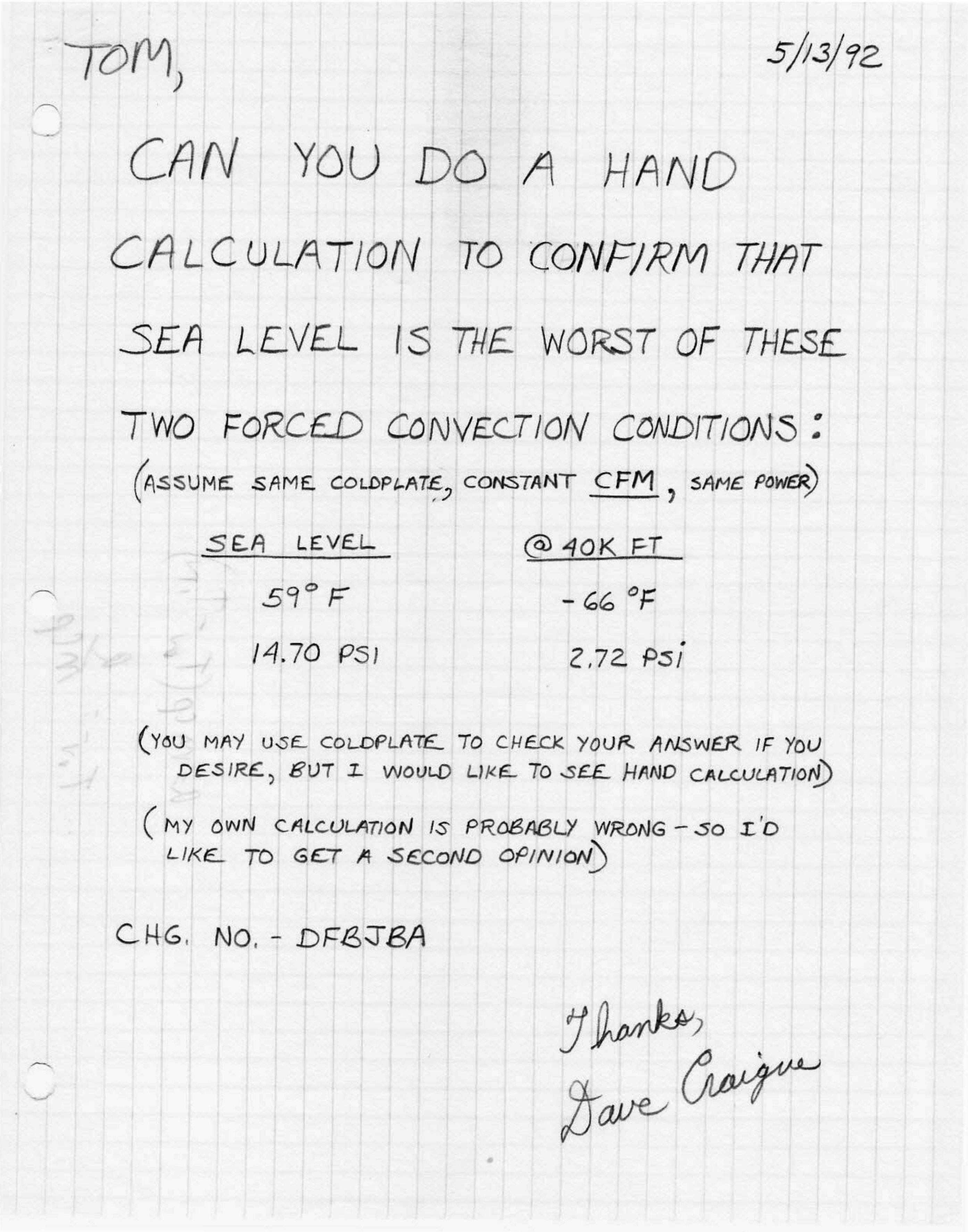
This example compares a hand analysis results to COLDPLATE results.

- Not that there is a slight difference in results between the two, because COLDPLATE iterates to the correct fluid temperature properties, i.e. the density and viscosity values.

- The Colburn (j) and Fanning (f) curves come from Compact Heat Exchangers by Kays and London.



TOM,

5/13/92

CAN YOU DO A HAND CALCULATION TO CONFIRM THAT SEA LEVEL IS THE WORST OF THESE TWO FORCED CONVECTION CONDITIONS:

(ASSUME SAME COLDPLATE, CONSTANT <u>CFM</u>, SAME POWER)

SEA LEVEL	@ 40K FT
59° F	- 66 °F
14.70 PSI	2.72 PSI

(YOU MAY USE COLDPLATE TO CHECK YOUR ANSWER IF YOU DESIRE, BUT I WOULD LIKE TO SEE HAND CALCULATION)

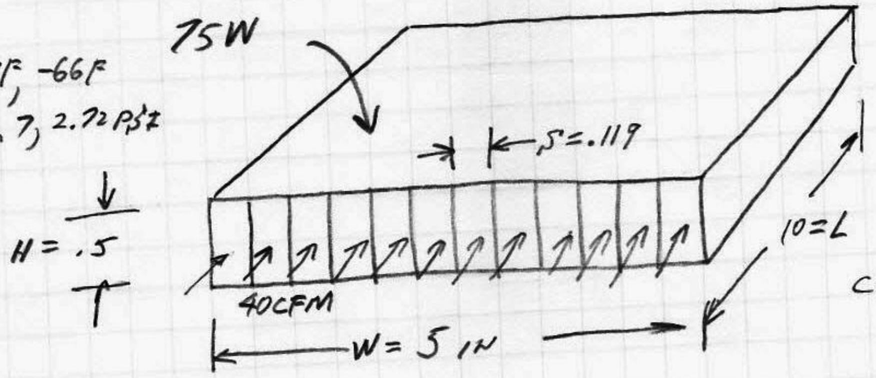
(MY OWN CALCULATION IS PROBABLY WRONG - SO I'D LIKE TO GET A SECOND OPINION)

CHG. NO. - DFBJBA

Thanks,
Dave Craigue

T. RENAUD
5/19/92
SHT. 1

$T_{IN} = 59F, -66F$
$P_{IN} = 14.7, 2.72\ PSI$



$CFM = V A_{FFA}$

8 FIN/IN
$t_{FIN} = .006$ THICK FINS

$N = (8\ FIN/IN)(5\ IN) = 40\ FINS$

$$A_{FIN} = 2HLN = (2)(.5\ IN)(10\ IN)(40\ FINS) = 400\ IN^2$$

$$A_{BASE} = (W - N t_{FIN})L = [5 - (40)(.006)][10] = 10\ IN^2$$

$$A_{\substack{CROSS\\SECTIONAL\\FLOW\ AREA}} = A_{FFA} = WH\left(1 - \frac{N t_{FIN}}{W}\right) = (5)(.5)\left(1 - \frac{(40)(.006)}{5}\right) = 2.38\ IN^2$$

$$D_{HYD} = \frac{2HS}{H+S} = \frac{(2)(.5)(.119)}{.5 + .119} = .192\ IN$$

$$\rho_{\substack{59F\\14.7\ PSI}} = \frac{P}{RT} = \frac{(14.7)(144)}{(53.34)(460+59)} = .0765\ LB/FT^3$$

$$\rho_{\substack{-66F\\2.72\ PSI}} = .0186\ LB/FT^3$$

$$Re_y = \frac{\rho V D_{HYD}}{\mu} = \frac{\rho D_{HYD}\ CFM}{\mu A_{FFA}}$$

$$\mu_{@59F} = .04635\ \frac{LB}{HR\text{-}FT} \qquad \mu_{-66F} = .03455\ \frac{LB}{HR\text{-}FT}$$

T. RENAUD
5/14/92
SHT 2

$$\underset{\substack{59F\\14.7PSI}}{Rey} = \frac{\left(.0765\,\frac{LB}{FT^3}\right)\left(.192\,IN\right)\left(40\,\frac{FT^3}{MIN}\right)}{\left(.04635\,\frac{LB}{HR\text{-}FT}\right)\left(\frac{1\,HR}{60\,MIN}\right)\left(2.30\,IN^2\right)\left(\frac{1\,FT}{12\,IN}\right)} = 3835$$

$$\underset{\substack{-66F\\2.72\ PSI}}{Rey} = 1250$$

$$\alpha = \frac{H}{S} = \frac{.5}{.119} = 4.2$$

$$\frac{L}{D_{HYD}} = \frac{10}{.192} = 52$$

from Kays & London Fig 7-3 & 7-4

$$\underset{\substack{59F\\14.7PSI}}{j} = .0035 \qquad \underset{\substack{-66F\\2.72PSI}}{j} = .0053$$

$$j = \frac{h\,A_{FFA}\,Pr^{2/3}}{\dot{m}\,c_p} = \frac{h\,A_{FFA}\,Pr^{2/3}}{\rho\ CFM\ c_p}$$

$$h = j\,\frac{\rho\ CFM\ c_p}{A_{FFA}\,Pr^{2/3}}$$

$$\underset{59F}{c_p} \approx \underset{-66F}{c_p} = 7.6\ \frac{W\text{-}MIN}{LB\text{-}°C}$$

$$\underset{59F}{P_r} = .711 \qquad \underset{-66F}{P_r} = .732$$

T. RENAUD
5/14/92
SHT. 3

$$h_{\substack{59F\\14.7\,PSI}} = .0035\,\frac{\left(.0765\,\frac{LB}{FT^3}\right)\left(40\,\frac{FT^3}{MIN}\right)\left(7.6\,\frac{W\text{-}MIN}{LB\text{-}°C}\right)}{\left(2.38\,IN^2\right)\left(.711\right)^{2/3}} = .0429\,\frac{W}{IN^2\text{-}°C} = 11.7\,\frac{BTU}{HR\text{-}FT\text{-}F°}$$

$$h_{\substack{-66F\\2.72\,PSI}} = .0155\,\frac{W}{IN^2\text{-}°C} = 4.23\,\frac{BTU}{HR\text{-}FT^2\text{-}F°}$$

FIN EFF.
$$\eta = \frac{TANH\left[\left(\frac{2h}{Kt_{FIN}}\right)^{1/2} H\right]}{\left(\frac{2h}{Kt_{FIN}}\right)^{1/2} H}$$

$$K_{ALUM} = 3.9\,\frac{W}{IN\text{-}°C}$$

$$\left(\frac{2h}{Kt_{FIN}}\right)^{1/2}_{\substack{59F\\14.7}} H = \left[\frac{(2)\,.0429\,\frac{W}{IN^2\text{-}°C}}{\left(3.9\,\frac{W}{IN\text{-}°C}\right)(.006\,IN)}\right]^{1/2}\left[.5\,IN\right] = .9574$$

$$\left(\frac{2h}{Kt_{FIN}}\right)^{1/2}_{\substack{-66F\\2.72}} H = .5755$$

$$\eta_{\substack{59F\\14.7\,PSI}} = \frac{TANH\,(.9574)}{.9574} = .776$$

$$\eta_{\substack{-66\\2.72\,PSI}} = \frac{TANH\,(.5755)}{.5755} = .902$$

T. RENAUD
5/14/92
SHT. 4

$$C_1 = h\left(A_{FIN}\,\eta + A_B\right) = \frac{1}{\Theta_{HA}}$$

$$C_{1_{59F}} = \left(.0429\,\frac{W}{IN^2\text{-}°C}\right)\left(400 \times .776 + 10\right) IN^2 = 13.7\ W/°C$$

$$\Theta_{HA_{59F}} = .0727\ °C/W$$

$$C_{1_{-66F}} = (.0155)\left(400 \times .902 + 10\right) = 5.75\ W/°C$$

$$\Theta_{HA_{-66F}} = .174\ °C/W$$

$$\dot{m}\,C_{p_{59F}} = C_2 = \rho\ CFM = \left(.0765\,\frac{LB}{FT^3}\right)\left(40\,\frac{FT^3}{MIN}\right)\left(7.6\,\frac{W\text{-}MIN}{LB\text{-}°C}\right) = 23.256\ W/°C$$

$$C_2 = \dot{m}\,C_{p_{-66F}} = 5.65\ W/°C$$

NTU = NO. OF THERMAL UNITS = C_1/C_2

$$NTU_{59F} = \frac{13.7}{23.256} = .589 \qquad NTU_{-66F} = 1.018$$

ϵ = HEAT SINK EFFECTIVENESS = $1 - e^{-NTU}$

$$\epsilon_{59F} = 1 - e^{-.589} = .445 \qquad \epsilon_{-66F} = .638$$

T. RENAUD
5/14/92
SHT. 5

$$Q = \epsilon \dot{m} c_p (T_{CP} - T_{AIR_{IN}})$$

$$\Theta_{ACP} = \Theta_{AIR\,TO\,CP} = \frac{T_{CP} - T_{AIR_{IN}}}{Q} = \frac{1}{\epsilon \dot{m} c_p} = \frac{1}{\epsilon C_2}$$

THERMAL RESISTANCE
INLET AIR TO
COLDPLATE

$$\Theta_{ACP_{59F}} = \frac{1}{(.445)23.256\ W/C} = .0966\ {}^\circ C/W$$

$$\Theta_{ACP_{-66F}} = .277\ {}^\circ C/W$$

$$T_{CP} = Q\Theta_{ACP} + T_{IN}$$

$$T_{CP_{59F}} = (75W)(0966) + 15C = \underline{22.2\ {}^\circ C}$$

$$T_{CP_{-66F}} = (75)(.277) + (-54C) = \underline{-33\ {}^\circ C}$$

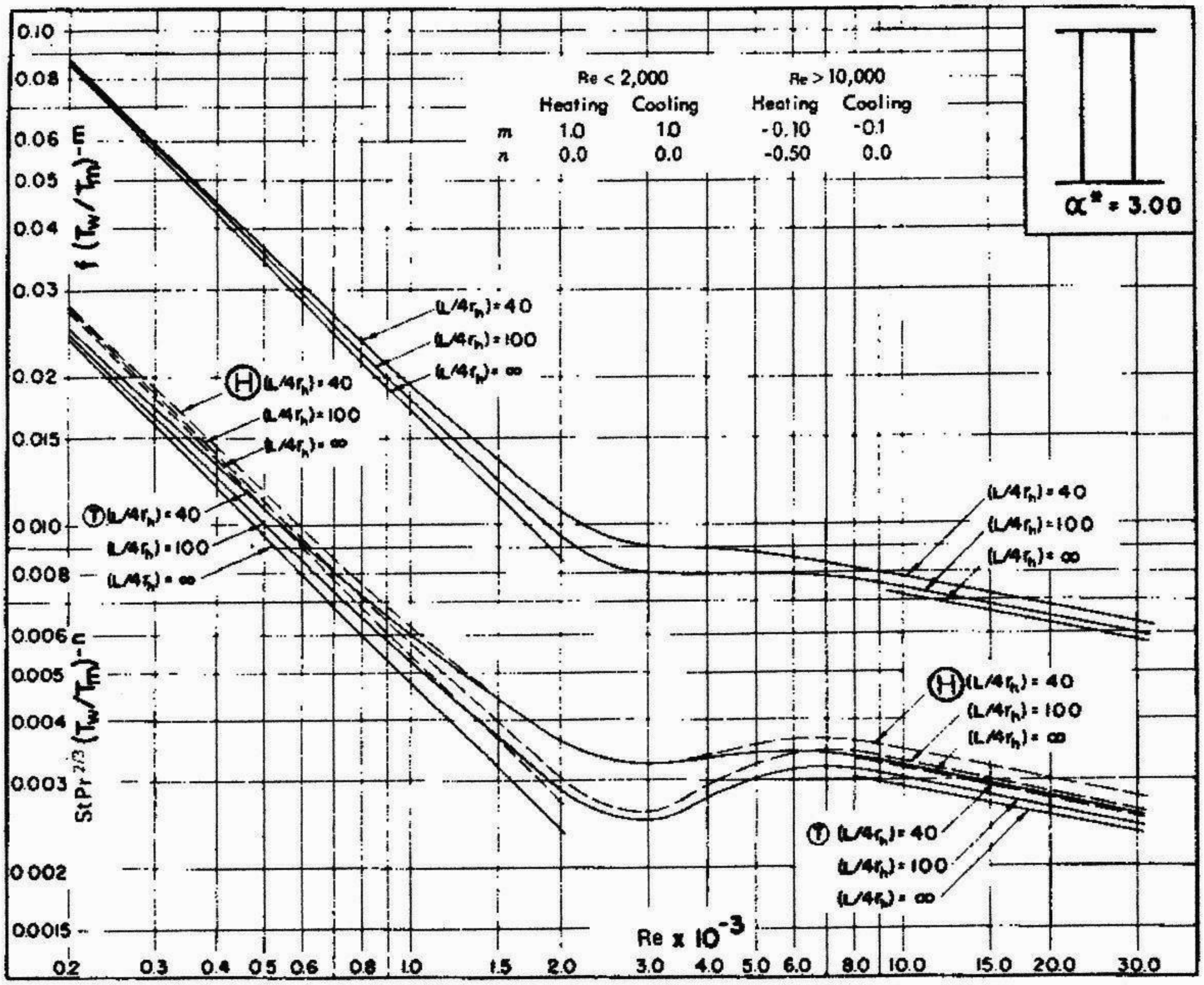
Calculate the coldplate temp by adding the exhaust air temp to the convection air temp. rise

$$T_{CP} = T_{IN} + \frac{Q}{\dot{m} c_p} + \frac{Q}{hA} = T_{IN} + \frac{Q}{C_2} + Q\Theta_{HA}$$

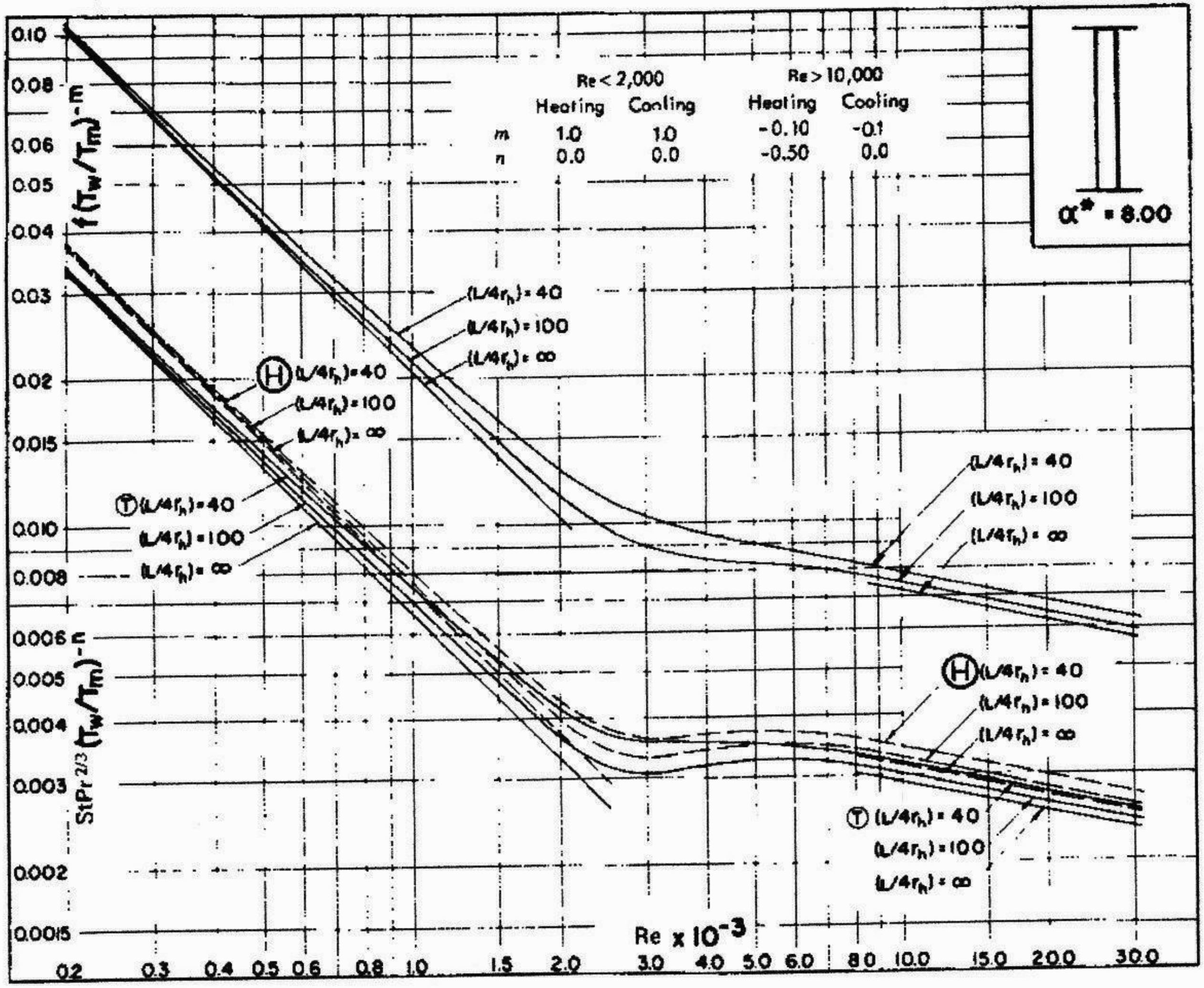
$$T_{CP_{59F}} = 15C + \underbrace{\frac{75W}{23.25C\ W/C}}_{3.2\,{}^\circ C} + \underbrace{(75W)(.0727\ W/C)}_{5.4\,{}^\circ C} = \underline{23.7\ {}^\circ C}$$

$$T_{CP_{-66F}} = -54 + 13.3 + 13 = \underline{-27.6\ {}^\circ C}$$

Gas flow inside rectangular tubes with abrupt-contraction entrances; a summary of experimental and analytical data.



Gas flow inside rectangular tubes with abrupt-contraction entrances; a summary of experimental and analytical data.



Correlation between hand analysis and Coldplate

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                        HEATING ON ONE SIDE ONLY

************************* VARIABLE INPUTS **************************
THE TYPE OF FINS SPECIFIED ARE:                    RECTANGULAR
FIN HEIGHT, INCHES                                       0.500
BASE THICKNESS, INCHES                                   0.062
FIN THICKNESS, INCHES                                    0.0060
FIN DENSITY, FINS PER INCH                               8.0
STATIC INLET FLUID TEMPERATURE, DEG C                   15.0
INLET PRESSURE, LBS/IN2                                 14.70
VOLUME FLOWRATE, FT3/MIN                                40.00
THE POWER APPLIED TO ONE SIDE ONLY, WATTS               75.00
THE COOLING FLUID IS:                            AIR

**************** INTERMEDIATE CALCULATED PARAMETERS ****************
FREE FLOW CROSS SECTIONAL AREA, IN2                      2.38
HYDRAULIC DIAMETER, INCHES                               0.192
COLDPLATE WEIGHT, LBS                                    0.67
TOTAL MASS FLOWRATE, LBS/MIN                             3.04
COLD PLATE MASS FLOWRATE, LBS/MIN                        3.04
COLDPLATE VOL FLOWRATE, [GAL/MIN] FT3/MIN [   299.2]    40.00
COLDPLATE VELOCITY, FT/SEC                              40.34
REYNOLDS NUMBER                                       4070.
EQUIVALENT FRICTION LOSS COEFFICIENT, KFRICTION          1.84
INLET LOSS COEFFICIENT, KINLET                           0.82
EXIT LOSS COEFFICIENT, KEXIT                            -0.73
FILM COEFFICIENT, [BTU/(HR-FT2-F)] W/(IN2-C)  [  10.90]  0.0399
THE FIN EFFICIENCY WITH HEAT ON ONE SIDE ONLY IS         0.748

*************************** PRESSURE *******************************
INLET PRESSURE, [LB/IN2] INCHES-H2O      [ 14.700]     407.077
INLET PRESSURE DROP, INCHES-H2O                          0.336
ACCELERATION PRESSURE DROP, INCHES-H2O                   0.009
FRICTIONAL PRESSURE DROP, INCHES-H2O                     0.679
EXIT PRESSURE DROP, INCHES-H2O                          -0.307
TOTAL PRESSURE DROP, INCHES-H2O                          0.717
EXIT PRESSURE, [LB/IN2] INCHES-H2O       [ 14.674]     406.360
DENSITY RATIO TIME PRESSURE DROP, INCHES-H20             0.7127

************************ THERMAL RESISTANCE ************************
THERMAL RESISTANCE FROM INLET FLUID TO COLDPLATE, C/W    0.090
THERMAL RESISTANCE FROM LOCAL FLUID TO COLDPLATE, C/W    0.066

************************** TEMPERATURES ****************************
STATIC INLET FLUID TEMPERATURE, DEG C                   15.0
STAGNATION FLUID TEMP RISE ALONG COLDPLATE, DEG C        3.2
TOTAL STAGNATION FLUID TEMP RISE, DEG C                  3.2
STATIC EXIT FLUID TEMPERATURE, DEG C                    18.2
ISOTHERMAL COLDPLATE TEMPERATURE, DEG C                 21.8
MAXIMUM COLDPLATE TEMPERATURE, DEG C                    23.2
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                 INLET FLUID TEMPERATURE=  15.0 C
   Correlation between hand analysis and Coldplate

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                        HEATING ON ONE SIDE ONLY

************************* VARIABLE INPUTS **************************
THE TYPE OF FINS SPECIFIED ARE:                    RECTANGULAR
FIN HEIGHT, INCHES                                       0.500
BASE THICKNESS, INCHES                                   0.062
FIN THICKNESS, INCHES                                    0.0060
FIN DENSITY, FINS PER INCH                               8.0
STATIC INLET FLUID TEMPERATURE, DEG C                  -54.0
INLET PRESSURE, LBS/IN2                                  2.72
VOLUME FLOWRATE, FT3/MIN                                40.00
THE POWER APPLIED TO ONE SIDE ONLY, WATTS               40.00
THE COOLING FLUID IS:                            AIR

**************** INTERMEDIATE CALCULATED PARAMETERS ****************
FREE FLOW CROSS SECTIONAL AREA, IN2                      2.38
HYDRAULIC DIAMETER, INCHES                               0.192
COLDPLATE WEIGHT, LBS                                    0.67
TOTAL MASS FLOWRATE, LBS/MIN                             0.72
COLD PLATE MASS FLOWRATE, LBS/MIN                        0.72
COLDPLATE VOL FLOWRATE, [GAL/MIN] FT3/MIN [   299.2]    40.00
COLDPLATE VELOCITY, FT/SEC                              40.34
REYNOLDS NUMBER                                      1179.
EQUIVALENT FRICTION LOSS COEFFICIENT, KFRICTION          3.70
INLET LOSS COEFFICIENT, KINLET                           0.82
EXIT LOSS COEFFICIENT, KEXIT                            -0.73
FILM COEFFICIENT, [BTU/(HR-FT2-F)] W/(IN2-C)   [    4.18]  0.0153
THE FIN EFFICIENCY WITH HEAT ON ONE SIDE ONLY IS         0.882

*************************** PRESSURE *******************************
INLET PRESSURE, [LB/IN2] INCHES-H2O      [  2.720]      75.323
INLET PRESSURE DROP, INCHES-H2O                          0.078
ACCELERATION PRESSURE DROP, INCHES-H2O                   0.011
FRICTIONAL PRESSURE DROP, INCHES-H2O                     0.324
EXIT PRESSURE DROP, INCHES-H2O                          -0.075
TOTAL PRESSURE DROP, INCHES-H2O                          0.339
EXIT PRESSURE, [LB/IN2] INCHES-H2O       [  2.708]      74.985
DENSITY RATIO TIME PRESSURE DROP, INCHES-H20             0.0798

************************ THERMAL RESISTANCE ************************
THERMAL RESISTANCE FROM INLET FLUID TO COLDPLATE, C/W    0.259
THERMAL RESISTANCE FROM LOCAL FLUID TO COLDPLATE, C/W    0.148

************************** TEMPERATURES ****************************
STATIC INLET FLUID TEMPERATURE, DEG C                  -54.0
STAGNATION FLUID TEMP RISE ALONG COLDPLATE, DEG C       13.7
TOTAL STAGNATION FLUID TEMP RISE, DEG C                 13.7
STATIC EXIT FLUID TEMPERATURE, DEG C                   -40.3
ISOTHERMAL COLDPLATE TEMPERATURE, DEG C                -34.6
MAXIMUM COLDPLATE TEMPERATURE, DEG C                   -29.1
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