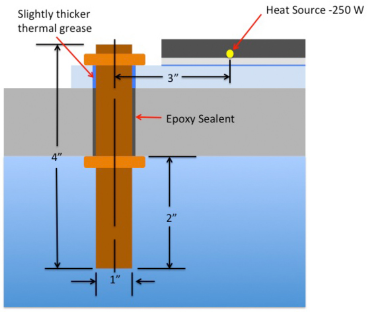
xFOCE Thermal Analysis Spreadsheet



Input values in tan boxes only

250 Watts
Q Heat Flux in BTU / watt-Hr   3.4 BTU : 1 Watt/HR

covertin 250 * 3.41 = 852.5 BTU/Hr = Q

equation to solve:

Ti - Te = Q * Rt

Ti = Temp Internal	Ti =	80 C	176 F
Te = Temp External	Te =	15 C	59 F

ΔT = Ti - Te   ΔT = 176 - 59
Maximum ΔT = 117 F

resistor network calcs:

R = L / (k*A)   [BTU/ HR F] ^ -1

Assume we will need 2 bolts for securing the internal heat sink.
The image below shows equivalent thermal resistor values for each interface and each material path.

Thermal Transfer Coefficients

Thermal Grease = .381 $\frac{BTU}{Hr\ Ft\ {}^0F}$

Aluminum = 118.53 $\frac{BTU}{Hr\ Ft\ {}^0F}$

PVC = 1.02 $\frac{BTU}{Hr\ Ft\ {}^0F}$

Copper Nickel = 26.0 $\frac{BTU}{Hr\ Ft\ {}^0F}$

Seawater = .346 $\frac{BTU}{Hr\ Ft\ {}^0F}$

Resistor Math

Resistors in Series

$R_{total} = R_1 + R_2 + R_3 + \ldots$

Two Resistors in Parallel

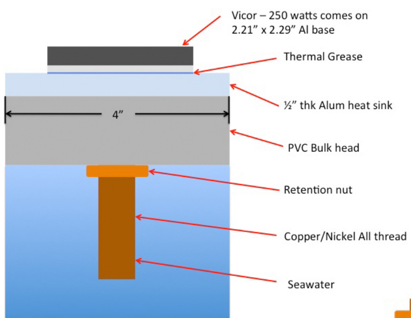
$R_t = \frac{R_1 R_2}{R_1 + R_2}$ $R_1 = \frac{R_t R_2}{R_2 - R_t}$

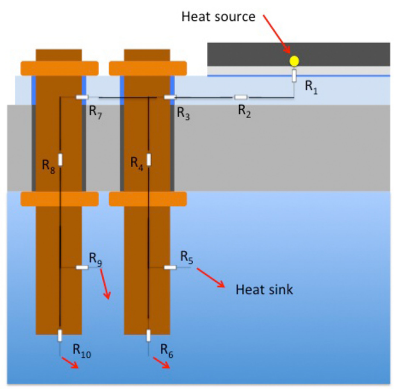
Equal Resistors in Parallel

$R_{total} = \frac{R}{n}$, **Where n is the number of resistors**

Resistors in Parallel, General Formula

$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$





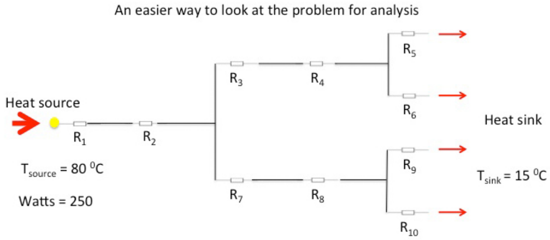
For purposes of general heat transfer calculations we can think of each piece in the path as a resistor and each interface between paths as an additional resistor.

This example shows the assembly with a second parallel path which effectively cuts the resistance to heat transfer in ½ from R_2 on.

Also, being more accurate we've included the rods ends as a transfer surface

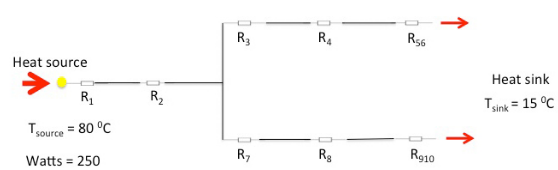
Layout of Resistor Network

An easier way to look at the problem for analysis



Layout of Resistor Network - 2

Network substitution for analysis



$R_{56} = (R_5 * R_6) / (R_5 + R_6)$

$R_{910} = (R_9 * R_{10}) / (R_9 + R_{10})$

R5 = R9 and R6 = R10   Area of R5 = exposed length of rod * perimeter in ft2

Length of rod in inches = 3 inches
= 0.25 ft

These are pushing heat into the water with a k = .346

Diameter of rod in inches = 0.5 inches
perimeter of rod = 0.1309 ft

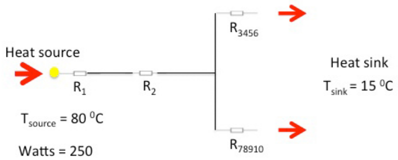
R5 = 0.00736   R56 = 0.00707 = R910

Area of rod end = 0.00136

R6 = 0.17664

Layout of Resistor Network - 3

Network substitution cont'd for analysis



$R_{3456} = R_3 + R_4 + [(R_5 * R_6) / (R_5 + R_6)]$

$R_{78910} = R_7 + R_8 + [(R_9 * R_{10}) / (R_9 + R_{10})]$

Continuing on with our reduction refer to diagram Network 3:

These are pushing heat into the copper nick
k = 26

Again R3 = R7 and R4 = R8

R4 is the entire rod length now so it must be longer than the above calculation:

Length of rod in inches = 5 inches R4 = 0.1224 = R8
= 0.4167 ft

R3 is a little more involved since it has a surface interface in the aluminum heat sink:

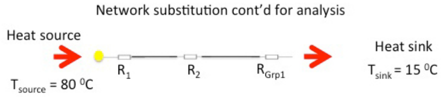
The heat sink thickness is = 0.5 inches and the same perimeter as for R5
= 0.0417 ft
assume thermal thickness is .005 R3 = 0.0029 = R7

We further reduce the network of resistors by the formula to the left

>>>>>> R3456 = 0.1324 = R78910

Layout of Resistor Network - 4

Network substitution cont'd for analysis



$R_{Grp1} = (R_{3456} * R_{78910}) / (R_{3456} + R_{78910})$

Further reducing the R3456 adnd R78910 into an equivalent thermal resistor we get:

R grp1 = 0.06622

The heat sink is R2 and made of Aluminum with a k = 118.53

L we will estimate as being slightly longer than half the Vicor and 1/2 the rod diameter ~ 3 inch

L = 3 inches A is the width of the heat sink times the thickness
0.25 ft Width = 2.5 inches = 0.2083 ft

Thk = 0.5 inches = 0.0417 ft

R2 = 0.24298

The Vicor base is the area of R1 for the calc = 5.0609 sq in 0.0351 Sq ft

We'll say the thermal grease is the limiting thermal coefficient k = .381

R1 = 0.06249

R total = R1 + R2 + Rgrp1 R total = 0.37169

Back to our original equation: Delta T = Q * Rt = 316.86 This must be a positive number to work properly:

Delta Max - Delta T = -199.86 Red = Bad Green = Good

If we doubled the number of rods again: R new = 0.1858

Delta T = Q * Rt = 158.43 Delta Max - Delta T = -41.43 Red = Bad Green = Good

now 6 rods: R new = 0.0929

Delta T = Q * Rt = 79.216 Delta Max - Delta T = 37.784 Red = Bad Green = Good