Case – 5 Manual Selection of Water Cooled Condenser and Water Cooler

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Case Background:

This case is to demonstrate the use of manufacturer's standard design of shell-and-tube heat exchangers and the performance curves of the water cooled condenser and the water cooler.

1.0 Attached Figure 5-1 is the condenser performance curve for the model HC-176 condenser for R-22, the Figure 5-2 is the curves for fouling factor penalties and the Figure 5-3 is the water pressure drop. The condenser is to be used to suit the following operating conditions:

Reciprocating Compressor selected for the water chiller unit:

Evaporative Capacity:	1,488,000 Btu/Hr.
Refrigerant:	R-22
Evaporative Temperature:	35°F
Condensing Temperature:	109°F
Power Consumption at design:	144 BHP

Cooling Water for the condenser:

Inlet temperature:	90°F
Maximum outlet water temperature:	100°F
Fouling factor:	0.001
Maximum pressure drop:	10 ft.

HC-176 condenser is to be used.
The data for the HC-176 condenser:

External tube surface:	870 Sq.Ft.
Number of tubes:	180
Size of the condenser:	16"OD x 8'-0" NTL

Information is to be derived from the above conditions are:

(a) What pass-arrangement shall be used for the condenser.
(b) What is the cooling water GPM flow.

(c) Water is the pressure drop through condenser for the pass arrangement used.

2.0 Same as 1.0, what will be the condensing temperature if the unit is operating at partial load of 80%; the heat rejection drops to 1,480,000 Btu/Hr. instead of full load; the cooling water entering temperature drops to 85°F instead of 90°F original design.

3.0 The Figure 5-4 is the performance curve for the water cooler model C-2212. The data for C-2212 is as the following:

Size:	22"OD x 12'-0" NTL
Number of tubes:	150
Effective External Surface:	893 Sq.Ft.
Pass Arrangement:	2-P
Capacity:	123 TR
Chilled water return:	50°F
Chilled water supply:	42°F

The information is to be derived based on the data given above:

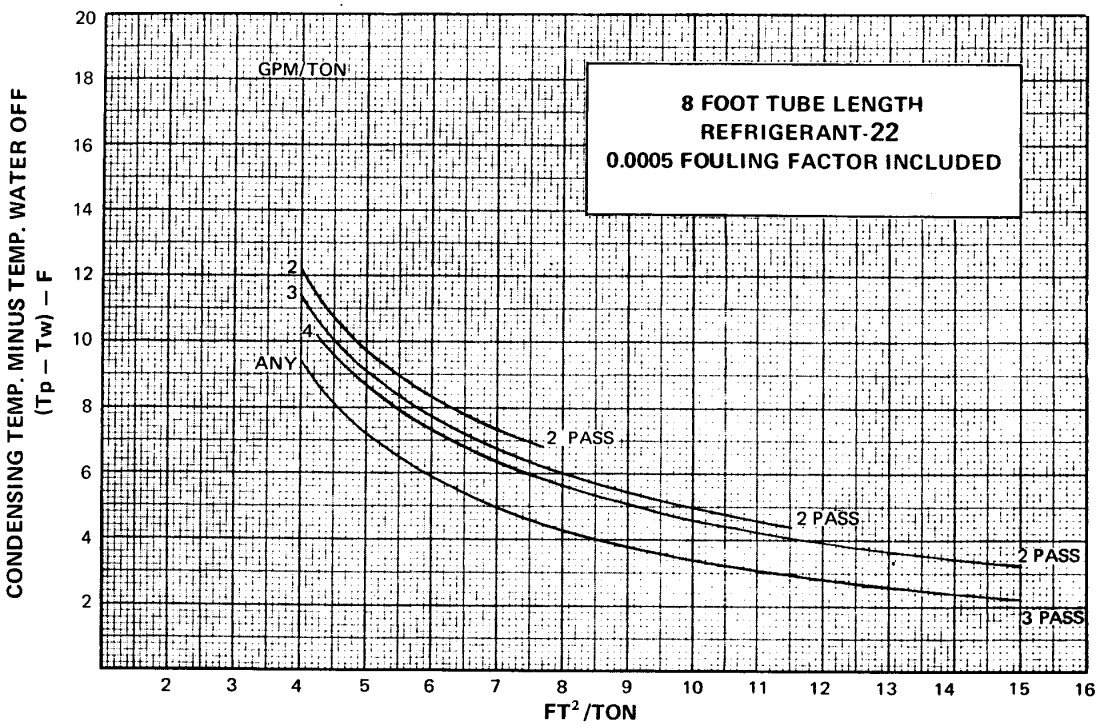
3.01 What is the evaporative temperature and chilled water flow for the water cooler?

3.02 After the cooler is installed, it is discovered that the cooling load was under estimated by 10%; what shall be the new evaporative temperature to maintain 42°F leaving chilled water temperature? Assuming the compressor provided is having the excess capacity to overcome this mistake.

Fill in the Data for the Summary Sheet:

1.0 Condenser Exercise	Pass Arrangement	
	Cooling Water Flow, GPM	
	Water Pressure Drop, Ft.	
2.0 Condenser at 80% Partial load operation	New Condensing Temperature, °F	
3.0 Water Cooler	Evaporative Temperature, °F	
	Chilled Water Flow, GPM	
	New Evaporative Temperature, °F	

Related Technical Data and Engineering Information:



Limitations:

Maximum tube water velocity:	12 ft/sec.
Minimum tube water velocity:	3.33 ft/sec
Minimum external tube surface:	4 ft^2 /TR

0.793 GPM/Tube/Pass = 1.0 ft/sec WV

Figure 5-1 Water Cooled Condenser Performance, R-22

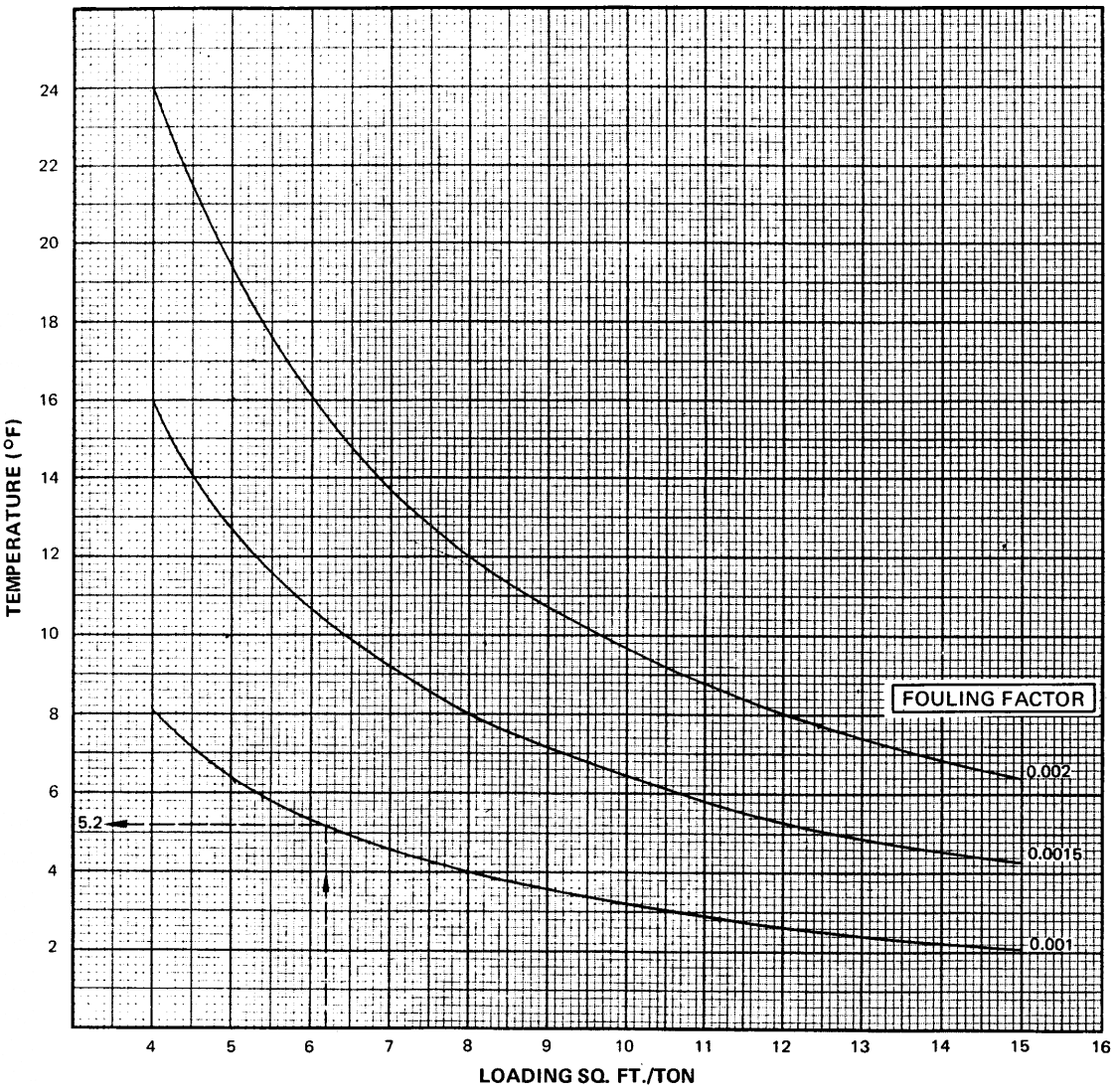


Figure 5-2 Condensing Temperature Penalty for Fouling Factor

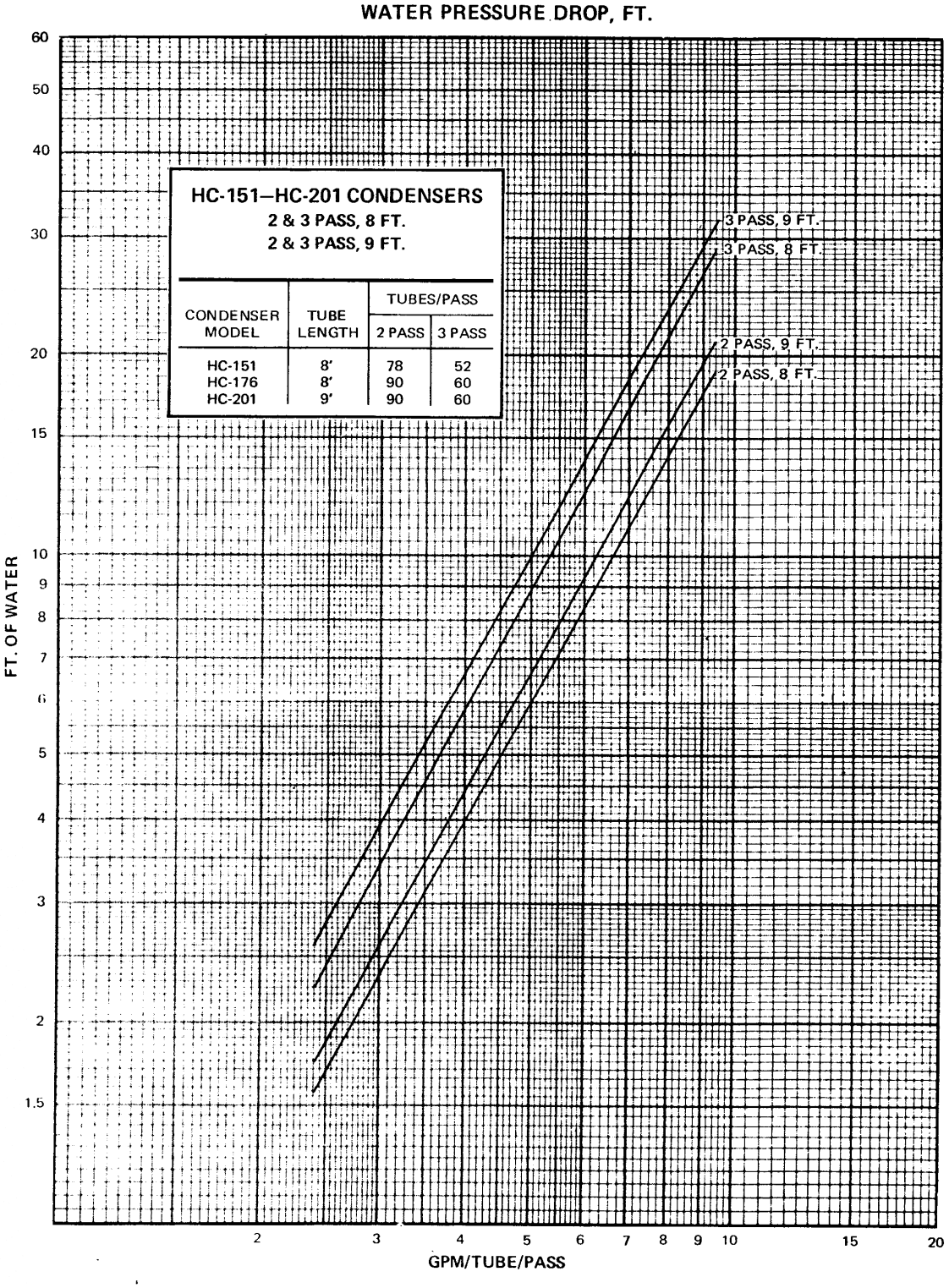


Figure 5-3 Water Pressure Drop for Condenser 8 Ft. NTL and 9 Ft. NTL

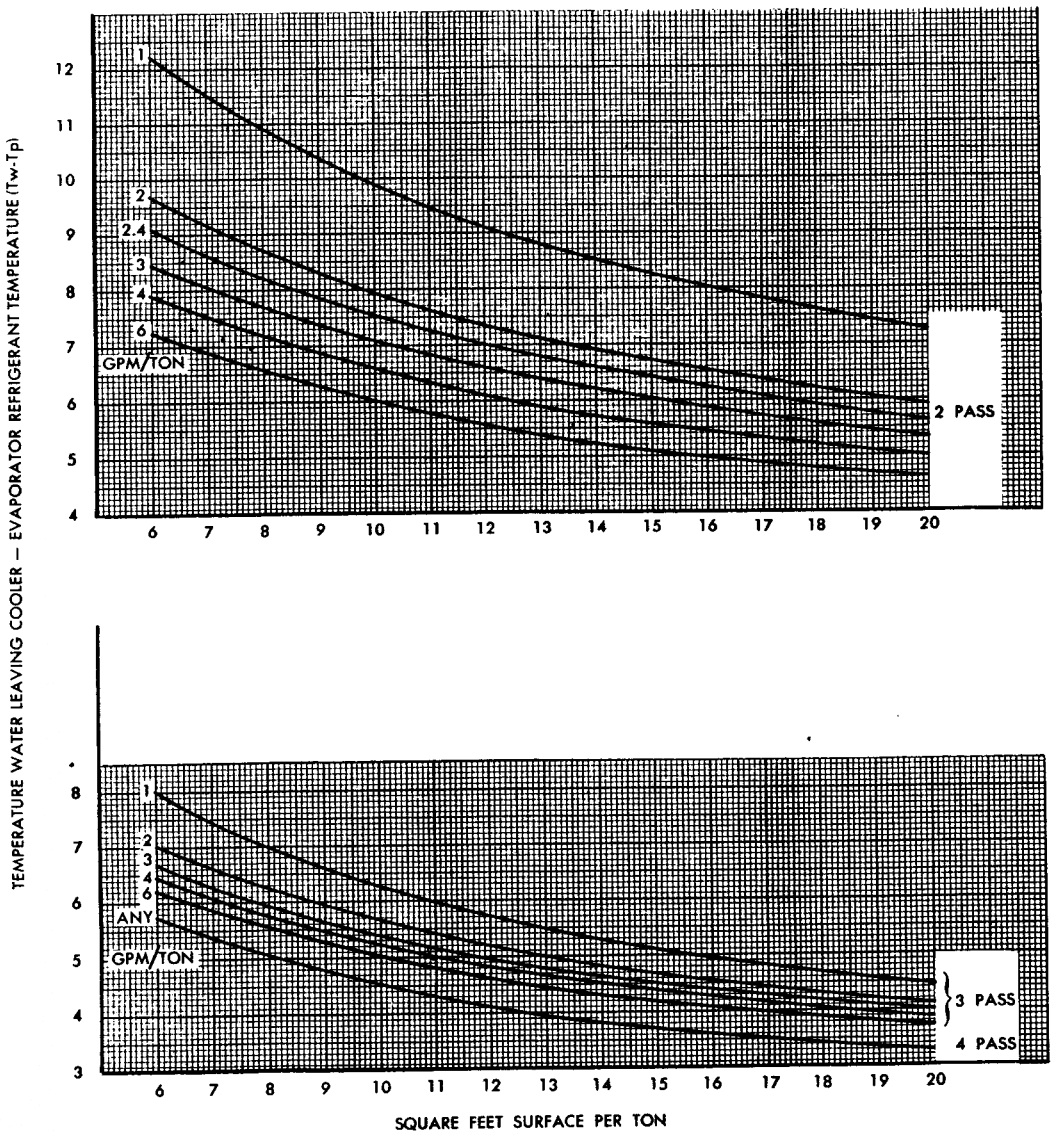


Figure 5-4 Shell-and-Tube Water Cooler Performance Curves

Cogitation

1.0 Case for the HC-176 Condenser:

Recap the specifications for the condenser:

Evaporative Capacity:	1,488,000 Btu/Hr.
Refrigerant:	R-22
Condensing Temperature:	109°F
Power Consumption at design:	144 BHP
Inlet cooling water temperature:	90°F
Maximum outlet water temperature:	100°F
Fouling factor:	0.001
Maximum pressure drop:	10 ft.

The data for the HC-176 condenser:

External tube surface:	870 Sq.Ft.
Number of tubes:	180

Heat rejection from the compressor at design load:

= 1,488,000 + 144 x 2545
= 1,854,480 Btu/Hr.

$$\text{Condensing Ton} = \frac{1{,}854{,}480}{14{,}545} = 127.5$$

$$\text{Sq.Ft./Ton} = \frac{870}{127.5} = 6.82$$

Try to use 3-Pass arrangement at any GPM/Ton water flow:

From the curves of Figure 5-1:
At Sq.Ft./Ton = 6.82 and 3-Pass at any GPM/Ton, $T_p - T_w = 5.1°F$

From the curves of Figure 5-2.
At Sq.Ft./Ton = 6.82 and Fouling 0.001, the penalty is 4.7°F

$T_p - T_w$	=	5.1°F
Fouling 0.001	=	4.7°F
$CT - T_2$	=	9.8°F

Maximum cooling water range is 10°F, maximum leaving cooling water temperature is 100°F for the condenser as specified.

Try water flow 3 GPM/Ton for the condenser.

Water flow = 3 GPM/Ton x 127.5 = 383 GPM

$$\text{Btu/Hr.} = 500 \times \text{GPM} \times Cp \times \text{S.G.} \times (T_2 - T_1)$$
$$= 500 \times \text{GPM} \times (T_2 - T_1)$$

$$T_2 = T_1 + \frac{\text{Btu/Hr.}}{500 \times \text{GPM}}$$

$$= 90 + \frac{1{,}854{,}480}{500 \times 383} = 90 + 9.68 = 99.68\ °F$$

$$CT - T_2 = 9.8°F$$

$$CT = T_2 + 9.8 = 99.68 + 9.8 = 109.48\ °F \quad > 109°F$$

The CT is too high because the compressor is selected for 109°F condensing temperature. Therefore, need to increase water flow to keep the CT below 109°F.

If CT is to be 109°F, the leaving cooling water temperature T_2 is to be:

$$T_2 = CT - 9.8°F = 109 - 9.8$$
$$= 99.2°F$$

$$\text{Btu/Hr.} = 500 \times \text{GPM} \times (T_2 - T_1)$$

$$1{,}854{,}480 = 500 \times \text{GPM} \times (99.2 - 90)$$

GPM = 403

Therefore, the cooling water flow is increased from 383 GPM to 403 GPM

$$\text{GPM/Tube/Pass} = \frac{\text{GPM} \times \text{Pass}}{\text{Tubes}}$$

$$= \frac{403 \times 3}{180} = 6.72$$

Check Tube Water Velocity (WV):

$$WV = \frac{6.72}{0.793} = 8.47 \text{ ft/sec.} \quad < 12 \text{ ft/sec, O.k.}$$

From Water Pressure Drop Curve:

Pd = 15.5 ft. (Over the 10 ft. maximum allowed. No good)

Try to use 2-Pass arrangement at 4 GPM/Ton water flow:

Water flow = 4 GPM/Ton x 127.5 = 510 GPM

Again, from the curves and use new input:

$T_p - T_w$ = 6.5°F
Fouling 0.001 = 4.7°F

$CT - T_2$ = 11.2°F

Btu/Hr. = 500 x GPM x $(T_2 - T_1)$

$$T_2 = T_1 + \frac{\text{Btu/Hr.}}{500 \times \text{GPM}}$$

$$= 90 + \frac{1{,}854{,}480}{500 \times 510} = 90 + 7.27 = 97.27 \text{ °F}$$

$CT - T_2$ = 11.2°F

$CT = T_2 + 11.2 = 97.27 + 11.2 = 108.47$°F (Below 109°F, Ok)

$$\text{GPM/Tube/Pass} = \frac{\text{GPM x Pass}}{\text{Tubes}}$$

$$= \frac{510 \times 2}{180} = 5.67$$

Check Tube Water Velocity (WV):

$$WV = \frac{5.67}{0.793} = 7.15 \text{ ft/sec.} \quad \text{O.k.}$$

From Water Pressure Drop Curve:

Pd = 7.45 ft. (Below 10 ft. maximum Pd allowed, Ok)

Therefore, the information established for the HC-176 condenser shall be:

(d)	Pass-arrangement of the condenser:	2-P arrangement.
(e)	Cooling water GPM flow:	510 GPM
(f)	Water pressure drop through condenser:	7.5 ft.

2.0 Same HC-176 condenser for partial load operation:

External surface:	870 ft²
Pass arrangement:	2- P
Cooling water flow:	510 GPM
Cooling water inlet temperature:	85°F
Partial load heat rejection:	1,480,000 Btu/Hr.

Heat rejection to the condenser
= 1,480,000 Btu/Hr.

$$\text{Condensing Ton} = \frac{1{,}480{,}000}{14{,}545} = 101.8$$

$$\text{Sq.Ft./Ton} = \frac{870}{101.8} = 8.55$$

From the curves of Figure 5-1 and Figure 5-2:

$T_p - T_w$ = 5.3°F
Fouling 0.001 = 3.8°F

$CT - T_2$ = 9.1°F

Btu/Hr. = 500 x GPM x ($T_2 - T_1$)

$$T_2 = T_1 + \frac{\text{Btu/Hr.}}{500 \times \text{GPM}}$$

$$= 85 + \frac{1{,}480{,}000}{500 \times 510}$$

$$= 85 + 5.80 = 90.80\ °F$$

$CT - T_2 = 9.1°F$

$CT = T_2 + 9.1$
$= 90.80 + 9.1 = 99.9°F$

The condensing temperature drops to 99.9°F from original 108.5°F.

3.0 The case of C-2212 water cooler:

Recap the specifications:

Size:	22”OD x 12’-0” NTL
Number of tubes:	150
Effective External Surface:	893 Sq.Ft.
Pass Arrangement:	2-P
Capacity:	123 TR
Chilled water return:	50°F
Chilled water supply:	42°F

3.01 To calculate the evaporative temperature:

Btu/Hr. = 500 x GPM x ($T_1 - T_2$)
T_1 = Chilled water return, 50°F.
T_2 = Chilled water leaving, 42°F

123 x 12000 = 500 x GPM x (50 – 42)

GPM = 369 gpm

GPM/TR = 369/123 = 3 GPM/TR

Sq.Ft./TR = 893/123 = 7.26 ft²/Tr

From the curve Figure 5-4: $T_w - T_p = 7.95°F$

$T_w - ET = 7.95°F$

$ET = T_w - 7.95°F = 42°F - 7.95°F$

$= 34.05°F$

3.02 If the cooling load is under estimated by 10%

$$\text{The new actual cooling load} = \frac{123}{0.9} = 136.7 \text{ TR}$$

GPM/TR = 369/136.7 = 2.7 GPM/TR

Sq.Ft./TR = 893/136.7 = 6.53 ft²/Tr

From the curve Figure 5-4: $T_w - T_p = 8.52°F$

$T_w - ET = 8.52°F$

$ET = T_w - 8.52°F = 42°F - 8.52°F$

$= 33.48°F$

The ET required for the new actual load shall be 33.48°F instead of 34.05°F.

Fill in the Data for the Summary Sheet:

1.0 Condenser Exercise	Pass Arrangement	2-P
	Cooling Water Flow, GPM	510 GPM
	Water Pressure Drop, Ft.	7.5 Ft. (Max. 10 Ft Specified)
2.0 Condenser at 80% Partial load operation	New Condensing Temperature, °F	99.9°F
3.0 Water Cooler	Evaporative Temperature, °F	34.05°F
	Chilled Water Flow, GPM	369 GPM
	New Evaporative Temperature, °F	33.48°F