U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

REACTOR COOLANT SYSTEM

Section 3.2

HRTD
Human Resources Training & Development

Objectives

1. State the purpose of the Reactor Coolant System (RCS).
2. List and state the purpose of the following RCS penetrations:
   a. Hot Leg (T_h)
      1. Pressurizer surge line
      2. Residual Heat Removal (RHR) suction
      3. Sample line
      4. RHR recirculation/Safety Injection (SI)

b. Intermediate Leg

1. Elbow flow taps
2. Chemical and Volume Control System (CVCS) letdown
3. Loop drain

c. Cold Leg (T_c)

1. Pressurizer spray line
2. CVCS charging
3. Common injection penetration for RHR, SI, and an Accumulator
4. High head injection
5. Excess letdown

3. Describe the primary and secondary flow paths through the steam generator.

4. State the purposes of the following components of the reactor coolant pump.
    a. Thermal barrier heat exchanger
    b. Seal package
    c. Flywheel
    d. Anti-reverse rotation device
    e. Number 1 seal bypass valve
    f. Number 1 seal leak off valve
    g. Seal stand-pipe

5. Explain why seal injection flow is supplied to the reactor coolant pumps.

6. State the purposes of the following:

a. Pressurizer (PZR)
b. Code safety valves
c. Power-operated relief valves (PORVs)
d. PORV block valves
e. Pressurizer relief tank (PRT)
f. PZR spray valves
g. PZR heaters

7. Describe the methods for determining pressurizer relief and safety valve position and/or leakage.

8. Explain the following:
   a. Pressurizer spray driving force
   b. Purpose of pressurizer spray bypass

9. Explain how failure of the following components could lead to core damage.
   a. Reactor coolant pump seals
   b. Power-operated relief valves

Purposes of the Reactor Coolant System (RCS) (Obj.1)

- Transfer heat from reactor to power conversion system.
- Provides a barrier to limit the escape of radioactivity to the containment.

FIGURE 3.2-1 Reactor Coolant Loop Penetrations

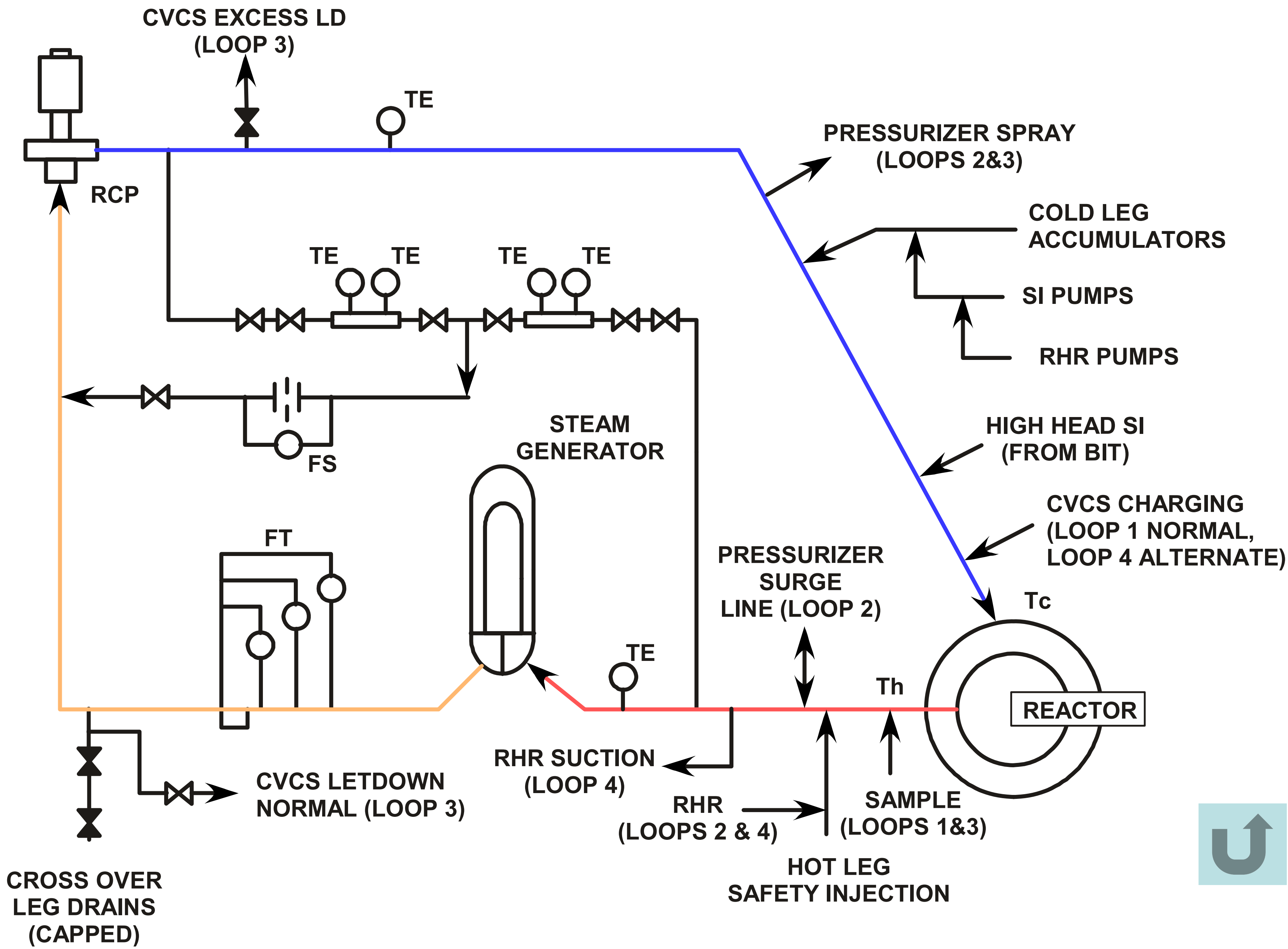


Figure 3.2-3 Pressurizer Spray Scoop

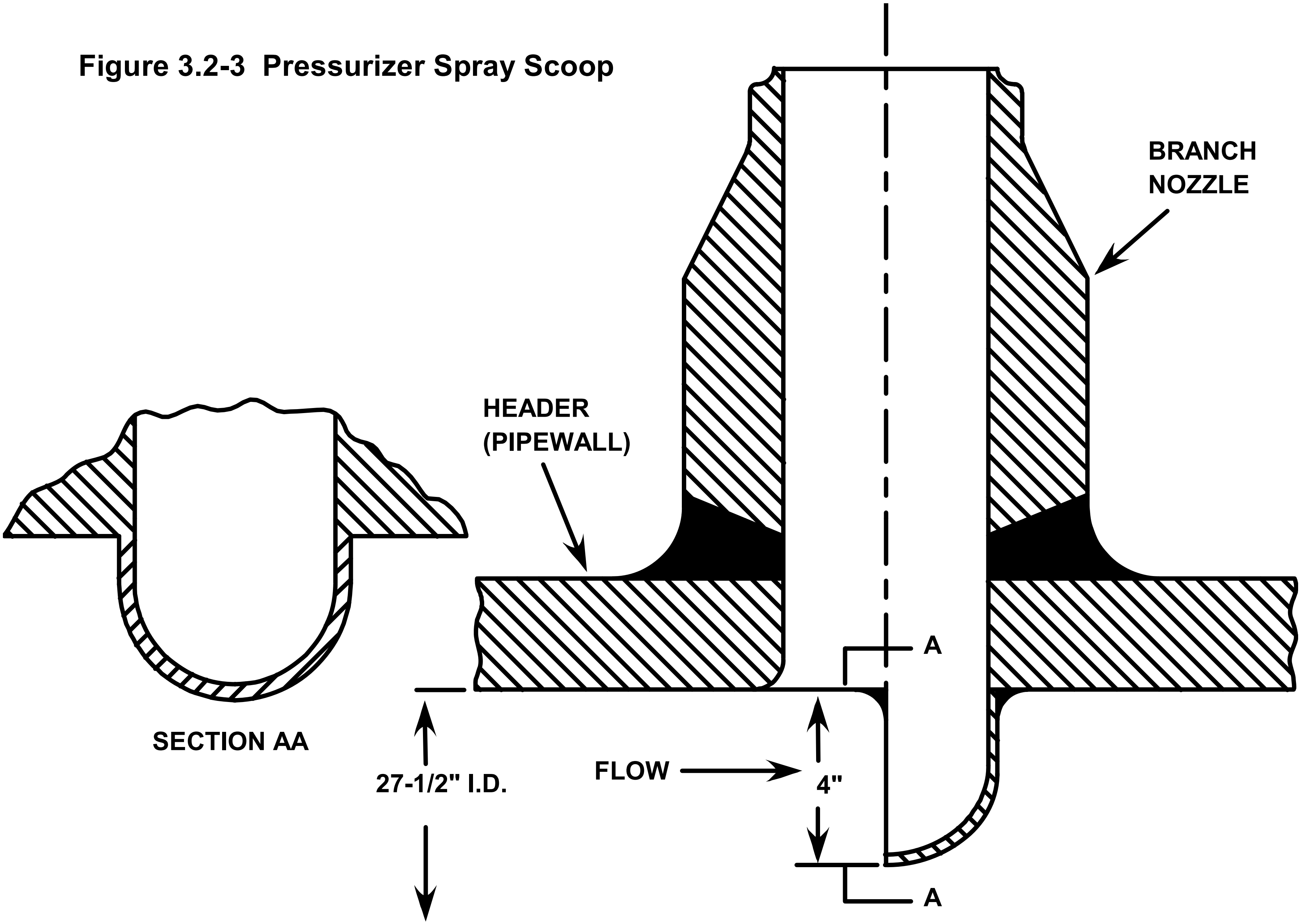


Figure 3.2-4 Sample Connection Scoop

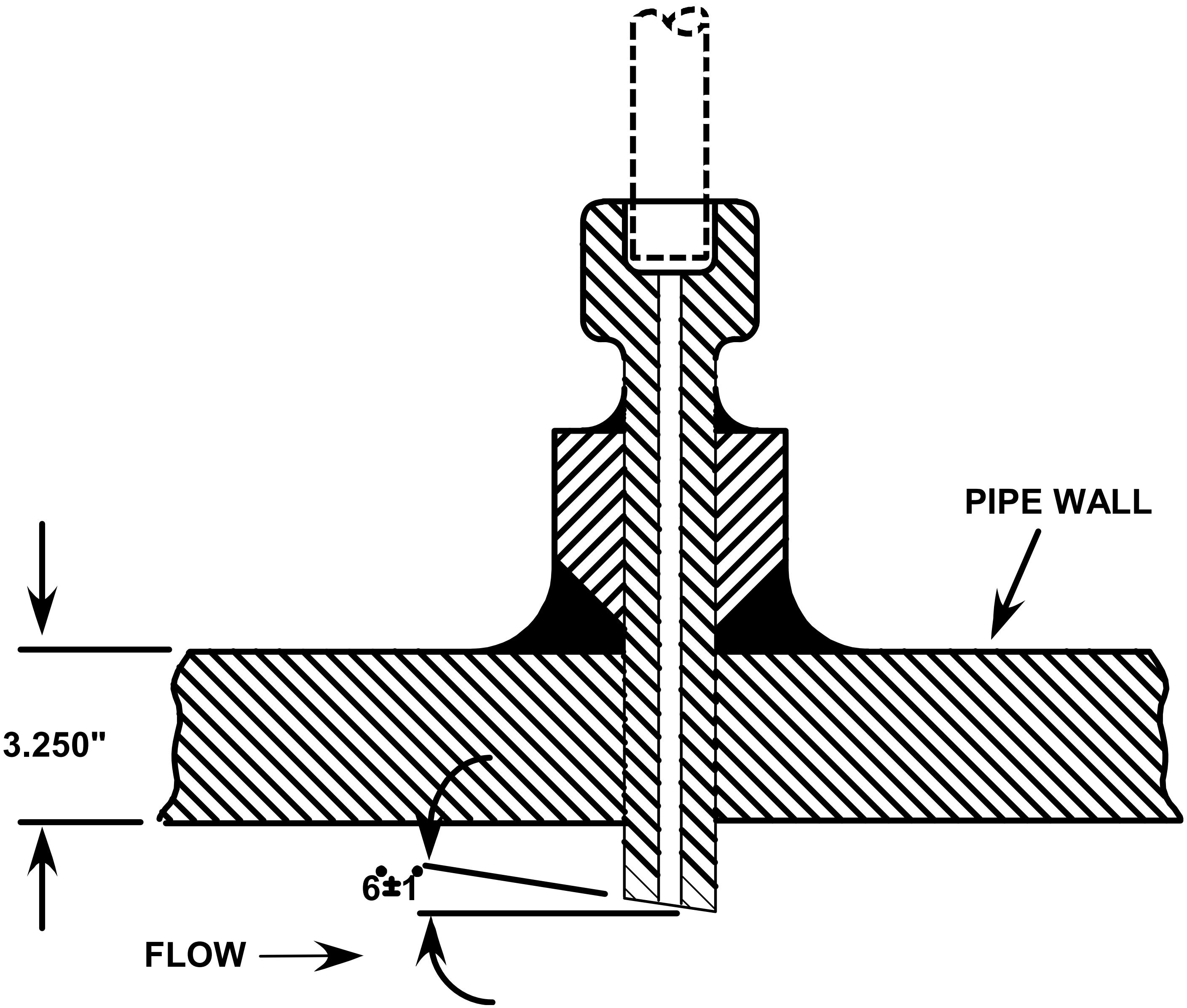


Figure 3.2-5 Hot Leg RTD Tap

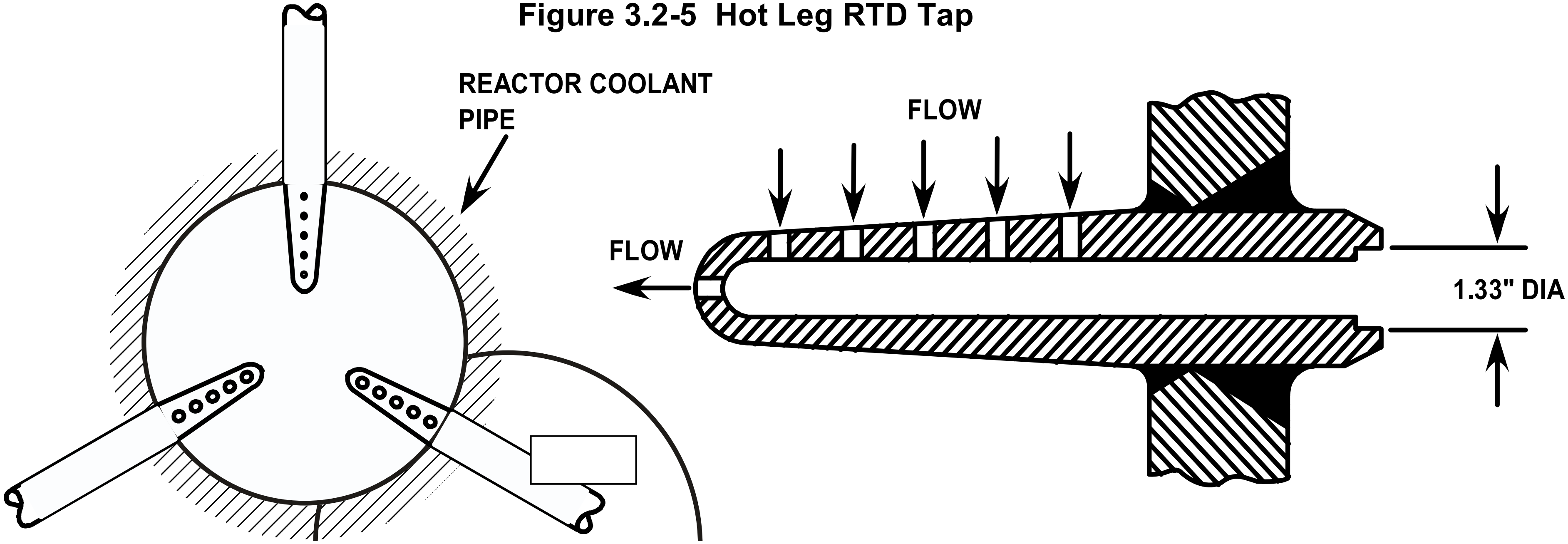


Figure 3.2-6 Reactor Coolant Flow Taps

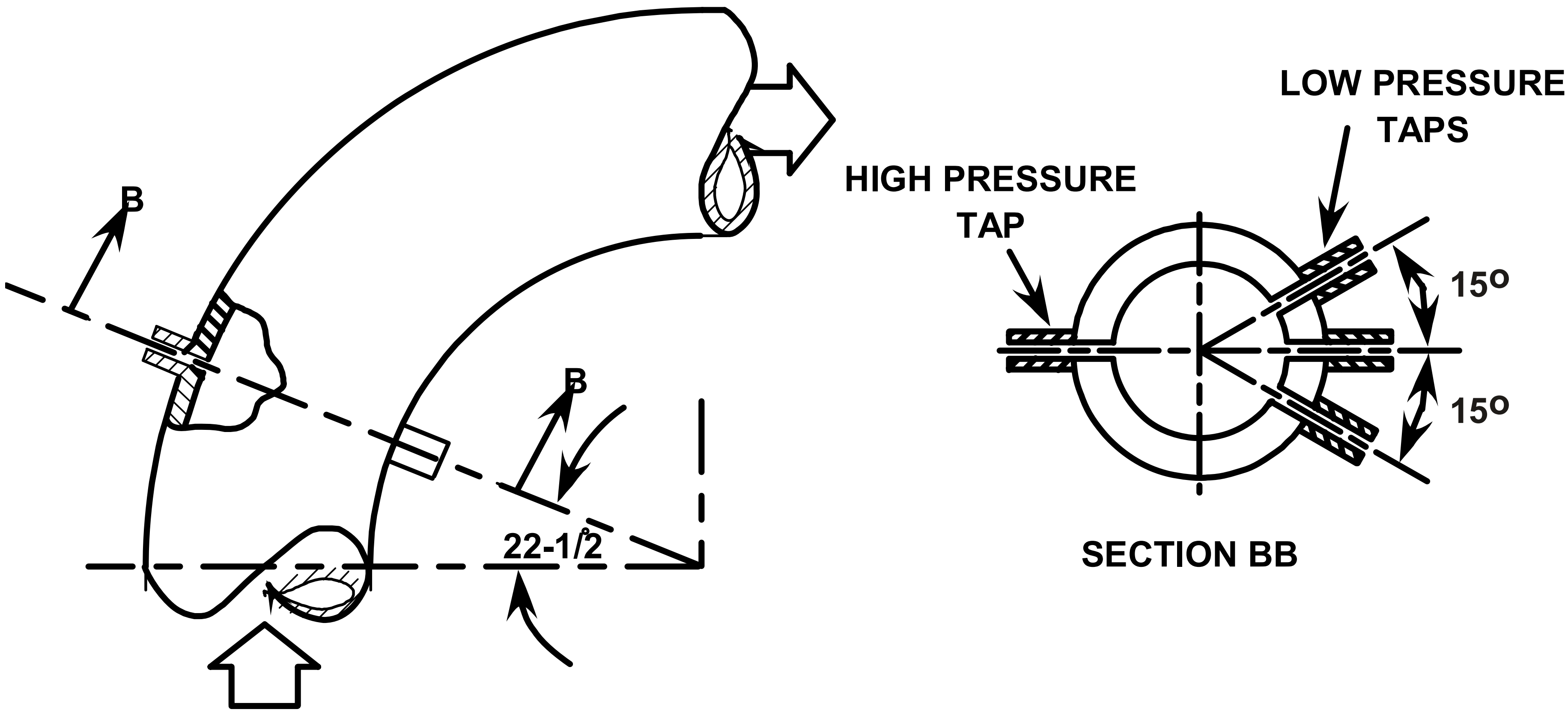


Fig. 3.2-6 Rx Coolant Flow Taps

Pressurizer

Fig 3.2-7

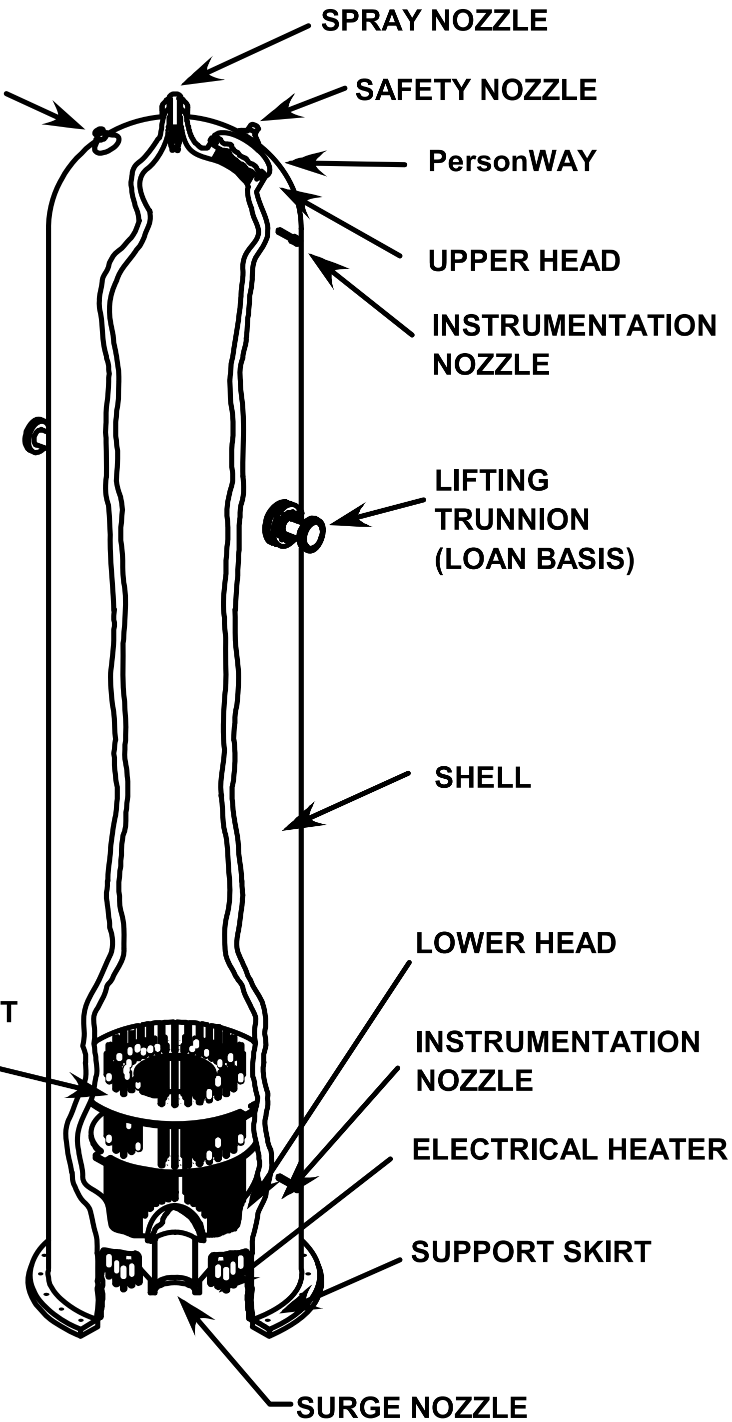


Figure 3.2-7
Pressurizer

- Purposes of PZR **(Obj 6.a)**
  - pressurize RCS during plant start-up
  - maintain normal RCS pressure during steady state operation (2235 psig)
  - limit pressure changes during RCS transients to w/in allowable values.
  - prevent RCS pressure from exceeding design value (2485 psig)

- Purpose of spray valves (loops 2 & 3 cold legs) (4 “ lines) **(Obj 6.f)**
  - to limit RCS pressure changes during transients.

- PZR spray driving force - **(Obj 8.a)**
  - The differential pressure across the Rx provides the driving force to spray the PZR.
  - The PZR spray scoops are used so the velocity of the RCS flow is added to the differential pressure across the Rx.

- Purpose of PZR Spray Bypass - manual throttle valves. (3/4") **<u>(Obj 8.b)</u>**
  - provides small continuous flow around spray valves. (Tc ~ 556 deg)
  - Reduces thermal stress/shock on spray nozzle. (2235# ~ 653 deg.)
  - Helps promote mixing in PZR to avoid thermal stratification
  - Aids in maintaining uniform chemistry in RCS & PZR.

- Purposes of PZR Heaters <u>**(Obj 6.g)**</u>
  - to limit RCS pressure changes during transients,
  - to maintain PZR at saturated conditions. PZR heater elements (78 elements) (1794 KW total) (raise temperature ~ 55 deg/hr)
  - To draw a bubble in the PZR during startup.

- PZR Code Safety Valves (6”)

  Purpose: **(Obj 6-b)**

  – to prevent RCS from exceeding design pressure by more than 10%.

  – Setpoint: 2485 psig.

- PZR PORVs Purposes: **(Obj 6.c)**
  - Minimize probability of a high pressure reactor trip (2385#) following a 50% load rejection.
  - Limit the operation of the code safety valves.
  - Mitigate overpressure transients during cold shutdown.
  - Remove decay heat if S/G not available.

- PORV Block Valves. **(Obj 6.d)**
  - Purpose – to isolate PORV if excessive leakage.

Pressurizer Relief Tank (PRT) <u>**(Obj 6.e)**</u>

– Purpose - Collects, condenses, and cools discharge from PORVs and code safety valves.

- Describe methods of determining PZR PORV & Position Indication & Leak Detection **(Obj 7)**
  - PORV -stem mounted valve position switch gives actual valve position
  - temperature detector on common discharge
  - Control room indication and alarm

Describe methods of determining PZR Code Safety Position Indication & Leak Detection **(Obj 7)** (cont)

- Code Safety - indirect valve position indication
- Acoustic monitor on tailpipe of each valve
- Temperature detector on tailpipe of each valve
- Control room indication and alarm

Steam Generators

- Functions:
  - transfers energy from primary to the secondary
  - produces dry, saturated steam for use in the main steam system
  - provides a boundary between primary and secondary (U-tubes)

Model 51 Steam Generator Fig. 3.2-9

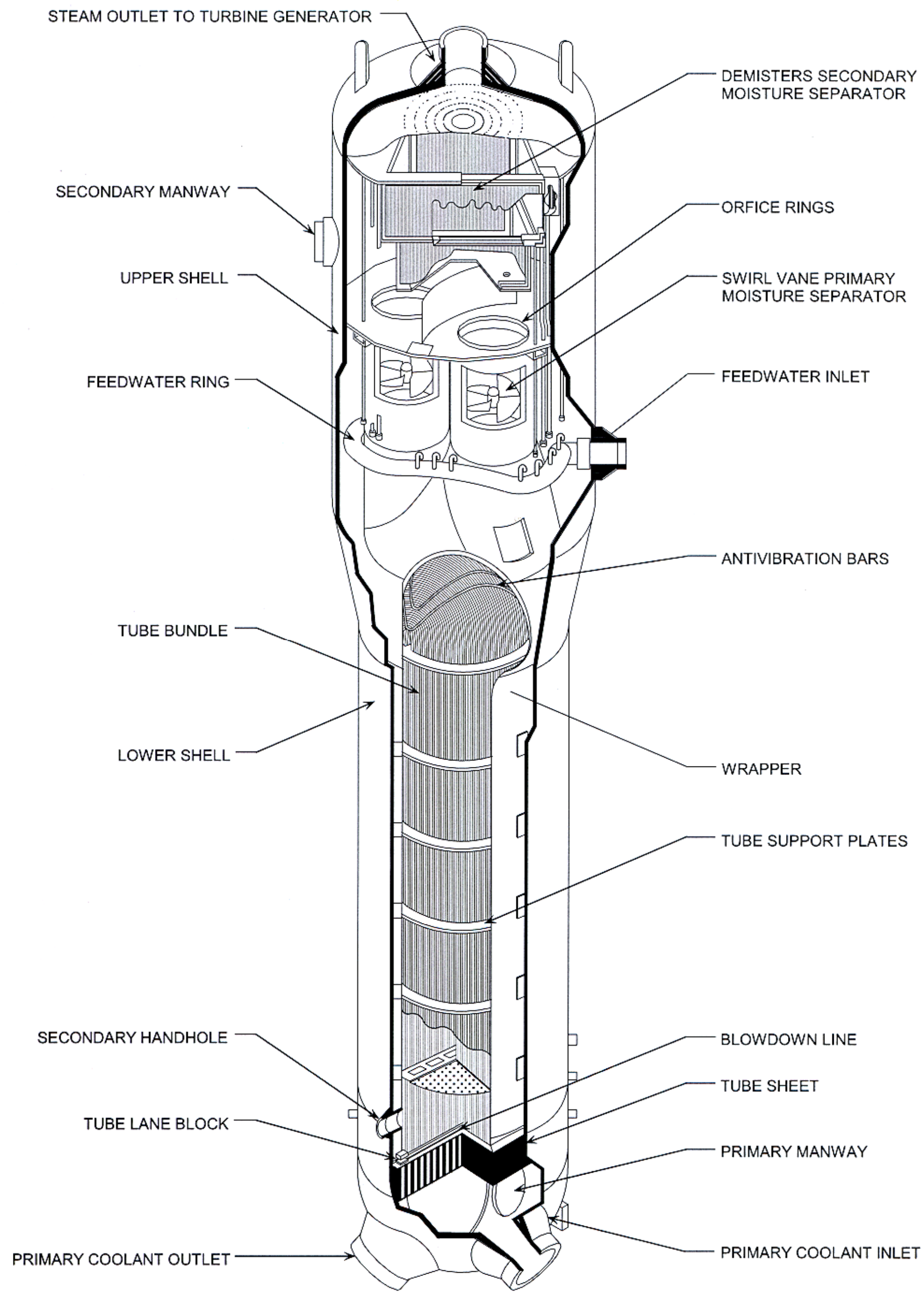


FIGURE 3.2-10 Steam Generator Flow Paths

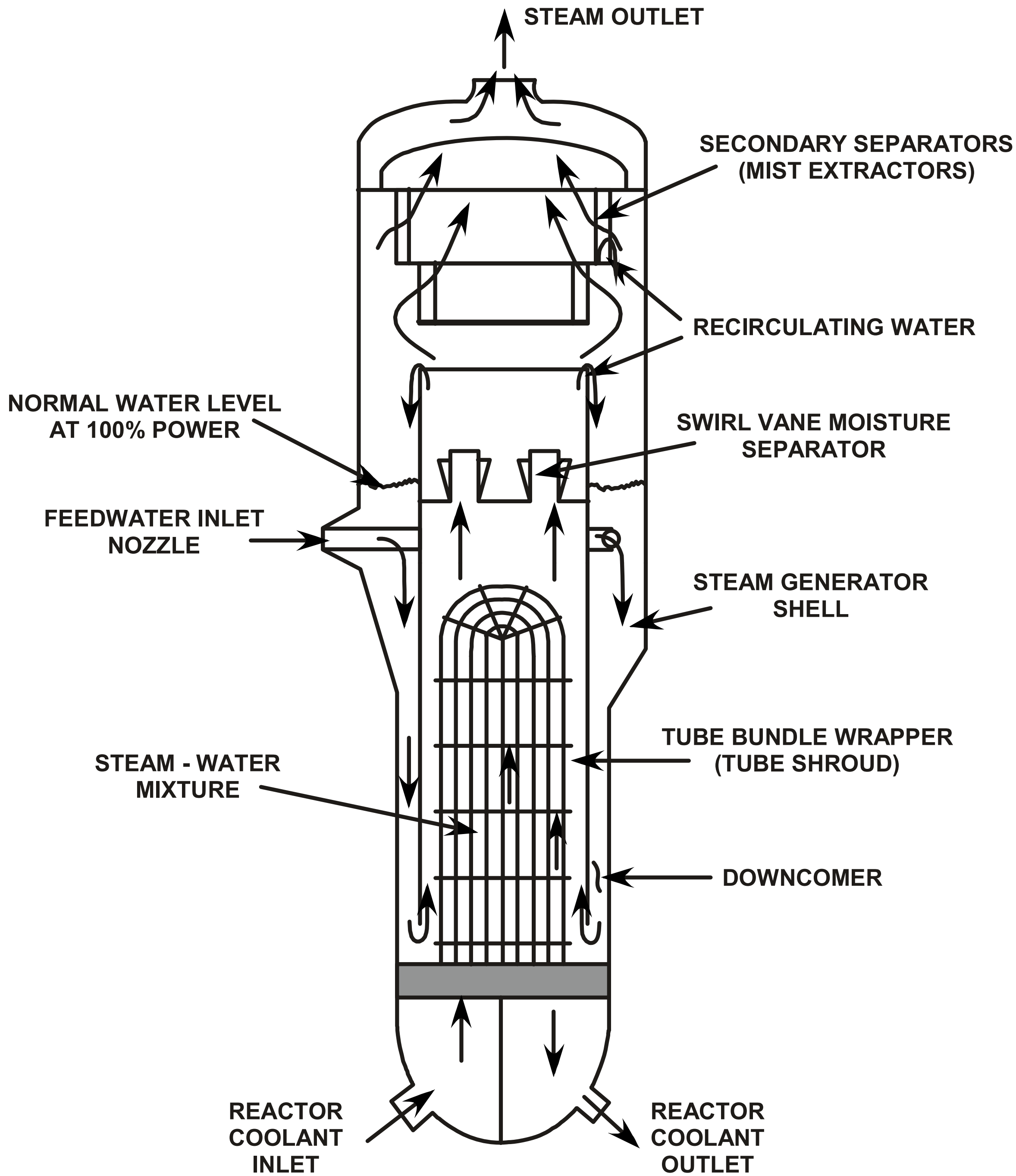
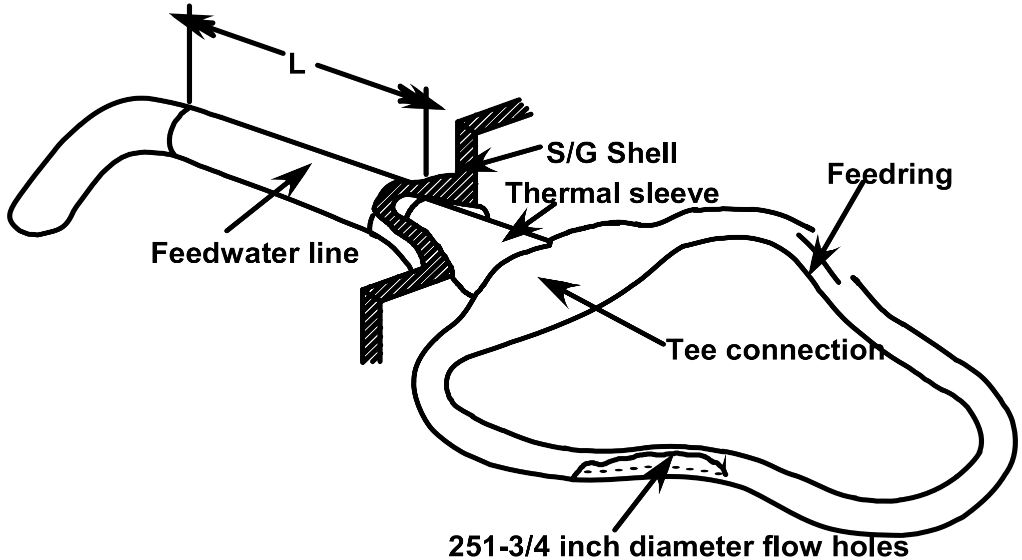


Figure 3.2-11 Feed Ring Assemblies

FEEDRING ASSEMBLY
FEEDRING TYPE STEAM GENERATOR



J-TUBE CONFIGURATION
FEEDRING STEAM GENERATOR

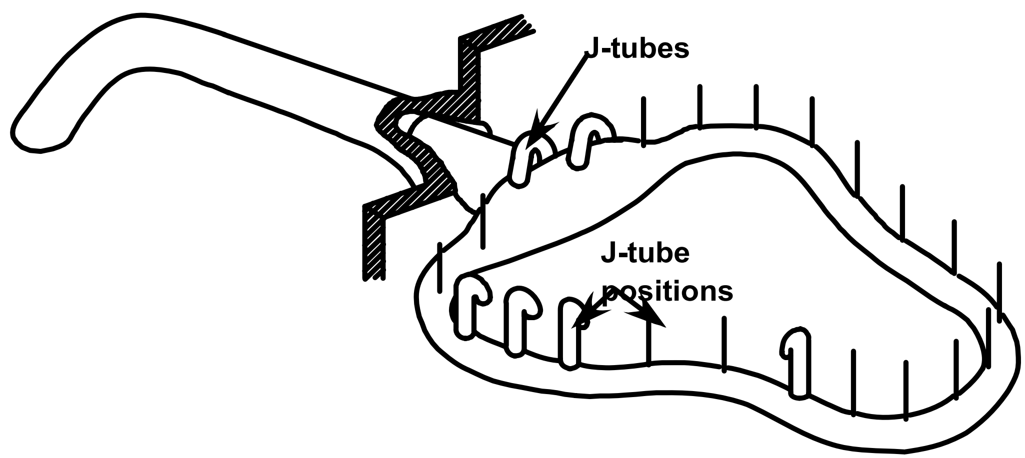


Figure 3.2-12 Feedring and Moisture Seperators

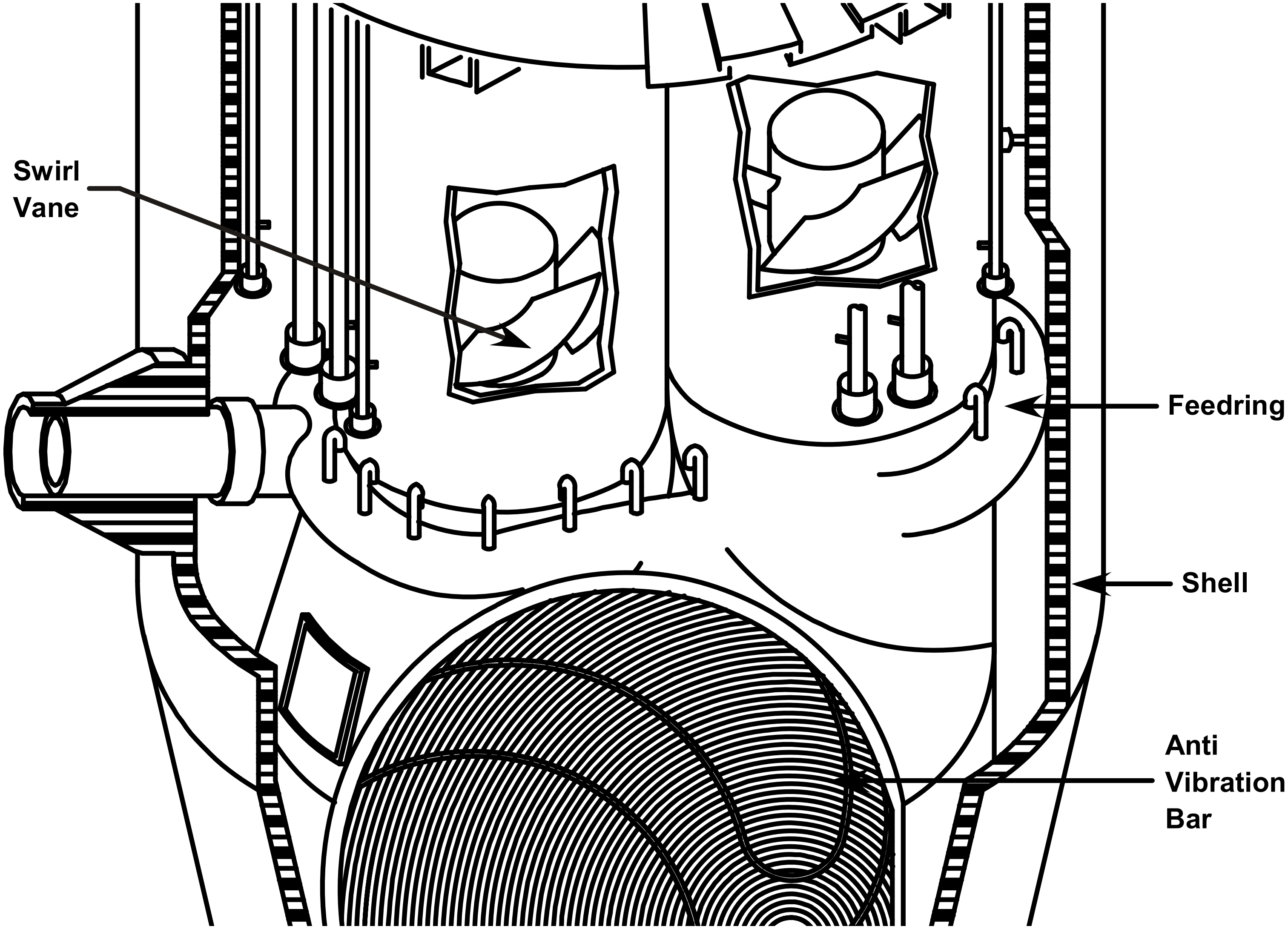


Figure 3.2-13a Steam Generator Moisture Seperators

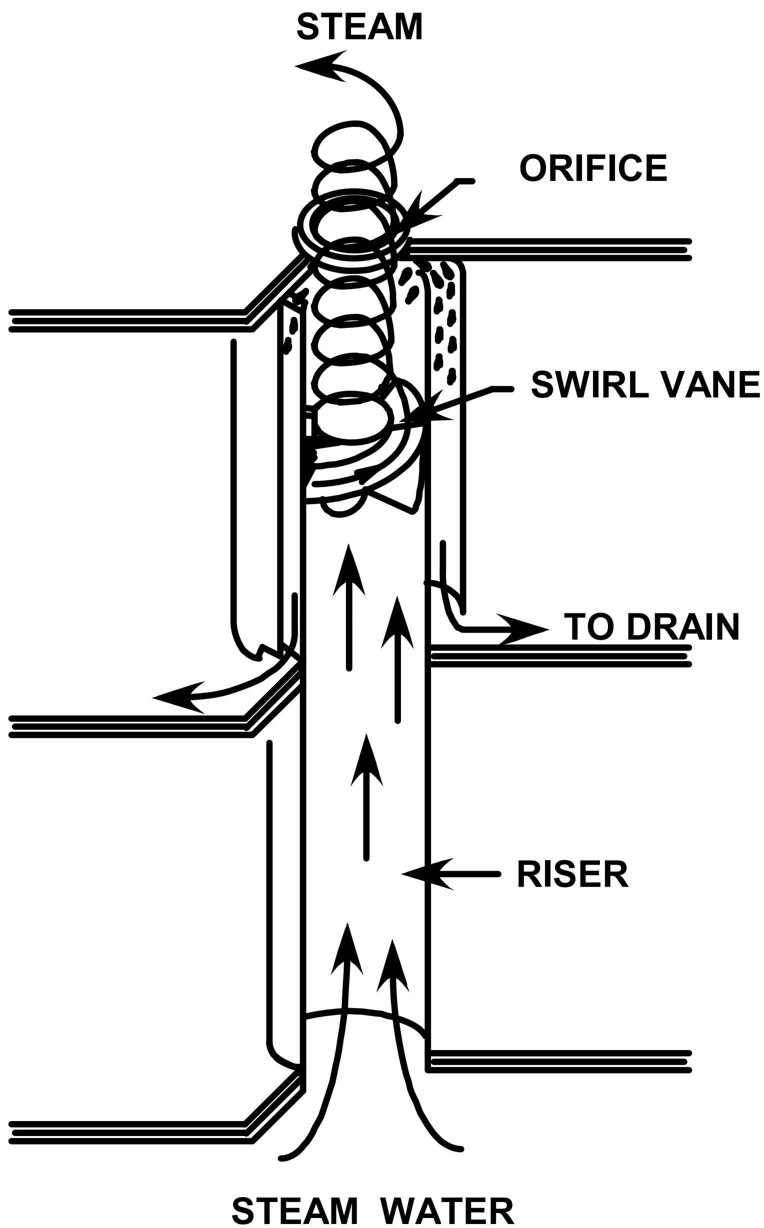


Figure 3.2-13b Steam Generator Moisture Separators

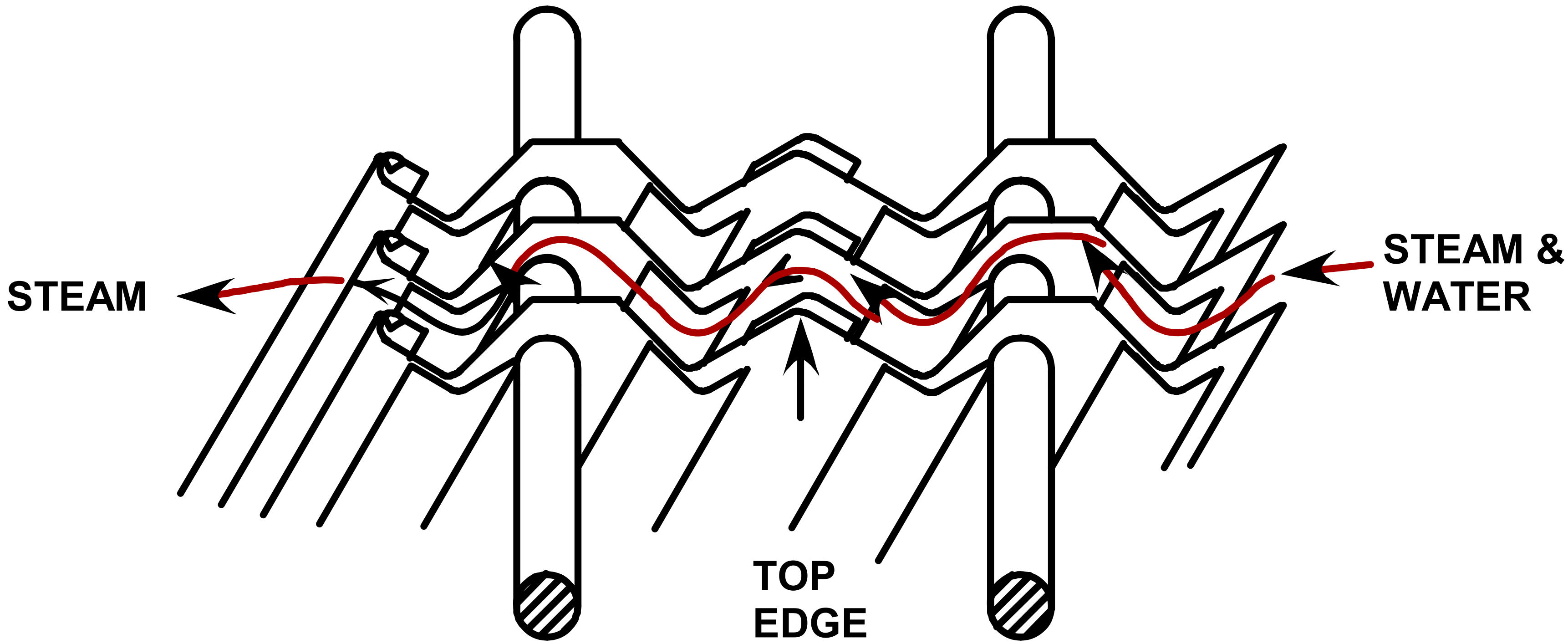
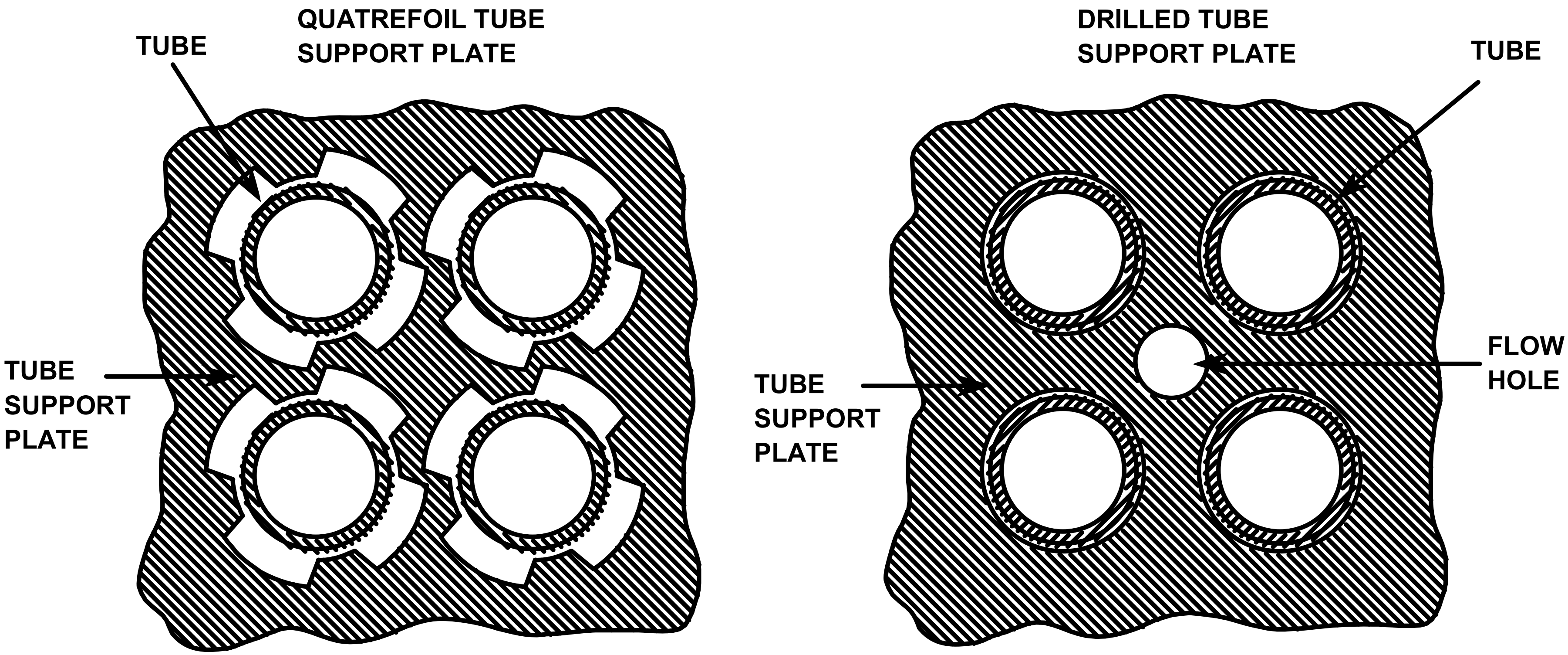


Figure 3.2-14 Tube Support Plate

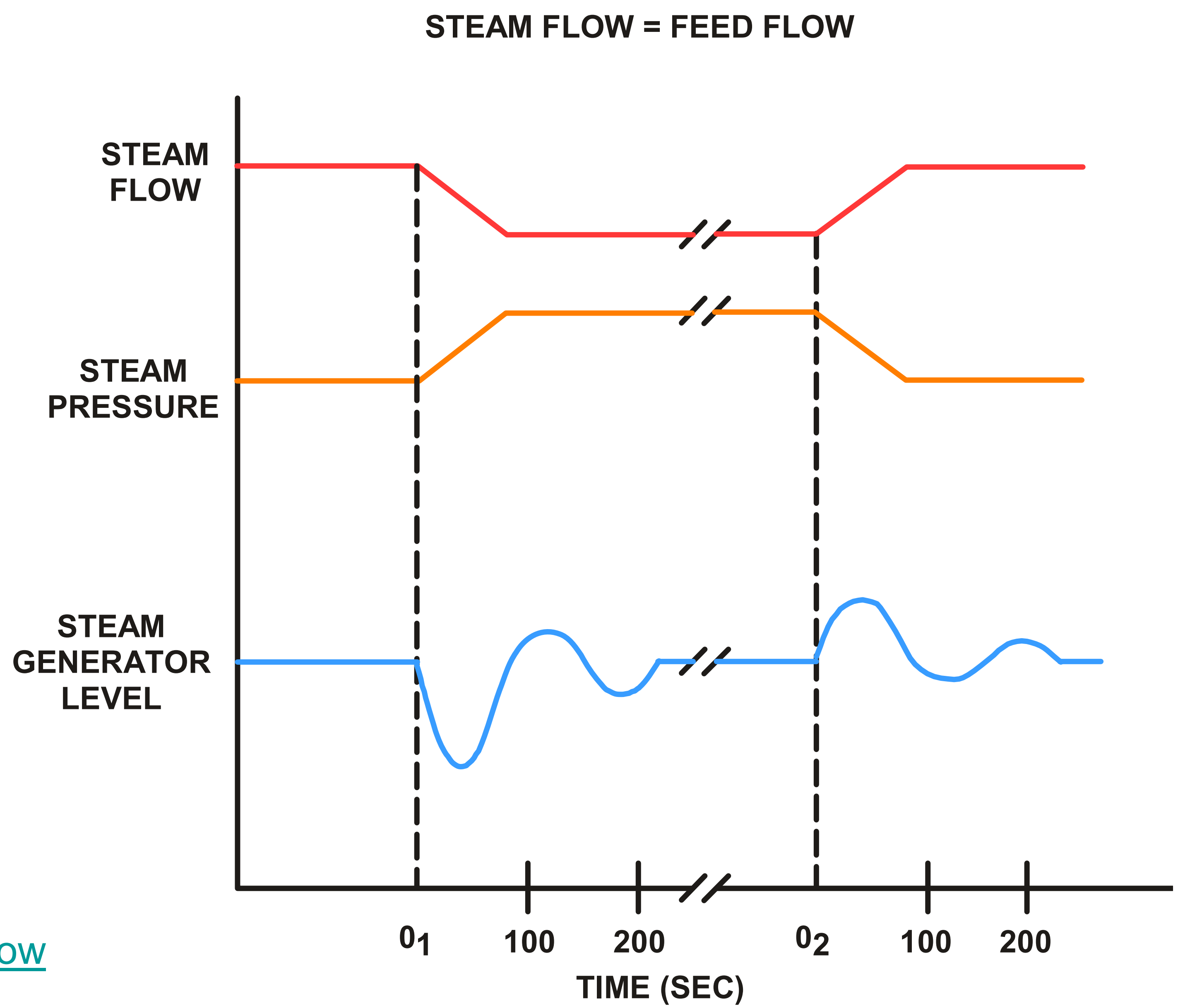


- Describe the Primary and Secondary flow paths in the Steam Generator **(Obj 3)**
  - Primary - enter hot leg, divider plate directs flow through tube sheet and up U-tubes, exit cold leg.

SECONDARY (STEAM SIDE) FLOW PATH. (Obj-3)

- Feedwater enters through feed ring nozzle (~430 deg. F).
- In downcomer feedwater mixes with recirc water.
- Mixture flow under tube bundle wrapper into tube bundle, producing a steam - water mixture.
- Flows up swirl-vane moisture separator. Moisture removed and drains back to downcomer.
- Flows through chevron separator. Moisture removed and drains back to downcomer.
- At S/G outlet to main steam system (main turbine generator) (<0.25% moisture content)

Figure 3.2-15 Steam Generator Shrink and Swell



SG Flow Path

Figure 3.2-16 Reactor Coolant Pump

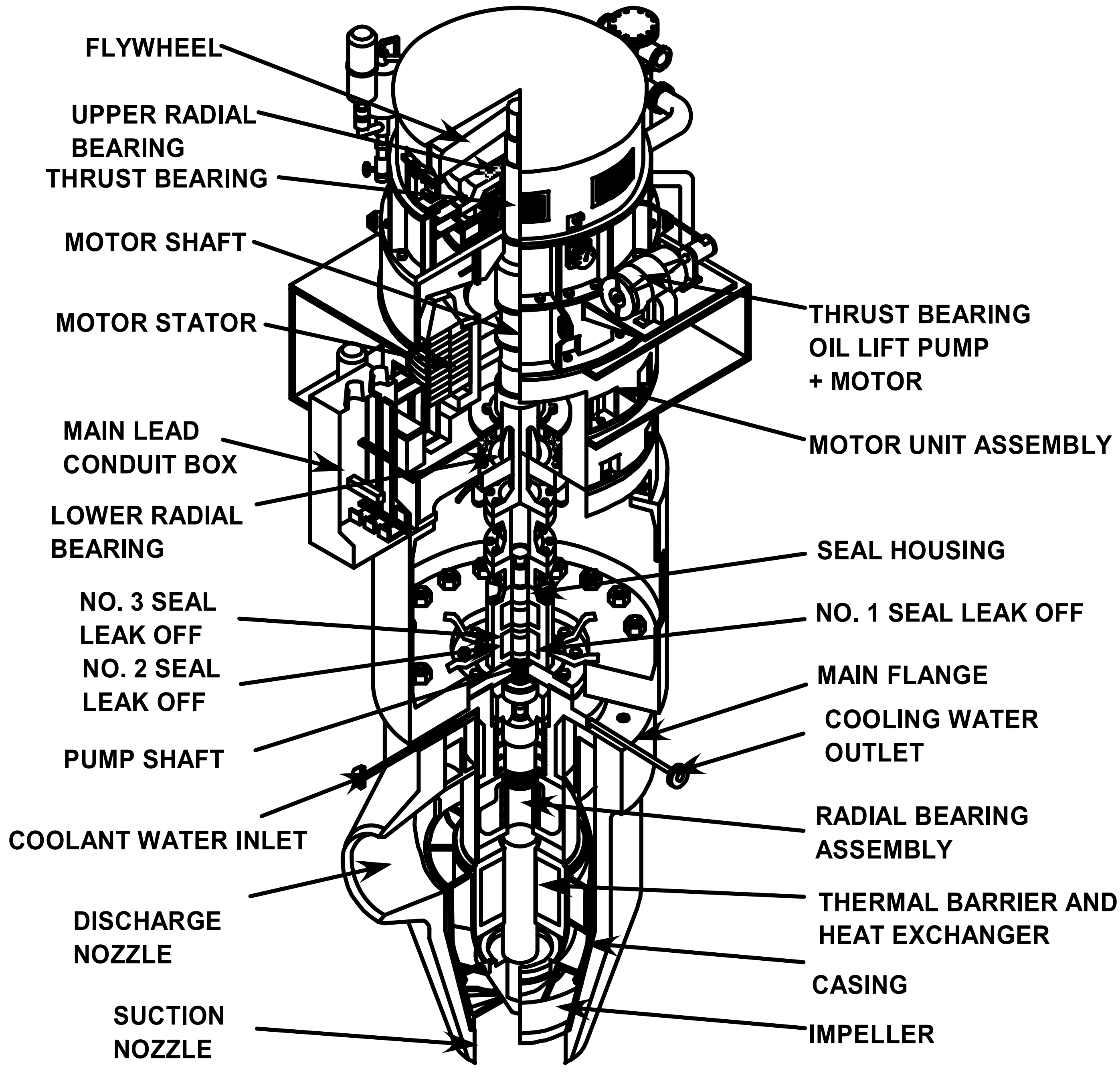
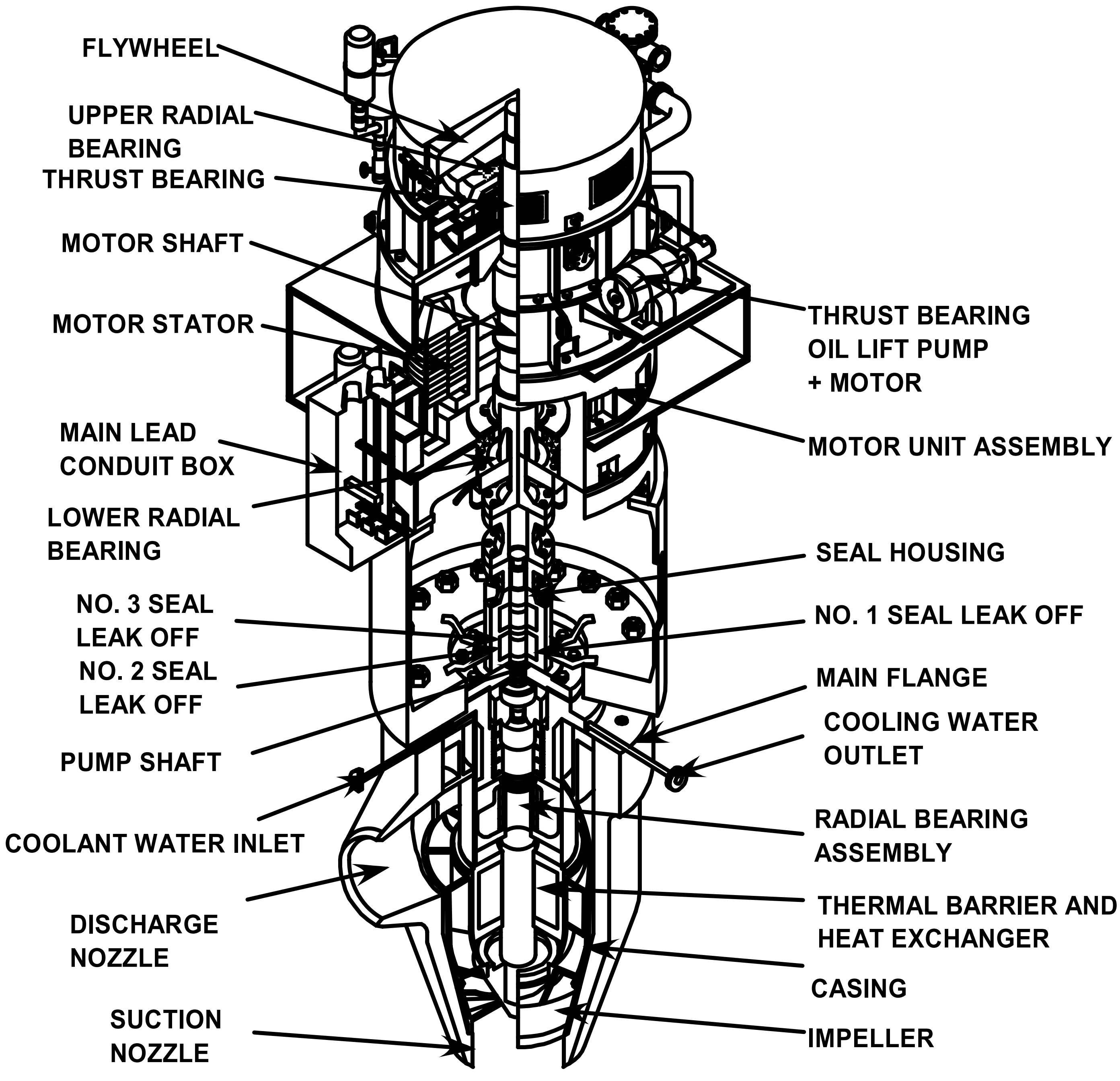
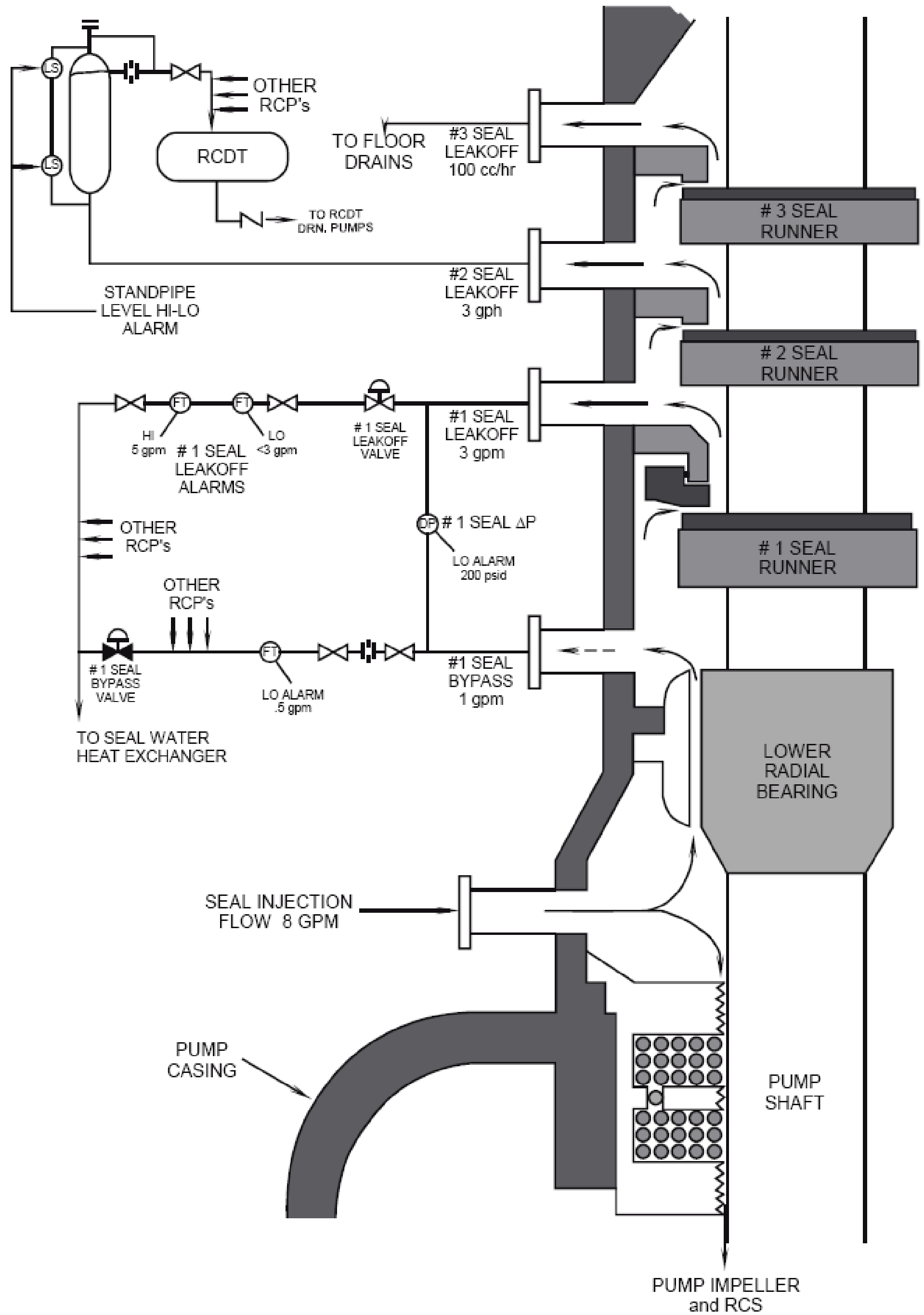


Figure 3.2-16 Reactor Coolant Pump



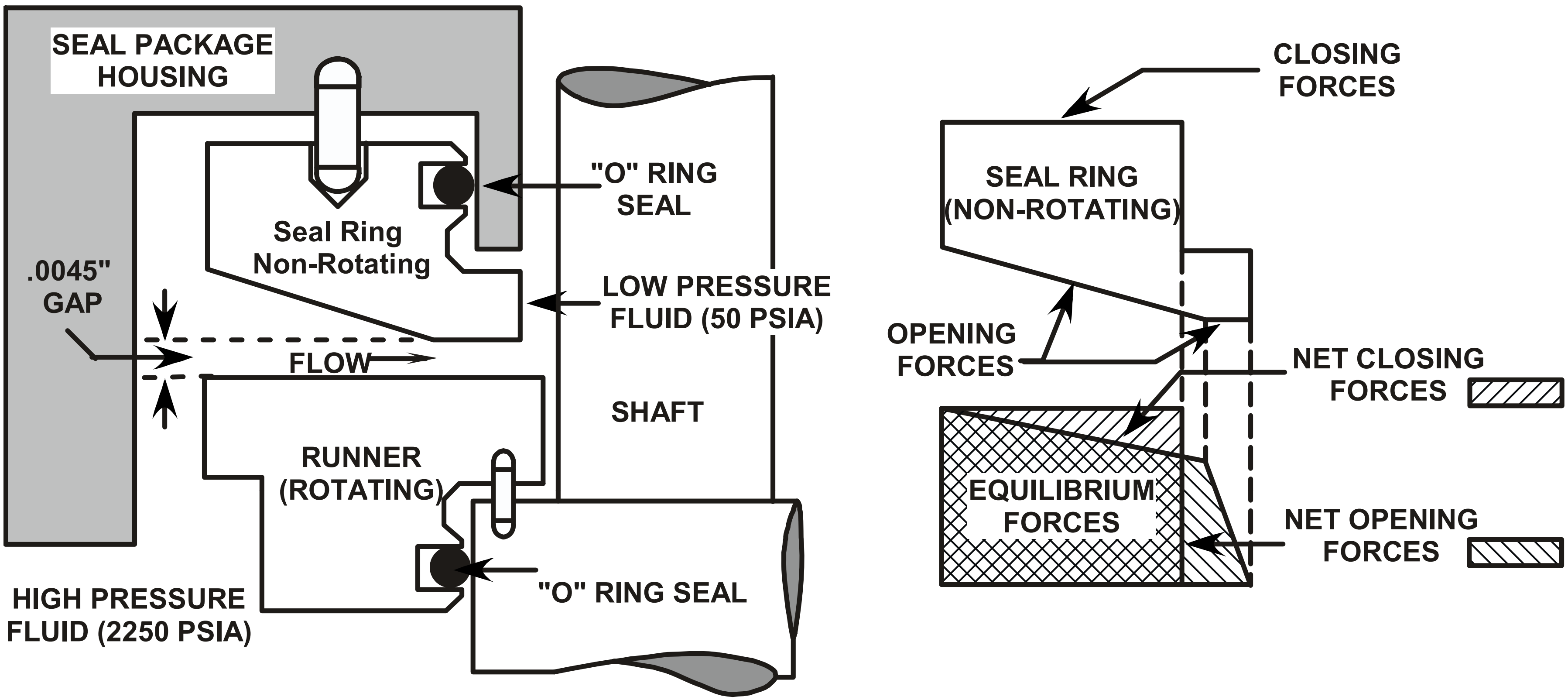
RCP Seal Package

Fig. 3.2-19



- Seal Package **<u>(Obj 4.b)</u>**
  - Purpose - to provide essentially zero leakage from RCS (up the pump shaft into containment) during normal operation.
- Purpose of RCP Seal Injection **<u>(Obj 5)</u>**
  - RCP Seal Injection supplies cool, purified, filtered water from CVCS to pump radial bearing and seal package to prevent seal damage. (3 gal up / 5 gal down)

Figure 3.2-20 Controlled Leakage Shaft Seal



- Purpose RCP Seal Standpipe **(Obj 4.g)**
  - to maintain sufficient back pressure on number 2 seal to ensure flow thru number 3 seal.

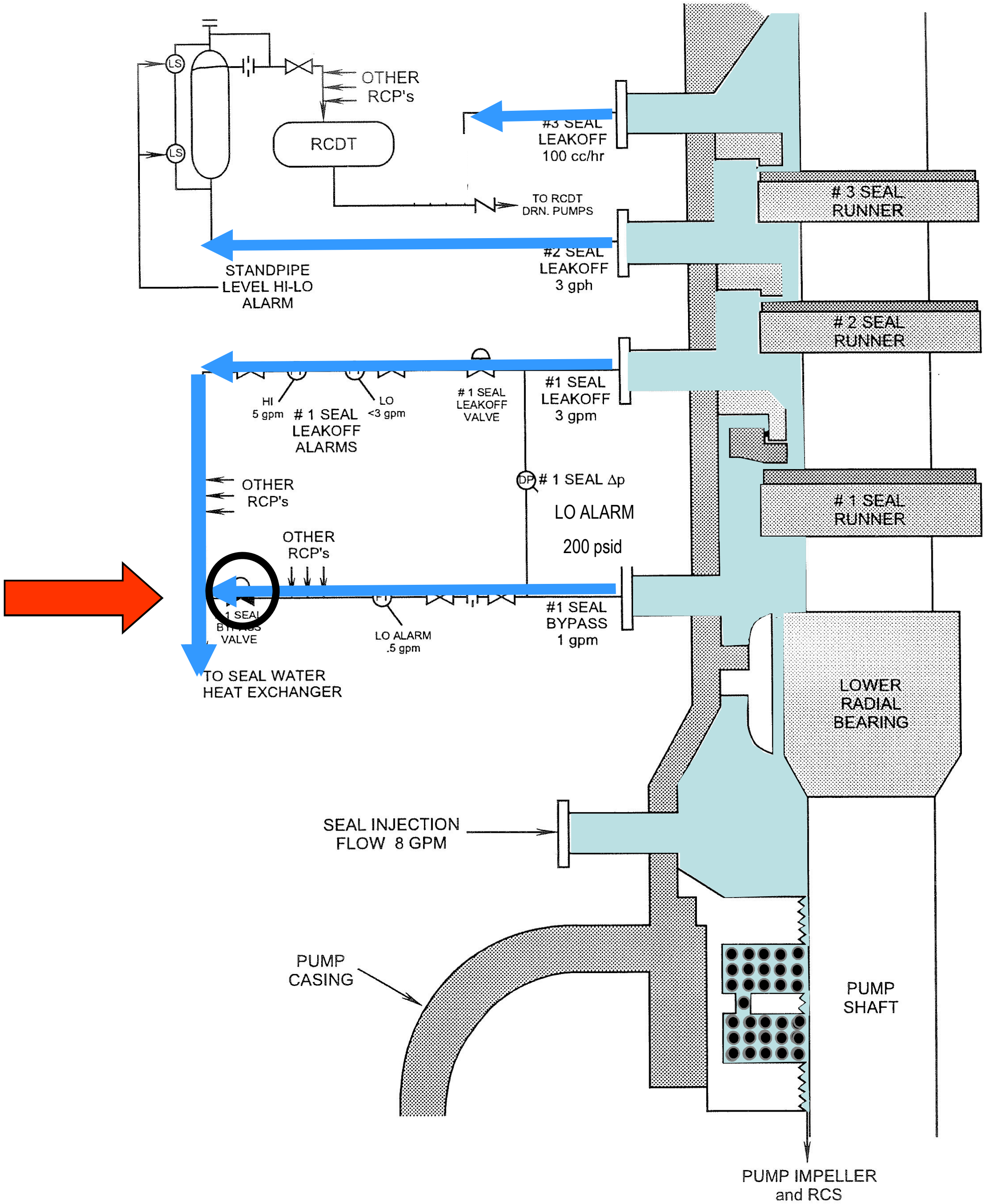


Figure 4.3-2 Seal Flow Diagram

No. 1 Seal Bypass Valve:

(Obj 4.e)

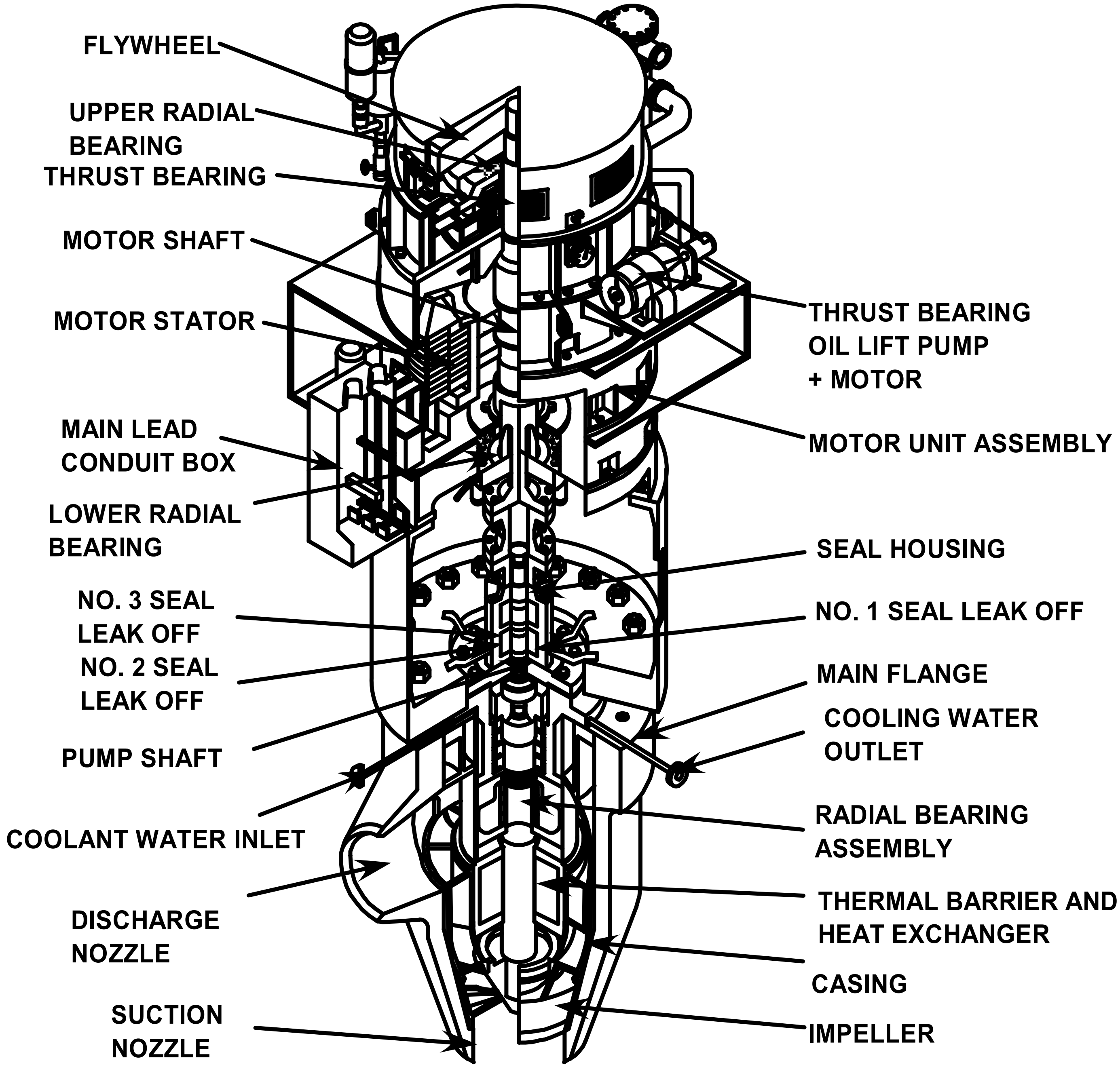
Purpose: It is opened to ensure adequate cooling to RCP lower radial bearing during low RCS pressure operations.

- RCP Thermal Barrier & Thermal Barrier Heat Exchanger (HX) **(Obj 4.a)**
  - Purpose - to cool any reactor coolant leaking up the shaft to protect the radial bearing and shaft seal package.
  - Thermal Barrier HX cooled by CCW.

Number 1 Seal Leakoff Valve. **<u>(Obj 4.f)</u>**

– Purpose - the number 1 seal leakoff valve is closed to place the number 2 seal in service.

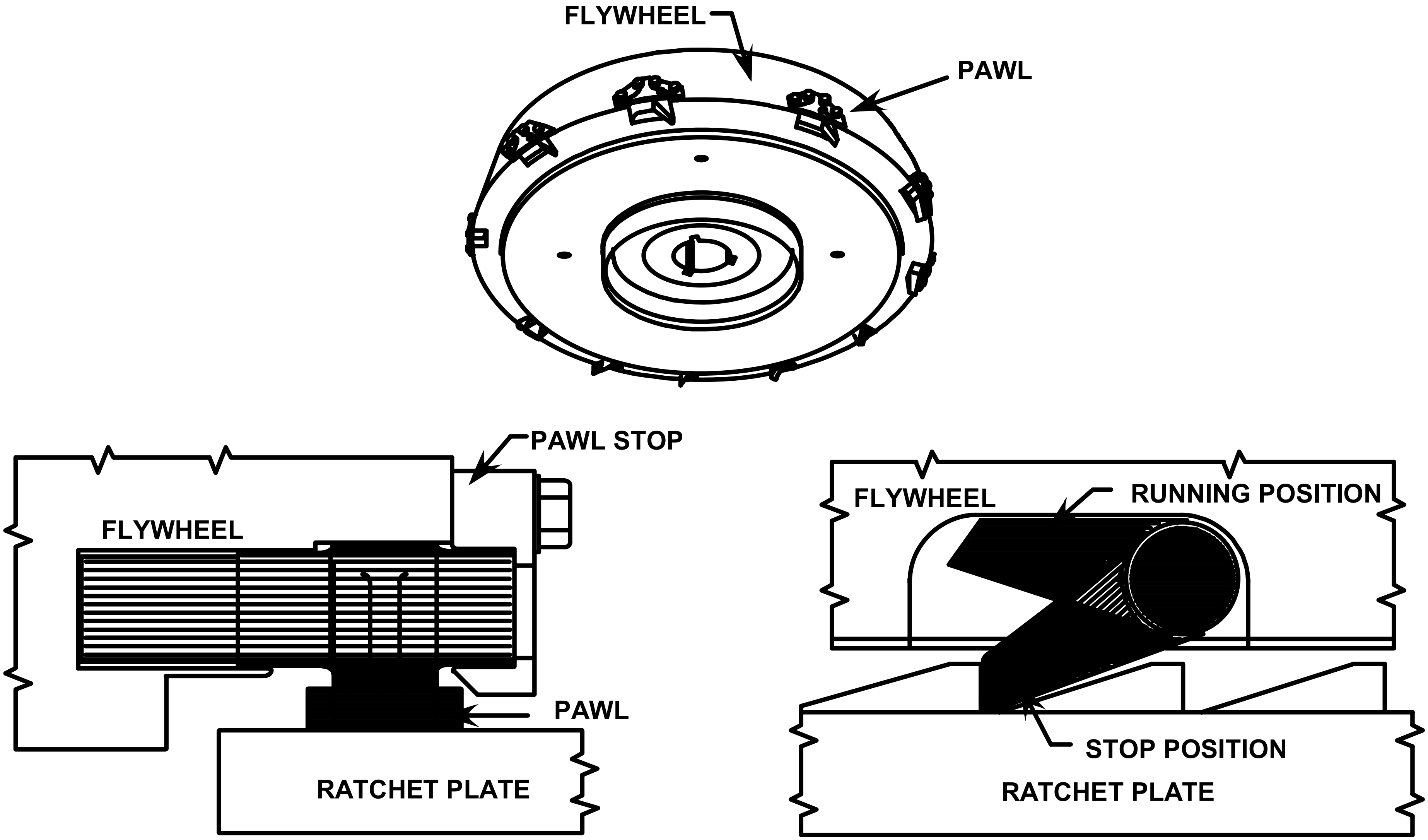
Figure 3.2-16 Reactor Coolant Pump



- Flywheel **(Obj 4.c)**
  - Purpose - Extends forced cooling (coast down) for ~ 30 seconds following a loss of offsite power. This helps to maintain heat transfer and establish natural circulation. Uses stored energy in flywheel.

- Anti-reverse rotation device. **(Obj 4.d)**
  - Purpose - prevents pump from turning backwards due to reverse flow in loop. This prevents excessive starting current (overheat motor windings).

Figure 3.2-21 RCP Flywheel and Anti-reverse Rotation Device



RCS Leakage Detection

- Containment Rad Monitoring System
- Increase in Makeup requirements to maintain PZR level
- Rx Vessel Flange O-Ring high temp alarm
- Containment pressure, humidity, temperature, sump pumping frequencies,
- Primary to Secondary leakage: sampling, Condenser off-gas, SGBD, MSL radiation

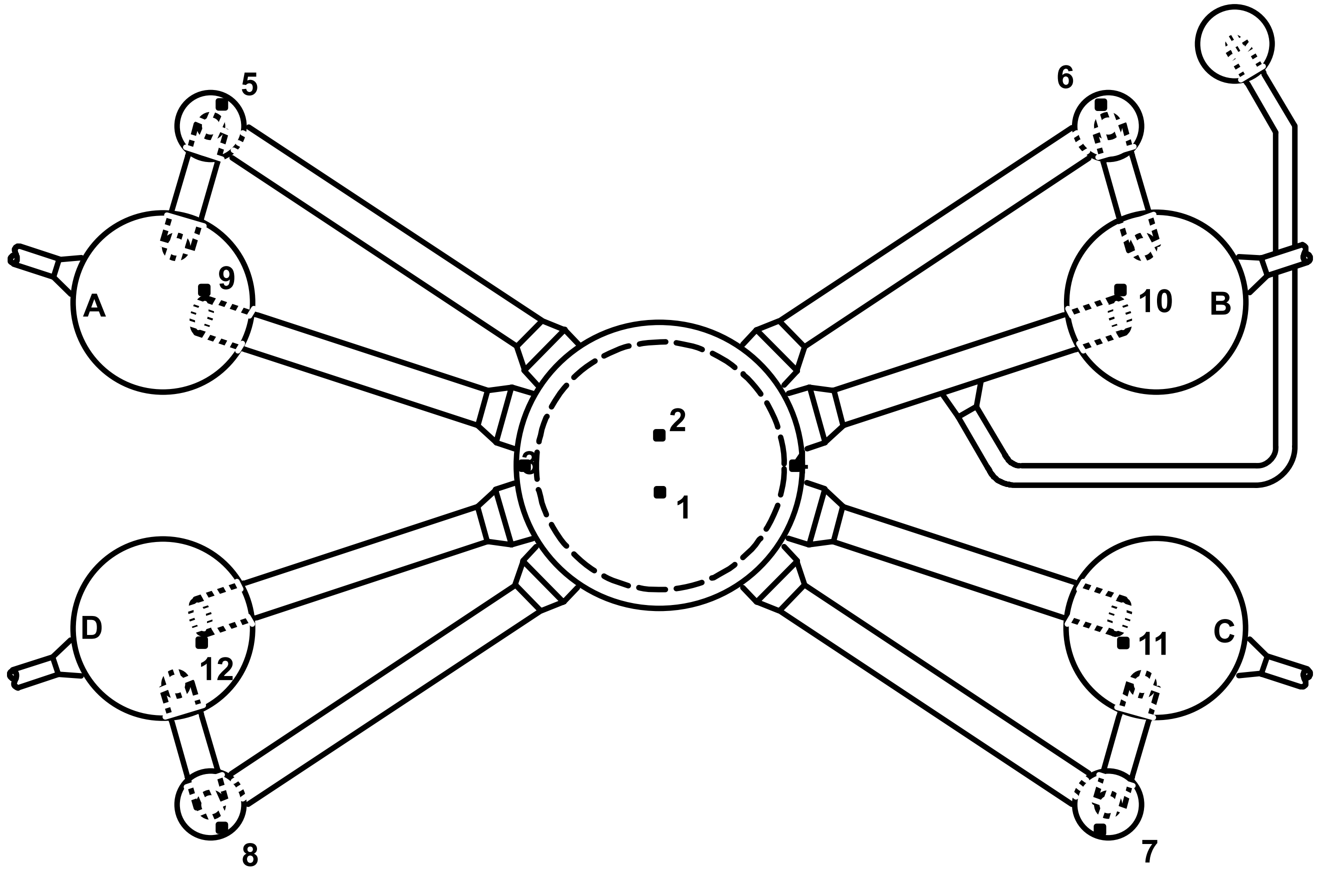
- How could failure of RCP Seals lead to core damage? **(Obj 9.a)**
  - RCP seal package failure results in a SBLOCA.
  - If there is no high head injection pumps to provide make-up water to the RCS, the core will become partially or fully uncovered. (No operator action to reduce RCS pressure is assumed.)
  - Decay heat will cause fuel temperature to increase. Could lead to fuel damage. Time to core damage is dependent on assumed size of leak.

- How could PORV Failures Lead to core damage? **<u>(Obj 9.b)</u>**
  - Failure to close results in a LOCA.
  - If PORV block valve does not shut AND if containment sump recirculation mode of ECCS is unavailable, then core will become partially or fully uncovered.
  - Decay heat will cause fuel temperature to increase. Could lead to fuel damage.

- How could PORV Failures Lead to core damage? **<u>(Obj 9.b)</u> (cont)**
  - Failure to open (when needed) during emergency operations (i.e., once through core cooling)
  - Unable to remove decay heat w/ once through core cooling.
  - Decay heat will cause fuel temperature to increase. Could lead to fuel damage.

Purpose is to detect any loose or drifting metallic parts within the RCS pressure boundary

Figure 3.2-22 Vibration and Loose Part Monitoring Transducer Locations

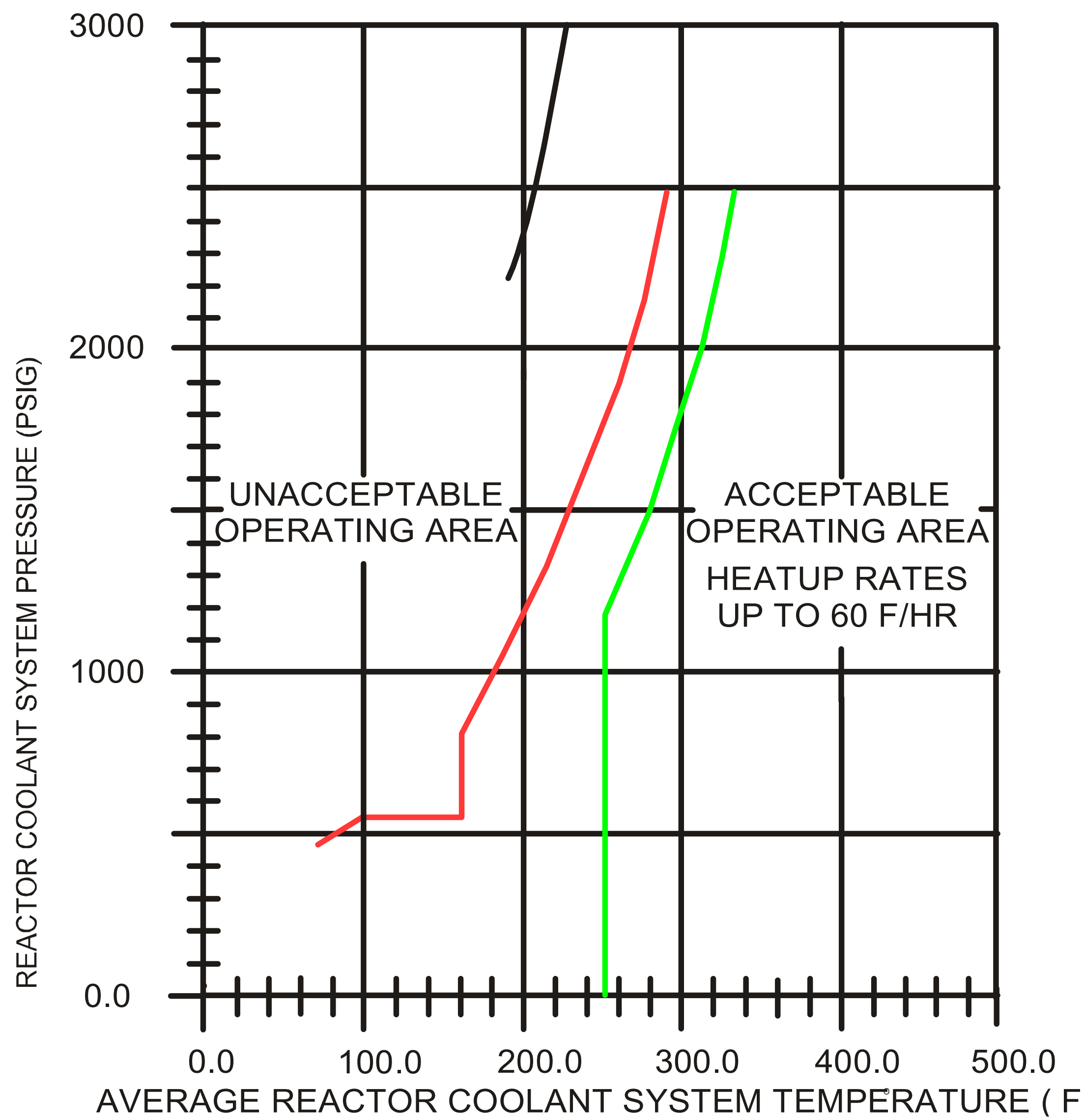


CHANNEL	LOCATION	CHANNEL	LOCATION
1	LOWER VESSEL (WEST)	7	RC PUMP C
2	LOWER VESSEL (EAST)	8	RC PUMP D
3	UPPER VESSEL (NORTH)	9	STEAM GENERATOR A
4	UPPER VESSEL (SOUTH)	10	STEAM GENERATOR B
5	RC PUMP A	11	STEAM GENERATOR C
6	RC PUMP B	12	STEAM GENERATOR D

RCS Heatup Limits: TS

- Max. H/U limited to 100 deg. F in any one hour.

Figure 3.2-26 Reactor Coolant System Pressure - Temperature Limits (Heatup)



RCS Cooldown Limits: TS

- Max C/D limited to 100 deg. F in any one hour.

Figure 3.2-27 Reactor Coolant System Pressure - Temperature Limits (Cooldown)