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HRR Heat Exchangers

A study has been made to determine the approximate size of heat exchangers required for heat removal from the homogeneous research reactor. Although limited time prevented the selection of an optimum size heat exchanger, sufficient calculations were made to select one near the optimum size.

Six 83.3 Mw heat exchangers are required to remove 500 Mw of heat from the reactor. Calculations show that the requirements for these heat exchangers is very similar to the blanket heat exchanger for the TBR. On the basis of the TBR studies¹, a two drum steam generator is selected with the specifications listed in Table I.

Table I

Steam Generator Specifications

Reactor Fluids, Forced Circulation, (Tube Side)

Inlet Temperature, °F	527
Outlet Temperature, °F	437
Flow Rate, lbs/hr	2,730,000
Pressure, psia	1400
Velocity through tubing, ft/sec	10

Steam, Natural Recirculation, (Shell Side)

Generation Temperature, °F	417
Pressure, psia	300
Generation Rate, lbs/hr	351,600
Heat Load, Btu/hr	284,300,000
Heat Load, Mw	83.3

¹ TBR Data Book No. 1

Steam Generator

No. of 3/8 in. 18 BWG Tubes	3280
Pitch, in.	5/8, Triangular
Effective Length of Tubing, ft	25.9
Heat Transfer Surface, sq. ft	8330
Shell Internal Diameter, in.	38-1/2
Shell Thickness, in.	1-7/8
Tube Sheet Thickness, in.	5
Reactor Fluid Connections	14 inch schedule 100 pipe
Number of Risers	12
Number of Downcomers	6
Size of Risers and Downcomers	5 inch schedule 40 pipe

Steam Drum

Internal Diameter, in.	36
Length, ft	16
Wall Thickness, in.	1-3/4
Height above Generator, ft	15

Costs per Exchanger

Installed, \$	210,000
Annual, \$	39,200

The method of calculation of this heat exchanger size is described in the TBR Data Book.¹ Physical data for the fuel solution was obtained from TBR Memo No. 7.²

The rate of flow of the fuel solution through the heat exchanger may be found by a simple heat balance.

² A. L. Gaines, TBR Memo No. 7, ORNL CF 54-11-122 (11/12/54)

$$W = \frac{Q}{\int_{T_1}^{T_2} c dT} = \frac{83.3 \times 3.4 \times 13 \times 10^6}{104.3} = 2.73 \times 10^6 \text{ lbs/hr}$$

The outside surface area of each heat exchanger tube may be found by the following relation¹

$$a = w c \left(\frac{D_o}{D_i h_i} + \frac{D_o}{D_w h_w} + \frac{1}{h_s} \right) \ln \frac{\phi_1}{\phi_2} + \frac{w c}{\beta} \left(\frac{1}{\alpha} \right)^{\frac{1}{\beta+1}} \left[\phi_2^{-\frac{\beta}{\beta+1}} - \phi_1^{-\frac{\beta}{\beta+1}} \right] \quad (1)$$

where w is the mass rate of flow of fuel solution through the tube. This relation assumes that the inside, walls, and scale coefficients are constant for the length of the tube, but the outside boiling coefficient varies with the length of the tube.

The inside coefficient h_i was estimated by the following relation²

$$\begin{aligned} h_i &= 0.023 \frac{k}{D_i} \left[\frac{D_i G}{\mu} \right]^{0.8} \left[\frac{c \mu}{k} \right]^{0.3} \\ &= \phi_i w_i^{0.8} D_i^{-1.8} \end{aligned} \quad (2)$$

where w_i = pounds per hour, and D_i = ft. The wall coefficient was assumed to be

$$h_w = \frac{k_w}{x_w} = \frac{105}{0.049} \quad (3)$$

and the scale coefficient h_s was assumed to be 2000. The boiling coefficient h_o is in the form of

$$h_o = \alpha (\Delta T)_o^\beta \quad (4)$$

where $(\Delta T)_o$ is the temperature drop across the boiling film. α is a function of pressure and was evaluated from the information given in the TBR Data Book.¹

β was assumed to be 2.42.

ϕ_1 the heat flux at the hot end of the tube and ϕ_2 the heat flux at the cold end of the tube are then evaluated by the following relation.¹

$$\Delta T_m \propto \frac{1}{\beta+1} \phi_m - \frac{1}{\beta+1} \phi_m - \frac{1}{\beta+1} \left(\frac{D_o}{D_i h_i} + \frac{D_o}{D_w h_w} + \frac{1}{h_s} \right) \phi_m^{\frac{\beta}{\beta+1}} = 1 \quad (5)$$

Calculations using these equations were made for heat exchangers with 3/8 inch 18 gauge tubing and with 1/2 inch 18 gauge tubing. Various velocities were assumed at various steam pressures, and the length of tubing was found by Equation (1) through (5). The number of tubes was found by a simple material balance.

The costs of the various heat exchangers were estimated by the information in TBR Memorandum No. 4³, and by the letter from A. L. Gaines to C. B. Graham.⁴

From these calculations, the heat exchanger described in Table I appeared to be of a practical size. Heat exchangers with 1/2 inch tubing were too long to be practical and therefore heat exchangers with 3/8 inch tubing were selected.

Wall thicknesses were obtained from the A.S.M.E. Boiler and Pressure Vessel Code⁵ and tube sheet thickness was obtained from the TEMA Code⁶.

Howard A. McLean

³ M. I. Lundin, TBR Memorandum No. 4, ORNL CF 54-10-111 (10/25/54).

⁴ A. L. Gaines, Letter to C. B. Graham (3/25/55).

⁵ A.S.M.E. Boiler and Pressure Vessel Code, Section VIII, Unfired Pressure Vessels, (1952).

⁶ TEMA Code, (1952).