Reactor, Boiler & Auxiliaries - Course 133

MAIN HEAT TRANSPORT CIRCUIT CONSIDERATIONS

In this section we will look at the main common features of the primary heat transport system used on our reactors, that are necessary for it to perform its principle tasks, and point out the variations that have occurred as the units increase in size.

These main features are listed and discussed in turn.

(a) Continuous coolant circulation providing heat transport to the main boiler(s).

(b) Core coolant flow should accomodate different channel powers to provide common outlet header temperature.

(c) Pump flywheels prevent sudden loss of coolant flow after loss of pumping power.

(d) Provision for adequate thermal circulation of coolant through the core after loss of pumps.

(e) Standby cooling system independant of the main boilers and pumps.

(f) Pressure control of the circuit.

(g) Overpressure relief for the main circuit pipework.

(h) Addition, removal and storage of coolant from the circuit.

Table 1 compares the heat transport features of our reactors which we shall now discuss.

(a) CONTINUOUS COOLANT CIRCULATION

NPD

The simplest type of main coolant circuit that is practical, allowing for the CANDU requirement of bi-directional flow in adjacent channels, is best illustrated by the NPD system (Figure 1). This represents a parallel pump type operation and consists of the following major components:

- 3 x 50% main coolant pumps (one on standby) in parallel configuration with suction and discharge headers for the bank of 3.

TABLE 1

PHT System Features of CANDU Stations

STATION	NPD	DOUGLAS POINT	PICKERING	BRUCE	PHW 600
No. of primary pumps	3	10	16	4	4
No. of primary pumps for 100% operation	2	8	12	4	4
Pump motor rating MW(e)	0.6	0.9	1.2	8.2	6.7
No. of coolant channels	132	306	390	480	380
Maximum channel power (MW(th))	1.0	2.7	5.1	5.7	6.5
Heat transferred to boilers MW(th)	80	659	1661	2387	2027
Total coolant flow rate (Mg/sec)	0.7	3.4	7.8	11.4	7.4
Pump Capacity (m^3/sec)	0.38	0.72	0.76	3.3	2.2
Total D_2O in system cold (Mg)	13	50	160	230	180
Reactor inlet header temperature °C	252	249	249	253/264	266
Pressure MPa(a)	7.9	10.0	9.7	10.0	11.2
Reactor outlet header temperature °C	277	293	293	300	310
Pressure MPa(a)	7.3	9.2	9.1	9.0	10.0
Pressurizing system	pressurizing tank	feed & bleed	feed & bleed	pressurizing tank	pressurizing tank

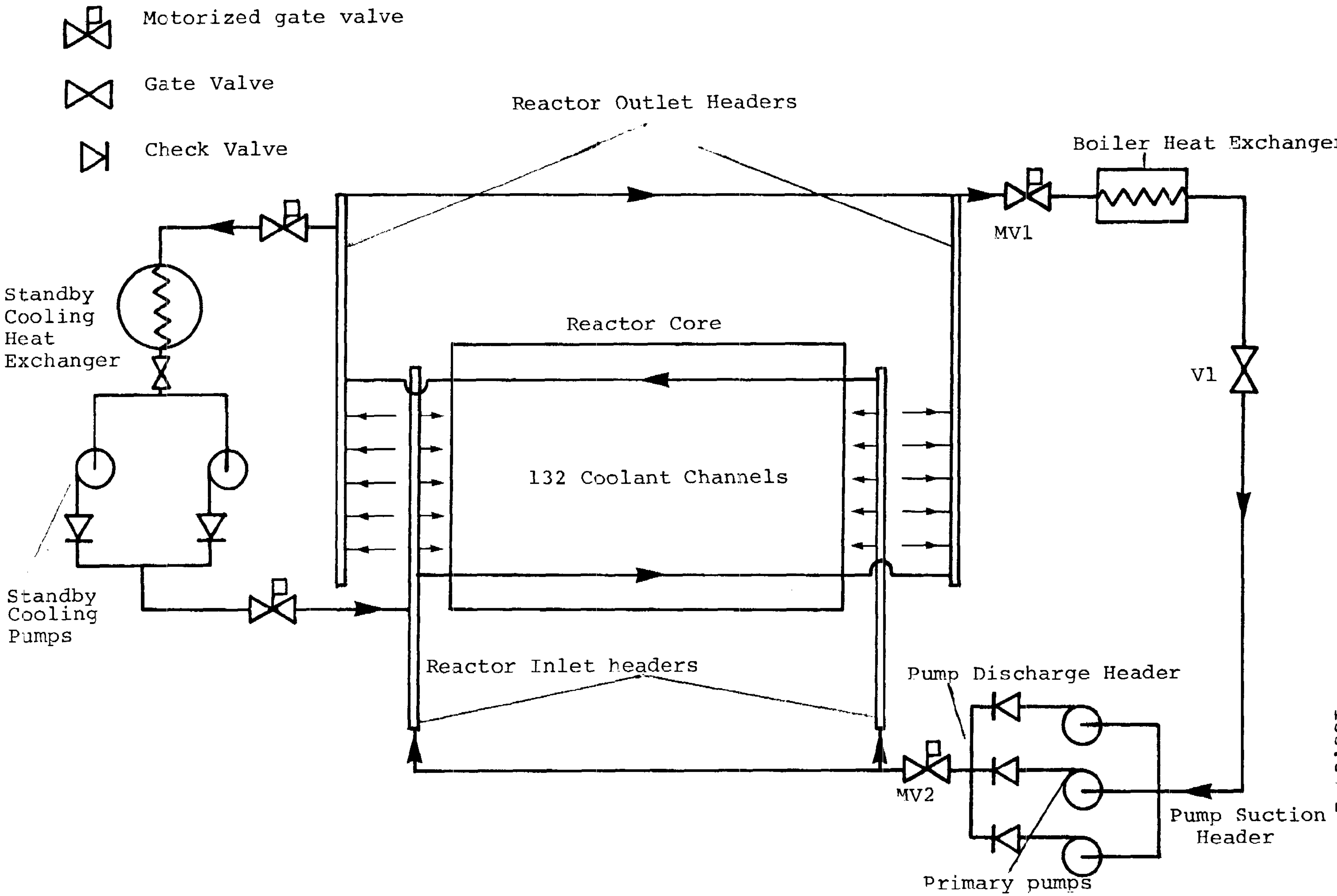

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Figure 1: NPD Main PHT Circulating System

- 1 main boiler heat exchanger, situated upstream of the pump suction headers to reduce the possibility of cavitation.

Isolation is provided for the boiler, and the three pumpsets as a group, by isolating valves MV1 and MV2. Valve V1 then allows individual isolation for the boiler. Check valves on each of the pump discharge lines prevent back flow and reverse rotation through the idle standby pump although a small amount of flow is allowed to pass through the closed check valve to maintain the standby pump close to system temperature, to avoid pump casing stresses on startup.

This method of component isolation is not identical to other stations, nor indeed necessary, and the differences will be mentioned for other reactor units.

Douglas Point

At Douglas Point, and as in all future units, the basic circulating system was changed to a series/parallel "figure of 8" type pumping circuit, Figure 2. This system provides a symmetrical double ended arrangement of pumps and boilers in series at each end of the reactor, making up a single coolant loop. The pumps and boilers are then in parallel groups at each end of the reactor, larger numbers than NPD being required because of increased size and flow of the system.

This arrangement has the following advantages over the simpler parallel pumping circuit of NPD.

(a) less pumping power is required as a fraction of total reactor power.

(b) in a parallel system connecting pipes are required around the reactor to join the common headers at opposite ends of the reactor increasing D_2O hold up and hardware costs. In a series/parallel system the headers do not have to be joined in this manner.

A disadvantage of a series parallel pumping system is the pressure differential which can result between corresponding headers at opposite ends of the reactor and is called system unbalance. This is not serious in a parallel system as the headers are connected by large diameter piping but can be a problem with series/parallel pumping.

In addition a series parallel arrangement means usually that for adequate reliability a large number of pumps at each end of the coolant loop may be required as loss of a pump set with a smaller number/end means that overloading occurs more easily than in a parallel arrangement.

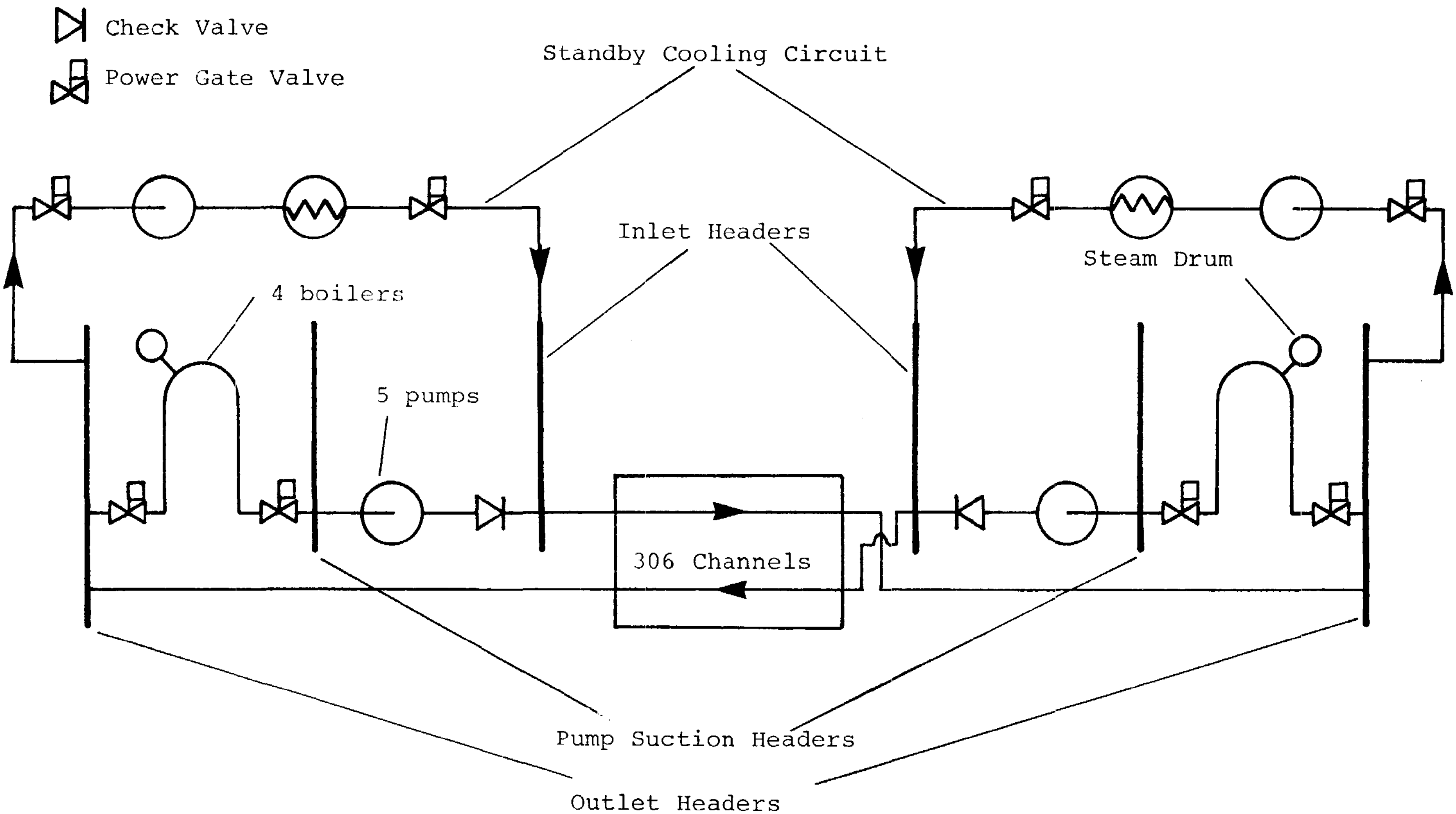

Figure 2: Douglas Point PHT Main Circulating System

Isolation here is provided for each individual boiler as shown, by gate valves and for each bank of pumps by provision of check valves on the pump discharge lines which can if required, be locked to provide isolation and are hence called stop and check valves.

A schematic of the boilers, pumps and headers is shown for Douglas Point in Figure 3.

Pickering A & B

As a result of the larger coolant flow required for these units and the limited pump size available at the time of design the circuit here comprises of two series/ parallel coolant flow loops (Figure 4).

This has the advantages of reducing the lengths of the main headers required, although now two inlet and two outlet headers are needed at both ends of the reactor (Figure 5), and reduces the rate of coolant blowdown after a header rupture.

To compensate for system unbalance between the headers, more of a problem now with 2 loops than with one, small diameter piping connects the headers via motorized valves which can be closed on a loss of coolant accident (LOCA) to reduce the blowdown rate.

Isolation of the components here, is similar to Douglas Point, and is for the boilers (12) individually and for each bank of pumps (4 operating, 1 standby) provided by motorized gate valves on the pump discharge lines, no check valves being used as a result of poor reliability and leakage experienced with the Douglas Point check valves, which require considerable maintenance.

The two coolant loops cannot function with one shutdown and one operating but future 1200 MW(e) and 2000 MW(e) units are expected to have the flexibility of independant coolant loop operation.

Bruce A & B, 600 MW(e) and larger units

A major change in the main circulating system was made for these units in that no standby pumps are available, sufficient reliability being available from previous experience, to justify this. Single loops (Bruce) or double loops (600 MW(e)) can be used according to pump size, header costs and safety requirements from LOCA considerations.

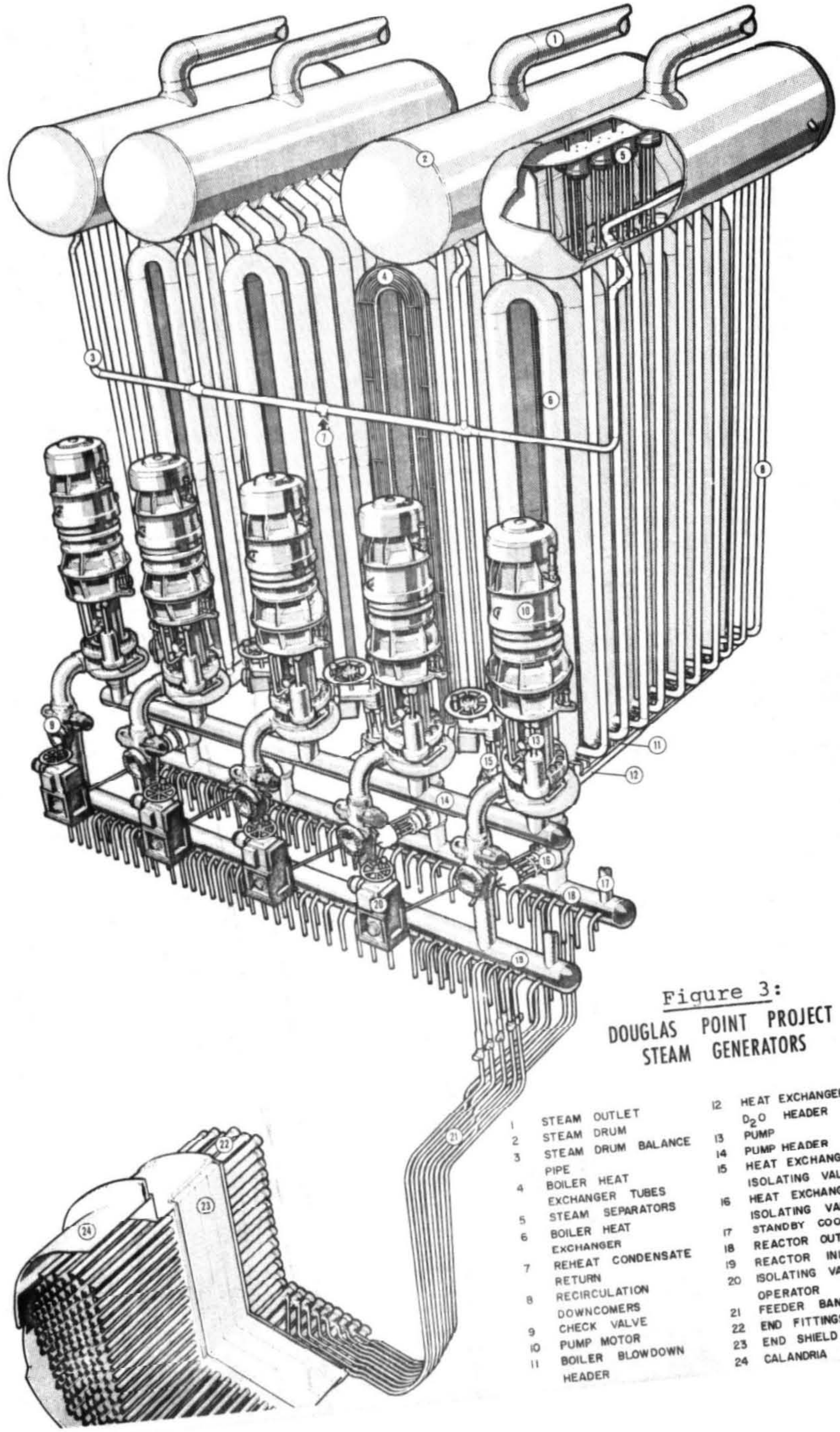

Figure 3:
DOUGLAS POINT PROJECT
STEAM GENERATORS

1 STEAM OUTLET
2 STEAM DRUM
3 STEAM DRUM BALANCE PIPE
4 BOILER HEAT EXCHANGER TUBES
5 STEAM SEPARATORS
6 BOILER HEAT EXCHANGER
7 REHEAT CONDENSATE RETURN
8 RECIRCULATION DOWNCOMERS
9 CHECK VALVE
10 PUMP MOTOR
11 BOILER BLOWDOWN HEADER
12 HEAT EXCHANGER D_2O HEADER
13 PUMP
14 PUMP HEADER
15 HEAT EXCHANGER OUTLET ISOLATING VALVE
16 HEAT EXCHANGER INLET ISOLATING VALVE
17 STANDBY COOLING INLET
18 REACTOR OUTLET HEADER
19 REACTOR INLET HEADER
20 ISOLATING VALVE OPERATOR
21 FEEDER BANK
22 END FITTINGS
23 END SHIELD
24 CALANDRIA

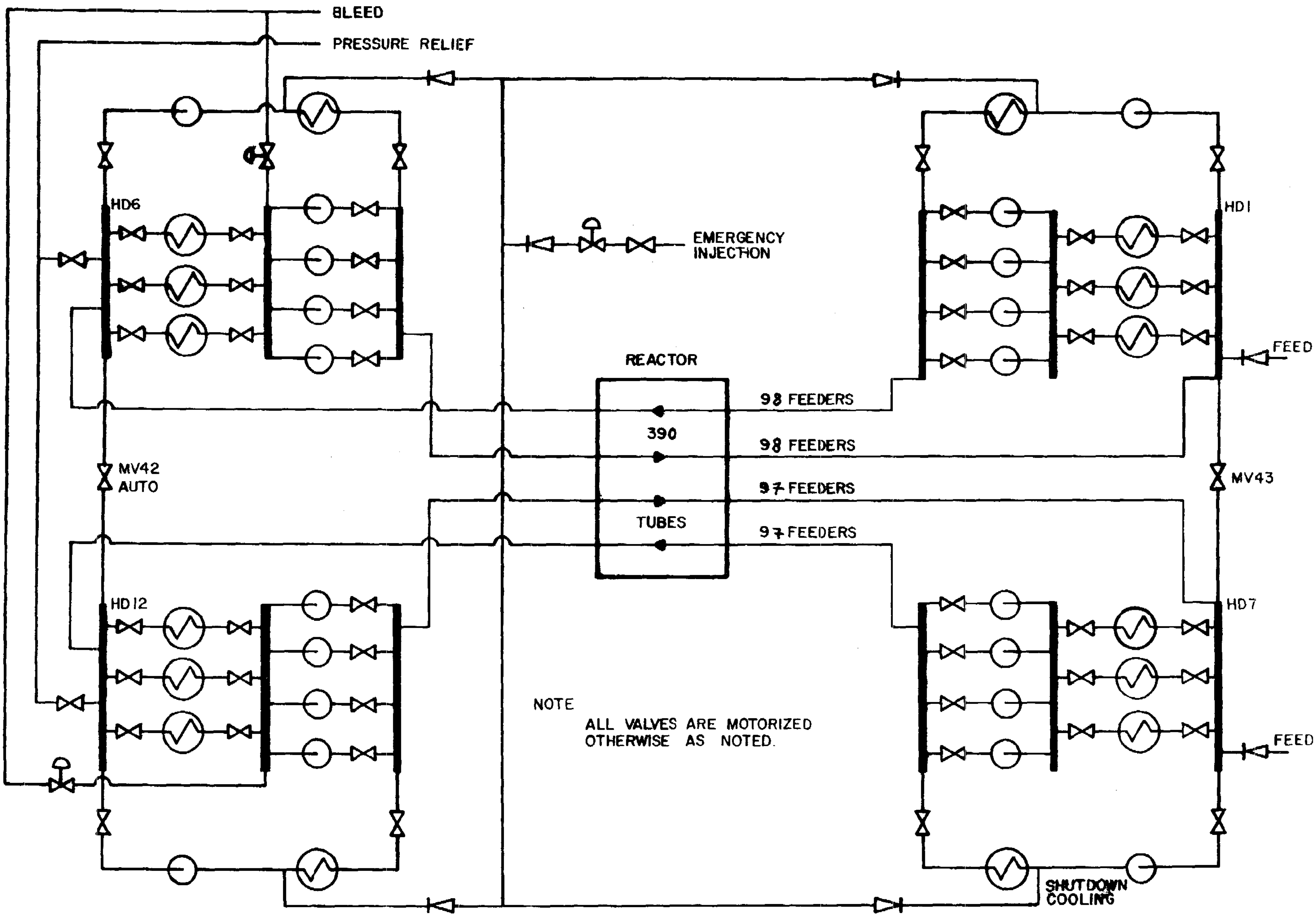

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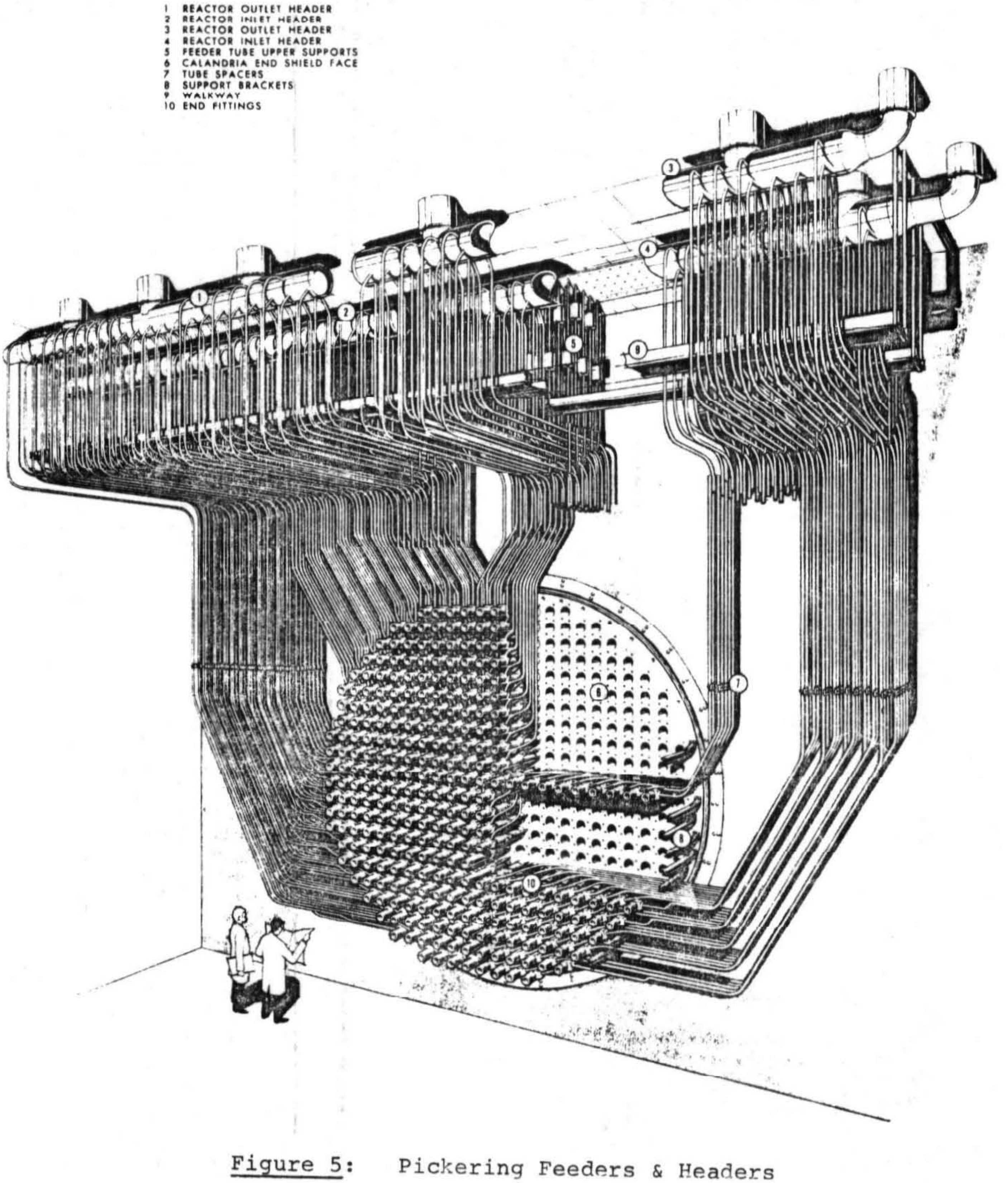
Figure 4: Pickering PHT Circulating System



<u>Figure 5:</u> Pickering Feeders & Headers

In addition these stations have no valves in the main circuit which is all welded construction, except for bolted Grayloc couplings joining the feeder pipes to the end fittings. The Man-rem maintenance and capital cost of valves is now considered too high to warrant their use. Reverse flow through a non-operating pump is reduced by locking the pump, the flow then continuing through this pump and the rest of the circuit at a reduced rate, hence derating is required with a non operating pump.

The other difference with these newer systems is the provision of feedwater preheaters through which part of the primary coolant flow passes. This part of the coolant flow is then cooled in the preheater, the extracted heat being used to raise the boiler feedwater temperature (preheating). This flow then passes through the inner zone of the reactor core which is split into a "two-zone-core" and experiences a larger temperature rise through the inner zone than the coolant moving directly through the outer zone (Table 1).

The reasons for this two zone system, which allows some channels in the outer zone to achieve about 3% steam quality is that this allow the outlet headers to run under saturated conditions whereas in previous units the headers ran with sub cooling. This allows better fuel burn up to be achieved and in addition the two-zone core enables a higher secondary side steam pressure to be achieved than a single zone core which would need to have many more boiling channels to achieve the same steam pressure.

Isolation of the main pumps and boilers in these systems is achieved by depressurizing the main system, circulating through the maintenance cooling circuit, (section (e)) and draining the heat transport system to any level above the main header. The pumps and boilers being situated above the header are then isolated for maintenance such as boiler tube repair or pump maintenance.

(b) CORE COOLANT FLOW

In order to obtain a common channel outlet temperature and hence a common outlet header temperature to reduce thermal stresses, individual channel flow rates must be matched with their (different) channel power ratings.

Four general methods are available of achieving this flow matching:

(i) the use of different size feeder pipes

(ii) the use of orifice plates in the inlet feeders or end fittings.

(iii) the use of orifice holes in channel shield plugs.

(iv) channel flow can be maintained nominally the same and different inlet temperatures used.

Different combinations of these methods are used in the stations according to whether it is possible to achieve adequate trimming by one method alone and also to achieve flexibility to be able to change flow requirements at some time.

For instance, at NPD, same diameter feeders are utilized and each channel has an orifice plate in the end fitting. These are removable by the fuelling machine and proved their flexibility when NPD was used in a coolant boiling mode some years ago when flow rates needed to be adjusted.

Douglas Point uses different feeder pipe sizes, or orifice plates in the inlet feeders and also (replaceable) orifices in channel shield plugs.

At Pickering, however, shield plugs are identical and flow trimming uses feeder pipe sizing and inlet feeder orifice plates.

Bruce, on the other hand, as a result of allowing some boiling in the outer zone of its two zone core uses different feeder pipe sizes and the same coolant flow/channel. The different channel inlet temperatures (Table 1) then allow (within limits) uniform channel outlet temperatures to be achieved. Here then the inner zone channels will experience larger temperature rises than the outer zone (lower power rating) channels.

There is a limit on the channel coolant velocity that is allowed (<10 m/sec) and hence on the coolant flow rates and this is set by the problem of fretting of the fuel bundle on the inside of the pressure tube.

(c) PUMP FLYWHEELS

A heavy flywheel is always attached to primary pumps to maintain impeller rotation for a short time after power has been lost such as a complete class IV power failure. This maintains forced coolant circulation which is sufficient to match the power run down behaviour of the fuel.

Figure 6 shows this behaviour after a reactor trip on loss of pumping power. Initially the rate of power decrease (fission power mainly) depends on the prompt neutron decay rate (first few seconds) and then on delayed neutron decay, up to about 3 minutes after which overall rate of power decrease is essentially that of the fission product decay rate only.

After the pumps come to rest typically a few minutes or so after tripping there will be ~3% of full power to be removed from the fuel and this is achieved by:-

(d) THERMAL CIRCULATION OF THE COOLANT

To take over heat removal after the main coolant pumps have tripped and run down, natural convection circulation of the coolant is adequate and can be conveniently used during an extended class IV outage. The boiler location is always above the reactor to achieve this by acting as a heat sink enabling thermosyphoning to remove the decay heat. The temperature of the PHT system can also be cooled down from ~250°C to ~150°C by this means in about 30-40 minutes, if, say, the class IV outage is expected to result in a poison shutdown. The heat is removed in this case by generating steam in the boilers. This steam can be removed from the secondary side of the boilers via steam discharge (or reject) valves by venting to atmosphere or the lake, as at Douglas Point and Pickering.

At NPD steam rejection is via the reject condenser. At Bruce it is via the main condenser, the turbine being bypassed, or to atmosphere via reject valves.

If it is necessary to cool below ~150°C there is not enough steam generating capability available to do this using natural convection and hence the temperature becomes self regulating and stabilizes.

This type of cooling could be used for a few hours on an extended class IV outage, until boiler water is no longer available and the boilers become depressurized, boiler feed pumps being on class IV power.

At Pickering 2 large emergency supply tanks of feed water are available to extend this time for about another 2 hours. However, here the feed pumps have a backup pump (rated at 2% normal feedwater flow) on class III supply capable of supplying cooling feedwater indefinitely.

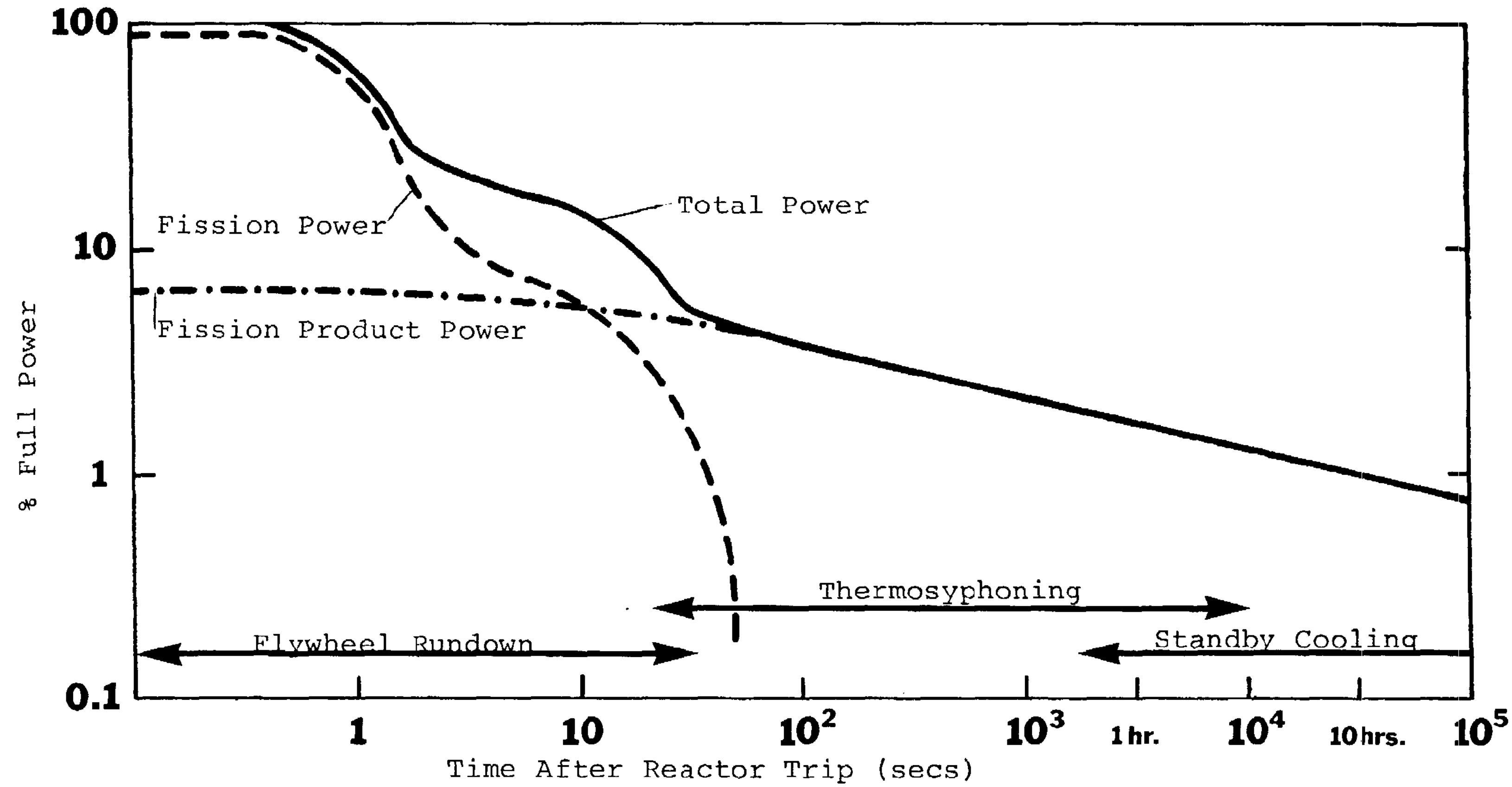


Figure 6: Power Rundown After Reactor Trip and Heat Removal Methods in Absence of Primary Pumps.

For indefinite long term cooldown requirements and for cooldowns below 150°C however a separate system is provided by the:-

(e) STANDBY COOLING CIRCUIT

This circuit is used as an independant PHT cooling system under the following conditions:-

(i) To enable the PHT system to be cooled and controlled below the ~150°C limit achievable by thermosyphoning through the main boilers, down to the cold (~60°C) shutdown state, and still maintain the system pressurized.

This use might be required after a class IV power failure resulting in a poison shutdown when thermosyphoning is not available long enough to maintain hot, pressurized conditions in the PHT system. The standby cooling circuit is thus rated to remove, indefinitely, long term fission product decay heat, which is ~ 1-2% of full power (see Figure 6).

(ii) To cool the reactor down to cold depressurized conditions when main boiler and pump isolation is required for maintenance.

(iii) To cool the PHT system down, in an emergency from hot pressurized operation to cold depressurized operation. This might be required, for instance at Pickering, when the steam discharge valves are not available to cool the system down quickly via thermosyphoning from 250°C to ~150°C and would be carried out immediately following main pump rundown when thermal power would be ~5% full power.

Thermal stresses resulting in the tube to tubesheet joints of the heat exchanger would however be undesirable in this case and there is a limit on the number of times the standby cooling heat exchangers can tolerate use of this emergency "crash cooling" mode of operation.

Typical equipment required is illustrated in Figures 1, 2 and 4 and consists of a pump, heat exchanger and isolating valves which short circuit the main boilers and pumps of the main system. Each station has a single standby cooling loop for each main pump/boiler bank giving, for instance, 4 loops at Pickering.

Usually the pump is situated upstream of the heat exchangers (except at NPD) to reduce the possibility of pump cavitation due to pressure drop across the heat exchanger. The heat exchangers are usually of the U-tube and shell type with monel or inconel tubes and carbon steel shells with double tube sheets.

No backup standby pumps are provided, all normally operate (from class III supplies). Failure of one standby pump in a loop will result in reduced flow which will still be sufficient to remove normal decay heat via the other pump(s) at somewhat higher temperature.

Under normal conditions isolating valves as shown ensure the standby cooling circuit is not operating during the main PHT pump operation and vice versa.

At Bruce, the standby cooling system is somewhat different, separate pumps and heat exchangers not being provided. As a result of the provision of preheaters for the two-zone core, cooling from ~180°C down to ~55°C is achieved by transferring heat from the PHT system to H_2O service water via the preheaters. With this system the main coolant pumps have to be kept running and the system maintained pressurized.

When main coolant pumps have to be stopped a separate maintenance cooling system is used, similar to the standby cooling system of previous units having a heat exchanger and pump to redirect the PHT system. By use of the MCS then the main system can be depressurized and partially drained to allow pump, preheater or boiler maintenance to be performed.

(f) PRESSURE CONTROL

The purpose of the pressure control system is to maintain the PHT system pressure constant and to allow for system volume changes during warm up (swell) and cool down (shrinkage).

Two different methods are used in CANDU stations for heat transport system pressure control:-

(i) pressurizing surge tank method

(ii) feed and bleed or "solid" system.

The detailed control of these two methods is dealt with in level 3 Instrumentation and Control so we shall only be concerned with the general operation and hardware features of the systems. Basically the choice between which system is utilized depends on whether the unit is designed for load-following or reactor-following.

For load following units such as Bruce and NPD (originally) fairly large volume changes may be occurring quickly in the PHT system and here the surge tank is preferred to accomodate these changes. As these units allow (or have allowed; NPD) coolant boiling, again this system is preferred.

The feed and bleed system, as described later, depends on the natural compressibility of D_2O to absorb volume changes without experiencing excess pressure variations and hence is more limited than the surge tank in principle. Hence for base load stations such as Pickering and Douglas Point then the feed and bleed system was chosen.

An advantage of the feed and bleed system is that purification circuit flow can be incorporated into this system easily while with a pressurizer tank an additional circuit is needed for purification, and this in fact forms essentially a feed and bleed type system which has to provide low temperature low pressure conditions for IX column resins.

Pressurizing Surge Tank

With this pressurizing system a tank is used and connected directly onto the heat transport main circuit at the reactor outlet header, where the pressure is measured. (Figure 7) The level of D_2O, in this tank is maintained to cover electric heaters immersed in the D_2O, which provide the means of pressurizing the vapour space above the liquid.

A D_2O spray system may be incorporated into the tank for rapid depressurization by vapour condensation and also for fine pressure control. This supply, if used, would be taken from a high pressure point, such as the reactor inlet header, and controlled by a regulating valve.

The surge tank D_2O level is then controlled to cover the heaters and also to accommodate the swell from the main circuit while raising the power and as a result the pressurizer level set point will vary with the reactor power due to swell or shrinkage; being a minimum at low reactor power. Deviation of this level from the set point, at a given power, is then taken care of via a feed and bleed control.

At NPD this control is called a charging circuit and serves in addition to provide coolant feed for the purification IX columns.

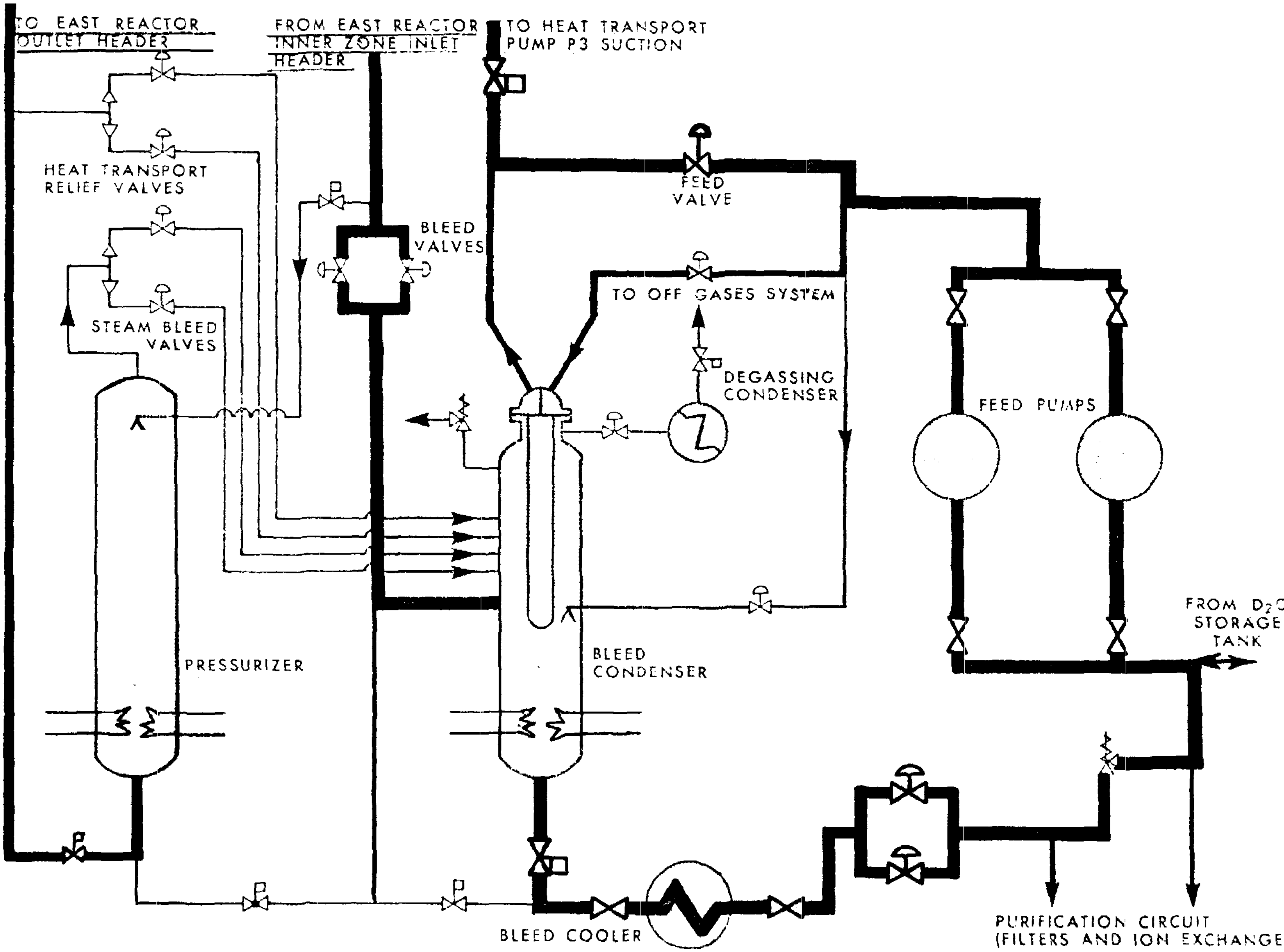


FIGURE 7: HEAT TRANSPORT PRESSURIZER, FEED, BLEED & RELIEF CIRCUIT
(Bruce GSA)

At Bruce this feed and bleed takes essentially the same form as the feed and bleed pressure control system as used at Pickering (next section) but it is not actually used for pressure control but rather to control the feed flow in order to maintain the D_2O level in the pressurizer. In addition, it conveniently provides temperature and flow control for the purification IX columns. The combination of the pressurizer and feed and bleed circuit is shown for Bruce in Figure 7.

Feed and Bleed System

In this method of pressurization, use is made of the compressibility of D_2O, the system being said to be "solid" in contrast to the vapour space above the D_2O in the pressurizing tank system. To allow for shrinkage D_2O is pumped into the main circuit by the feed system and to allow for swell, D_2O is released from the main circuit by the bleed system. Figure 8 shows a typical feed and bleed system based on Pickering GS. Douglas Point is similar in principle but the detailed design was modified considerably for Pickering.

The bleed circuit, as shown takes off D_2O from the main circuit from the primary pump suction headers on one side of the reactor, (the lowest temperature and pressure point of the main system) via two control bleed valves, for reliability.

The bled D_2O is then flashed to a lower pressure ~2 MPa, at saturation temperature ~210°C, into a bleed condenser, Figure 9, designed to condense the flashed vapour.

The flashed D_2O in the bleed condenser can be condensed by two methods:-

(i) reflux cooling - this is indirect cooling provided by D_2O coolant, in reflux coils, taken from the feed and bleed pressurizing pumps discharge (see below).

(ii) spray nozzle cooling - this is direct cooling utilizing D_2O coolant taken from the feed and bleed pressurizing pump discharge, used as a back up for (a).

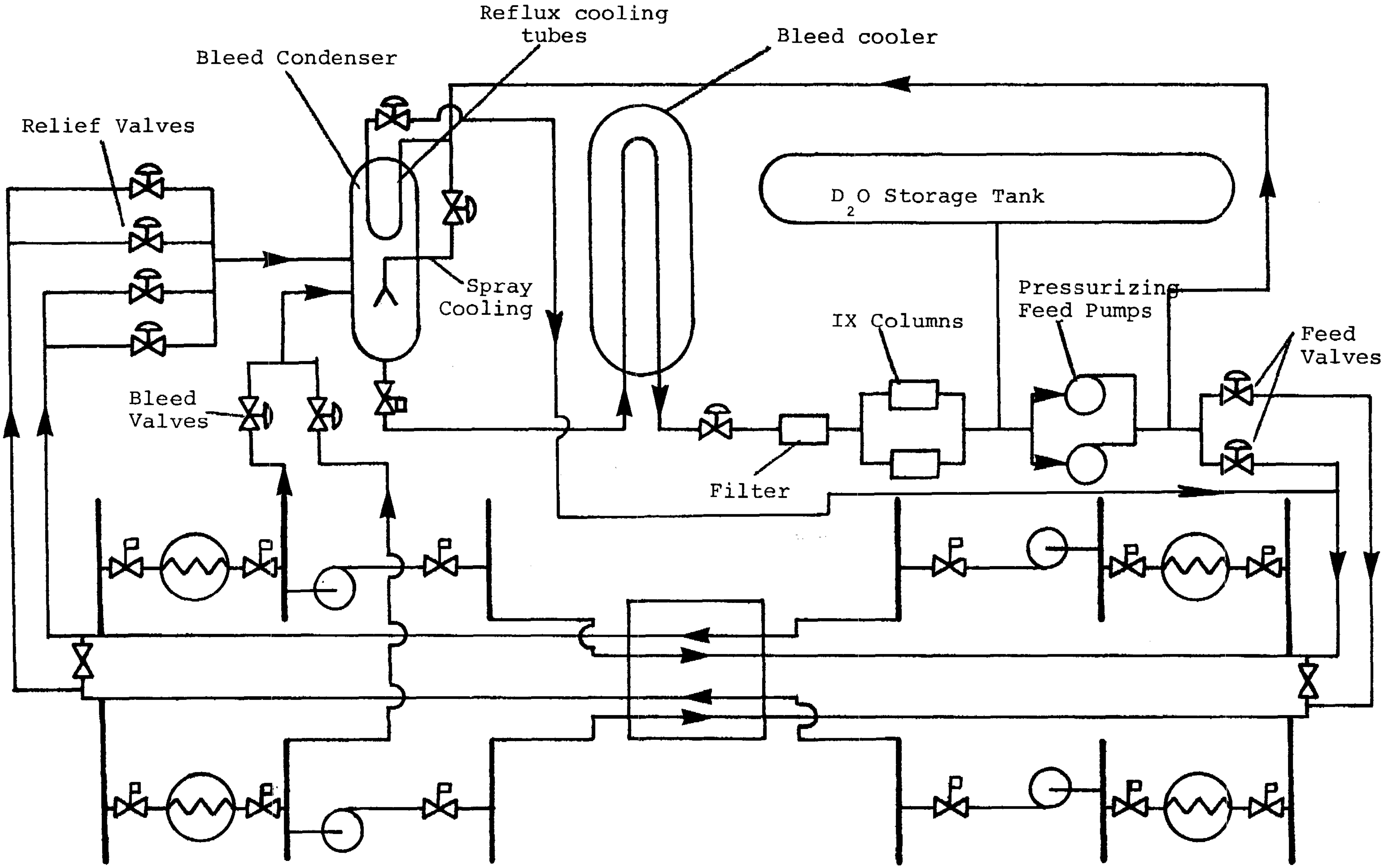


Figure 8: Feed and Bleed Pressurizing System (Pickering GSA)

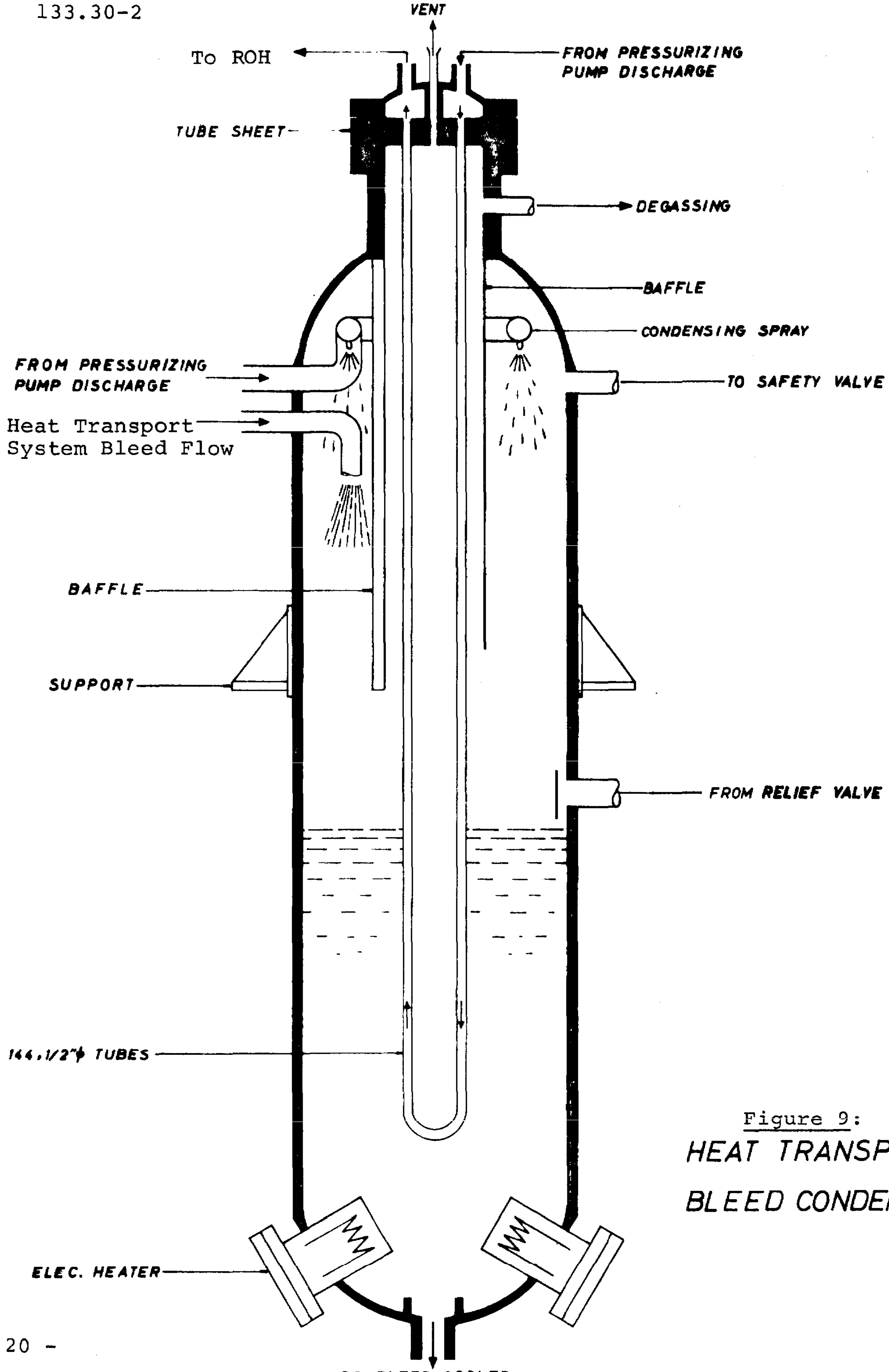


Figure 9:
HEAT TRANSPORT BLEED CONDENSER

This condenser at Pickering eliminated what was called the bleed tempering equipment at Douglas Point where condensing bleed was mixed directly with a portion of the cooled bleed flowing out of the bleed condenser. This equipment turned out to require redesign and so at Pickering the indirect reflux cooling was utilized.

The bleed condenser also provides a means for degassing and also convenient direct relief capacity for main system overpressurization, unlike Douglas Point which has a, more inconvenient, separate surge cooler and receiver for this purpose.

The condensate in the bleed condenser is then drained away to a bleed cooler the purpose of which is to reduce the temperature of the bleed flow to ~40°C and pressure to ~900 kPa. This is not practical to achieve in the bleed condenser alone due to thermal stresses. Coolant on the shell side of the bleed cooler is recirculating service water.

These requirements on temperature and pressure are because the feed and bleed circuit provides a convenient D_2O flow directly to the IX purification system, the columns of which require relatively low pressure low temperature water (section 30.3).

The outflow of the bleed cooler then passes through the IX columns into the feed system back into the main circuit. The feed system consists of 2 x 100% pressurizing feed pumps providing a high discharge pressure. From the pump discharge feed is made via 2 feed valves, back into the main circuit at the reactor outlet headers, at main system pressure, but at low temperature.

Under normal operating conditions then the volume of D_2O in the main system remains constant and a small feed flow is fed continually into the main system and at the same time an equal amount of D_2O is bled from the system via the bleed valves. Pressure signals from the reactor outlet headers (which represent the best average pressure conditions in the main circuit) then manipulate the feed and bleed valves to maintain the required pressure set point in the headers.

Under transient pressure changes in the PHT system, such as cooling with consequent shrinkage then feed flow will increase. If heating and consequent swelling in the main circuit occurs then the bleed valves will adjust to increase the bleed. The capacity required of the feed and bleed system is designed to be adequate for most transient conditions during normal operation such as reactor power changes or the tripping of a main heat transport pump.

(g) PRESSURE RELIEF

Overpressurization of the PHT system could occur as a result of the following conditions:-

(i) failure of the pressurizing system, eg with a press surizing tank if the heaters fail to turn off when the pressure set point is reached.

(ii) loss of class IV power resulting in loss of primary pumps; this could result initially in low coolant flow, high temperature and hence high pressure in the coolant.

(iii) steam flow from the boilers is suddenly stopped say by the emergency stop valve closing, resulting in lower boiler level and higher PHT system pressure.

(iv) transient changes in boiler feed water flow or temperature, steam pressure and reactor power.

(v) abnormal rise in reactor power resulting from say a loss of regulation incident such as inadvertent booster insertion or sudden draining of the zone control system compartments.

Very large direct relief capacity is not desirable, as it is in a fossil plant for instance, as a result of the inherent problem of core voiding resulting in loss of coolant and possible core meltdown.

In an indirect steam cycle such as ours the most convenient line of defence against overpressure, although only utilized at Pickering, is to discharge steam from the boilers via steam discharge valves and is thus an indirect pressure relief.

To cope with pressures which continue to rise beyond this relief capacity direct pressure relief can be utilized via relief valves on the reactor outlet headers if a feed and bleed system is used (Douglas Point and Pickering). This take off point will reduce any coolant voiding effect compared to using the (higher pressure) inlet headers. If a pressurizing tank is used (NPD) relief is taken from the vapour space in the tank. As Bruce has both a pressurizer and a feed and bleed circuit then both these relief points are utilized there as shown in Figure 7.

The hot discharge from the relief valves vents to a condenser the location of which varies according to the station. For example NPD and Douglas Point use condensers (called either relief condensers or surge coolers) and holding tanks (surge receivers) independent of the main circulating system.

At Pickering and Bruce the relief is more convenient, being into the bleed condenser (Figures 7 and 8) of the feed and bleed circuit itself.

As a result of the inherent safety limitation on the direct relief capacity, available volume and heat capacity of the bleed condensers, the final line of defense is not direct relief but is a reactor trip (on high heat transport pressure), or failing this, discharge of steam via the steam safety valves on the secondary side.

(h) ADDITION, REMOVAL AND STORAGE OF COOLANT

For PHT coolant storage and to allow for shrinkage and swell during cooldown and warmup a storage tank is provided. This is shown, typically, in Figure 7 situated after the IX columns, giving the most convenient removal point to the tank, with addition from the tank, (via feed pumps) into the feed valves. Tank pressure will be around atmospheric with a He cover gas used to prevent corrosion.

If a pressurizing tank is used, as at NPD, shrinkage and swell of the D_2O is accommodated conveniently in this tank as already mentioned in discussion of this system. (section (f)).

ASSIGNMENTS

1. What are the functions of the main heat transport circulating system? Explain the reasons for the design features of the heat transport system and how the system hardware satisfies these.

2. Under what circumstances may standby cooling have to be provided?

3. Why is a standby cooling system not considered a backup to the heat transport system?

4. What are the heat removal requirements of a standby system:

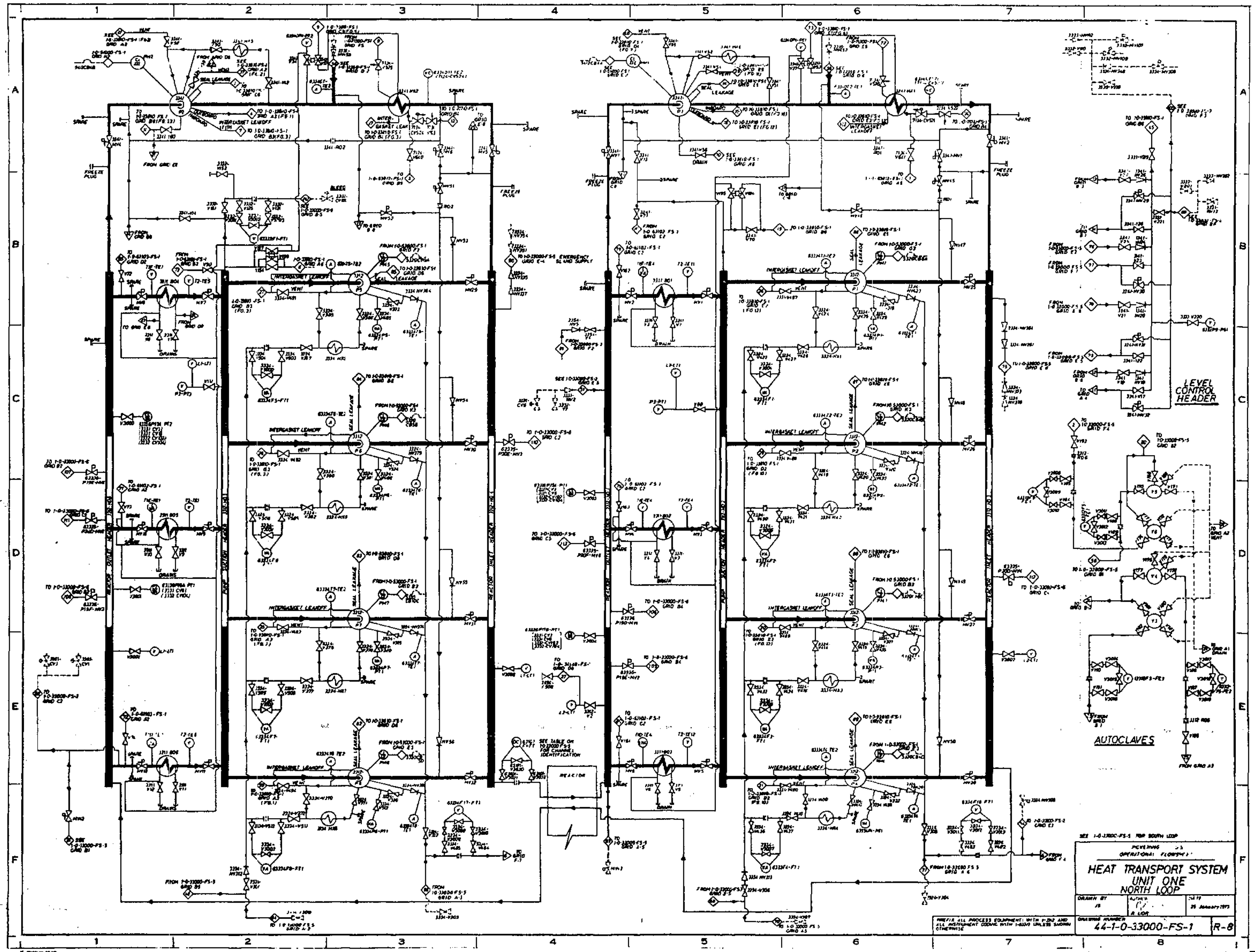
   (a) under normal operation?
   (b) under emergency operation?

5. What can cause overpressurization in a heat transport system and how can protection be provided?

6. Describe the function of a feed and bleed pressurizing system, its major components and how it is tied into the main circulating system.

7. Explain the function of a pressurizing surge tank used for pressure control and how shrinkage and swell is taken care of with this system.

D. Winfield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UNIT ONE
NORTH LOOP
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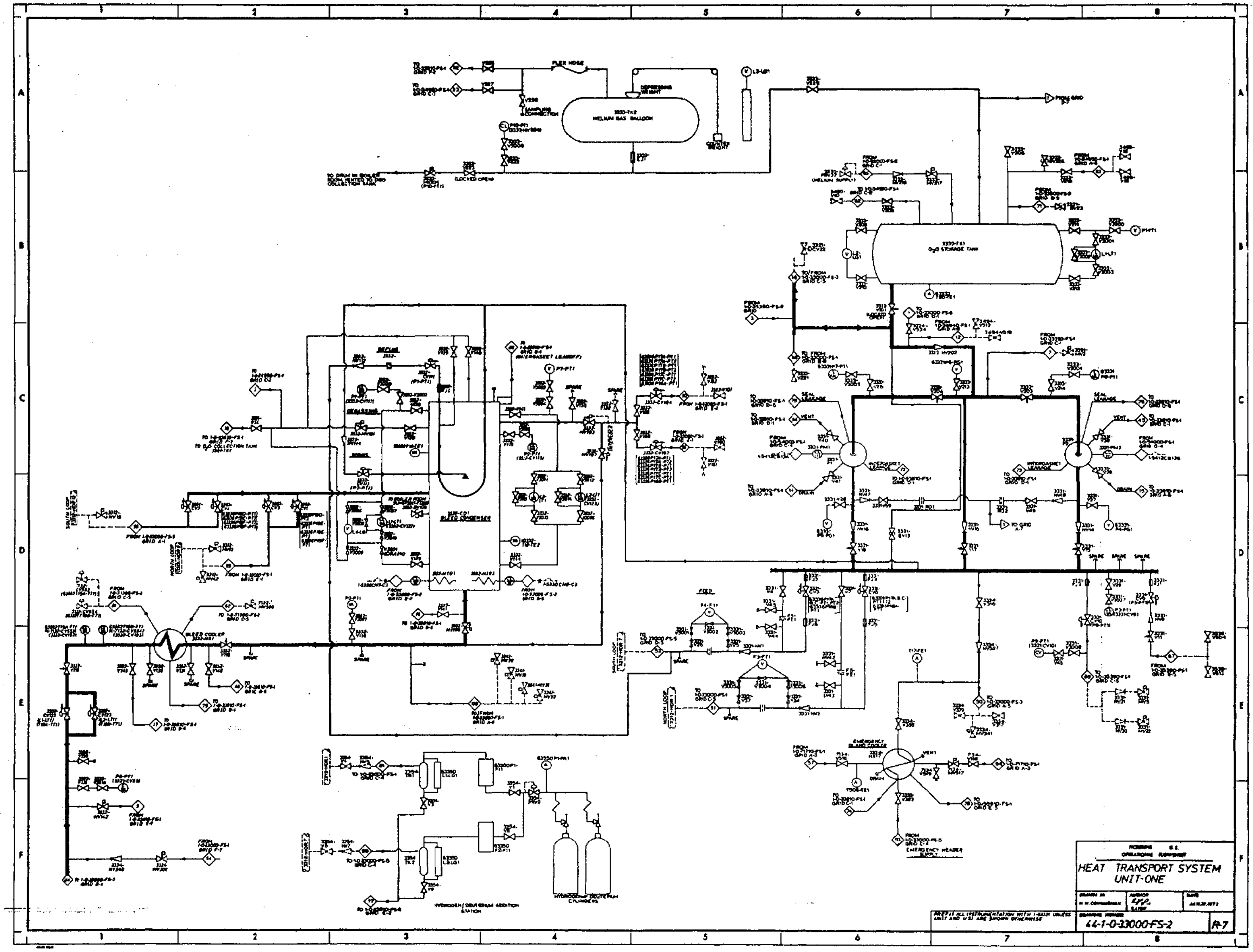
R-8
LEVEL CONTROL HEADER
AUTOCLAVES
REACTOR


HEAT TRANSPORT SYSTEM
UNIT-ONE
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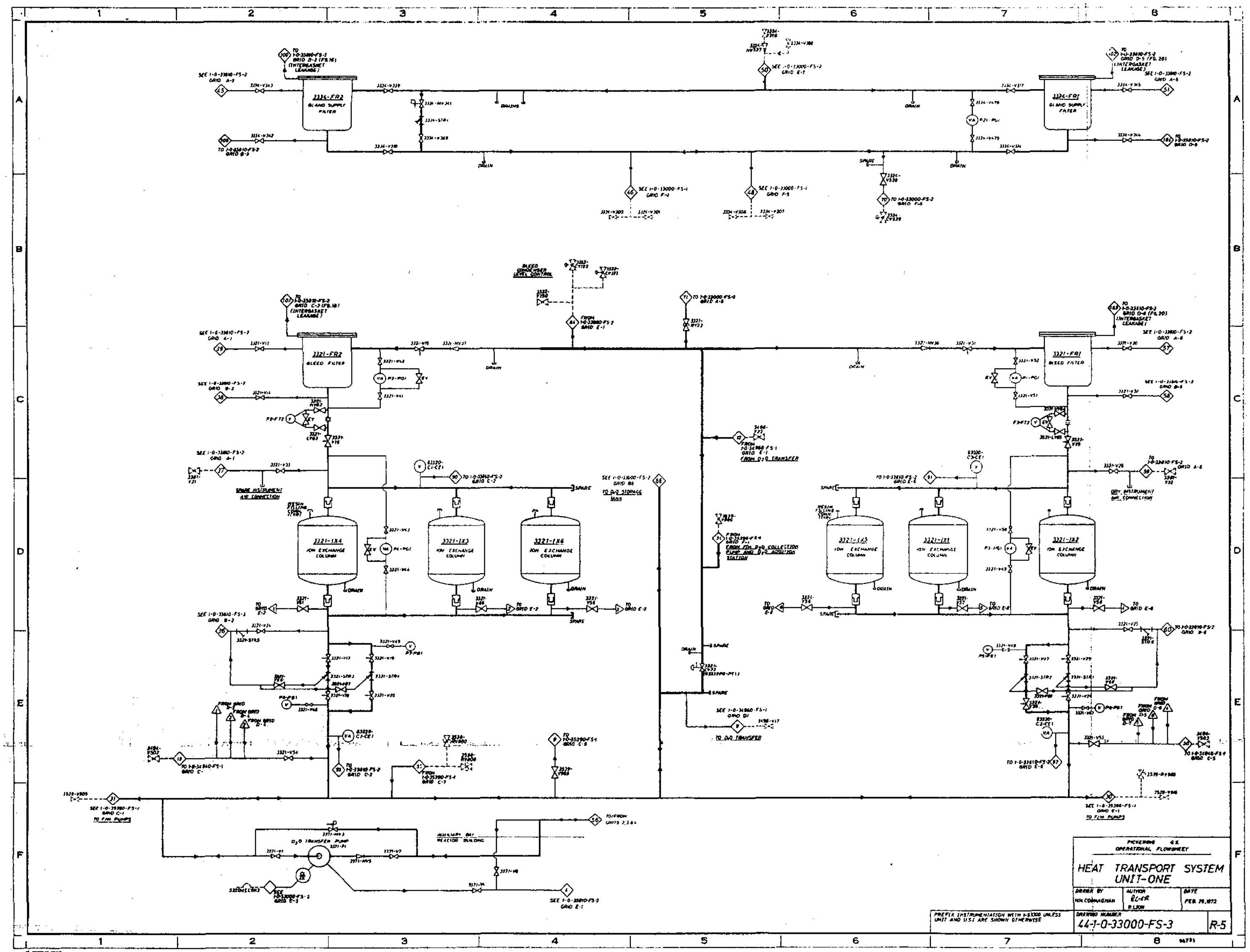
R-7
HELIUM GAS BALLOON
D2O STORAGE TANK
BLEED CONDENSER
BLEED COOLER
HYDROGEN / DEUTERIUM ADDITION STATION
HYDROGEN / DEUTERIUM CYLINDERS


PICKERING G.S.
OPERATIONAL FLOWSHEET
HEAT TRANSPORT SYSTEM UNIT-ONE
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M.N. CONNAGHAN
AUTHOR
R. LEW
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PREFIX INSTRUMENTATION WITH 1-33300 UNLESS UNIT AND U.S.I. ARE SHOWN OTHERWISE
HEAT TRANSPORT SYSTEM
ION EXCHANGE COLUMN
BLEED FILTER
GLAND SUPPLY FILTER
D2O TRANSFER PUMP