

## LETTERS TO THE EDITORS

### *Determination of the Thermal Diffusivity of Rubber*

The thermal diffusivity  $K$  of rubber has been determined by Rehner<sup>1</sup> by measuring the temperature change of a thermocouple embedded at the center of a rubber sphere after the sphere is suddenly plunged into a bath at another temperature. Frensdorff<sup>2</sup> has recently reported that heat conduction by the thermocouple wires, as shown by varying the wire diameter, resulted in erroneously high initial values of the thermal diffusivity.

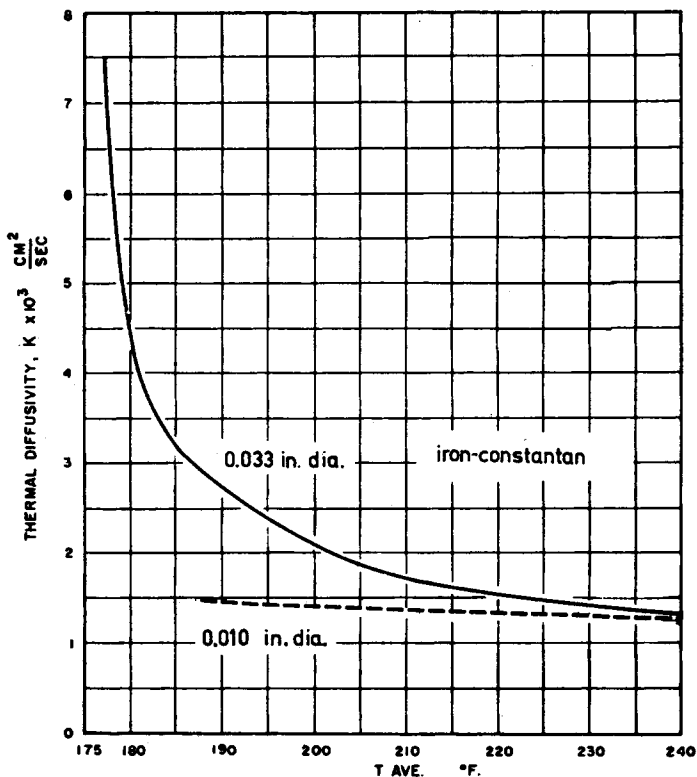


Fig. 1. Thermal diffusivity vs. mean temperature, showing the elimination of the initially high  $K$  values resulting from heat conduction by the oversized 0.033 in. iron-constantan thermocouple by reducing the couple diameter to 0.010 in.

This clarified the work of Gengrinovich and Fogel<sup>3</sup> which stated that the high  $K$  values were due instead to the unjustified assumption of Rehner that the surface temperature of the sphere immediately assumes the temperature of the bath.

Both effects (1) that the thermocouple wires may contribute to the heat conduction thereby giving initially high  $K$  values, and (2) that there is a heat barrier at the bath-sphere interface have been reported previously in experiments by Mac Rae and Zapp.<sup>4</sup>

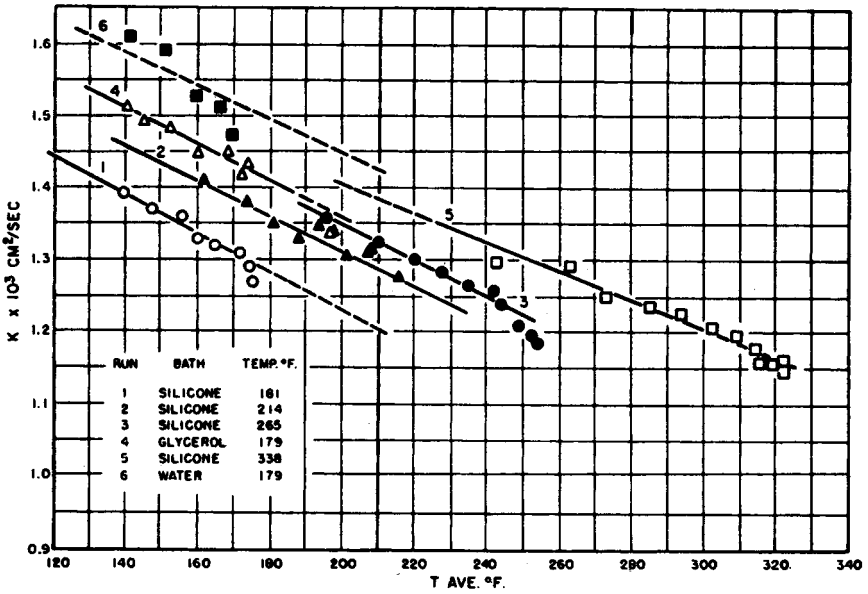


Fig. 2. Thermal diffusivity measurements vs. mean temperature, showing the pronounced effect of different bath temperatures and fluids on the measured  $K$  values.

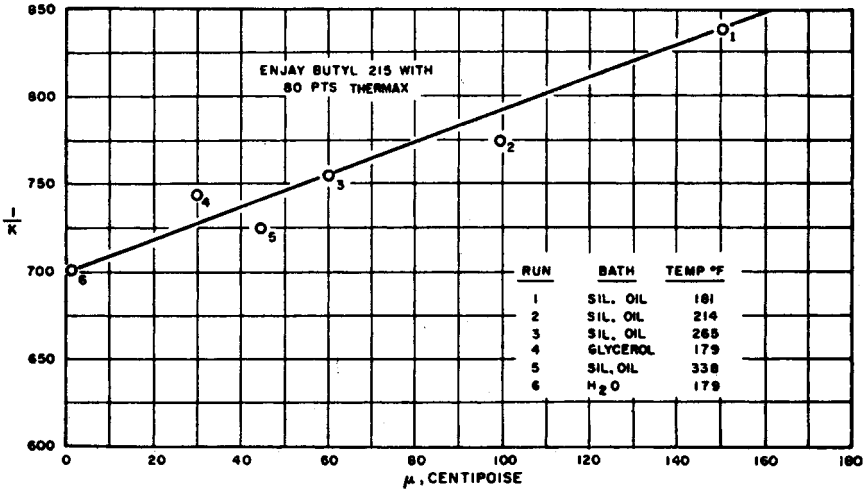


Fig. 3. Correlation of the thermal diffusivity data at 210°F. from Figure 2 as a function of the bath viscosity at the given bath temperature.

(1) Heat conduction by a 0.033 in. diameter iron-constantan thermocouple had increased greatly the initially measured  $K$  values. This effect was eliminated by using a smaller 0.010 in. couple (Fig. 1) resulting in the linear  $K$ -temperature dependence. Iron-constantan couples are recommended rather than copper-constantan due to the lower thermal diffusivity of iron compared to copper: copper, 1.2 cm.<sup>2</sup>/sec.; iron, 0.19 cm.<sup>2</sup>/sec.; constantan, 0.062 cm.<sup>2</sup>/sec.; 20°C. While a 0.010 in. iron-constantan couple

did not influence the measurements, it was necessary for Frensdorff to use a much smaller 0.0035 in. copper-constantan couple.

(2) The problem of heat transfer between sphere and bath involves not only the initial sudden heating of the surface to the bath temperature but even more important the effect of temperature difference at the bath-sphere interface during the total experimental run. The measured  $K$  values were observed to be a pronounced function of not only the bath temperature but also the bath fluid (Fig. 2). This effect was explained by considering that the total resistance to heat transfer was due to the combined heat resistance of the sphere itself and of the contact film at the bath-sphere interface. The heat resistance at the bath-sphere interface was assumed to be proportional to the viscosity of the bath liquid, as was verified by the linear correlation of the reciprocal of the measured  $K$  values versus the bath viscosity, (Fig. 3). From Figure 3, the measured  $K$  values were corrected to zero bath viscosity (equivalent to zero heat resistance at the interface) giving the absolute values for the thermal diffusivity of the rubber. Figure 3 shows that when water is used as the bath liquid, as was the case for Rehner, Gengrinovich and Fogel, and Frensdorff, the interfacial heat resistance is eliminated. It is recommended that a wetting agent is added when water is used as bath fluid. For measurements at higher temperatures, simulating more nearly the actual vulcanization temperatures, and where silicon oil is used, the bath temperature should be increased until there is no noticeable effect on the measured  $K$  values. This is recommended rather than correcting the values to zero viscosity as done by Mac Rae and Zapp. For both water and oil baths the agitation should be increased until this effect is also eliminated. The rubber stocks consisted of Butyl 215 plus 80 parts Thermax carbon black, except for the data of Figure 1, where the carbon black was Kosmobil 66.

#### References

1. Rehner, J., Jr., *J. Polymer Sci.*, **2** 263 (1947).
2. Frensdorff, H. K., *J. Appl. Polymer Sci.*, **6** s28 (1962).
3. Gengrinovich, V. I., and V. O. Fogel, *Rubber Chem. Technol.*, **32** 444 (1959).
4. Mac Rae, D. R., and R. L. Zapp, *Rubber Age* **82** 831 (1958).

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### *Calibration Device for an Extensometer*

An extensometer is an instrument used for measuring the elastic properties of metals and plastics. There are several types of extensometers, but the one used in these laboratories is the microformer type. The microformer is essentially a variable differential transformer with a moveable core which varies the magnetic coupling between the primary winding and two balanced secondary windings in each microformer. These secondary windings are connected in phase opposition so that the output voltage from each microformer will vary linearly with the position of the core. Furthermore, this movement of the transformer core induces a change of the output of the transformer, upsetting the balance between it and a similar microformer in the recorder. This unbalanced signal is amplified and drives a Servo motor which in turn activates an X-Y recorder. In operation, the microformer type extensometer is attached to a plastic specimen by means of a pair of knife edges (one at each end of the gage length) which are held in contact with the flat surface of the specimen by coiled springs. The specimen