs.
Multiply	15.25 micro secs.
Divide	42.75 micro secs.
Conditional Branch	2 micro secs.

An executive programme always loaded into the fast memory supervises the bringing forward of sub-programmes in blocks from the slow memory and their execution by the computer. Tasks are carried out in accordance with a priority system which is able to take time into account so that low priority tasks are not left unattended indefinitely. A large section of the drum memory normally has its write channels disconnected, so that the likelihood of the information in it being mutilated is very remote. The full programme is written in this section. If for any reason the computer is disabled for a period and its running programme is mutilated, it will automatically reload its executive programme from the drum and restart at any time when conditions return to normal.

The programme concerned with this automatic restart is contained in a separate section of the core memory and cannot be altered by any operations in the main core memory. There is also an arrangement giving a degree of protection of the programme against errors in a sub-programme which is being tested and worked upon. The Douglas Point computer does not have the protection feature, but the automatic restart was added some time after the system came into use.

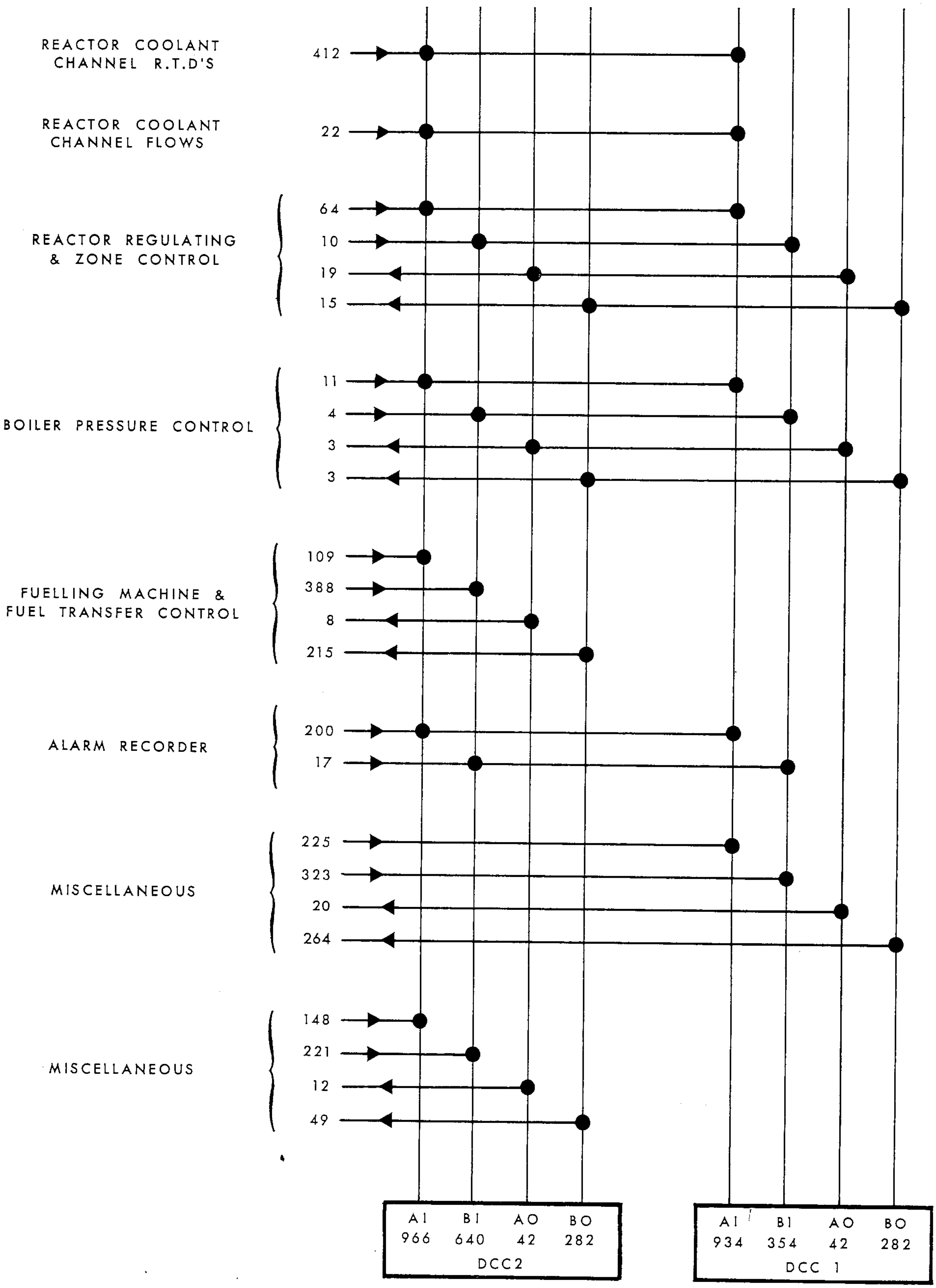
A Di-An high speed printer, which prints complete lines of 32 characters at a rate of 20 lines per second, is provided with each computer and is used as the basic method of communicating to the operator. The print-outs are planned for clarity, making liberal use of spacing, and in some cases will resemble mimic diagrams of the system concerned. Normal or irrelevant information can be filtered out, leaving concise and meaningful presentations which give the operator the same information as would be given by meters and recorders but with the further advantage of a permanent record. As an example, Figure 7.6-2 and 7.6-3 show print-outs covering the state of the reactor. They are explained in Section 7.6.2.

Each computer also has an IBM model 1816 printer-keyboard which can print out 15 characters per second on a page which is 156 characters wide. This is used for print-outs when speed is not of primary importance. The keyboard will be one means by which the operator can communicate into the computer.

There is a control panel for each computer located, with the high speed printers, between the reactor control panel and the fuelling machine control panel. The operator will be able to supervise and control the modes of operation of the computers and to give permissive signals where needed.

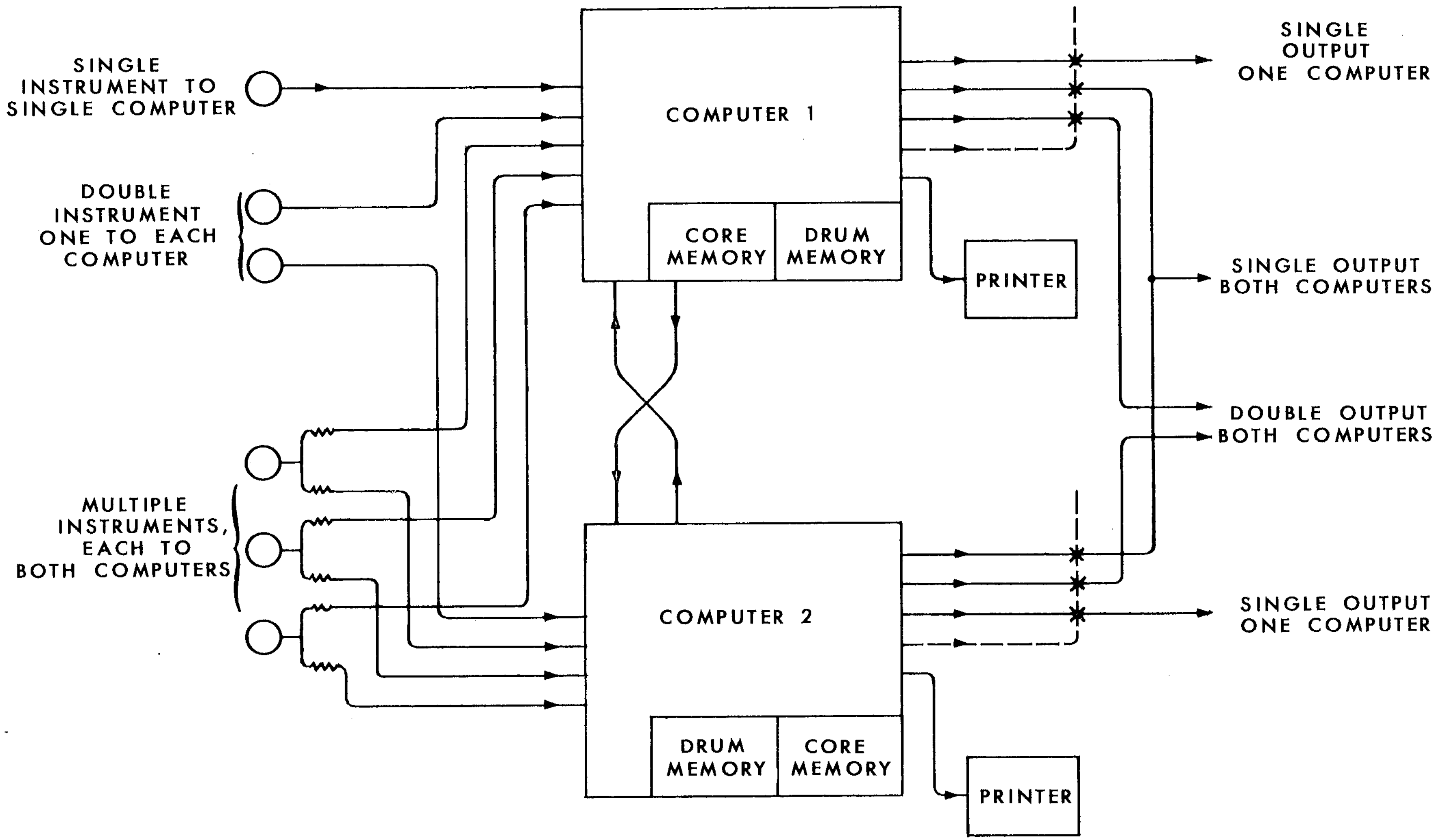
Most instruments which are connected to the computers supply a signal in the form of a voltage which is an analogue of the measured variable. These are referred to as analogue inputs. The voltages are converted to digital form one at a time, but at such a rate that the flow of information is virtually continuous. This process is called "multiplexing". Ninety-six analogue inputs are switched by solid state methods at a rate of 10,000 points per second. An additional 837 inputs are switched first in blocks of 32 by reed relays and then by solid state gates at a typical overall rate of 4,000 points per second. The multiplexing process is under the control of the computer programme, but most of the multiplexing is carried out without taking the time of the main computer.

Other signals are "binary" in form, that is, they have only two states, such as a switch being open or closed. These binary inputs are also brought into the computer under programme control at rates up to 8×10^6 points per second.



7.3-1 COMPUTER INPUTS AND OUTPUTS

44.66000.2
REV.1, 1968



7.3-2 ARRANGEMENT OF COMPUTERS WITH PERIPHERAL EQUIPMENT

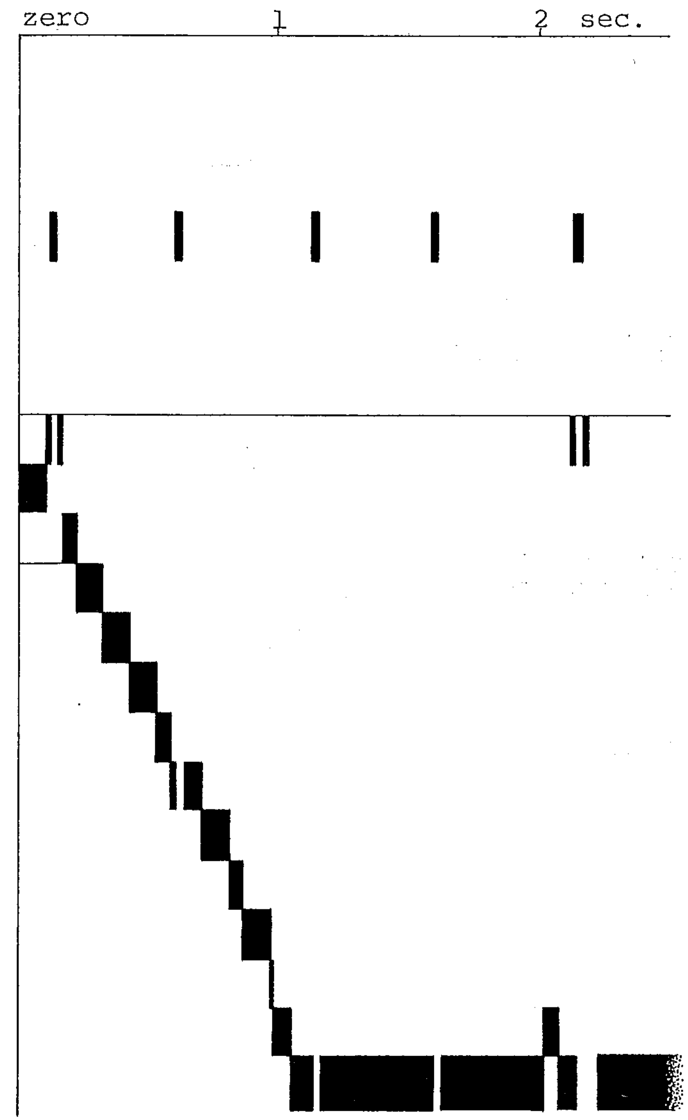
44.66000-4

TABLE 7.3-1

WORST CASE FUNCTION TIMING DIAGRAM FOR PICKERING COMPUTER PROGRAMS

Function	Period sec.	Duration sec.	Priority Level
Reactor Control Equ'ns	.5	.010	3
Fuelling Machine Pos'n Loop #1	.5	.002	3
Fuelling Machine Pos'n Loop #2	.5	.002	3
Fuelling Machine Press Control	.1	.002	3
Fuelling Machine Temp. Control	.1	.002	3
Auto Synchronizer	1	.005	3
Boiler Press Control Loop	.5	.002	3
Reactor Control Supervisor	2	.05	2
Plant Power Controller	4	.1	2
Turbine Speed Control	4	.05	2
Turbine Supervisor	20	.1	2
Fuelling Machine Supervisor	16	.1	2
Moderator Poison Control	30	.1	2
Condenser Vacuum Control	30	.05	2
Temperature Monitor	2	.1	2
General Alarm Scan	8	.1	2
Computer Availability Check	16	.05	2
Boiler Press Supervisor	4	.1	2
Program Frequency Control	.1	.001	4
Executive and Miscellaneous	N.A.	.065	1
FREE TIME			

Timing



Many input signals are checked for rationality before being used by the computer. This can easily be done if failures in the instrument can be arranged to result in an output signal which is outside the range of correct indication. Alternatively, the computer can be made to check that the instrument signal is consistent with the signals from other instruments for example that the coolant outlet temperature of a fuel channel is not less than the inlet temperature.

Basically, each computer can only carry out one controlling or monitoring function at a time. Normally, each function will be carried out at regular intervals as shown in Table 7.3-1, but it is arranged that important functions can receive priority if necessary. If a function is not completed in a pre-determined maximum time, the computer will automatically leave that function and sound an alarm, so that all functions are not lost because of trouble in one.

7.4 REACTOR CONTROL

7.4.1 General

After a reasonably long period of steady operation has been achieved and all the initial start up transients have died away, the most important method of controlling reactivity is by on-power refuelling. Two bundles per refuelling operation will be inserted in the core and two spent bundles will be removed. The reactivity change due to a normal refuelling procedure will be less than 0.15 mk and the maximum rate of change of reactivity will be less than 0.01 mk per second. Reactivity changes due to refuelling during full power equilibrium operation are estimated to be:

Normal refuelling of central channel	0.13 mk (2 bundles)
Normal refuelling of outer channel	0.03 mk (2 bundles)
Reactivity decline if no refuelling takes place	0.42 mk per day
Average number of refuelling operations per day	4.5 per day
Replacement of all fuel in central channel with new fuel	0.22 mk

7.4.2 Reactivity Controlling Devices

Additional reactivity control is required in order to: shape the neutron flux to produce the desired power level from the reactor, vary the thermal output of the reactor, compensate for adverse flux distribution due to local disturbances of reactivity in the core, override Xenon^{-135} poison following a reactor trip from high power equilibrium operation and overcome temporary increase in reactivity due to the absence of Xenon^{-135} following a long shutdown. These reactivity changes are accomplished by the following devices:

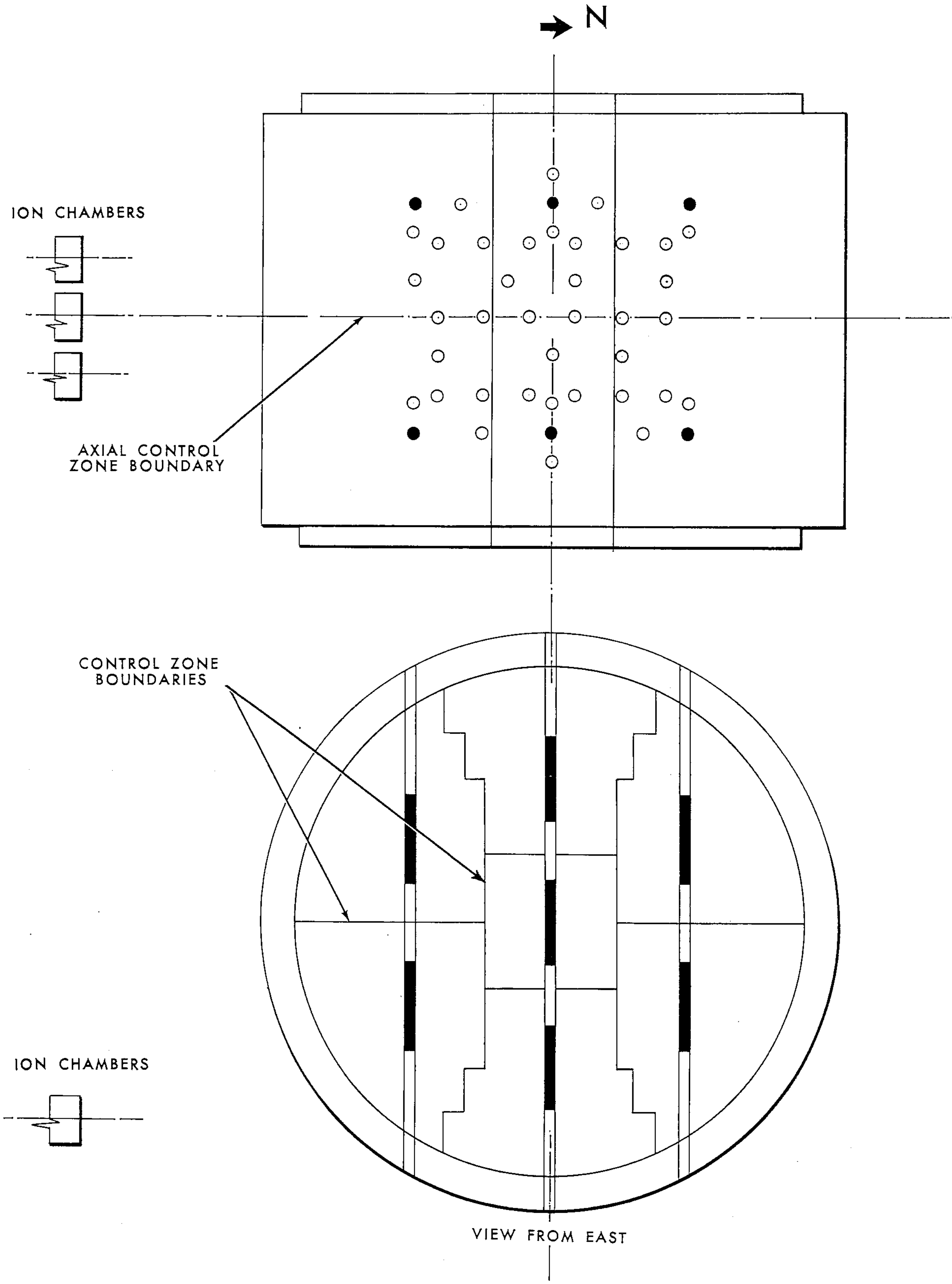
Devices	Use
18 adjuster rods	to adjust the neutron flux shape to optimum and, by being removed, to permit the Xe^{-135} poison to be overridden following a trip.
14 zone control compartments	to suppress major changes in flux distribution and to provide operating control of reactivity.
Moderator poison (B—10)	to compensate for absence of Xe^{-135} and for excess reactivity of new fuel.

The reactor will normally be operated with a full calandria, but the moderator level will be lowered automatically if other methods of reactivity control do not produce the required effect, and will be under control of the reactor control system at any time that it is below the full tank level.

The reactor is so large that there is a tendency for the neutron flux to deviate from its intended distribution through the core as a result of minor local disturbances of reactivity, which will be magnified by the behaviour of the I^{135} Xe^{135} fission product chain. To suppress this tendency and to make each part of the core contribute its intended power output, the flux will be controlled in a number of "zones" in each of which the flux will be measured and controlled.

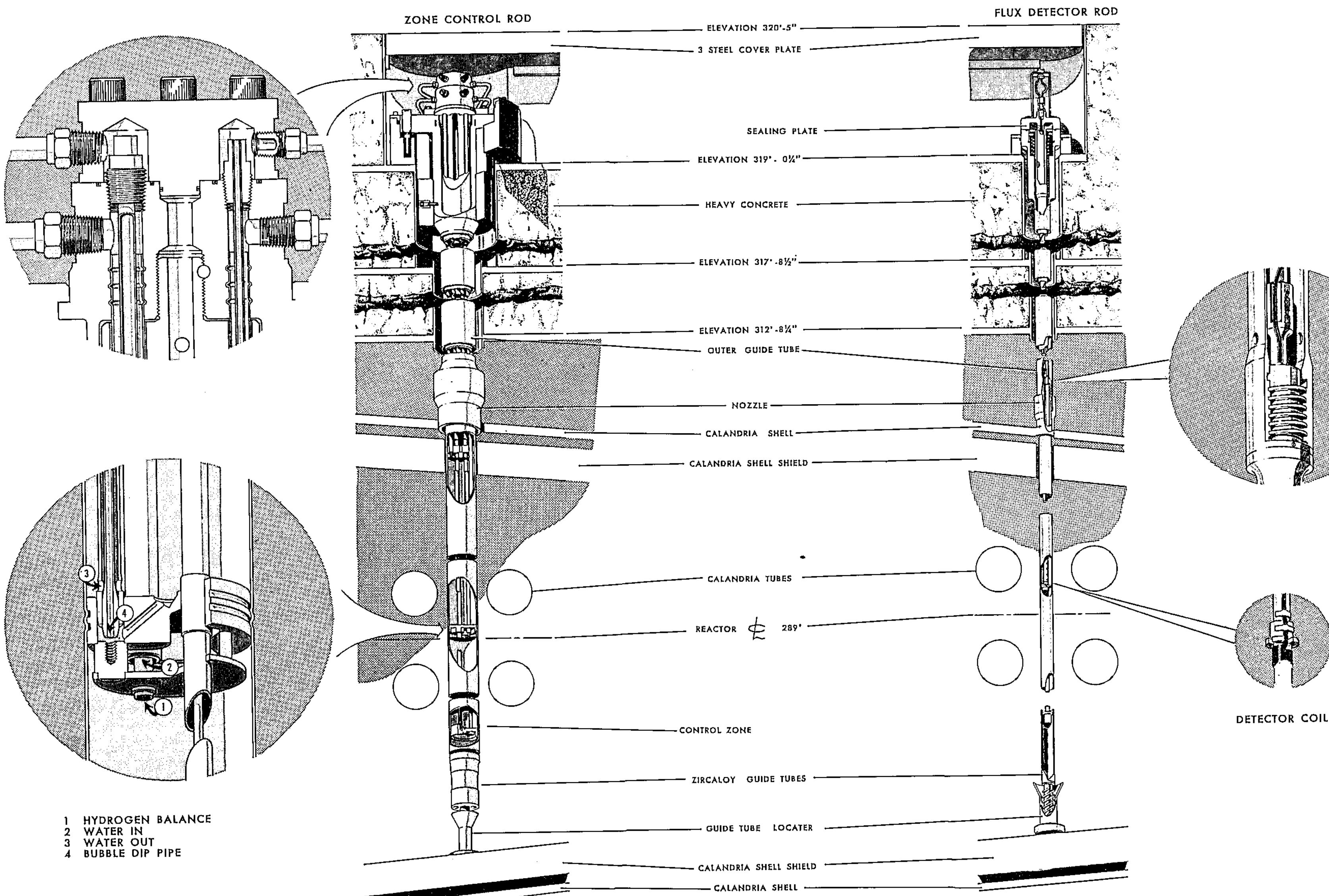
7.4.2.1 Light Water Zone Control System

The reactor is divided for zone control purposes into two axial slices and each slice is divided into one central and six outer zones, giving fourteen zones in all. Zone control compartments are located at the middle of each control zone in six vertical Zircaloy through-tubes as shown in Figure 7.4-1. The bottom of each compartment is a closure of the tube but the top is merely a point of symmetry. Light water is introduced into each compartment for control purposes by small diameter tubing. The water level may rise if necessary to the bottom of the next compartment above or to the reactor boundary. The light water in each compartment is continuously circulated for cooling and chemical control. In the case of a tube containing three control zones there will be twelve feed tubes, two tubes for inflow and outflow of water and two tubes for inflow and outflow of the cover gas, the cover gas tubes being contained within the water flow tubes and concentric with them, as shown in Figure 7.4-2. The through tubes are flanged at the top end and are located in stainless steel guide tubes attached to the reactor shell. Spring assemblies in the bottom of the Zircaloy through-tubes tension the tubes to approximately 1200 pounds when they are screwed into sockets at the bottom end.



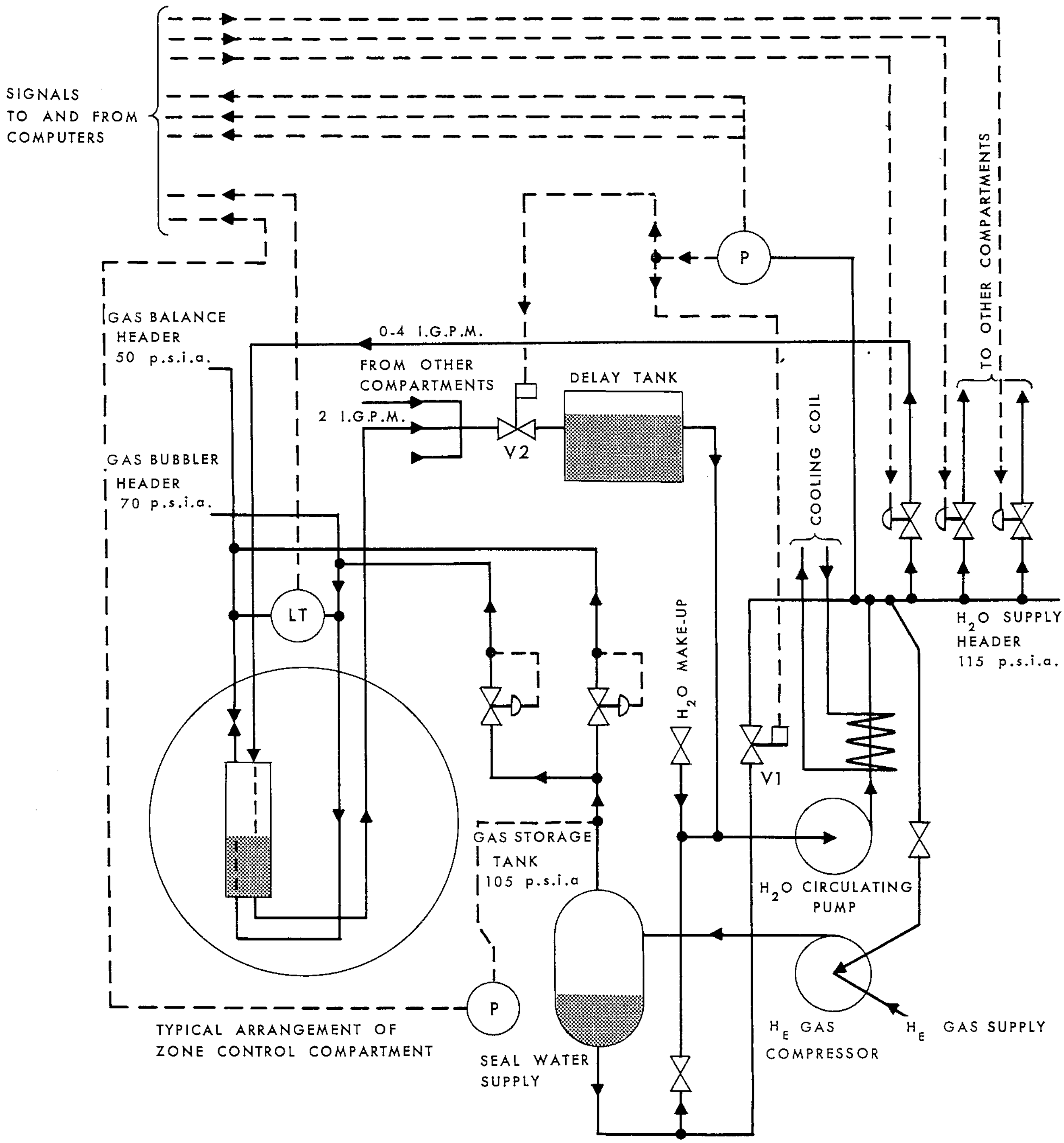
7.4-1 ZONE CONTROL ABSORBERS

44-31720-2
1967



7.4–2 ZONE CONTROL AND FLUX DETECTOR RODS

44.3171Q-3
REV. 1, 1969



LT. - LEVEL MEASUREMENT
VALVES V1 & V2
BOTH CLOSE ON LOSS OF PRESSURE IN H_2O SUPPLY HEADER
BOTH CLOSE ON RAPID LOSS OF H_2O FROM SYSTEM

7.4-3 SIMPLIFIED FLOW SHEET FOR ZONE CONTROL SYSTEM

44.60000-2
REV. 1, 1968

The controlled range of reactivity from all compartments empty to all full is greater than the power coefficient of reactivity. It amounts to about 6 mk and will enable the power to be controlled over the full range by means of this system alone. The internal diameter of the compartments is 3.5 inches; and four connecting tubes of 0.62 inch internal diameter are needed for each compartment. About 450 lbs. of light water are needed to fill all the compartments. The requirements for leak tightness between the light and heavy water systems are not unduly severe, but as a precaution a single outer tube with simple geometry is used to separate the light water and heavy water (moderator) in the reactor core. From the points of view of radiation chemistry, metallurgy, corrosion and hydraulics, the system appears much like an extension of the moderator systems which have been used in most Canadian reactors.

A simplified flow sheet is shown in Figure 7.4-3. There is a constant outflow of 2 Igpm from the bottom of each compartment and a controlled inflow from the top of 1/4 to 4 Igpm, which runs down the wall of the tube. This arrangement ensures that the light water in the compartment is always circulated and cooled. A delay tank permits the induced 0-19 and N-16 activity to decay so that most of the valves and all pumps and blowers can be accessible during operation.

An electropneumatically operated control valve, accessible during operation, continuously controls the rate of change of level of the light water in each compartment between approximately equal upward and downward rates, with zero rate near the middle of its travel. These valves are positioned by the control computers. The level of water in each compartment is measured by the gas bubbler method and fed into the computer, together with levels and pressures in tanks and headers.

If the pump supply pressure to the system fails, an emergency reservoir of 50 Imperial gallons of water stored and used as a seal in the base of the gas storage tank is used. This is made available by the computer sensing loss of the circulating pump normal discharge pressure and opening a valve (VI in Figure 7.4-3) connecting the bottom of the storage tank to the H_2O supply header. The system can thus operate for about 1.8 minutes without power to the pumps.

If the supply header pressure fails, the return header V2 valve is closed to avoid uncontrolled lowering of the water level in the compartments, and the reactor power is set back.

Commercial grade helium will be used as the cover gas. An ion exchange column is provided to maintain water purity. It is believed that this alone will be enough to reduce the net dissociation of the water to the point that explosive concentrations of hydrogen and oxygen will not form in the cover gas. As an extra precaution, a recombiner is also provided. An experimental water control rod in NRU has shown that the hydrogen builds up very slowly (about 1.5% by volume per day) when the ion exchange column and recombiner are not used. The cover gas in the Pickering zone control system will be sampled regularly to determine the hydrogen and oxygen levels.

The physical dimensions of the compartments, the reactivity effects due to changes in water level, and the maximum rate of reactivity change of the zone control rods are as follows:

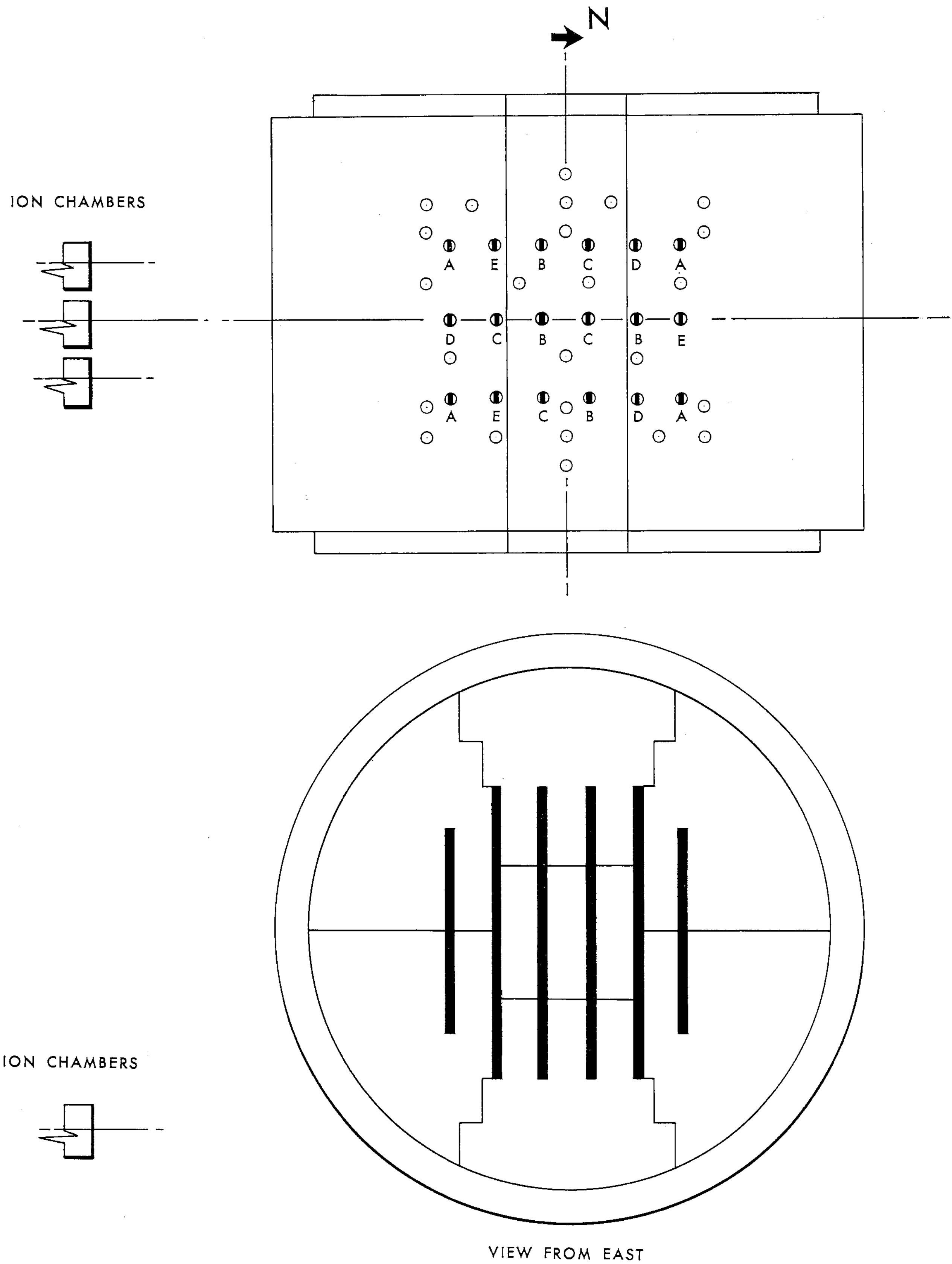
Through-tube internal diameter	3.5" approximately
Length of compartment	From 6 ft to 9 ft
Reactivity effect - all tubes empty to all shaded zones in Figure 7.4-1 filled	4.0 mk approximately
Reactivity effect - all tubes empty to all compartments filled to top	6.0 mk approximately
Rate of increase of reactivity, all zones being emptied simultaneously at maximum rate	0.15 mk per second maximum
Rate of decrease of reactivity, zones being filled at maximum rate	0.20 mk per second maximum

The reactivity value (6 mk total effect) is so chosen that effective zone control and control of the total power output can be achieved by the zone control absorbers alone during the withdrawal and insertion of the adjuster rods (see below). It will usually permit control of the neutron power over its full range.

7.4.2.2 Adjuster Rods

The primary function of the adjuster rods is to shape the neutron flux to the optimum shape for reactor power and burnup and provide excess reactivity which is needed to overcome surges of Xe^{135} following reduction of power. These rods use cobalt as a neutron absorber and are normally all inserted so as to produce a flattened neutron flux pattern. Eighteen rods are used, and they are inserted and withdrawn in three groups of four and two groups of three as shown in Figure 7.4-4, all the rods in a group moving together. Only one group is allowed to move at a time. The reactor is designed to develop full power output with all the adjuster rods inserted. When some or all of the adjuster rods are removed, the flux pattern is thereby distorted, but it is corrected as much as possible by the zone control absorbers. The adjuster rods are inserted and removed at approximately constant speed, smooth control being retained by adjustment of the zone control absorber water level.

The adjuster rods are raised and lowered into the core through guide tubes by a winch and cable drive as shown in Figure 7.4-5. The cobalt element assembly consists of cobalt pencils, 1/4 inch in diameter arranged circumferentially within a 2-1/2 inch diameter circle, and carried on spiders. Zircaloy is used in the construction of



7.4-4 ADJUSTER RODS (COBALT)

44-31710-4
1967

the cobalt assembly.

The guide tubes are made from Zircaloy within the reactor vessel, and stainless steel outside the vessel. The Zircaloy portions of these tubes are perforated over their lengths. They are flanged at one end and are located in nozzles attached to the reactor shell at the top end. Into the bottom end of the tubes is built a spring assembly which is used to put a tensile load of approximately 1300 lbs. in the tube when screwed into sockets, which are in turn welded to the shell shield sockets, which are in turn fastened to the shell shields. Heavy water is pumped down the guide tubes via the drive mechanism to cool the cobalt assembly in the event of a moderator dump. In addition, the assembly is spray cooled through the perforations. On removal of the rods from the core no cooling is required.

At the top of the stainless steel tube where it comes through the vault is a combined seal spring-balancer unit and shielding to prevent radiation streaming. The seal prevents leakage between the boiler room atmosphere and the reactor vault, the spring balancer unit carries part of the weight of the shielding and drive mechanisms, and ensures that the portion of the guide tube outside the vessel is always in tension.

The drive mechanism consists of a cable, drum, guide pulley, speed reducer and an electric motor. The drive is provided with positive stops by means of a counter mechanism in the gearbox, and with a position indicator by means of a take-off from the gearbox. The cable drum, guide pulley and cable assembly is separate from the gearbox; this housing is thus in direct communication with the calandria atmosphere. The input shaft to the cable drum is sealed by a carbon face seal on the heavy water side and a lip seal on the oil side. The space between the seals is drained. Connections between the motor and gearbox, and gearbox and winch are by splined shafts.

The rate of rod insertion or withdrawal from the core is essentially constant since the drive motor is a three phase induction motor operating at 1760 rpm (unloaded) when supplied with 550 volt 60 cycle power.

The physical dimensions of the adjuster rods, the total reactivity worth, and the maximum change in reactivity is shown below:

Number of adjuster rods	18
Diameter of guide tube	3.5 inches
Length of adjuster elements	12 at 13.1 feet, 6 at 9.3 feet
Total reactivity worth	18 mk
Reactivity worth of most effective group	4 mk
Rate of reactivity increase when most effective group is being withdrawn	0.07 mk per second maximum
Time for full travel (610 cm) of an adjuster rod at maximum drive speed	67 seconds

7.4.2.3 Neutron Poison Dissolved in the Moderator

This system is very similar to that used at Douglas Point. Natural boron in the form of B_2O_5 dissolved in D_2O is added to the moderator to suppress excess reactivity which is beyond the capacity of the other systems. Its main uses are for the initial period before the fuel charge has burned down to equilibrium and when the Xe^{135} load is below normal after a shutdown. The boron is removed by ion exchange when necessary. The moderator poison system is described in Section 4.

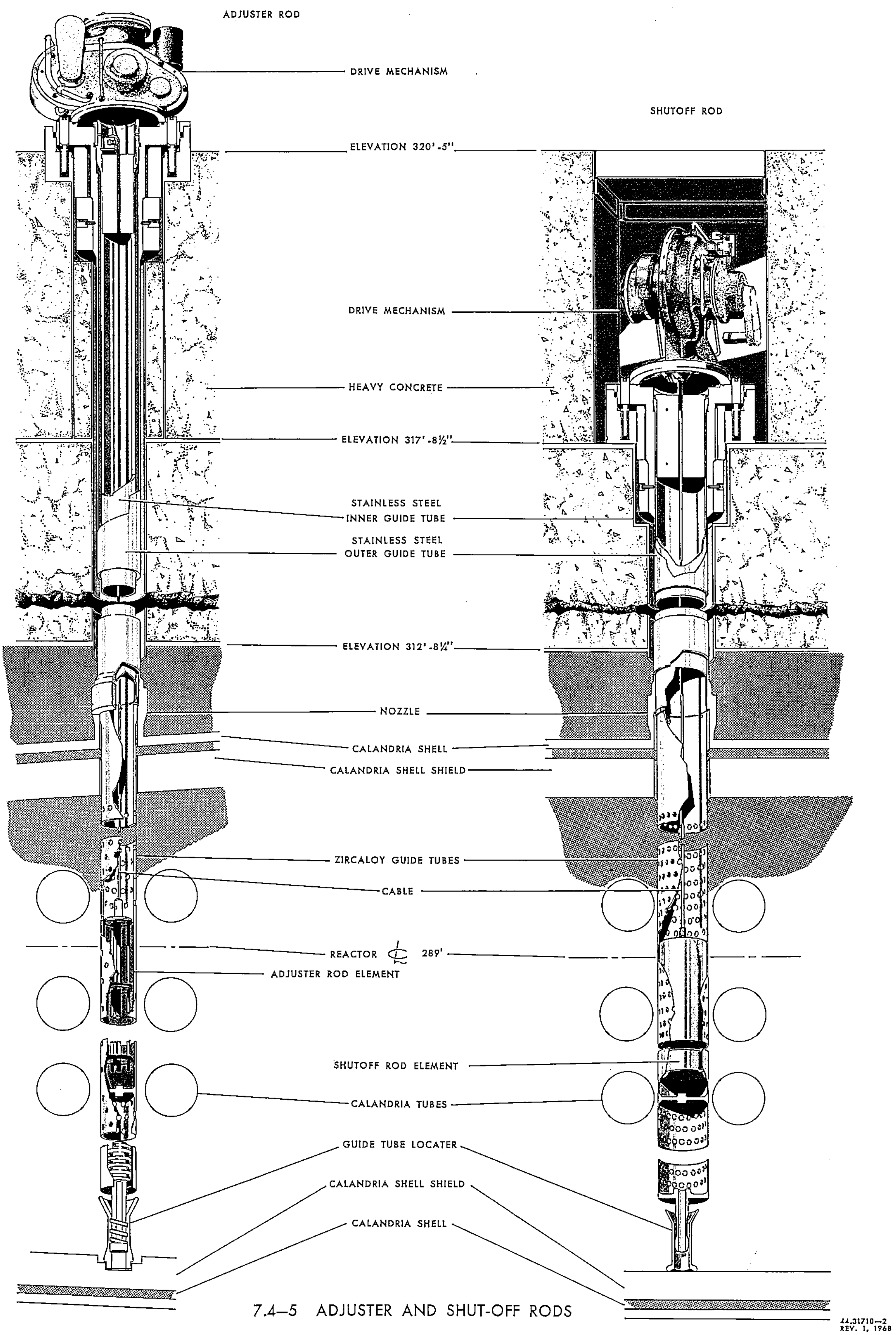
7.4.2.4 Moderator Level Control

The gas balance system is described in Section 4 of this volume.

7.4.2.5 Shut-off Rods

Although these are safety devices as opposed to control devices, their removal after a trip must be treated as part of the control problem. Since the shut-off rods are the fast component of the protective system, they must be raised, and thus made available for their protective function, before operation at high power is allowed. The shut-off rods are arranged as shown in Figure 7.4-6. Normally the shut-off rods are raised in two successive groups, but when the moderator level is less than 90% they are raised in four successive groups in order to limit the rate of increase of reactivity. The interlocks are so arranged that any rod may be dropped approximately four feet as an operational test. This is done by inserting a resistance in series with its clutch for a controlled interval of approximately 200 milliseconds. Since some current is left passing through the clutch, the test is more severe than a normal trip. If a genuine trip signal occurs during a test, the rod is fully available for its protective purpose. The test produces a small reactivity perturbation (about 0.1 mk) which can be detected by the reaction of the reactor control system. The shut-off rod returns to its raised position at its controlled rate immediately after the test.

The shut-off rods consist of stainless steel - cadmium stainless steel sandwiches in the form of tubes. These tubes run through guide tubes. The rods fall under gravity and are raised by a motorized winch. The general layout is similar to that of the adjuster rods, including the provision of a heavy water circuit through the rods, and helium vent, but differs in detail (see Figure 7.4-5). The rod has an outside diameter of 4.875 inches and the effective length is 14.5 feet.



7.4–5 ADJUSTER AND SHUT-OFF RODS

The guide tubes are as described for the adjuster rods except that the diameter and the extent of the perforations are different.

The cable drum is driven via an electromagnetic friction clutch which releases when de-energized. The rods are held in the raised position by the self-locking capability of a 60:1 worm reducer. The rate of withdrawal of the shut-off absorber is essentially constant since the drive motor is a three phase induction motor operating at 1760 rpm (unloaded) when supplied with 550 volt, 60 cycle power.

When the clutches are de-energized, the rods are free to fall into the reactor. Apart from the inclusion of the clutch and the different gear ratio, the mechanism is similar to the adjuster rod drive.

The shut-off rod components are so designed that over-pressurization of the calandria will not prevent normal entry of the shut-off rods and will not permit the rods to be blown out.

Number of rods	11
Reactivity worth	24 mk approximately
Reactivity worth of most effective rod	less than 4 mk
Reactivity worth on insertion, following trip signal	2 mk within 1.0 sec. 10 mk within 1.5 sec. 20 mk within 2.0 sec.
Time to raise shut-off rod through full travel (663 cm)	160 seconds (4.15 cm/sec)
Maximum rate of increase of reactivity:	
(a) 2 of 4 groups moving, 90% moderator level	0.28 mk/sec approximately
(b) 1 of 4 groups moving, 50% moderator level	0.27 mk/sec approximately

7.4.2.6 Moderator Dump

The moderator cover gas dump system and pump up system is described in Section 4. The Pickering dump system is capable of producing a reduction of reactivity after a trip signal of at least:

2 mk in 4 seconds after a trip signal

10 mk in 7 seconds after a trip signal

20 mk in 11 seconds after a trip signal

7.4.2.7 Combined Rates of Reactivity Change

The interlocks described, and those referred to in Section 7.5.2 below, ensure that no combination of movement of reactivity controlling devices will give a rate of increase of reactivity greater than 0.33 mk per second.

The interlocks are backed up by the same restrictions in the control programme and in the operating instructions when manual control is being used.

7.4.3 Reactor Measuring Devices

7.4.3.1 In-Core Flux Monitors (Hilborn Detectors)

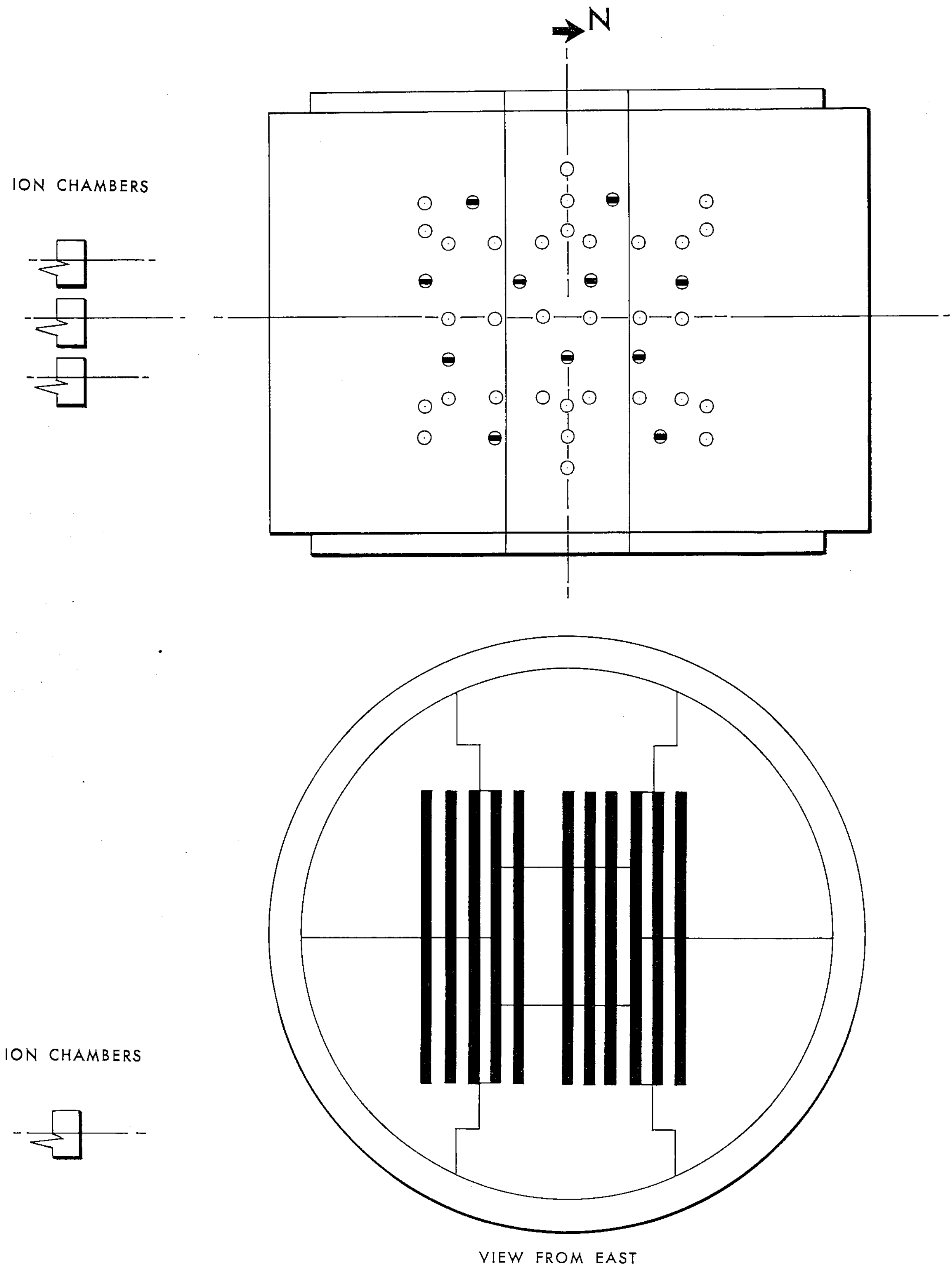
The in-core flux monitors are a self-generating type of detector. Each consists of a length of magnesium oxide insulated coaxial cable with a zirconium inner conductor and a solid nickel alloy sheath, coiled onto a Zircaloy former. This Zircaloy former is located inside a spring loaded inner guide tube. One end of the tube is screwed into locations which are in turn welded to the shell shield. The other end is flanged and located in the outer guide tube. A cooling water flow is provided to ensure that the detector coils are not overheated at any moderator level. Gamma radiation in the reactor core produces Compton electrons in the inner conductor which have enough energy to traverse the insulation and thus produce a net current, from a virtual source of very high impedance, in the detector. Most of the gamma field so detected is prompt and proportional to neutron flux, but an appreciable background due to fission products and activation of the materials of the detector builds up. The signals are mainly used for relative and short term purposes, but corrections for background may be computed if necessary. The gamma principle of detection was chosen because the life of the detectors is virtually infinite and the response is prompt. The detectors are disposed as shown in Figure 7.4-7. The central zones each have two detectors straddling the zone control compartment and connected in parallel. The outer zones have one detector on the inner side only.

In each position, there will be two completely independent detectors, so that each control computer will have its own independent system. An amplifier will be used with each detector to raise its signal to a level suitable for the computer input multiplexers.

7.4.3.2 Ion Chambers

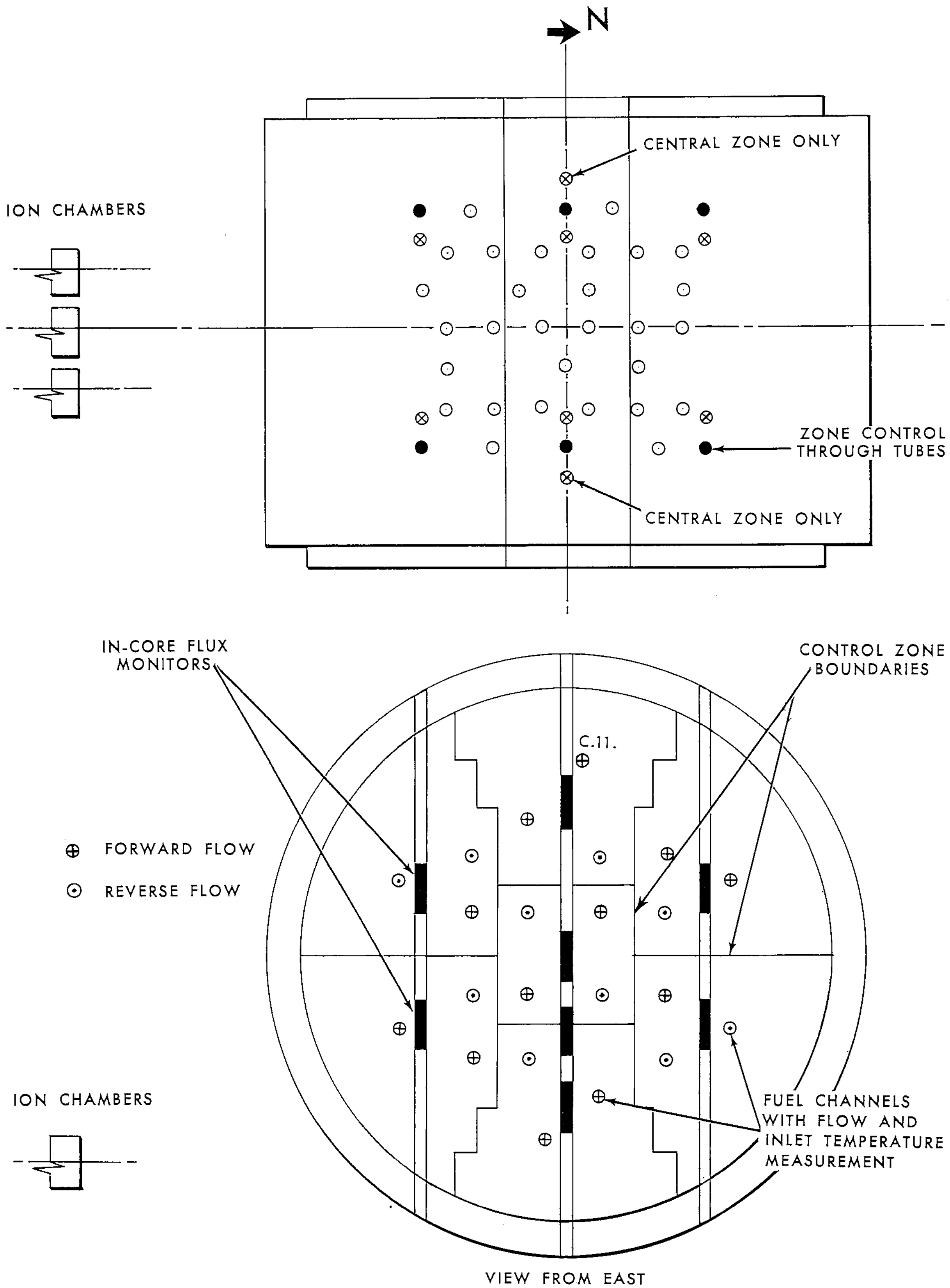
A total of six uncompensated ion chambers will be provided - three for reactor regulation and one for each of the reactor triplicated reactor protective channels. The output current from each chamber will be used to generate both linear and log N and linear and log rate signals.

These will be located on the south side of the calandria and will penetrate through the heavy concrete south wall of the vault structure. They will be enclosed in water jacketed lead filters, and will have test absorbers. Their position relative to the reactor is shown in Figure 7.4-8. The whole system is very similar to that at Douglas Point except that improved amplifiers using field effect transistors of the type developed by the Chalk River Electronics Branch will be used. The reactor has thermal shielding within the calandria shell, and windows will be provided to enable a suitable



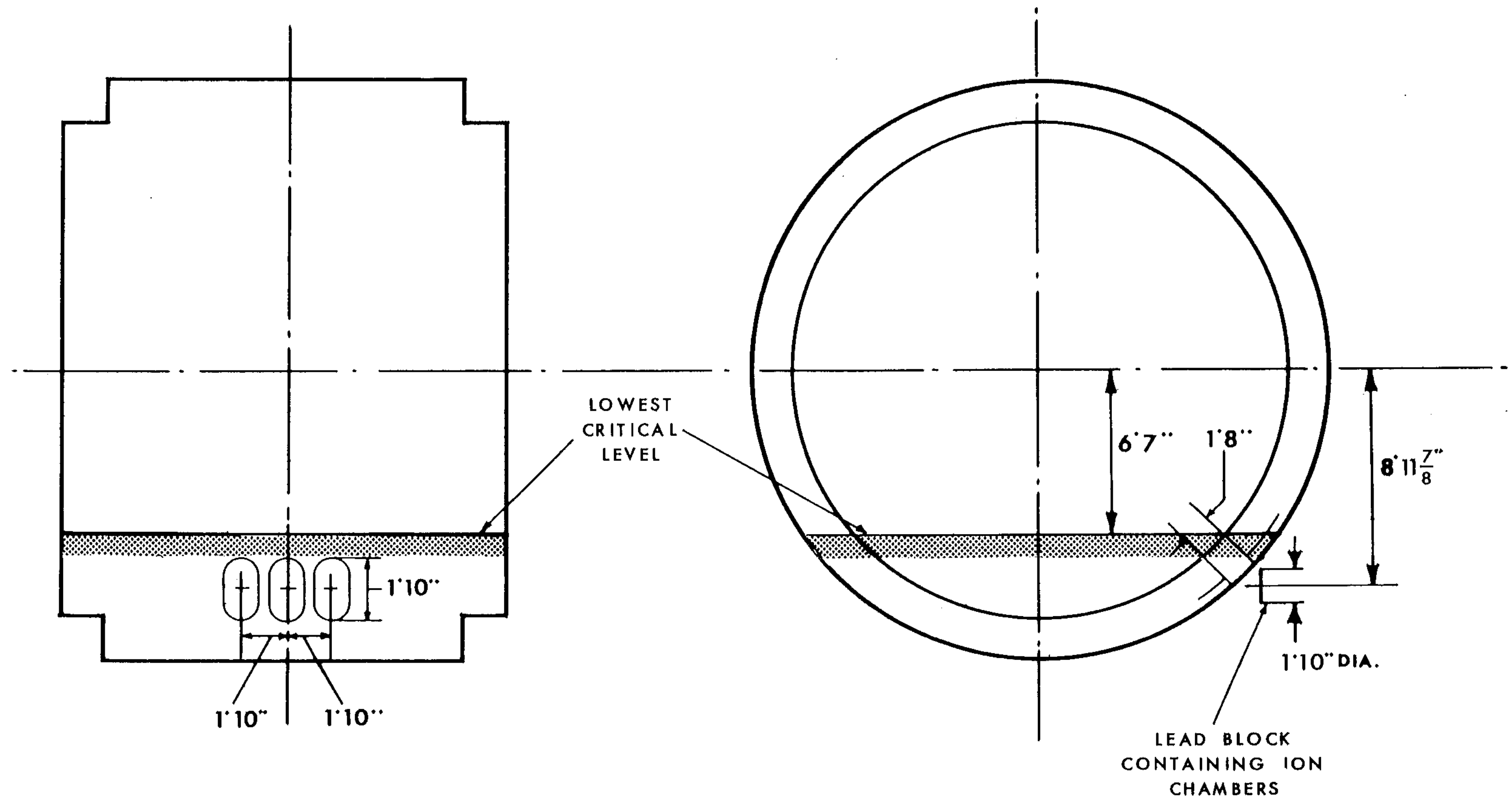
7.4-6 SHUT-OFF RODS

44-31730-2
1967



7.4-7 IN-CORE FLUX MONITORS AND FUEL CHANNELS WITH INLET FLOW AND TEMPERATURE MONITORING

44-31740-2
1967



7.4-8 ION CHAMBER LOCATIONS

44.63104-1

flux to reach the ion chambers. The neutron flux will not be collimated. The ion chamber indication will represent the neutron flux at the lower half of one side of the core, and this is not of great use if close control of the distribution of flux is needed. However, at low power levels when the flux is only important as an indication of reactivity, this is not a problem.

7.4.3.3 Thermal Measurements

Each reactor coolant channel will have two surface type resistance temperature detectors (RTD's) on its outlet feeder near the connection to the reactor face. Each channel outlet temperature measurement will be scanned regularly and the dual measurements in each channel compared. In the event of disagreement between temperature measurements in a channel an alarm would occur. If channel temperatures tend to exceed the maximum allowable channel outlet temperature of 568°F, an alarm will occur.

Temperature measurements at the inlet feeder will also be made in all fuel channels in which coolant flow is measured.

Separate groups of resistance temperature detectors will be installed in the inlet pipes of the boilers to be used for reactor outlet temperature signals for the protective system.

7.4.3.4 Fuel Channel Flow Measurements

Inlet flow to twenty-two fuel channels distributed over the reactor core as shown in Figure 7.4-4 will be measured by venturis installed in the inlet feeders of these selected channels. Coolant inlet temperatures to these same channels will also be measured using resistance temperature detectors. The thermal power in these twenty-two channels can therefore be computed, and this permits the total thermal power in each axial pair of control zones and in the whole reactor to be computed. If the fuel in one of these channels is in an abnormal state of burnup, it may be necessary to compute a correction for control purposes.

7.4.3.5 Zone Control Compartment Water Levels

These are indicated by differential pressure (DP) cells in the bubbler circuits in Figure 7.4-2.

7.4.3.6 Adjuster Rod and Shut-Off Rod Positions

These will be received from potentiometers coupled to the drum shafts by toothed-belt drives.

7.4.3.7 Fuel Failure Monitoring

A gaseous fission product (GFP) monitor, with separate connections to the two halves of the primary system but otherwise similar to that at Douglas Point, will be used to indicate the presence of faulty pencils in the fuel charge.

In view of the excellent record of NPD and the similar albeit very brief record with Douglas Point, no fuel failure location system is being provided for the Pickering reactors.

If a fuel failure occurs, it may be possible to deduce its location by the record of fuel movements beforehand. If this is not possible, the GFP monitor will show in which half of the channels it is located, and it will then be necessary to move the fuel string in each channel in turn by means of the fuelling machine until the change in level of a shorter lived fission gas (say Xe^{138}, 17 minutes half life) as shown by the GFP monitor reveals that the faulty bundle has been moved. Alternatively, it may be possible during a shutdown to locate the affected channel by the deposited radioactivity in its outlet feeder.

A sample connection to each boiler inlet pipe is being provided. These twelve sample tubes will be terminated in the accessible area on the 289 foot level. No fixed activity monitor or other instrumentation is being provided at this time in connection with the sample lines.

7.4.4 Reactor Control

7.4.4.1 General

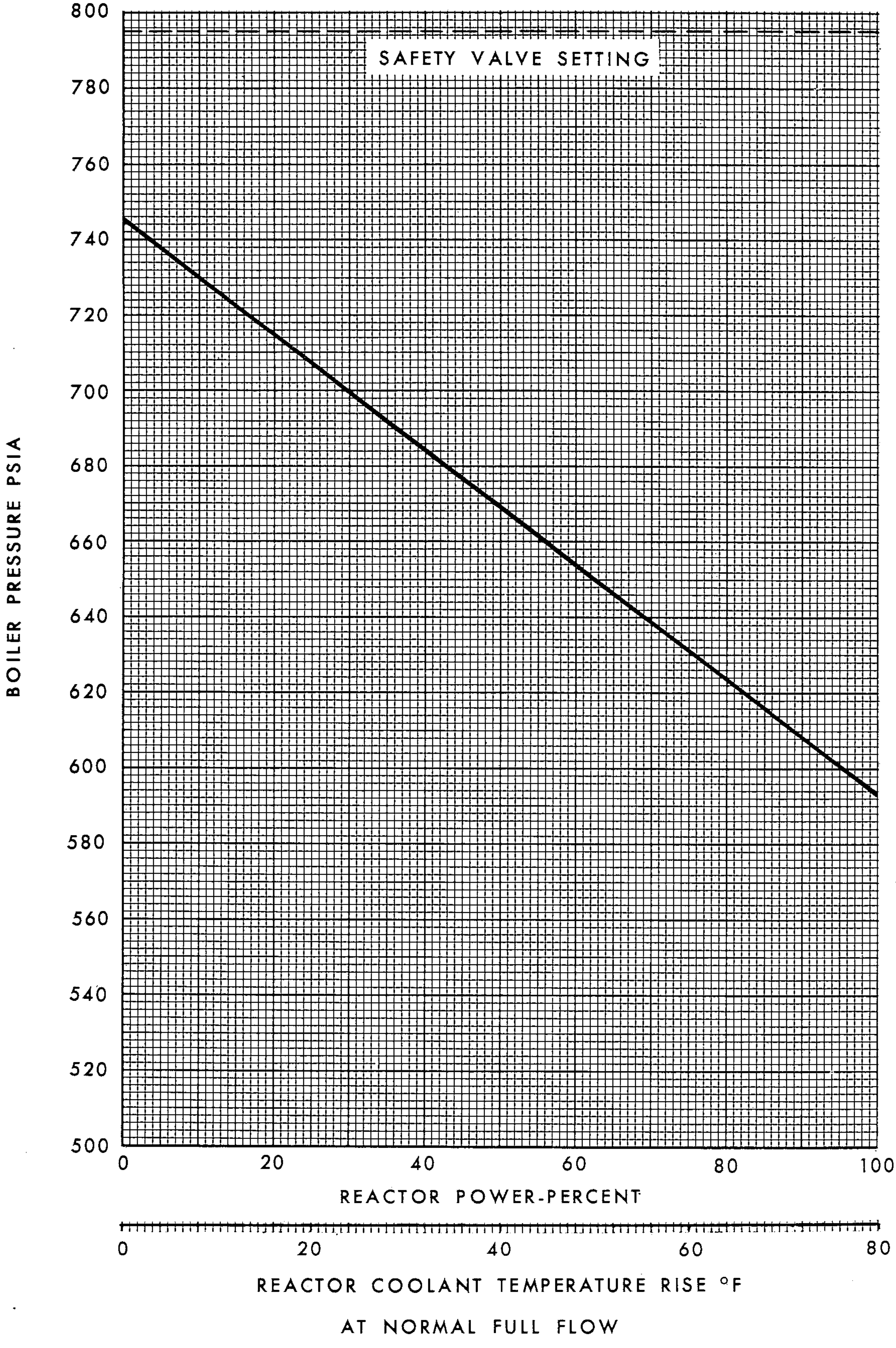
Electronic digital control computers will be used as the basic controlling devices because of the complexity of the overall control problem, favourable overall economics, and their inherent suitability for this type of work. At the present stage of development of the technology, it is not thought that a single computer would meet reliability requirements for the most important controls, so two computers will be used for each generating unit. This permits complete redundancy of the most important control functions. In previous Canadian nuclear reactors, redundancy has been achieved by the use of three separate channels, a faulty channel being indicated by its disagreement with the other two. The digital control computer operates in such a way that a searching self-check can be provided, so that a system with only two channels can be given a similar immunity to the effects of a single fault. Many transducing instruments will be triplicated or arranged with effectively equivalent redundancy because the computer self-check does not inherently cover them.

7.4.4.2 Reactor Control

Overall control can be considered as made up of the following elements, which will usually be represented by separate sections of the computer programme.

(a) A relatively fast acting control which will respond to signals from the Hilborn in-core detectors and will adjust the indicated power in each control zone to its desired value by changing the light water level in the zone control compartment.

(b) Computation, at a slower rate, of a correction factor for the Hilborn detector signals which will make allowance for predicted fission product buildup and will make them agree with thermal measurements



7.4-9 BOILER PRESSURE CONTROL CHARACTERISTIC

44.66000-3
REV. 1 1967

computed from coolant flow and temperature rise measurements. (This computation may not prove to be necessary.)

(c) A control similar to (a) but using the log N signal from the ion chambers when the reactor power is very low. Since the in-core flux detectors are ineffective and since the flux distribution is not important, the zone compartment water levels will be made equal in these conditions.

(d) Moderator level valve control. This will normally hold the moderator level at nominal full tank. However, if at any time the other controlling devices are unable to maintain control of the neutron flux or thermal power, moderator level control will come into effect in the same way as at Douglas Point. If the moderator is lowered or fully dumped, the control will supervise the subsequent pump-up in the same way.

(e) A control for the adjuster rods, which are moved in groups of 4 or 3 rods each. Precautions will be taken to prevent more than one group of adjuster rods from moving out at one time, and to prevent any adjuster rods from moving out unless at least 10 of the 11 shut-off rods are raised. When symptoms of a deficiency or an excess or reactivity are detected, the most suitable group of rods having regard to flux tilt will be raised or lowered.

(f) A control for the shut-off rod drive motors. This will cause the shut-off rods to be raised in two or four groups as described in Section 7.5.2 when the trip lines have cleared and a subsequent permissive signal has been received from the operator. If symptoms of a close approach to critical (say less negative than 5 mk) are detected before the shut-off rods are all out, the raising of the rods will be stopped and an alarm sounded. All other methods of increasing reactivity except the moderator pump-up as explained in 7.5.2 are prohibited until all shut-off rods are within 4 feet of their uppermost position.

(g) A control for the addition and removal of poison dissolved in the moderator. This will be very similar to the Douglas Point scheme. The reactor will first be checked to see whether it is critical. If so, the decision to add or remove boron will be based on the levels of light water in the zone control system, which indicate the reactivity state. If the reactor is not critical, the addition and removal of boron are based on the Xe^{135} load as computed from the power history of the reactor.

(h) A plant power control which would in effect provide the set points for controls (a) and (c). It would be slower acting than those controls and would be similar to that used at Douglas Point. Normally, the power would be adjusted to the maximum that could be obtained from the station without transgressing any of a number of potential limits, such as excessive fuel channel outlet temperature, excessive power in one control zone, discharge valves lifting, and excessive temperatures in electrical windings. However, the power may be set at any lower value either manually or by remote control from a dispatching centre. During warm up of the plant, the limitation of thermal stresses becomes the limiting factor.

(i) Comparison of signals from multiple instruments measuring the same variable to detect faults and to extract acceptable signals for control purposes, typically median signals of three.

(j) Comparison of signals from instruments which should be related in a known manner so as to detect faults and extract best signals for control.

(k) Testing of signals from instruments for irrationality within themselves - e.g. signal below zero or above full scale.

(l) Self checking of each computer by carrying out operations which give known answers from known inputs.

(m) A startup consistency check to guard against the possibility that the whole ion chamber system has been disabled or has failed during a shutdown. The computer will check that the ion chamber signals increase in the correct manner as reactivity is increased by raising the moderator level. If inconsistency is detected, the moderator level will be lowered and an alarm sounded.

(n) A system of manually selected or automatically originated print-outs of the status of reactivity controlling devices and instrument signals. These will be carefully designed to give concise and readily assimilable information to the operator. They will replace many indications used in past reactors and will confer the advantage of permanent records and elimination of large amounts of information which is insignificant because it is normal.

7.4.5 Boiler Pressure Controller

The boiler pressure controller controls the steam pressure to a value related to reactor power as determined by coolant temperature rise, through the reactor times channel flow as shown in Figure 7.4-9. In normal operation this system maintains the boiler pressure at its desired value by adjusting the speeder gear of the turbine, which alters the throttle valve position via the governor and thus alters the steam flow out of the boilers. As shown in Figure 7.4-9, the controlled value of the boiler pressure varies continuously between 593 psia (485°F saturated) at full power and 744.3 psia (510°F saturated) at zero power. This programme minimizes swell and shrinkage of the primary coolant and reduces thermal shock, particularly when the reactor is tripped.

If the turbine is unable for any reason to accept all the steam generated, the discharge valves will be opened progressively to maintain the boiler pressure. Opening of the discharge valves will result in an automatic set-back at a rate of one percent per second until the reactor power has been reduced to 70% of full power. This helps in obtaining the maximum ability to override Xenon in a short shutdown, but may be overridden by the operator.

The system also takes care of start up conditions and is used to impose various manually selected rates of cooldown in emergency. In Douglas Point, this system is mainly carried out by process type analogue equipment and is triplicated. In Pickering Units 1 and 2, the twin control computers will carry out these functions. The transducing instruments will be either in triplicate or quadruplicate, and the discharge valves form a redundant group. However there is only a single oil hydraulic-mechanical governor system for the turbine-generator.

7.4.6 Boiler Feedwater and Level Control

There are twelve boilers in each unit divided into four groups of three in each group. There are four feedwater lines entering the Reactor Building and each supplies one of the boiler groups. The water level in each steam drum is measured and the median used in conjunction with the measurement of feedwater flow and steam flow to regulate the main feedwater control valves. There are motorized gate valves on the feedwater lines to each boiler. These gate valves will be used to manually trim the flow to each boiler using level and valve position information in the control room. Reheater condensate return lines feed water into each steam drum. In the event of isolation of a boiler the manual valve on the reheater condensate line would be closed to prevent flooding of the boiler.

Two boiler water level measurements are made on each boiler. These measurements are used to initiate the following actions:

(1) Turbine Run-Back

If two out of two measurements in any boiler indicate high water level (i.e. ten inches above normal full power operating level) the turbine governor valves are run back.

(2) Reactor Set Back

If two out of three boilers in a bank indicate low water level (16 inches below zero power operating level) the reactor power is automatically set back.

7.4.7 Turbine-Generator Controls

These will be the same in principle as at Douglas Point except that no separate automatic synchronizer will be used. Synchronization will be carried out by the control computers with manual alternative.

As discussed in Section 7.4.5, the boiler pressure is adjusted by regulating the steam flow into the turbine. The controlling signal is connected to the speeder motor which in effect controls the governor set point. When the generator is connected to the outside line (synchronized), the turbine-generator speed is held constant and movement of the speeder motor results in proportional movement of the governor valve. The boiler pressure is thus controlled as desired while the governor system is left full operative, to guard against a runaway if the turbine load is lost for any reason.

7.4.8 Primary Pressure Control

The primary system pressurizing and pressure control is described in some detail in Section 4. The primary heat transport system is kept in a pressurized liquid state by controlling valves which "feed" or "bleed" heavy water to and from the system. The normal operating pressure at the reactor outlet header is 1280 psia. The low and high pressure reactor trip settings are at 1200 psia and 1384.6 psia.

7.5 PICKERING PROTECTIVE SYSTEM

7.5.1 General

A combined scheme of 11 shut-off rods worth about 24 mk in reactivity and a gas balance moderator dump system has been selected as the shutdown mechanism for Pickering. Either system alone would provide adequate protection. The reasons for the selection of the combined arrangement are as follows:

1) To avoid a poison-out following a rapid shutdown from high power equilibrium operation, a shutdown system is required which can be restored to its pre-shutdown position in a short period of time, without violating a safe limit on rate of increase in reactivity. With the dump system a very large change in reactivity results from a trip and a large quantity of water is transferred to the dump tank. Restoring the plant to full power in a short period is difficult following a complete dump of moderator.

2) The dump system is a relatively slow albeit highly reliable method of shutting down a reactor. For certain loss of coolant accidents analyzed in Volume II of this report the fission heat generated between the arrival of a trip signal and shutdown by moderator dump would cause an increase in calculated fuel temperature (average) of about 250°F. Using a relatively fast shutdown device this power produced in the fuel after a reactor trip has been called for will be at a minimum.

3) To provide an adequate margin of negative reactivity for the most reactive situation in a shutdown system using only shutdown rods would require a relatively large number of penetrations through the calandria and a like number of rods and drives. The dump system provides a very reliable large negative reactivity effect.

4) The dump system provides a large opening into the dump tank which is of value because it cushions the effects of a postulated pressure tube failure into the calandria.

5) A single, triplicated shutdown method would appear to provide quite adequate protection for the reactor. A combined shutdown system employing two separate types of devices to shut down the reactor and a multitude of detection systems makes it virtually impossible to have a loss of protection accident in the Pickering reactors.

7.5.2 Emergency Shutdown

The principal means of emergency shutdown is a bank of 11 shut-off rods which are worth approximately 24 mk. They are of the winch and cable type and are released by de-energizing an electromagnetic clutch, whereupon the drums unwind freely and the absorbers fall under gravity. The secondary method is by dumping the moderator in the same way as is done in NPD and Douglas Point.

When the moderator level is low, a given movement of the shut-off or adjuster rods tends to cause a greater change of reactivity than when the moderator level is high. This means that the rods must be moved more slowly, or fewer rods must be moved at once in order that the usual limit of rate of increase of reactivity shall be observed.

The overall protective scheme is governed by the following conditions and interlocks:

(i) If the moderator is fully dumped, no other method of increasing reactivity will be permitted until the moderator level has been raised to 50% of full tank.

(ii) When the moderator level is between 50% and 90%, the shut-off rods will be raised in four banks, one bank at a time. The combination of the moderator level rising at a maximum rate and one bank of shut-off rods being raised will not increase the reactivity at a rate of more than 0.33 mk per second. Moderator poison may be removed by ion exchange, but no other means of increasing reactivity will be permitted.

(iii) When the moderator level is greater than 90%, which will almost always be the case, the shut-off rods may be raised two banks at a time.

(iv) When 10 or more shut-off rods are raised and the moderator level is greater than 90%, the normal control methods become effective: the light water zone control system becomes the normal method of reactivity control, the adjuster rods may rise one bank at a time.

(v) If less than 10 shut-off rods are up, all light water zones are filled at the maximum rate and the adjuster rod out-drive is prevented.

(vi) If a trip signal exists, all light water zones are filled at the maximum rate and the adjuster rods are driven in unconditionally.

(vii) If (a) the shut-off rods are not up, and
(b) the neutron power is not suitably low and/or suitably decreasing,
the dump valves are opened if a time of 2.2 seconds has elapsed since the trip signal.

(viii) If the moderator level is 90%, the reactor power must be less than 1% of full power.

It will thus be seen that if a trip signal occurs, the shut-off rods will drop, and provided the reactor power starts to fall within 2.2 seconds and remains suitably low ((vii) above), the dump valves will not open. The light water zone control valves open to back up the shutdown. Normal operation cannot be resumed until the shut-off rods are raised ((iv) above).

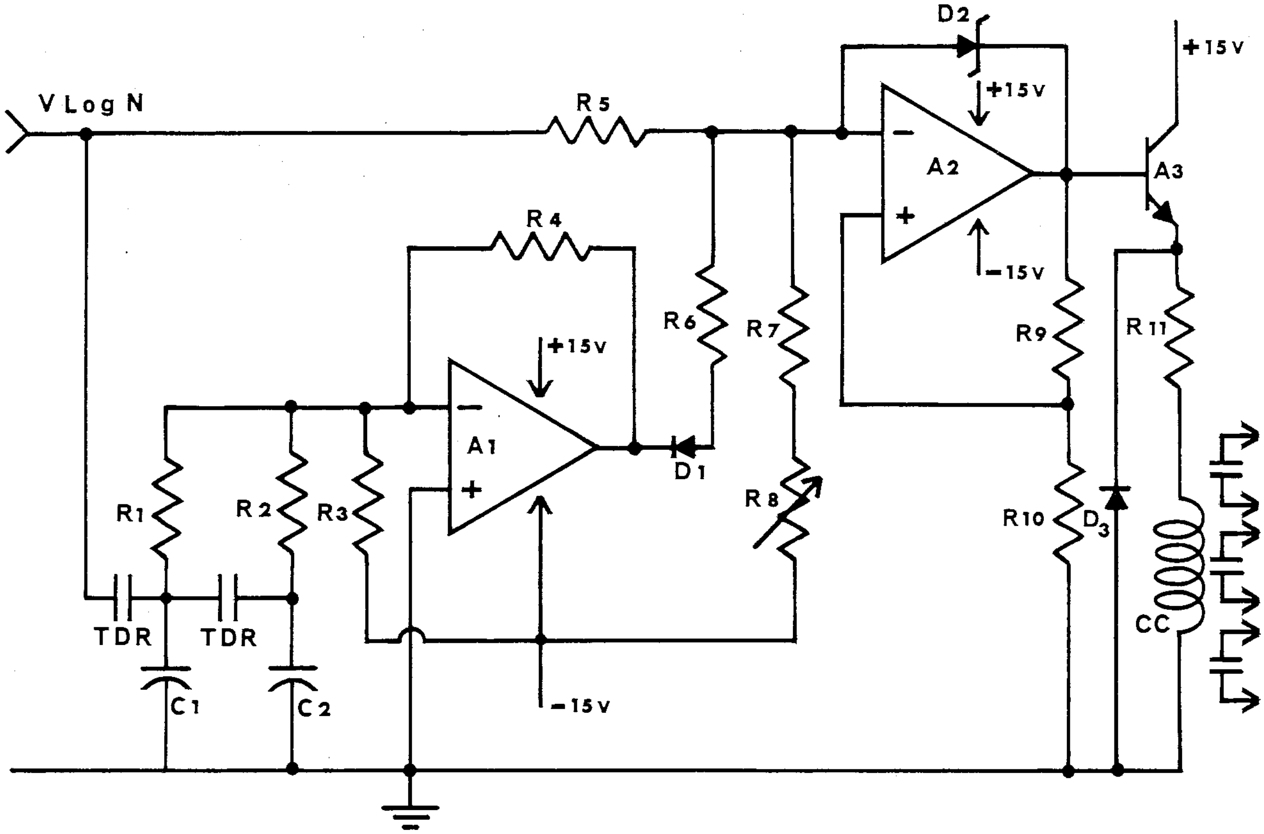
If the moderator is dumped, it must be pumped back to 50% level before the shut-off rods are raised, thus avoiding the need to raise the shut-off rods when only their bottom ends are inserted into what is, in effect, a very small reactor. The reactor power would be expected to be very low ((viii)) if the calandria is not full. If difficulty arises during pumping up, the moderator would be dumped.

7.5.3 Dump Arrest System

This system is designed to control the operation of the secondary shutdown devices, in this case the moderator dump. It works on the principle that a trip signal will open the dump valves unless the reactor power as indicated by the log N signal from the ion chambers falls at an acceptable minimum rate to about 1% of rated neutron power and remains below this as long as the trip signal persists.

The "acceptable" minimum rate of reduction in reactor power is established as the rate of decrease in neutron power if six of the shut-off rods operate properly, and with no untoward increase in reactivity. The minimum acceptable rate of reduction of ion chamber current is simulated by the decay of charge on capacitors (in a R-C network) which during operation are charged to a voltage in proportion to the log of neutron flux. When a trip signal occurs the actual ion chamber output is compared to the reference curve condition as derived from the discharging R-C network. Following receipt of a reactor trip signal, if the actual ion chamber current is less than that representing the minimum acceptable rate of reduction of power current, the dump valves are held closed. If the actual ion chamber current exceeds the reference curve of the minimum acceptable rate of reduction of power the moderator is automatically dumped.

A simplified diagram of the dump arrest unit in one protective channel is shown in Figure 7.5-1. The operation of the system is as follows:



R_1 — 185 MΩ		R_7 — 23 KΩ		C_1 — 0.0054 μF			
R_2 — 10 MΩ		R_8 — 0.5 KΩ		C_2 — 16 × 6.8 μF			
R_3 — 22 MΩ		R_9 — 10 KΩ		D_1 — FD600 FAIRCHILD			
R_4 — 9.5 MΩ		R_{10} — 20 Ω		D_2 — IN758A			
R_5 — 10 KΩ		R_{11} — 30 Ω		D_3 — IN4001			
R_6 — 8.5 KΩ		A_3 — 2N3053		CC — RELAY			

7.5-1 DUMP ARREST CIRCUIT

44.63721-1
1968

(1) During operation the dump valves are held closed by the dump valve relay. The trip signal of each channel which goes to the shut-off rods is also transferred by contacts on the dump valve relay to the dump valves of that channel.

(2) The contacts of the output relay (CC) of the dump arrest unit hold the dump valves closed in parallel with the dump valve relay contacts when there is no requirement for a dump.

(3) Relay contacts keep capacitors in the resistance-capacitance network charged to the same voltage as the log N signal during operation.

(4) In the event of a reactor trip signal the relay contacts (TDR) open after a delay of 2.2 seconds allowing the discharge of the capacitors through the resistance network. The voltage applied to the lower input of the comparator represents the minimum acceptable rate of shutdown. The voltage applied to the upper input of the comparator as derived from ion chambers represents the actual rate of shutdown.

(5) Following a reactor trip if the actual log N signal falls faster than that representing the minimum acceptable rate the voltages across the comparators are such as to hold the dump arrest relay output contacts (CC) closed. The dump valves therefore remain closed.

(6) Following a reactor trip if the actual log N signal does not fall as fast as the minimum acceptable rate the voltage across the comparator is such as to release the dump arrest relay output contacts and the dump valves are opened.

(7) If a signal to open the dump valves persists for three seconds or more, the dump valves will be locked open.

(8) The bias is so arranged that when the capacitors are fully discharged the comparator contacts will open if the log N signal is greater than approximately one percent of full power.

(9) The log N signal is considerably affected by the amount of poison in the moderator. The ion chamber rundown curve with no poison in the moderator is shown in Figure 7.5-2. With poison in the moderator such that the ion chamber signal is reduced by a factor of four the ion chamber rundown curve is as shown in Figure 7.5-3.

The dump arrest unit can be tested during operation by a simple sequence to prove that it performs correctly following a reactor trip signal. The full rundown curve of the "plug in" dump arrest units can be checked by a separate permanent test unit. A spare dump arrest unit would be first checked on the permanent test facility and then "plugged in" in place of a dump arrest unit in one of the three protective channels. The removed dump arrest unit would then be tested and subsequently used to replace a dump arrest unit in another channel. If a channel does not have a dump arrest unit plugged in the dump valves of that channel will open unconditionally if a reactor trip signal occurs. The removal of the dump arrest unit for test is thus an inherently safe operation.

7.5.4 Trip Signal

The parameters selected to protect the reactor and the associated trip settings or limits are shown in Table 7.5-1. For each parameter (except the manual trip) at least three signals are obtained from separate pickups. The reactor will be automatically tripped if any two out of three signals for each parameter exceeds the limits indicated. It is believed that for all serious system failures two or more parameters will cause the reactor to trip.

7.5.5 Setback System

When trouble is detected of a lesser degree than that which calls for a reactor trip, the reactor setback is initiated through the control system of the reactor. The reactor power would be reduced under control at a rate of about one percent per second until either the setback signal disappears or the power is reduced to a specified low value.

The setback signals are given in Table 7.5-2.

7.6 CONTROL CENTRE DATA PRESENTATION

7.6.1 Control Panels

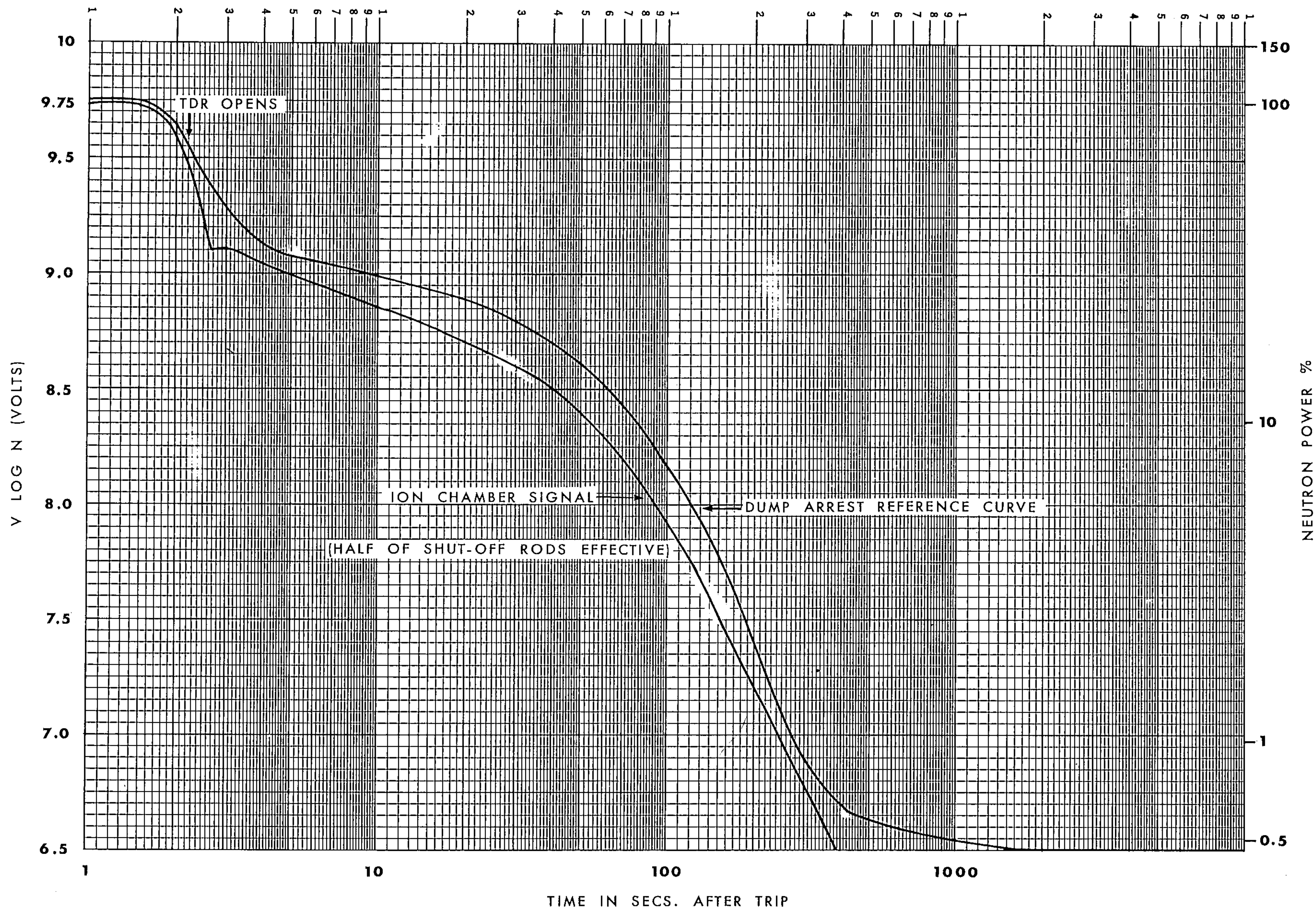
The centralized control concept will be followed as at Douglas Point where any control which may need alteration within 15 minutes of an abnormal indication in order to keep the plant operating and safe is located in the control room. The number of recorders, indicators, lights, etc. provided and the degree to which manual intervention is permitted into systems which are normally automatic is always a compromise, since minor tasks may distract an operator from major ones. Some further condensation of control panel displays compared with Douglas Point will be aimed at but such changes will only be a matter of degree.

Figure 7.6-1 shows the functional layout of the control panels for one unit. The other unit will be of the same form, i.e. not a mirror image.

7.6.2 Annunciation

The annunciation system will consist of a main control room annunciator and local annunciators mounted in field panels.

In the main control room the annunciator will provide the operator with a printed record of all alarm conditions printed in chronological order of occurrence. For alarms of a very important nature lighted message windows are also provided. These windows are restricted to the following



7.5-2 ION CHAMBER SIGNAL FOLLOWING TRIP - WITH NO POISON IN MODERATOR

44.63721-2
1968

TABLE 7.5-1

REACTOR PROTECTIVE SYSTEM TRIP SIGNALS

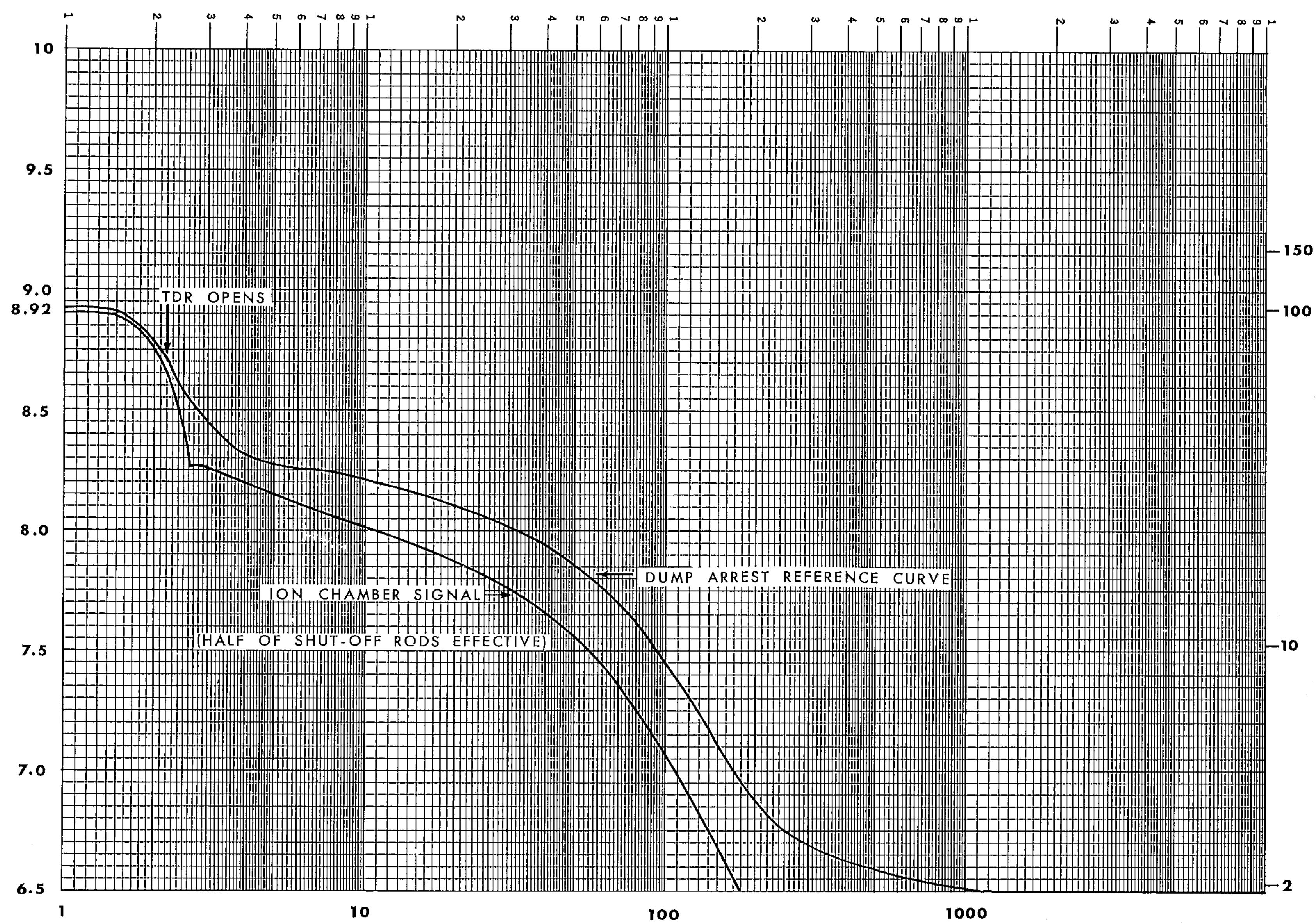
REFERENCE SECTION	REACTOR TRIP SIGNALS	LIMITS	RESPONSE TIME (sec.)	TYPE	TEST FACILITY
7.4.8 and figure 4.5.4	High primary system pressure	1384.6 psia	Instantaneous	Absolute	Complete
7.4.3.2	High neutron flux	110% of full power	Instantaneous	Absolute	Complete
	High neutron log rate $\frac{d}{dt} \log N$	10% per second	Instantaneous	Absolute	Complete
	Manual trip		Instantaneous	Absolute	Complete
7.4.8 and figure 4.5.4	Low primary system pressure	1200 psia	Instantaneous	Conditional	Complete
3.2.6	High Reactor Building pressure (boiler rm)	0.5 psig	Instantaneous	Conditional	Complete
7.4.3.3	High reactor outlet coolant temperature	565°F	5 seconds	Conditional	Partial

A conditional trip always alarms.

TABLE 7.5-2

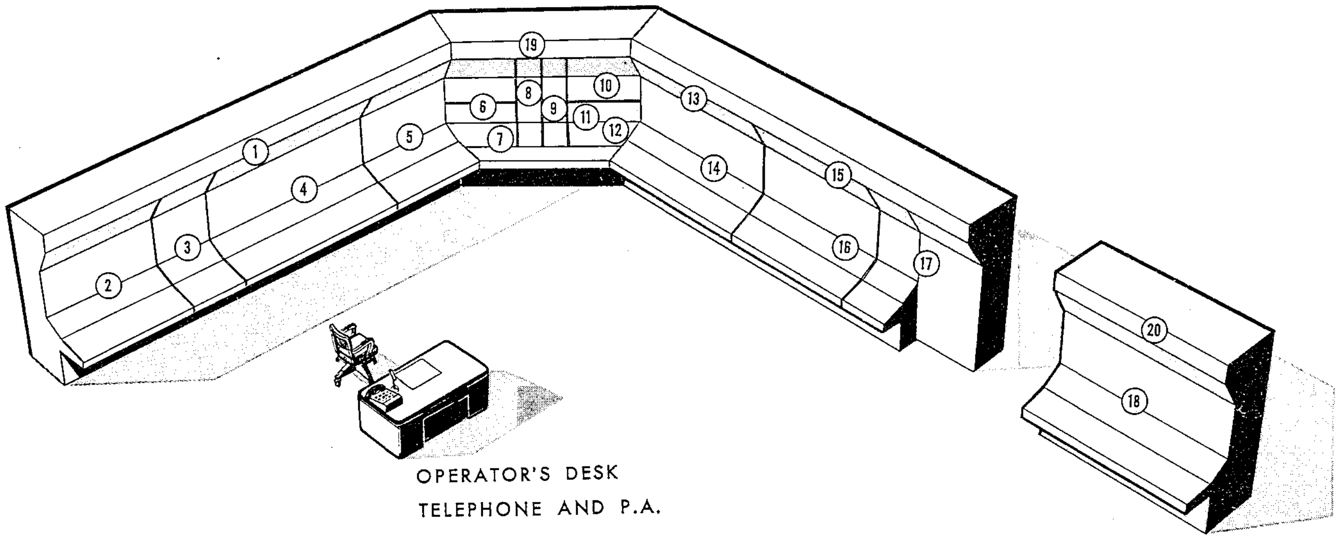
REACTOR SETBACK SETTINGS

REFERENCE SECTION	SETBACK SIGNAL	LIMIT FOR INITIATION	LIMIT FOR AUTOMATIC TERMINATION
7.4.3.3	High Reactor Outlet coolant temperature	>564°F	564°F
4.5.2.3	High level in bleed condenser	>46.5 inch above bottom of condenser	<46.5 inch
7.4.2.1	Low supply pressure light water zone control system	≤60 psia	0.1% of full neutron power
7.4.5	Steam discharge from secondary discharge valves	valve open	valve closed or ≤70% FP
7.4.6	Multiple low water level in boilers	water level in two drums out of three in a bank 16 inches below zero power level	Reverse of initiation
7.5.3	Manual	no specified limit	0.1% of full neutron power



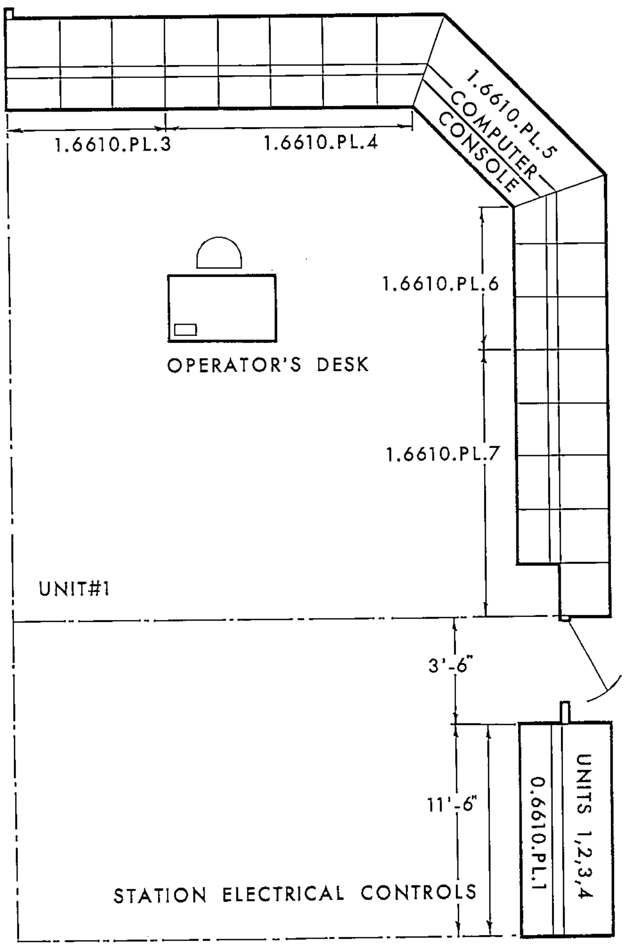
7.5-3 ION CHAMBER SIGNAL FOLLOWING TRIP - WITH SIGNAL REDUCED BY A FACTOR OF FOUR DUE TO POISON IN MODERATOR

44.63721-3
1968



CONTROL PANEL ARRANGEMENT

PLAN



1 25 ANNUNCIATOR WINDOWS
2 TURBINE— GENERATOR AND AUXILIARIES
3 BOILERS AND STEAM
4 PRIMARY HEAT TRANSPORT
5 REACTOR CONTROL AND MODERATOR
6 32 COLUMN PRINTER
7 PRINTER–KEYBOARD
8 COMPUTER NO 1 CONTROLS
9 COMPUTER NO 2 CONTROLS
10 CLOSED CIRCUIT T.V. CONTROLS
11 32 COLUMN PRINTER
12 PRINTER–KEYBOARD
13 CLOSED CIRCUIT T.V.
14 FUELLING MACHINES AND FUEL TRANSFER
15 5 ANNUNCIATOR WINDOWS
16 PLANT AUXILIARIES
17 CHANNEL ACTIVITY MONITOR, HEALTH MONITOR AND MISCELLANEOUS
18 UNITS NO 1 AND NO 2 ELECTRICAL CONTROLS AND STATION COMMON EQUIPMENT
19 54 ANNUNCIATOR WINDOWS
20 18 ANNUNCIATOR WINDOWS

7.6—1 CONTROL ROOM LAYOUT

44-66100-1
REV. 1, 1968

```
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 65JUN19   0327          16 OPERATOR REQ.
      12345  678901  234567  89012
      -----  ------  ------  -----
   A -----  --            --  ----- A
   B -----                    ----- B
   C ---            *            --- C
   D --                           -- D
   E --                           -- E
   F -       * HHH *        *      - F
   G -      AHHH                   - G
   H -      AHH  H                 - H
   I -      *HHH  H         *      - I
   J -       H       *             - J
   K -      H  H                   - K
   L -     H                       - L
   M -      H        *             - M
   N -       *              L  *   - N
   O -                             - O
   P -                      B      - P
   Q -       *       *   L   *     - Q
   R --              BLLL         -- R
   S --          L    L    L      -- S
   T ---         LL*   LL        --- T
   U -----                    ----- U
   V -----  --            --  ----- V
      -----  ------  ------  -----
      12345  678901  234567  89012
 H-566 F UP A-96% UP MEAN 94.3%FP
 L-560 F DN B-92% DN EAST ABOVE
                     WEST BELOW
 HOT CHANNEL F8.567.3F
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

FIGURE 7.6-2

TYPICAL REACTOR PRINTOUT - AXIAL VIEW

```
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 65JUN27  1532               OPERATOR REQ

                   EAST
 NORTH             +01DET              SOUTH

   Z26U            Z15U                Z23U
         UPSO      Z13M   UPSO
   Z19L            Z19L                Z18L

  +03DET          -01DET              +01DET
 ADJ   DN   17    DN   DN   23    DN   ADJ

                UPSO    UPSO

 ADJ   DN   DN    DN   DN   DN    DN   ADJ

         UPSO            UPSO       UPSO

 ADJ   DN   19    DN   DN   20    DN   ADJ
   +01DET           -02DET            -03DET

   Z14U              Z16U              Z18U
         UPSO        Z18M    SOUP
   Z12L              Z16L              Z21D

 NORTH               +03DET            SOUTH

                     WEST

 DETECTOR MEAN 103.2%
 ION CHAMBER SIG 1.27 DECADE 0
 THERMAL POWER 101.7%

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

FIGURE 7.6-3

TYPICAL COMPUTER PRINTOUT

alarms:

(a) Reactor trips and setbacks

(b) Turbine-Generator trips

(c) 230 kV circuit breaker trips

(d) Very important process alarms such as emergency injection conditions.

An audible alarm will sound whenever an alarm message is printed. A means of conditioning alarms so that meaningless alarms are ignored is provided; also a summary of all existing alarms will be produced at the request of the operator.

The system provides for 800 contact inputs and 400 analogue inputs. The contact inputs will be connected to a scanning unit, the output of which will be fed to either of the two computers associated with each unit. Provision will be made for both automatic and manual changeover of this input. The analogue inputs will be divided between both computers with no provision for changeover.

The printed message, alarm conditioning and audible alarm initiation functions are performed in the computers and are described in Section 7.6.3.2.

Another feature of the annunciator system will be a means of indicating to the operator that selected handswitches are in an off-normal position. A lamp will be lighted above the affected portion of the control panels whenever such a condition exists. This feature is independent of the computers.

The annunciators mounted in the field panels will be of the conventional type with flashing message windows and an audible alarm. All circuitry will be of the solid state type.

7.6.3 Computer Print Out

As mentioned above, the high speed printers associated with the computers will replace some indicators and recorders. Information will automatically be printed out when the computer detects important changes in conditions, and the operator can readily demand the printing out of general or particular information at any time. Figures 7.6-2 and 7.6-3 show typical print-outs of the state of the reactor controlling devices and instrument measurements. It will be seen that a very concise indication and record can be obtained. Unlike the more conventional displays on fixed control panels, these printed displays can be changed by alteration of the programme to incorporate improvements as a result of operating experience. The load in the computer time and memory represented by this type of programme is not large so that eventually a wide range of print-outs for particular contingencies would probably be accumulated.

The special purpose alarm recorder used at Douglas Point is not used at Pickering. Alarms of sufficient importance that a sequential record is needed would either be derived by the computer or would be recorded by it.

7.6.4 Summary of Functions Performed by Computers

7.6.4.1 Functions Performed by Both Computers

(a) <u>Channel Temperature Monitor</u>

Monitoring of the 390 fuel channels and alarming and limiting of reactor power if any are too high. Two separate RTD's are provided for each channel and one of these is monitored by each computer. All channels are checked once every two seconds and an alarm is given if either RTD shows an excessive temperature.

(b) <u>Reactor Regulating and Zone Control System</u>

Control of the reactor is in two main sections, power regulation and control of the neutron flux distribution. These functions are performed by individual control of the neutron flux in each of 14 "zones". The reactor control functions involve direct control of the light water absorbers, the adjuster rods, shut-off rods, moderator level, and moderator poison concentration.

(c) <u>Boiler Pressure Control</u>

The aim of this function is to control the boiler pressure to follow a programme which is a function of reactor power level.

7.6.4.2 Functions Performed by One Computer Only

(a) <u>Alarm Recording</u>

The computer will print out the occurrence and clearance of alarm signals in sequence, complete with time to a fraction of a second, and initiate the audible alarm. It will also check alarm signals against associated plant parameters to determine whether or not an alarm is meaningful at the particular value of the parameter. If the alarm is meaningful the message will be printed, if not it will be ignored.

All alarms initiated by contact inputs only require the use of one computer, however the function is transferrable between the two computers. The transfer can be made manually or automatically. The analogue input alarms are processed by the computer to which they are connected with no provision for changeover. For the convenience of the operator all alarm messages will be printed by whichever computer is processing the contact input alarms.

(b) <u>Sequence of Events Recorder</u>

For a group of several hundred alarm points, mostly associated with the electrical protective relaying in the conventional part of the Pickering station, it is desirable to record sequences of operation with timing to an accuracy of a few milliseconds. This will be carried out by one of the control computers.

(c) Fuelling Machine and Fuel Transfer Controls

This function involves positioning of the fuelling machine rams and carriage. Control of the fuelling machine magazine pressure and temperature and control of the fuel transfer mechanisms. It also involves, using one computer only, the control of the sequence of actions performed by the fuelling machine in changing fuel.

(d) Automatic Turbine Run-up

This function brings the turbine up to synchronous speed from a cold start off the barring gear following a programme which is a function of turbine rotor speed, condenser vacuum, bearing vibrations, shaft eccentricity, rotor to casing differential expansion, and high pressure casing temperature.

(e) Control of the Condenser Vacuum

This function is concerned with the achievement and maintenance of the correct condenser vacuum by the proper employment of three mechanical vacuum pumps. All three are used for hogging and when the proper vacuum has been reached the programme progressively reduces the number of pumps in action to one. Thereafter continuous monitoring of the condenser vacuum is carried out and additional pumps are brought into use if the condenser vacuum shows a tendency to droop. Under these latter circumstances the computer will print out the appropriate alarm messages to inform the operator of the situation.

(f) Station Hourly Log

This function produces a conventional hourly log of important plant parameters on a special log sheet incorporating pre-printed headings.

(g) Plant Performance Calculations

This function involves the gathering and averaging of information from about 90 analogue inputs, then using these averages the programme will calculate the efficiencies of each of four turbine stage groups.

(h) Xenon Calculations

The computer keeps a running account of the concentrations of Xenon 135 and Iodine 135 in the reactor as knowledge of these is required to control the shimming of the reactor and for effective forecasting of reactor capability.

(i) Poison Override Interval Prediction

This will be an on demand function which will predict from the existing Xenon 135 and Boron 10 concentrations in the reactor what the consequences will be of any specified reduction in power, in terms of time until "poison-out".

(j) Trend Programme

On demand the computers will print out at specified time intervals the values of up to twenty specified variables plus, if desired, their first and second derivatives with respect to the selected time intervals.

(k) Hourly Channel Temperature Log

The coolant outlet temperature from each reactor fuel channel shall be logged hourly on paper tape in format such that when reproduced on a typewriter the channel temperatures will be spaced on the log sheet in positions corresponding to their relative positions in the reactor.

(l) On Demand Channel Temperature Log

This will be similar to the hourly channel temperature log except that it will be printed out only on demand and only those temperatures above a limit specified by the operator will be printed out.

8. PLANT SERVICES

8.1 WATER SUPPLY SYSTEMS

8.1.1 General

Water for all purposes at the Pickering Generating Station will be drawn from Lake Ontario through the intake channel, which is common for four units, through the screenhouse and into gravity fed ducts running the length of the Turbine Auxiliary Bay. Three independent sets of pumps mounted in separate wells in the Turbine Auxiliary Bay duct supply water to the condenser circulating water systems, the plant service water systems, and for standby and firefighting. An eight-inch connection to the Pickering Township domestic water system constitutes a standby supply of domestic water.

8.1.2 Condenser Circulating Water System

The circulating water system will be an open loop system design to supply a sufficient quantity of cooling water to the condensers to maintain the design back pressure of the turbine exhaust during full load operation. The pumping equipment consists of two vertical pumps each capable of supplying 50 percent of the required flow of 314,000 Igpm. The pumps are mounted in independent wells in the water supply duct in the Turbine Auxiliary Bay and are driven by induction motors using 4000 volt, Class IV power.

To prevent debris and weeds from entering the circulating water system travelling screens will be located in the screenhouse. To prevent algae formation in the condensers chlorine will be periodically discharged into the inlet duct of the condenser.

The discharge ducts from the condensers, which form a syphon to recover the elevation head in the system, carry the water to closed ducts which run parallel to the Turbine Building. The circulating water is discharged back to the lake through an open cut in the lake bed at the west end of the No. 4 unit.

8.1.3 Service Water System

Each unit has an individual service water system. The system consists of three separate supplies; a low pressure lake water supply, a high pressure lake water supply and a recirculated service water circuit.

The low pressure service water is supplied by three vertically mounted 25,000 Igpm pumps in the duct in the Turbine Auxiliary Bay operating on Class IV power. Two pumps are capable of supplying the summer demand of each unit, hence there is a 50 percent standby in low pressure service water supply to each unit. Under normal operating conditions each pump delivers water directly through a strainer into a discharge header serving all three pumps. Isolating valves in the interconnecting lines between pump discharges allow the operation of any combination of pumps and strainers. The strainers are of the automatic back flushing type with a strainer opening of 0.010 inch.

Two 50 percent capacity low pressure pumps operating on Class III power with a capacity of 4,160 Igpm each are provided to supply cooling water in the event of failure of Class IV power. These pumps discharge to the low pressure service water header through a single strainer.

The low pressure service water is distributed to the nuclear and conventional parts of the plant from the pump outlet header at a pressure of 76 feet above grade elevation.

The high pressure service water is taken from the low pressure outlet header and raised in pressure to 230 feet above grade by pumps discharging into the high pressure discharge header. There are two vertically mounted pumps operating on Class IV power each capable of delivering 7,500 Igpm, and two vertically mounted pumps operating on Class III power each capable of delivering 4,160 Igpm. Under normal operating conditions the high pressure service water requirements are supplied by one of the large high pressure pumps with the other large pump acting as standby. In the event of loss of Class IV power the high pressure service water requirements are supplied by one of the smaller pumps operating on Class III power. The other small high pressure pump provides 100 percent standby pumping capacity. With the primary heat transport system operating on the standby cooling, both large high pressure service water pumps and one of the smaller pumps are required.

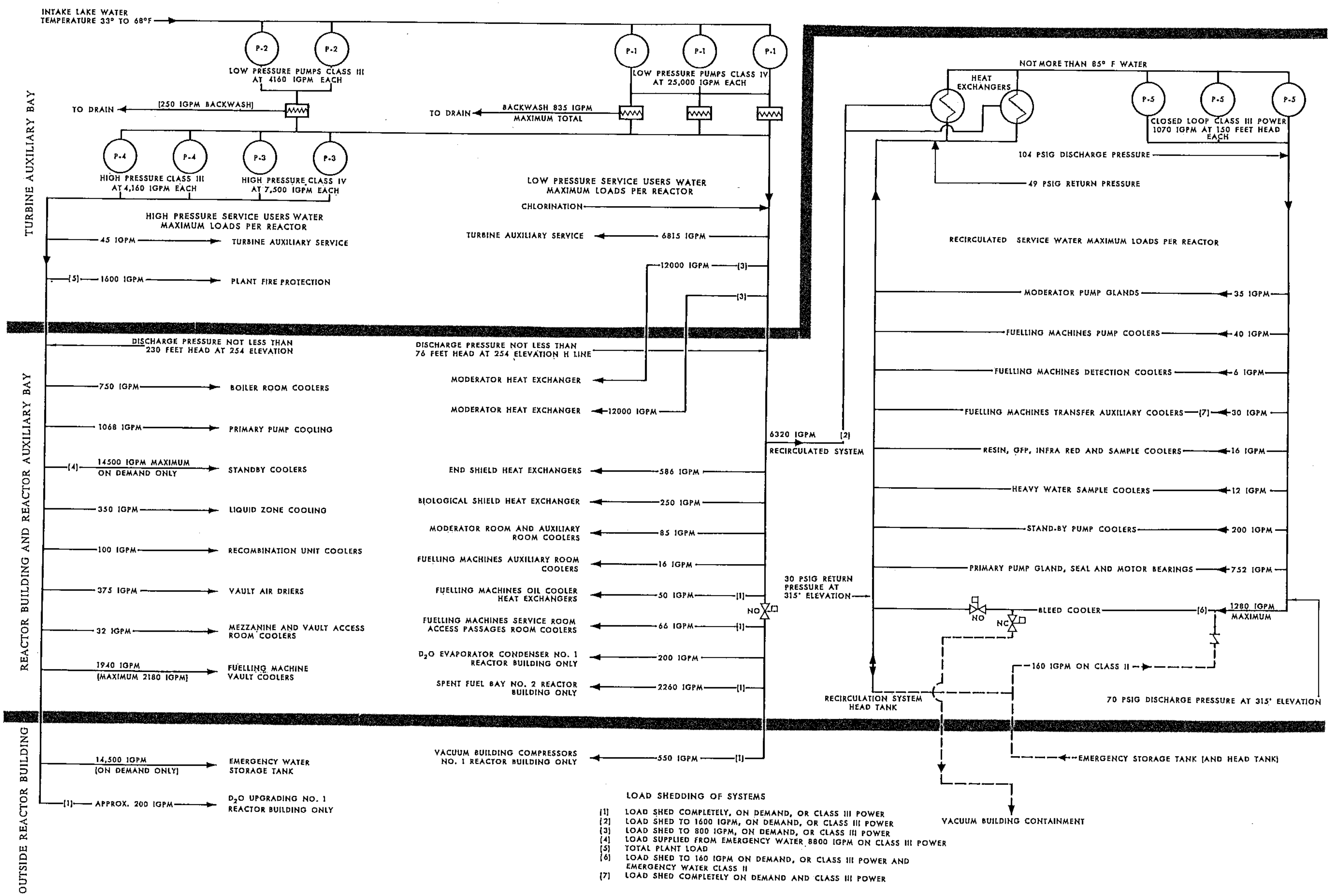
The recirculated service water system is installed to provide clean cooling water at a minimum head of 120 feet above grade and a temperature of 85°F to equipment which might otherwise become fouled or plugged by impurities if supplied by raw lake water. The circulation is provided by three 50 percent capacity pumps and the heat is removed by two 50 percent capacity heat exchangers cooled by low pressure service water.

Each pump has a capacity of 1070 Igpm and any one of the three pumps can be operated on Class III power.

The water storage tank in the top of the Vacuum Building serves as an emergency supply of service water to all reactor units in the event of failure of both Class IV and Class III power, and as a head tank for the recirculation system.

A 24 inch diameter common header connects the high pressure service water supply of each unit to the emergency water storage tank in the Vacuum Building. The tank may be filled from any of the high pressure systems and, conversely, in the event of failure of both Class IV and III power, the common header is used to supply cooling water from the tank to the units. The available head is 120 feet above grade elevation.

The flow distribution for the high and low pressure open



8.1—1 HIGH PRESSURE, LOW PRESSURE OPEN AND RECIRCULATED COOLING WATER SYSTEMS

44.71300—9
REV. 1, 1968

systems and the recirculated water system is shown in Figure 8.1-1.

Six different conditions have been considered in designing the service water system. These conditions, as illustrated in Figures 8.1-2 to 8.1-7, are:

(1) Normal operation	— Class IV power	Figure 8.1-2
(2) Hot shut down	— Class III power	Figure 8.1-3
(3) Hot shut down	— Class II power	Figure 8.1-4
(4) Primary heat transport on standby cooling	— Class IV power	Figure 8.1-5
(5) Rapid cool down - using standby coolers	— Class IV power	Figure 8.1-6
(6) Primary heat transport on standby cooling	— Class III power	Figure 8.1-7

Total flows for the above conditions are shown in Table 8.1-1.

8.2 DRAINAGE AND SEWAGE

The roof and site drainage for the station will be conventional. Special under-drainage systems with monitors will be provided for the Reactor Buildings, the spent fuel transfer duct, the Vacuum Building, the spent fuel storage bay, and the waste management area.

Wash water from Zone 2 and Zone 3 washrooms and showers in the Service Wing and floor drains in the Service Wing, Reactor Building and Reactor Auxiliary Bay are considered active drainage and will be piped to the active waste management system. Sewage from all urinals and toilets and wash water from Zone 1 will be piped through the interconnecting sewage pipe to the Pickering Township sewage main.

8.3 HEAT AND VENTILATION

8.3.1 Heating System

During normal operation, bleed steam from the turbine will be used to heat all the buildings. An immersed electrode type electric boiler will supply steam to the heating system when bleed steam from the turbine is not available.

8.3.2 Ventilation

Separate ventilation systems will be provided for each building according to the zone classification, and to control any airborne activity within the buildings. In general, air for the Reactor Building, Auxiliary Bay and spent fuel storage bay will be drawn in through separate plenums at the south face of the second floor of the Reactor Auxiliary Bay. Discharge will be through local exhaust ducts and fans through the roof of the Reactor Auxiliary Bay. For the Service Wing, Reactor Buildings and the spent fuel storage bay the discharge ducts will be at the south side of the Powerhouse, terminating in a dispersal stack about 15 feet above the Powerhouse roof. Separate absolute and charcoal filters will be provided on bypasses in the discharge ducts for the Reactor Building and fuel storage bay ventilation exhaust systems.

8.3.2.1 Reactor Building Ventilation System

The ventilation system supplies 6500 cfm of tempered air to the areas in the Reactor Building which are accessible during reactor operation. The ventilated areas are listed in Table 8.3-1. Air is drawn into the system through a plenum on the south side of the Reactor Auxiliary Bay and is exhausted out of the exhaust duct. The temperature in these accessible areas will normally be in the range 78 to 85°F and will not exceed 105°F. The pressure in these areas will be slightly negative (1 to 2 inches of water) with respect to atmosphere as determined by the ventilation arrangement with fans on the system discharge. This exhaust air will be monitored for activity (see Section 9) and will not normally be filtered. In the event of high activity levels in the exhaust, the ventilation dampers on the Reactor Building will close. The exhaust can be directed through filters by manual operation of dampers.

The areas in the Reactor Building in which there is a significant likelihood of heavy water leakage are not normally ventilated. These areas are normally connected in a closed circuit in which a dryer is located to maintain the dew point at about 0°F. The areas on closed circuit dried systems and the dryer flows are listed in Table 8.3-1. These areas are held at a pressure slightly negative with respect to the ventilated areas in the building by a small bleed flow from the dryer return line to the ventilation exhaust.

These non-ventilated areas may be purged when required by diverting ventilation air through a ductwork and damper system. The purge flow rates are listed in Table 8.3-1. All purge air exhaust as well as normal ventilation exhaust may be filtered prior to discharge to atmosphere. The boiler room is the largest single area in the Reactor Building. A boiler room purge flow of 10,000 cfm can be obtained by operating the standby exhaust fan and by diverting all ventilation through the boiler room.

All areas with the exception of the calandria vault will be provided with room coolers using service water as a heat transfer medium. There is no ventilation flow, drying or cooling of the calandria vault atmosphere but the vault is maintained at a pressure slightly below the rest of the building by a small bleed flow to the building exhaust.

Design air flow rates and pressure balances are to be maintained by means of butterfly-type balancing dampers with position stops where the same dampers are to be used for purge control.

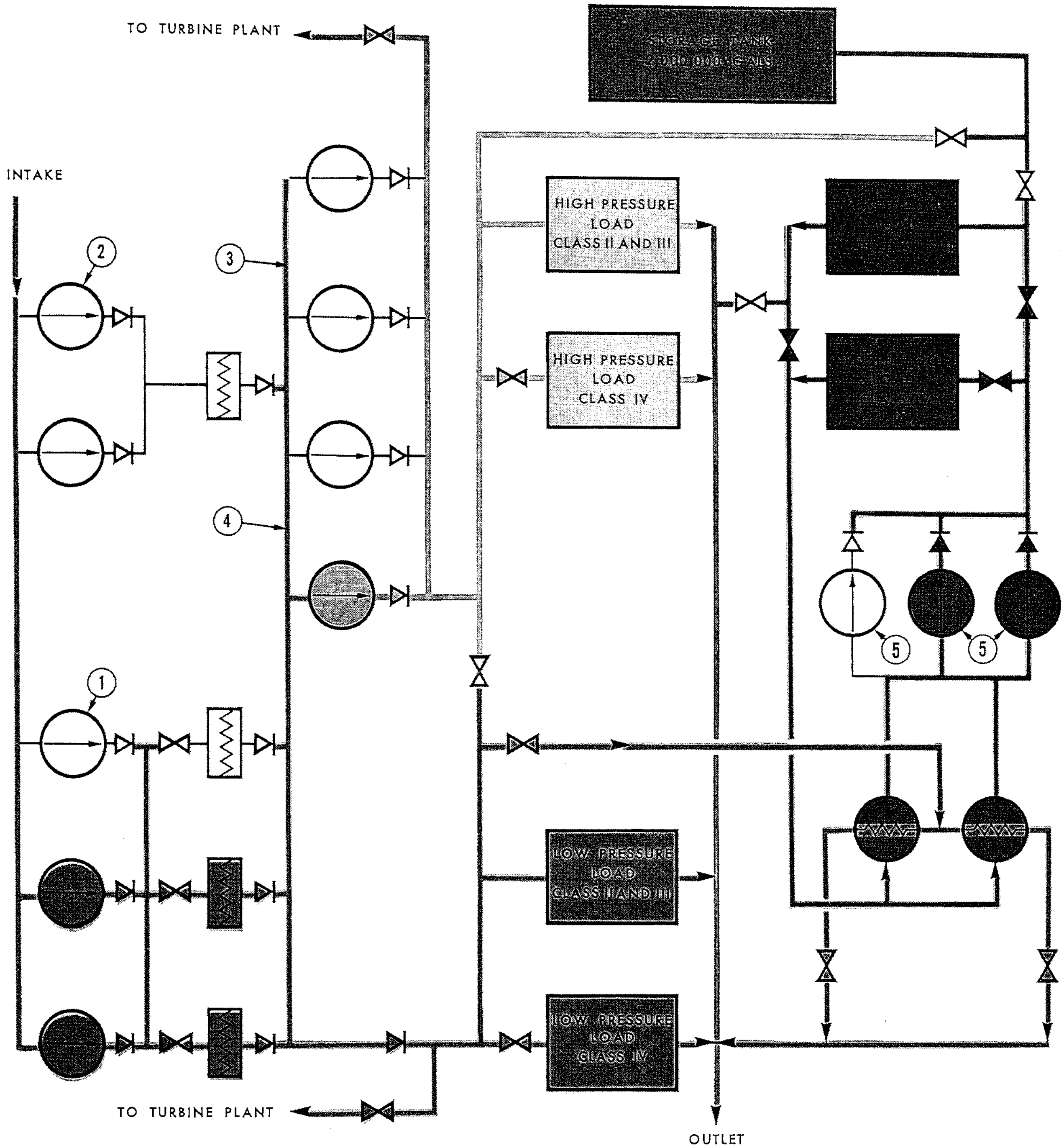
Pressure balance control will also require the possibility

TABLE 8.1-1

SERVICE WATER SUPPLIED TO UNIT AUXILIARIES

Condition	FLOW IN IGPM PER UNIT					
	Normal Operation Class IV	Shut Down Class III	Shut Down Class II	Standby Cooler OP Class IV	Em. Shut Down Class IV	Standby Cooler OP Class III
L.P. Service Water Reactor Auxiliaries	33,633	4,197		4,313	20,597	4,197
L.P. Service Water Turbine Auxiliaries	7,700	250		7,700	7,700	250
H.P. Service Water	4,465	4,465		18,965	19,205	4,465
Total (L.P. supply req.)	45,798	8,912		30,978	47,502	8,912
Recirculation System	2,140	1,070	160 direct from storage	1,070	1,070	1,070
Flow from Storage Tank			160			8,800
* Fire Prot. from H.P. System	1,666	1,666	from emergency storage tank	1,666	1,666	1,666

* Total for Plant



PUMPS

1. LOW PRESSURE, CLASS IV, 3 AT 25000 IGPM
2. LOW PRESSURE, CLASS III, 2 AT 3750 IGPM
3. HIGH PRESSURE, CLASS IV, 2 AT 7500 IGPM
4. HIGH PRESSURE, CLASS III, 2 AT 4200 IGPM
5. CLOSED LOOP, CLASS III, 3 AT 1070 IGPM

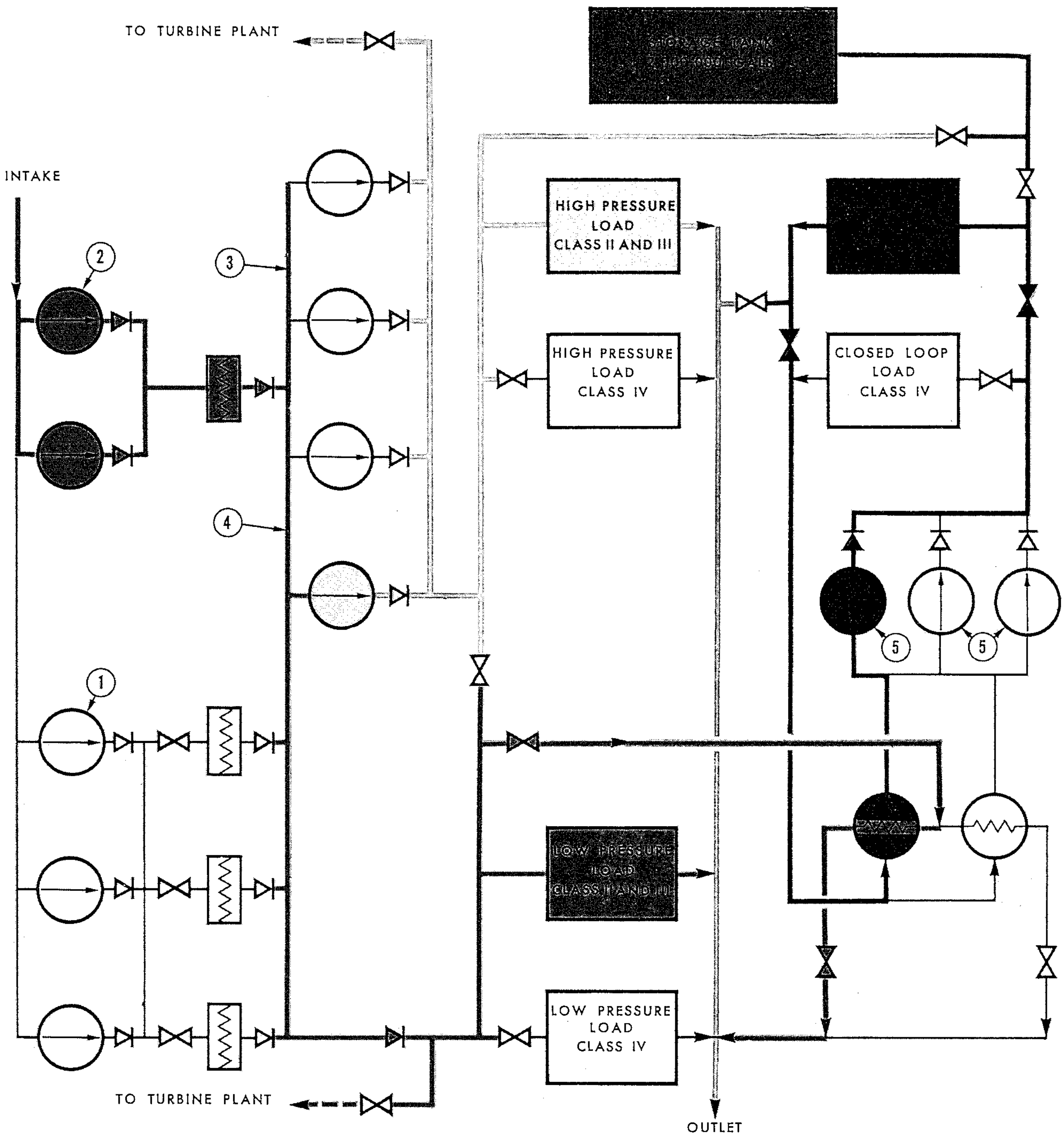
COLOUR CODE

- LOW PRESSURE
- HIGH PRESSURE
- CLOSED LOOP
- STORAGE TANK
- INLET AND DRAIN

8.1-2 REACTOR SERVICE WATER SYSTEM

CONDITION NO.1—NORMAL OPERATION, CLASS IV POWER

44.71300-3
REV. 1 1967



PUMPS

1. LOW PRESSURE, CLASS IV, 3 AT 25000 IGPM
2. LOW PRESSURE, CLASS III, 2 AT 3750 IGPM
3. HIGH PRESSURE, CLASS IV, 2 AT 7500 IGPM
4. HIGH PRESSURE, CLASS III, 2 AT 4200 IGPM
5. CLOSED LOOP, CLASS III, 3 AT 1070 IGPM

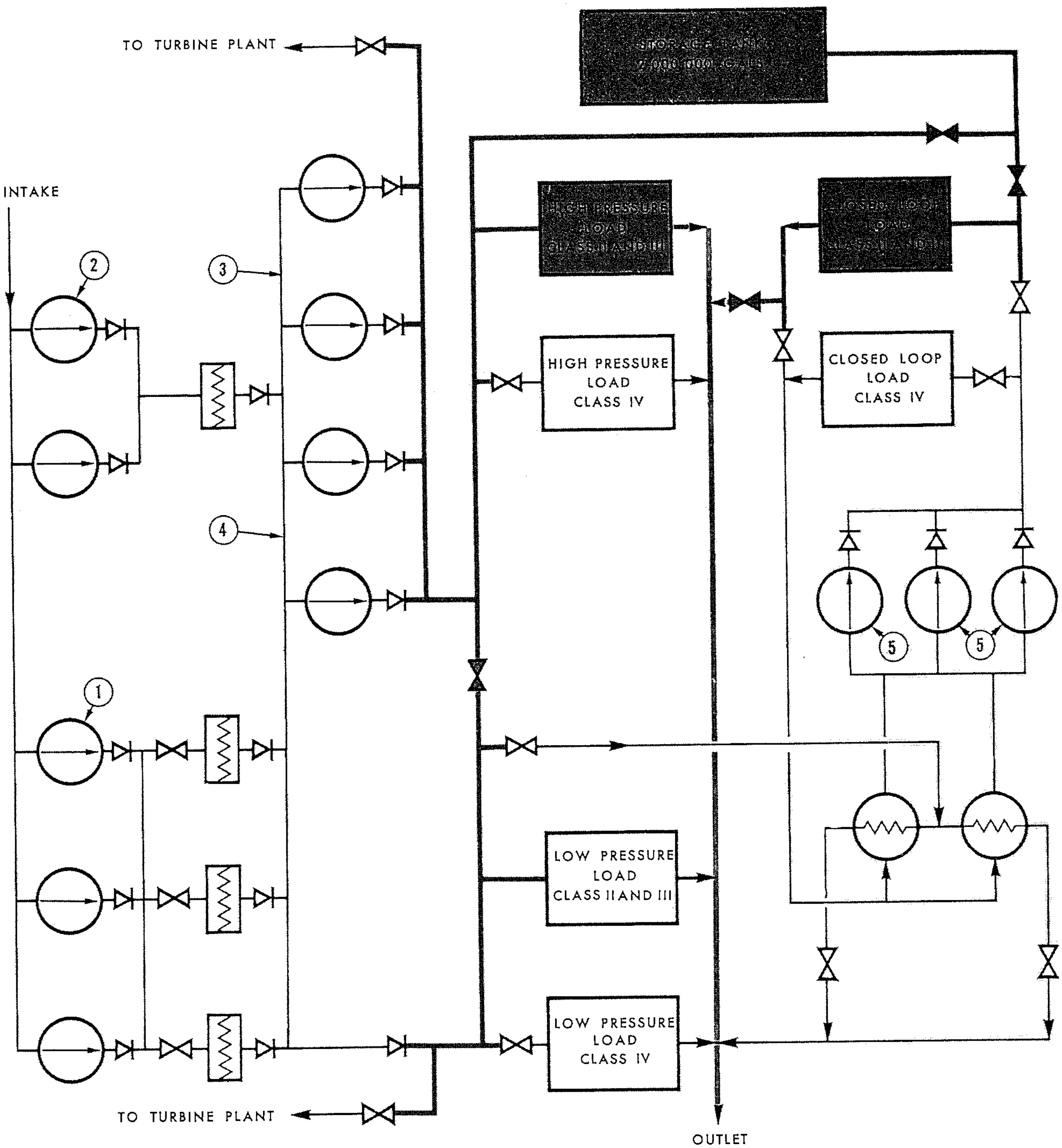
COLOUR CODE

- LOW PRESSURE
- HIGH PRESSURE
- CLOSED LOOP
- STORAGE TANK
- INLET AND DRAIN

8.1-3 REACTOR SERVICE WATER SYSTEM

CONDITION NO.2—SHUT DOWN CLASS III POWER

44.71300-4
REV. 1 1967



PUMPS

① LOW PRESSURE, CLASS IV, 3 AT 25000 IGPM

② LOW PRESSURE, CLASS III, 2 AT 3750 IGPM

③ HIGH PRESSURE, CLASS IV, 2 AT 7500 IGPM

④ HIGH PRESSURE, CLASS III, 2 AT 4200 IGPM

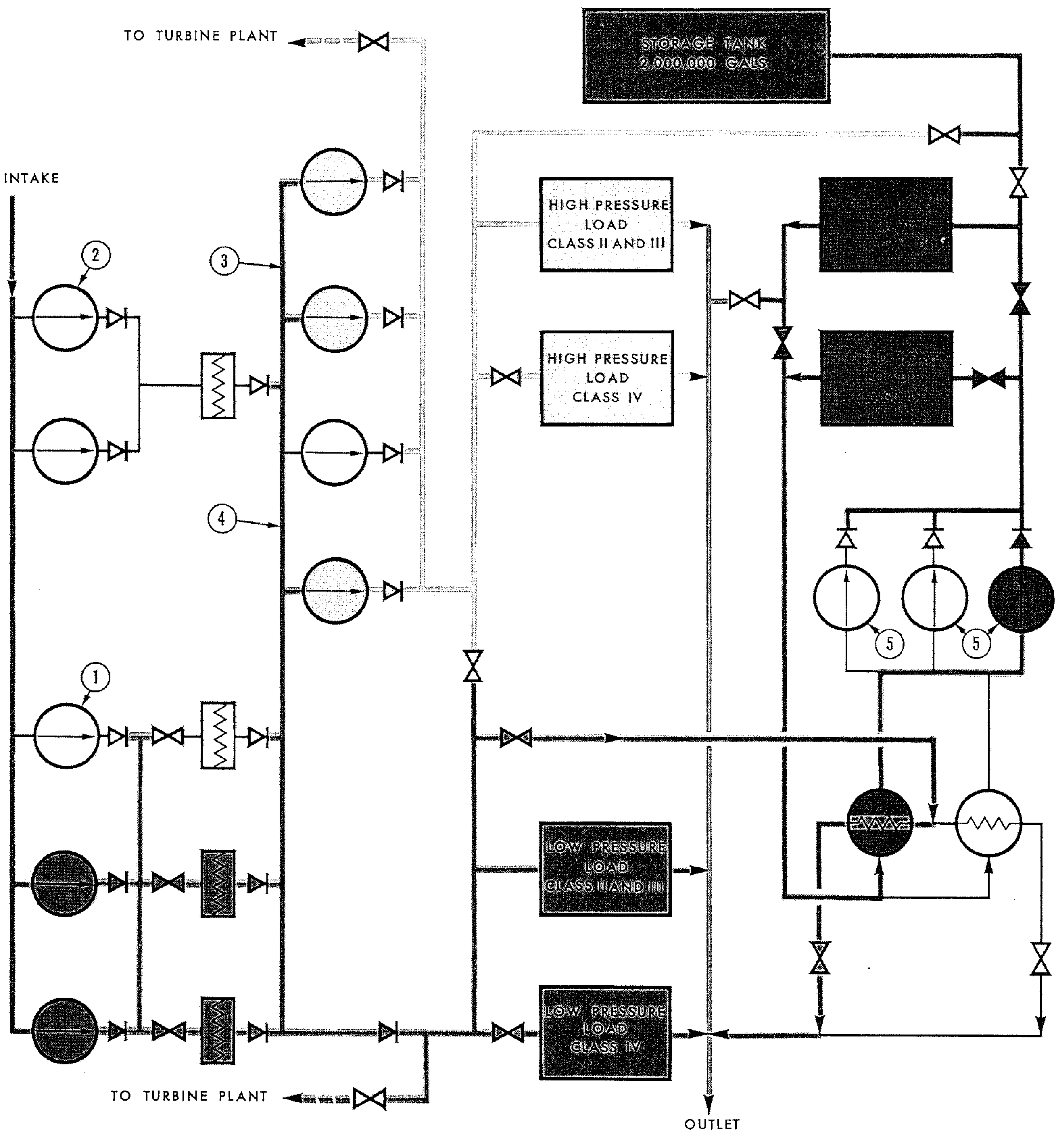
⑤ CLOSED LOOP, CLASS III, 3 AT 1070 IGPM

COLOUR CODE

- LOW PRESSURE
- HIGH PRESSURE
- CLOSED LOOP
- STORAGE TANK
- INLET AND DRAIN

8.1-4 REACTOR SERVICE WATER SYSTEM
CONDITION NO.3—SHUT DOWN CLASS II POWER

44.71300-5
REV. 1 1967



PUMPS

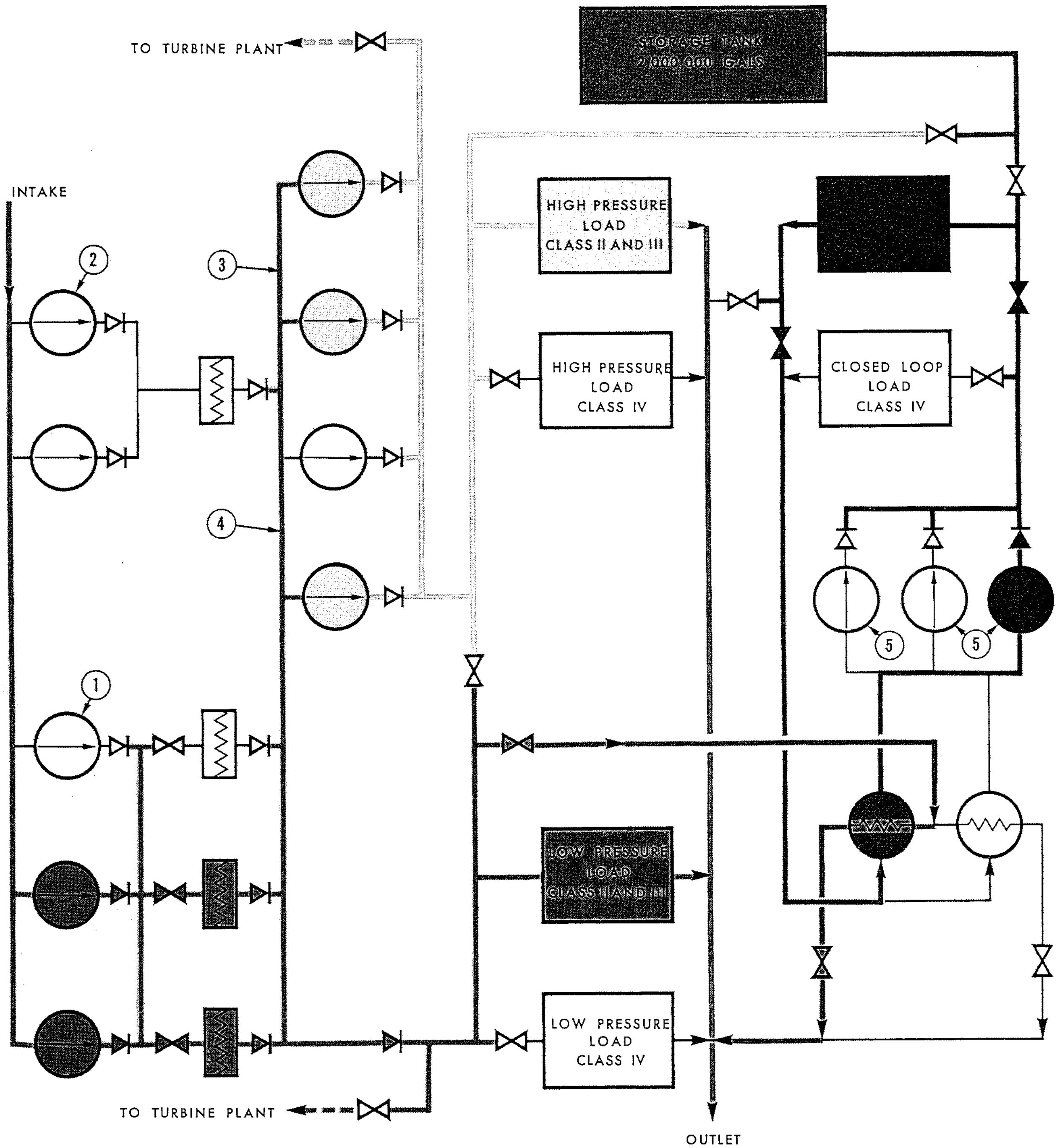
(1) LOW PRESSURE, CLASS IV, 3 AT 25000 IGPM
(2) LOW PRESSURE, CLASS III, 2 AT 3750 IGPM
(3) HIGH PRESSURE, CLASS IV, 2 AT 7500 IGPM
(4) HIGH PRESSURE, CLASS III, 2 AT 4200 IGPM
(5) CLOSED LOOP, CLASS III, 3 AT 1070 IGPM

COLOUR CODE

LOW PRESSURE
HIGH PRESSURE
CLOSED LOOP
STORAGE TANK
INLET AND DRAIN

8.1-5 REACTOR SERVICE WATER SYSTEM
CONDITION NO.4—SHUT DOWN CLASS IV POWER STANDBY COOLER OPERATION

44.71300-6
REV. 1 1967



PUMPS

(1) LOW PRESSURE, CLASS IV, 3 AT 25000 IGPM
(2) LOW PRESSURE, CLASS III, 2 AT 3750 IGPM
(3) HIGH PRESSURE, CLASS IV, 2 AT 7500 IGPM
(4) HIGH PRESSURE, CLASS III, 2 AT 4200 IGPM
(5) CLOSED LOOP, CLASS III, 3 AT 1070 IGPM

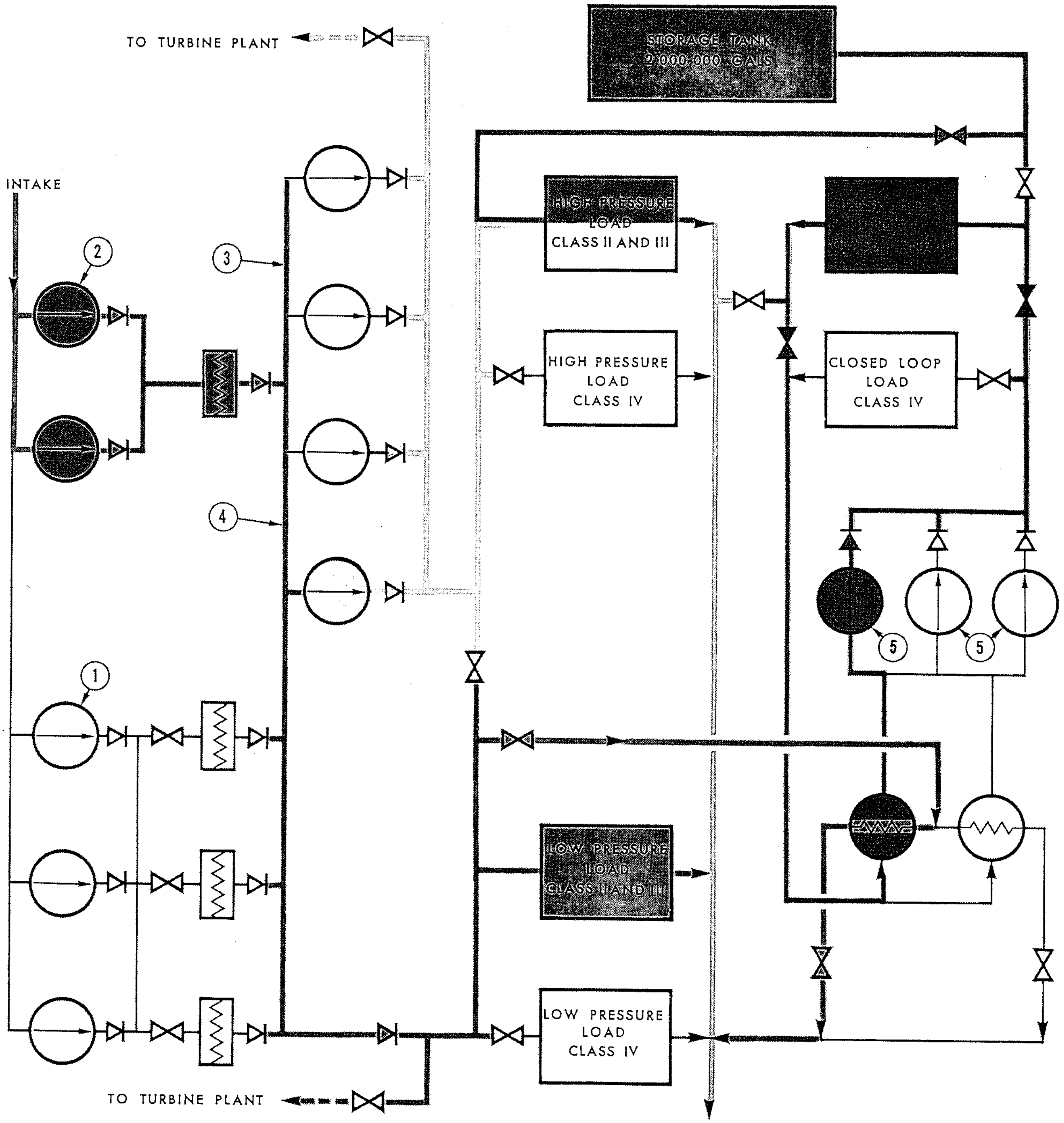
COLOUR CODE

- LOW PRESSURE
- HIGH PRESSURE
- CLOSED LOOP
- STORAGE TANK
- INLET AND DRAIN

8.1-6 REACTOR SERVICE WATER SYSTEM

CONDITION NO.5—EMERGENCY SHUT DOWN CLASS IV POWER ACCIDENT CASE

44 71300-7
REV. 1 1967



PUMPS

1. LOW PRESSURE, CLASS IV, 3 AT 25000 IGPM
2. LOW PRESSURE, CLASS III, 2 AT 3750 IGPM
3. HIGH PRESSURE, CLASS IV, 2 AT 7500 IGPM
4. HIGH PRESSURE, CLASS III, 2 AT 4200 IGPM
5. CLOSED LOOP, CLASS III, 3 AT 1070 IGPM

COLOUR CODE

- LOW PRESSURE
- HIGH PRESSURE
- CLOSED LOOP
- STORAGE TANK
- INLET AND DRAIN

8.1.7 REACTOR SERVICE WATER SYSTEM
CONDITION NO.6—SHUT DOWN CLASS III POWER STANDBY COOLER OPERATION

44.71300.8
REV. 1 1967

TABLE 8.3-1

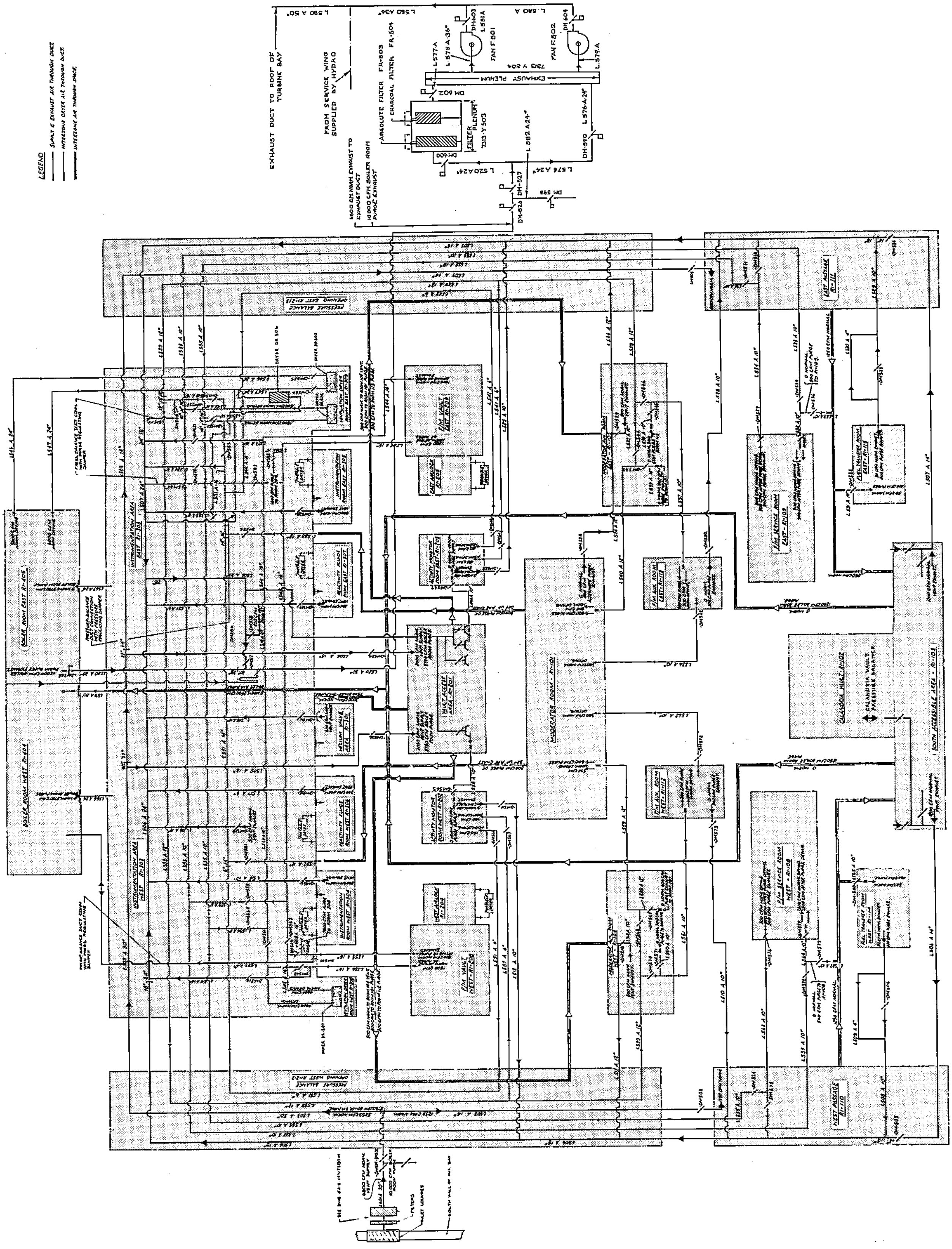
REACTOR BUILDING VENTILATION AND DRYING SYSTEM

Room No.	Main Purpose	Flow Rates (cfm) Ventilation	Purge	Drying	Moisture Removal Rate* at design Conditions
101	Moderator Room	None	1600 from 201 via 104/5	1600** including 112 & 113	113 lb/day
102	Calandria Vault	None	None completely inaccessible	None	
102	South Accessible Area	2400 from 110/1 to bldg exhaust	None	None	
104 & 105	Moderator Aux. E & W	500 each from 201 to bldg exhaust	None	None	
106 & 107	Airlocks E & W	Separate	None	None	
108 & 109	F/M Service E & W	None	500 each from 110 & 111 to bldg. exhaust	200 each	10 lb/day each after purge 500 cfm each to remove light water and prevent D_2O down-grading during normal operation
110 & 111	Passages E & W	1250 each	None	None	
112 & 113	F/M Aux. E & W	None	300 each from 201 via 104/5	300 each dryer return flow to 101	17 lb/day each
114 & 115	Fuel Transfer Rooms E & W	None	50 each to bldg. exhaust 400 each rapid purge when req'd from 110/111	None	
201	Vault Access Area	4000 to exhaust via 104/5 (1000 cfm) & part to exhaust via 301 to 309 inc. (3000 cfm). During boiler room purge, 7500 cfm to exhaust via 302/3 & blr.rm.	None	None	
202 & 203	Primary System Auxiliaries Rooms	None	430 each from 201 to bldg exhaust	150 each	8.5 lb/day each
204 & 205	F/M Vault Air-locks E & W	Separate	None	Connections for mobile dryer	
206 & 207	Airlocks E & W	Separate	None	None	
208 & 209	F/M Vaults E & W	None	1800 each from 201 to bldg exhaust	2000 each	113 lb/day each
210 & 211	Interspace E & W	None	None	None	
212 & 213	Press. Equalizing Passages E & W	500 each from 201 to 104/5	None	None	
301	Helium Valve Access Room	600 from Zone 3 through hood over helium valves	None	None	
304 & 305	Flow Monitoring Rooms E & W	500 each from 201 to bldg exhaust	None	Connections for mobile dryer	
306 & 307	Reactivity Fluid System Rooms E & W	200 each from 201 to bldg exhaust	None	Connections for mobile dryers	
Areas 308/9	Air Drying Equipment Rooms E & W	Included with areas 302/3 above	None	None	
401 to 405	Boiler Room General area	None	10,000 total (2500 cfm from 110 & 111 via 103 and 7500 cfm from 201 via 302 & 303)	4000 or 8000***	226 lb/day or 450 lb/day
406 & 407	Airlocks E & W	Separate	None	None	
R/B total	Pressure balance			500 max.	12 lb/day

* 0°F dewpoint 80°F

** Total Capacity of this Dryer is 4,000 cfm

*** Including Moderator Room Dryer



8.3—1 REACTOR BUILDING VENTILATING AND PURGE SYSTEM

44.73130—2
REV. 2, 1968

of feed and bleed to allow for pressure relief in major areas due to temperature fluctuation. Since all restricted or inaccessible areas are provided with individually controlled room coolers of sufficient capacity to remove maximum internal heat gain, the occurrence of a rapid large temperature rise in any area is not probable. The temperature rise that will occur during startup after a scheduled shutdown will require relief bleed to exhaust from areas that have been recently purged.

To establish a possible maximum bleed rate, a simultaneous temperature rise rate in all inaccessible areas of 1°F per hour would result in a discharge of approximately 42 cfm into the exhaust system. This rate would also accommodate the relief discharge from the boiler room as a result of temperature rise due to the failure of one cooling unit in that area.

All ducts will be of round, spiral-weld construction with die-formed or mitre-welded fittings, adequately supported and tested for leakage and with pressure capabilities to withstand a maximum external or internal pressure of 6 psi where required.

At the points where the supply and exhaust ducts penetrate the Reactor Building wall, two quick-closing dampers in series will be installed to close on rise in pressure and effectively contain the building atmosphere in the event of a major energy release and pressure rise. The ventilation and purge flow sheet is shown in Figure 8.3-1.

8.3.2.2 Reactor Auxiliary Bay

The entire Reactor Auxiliary Bay is classed as a Zone 3 area with the exception of the fuel storage bay and the control centre. For ventilation and purge the minimum flow rate planned for the Auxiliary Bay is three air changes per hour. Certain areas will have higher design flow rates.

8.3.2.2.1 Spent Fuel Storage Bay

The spent fuel storage bay is an enclosed area and will be held at a slightly negative pressure to that in the surrounding Reactor Auxiliary Bay. The system will be designed to prevent back flow of air from the spent fuel storage bay to the surrounding area. The spent fuel storage bay ventilation system will be capable of providing six air changes per hour, 12000 cfm, discharged up the exhaust duct of No. 2 unit on the south side of the Powerhouse. When local or stack monitors indicate activity release in the fuel storage bay, the exhaust air will be diverted through absolute filters and activated charcoal beds.

8.3.2.2.2 Station Control Centre

The station control centre located on the second floor of the Reactor Auxiliary Bay above the spent fuel storage bay will be cooled and maintained at comfort conditions by a conventional air conditioning unit.

8.3.2.3 Vacuum Building

The equipment area in the basement of the Vacuum Building is treated in a conventional manner with a local intake and exhaust for the ventilating system.

8.3.2.4 Service Wing

Ventilation air for the Service Wing will be drawn from an intake plenum on the upper south wall of the Service Wing. Areas within the Service Wing where there are no sources of contamination will be treated in a conventional manner. Ventilation air exhaust from these areas will be through local mushroom type exhaust outlets in the roof of the Service Wing. Areas where airborne contamination is a possibility will be supplied with ventilation air from the common source. Exhaust air from these areas will be filtered where necessary, collected in a common header duct and discharged through the exhaust duct for No. 1 Reactor Building. There are monitors on this discharge system which will automatically direct flow through filters on indication of activity in the discharge flow.

The following areas in the Service Wing are in the latter category:

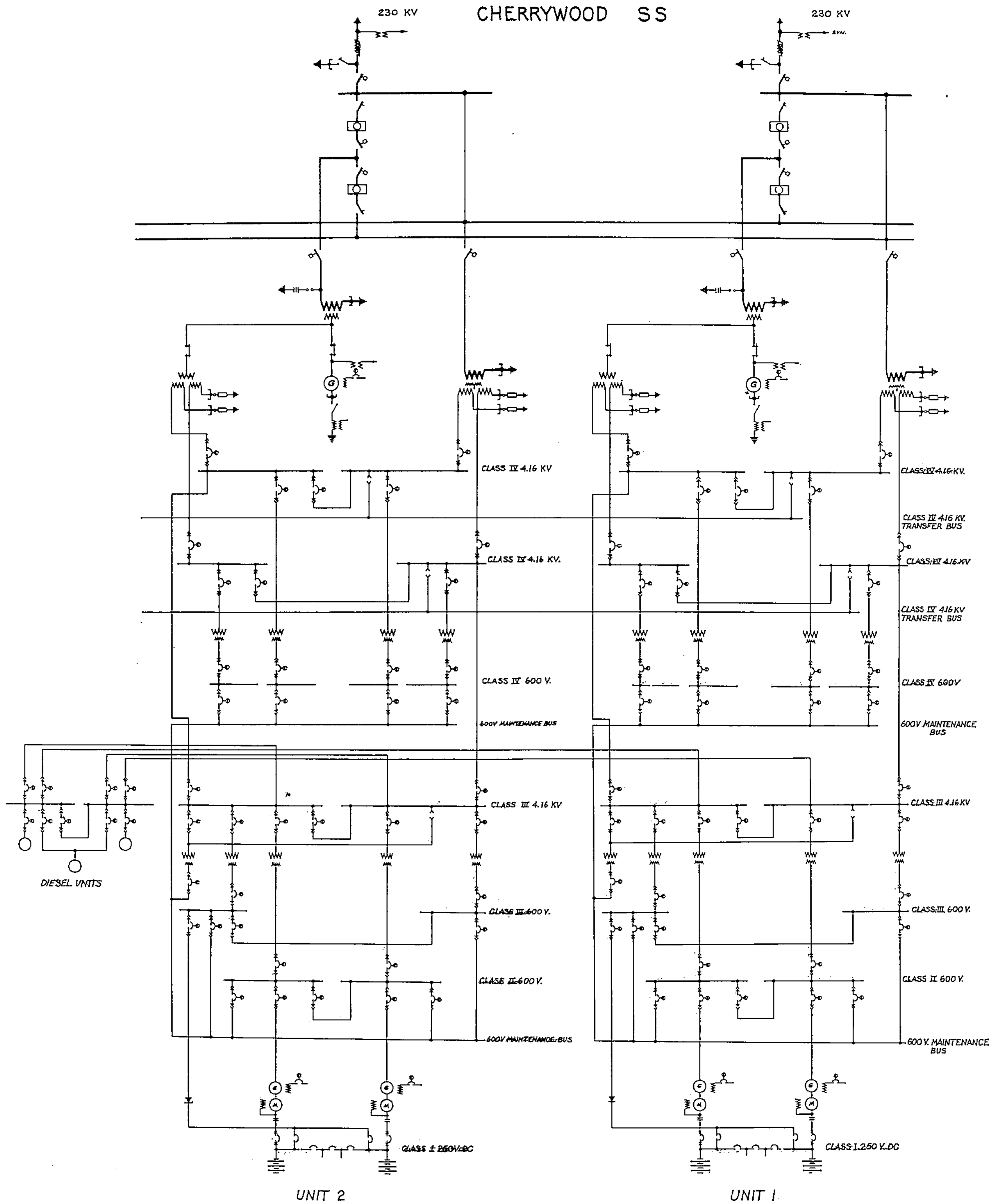
- waste management area in the basement
- local exhaust from the zone 3 mechanical maintenance shop
- all cleaning and active overhaul shops on the grade floor
- fuelling machine maintenance areas
- decontamination centre (four rooms)
- fume hoods in the zone 2 chemical control laboratory, bioassay laboratory, and zone 3 chemical control laboratory
- radiation control area
- cotton goods laundry
- plastics and rubber goods decontamination area

8.3.2.5 Powerhouse and Conventional Part of the Station

The conventional section of the station, i.e. Powerhouse, Screenhouse, Intake and Outfall Structures, Water Treatment Building, Standby Generator Building, Administration Building and miscellaneous structures, are treated in a conventional manner following accepted practice. Air intakes for these areas will be placed to avoid recirculation of exhaust from the Reactor Building exhaust ducts. Intakes are provided with dampers to eliminate recirculation of discharged gases if it should occur.

8.4 STATION SERVICE ELECTRICAL SYSTEM

8.4.1 General



8.4-1 UNIT SERVICE ELECTRICAL SUPPLY

As far as possible each reactor-turbine generator unit in the station has an independent service electrical system. Some interconnections exist such as at the high voltage bus and the connections to the standby power units.

Power for the station service electrical system is normally available from two sources. These are the unit station service transformer which is directly connected to the generator output, and the reserve station service transformer which is connected to the 230 kilovolt bus and through it to the 230 kilovolt system of Ontario Hydro. Both transformers are capable of supplying the total service electrical power requirements for a unit. During normal operation the load is divided equally between them. In the event of failure of either source of power, the load being supplied from one source will be automatically transferred by fast-closing stored-energy breakers to the alternate source. The 230 kilovolt switching arrangement is shown on the one-line diagram, Figure 8.4-1.

The maximum unit station service power requirement is estimated to be 40 MVA or about 6.5 percent of the generator rating. Each unit station service consists of four classes of power, each with its own set of buses. These are listed in descending order of reliability. The Class IV buses are supplied from the generator and transmission lines through the unit station service transformer and the reserve station service transformer. The Class III buses are normally supplied from Class IV buses, but in the event of failure of Class IV power they are supplied by the Class III standby power supply system. The Class II buses are normally supplied from Class III buses, but on failure of Class III power they are supplied, without break, from solid state convertors or motor generator sets operating on the station direct current supply. Class I power is the station direct current supply. It is normally fed through the Class II supply but, in the event of failure of the motor generator sets, would be supplied directly from the station battery.

The preliminary station service arrangement shown on a one-line diagram in Figure 8.4-1 illustrates the buses and switchgear for the 230 kV, 24 kV, 4.16 kV Class IV and Class III, and the 600 volt Class IV, Class III and Class II, and the 250 volt dc Class I systems. For each reactor unit each class of power is supplied by at least one pair of duplicate buses. Each load is connected to a class of bus which has a degree of reliability appropriate to the requirements of the load. The entire service electric system is arranged so that each bus is automatically connected to an alternate power source if its normal supply should fail.

8.4.2 Class IV Power

Class IV power is used to supply loads which can be interrupted without affecting the safety of the station. The major loads on the Class IV system are: the primary coolant circulating pumps and primary system feed pumps, boiler feed pumps, the condenser circulating water pumps and service water pumps, cooling fans and normal lighting.

8.4.3 Class III Power

Class III power is used to supply loads which can be interrupted for one minute without affecting the safety of the station. The loads on Class III power include: standby water pumps, three moderator pumps, primary system standby cooling pumps and others.

Class III power is supplied by a 4.16 kV ac standby power supply system. The power is generated by three gas turbine-generator units, each rated at 5 MWe at summer temperatures, or up to 7 MWe under winter operating conditions. These units can be started, under automatic control, within one minute following the loss of Class IV power. The group of three standby gas turbine-generators provides the Class III power for two reactor units. The total arrangement thus includes six standby gas turbine-generators.

For each reactor unit there is an independent Class III bus system consisting of two 4.16 kV buses, and two 600 V buses. There are cross-connections between the two groups of Class III standby generators so that either group can provide standby power to any of the four reactor units of the station.

8.4.4 Class II Power

Class II power is used to supply loads which must not be interrupted. The loads on Class II power include: the fuelling machine water supply pumps and most of the instrumentation and control devices.

8.4.5 Class I Power

Class I power is a 250 volt dc supply. Loads on Class I power are: direct current instrument power and relays and motors for switchgear.

The Class I power is normally supplied from the Class II bus system. Batteries which float on the Class I bus system constitute the ultimate Class I energy source. These batteries will have the capability of supplying the Class I power requirements and of providing the energy which will provide emergency Class II power for a minimum of 15 minutes.

8.5 DECONTAMINATION SERVICES

Removal of radioactive contamination which may occur either as a result of routine station operation and maintenance or from accident conditions is carried out either in the Reactor Buildings or in the Service Wing. Facilities will be provided for:

i) Handling of large equipment

ii) Handling of highly contaminated equipment

iii) Handling and decontamination of equipment and supplies generally

iv) Routine decontamination of plant clothing

TABLE 8.7-1

COMPRESSED AIR SERVICES

Service	Pressure at Extreme Point in System (psig)	Conditions	Power Supply	Distribution & Storage	Normal Max. Demand	
					Single Unit (scfm)	Four Units (scfm)
Instrument Air High Pressure	150	-40°F Dew Pt. Filtered, Oil-free	Class III	Single Distribution & Storage	800	3200
Instrument Air Low Pressure	75	-40°F Dew Pt. Filtered, Oil-free	Class III	Single Distribution & Storage	1200	4800
Breathing & Cooling Air	65	Moist Filtered, Oil-free	Class IV	Single Distribution	800	800
Service Air	100	Moist & Oily	Class IV	Single Distribution	1200	1200

v) Personnel decontamination

Interzone control of contamination and the handling and disposal of solid, liquid or airborne contamination resulting from the decontamination operations are described in Section 9. The common facilities in the Service Wing are designed to handle the load of an eight unit station.

In situ decontamination is anticipated in each Reactor Building. Steam and air connections are provided to facilitate these cleaning operations. Local exhausts supplied at certain areas in conjunction with plastic tents and temporary hose connections control airborne contamination and dispose of it through the ventilation system.

Large contaminated equipment such as fuelling machine heads, pumps, etc., which requires major maintenance work will be removed under plastic sheet wraps to the active maintenance bays at the southern end of the first floor of the Service Wing. These bays will be furnished with decontamination facilities such as steam connections, air connections and high rate ventilation exhausts as well as maintenance equipment and monitors.

This will permit decontamination, dismantling, major refitting and general overhaul work in one location. Steam, ultrasonic and manual cleaning facilities are provided in this location for the further decontamination of components which may require further work in non-active maintenance areas of the machine shop.

A decontamination centre is provided in the Service Wing immediately north of the active maintenance area. Ultrasonic and manual facilities will permit cleaning a wide range of small contaminated items such as tools, instruments, and machine parts.

Change rooms, showers, locker rooms, cotton goods laundry and a clothing crib are provided on the second floor of the Service Wing to facilitate the decontamination of personnel and their clothing. The arrangement of rooms provides for a progressive pedestrian movement with a minimum need for re-entry into any room. Monitors are located at points where personnel pass into areas of lesser activity. The second floor also accommodates separate facilities for the decontamination and laundering of protective clothing, and rubber and plastic goods.

Emergency deluge showers and local clothing change stations are located outside the equipment airlocks and personnel airlocks at the 254 foot and 274 foot elevations of the Reactor Buildings respectively (see Figure 9-1). These facilities provide for immediate decontamination in case of accident, and afford more convenient clean-up as a matter of routine. More extensive facilities are provided in the dressing stations at the 317 foot elevation which give access through the north west personnel airlocks to the boiler rooms.

8.6 COMMUNICATION SYSTEMS

Three independent communication systems will be installed in the Pickering Generating Station. These are:

i) a telephone system

ii) a public address system for routine and emergency announcements

iii) a pneumatic tube conveyor system for the transmission of messages and/or small articles between certain locations.

8.6.1 Telephones

Consideration of the telephone system is presently under way.

The main telephone equipment room is located in the basement of the Administration Building. The telephone equipment will be typical of modern practice in communication systems and any phone can be dialed into the P.A. systems. During normal business hours incoming calls to the Pickering station will be received at the switchboard and routed manually to the appropriate extension. Outside normal business hours the switchboard is closed and the control room is required to handle outside calls. In the control room a separate "call director" for each unit control desk will permit the station operator to switch incoming calls between selected areas throughout the station without reconnecting through the station switchboard and without blocking the control room telephone.

8.6.2 Public Address System

Consideration of the public address system is presently under way.

The equipment will be located in the basement of the Administration Building and the wiring throughout will be by cable in the control cable pans with take-off points through conduit where required.

All areas accessible to personnel at any time will be covered by the P.A. system. The system will be arranged for zoning of calls to each of the major areas of the plant.

8.6.3 Pneumatic Messenger System

The pneumatic tube conveyor system will provide two-way transmission of messages or small objects between 26 different locations in the four unit station. These locations are:

1. Control Room (1)

2. Reactor Buildings (16)
   entrance to manway of boiler room

airlocks on 274 foot floor
airlocks on grade floor, east and west

3. Service Wing (5)
   chemical control laboratory
   maintenance shop
   stores
   control maintenance shop
   production control office

4. Powerhouse (2)
   between units 1 and 2, and units 3 and 4, at elevation 294 feet

5. Administration Building (2)

8.7 COMPRESSED AIR SERVICES

8.7.1 General

The compressed air services consist of the instrument air (high pressure and low pressure), breathing air and service air systems. Each of the four systems is supplied with compressed air by its own group of compressors. The condition, pressure, and flow rate of the air supplied to each system is summarized in Table 8.7-1.

The high pressure instrument air for units No. 1 and No. 2 is supplied by one group of compressors, and the low pressure instrument air for the same units is supplied by another group of compressors. Each group consists of three compressors (two operating, one on standby) with a total capacity equivalent to the maximum unit demand. The normal steady state demand is estimated at half the maximum. Both instrument air systems will use local storage tanks. The arrangement of compressors is duplicated to provide high pressure and low pressure instrument air for Units No. 3 and No. 4.

The breathing and cooling air for all four units of the station is supplied by two compressors operating at 400 scfm each. The total flow rate of 800 scfm will supply 32 plastic suits at 25 scfm per suit.

The service air for all four units of the station is supplied by three compressors each capable of supplying 600 scfm (normally two compressors are operating and one is on standby).

Each of the four compressed air systems use a single line distribution piping system.

8.8 FIRE PREVENTION SYSTEM

Details of the fire prevention arrangements are still under study.

The equipment installed at Pickering for detecting and extinguishing fires will comply with standards of the Hydro Electric Power Commission of Ontario and the requirements of the Ontario Fire Marshall. It is expected that the detection and alarm equipment will be similar to that at Douglas Point. A central and local alarm will be sounded and annunciation will take place in the control centre in the event of a fire in any area considered a potential fire hazard.

The high pressure service water system for each unit will supply the fire fighting water headers in the plant. There will be a check valve between the supply from each unit and the fire fighting header. This arrangement provides redundant sources of water which are normally operating and which are automatically backed up by additional pumps on loss of Class IV power. Water can also be obtained from the emergency water storage tank in the Vacuum Building if required.

It is proposed that fire extinguishing equipment in the Reactor Buildings be of the carbon dioxide or portable type since there appears to be no flammable equipment in the Reactor Building on which water would be used for extinguishing a fire. The fire extinguishing equipment in the remainder of the plant will include water in the form of fog and solid stream as well as CO_2 and other portable equipment.

9. RADIATION HAZARDS CONTROL AND RADIOACTIVE WASTE MANAGEMENT

9.1 GENERAL

The limitation of radiation exposures and the prevention of excessive discharge of radioactive wastes are effected by a combination of facilities incorporated into the station design and by adherence to a set of approved operating procedures and regulations.

Exposure of plant personnel to radiation hazards is limited by shielding and by control of access to areas of high activity or of possible contamination. In addition, protective clothing, air masks and decontamination facilities are available for use when required.

Exposure of the surrounding population is limited by exclusion from the plant area and by preventing, in accordance with AECB requirements, any habitation nearer than 3000 feet. The release of all effluents, liquid and gaseous, which might conceivably carry activity is monitored and controlled. Active solids are retained on site in a form which prevents release of activity. Thus, any activity which may reach the public through the air or in water can be maintained below permissible concentration levels.

9.2 CONTAMINATION CONTROL

The station will be divided into three zones according to the potential contamination hazard in each area as shown in Figure 9—1. The zones will be as follows:

Zone 1 - This zone will contain no radioactive equipment and normally will be free of contamination. It will include the Administration Building and the main entrance hall and the locker room in the Service Wing.

Zone 2- This zone will contain a minimum of radioactive equipment and should not normally be contaminated. However, some contamination will probably get into this area with the movement of personnel, equipment and/or tools. Contamination will be cleaned up as soon as discovered or suitably controlled. This zone includes the Powerhouse, the Screenhouse, the Water Treatment Building, Control Room, Reactor Auxiliary Bay and the non-active shops, stores, shower and laundry facilities in the Service Wing.

Zone 3- This zone contains the main items of equipment that act as sources of contamination. It includes the Reactor Buildings, the decontamination centre, the active overhaul and fuelling machine maintenance areas, the D_2O upgrading building, the spent fuel bay, and parts of the waste management area in the Service Wing basement. The sources of contamination will be localized and under control in this zone but the existence of contamination in parts of it will be normal.

Monitors will be provided for contamination control as shown in Figure 9—1. Where necessary, rubber stations and protective clothing change facilities will be provided on a temporary basis in addition to the facilities shown on Figure 9—1.

The movement of personnel and equipment and requirements for the use of monitors and protective clothing will be governed by Operational Procedures.

Contamination surveys will be carried out and decontamination operations will be performed as necessary.

Within Zones 2 and 3, including the Reactor Building, air contamination will be dealt with by control and adjustment of ventilation and use of local exhaust connections. Ventilation arrangements are designed so that any transfer of atmosphere between different areas due to pressure difference will go from the potentially less to the potentially more contaminated area. The particular hazard of airborne tritium within the Reactor Building is monitored by the system arrangements described in Section 9.6.4.3.

Normal exits from the station to the Administration Building will be via the Service Wing and through the overhead bridge. Exit to outdoors is provided at the grade level at convenient locations near stairwells and traffic routes. Some large doors in the Reactor Auxiliary Bay are provided to permit transfer of large or heavy equipment directly outdoors.

9.3 RADIATION LEVELS AND ACCESS CONTROL

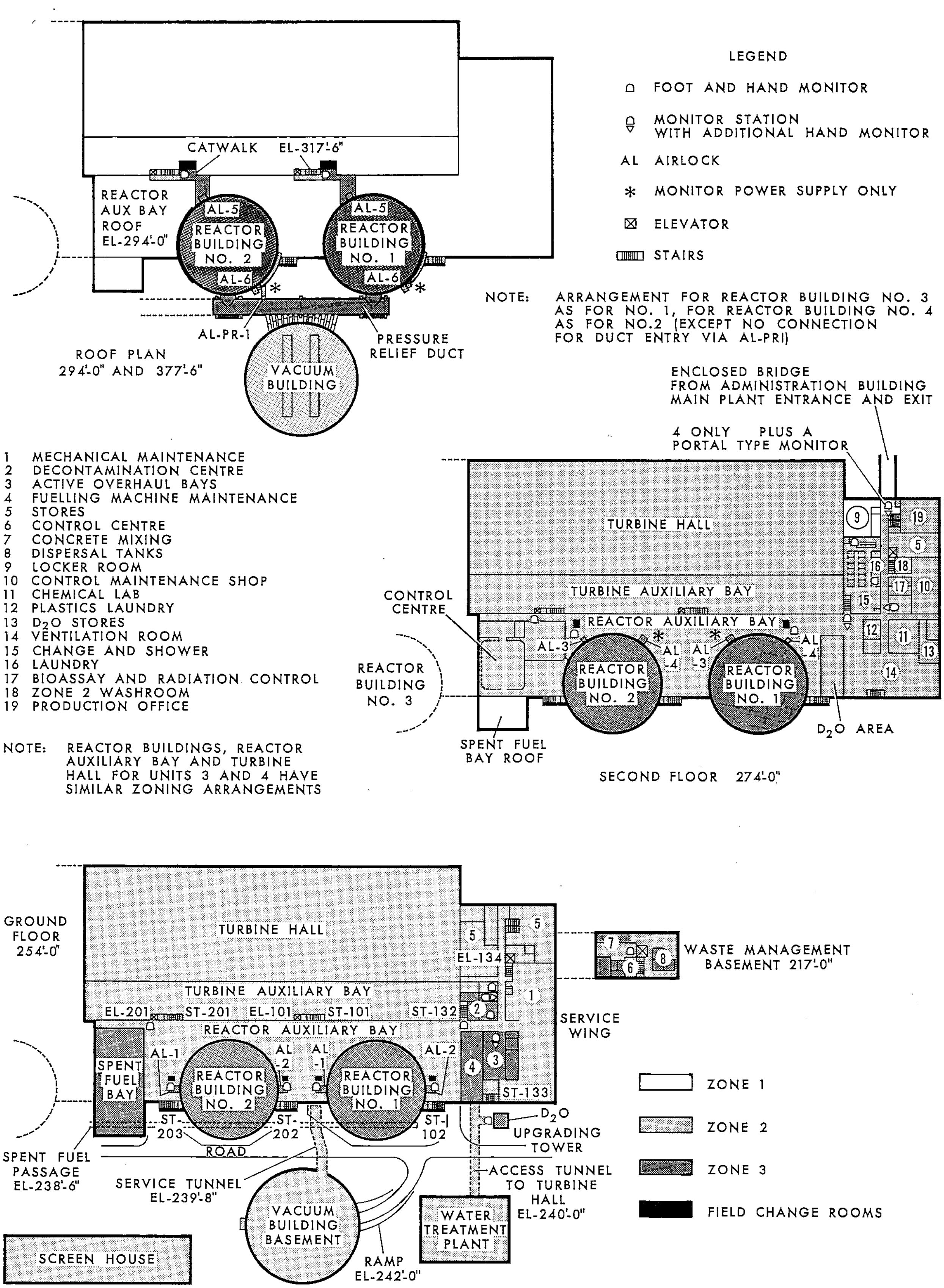
9.3.1 Radiation Levels

The shielding has been designed to reduce the radiation intensity generally below 0.25 mr/hr in all areas intended for normal full-time occupancy. In areas where periodic and temporary occupation only is necessary, the shielding design permits higher radiation levels. Examples of this are the waste management basement in the Service Wing, the spent fuel storage bay, and some areas in the Reactor Building.

During shutdown the boiler room is expected to have a general radiation level of about 50 mr/hr, while local fields near the primary pumps and boilers will probably be higher due to crud deposition. Similar fields during shutdown are expected near the end fittings in the fuelling machine vaults.

Surveys will be carried out during commissioning to establish the radiation levels occurring under various operating conditions. Where necessary, modifications or additions to shielding will be made at that time.

9.3.2 Access Control



9—1 PLANT ZONING ARRANGEMENT

44.20300—3
REV. 1, 1967

9.3.2.1 General

Access to the Reactor Building will be restricted by Operational Procedures to qualified personnel and those under escort by personnel with full radiation protection qualifications. The entire Reactor Building is classified Zone 3 for contamination control. Monitors are placed at the airlock entrances to the building.

9.3.2.2 Basis of Operation in Access Controlled Areas

There are two types of operation requiring different degrees of access control:

(1) Operation below "X"% full power where "X"% is some power level which can be determined by experience following start-up. The radiation fields will be at a level considered safe for personnel to freely enter these areas. A system of personnel accounting will be the only necessary control. The doors will be equipped with keys which are available from the control room. The keys may be left in the doors for extended periods while operating at or below "X" percent. Signs will be used to delineate the areas requiring access control. A key-accounting-alarm system will be provided to warn against bringing reactor power above "X"% unless:

    (a) All personnel have vacated the area, and

    (b) The doors to the access controlled areas are closed, locked and the keys returned to the control centre.

    There will be no reactor power trip, setback or limit associated with this system.

    The reactor power of "X"% would be set so the general gamma fields are less than 300 mrem/hr and/or neutron fields are less than 0.5 mrem/hr.

(2) Operation above "X"% full power with all doors locked. When reactor power is greater than "X"% the keys are available from the key-accounting-alarm system for procedure-controlled entry. An alarm will be printed on the computer advising that the key to a room is not in the control centre. This type of entry is non-routine and would require special authorization.

9.3.2.3 Summary of Provisions in Specific Areas

The specific areas referred to below are shown in Figure 9—2, and have been coloured to indicate the degree of access control. The calandria vault shown in white is not accessible at any time.

(1) Moderator Room, Boiler Room and Fuelling Machine Vaults

    (a) The doors to these areas would be locked and key-accounting slots provided in the control centre.

    (b) Where air locks are entry points the key system may be associated either with the inner door control or with a special barrier gate.

    (c) Access to fuelling machine vaults from the boiler rooms will be prevented by locked doors. When locked, these doors may be opened from the fuelling machine vault side but not from the boiler room side.

(2) Fuelling Machine Service Rooms

    The shielding doors to these rooms will be normally locked and keys will be available from the control centre. There are interlocks provided to prevent the fuelling machine bridge from moving up when the door is open and to prevent the door to the service room being opened when the fuelling machine bridge is up. Radiation monitors will warn against high fields if doors are open, or if spent fuel is present in the fuelling machine.

(3) Fuel Transfer Rooms

    The doors to these rooms will be normally locked and keys will be available from the control centre. Interlocks will prevent entry into the rooms when the fuelling machine bridge is up. A radiation monitor will alarm if high fields from spent fuel exist in the room or the fuelling machine service room while the door is open.

(4) Heat Transport Filter Rooms and Moderator Purification Rooms

    The doors will be signed "HIGH RADIATION FIELDS MAY EXIST IN THIS ROOM — DO NOT ENTER WITHOUT A GAMMA METER". The doors will not normally be locked.

(5) Pressure Relief Duct

    Either a barrier gate or the airlock controls will normally be locked. Keys will be available from the control centre.

9.4 RADIATION MONITORING

Fixed radiation area monitoring will be provided permanently in suitable areas to detect the occurrence of radiation hazards and warn personnel of high fields in these and associated areas.

An alarm will operate when the short term change of dose rate is greater than a preset percentage. It will be annunciated in the control centre and will operate the alarm(s) and light(s) in the area concerned. The percent change alarm will be adjustable (internally) if experience indicates another value should be set. The alarm condition, time, location and percent change of dose rate will be printed out by the computer.

The units to be provided will have a "live" zero alarm to indicate failure of the geiger tube. If this alarm comes on it will be annunciated and printed out giving time and location.

A final list of fixed monitor locations has not yet been prepared pending a review of equipment, system layouts and evaluation of Douglas Point experience.

Ambient radiation monitoring on the station property will be done by means of suitable dosimeters located at various places on the station property to effectively integrate the radiation level. These dosimeters will be collected at suitable intervals for laboratory analysis. No recording or alarming is intended for outside ambient radiation monitoring.

9.5 OFF-SITE MONITORING AND SAMPLING

Monitoring and sampling of water supplies and foodstuffs in the area will be discussed with the appropriate public health authorities.

9.6 ACTIVE WASTE MANAGEMENT AND HAZARDS CONTROL

9.6.1 General Waste Treatment

Facilities will be provided on the plant site for safe disposal of all radioactive solid, liquid and gaseous wastes. The equipment, tankage and facilities for handling liquid and solid wastes will be flexible enough to cope with the increase in waste volume and activity anticipated during periods of major maintenance work or adverse reactor operation.

Several basic treatment processes will be used in the management of the liquid and solid wastes depending upon the type and activity. These processes will include:

(a) Holding for natural decay of the radioactive isotopes.

(b) Dilution of activity in active waste liquids with water, including employment of the plant condenser cooling water during disposal to the lake.

(c) Ion exchange and filtration to remove the radioactive materials.

(d) Reduction in volume of compressible solids by baling.

(e) Transport of solid wastes to storage areas elsewhere.

Space has been allocated for facilities for concentration of liquid wastes by evaporation, the solidification of liquids in concrete, the reduction of activity in liquids by ion exchange or filtration and/or the reduction of active solid wastes by incineration. None of these processes appears economically justified at present.

Gaseous wastes from the Reactor Building must pass activity monitors before being released to atmosphere. If these gases contain an unacceptable level of activity they will be filtered through absolute and/or iodine filters before being released up the discharge duct. Off-gases from the heat transport system will be held in a delay tank prior to release if required. The small quantities of active gases which originate in other areas of the plant will be monitored prior to discharge with building ventilation exhaust.

9.6.2 Active Waste Solids

The sources and methods of treatment and storage for solid wastes are shown schematically in Figure 9-3.

Spent fuel will be stored under water in the storage bay in the Reactor Auxiliary Bay. Space will be provided initially for approximately 52 reactor years. If necessary, fuel bundles may be sealed in cans to contain any activity leakage before being placed in storage. Consideration is being given to shipping spent fuel and to the storage and shipping of cobalt material. The storage bay has been laid out to provide for these possibilities.

Spent resin from the moderator ion exchange system will be blown dry into storage tanks in a concrete pit below the Reactor Auxiliary Bay floor adjacent to each Reactor Building. These tanks will be large enough to contain predicted quantities for 30 years of operation.

Heat transport system filter solids, and spent resin and other radioactive solids will be disposed of off-site.

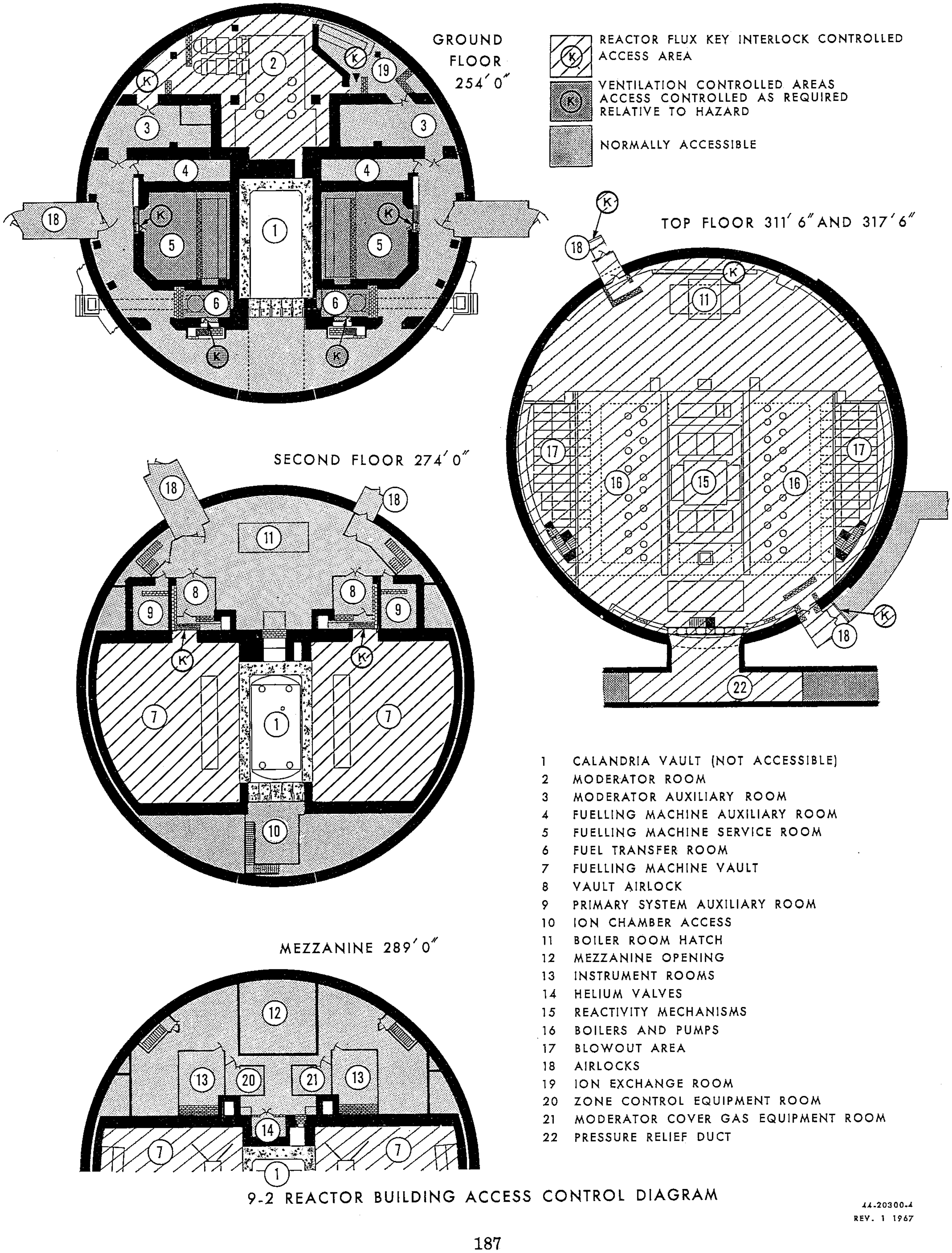
9.6.3 Active Liquids

9.6.3.1 General

All waterborne activity leaves the plant either through the turbine condenser cooling water discharge channels or the service water effluent system. This activity may arise either from D_2O leakage into cooling water in heat exchangers or from the liquid waste management system.

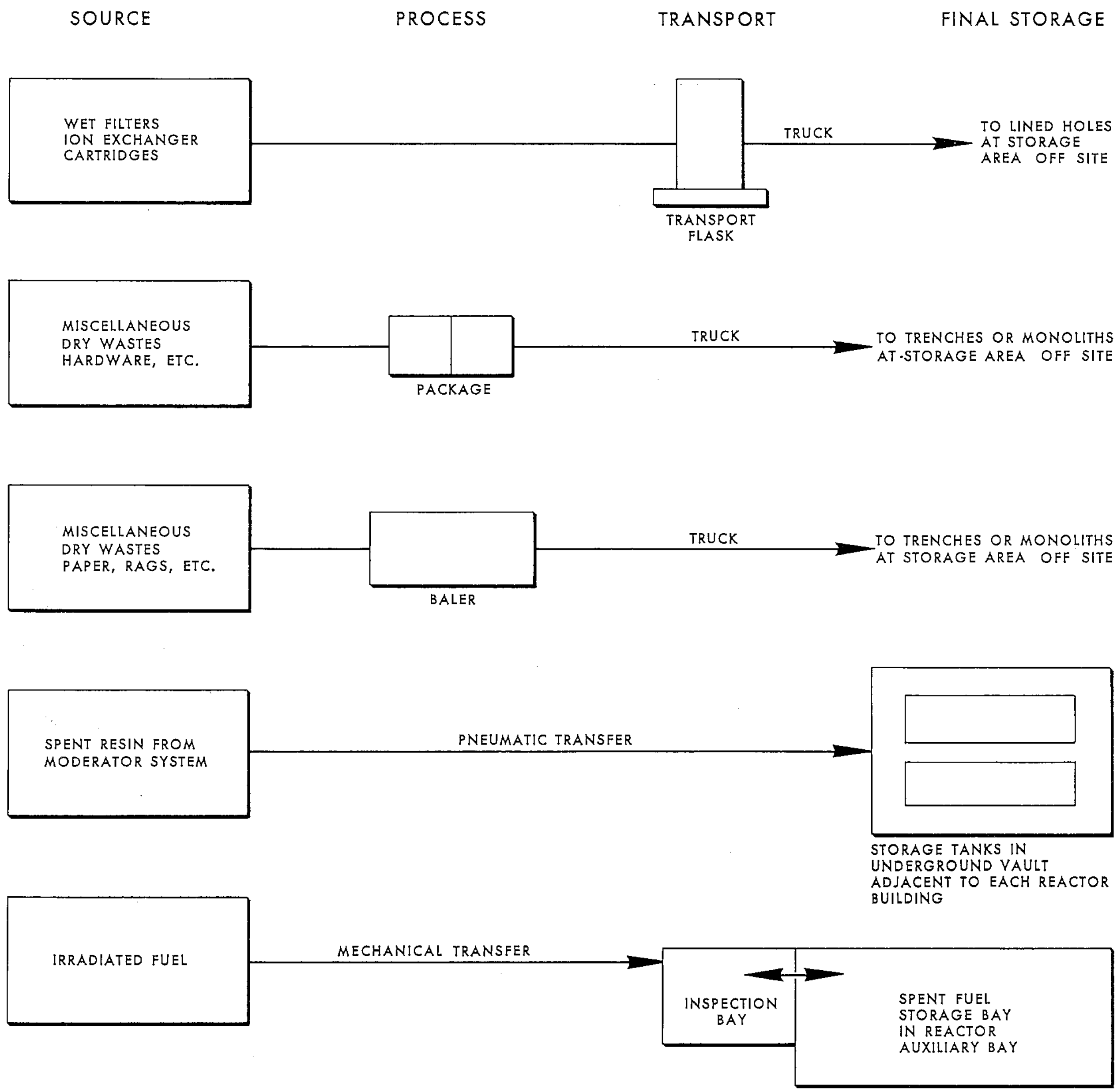
The release of activity from the waste management system can be carefully controlled, as described below, so that no significant amounts of activity should ever be discharged from this source. The amount of activity discharged by D_2O leaking into process water is also expected to be very small because most potential leak points are monitored for the presence of D_2O and systems have been designed so that offending equipment can be shut off before significant activity is released.

The maximum continuous release of activity to the lake which could be permitted at Pickering without exceeding acceptable levels of contamination in public drinking water or food is not known. However, it would seem to be more



9-2 REACTOR BUILDING ACCESS CONTROL DIAGRAM

44-20300-4
REV. 1 1967



9-3 ACTIVE SOLID WASTE MANAGEMENT SCHEMATIC FLOW SHEET

44-79100-1
REV. 2, 1968

than safe if the station effluent itself does not exceed the drinking water tolerances proposed by the ICRP* for persons resident near a nuclear installation. This takes no credit for decay or dilution in the lake. Since it presently seems possible to operate within this limit, it has been taken as a working design figure. That is, the plant will be designed so that the average effluent should not contain an activity concentration higher than $4 \times 10^{-7} \mu$ C/ml when there is any possibility that an appreciable part of the activity could be due to Sr 90. (It is assumed that there is no chance of significant release of radium or thorium decay products.) The above concentration is to be used as an annual average. For periods of a few days, average concentrations of ten times the above figure are entirely safe and no operating restrictions will be imposed if the rate of discharge of activity should reach such a level.

All effluent streams will be sampled routinely before they enter the lake. In addition, the liquid waste systems will be monitored before they enter the effluent streams, and automatic valves controlled by the monitor will prevent any excessive release of activity.

9.6.3.2 Active Liquid Waste Management

The handling and the disposal of active waste liquids will be facilitated by separating them into three categories, namely:

(i) normally inactive liquid wastes

(ii) active liquid wastes

(iii) active chemical liquid wastes

The activity originates from contamination by mixed fission products and process system activated corrosion products. Tritium activity is not expected to be significant in any of the liquids being discarded since any waste containing any appreciable amount of D_2O, and hence tritium, originates in areas where they are contained and sampled prior to release; thus wastes containing an appreciable amount of D_2O will be retained for reclamation. The magnitude and type of contamination in the wastes will vary appreciably depending upon the operational status of the reactor plants and the work being performed.

Figure 9-4 shows a flow diagram of the system. The facilities will be housed in the basement (217 foot elevation) of the Service Wing. In the unlikely event of complete failure of all tanks, the basement would be flooded to a depth of about 4 feet but would contain the liquid. The lowest immediate neighbouring area is at elevation 225 feet.

Routine operations and monitoring will be carried out from a central valve room. The features described below are indicated on the flow sheet. It should be noted that the mode of operation is to collect the three categories in tank(s) and then process and/or disperse on a batch basis.

(i) Normally Inactive Liquid Wastes

This category will consist mainly of shower and washroom drainage and cotton goods laundry discharge. It will not normally contain any measurable activity. In addition, the Reactor Buildings and Reactor Auxiliary Bay floor drains will normally be pumped into this system from local collection sumps. After collection in the dispersal tanks, it will be pumped to a point in the plant cooling water discharge line for mixing and discharge to the lake. An in-line monitor acts to divert the flow automatically into the holdup tanks if abnormal levels of activity occur.

(ii) Active Liquid Wastes

This category will normally be of low activity and acidic concentrations, so that after initial holdup for decay and checking, it can normally be discharged for dilution in the plant cooling water.

The majority of these wastes are from the decontamination facilities, plastics laundry and Service Wing active area floor drains. They will be collected by gravity in two holdup tanks having a total capacity of 50,000 Imp. gals.

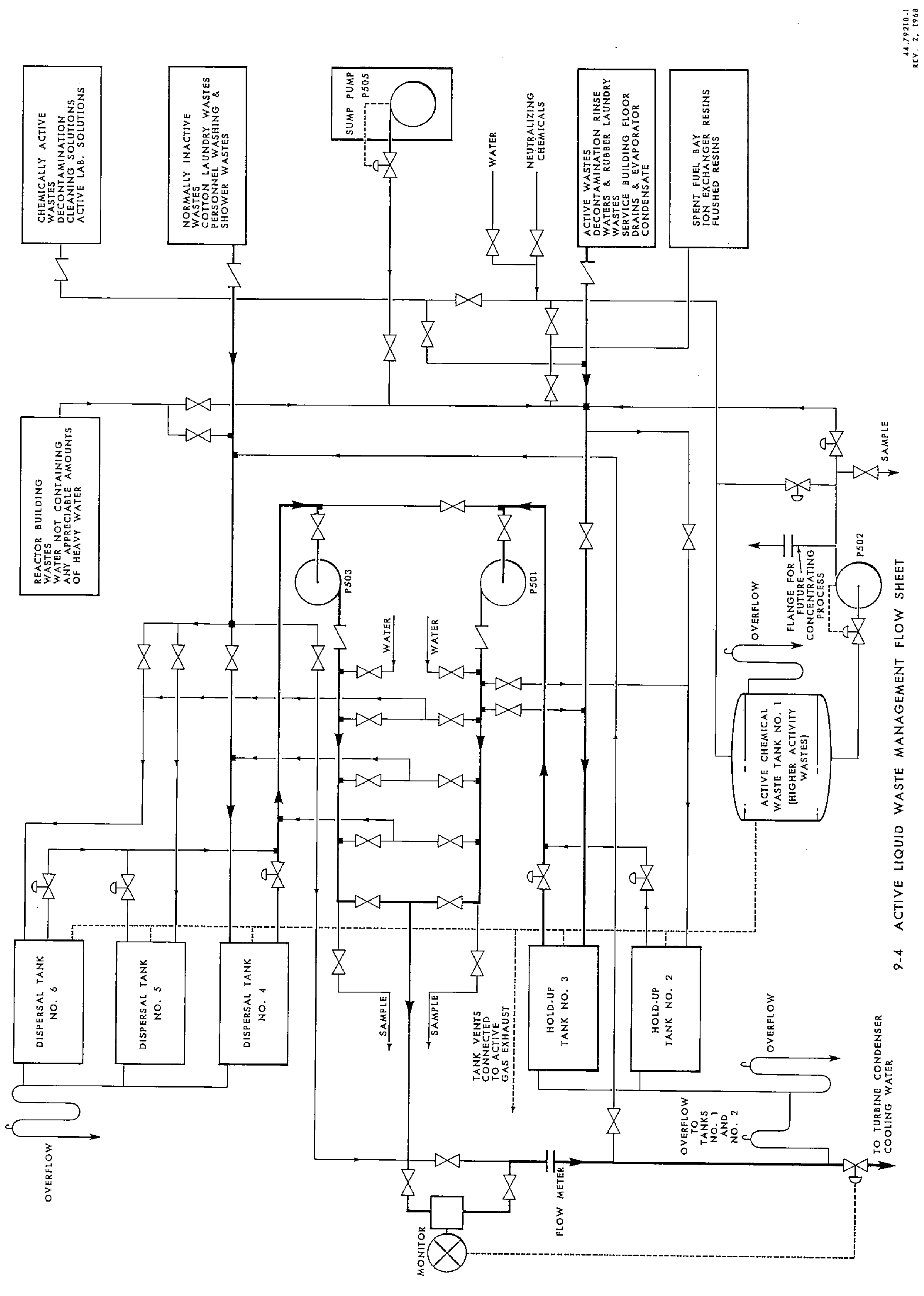
When it is necessary to empty a holdup tank, the contents will be circulated and sampled, and normally discharged directly to the cooling water channels with the category (i) wastes or transferred to one of the three 50,000 Imp. gal. dispersal tanks. The latter would be particularly required in the unlikely event of a complete station shut-down when no condenser cooling water pumps are operating.

If the activity in a holdup tank is found to be higher that can safely be dispersed in the normal manner, preliminary dilution may be used wherein a specific amount of the held-up waste will be released to a dispersal tank and a specific amount of clean water or category (i) wastes added to bring the concentration of the mixture to a safe dispersal level.

The dispersal tank discharge will be controlled to ensure that the plant cooling water activity does not exceed $4 \times 10^{-7} \mu$ C/ml by reference to the specific activity of the tank contents and the cooling water discharge flow rate. There will be an automatic shut-off of the discharge if the activity rises above the preset level.

Three dispersal tanks are provided. One will be used to receive wastes while the other(s) can be discharged. This minimizes the possibility of discharging liquid which had not been included in the final sampling.

* *ICRP — Publication 2; Report of Committee II on Permissible Dose for Internal Radiation, 1959.*



9-4 ACTIVE LIQUID WASTE MANAGEMENT FLOW SHEET

(iii) Active Chemical Liquid Wastes

This category will normally consist of liquids which, due to their chemical and/or activity content, may not always be suitable for release to the plant effluent cooling water. The major sources will be the active laboratory and the decontamination centre. Collection will be in a stainless steel tank.

The contents of the tank will be circulated and analysed on a regular basis. Any acidity will be neutralized. Wastes having activities of $10^{-2}\mu$ Ci/ml or less will be pumped into the category (ii) holdup tanks as required without restriction. Greater activities will require transfers of limited quantities to prevent the holdup tanks from having an activity of greater than $10^{-2}\mu$ Ci/ml. Activities of $10^{-1}\mu$ Ci/ml or worse are not anticipated, but should they arise, consideration will be given to facilities for concentration of the activities and concreting for burial off-site as mentioned in subsection 9.6.1 above.

9.6.3.3 Spent Fuel Bay Water and Ion Exchange Equipment

A closed recirculation system will be provided for purifying the spent fuel bay water. No overflow or discharge from the system will normally exist. Waste water arising from rinsing and back-washing the filters and ion exchange units will be discharged to the liquid waste management system. The bay water can also be pumped out via this system as category (i) or (ii) waste.

9.6.3.4 Activity Leaks into Service Cooling Water

Almost all D_2O to H_2O heat exchangers are on a recirculation system. The only D_2O heat exchangers cooled by service water are the moderator heat exchangers and the heat transport standby coolers. The difference in pressure between service cooling water and heavy water in these heat exchangers may make it possible for D_2O to leak into the service cooling water, and to be discharged to the lake. The process systems are designed so that heat exchangers can be valved off or other corrective action can be taken to stop the discharge of heavy water as soon as a leak is detected. The occurrence of a very large leak of heavy water into the service water is quite improbable. Such an occurrence would most likely be due to a serious fault in a tube or a tube-to-tube sheet joint, and the maximum credible leak would correspond to the complete severance of one of the tubes in the unit.

Because of the low probability of major losses of heavy water to the lake, the magnitude of the escape of activity which could be tolerated under such circumstances is relatively high, corresponding to a large fraction of the activity release which would be permissible for a year's normal operation. The design objective is to limit the activity escape which would result from complete failure of a heat exchanger tube to an amount not exceeding ten percent of the total amount which would be discharged annually, if the average concentration of all effluents discharged was equal to the upper level permitted by the ICRP for public drinking water. Thus facilities would be incorporated to achieve the above objectives as well as from an economic standpoint, to stop a major D_2O leak in as short a time as possible.

Protection against significant activity entering the service water from heavy water leaks is provided by sensitive gamma monitors installed in the service water effluent lines. These monitors will not detect tritium directly but N^{16} and O^{19} activities in the heavy water provide good sensitivity for detection of heavy water leaks during reactor operation. The sensitivity is much reduced during reactor shutdown periods when the N^{16} and O^{19} are absent, but relatively long-lived minor gamma activities present in both primary and moderator heavy water will provide useful indication of large heavy water leaks. The sensitivity for detection of moderator leaks during reactor shutdown periods is enhanced by the very considerable reduction in the flow of service water which passes through the moderator coolers during such periods. In operation, the estimated limits of detection of heavy water leaks by the gamma detectors in the service water effluent are 0.02 gpm for primary water and 0.06 gpm for moderator; during shutdown the estimated sensitivity is about 6 gpm for primary leaks and about the same for moderator leaks. These estimates of limits of detectability in the shutdown case are based on the assumption of a gamma activity of 0.05 μC/ml in primary water and 0.005 μC/ml in the moderator.

The gamma monitors are installed in wells in the main discharge pipe from each Reactor Building. The units will detect a gamma activity in the service water of 5×10^{-5} μC/ml. The monitors alarm and record in the control room. If the service water monitors show that heavy water is leaking at a serious rate from one of the heat exchangers in the moderator or primary systems, the leak can be quickly and safely stopped by shutting down the reactor and valving off all of the heat exchangers which might be responsible. The heat exchangers may not all be kept valved-off for long periods. For example, one or other of the moderator coolers should be kept in operation at all times, except for brief periods, but turning off the coolers one at a time will quickly identify a unit with a bad leak.

To protect against loss of heavy water from small chronic leaks in boilers and heat exchangers, a sample of the service water effluent from each exchanger will be periodically withdrawn and analysed in the laboratory for D_2O content. A tolerable chronic leak rate of heavy water into the lake will be based on the equilibrium tritium concentration in the moderator and an allowed tritium concentration of 3×10^{-3} μC/ml in 400,000 gpm/unit of plant effluent.

9.6.3.5 Final Activity Check

The monitors which will be used for operational control of discharge of activity in the various liquid streams leaving the plant have been described in the previous sections. As a check on the amount of activity which is actually released, a sampling pump will be installed at the end of the condenser cooling water channels. This collects samples which will represent the average effluent over a period of weeks. Such samples will be checked in the laboratory once or twice a month to determine the long-lived activity which reaches the lake in the effluent. Samples will also be taken regularly from all plant and external drainage sumps. These will be analysed to ensure that liquid activity is not reaching the environment through ground water.

9.6.4 Active Gases

9.6.4.1 General

All active or potentially active gases, vapours or airborne particulates which may be expected to occur in the Reactor Buildings will be monitored and, if necessary, filtered or held up in a delay tank prior to release to the atmosphere. In areas where there is a probability of continuous activity release to the building atmosphere, closed ventilation systems which recirculate the air are used. Provision will be made to install filters.

From other parts of the plant where gaseous activity may occur, in particular the spent fuel storage bay and the service areas and active laboratories in the Service Wing, the vents and exhausts will be monitored, filtered if necessary, and discharged with the nearest Reactor Building ventilation exhaust. None of these possible sources is considered likely to be a significant hazard.

In the case of the Vacuum Building, the main pump discharge will normally be led out clear of the building and released locally to the atmosphere. The pumps are shut off automatically by a $\beta\gamma$ monitor in the duct if the activity present actuates a high level alarm. If activity is to be released under control, as for example when restoring the vacuum after an accident, this would be done through a duct connection to a Reactor Building ventilation exhaust duct. See Section 9.6.4.3 below.

The maximum continuous release of activity to the atmosphere permissible by the Reactor Safety Advisory Committee Siting Guide is defined to be that which would give an exposure of 0.5 Rem/year whole body radiation (or 3 Rem/year to the thyroid) to someone outside of the controlled area, or a total population dose of 10^4 man-Rem or 10^4 thyroid Rem/year whichever is greater. The rate at which activity could be uniformly released and meet the criterion depends upon the dilution or dispersion factor which applies from the site to the location of the person receiving the maximum dose.

The Reactor Safety Advisory Committee Siting Guide states that: pending data on Southern Ontario meteorological conditions Pasquill D conditions should be used for evaluation of dispersion of gases. The guide also suggests that the report by P.J. Barry, AECL 1624, be used as a reference in determining allowable concentration of various isotopes and the conversion between concentration and dose.

The table following has been prepared using Barry's suggested allowable concentrations and Pasquill's D criteria as interpreted by Bryant* to give permissible average release rates of various radionuclides from the plant.

TABLE 9.6-1

PERMISSIBLE AVERAGE RELEASE OF VARIOUS RADIONUCLIDES (FROM 4-REACTOR PLANT)

Nuclide	Curies/day
Argon-41	4500
Tritium (as oxide)	2250
Fission product noble gases	1680
Strontium-89	24.8
Strontium-90	0.22
Caesium-137	0.112
Iodine-131 (accompanied by other iodines)	2.8×10^{-2}

For a release which is made up of a mixture of radionuclides the total permissible release per day would be a weighted average taken in proportion to the relative amount of the various constituents and inversely to their permissible release rates.

Barry suggests that for short periods, up to about two hours, the dispersion might be poorer than average by a factor which may be as high as 100. The effect of the occasional period of poor dispersion would be negligible in its effect on the annual dose received by anyone unless an appreciable portion of the annual release, say one-half of one percent, should occur during a period of periods when such abnormally poor dispersion applies for the particular recipient. To avoid any risks of high exposure from high release during periods of poor dispersion, Barry suggests that discharge rates for airborne activity should be limited to ten times the permissible average rates. Alternatively, activity should be discharged at high rates only after determining that the dispersion conditions are satisfactory. It is not expected that the above limitation will restrict purging operations required in the Reactor Building or vaults to clear the atmosphere for maintenance work.

The emission limitations given above and the description of the provisions for control of releases of activity given in the following sections apply only under conditions of normal operation or maintenance of the plant. Provisions for preventing release of activity to the atmosphere under accident conditions are described elsewhere in this Report,

* *Bryant, P.M. – AHSP (RP) R42.*

and the potential release under such conditions is analyzed in Volume II.

9.6.4.2 Sources of Airborne Activity

Activity may enter the air in a Reactor Building from leaks of heavy water. The main activity which results is tritium, in the form of tritiated heavy water vapour. Small amounts of some fission products and activated corrosion products may also enter the air as gases or particulates from heavy water leaks. The tritium content of moderator heavy water will be higher than primary water but other long-lived activities will ordinarily be much lower. Any heavy water vapour present in gases intentionally vented to the ventilation exhaust system would have an effect similar to leaks in causing release of activity from the plant.

Activity from the heat transport system can also enter the exhaust air system from the off-gases tank which collects gaseous impurities, including gaseous fission products, from the heat transport heavy water. These activities can be held for decay if desired, but they are ultimately discharged to the building exhaust system bleed under control of the station operator.

Particular care has been taken in the layout and design of areas in the vicinity of the reactor and in ventilation control measures to ensure that no significant active gases will be released chronically to the atmosphere. In areas where there is a probability of continuous activity release to the building atmosphere, closed ventilation systems will be used which recirculate and clean up the air.

Contamination can be picked up from the surface of contaminated liquids or solids at various places in the buildings. The decontamination centre fume hoods are a source where such activity may be expected. The ventilation exhaust from the fuel transfer or service rooms may also carry some activity, although there are filters provided to minimize particulate release. Some activity may also be released from the surface of the water in the spent fuel storage bay, possibly from contamination in the water but more likely from gaseous fission product escape from a defective fuel element which has not yet been sealed in a can. The possibility also exists of picking up some contamination in the ventilation systems from dry surfaces where contaminated or activated reactor components have been handled. The total amount of airborne activity discharged from these miscellaneous sources is expected to be very small.

9.6.4.2.1 Calandria Vault

The calandria vault atmosphere surrounding the calandria will not be ventilated. There are no high temperature, high pressure heavy water systems in the calandria vault which could leak to the atmosphere around the calandria. All low pressure, heavy water piping and connections in the calandria vault are welded. The annulus between the calandria tubes and pressure tubes is sealed and on a closed circuit. It is believed that no chronic heavy water leaks and resulting tritium will occur in the calandria vault. There will be some argon-41 activity in the air atmosphere as the result of neutron activation of the argon in the air but the level will be low because of the low neutron flux outside the calandria due to the internal thermal shields in the calandria. The estimated equilibrium argon-41 activity in the calandria vault atmosphere is 30 millicuries per cubic meter or a total contained activity in the vault of 17.8 curies.

The calandria vault will be held at a pressure of about one inch of water below the boiler room pressure by a small exhaust duct connected to the Reactor Building ventilation system main exhaust duct. The estimated leakage into the vault at this pressure difference is 1 cfm. The activity carried in the 1 cfm would be 850 microcuries per minute or about 1.2 curies per day.

No other activities should originate in the calandria vault.

9.6.4.2.2 Fuelling Machine Vaults and Service Rooms

The fuelling machine vault and service room atmosphere is physically separated from that of the calandria vault and is on a separate closed cycle ventilation and drying circuit. The neutron flux is very low due to the reactor end shields and heavy concrete vault structure. There is no connection between the pressure tube-calandria tube annulus and the fuelling machine vaults or service rooms. There should be no argon-41 of any significance in the fuelling machine vaults.

There will be a tritiated atmosphere in the fuelling machine vaults and service rooms since these enclosures are designed to contain heavy water leakage from the mechanical seals on the high pressure primary system. However, with a dried atmosphere, the tritium activity should also be low. If the dew point is held at the design figure of $0^{\circ}F$ the total heavy water vapour in the vault will be about 13 pounds. The equilibrium activity of the primary coolant will be about 1.2 curies per pound, so that the total tritium activity in the vault may be about 15 curies, or about 4.2 millicuries per cubic meter.

In addition, there may be some fission product gases in the fuelling machine vaults if there is failed fuel in the reactor. However, the fission product activity carried into the vaults is expected to be negligible, as can be demonstrated by assuming that 10 percent of the primary coolant leaks into a fuelling machine vault per year and that the reactor operates continuously with one average rated fuel element failure. With the primary system ion exchange and off-gases system in operation, which has a time constant of 7 hours, the total fission product activity released to the vault would be about 0.7 microcuries per hour (chiefly Xe and Kr isotopes). The fuelling machine vault has a closed cycle dried ventilation system so that the equilibrium total activity in the vault would be about 0.1 millicuries of mixed volatile fission products.

The continuous leakage of fuelling machine vault atmosphere is expected to be extremely small and should not contribute any significant continuous activity release from the plant. Occasionally, however, it will be desirable to purge the fuelling machine service rooms (about 15 percent of the combined volume) and once in a while a purge of the fuelling machine vault may be necessary.

9.6.4.2.3 Boiler Room

The boiler room atmosphere is also on a closed cycle ventilation system with drying. The tritium and fission product activity may build up in the boiler room to levels near those calculated for the fuelling machine room if the H_2O leakage into the boiler room is small. If the H_2O leakage is large the D_2O content (and thus tritium level) of the atmosphere will be low. It is not expected that significant leakage will take place from the boiler room to other connected areas in the plant. However, occasionally it may be desirable to purge the boiler room for extended maintenance work. In this case, a volume of 1.2×10^6 cubic feet of air and water vapour at a dew point 0°F may be discharged containing about 150 curies of tritium.

9.6.4.2.4 Moderator Room

The moderator room atmosphere is also on a closed cycle dried ventilation system. In addition there is not expected to be any significant leakage of heavy water from the lower pressure moderator system, so that the moderator should not contribute to any chronic release of activity from the plant.

The above paragraphs and Table 9.6-2 describe the various sources of activity which can be released with the gaseous effluents from the plant. It is very difficult to make a meaningful quantitative estimate of the total continuous activity release to be expected, but it is expected to be several orders of magnitude below the allowable figures given in Table 9.6-1.

TABLE 9.6-2

ESTIMATED EQUILIBRIUM ACTIVITIES IN ONE REACTOR BUILDING

Calandria Vault	
Tritium	0
Argon-41	17.8 curies
Other activity	0
Fuelling Machine Vaults and Service Rooms	
Tritium	15 curies
Argon-41	0
Other (including fission products and activation products)	16 millicuries
Boiler Room	
Tritium	150 curies
Argon-41	0
Other Activity	0.16 curies
Moderator Room	
Tritium	7 curies
Argon-41	0
Other	0

9.6.4.3 Monitoring and Control of Effluent

Reactor Building ventilation system bleed exhausts are led to ducts running vertically up to the south roof edge of the Powerhouse. They are discharged by outlets with an effective height of 130 feet above grade. Activity in the ducts will be measured by monitors either mounted on the ducts or by monitors, located near the duct, which monitor a sample from the duct.

The four types of fixed monitoring on the ventilation system are: (1) gross $\beta\gamma$ monitors, (2) particulate activity monitors, (3) iodine activity, (4) tritium monitor and heavy water loss measurements.

(1) Gross $\beta\gamma$ monitors are installed on each Reactor Building exhaust in a redundant scheme to provide monitoring with backup protection over a wide range. Since the exhaust system for Reactor Building No. 1 is mixed with the Service Wing exhaust, two wide range $\beta\gamma$ monitors measure the activity in the Reactor Building exhaust only and a third $\beta\gamma$ monitor measures the activity on the combined effluent. The exhaust of Reactor Building No. 2 mixes with that of the spent fuel storage bay and is similarly monitored. Reactor Buildings No. 3 and No. 4 each have three $\beta\gamma$ monitors on their exhaust ducts.

    The two $\beta\gamma$ monitors in the Reactor Building exhaust ducts for units No. 1 and No. 2 can close the Reactor Building ventilation isolation dampers in a one-out-of-two logic scheme. Similarly for units No. 3 and No. 4, two monitors from each are arranged to provide a one-out-of-two logic for damper isolation. This arrangement for units No. 3 and No. 4 is selected so that damper isolation is identical to No. 1 and No. 2. This logic approach is acceptable in this instance as compared with the two-out-of-three logic approach since an inadvertent closure of the Reactor Building is not a major operating inconvenience nor can it shut the plant down.

    The output signal of the three $\beta\gamma$ monitors on each exhaust duct are scanned by the computer and a high level indication on any of these monitors will annunciate in the control room. A single alarm with an adjustable setting is used.

    A $\beta\gamma$ monitor is also provided for the Vacuum Building exhaust. HIGH level alarm causes an air sample of the exhaust of the Vacuum Building to be taken and the vacuum pumps will be stopped.

    The $\beta\gamma$ instruments for ventilation system monitoring will cover a wide range by using one of two detector heads.

(2) A particulate activity monitor is installed on the final exhaust duct to each stack. In addition, there is a particulate monitor on the Administration Building intake, and in the vicinity of the intakes for the Service Wing, Reactor Buildings and Reactor Auxiliary Bay. In the event of recirculation of discharged activity the intake concerned would be manually shut down and an alternative intake selected.

Each particulate activity monitor annunciates on high level. The monitors have a single alarm adjustable setting. Monitoring is done by collecting activity on a particulate filter and detected by a scintillation head.

(3) Iodine activity is monitored in the exhaust duct of each Reactor Building. Each monitor has a computer input to record readings and provide control room annunciation on high level. Monitoring by either rate or integrating systems is being considered.

(4) Tritium Monitoring and D_2O Loss Measurements

A 40 litre double ion chamber tritium detector will be provided for each unit. This detector will be capable of detecting a change in tritium activity equivalent to IMPC in 100 seconds. The monitor will normally be used to monitor unit effluents.

A heavy water loss measurement will be carried out on a sample from each Reactor Building exhaust discharge. The measurement will be made by sampling the flow and adjusting for a constant dew point. An infra-red analyzer will monitor the D_2O loss concentration and this will be used by the computer to calculate the total loss. Annunciation for "high" D_2O loss will be given in the control room. The sample lines described below for tritium monitoring will be used to localize the D_2O leakage. The measurement sensitivity with an infra-red analyzer that detects 100 ppm will be 1 pound of D_2O per day with 6500 scfm flow in the Reactor Building exhaust.

As a further aid in controlling the effects from airborne activity released from the plant, some meteorological equipment will be provided at the station. Wind speed and direction will be measured by instruments mounted at the top of a mast located on the roof of the Vacuum Building. The information from the instruments is recorded in the station control centre.

9.6.4.4 Control of Exposure of Plant Personnel

The preceding subsections have described the provisions for control of release of activity from the plant for the purpose of protecting the public. The type of control required to protect the plant staff is somewhat different.

The main airborne activity of concern to the station operating and maintenance staff is tritium. Whenever significant leaks of heavy water can occur the tritium concentration will be above the level permitted for continuous breathing unless the ventilation is abnormally good and carries the vapours away from the person. Where heavy water may occasionally be open to the air as a normal procedure, some type of fume hood is provided so that the room air does not become contaminated.

Tritium monitoring will be done by various portable instruments depending on the location, application and sensitivity required. Portable monitors with low sensitivity for personnel protection will be provided by Operations. Also provided is a more sensitive monitor. This is a semi-portable unit mounted on a dolly which uses a 40 litre double ion chamber as detector and has a local record and alarm facility. Bubbler units will be used to check areas where speed of response is not needed but accuracy is required. Permanently installed sample lines with connections in accessible areas suitable for any type of tritium monitor are provided to obtain samples from areas of possible high concentration.

Local exhaust outlets are also provided to give special ventilation when required. These connections would probably be used with plastic tent-like structures over and around equipment which is contaminated or wet with heavy water to minimize the amount of particulate activity or of tritium getting into the building air. When it is necessary to work in the neighbourhood of leaks or on equipment with exposed D_2O, personnel wear an air mask or a ventilated plastic suit. For use in locations with particularly high tritium or with high temperature, high integrity suits complete with headpiece are available. This type has an internal cooling and ventilation system.

An air service system, together with associated telephone connections, will supply flexible hose stations throughout the plant where required.

A urinanalyser installed in a washroom is expected to be used to monitor personnel for tritium absorption. It has its own local alarm and recording facilities. Samples and laboratory analysis will be used for detection and evaluation of internal exposures.

Spread of particulate activity into and by the ventilation systems in the buildings is controlled to the maximum extent feasible by using appropriate procedures and the facilities provided. Contaminated equipment will be wrapped in plastic for transportation and is kept wrapped at all times when direct contact is not required for essential dismantling and maintenance operations. When the size of the equipment permits, the contaminated items will be transported under wrap to the decontamination centre or the active maintenance bays where cleaning and dismantling can be performed with special equipment and ventilation which prevents the spread of activity.

Under certain conditions it is possible for some persons on the plant staff to be exposed to concentrations of airborne activity higher than the normally permissible levels as a result of peculiar behaviour of the effluent due to unusual weather conditions or some feature of the building arrangements. The probability of this occurrence, however, is considered to be very low. The "normal" effluent from any of the duct outlets at the Powerhouse roof is unlikely ever to exceed a concentration more than 100 times the ICRP value for 40 hour exposure for occupational workers. Even with strong down-drafts and occasional trapping, a short-term dilution factor of at least 200 can be expected from the duct outlets to the ground, so the exhaust activity should not be a concern to anyone outside the buildings during normal operation.

10.1 GENERAL

The reactor physics calculations completed to date have been directed mainly towards determination of the locations and sizes of the control mechanisms, particularly the adjuster rods and shutoff rods. This was done using the two-group two-dimensional diffusion code EQUIPOISE-3A (Reference 1) and the three-dimensional version WHIRLAWAY (Reference 2). It was assumed in all cases that the fuel would be irradiated to the same terminal exposure throughout the core. Calculations of reactivity variation with moderator height, shutoff rod worth versus position, fuel temperature effects and coolant void effects have also been done.

The criteria used to determine the number, locations and lengths of the adjuster rods were:

(a) the total reactivity worth should be such that complete withdrawal of the rods will permit a return to high power operation 45 minutes after a shutdown.

(b) the flux distribution with the rods fully inserted should be such that the permissible limits on fuel temperature (local power) or coolant temperature rise (channel power) are not exceeded.

(c) they are located in positions of maximum statistical weight within the limitations imposed by (b) so that the reactivity worth required for (a) is obtained with minimum parasitic absorption.

The specified characteristics of the adjuster rod system (see Section 7) are considered to meet adequately all of these requirements.

The criteria used to determine the number, locations and lengths of the shutoff rods were:

(a) the total reactivity worth of the rods should be 24 milli-k.

(b) the rods are "black" to neutrons, of minimum number consistent with the maximum allowable diameter (4-3/4 inches) and 14.5 feet in length.

(c) the rod positions were chosen so as to provide an average statistical weight judged to be close to the maximum obtainable. However, the requirement that the rods have at least 24 milli-k worth when the moderator is at the dump port level dictated that their "full in" position be off centre with the bias being in the downward direction.

A summary of reactor physics properties is given in Table 10-1.

10.2 LATTICE CALCULATIONS

The Power Projects' lattice physics program POWDERPUFS was used to generate the parameters listed in Table 10-1. This program is basically the same as the Chalk River program SPOOOF. However, the method used to solve the burn-up equations is that used in the DEEMS program (Reference 3). This made it possible to allow for the effect of self-shielding in Pu-240 and to produce in the output the isotopic number densities as either

$$N_i(\omega) \text{ or } \overline{N_i}(\omega) = \frac{1}{\omega}\int_0^{\omega} N_i(\omega)\, d\omega$$

The latter are used to obtain the "homogeneous" lattice properties for a bi-directionally fuelled system.

This program also includes the $\sqrt{T_F}$ dependence of the resonance integral (Reference 4) and Jarvis' revised heavy water data (Reference 5).

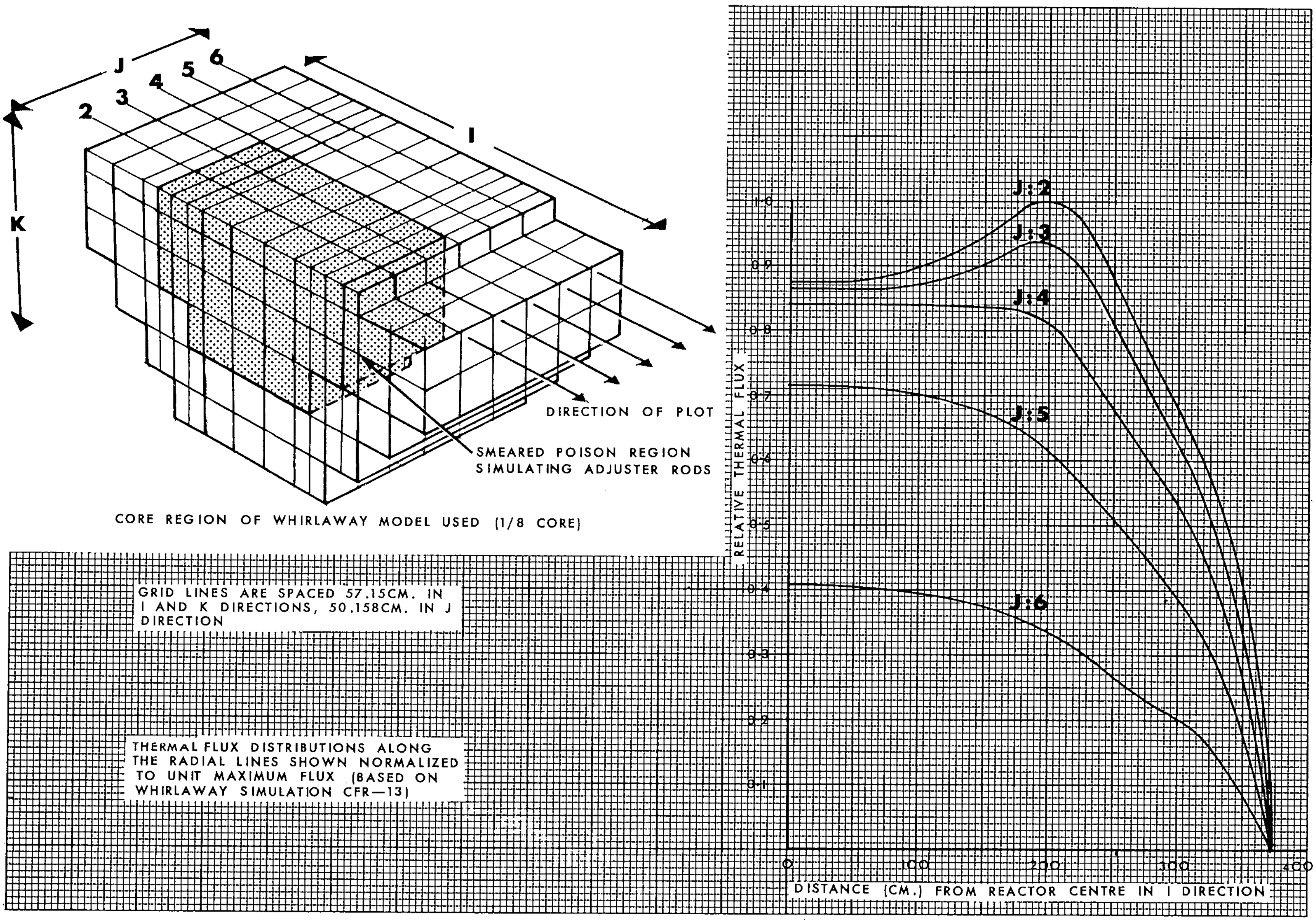
The bundle geometry was obtained from Section 5 of this Report. The separation of the outer pencils was assumed to be 0.05 inch. The basic dimensions and areas after adjustment for end effects are listed in Table 10-2. The fuel sheath and void volumes per bundle were adjusted by factors deduced from the as-built 3-1/4 inch bundle data. The coolant volume was then chosen so that the sum of fuel, sheath, void and coolant volumes equalled the product of the area enclosed by the rubber band perimeter and the bundle length. These values were used in the program, and are shown together with the other input data in Table 10-2.

Note that the original design figures as reported in Reference 6 were used for coolant tube and calandria tube dimensions. The revised values (see Section 4) are slightly different, but the differences are not too significant from the reactor physics viewpoint.

10.3 CRITICAL SIZE, BURNUP, FUELLING PATTERN

The optimization studies for this reactor which established the calandria dimensions, number of channels, lattice pitch, and unit cell geometry were carried out assuming a fuelling pattern similar to that for Douglas Point. That is, that differential fuelling would be employed to "flatten" the flux radially and booster rods would be used for xenon override so that only the zone control absorbers would be in the core during normal operation.

When the decision was made to use adjuster rods for xenon override it was considered impractical to consider any re-optimization of the system based on this modified scheme because of the complexity involved and the time factor. The results of a re-optimization were not expected to differ much in any case. It was decided also that no attempt would be made to find the "optimum" combination of differential fuelling and adjuster rod loading within this "fixed" physical system. Instead, it was



10.3-1

44.01100—1

assumed that the fuel would be taken to the same terminal irradiation through the core, and the adjuster rod loading would be chosen so that the required flux distribution (to avoid excessive local or channel power) and the necessary xenon override capability, would be provided simultaneously. Since it is possible that more than one loading would satisfy these conditions, a further criterion was imposed. This was that the average statistical weight of the rods should be kept as high as possible.

The characteristics of the adjuster rods which were finally adopted (see Section 7) are considered to satisfy the requirements reasonably well. This loading was arrived at after a series of 2-group calculations using the two-dimensional computer code EQUIPOISE-3A and the three-dimensional version WHIRLAWAY.

In all of these studies, the material properties of the homogenized unit cell were arbitrarily taken to be those used for the outer burnup zone in the differential fuelled scheme. These properties are given in Table 10-3. The final loading adopted displayed the following characteristics:

Eigenvalue	$(\frac{1}{k})$	= 1.00494
$\bar{\phi}_{core}/\phi_{max}$		= 0.573
Maximum channel power		= 5.17 MW
Maximum fuel linear rating		= 12.3 kW/cm of bundle
Maximum fuel pencil rating $\int \lambda\, d\phi = 40$		watts/cm

The fuel burnup obtained from the POWERPUFS program using material properties in Table 10-3 is 8120 MWd/teU. However, it is known that the lattice recipes used in POWDERPUFS program do not agree with experiment for the large coolant tubes used in Pickering. The error is thought to be mainly in the calculations of the resonance escape probability "p". This error is thought to result in underestimation of the fuel burnup by about 400 MWd/teU. Since the simulated system was found to be 4.9 milli-k under critical with the properties assumed, an adjustment of about -500 MWd/teU is required for this reason. Therefore, the burnup for units 1 and 2 is expected to be about 8000 MWd/teU.

The reactors for units 3 and 4 of the Pickering Generating Station are expected to be nearly identical to the reactors for units 1 and 2. The only known difference significantly affecting reactor physics results, is the change of coolant tube material. The change from Zircaloy-2 (units 1 and 2) to the higher strength zirconium-2.5% niobium heat treated alloy (units 3 and 4) will result in a reduction in wall thickness based on the same design criteria. If the minimum wall thickness of 0.160 inch in place of 0.1965 inch is selected the reactivity would be increased about 3 mk and the burnup would increase by about 350 MWd/te.

The thermal flux distributions obtained from the WHIRLAWAY simulation of the reactor with adjuster rods fully inserted are shown in Figures 10.3-1, 10.3-2, and 10.3-3. Note that the adjuster rods were simulated by a uniform poison smeared out over the "region of influence" of the adjuster rods. This was necessary because of the limitations of the WHIRLAWAY program. Two-dimensional simulations in r-z geometry were also made of the reactor with the adjuster rods fully inserted by representing each of the three banks of adjuster rods by a uniform poison smeared out over a "disc 200 cm in radius and 7.72 cm thick". The EQUIPOISE-3A two-group diffusion code was used for this simulation. Flux distributions obtained in this case are plotted in Figures 10.3-4 and 10.3-5.

Neither the three-dimensional model nor the two-dimensional model are adequate to show the flux distribution in the immediate vicinity of the adjuster rods. However, it is felt that the three-dimensional results provide a reasonably good indication of the radial flux distributions to expect in a macroscopic sense, while the two-dimensional results give a better indication of the axial distribution, particularly in the central region of the core.

10.4 XENON LOAD AND INSTABILITY

The equilibrium xenon load for this reactor has been estimated to be 28.2 milli-k and the maximum rate of growth of this load on shutdown is 23.4 mk/hr. After 45 minutes of shutdown time, the xenon load has increased by 16.4 milli-k.

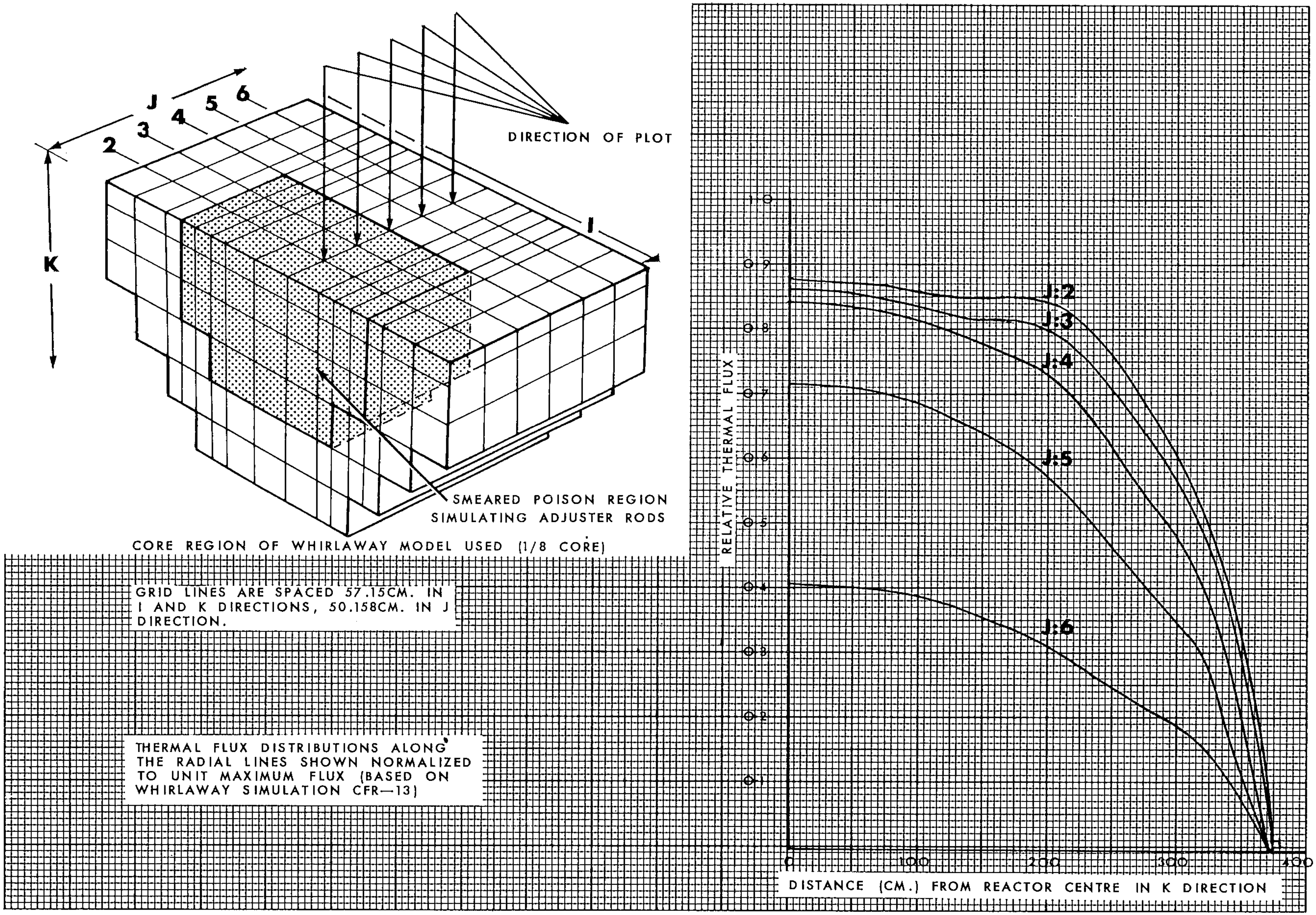
When the adjuster rods are removed to compensate for the xenon build-up during a 45 minute shutdown, the flux shape in the core is significantly altered since the adjusters serve to flatten the flux when they are fully inserted. It has been estimated that it will be necessary to operate at 70% of full power with all the adjusters removed to avoid exceeding the permissible limits on local power. This is adequate to "burn out" the xenon which has built in during the shutdown so the adjusters can be re-inserted.

No detailed analysis has yet been done of the stability of the system with respect to xenon-induced spatial growth of flux disturbances. However, some steady state work was done to determine how effectively the flux distribution can be altered by small local changes in reactivity. The results of this work give good grounds for confidence that the 14-element zone control system described in Section 7 can effectively prevent serious xenon induced spatial flux growth.

10.5 TEMPERATURE COEFFICIENTS

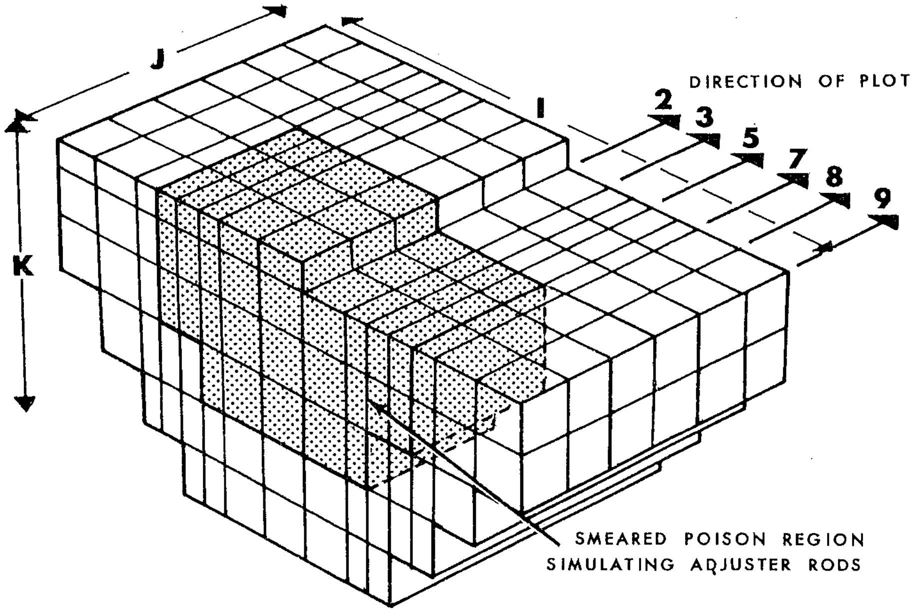
The reactivity variation with fuel temperature has been calculated for fresh and equilibrium fuel using the POWDERPUFS lattice parameter program and the CRNL LATREP program (Reference 7). The results are plotted in Figure 10.5-1.

It is evident that the difference between the POWDERPUFS and LATREP results is not very significant

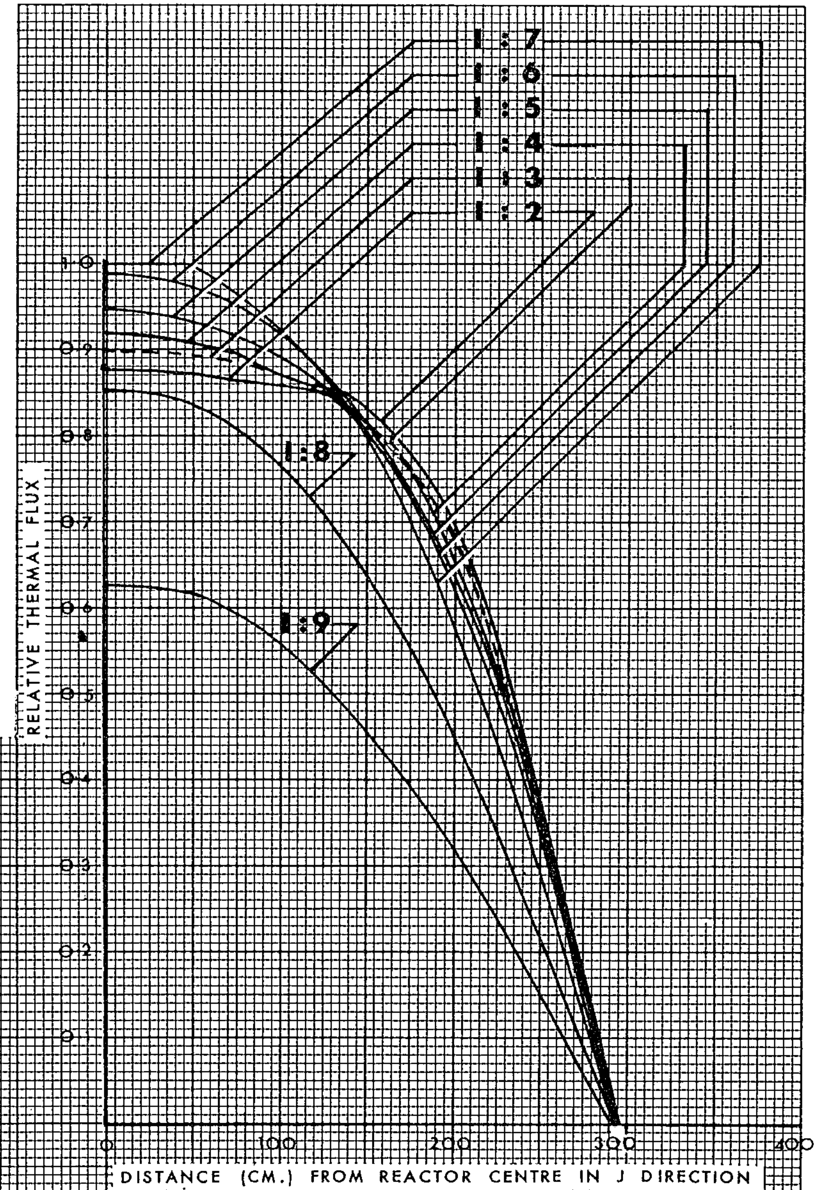


10.3-2

44.01100—2



CORE REGION OF WHIRLAWAY MODEL USED (1/8 CORE)

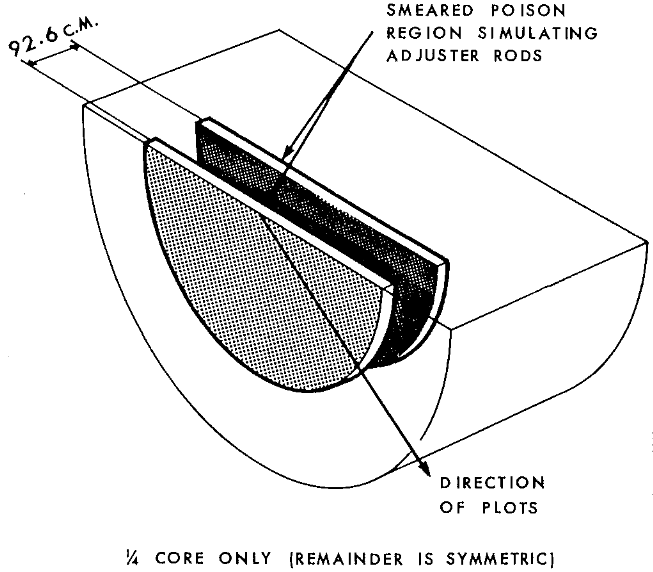


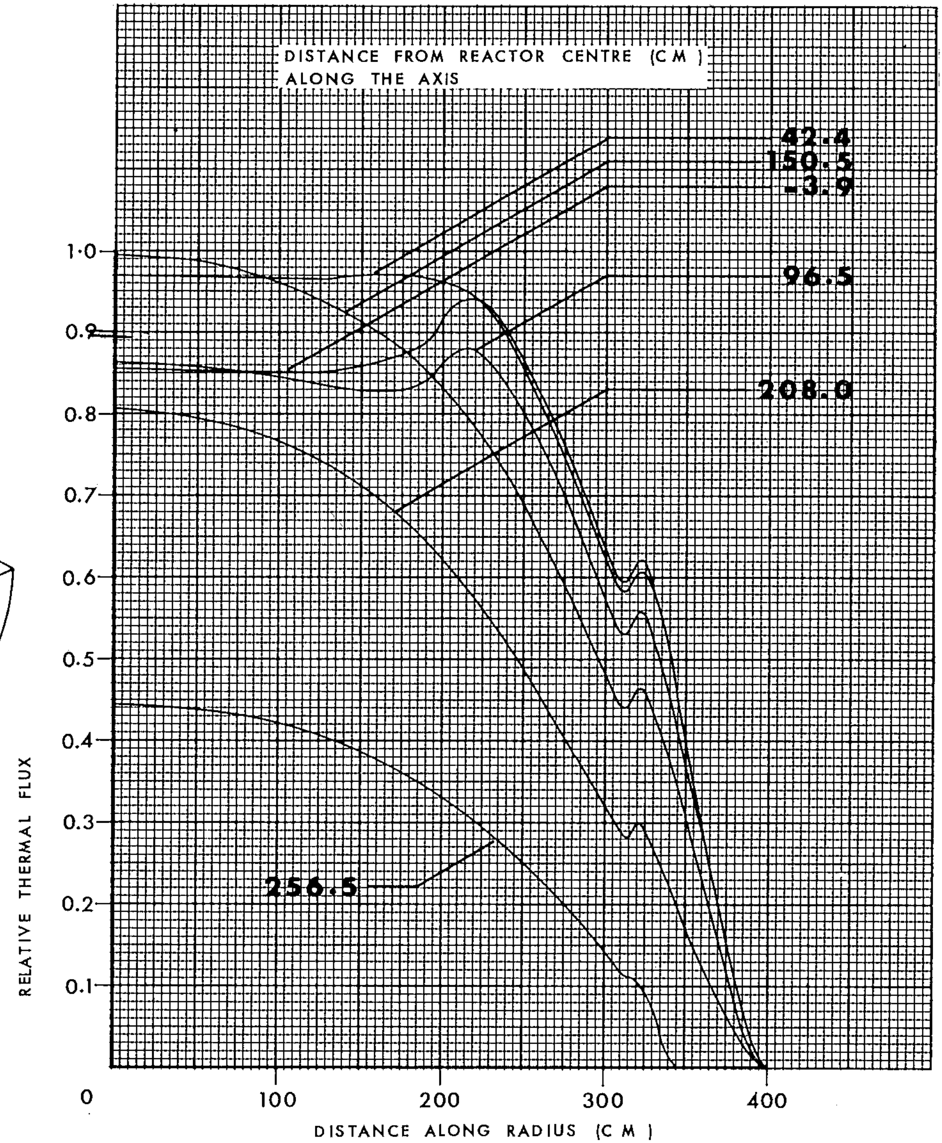
GRID LINES ARE SPACED 57.15CM. IN I AND K DIRECTIONS 50.158CM. IN J DIRECTION.

THERMAL FLUX DISTRIBUTIONS ALONG THE RADIAL LINES SHOWN NORMALIZED TO UNIT MAXIMUM FLUX (BASED ON WHIRLAWAY SIMULATION CFR—13)

10.3-3

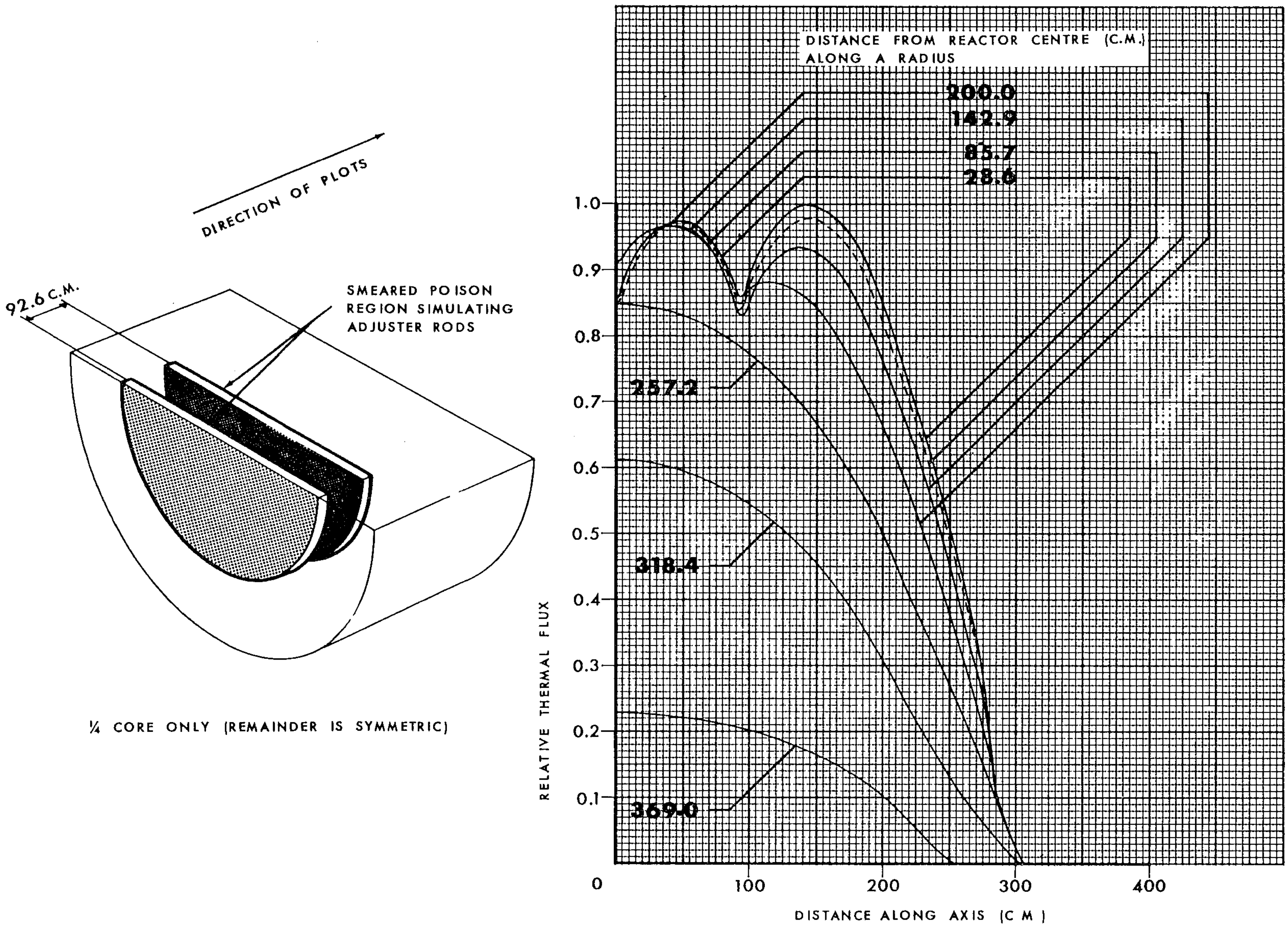
44.01100—3



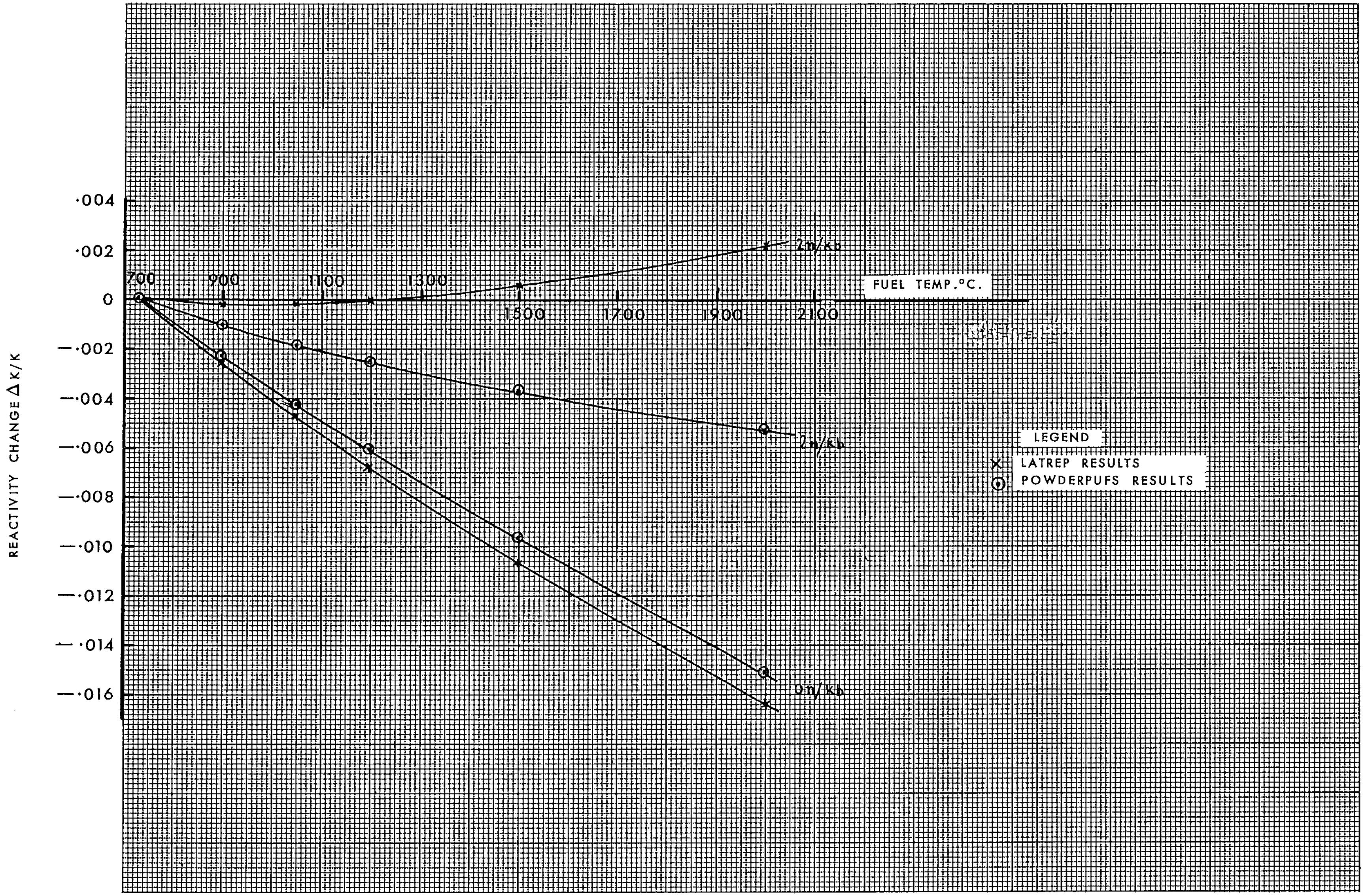


10.3-4 THERMAL FLUX DISTRIBUTIONS ALONG RADIAL LINES AT VARIOUS DISTANCES FROM REACTOR CENTRE (NORMALIZED TO UNIT MAXIMUM FLUX) EQUIPOSE 3A SIMULATION OF ADJUSTER RODS.

44.01100—4



10.3-5 THERMAL FLUX DISTRIBUTIONS AXIAL LINES AT VARIOUS DISTANCES FROM REACTOR CENTRE (NORMALIZED TO UNIT MAXIMUM FLUX) EQUIPOISE 3A SIMULATION OF ADJUSTER RODS.



10.5-1 FRACTIONAL CHANGE IN REACTIVITY WITH FUEL TEMPERATURE

44.01100—6

for fresh fuel. However, the difference found for equilibrium fuel (terminal exposure of 2 n/kb) is important from the safety point of view because the LATREP results indicate that virtually no change in reactivity would occur due to a full power increase in fuel temperature (460°C), whereas the POWDERPUFS results indicate a decrease of about 2.5 milli-k would take place.

Although the LATREP calculation is considered to be more reliable than POWDERPUFS, sufficient incertainty remains about the accuracy of calculating reactivity effects associated with temperature perturbations, particularly for irradiated fuel, that one cannot be sure whether the fuel temperature coefficient is in fact negative, positive or zero. It is known that the net reactivity effect is the result of relatively large negative and positive effects tending to cancel, so even small errors could easily change the sign of the coefficient. It is felt, therefore, that assuming the fuel temperature coefficient for equilibrium fuel to be either positive or negative cannot be justified on the basis of present knowledge.

10.6 COOLANT VOID EFFECTS

The POWDERPUFS lattice parameter program was used to calculate the reactivity effect of voiding all coolant channels for different operating conditions. The following were used as parameters in the study: the initial temperature of coolant and fuel; the irradiation of the fuel; and the amount of natural boron in the moderator.

Three different initial temperature conditions were examined:

(a) Fuel and Coolant at 100°C ("cold" case).

(b) Fuel and coolant at 249°C (hot shutdown case).

(c) Fuel at an average temperature of 730°C and coolant at 271°C (full power case).

For each of these temperature conditions, the void coefficient was calculated as a function of terminal exposure (assuming equilibrium bi-directional fuelling) for zero boron concentration. The results are shown in Figures 10.6-1, 10.6-2 and 10.6-3. Results have been obtained from the CRNL LATREP code (Reference 8) at zero exposure and at a terminal exposure of 2.0 n/kb for the full power case (c). The results were 15.8 mk and 7.4 mk respectively. The equilibrium fuel irradiation is expected to be close to 2.0 n/kb. The LATREP results are considered more reliable than POWDERPUFS results, which means that the latter are probably on the conservative side from the point of view of safety considerations. Further support for this comes from the fact that the POWDERPUFS program also gives a larger void coefficient than that based on measured bucklings in ZED-2 with fuel and coolant at room temperature.

For each of the three temperature conditions assumed, the void coefficient was also calculated as a function of the boron concentration in the moderator with the fuel at zero exposure. The results are plotted in Figure 10.6-4. The range of boron concentrations examined for each of the temperature conditions were chosen to approximate the range of concentrations likely to be present in practice. However, it is evident from Figure 10.6-4 that the variation of the void coefficient with boron concentration is quite linear so extrapolations to boron concentrations outside the range examined can probably be made quite safely.

The evaluation of the void "coefficient" from the lattice parameters for all cases is based on the "bare pile" approximation:

$$\frac{\Delta k_{eff}}{k_{eff}} = \frac{\Delta k_{oo}}{k_{oo}} - \frac{\Delta L^2}{L^2}\left(\frac{L^2B^2}{1+L^2B^2}\right) - \frac{\Delta L_s^2}{L_s^2}\left(\frac{L_s^2B^2}{1+L_s^2B^2}\right)$$

10.7 REACTIVITY EFFECTS OF MODERATOR VOLUME CHANGES

The reactivity variation with moderator level has been studied for two different reactor conditions:

(a) Fuel at equilibrium irradiation, all adjuster rods fully inserted, and the system at operating temperatures.

(b) The reactor in its most reactive condition, i.e. most reactive fuel, no boron in the moderator, no control rods in the core, and the system at room temperature.

The EQUIPOISE-3A two-group, two-dimensional diffusion code was used to estimate the reactivity variation with height for both reactor conditions. As a result, the following approximations were necessary:

(a) The effect of the reduced thickness of the reflector at the ends of the reactor was ignored.

(b) In the equilibrium case, the adjuster rods were simulated by a uniform poison smeared out over the central region of the core.

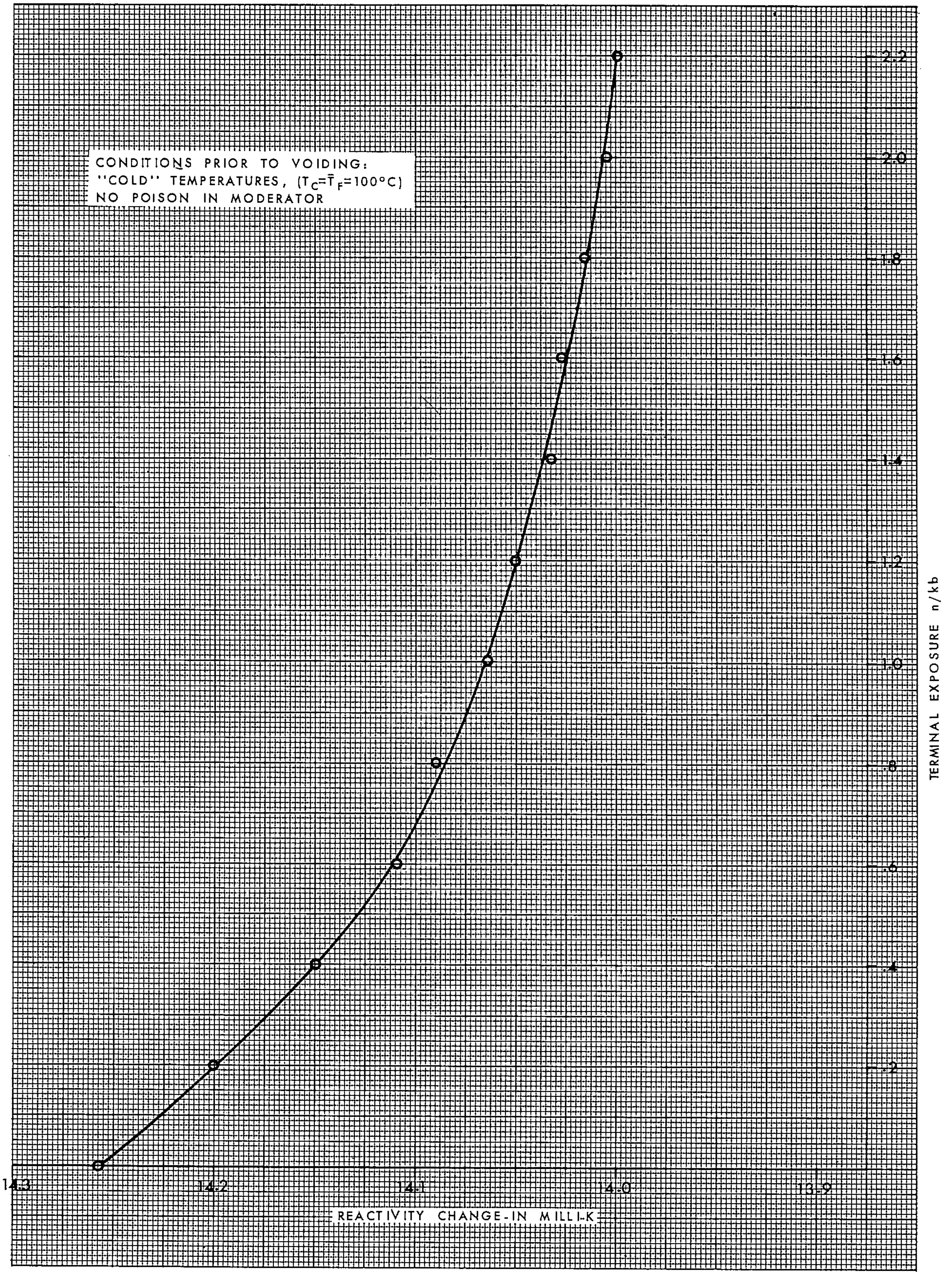
A 5 cm extrapolation distance above the free moderator surface was used in both cases. The results have been plotted in Figure 10.7-1 for the equilibrium case and Figure 10.7-2 for the most reactive case. The slightly higher unit cell reactivity in units 3 and 4 means that the curve in Figure 10.7-2 would move about 2cm to the right.

10.8 SHUT-OFF ROD WORTH CALCULATIONS

The variation of shut-off rod worth with position has been calculated for three different conditions:

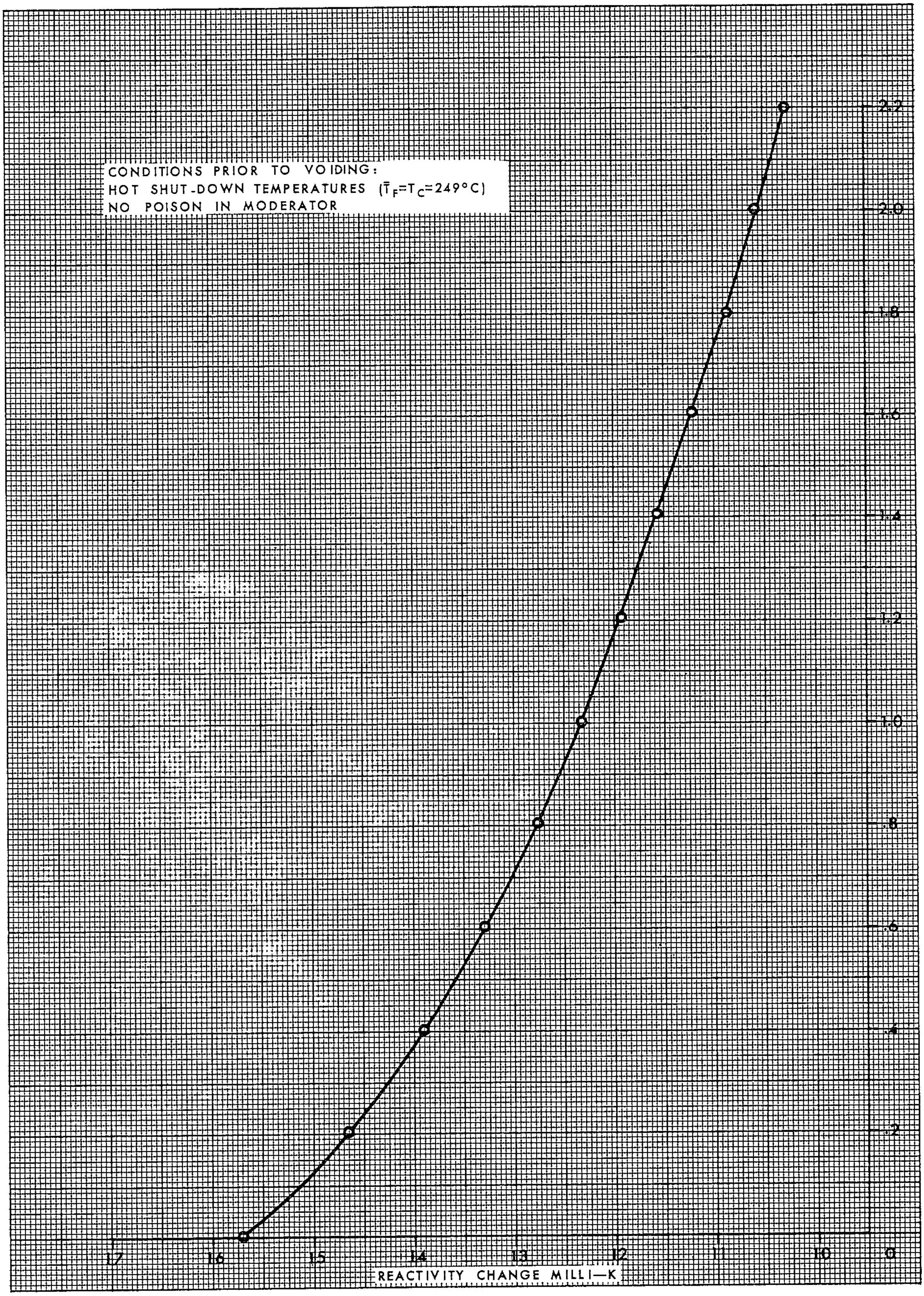
(a) Fuel at equilibrium irradiation, moderator at the full tank level, and the adjuster rods fully inserted.

(b) Same as (a) except the moderator was at the half-tank level.



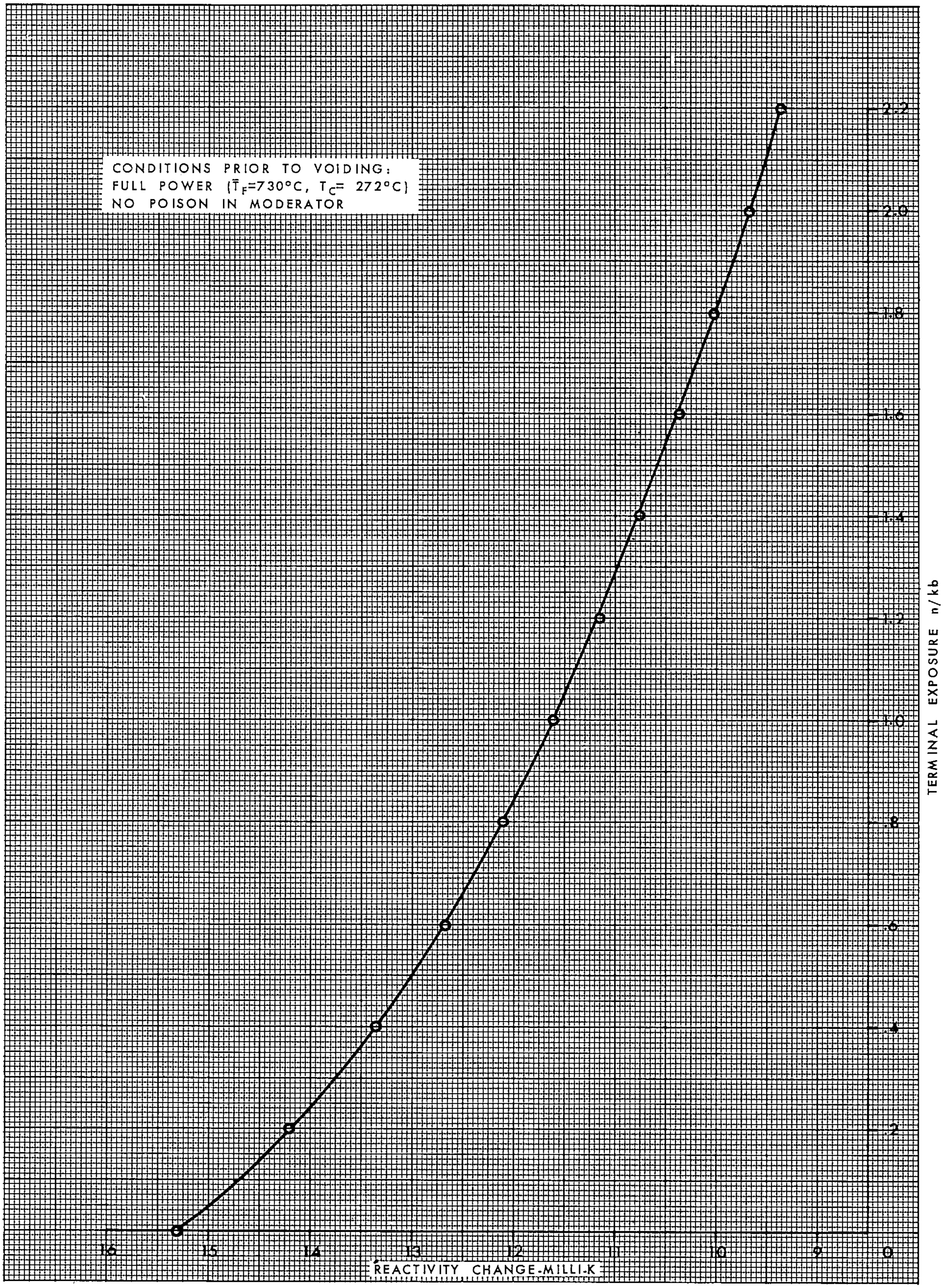
10.6-1 VOID COEFFICIENT V S FUEL EXPOSURE

44.01100—7



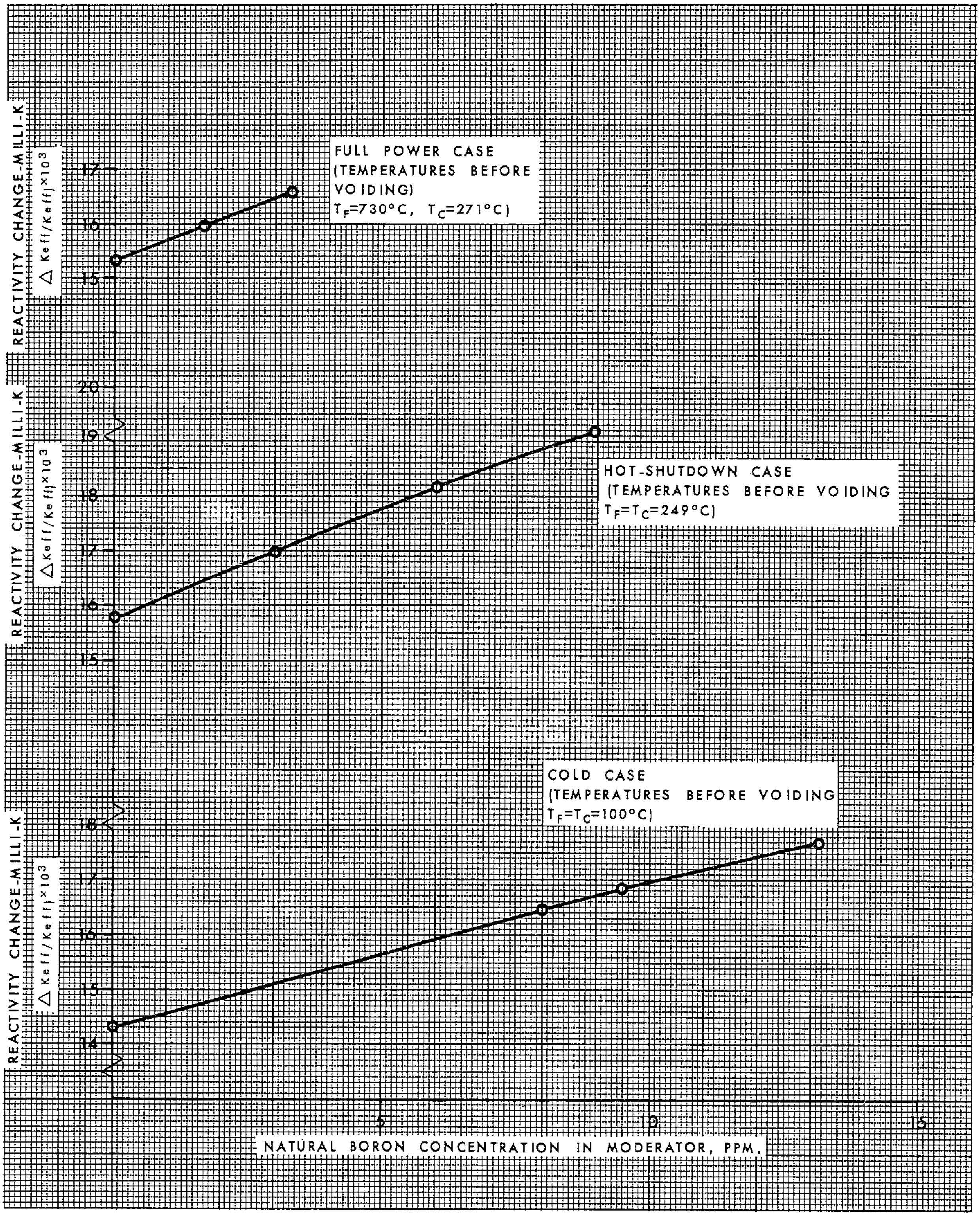
10.6-2 VOID COEFFICIENT V S FUEL EXPOSURE

44.01100—8



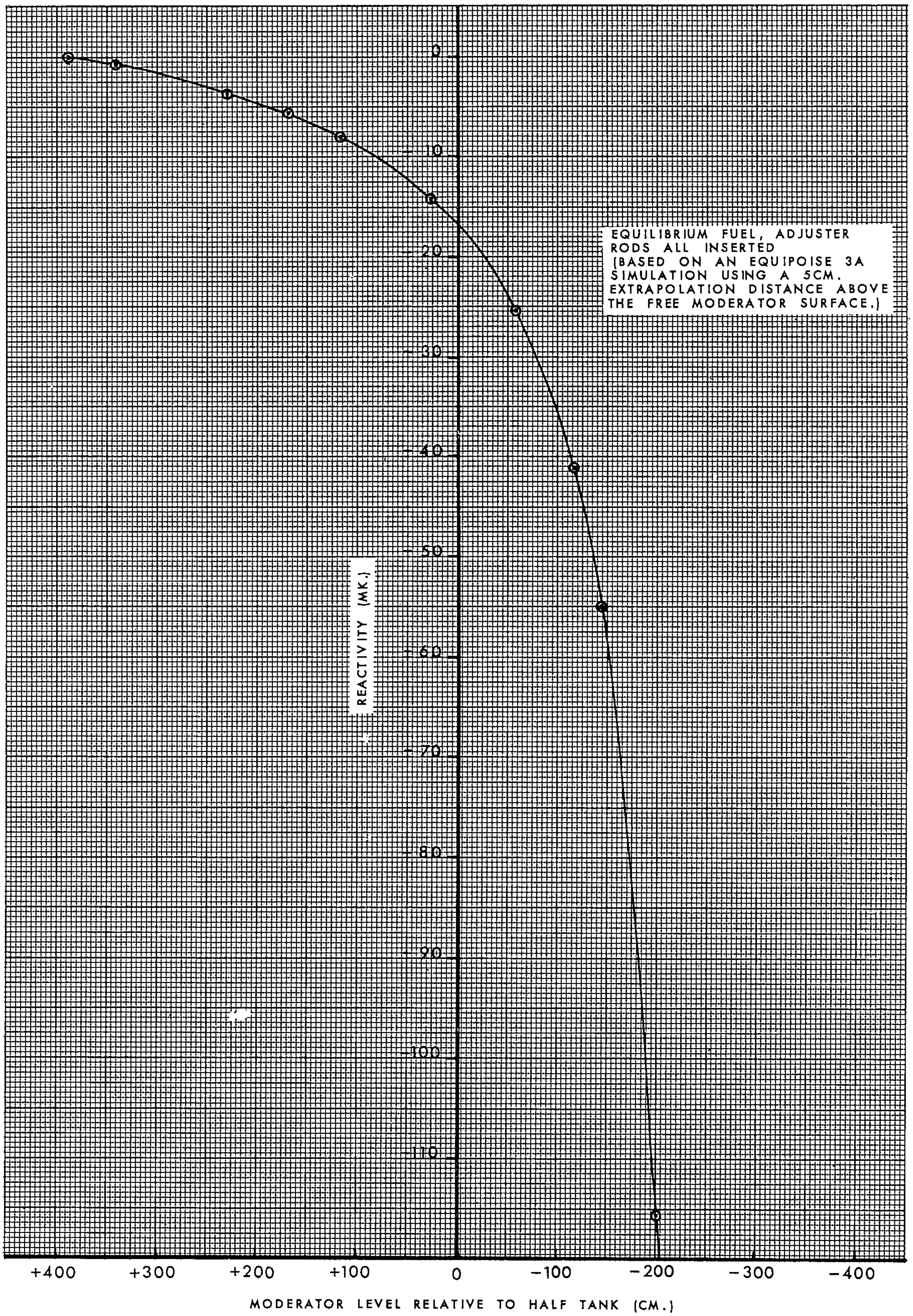
10.6-3 VOID COEFFICIENT V S FUEL EXPOSURE

44.01100—9



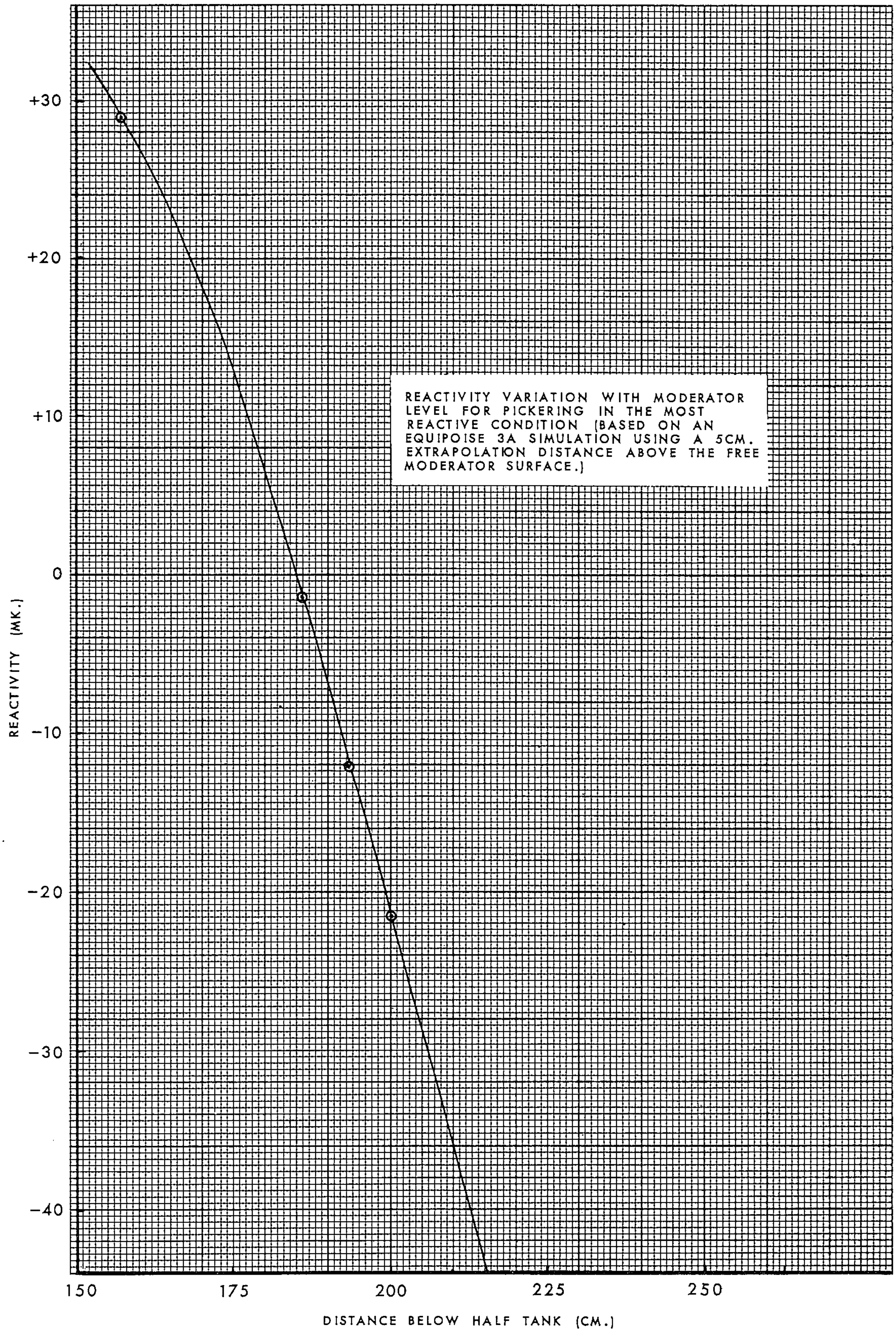
10.6-4 VOID COEFFICIENT VERSUS MODERATOR POISON CONCENTRATION AT ZERO FUEL EXPOSURE

44.01100—10



10.7-1 REACTIVITY VS. MODERATOR LEVEL

44.01100—11



10.7-2 REACTIVITY VS. MODERATOR LEVEL

44.01100—12

(c) Fresh fuel, moderator level at 200 cm below half-tank, coolant and moderator at 25°C.

The WHIRLAWAY three-dimensional, two group diffusion code was used for these calculations, using a model in which the shut-off rods were simulated by a uniform poison smeared out over the "region of influence" of the rods.

The results are plotted in Figures 10.8-1, 10.8-2 and 10.8-3 for cases (a), (b) and (c) respectively. The maximum rate of change of reactivity per cm. of movement estimated from the graphs is also indicated.

10.9

10.10

(to be issued later)

10.11

10.12

10.13 SHIELDS AND RADIATION LEVELS

10.13.1 Summary of Shielding Formulas

The shielding calculations have been based upon the formula for the flux from a point source

i.e. $$\phi = \frac{BSe^{-\Sigma x}}{4\pi r^2}$$

where ϕ = flux (particles/cm^2—sec)

B = buildup factor

S = point source strength (particles/sec)

Σ = attenuation coeeficient (cm^{-1})

x = absorber thickness (cm)

r = source to detector distance (cm)

For photons the attenuation coefficient is the total linear absorption coefficient as given in Reference 9 and the buildup factor is taken from Reference 10. For neutrons, effective removal cross sections from Reference 11, mean free paths from Reference 13, and relaxation lengths from Reference 9 have been utilized. Where the geometry can be idealized, curves given in References 12, 14 and 9 were used. Otherwise, numerical integration over the source region was performed.

Induced radioactivity in materials under neutron irradiation was calculated from the formula

$$A = \Sigma\phi\,(1 - e^{-\lambda t})$$

and for fluids which are irradiated periodically in a circulating cycle from the formula

$$A = \frac{\Sigma\phi\,(1 - e^{-\lambda t})}{1 - Fe^{-\lambda T}}$$

where A = specific activity $\left(\frac{d}{\text{sec-cm}^3}\right)$

Σ = activation cross section (cm^{-1})

ϕ = activation flux (n/cm^2-sec)

λ = decay constant (sec^{-1})

t = time in high flux region (sec)

T = total circuit time (sec)

F = fraction of fluid which is not bypassed to the purification system.

10.13.2 Summary of Design Radiation Levels

The shielding has been designed to reduce the radiation levels as indicated in Table 10.4.

10.13.3 Summary of Shield Dimensions and Calculations

The shielding calculations are summarized in Tables 10.5 to 10.7 inclusive and in Figures 10.13-1 to 10.13-6 inclusive.

TABLE 10.1

SUMMARY OF REACTOR PHYSICS PROPERTIES OF THE 500 MWe REACTOR

Number of channels	390			
Lattice spacing	11.25	in	28.575	cm
Core radius	125.4	in	318.5	cm
Core length	234	in	594.4	cm
Average reflector thickness	28.1	in	71.4	cm

Average lattice properties at 2.0 n/kb exposure (8300 MWd/te approx.)

	28 element fuel
ϵ	1.02695
η	1.19822
f	0.9365
p	0.89870
k	1.03564
L^2	223.63 cm^2
L_s^2	145.80 cm^2
B^2	0.9567 $\overline{m}^2$
r	0.0461
ϕ eff. fuel	0.677 x 10^{14} n/cm^2 sec
I.C.R.	0.818
Max. Thermal Flux	0.91 x 10^{14} n/cm^2 sec

Distribution of neutron absorption in the unit cell:

Fuel	0.93650

Sheaths	0.00673
Coolant & calandria tubes	0.03734
Moderator	0.01943

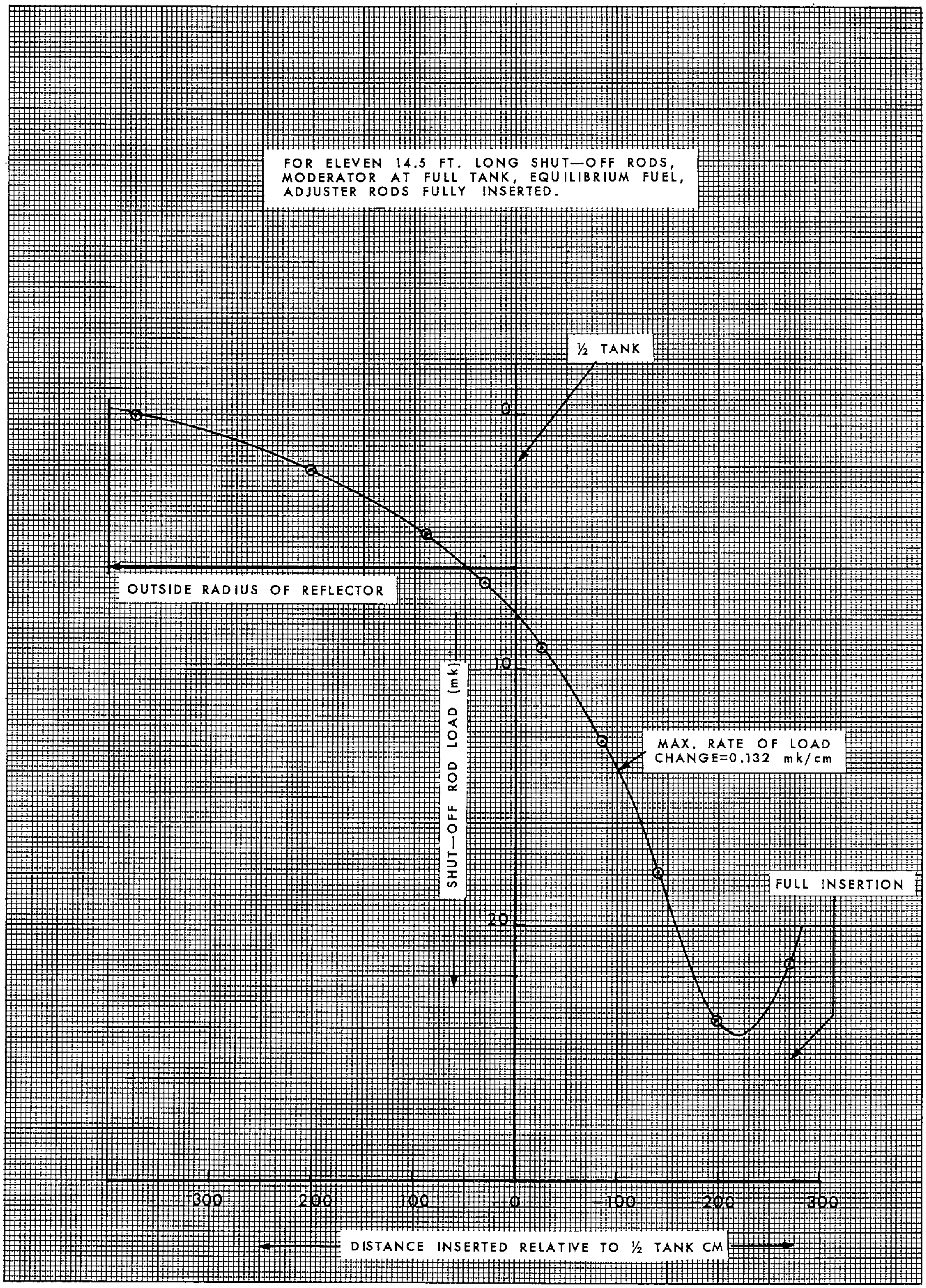
Relative neutron distribution in the unit cell:

Fuel	0.47
Coolant & calandria tubes	0.68
Moderator	1.00

TABLE 10.2

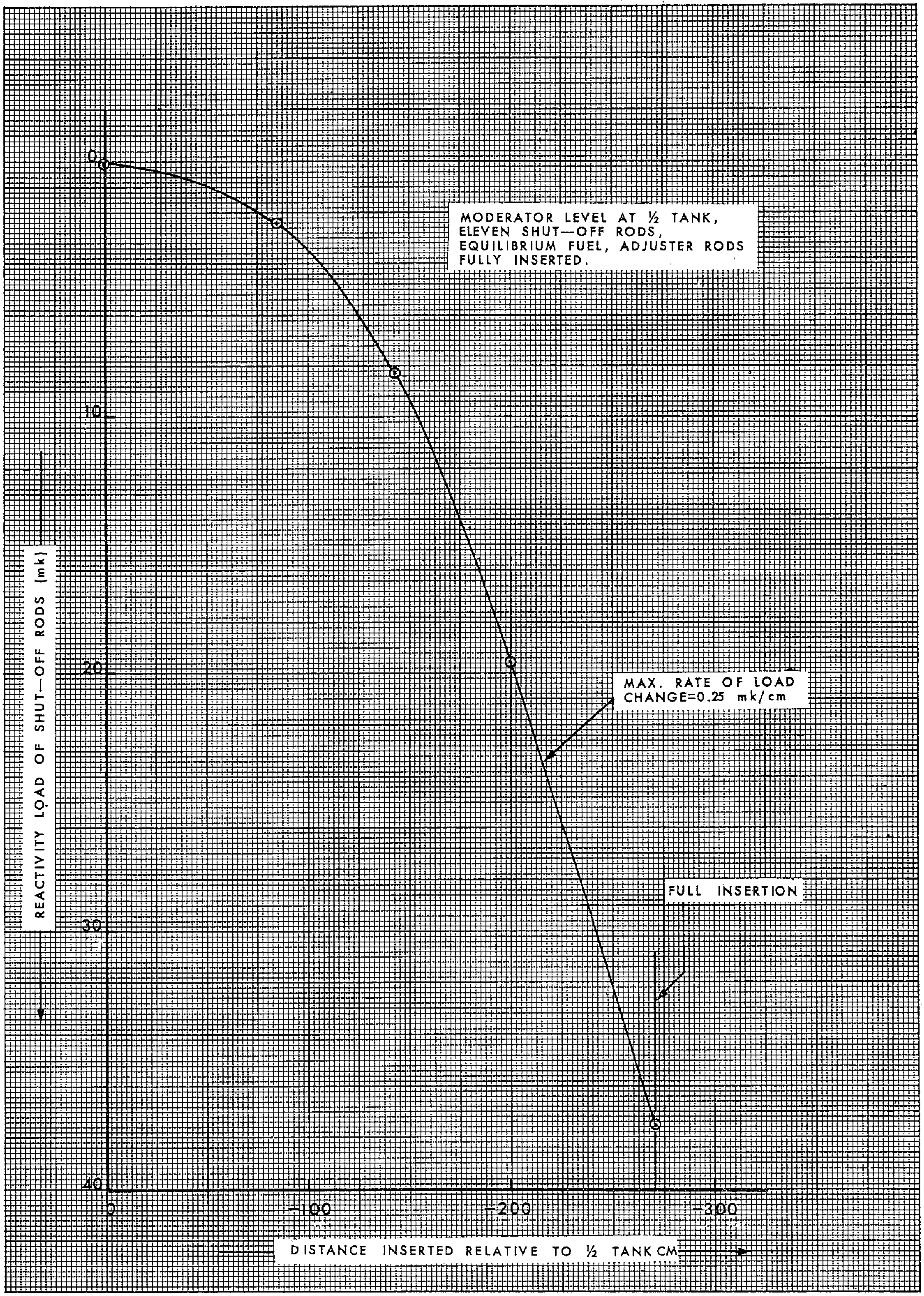
LIST OF INPUT DATA

		28 Element	R000
Spectral Parameter	r		
Neutron Temp. in Fuel	T_N	236.0°C	2
Fuel Enrichment	$N_5(0)/N_8$	.00725689	3
Moderator Temp. (Physical)	T_M	60.0°C	4
Coolant Density	P_c	0.8382gm/cm	5
Fuel Density	P_F	10.5gm/cm	6
Fuel Temperature (Physical)	T_F	600°C	7
Neutron Temp. in Annuli	T_{NA}	150.5°C	8
Neutron Temp. in Moderator	T_{NM}	65.0°C	9
Rubber Band Perimeter (Fuel)	S_o	30.8354cm	11
Fuel Total Perimeter	S_a	126.01505cm	12
Equivalent Coolant thickness	d	.43258cm	13
No. of Annuli	N	4	14
D_2O Purity (homogenized)	$D_2O\%$	99.722%	15
Void Volume (homogenized)	V_v	0.8236cm^3/cm	17
Fuel Volume (homogenized)	V_F	43.1547cm^3/cm	18
Sheath Volume (homogenized)	V_S	6.5632cm^3/cm	19
Coolant Volume (homogenized)	V_C	25.7486cm^3/cm	20
Homogeneous fuel radius	R_o	4.9279cm	21
Pressure Tube Inside Radius	R_1	5.169cm	22
Pressure Tube Outside Radius	R_2	5.677cm	23
Calandria Tube Inside Radius	R_3	6.4389cm	24
Calandria Tube Outside Radius	R_4	6.59435cm	25
	R_5	0	26
Total Coolant Volume	V_{CT}	33.3948cm^3/cm	28
Coolant/fuel Flux ratio	ϕ_c / ϕ_o	1.0	29
Lattice Spacing (Square)	S	28.575cm	30
Material Indicators	x	20	32
Material Indicators	y	50	33
Material Indicators	z	0	34
Material Indicators	m	50	35
Material Indicators	n	0	36
Fuel Heat Rating (at Max. Flux)	R_T	12.85KW/cm	42
Fraction of fission energy to coolant	1-y	0.943	43
	$R_{o\epsilon}$	4.9279cm	46
	$V_{c\epsilon}$	25.7486cm	47
	$V_{s\epsilon}$	6.5632cm	48
Exposure Increment	ΔW	0.2 neut/kb barn	51
MWd/te Increment	$\Delta\Omega$	0	52
	Indicator	3.0	53
	"	0	54
Maximum Exposure	W_{max}	3.4 neut/kb barn	55
	Indicator	0	56
Geometric Buckling	Y_c^2	1.0x10^{-4}cm^{-2}	57
	Indicator	0	58
ϕeff / ϕmax (for xenon calculation)		0.776	60



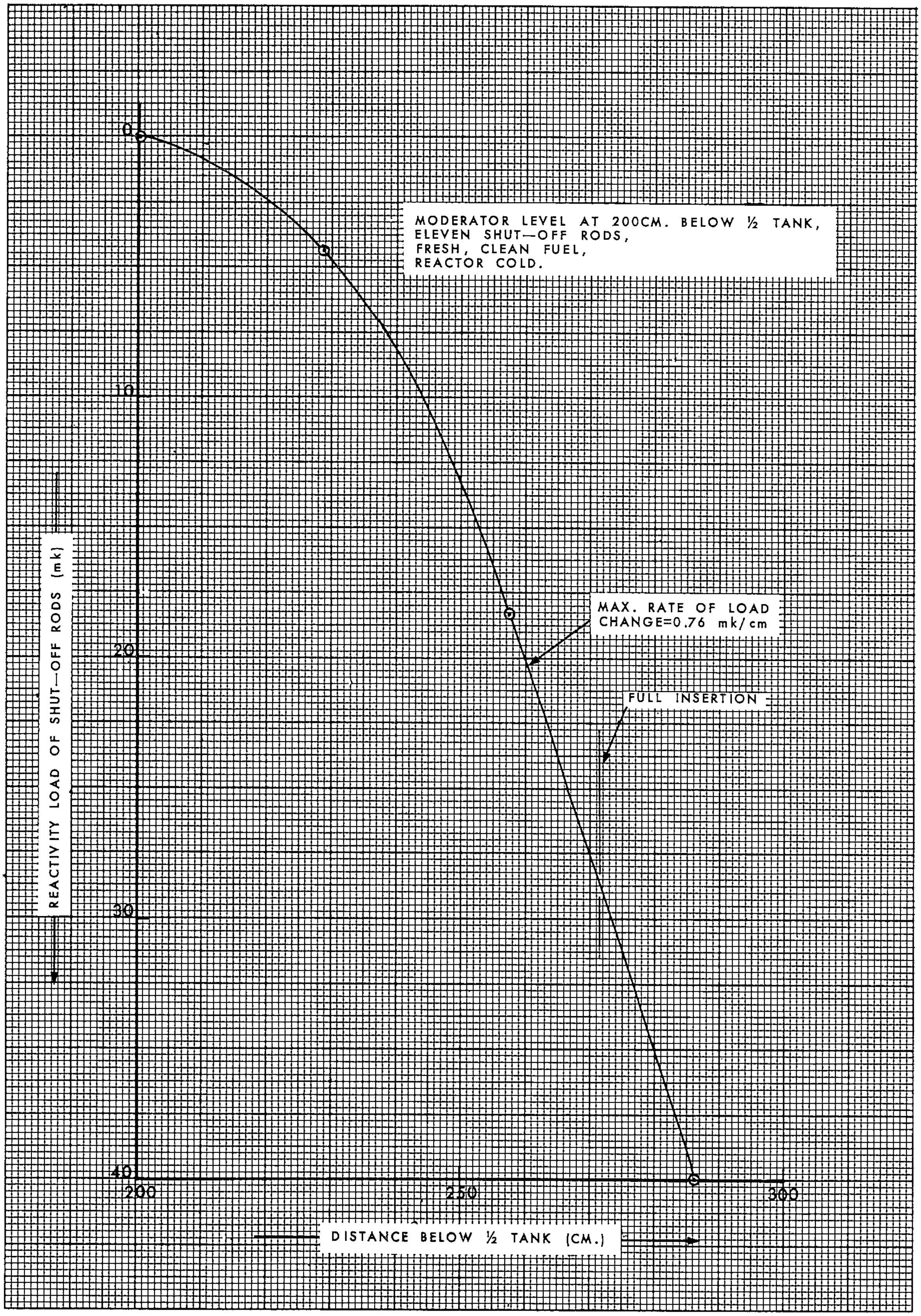
10.8-1 SHUT-OFF ROD LOAD V S. INSERTION

44.01100—13
1967



10.8-2 SHUT- OFF ROD LOAD V S. INSERTION

44.01100—14
1967



10.8-3 SHUT-OFF ROD LOAD V S. INSERTION

44.01100—15

TABLE 10.3

MATERIAL PROPERTIES FOR 2 GROUP DIFFUSION CALCULATIONS OF FLUX DISTRIBUTIONS FOR PICKERING

		Σ_a	Σ_f	D	Σ_R
CORE	FAST	0.000968712	0	1.394352	0.00859424
	THERMAL	0.00413348	0.00477014	0.924866	0
REFLECTOR	FAST	0	0	1.307748	0.0101961
	THERMAL	0.0000885976	0	0.869292	0

These were based on the following lattice parameters:

CORE

$k = 1.037123$

$L^2 = 223.70$

$L_s^2 = 145.8077$

Also $D_{fast} = \frac{L_s^2}{8.66}$

REFLECTOR

$L_s^2 = 128.259$

$\Sigma_T = 0.38345$

TABLE 10.4

Region	Design Radiation Level
Control Room	0.25 mr/hr
Service Building	0.25 mr/hr
Waste Disposal Accessible Area	0.25 mr/hr
Waste Disposal Maintenance Area	2.5 mr/hr
Reactor Building	1.0 mr/hr (nominal)
Accessible Areas	2.5 mr/hr (maximum)
Fuelling Machine Vaults	50 mr/hr
(Reactor Shutdown)	
Steam Generator Area	$<$50 mr/hr (nominal)
(Reactor Shutdown)	100 mr/hr (maximum)
Reactor Building Exterior	1.0 mr/hr

TABLE 10.5

SHIELD CALCULATIONS

Shield Reference	Figure Reference	Purpose	Material and Thickness
A	10.13-1	Shield north accessible area to 2.5 mr/hr	20.5 in. Ilmenite concrete 3.5 in. steel
B	10.13-2	Shield airlock opening in the perimeter wall at the boiler room level to 1.0 mr/hr	20 in. Ilmenite concrete
C	10.13-3	Shield adjuster rods in the parked position to get 100 mr/hr at the boiler room floor	8.5 in. steel
B	10.13-3	Shield reactor building accessible areas to 1.0 mr/hr	4.5 ft Ilmenite concrete 4.5 ft ordinary concrete
D	10.13-3	Shield reactor building accessible area to 1.0 mr/hr	7 ft Ilmenite concrete
E	10.13-3	Shield reactor building accessible area to 1.0 mr/hr	4 ft 4 in. ordinary concrete
F	10.13-3	Shield reactor building accessible areas to 1.0 mr/hr	3.5 ft ordinary concrete
B	10.13-1	Shield reactor building accessible areas to 1.0 mr/hr	4.5 ft ordinary concrete
A	10.13-5	Shield control room and service building to 0.25 mr/hr	5 ft ordinary concrete
B	10.13-5	Shield exterior of reactor building to 1.0 mr/hr	4 ft ordinary concrete
C	10.13-5	Shield steam generator area to <50 mr/hr (reactor shutdown)	5 ft Ilmenite concrete
D	10.13-5	Shield fuelling machine vault to 50 mr/hr (reactor shutdown)	3.8 ft steel and water
A	10.13-3	Shield concrete surface to 40 mw/cm^2	5.5 in. steel
A	10.13-6	Shield on the active chemicals holdup tank to reduce intensity to 0.25 mr/hr	2.28 ft ordinary concrete
B	10.13-6	Shield on active holdup tanks to reduce intensity to 0.25 mr/hr	0.82 ft ordinary concrete
C	10.13-6	Shield on active holdup tanks to reduce intensity to 2.5 mr/hr	0.28 ft ordinary concrete
F	10.13-6	Shield on dispersal tanks to reduce intensity to 0.25 mr/hr	0.14 ft ordinary concrete
E	10.13-6	Shield on dispersal tanks to reduce intensity to 2.5 mr/hr	0.0 ft

TABLE 10.6

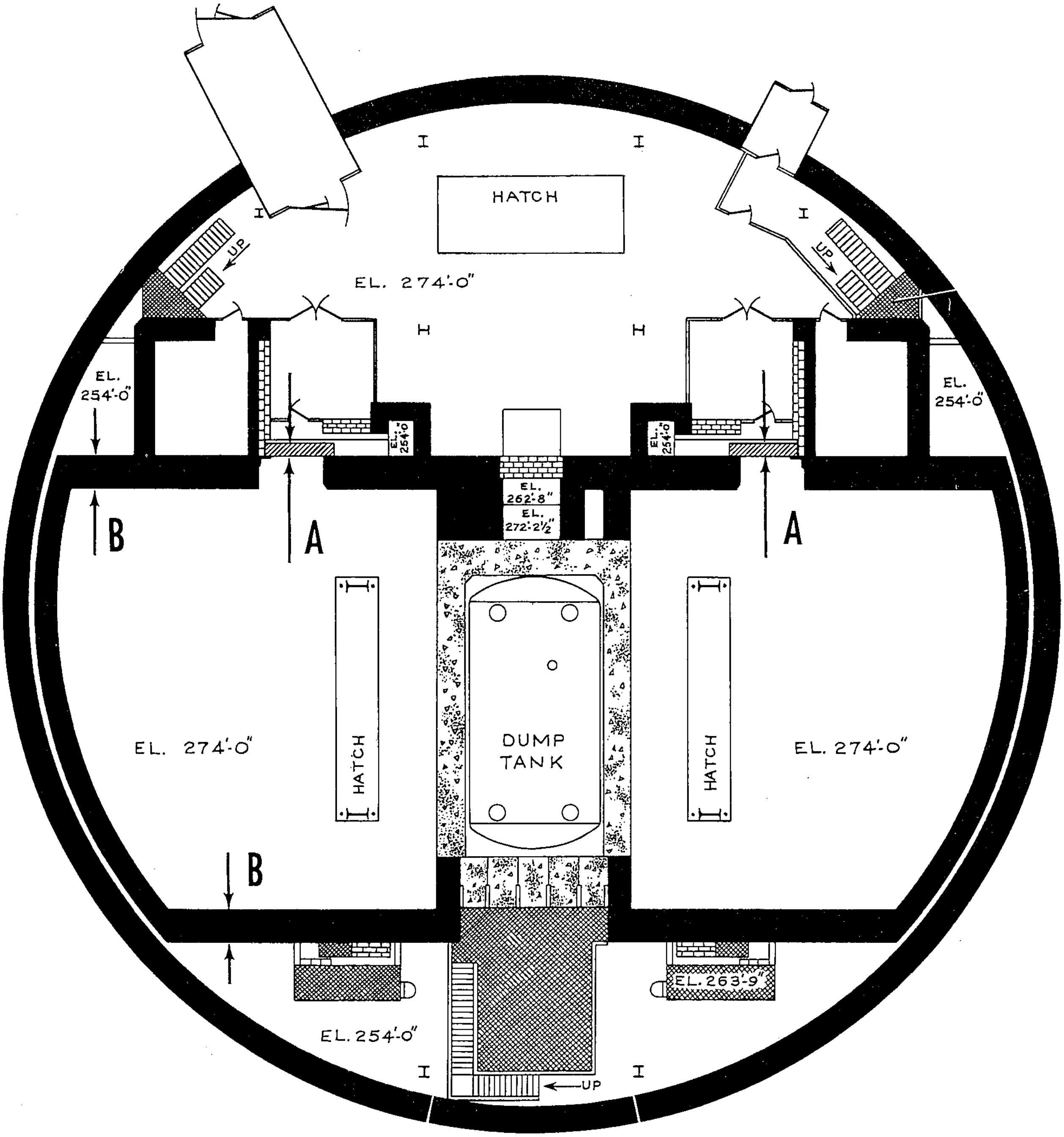
FAST NEUTRON FLUX CALCULATIONS

Point	Figure Reference	Purpose	Fast (>1 Mev) Flux n/cm²-sec
D	10.13-4	Fast neutron flux in the ring thermal shield cooling pipes	1.09×10^{9}
E	10.13-4	Fast neutron flux at the end of the end fitting	1.63×10^{11}
F	10.13-4	Fast neutron flux at the pressure tube to end fitting joint	6.4×10^{10}
H	10.13-4	Fast neutron flux in the end thermal shield ring	1.3×10^{10}

TABLE 10.7

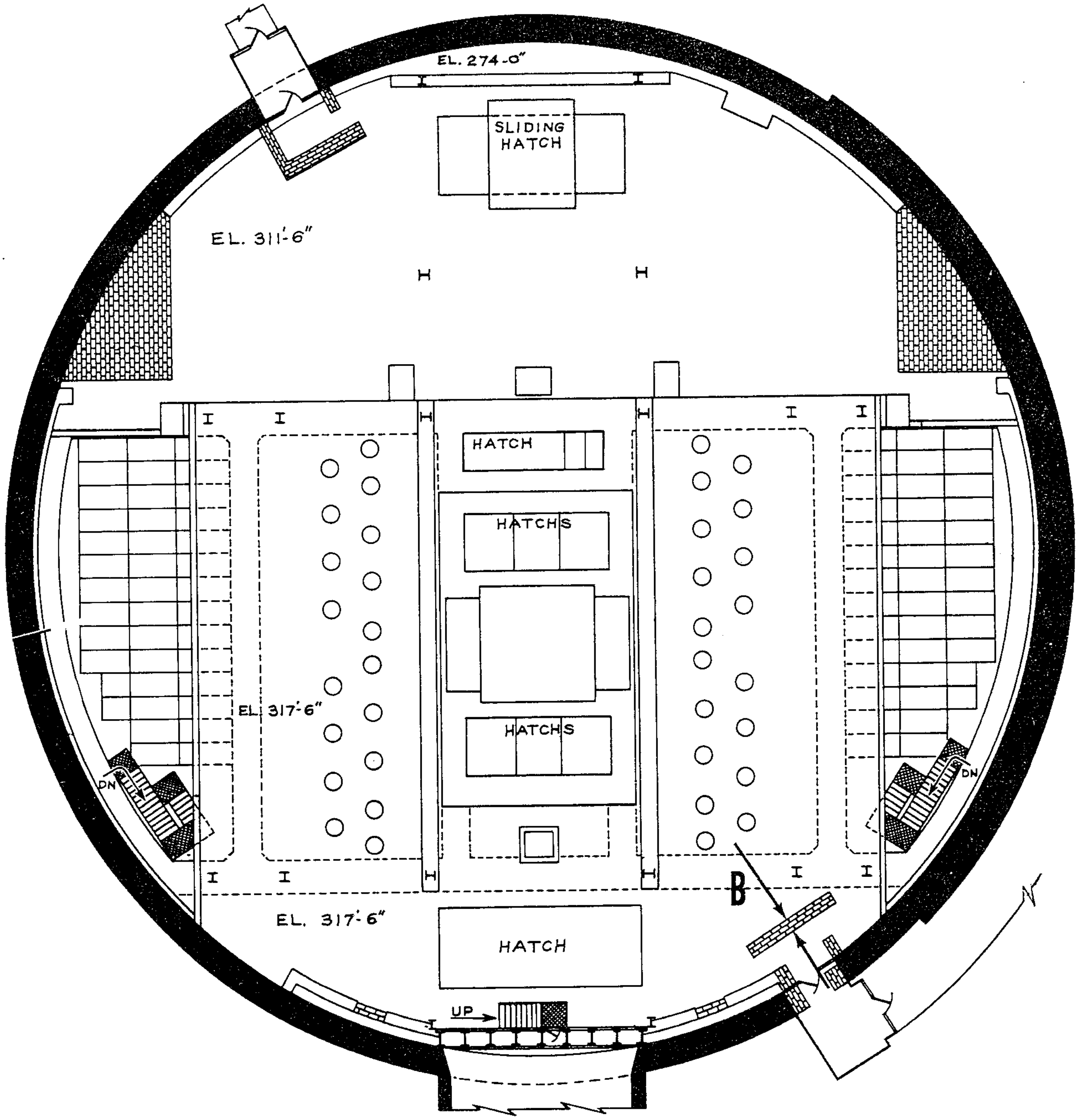
HEAT GENERATION CALCULATIONS

Point	Figure Reference	Purpose	Heat Generation
G	10.13-4	Heat generation rate in zone control rods	0.596 W/cm^3
H	10.13-3	Shutdown heat current into the concrete near the calandria pressure relief duct	28.6 mW/cm^2
J	10.13-4	Axial variation of heat generation in the thermal shield and calandria wall	.59 W/cm^3
K	10.13-4	Axial variation of heat generation in the thermal shield and calandria wall	.1567 W/cm^3
L	10.13-4	Shutdown heat generation in one end shield ring	121 kW
M	10.13-3	Heat current into concrete block closure of calandria vault	15.34 mW/cm^2
J	10.13-4	Heat generation in the calandria wall and thermal shield	0.59 W/cm^3 maximum
N	10.13-3	Heat generation in ion chamber shielding	2.66 kW
G	10.13-4	Shutdown heat generation in calandria tubes	730 kW
L	10.13-4	Operating heat generation in one end shield ring	69.9 kW
E	10.13-4	Heat generation in one tube sheet	420 kW
F	10.13-4	Heat generation in one end shield	530 kW
G	10.13-4	Heat load to moderator	88.6 MW



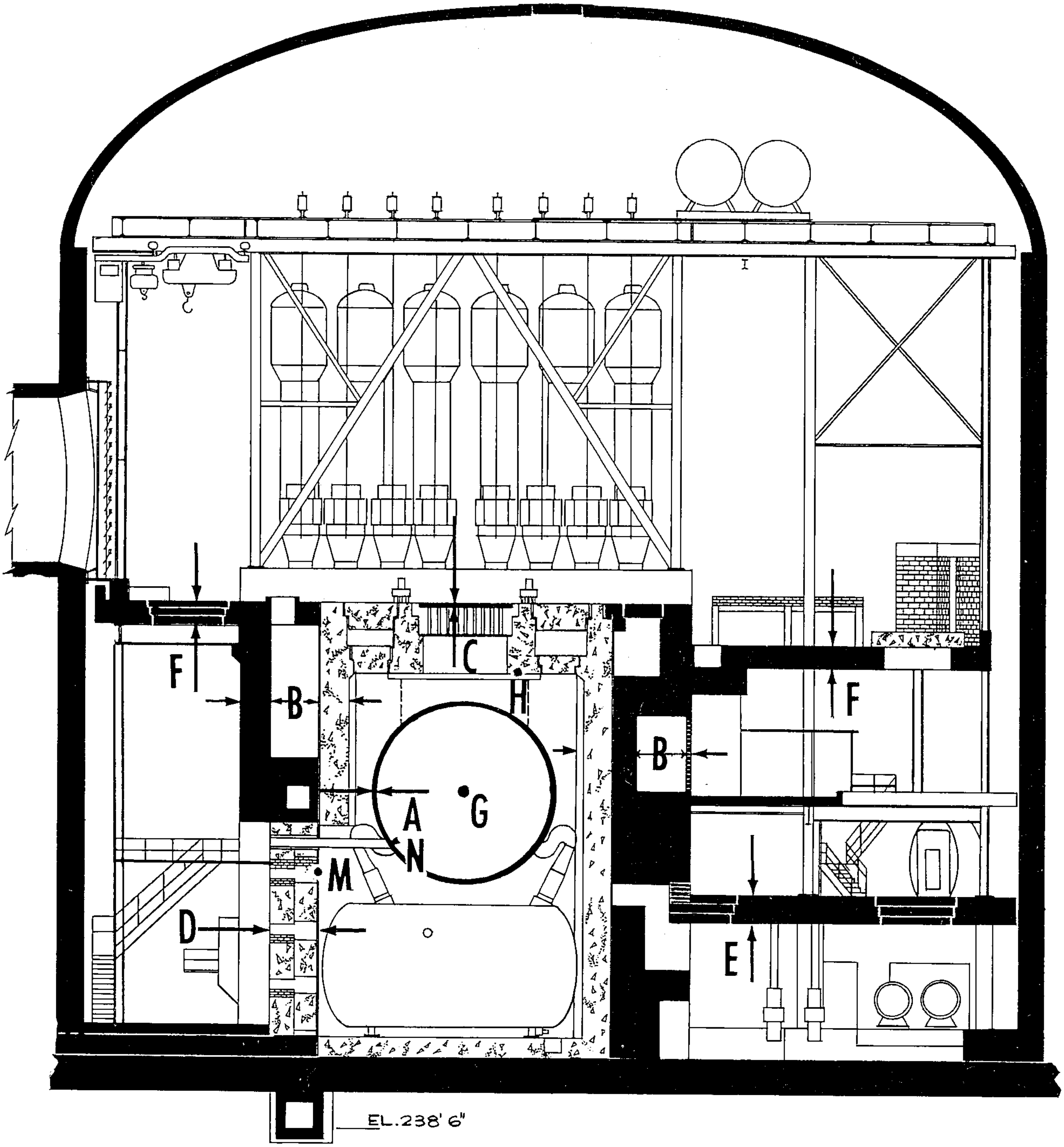
10.13-1 REACTOR BUILDING SHIELDING

44.01100—16
REV. I 1968.



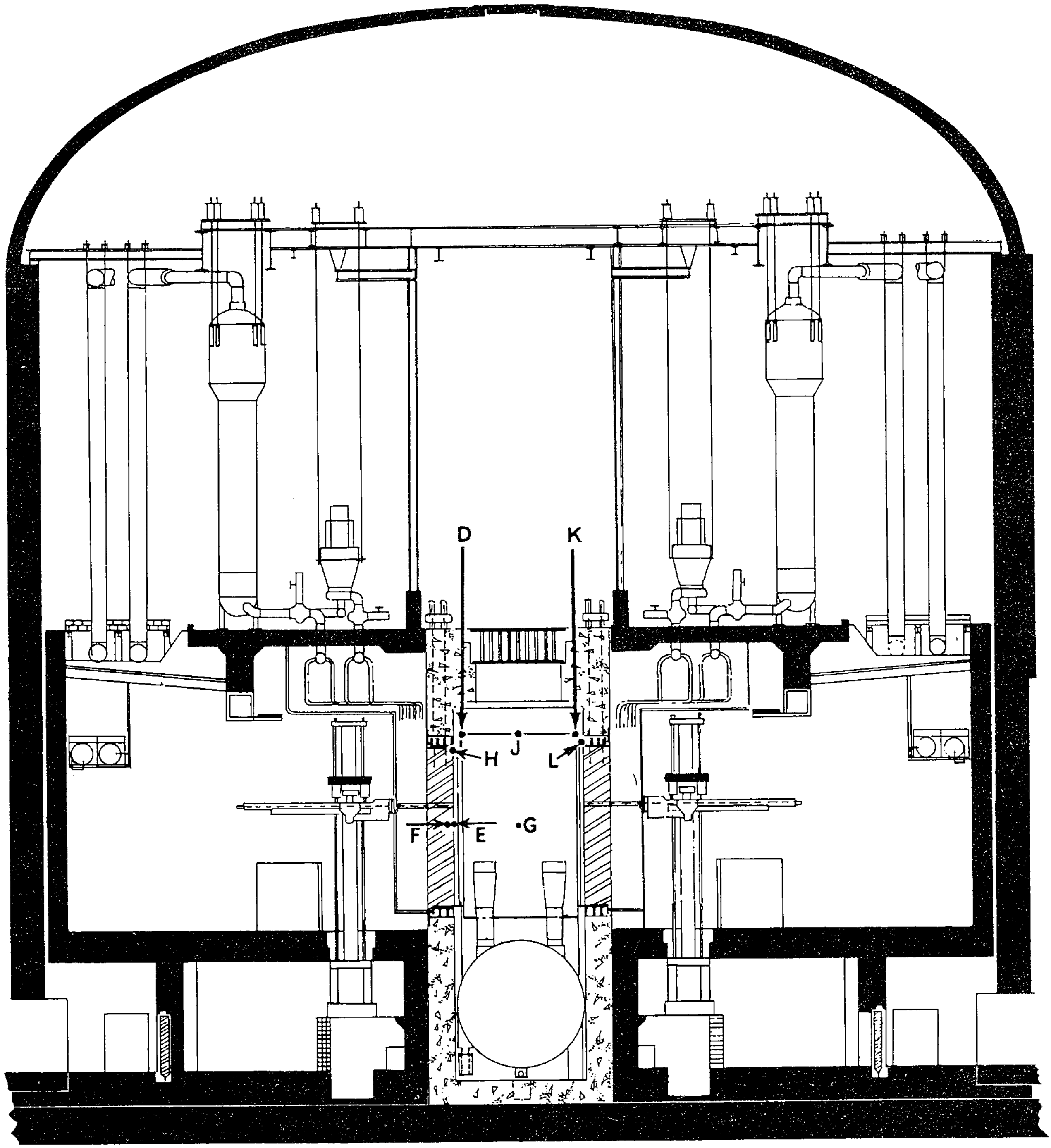
10.13-2 REACTOR BUILDING SHIELDING

44.01100—17



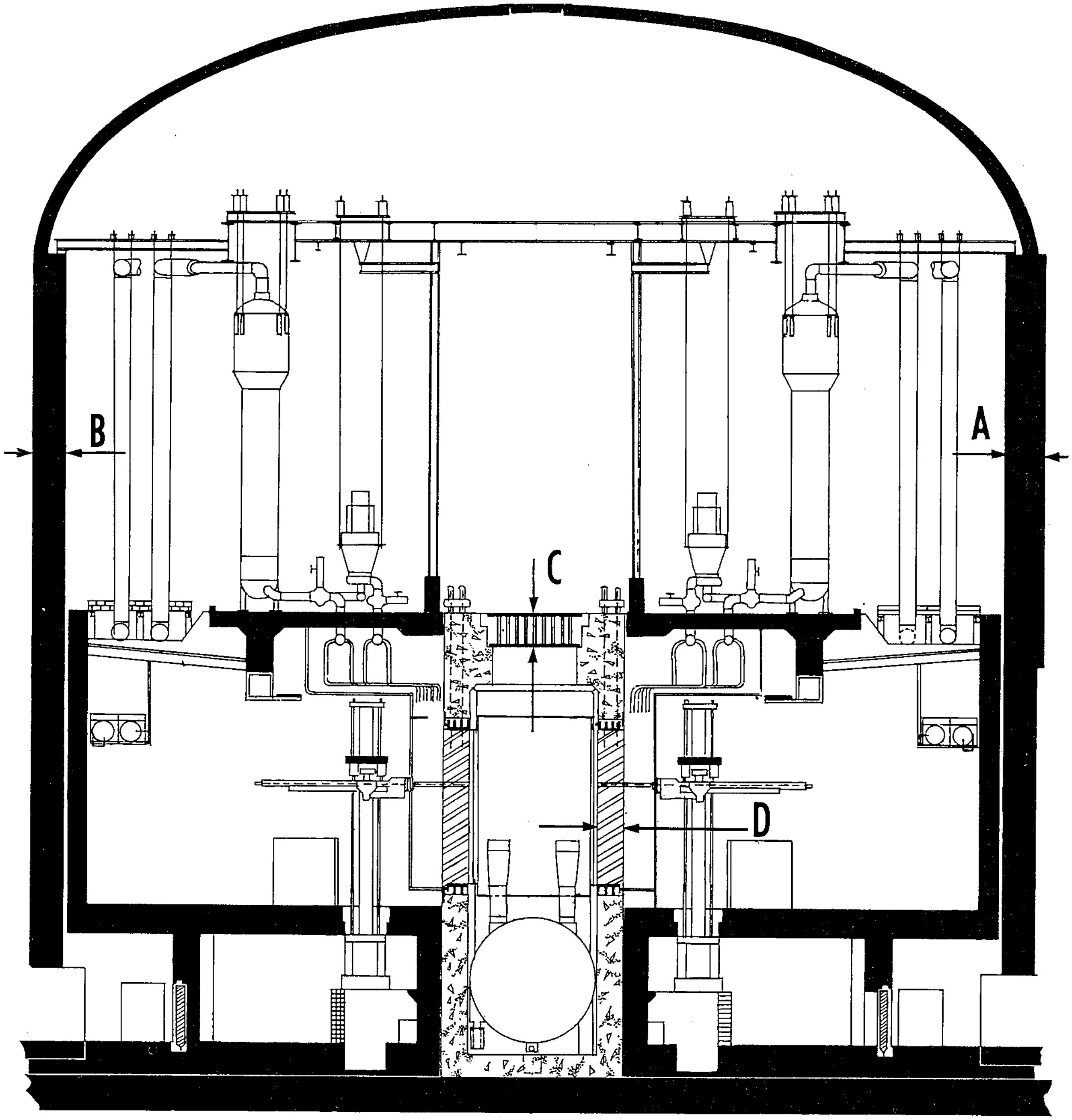
10.13-3 REACTOR BUILDING SHIELDING

44.01100—18



10.13-4 REACTOR BUILDING SHIELDING

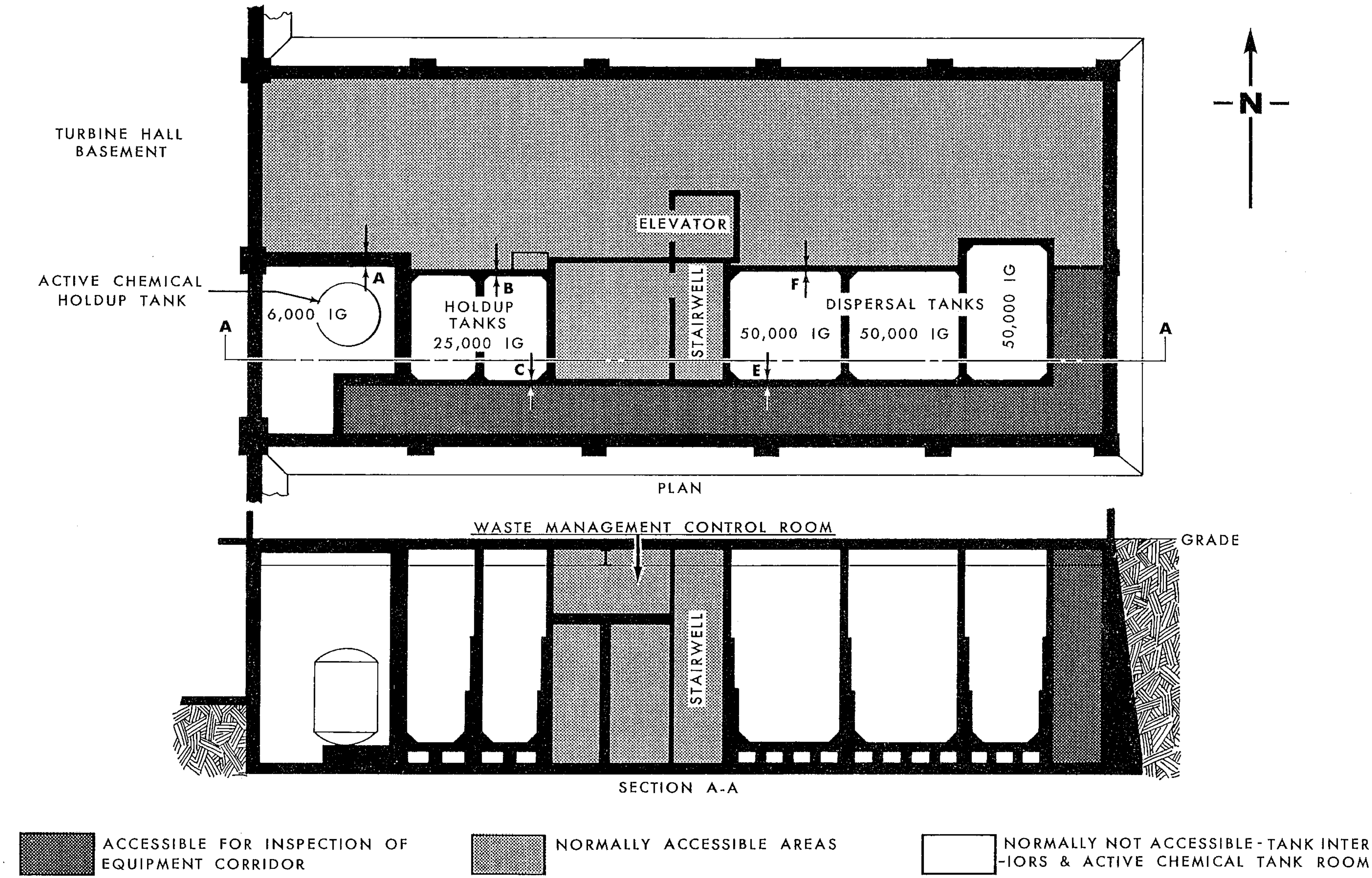
44.01100—19



LOOKING NORTH

10.13-5 REACTOR BUILDING SHIELDING

44.01100—20



10.13-6 LIQUID WASTE MANAGEMENT CONCRETE TANK ARRANGEMENT
(SERVICE WING BASEMENT)

44.01100-21
REV. 1, 1968

REFERENCES

(1) Fowler, T.B., and Tobias, M.L. "EQUIPOISE-3: A Two-Dimensional, Two-Group, Neutron Diffusion Code for the IBM 7090 Computer". ORNL-3199 — February 21, 1962

See Also:

Nestor, C.W. Jr., "EQUIPOISE-3A" ORNL-3199 ADDENDUM — June 6, 1962

(2) Fowler, T.B., and Tobias, M.L. "WHIRLAWAY-A Three-Dimensional, Two-Group Neutron Diffusion Code for the IBM 7090 Computer". ORNL-3150 — August 15, 1961

(3) Pease, L. "DEEMS, A Fortran Program for Solving First Degree Coupled Differential Equations by Expansion in Matrix Series". TDSI-49 — October, 1963

(4) Progress Report, Advanced Power Plant Engineering Division, PR-APPE-4 — July 1 to September 30, 1964

(5) Jarvis, R.G. "A Review of Diffusion Parameters for Thermal Neutrons in Light and Heavy Water, with an Appendix on the Thermal Neutron Absorption in Boron". AECL-2072 (CRRP-1203) — August, 1964

(6) "Project Outline for First Two 500 MWe Units of a Proposed Multi-Unit Nuclear Power Station for Ontario". TDI-3 — July, 1964

(7) Memorandum from Townes, B.M. to Duret, M.F. "LATREP Calculations for Pickering". — March 1, 1966

(8) Memorandum from Townes, B.M. to Duret, M.F. "Pickering Void Coefficient". — September 7, 1966

(9) Henderson, W.J. and Whittier, A.C. "Handbook of Shielding and Heat Production Calculations for the NRU Reactor". AECL CRR-578 (Revised) — January, 1955

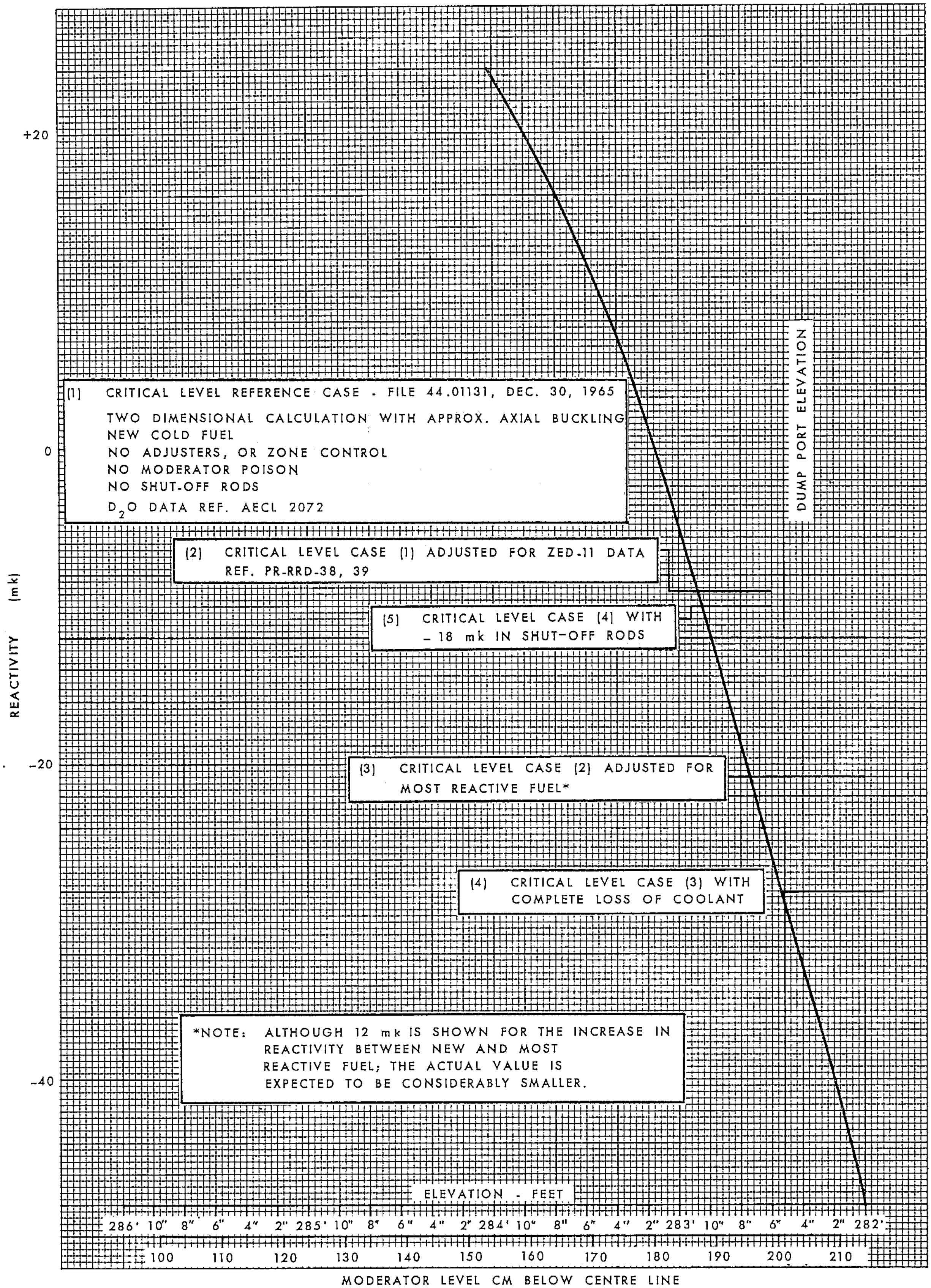
(10) Moteff, J. "Miscellaneous Data for Shielding Calculations". USAEC APEX-176 Oak Ridge. — December, 1954

(11) Chapman, G.T. and Storrs, C.L. "Effective Neutron Research Cross Sections for Shielding". USAEC AECD-3978 Oak Ridge. — September, 1955

(12) Whittier, A.C. Report No. 02-1-011300D. Official Use Only. Canadian General Electric Co. Ltd. — March, 1959

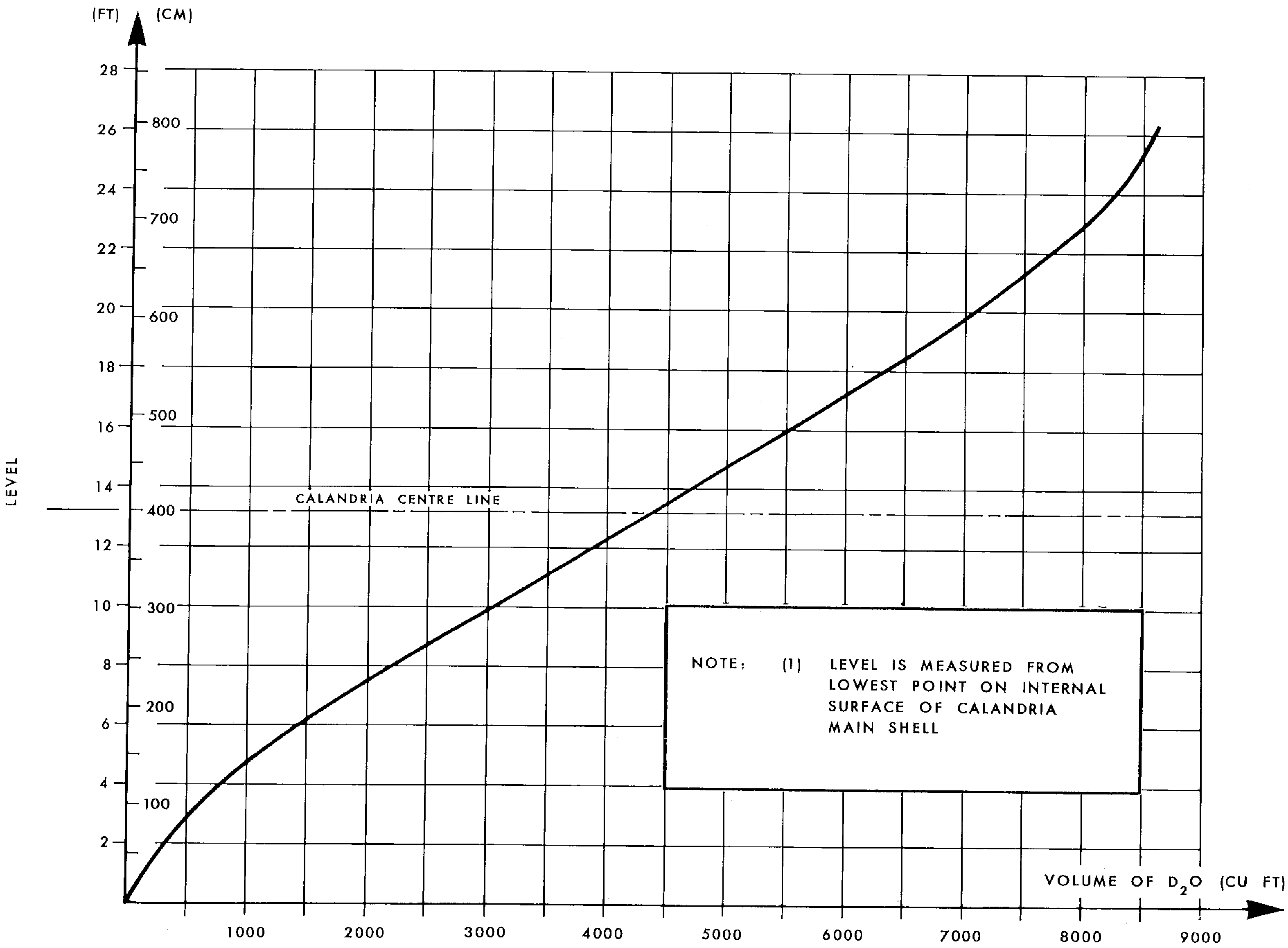
(13) Robson, J.M. "The Attenuation of Neutrons by the Side Shield of the NRU Reactor". AECL CRP-860 — October, 1959

(14) Rockwell, T. "Reactor Shielding Design Manual" (Chapter 9). McGraw-Hill — 1956



A-1 REACTIVITY VS. MODERATOR LEVEL

44.31200-2
1967



A-2 LEVEL VS. VOLUME OF D_2O IN CALANDRIA

44.31200-1
1967

APPENDIX I

DUMP TANK AND CALANDRIA CAPACITY

The dump tank is designed to hold all the moderator from the calandria drained to the lip of the dump ports (200 cms below the calandria centreline) plus one-half the primary coolant. A curve of reactivity against moderator level in the calandria, and one of calandria volume against level are attached. Critical levels for five specific conditions are shown in Figure A-1. Providing the extrapolation distance is 6 cm or less (as expected) the critical level will be less than 200 cms below the calandria centreline for the most reactive situation possible and dump alone would shut down the reactor.

In addition, all the shutoff rods are to drop to 271.5 cms below the reactor centreline. These rods will provide a minimum reactivity of -24 mk in the section of the core which is covered by moderator after a moderator dump. It would also be possible to drain all of the moderator out of the calandria into the dump tank by opening a valve in the lines from the dump tank and calandria to the circulation pump suction header.

To cope with the postulated accident situation in which all of the primary coolant somehow enters the moderator at a time when the core is in a very reactive condition, a 12 inch diameter drain line is provided from the calandria-dump tank to the helium storage tank. Any heavy water which is transferred to the helium storage tank would be available for emergency injection (either automatically or by remote-manual operation of a valve from the control room) if the dump tank level became low. The amount of heavy water which can be transferred back through the 12 inch diameter line would exceed that required for emergency injection at the time that the moderator in the dump tank would be expended.