Construction of Thermocouples

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The classic equation for the transient flow of heat in a given direction X in any medium is

$$(1) \qquad \frac{\partial t}{\partial \tau} = \propto \frac{\partial^2 t}{\partial x^2}$$

where t is temperature, τ is time, and $\propto$ is a constant characteristic of the medium and called the thermal diffusivity. In order to evaluate heat flow by means of equation (1) it becomes necessary to evaluate the rate of change of temperature both with respect to time and with respect to position. When steep front thermal transients of large amplitude are measured in the laboratory, thermocouples are usually employed that have small thermal capacity to secure the greatest sensitivity and small size to fix the position at a point. This paper has been prepared with the experiences in mind of assembling large numbers of thermocouples having small thermal capacity, and at the same time strong enough to withstand the stresses of high pressures and shock. The claims are not so much for new methods as for the possible improvement of old techniques.

Three methods of constructing thermocouples that have been found useful are described herein. Apparatus for each of the methods was constructed from items commonly found in every research laboratory.

Mercury Pool Welder. The circuit for this welder was arranged as shown in Figure 1. The small glass vessel—a 30 ml. beaker—was filled to a depth of one-half inch or more with mercury. About one-fourth inch of lubricating oil floating on top of the mercury prevented splashing and resulted in cleaner welds. Power for welding was obtained from a 110 volt power outlet. To make a thermocouple, the ends of the wire were twisted together and then connected to one side of the 110-volt power line at A. The heat generated by the arc formed when the twisted ends contacted the mercury accomplished the welding. Excellent welds were obtained with all kinds of base metal thermocouple wires smaller than about #20 gaugs, with this welder.

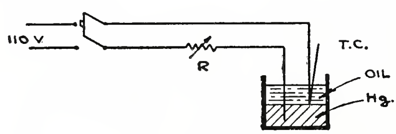

FIG. 1 CIRCUIT DIAGRAM FOR THE MERCURY POOL WELDER

Spark Welder. This welder was constructed according to the circuit shown in Figure 2. When the switch was thrown to position 1, the condensers C(300-900 mf) were charged to a potential of 100 volts or more through the rectifier X. When the switch was thrown to position 2 and the two thermocouple wires (T.C.) were quickly brought together, the energy in the arc produced a butt weld. In order to secure a good weld it was found necessary to grind the ends of the wires flat. The wires were positioned to meet end to end by clamping them to the wooden blocks B,B which were constrained to move in a straight line by guides.

This welder was also found to be useful for attaching thermocouples to many kinds of surfaces. The jig carrying the blocks B,B was removed and connections to the surface were made at P. The thermocouple to be attached to the surface is connected at Q. When the condensers were charged and the thermocouple junction brought into contact with the surface, a weld occurred and the thermocouple was firmly attached to the surface. Obviously the method doesn't work well when the surface has a high thermal diffusivity.

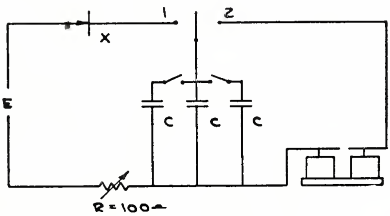

FIG. 2 CIRCUIT DIAGRAM FOR THE SPARK WELDER

Concentric Assembly. Recently a thermocouple has been developed in which one element was an oxidized wire threaded through a length of small tubing which forms the second element. The inside diameter of the tube and the diameter of the wire were very nearly the same. The tubing was then stretched until it contracted firmly around the wire. A thermal junction was formed by grinding and polishing the end of the assembly and then plating the end with any desired metal. The oxide coating on the inner wire served to insulate it from the surrounding tube. An iron-constantan thermocouple made from #30 gauge constantan wire and a small bore iron tube will have a time constant of the order of microseconds when the plating forming the junction is about one micron thick.

In order to form the oxide coating on the constantan wire enough current from the 110-volt line was passed through it to bring it to a dull red heat. After about fifteen minutes of heating in the open a heavy oxide coating would be formed on the wire. This oxide coating gave an insulation resistance of several megohms between the wire and outside tube before the junction was formed.

A jig for assembling the thermocouple is shown in Figure 3. The outer tube (T) was fastened to the blocks (b) by means of soft solder and the oxidized wire threaded through the tube. The blocks (b), constrained to move in guides, were moved by means of the screws (s) and the tube stretched and contracted until it gripped the inner wire firmly. A resistance measurement was indicative of when the tube had contracted securely around the wire, i.e., the resistance before stretching being 200 megohms or more and dropping to about 20 megohms when stretching

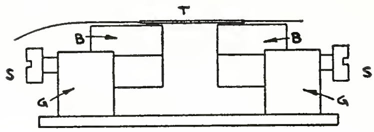

FIG. 3 JIG FOR CONCENTRIC TUBE THERMOCOUPLE ASSEMBLY

ceased. The tube was then annealed and removed from the jig. Thermocouples made in this manner have withstood the stresses of high fluid pressures and the shock of vibrating mechanisms.

Conclusion

Three methods for making thermocouples from small wires have been described. One of the methods has been especially useful for constructing thermocouples having high sensitivity and also resistance to shock and pressure.