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HRT Report No. I A(4)a

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PRESSURE DROP CALIBRATION OF FUEL HEAT EXCHANGER

HRT Report No. I A(4)a

Summary:

The pressure drop across the main fuel heat exchanger was measured as a function of flow rate using potable water. The pressure drop was also measured as a function of water temperature at a constant flow rate of 300 gpm. The ranges covered by the calibrations were 121 to 395 gpm for the first test and 7°C to 250°C for the other.

The results of the calibration may be expressed by the following equation:

$$\Delta P = 5.11 \times 10^{-4} F^{1.83} e^{-0.00276T}$$

where

ΔP = pressure drop, psi

F = flow rate, gpm

T = water temperature, °C

This equation gives the pressure drop between the feed line to the chemical processing cell (line 167) and the head drain (line 142). The pressure drop calculated by this equation is within 3% of the measured values above 200 gpm.

Based on the experimental results, a similar equation was set up for a D₂O solution of UO₂SO₄ containing 1% uranium by weight. This equation expresses the pressure drop between the two chemical processing lines (lines 167 and 166) as follows:

$$\Delta P = 6.47 \times 10^{-4} F^{1.83} e^{-0.00276T} + \frac{1}{144} (\Delta H) (\rho_{D_2O} - \rho_s)$$

where

ΔH = elevation difference between pressure taps, ft.

ρ_{D_2O} = density of D_2O in D/P cell legs, lb/ft³

ρ_s = density of fuel solution in line 102, lb/ft³

Description of Tests:

Low Temperature Tests

For the measurement of pressure drop as a function of flow rate, the heat exchanger was connected directly to the building water supply in Building 9204-1. Line 102 was mocked up from 3-in. schedule-40 galvanized pipe and connected between the heat exchanger discharge nozzle and a large calibrated tank for collecting the water. Provision was made for measuring the water level in the tank. A 100-inch mercury manometer was connected across the heat exchanger with the high-pressure tap on the inlet nozzle at line 167 and two low-pressure taps, one in the head drain at line 142 and one on the 3-in. discharge line at a position corresponding to line 166. For this test, the discharge line was laid out horizontally rather than vertically as it will be in the final installation. Figure 1 is a schematic diagram of the arrangement for this test.

Water at building supply temperature, 7°C, was passed through the heat exchanger at several flow rates from 121 to 395 gpm, the latter being the highest attainable with the available supply pressure. The flow rate was determined by measuring the time required for the liquid level in the collection tank to rise a given distance. The pressure drop was measured between the inlet tap and each of the outlet taps for the various flow rates.

High Temperature Tests

The measurements at elevated temperatures were made during the operation of the heat exchanger in the 400-B pump loop. The primary objective of this

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LOW TEMPERATURE CALIBRATION OF FUEL HEAT EXCHANGER Schematic Diagram

FIG. 1

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operation was to accomplish a cleanup of the tube side of the exchanger. An orifice was incorporated in the loop for flow measurement and provisions were made for measuring the heat exchanger pressure drop between lines 167 and 142. Both the pressure drop across the orifice and that across the heat exchanger were measured with D/P cells.

Several preliminary tests were made at low temperature to check the calibration of the measuring orifice against the heat exchanger pressure drop. Measurements of flow rate and pressure drop were then made with the pump loop running at temperatures up to 250°C.

Results:

Figure 2 is a graphical presentation of the results obtained at low temperature. The heat exchanger pressure drop was found to vary as the 1.83 power of the flow rate to either of the low-pressure taps. The pressure-drop measurements between lines 167 and 142 at elevated temperatures are also plotted on this figure.

The variation of pressure drop with temperature at 300 gpm is plotted in Fig. 3. This variation was fitted to the following equation:

$$\Delta P = \Delta P_0 e^{-0.00276T}$$

where

ΔP = actual pressure drop at temperature T, psi

ΔP_0 = pressure drop extrapolated to 0°C, psi

T = temperature, °C

Assuming that the temperature dependence is the same at all flow rates, the following equation was obtained to predict the pressure drop at any flow rate and temperature:

$$\Delta P = 5.11 \times 10^{-4} F^{1.83} e^{-0.00276T}$$

Fig. 2

Fig. 3

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Discussion:

The above empirical equation predicts the pressure drop across the heat exchanger within 3% in the range of interest. The exponential terms depend only on the physical properties of the circulating fluid. Since the properties of H_2O and D_2O vary in the same way with temperature, the same exponents may be employed in predicting the pressure drop with a D_2O solution. An equation of the following form results:

$$\Delta P = C F^{1.83} e^{-0.00276T} + K$$

The constant, C , must be evaluated from the pressure drop at a given set of conditions. Since no measurements were made with a $D_2O-UO_2SO_4$ solution, the pressure drop was calculated at 300 gpm and $280^\circ C$ using physical properties applicable to a 1% U by weight solution of UO_2SO_4 in D_2O . The pipe friction losses were computed from the Fanning friction equation using a friction factor corrected for pipe roughness. Entrance and exit losses were obtained from the area ratios and fluid velocities. The validity of these techniques was verified by calculating a pressure drop for water at 300 gpm and $250^\circ C$ and comparing it with the measured value. This calculation also provided the necessary correction to the friction factor for pipe roughness.

The value of K depends on difference in elevation between the pressure taps and the fluid density. Expressed in psi,

$$K = \frac{1}{144} (\Delta H) (\rho_{D_2O} - \rho_s)$$

where

ΔH = elevation difference between taps, ft.

ρ_{D_2O} = density of D_2O in D/P cell legs, lb/ft³

ρ_s = density of fuel solution in line 102, lb/ft³

Incorporation of these factors in the general equation gives the final equation for predicting the heat exchanger pressure drop as a function of flow rate and temperature:

$$\Delta P = 6.47 \times 10^{-4} F^{1.83} e^{-0.00276T} + \frac{1}{144} (\Delta H) \left(\sqrt{D_{20}} - \sqrt{s} \right)$$

This equation is based on information obtained under essentially isothermal flow conditions. The temperature difference between the inlet and outlet of the heat exchanger under normal operating conditions will undoubtedly have some effect on the pressure drop across the unit. However, the use of an average temperature in the equation should minimize the error involved. The estimated accuracy of the equation under reactor conditions is $\pm 5\%$ provided the flow rate is at least 200 gpm.

Several readings of flow rate and pressure drop were taken during the time the heat exchanger was operated at 250°C. After about two days of high temperature operation, the flow through the heat exchanger had increased by 1% for a given pressure drop. This may have been due to the removal of foreign matter from the tubes. However, no allowance was made for this change since the trend may be expected to be reversed as an oxide scale builds up in the tubes during operation.

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