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EVALUATION OF HEAT LOSS AND INSULATION PERFORMANCE ON FUEL HEAT EXCHANGER DURING PRELIMINARY TEST

SUMMARY

The overall heat loss from the heat exchanger shell to air was found to be 19,350 Btu/hr for a shell to air ΔT equal to 317°F. Taking the median heat transfer area to be equal to 117 ft², the overall heat transfer coefficient through shell, insulation, blast shield, and air film is $U = 0.53$ Btu/hr-ft²-°F.

INTRODUCTION

Heat loss from the shell side of the HRT fuel heat exchanger was determined while this heat exchanger was connected to the cleaning loop at Y-12. From the determined heat loss an overall heat transfer coefficient was calculated, permitting an evaluation of the effectiveness of the insulation used on the heat exchanger, and also determining the appropriate value to be used in future heat balances and evaluation of tube-to-shell heat transfer coefficients.

DESCRIPTION OF TEST

Upon completion of the clean-out operation, the fluid circulating through the tubes was at 450°F, and the shell contained saturated steam at 220-225 psig. Since it was desired that all heat lost through the shell would come from the condensation of steam, the loop heaters and pump were turned off. When the temperature of the fluid in the tubes was the same as the temperature of the steam in the shell (as determined by thermocouples in the inlet and exit nozzles and in the steam feed line), the steam trap drain line was closed and condensate permitted to accumulate in the shell. At the end of two hours the steam feed line was closed, isolating the collected condensate and steam remaining in the shell. After cooling for sixteen hours, the shell temperature had fallen to 162°F and the collected condensate was withdrawn and weighed. The shell heat loss was determined from the rate of condensation of steam. During the two-hour

test period a temperature traverse of the blast shield was made using a thermocouple and recorder, the thermocouple being held to a chosen spot on the shield with a piece of wood. 3.

RESULTS

Fifty-seven pounds of condensate was drained from the shell. A correction is necessary to allow for condensation of the steam remaining in the shell at the end of the test period. Collection of condensate during the clean-out operations indicated that this correction should be approximately 7 pounds. Heat loss during the two-hour test period was therefore equal to condensing 50 pounds of steam with a resulting enthalpy change of 774 Btu/lb, a total heat loss of 38,700 Btu or 19,350 Btu/hr. The temperature of the inlet steam was nearly constant at 361°F and the ambient temperature was 44°F for a ΔT from shell to air of 317°F. The shell area was calculated as 115 ft² and the blast shield area as 119 ft²; therefore, an average area of 117 ft² was used in determination of the overall coefficient.

$$\text{then } UA = Q/\Delta T = 61 \text{ Btu/hr-}^\circ\text{F}$$

$$\text{and } U = Q/A\Delta T = 0.53 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

Since part of the heat loss is around rather than through the insulation, it is indicated that the performance of the insulation is better than predicted.¹

DISCUSSION

Part of the condensate collected during the two-hour test period and subsequent cooling period was lost through the trap drain valve, but information obtained from three similar cooling-off periods in which both trap and feed lines were closed showed that approximately 7 pounds of condensate would remain in the shell. This was the value used; therefore, in allowing for heat losses after the test period and before drain-out, to compensate for the quantity of undensified steam in the shell.

¹I. Spiewak, "Aluminum Insulation (Report No. 2)," ORNL CF 55-8-121.

The figure of 61 Btu/hr-°F for UA does not distinguish between heat lost across the insulation and heat lost by conduction at points of contact between the blast shield and shell, but since both losses are directly proportional to ΔT , if the actual ΔT from shell to ambient cell conditions are used, the answer should be close to the true heat loss. If anything, this answer should be conservative since in the test there were several connections to the shell which were uninsulated, but which will be insulated in the final installation.

The temperature distribution on the surface of the blast shield is shown in Fig. 1. Based on these temperatures, an approximate loss by conduction around the insulation was calculated for the highest possible case. This loss was found to be 1950 Btu/hr or about 10% of the total loss. This indicates that only a small part of the heat loss is by-passing the insulation through the head flange.

It is of interest to note that if an average blast shield temperature is used to find a ΔT from shield to air, and the shield is assumed to act as a hot water radiator, having an overall heat transfer coefficient of $2 \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F}}$,² the calculated heat loss is very close to the measured value.

²J. H. Perry, Editor, Chemical Engineering Handbook, 3rd Edition, p. 481, Table 2.

Figure No. 1

Temperature Distribution in °C
on Blast Shield of Fuel Side
Heat Exchanger During Test Period

CALCULATIONS

1. Heat transfer coefficient - shell side to air

$$\Delta H_v \text{ at } 200^\circ\text{C} = H_g - H_l = 1204 - 430 = 774 \text{ Btu/lb}$$

57 lb H_2O collected - 7 lb condensed after test run = 50 lb condensed during test

$$50 \text{ lb} \times 774 \text{ Btu/lb} = 38700 \text{ Btu heat lost in 2 hr}$$

$$\therefore \text{heat loss} = 19350 \text{ Btu/hr}$$

$$\Delta T = T_{(\text{steam})} - T_{(\text{ambient})} = 200.5^\circ\text{C} - 24.5^\circ\text{C} = 176^\circ\text{C}; 317^\circ\text{F}$$

$$UA \frac{\text{Btu}}{\text{hr-}^\circ\text{F}} = Q \frac{\text{Btu/hr}}{\Delta T_{^\circ\text{F}}} = \frac{19350}{317} = 61$$

$$A(\text{avg}) \text{ taken as } 117 \text{ ft}^2$$

$$U = \frac{Q}{A \Delta T} = \frac{19350}{317 \times 117} = 0.53 \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F}}$$

2. Heat loss by conduction around insulation (based on largest
- ΔT
- per unit length along blast shield)

$$Q (\text{flowing through}) = \frac{kA \Delta T}{l} = 26 \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F/ft}} \times$$

$$x = \frac{1 \text{ in.}^2 \times 2.45^\circ\text{C} \times 1.8^\circ\text{F/}^\circ\text{C}}{144 \text{ in.}^2/\text{ft}^2 \times 1.3 \text{ ft}} = 6.1 \text{ Btu/hr - in. of perimeter}$$

$$Q (\text{radiated}) = UA \Delta T = 2 \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F}} \times 1.3' \times \frac{1''}{12''/\text{ft}} \times 94.7 - 52.5 \times 1.8$$

$$= 16.5 \text{ Btu/hr-in. of perimeter}$$

(for ΔT , T_1 is taken as avg of 107 to 82.5 and T_2 is taken as lowest measured shell temperature)

$$\therefore Q_{\text{Total}} = (6.1 + 16.5) \frac{\text{Btu}}{\text{hr-in. of perim.}} \times \pi \times 27.4" = 1950 \frac{\text{Btu}}{\text{hr}}$$

$$Q = UA\Delta T = 2 \frac{\text{Btu}}{\text{hr-ft}^2-\text{°F}} \times 119 \text{ ft}^2 \times 45\text{°C} \times 1.8\text{°F/°C} = 19,280 \text{ Btu/hr.}$$

where

U value given in Perry's Handbook is 1-3 Btu/hr-ft²-°F,

A, the surface area of the blast shield calculated as 119 ft²

$\Delta T = T_{\text{avg}} - T_{\text{air}}$, where T_{avg} is the arithmetic average of the measured

surface temperatures from Fig. 1.

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