the restriction can, in fact, be calibrated directly in terms of the time lead (or dynamic compensation factor) introduced by it.

Adjustment of the dynamic compensation factor can be made in a number of ways. Generally, the lag of the thermal element can be estimated from tables with sufficient accuracy and the dynamic compensation factor is set equal to this lag.

It is believed that the use of a derivative transmitter to achieve dynamic compensation for the inevitable lag of thermal elements offers a valuable and unique tool in the field of temperature measurement and control which makes possible a degree of speed and accuracy not previously obtained.

Velocity and Flow Measurements with an Improved Thermal Instrument

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Precise measurement of the velocity of free air currents moving at rates as low as 5 ft/min has always been a difficult problem. It is one, however, that is constantly present in a wide variety of applications such as meteorology and microclimatology research, air conditioning, heating and ventilating work, measurement of rate of flow in gas or air systems, hay and tobacco drying processes, and general process control.

A new type of electrical anemometer that has recently been developed for applications such as these allows velocities as low as 5 ft/min to be determined with accuracies previously limited to high velocity measurements. The new instrument, which is known as an Air Meter, operates by placing a heated precious-metal thermopile in the airstream. The flow of air past the thermopile tends to bring the thermopile wire, consisting of a succession of thermojunctions, to the same temperature throughout. The thermal differences between these junctions induce a thermal direct voltage proportional to the temperature differences. Thus, flow of air past the thermopile tends to reduce this temperature difference and, therefore, to reduce the direct voltage generated by the thermopile.

The thermopile, or sensitive element of the anemometer, is made up of alternate sections of thermocouple materials butt-welded to obtain a continuous wire. This wire is then heated by passing an alternating current through it. Cold junctions of the thermopile are obtained by attaching alternate junctions to copper mounting studs, thereby supplying sufficient heat conductivity away from the junctions to keep them at ambient temperature. The other junctions, not in contact with the copper studs, are heated by the alternating current. Alternate junctions therefore become the hot and cold junctions of the thermopile.

Normally, maximum voltage is obtained with zero air velocity, and zero output represents a large cooling effect by a high air velocity. However, when high accuracy is desired over a wide range of velocities, a second series of thermocouples can be arranged with opposite polarity and shielded from any air currents. With these couples arranged to buck the voltage from the velocity pickup thermopile, zero voltage output is obtained for zero air velocity and full-scale indication of the indicating or recording instrument is obtained for the particular air velocity desired. Sensitive instruments of this type are well suited to process control, the rapid response of the electric signal operating controls and giving warning of deviations.

The principle of placing a heated thermopile in an airstream for determining air velocities has many advantages over older types of anemometers. Thermal anemometers have no moving parts to introduce frictional errors, which are very important in low velocity measurement. Also, they are not affected by icing. This thermopile type anemometer has additional advantages over the usual hot-wire types in that the indicating or recording instrument consists of a measurement of direct current voltage instead of a small change in resistance. The errors introduced by lead resistance are thus much less. Errors introduced due to change in air temperature are compensated for, since both cold and hot junctions are equally affected by any change in ambient temperature. The instrument measures the temperature difference between these junctions, all of which are exposed to the airstream. Likewise, radiation effects tend to cancel.

A two-thermocouple arrangement which lends itself to an inexpensive type of construction has been incorporated into a standard low-cost model which has proven very versatile and reliable in laboratory and field use. The indicating meter is small and can easily be held in the palm of the hand while taking readings. The thermopile element is a separate probe which may be plugged directly into the indicating meter, or which may be used at the end of graduated extension wands or cables. For applications requiring extreme sensitivity and accuracy for very exacting research measurements, a larger instrument has also been developed.

Experience has proved this type of thermal anemometer to be exceptionally stable. One instrument has operated continuously for a year in the laboratory and a second instrument, designed for indication of nondirectional air flow, has operated for the same period on top of a building and has consistently indicated wind velocity without failure or zero shifts.

The Air Meter is well adapted to remote recording on standard strip-chart potentiometers or other standard types of indicating or recording instruments which operate from direct voltage. The ability of anemometers of this type to measure extremely low velocities, combined with their inherent stability, ease of operation, low power requirements, and adaptability to remote indication or recording, suggests many applications of a widely varying nature.