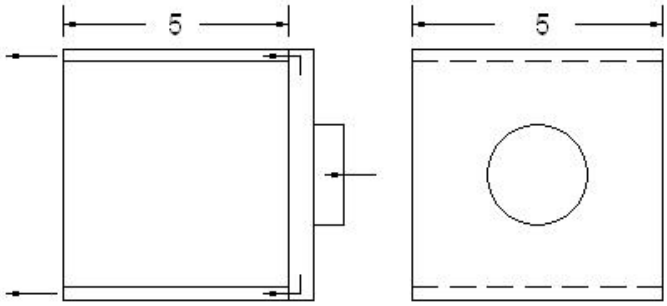
Fan Cooled Example

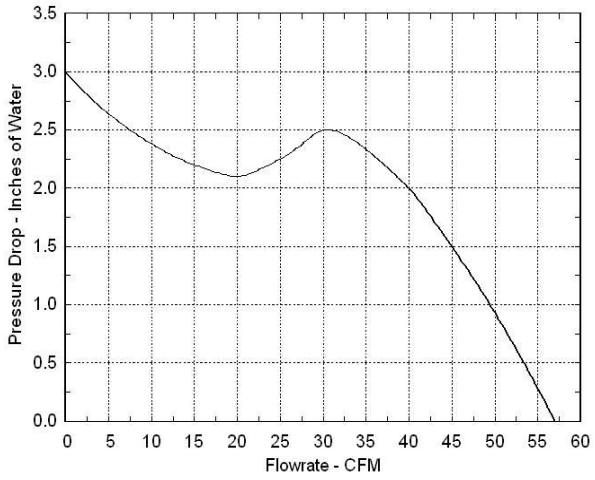
This example will demonstrate modeling a box with 2 cold plates cooled by a single fan. The resulting flow rate and temperature for the two conditions listed will be determined..



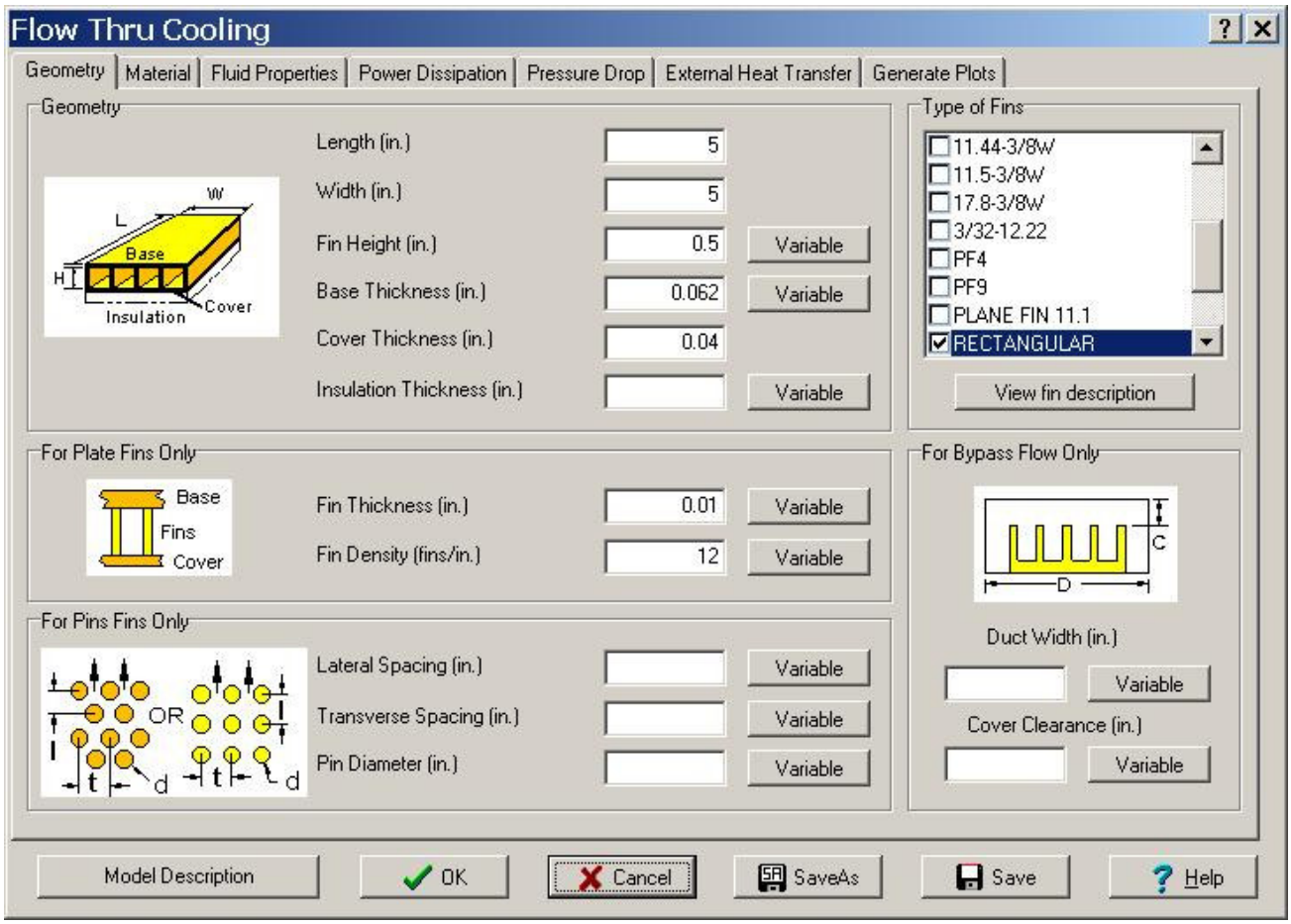
- Operation is required at sea level and 40,000 feet (2.72 PSI), 55C and 30C inlet air, respectively.
- The fins are: .01 inches thick, 12 fins/inch, .5 inches high, rectangular, aluminum.
- The 6061-T6 base is .062 thick and the cover is.04 thick.
- The fan manufacturer's data (curve below) was measured at standard conditions of 14.7PSI and 15C.
- Total box power is 200 Watts, nearly uniform on both sides while the fan power is 38 Watts.
- Assume a "**System Inlet Section**" loss parameter of 1.0 inches high by 5.0 inches wide with a loss coefficient of 1.0
- Assume an "**Inlet Section**" loss parameter of .5 inches high by 5.0 inches wide with a loss coefficient of 1.0

Hints:

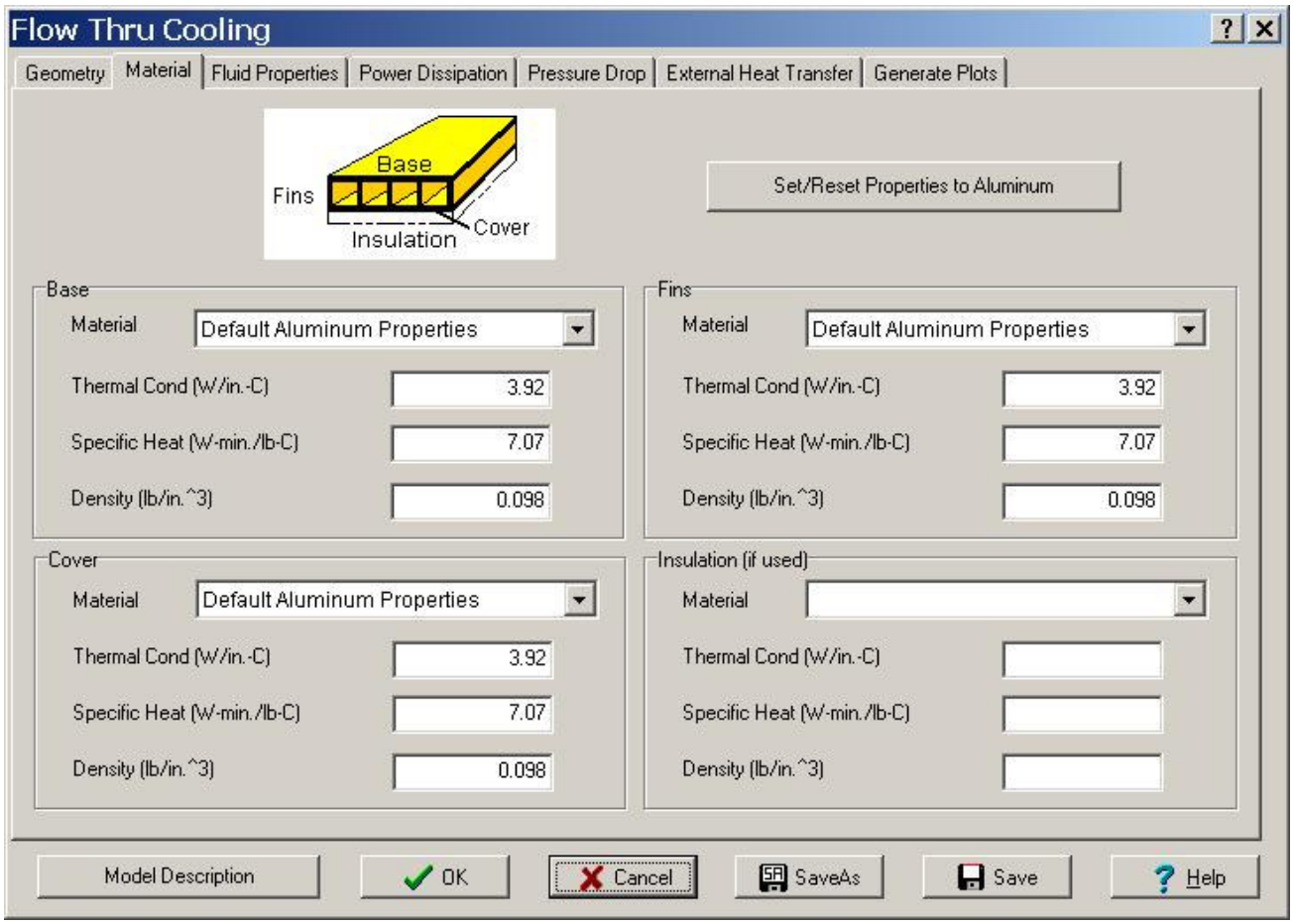
- Since the altitude condition is above 30KFT, use the Sigma Delta P versus Mass Flow Rate plot to determine fan operations conditions.
- Under the Fan Configuration tab be sure to select the 2 cold plates per fan option.
- Use a mass flow rate range of .05 to 5 lbs/min.
- Since the plot to be generated is log-log, use near 0.0 values at the limits of fan curve input.
- Since there are 2 cold plates, the power per cold plate is 200/2 = 100 Watts.
- The total fan power of 38 Watts is input, the program will account for the proper power to use in heating up the air prior to the cold plates.



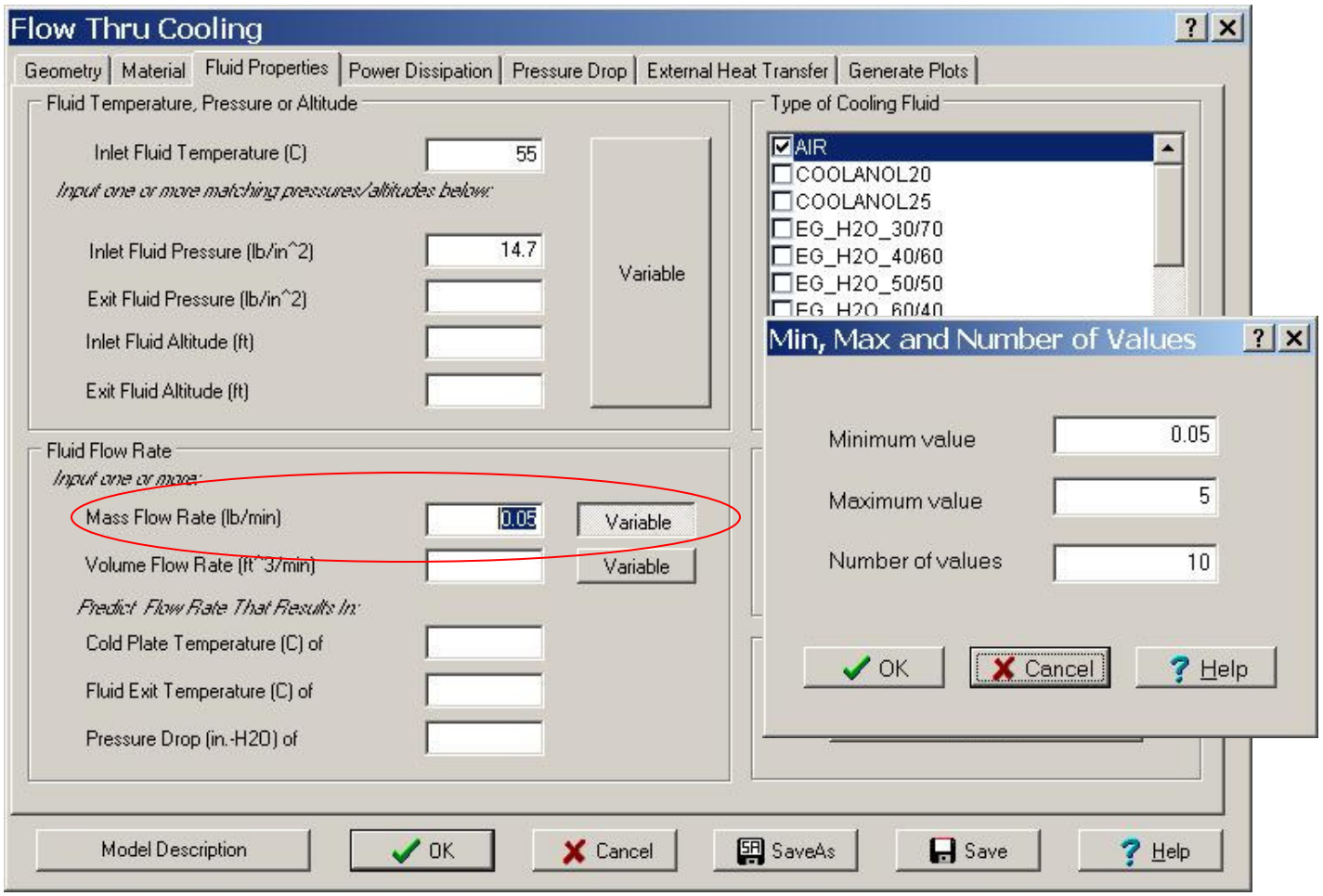
Input the geometry parameters on this tab.



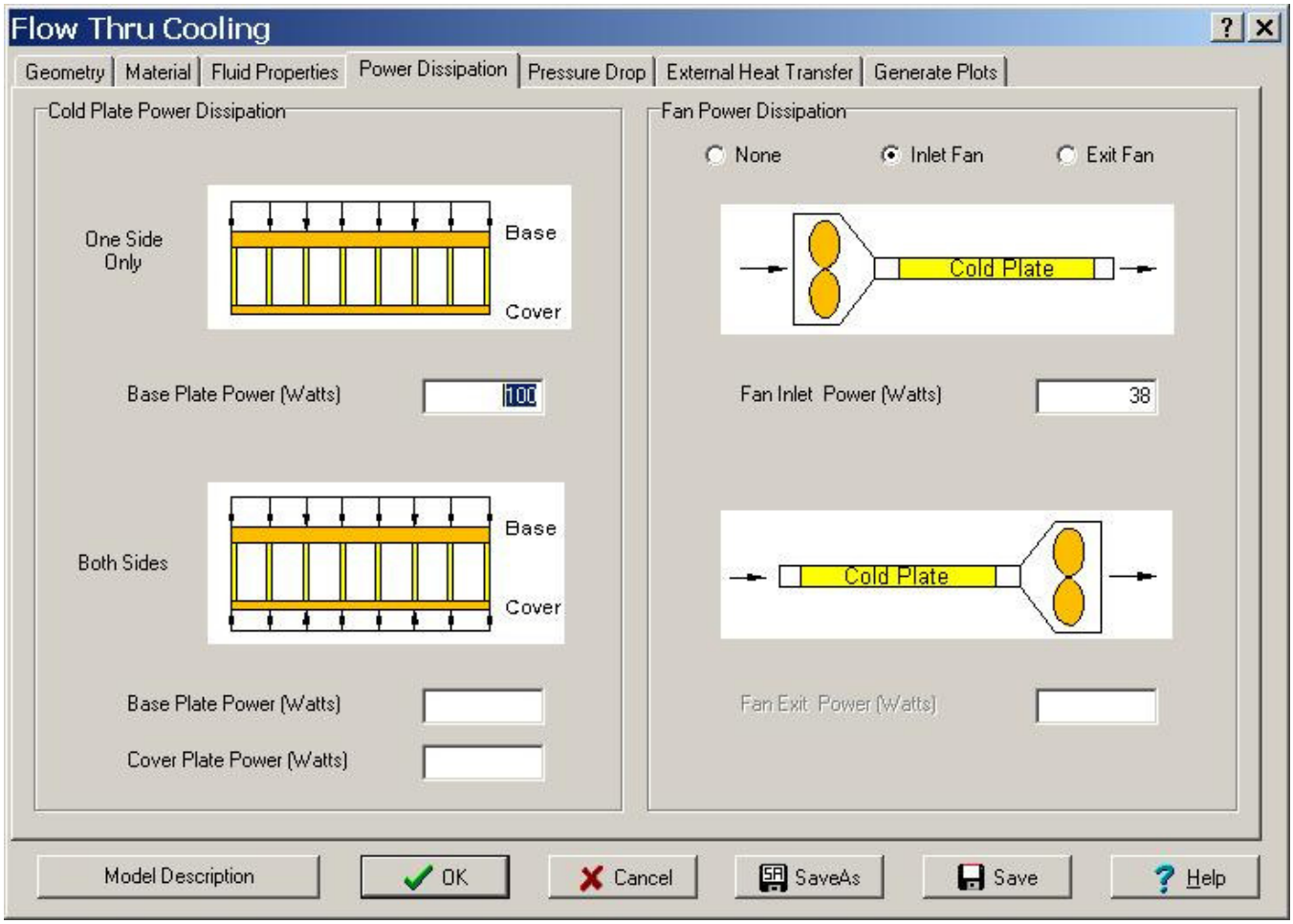
Select Default Aluminum Properties on this tab



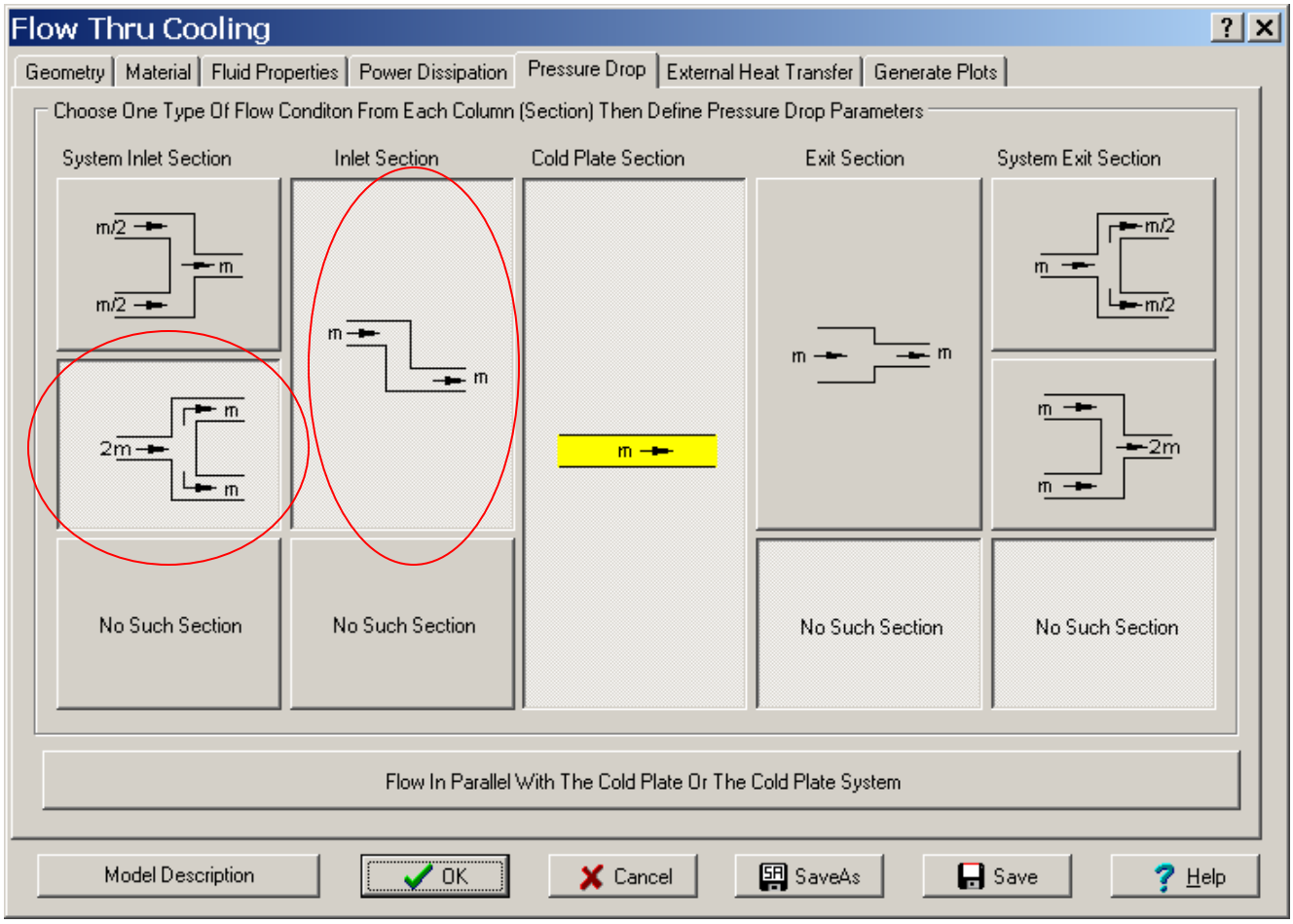
Input the Inlet fluid temperature, pressure, mass flow rate and select “Air “ as the cooling fluid. The flow rate is varied from .05 to 5 lb/min with 10 different values.



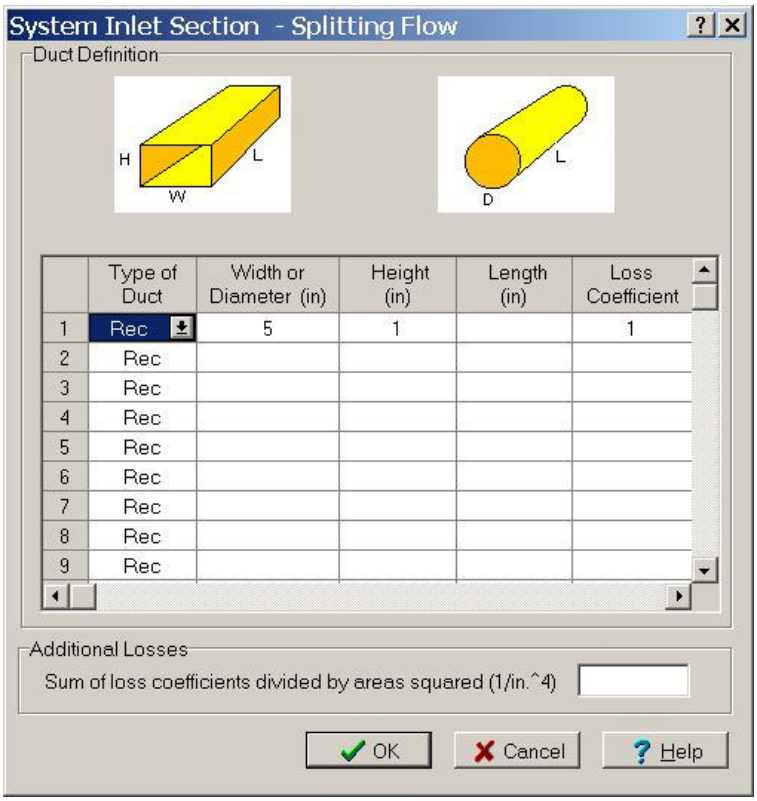
Input ½ the box power (power per cold plate) and the total inlet fan power.



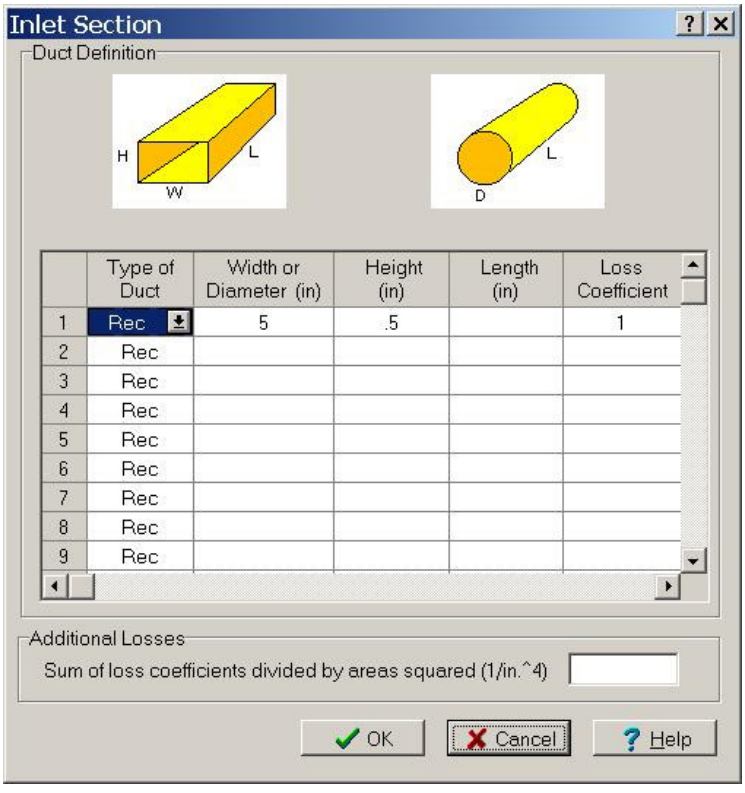
The “System Inlet Section” button is selected to specify the duct dimensions at the fan. In addition, the “Inlet Section” button is selected to specify the dimension just prior to the cold plate.



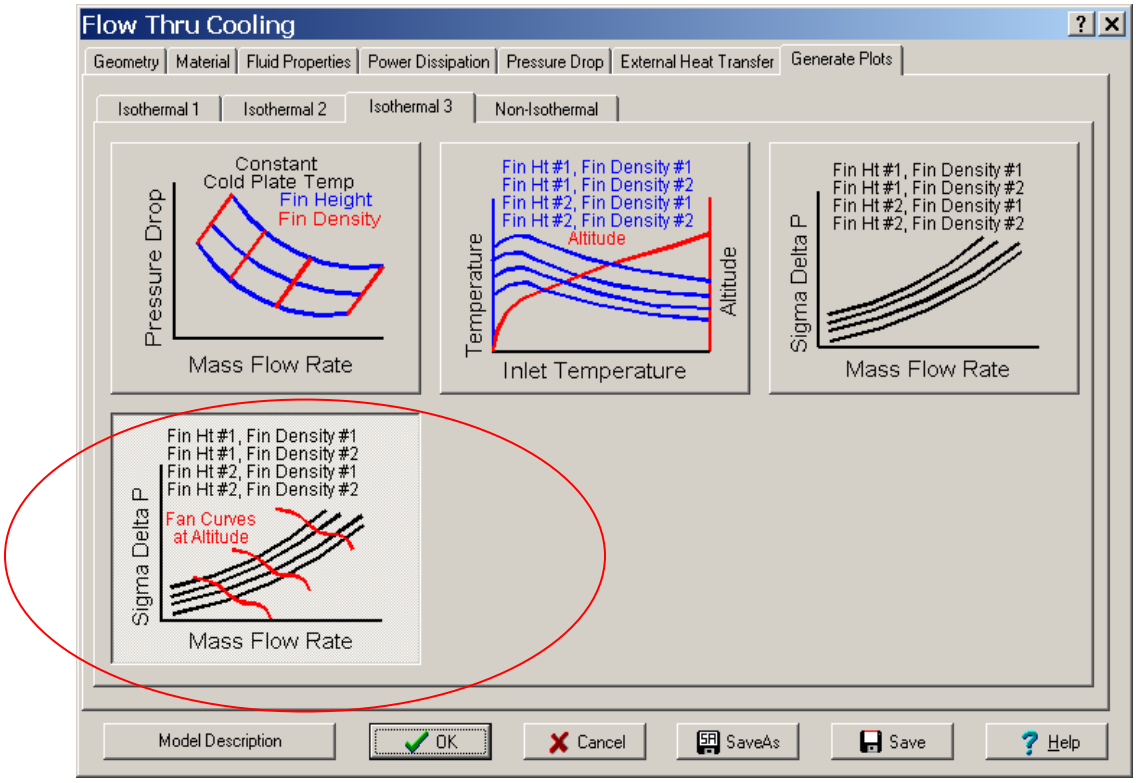
The “System Inlet Section” geometry at the fan is here.



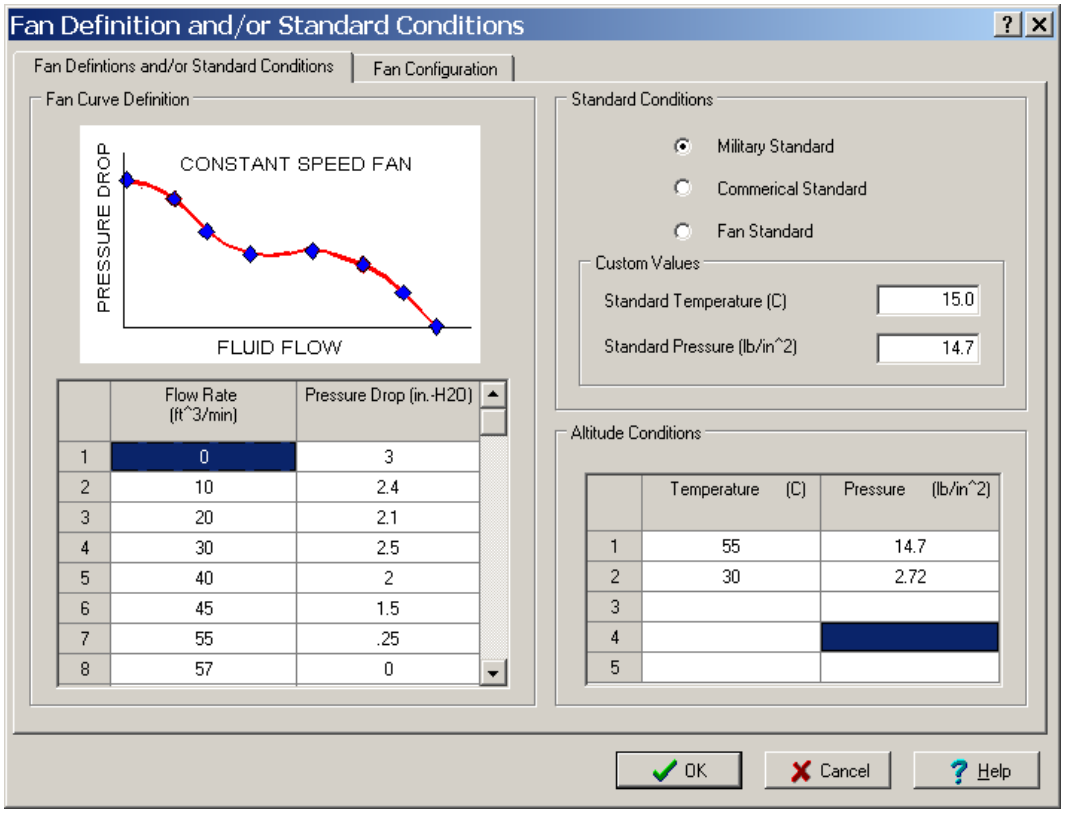
The “Inlet Section” geometry just prior to the cold plate is input here.



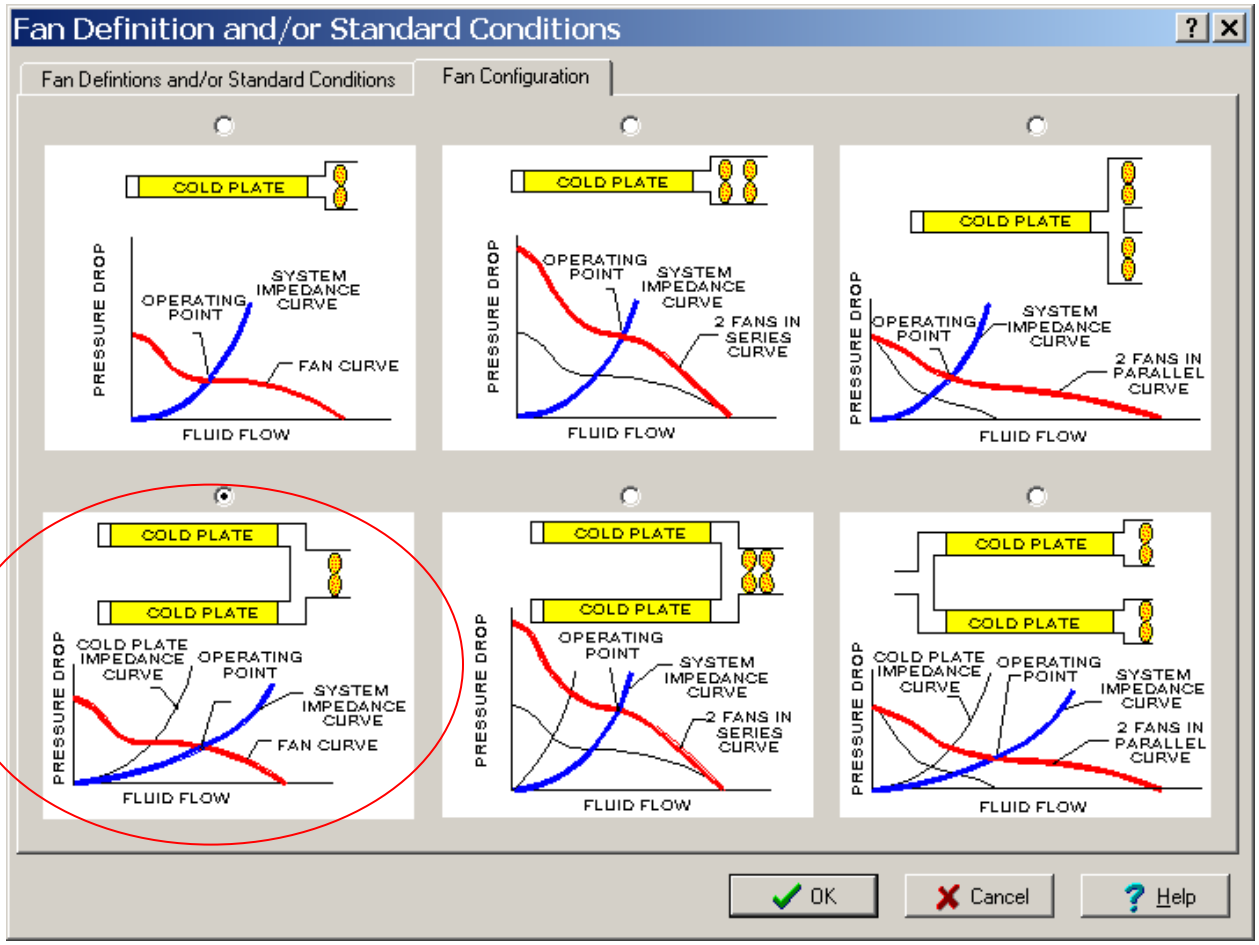
The Fan Curve Data is input on the next 3 forms. The first selects that the Sigma Delta P versus Mass Flow Rate curve will be generated.



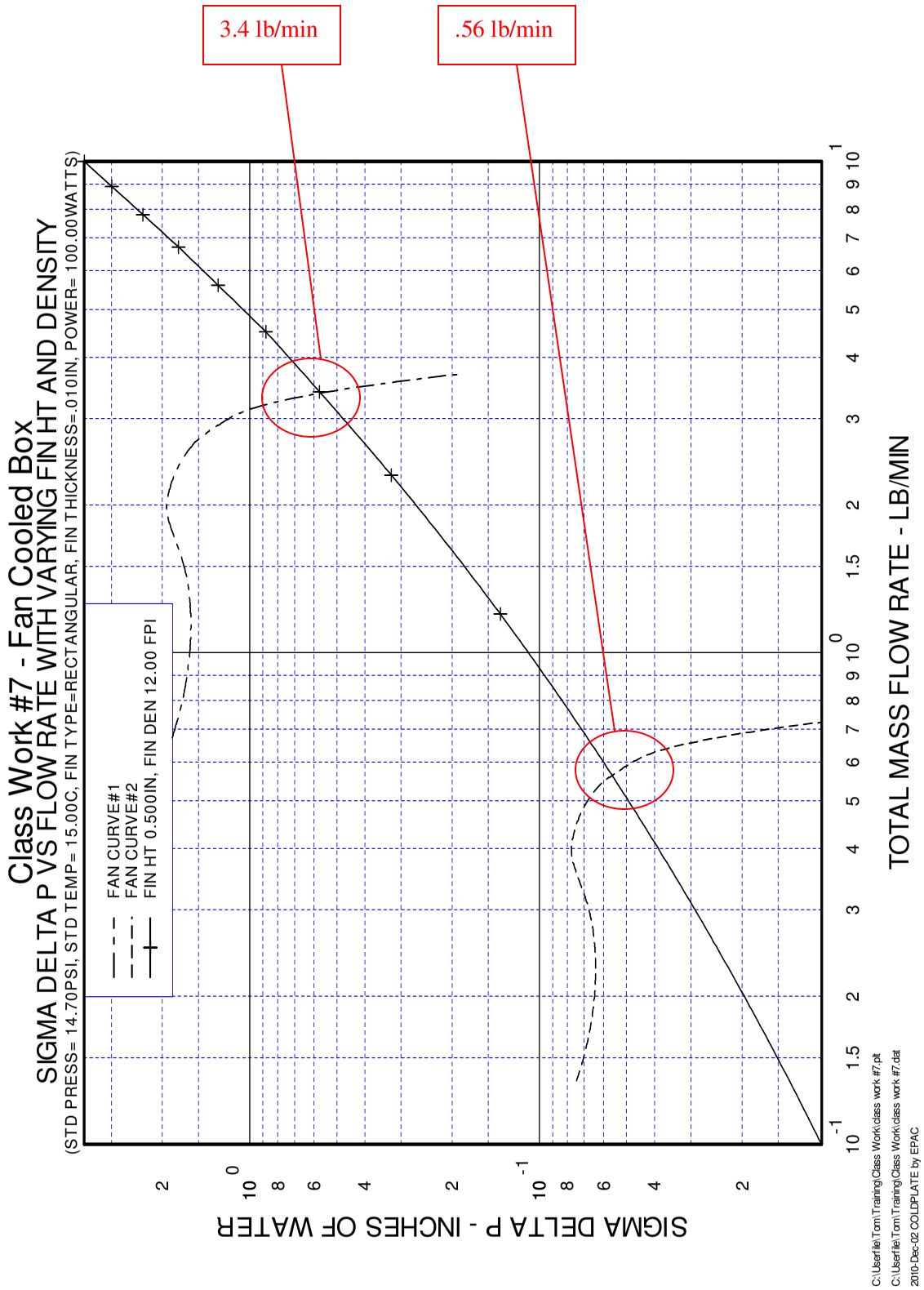
This form is to specify the fan curve.



This form is to select the 2 cold plates per fan configuration.

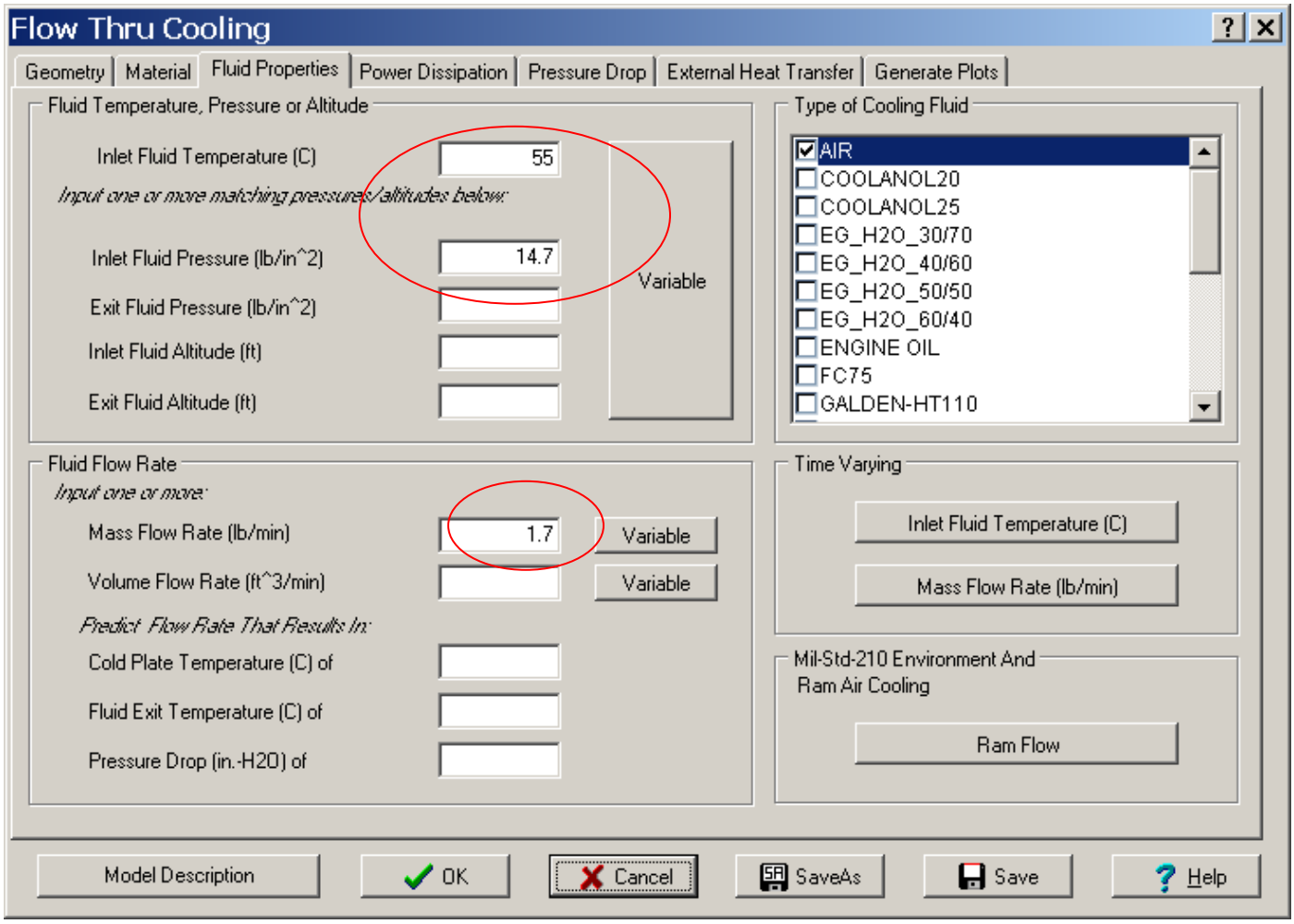


The model is run and from the plot it shows that the operating point (flow rate) is 3.4 lb/min at sea level .56lb/min at 40,000 feet.

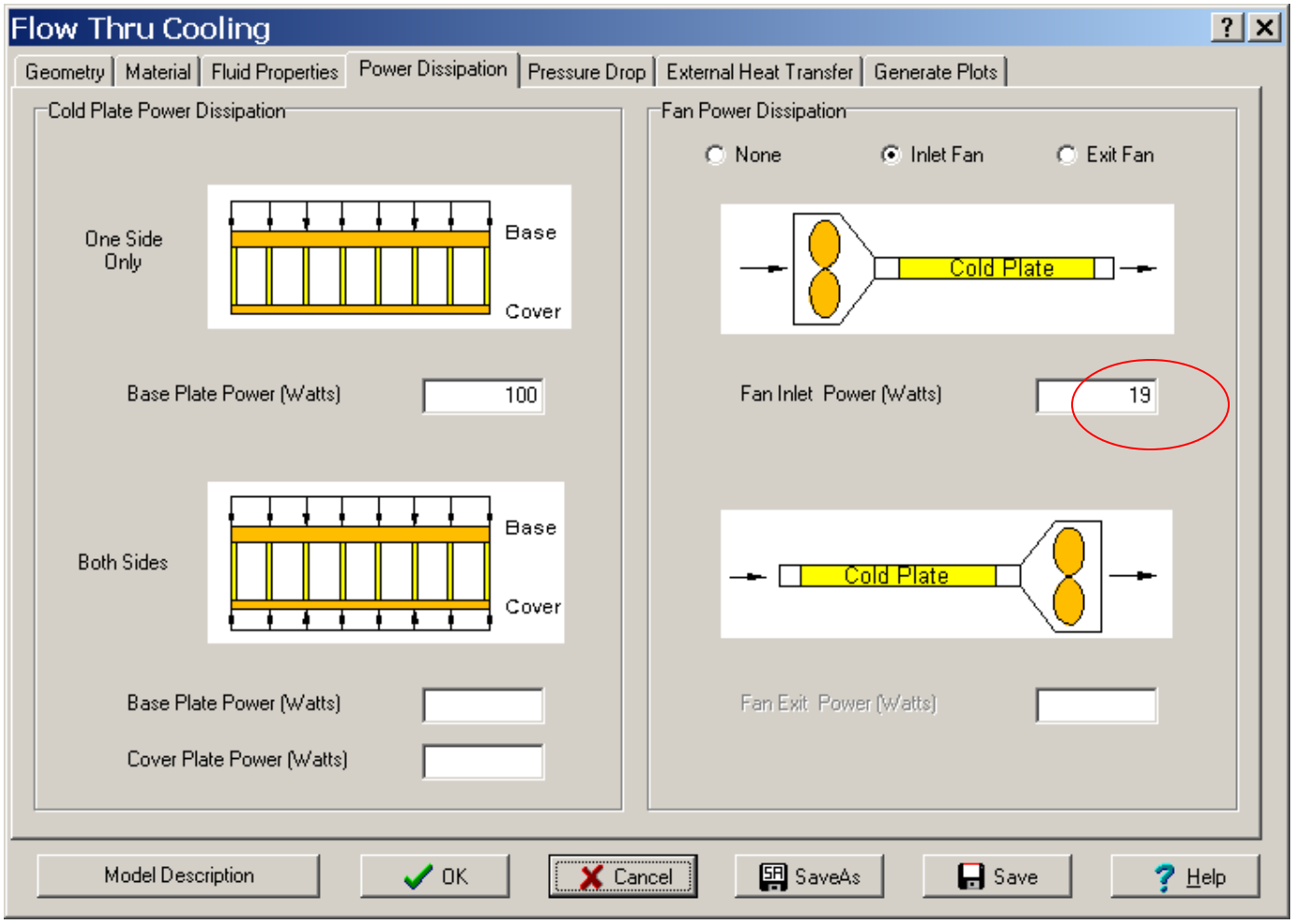


Now that the flow rate at sea level and 40KFT has been determined, the temperature can be determined by looking at each cold plate by itself using ½ half the box mass flow rate. A new model with the same geometry was created for each condition (sea level and 40KFT) but now with the correct flow at each altitude is used.

The sea level conditions are modeled here.



With the new model, fan curve is not include, just the flow rate at each condition. In this case and model, ½ the fan power is input.



Results with flow rates determined from first part of the analysis – Sea Level

Fan Cooled Box at Sea Level, 3.4 lb/min Total, 1.7 lb/min per cold plate

********** VARIABLE INPUTS **********	
THE TYPE OF FINS SPECIFIED ARE:	RECTANGULAR
FIN HEIGHT, INCHES	0.500
BASE THICKNESS, INCHES	0.062
FIN THICKNESS, INCHES	0.0100
FIN DENSITY, FINS PER INCH	12.0
STATIC INLET FLUID TEMPERATURE, DEG C	55.0
INLET PRESSURE, LBS/IN2	14.70
MASS FLOWRATE, LBS/MIN	1.70
THE POWER APPLIED TO ONE SIDE ONLY, WATTS	100.00
THE COOLING FLUID IS:	AIR
********** INTERMEDIATE CALCULATED PARAMETERS **********	
FREE FLOW CROSS SECTIONAL AREA, IN2	2.20
HYDRAULIC DIAMETER, INCHES	0.128
COLDPLATE WEIGHT, LBS	0.40
TOTAL VOL FLOWRATE, [GAL/MIN] FT3/MIN [192.1]	25.67
COLDPLATE VOL FLOWRATE, [GAL/MIN] FT3/MIN [192.1]	25.67
COLDPLATE VELOCITY, FT/SEC	28.01
REYNOLDS NUMBER	1487.
EQUIVALENT FRICTION LOSS COEFFICIENT, KFRICTION	2.50
INLET LOSS COEFFICIENT, KINLET	0.87
EXIT LOSS COEFFICIENT, KEXIT	-0.66
FILM COEFFICIENT, [BTU/(HR-FT2-F)] W/(IN2-C) [10.13]	0.0371
THE FIN EFFICIENCY WITH HEAT ON ONE SIDE ONLY IS	0.848
********** PRESSURE **********	
INLET PRESSURE, [LB/IN2] INCHES-H2O [14.700]	407.077
INLET PRESSURE DROP, INCHES-H2O	0.167
ACCELERATION PRESSURE DROP, INCHES-H2O	0.009
FRICTIONAL PRESSURE DROP, INCHES-H2O	0.388
EXIT PRESSURE DROP, INCHES-H2O	-0.139
FLOWLOSS SYSTEM INLET PRESSURE DROPS, INCHES-H2O	0.119
FLOWLOSS INLET PRESSURE DROPS, INCHES-H2O	0.119
TOTAL PRESSURE DROP, INCHES-H2O	0.662
EXIT PRESSURE, [LB/IN2] INCHES-H2O [14.676]	406.415
DENSITY RATIO TIME PRESSURE DROP, INCHES-H20	0.5731
********** THERMAL RESISTANCE **********	
THERMAL RESISTANCE FROM INLET FLUID TO COLDPLATE, C/W	0.136
THERMAL RESISTANCE FROM LOCAL FLUID TO COLDPLATE, C/W	0.091
********** TEMPERATURES **********	
STATIC INLET FLUID TEMPERATURE, DEG C	55.0
STAGNATION FLUID TEMP RISE ACROSS INLET FAN, DEG C	1.5
STAGNATION FLUID TEMP RISE ALONG COLDPLATE, DEG C	7.7
TOTAL STAGNATION FLUID TEMP RISE, DEG C	9.2
STATIC EXIT FLUID TEMPERATURE, DEG C	64.2
ISOTHERMAL COLDPLATE TEMPERATURE, DEG C	70.0
MAXIMUM COLDPLATE TEMPERATURE, DEG C	73.3

The model was run again but with an inlet temperature of 30C, 2.72 lb/in^2 and .28 lbs/min. Results are shown below for the 40 KFT condition.

Fan Cooled Box at 40KFT, .56 lb/min Total, .28 lb/min per cold plate

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************************ VARIABLE INPUTS ************************
THE TYPE OF FINS SPECIFIED ARE:                      RECTANGULAR
FIN HEIGHT, INCHES                                         0.500
BASE THICKNESS, INCHES                                     0.062
FIN THICKNESS, INCHES                                      0.0100
FIN DENSITY, FINS PER INCH                                12.0
STATIC INLET FLUID TEMPERATURE, DEG C                     30.0
INLET PRESSURE, LBS/IN2                                    2.72
MASS FLOWRATE, LBS/MIN                                     0.28
THE POWER APPLIED TO ONE SIDE ONLY, WATTS                100.00
THE COOLING FLUID IS:                                AIR

*************** INTERMEDIATE CALCULATED PARAMETERS ***************
FREE FLOW CROSS SECTIONAL AREA, IN2                        2.20
HYDRAULIC DIAMETER, INCHES                                 0.128
COLDPLATE WEIGHT, LBS                                      0.40
TOTAL VOL FLOWRATE,     [GAL/MIN] FT3/MIN [   169.1]      22.60
COLDPLATE VOL FLOWRATE, [GAL/MIN] FT3/MIN [   169.1]      22.60
COLDPLATE VELOCITY, FT/SEC                                24.66
REYNOLDS NUMBER                                          246.
EQUIVALENT FRICTION LOSS COEFFICIENT, KFRICTION           12.61
INLET LOSS COEFFICIENT, KINLET                             0.87
EXIT LOSS COEFFICIENT, KEXIT                              -0.66
FILM COEFFICIENT, [BTU/(HR-FT2-F)] W/(IN2-C)  [   8.36]   0.0306
THE FIN EFFICIENCY WITH HEAT ON ONE SIDE ONLY IS           0.871

************************** PRESSURE ******************************
INLET PRESSURE, [LB/IN2] INCHES-H2O      [  2.720]        75.323
INLET PRESSURE DROP, INCHES-H2O                            0.023
ACCELERATION PRESSURE DROP, INCHES-H2O                     0.008
FRICTIONAL PRESSURE DROP, INCHES-H2O                       0.284
EXIT PRESSURE DROP, INCHES-H2O                            -0.022
FLOWLOSS SYSTEM INLET PRESSURE DROPS, INCHES-H2O           0.016
FLOWLOSS INLET PRESSURE DROPS, INCHES-H2O                  0.016
TOTAL PRESSURE DROP, INCHES-H2O                            0.325
EXIT PRESSURE, [LB/IN2] INCHES-H2O       [  2.708]        74.998
DENSITY RATIO TIME PRESSURE DROP, INCHES-H20               0.0526

*********************** THERMAL RESISTANCE ***********************
THERMAL RESISTANCE FROM INLET FLUID TO COLDPLATE, C/W      0.475
THERMAL RESISTANCE FROM LOCAL FLUID TO COLDPLATE, C/W      0.108

************************** TEMPERATURES ******************************
STATIC INLET FLUID TEMPERATURE, DEG C                     30.0
STAGNATION FLUID TEMP RISE ACROSS INLET FAN, DEG C         8.9
STAGNATION FLUID TEMP RISE ALONG COLDPLATE, DEG C         46.9
TOTAL STAGNATION FLUID TEMP RISE, DEG C                   55.8
STATIC EXIT FLUID TEMPERATURE, DEG C                      85.7
ISOTHERMAL COLDPLATE TEMPERATURE, DEG C                   86.4
MAXIMUM COLDPLATE TEMPERATURE, DEG C                      96.6
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