

How To Make A Cheap And Effective Seebeck Calorimeter

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The Seebeck calorimeter is very effective in measuring heat generation over a wide range of power and with high sensitivity and stability. Such a device can be constructed cheaply and easily, although with considerable investment of time. A successful example is described.

INTRODUCTION

A Seebeck calorimeter consists of a thermal barrier that surrounds the active volume. Many thermocouples are placed uniformly throughout this barrier so that they are in series, with one junction on the inside and the other on the outside. Heat generated within the active region generates a voltage that is proportional to the difference between the interior and exterior temperatures. Because the thermocouples are uniformly placed, measurement is theoretically independent of where heat leaves through the wall. Stability of the calorimeter requires that the outside temperature is constant and the external thermocouple junctions are fully in contact with cooling water. Only two variables are important in determining the characteristics of the instrument. These are the thermal conductivity of the barrier and the number of thermocouples. Use of interior fans improves the stability and reduces time required to reach steady state.

DESCRIPTION

Figure 1 shows a photograph of the Seebeck and the supporting equipment. A pumped, constant-temperature bath is located below the calorimeter and supplies cooling water to the jacket that surrounds the wall in which the thermocouples are located. Water entering the jacket is caused to assume a swirling motion so that it removes heat from the active wall as quickly as possible. The inner wall is made of 5" diameter PVC tubing and the outside is 6" diameter PVC. The lid and bottom also contain thermocouples and are water-cooled. Wires entering the lid are conducted through about 12" of watertight plastic tubing so that they can achieve the temperature of the cooling water, as shown in Fig. 2. These features make the calorimeter independent of room temperature.

The thermocouples are made of 0.03" diameter Constantan and Iron wire that are butt-welded using electric discharge. About 1000 of these are placed on 1/2" centers and hooked in series by soldering the wires on the outside of the active wall. The welded beads are flattened and placed as close to the inner surface as possible. A picture showing the interior is seen in Fig. 3. Fans are located on the lid and at the bottom.

The thermocouples were introduced by drilling the inner wall using a milling machine so as to give a line of holes 0.5" apart having an alternate distance of 0.4" and 0.1" between holes within each line. This allows the thermocouple leads to be joined on the outside where they met the next thermocouple at the 0.1" interval. After all leads

were joined using lead solder, the outside was painted with waterproof paint (Fisher Cat. UN1263 Sealit).

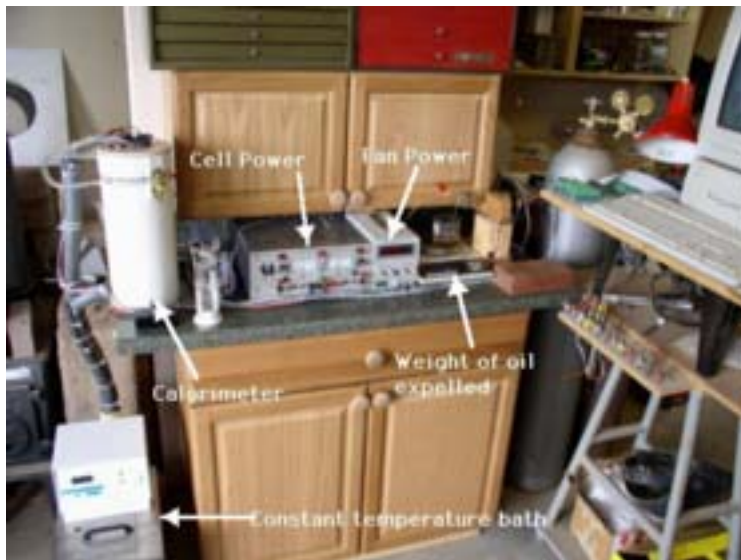


FIGURE 1. Overview of the Seebeck Calorimeter. The expelled oil measures how much gas leaves the cell.

Flat pieces of PVC, required for the ends, were made by heating pieces cut from the 6" tube in a furnace at 130°C until they had been forced flat by a weight that is separated from the PVC by a sheet of glass. Pieces were either sealed together using PVC cement or by a rubber gasket.

Figure 4 shows a typical calibration curve using an internal Joule heater. The points deviate from the least-squares line by ± 35 mW, which is equivalent to an average error of $\pm 0.2\%$ relative to the amount of applied power. Stability over a long time is equally small because very few external conditions affect the values. Experience using a Seebeck below 15 watts of applied power shows that uncertainty can be reduced to ± 10 mW.

Two disadvantages of the Seebeck method exist. The cell is not cooled as effectively as is the case when the flow- or isoperibolic-methods are used so that the cell temperature is more sensitive to applied power. The time constant to reach steady state is much longer compared to other methods. An internal fan can be used to reduce this time. On the other hand, the results are more stable and reproducible than any other method over a very wide range of applied power. In addition, the math used to calculate excess power is very simple.

The parts cost about \$150 for the Seebeck described here. Most of the considerable time is spent in making the individual thermocouples and mounting them into holes drilled in the wall.



FIGURE 2. Interior of the lid showing the way in which water is caused to swirl, how the wires are passed through constant-temperature water, and the water-proof paint applied to the surface in which the thermocouples are located.



FIGURE 3. Interior of calorimeter shown with a fan attached to the lid. A fan at the bottom is not visible.

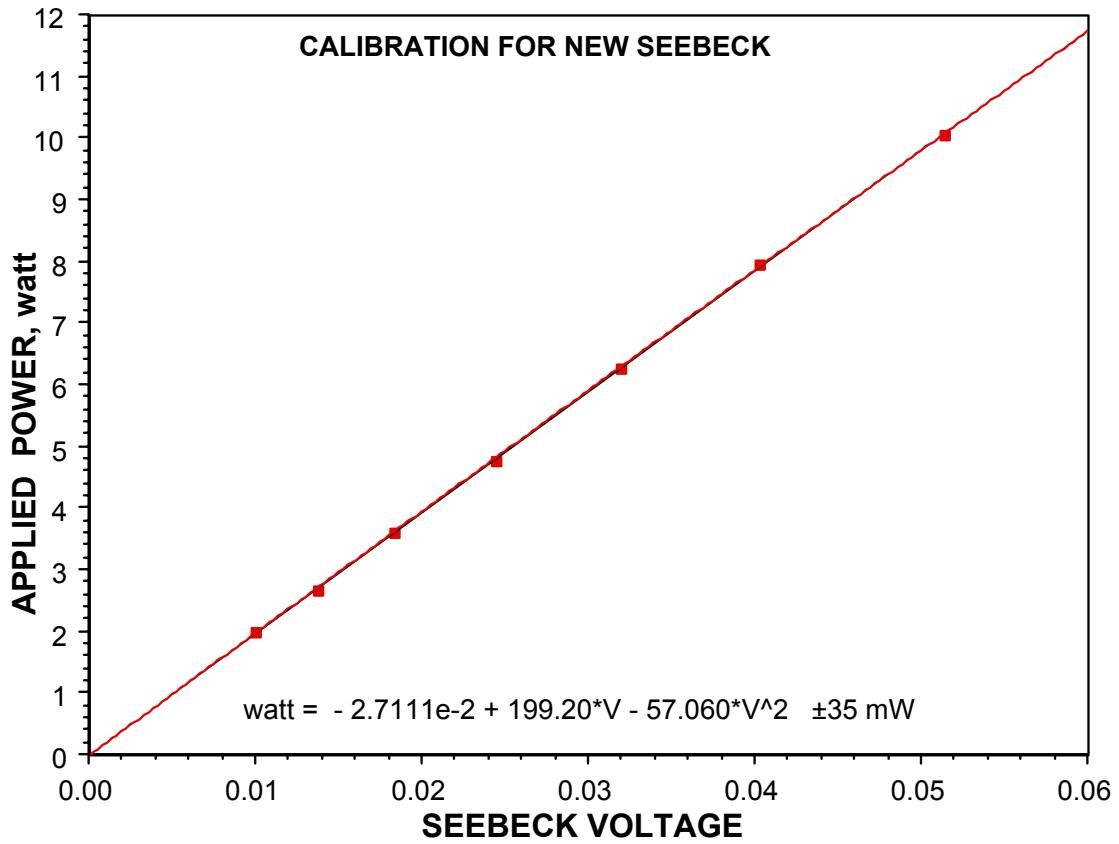


FIGURE 4. Typical calibration curve using a Joule heater. Anomalous energy is calculated using the equation shown on the figure from which electric power applied to the cell and fans is subtracted.