USE OF STEAM-CONDENSATE EXCHANGE PROCESS FOR RECOVERY OF DEUTERIUM FROM CONDENSATE OF AMMONIA PLANT AS ADOPTED AT HEAVY WATER PLANT, TALCHER

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INTRODUCTION:

Heavy Water Plant Talcher is based on bithermal ammonia hydrogen exchange process and uses the synthesis gas ($3H_2+N_2$) produced by the ammonia plant of Fertilizer Corporation of India Talcher (M/s FCI, Talcher), as the basic feed stock. FCI, Talcher is a coal based plant, in which synthesis gas is produced by the following main steps.

- Coal gasification
- Desulphurisation
- CO shift conversion
- CO_2 removal
- Final gas purification

NEED FOR STEAM AND CONDENSATE (HDO) EXCHANGE UNIT:

Production capacity of any heavy water plant is directly proportional to the deuterium content in the feed synthesis gas. Achieving maximum possible deuterium concentration in the feed gas is therefore of paramount importance in realising desired production from any heavy water plant. Deuterium concentration in synthesis gas produced in the ammonia plant of FCI, using coal as the basic raw material, would theoretically be close to the natural deuterium concentration in water i.e. 150 ppm. However loss of deuterium from the process at any stage in the production of synthesis gas would reduce this deuterium concentration.

In the CO shift conversion section of FCI, Carbon monoxide present in the raw gas is converted to CO_2 according to the following reaction.

$$CO + H_2O(\text{steam}) \rightleftharpoons CO_2 + H_2$$

This reaction takes place in the presence of iron catalyst. In order to shift the equilibrium of the above reaction towards right, excess steam is used in the CO shift converter. During the course of the above reaction, exchange of deuterium also takes place between steam and hydrogen as per the following reaction.

$$HD(\text{gas}) + H_2O(\text{steam}) \rightleftharpoons HDO(\text{steam}) + H_2(\text{gas})$$

The iron catalyst used in the shift converter also catalyses this reaction. The operating temperature of CO shift converter is around 350 deg. C. At this temperature the equilibrium constant for this reaction is around 1.5. This reaction, therefore, would result in depletion of deuterium in hydrogen and a correseponing enrichment in surplus steam.

The surplus steam used during CO shift conversion is subsequently condensed and is normally drained. Loss of this condensate - rich in deuterium - from the system would result in lower deuterium content in the synthesis gas. It is calculated that, if deuterium from this rich condensate is not recovered i.e. the entire quantity of deuterium rich condensate is drained, maximum deuterium concentration in the synthesis gas would only be 110-115 ppm. However, with complete recovery of deuterium from the rich condensate, the synthesis gas produced by coal gasification process should contain around 150 ppm deuterium.

Simplest way to avoid this depletion of deuterium in the synthesis gas is to reuse the deuterium-rich condensate in the process, e.g. as a feed in a separate process boiler. In the ammonia plant at Talcher this is not possible due to the impurities in the condensate. It was, therefore, proposed to extract deuterium from the rich condensate by exchanging it with steam, and using this steam - rich in deuterium - in the CO shift converter. The ratio of vapour pressure of H20 and HDO (separation factor) is approximately 1 at normal steam temperature and decreases with increase in temperature (Ref. Table 1). At the operating temperature of 257 deg. C of the steam-condensate exchange system, the separation factor is around 0.995. Therefore, deuterium concentration in the condensate leaving the steam-condensate exchange column can be brought down very close to the deuterium concentration in the feed steam i.e. natural deuterium concentration in water thereby achieving practically complete deuterium recovery.

PROCESS DESCRIPTION:

A brief description of the steam-condensate exchange (HDO exchange) unit is given in figure I. Condensate generated in the CO-shift converter section of FCI is available at two different pressures. They are separately pumped to the steam-condensate exchange column. Before entering the exchange column the condensate is heated by hot condensate stream from the exchange column. The depleted condensate from the exchange column after passing through the heat exchanger is drained. Desired quantity of steam is drawn from FCI's steam heater leading to CO shift converter. After exchanging its sensible heat with the steam outlet from the exchange column this steam is fed to the steam-condensate(HDO) exchange column. The enriched steam from the exchange column joins FCI's steam header to CO shift converter. Though the steam joining FCI's steam header from the exchange column is slightly lower in temperature than the steam drawn from the header this slight drop in temperature does not affect the performanc of the CO shift converter. The steam-condensate exchange column operates at a pressure of around 33 kg/sq.cm (pressure of FCI's CO shift conversion section) and at a temperature of around 250 deg. C (saturation temperature at 33 kg/sq.cm). The column has 15 no. valve trays as steam-condensate contacting device.

PERFORMANCE OF THE STEAM-CONDENSATE EXCHANGE UNIT:

Performance of the steam-condensate exchange unit can be judged by the depletion of deuterium in the condensate and also by the increase in deuterium concentration in the steam outlet from the exchange column. The overall performance is also reflected in the deuterium concentration of the synthesis gas available at the battery limit of the heavy water plant. Data collected during continuous stable operation of the exchange unit is given in table 2. Analysis of all the data indicates that during stable operating conditions, the deuterium content in the condensate could be reduced from approximately 195 ppm to approximately 160 ppm. The corresponding increase in deuterium concentration in the steam has been from 156 ppm to approximately 190 ppm. Also the deuterium concentration in the feed synthesis gas to heavy water plant could be improved to as much as 144 ppm.

The steam-condensate exchange process for recovery of deuterium is superior to a 'dedicated boiler' producing steam from the rich condensate. The operation is extremely simple and since the enriched steam from the exchange column passes directly to the co-shift converter any possible loss of deuterium by way of blow down, venting or any other use not related to the production of synthesis gas is completely eliminated.

Conclusion:

By using the steam condensate exchange system loss of deuterium in the deuterium rich condensate from the ammonia plant could be avoided. The performance of this system has been extremely encouraging. While the deuterium content in the condensate could be reduced to within 4 to 5 ppm of that in natural water, the deuterium content in the feed synthesis gas to heavy water plant could be improved to around 140 ppm which is within 10-15 ppm of that in natural water. But for the HDO exchange system the deuterium concentration in the synthesis gas would have been as low as 115 ppm.

Table - 1

RATIO OF THE VAPOR PRESSURES OF H2O AND HDO

Temperature deg. C	PH2O/PHDO
0	1.12
10	1.08
20	1.07
30	1.06
40	1.05
50	1.052
60	1.046
70	1.040
80	1.035
90	1.030
100	1.026
110	1.022
120	1.019
130	1.016
140	1.0135
150	1.011
160	1.009
170	1.007
180	1.005
190	1.004
200	1.002
210	1.001
220	1.000
230	0.999
240	0.997

DATA COLLECTED DURING CONTINUOUS STABLE OPERATION OF HDO EXCHANGE UNIT

Sampling	Time	(D/D+H) (ppm)				Ratio steam to condensate flow	(D/D+H) (ppm) gas outlet of CO shift convertor	Ratio of (D/D+H) in condensate to gas from Co-shift convertor
		Steam		Condensate				
		In	Out	In	Out			
1.5.81	11.30	156	168	171	162	1.25	127	1.35
1.5.81	19.30	156	163	173	157.5	1.25	-	-
3.5.81	09.45	157	168	180	160	1.24	-	-
3.5.81	15.15	157	172	181	161	1.25	-	-
4.5.81	05.20	152	166	184	156	1.2	-	-
4.5.81	19.30	153	166	184	157	1.2	134	1.37
5.5.81	04.30	160	172	187	161	1.3	-	-
5.5.81	13.30	158	182	184	161	1.25	-	-
6.5.81	05.00	159	189	197	162	1.35	-	-
6.5.81	16.00	159	189	196	160	1.25	140	1.40
7.5.81	A-shift	159	190	194	-	1.3	-	-
7.5.81	20.30	156	189	195	159	1.3	144	1.35

Note: Collection of data started after seven days continuous stable operation

SCHEMATIC DIAGRAM OF HDO-EXCHANGE SYSTEM

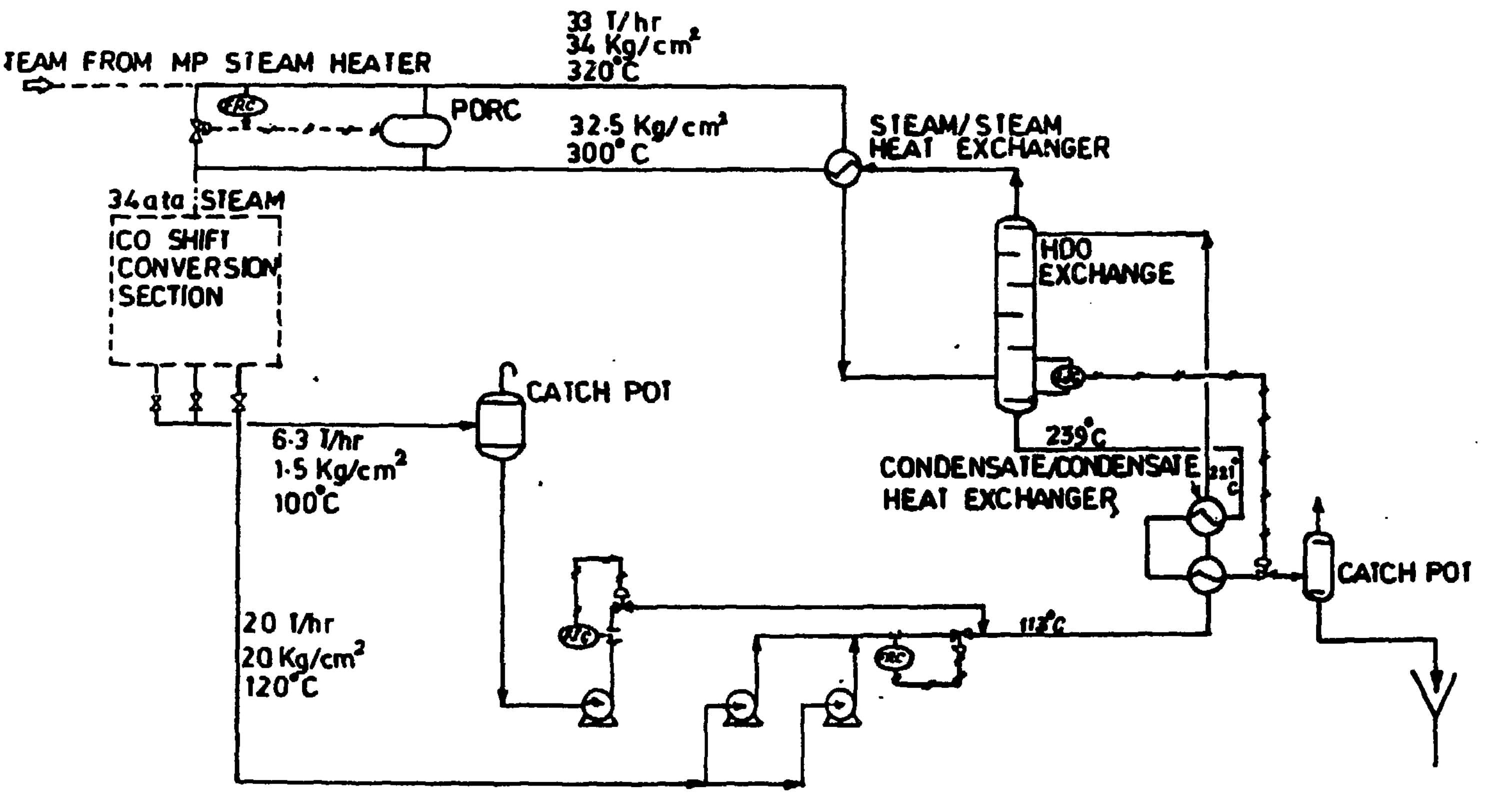

FIG. 1

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