ON THE RELATION BETWEEN HEAT CONDUCTIVITY AND DENSITY IN SOME OF THE COMMON WOODS.

LOUIS W. AUSTIN AND C. W. EASTMAN.

In 1828 De la Rive and De Candolle,[1] after examining the conductivities of five varieties of woods, announced the interesting fact that along the fibers the thermal conductivities of the different woods were approximately proportional to their densities. Some observations made by C. G. Stangel[2] in 1899 in connection with his work on the effect of moisture on the heat conductivities of woods and rocks called attention again to the relations between the conductivities and densities of woods. As far as has been ascertained no other work has been done on the subject since that of De La Rive and De Candolle, the extensive work of Tyndall[3] on woods being confined to the rapidity of propagation of the heat wave, or, diffusivity.

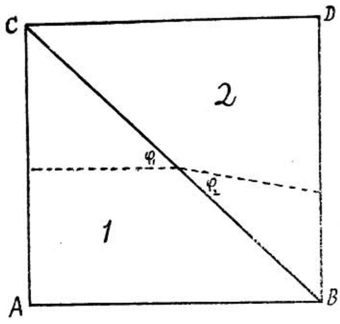
In our own experimental work a method was made use of which was presented in outline by Voigt[4] in 1898, the general plan of which is as follows: The specimens whose heat conductivities are to be compared are cut in the form of right angled triangles and joined along the hypotenuse, as shown in the figure. If one of the edges AB be heated until a steady flow of heat is established so that the temperature at each point becomes constant, the isothermal lines in the lower specimen will be parallel to the base AB, while in the upper specimen they will be bent upward or downward depending on whether the conductivity is greater or less than in the lower. Accord-

1 De la Rive and De Candolle, Pogg. Ann., vol. 14, 1828, p. 590.
2 C. G. Stangel, University of Wisconsin Thesis, 1899.
3 Tyndall, Phil. Trans. Roy. Soc., vol. 143, 1853, p. 217.
4 Voigt, Wied. Ann., vol. 64, 1898, p. 95.

ing to the tangential law of refraction of a disturbance crossing the boundary of two media in which it is propagated with conductivities k_1 and k_2,

$$\frac{K_1}{K_2} = \frac{\tan.\ \phi_1}{\tan.\ \phi_2}.$$

The determination of the relative conductivities then resolves itself into the measurement of the angles ϕ_1 and ϕ_2. In practice the isothermal line is determined by the melting of a thin layer of wax spread over the specimen.



In applying this method to determining the relative conductivities of woods the following arrangement was used: Blocks of wood about 8 cm. square and 2 cm. thick were cut in triangular form and placed in a wooden frame with their fibers parallel to AC, as shown in the figure. These were covered on the bottom and on the sides AC and BD with thick pieces of asbestos to cut down the loss of heat. A uniform distribution of heat along AB was obtained by pressing a strip of iron of about the same dimensions as the edge of the block against the wood, and heating this by means of a row of small gas flames. The wax used to show the isothermal line was composed of paraffin mixed with a little turpentine. This mixture had a melting point of about 40° and gave a sharp line of demarcation between the melted and unmelted portions. To prevent the wax soaking into the wood and also to insure a more uniform radiation both blocks were covered with a sheet of tinfoil on which the melted wax was painted with a flat brush. This device was first used by C. G. Stangel in his work on heat conductivity to which reference has already been made.

It was found that there were two chief sources of error to be guarded against, the first of which is the direct effect on the wax of radiation from the source of heat. To prevent this the metal from which heat is communicated to the wood must not be allowed to extend above the edge of the wood, this being much more effective than any system of screens used with a larger heating plate. The second possible source of error lies in the difficulty in obtaining a perfectly good contact between the specimens. To insure this as far as possible, two strips of tinfoil were placed between and the blocks pressed tightly together by means of wedges. It was also found necessary in order to preserve the contact, to plane the blocks frequently as they became warped by the heat. With these precautions very uniform results were obtained.

In our experiments only the conductivities parallel to the fibers were tested. The piece next to the source of heat (position 1 in the figure) was in all cases the same specimen of white oak, the others being placed in position for comparison with it. The densities were determined partly by weighing and measuring the specimens and partly by the method of immersion. Five sets of angles were taken for each wood and the average of these used in computing the conductivity. These measurements were estimated to be correct to within two per cent. Some errors are undoubtedly introduced into the results by the fact that in the second specimen the flow of heat is not in general strictly parallel to the fibers, and since the conductivity at right angles to the fibers is smaller, the true values of the conductivities of some of the lighter woods may be slightly greater than those given. In order to reduce the relative conductivities at least approximately to absolute units, the value for walnut parallel to the fibers, found by Péclet[1] is assumed to be correct for our specimen and the conductivities of all the other woods are expressed in the same terms.

---

[1] C. G. S. System of Units, Everett, p. 128.

In the following table are given the conductivities and densities of the twelve woods examined:

Wood.	Density.	Cond'ctivity.	Wood.	Density.	Cond'ctivity.
Sequoia...........	0.380	0.000342	Gum	0.559	0.000458
Butternut.........	0.394	372	Walnut...........	0.609	480
Pine...............	0.406	358	White oak.	0.615	472
Linden	0.408	391	Brown ash.......	0.649	539
White wood.......	0.506	426	Georgia pine.....	0.657	540
Cherry.............	0.534	451	Red birch..... ..	0.711	528

The results of the work seem to indicate that the law of proportionality between heat conductivity and density, as announced by De la Rive and De Candolle is at least very approximately obeyed. It is true that in our results slight exceptions to this are shown but it is quite possible that all the variations observed are due to errors of observation. It seems more probable, however, that slight variations really do exist, as the difference in form of the cells in different woods must produce a difference in the distribution of material which would in itself, at least in some degree, affect the conductivity.

The University of Wisconsin, December, 1900.