

PLUMBERS' HANDBOOK

SECTION 1

HEAT ¹

When a body is touched by the hands, two distinct sensations are experienced, one a feeling of pressure and the other of warmth or coldness. The latter effect results when a hot steam pipe is touched. The words hot and cold simply refer to the condition of the body as judged by one's sense of heat. By means of this sense, we say that one body is hot and that another is cold. For instance, we can by the sense of heat alone arrange several pieces of the same substance in such order that each will be hotter than all that precede it. We are thus led to the idea of temperature as measured by means of the mercury thermometer.

Temperature.—Imagine three tanks of water *A*, *B*, *C*, (Fig. 1), each containing a different quantity of water. If *A*

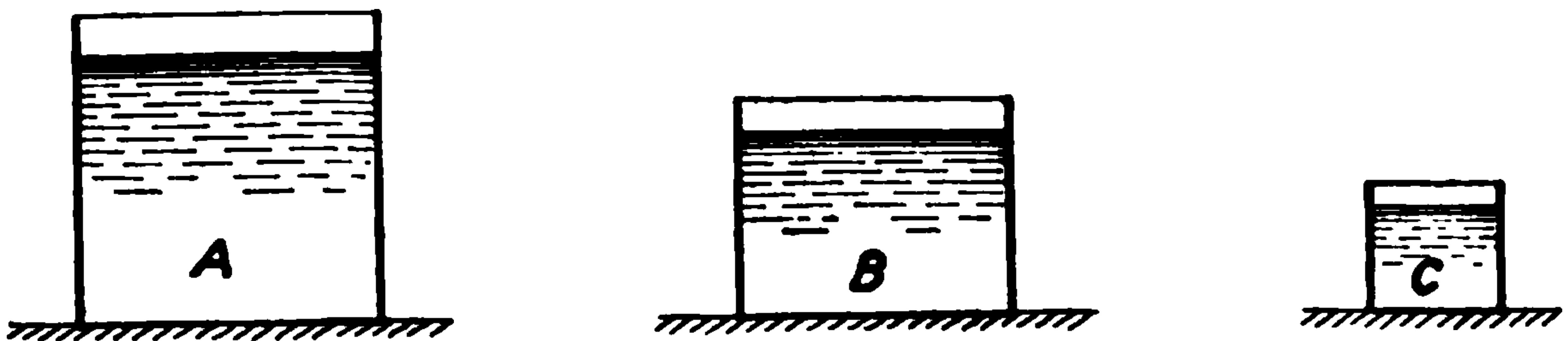


FIG. 1.

and *B* are placed side by side in contact, and we observe by means of a mercury thermometer placed first in *A* and then in *B* that the temperature of the water in *B* increases while that in *A* drops, we say that *A* has given up heat to *B*. Put *C* in contact with *B*; if *B* thereby loses heat, be it ever so little, heat has passed to *C*, and *C* is said to be at a lower temperature than *B*.

It is evident that in general when one body is placed in contact with another, the difference in temperature between the bodies is that which determines which way the heat will flow. That is, whether heat flows from A to B or the reverse, depends not at

¹ See "Heating Systems," page 464. See also "Domestic Hot Water Supply," page 107.

all upon the size of the tanks, but upon their difference of temperature.

Effects of Heat.—One of the most general effects with change of temperature in any body is change of bulk, or as it is called *expansion*. The size or bulk of any body is found to increase continuously with its hotness. Thus the metal rails of a railroad track are not laid with their ends in contact, but with a short space between to allow for expansion in summer (see section on "Expansion of Pipes," page 88).

Another general effect of heat is a change in the physical state or form of matter; that is, by sufficiently increasing the temperature, solids are changed to liquids, and liquids into vapors. This is well illustrated by the melting of ice to water and the boiling away of water into steam.

Thermometers.—Since heat itself is invisible and can be perceived only through its effects upon bodies, we are forced to employ some one of these effects for the measurement of heat. For ordinary purposes, the universal choice has been change in size, which always accompanies a change in temperature.

For various reasons, mercury appears to be very well adapted to temperature measurements. The indications of temperature which are given by the mercurial thermometer hinge upon the fact that mercury expands with rise of temperature more rapidly than glass. If, therefore, a glass tube having a bulb blown in one end be partially filled with mercury and inserted in water at a higher temperature than its own, the mercury will rise in the tube. If the instrument is inserted in water of lower temperature, heat will flow from the mercury to the colder water, and the column of mercury will contract or grow shorter.

The steps in the manufacture of a thermometer are as follows:

1. The selection of a piece of thick-walled capillary tubing of uniform bore.
2. A bulb is blown in one end of this tube.
3. The bulb is filled with mercury, heated and sealed off.
4. The tube of the thermometer is graduated.

This last step is of great importance. It so happens that there are two temperatures which can be easily produced; one of them, the melting point of ice, the other, the boiling point of water. Hence, these two temperatures, the melting point of ice and the boiling point of water, are called 32 degrees and 212 degrees respectively on the Fahrenheit thermometer, and are fixed points. The interval between these two fixed points

is divided into 180 steps, or degrees. The zero point on the thermometer tube is located by marking off 32 divisions below the 32-degree point and calling this last mark zero.

Quantity of Heat.—Temperature is merely a condition determining the direction of flow of heat, very much as pressure is a condition governing the direction of flow when two tanks of compressed air are connected. Just as we need a means of measuring the amount of air which escapes from either of the two tanks into the other, so we need a method of estimating the quantity of heat which passes from one body to another of different temperature, when they are brought into contact.

We measure water in gallons and cubic feet; eggs by the dozen or by weight in pounds. That is, some suitable unit is always selected when measuring the quantity of various substances. *In the case of heat the unit chosen is that quantity of heat which raises the temperature of 1 lb. of water 1°F. , and is called the British Thermal Unit (B.t.u.).* For instance, if we heat 1 lb. of water, raising its temperature from 60 to 100°F. , we have added 40 B.t.u. of heat to the water over and above what it possessed at 60°F.

Transfer of Heat.—Heat is transferred from one body to another or is diffused throughout a liquid by three general methods, *viz.*: (1) **Conduction**, (2) **Convection**, and (3) **Radiation**.

1. Conduction.—If one end of an iron rod is placed in a hot fire while the other is held in the hand, the end held in the hand soon commences to get warm and finally may become unbearably hot. The process by which the heat is transferred from the heated end of the rod to the cold end is called “conduction.” The same rod, when used with ice, may become quite cold. In this case heat has been transferred by conduction from that end of the rod held in the hand, to the end immersed in the ice water.

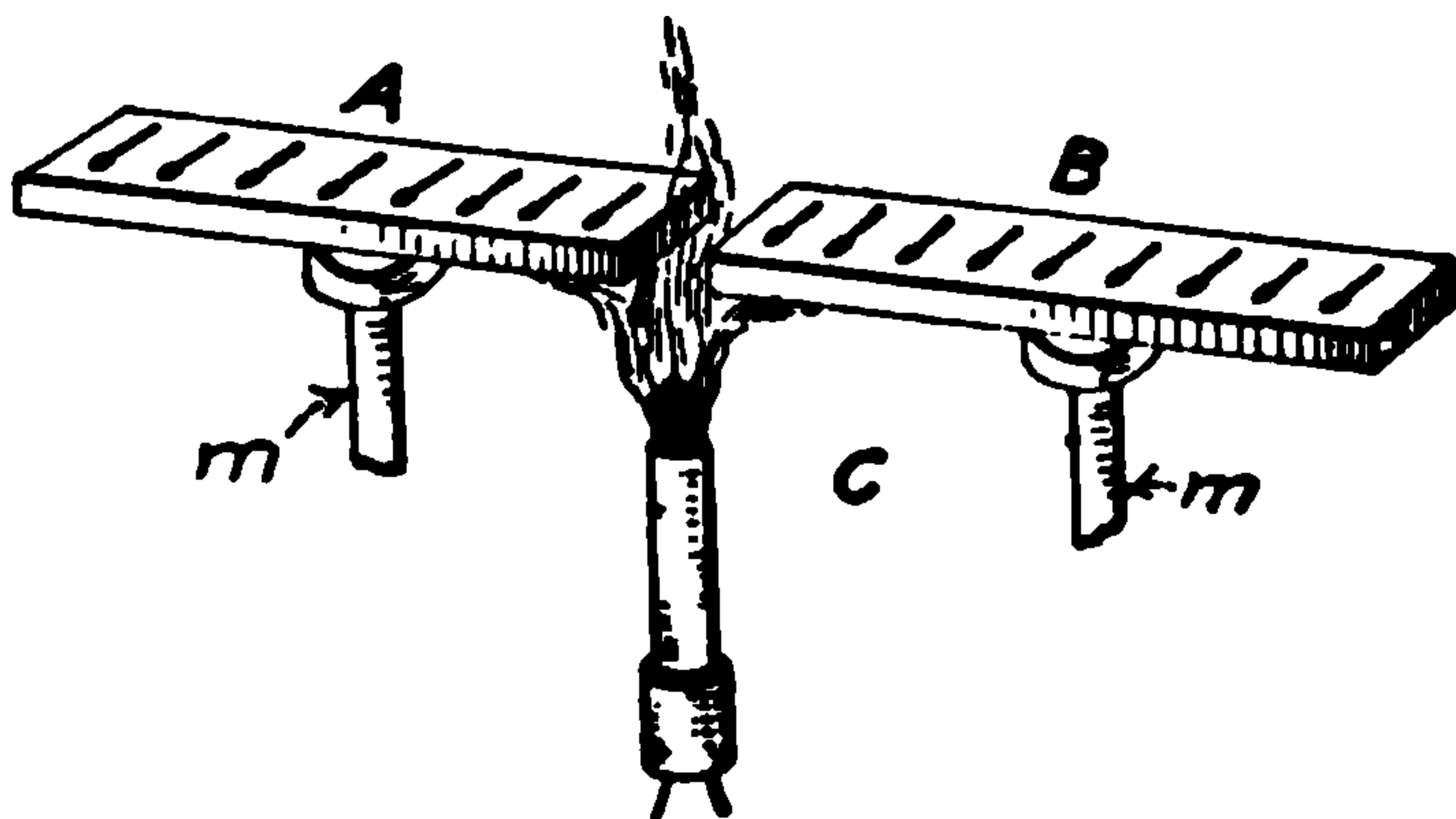


FIG. 2.

The rate at which different substances conduct heat varies between wide limits. For instance, in Fig. 2 are shown an iron rod *A* and a copper rod *B*, both resting on pedestals. Both rods are of the same length, 1 ft., and of the same cross-section.

Each has one end in the same gas flame, *C*. If matches are now placed at equal distances from the flame of each rod, those on the copper will burn earlier than those on the iron rod.

2. Convection.—The hot air of a chimney rises, mixes with the outside air, and gives some of its heat to the outside air. The hot air rises because its weight is less than that of cold air. This process of carrying the hot air up the chimney is called convection. Again, a can of water (Fig. 3) to which

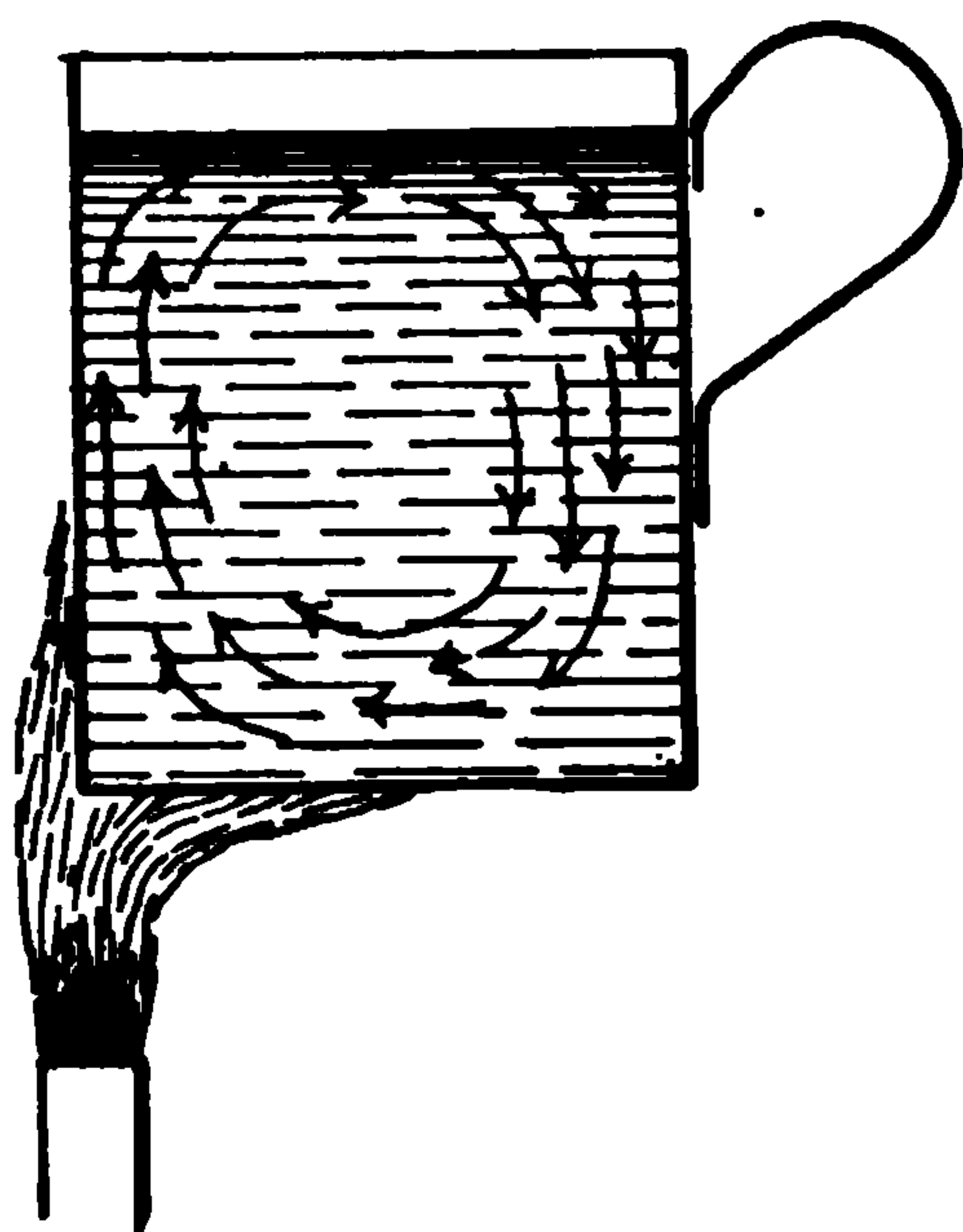


FIG. 3.

a gas flame is applied on one side, becomes equally heated throughout. First of all, the water just over the flame becomes hot by conduction through the walls of the can. Then, by convection, the hot water just over the flame is displaced by the colder water which is heavier, and therefore sinks to the bottom, as indicated by the arrows. This cold water, in turn, becomes heated by conduction through the bottom of the can.

3. Radiation.—When the hand is held some inches from the side of, or underneath, an incandescent electric bulb, the sensation of heat is distinctly recognized. We hold our hands before an open-grate fire to warm them. How does the heat pass from the fire to the hands? Certainly not by conduction, since air is one of the very poorest conductors of heat known. It can readily be shown that conduction or convection have nothing whatever to do with the conveyance of this heat, for even in the case of the incandescent bulb, the air has been almost entirely exhausted from the bulb, yet heat is delivered from the filament to outside objects. There is every reason for believing that the space which separates us from the sun is more nearly a perfect vacuum than any other known; yet across this vast and empty region the earth daily receives enormous quantities of heat and the heat so received is called radiant heat.

EFFECTS OF HEAT ON WATER

Pressure and Temperature.—In the first place, a glass of water as long as it contains ice and is stirred does not become either hotter or colder on standing. The ice may melt away,

but as long as there is any ice left, the water will remain approximately at what we call "the temperature of melting ice." Secondly, the temperature of melting ice can be changed by placing the ice under pressure.

In like manner, however much you boil the water in a tea-kettle, its temperature does not change after boiling has once begun. But if the pressure on the surface of the water in the tea-kettle is changed, then the temperature of the boiling water will also be changed. This is most easily proved by boiling in a kettle of water a bottle partly filled with water. If this bottle be corked while still boiling, and then removed from the water in the kettle, the steam over the surface of the water in the bottle is partly condensed, thus reducing the pressure on the water. Under these circumstances, the water in the bottle will continue to boil long after it has reached a temperature not uncomfortable to the hand. We can thus say that the boiling temperature of water increases with the pressure on the surface of the water. When the water surface is exposed to the atmosphere, the pressure on it will be that of atmosphere, and the boiling temperature will be 212°F . Any reduction of pressure below that of the atmosphere will reduce the boiling temperature below 212° , while any increase of pressure above that due to the atmosphere will raise the boiling temperature above 212° . The relation between the external pressure and the temperature at which boiling takes place is not a simple one. For the sake of accuracy and convenience, it is customary to refer to the columns of a steam table for its determination. The data found in the steam tables has been derived from experiments many times repeated.

Volume and Temperature.—If account be taken of the volume of steam produced during the evaporation of the water in a closed vessel, it will be found in each case that a definite volume has always been developed by the time that 1 lb. of water has been entirely evaporated. This volume is called the **specific volume** of saturated steam. It, too, will be found to have different volumes under different conditions as to pressure and temperature; but under the same conditions it is always the same.

Superheat and Saturation.—If the heating of 1 lb. of water in a closed vessel be continued after all of the water is evaporated, it will be found that the temperature again begins to rise, and this time it will continue to rise as long as heat be

added to it. Just at the point where evaporation is complete and the final rise in temperature begins, the steam is known as **dry saturated steam**. At any temperature above that it is known as **superheated steam**. At any point between the beginning of boiling and complete saturation, when the original 1 lb. is partly water and partly steam, the steam is known as **wet saturated steam**. *In other words, steam in contact with water is always saturated steam and must always have a definite temperature and a definite volume when under a given pressure.*

If heat be added to saturated steam, it will become superheated; if heat be abstracted from it, it will condense. If the pressure be released from wet steam, more steam will be formed; if the pressure upon it be increased, some will condense.

The total number of B.t.u. taken up by 1 lb. of water in changing from water at 32°F. into dry, saturated steam at any higher temperature consists largely of two parts.