Reactor, Boilers & Auxiliaries - Course 233

ANNULUS GAS SYSTEM

I. SYSTEM PURPOSE AND REQUIREMENTS

The main purpose of the annulus gas system is to provide thermal insulation between the hot pressure tubes and the relatively cool calandria tubes and surrounding moderator, to reduce heat losses from the pressure tubes. This then helps to maintain the overall reactor thermal efficiency and minimizes the heat removal requirements of the moderator system. At Pickering, for example, the amount of heat lost from all pressure tubes in a unit through the annulus gas to the moderator via conduction, convection and heat radiation is about 2.6 MW(th), at full power.

A second function of the system is to provide an indication of leaking calandria or pressure tubes via the presence of D_2O in the gas.

Important operating requirements of the annulus gas system are:

(a) to prevent corrosion of coolant tubes, calandria tubes and garter spring spacers, by maintaining a low dew point, by drying the gas and periodically purging the system.

(b) to maintain low radiation fields in the gas system, by periodically purging the system.

II. CHOICE OF GAS

CANDU units use one of three gases for this system. (Helium is not among the choices because of its high thermal conductivity and cost. An evacuated annulus is also not used because of the extra force which would be exerted on calandria tubes.)

(a) Air

NPD NGS and Douglas Point NGS both use air in the annuli. This air forms part of the reactor vault air circulating system. This is effectively a closed loop system maintained at a slightly negative pressure with respect to atmosphere, resulting in some air in-leakage. The exhaust fans discharge the equivalent in-leakage out through the stack.

Disadvantages of the use of air are the radiation fields in the system from Ar-41 and the possibility of corrosion with the presence of oxygen, nitrogen and water vapour. Water vapour is kept to a minimum by the vault air driers.

Pressure tube and calandria tube leaks would lead to an increase in the D_2O vapour recovery rate in the vault enabling such leaks to be detected, and would cause high tritium fields in the reactor vault.

(b) Nitrogen

Pickering A uses nitrogen, which avoids the corrosion and radiation problems mentioned above. This system is separate from the reactor vault air system and forms its own closed circulating system. This has the advantage of retaining any D_2O from leaks within the system. It also avoids the problem of reactor vault radiation fields from Ar-41 as no air now circulates inside the core. However, radioactive C-14 is produced, which is a disadvantage.

(c) Carbon Dioxide

All reactors built after Pickering A use CO_2 rather than N_2. The reasons are:

1. CO_2 is less corrosive than N_2 in a wet annulus, providing the O_2 concentration is low in the CO_2 supply.

2. The production of active C-14 from CO_2 is less than from N_2.

III. SYSTEM EQUIPMENT

A simplified flow diagram of a typical closed system is shown in Figure 1. Gas flows through the annuli, via inlet and outlet headers through an air-cooled natural convection heat exchanger, HX1. This cools down the hot, outlet gas from ∿230°C to ∿70°C, to minimize heat damage to the concrete walls of the biological shield conducting the gas piping outside containment. A water-cooled heat exchanger HX2, used in some stations, cools the gas down further, to close to ambient temperature outside containment.

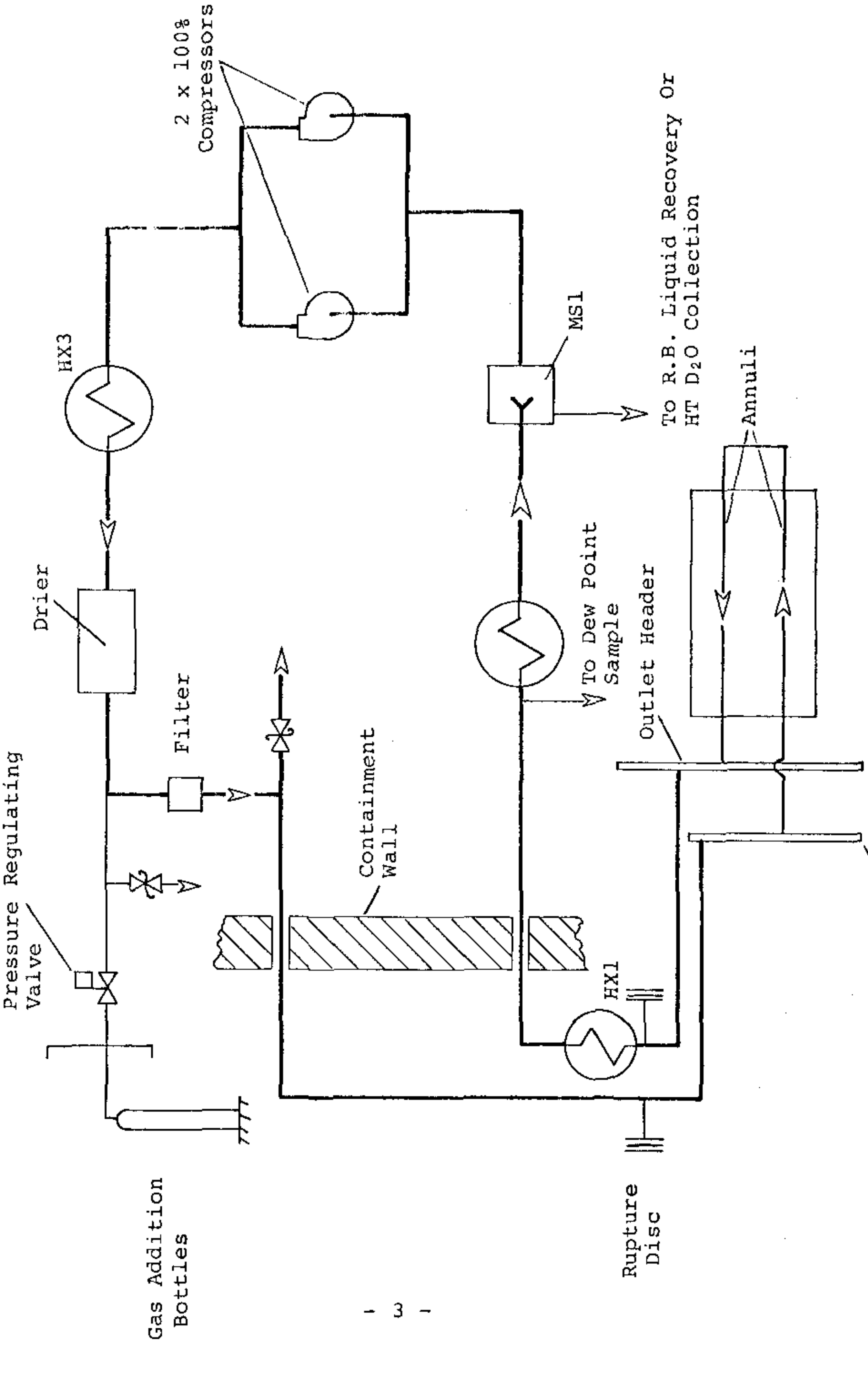

Figure 1: Simplified Gas Annulus System

A moisture separator MS1 at HX2 outlet provides for collection of moisture (leakage) in the system. Two 100% compressors then recirculate the gas from this point through a water cooled heat exchanger, HX3, installed in some stations, to remove the heat generated by compression.

The gas then passes through a drier and a filter (which traps escaping desiccant from the drier), and into the annuli inlet header.

Indication of D_2O leakage into the annulus gas system from a leaking pressure or calandria tube will be available from a dew point measurement taken from a typical sample point as shown in Figure 1.

For the self contained N_2 and CO_2 system pressure is maintained typically at 14 kPa(g) when the HT system is cold. Gas supply is from a gas supply system (bottles or bulk storage) via a pressure regulating valve. At the HT system heats up, the annulus gas pressure will rise to around 100 kPa(g) where it remains during full power operation. Over-pressure relief will typically be provided by rupture discs and relief valves as shown.

It is possible to operate the system without gas compressors for recirculation, and the system can be operated in a 'stagnant' mode with only regulating pressurization, without forced flow, relying on natural convection for recirculation. However, forced recirculation is preferred as this provides for a more representative dew point sample to detect leakage.

ASSIGNMENT

1. How is it possible for large radiation fields to build up in the CO_2/N_2 annulus gas systems? What steps would be taken to reduce these fields?

2. How is C-14 formed for (a) N_2 gas?
   (b) CO_2 gas?

   What is its half life and decay mode?

3. What would be the effects on the annulus gas system of

   (a) a leaking pressure tube?
   (b) a leaking calandria tube?
   (c) a ruptured pressure tube?

   What routine checks in your plant determine (a) or (b).

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