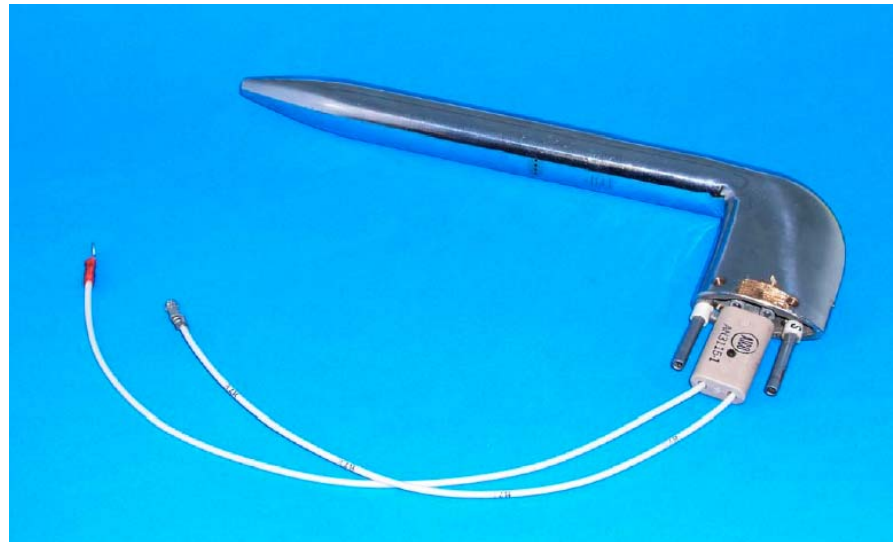# Gauging Pitot Heater Performance

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Common questions in any heated de-ice system are:

(1) How well do calories of heat (watts) move from the originating source (heater) to the point where the heat is needed (surface of the tube where ice is melted)?

(2) How much power is needed to operate the system in a worst case scenario?

Whether you're trying to cool the internal workings of a semi-conductor device on a heat-sink or transfer heat from a heater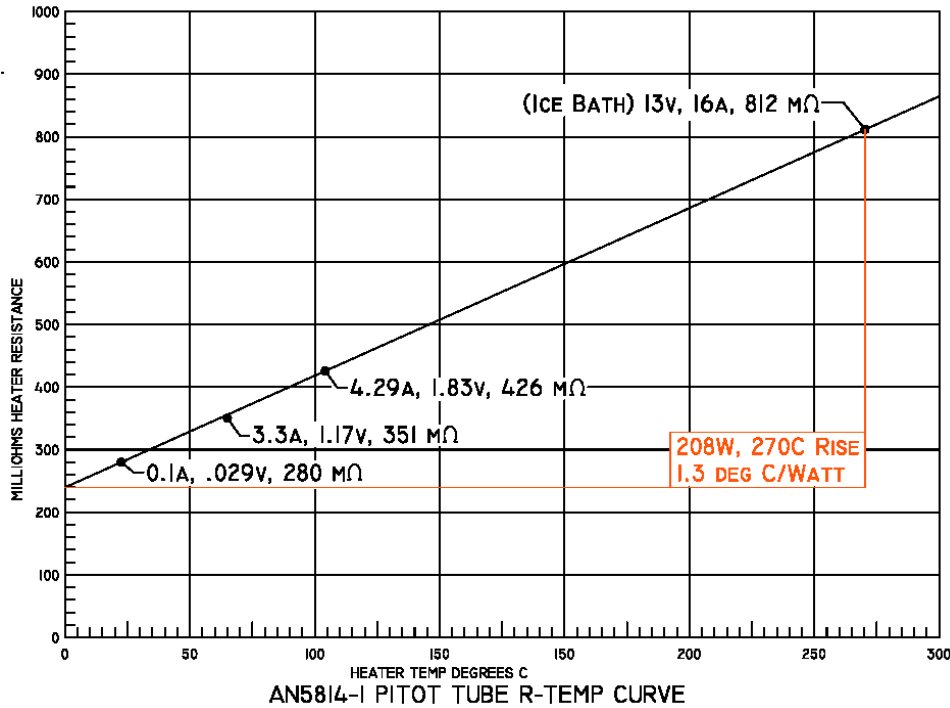 to a blob of ice, there are limitations on our ability to rigidly connect the heat source to the place where the energy is to be dissipated. One way to think of the problem is to imagine a quantity called "thermal resistance" which is analogous to electrical resistance.
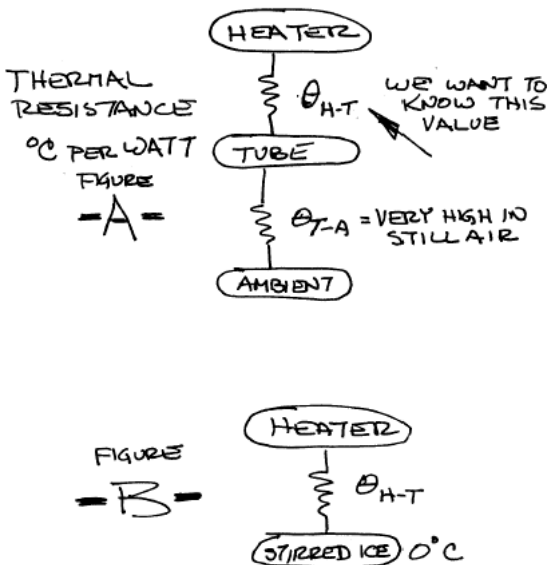
Electrical resistance is quantified in OHMS wherein 1-ohm produces 1 volt of drop when a current of 1 amp flows through the resistor. Thermal resistance in many discussions is given the symbol Theta, a character in the Greek alphabet. Theta is quantified in temperature differential across the resistance when impressed with a known energy flow. In our case, we're going to discuss "degrees-C per watt."

To measure the Theta (heater to tube) on an AN5814 pitot tube, I needed to fabricate a test setup with the highest practical value for Theta (tube-to-ambient). I attached a thermocouple on the outside surface of the tube and wrapped the tube up in Fiberglas insulation. It would have been even better to conduct the experiment in a vacuum. If I can increase Theta (tube to ambient) to the largest possible value, I know that temperature drop across Theta (heater-to-tube) in Figure –A- will be minimized. Under these conditions, pitot tube surface temperature is close to actual heater temperature.

I applied 100 mA of constant current to the tube's heater and went away for a couple of hours. The tube's surface temperature stabilized at about 22C. I increased the current to 3.3A and after several hours the tube's temperature rose to 70C. Increasing current to 4.29 amps, temperature stabilized at 105C. This temperature will sizzle-spit yet the tube required only 1.83v at 4.29A or 7.85 watts to achieve the temperature rise. Assuming 20C room temperature, this translates into a TOTAL thermal resistance of about 10 degrees C/watt while

AN5814-1 PITOT TUBE R-TEMP CURVE

Graph labels: MILLIOHMS HEATER RESISTANCE (y-axis), HEATER TEMP DEGREES C (x-axis)

(ICE BATH) 13v, 16A, 812 MΩ
4.29A, 1.83v, 426 MΩ
3.3A, 1.17v, 351 MΩ
0.1A, .029v, 280 MΩ
208W, 270C RISE 1.3 DEG C/WATT

nested in a wad of Fiberglas. This is a relatively small value which I can attribute to the large surface area of the pitot tube. The same experiment in a vacuum would have produced a Theta (heater-to-ambient) value 5 to 10 times larger.
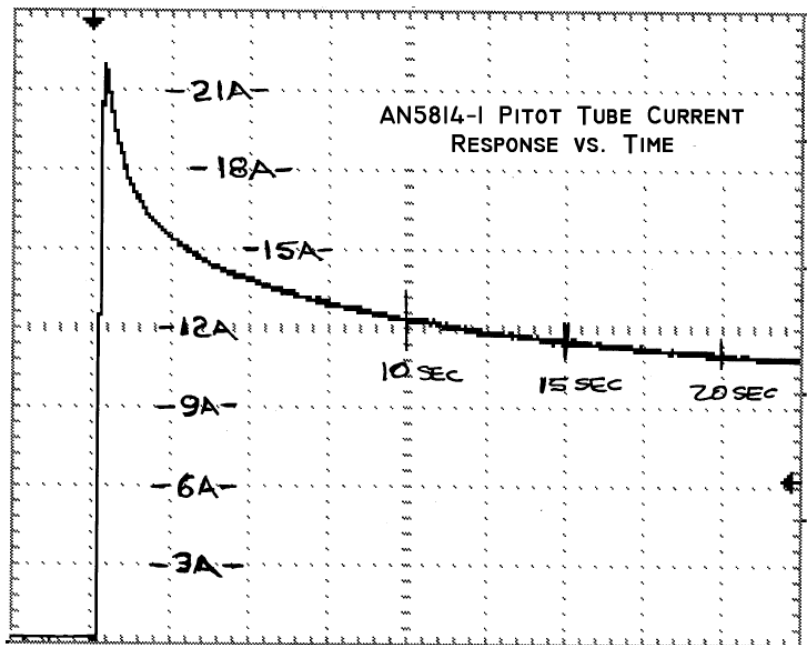
Plotting the data points on a graph, we can plot the resistance vs. temperature curve as shown here. Further, we can extrapolate temperature/resistance for values much hotter than 100C by extending the curve on the same slope to the higher temperature values. An operating resistance determination was made while applying 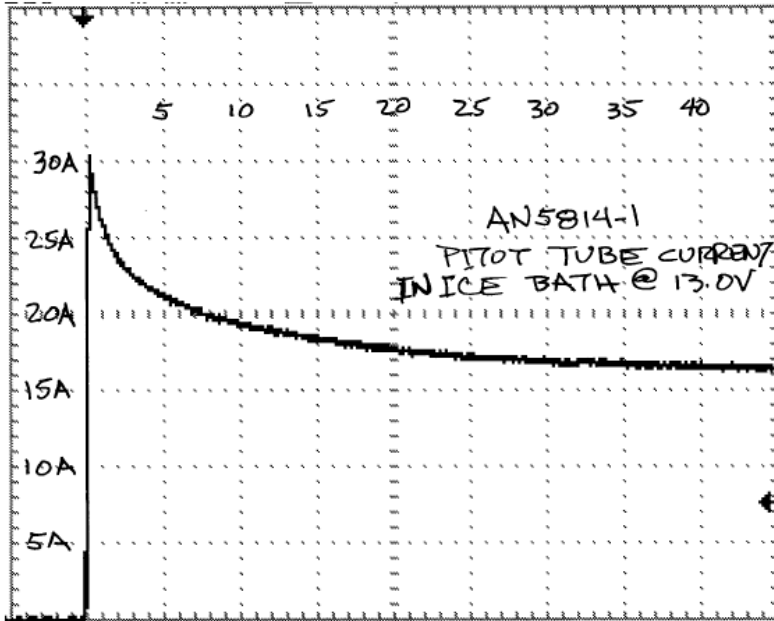full system voltage (13v) to the tube and holding the tube's surface at 0C by swishing it in a bath of crushed ice and water (Figure -B-). In this case, the tube's current draw settled out at 16A. Tracking up the curve established by the first three data points, we find that the operating resistance of the tube under worst case for melting ice is about 800 mOhms and produces a power drain of 208 watts.

We deduce that the value of Theta (heater-to-tube) is on the order of 1.3 degrees C per watt. When the tube is doing its best to keep supercooled water from becoming ice on the tube's surface at 0C, the tube's internal temperature at the heater is running about 270C. Pretty toasty!!!

More modern designs have much lower values for Theta (heater-to-tube). A tube off a bizjet was subjected to a similar study and found to have a Theta (heater-to-tube) on the order of 0.5 degrees C per watt. Interestingly enough, while internal temperature for this tube was lower, the tube was still consuming about 9 amps at 26 volts for a total power requirement of 230 watts. This underscores the notion that energy is energy is energy . . . if you're trying to shed x grams of ice the power required is constant irrespective of how efficiently that power is moved from heater to a pitot tube's surface.

I've shown a current vs. time plot for the AN5814 tube under free air conditions above. Note the correlation with measurements by others folks where they've observed a free air current on the

AN5814-1 PITOT TUBE CURRENT RESPONSE VS. TIME

21A, 18A, 15A, 12A, 9A, 6A, 3A
10 SEC, 15 SEC, 20 SEC

Plot labels (handwritten): 5, 10, 15, 20, 25, 30, 35, 40 (horizontal axis); 30A, 25A, 20A, 15A, 10A, 5A (vertical axis)

AN5814-1
PITOT TUBE CURRENT
IN ICE BATH @ 13.0V

bench on the order of 8-10 amps. Note the measured turn-on spike of 21A.

The plot here shows that it takes about 40 seconds for the tube to stabilize in stirred ice. Current draw settles out at about 16 amps which correlates with data depicted on the earlier resistance vs. temperature plot. Note the 30A "spike" at turn-on.

If you are considering an AN5814 heated pitot tube installation, the data gathered suggests that the tube be wired with 14AWG in a metal airplane and perhaps 12AWG in a plastic airplane. Further, fuse sizing for the installation would be 30A to avoid nuisance tripping the circuit protection during power-up in cold conditions.

Tubes other than the AN5814 will have similar characteristics but with numbers that are scaled depending on wattage rating of the tube. Note that bench or ramp tests of pitot tube current represent a lower bound on expected current draw. Pilots who encounter conditions that push a pitot tube to a max performance de-icing effort probably have mere minutes to live and don't care about pitot tube current draw. None-the-less, experiments described here herein establish an upper bound on pitot tube current draw which the prudent pilot will never see. The experiments illustrate thought processes used to craft a well considered, heated pitot tube installation.

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