Reactor, Boiler & Auxiliaries - Course 233

HEAT TRANSPORT GLAND SEAL CIRCUIT

I. INTRODUCTION

As this course is not a station systems course, the detailed aspects of equipment design and operation are not discussed. For the main HT pumps, however, the pump gland seal circuit principles are particularly important for HT pump operation and are discussed here. As the HT pumps operate at high temperature and high pressure a gland seal cooling supply which is supplied from a low temperature, high pressure source is necessary. The reason for this is that gland seal temperature has to be maintained below a specified maximum (typically 60-70°C) above which the seal is at risk of damage requiring shutdown. In addition, adequate pressure has to be available to ensure that some gland seal water can leak into the main pump volute from the mechanical seal to prevent outleakage of undesirably hot main HT system water. For these reasons a gland seal supply separate from main system D_2O is used for the normal supply of gland seal water.

II. SYSTEM PURPOSE

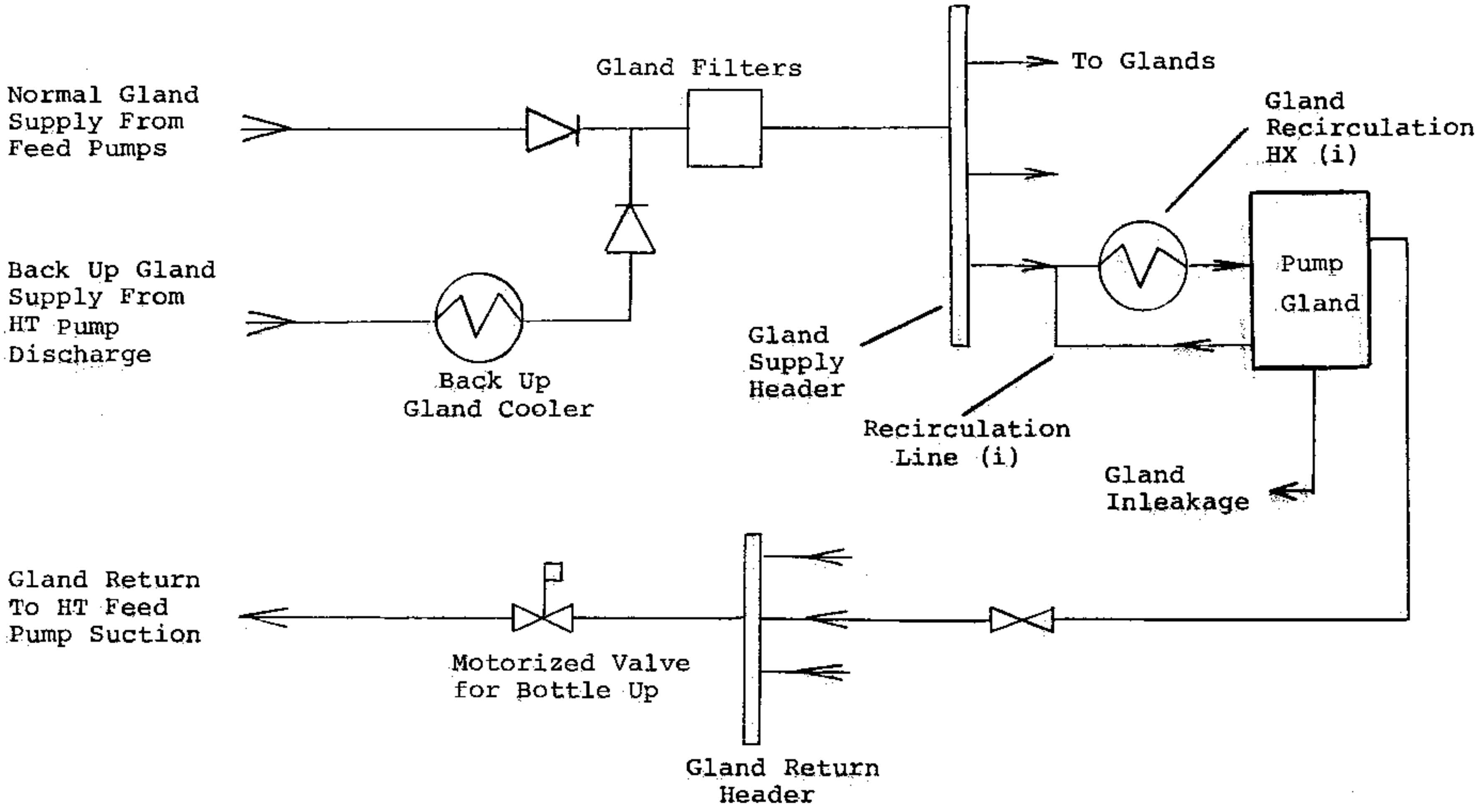
The purposes of the system (sometimes called the gland injection system) are to:

(i) provide a flow of cool, filtered D_2O to the primary HT pumps for cooling and lubrication of the pump gland seals. (Some pumps incorporate pump bearing cooling and lubrication into this system also.)

(ii) prevent hot main HT system D_2O from entering the pump gland by maintaining the seal cavities at a higher pressure than the D_2O in the pump volute.

Failure to supply adequate cooling to a pump gland seal for more than a few minutes while the pump is running will result in seal failure. Depending on the pump seal design, it may be possible to operate with one seal damaged, ie, leaking. However, if multiple seal failure occurs such that leakage to the HT D_2O collection exceeds the pump back capability, or if leakage is to atmosphere, then the reactor would have to shut down and the HT pump isolated for seal replacement. Leakage past the seals to plant atmosphere would of course be a small LOCA, which is a serious type of failure.

Figure 1   Typical HT Pump Gland Seal Supply Circuit



(i) used if pump bearing is part of gland.

III. TYPICAL SYSTEM LAYOUT

(a) Normal Gland Supply

The required cool D_2O supply flow is obtained from the discharge of the feed pumps of the pressurizing system, see Figure 1.

The supply has to be HT D_2O as the seal D_2O mixes with HT D_2O by seal outleakage into the main HT system at the pump volute, via a throttle or restriction bushing. The high pressure ($\sim$12 MPa) at the feed pump discharge supplies the necessary pressure head for gland flow.

To ensure a clean water supply, a number of gland filters (two or three in parallel) may be used as indicated in Figure 1 and in Section 233.30-3, Figure 4. This minimizes the risk of particulates getting into the rotating seal and causing abrasive damage, eventually resulting in higher seal leakage. As the feed pump discharge water has just been cleaned by the HT bleed filters, the gland filters are a precautionary but essential measure, and should not require changing very frequently.

A header downstream of the filters supplies each HT pump gland seal with the required flow at the required pressure. Of the D_2O supplied to the pump seal cavity, some, $\sim$70%, will flow into the main HT system via the throttle bushing, see Figure 2. The remainder will flow between the various seal cavities (primary, secondary and tertiary, if used) via seal throttles (sometimes called breakdown cells), which are arranged in parallel to the seal faces, see Figure 2. The successive seal cavities operate at successively decreasing pressures. A very small amount ($\sim cm^3/min$) of water will pass between the seal faces if the seal is intact. A badly damaged seal will result in most of the seal flow passing between the faces of the seal instead of through the seal throttle. The gland seal return flow is taken, as shown in Figure 2, from the tertiary seal cavity. A small amount of leakage will occur from this cavity via the tertiary seal faces, and be routed by a leakoff line to the HT D_2O collection system. This particular leakoff to collection is usually the main contributor to the HT D_2O collection rate. (Pump seal arrangements may vary somewhat from those of Figure 2 in that the gland return and D_2O collection leakoff lines may be from the secondary seal cavity and tertiary seal cavity, respectively. Also some pump seals may not have breakdown cells in parallel with the seals, but allow all the seal flow to pass between the seal faces).

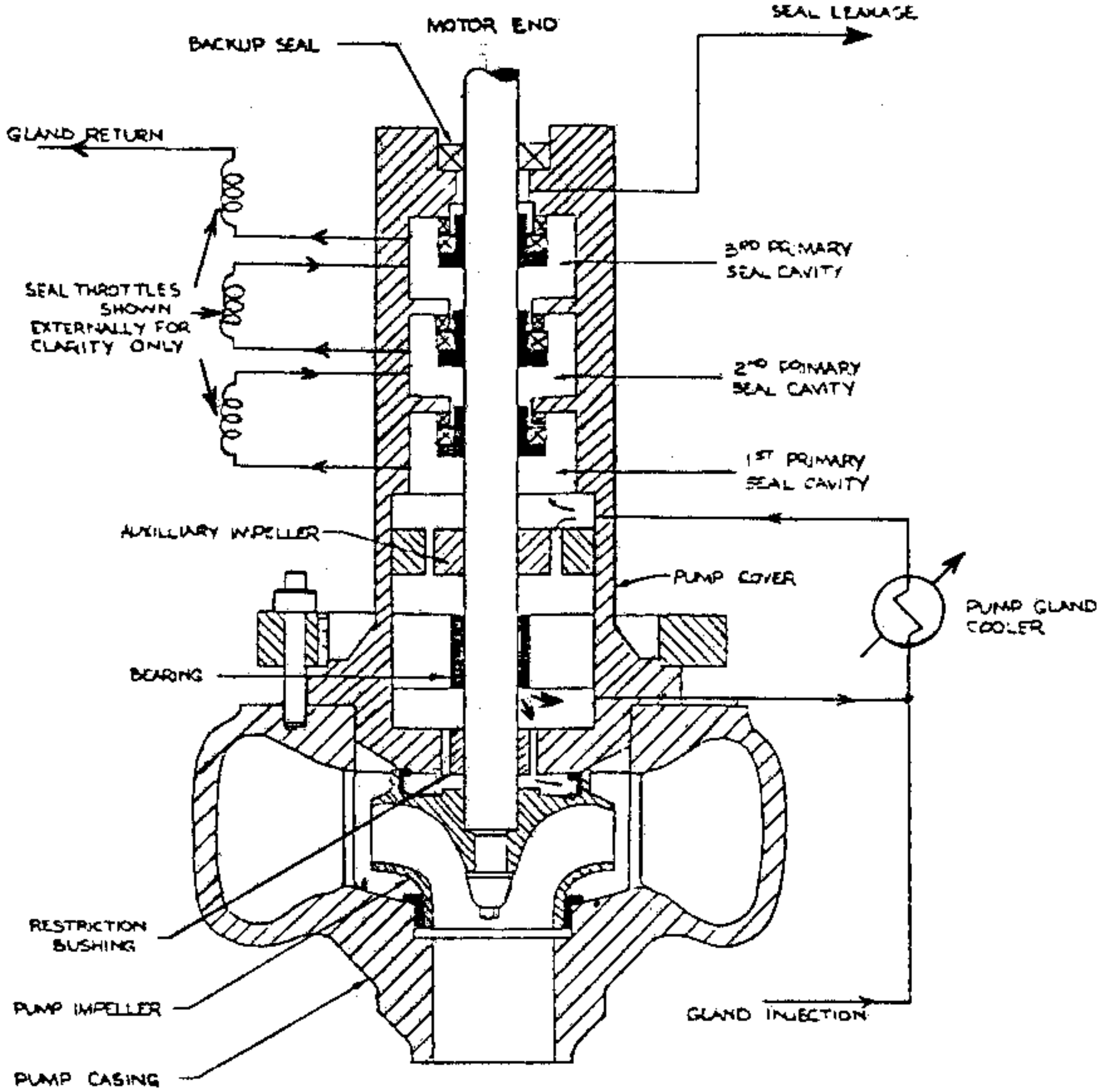


Figure 2: Simplified HT Pump Gland

Total seal flow per pump has to be adequate to provide make up for:

- seal inleakage to HT system

- seal outleakage to HT collection system

as well as to provide seal cooling.

For some HT pumps (PNGS in particular) there may be a gland recirculation line on the supply, as shown in Figure 1, with a gland recirculation heat exchanger. The reason for this is that the pump bearing in this case is part of the gland, and the extra cooling required necessitates the inclusion of a heat exchanger in a recirculation line.

(b) Gland Return

Return lines from each pump gland lead back to the feed pump suction. Each pump gland return line will usually have a manually operated valve available to adjust the seal cavity pressure by changing return flow.

A motorized isolating valve, Figure 1, on the return line is available to be closed automatically (or remote manually) on low gland supply flow. This action will bottle up the gland D_2O available, as supply line check valves prevent backflow. This action will help to prevent seal overheating in circumstances where gland flow is reduced by an undesirable amount. An example of this would be low flow caused by a clogged gland filter, which would result in automatic gland seal bottle up. Cooling of the bottled up water will then be available only via the pump jacket cooling circuit, or via the pump gland recirculation heat exchanger, if used. Therefore normal supply flow should be re-established as soon as possible to prevent seal damage for overheating.

(c) Back Up or Emergency Gland Supply

If the normal gland supply fails, for example if both feed pumps failed, a back up gland supply must be provided or the seal will overheat. Back up or emergency gland supply is therefore provided from a HT system high pressure point (either HT pump discharge or inlet header).

A back up gland cooling heat exchanger, cooled by recirculating cooling water cools the back up supply D_2O down from HT temperature to $\sim 40°C$, and then the supply is injected upstream of the gland filters to join the normal supply line. Check valves (see Figure 1) prevent both supplies from interacting under normal conditions, as the feed pump discharge pressure is greater than the emergency gland supply pressure. The reason the HT pump discharge is not used as the normal gland supply is because it requires cooling via the emergency gland cooler. The required temperature decrease of the HT D_2O through this emergency gland cooler is then quite large: from HT normal operating temperature down to $\sim 40°C$. Hence supplying already cold water from the feed pump discharge is a more reliable method to use for the normal seal supply.

IV. MONITORING OF PRIMARY PUMP SEAL PERFORMANCE

Monitoring of seal conditions is important, and the control room will have indication of the following:

- individual pump gland supply flow
- gland return temperature
- gland interseal temperatures and pressures
- gland filter ΔP

No reactor or HT pump trips are initiated directly from these parameters nor are there any automatic control loops to control any of these parameters. Operator manual intervention is required to trip the pump or to adjust the parameter value on alarms which require action. The two general types of failure in the gland are:

(a) a failed (leaking) seal

(b) a plugged breakdown cell

From observation of the interseal pressures, in particular, it should be possible to determine where the failure is for a given seal design.

V. IN SERVICE OPERATION OF GLAND SEAL CIRCUIT

Because the gland is designed to operate at low temperature using a clean D_2O supply, the gland seal circuit is required to be in service under the following conditions:

- HT System cold pressurized, main pumps either off or on.
- HT System hot pressurized, main pumps either off or on.

Valving in the gland seal supply before the HT is pressurized will prevent relatively dirty main system D_2O backing up into the seal. In addition having the seal supply already in service when the HT D_2O is subsequently being heated up will then prevent hot main system water from backing up into the seal.

ASSIGNMENT

1. State why (a) a low temperature and (b) a high pressure gland seal D_2O supply is required for the HT main pumps.
2. State typically how long it will take to damage a main pump seal on loss of gland seal supply. State the consequences of this damage.
3. State where the normal gland supply is taken from and state typically what % of the supply goes to (a) inleakage to the HT system (b) the gland return line back to HT system.
4. State why pump gland bottle up (or box up) is a feature of the system.
5. State where the emergency gland supply is taken from. Check in your own plant to see if there are any differences to the description in the notes.

6. Draw a clear, simplified diagram of a primary pump seal for your own plant. Show the relative location of the following:

   - gland injection flow
   - gland recirculation cooler
   - primary/secondary/tertiary seals and seal cavities
   - interseal throttles
   - restriction bushing in casing
   - gland return line
   - seal leakage to collection.

7. State which seal parameters are monitored for question 6 above.

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