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SUBJECT: HRT Blanket Dump Tank Pressure

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SUMMARY

In changing the dumping program for the HRT, it is possible that the entire contents of the reactor will flow into the blanket dump tanks. This study investigates whether the resulting dump system pressure exceeds the allowable limit. For the case of a dump of the entire contents of the HRT high pressure system, commencing two minutes after shutdown from an operating power of 5 Mw and with an average fuel temperature of 280°C, into the blanket dump tanks, the resulting maximum pressure has been calculated to be about 375 psia. This maximum pressure which will occur about six minutes after the start of the dump, is well below the permissible limit of about 500 psia.

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HRT Blanket Dump Tank Pressure

Results and Conclusions

Three approaches have been employed in this investigation of dump tank pressures:

1. An instantaneous adiabatic dump.
2. A dump at 658 lb/min with heat removal in the flooding recombiner condenser.
3. A dump at 658 lb/min with heat removal in the flooding recombiner condenser, and accounting for the heat capacity of the blanket dump tanks.

In each case the dump was assumed to start two minutes after shutdown from a 5 Mw power level with an average fuel temperature of 280°C. The resulting maximum calculated pressures were 790, 600 and 375 psia respectively.

Approaches "1" and "2" above, are of interest only in that they indicate the maximum obtainable pressure assuming no heat removal from the fuel solution and the relative effectiveness of the recombiner condenser. Actual operating conditions which will be obtained on a dump will probably be very nearly those of approach "3".

It is concluded that dumping of the entire contents of the HRT high pressure system into the blanket dump tanks will not generate excessive dump tank pressure.

Discussion

The basis for these calculations is as follows:

(a) The reactor power level is assumed to be 5 Mw, with an average fuel temperature of 280°C; (b) the dump commences two minutes after shutdown, with the fuel temperature still at 280°C; (c) after the start of the dump it is assumed that no heat is removed from the high pressure system and the only heat generation is due to fission product decay.

Reference (1) indicates the rate of heat generation in the fuel solution. The maximum dump rate has been set at 658 lb/min. This dump rate is assumed to persist until the pressures in the high and low pressure systems are equal. After the period of maximum dump rate, there is a sharp decrease in the rate. This model corresponds well with the actual observed experimental dump characteristics. (2)

The recombiner condenser is assumed to flood during the dump, (3) thus no condensate can escape from the condenser during the period of maximum dump rate. After the condenser empties itself of condensate, at the end of the period of maximum dump rate (about 5 minutes after the start of the

dump), or very shortly thereafter, the dump tank pressure will decrease quite rapidly. The recombiner condenser characteristics are assumed to be those specified in CF 54-11-1.⁽³⁾ Based on actual performance of the HRT, these heat transfer characteristics are apparently conservative. This will cause the calculated pressure to be slightly high. It is assumed that the condenser starts the dump completely empty of condensate, and heat transfer to and from the condensate during the dump is neglected.

Effects not considered in this calculation include: radiolytic and dissolved gases, heat transfer in the main heat exchangers during the dump, and convective heat transfer from the high and low pressure system piping. The effect of the dissolved gases will be to increase the calculated pressure somewhat, due to their partial pressure in the dump tank, heat of recombination in the recombiner, and gas binding of the recombiner condenser. As was stated previously, the heat transfer characteristics of the recombiner condenser are considered conservative, perhaps by as much as a factor of 2.⁽⁴⁾ Consequently, the gas binding should not appreciably affect the calculated pressure. The most pessimistic assumption of the effects of these gases would be for the case of an instantaneous adiabatic dump. Assuming that the solution is saturated with D_2 and O_2 at the moment of shutdown, and that the D_2 concentrations of Figure 4 of CF 57-1-103⁽⁵⁾ apply, the gas partial pressure may be calculated. If the dump is assumed to occur at the instant of shutdown, the resultant partial pressure is about 85 psia. If the dump starts two minutes after shutdown (the same condition assumed in the remainder of this report), the gas partial pressure is about 32 psia. For a gradual dump, this pressure would be reduced even further by recombination in the solution and in the low pressure recombiner. It can thus be seen that for the condition considered here, the radiolytic and dissolved gas contributions to the dump tank pressure are small.

Heat transfer in the main heat exchangers after the start of the dump will not contribute significantly toward cooling of the system since these units are located high in the system and would drain quickly. Convective heat transfer from the high and low pressure piping will lower the maximum calculated pressure somewhat. This effect is difficult to estimate accurately and has been neglected, thus making the results even more conservative.

If the dump should be caused by failure of the circulating pump, it would be expected that the average fuel temperature might rise above the 280°C considered here.⁽⁶⁾ Calculations based on average fuel temperatures of 290°C and 300°C yield maximum predicted pressures of about 445 and 530 psia respectively. Consequently, in case of main circulating pump failure it may be desirable to dump the reactor sooner than two minutes after shutdown, 290°C appearing to be a reasonable allowable limit for the average fuel temperature.

Method of Calculation

The method of calculation was a trial and error solution of the heat and material balances of the system.

Let, x = the weight fraction of fuel solution which is vaporized.

H = total heat content of the solution in the system, Btu/lb

h_f = enthalpy of saturated fuel solution, Btu/lb

h_{fg} = heat of vaporization of solution, Btu/lb

V = specific volume of the system being considered,
 $\frac{\text{Volume of the system}}{\text{weight of fuel present}}$, ft³/lb

v_f = specific volume of saturated fuel solution, ft³/lb

$$\text{Then, } x = \frac{H - h_f}{h_{fg}} \quad (1)$$

$$\text{and } x = \frac{V - v_f}{v_{fg}} \quad (2)$$

Values of "h" and "v" were taken as those for light water as listed in the Steam Tables, no correction factor being applied to convert to the actual fuel solution. The error thus introduced is small.

Case I - Instantaneous Adiabatic Dump

In the case of an instantaneous adiabatic dump, the value of "H" for the system will be equal to the heat content of the 280°C, 2000 psia fuel solution, or about 537 Btu/lb. The value of "V" will be given by the total volume of the blanket dump tank system plus the high pressure system divided by the total weight of solution, or 0.0433 ft³/lb. Solution of equations (1) and (2) then predicts a maximum pressure of 790 psia.

Case II - Dump at 658 lb/min with Heat Removal in the Recombiner Condenser

For a gradual dump, with heat removal in the recombiner condenser, a step-wise method may be employed for solving equations (1) and (2). Choosing a time, measured from the start of the dump, establishes the total contents of the dump tank system. The amount of heat in the dump system is then determined by the original heat content of the solution at the start of the dump, plus heat generated by fission product decay,⁽¹⁾ less any heat removed previously by the recombiner condenser, less the amount of heat removed by

the condenser in the time interval under consideration. Assuming a dump tank pressure, using the heat transfer characteristics specified in CF 54-11-1,⁽³⁾ and accounting for partial flooding of the condenser by the vapor which was condensed in previous steps, the heat removed by the recombiner condenser in the particular time interval may be determined. The value of "H" is then obtained by dividing the total heat content of the dump tank system by the weight of fuel solution in the dump tank system. The value of "V" to be employed is obtained by dividing the dump tank system volume by the weight of fuel solution in the system. Equations (1) and (2) may now be evaluated to determine whether the assumed dump tank pressure was correct. Proceeding in this manner step-wise from the start of the dump, using time intervals of 5 to 30 seconds, the pressure in the dump tank at any given time may be calculated.

A similar calculation may be performed for the high pressure system, but neglecting any heat loss except through loss of fluid. Comparing the two solutions will indicate the time at which the pressures in the high and low pressure systems become equal, and hence the approximate time at which the dump rate decreases and the condenser empties itself of condensate. The maximum dump tank pressure will occur at this time.

Results of this calculation indicate a maximum pressure of 600 psia at 5.1 min. after the start of the dump.

Case III - Dump at 658 lb/min with Heat Removal in the Recombiner Condenser and Accounting for the Heat Capacity of the Dump Tank

This calculation represents an attempt to approach more nearly the actual operating conditions which will be encountered, by taking into account the reduction in pressure due to heating of the steel in the dump tank system. This problem corresponds very closely with Case II, except now the total heat content of the fuel in the dump tank system is decreased by the amount of heat required to raise the 9000 lb, steel dump tank up to the temperature of its contents. The value of "H" is thus reduced, and a new trial and error solution of equations (1) and (2) is obtained. This calculation indicates a maximum dump tank pressure of 375 psia at about 5.6 min. after the start of the dump.

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