Case – 6 Impact of Fouling Factor and Special Material for Heat Exchanger

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Case Background:

A screw refrigeration system was originally designed for copper tubes and 0.0005 Ft²-Hr-°F/Btu fouling factors for both the condenser and cooler. The details are as the following:

Capacity:	163 TR
Condensing temperature:	105°F
Evaporative temperature:	3°F
Refrigerant:	R-22
Discharge external P.D.	3.5 Psi
Suction external P.D.	0.6 Psi
Suction superheat:	7.5°F
Oil cooling:	Water cooled
Oil pump:	Pre-lube
Condenser:	Shell-and-tube
Tubes:	¾" OD, 19 FPI, 20 BWG
Loading:	8 S.F./TR
Cooler:	Shell-and-tube, Flooded design
Tubes:	¾" OD, 19 FPI, 20 BWG
Loading:	10 S.F./TR
Power supply:	6000-3-50
Economizing:	DX Liquid subcooling
Port P.D.	4.5 Psi
Temperature approach:	10°F

Compare the screw compressor selection and the power consumption for each of the following alternates:

1.0 The original design with standard scale factor and standard tube materials.

2.0 Same as the original design, except the fouling factor is changed to 0.002 for both condenser and cooler.

3.0 Same as the original design, except:
The fouling factor is changed to 0.002 for both condenser and cooler.
The tube material for condenser is changed to 18 BWG, 70/30 Cu.Ni.
(Assuming no effect on heat transfer by changing BWG)

4.0 Same as the original design, except:
The fouling factor is changed to 0.003 for both condenser and cooler.
The tube material for condenser is changed to 16 BWG, 304 SS.
The tube material for the cooler is also changed to 16 BWG, 304 SS.
(Assuming no effect on heat transfer by changing BWG)

Comparisons:
Fill in the Compressor Selected and the Power Consumption for each of the case

Case #	System Description	CT	ET	Compressor Model Selected	Power Consumption
Case-1	0.0005 FF 20 BWG Cu Tubes in condenser 20 BWG Cu Tubes in Cooler	°F	°F		BHP
Case-2	0.002 FF 20 BWG Cu Tubes in condenser 20 BWG Cu Tubes in Cooler	°F	°F		BHP
Case-3	0.002 FF 18 BWG CuNi Tubes in condenser 20 BWG Cu Tubes in Cooler	°F	°F		BHP
Case-4	0.003 FF 16 BWG 304SS Tubes in condenser 16 BWG 304SS Tubes in Cooler	°F	°F		BHP

Related Technical Data and Engineering Information for the Case:

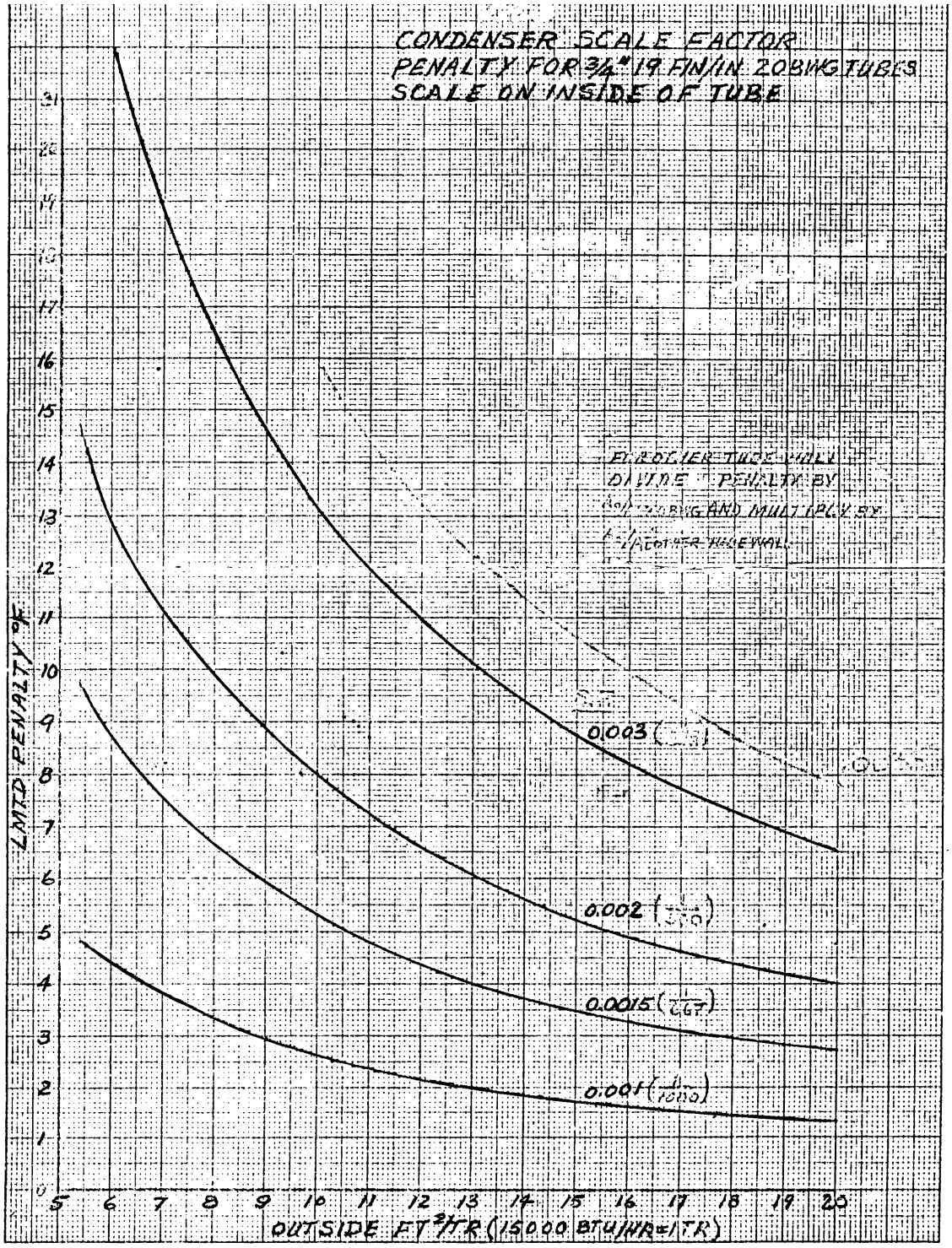

Figure 6-1 Scale Factor Penalty Curves for Condenser

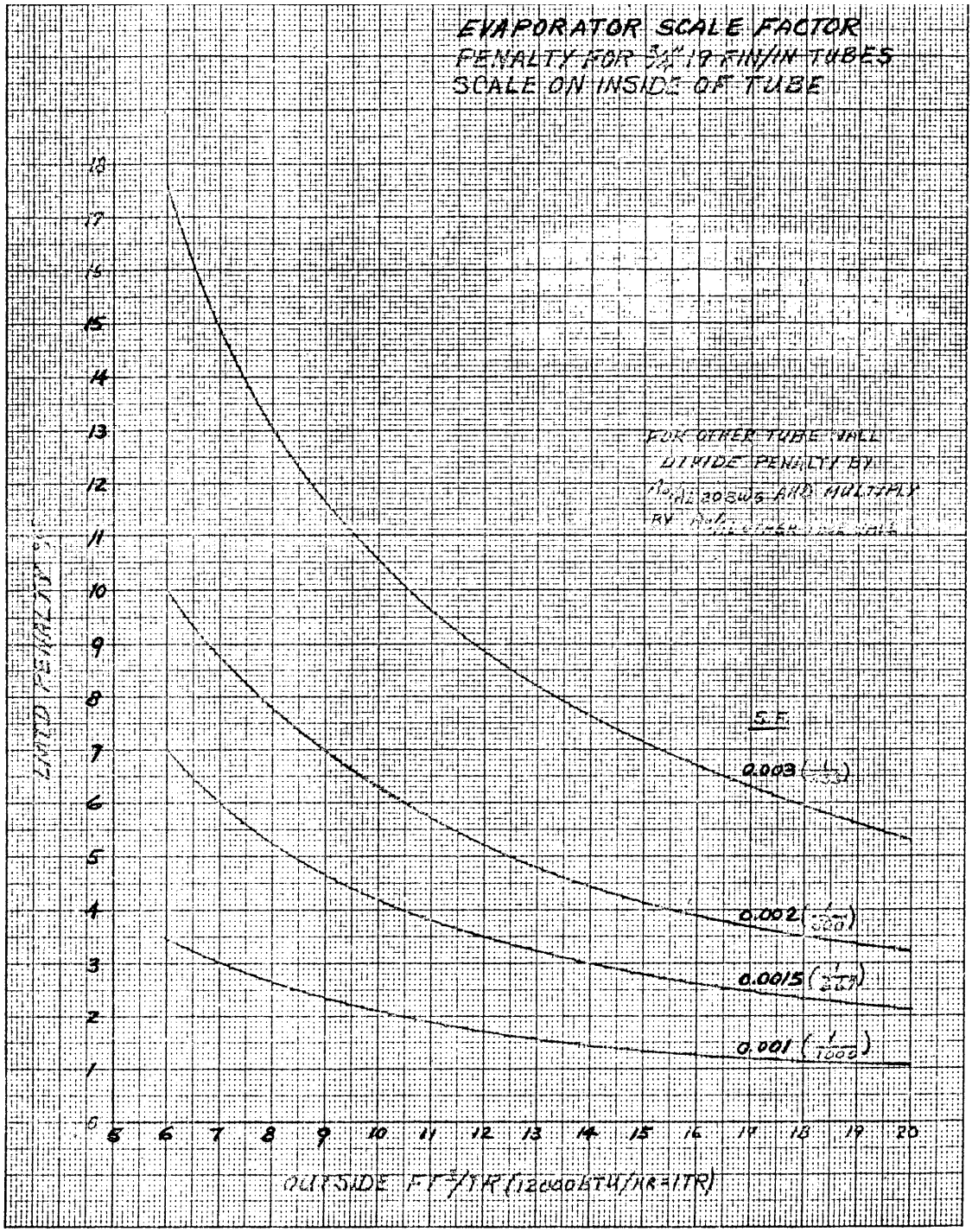

Figure 6-2 Scale Factor Penalty Curves for Cooler

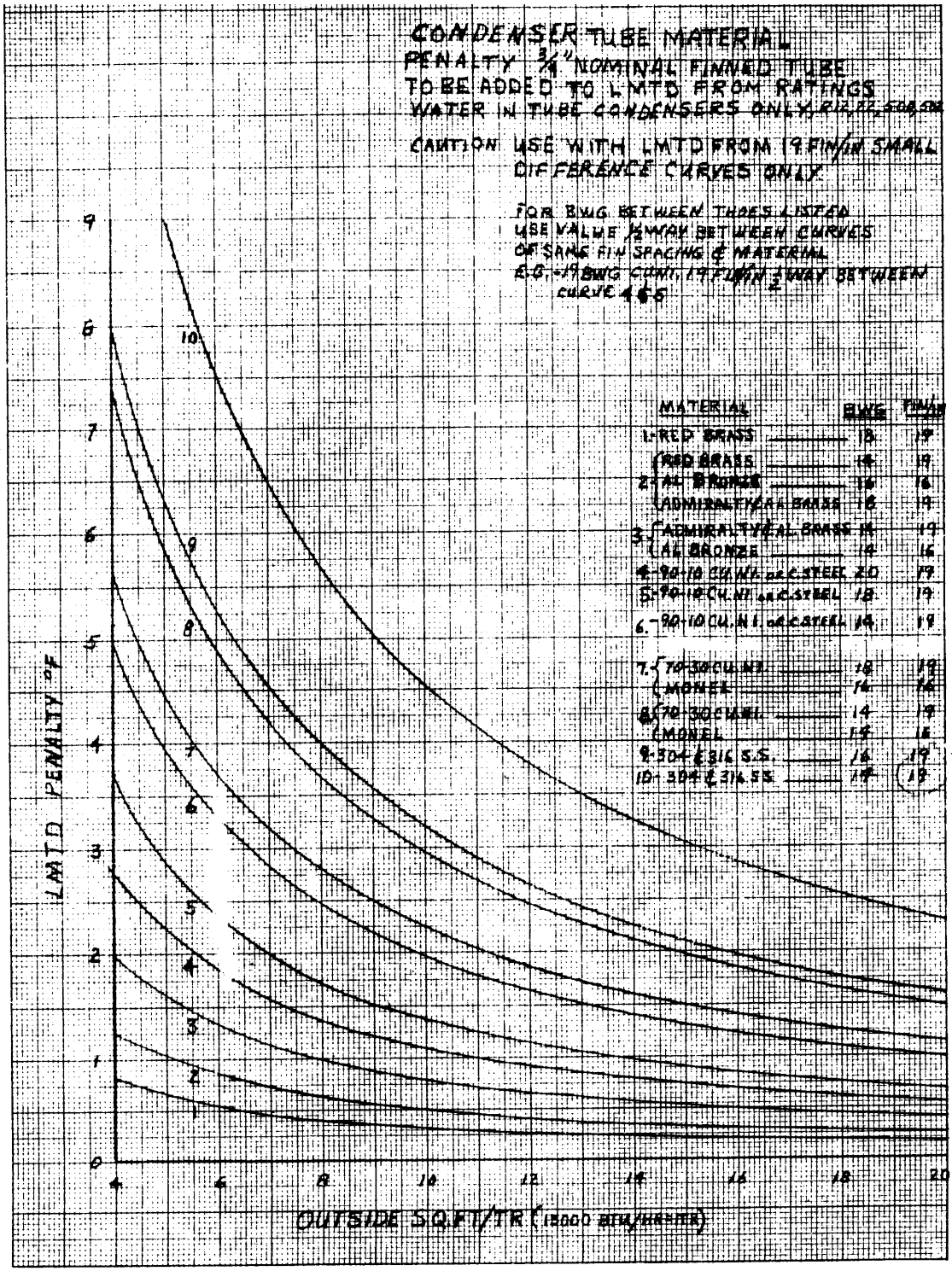

Figure 6-3 Tube Material Penalty Curves for Condenser

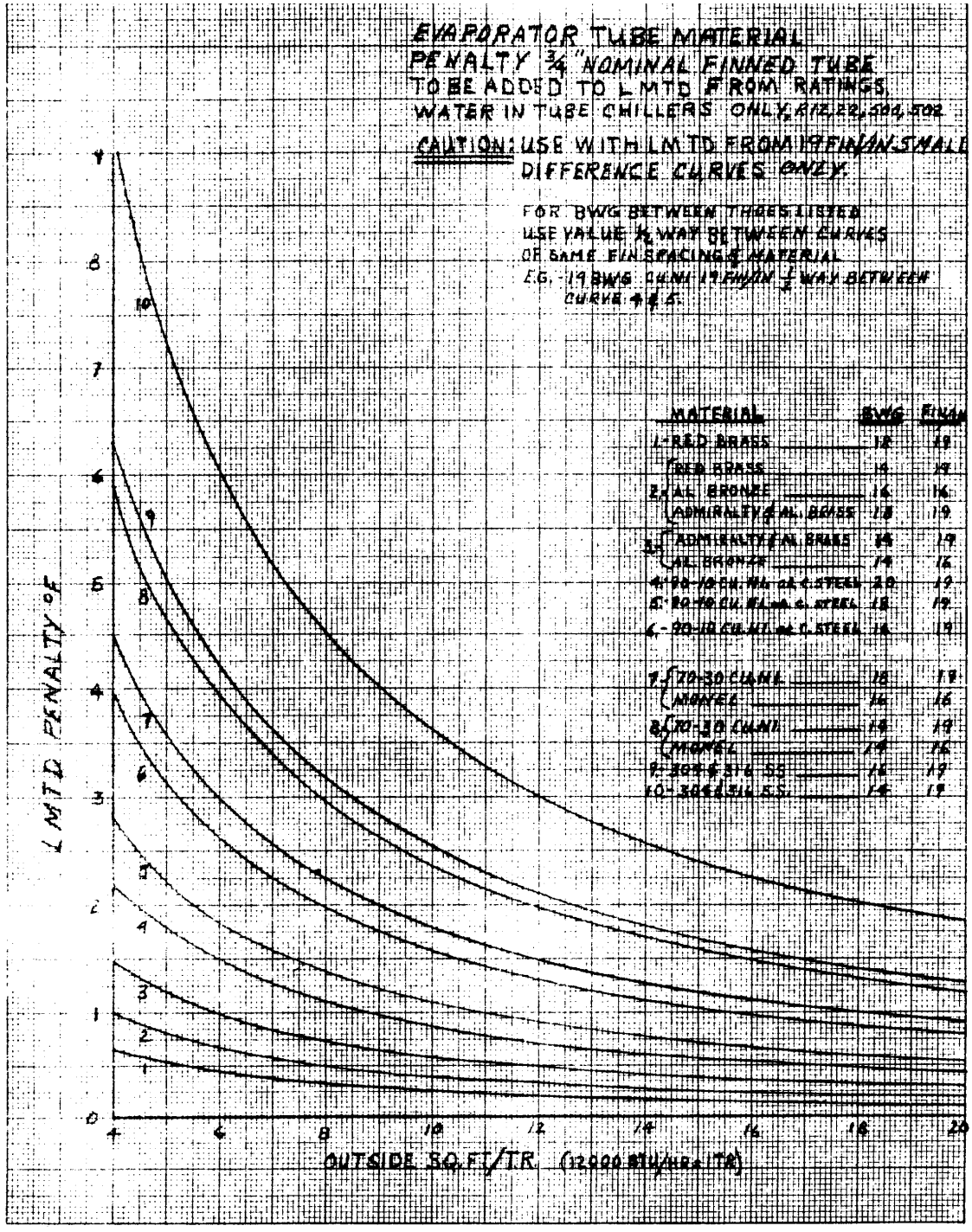

Figure 6-4 Tube Material Penalty Curves for Cooler

Cogitation:

Recap the specification and operating conditions given for the screw refrigeration unit as original design:

Capacity:	163 TR
Condensing temperature:	105°F
Evaporative temperature:	3°F
Refrigerant:	R-22
Screw Compressor:	
Discharge external P.D.	3.5 Psi
Suction external P.D.	0.6 Psi
Suction superheat:	7.5°F
Oil cooling:	Water cooled
Oil pump:	Pre-lube
Valves:	Standard
Condenser:	Shell-and-tube
Tubes:	Copper, ¾" OD, 19 FPI, 20 BWG
Fouling:	0.0005 Ft²-Hr-°F/Btu
Loading:	8 S.F./TR
Cooler:	Shell-and-tube, Flooded design
Tubes:	Copper, ¾" OD, 19 FPI, 20 BWG
Fouling:	0.0005 Ft²-Hr-°F/Btu
Loading:	10 S.F./TR
Power supply:	6000-3-50
Economizing:	DX Liquid subcooling
Port P.D.	4.5 Psi
Temperature approach:	10°F

Case-1
No changes, same as the original design.

From computer selection,

Compressor selected:	RWB-II-134E
Power Consumption:	301.8 BHP
Oil heat rejection:	271,200 Btu/Hr.

Heat rejection to condenser

= TR x 12000 + BHP x 2545 – Oil cooling

= 163 x 12000 + 301.8 x 2545 – 271200

= 2,506,881 Btu/Hr.

$$\text{Condensing Tr} = \frac{2,505,881}{15,000} = 167.13 \text{ cTR}$$

Original loading as design = 8 S.F./cTR

Therefore, condenser tube surface = 167.13 x 8

= 1337 Sq.Ft.

Case-2

Same as the original design, except the fouling factor is changed to 0.002 for both condenser and cooler.

From penalty curves:

Condenser fouling factor penalty	= 9.9 °F
Cooler fouling factor penalty	= 6.3°F

Condensing temperature change = 105 + 9.9 = 114.9°F

Evaporative temperature change = 3 – 6.3 = -3.3°F

From computer selection:

Compressor selected:	RWB-II-177E
Power Consumption:	384.5 BHP
Oil heat rejection:	451,600 Btu/Hr.

Heat rejection to condenser:

= TR x 12000 + BHP x 2545 – Oil cooling

= 163 x 12000 + 384.5 x 2545 – 451,600

= 2,482,953 Btu/Hr.

$$\text{Condensing Tr} = \frac{2,482,953}{15,000} = 165.53 \text{ cTR}$$

Check loading change:

$$S.F./cTR = \frac{1337}{165.53} = 8.08 \ S.F./cTR$$

Change is negligible, Ok.

Case-3

Same as the original design, except:

The fouling factor is changed to 0.002 for both condenser and cooler.
The tube material for condenser is changed to 18 BWG, 70/30 Cu.Ni.
(Assuming no effect on heat transfer by changing BWG)

From penalty curves:

Condenser fouling factor penalty	= 9.9 °F
Cooler fouling factor penalty	= 6.3°F
Condenser material penalty	= 2.8°F

Condensing temperature change = 105 + 9.9 + 2.8 = 117.7°F

Evaporative temperature change = 3 – 6.3 = -3.3°F

From computer selection:

Compressor selected:	RWB-II-177E
Power Consumption:	396.9 BHP
Oil heat rejection:	482,300 Btu/Hr.

Heat rejection to condenser:

= TR x 12000 + BHP x 2545 – Oil cooling

= 163 x 12000 + 396.9 x 2545 – 482,300

= 2,482,811 Btu/Hr.

$$\text{Condensing Tr} = \frac{2{,}482{,}811}{15{,}000} = 165.60 \text{ cTR}$$

Check loading change:

$$\text{S.F./cTR} = \frac{1337}{165.60} = 8.07 \text{ S.F./cTR}$$

Change is negligible, Ok.

Case-4

Same as the original design, except:

The fouling factor is changed to 0.003 for both condenser and cooler.
The tube material for condenser is changed to 16 BWG, 304 SS.
The tube material for the cooler is also changed to 16 BWG, 304 SS.
(Assuming no effect on heat transfer by changing BWG)

From penalty curves:

Condenser fouling factor penalty	= 16.4°F
Cooler fouling factor penalty	= 10.55°F
Condenser tube material penalty	= 4.0°F
Cooler tube material penalty	= 2.55°F

Condensing temperature change = 105 + 16.4 + 4 = 125.4°F

Evaporative temperature change = 3 – 10.55 – 2.55 = -10.1°F

From computer selection:

Compressor selected: RWB-II-222E
(**Warning: System pressure at breaking point**)
(**Condenser pressure 294.1 Psia**)

Power Consumption:	493.2 BHP
Oil heat rejection:	713,700 Btu/Hr.

Heat rejection to condenser:

= TR x 12000 + BHP x 2545 – Oil cooling

= 163 x 12000 + 493.2 x 2545 – 713,700

= 2,497,494 Btu/Hr.

$$\text{Condensing Tr} = \frac{2{,}497{,}494}{15{,}000} = 166.50 \text{ cTR}$$

Check loading change:

$$\text{S.F./cTR} = \frac{1337}{166.50} = 8.03 \text{ S.F./cTR}$$

Again, change is negligible, Ok.

Comparison:

Compressor Selected and the Power Consumption Comparison Data Sheet:

Case #	System Description	CT	ET	Compressor Model Selected	Power Consumption
Case-1	0.0005 FF 20 BWG Cu Tubes in condenser 20 BWG Cu Tubes in Cooler	105°F	3°F	RWB-II-134E	301.8 BHP
Case-2	0.002 FF 20 BWG Cu Tubes in condenser 20 BWG Cu Tubes in Cooler	114.9°F	-3.3°F	RWB-II-177E	384.5 BHP
Case-3	0.002 FF 18 BWG CuNi Tubes in condenser 20 BWG Cu Tubes in Cooler	117.7°F	-3.3°F	RWB-II-177E	396.9 BHP
Case-4	0.003 FF 16 BWG 304SS Tubes in condenser 16 BWG 304SS Tubes in Cooler **System pressure at breaking point**	125.4°F	-10.1°F	RWB-II-222E	493.2 BHP