C-2278

STP 3053 (10/91)
OEP-3.070

SOUTH TEXAS PROJECT ELECTRIC GENERATING STATION
HOUSTON LIGHTING & POWER COMPANY

CALCULATION COVER SHEET

CALC NO.	MC-6406
PRELIM.	
FINAL	XXXX
VOID	

BUILDING/AREA/SYSTEMS: /CH

UNIT: 1&2

SUBJECT: Essential Chiller Performance Test

DISCIPLINE: MECHANICAL

QUALITY CLASS: 3

OBJECTIVE

See Section 1.0 Purpose

MC-06406- 0
STA-999 11/02/93 001/001
LBL 001/002
NO OPEN AMENDMENTS
FOR THIS DOCUMENT

INFORMATION ONLY

SCOPE

See Section 2.0 Scope

SUMMARY OF RESULTS

See Section 3.0, Summary Of Results

CHRISTOPHER A. DAVENPORT
63503

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TOTAL NO. OF SHEETS

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ATTACHMENTS

Attachment A
Copies of References 4, 5, 19, and 20
Total of 19 Pages

1.PURPOSE

The purpose of this calculation is to determine the acceptance criteria for the Essential Chiller Performance test for 300 ton and 150 ton essential chillers in both STP Units 1 and 2. It also establishes the ~~the~~ margin for plugging the condenser tubes.

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2. SCOPE

This calculation covers both 150 ton and 300 ton machines. The essential chiller performance test should be performed with the hot gas bypass valve closed. This will provide better calculational heat balance between the condenser heat load and evaporator load and compressor power input.

3. SUMMARY OF RESULTS

The calculated U values for the 300 ton and 150 Ton should be greater than 40 Btu/hr ft^2 °F. These values are absolute minimum values and are at the design conditions with the condenser and evaporator tubes fouled up to the design values of 0.002 and 0.0005 hr ft^2 °F/Btu. Normally, the calculated values will be greater than 93 and 73 Btu/hr ft^2 °F for 300 ton and 150 ton respectively, demonstrating a clean condenser and evaporator. As discussed in the calculation the fouling of evaporator is not expected to cause any problems due to controlled water chemistry. The overall heat transfer lower than the normal range should be evaluated for the chiller performance. The lower values may show either a fouled condenser or presence of noncondensables in the condenser.

These values do provide trending for the performance of the chiller condenser. The plugging of condenser tubes is assumed to be 3% and this number can be increased in the future by reducing the water side design fouling factor of the condenser and maintaining the condenser tubes in clean condition.

4. REFERENCES

1.ASHRAE Handbook, 1989 Fundamentals, Inch-Pound Edition
American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
Atlanta, Ga

2. Performance Test Report for 300 ton chiller, 4310-00166-AYD
STPS-36, Performance, Sound and Vibration Test Report for Model OTK5C1-IMCS
Refrigerant 11 Essential Water Chiller

3. Essential Cooling Pond Thermal Performance Analysis , 0400-00012-BNU
(NUS-4325 Revision 1)

4. Wolverine Tube, Inc. Decatur, Alabama
Type S/T Trufin Titanium Finned Tube - 32 FPI
(Attached to this Calculation)

5. Wolverine Tube Inc., Decatur, Alabama
Type S/T Trufin Copper and Copper Alloy Finned Tube 26 & 40 FPI
(Attached to this calculation)

6. Principles of Heat Transfer, Frank Kreith, 3 rd Edition
Intext Educational Publishers, New York, N. Y.

7. Vendor Manual 4310-00180 - YD Revision D
Installation, operation & Maintenance Instructions for York Model OTK5C1 - IMCS
Open Turbopak Centrifugal Liquid Chilling Units

8.Vendor Manual 4102 - 01033 BY Submittal G
Installation, Operation & Maintenance Instructions for York Model HTH4B1-BBCS R-11
Hermatic Turbopak Centrifugal Liquid Chilling Units
Including ECN 90-J-0008-C

9. Bistable Instrument Analog Scaling Data, A1CH-PSH-9474, Revision 0

10. ASHRAE Handbook, 1988 Equipment
American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
Atlanta, Ga

11 Bistable Instrument Analog Scaling Data, B1CH-PSH-9484, Revision 0

12. Bistable Instrument Analog Scaling Data, C1CH-PSH-9494, Revision 1

13. Bistable Instrument Analog Scaling Data, A1CH-PSH-9504, Revision 0

14. Design Basis Document 5V369VB0120 Revision 0
Essential Chilled Water System

15. Standards of the Tubular Exchanger Manufacturers Association, Seventh Edition 1988

16. Bistable Instrument Analog Scaling Data, B1CH-PSH-9510, Revision 0

17. Bistable Instrument Analog Scaling Data, C1CH-PSH-9516, Revision 1

18. York Letter ST-BY-YB-0005 Dated November 5, 1982
Subject: Technical Evaluation Report for the STP Nuclear Safety and Non-Safety Related Water Chillers
(Vendor Document 4101-00001-ABJ)

19. Code CMTR for condenser tubes (Attached to this calculation)

20. York Letter ST-BY-YB-0044 Dated August 30, 1984
Letter from F. C. Bahr (York) to Project Engineering Manager
Subject: Safety Class Water Chillers
(Attached to this calculation)

21. ASHRAE Standard 22-1992
Methods of Testing for Rating Water-Cooled Refrigerant Condensers

5. ASSUMPTIONS

1. In evaluating the performance of the chiller condensers, the effect of desuperheating of refrigerant vapor and subcooling of the refrigerant liquid is not considered. The justification for this is as follows:

a. As per Reference 1 (Chapter 4 Page 4.9) When the superheated vapor is condensed, the heat transfer coefficient depends upon the surface temperature. If the surface temperature is below saturation temperature, little error is made if the value of h for condensation of saturation vapor is used with the difference between the saturation temperature and the surface temperature.

b. The amount of condensate subcooling provided by the condensing surface in a shell and tube condenser is small, generally in the range of 2 °F. The York chillers do not have any additional submerged tubes to provide subcooling. Any subcooling is obtained by the normal gravity drainage of the condensed refrigerant. The condensed refrigerant drains to a float chamber which controls the flow of refrigerant to the system.

6. METHODOLOGY

This section provides general discussion and methodology for evaluating the performance of the chiller:

DISCUSSION

A field test of the essential chillers at STP is more difficult than might be expected because the chillers are designed to operate at higher ECW temperatures than normal, and because the actual heat load in the essential chilled water system is significantly less than the 300 ton chiller capacity. Demonstrating the capability to meet the design basis conditions requires the test criteria be independent of the load and inlet water conditions, or the results be adjustable to design basis conditions.

The 3 major components of each essential chiller are:

1. Compressor
2. Condenser
3. Evaporator

The chiller performance could be affected by degradation of any of these components. Degradation of either of the heat exchangers would be caused by fouling of the heat exchangers either inside of the tubes or the outside of the tubes.

The fouling of the evaporator is not considered a credible occurrence because the chilled water inside the tubes is treated demineralized water, and because small amounts of oil would not significantly change the boiling heat transfer coefficients.

Fouling inside the condenser tubes is possible because ECW water is relatively high in dissolved solids and the water is heated as it passes through the condenser, which decreases the solubility of calcium carbonate. Chemical dispersants are added to the Essential Cooling Pond to minimize the amount of scale buildup. This has been effective to date, but scale buildup over a long time period is still considered possible. In addition a small amount of oil contamination of the tube outside surface would have a disproportional affect on the condensing heat transfer surface by affecting the surface tension of the R-11 to tube surface. Lastly the presence of a small amount of non-condensable gas can significantly decrease the condensing heat transfer coefficient in the condenser.

For the above reasons, the most likely cause of performance degradation of an essential chiller is decreased heat transfer in the condensing section of the chiller.

High condenser pressure could limit chiller capacity through several possible avenues. First and most immediately, condenser pressures above a nominal 30 psig (or 26 psig considering instrument tolerance) will trip the chiller. Secondly, higher condenser pressure could cause reduced compressor flow. This would reduce the capacity of the chiller and result in an increase in leaving water temperature

The chillers are complex machines that have purge systems to vent the noncondensables from the condenser. The purge systems should be functioning properly. Any malfunctioning of the purge unit should be detected during the plant system walkdown. Hence it is concluded that the high pressure developed in the chiller condenser will be due to high ECP temperature.

As per Reference 14 (Section 4.0) the chiller condensers are designed for tube side (ECP water side) fouling factor of 0.002 and for the evaporator side fouling factor of 0.0005.

The fouling factor is a thermal resistance referenced to the waterside area of the heat-transfer surface. Thus, the temperature penalty imposed on the condenser surface is equal to the heat flux at the waterside area, multiplied by the fouling factor. Increased fouling increases the overall heat transfer resistance. Fouling increases the temperature difference required to obtain the same capacity- with a corresponding increase in condenser pressure and system power- or lowers system capacity. As the system is designed for high fouling factor of 0.002, the condenser has additional very large surface area available to meet the design conditions. During normal plant operations and at lower condenser water (ECP Temperature) the condenser will operate at lower condensing temperature and corresponding saturation pressure. As per Reference 10 (page 15.3) under the worst case scenario the surface area required doubles with a fouling factor of 0.00049 as compared with that with no fouling case allowance. Under normal circumstances a fouling factor of 0.00072 doubles the required surface area compared with that with no fouling allowance. Water velocities above 3 fps are recommended to minimize the fouling. (Reference 10 page 15.4)

CALCULATION OF OVERALL HEAT TRANSFER FROM TEST

The performance of the chiller can be monitored by determining the overall heat transfer coefficient of the condenser. The overall heat transfer coefficient can be determined by measuring the condenser pressure, entering condenser water temperature, leaving condenser water temperature and condenser cooling water flow. The equations for determining the overall heat transfer coefficient are provided below (Reference 6, page 563):

$Q = E\,C_{min}\,(T_S - T_1)$

Q = Condenser heat Load, Btu/Hr

E = Thermal effectiveness, dimensionless

C_{min} = Product of mass and specific heat lesser of the two fluids
With condensation this will always be the water flow of ECW side
Btu/ hr °F

C_{min} can be calculated from the ECW condenser water flow. The specific heat of the water for the temperature range is 1.0. The condenser water mass flow rate in lbs/hr can be calculated from the known or measured flow in GPM multiplied by conversion factor of 500.

C_{min} = Condenser water flow rate (GPM) x 500 x 1.0 , Btu/hr °F

The thermal effectiveness is given by

$E = (T_2 - T_1)/(T_s - T_1)$

T_s = Saturation temperature of R-11, °F

T_1 = ECW Inlet Temperature, °F

T_2 = ECW leaving Temperature, °F

The thermal effectiveness for condensing of refrigerant vapor is defined as:

$E = 1 - e^{-NTU}$

Where NTU is defined as number of heat transfer units and defined as

$NTU = UA/ C_{min}$

where

U = Overall heat transfer coefficient, Btu/hr ft^2 °F

A = Condenser heat transfer surface area, ft^2

The condenser heat transfer surface area is known for the condenser and is determined by the condenser tube geometry and available from the vendor drawings.

Substituting the above NTU equation in the thermal effectiveness equation and rearranging for U, following equation is obtained:

$U = - C_{min} \ln(1 - E)/ A$

Hence from the known condenser pressure and its corresponding saturation temperature, measured inlet and outlet condenser water temperature, and condenser water flow, the value of U, overall heat transfer coefficient, can be calculated.

Heat Balance

The condenser heat load is determined from the ECW water flow rate and ECW inlet and outlet temperature through the condenser. The condenser heat load based on the flow and temperature is:

Q = Condenser water flow rate (GPM) x 500 x (T_2-T_1)

The evaporator load can be determined from the known chilled water flow through the chiller evaporator and entering and leaving chilled water temperature. The evaporator load is calculated as:

Q_{evp} = Chilled water flow rate (GPM) x 500 x $(T_{Ent}-T_{Lvg})$

Where

T_{Ent} = Entering Chilled Water Temperature, °F

T_{Lvg} = Leaving Chilled Water Temperature, °F

The electrical energy input to the compressor can be measured. For open motor chiller machine (300 Ton Chiller) the electrical energy to the compressor will require motor efficiency correction to account for the motor losses to the ambient air. For hermatic motors (150 Ton Chiller), no efficiency correction is required as all the heat goes into refrigerant. The motor efficiency for 300 ton chiller can be obtained from Reference 7. The motor efficiency for hermatic machine is 1.0.

The heat balance check is calculated as follows:

Heat balance check = $(1 - (Q_{evp}$ + kw (Input) x Motor Efficiency)/Q) x 100

The above equation assumes that the hot gas bypass valve is closed.

As per Reference 21, the heat balance should be within +/- 3%.

CALCULATION OF OVERALL HEAT TRANSFER COEFFICIENT

The overall heat transfer coefficient equation is given as (Reference 15 Page 103):

$$(1/U_0) = 1/(h_0 E_f) + r_o/E_f + r_w + r_i (A_0/A_i) + (1/h_i) (A_0/A_i)$$

U_0 = Overall heat transfer coefficient , based on the external surface and the mean temperature difference between the external and internal fluids, Btu/hr ft^2 °F

h_0 = Outside or refrigerant side coefficient, Btu/hr ft^2 °F

(A_0/A_i)= Ratio of external to internal surface area of tube, dimensionless

h_i = Internal or water-side film coefficient, Btu/hr ft^2 °F

r_i = fouling resistance water side, ft^2 hr °F/ Btu

E_f = Weighted fin efficiency, dimensionless

r_o = fouling resistance refrigerant side, ft^2 hr °F/ Btu

r_w = finned wall metal thermal resistance,ft^2 hr °F/ Btu

The outside heat transfer coefficient for condensing refrigerant is given as (Reference 1 page 4.8):

$$h_0 = 0.689\ F1\ (h_{fg}/ dt\ \ D_e)^{0.25}$$

where

F1 = Condensing coefficient factor for R-11

h_{fg} = latent heat of condensation, Btu/lb

dt = temperature difference, °F

D_e = equivalent diameter, ft

The equivalent diameter is determined from the following relationship:(Reference 1 page 4.8)

$$1/(D_e)^{0.25} = 1.30\ (A_s\ E_f)/(A_{ef}\ (L_{mf}\ )^{0.25}\ ) + A_p/\ (A_{ef}\ (D)^{0.25})$$

where

$$A_{ef} = A_{so} + A_p$$
$$L_{mf} = a_f/\ D_o$$

Where

As = Finned area, ft^2

E_f = Fin efficiency, dimensionless

A_p = Unfinned area or prime area, ft^2

L_{mf} = Mean fin height, inches

a_f = Area of one fin, in^2

D_o = Outside diameter of the tube, inches

D = Root diameter of the tube, inches

The inside heat transfer coefficient for water at ordinary temperatures, 40 °F to 200 °F is given by (Reference 1, Table 6 Page 3.14):

$$h_i = 150\ (1+0.011\ twm)\ V^{0.8} / d^{0.2}$$

twm = mean water temperature, °F

V = water velocity, feet per second

d = tube inside diameter, inches

The fin efficiency is calculated from Figure 12 of Reference 1 page 3.16.

The metal thermal resistance is given by (Reference 15 page 104)

$$r_w = (t/(12\ k))\ (\ (d + 2\ N\ w\ (d+w))/(d-t))$$

Where

t = thickness of tube wall, ft

k = Thermal conductivity of tube material, Btu/hr ft °F

d = outside tube diameter or root diameter, inches

N = number of fins per inch

w = fin height, inches

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GENERAL COMPUTATION SHEET

SUBJECT Essential Chiller Performance Test UNIT/S 1 &2

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Following steps are used in determining the overall heat transfer coefficient , and establishing the instrumentation calibration and condenser tube plugging requirements:

1. Determine the worst case overall heat transfer coefficient from the maximum condenser pressure and corresponding saturation temperature with the maximum ECW entering water temperature and design basis load with the consideration of the design fouling factors. Calculate the design basis load from the known chiller capacity(evaporator cooling load) and compressor heat input

2. From the factory performance test results of the chiller, calculate the overall heat transfer coefficient . The test results already account for the effect of fouling by increasing the inlet ECW temperature from the normal design temperature.

3. Calculate the overall heat transfer coefficient from the known theoretical equations. This is determined by calculating the refrigerant side heat transfer coefficient and water side heat transfer coefficient.

4. Evaluate the impact of condensing refrigerant coefficient due to part load and inside heat transfer coefficient due to change in water temperature on the overall heat transfer coefficient

5. Establish the instrumentation calibration requirements.

6. Establish the plugging of the condenser tubes.

7. Input Data, Calculations and Results

1. Calculation of Overall Heat Transfer Coefficient, Factory Test Evaluation, and Theoretical Overall Heat Transfer Coefficient Calculation for 300 Ton Chiller

Properties Of 300 Ton chiller Condenser

Condenser Tubes (References 4, and 7 Attachment 21, 22, 23, 24)

Total Number of Tubes = 800

Wolverine Model 70-325035

Average outside surface area = 0.503 ft^2 /ft

Surface area ratio (outside/inside) = 3.14

Internal cross sectional area = 0.294 in^2

outside diameter = 0.75 in

wall thickness = 0.035 in

Root diameter = 0.675 in

Minimum wall thickness = 0.031 in

Material Titanium

Number of fins 32

Inside diameter = 0.612 in

Fin width = 0.010 inch

Fin height = 0.030 inch

Overall outside heat transfer area = 5546.4 ft^2

(The overall outside heat transfer surface area is calculated as 800 tubes x 0.503 x 13.78 feet tube length. The condenser tube length is 171.375 inch(Reference 19). The heat transfer length is assumed to be same as 150 ton chiller to account for the tube supports.)

A. Minimum Overall Heat Transfer Coefficient for 300 Ton Machine

The minimum overall heat transfer coefficient required to operate the chiller at design basis conditions is determined from the known design conditions. The overall heat transfer coefficient as calculated as follows:

$U = Q / (A\ dtm)$

Where

U = Overall heat transfer coefficient, Btu/hr ft^2 °F

Q = Total heat load, Btu/hr

A = Condenser surface area, ft^2

dtm = Log mean temperature difference, °F

As per reference 3, the maximum ECW temperature is 105.2 to 105.7 °F based on the spent fuel assemblies stored. For the calculation purposes a value of 106 °F is used. This is conservative for the analysis. In reality the peak ECW temperature would be reached several days after the accident initiation while the peak chiller load would occur in first few hours of the accident.

As per reference 7 (Section 5, Table 1, Page 186 or page 21, Form 160.44-01), the condenser high pressure cutout is set at 30 psig and high compressor discharge temperature is 220 °F.

As per References 13, 16, and 17 the required compressor trip setpoint on high condenser pressure is 30 psig and reset point is 24 psig. The tolerance for this trip and reset points is +/- 2 .012 psig. For the calculation purposes the maximum reset value of 26 psig is used. The saturation temperature at 26 psig or 40.7 psia is 132.7 °F (From Ref 1, Chapter 17.3 Refrigerant Tables For R - 11).

Total load on the condenser is the sum of design basis load 300 tons plus the heat input from the compressor. The 300 ton machine is an open machine, hence the heat input to the condenser is the power input to the compressor multiplied by the electrical efficiency of the compressor motor. From reference 20, the compressor power requirement is 354 kw. The motor efficiency is 94.6%.(Reference 7, page 130)

Heat load = 300 tons x 12,000 Btu/hr/ton + 354 kw x 0.946 x 3413 Btu/hr/kw

$= 3.6 \times 10^6 + 1.143 \times 10^6$ Btu/hr

$= 4.743 \times 10^6$ Btu/hr

Condenser surface area = 5546.4 ft^2

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Mass flow of ECW water = 1100 GPM x (60 min/hr) (1/0.01619) (1/7.48)

= 544,998 lb/hr

ECW temperature rise = Q/ (mass x specific heat)

= 4.743×10^6 / (544,998 x 0.999)

= 8.71 °F

Leaving water temperature= 106 + 8.71 = 114.71 °F

Lmtd = (T2 - T1) / (ln (Ts-T1)/(Ts-T2))

Lmtd = (8.71)/(ln ((132.7-106)/(132.7-114.71))

= 22.06 °F

U = (4.743×10^6)/(5546.4 x 22.06)

U = 38.77 Btu/hr ft^2 °F

This is the minimum value of the overall heat transfer coefficient at the design conditions. If the U is greater than or equal to the above calculated value the chiller is capable of performing its design function.

Justification for use of Discharge Pressure vs Temperature

The chiller also trips on high condenser temperature, however it is anticipated that pressure trip either will occur earlier than temperature trip or simultaneously with the temperature trip. Performance test result for the 300 Ton chiller (Reference 2) are used in demonstrating this.

From the test:

Condenser discharge pressure	= 19.5 psig + 14.7 = 34.2 psia
Compressor discharge temperature	= 183.84 °F Use 184 °F
Compressor suction temperature	= 41.72 °F
Saturated pressure @ 41.72 °F	= 7.35 psia
Pressure ratio	= 34.2/7.35 = 4.65
Discharge temperature	= $T_1 (P_2 /P_1)^{(k-1)/k}$

k = 1.13

Saturated Discharge Temperature = $(460+41.72)\ (4.65)^{0.115}$

= 598.7 °R

= 138.7 °F

Compressor efficiency Ratio = (598.7 - 501.72)/(184-41.72)

= 0.68

At discharge pressure of 26 psig or 40.7 psia, the pressure ratio is (40.7/7.35) = 5.53

Calculating the discharge temperature using the suction temperature of 41.72 °F and pressure of 7.35 psia as

Saturated temperature = $501.72\ (5.53)^{0.115}$

= 610.7 °R

Difference = 610.7 - 501.72 = 109. °F

Compressor Discharge temperature = 41.72 + (109.0/ 0.68)

= 202.0 °F

Hence the pressure trip will be reached prior to the temperature limit.

B. Evaluation of Factory Performance Test 300 Ton Chiller

Reference 2 documents the performance test of the 300 ton chiller. The test accounted for the evaporator and condenser side fouling factors by adjusting the chilled water and condenser water temperatures in accordance with ARI standards 450 and 480-74.

The test data shows that the compressor discharge is superheated and the liquid is subcooled. As per page 8 of Reference 2 the compressor discharge temperature is 183.84 °F and the condenser temperature is 122.3 °F and the liquid discharge temperature is 118.9 °F. Hence the condenser provides for desuperheating and subcooling of the refrigerant. As explained in Section 5, Assumptions, the overall heat transfer coefficient is calculated using the saturated conditions in the condenser. The surface area required for desuperheating and subcooling of refrigerant is in the same proportion to the desuperheating and subcooling load and thus would not impact the overall heat transfer coefficient.

Condenser pressure = 19.5 psig + 14.7 = 34.2 psia

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Saturation temperature = 121.76 °F

Measured condenser temperature = 122.3 °F

Entering condenser water temperature = 111.67 °F

Leaving condenser water temperature = 120.25 °F

Condenser surface area = 5546.4 ft^2

Condenser heat rejection = 4.715×10^6 Btu/hr

Log mean temperature difference based on saturation temperature

Lmtd = 8.58/(ln ((121.76-111.67)/(121.76-120.25))

= 4.51 °F

Log mean temperature difference based on the measured condenser temperature

Lmtd = 8.58/(ln ((122.3-111.67)/(122.3-120.25))

= 5.21 °F

Calculating the Log mean temperature difference based on the average temperature of condenser saturation pressure and the measured condenser temperature.

Average condenser temperature = (121.76 + 122.3)/2 = 122.03 °F

Lmtd = 8.58/(ln ((122.03-111.67)/(122.03-120.25))

= 4.87 °F

Overall heat transfer coefficient based on the saturation temperature

U = (4.715×10^6) / (5546.4 x 4.51)

= 188.5 Btu/hr ft^2 °F

Overall heat transfer coefficient based on the averaged condenser temperature

U = (4.715×10^6) / (5546.4 x 4.87)

= 174.6 Btu/hr ft^2 °F

Overall heat transfer coefficient based on the measured condenser temperature

U = $(4.715 \times 10^6) / (5546.4 \times 5.21)$

= 163.17 Btu/hr ft^2 °F

C. Calculation of the Overall Heat Transfer Coefficient using Equations

Metal Thermal Resistance

The metal thermal resistance is given by (Reference 15 page 104)

$r_w = (t/(12\ k))\ (\ (d + 2\ N\ w\ (d+w))/(d-t))$

Where

t = thickness of tube wall, 0.035 inch

k = Thermal conductivity of tube material, Titanium 12.35Btu/hr ft °F

d = outside tube diameter or root diameter, 0.675 inches

N = 32 number of fins per inch

w = fin height, 0.030 inches

$r_w = (0.035/(12 \times 12.35))\ (\ (0.675 + 2 \times 32 \times 0.030\ (0.675+0.030))/(0.675-0.035))$

= 0.0007486

Calculation of inside heat transfer coefficient

$h_i = 150\ (1+0.011\ twm)\ V^{0.8} / d^{0.2}$

twm = (106 + 114.71)/2 = 110.35 °F

d = 0.612 inches

Water velocity = 1100 gpm/ (200 tubes per pass x 7.48 x 60 x 0.294 / 144)

= 6.0 feet per second

h_i = $150\ (1+0.011 \times 110.35)\ (6)^{0.8} / (0.612)^{0.2}$

= 1536.0

Outside Heat Transfer Coefficient Calculation

The outside heat transfer coefficient for condensing refrigerant is given as

$$h_0 = 0.689 \, F1 \, (h_{fg} / (dt \; De))^{0.25}$$

where

F1 = Condensing coefficient factor for R-11

= 151 (From Reference 1 page 4.9 Table 4)

h_{fg} = latent heat of condensation, Btu/lb

dt = temperature difference, °F

De = equivalent diameter, ft

The temperature difference is determined from the following relationship based on the resistances being proportional to total heat transfer

$$dt = Q / (ho \; Ao \; Ef)$$

Substituting the dt from the above equation in the ho equation and rearranging, following equation is obtained:

$$ho = (0.689 \times F1)^{4/3} \; (hfg \; Ao \; Ef/Q)^{1/3} \; (1/De)^{1/3}$$

De = 0.1839 inch = 0.0153 feet

hfg = 72.69 Btu/lb

Ao = 5546.4 ft^2

Ef = 0.73

Q = 4.743×10^6 Btu/hr

ho = 779.7 Btu/hr ft^2 °F

Overall Heat Transfer Calculation

For clean condenser inside fouling factor 0.00025 and outside fouling factor 0.00025 (Reference 2), the overall heat transfer coefficient is calculated as:

$$(1/U_0) = 1/(h_0 \, E_f) + ro/E_f + r_w + r_i \, (A_0/A_i) + (1/h_i) \, (A_0/A_i)$$

$(1/U_0) = 1/(779.7 \times 0.73) + 0.00025/0.73 + 0.0007486 + 0.00025 \times 3.1$
$+3.14/1536$

$= 0.001756 + 0.0003424 + 0.0007486 + 0.000785 + 0.002044$

$= 0.005677$

$U_o = 176.14$ Btu/hr ft^2 °F (For clean Condenser)

For a fouled condenser with 0.002 fouling factor the overall heat transfer coefficient is calculated as:

$(1/U_d) = 0.001756 + 0.0003424 + 0.0007486 + 0.002 \times 3.14 + 0.00204$

$= 0.01117$

$U_d = 89.50$ Btu/hr ft^2 °F

This value is much higher than calculated from the worst case.

Fin Efficiency Calculation

The fin efficiency is calculated from Figure 12 as per Reference 1 page 3.16, the value of ho is assumed as 850

$x_e/x_b = 0.75/0.675 = 1.11$

$w\,(h/k\,y)^{1/2} = (0.030/12)\,(800/(11.5 \times (0.010/2 \times 12))^{1/2}$

$= 1.021$

From the graph fin efficiency is 0.73

The calculated value of ho is 779 vs 800 assumed for fin efficiency calculation. The calculated value is close to the assumed value, hence no iteration of efficiency and ho calculation is performed.

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Calculation of Equivalent Diameter for 300 Ton Machine

The fin surface area, tube primary surface area , effective area is calculated based on one foot length of the tube. The equivalent diameter is calculated from the following equation (Reference 1, page 4.8):

$$1/(D_e)^{0.25} = 1.30\,(A_s\,Ef)/(A_{ef}\,(L_{mf})^{0.25}) + A_p/\,(A_{ef}\,(D)^{0.25})$$

where

$A_{ef} = A_{so} + A_p$

$L_{mf} = a_f/\,D_o$

Where

a_f = area of fin $= \text{pi}\,(D_o^2 - D_r^2)/4$

$= \text{pi}\,(0.750^2 - 0.675^2)/4$

$= 0.0839$

$L_{mf} = 0.0839/\,0.750$

$= 0.1119$ inch

Finned surface area = 0.0839 x 2 x 32 fins/inch x 12 inch/foot/144

$= 0.4476\ \text{Ft}^2/\text{ft}$

Primary surface area based on one foot length

primary length per inch = 1 inch - (32 fins x 0.010 fin width)

= 0.68 inch/inch length

Area = pi x 0.675 x (0.68) x 12 /144

$= 0.1201\ \text{ft}^2/\text{ft}$

Total effective area = finned surface + primary surface

$= 0.4476 + 0.1201$

$= 0.5677$

Fin efficiency $= 0.73$

$1/(D_e)^{0.25} = 1.30\ (0.4476 \times 0.73)/(\ 0.5677 \times (0.1119\ )^{0.25}\ ) + 0.1201/\ (0.5677\ (0.675)^{0.25})$

$= 1.2935 + 0.2334$

$= 1.5270$

De = 0.1839 inch

2. Calculation of Overall Heat Transfer Coefficient, Factory Test Evaluation, and Theoretical Overall Heat Transfer Coefficient Calculation for 150 Ton Chiller

Properties of 150 ton chiller

Condenser Tubes (Reference 5, and 18)

Total Number of Tubes = 347

Wolverine Model 65-265049

Average outside surface area = 0.640 ft^2 /ft

Surface area ratio (outside/inside) = 4.61

Internal cross sectional area = 0.221 in^2

outside diameter = 0.75 in

wall thickness = 0.049 in

Root diameter = 0.625 in

Minimum wall thickness = 0.044 in

Material 90-10 Cu-Ni

Number of fins 26

Inside diameter = 0.53 in

Fin width = 0.012 inch

Fin height (minimum) = 0.056 inch

Overall total outside surface area
(Reference 18 Page 16) = 3061 ft^2

A. Minimum Overall Heat Transfer Coefficient for 150 Ton Machine

As per Reference 8 (Drawing 076- 12921 D), the condenser high pressure cutout is set at 30 psig and high compressor discharge temperature is 220 °F.

As per References 9, 11, and 12 the required compressor trip setpoint on high condenser pressure is 30 psig and reset point is 24 psig. The tolerance for this trip and reset points is +/- 2 .012 psig. For the calculation purposes the maximum reset value of 26 psig is used. The saturation temperature at 26 psig or 40.7 psia is 132.7 °F (From Ref 1 Chapter 17.3 Refrigerant Tables For R - 11).

Total load on the condenser is the sum of design basis load 150 tons plus the heat input from the compressor. The 150 ton machine is a hermatic machine, hence the heat input to the condenser is the power input to the compressor. From reference 20, the compressor power requirements is 186 kw. The maximum power input requirement is 215 kw. Hence for conservatism, the maximum power input value is used in the analysis.

Heat load = 150 tons x 12,000 Btu/hr/ton + 215 kw x 3413 Btu/hr/kw

$= 1.8 \times 10^6 + 0.734 \times 10^6$ Btu/hr

$= 2.534 \times 10^6$ Btu/hr

Condenser surface area = 3061 ft^2

Mass flow of ECW water = 600 GPM x (60 min/hr) (1/0.01619) (1/7.48)

= 297272 lb/hr

ECW temperature rise = Q/ (mass x specific heat)

$= 2.534 \times 10^6 / (297272 \times 0.999)$

= 8.53 °F

Leaving water temperature = 106 + 8.53 = 114.53 °F

Lmtd = (T2 - T1) / (ln (Ts-T1)/(Ts-T2))

Lmtd = (8.53)/(ln ((132.7-106)/(132.7-114.53))

= 22.16°F

U = (2.534×10^6)/(3061 x 22.16)

U = 37.35 Btu/hr ft^2 °F

This is the minimum value of the overall heat transfer coefficient at the design conditions. If the U is greater than or equal to the above calculated value the chiller is capable of performing its design function.

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B. Evaluation of Factory Performance Test 150 Ton Chiller

There is no actual in shop test data available for these chillers and hence are not evaluated.

C. Calculation of the Overall Heat Transfer Coefficient using Equations

Metal Thermal Resistance

The metal thermal resistance is given by (Reference 15 page 104)

$$r_W = (t/(12\ k))\ (\ (d + 2\ N\ w\ (d+w))/(d-t))$$

Where

t = thickness of tube wall, 0.049 inches

k = Thermal conductivity of tube material 90-10 Cu Nickel, 30.0 Btu/hr ft °F

d = outside tube diameter or root diameter, 0.625 inches

N = 26 number of fins per inch

w = fin height, 0.056 inches

$$r_W = (0.049/12 \times 30.0)\ (\ (0.625 + 2 \times 26 \times 0.056\ (0.625+0.056))/(0.625-0.049))$$

$$= 0.000616$$

Calculation of Inside Heat Transfer Coefficient

$$h_i = 150\ (1+0.011\ twm)\ V^{0.8} / d^{0.2}$$

twm = mean water temperature, °F

V = water velocity, feet per second

d = tube inside diameter, inches

twm $= (106 + 114.53)/2 = 110.26$ °F

d = 0.53 inches

Water velocity = 600 gpm/ ((347/4) tubes per pass x 7.48 x 60 x 0.221 / 144)

= 10.0 feet per second

h_i = 150 (1+0.011 x 110.26) $(10.0)^{0.8}/(0.53)^{0.2}$

= 2370.3

Outside Heat Transfer Coefficient Calculation

$ho = (0.689 \times F1)^{4/3}\ (hfg\ Ao\ Ef/Q)^{1/3}\ (1/De)^{1/3}$

De = 0.2839 inch = 0.0237 feet

hfg = 72.69 Btu/lb

Ao = 3061 ft^2

Ef = 0.71

Q = 2.534×10^6 Btu/hr

ho = 675.7 Btu/hr ft^2 °F

Overall Heat Transfer Calculation

For clean condenser inside fouling factor 0.00025 and outside fouling factor 0.00025 (Reference 2), the overall heat transfer coefficient is calculated as:

$(1/U_0) = 1/(h_0 E_f) + ro/E_f + r_w + r_i (A_0/A_i) + (1/h_i) (A_0/A_i)$

$(1/U_0)$ = 1/(675.7 x 0.71)+ 0.00025/0.71+0.000616 + 0.00025 x 4.61 +4.61/2370.3

=0.002084 +0.0003521+0.000616+0.001152 +0.001944

= 0.006149

Uo = 162.6 Btu/hr ft^2 °F(For clean Condenser)

For a fouled condenser with 0.002 fouling factor the overall heat transfer coefficient is calculated as:

(1/Ud) =0.002084 +0.0003521+0.000616+0.002 x 4.61 +0.001944

= 0.01421

Ud = 70.33 Btu/hr ft^2 °F

This value is much higher than calculated from the worst case.

Fin Efficiency Calculation

The fin efficiency is calculated from Figure 12 as per Reference 1, page 3.16.

$$x_e/x_b = 0.75/0.625 = 1.20$$

$$w\,(h/k\,y)^{1/2} = (0.056/12)\,(\,700/(\,26 \times (0.012/2.0 \times 12))^{1/2}$$

$$= 1.083$$

From the graph fin efficiency is 0.71. The calculated value of ho is very close to the assumed value for the fin efficiency calculation.

Calculation of Equivalent Diameter for 150 ton Machine

The fin surface area, tube primary surface area , effective area is calculated based on one foot length of the tube

$$1/(D_e)^{0.25} = 1.30\ (A_s\ O)/(A_{ef}\ (L_{mf}\ )^{0.25}\ ) + A_p/\ (A_{ef}\ (D)^{0.25})$$

where

$A_{ef} = A_{so} + A_p$
$L_{mf} = a_f/\ D_o$

Where

a_f = area of fin = pi $(Do^2 - Dr^2)/4$

= pi $(0.750^2 - 0.625^2)/4$

= 0.1349 in^2

L_{mf} = 0.1349/ 0.750

= 0.1799 inch

Finned surface area = 2 x 0.1349 x 26 fins/inch x 12 inch/foot/144

= 0.5849 Ft^2 /ft

Primary surface area based on one foot length

primary length per inch = 1 inch - (26 fins x 0.012 fin width)

= 0.688 inch/inch length

Area = pi x 0.625 x (0.688) x 12 /144

= 0.1125 ft^2/ft

Total effective area = finned surface + primary surface

= 0.5849 + 0.1125

= 0.6974

Fin efficiency = 0.71

$1/(D_e)^{0.25} = 1.30\ (0.5849 \times 0.71)/(\ 0.6974 \times (0.1799\ )^{0.25}\ ) + 0.1125/\ (0.6974\ (0.625)^{0.25})$

= 1.1883 + 0.1815

= 1.3698

De = 0.2839 inch

3. Evaluation of Impact of Part Load Chiller Operation and Lower Than Design Condenser Cooling Water Temperature

During the part load conditions, the condenser will have excess surface area available and would result in efficient operation of the chiller.The condensing coefficient is given as

$$ho = (0.689 \times F1)^{4/3} \ (hfg\ Ao\ Ef/Q)^{1/3} \ (1/De)^{1/3}$$

hence ho is inversely proportional to 1/3 power of the rejected heat load. as the heat load decreases, the ho will increase and condenser will act efficiently.

The inside heat transfer coefficient is given as:

$$h_i = 150\ (1+0.011\ twm)\ V^{0.8}/d^{0.2}$$

From the above equation inside heat transfer coefficient is function of mean water temperature at constant velocity. Lower condenser water temperature will result in lower inside heat transfer coefficient. As the magnitude of the inside heat transfer coefficient is in the 1100 Btu/ hr ft^2 °F range, change in the water temperature is not expected to significantly impact the overall heat transfer coefficient. Any effect of the lower inside heat transfer coefficient will also be compensated by the increase in condensing heat transfer coefficient. However to establish the criteria, overall heat transfer is calculated assuming the condenser inlet water temperature at 72 °F.

300 Ton Chiller

Condenser leaving temperature = 72 + 8.71 = 80.71 °F

Average temperature = (72 + 80.71) = 76.35 °F

$$h_i = 150\ (1+0.011\ twm)\ V^{0.8}/d^{0.2}$$

d = 0.612 inches

V= 6.0 feet per second

$$h_i = 150\ (1+0.011 \times 76.35)\ (6)^{0.8}/(0.612)^{0.2}$$

$$= 1276.6$$

overall heat transfer coefficient:

$$(1/Ud)=0.00176 +0.0003424+0.0007486+0.002 \times 3.14 +3.14/1276.6$$

=0.011590

Ud = 86.27 Btu/hr ft^2 °F vs 89.50 Btu/hr ft^2 °F

Hence higher value should be used for acceptance criteria.

Similarly for 150 ton chiller higher value should be used for the acceptance criteria.

4. Instrumentation Calibration

The test is performed by measuring the condenser water flow , condenser inlet and outlet temperature and condenser pressure. Accuracy of the test instrumentation is critical in determining the overall heat transfer coefficient. It is recommended that the following accuracy of instruments be used:

Temperature = +/-0.2 °F

Pressure = +/-0.1 psi

Flow = +/-2 %

These factors should be considered in evaluating the test results in the test procedure.

5. Establish Condenser Tube Plugging Margin

As stated earlier, the chiller condenser has large surface area to account for high fouling factors and if required, some condenser tubes can be plugged without having any significant impact on the chiller performance. To account for plugging, a 3% plugging margin is considered and can be included in the overall heat transfer acceptance criteria.

300 Ton Chiller = 89.50 x 1.03 = 92.2 Btu/hr ft^2 °F say 93 Btu/hr ft^2 °F

150 Ton Chiller = 70.33 x 1.03 = 72.44 Btu/hr ft^2 °F say 73 Btu/hr ft^2 °F

Minimum overall heat transfer with tube plugging

300 Ton Chiller = 38.77 x 1.03 = 39.93 Btu/hr ft^2 °F say 40 Btu/hr ft^2 °F

150 Ton Chiller = 37.35 x 1.03 = 38.47 Btu/hr ft^2 °F say 40 Btu/hr ft^2 °F

SOUTH TEXAS PROJECT
ELECTRIC GENERATING STATION
HOUSTON LIGHTING & POWER

GENERAL COMPUTATION SHEET

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0	DB 9/9/93	caD 9/16/93

ATTACHMENT A

Copies of References 4, 5, 19, and 20

Total of 19 Pages

REFERENCE 4

CALC MC 6406 R/0
ATTACH. REF 4
SH. 1 OF 2

TYPE S/T TRUFIN® TITANIUM FINNED TUBE - 32 FPI

Wolverine tubemanship®

Titanium Type S/T Trufin is an integral finned tube produced from welded and/or seamless purchased tubes of Grade 1 or Grade 2 Titanium made to requirements of ASTM standard B338, or ASME standard SB338.

All Trufin which meets the requirements of Paragraph UG-6(b), ASME Boiler and Pressure Vessel Code, Section VIII, is made to an average wall in the fin area. When a minimum wall is required, the next heavier wall size should be ordered.

Range of sizes - See Table 1.

The standard maximum length for shipment by truck is 44 feet (13.4 meters). For shipment of longer lengths, contact the Wolverine Marketing Department.

Engineering Data - See Table 2.

Testing-All Trufin is eddy current and air tested, at 250 psi, after finning per ASME standards.

Tempers-Grade 2 Titanium is supplied in the "as finned" temper. Plain ends and lands are supplied in the condition as described by the governing plain tube ASTM or ASME standard.

Plain tube mechanical properties per governing ASTM and/or ASME standard - minimum tensile strength, 50 KSI (345MPa); minimum yield strength, 40 KSI (275 MPa). The UNS number for this alloy is R50400.

Tolerances - Applicable tolerances for diameter and wall thickness are shown in Table 1. Other tolerances are per the governing ASTM or ASME standard.

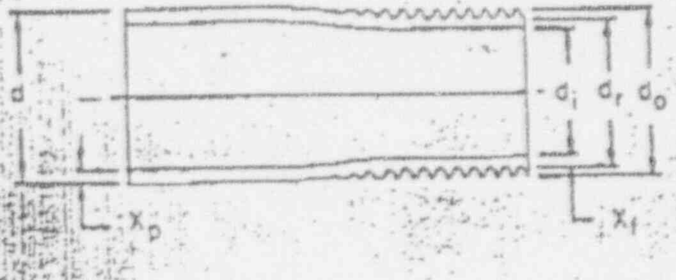
Plain Section Requirements-Plain end lengths 1" (25.4 millimeters) and over are supplied as standard. If plain ends less than 1" (25.4 millimeters) are required, contact the Wolverine Marketing Department.

Land Lengths 1" (25.4 millimeters) and over are supplied as standard. If land lengths down to 5/8" (15.9 millimeters) minimum are required, contact the Wolverine Marketing Department.

Distances of 18" (457.2 millimeters) and over between lands are supplied as standard. If distances down to 8" (203.2 millimeters) minimum are required, contact the Wolverine Marketing Department.

Titanium can also be provided in S/T Turbo-Chil® (both external and internal enhancement). Please refer to type S/T/ Turbo-Chil® Brochure.

DIMENSIONAL NOMENCLATURE USED FOR TYPE S/T TRUFIN



d - outside diameter of plain end
d_o - diameter over fins
d_r - root diameter of finned section
d_i - inside diameter of finned section
x_p - wall thickness of plain section
x_f - wall thickness of finned section

CALC MC 6406 R/0
ATTACH. REF. 4
SH. 2 OF 2

STANDARD SIZES - TYPE S/T TRUFIN

32 Fins per inch (25.4 millimeters)

Table 1

Standard Sizes			Plain Section Dimensions and Tolerances				Fin Section Dimensions	
			(d) Outside Diameter		(Xp) Wall Thickness			
Outside Diameter in. (mm)	(Y_f) Wall Thickness in. (mm)	Catalog Number	Nominal Size in. (mm)	Tolerances in. (mm)	Nominal Size in. (mm)	Tolerances in. (mm)	At-A-Point Root Diameter (d_r) in. (mm)	Minimum Wall Thickness in. (mm)
5/8 (15.9)	.028 (.71)	70-324028	.625 (15.9)	.004 (.10)	.049 (1.25)	.0050 (.13)	.557 (14.1)	.025 (.64)
	.035 (.89)	70-324035			.058 (1.47)	.0055 (.14)		.031 (.79)
	.042 (1.07)	70-324042			.065 (1.65)	.0060 (.15)		.037 (.94)
	.049 (1.25)	70-324049			.072 (1.83)	.0070 (.18)		.044 (1.12)
	.065 (1.65)	70-324065			.083 (2.11)	.0085 (.22)		.058 (1.47)
3/4 (19.1)	.028 (.71)	70-325028	.750 (19.1)	.004 (.10)	.049 (1.25)	.0050 (.12)	.675 (17.1)	.025 (.64)
	.035 (.89)	70-325035			.058 (1.47)	.0055 (.14)		.031 (.79)
	.042 (1.07)	70-325042			.065 (1.65)	.0060 (.15)		.037 (.94)
	.049 (1.25)	70-325049			.072 (1.83)	.0070 (.18)		.044 (1.12)
	.065 (1.65)	70-325065			.083 (2.11)	.0085 (.22)		.058 (1.47)
	.083 (2.11)	70-325083			.109 (2.77)	.0100 (.25)		.075 (1.91)
7/8 (22.2)	.028 (.71)	70-326028	.875 (22.2)	.004 (.10)	.049 (1.25)	.0050 (.12)	.807 (20.5)	.025 (.64)
	.035 (.89)	70-326035			.058 (1.47)	.0055 (.14)		.031 (.79)
	.042 (1.07)	70-326042			.065 (1.65)	.0060 (.15)		.037 (.94)
	.049 (1.25)	70-326049			.072 (1.83)	.0070 (.18)		.044 (1.12)
	.065 (1.65)	70-326065			.083 (2.11)	.0085 (.22)		.058 (1.47)
	.083 (2.11)	70-326083			.109 (2.77)	.0100 (.25)		.075 (1.91)
1 (25.4)	.028 (.71)	70-327028	1.000 (25.4)	.004 (.10)	.049 (1.25)	.0050 (.13)	.932 (23.7)	.025 (.64)
	.035 (.89)	70-327035			.058 (1.47)	.0055 (.14)		.031 (.79)
	.042 (1.07)	70-327042			.065 (1.65)	.0060 (.15)		.037 (.94)
	.049 (1.25)	70-327049			.072 (1.83)	.0070 (.18)		.044 (1.12)
	.065 (1.65)	70-327065			.083 (2.11)	.0085 (.22)		.058 (1.47)
	.083 (2.11)	70-327083			.109 (2.77)	.0100 (.25)		.075 (1.91)

Tolerances are plus or minus.

ENGINEERING DATA - TYPE S/T TRUFIN

32 Fins per inch (25.4 millimeters)

Table 2

Catalog Number	Average Outside Area		Surface Area Ratio (Outside to Inside)	I.D. Cross Sectional Area-Average		Approx. Weight (Titanium)	
	ft²/ft	cm²/cm		in²	cm²	lbs/ft	kgs/m
70-324028	.415	12.6	3.16	.197	1.27	.145	.22
70-324035	.415	12.6	3.25	.186	1.20	.170	.25
70-324042	.415	12.6	3.35	.176	1.14	.188	.28
70-324049	.415	12.6	3.45	.165	1.06	.206	.31
70-324065	.415	12.6	3.71	.143	0.92	.232	.35
70-325028	.503	15.3	3.07	.304	1.96	.177	.26
70-325035	.503	15.3	3.14	.294	1.90	.207	.31
70-325042	.503	15.3	3.21	.281	1.81	.230	.34
70-325049	.503	15.3	3.29	.268	1.73	.252	.37
70-325065	.503	15.3	3.45	.238	1.54	.286	.43
70-325083	.503	15.3	3.72	.209	1.35	.361	.54
70-326028	.591	18.0	3.01	.443	2.86	.209	.31
70-326035	.591	18.0	3.06	.427	2.76	.248	.36
70-326042	.591	18.0	3.12	.411	2.65	.272	.40
70-326049	.591	18.0	3.18	.395	2.55	.300	.44
70-326065	.591	18.0	3.33	.360	2.32	.339	.50
70-326083	.591	18.0	3.52	.323	2.08	.431	.64
70-327028	.679	20.7	2.96	.603	3.89	.241	.36
70-327035	.679	20.7	3.01	.584	3.77	.282	.42
70-327042	.679	20.7	3.06	.565	3.65	.314	.47
70-327049	.679	20.7	3.11	.546	3.52	.348	.51
70-327065	.679	20.7	3.23	.500	3.26	.393	.58
70-327083	.679	20.7	3.38	.461	2.97	.501	.75

Fins per inch - 32 +0, -2
Fin Width - .010 in Avg.
Fin Height - 0.30 in. min., .033 in. Avg.

WOLVERINE TUBE, INC.
2100 Market Street N.E. • P.O. Box 2202
Decatur, Alabama 35609-2202
Telephone 205•353-1310

REFERENCE 5

TYPE S/T TRUFIN® COPPER & COPPER ALLOY FINNED TUBE - 26 & 40 FPI

Wolverine tubemanship®

CALC MC 6406 R/0
ATTACH. REF. 5
SHT. 1 OF 4

Type S/T Trufin is manufactured from copper, and copper alloys produced by Wolverine, in accordance with ASTM standard B-359 or ASME standard SB-359.

All Trufin which meets the requirements of Paragraph UG-8 (b), ASME Boiler and Pressure Vessel Code, Section VIII, is made to an average wall in the fin area. When a minimum wall is required, the next heavier wall size should be ordered.

Range of sizes - See tables 1 and 3 for 26 Fin and 40 Fin Trufin.

The standard maximum length for shipment by truck is 44 feet (13.4 meters). For shipment of longer lengths, contact the Wolverine Marketing Department.

Packaging - Unless otherwise specified, type S/T Trufin is packaged in wooden boxes.

Temper - Copper and copper alloy Trufin are supplied in either the "as-finned" or annealed condition.

Alloys - Applicable plain tube specifications and mechanical properties - see table 5.

Engineering Data - See tables 2 and 4 for 26 Fin and 40 Fin Trufin.

Tolerances - Applicable tolerances for diameter and wall thickness are shown in Tables 1 and 3. Other tolerances are per the governing ASTM or ASME standard.

Plain Section Requirements - Plain end lengths 1" (25.4 millimeters) and over are supplied as standard. If plain ends less than 1" (25.4 millimeters) are required, contact the Wolverine Marketing Department.

Land lengths 1" (25.4 millimeters) and over are supplied as standard. If land lengths down to 5/8" (15.9 millimeters) minimum are required, contact the Wolverine Marketing Department.

Distances of 18" (457.2 millimeters) and over between lands are supplied as standard. If distances down to 8" (203.2 millimeters) minimum are required, contact the Wolverine Marketing Department.

Stripped ends are available in length up to 4 inches (101.6 millimeters) maximum. The shortest over-all tube length that can be stripped is 12 inches (304.8 millimeters).

Testing - All Trufin is eddy current and air tested, at 250 psi, after finning per ASME standards.

Type S/T U-Bends - U-Bends of type S/T Trufin can be made with either full finned or plain surface in the bend area. U-Bends are air tested, at 1000 psi, after bending. All brass Trufin is relief annealed in the bend area after bending and before air testing. Bends normally show some discoloration because of the relief annealing operation.

Duplex type S/T Trufin - This is available in a variety of combinations (copper finned tube over a steel liner, admiralty finned tube over a copper-nickel liner, etc.). Tubes in this catagory can be furnished with ferrules of the liner material up to and including 2 inches (50.8 millimeters) in length, applied to one or both ends.

CALC MC 6406 R/0
ATT. REF. 5
SHT 2 OF 4

STANDARD SIZES - TYPE S/T TRUFIN
26 Fins per Inch (25.4 millimeters)

Table 1

Standard Sizes			Plain Section Dimensions and Tolerances				Fin Section Dimensions		
			(d) Outside Diameter		(X_p) Wall Thickness				
Outside Diameter in. (mm)	(X_f) Wall Thickness in. (mm)	Catalog Number	Nominal Size in. (mm)	Tolerances in. (mm)	Nominal Size in. (mm)	Tolerances in. (mm)	At-A-Point Root Diameter (d_r) in. (mm)	Minimum Wall Thickness in. (mm)	Available Alloys See Table 5
5/8 (15.9)	.049 (1.24)	65-264049	.625 (15.9)	.003 (.076)	.069 (1.75)	.0040 (.10)	.500 (13.0)	.044 (1.12)	01,02,26 53, 55
3/4 (19.1)	.028 (.71)	65-265028	.750 (19.1)	.003 (.076)	.049 (1.25)	.0035 (.089)	.625 (15.9)	.025 (.64)	01, 02 53, 55
	.035 (.89)	65-265035			.055 (1.39)	.0035 (.089)		.031 (.79)	
	.042 (1.07)	65-265042			.062 (1.57)	.0040 (.10)		.037 (.94)	
	.049 (1.25)	65-265049			.069 (1.75)	.0040 (.10)		.044 (1.12)	01,02,26 53,55
	.058 (1.47)	65-265058			.079 (2.00)	.0040 (.10)		.049 (1.25)	01,02,26 51,53,55
	.065 (1.65)	65-265065			.086 (2.18)	.0050 (.13)		.058 (1.47)	
	.072 (1.83)	65-265072			.092 (2.33)	.0050 (.13)		.065 (1.65)	
1 (25.4)	.028 (.71)	65-267028	1.000 (25.4)	.003 (.076)	.050 (1.27)	.0035 (.089)	.875 (22.2)	.025 (.64)	01,02 26,51 53,55
	.032 (.81)	65-267032			.052 (1.32)	.0035 (.089)		.028 (.71)	
	.042 (1.07)	65-267042			.062 (1.57)	.0040 (.10)		.037 (.94)	
	.049 (1.25)	65-267049			.069 (1.75)	.0040 (.10)		.044 (1.12)	
	.058 (1.47)	65-267058			.079 (2.00)	.0040 (.10)		.049 (1.25)	
	.065 (1.65)	65-267065			.086 (2.18)	.0050 (.13)		.058 (1.47)	
	.072 (1.83)	65-267072			.092 (2.33)	.0050 (.13)		.065 (1.65)	

Tolerances are plus or minus.

STANDARD SIZES - TYPE S/T TRUFIN
40 fins per inch (25.4 millimeters)

Table 3

Standard Sizes			Plain Section Dimensions and Tolerances				Fin Section Dimensions		
			(d) Outside Diameter		(x_p) Wall Thickness				
Outside Diameter in. (mm)	(X_f) Wall Thickness in. (mm)	Catalog Number	Nominal Size in. (mm)	Tolerances in. (mm)	Nominal Size in. (mm)	Tolerances in. (mm)	At-A-Point Root Diameter (d_r) in. (mm)	Minimum Wall Thickness in. (mm)	Average Fin Height in. (mm)
3/4 (19.1)	.028 (.71)	70-4050128	.750 (19.1)	.003 (.076)	.043 (1.09)	.003 (.076)	.675 (17.1)	.025 (.64)	.034 (.86)
	.035 (.89)	70-4050135			.052 (1.32)	.003 (.076)		.031 (.79)	
	.042 (1.07)	70-4050142			.058 (1.47)	.004 (.102)		.037 (.94)	
	.049 (1.25)	70-4050149			.065 (1.65)	.004 (.102)		.044 (1.12)	
	.065 (1.65)	70-4050165			.083 (2.11)	.005 (.127)		.058 (1.47)	
3/4 (19.1)	.028 (.71)	70-4050228	.750 (19.1)	.003 (.076)	.052 (1.32)	.003 (.076)	.625 (15.9)	.025 (.64)	.056 (1.42)
	.035 (.89)	70-4050235			.055 (1.40)	.004 (.102)		.031 (.79)	
	.042 (1.07)	70-4050242			.062 (1.57)	.004 (.102)		.037 (.94)	
	.049 (1.25)	70-4050249			.065 (1.65)	.004 (.102)		.044 (1.12)	
	.065 (1.65)	70-4050265			.083 (2.11)	.005 (.127)		.058 (1.47)	

Available Alloys - 01 and 53, also in 51 for .035 inch wall and heavier - See Table 5.
Tolerances are plus or minus.

CALC MC 6406 R/0
ATTACH. REF. 5
SHT. 3 OF 4

ENGINEERING DATA - TYPE S/T TRUFIN
26 Fins per Inch (25.4 millimeters)

Table 2

Catalog Number	Average Outside Area		Surface Area Ratio (Outside to Inside)	I.D. Cross Sectional Area - Average		Approx. Weight (Copper)	
	ft²/ft	cm²/cm		in²	cm²	lbs/ft	kgs/m
65-264049	.549	16.73	5.16	.129	.832	.407	.605
65-265028	.640	19.50	4.27	.257	1.657	.374	.557
65-265035	.640	19.50	4.38	.245	1.580	.411	.612
65-265042	.640	19.50	4.49	.232	1.496	.458	.682
65-265049	.640	19.50	4.61	.221	1.425	.503	.748
65-265058	.640	19.50	4.77	.206	1.329	.560	.833
65-265065	.640	19.50	4.91	.195	1.258	.603	.897
65-265072	.640	19.50	5.05	.185	1.193	.646	.961
65-267028	.893	27.22	4.06	.534	3.445	.507	.754
65-267032	.893	27.22	4.09	.527	3.400	.547	.814
65-267042	.893	27.22	4.31	.491	3.168	.644	.958
65-267049	.893	27.22	4.40	.474	3.058	.711	1.058
65-267058	.893	27.22	4.49	.452	2.916	.795	1.183
65-267065	.893	27.22	4.57	.436	2.813	.860	1.280
65-267072	.893	27.22	4.68	.420	2.710	.955	1.421

Fins Per Inch - 26 + 1, -0
Fin Width - .012 in. Avg.
Fin Height - .056 in. Min., .057 in. Avg.

ENGINEERING DATA - TYPE S/T TRUFIN
40 Fins per Inch (25.4 millimeters)

Table 4

Catalog Number	Average Outside Area		Surface Area Ratio (Outside to Inside)	I.D. Cross Sectional Area - Average		Approx. Wt. (Copper)	
	ft²/ft	cm²/cm		in²	cm²	lbs/ft	kgs/m
70-4050128	.645	19.66	3.97	.302	1.949	.352	.524
70-4050135	.645	19.66	4.06	.288	1.858	.421	.626
70-4050142	.645	19.66	4.17	.275	1.774	.472	.702
70-4050149	.645	19.66	4.27	.262	1.690	.522	.777
70-4050165	.645	19.66	4.52	.233	1.503	.630	.937
70-4050228	.924	28.16	6.07	.266	1.716	.391	.582
70-4050235	.924	28.16	6.22	.253	1.632	.460	.684
70-4050242	.924	28.16	6.37	.241	1.555	.507	.754
70-4050249	.924	28.16	6.54	.229	1.478	.552	.821
70-4050265	.924	28.16	6.71	.192	1.239	.669	.995

Fins Per Inch - 40 + 1, -0
Fin Width - .009 in. Avg.

CALC. MC 6406 R/0
ATTACH. REF. 5
SHT. 4 OF 4

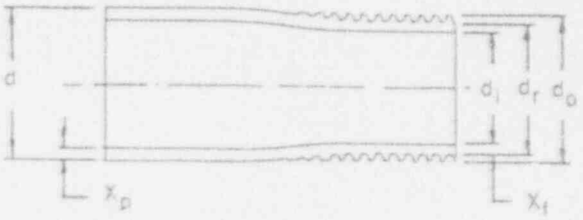
ALLOYS - APPLICABLE PLAIN TUBE SPECIFICATION AND MECHANICAL PROPERTIES

Table 5

Wolverine Alloy Number	UNS Number	*ASTM Spec. Number	Tensile Strength Minimum		Yield Strength Minimum		Temper
			KSI	MPa	KSI	MPa	
01	C12200	B359	30	205	9	62	Annealed
			36	250	30	205	Lt. Drawn
02	C14200	B359	30	205	9	62	Annealed
			36	250	30	205	Lt. Drawn
26	C44300	B359	45	310	15	105	Annealed
28	C23000	B359	40	275	12	85	Annealed
30	C68700	B359	50	345	18	125	Annealed
51	C71500	B359	52	360	18	125	Annealed
53	C70600	B359	40	275	15	105	Annealed
			45	310	35	245	Lt. Drawn
55	C70400	B359	38	265	12	85	Annealed
			40	275	30	205	Lt. Drawn

*For equivalent ASME specification, mechanical property data is identical.

DIMENSIONAL NOMENCLATURE USED FOR TYPE S/T TRUFIN



d - outside diameter of plain end
d_o - diameter over fins
d_r - root diameter of finned section
d_i - inside diameter of finned section
x_p - wall thickness of plain section
x_f - wall thickness of finned section

Wolverine

one of The Signal Companies

Wolverine
P.O. Box 2202 • Decatur, Alabama 35602
one of The Signal Companies

TYPE "A" AFFIDAVIT

DECATUR PLANT

CUST. ORDER NO. 05310 -02		CUST. PART NO. 007-07508-000			3A	011202
CUST. SPEC. NO. SB338 GR 2/R1043		007-07508A			NO. OF ITEMS 02	CER 7452202
ITEM 02	QTY. ORD. 2425 pc	POUNDS 7168	WT/FT/PC .20700ft	PIECES	TUBE/WOLV. PART NO. 570322	DATE ORD. 7/11/84

CUST. DESC.
TI-2- WELDED FINNED 70-305035-14 (171 3/8" W/2" P.E. & 4 LANDS NUCLEAR SEC III CL 3

MAIL TO:
DORCUS JACOBS
YORK DIV PURCH DEPT
P.O. BOX 1592
YORK, PA. 17405

FOR PARTIAL SHIPMENTS
DATE 11/24/84
PIECES 1927
FEET
FOOTAGE

SHIP TO:
BORG WARNER AIR COND. INC.
CENTRIFUGAL SYSTEMS PLANT
MANCHESTER ST., BLDG 36 STORAGE
YORK, PA. 17401

CHEMICAL ANALYSIS (PER CENT)

LOT NO.										
HEAT #340386T										
HEAT #340388T										
HEAT #340407T										

MECHANICAL PROPERTIES

EG %	TS KSI	YS KSI	WALL P.E.	UNDER FIN
38	70.0	57.4	.058 .058	.036 .037
36	73.7	60.7	.058 .058	.036 .036
40	69.4	57.0	.058 .059	.037 .037

TEST RESULTS

EDDY CURRENT	HYDROSTATIC (PSI)	AIR (PSI)	FLATTENING	EXPANSION	BEND	FLARE	FLANGE	Reverse Flattening XXXXXXXXXXXX	ULTRASONIC
OK * & **	OK 2800	OK 250 **	OK*			OK*		OK*	

* BEFORE FINNING ** AFTER FINNING *** AFTER FINAL ANNEAL

REMARKS:
MATERIAL WAS MANUFACTURED (PRODUCED) IN ACCORDANCE WITH WOLVERINE-A SIGNAL CO'S. QUALITY ASSURANCE PROGRAM DATED MAY 15, 1981, WHICH HAS BEEN SURVEYED, QUALIFIED, AND IS BEING AUDITED BY BORG WARNER AIR CONDITIONING, INC.

I HEREBY CERTIFY THIS MATERIAL CONFORMS TO SPECIFICATION
R1043/ASME SB 338, GR 2, SEC III, Cl 3, DIV 1, NCA 3800C, 83 ED, W/83 ADD.
T. O. BARRINGTON
ORIGINAL SIGNED BY METALLURGIST
2/25/85
DATE

PO- 05310- 02.
PN- 007- 07508-000
SO — 88-916529
1927 pcs.
Rec'd @ 214 1-22-85

OK Rodney L Lentz
3-11-85

BECHTEL
745

REFERENCE 19
CALC MC 6406 R/0
ATTACH. REF. 19
SHT. 1 OF 6

25

SOLD TO
WOLVERINE UNIT OF SIGNAL CO
2100 MARKET STREET N.E.
DECATUR, AL 35602

SHIP TO SAME AS SOLD TO UNLESS SHOWN BELOW

SHIP TO
WOLVERINE

CALC MC 6406 R/D
ATTACH. REF. 19
SHT. 2 OF 6

MILL ORDER NO 49-064-002-001			PROD LOC
DATE ENTERED	DATE ACKN	CUST ORDER NO A2123	
ACKNOWLEDGED DELIVERY DATE		ORDERED PCS	
ORDER FEET	LBS PER FT	ORDER WEIGHT	
GRADE CPTIG2			

O D	WALL	LENGTH	SPECIAL GAUGE TOL	SPECIAL OD/ID TOL	SPECIAL LENGTH TOL
750"	55M				

HARDNESS	TENSION	FLAT	FLARE	FLANGE	REV BEND	R FLAT	A/T	E/C	HYDRO	U.T.	CORR
	XX	XX	XX		XX	XX	XX		XX		

SPECIFICATION NC	CERT COPIES
ASTM B338 &ASME SA 338(NUCLEAR)	YES-BOTH(3)

SEC III, DIV 1 NO 1983 ED WINTER 1983 ADDENDUM

CERTIFICATE OF TEST

ALS Metals Company

P.O. BOX 410
PITTSBURGH, PA 15230

Corrected Certificate.
March 14, 1985

DATE	INVOICE	QUANTITY
September 26, 1984	220026	1511 Pieces

CHEMICAL

HEAT NO	N	C	H	Fe	O	Pd	Al	V	Mo	Zr	Sn	Ni	Ti
340388T	.01	.01	.0002	.04	.11								
CHECK	.01	.01		.04	.13								
340386T	.01	.01	.001	.04	.11								
CHECK	.01	.01		.04	.12								

MECHANICAL

HEAT NO	NO PCS	TENS KSI	YIELD KSI	% ELONG		TENS KSI	YIELD KSI	% ELONG
340388T		70.5	56.0	36		70.5	55.5	37
340386T		67.0	53.5	38		70.0	56.0	36
		71.0	56.0	38		71.5	57.6	36

				AIR TEST (PSI)	EDDY CURRENT	ULTRASONIC	HYDRO TEST
		12-OK	12-OK	12-OK	Completed	Completed	Completed	

Other test requirements passed and/or completed.
The Ultra Sonic test completed per ASME SB338.
Authorization; Telex 11-2-84 S.L. Patton, Wolverine to T. Scholl ALS Metals.
Finish tube H. content 340388T .006 340386T .0016
Material was manufactured "produced" in accordance with Tubular Products Division QA program dated 8/19/85, which has been Surveyed, Qualified and audited by Wolverine, one of the Signal

AL 6307 683

March 14, 1985

PO-05310-02
P/N-007-07508-000
50-83-916529
QUAN. 1927 PCS. TOTAL
OK 3/11/85

BECHTEL
745

Glenna Pennington

WOLVERINE UNIT OF SIGNAL CO
2100 MARKET STREET N.E.
DECATUR, AL 35602

SHIP TO SAME AS SOLD TO UNLESS SHOWN BELOW

WOLVERINE

CALC MC 6406 R/0
ATTACH. REF. 19
SHT. 3 OF 6

MILL ORDER NO 49-064-002-001		PROD LOC
DATE ENTERED	DATE ACKN	CUST ORDER NO A2123
ACKNOWLEDGED DELIVERY DATE		ORDERED PCS
ORDER FEET	LBS PER FT	ORDER WEIGHT
GRADE CPTIG2	[redacted]	

OD	WALL	LENGTH	SPECIAL GAUGE TOL	SPECIAL OD/ID TOL	SPECIAL LENGTH TOL
750"	55M				

HARDNESS	TENSION	FLAT	FLARE	FLANGE	REV BEND	R FLAT	A/T	E/C	HYDRO	UT	CORR
	XX	XX	XX		XX	XX	XX		XX		

SPECIFICATION NO	CERT COPIES	
ASTM B338 &ASME SA 338(NUCLEAR)	YES-BOTH(3)	[redacted]

SEC III, DIV 1 NO 1983 ED WINTER 1983 ADDENDUM

CERTIFICATE OF TEST

ALS Metals Company

P.O. BOX 410
PITTSBURGH, PA 15230

Corrected Certificate.
March 14, 1985

DATE	INVOICE	QUANTITY
November 7, 1984	220038	411 Pieces

HEAT NO	N	C	H	Fe	O	Pd	Al	V	Mo	Zr	Sn	Ni	Ti
340388T	.01	.01	.0002	.04	.11								
CHECK	.01	.01		.04	.13								
340386T	.01	.01	.001	.04	.11								
CHECK	.01	.01		.04	.12								
440407T	.004	.01	.0001	.04	.12								
CHECK	.004	.002		.04	.11								

HEAT NO	NO PCS	TENS KSI	YIELD KSI	% ELONG		TENS KSI	YIELD KSI	% ELONG
340388T		73.0	57.0	36		72.5	57.0	36
340386T		70.5	56.0	37		71.0	58.5	37
440407T		70.0	54.0	35		70.5	54.0	34
		72.0	54.0	35		71.5	56.0	34

FLAT	FLARE	REV FLAT	AIR TEST / PSI	EDDY CURRENT	ULTRASONIC	HYDRO TEST / PSI
4-OK	4-OK	4-OK	Completed	Completed	Completed	

Other test requirements passed and/or completed,
The Ultra Sonic test completed per ASME SB338.
Authorization; Telex 11-2-84 S.L. Patton, Wolverine to T. Scholl ALS Metals.
Finish tube H. content 340388T .006 340386T .0016 440407T .0015
Material was manufactured "produced" in accordance with Tubular Products Division QA program dated 8/19/35, which has been Surveyed, Qualified and audited by Wolverine, one of the Signal

GOL967 683

March 14, 1985

BECHTEL
748

Glenna Pennington

27

CALC MC 6406 R/0
ATTACH. REF. 19
SHT. 4 OF 6

Wolverine Division
P.O. Box 2202 • Decatur, Alabama 35602
Telephone 205 353-1310

EDDY CURRENT TEST REPORT

DATE 11-17

SHIFT 1

CUSTOMER YORK

P.O. 011202

TUBE SIZE 305 (O.D.) 035 (WALL)

ALLOY 14

TEST SPECIFICATION SB-338

NOTCH DEPTH

TEST PROCEDURE G-1390-BF/R-1043

DRILL SIZE 031

LEVEL I OPERATOR

BADGE 4007

LEVEL III APPROVAL JK Benfield

TIME CHECKED	NUMBER NOTCHES OR HOLES DETECTED	NUMBER OF PCS. ACCEPTED
8:15	4	150
9:20	4	275
1020	4	395
1120	4	575
1230	4	720
1:30	4	827
	827 pcs RAN	0 rejects
	PO-05310-02	P.N-007-07508-000
	SO-83-916529	1927 pcs.
	Rec't # 214	1-22-85

Rodney L Lentz
3-11-85

BECHTEL
745

CALC MC6406 R/0
ATTACH. REF. 19
SHT. 5 OF 6

Wolverine Division
P.O. Box 2202 • Decatur, Alabama 35602
Telephone 205-353-1310

EDDY CURRENT TEST REPORT

DATE 11-18

SHIFT 1

CUSTOMER YORK

P.O. 011202

TUBE SIZE 305 O.D. 035 WALL

ALLOY 14

TEST SPECIFICATION SB-338

NOTCH DEPTH

TEST PROCEDURE G-1390 BF/R-1043

DRILL SIZE

LEVEL I OPERATOR J S Sharp

BADGE 4007

LEVEL III APPROVAL George Johnson

TIME CHECKED	NUMBER NOTCHES OR HOLES DETECTED	NUMBER OF PCS. ACCEPTED
8:10	4	130
9:15	4	280
1020	4	395
1120	4	560
12 30	4	696
	696pcs ran	Org/js
	PO-05310-02	P.N.-007-075-18-000
	SU-85-516525	1027 pcs
	Cert # 214	1-22-85

Rodney L Lantz
3- 85

BECHTEL
745

30

UOP inc. UOP-24-1609

CALC. MC 6406 R/0
ATTACH. REF. 19
SHT. 6 OF 6

Wolverine Division
P.O. Box 2202 • Decatur, Alabama 35602
Telephone 205-353-1310

EDDY CURRENT TEST REPORT

DATE 11-17

SHIFT 3

CUSTOMER YORK

P.O. 011202

TUBE SIZE 305 O.D. 035 WALL

ALLOY 14

TEST SPECIFICATION SB-338

NOTCH DEPTH

TEST PROCEDURE G-1390 BF/R-1043

DRILL SIZE 031

LEVEL I OPERATOR J J Sharp

BADGE 4007

LEVEL III APPROVAL George Johnson

TIME CHECKED	NUMBER NOTCHES OR HOLES DETECTED	NUMBER OF PCS. ACCEPTED
4:30	4	100
530	4	175
6.30	4	325
7.30	4	444
444 pcs tested		1 reject
	PO-05310-02	P.N-007-01508-000
	SO-85-916529	1927 pcs.
	Leit # 214	1-22-85

(1 reject)

Rodney L Lentz
3-11-85

BECHTEL
740

29

REFERENCE 20

CALC MC6406 R/0
ATTACH. REF. 20
SH. 1 OF 7

Engineered Machinery
Air Conditioning Group

Borg Warner Corporation
P O Box 1592 York Pennsylvania 17405
Telephone 717/771 7890
TWX 510-657 4853
Telex 840416

ST-BY-YB-0044
ST-YD-YB-0075
August 30, 1984

MN-1695

CC: J.H. KOLESSAR
STP-RMS (2)

Bechtel Energy Corporation
South Texas Project
P.O. Box 2166
Houston, Texas 77252-2166

RECEIVED
OCT 24 1984
STP RMS

ORIG. — 2

Attention: Project Engineering Manager

Subject: South Texas Project
Electric Generating Station
Units 1 and 2
Houston Lighting & Power Company
Job No. 14926
Purchase Order Nos. 35-1197-4102/8102
York Orders 77-780615 and 77-780616
Purchase Order Nos. 14926-4310/8310
York Orders 83-916519 and 83-916529
Safety Class Water Chillers

M8.11.1

Reference: Bechtel/Borg-Warner 8-23-84 Conference

Gentlemen:

The following attachments contain summaries of the 150 and 300 ton STP chiller performance data discussed and data requested by Bechtel during the August 23, 1984 meeting:

ATTACHMENT

A	STP EAB Safety Class 150 Ton Water Chillers Customer P.O. Nos. 35-1197-4102/8102 B-W S.O. Nos. 77-780,615/616(H)
B	STP Essential Safety Class 300 Ton Water Chillers Customer P.O. Nos. 14926-4310/8310 B-W S.O. Nos. 83-916,519/529(H)
C	Full Load Design Performance Data for a York Turbopak Model HTH4B1-BBCS, R-11, Unit Duty 150 T_R
D	Predicted Full and Part Load Performance Curve for a York Model HTH4B1-BBCS R-11 Turbopak
E	Predicted Full and Part Load Performance Curve for a York Model OTK5C1-IMCS R-11 Turbopak

CALC MC 6406 R/0
ATTACH. REF. 20
SH. 2 OF 7

If there are any questions, please call Tony Shanko, Ext. 7274.

Very truly yours,

F C Bahr

F. C. Bahr
Contract Supervisor

FCB/njm

-Attachments-

cc: R.A. Friede - EM Houston
A.R. Shanko - 083A

CALC MC 6406 R/0
ATTACH. REF. 20
SH. 3 OF 7

ATTACHMENT "A"

STP EAB SAFETY CLASS 150 TON WATER CHILLERS

CUSTOMER P.O. NOS. 35-1197-4102/8102

B-W S.O. NOS. 77-780,615/616(H)

Predicted compressor motor KW Input, minimum ECWT and corresponding condenser pressures allowed at various load conditions at a design condenser water flow rate of 600 GPM follow:

LOAD CONDITION EVAPORATOR TONS	% LOAD	KW INPUT	MINIMUM ECWT, °F	CORRESPONDING CONDENSING PRESSURE IN HG Vac
150	100	111	53.8	3.41
113	75	84	52.1	6.02
75	50	63	50.2	8.52
38	25	53	48.5	10.6
15	10	51	47.4	11.82

Predicted compressor motor KW Input and minimum condenser water flow rates at various load conditions and head pressure valve controller settings follow:

LOAD CONDITION EVAPORATOR TONS	% LOAD	KW[2] INPUT	HEAD PRESSURE VALVE CONTROLLER SETTING IN HG Vac	CONDENSER WATER FLOW, GPM
150	100	111	3.41	136
75[2]	50	72	3.41	69
75[2]	50	63	8.52	96
38[2]	25	57	3.41	43
15	10	51	11.82	50

NOTES:

1. Constants: 319 GPM of chilled water.
   42°F Leaving Chilled Water Temperature.
   32°F ECWT
2. Data requested by Bechtel during the August 23, 1984 meeting in York, PA.

ARS, 8/24/84

CALC MC6406 R/0
ATTACH. REF. 20
SH. 4 OF 7

ATTACHMENT "B"

STP ESSENTIAL SAFETY CLASS 300 TON WATER CHILLERS

CUSTOMER P.O. NOS. 14926-4310/8310

B-W S.O. NOS. 83-916,519/529(H)

Predicted compressor motor KW Input, minimum ECWT and corresponding condenser pressures allowed at various load conditions at a design condenser water flow rate of 1,100 GPM follow:

LOAD CONDITION, EVAPORATOR TONS	% LOAD	KW INPUT	MINIMUM ECWT, °F	CORRESPONDING CONDENSING PRESSURE IN HG Vac
300	100	354 ✓	53.3	5.2
225	75	265	51.8	6.9
150	50	194	50.1	9.2
75	25	139	48.4	11.1
30	10	125	47.5	12.2

Predicted compressor motor KW Input and minimum condenser water flow rates at various load conditions and head pressure valve controller settings follow:

LOAD CONDITION EVAPORATOR TONS	% LOAD	KW^2 INPUT	HEAD PRESSURE VALVE CONTROLLER SETTING IN HG Vac	CONDENSER WATER FLOW, GPM
300	100	202	5.2	260
150^2	50	120	5.2	150
150^2	50	103	9.2	198
75^2	25	93	5.2	102
30	10	87	12.2	105

NOTES:

1. Constants: 637 GPM of chilled water.
   42°F Leaving Chilled Water Temperature.
   32°F ECWT
2. Data requested by Bechtel during the August 23, 1984 meeting in York, PA.

ARS. 8/24/84

ATTACHMENT "C"

WED. AUG 22. 1984. 8:47 AM

CALC MC 6406 R/0
ATTACH. REF. 20
SH. 5 OF 7

USER NAME HOUSTON LIGHTING & POWER CO.

LOCATION WADSWORTH, TEXAS

77-780615 /616(H)
SOUTH TEXAS PROJECT
SAFETY CLASS WATER CHILLERS

BY A.R. SHANKO, JR.

NO. UNITS SIX (6)

POWER INPUT 186 KW

MAXIMUM KW = 215

VOLTS 460 / 3 / 60

FLA 259.5

LRA DELTA 1209

LRA STAR ---

STARTER TYPE ACROSS-THE-LINE

FULL LOAD DESIGN PERFORMANCE DATA FOR A
TURBOPAK MODEL NO HTH4B1-BBCS, R-11, UNIT DUTY 150 TR

	CONDENSER	COOLER
FLUID TYPE	WATER	WATER
GPM	600.	319.
TEMP ON - F	107.9	53.3
TEMP OFF - F	116.1	42.0
FOULING FACTOR	.00200	.00050
PASSES	4	4
TUBE VEL - FPS	10.17	6.17
PRESS DROP - FT	46.60	22.28
TUBE TYPE	STANDARD FIN	STANDARD FIN
TUBE MATL & NO.	90/10 CU NI - 347	COPPER - 304
EXT SURF - SQ FT	3061. (26 FPI)	2681. (26 FPI)
DWP - WATER SIDE	150 PSIG	150 PSIG

COMPR MODEL B1 SPEED CODE LP REFR 11

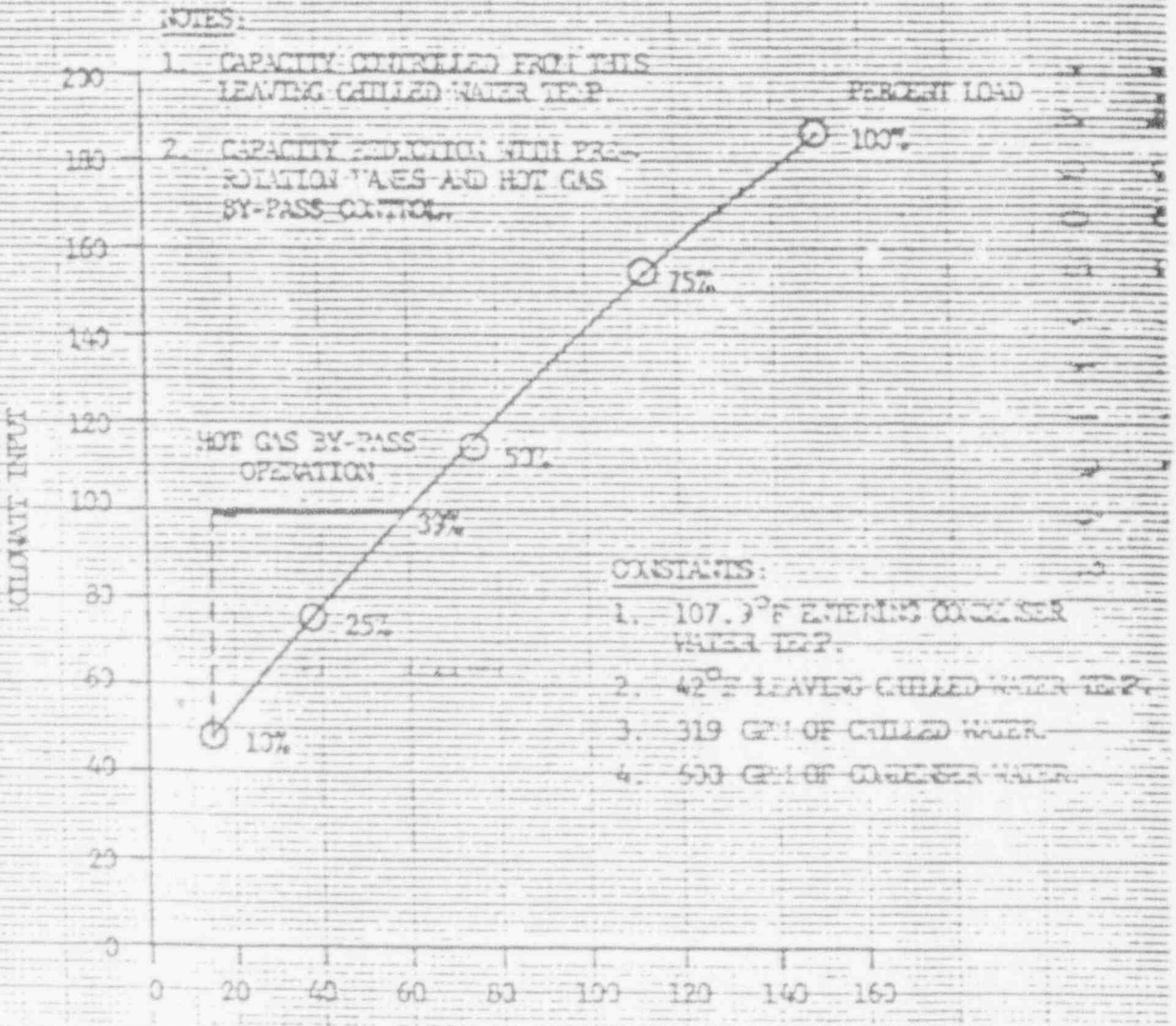
NOTE:

REVISED PERFORMANCE PARAMETERS SPECIFIED IN ADDENDUM 1 TO SPECIFICATION 3V249VS0004 REV. 0 DATED 5-29-84.

CALC MC6406 R/0, CALC REF 20 ATTACH.
SH. 6 OF 7

ATTACHMENT "D"

PREDICTED FULL AND PART LOAD
PERFORMANCE CURVE FOR A
YORK MODEL HTM481-BBCS R-11 TURBOPAK
STP EAS SAFETY CLASS WATER CHILLERS
CUSTOMER P.O. NO. 35-1197-4102/8102
BORG-WARNER S.O. NOS. 77-730,615/616(M)
SPECIFICATION 3V249VS0004 REV. 0 ADDENDUM 1



NOTES:
1. CAPACITY CONTROLLED FROM THIS LEAVING CHILLED WATER TEMP.
2. CAPACITY REDUCTION WITH PRE-ROTATION VANES AND HOT GAS BY-PASS CONTROL.

CONSTANTS:
1. 107.9°F ENTERING CONDENSER WATER TEMP.
2. 42°F LEAVING CHILLED WATER TEMP.
3. 319 GPM OF CHILLED WATER.
4. 600 GPM OF CONDENSER WATER.

BORG-WARNER AIR CONDITIONING, INC.

CALC MC 6406 R/0
ATTACH. REF 20
SH. 7 OF 7

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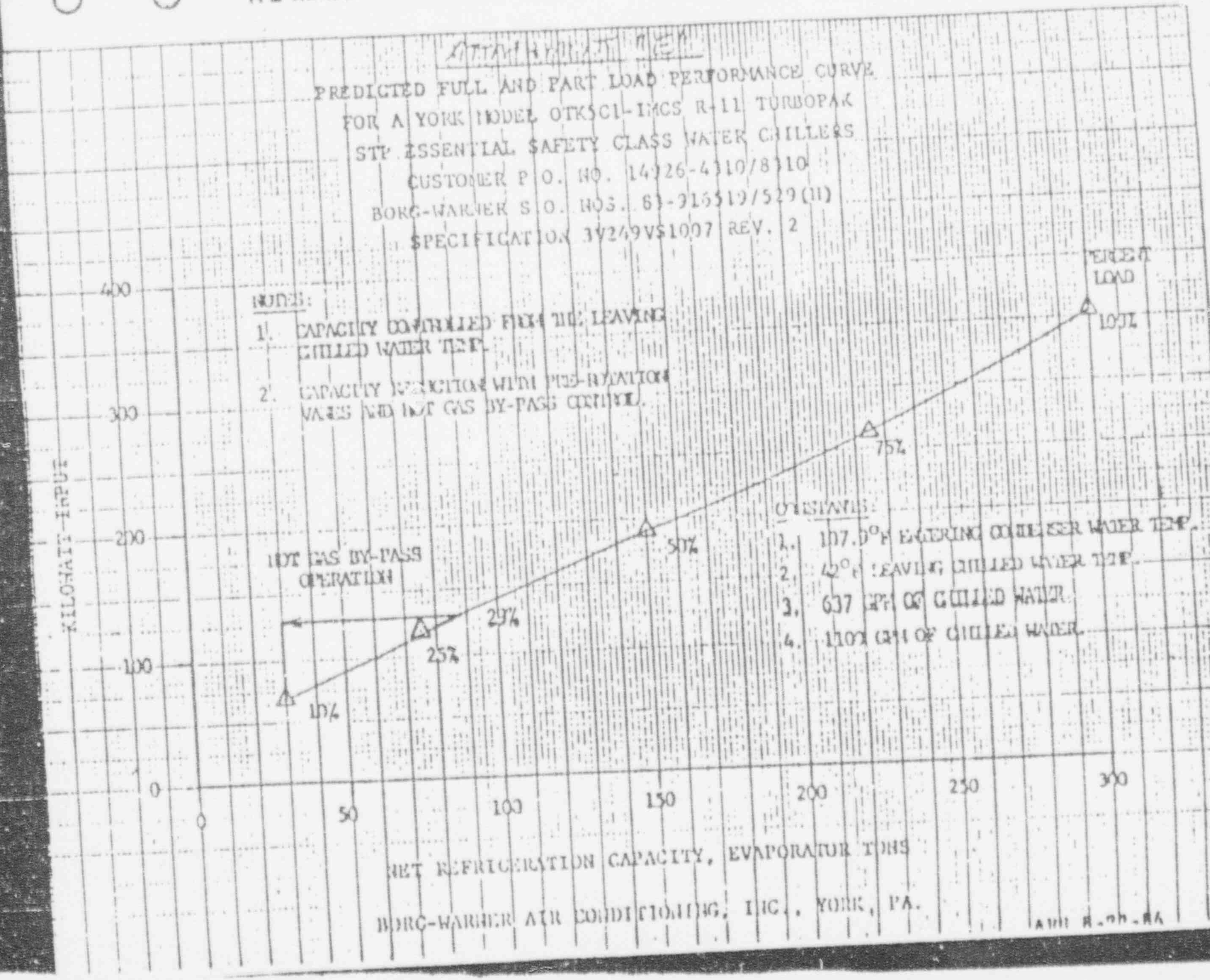

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PREDICTED FULL AND PART LOAD PERFORMANCE CURVE
FOR A YORK MODEL OTK5C1-IMCS R-11 TURBOPAK
STP ESSENTIAL SAFETY CLASS WATER CHILLERS
CUSTOMER P.O. NO. 14926-4310/8310
BORG-WARNER S.O. NOS. 63-916519/529(II)
SPECIFICATION 3V249VS1007 REV. 2

NOTES:

1. CAPACITY CONTROLLED FROM THE LEAVING CHILLED WATER TEMP.
2. CAPACITY REDUCTION WITH PRE-ROTATION VANES AND HOT GAS BY-PASS CONTROL.

CONSTANTS:

1. 107.0°F ENTERING CONDENSER WATER TEMP.
2. 42°F LEAVING CHILLED WATER TEMP.
3. 637 GPM OF CHILLED WATER.
4. 1103 GPM OF CHILLED WATER.

BORG-WARNER AIR CONDITIONING, INC., YORK, PA.