Caloristors

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OBJECTIVE

The objective here is to define and describe the nature and use of caloristors in the making of calorimeters.

DEFINITION

A caloristor is (defined here as) a high thermal conductivity rod, possibly copper or aluminum, surrounded by very good insulation, with a metal heat transfer surface exposed at both ends. About 1/3 from either end of the insulation a thermistor (or thermocouple or RTD) is located under the insulation and in contact with the metal rod, possibly imbedded in the rod. The two temperature measuring points are used to determine the heat flux through the metal rod. Such caloristors can be made in all sizes and can accommodate and measure any sized heat flow.

DESCRIPTION AND DISCUSSION

It is likely useful to pre-make and calibrate caloristors for general purpose use.

Thermistors provide accurate and cheap temperature measuring at boiling temperatures or less. Thermistors can be read by very fast pulses to avoid heating the rods. Use of 100K ohm thermistors can also help avoid heat contamination from the measuring current. See:

http://www.mtaonline.net/~hheffner/Thermo.pdf

for a discussion of thermistors vs thermocouples. Alternatively, thermocouples or differential thermocouples can be used to measure the delta temp, or RTDs can be used.

The "cold" end of the caloristors can be attached to plumbing/hoses that carry cooling water (or air flow) and exchange heat with the cold end of the rod. In that manner a dual form of calorimetry can be made by using the (thermal mass flow)*(delta temp) from the cooling water (or air flow). The caloristors provide localized heat flow data while the cooling water (or air) flow can provide fully integrated flow calorimetry using only two additional thermistors in the flow.

A variation especially useful for very high temperature operation is to use cooling fins on the hot ends and then measure the (thermal mass flow)*(delta temp) for airflow into and out of an outer chamber. This method also has the advantage of providing a measure of heat flow through the insulation in addition to that measured through the caloristors.

The "hot" end of the caloristors can be pre-attached to metal plates so as to make building a calorimeter box easy, or can simply be made so it is easy to make thermal contact of the "hot" ends of the rods with any metal structure, possibly using machine screws.

Hot and cold are in quotes above because the heat flow can actually be in either direction.

With a supply of caloristors on hand, and a multiplexing A/D converter, making an ad hoc calorimeter becomes fairly simple. Surround the volume of interest with a highly conductive metal envelope, say copper, aluminum, titanium, magnesium alloy, or thick steel, which is in turn surrounded by a blanket of insulating material through which the insulted caloristors protrude to thermally connect with the envelope. A second blanket of insulation, say fiberglass, should cover the plumbing or air duct system if it is used. A thermally controlled jacket can form an outer layer if needed.

The accuracy of the calorimeter so built then seems to depend primarily on how good the innermost surrounding insulation is, and if that insulation is good, to a much lesser degree on how good the surrounding innermost metal box conducts heat and avoids hot spots where there are no caloristors. The ideal insulation material is aerogel, but that is expensive. One advantage to this design is it can be used with any internal operating temperature desired - limited only by the melting point of the metal and insulation chosen and the limits on the temperature measuring device chosen.

If enough caloristors are used a picture can be gained of any hot spots that develop or move around and a determination can be made as to the thermal stability and the accuracy of the data. The main problem with accuracy may be a long stabilization time, but copper or aluminum rods conduct heat pretty fast and a well insulated thick internal metal box should at least provide a good integrated total heat flow. The other problem is the cost and complexity of building the thermistor multiplexer. One advantage is that enormous variations in scale are available by simply varying the size of the rods used in the caloristors.

Also of interest is that a single caloristor and "hot-end" plate could be placed on the outer surface of the inner layer of insulation in order to measure the heat flow lost through the insulation per area of insulation. This should be placed at the location of greatest heat flow through the insulation so as to establish a maximal error value.

One key to making all this work is obtaining or building a good and cheap analog multiplexer with lots of channels, and the driver software to calculate and sum the heat flows. Once you have those, and a bunch of pre-made caloristors handy, throwing together a custom dual method calorimeter of any size or operating temperature becomes fairly quick. It is just a matter of building a right sized metal box, insulating the box, and inserting caloristors through that insulation, and calibrating using control heat sources.