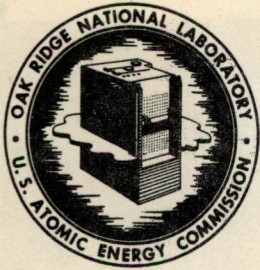


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DATE: May 3, 1954
SUBJECT: HRT Evaporator Design Study
TO: Distribution
FROM: C. L. Segaser

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Introduction. As a first approach to the problem of designing an evaporator for the HRT, an arrangement similar to that designed for the HRE was considered, as shown by Figure 1. It was originally proposed to evaporate at a rate of 1/2 gpm to atmospheric pressure in the evaporator body, hence, this analysis is based on this criterion. However, assuming all conditions but the evaporation rate remaining constant, the heat transfer area required will be directly proportional to the rate of evaporation.

As an alternative arrangement to the HRE evaporator, a standard calandria-type of shell and tube evaporator is suggested as shown by Figure 2. It is believed that a design of this type may have several advantages over the HRE design. This design may be modified to be hung below the inner dump tanks as in the HRE installation, and, the vapor-gas-moisture separator may also be rearranged to suit if desired.

Assume an HRE Type of Evaporator

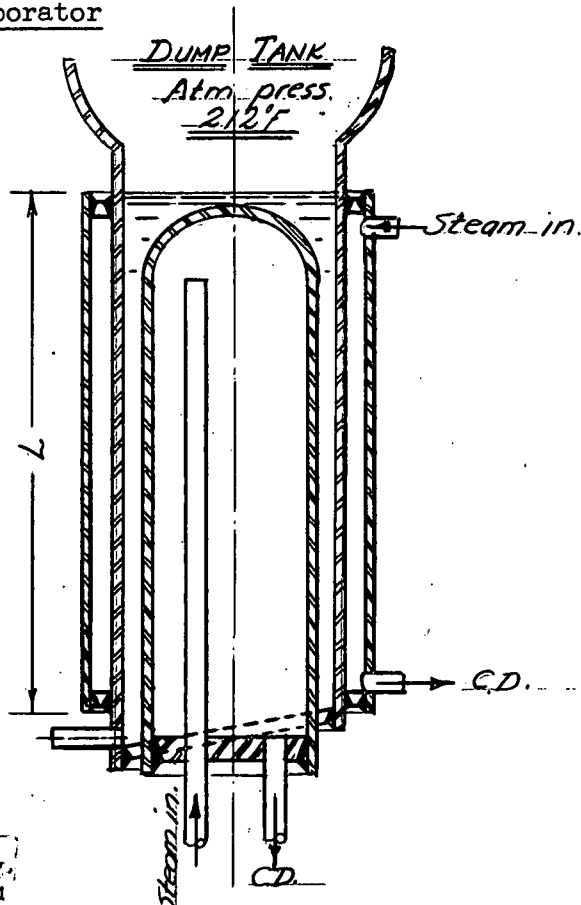


Figure 1

Heat transfer surface area:

$$\frac{1}{UA} = \frac{1}{h_s A_s} + \frac{1}{h_w A_w} + \frac{1}{h_L A_L}$$

$$Q = UA\Delta T$$

$$\Delta T = \Delta t_s + \Delta t_w + \Delta t_L$$

$$\Delta t_s = \frac{Q}{h_s A_s}$$

$$\Delta t_w = \frac{Q}{h_w A_w}$$

$$\Delta t_L = \frac{Q}{h_L A_L}$$

$$\Delta T = \frac{Q}{h_s A_s} + \frac{Q}{h_w A_w} + \frac{Q}{h_L A_L}$$

Metal wall thickness = 0.250

$$\therefore h_w = \frac{k}{l} = \frac{130}{0.250} = 520 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

$h_s = 1500 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$ for condensing steam

Boiling Side Coefficient

$$h_L = 2.3 \Delta t_L^2 \quad (\text{For vertical surfaces})$$

$$\frac{Q}{A_L} = h_L \Delta t_L$$

$$\text{or } \frac{Q}{A_L} = 2.3 \Delta t_L^3$$

$$\Delta T = \frac{Q}{A} \left[\frac{1}{\frac{D_s}{D} h_s} + \frac{1}{\frac{D_w}{D} h_w} + \frac{1}{\frac{D_L}{D} h_L} \right]$$

Since the diameters are large in comparison to the thicknesses, the ratios may be assumed unity, and

$$\Delta T = \frac{Q}{A} \left[\frac{1}{h_s} + \frac{1}{h_w} + \frac{1}{h_L} \right]$$

or,

$$\Delta t_L^3 = \frac{Q}{2.3 A}$$

$$\Delta t_L = \left(\frac{Q}{2.3A} \right)^{1/3}$$

and

$$\Delta T = \frac{\frac{Q}{A}}{1500} + \frac{\frac{Q}{A}}{520} + \left(\frac{Q}{2.3A} \right)^{1/3}$$

$$\Delta T = \frac{(Q/A)}{1500} + \frac{(Q/A)}{520} + \frac{(Q/A)^{0.333}}{1.32}$$

Tabulated Calculations

(Q/A)	1000	5000	10,000	20,000
ΔT	10.18	25.85	42.17	72.30
Steam Temp. (°F)	~ 222	238	254	284
Steam Press. (psig)	3.2	9.3	17.3	37.7
Temp. Drop thru Metal Wall, °F	1.92	9.62	19.2	38.4
Heat Trans. Area, Ft ²	2.76x10 ²	55.2	27.6	13.8
Therm. Stress Metal Wall psi	370	1860	3700	7400

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To evaporate 1/2 gpm of water from 212°F:

$$\frac{(0.500)(60)}{7.48} = 4 \text{ ft}^3/\text{hr}$$

$$Q = (4) \left(\frac{1}{0.0167} \right) 1150 = 2.76 \times 10^5 \text{ Btu/hr}$$

Thermal stress in evaporator surface area due to heat conduction

$$S_t = \frac{\alpha E \Delta t_w}{2(1 - \nu)}$$

Assume $\left\{ \begin{array}{l} \alpha = 9.3 \times 10^{-6} \\ E \cong 29 \times 10^6 \\ \nu = 0.3 \end{array} \right.$

$$S_t = \frac{(9.3 \times 10^{-6})(29 \times 10^6) \Delta t_w}{2(1 - 0.3)}$$

$$S_t = 193 \Delta t_w$$

Stress due to Internal Steam Pressure

$$S_p \cong \frac{PR}{t} = P \left(\frac{1.75}{0.250} \right) = 7 P$$

Q/A	1000	5000	10,000	20,000
S _p	48	65	121	264
S _t	370	1860	3700	7400
S (Total)	418	1925	3821	7664

Heat Transfer Area on Solution Side

$$A \cong \pi L \left[\frac{4.5}{12} + \frac{5.5}{12} \right] \text{ (Ft}^2\text{)}$$

$$A \cong 2.62 L \text{ (Ft}^2\text{)}$$

$$A = 8.5 \text{ Ft}^2$$

$$L \cong \frac{8.5}{2.62} = 3.24 \text{ Ft}$$

Hold-Up Volume

$$V = \frac{\pi}{4} \left[\left(\frac{5.5}{12} \right)^2 - \left(\frac{4.5}{12} \right)^2 \right] L$$

$$V = 2.54 \left[\frac{30.3 - 20.2}{144} \right] = \frac{256}{144}$$

$$V = 1.78 \text{ Ft}^3 = (1.78)(28.3) = 50.3 \text{ Liters}$$

Vapor Disengagement

(1) Maximum disengagement surface

$$A = \frac{\pi}{4} \left(\frac{5.5}{12} \right)^2 = \frac{\pi}{4} \left(\frac{30.3}{144} \right) = \frac{95.2}{576} = 0.165 \text{ Ft}^2$$

(2) Minimum disengagement surface.

$$A = \frac{\pi}{4} \left[\left(\frac{5.5}{12} \right)^2 - \left(\frac{4.5}{12} \right)^2 \right]$$

$$A = \frac{\pi}{4} \left[\frac{30.3 - 20.2}{144} \right] = 0.785 \left[\frac{10.1}{144} \right] = \frac{7.93}{144}$$

$$A = 0.0552 \text{ Ft}^2$$

Rate of Vapor Disengagement.

$$\text{Maximum} = \frac{(4)(60)}{0.0552} = 4350 \text{ Lb/hr-Ft}^2$$

$$\text{Minimum} = \frac{(4)(60)}{0.165} = 1450 \text{ Lb/hr-Ft}^2$$

Apparent Overall U

$$U = \frac{2.76 \times 10^5}{(8.5)(108)} = 300 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

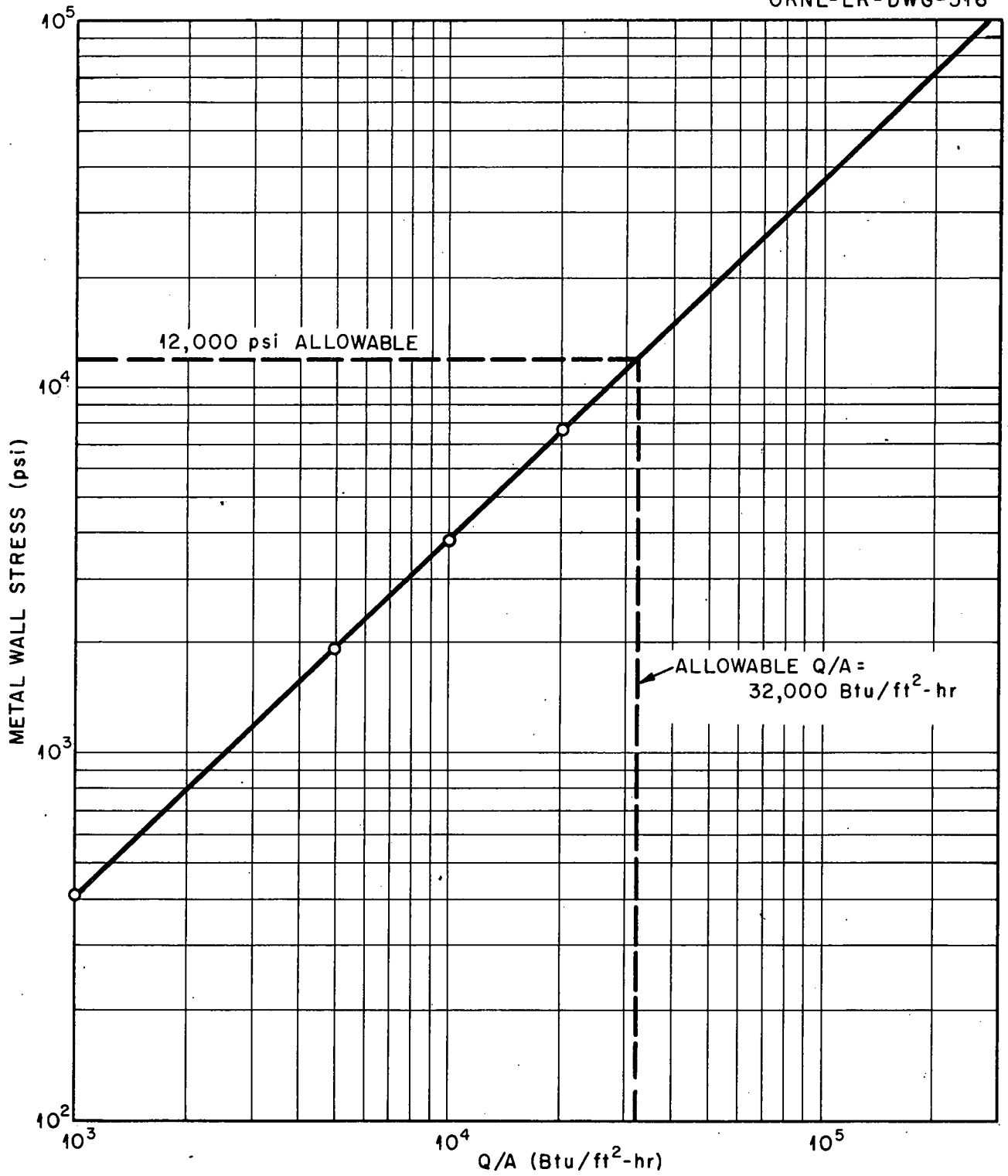


Fig. 3. Thermal Stress in Metal Wall

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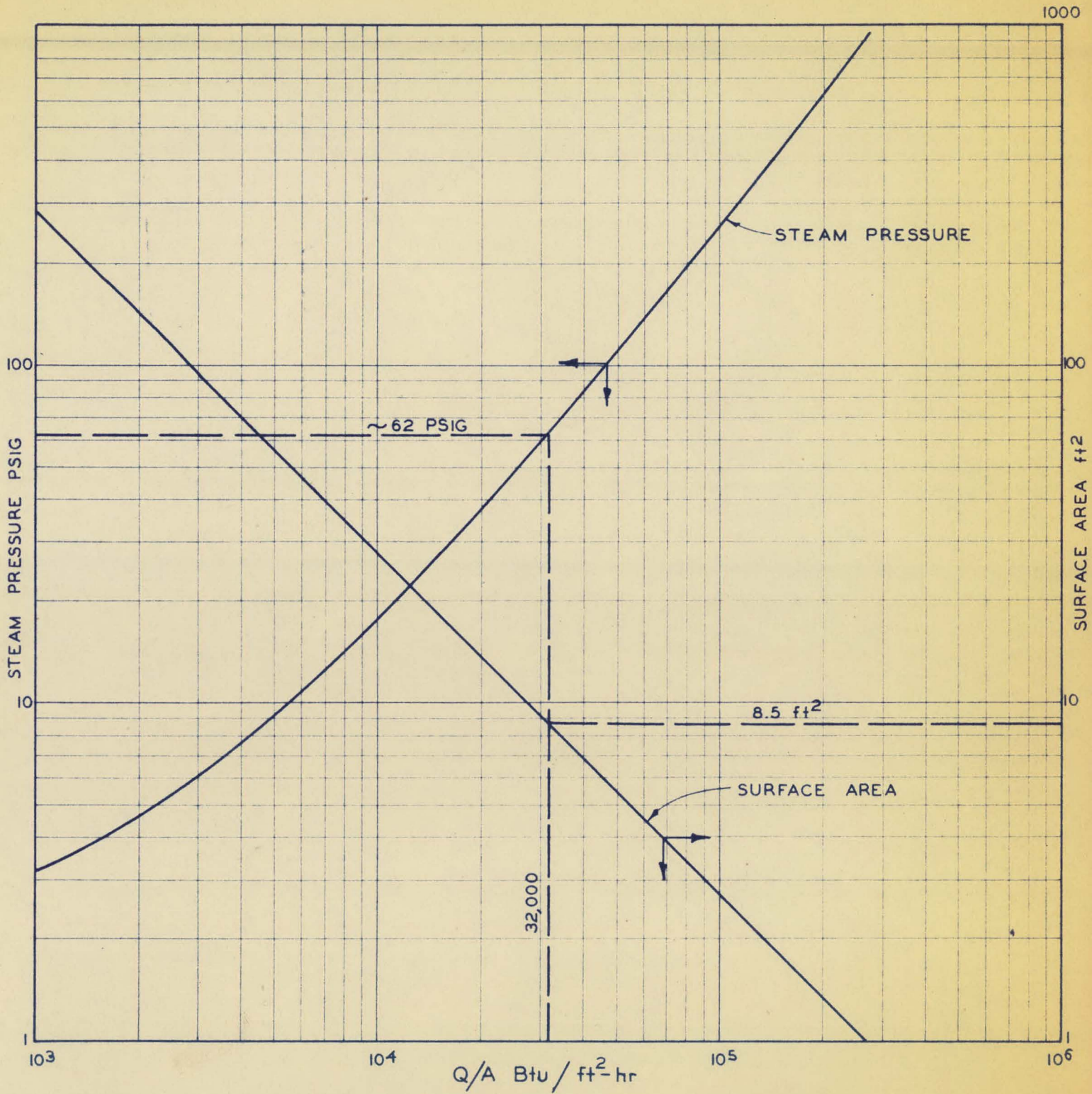


FIG. 4
SURFACE AREA & STEAM PRESSURE REQUIRED IN EVAPORATOR

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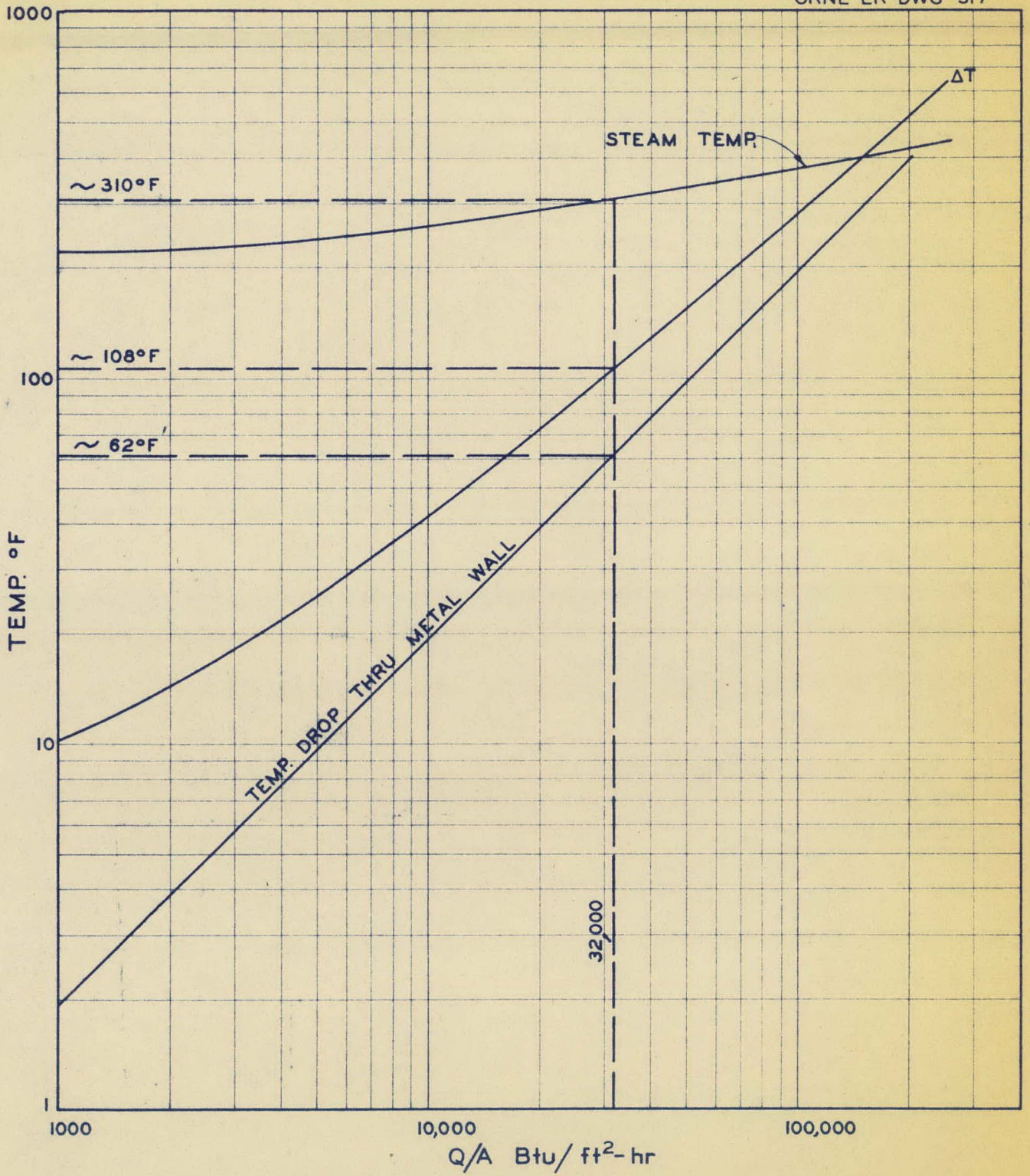


FIG. 5
TEMPERATURES IN EVAPORATOR

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Calandria Type of High Performance Low Hold-up Evaporator

An evaporator of this type is shown by Figure 2. The mixture of solution and gases let-down from the high pressure system enter the separator drum through a 2-inch tangential inlet pipe. The mixture is given a further centrifugal motion by means of the spiral baffle which is intended to separate initially the gases of dissociation from the entrained moisture. These gases flow upward through the 3-inch outlet pipe and join the vapor from the evaporator body at the split in the gas-vapor outlet pipe. The separated moisture collects at the bottom of the separator drum and is introduced into the bottom of the evaporator through the external 2-inch downcomer pipe. Thus, the density difference caused by the temperature differential existing between the fluid in the evaporator and that in the downcomer aids circulation through the evaporator.

Since the original proposal specified low-holdup, filler blocks are shown in the bottom evaporator head. An alternate to this arrangement would be to modify a standard 10-inch pipe cap by machining off part of the straight lip. The solution then flows upward through 24 3/4-inch O.D. - 16 BWG stainless steel tubes 18-inches long and part of the water is evaporated in the tubes by steam at not more than 62 psig. pressure surrounding the tubes. A 2-1/2 inch schedule 40 downcomer is placed in the center of the tube bundle to promote natural circulation. Such a downcomer shall have a flow area equal to or not less than 1/2 that of the total flow area of the tubes.

* Ordinarily, a standard evaporator of this type is designed for a vapor disengagement rate not to exceed 40 lb/hr-ft^2 from the free surface and to have a vapor volume over the surface proportioned on the basis of one cubic foot of vapor space for every cubic foot per second of vapor evaporated in order to minimize excessive splashing and liquid carry over. In this evaporator,

the disengagement rate of 1/2 gpm will be equivalent to 438 lb/hr-ft² and the vapor volume is fairly low so that an excessive amount of spouting and carry-over of liquid could be expected. It is to provide for this contingency that the vapor baffle, outlet pipe and spiral baffle arrangement in the separator drum are shown.

The general specifications for this type of evaporator for 1/2 gpm are as follows: For 1 gpm the surface area required will be proportional to the increase in evaporation rate.

General Specifications

1. Fuel solution
2. Evaporation rate 0.500 gpm
3. Evaporation pressure Atm.
4. Evaporation temperature 212°F
5. Flow in:
 - Gas 0.527 lb/min
 - Liquid 1.21 gpm
6. Heat balance:
 - Evap. rate 240 lb/hr
 - Heat transfer 2.76 x 10⁵ Btu/hr
7. Heat transfer surface based on 62 psig sat. steam:
 - Tubes 3/4" O.D. - 16 BWG 347 SS
 - Steam side coefficient 1500 $\frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F}}$
 - Wall coefficient 2000 $\frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F}}$
 - Boiling coefficient 230 Δt_B^2
 - Overall coefficient 658 $\frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F}}$

Steam pressure	62 psig
Steam temperature	310°F
ΔT	98°F
Area (calc)	4.28 Ft ²
8. Actual area	6.00 Ft ²
9. Apparent U	470 $\frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ\text{F}}$
10. Heat flux	46,000 $\frac{\text{Btu}}{\text{hr-ft}^2}$
11. Disengagement rate	438 $\frac{\text{lb}}{\text{hr-ft}^2}$

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1. Foulk, C. W., Ind. Eng. Chem. 21, 815 (1929)
2. Foulk, C. W., Ind. Eng. Chem. 30, 159 (1938)
3. Foulk, C. W., Ind. Eng. Chem. 25, 800 (1933)
4. Foulk, C. W., Ind. Eng. Chem. 24, 277 (1932)
5. Foulk, C. W., Ind. Eng. Chem. 23, 1283 (1931)
6. Foulk, C. W., Trans. ASME, 54-55, 105 (1932)
7. Foulk, C. W., Ind. Eng. Chem. 26, 263 (1934)

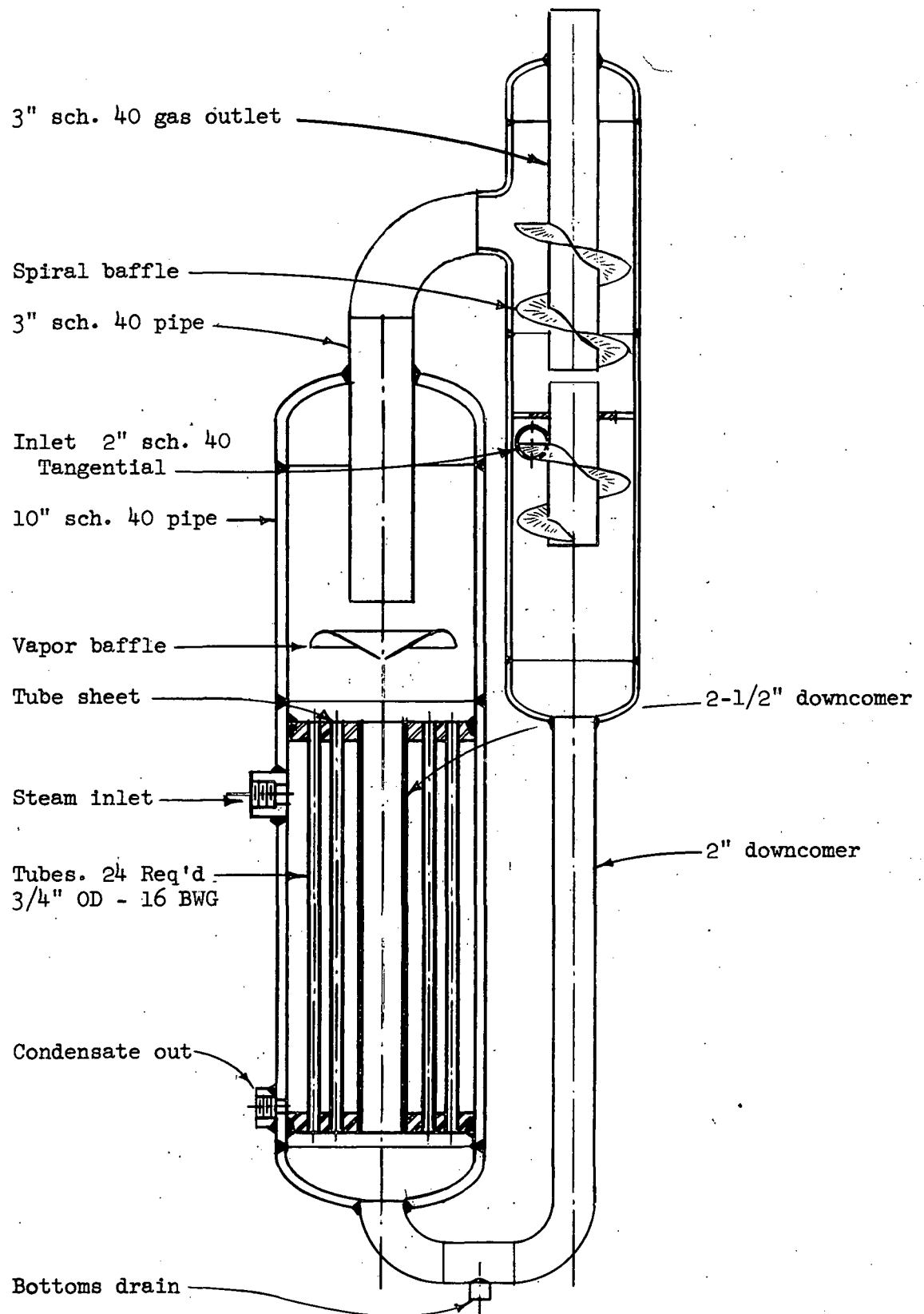


Figure 2

Calandria Type High Performance Evaporator

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