heated to a high temperature, producing violent evolutions of light and heat. Oxygen is the vital part of the atmosphere, and carbon is the fundamental ingredient in all fuel used for making steam, anthracite containing the larger per cent. of pure carbon.

When the fireman has learned to combine these two elements in proportions which shall produce the greatest amount of heat, he will have solved the problem of making steam with the greatest economy of fuel and manual labor. Take a locomotive fire-box for example : a common form of locomotive fire-box is 72x35 inches, which gives about seventeen square feet of grate area with the only draught through the ash pan. If an engine of this kind is required to draw a fairly heavy train at a running speed of forty miles per hour, it will be necessary to burn sixty pounds of coal per mile, or 2,400 pounds per hour, to maintain steam for this work. This would require the burning of about 141 pounds of coal on each square foot of grate surface every hour. In this case the supply of air must be liberal and the oxygen will be separated from the air and combines with the carbon in the proportion of twelve parts of carbon by weight, to thirty-two parts of oxygen, by weight, which produces carbonic acid gas. If, however, the supply of air is restricted the carbon takes up a smaller proportion of oxygen, giving us carbonic *oxide* gas, which produces much less heat than carbonic acid gas.

One pound of carbon uniting with oxygen to form carbonic acid gas generates 14,500 units of heat ; or, sufficient to raise eighty-five pounds of water from the tank temperature to the boiling point.

On the other hand, when one pound of carbon unites with oxygen to produce carbonic *oxide* gas, only 4,500 units of heat are generated ; or, sufficient to raise twenty-six and a half pounds of water from the temperature of the tank to the boiling point. In both cases the same quantity of fuel being used, the difference being that less oxygen is in the mixture.

The combining proportions of carbon and oxygen to produce carbonic acid gas being twelve to thirty-two, the combustion of each pound of carbon requires two and two-thirds pounds of oxygen. It takes 4.35 pounds of air to supply one pound of oxygen, therefore it will require eleven and a half pounds of air to provide the gas essential to the economical combustion of one pound of coal.

So far the problem seems simple enough, the solution being to give the fire plenty of draft ; but there are several practical objections to having the air blow through the grates like a hurricane.

The fuel should be kept saturated with the air containing oxygen, a large volume of air is required but it should not be forced through the furnace and tubes at too great a velocity, the result of which is to send the gases into the flues and through the stack without being ignited. Further, the heat in passing through too fast is not given time to impart itself to the water. From these statements it will be seen that loss of heat is threatened from two opposite directions. If there is not enough air admitted, a gas of inferior heating quality will be generated : if too much air is allowed, heat will be wasted.

It is a matter of common observation that fuel will not burn until it has attained a certain heat, and different materials require different degrees of heat to ignite them. Hence unless the fire in a fire-box be kept up to a condition to impart the necessary igniting temperature to its various parts as well to new fuel passed into it, a large amount of waste will occur in the distillation of the combustible gases and the passing away of these gases before ignition. This takes place proportionately to the power of the draught, both in the stationary and the locomotive fire-box, and requires constant watchfulness, so that sufficient intensity of heat be maintained at all points in the fire-box, and that, withal, the fire be not allowed to become so thin as to permit of the passage of a greater volume of cold air than the capacity of the fire to impart the required temperature.—*American Engineer.*

TANGENT GALVANOMETER.*

The tangent galvanometer is of great importance in electrical measurements, especially in the class relating to currents. The principal of the instrument is illustrated by Fig. 1. In a narrow coil of wire is suspended a short magnetized needle, whose length does not exceed one-twelfth the diameter of the coil. Two light pointers are connected with the needle at right angles thereto. When a current is sent through this coil, the needle is deflected to the right or left, according to the direction of the current, and the amount of deflection is dependent upon, but not proportional to, the strength of the current. It is, however, proportional to the tangent of the angle of deflection.

A practical tangent galvanometer is shown in Fig. 2. In this instrument the conductor is wound upon a grooved wooden ring 9 inches in diameter, the groove being $\frac{3}{8}$ inch wide and 1 inch deep. The wooden ring is mounted in a circular base piece, which is pivoted to the lower base to admit of adjustment. The lower base is provided with three leveling screws, which are bored longitudinally to receive pointed wires, which are driven into the table to prevent the instrument from sliding. The lower base is provided with an angled arm, which extends over the upper base piece, and is provided with a screw for clamping the latter when adjusted.

The winding of the ring is divided into five sections having different resistances, so that by means of a plug inserted in the switch on the base the resistance may be made 0, 1, 10, 50, or 150 ohms.

Fig. 3 is a diagram showing the coils and the switch connection stretched out. The first coil, *a*, is a band of copper $\frac{3}{4}$ inch wide and $\frac{1}{16}$ inch thick, with practically no resistance. The other coils are of iron. The coils, *b* and *a*, together, have a resistance of one ohm. The coils, *c*, *b*, *a*, have a combined resistance of 10 ohms. The coil, *d*, together with the preceding, offer a resistance of 50 ohms, and the combined resistance of all of the coils, *e*, *d*, *c*, *b*, *a*, is 150 ohms.

The conductors are connected with the binding posts, *f*, *g*, and the current flows through the coils in succession, until it reaches one of the smaller switch plates, which is connected with the plate, A, by the plug. In the present case the plug is inserted between the plate marked 1 and the plate, A, causing the current to flow from the binding post, *f*, through the coils, *a*, *b*, and plate A, to the binding post, *g*. The resistance of the galvanometer is obviously 1 ohm.

The magnetic needle, which is $\frac{3}{4}$ inch long, is located exactly at the centre of the ring, and delicately poised on a fine hard steel point. The needle should be jeweled to reduce the friction and wear to a minimum. To the sides of the needle are attached indexes of aluminum having flat ends, each of which is provided with a fine mark representing the centre line of the index. The box containing the scale and the needle is supported by a cross bar attached to the wooden ring. To the top of the wooden ring is attached a brass standard, which is axially in line with the compass needle.

Upon the standard is mounted a bar magnet, which may be

* From "Experimental Science," by Geo. M. Hopkins. In press. Munn & Co., publishers, New York.