Reactor, Boiler & Auxiliaries - Course 233

HEAT TRANSPORT PRESSURE RELIEF

I. IMPORTANCE OF HT PRESSURE RELIEF

The purpose of the HT pressure relief is to prevent overpressurization of the components in the HT main circulating system. Rupture of HT components as a result of overpressure could cause one or more of the following events:

- a HT D_2O spill requiring the use of emergency injection if the loss of coolant is large enough
- fuel failure due to a reduction in HT cooling capacity
- a reactor power rise due to an increase in reactivity (from the positive void coefficient effect when a loss of coolant occurs), requiring shutdown system(s) to operate to reduce power.

Since these events in extreme cases could become major accidents, HT pressure relief capacity is vital.

II. CAUSES OF OVERPRESSURE IN THE HT SYSTEM

The HT system could become overpressurized (ie, to a pressure greater than the normal set point of the pressure control system) due to:

1. Mechanical compression of the D_2O by the pressurizing feed pumps should the bleed rate become less than the feed rate due to equipment malfunction (eg, bleed valves fail closed and feed valves fail open with feed pump(s) operating).

   Another way overpressurization can occur due to mechanical compression is via the F/M pressurizing pumps when a F/M is on a reactor channel. The F/M pressurizing pumps can produce pressure in excess of HT system operating pressure. However, relief devices on the F/M are provided for protection in these circumstances.

2. Coolant swell (thermal expansion) as a result of an increase in average HT D_2O temperature such that the resulting pressure increase could not be adequately controlled by the pressure control system. Several possible types of system failures can result in over-pressurization due to coolant swell. Such failures are described below. Generally they are potentially more hazardous than mechanical overpressurization as the potential overpressures reached may be very large.

Events Involving Main HT System Overpressurization Due to a HT Temperature Increase

(i) Surge tank (pressurizer) heater(s) failing to turn off when the HT pressure setpoint is reached. This event will cause a rise in surge tank D_2O temperature resulting in increased boiling in the surge tank. This will increase the D_2O vapour pressure in the surge tank (as the vapour is saturated) and consequently in the main HT system.

If the pressurizer were isolated from the main system and the heaters failed to turn off, then the potential pressure rise (in the pressurizer) would be much larger and faster than if the pressurizer were not isolated. However, even in this event, the pressurizer steam bleed valves will be adequate to cope with relieving the maximum steam production rate within the pressurizer.

(ii) A loss of regulation accident (LORA) in which reactor power increases above its normal full power setpoint. This would lead to a HT D_2O swell and accompanying HT pressure rise.

(iii) A loss of class IV power resulting in loss of primary pumps while at power, or the loss of one or more primary pumps while at power. This event will result in a large reduction of heat transported away from the fuel due to reduced flow. Thus the average HT D_2O temperature will rise resulting in a high HT D_2O pressure.

(iv) Steam flow from the boilers to the turbine is cut off by the closing of the turbine emergency stop valves and/or turbine governor valves while at power. (A turbine trip or loss of line could cause this.) A similar event would be the cut off of 'stretch' steam supplying, say, an upgrader, a steam plant or construction steam. These events could cause the steam reject valves (PNGS-A) or the atmospheric steam discharge valves and condenser steam discharge valves (BNGS-A) to lift. Depending upon the plant, a reactor setback or stepback would then automatically by initiated (by the turbine trip or by the opening of the steam valves) if the reactor was at full power. If the resulting power decrease does not happen quickly enough to prevent the steam pressure rising, then the main steam safety valves will lift. As the SRV's (or CSDV's and ASDV's) are lifting, the steam pressure and hence temperature (saturated system) are rising, and the heat transfer rate from the HT D_2O to the feedwater will decrease. Thus the HT D_2O average temperature will rise and cause a HT D_2O swell. The HT D_2O pressure will rise as a result. When the rate of steam release (via SRV's or safeties) matches the reactor power, only then will the HT D_2O pressure stop increasing.

(v) Loss of boiler feedwater due to the closure of feedwater control valves or a piping rupture, while at power. Initially what happens here is that the heat transfer rate across the boiler will be reduced as a result of the feedwater loss. Due to the feedwater inventory in the boilers, a heat sink will still be available, but only for a short period. Typically this will be for 1.5 full power minutes (except in the case of feedwater inlet rupture which will drain the boilers more quickly). As soon as the water level drops below the top of the boiler tubes, the heat transfer area available will be reduced, and this will be reflected as a reduction in the heat sink capacity, which will then cause a rise in HT temperature resulting in swell and hence a high HT pressure. However, if a boiler low level reactor trip is installed, the reactor trip is likely to prevent a high HT pressure from occurring.

III. SYSTEM/EQUIPMENT USED FOR HT PRESSURE RELIEF

There are two basic methods of reducing an overpressure transient in the HT system:

1. direct pressure relief, and

2. indirect pressure relief.

By direct pressure relief methods, we mean those methods which effect the HT D_2O by influencing the primary HT system immediately. Indirect pressure relief methods effect the HT D_2O only as a secondary effect, by first influencing the steam system, which in turn results in a subsequent effect on the HT D_2O. Strictly speaking, only the direct method comprises the HT pressure relief system as such, but the indirect relief methods are also discussed here.

Basically, the direct pressure relief mechanisms can handle overpressure incidents resulting from mechanical and HT temperature increase events while the indirect relief mechanisms are capable only of terminating overpressure transients from HT temperature increase events.

(A) Direct HT Pressure Relief

The reactor outlet header pressure is used to initiate the various relief actions, illustrated in Figure 1, which are discussed below.

(a) HT Pressure Relief Valves

HT pressure relief valves are the first line of defence against an uncontrolled HT pressure rise. Figure 2 shows them schematically, located in parallel and discharging from the reactor outlet header(s) into the bleed condenser.

It should be realized than these valves are <u>not</u> sized to be able to remove 100% of reactor power in the complete absence of the steam generator heat sink. (Steam safety valves by contrast can remove 100% reactor power via steam release from the boilers.) The reason for this limited capacity of HT relief valves is that the relief valves are designed for pressure rises caused by mechanical overpressurizations. Overpressurizations caused by coolant swell can be terminated by methods (b) and (c) below, which both rely for their effectiveness on the reactor being operated at power.

During coolant swell incidents, relief valve operation will still occur, but will be a supplementary rather than backup relief device during severe overpressurization incidents. Relief valve capacity sufficient to cope with severe coolant swell incidents

Reactor Outlet Header Pressure

----------> reactor trip (on high HT pressure)

----------> reactor step back (on high HT pressure)

----------> all HT pressure relief valves open

----------> single HT pressure relief valve open

----------> setpoint of HT pressure control system

Figure 1: Direct HT Pressure Reduction Methods

(Note that the hierachy of events shown here may vary from station to station and may also change with operating experience at any given station.

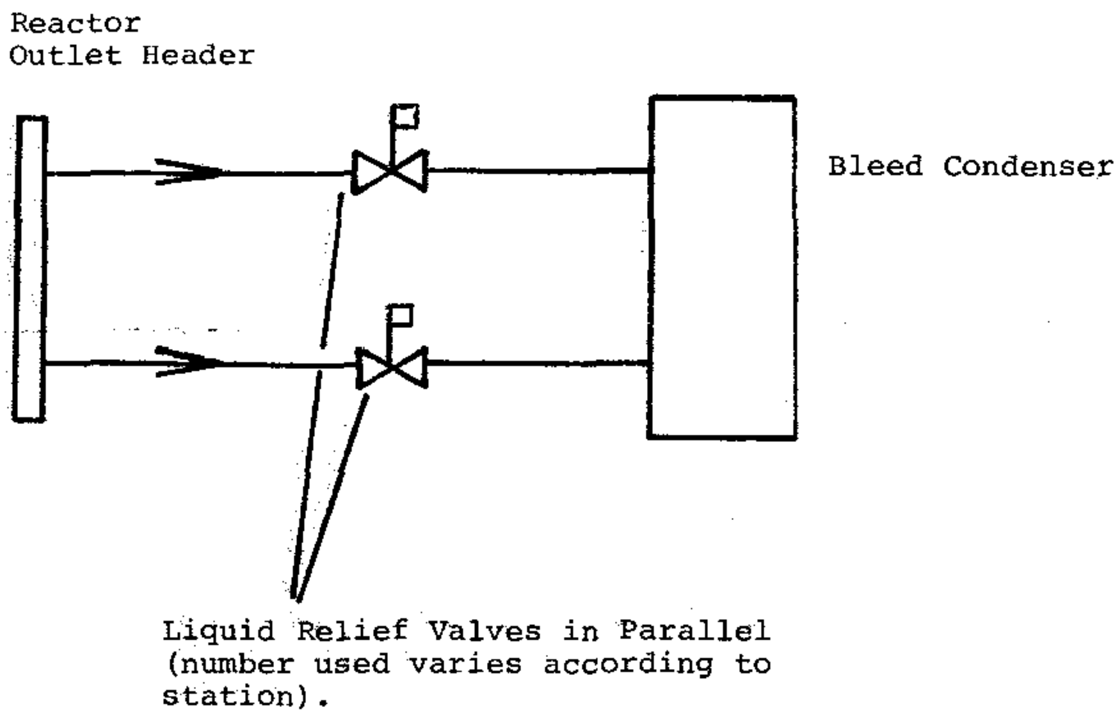

Figure 2: HT Pressure Relief Valves

would not be desirable as it would increase the risk of over-relief resulting in saturated conditions in the main system, and therefore to steam blanketing and fuel overheating.

(b) Reactor Stepback on HT High Pressure

If a pressure rise is not stopped by the relief valves, reactor power may be stepped back. A reactor stepback is a step decrease in power (of $\sim$30%) initiated by dropping control absorbers into core. A stepback results in rapid coolant shrink with associated sudden drop in pressure.

Reactors not equipped with control absorbers do not have the stepback feature. For example, at PNGS-A, high level in the bleed condenser during an overpressure incident initiates a reactor setback. A setback is a power ramp down, which results in a more gradual coolant shrink than that achieved with stepback, ie, pressure reduction is slower with setback than with stepback.

(c) Reactor Trip on HT Pressure

A pressure rise not terminated by either relief valves, or reactor stepback will eventually trip the reactor, reducing thermal power to $\sim$7% full power. This power reduction is accompanied by a rapid D_2O shrink and pressure reduction. A stepback is preferred to a trip as a pressure reduction device, because the risk of a poison outage is lower with the stepback. The stepback will not however, produce as large a shrink (and hence pressure reduction) as a trip will.

(B) Indirect HT Pressure Relief Using Boiler Steam Discharge

In addition to the direct methods above, there is an indirect method of HT overpressure reduction. This is indirect as it uses boiler pressure to reduce the HT average temperature (i). Reductions in HT average temperature result in coolant shrink and HT pressure reduction.

(i) Reduced boiler pressure results in reduced boiler H_2O temperature (saturated conditions). This results in a higher ΔT between H_2O and HT D_2O, with increased heat transfer from D_2O to H_2O, and hence in a reduced D_2O temperature discussed earlier).

The method used is to discharge steam from the secondary side. Figure 3 illustrates the methods used to discharge steam in relation to the parameter initiating steam discharge, which is secondary side steam pressure. Note that a rise in heat transport pressure caused by mechanical overpressure will not, by itself, cause the steam valves to open. Pickering uses steam reject valves, Bruce uses atmospheric steam discharge valves and condenser steam discharge valves, and all plants use safety valves (see Figure 3). The method will prevent a HT overpressure due to incidents in the steam/feedwater system which effectively reduce the heat sink in the steam/feedwater loop. (eg, II.2.(iv) and (v)), discussed earlier. Reduction in the steam/feedwater heat sink will result in a rise in steam temperature and hence a rise in steam pressure. Rising steam pressure is then used to initiate steam discharge as it is a more rapidly responding parameter to measure than temperature is. Discharging steam (to atmosphere or the main condenser) merely provides an alternative (or additional) heat sink to the turbine. If the heat removal provided by steam discharge is adequate to maintain boiler steam power equal to reactor power, then no HT pressure rise will occur.

As the steam reject valves at PNGS and the combined atmospheric and condenser steam discharge valves at BNGS have ~100% full power steam capacity, they are capable of handling fairly large upsets. However, should they prove inadequate to control steam pressure, then the steam safety valves (set at higher relief pressures) will provide a further heat sink. The safeties are capable of 100% steam power removal.

Steam rejection can also be used, together with direct methods of pressure relief to cope with coolant swell upsets (eg, events II.2(ii) and (iii)). In such events the steam reject valves could be opened manually by the unit operator. (Automatic opening of the SRV's could be employed on a HT pressure rise, but due to the time delay (~10 secs) from steam discharge to HT average temperature change, rapid HT overpressures caused by primary system events could not be controlled automatically by this method). Manual SRV opening is also of slow response, but, once initiated the effect is of large capacity. Note that opening of the SRV's (or ASDV's) may also be used (depending on the station) as an initiating parameter for a reactor setback to supplement the 'removal' of reactor heat. It should be emphasized however that automatic steam rejection would not be capable of assisting the direct relief devices, in the event of heat transport mechanical overpressurization with the reactor shut down and the heat transport system cold.

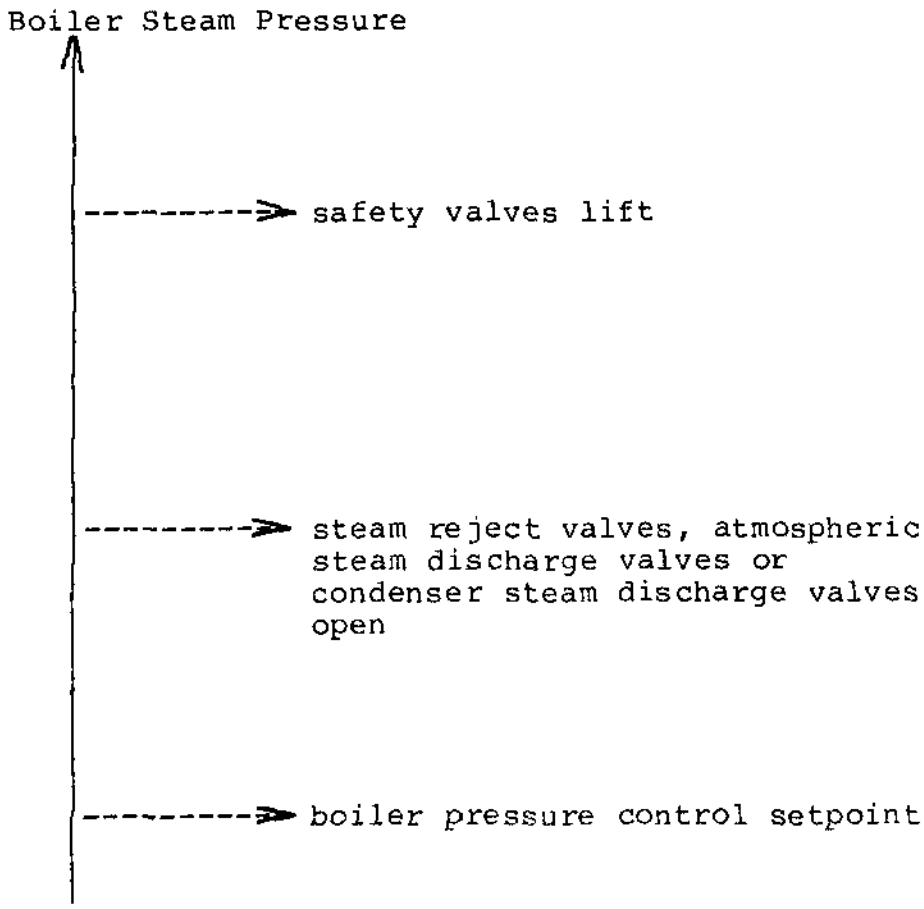

Figure 3: Indirect HT Pressure Reduction Methods

ASSIGNMENT

1. For your own plant, state what the direct HT pressure reduction methods are and compare with those of Figure 1. State the various setpoints involved.

2. For your own plant, state what the indirect HT pressure reduction methods are, and compare with those of Figure 3. State the various setpoints involved.

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