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CALCULATIONS FOR HRT MAIN HEAT EXCHANGER

Supplement To CF-53-12-94

By
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February 2, 1954

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Oak Ridge, Tennessee

Technical Information Extension, Oak Ridge, Tennessee

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OAK RIDGE NATIONAL LABORATORY
Operated By
CARBIDE AND CARBON CHEMICALS COMPANY

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

Calculations were reported in CF-53-12-94 for a 3000 kw vaporizing heat exchanger intended for use in the HRT. These calculations were based on a fuel solution of 25 g/l of UO_2SO_4 in H_2O. Since the date that CF-53-12-94 was issued, the primary design data has been changed to 5000 kw with a fuel solution of 10 g/l of UO_2SO_4 in D_2O. The attached calculations are for the new conditions, based on the procedures reported in CF-53-12-94. On the basis of these calculations, specifications for the HRT main heat exchanger have been prepared. Following are tabulated the principle calculated data used in preparing the specifications:

Flow rate	179,000 lb/hr of solution
Fuel outlet temperature	494.5°F
LMTD	53.2°F
Apparent U_F	670 Btu/hr-ft^2-°F
Velocity thru tubes	11 ft/sec
Heat transfer area	480 ft^2
Number of tubes	250

I. Design Data

Fuel solution	10 g/l - UO_2SO_4-D_2O
Fuel solution inlet temperature	572°F (300°C)
Power	5000 kw
Tube size	3/8" OD - 16 BWG
Fuel solution pressure	2000 psia
Flow rate	400 gpm (179,000 lb/hr)
Steam pressure	520 psia
Steam temperature	471°F

II. Heat Balance

$$Q = WC_p (572 - T_o)$$

$$W = \frac{(400)(60)}{7.48} \rho(T_o) = 3210\, \rho(T_o)$$

$$Q = 3210\, \rho(T_o) C_p \left[572 - T_o\right]$$

In this equation, C_p should correspond to the average temperature of solution in the tubes.

$$Q = (5 \times 10^3)(3.42 \times 10^3) = 1.71 \times 10^7 \text{ Btu/hr}$$

$$\frac{1.71 \times 10^7}{0.321 \times 10^4} = \rho\,(T_o)\, C_p\, \frac{T_i + T_o}{2} \left[572 - T_o\right]$$

$$533 \times 10^3 = \rho\,(T_o)\, C_p\, \frac{T_i + T_o}{2} \left[572 - T_o\right]$$

T_o	$\frac{T_i + T_o}{2}$	$\rho(T_o)$	$C_p \left[\frac{T_i + T_o}{2}\right]$	$\rho(T_o)C_p\left[\frac{T_i + T_o}{2}\right]\left[572-T_o\right]$
450	511	58.4	1.187	8.45×10^3
460	516	57.8	1.197	7.75×10^3
470	521	57.2	1.205	7.03×10^3
480	526	56.7	1.216	6.35×10^3
490	531	56.1	1.225	5.63×10^3
500	536	55.5	1.235	4.93×10^3

Temperature Data

$T_i = 572^\circ F$ $\qquad$ $T_B = 471^\circ F$

$T_o = 494.5^\circ F$ $\qquad$ $T_i - T_o = 77.5^\circ F$

$T_{avg} = 533^\circ F$ $\qquad$ $T_i - T_B = 101^\circ F$

$T_o - T_B = 23.5^\circ F$

Inside Tube H.T. Coefficient

$$h_i = (0.023)\left(\frac{k}{D_i}\right)\left(\frac{D_i\ V\ \rho}{\mu}\right)^{0.8}\left(\frac{C_p\mu}{k}\right)^{0.3}$$

$$T_{avg} = 533^{\circ}F$$

$$\begin{cases} k = 0.339\ \text{Btu/hr-ft}^2\text{-}^{\circ}\text{F/ft} \\ \rho = 53.4\ \text{lb/ft}^3 \\ C_p = 1.23\ \text{Btu/lb-}^{\circ}\text{F} \\ \mu = 0.266\ \text{lb/hr-ft} \\ D_i = 0.0204\ \text{ft} \end{cases}$$

$$\frac{k}{D_i} = \frac{0.339}{0.0204} = 16.6$$

$$h_i = (0.023)(16.6)(3.09)(0.99)\ V^{0.8}$$

$$h_i = 1.17\ V^{0.8}$$

$$A = WC_p\left[\frac{1}{0.778\ V^{0.8}}\ln\frac{\left(\frac{Q}{A_o}\right)_i}{\left(\frac{Q}{A_o}\right)_o} + \frac{1}{1650}\ln\left(\frac{\frac{Q}{A_o}}{\frac{Q}{A_o}}\right)_i - 0.105\left[\left(\frac{Q}{A_o}\right)_i^{-0.586} - \left(\frac{Q}{A_o}\right)_o^{-0.586}\right]\right]$$

$$\begin{cases} W = 179{,}000\ \text{lb/hr} \\ C_p = 1.23 \\ WC_p = 2.20 \times 10^5 \end{cases}$$

$$\text{LMTD} = \frac{101-23.5}{2.3\log\frac{101}{23.5}} = 53.2^{\circ}$$

Velocity, V		5 ft/sec 18,000 ft/hr	10 36,000	15 54,000	20 72,000	25 90,000
Surface Area	Clean	434	365	335	318	311
	Fouled	580	487	447	424	414
Apparent U	Clean	740	880	935	1010	1040
	Fouled	555	660	702	757	780
Number of Tubes		545	273	186	136	109
Tube Length (ft)	Clean	8.13	13.6	18.8	23.8	29.1
	Fouled	10.80	18.2	25.0	31.8	38.8
Pressure Drop (psi)	Clean	1.15	6.45	19.2	53.2	
	Fouled	1.53	8.63	25.5	71	
Hold-up in Tubes-Liters	Clean	41	34.4	32.4	30.0	29.4
	Fouled	54.4	46.0	43.2	40.2	39.2

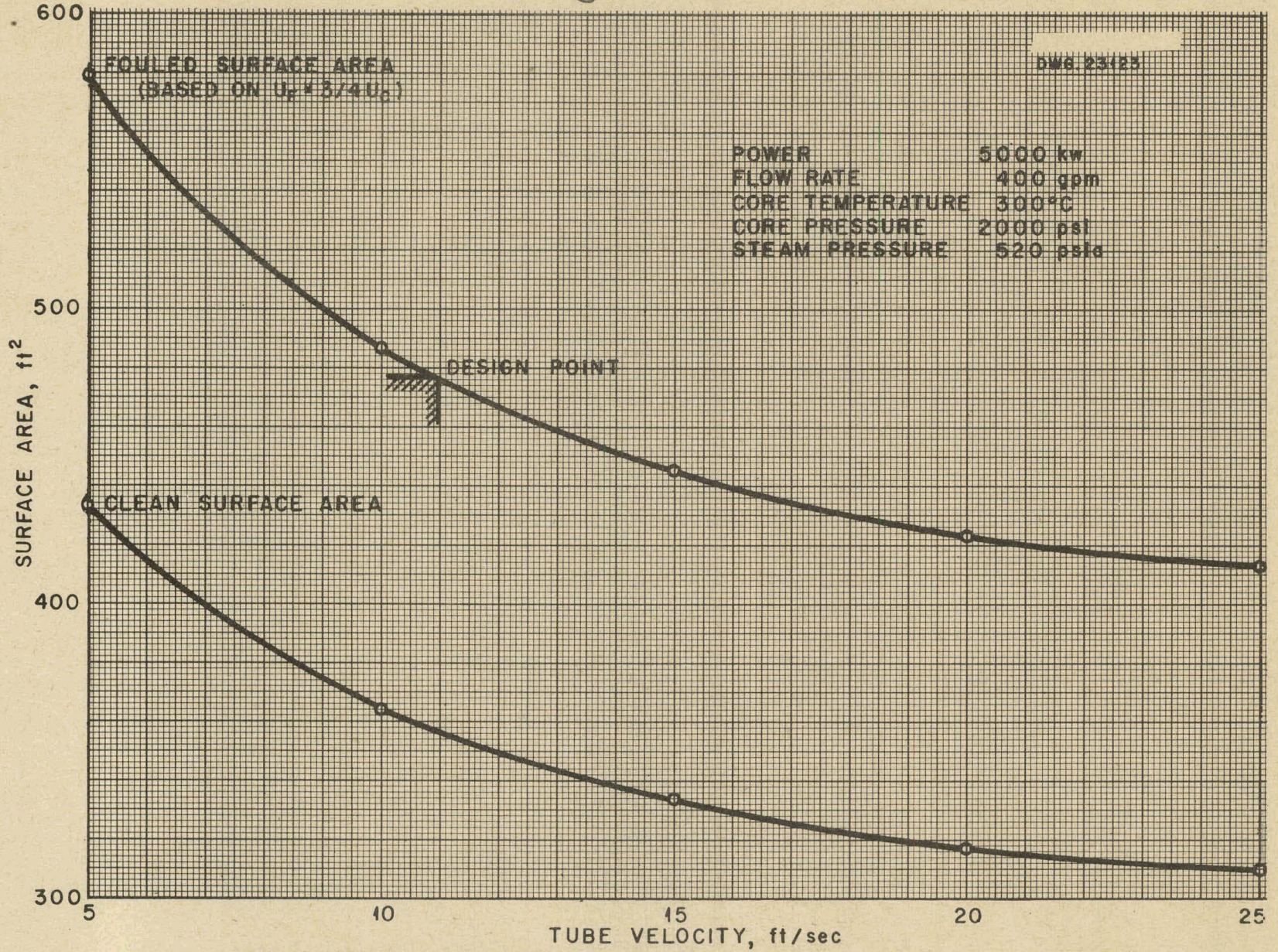

Fig. 1. HRT Main Heat Exchanger – Surface Area

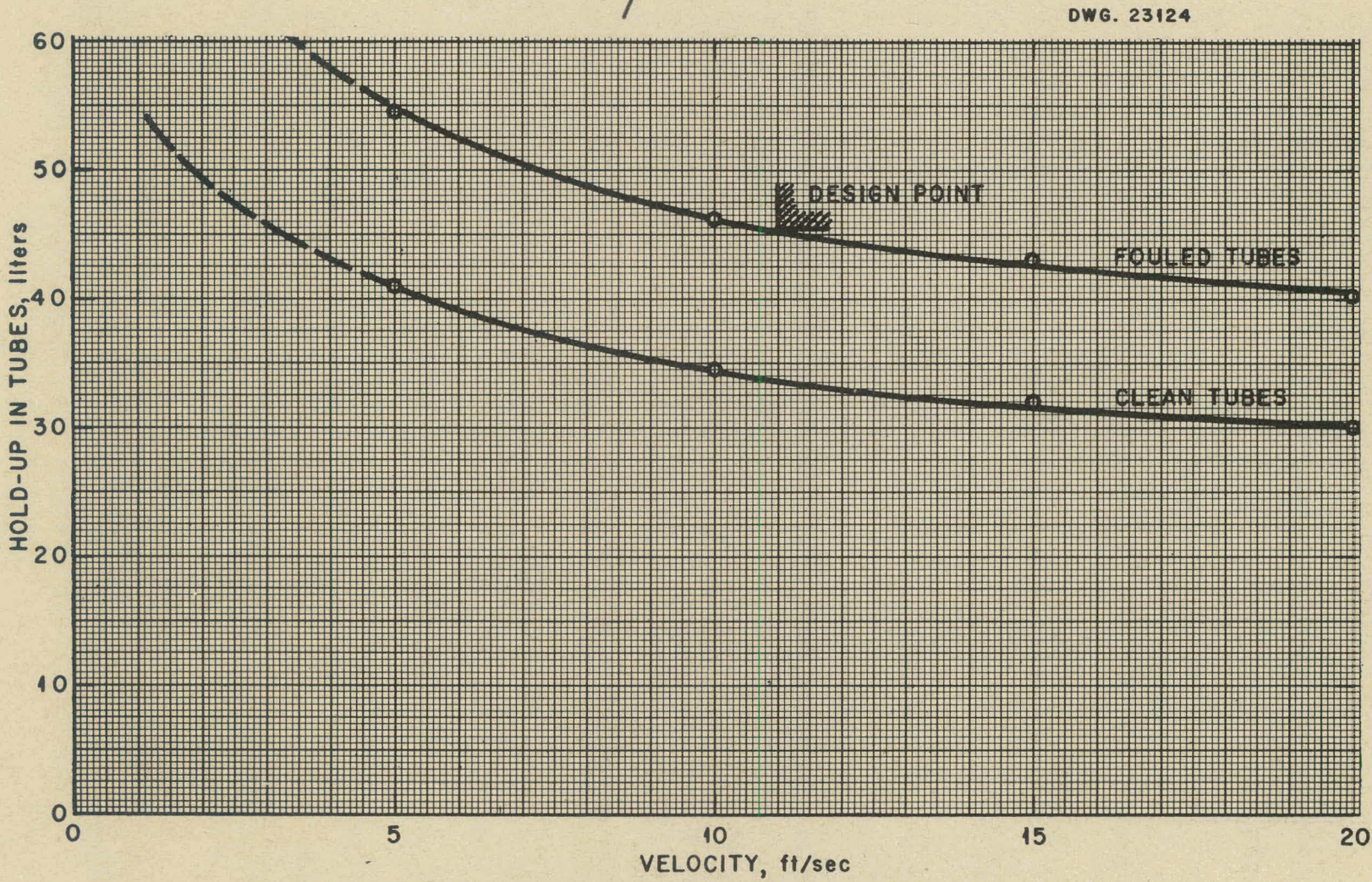

Fig. 2. HRT Main Heat Exchanger - Hold-up in Tubes

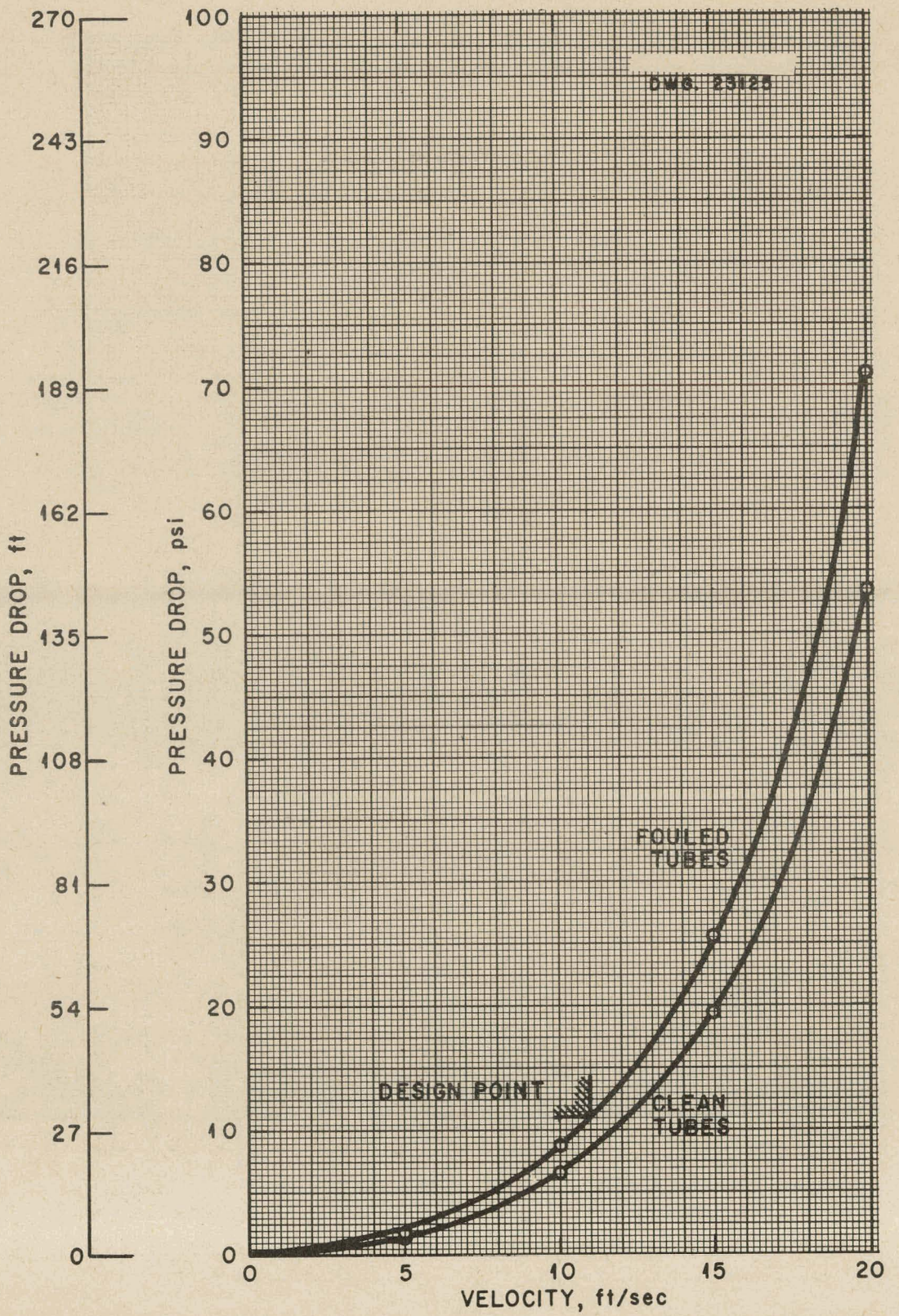

Fig. 3. HRT Main Heat Exchanger - Pressure Drop Through Tubes

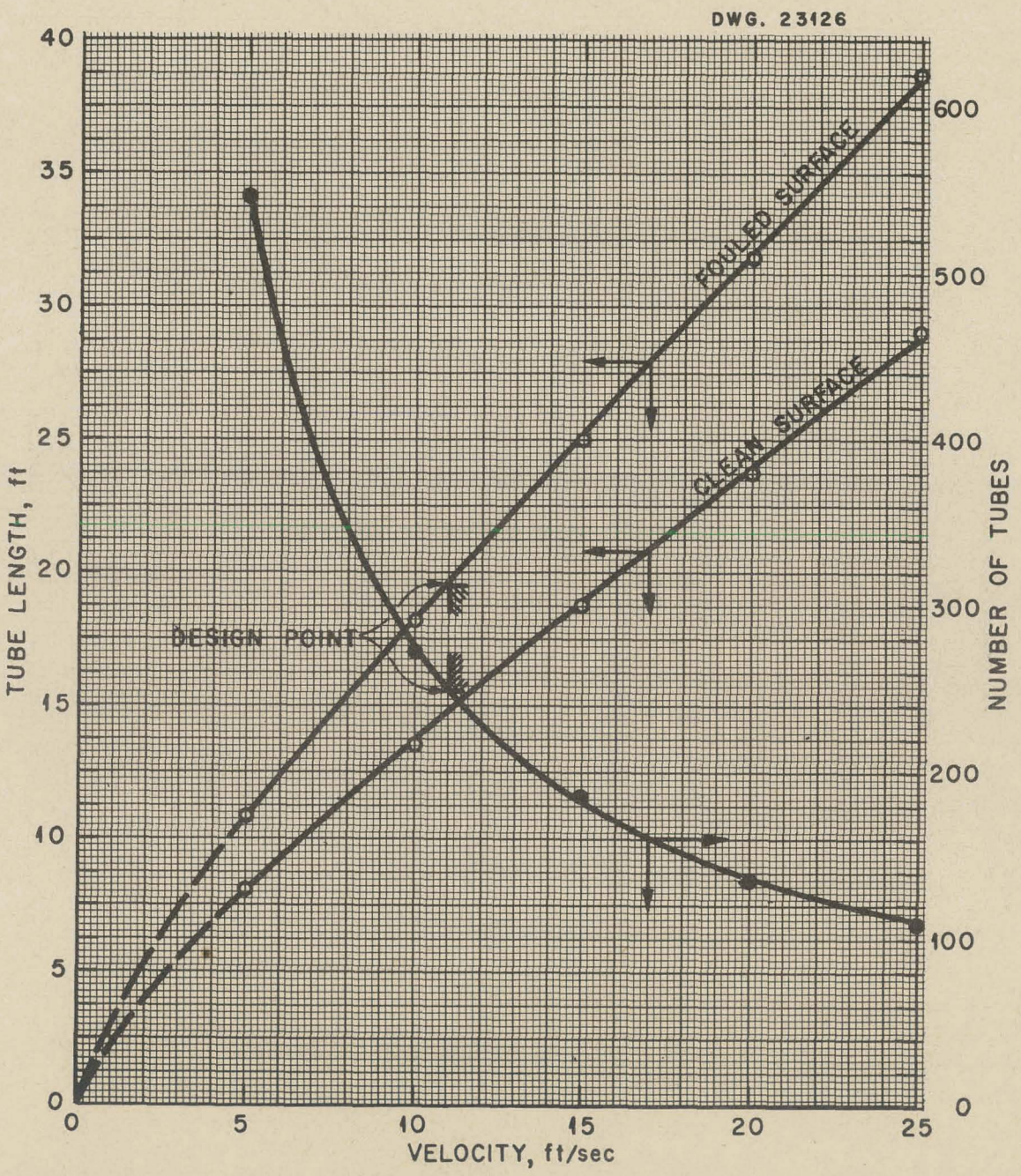

Fig. 4. HRT Main Heat Exchanger - Number and Length of Tubes

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