Reactor, Boiler & Auxiliaries - Course 233

HEAT TRANSPORT H_2 ADDITION

I. PURPOSE OF SYSTEM

The purpose of this system is to minimize the amount of dissolved O_2 gas in the HT system. The O_2 is a product of radiolysis of the HT D_2O caused by fast neutrons and rays inside the reactor.

The reversible radiolysis reaction (simplified) is:

$$2\ D_2O \underset{\text{recombination}}{\overset{\text{ionizing radiation}}{\rightleftharpoons}} 2\ D_2 + O_2 \quad ...(1)$$

The D_2 and O_2 gas produced will be in solution at the normal operating pressure of the HT system. H_2 gas is added to the HT D_2O to drive this reversible reaction to the left, and hence to reduce the O_2 concentration (scavenge the O_2) in the coolant to a tolerable limit (a few $\mu g\ O_2/kg\ D_2O$). An excess of dissolved H_2 must be avoided to prevent embrittlement of the Zircaloy pressure tubes.

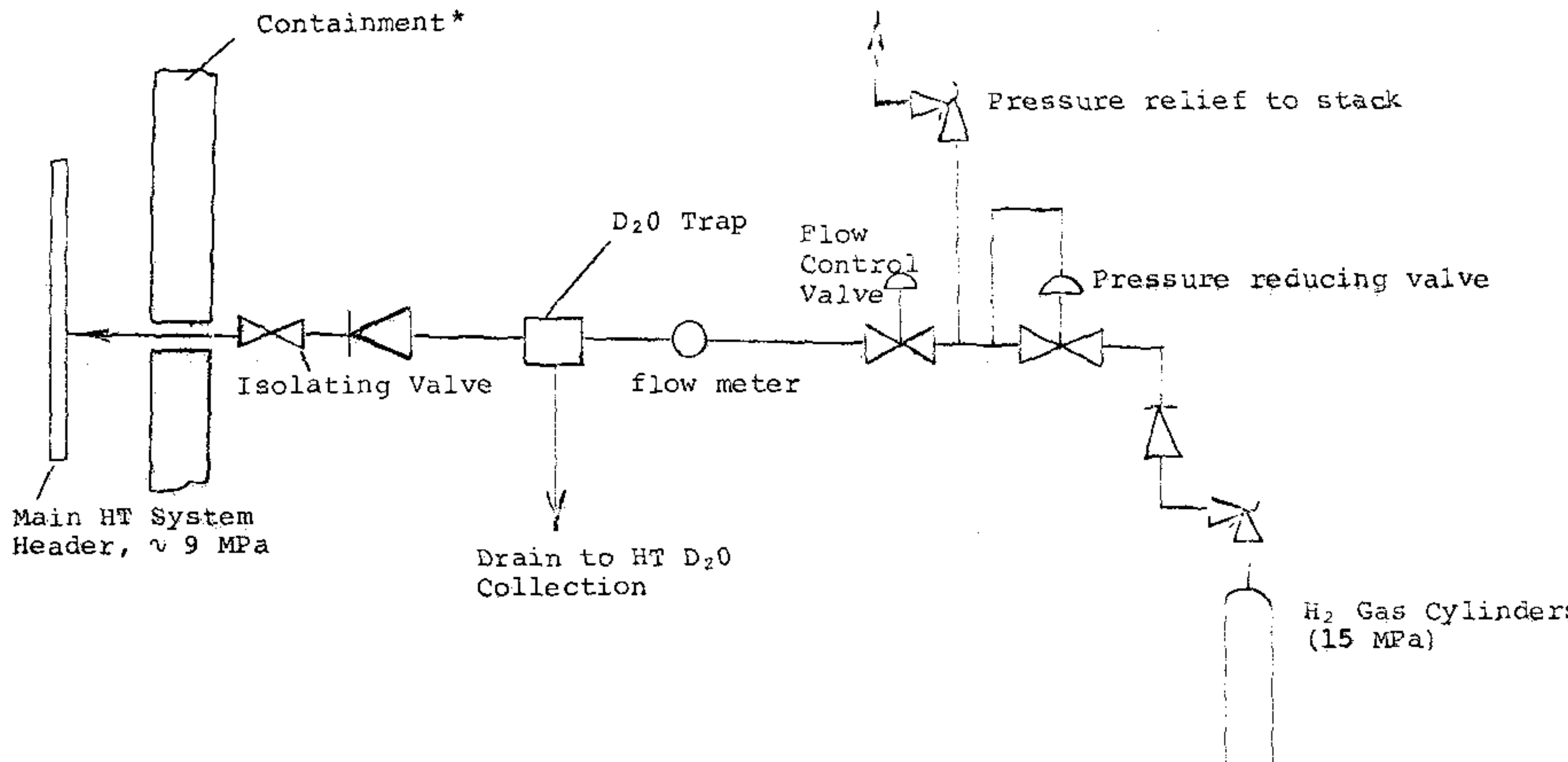
Oxygen control by H_2 addition is one of the most important chemical controls of the HT system. Dissolved oxygen promotes corrosion and hence crud formation and activated crud deposits cause undesirable high fields in the HT system. A longer term problem is wastage of system components due to corrosion.

II. SYSTEM DESCRIPTION

1. Choice of Gas

Because D_2 and H_2 behave identically as far as reaction (1) is concerned, either deuterium or hydrogen gas additions would scavenge the dissolved oxygen equally well.

Two economic considerations contribute to the choice between H_2 and D_2:



*Note this is the location of containment at BNGS, at PNGS containment is between the trap and flowmeter.

Figure 1 HT System H_2 Gas Addition

(a) Favouring H_2: D_2 cost much more than H_2.

(b) Favouring D_2: Use of H_2 downgrades HT isotopic (by typically ∿0.3% year). Recall that minimum acceptable HT isotopic is ∿97%.

2. Equipment

A typical H_2 addition system is shown in Figure 1, and consists of high pressure (15 MPa) H_2 cylinders, a pressure reducing valve, a flow control valve and check valve.

The pressure reducing valve maintains the H_2 addition pressure at HT system pressure, ∿9 MPa. Flow is controlled by a flow control valve (usually manual), and measured by a flow meter. A check valve prevents backflow of HT D_2O into the gas system. D_2O leakage past the check valve is collected in a D_2O trap, which can be drained to the HT D_2O collection system. Addition points to the HT system are usually at the main headers. Pressure relief should be provided on the gas bottles and also downstream of the pressure reducing valve.

Notice that this system is a place where the HT system penetrates containment. In the case of a piping rupture and subsequent loss of coolant this penetration would not be considered very large (the gas addition lines are typically ∿1 cm diameter).

III. OPERATING FEATURES

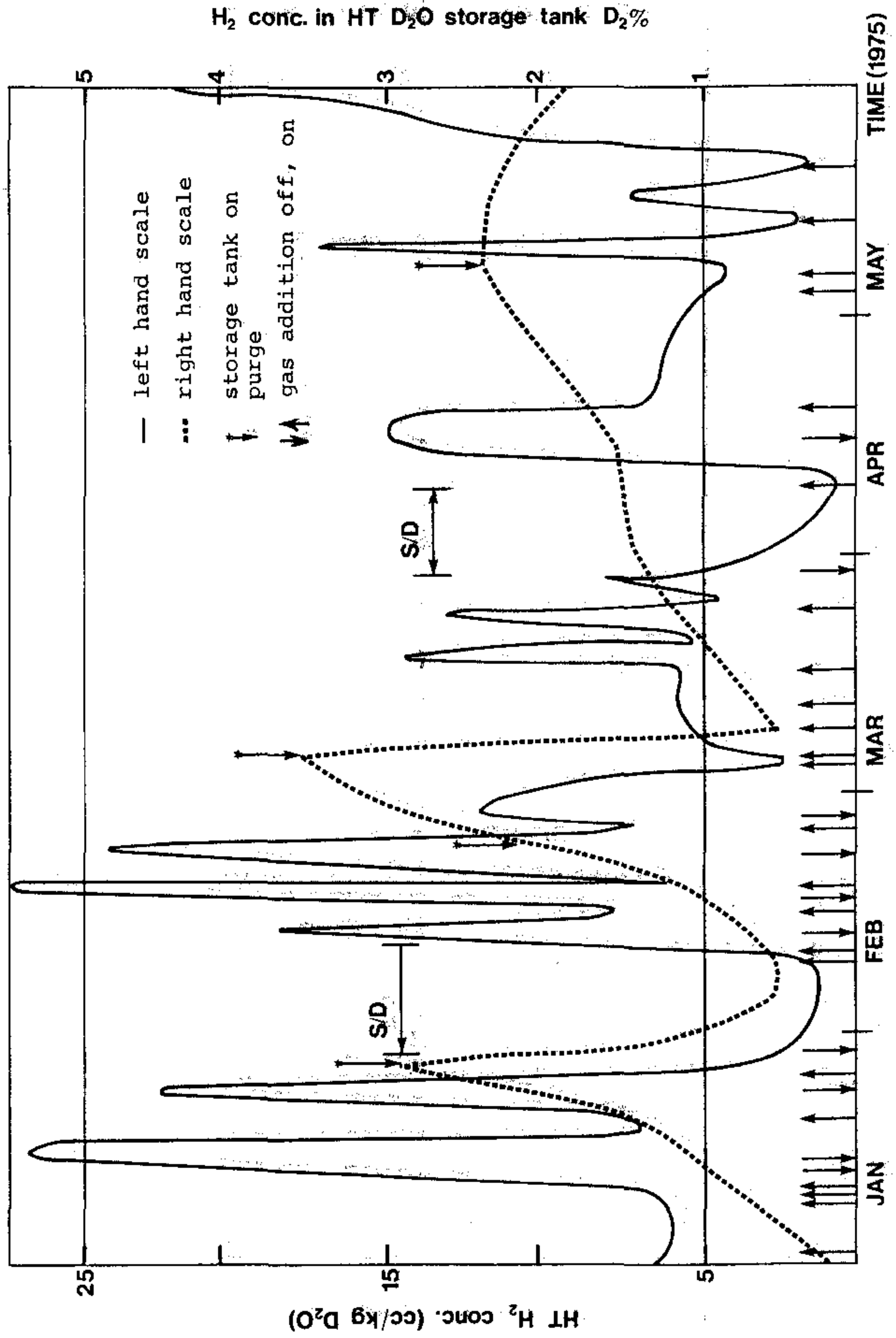
(a) HT H_2 Concentration Control

The addition rate of H_2 in this system is normally adjusted manually to maintain the H_2 concentration (and hence the O_2 concentration) within the specification, typically between 5 - 25 cc H_2/kg D_2O.[i]

As O_2 is difficult to measure, and hence control directly, it is the H_2 concentration that is controlled to provide an indirect control of O_2 concentrations. Periodic O_2 measurement will confirm that the control by H_2 addition is adequate.

(i) The desired H_2 concentration is usually ∿10cc H_2/kg D_2O.

Figure 2 - Average Daily H_2 concentration measurements PNGS-A Unit 1



A typical graph showing HT H_2 concentration is given in Figure 2 for PNGS-A Unit 1 during 1975. Manual adjustment of the H_2 gas addition flow control valve is shown as ↑ for a valve opening increase and ↓ for a valve opening decrease. Average H_2 concentration for the period is ∿10 cc dissolved H_2/kg D_2O. The control range between 5 - 25 cc H_2/kg D_2O is indicated on Figure 2. The effect of the H_2 flow rate changes on the concentration is clearly seen.

(b) Degassing of HT H_2 Into HT System Components

Not all the HT system equipment is under high pressure and there is HT equipment at lower pressures where dissolved H_2 is able to come out of solution (degas) and present a possible explosion hazard. Examples of such equipment are:

(a) the HT D_2O storage tank
(b) the bleed condenser

Both of these components have HT D_2O liquid in thermal equilibrium with D_2O vapour above the liquid.

In the D_2O storage tank the cover gas is helium but H_2/D_2 gas will also be present due to degassing. A high D_2/H_2 concentration (∿4%) means that purging is necessary to reduce the explosion hazard. Figure 2 shows typical H_2/D_2 concentrations in the D_2O storage tank corresponding to the H_2 gas addition flow rate changes. An increase of H_2 concentration in the storage tank as the HT H_2 addition rate is increased is evident. Purging the storage tank on high or rapidly increasing H_2/D_2 concentrations is used to reduce the concentration as shown.

In the bleed condenser the 'cover' gas is mainly saturated D_2O vapour with some D_2/H_2 gases and also fission product gases such as Xe and Kr. As these (non condensable) gases build up in the D_2O vapour space the heat transfer of the reflux cooling coils will be reduced and so the vapour temperature rises above that of liquid temperature. At a certain T the gases may then be degassed into the off gas system if one is installed. In practice if the off gas system is used to degas the bleed condenser it is done mainly to release the fission product gas activity rather than to release D_2/H_2 gases which pose little explosion hazard in the wet atmosphere of the bleed condenser.

(c) H_2 Gas Addition System Shutdown

The H_2 addition system is not used when the reactor is shutdown and will be isolated whenever this is the case. In these circumstances there is reduced radiolysis, because the reactor is not operating and isolating will prevent an excess of H_2 building up in the HT system.

(d) Changing of the H_2 Cylinders

It should be noted that the H_2 gas cylinders will be declared spent, and changed, when the cylinder pressure drops to $\sim$9 MPa (HT system pressure). Hence the spent cylinders are not empty, but still contain H_2 gas at $\sim$9 MPa.

To avoid this problem of incomplete usage of the H_2 in the cylinders Bruce A and B are currently (1980) proposing to add the H_2 to the feed pump suction (purification outlet). The disadvantage of this would be the risk of pump gas locking, on too high an addition rate.

ASSIGNMENT

1. Compare your own plant's H_2 gas addition flowsheet with Figure 1 and explain any differences.

2. In your own plant how many H_2 bottles/week are used in this system?

3. In your own plant, is the H_2 added by manual adjustment or by automatic control?

4. If there is a small or large LOCA in the HT system what should be done to the HT H_2 gas addition system? Explain.

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