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PROBLEM OF GAS RECOMBINATION CAUSED BY INITIAL OPERATION AT REDUCED TEMPERATURE

Introduction

The plan of operating the HRT at appreciable power first at low temperature and pressure followed by operation at higher temperature presents problems related to gas recombination. The problems arise because of the strong temperature dependence of the copper catalyst activity. The amount of copper required for full operation at an average core temperature of 250°C and any pressure under 2000 psia is several times that required at 2000 psia and a core average of 280°C.

Discussion

Although exact calculations have not yet been carried out to determine the amount of copper required at various pressures and powers at 250°C average, sufficient work has been done by Aven so that good estimates can be made. Table I shows copper concentrations required under a number of different operating conditions. The maximum capacity of the low-pressure recombination system is about 15 scfm of D₂, this limit being set by the capacity of the evaporators which supply steam to dilute the gas and hold down catalyst bed temperatures.

TABLE I

Gas Recombination Under Various Conditions

T _{av} °C	Pressure psia	Power Mw	[Cu ⁺⁺] mol/liter	Letdown Rate	
				scfm D ₂	scfm*
278	2000	5	0.0019	7.5	0.46
278	2000	5	0.0026	0	0
250	2000	5	0.007	0	0
250	2000	5	0.004	15	0.58
250	1400	5	0.014	0	0
250	1400	5	0.008	15	1.23
278	1460	5	0.008	2.1	0.46
250	1400	2.7	0.002	15	0.96
250	2000	3.4	0.002	15	0.53

* Wet gas at core exit.

The first line in Table I shows design conditions. For a letdown of 7.5 scfm of D_2 (equivalent to 1 Mw gas production) the required copper is 0.0019 mol/liter. If more than 0.0026 mol/liter is present, internal recombination will be essentially complete at 5 Mw, 278°C (average) and 2000 psia. At the same power and total pressure but at 250°C average, 0.007 mol/liter is required for complete internal recombination. By letting down the maximum amount of gas which the low-pressure system can handle, the copper could be reduced to 0.004 mol/liter.

The above figures show the effect of temperature at a constant total pressure. However, if the temperature is reduced, it is desirable to reduce the total pressure also. The reason for this is the explosion hazard in the event of a dump. High overpressure means a high concentration of dissolved radiolytic gases and a long waiting time after stopping power removal before internal recombination has reduced the concentrations to the point that explosive mixtures will not occur during the dump. A rule-of-thumb which has been used as a guide is to keep the ratio of overpressure to vapor pressure fixed while varying temperatures and pressures. At 2000 psia and a core exit temperature of 300°C, the overpressure at the core exit is 0.6 of the vapor pressure. At 5 Mw with an average temperature of 250°C, the temperature and vapor pressure at the core exit will be about 275°C and 860 psia. An overpressure of 0.6 of the vapor pressure gives a total pressure of approximately 1400 psia.

At 1400 psia and 250°C average, 0.014 mol/liter of copper would be required for complete internal recombination at a power level of 5 Mw. If gas is let down at the maximum rate of 15 scfm of D_2 , the reactor could operate with a copper concentration of 0.008 mol/liter.

If the reactor is operated at 278°C average and 2000 psia with 0.008 mol/liter of copper, there will be complete internal recombination at 5 Mw. If there is no gas letdown there is essentially no stripping of the gaseous fission products, so it is desirable to have some gas-forming bubbles. Under design conditions the gas separator removes 0.46 cfm of wet gas. In order to achieve this rate with 0.008 mol/liter of copper, 5 Mw and 278°C average, it would be necessary to lower the total pressure to 1460 psia. The overpressure at the core exit under these conditions is only 210 psi, which is undesirably low.

If just the copper required for high-temperature operation (0.002 mol/liter) were put in, the power could be raised only to 2.7 Mw at 250°C and 1400 psia without exceeding 15 scfm of D_2 letdown. Increasing the total pressure to 2000 psia would about double the rate of internal recombination, but the power would still be limited to 3.4 Mw.

Conclusions

It may be seen from the foregoing that a number of plans of operation could be followed. These include:

- (a) Put in only the copper required for high-temperature operation (280°C and 1700-2000 psia), and limit the power during 250°C operation to 2.5-3.0 Mw.

(b) Put in sufficient copper for full power at 250°C. Leave the copper in the reactor and have complete internal recombination in subsequent high-temperature operation.

(c) Put in sufficient copper for full power at 250°C. Before operation at 280°C remove part of the copper from the reactor so there will be some gas letdown at the higher temperature.

Course (c) is the most desirable in that it achieves the goal of full power during the early operation of the reactor and also permits efficient stripping of gaseous fission products during later high-temperature operation. It requires, however, that either some means of removing copper from the fuel solution be devised or part of the fuel charge be withdrawn from the reactor and replaced with fresh fuel containing no copper.*

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*The normal chemical processing cycle is a very slow way of reducing the copper concentration. At the normal rate of withdrawal of 2.5 gal/week, about 42 weeks would be required to reduce the copper concentration by a factor of two.