

Reactor, Boiler & Auxiliaries - Course 133

AUXILIARY PHT SYSTEM FEATURES

The previous section described the main requirements of the PHT system and the equipment used to meet these requirements. In addition to these there are a number of auxiliary features and systems that are associated with the PHT system, just as the moderator was convenient to supply D₂O for various moderator auxiliary systems.

These features and systems are now listed and described in turn:

- (a) Purification, degassing and chemical control systems
- (b) Fuelling Machine D₂O supply
- (c) D₂O collection and recovery systems
- (d) Emergency Injection system

(a) PURIFICATION, DEGASSING AND CHEMICAL CONTROL SYSTEMS

The purpose of these systems is to remove fission products, corrosion products, provide gas control and corrosion control of the coolant.

PURIFICATION

Filters and Strainers

It is important to remove undissolved corrosion and fission products from the main system to prevent deposition on heat transfer surfaces (fuel) and on instrumentation equipment and glands to prevent clogging, damage and activity build up.

This removal is achieved by filters and strainers for all undissolved solids larger than 10 microns and 180 microns respectively.

The heat transport system in general has the following filtration units associated with it.

- (i) Main Heat Transport Filters - shown in Figure 1. These are used for system clean up during commissioning and shutdown conditions. For this purpose, the filters are of the disposable paper cartridge type. Flow is

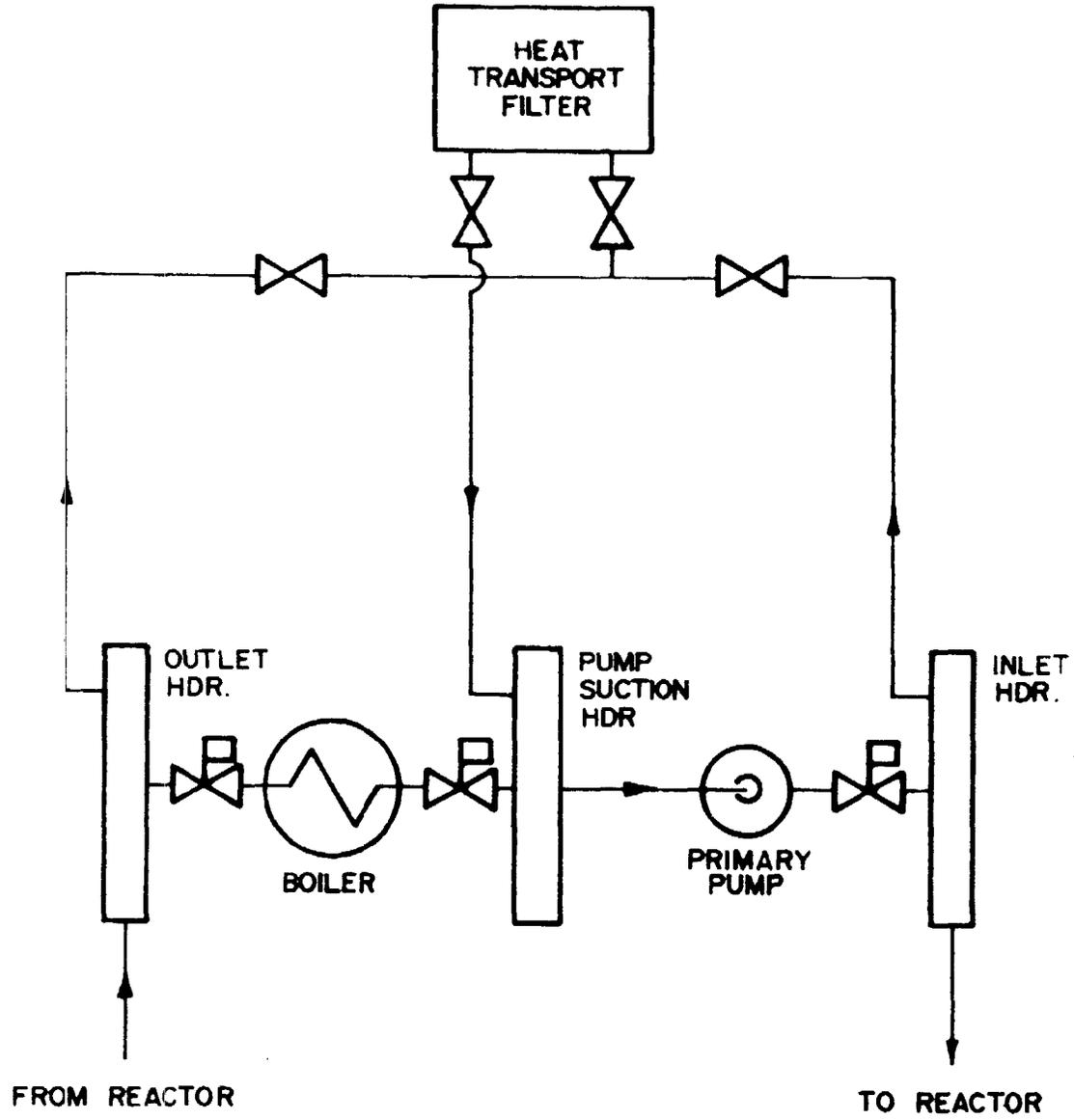


Figure 1: Main Heat Transport System Filter (PGSA)

from reactor inlets, via filters to the primary pump suction headers.

(ii) Bleed Circuit Filters - shown in Figure 2. They are situated on the outlet of the bleed cooler heat exchanger providing clean up of D₂O entering the IX columns (see below) to prevent clogging of these columns. As the D₂O passing these filters is relatively cool the filter elements are of the disposable paper cartridge type.

(iii) Gland Supply Filters Glands on the primary heat transport circulating pumps are supplied by PHT system D₂O. Supply is from the pressurizing pumps (Figure 3) of the feed and bleed circuit or via a gland supply heat exchanger (emergency) fed from the inlet headers. This D₂O supply passes through the gland supply filters before reaching the pump glands. The low temperature D₂O of this circuit enables disposable paper cartridge filter elements to be used.

(iv) Fuelling Machine Supply Filters The fuelling machine D₂O supply (section (b)) Figure 4 is filtered before delivery to the fuelling machine valve station. These filters are designed for high pressure service as they receive their supply from the fuelling machine pump discharge.

The main purpose of the strainers in the purification circuits is to trap any resin carried over from the IX columns. Strainers will then be needed in the following locations:

IX Column Discharge (Figure 2) and Gland Supply By Pass (Figure 3) - to protect the pump glands when the gland supply filters are clogged.

IX Columns

In addition to removal of undissolved particles in the system it is important to remove dissolved ions to also help prevent activity build up and to help decrease radiolysis.

This is achieved by IX columns (Figure 5) in a by pass purification circuit (In addition, the IX columns provide pD control next section).

There is a tendency for these soluble particles (including very finely divided particles "crud") to redeposit themselves out on HT system surfaces and during operation redeposition is typically a few minutes so ideally the purification system should pass a volume comparable to the HT volume every few minutes.

Full flow or extremely large by pass flow purification systems are not practical (IX columns operate at a maximum temperature of 60°C) and so fairly low flow (~10ℓ/s) by pass systems are used. For operating considerations then purification flow rates should always be as high as possible, in particular after any system transient (in pressure, temperature, pD or D₂ concentration) which tends to cause "crud bursts" in the system.

The system shown in Figure 2 and Figure 8, 30.2, is convenient, as far as temperature and pressure and flow is concerned, to incorporate into the feed and bleed circuit. The cool inlet to the columns being taken from the bleed cooler outlet and passes its outlet to D₂O storage and/or the pressurizing pump discharge.

DEGASSING

As the IX column purification circuit operates at low temperature and pressure gases will come out of solution and hence some provision must be made for venting in the system.

Gases present may consist of fission product gases, deuterium, hydrogen, oxygen and nitrogen.

If the PHT system has a bleed condenser then the flashing D₂O in this condenser will become degassed at this stage and provision is made (Figure 9 30.2) to vent off gases from this point. The gases can be vented to a condenser or delay tank where D₂O vapour can be collected and recovered, the remaining off gases being discharged via the stack to atmosphere.

If the PHT system has a pressurizing tank then this tank is a suitable take off point for the off gases in this case.

CHEMICAL CONTROL SYSTEMS

The purpose of HT system chemical control is to minimize corrosion of system equipment. The materials involved are (mainly) carbon steel (headers, feeders), austenitic stainless steel (end fittings) and Zircaloy (pressure tubes).

The parameters which have to be monitored and controlled are listed below, typical operating values have already been quoted for these in Table 1, section 30.1.

pH (or pD)

pH is controlled between 9.5 and 10.8 to minimize corrosion. To increase pH LiOD IX resin or LiOD solution addition is used and to reduce it D.OD resin addition is used. (Lithium is used as it produces no active isotopes).

Oxygen

Dissolved oxygen, resulting from radiolytic decomposition, increases corrosion rates in the system and is difficult to control. Control is achieved by maintaining an excess of dissolved H₂ and/or D₂ gas, which suppresses dissociation. Hydrogen or Deuterium gas is added, at high pressure, directly to the reactor outlet headers.

Chlorides

Chlorides in the system can cause stress corrosion cracking in particular in stainless steel. Usually chlorides are released by IX resin if they are operated above about 60°C. Control is by removal of the resin which is releasing chloride into the system. Concentrations >2ppm chlorides would require system shutdown and cooldown.

Fluorides

The presence of fluorine; if teflon tape was used anywhere in the system piping; would cause attack on pressure tubes, and so use of teflon should be avoided.

(b) FUELLING MACHINE D₂O SUPPLY

Heat transport system D₂O can be used for the cooling, heating, pressurizing and operation of the fuelling machines, so that isotopic, boron concentration and pD conditions of the D₂O are compatible with coolant channel D₂O.

The supply for the fuelling machines is taken from the IX column outlet of the main system via two fuelling machine pumps, see Figure 4, which are rated up to a high discharge pressure of 16.5 MPa. The suction location of these pumps then provides a purified, cool water supply for the pumps.

Fuelling machine design requires the provision of two separate D₂O supplies one at 80°C and the other 50°C-250°C with facilities to pressurize and depressurize these supplies. To obtain these required temperatures (Douglas Point and Pickering) heat exchangers utilizing steam heating, controlled by boiler steam, are used.

Pressure control is obtained by (typically) fuelling machine supply throttling valves (Figure 4), in parallel with the fuelling machine pumps.

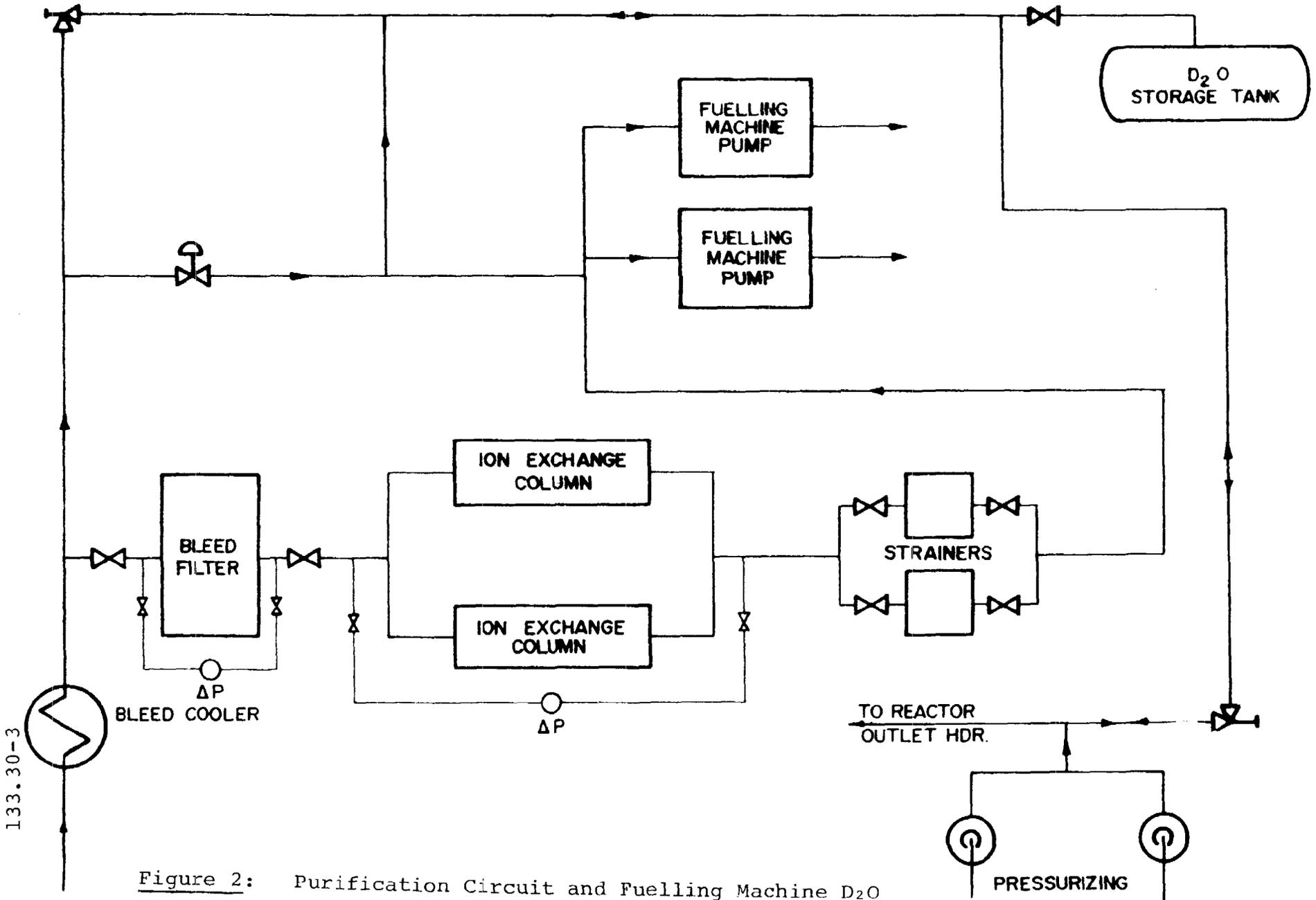


Figure 2: Purification Circuit and Fuelling Machine D₂O Supply (PGSA)

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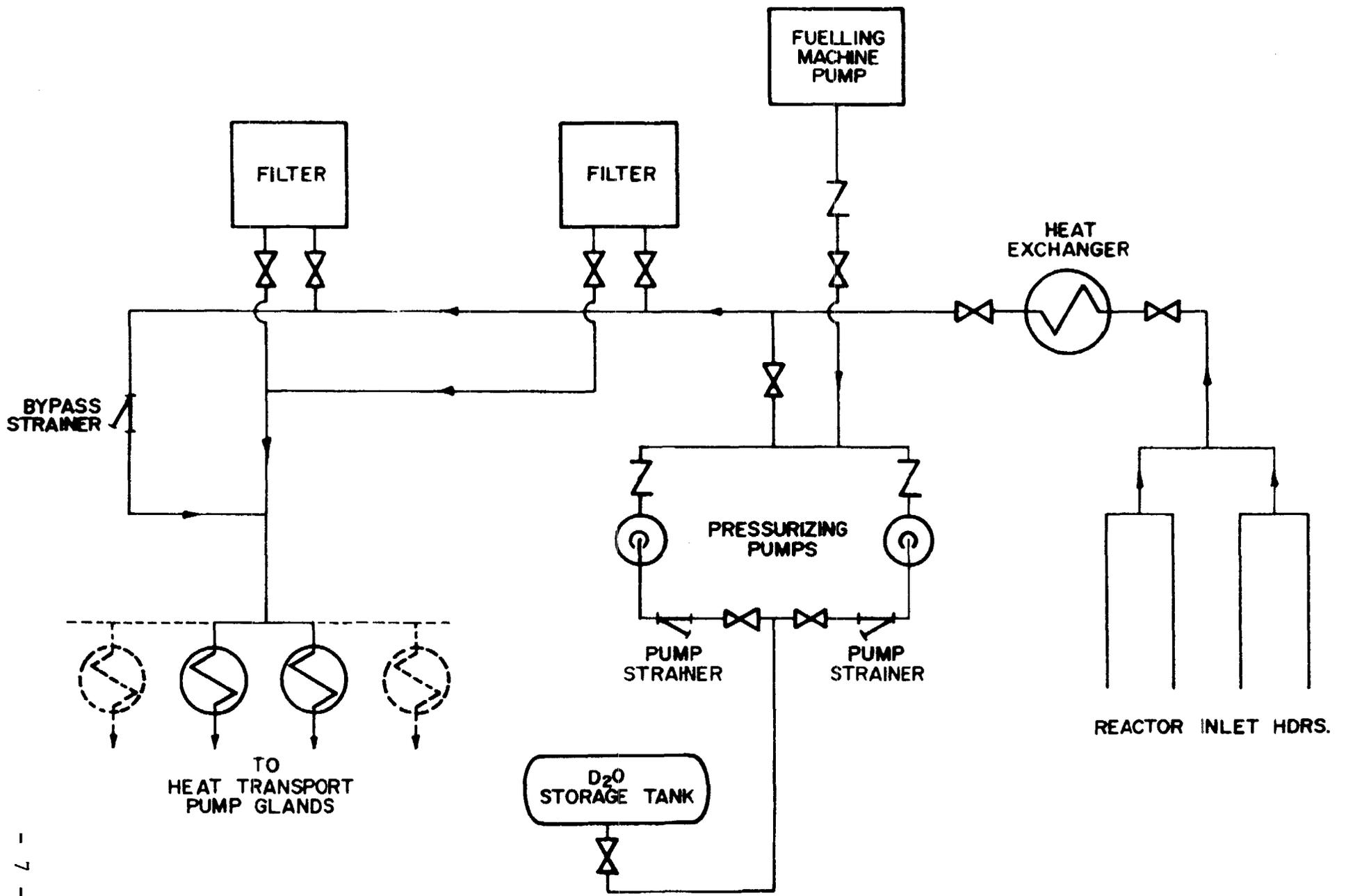


Figure 3: Primary pump gland D₂O supply circuit (PGSA)

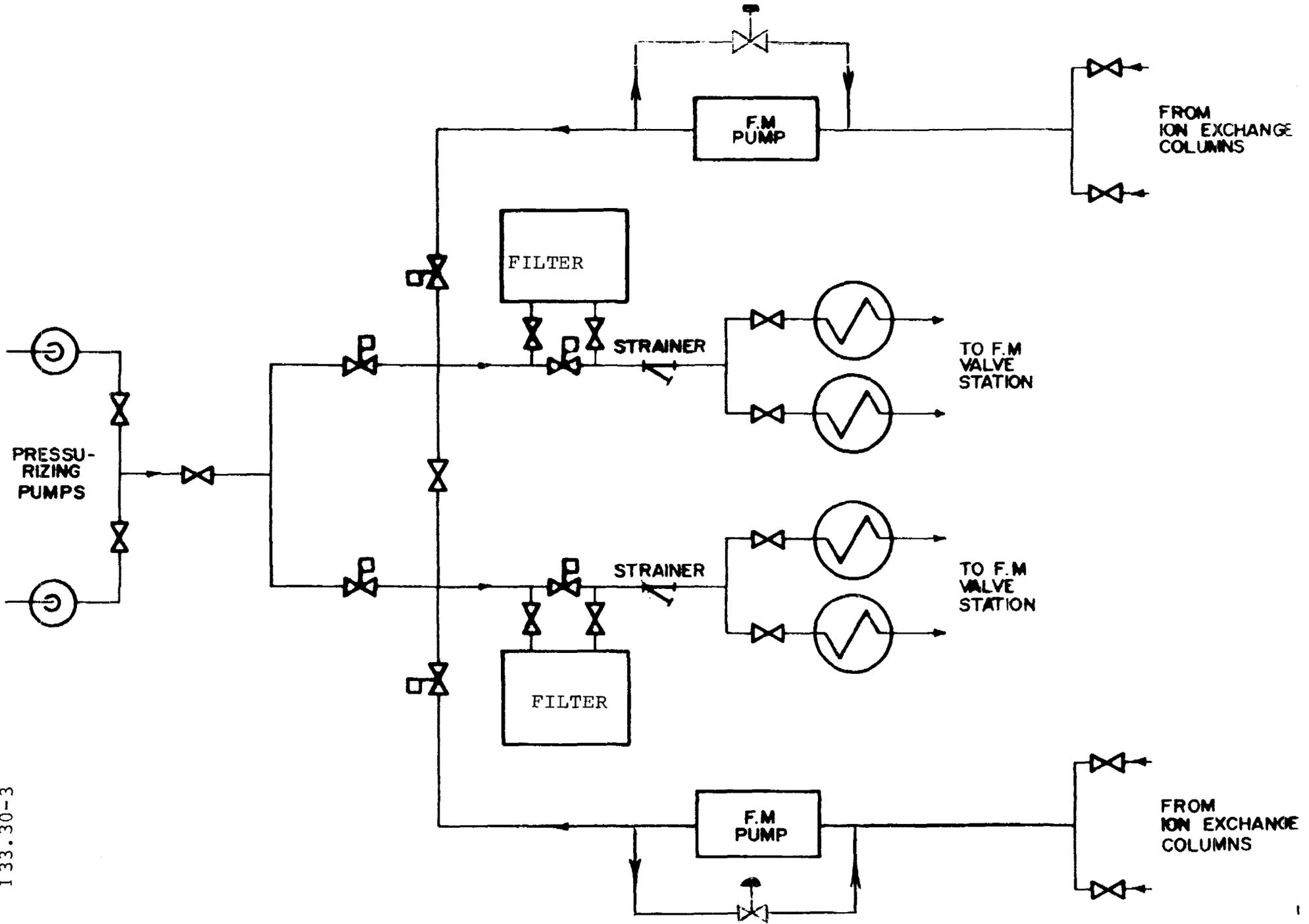


Figure 4: Fuelling Machine D₂O Supply

Each pump delivers D₂O to D₂O valve station, one for each fuelling machine head, via flexible metal hoses, "cateneries", to each head.

In the event of non availability of the fuelling machine pumps and the presence of spent fuel in the fuelling machine(s) adequate cooling to prevent overheating is provided by passing a flow via check valves from the discharge of the feed and bleed pressurizing pumps.

(At NPD, and Bruce each fuelling machine is served by its own self contained circulating system and not fed directly from the main PHT system).

(c) D₂O COLLECTION AND RECOVERY SYSTEMS

D₂O Collection System

Section 20.2 (h) discussed the moderator D₂O collection system and PHT D₂O collection system is similar. It is important to maintain these two systems independant as a result of the different chemical, isotopic and activity concentrations in these systems.

In general heat transport D₂O will be collected from the following locations.

- (i) valve stems
- (ii) pump seals
- (iii) bleed condenser degassing line
- (iv) inter gasket leakage on double gasketed flanges
- (v) drainage from equipment and lines before maintenance

The system will typically consist of a collection tank, pumps, drumfill and sample stations and associated valves and piping and operates as a closed system.

D₂O Recovery System

The purpose of the heat transport D₂O recovery system is to return coolant to the main circulating system in the event of a minor leak in the heat transport system where the system pressure can be maintained.

Coolant escaping into the fuelling machine vault or the boiler room would flow via floor drains and a recovery tank back to the suction of the pressurizing pumps of the heat transport system (Figure 6).

The system is designed to prevent having to use the Emergency Injection System (discussed below) to provide coolant make up which would result in the mixing of moderator and PHT D₂O. With the large size of current

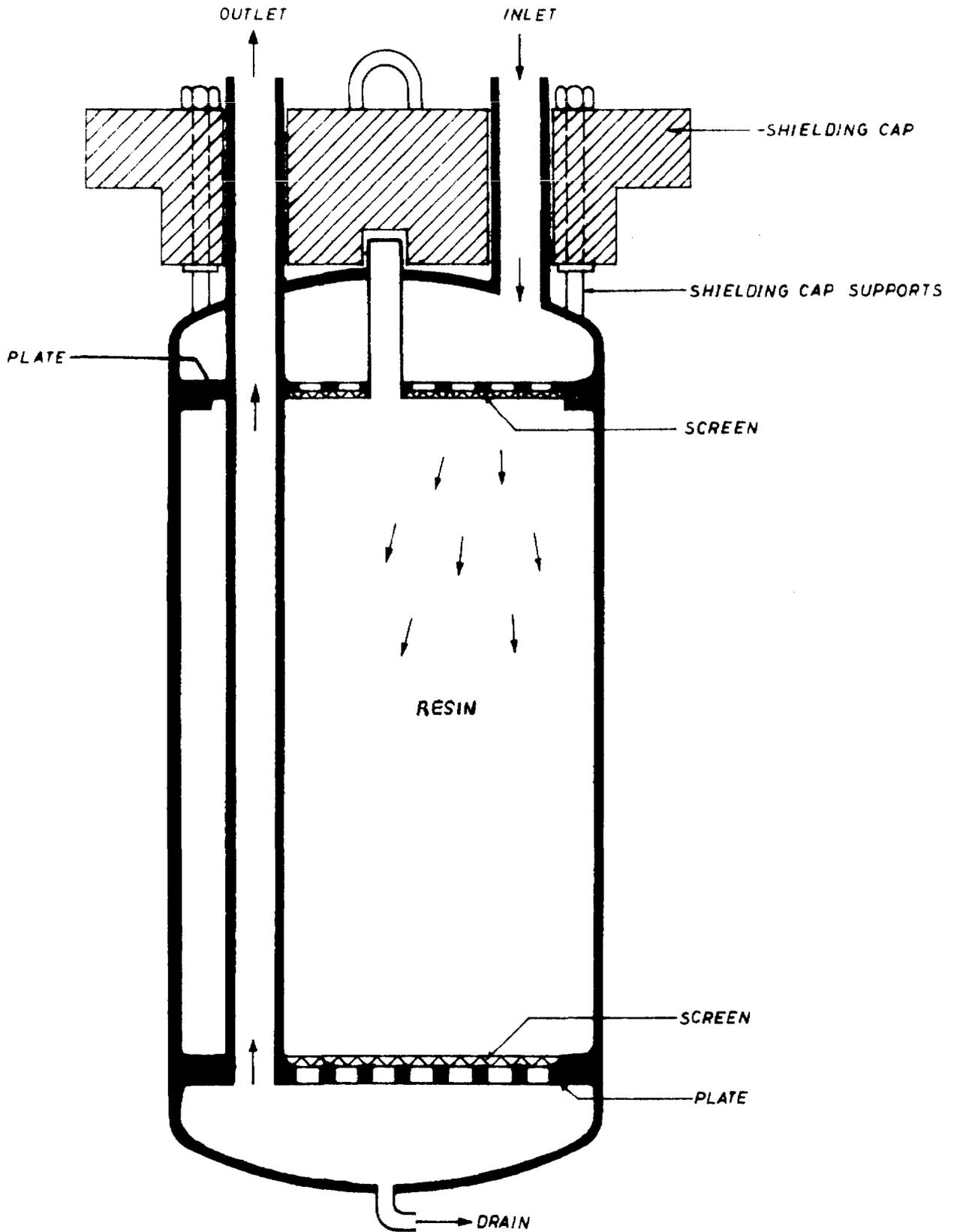


Figure 5:
HEAT TRANSPORT SYSTEM
ION EXCHANGE COLUMN

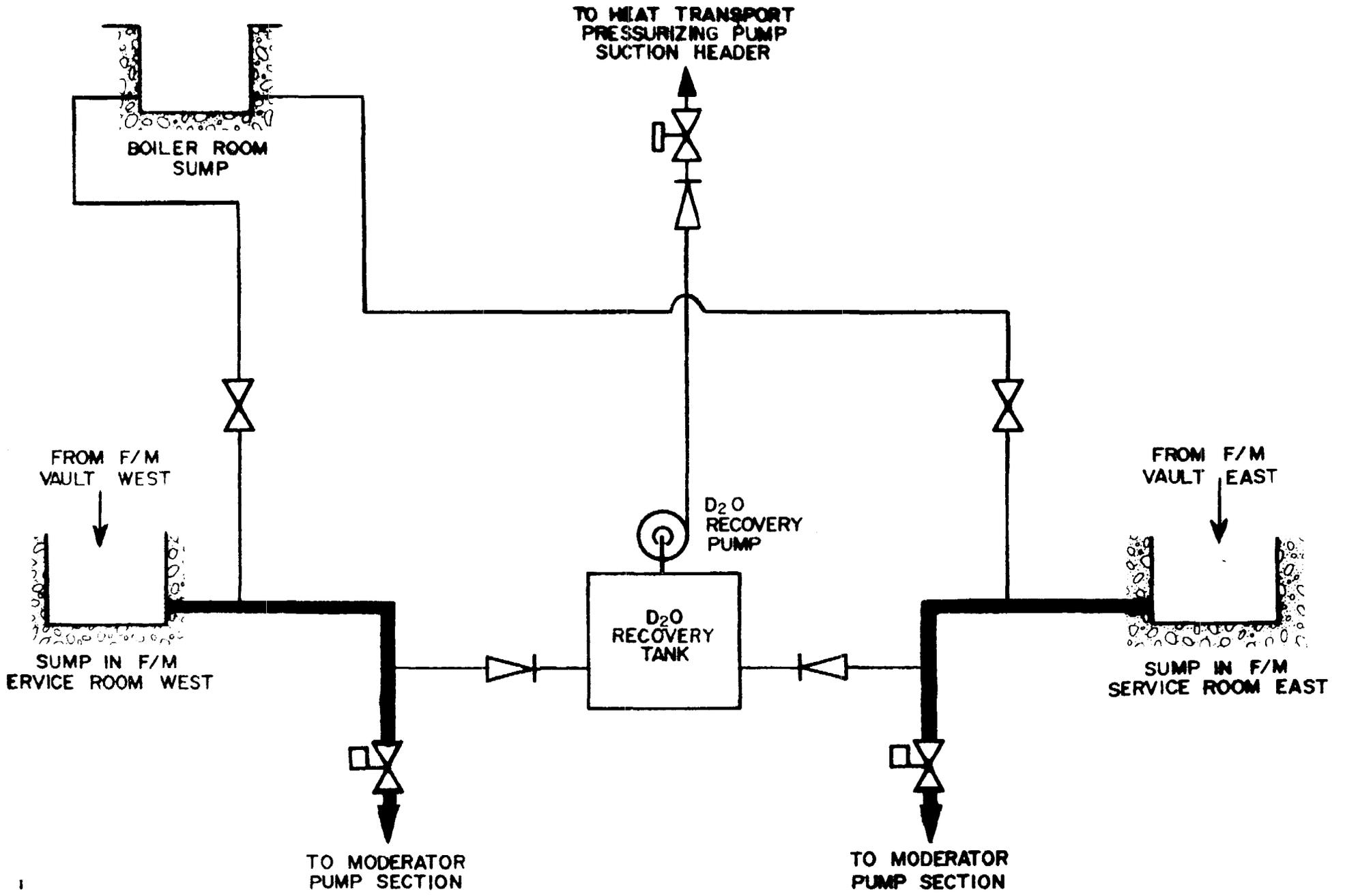


Figure 6: PHT D₂O Recovery System

reactor units having large D₂O inventories (Table 1) there is great economic incentive to maintain moderator and PHT D₂O separate, because of their different isotopic, chemical and activity properties.

(d) EMERGENCY INJECTION SYSTEM

The purpose of the emergency injection system, (Figure 7), (or emergency core cooling system, ECCS, as it is sometimes called) is to provide sufficient water to keep the fuel cool after a gross break of the heat transport system piping when large quantities of D₂O flash into steam from the system (ie, a loss of coolant accident, LOCA). In this situation the pressure decreases substantially in the system and the remaining coolant starts to boil. If the shutdown system responds rapidly enough, heat generation in the fuel is limited to that produced by fission product decay. However, if the fluid is not replaced fuel temperatures may rise sufficiently to cause fuel melting and allow the release of fission products into the system.

Recovery of the water spillage and its transfer back through the injection system is then required to maintain a cooling supply for an indefinite period.

NPD, Douglas Point and Pickering

Injection System

These units, (having similar systems) use emergency D₂O injection from the moderator system, the moderator being the most convenient source of water available and its use avoids serious downgrading of the PHT system. Its use will, however, increase the tritium content of the PHT D₂O and change its chemical composition.

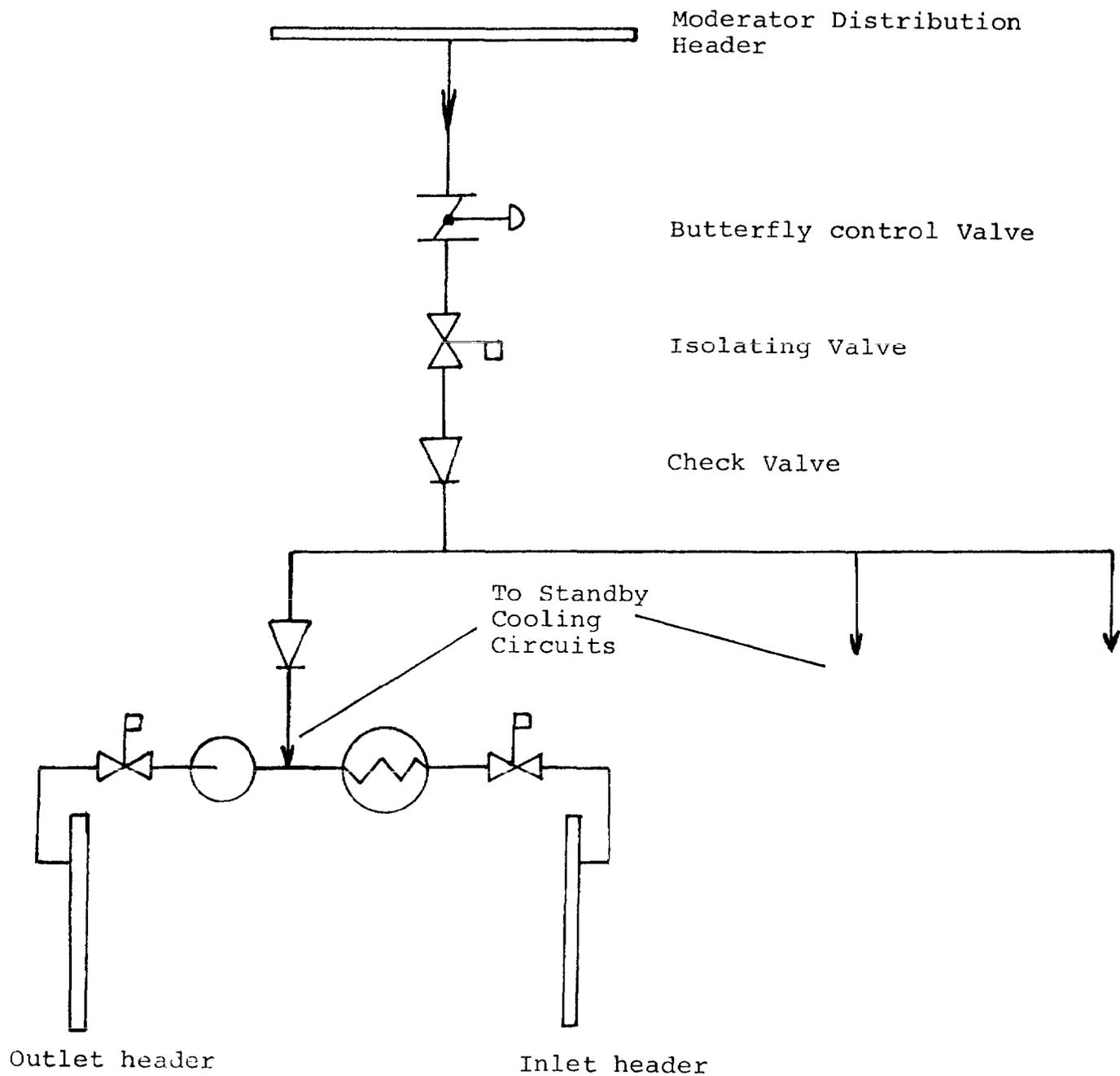
Injection take off point is from the moderator distribution header (Figure 7 20.2) which being at the moderator heat exchanger outlet, provides the coolest D₂O available.

Injection tie in point to the PHT system is into each standby cooling heat exchanger which being close to the reactor inlet headers is the best injection point of the PHT system. (At NPD injection is, however, directly into the inlet headers).

D₂O flow is then provided by operation of the main moderator circulating pumps. (At NPD a separate charging pump is used, however, to pump back into the system.)

The valves in the emergency injection line, shown in Figure 7, a flow control valve, an isolating valve, check valve at each standby cooling loop and the standby cooling

Figure 7: D₂O Emergency Injection into PHT System (PGS, DPGS)



isolation valves open automatically on a low pressure (~700 kPa) signal from the PHT system. Emergency D₂O will then feed via the injection pipework and when the main system pressure drops below injection pressure at the injection check valve, will provide a low pressure (~400 kPa) injection into the main PHT system.

At present the system directs injection flow into all the headers regardless of the location of a primary circuit rupture. (Original operation had location logic directing injection flow to prevent directly feeding D₂O into a header break but calculations showed that this automatic re-direction feature would be unreliable). Operator action is required (at Pickering) however to shut down main coolant pumps in the loop containing the break to prevent these pumps interfering with injection flow.

Emergency Injection Recovery System

D₂O recovery from major breaks in the heat transport system, when emergency recovery injection is in operation, will be via pumps in the fuelling machine vault and/or calandria vault. Recovery pipework then provides, via valves, for return of the D₂O to the emergency circulating water by connections made to the moderator pump suction headers (Figure 6).

If the recovery system proved to be unable to maintain an adequate level in the moderator to keep the fuel covered it is possible to add ordinary water H₂O to the emergency injection line by a connection outside the reactor building.

Bruce

The emergency injection system at Bruce (and at the 600 MW(e) stations) employs a different philosophy from previous stations in the following respects:

- (a) a light water H₂O system is used
- (b) injection of emergency coolant is from a common H₂O supply for all units in the station

The reason for these changes are that it was felt that by maintaining D₂O in the calandria after a LOCA this would help to provide a large heat sink which would not be available if moderator D₂O emergency injection was used.

The common H₂O supply for injection has the advantage of being economical and convenient for multi-unit stations such as Bruce.

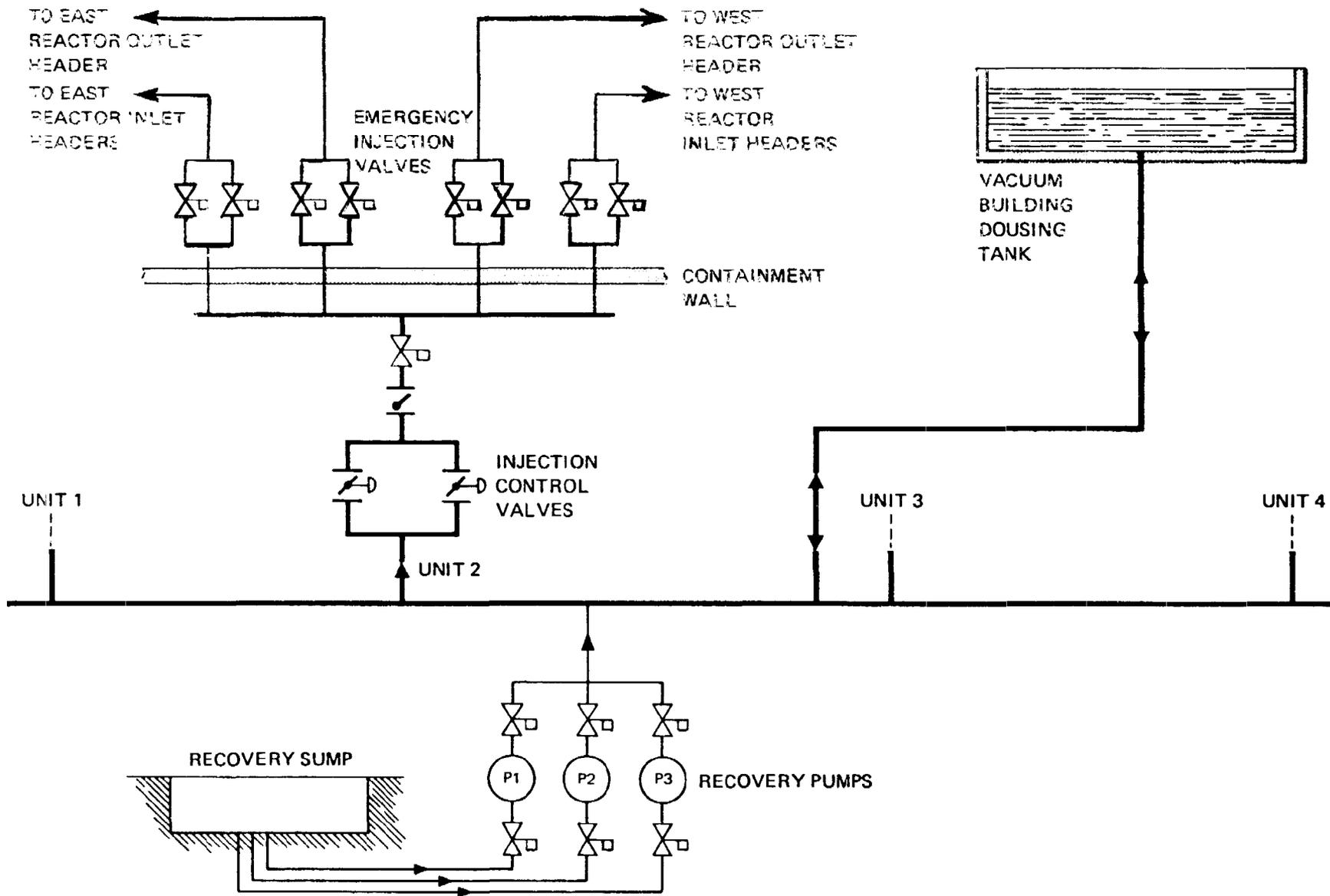


FIGURE 8: EMERGENCY CORE COOLING SYSTEM

The system is shown in Figure 8. Operation is essentially as described above for Pickering except that initial injection on a LOCA is provided by the hydrostatic head of H₂O from the emergency H₂O storage tank (or dousing tank as it is sometimes called as it also provides a dousing function) situated in the vacuum building.

Injection via the injection valves shown, is into all reactor headers directly (standby cooling circuits are of different design to Pickering).

After the water level in the storage tank falls, long term injection is maintained by (3 x 50%) recovery pumps which pump water accumulated in the fuelling machine recovery pump back to the storage tank. (see Figure 8).

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