4 Pass Liquid Cooled Cold Plate Model

This example builds a model of a 4 pass liquid tubed cold plate shown below. This models AAVID Thermalloy's water cooled Cold Plate, part number 416501U00000G (http://aavidthermalloy.com/product-group/liquidcoldplates/tube) and compares the COLDPLATE model results to AAVID Thermalloy performance curve. In addition, a plot of the plate temperature is shown at 2 GPM.

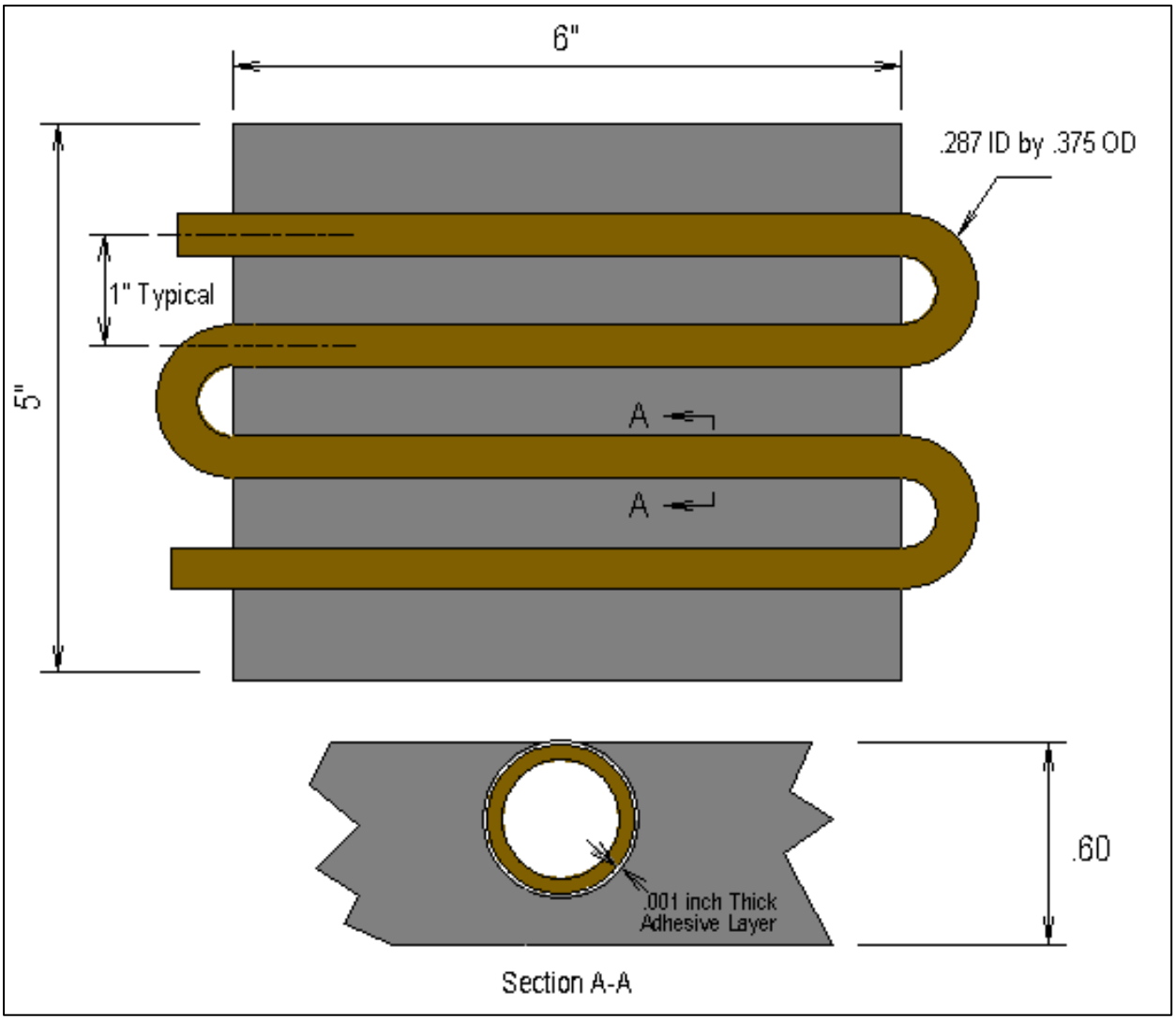
The cold plate design parameters are listed below:

- The base plate is .60 inches thick and made of extruded 6063-T6 aluminum.
- The .287 ID by .375 OD tube is bonded to the base plate with an assumed .002 thick bond line using 3M's Scotch Weld 2216 which has a thermal conductivity of .01W/(in-C). In addition, assume a 270 degree angle of adhesive contact. The thermal contact resistance per inch is calculated below:

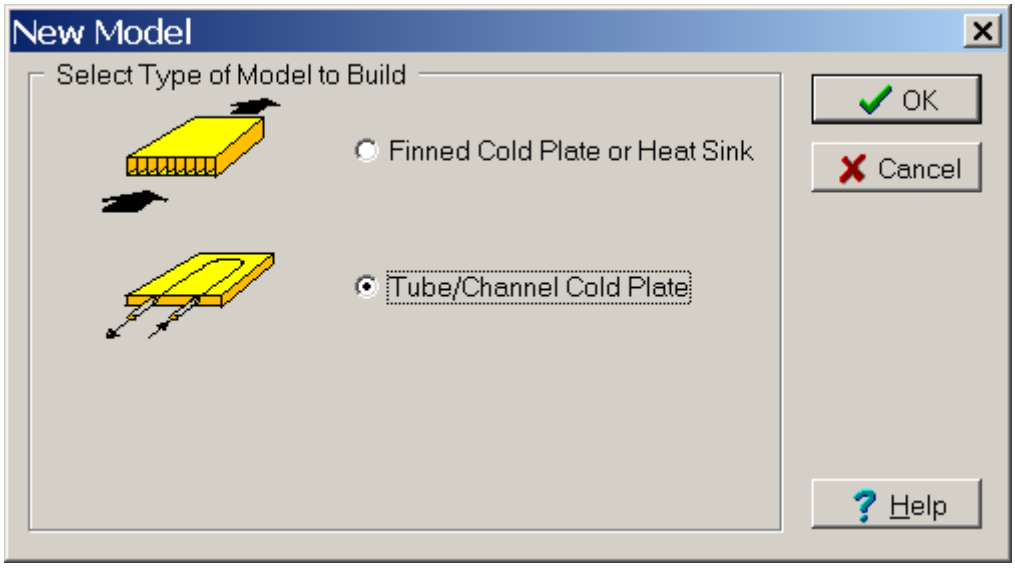
  Contact Area = 3.14 * (360-90)/90 * .375 inch OD * 1 in. length = .88 sq inches

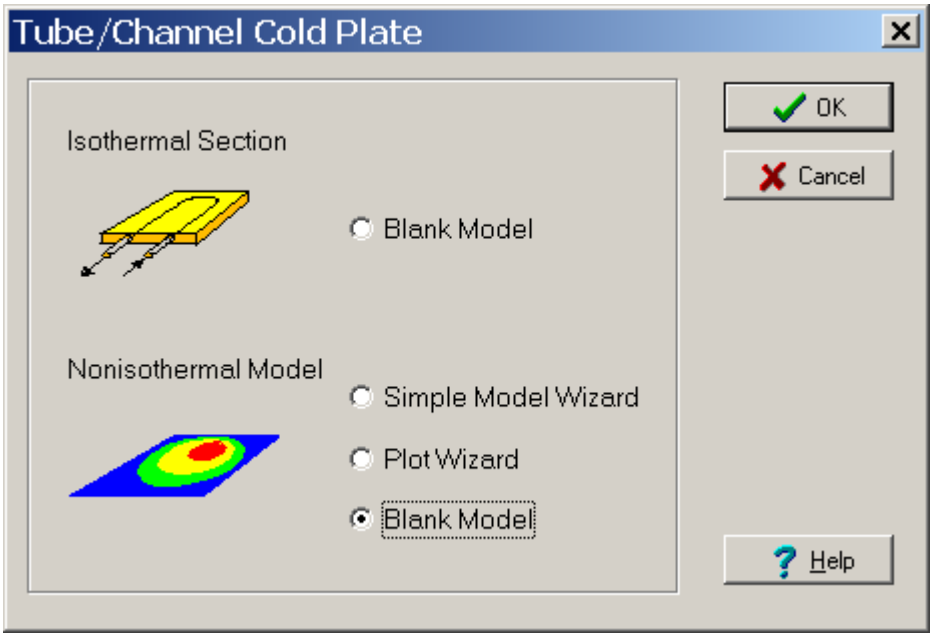
  Thermal Resistance (C-in/W) = t / KA = .002/(.01*.88) = .226
- Assume a power of 1000W (this does not affect the results)
- Assume the inlet water temperature is 20C at 200 PSI inlet pressure (this has minimal affect on the results).
- Use a pressure drop loss coefficient of 1.0 for each turn of the extended tubes, 3 turns times 1.0 for each turn equals a total loss coefficient of 3.0.
- Run the model with 10 flow rates from .5 to 5.0 GPM.

Shown below are the dimensions and location of the tube cooling loop.

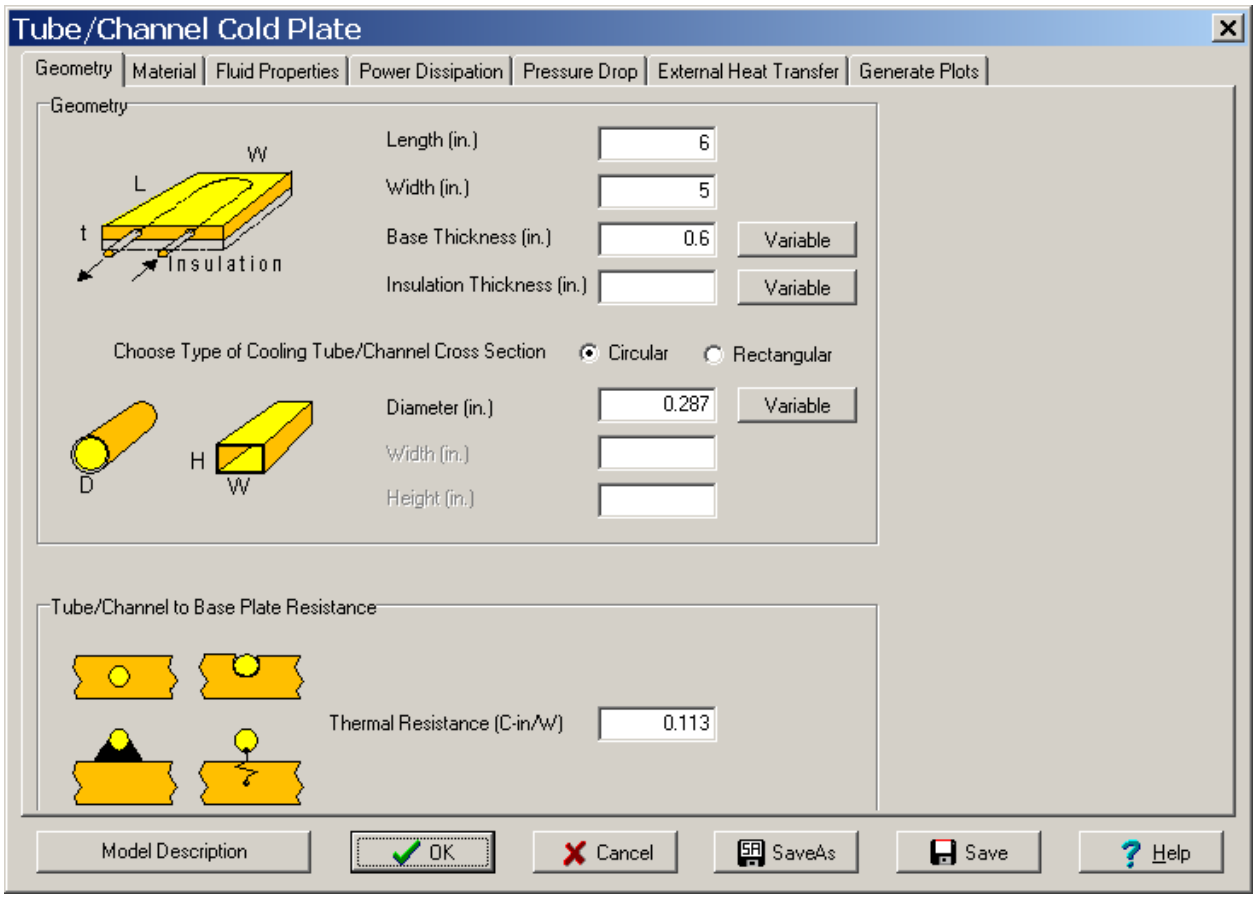


Select the "New Model" form then the "Tube/Channel Cold Plate" Form

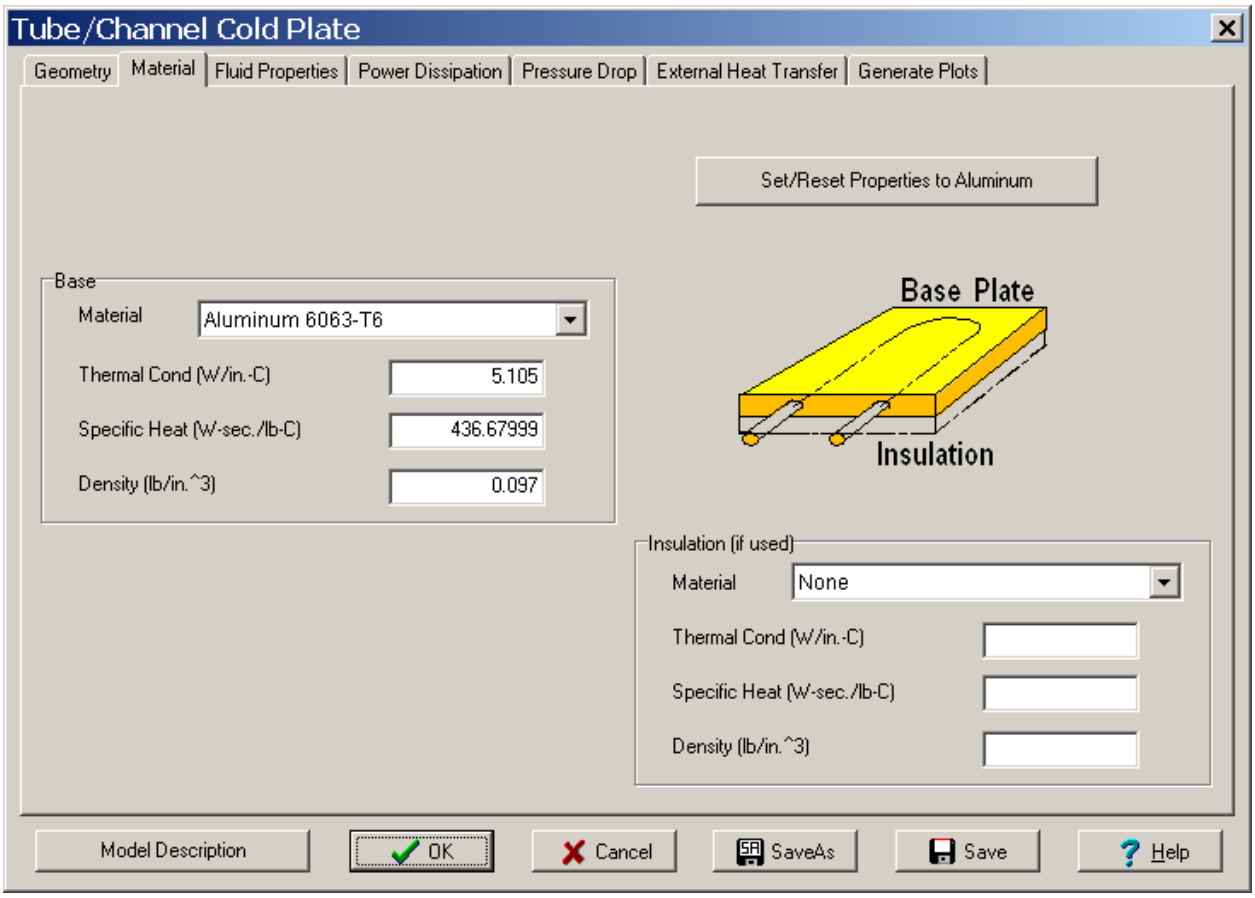




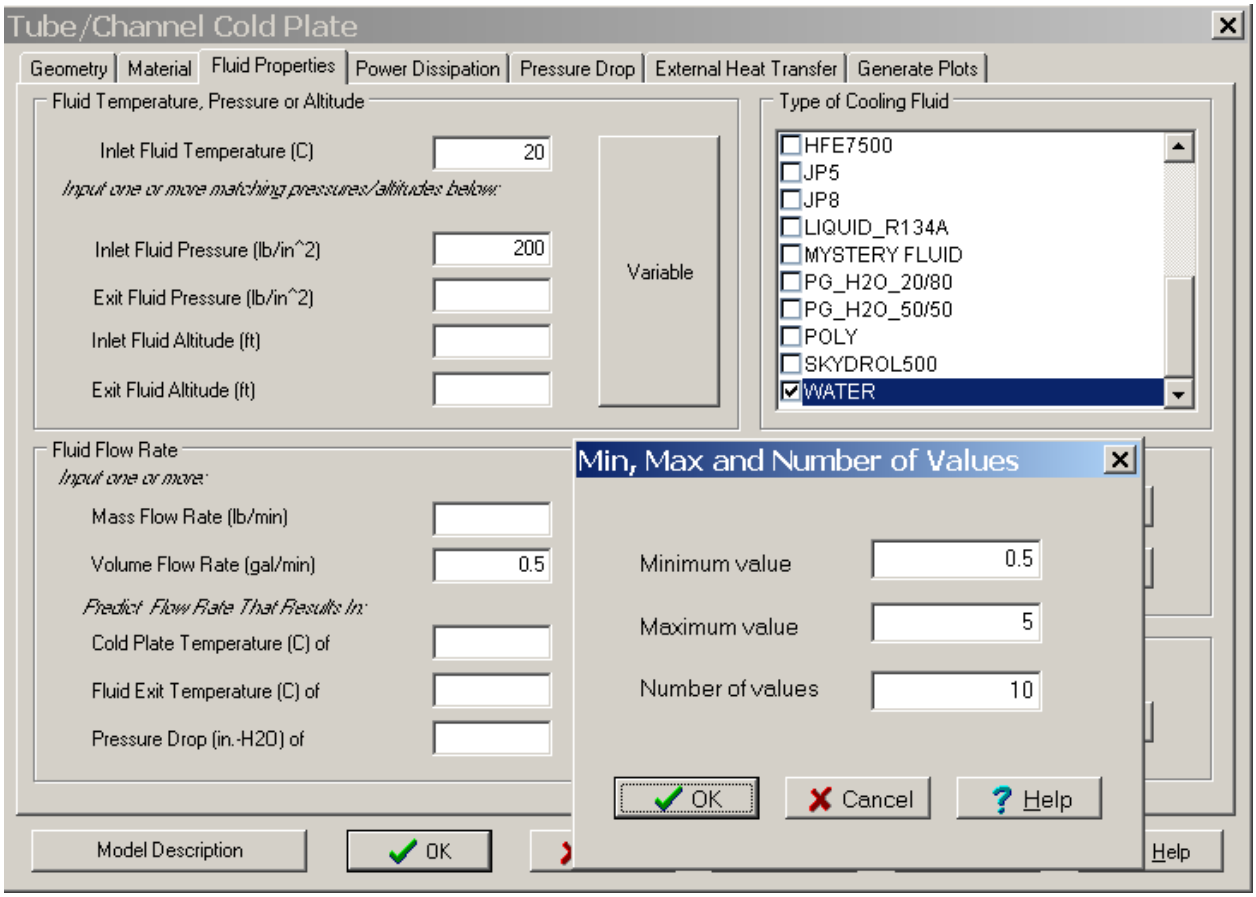
The plate and tube dimension as well as the thermal resistance from the tube to the plate are input on the Geometry Tab sheet shown below.



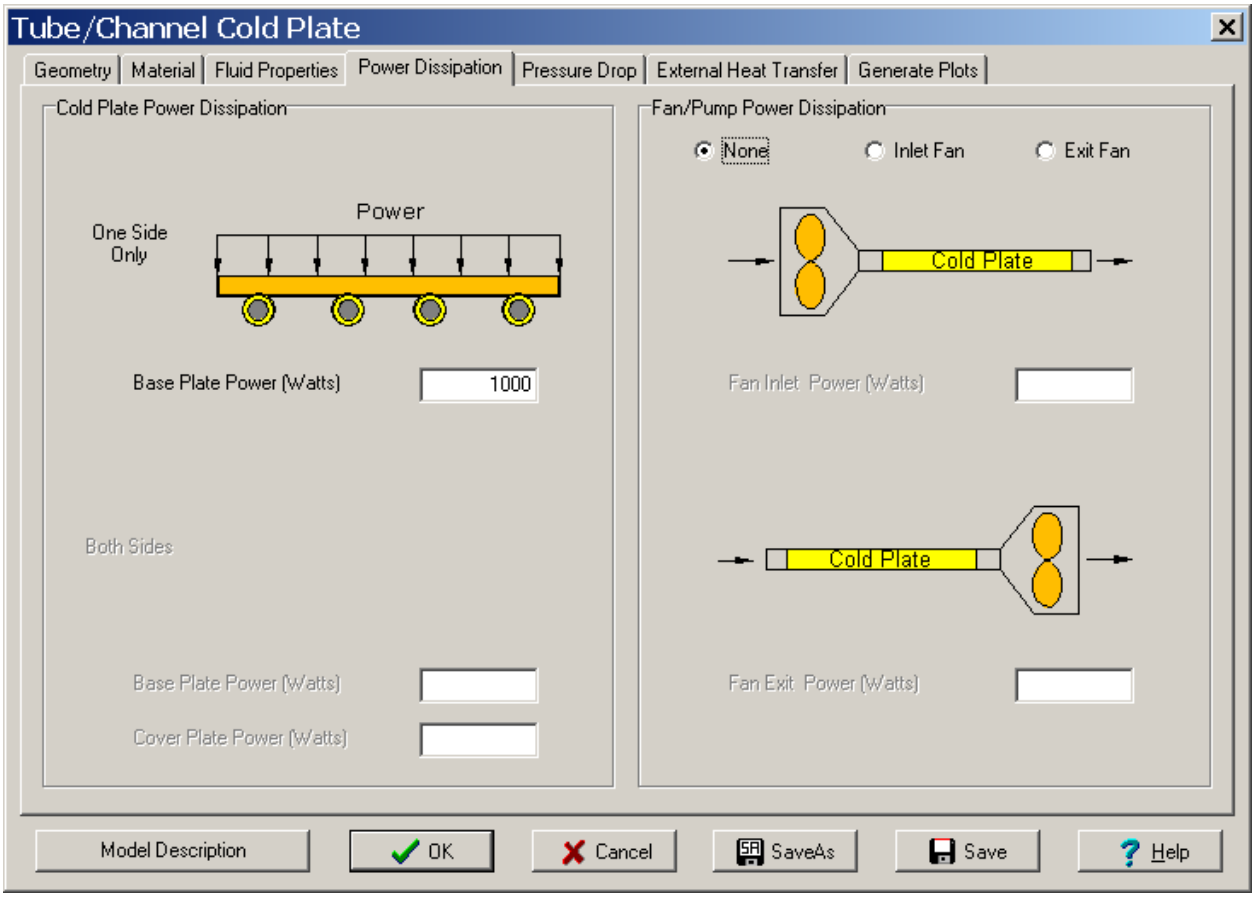
The plate material, 6063-T6 is selected from the material data base on the Material Tab sheet.



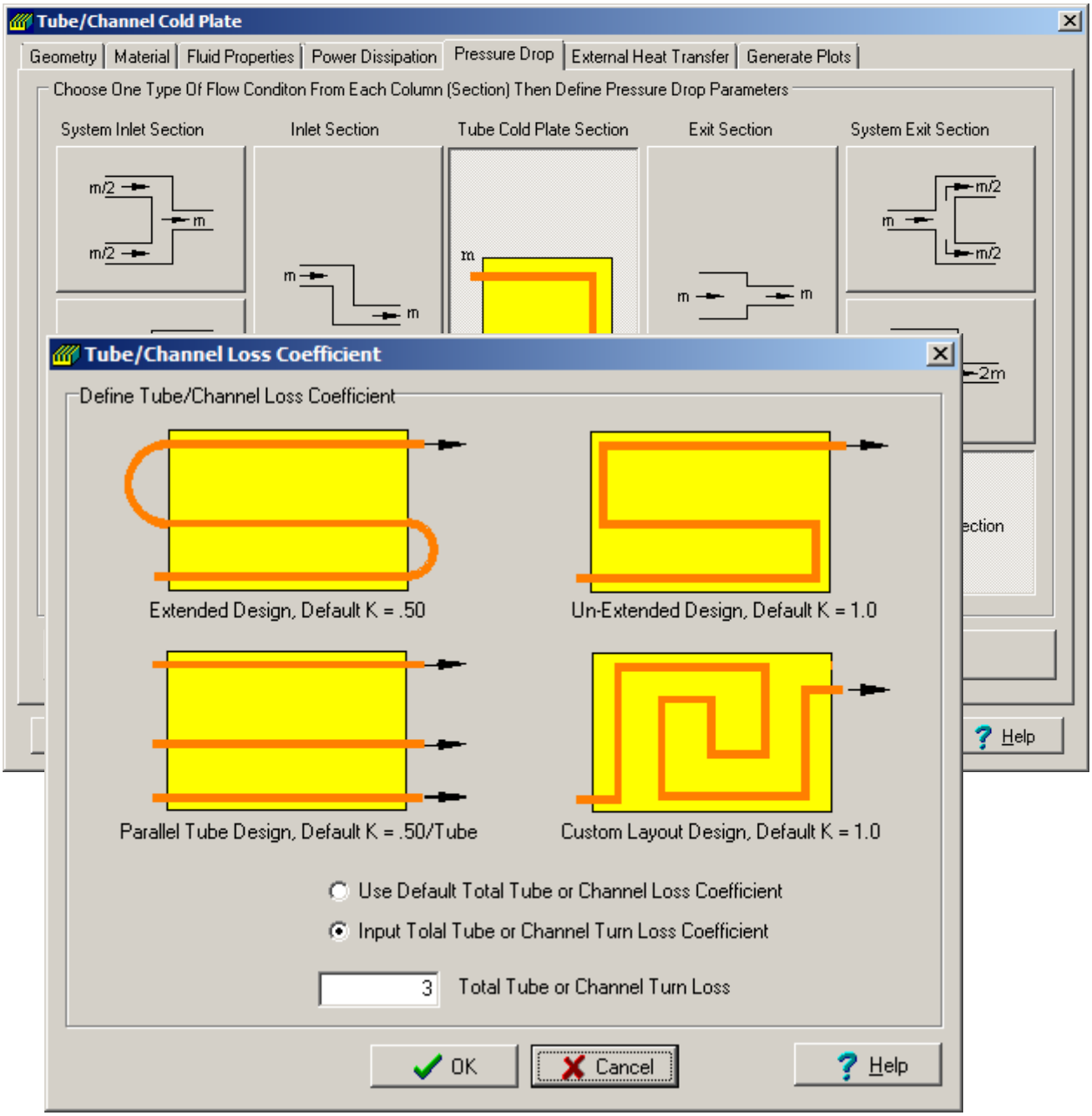
The fluid properties including the inlet temperature, pressure, type of fluid and flow rate are input on the Fluid Tab sheet. In addition, the range of fluid flow rates is input on the "Variable" button.



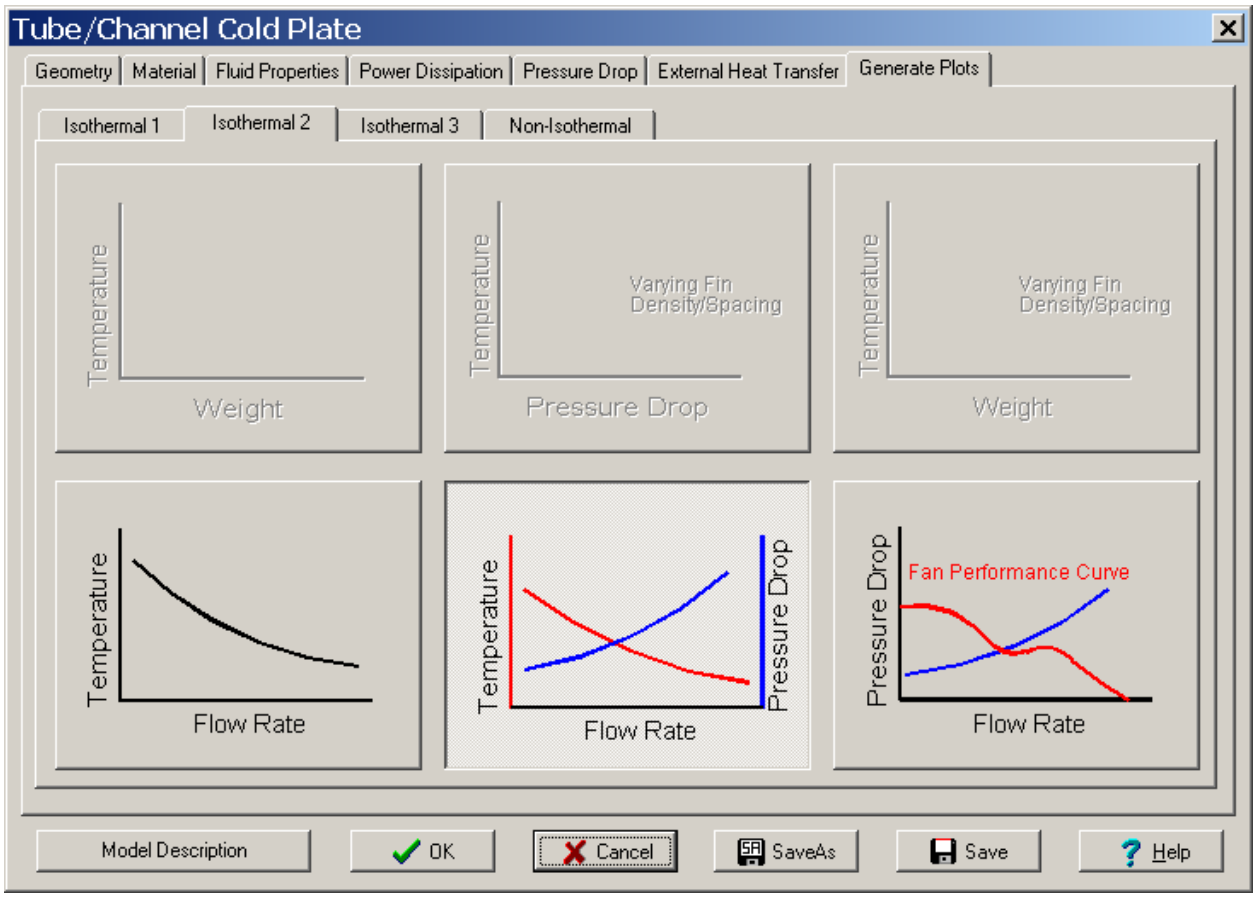
The power is input on the Power Tab sheet, it will be uniformly distributed on the cold plate.



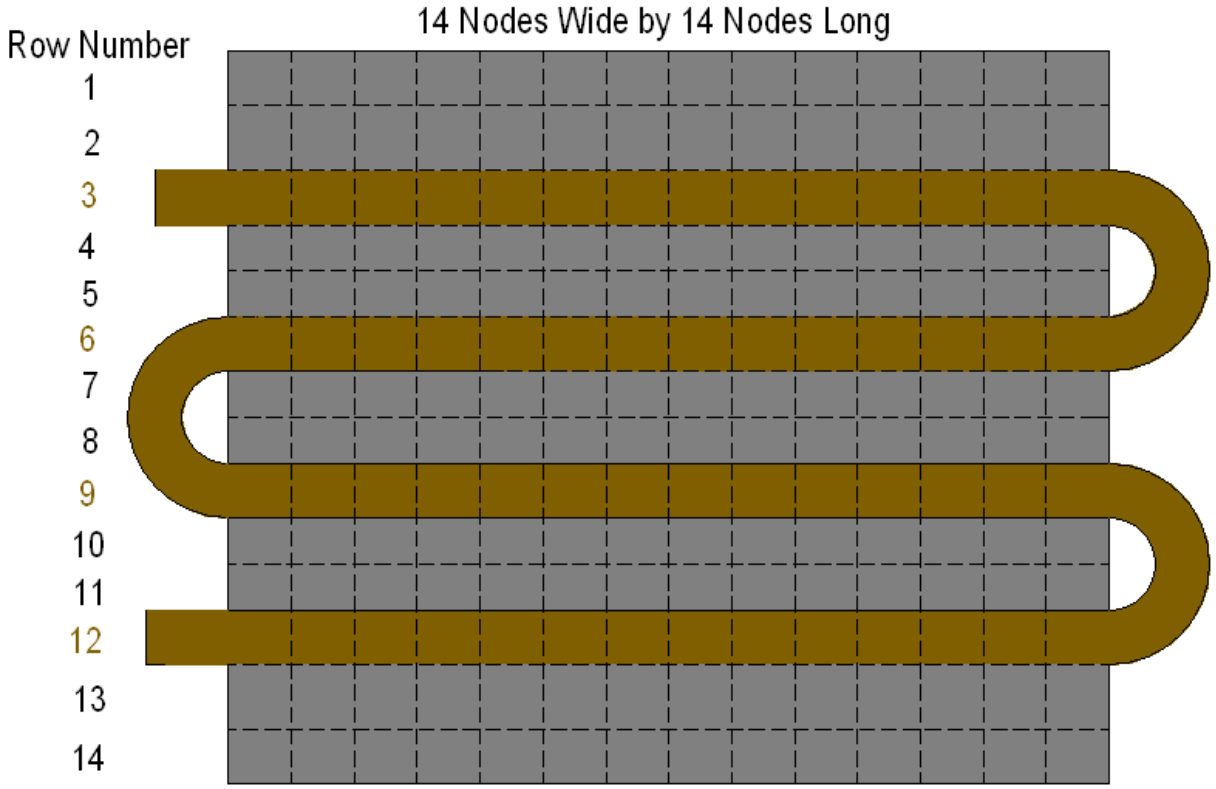
The pressure drop loss coefficient total of 3.0 is input by selecting the "Tube Cold Plate Section" button on the Pressure Drop Tab sheet.



The "Temperature and Pressure Drop versus Flow Rate" Plot button is select to generate the plot we need to compare to AAVID Thermalloy's performance curve. We just need to change the Temperature data to Thermal Resistance data since everything else is as we need it.

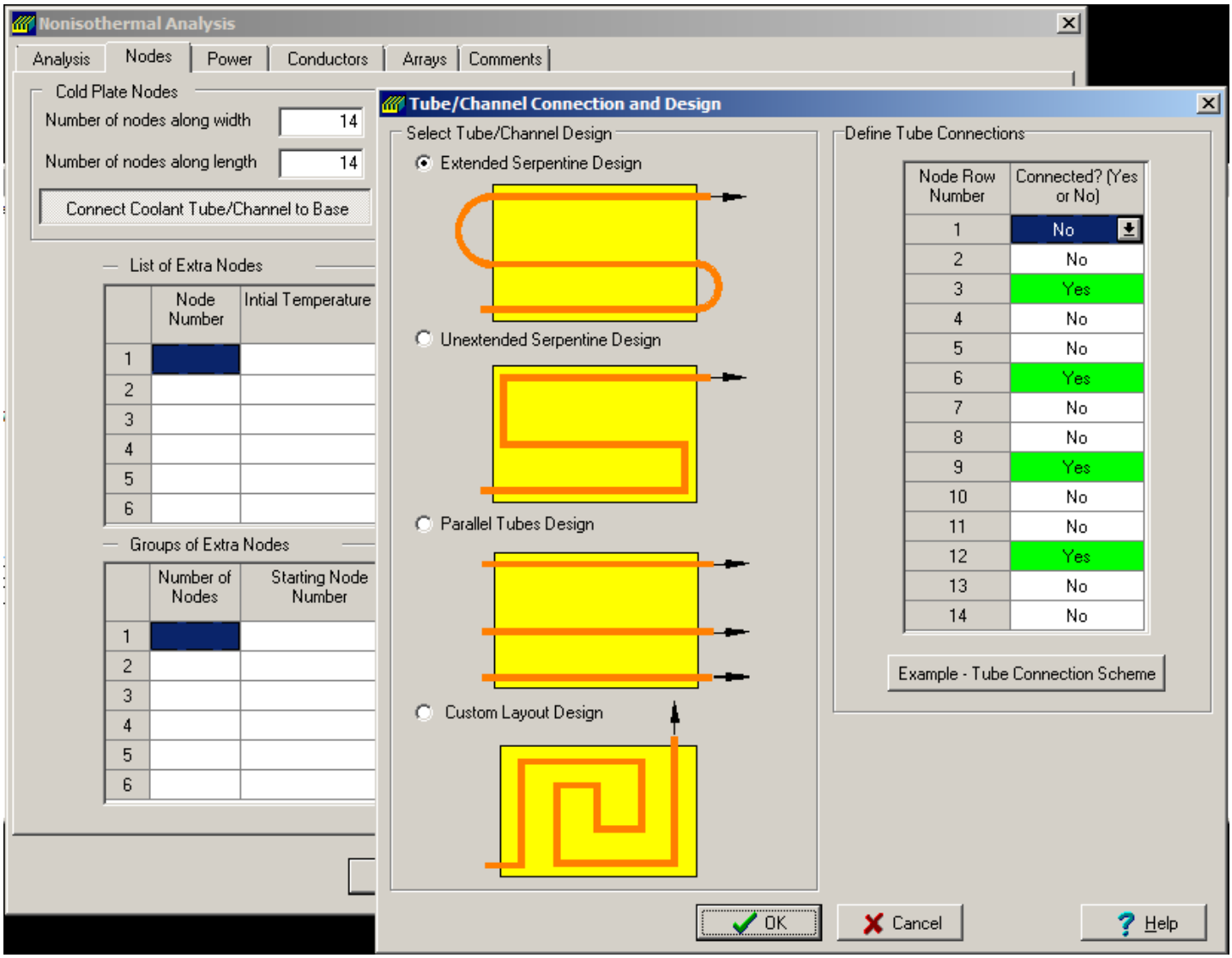


The next input data breaks the cold plate into 14 nodes along the width and 14 along the length. In addition, the tube is connected the plate at Row Numbers 3, 6, 9 and 12 as shown below. The number of nodes along the length was chosen somewhat arbitrary just to keep the node length and width equal, this is not necessary. This data is input on the Nonisothermal form shown in the next page.



Here, on the Nonisothermal form, the number of nodes along the width, 14 and the number of nodes along the length, 14 are input. The "Connect Coolant Tube/Channel to Base" button is clicked and then Row Numbers 3, 6, 9 and 12 are selected as "Yes" to connect them to the base plate. Notice also that the "Extended Design" radio button is selected to simulate the AAVID Thermalloy cold plate design.

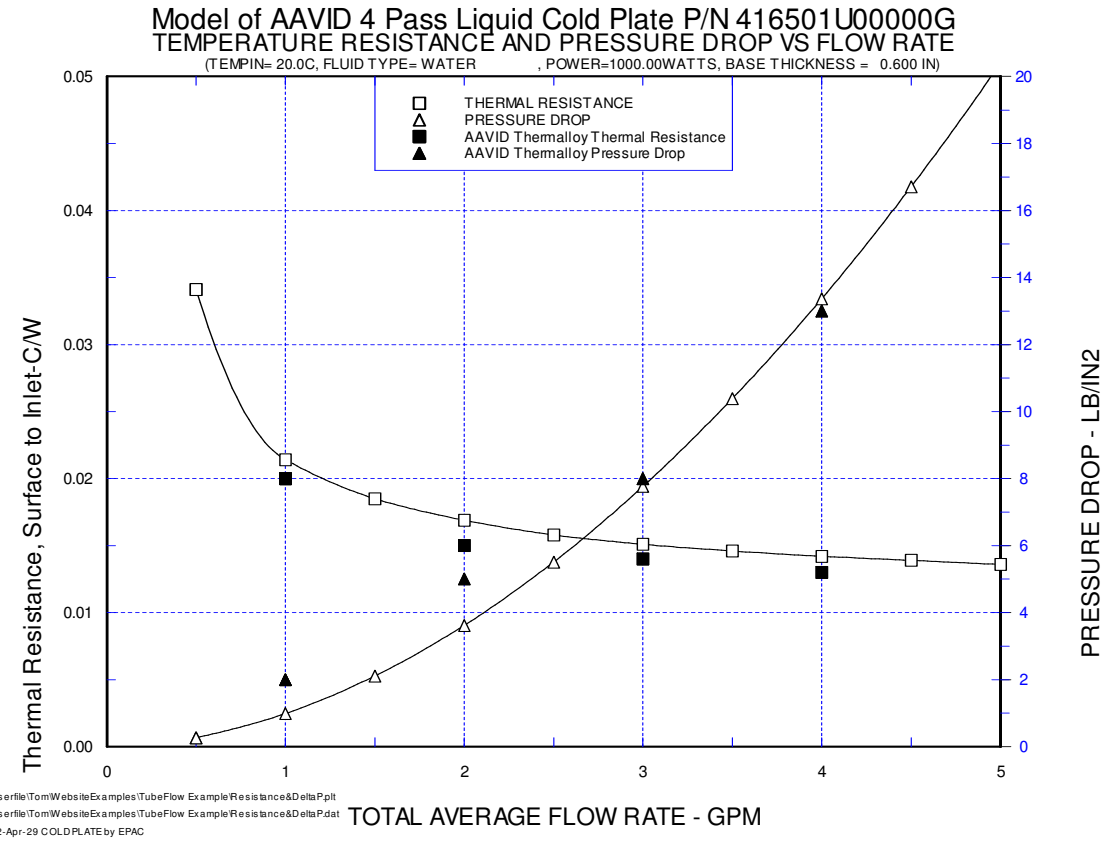
That's it, the model now ready to save and then run.



The model was run and then the Temperature values were replaced by the Thermal Resistance values from the .int, intermediate file, shown below. This is done by editing the CrvPlot table and plot which was automatically generated when the "Plot" button was selected.

MASS FLOW RATE LB/MIN	VOLUME FLOW RATE GAL/MIN	VELOCITY FT/SEC	SPECIFIC HEAT W-MIN/LB/C	REYNOLDS NUMBER	FILM COEFF. W/(IN2-C)	FILM COEFF. BTU/ (HR-FT2-F)	EFFICIENCY %	THERMAL RESISTANCE INLET FLUID TO COLDPLATE C/W	THERMAL RESISTANCE LOCAL FLUID TO COLDPLATE C/W
4.154	0.50	2.48	31.69	5939.	1.93451	528.20	0.0	0.0301	0.0241
8.311	1.00	4.96	31.71	11402.	4.62446	1262.66	0.0	0.0171	0.0131
12.468	1.50	7.44	31.71	16872.	6.35576	1735.38	0.0	0.0141	0.0108
16.625	2.00	9.92	31.72	22329.	7.97292	2176.93	0.0	0.0125	0.0095
20.782	2.50	12.40	31.72	27774.	9.50972	2596.53	0.0	0.0115	0.0087
24.939	3.00	14.88	31.72	33219.	10.98655	2999.77	0.0	0.0108	0.0081
29.096	3.50	17.36	31.72	38664.	12.41518	3389.84	0.0	0.0103	0.0077
33.253	4.00	19.84	31.72	44110.	13.80376	3768.98	0.0	0.0099	0.0074
37.410	4.50	22.32	31.72	49556.	15.15822	4138.80	0.0	0.0095	0.0071
41.567	5.00	24.80	31.72	55002.	16.48303	4500.53	0.0	0.0093	0.0069

The resultant plot is shown below with the AAVID Thermalloy's cold plate performance shown as solid squares and triangles. A comparison of this plot and AAVID Thermalloy's performance curve show very close agreement, especially considering that a number of design parameters had to be assumed. This demonstrates the capability and easy of use of the COLDPLATE software.



This next section lists the results at the 2.0 GPM flow rate. Note that data was calculated and written out at each of the 10 different flow rates, only the results at 2.0 GPM are shown below.

TUBE/CHANNEL FLOW MODEL

********** VARIABLE INPUTS **********	
BASE THICKNESS, INCHES	0.600
TUBE DIAMETER, INCHES	0.2870
STATIC INLET FLUID TEMPERATURE, DEG C	20.0
INLET PRESSURE, LBS/IN2	200.00
VOLUME FLOWRATE, GAL/MIN	2.00
THE COOLING FLUID IS:	WATER
********** INTERMEDIATE CALCULATED PARAMETERS **********	
FREE FLOW CROSS SECTIONAL AREA, IN2	0.065
HYDRAULIC DIAMETER, INCHES	0.287
TUBE LENGTH FOR PRESSURE DROP, INCHES	25.929
TUBE LENGTH FOR HEAT TRANSFER, INCHES	25.929
COLDPLATE WEIGHT, LBS	1.81
TOTAL MASS FLOWRATE, LBS/MIN	16.625
COLD PLATE MASS FLOWRATE, LBS/MIN	16.625
COLDPLATE VOL FLOWRATE, [GAL/MIN] FT3/MIN [2.00]	0.267
COLDPLATE VELOCITY, FT/SEC	9.92
AVERAGE DENSITY, LB/FT3	62.182
AVERAGE CONDUCTIVITY, W/(IN-C)	0.01529
AVERAGE SPECIFIC HEAT, W-MIN/(LB-C)	31.718
AVERAGE DYNAMIC VISCOSITY, LB/(MIN-IN)	0.003303
PRANDTL NUMBER	6.854
REYNOLDS NUMBER	22329.
EQUIVALENT FRICTION LOSS COEFFICIENT, KFRICTION	2.48
FILM COEFFICIENT, [BTU/(HR-FT2-F)] W/(IN2-C) [2176.93]	7.9729
********** PRESSURE **********	
INLET PRESSURE, LB/IN2	200.000
ACCELERATION PRESSURE DROP, LB/IN2	0.000
FRICTIONAL PRESSURE DROP, LB/IN2	1.638
TUBE TURN LOSS PRESSURE DROP, LB/IN2	1.980
TOTAL PRESSURE DROP, LB/IN2	3.619
EXIT PRESSURE, LB/IN2	196.381
********** THERMAL RESISTANCE **********	
THERMAL RESISTANCE FROM INLET FLUID TO COLDPLATE, C/W	0.017
THERMAL RESISTANCE FROM LOCAL FLUID TO COLDPLATE, C/W	0.014
********** TEMPERATURES **********	
STATIC INLET FLUID TEMPERATURE, DEG C	20.0
STAGNATION FLUID TEMP RISE ALONG COLDPLATE, DEG C	1.9
TOTAL STAGNATION FLUID TEMP RISE, DEG C	1.9
STATIC EXIT FLUID TEMPERATURE, DEG C	21.9
ISOTHERMAL COLDPLATE TEMPERATURE, DEG C	36.9
MAXIMUM COLDPLATE TEMPERATURE, DEG C	37.8

The following pages show the detail temperature results at 2.0 GPM

INLET FLUID TEMPERATURE= 20.0 C EXIT FLUID TEMPERATURE= 21.9 C

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------------
| CP TEMP  |
| FLD TEMP |
| POWER    |
| NODE NO. |
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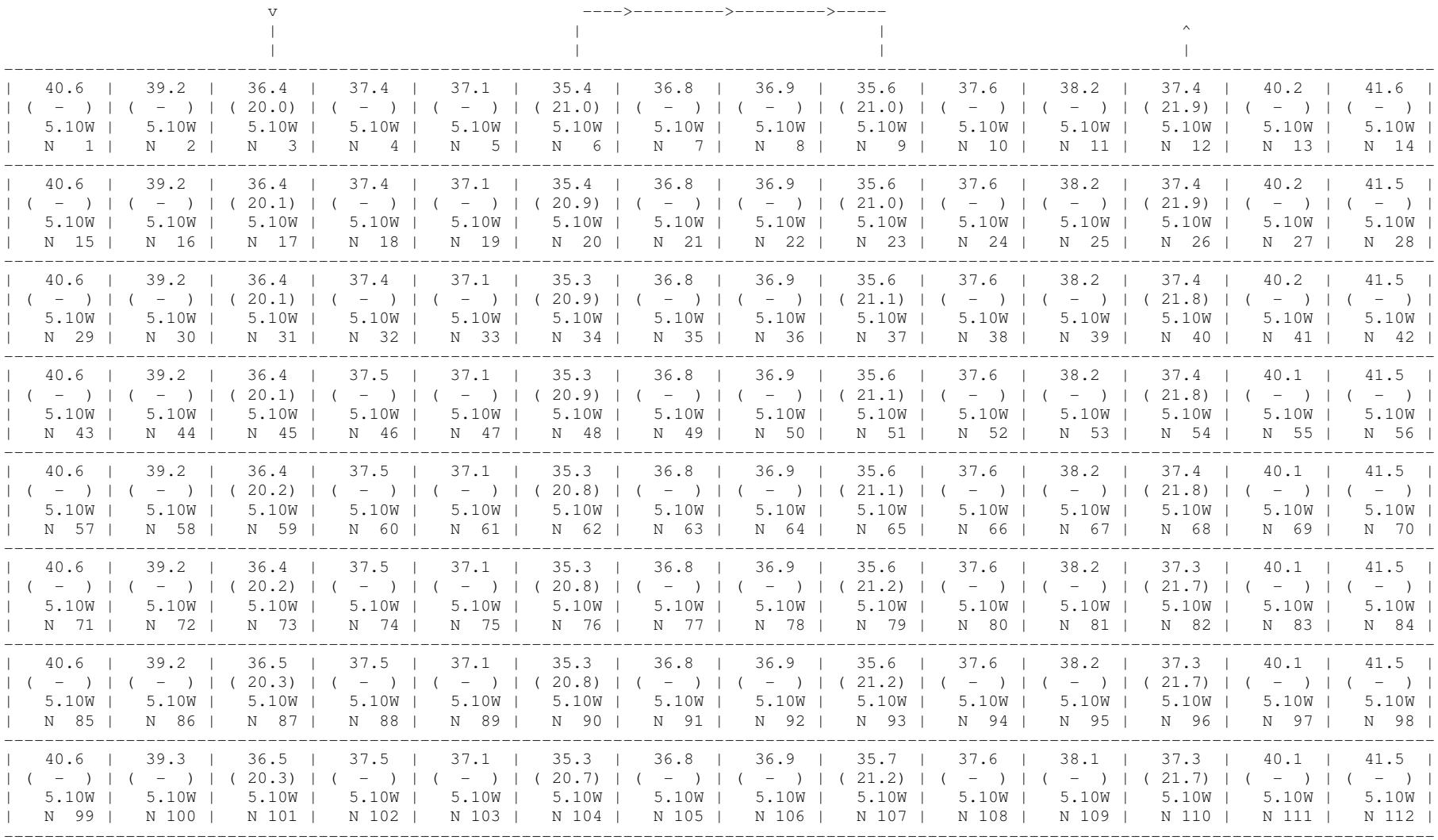

40.6	39.2	36.4	37.4	37.1	35.4	36.8	36.9	35.6	37.6	38.2	37.4	40.2	41.6
(-)	(-)	(20.0)	(-)	(-)	(21.0)	(-)	(-)	(21.0)	(-)	(-)	(21.9)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	N 11	N 12	N 13	N 14
40.6	39.2	36.4	37.4	37.1	35.4	36.8	36.9	35.6	37.6	38.2	37.4	40.2	41.5
(-)	(-)	(20.1)	(-)	(-)	(20.9)	(-)	(-)	(21.0)	(-)	(-)	(21.9)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 15	N 16	N 17	N 18	N 19	N 20	N 21	N 22	N 23	N 24	N 25	N 26	N 27	N 28
40.6	39.2	36.4	37.4	37.1	35.3	36.8	36.9	35.6	37.6	38.2	37.4	40.2	41.5
(-)	(-)	(20.1)	(-)	(-)	(20.9)	(-)	(-)	(21.1)	(-)	(-)	(21.8)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 29	N 30	N 31	N 32	N 33	N 34	N 35	N 36	N 37	N 38	N 39	N 40	N 41	N 42
40.6	39.2	36.4	37.5	37.1	35.3	36.8	36.9	35.6	37.6	38.2	37.4	40.1	41.5
(-)	(-)	(20.1)	(-)	(-)	(20.9)	(-)	(-)	(21.1)	(-)	(-)	(21.8)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 43	N 44	N 45	N 46	N 47	N 48	N 49	N 50	N 51	N 52	N 53	N 54	N 55	N 56
40.6	39.2	36.4	37.5	37.1	35.3	36.8	36.9	35.6	37.6	38.2	37.4	40.1	41.5
(-)	(-)	(20.2)	(-)	(-)	(20.8)	(-)	(-)	(21.1)	(-)	(-)	(21.8)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 57	N 58	N 59	N 60	N 61	N 62	N 63	N 64	N 65	N 66	N 67	N 68	N 69	N 70
40.6	39.2	36.4	37.5	37.1	35.3	36.8	36.9	35.6	37.6	38.2	37.3	40.1	41.5
(-)	(-)	(20.2)	(-)	(-)	(20.8)	(-)	(-)	(21.2)	(-)	(-)	(21.7)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 71	N 72	N 73	N 74	N 75	N 76	N 77	N 78	N 79	N 80	N 81	N 82	N 83	N 84
40.6	39.2	36.5	37.5	37.1	35.3	36.8	36.9	35.6	37.6	38.2	37.3	40.1	41.5
(-)	(-)	(20.3)	(-)	(-)	(20.8)	(-)	(-)	(21.2)	(-)	(-)	(21.7)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 85	N 86	N 87	N 88	N 89	N 90	N 91	N 92	N 93	N 94	N 95	N 96	N 97	N 98
40.6	39.3	36.5	37.5	37.1	35.3	36.8	36.9	35.7	37.6	38.1	37.3	40.1	41.5
(-)	(-)	(20.3)	(-)	(-)	(20.7)	(-)	(-)	(21.2)	(-)	(-)	(21.7)	(-)	(-)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 99	N 100	N 101	N 102	N 103	N 104	N 105	N 106	N 107	N 108	N 109	N 110	N 111	N 112

40.7	39.3	36.5	37.5	37.1	35.3	36.8	36.9	35.7	37.6	38.1	37.3	40.1	41.5
(–)	(–)	(20.3)	(–)	(–)	(20.7)	(–)	(–)	(21.3)	(–)	(–)	(21.6)	(–)	(–)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 113	N 114	N 115	N 116	N 117	N 118	N 119	N 120	N 121	N 122	N 123	N 124	N 125	N 126
40.7	39.3	36.5	37.5	37.1	35.3	36.8	36.9	35.7	37.6	38.1	37.3	40.1	41.5
(–)	(–)	(20.4)	(–)	(–)	(20.7)	(–)	(–)	(21.3)	(–)	(–)	(21.6)	(–)	(–)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 127	N 128	N 129	N 130	N 131	N 132	N 133	N 134	N 135	N 136	N 137	N 138	N 139	N 140
40.7	39.3	36.5	37.5	37.1	35.3	36.8	36.9	35.7	37.6	38.1	37.3	40.1	41.4
(–)	(–)	(20.4)	(–)	(–)	(20.6)	(–)	(–)	(21.3)	(–)	(–)	(21.6)	(–)	(–)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 141	N 142	N 143	N 144	N 145	N 146	N 147	N 148	N 149	N 150	N 151	N 152	N 153	N 154
40.7	39.3	36.5	37.5	37.1	35.3	36.8	36.9	35.7	37.6	38.1	37.3	40.0	41.4
(–)	(–)	(20.4)	(–)	(–)	(20.6)	(–)	(–)	(21.3)	(–)	(–)	(21.5)	(–)	(–)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 155	N 156	N 157	N 158	N 159	N 160	N 161	N 162	N 163	N 164	N 165	N 166	N 167	N 168
40.7	39.3	36.5	37.5	37.1	35.3	36.8	36.9	35.7	37.6	38.1	37.2	40.0	41.4
(–)	(–)	(20.5)	(–)	(–)	(20.6)	(–)	(–)	(21.4)	(–)	(–)	(21.5)	(–)	(–)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 169	N 170	N 171	N 172	N 173	N 174	N 175	N 176	N 177	N 178	N 179	N 180	N 181	N 182
40.7	39.3	36.5	37.5	37.1	35.3	36.8	36.9	35.7	37.6	38.1	37.2	40.0	41.4
(–)	(–)	(20.5)	(–)	(–)	(20.5)	(–)	(–)	(21.4)	(–)	(–)	(21.4)	(–)	(–)
5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W	5.10W
N 183	N 184	N 185	N 186	N 187	N 188	N 189	N 190	N 191	N 192	N 193	N 194	N 195	N 196

AVERAGE COLDPLATE TEMP.= 37.9
POWER DIRECTLY ON CP= 1000.00
NO. OF ITERATIONS REQUIRED= 80
ALLOW. NO. OF ITERATIONS= 5000
TEMP. RELAXATION CRITERIA=.00100
PERCENT ENGERY BALANCE= 0.0874

A color contour plot of the base plate is shown below.