

A NEW CALORIMETER.

BY CECIL H. PEABODY.

The form of calorimeter here described was devised to determine the quality of moist steam, and introduced into the mechanical engineering laboratory of the Massachusetts Institute of Technology. Several other forms have been in successful use there, but this one appears worthy of notice on account of the simplicity of its construction and the ease of operation. Its action depends on the fact that the total heat of saturated steam increases with the temperature or pressure, and that consequently saturated steam becomes superheated when it is allowed to expand without doing work. If the steam is moist, the excess of heat at the higher pressure, above that at the lower pressure, is expended first, in vaporizing the water present, and second, in superheating the steam.

In the figure *A* is a piece of steam pipe six inches in diameter and ten inches long, capped at both ends. Into the caps are screwed the several fittings required. A half-inch pipe *a* brings steam to be tested; the branch *c* has a drip cock at the end to allow the water condensed against the sides of the pipe to escape, the branch *b* leads to the calorimeter, and is provided with a globe valve which is opened a fraction of a turn to admit steam to the chamber *A*. An inch pipe *d*, diagonally opposite the mouth of the pipe *b*, allows the steam to escape at a lower pressure; it is also provided with a globe valve by which the pressure in the chamber can be regulated.

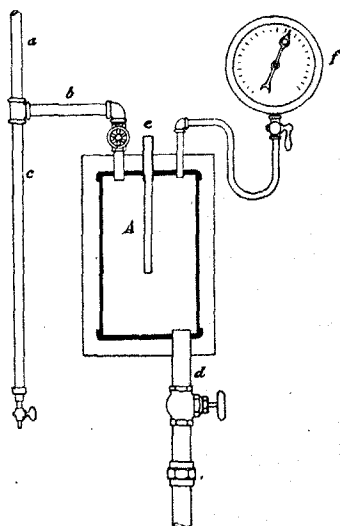
The thermometer cup, *e*, is made of a thin brass tube with the lower end closed, brazed into a thicker tube, which has a pipe thread cut on it, and which is screwed into the upper cap of the calorimeter with pipe tongs.

At *f* is a pressure gauge, which gives the pressure of the steam in the calorimeter. The pressure of the steam in the boiler or steam pipe from which the pipe *a* leads, should also be taken, pref-

erably by a gauge having a separate communication, but if the valve in the branch *b* is open only a slight amount, the gauge may be attached to the pipe *a*.

The chamber *A* is covered with asbestos board and hair felt, and may be enclosed in a case of sheet metal. The pipe *a*, the branch *b* and the valve in it are thoroughly wrapped with hair felt or other non-conducting substance. It is not necessary to wrap the pipes *c* and *d*.

To make a test, regulate the pressure in the chamber *A* by aid of the valve at *d*, so that the temperature shown by the thermometer at *e* shall be higher than that due to the pressure shown



by the gauge *f*. After the gauges and the thermometer have remained steady some minutes, note the pressures and the temperature, and also note the height of the barometer.

Let p be the absolute pressure in the steam pipe or boiler, and let q and r be the heat of the liquid and the latent heat of vaporization corresponding. Let p_1 be the absolute pressure in the chamber *A*, and let t_1 , q_1 and r_1 be the temperature, heat of the liquid and latent heat of vaporization corresponding. Let t_e be the temperature by the thermometer at *e*. Finally, let the mixture of steam and water in the pipe *a* be composed of x part of steam and $1-x$ part of water. The specific heat of superheated steam

is given by Regnault as 0.4805. Assuming that no heat is lost by radiation or changed into work

$$x r + q = r_1 + q_1 + 0.4805 (t_s - t_1)$$

$$\therefore x = \frac{r_1 + q_1 - q + 0.4805 (t_s - t_1)}{r} \quad (1)$$

and the per cent. of priming is

$$100 (1 - x) \quad (2)$$

The following table gives the results of several tests made in the Institute laboratory:

GAUGE PRESSURES.		Temperature	Per Cent.
Boiler.	Calorimeter.	Fahrenheit in Calorimeter.	of Priming.
71.2	38.5	286.7	1.1
60.3	26.8	271.8	1.2
63.0	17.5	264.9	1.3
60.6	7.0	258.8	1.1
69.0	3.7	258.1	1.2

In the use of this apparatus the following precautions are to be observed, all of which, however, apply to any continuous calorimeter for determining the quality of steam. The boiler pressure and the pressure in the calorimeter must remain constant for some minutes before the test is made, so that the whole apparatus shall be at a constant temperature and neither receive nor give up heat save that taken from the steam to supply the external radiation. In this calorimeter no attempt is made to correct for radiation, but it is probable that the temperature of the steam in the centre of the calorimeter is not much affected thereby. The errors of the gauges and the thermometer should be known from recent determinations. It is to be noted that if the steam is superheated five degrees or more an error of two degrees in the temperature will have a very slight effect on the result. The gauges used should be divided to single pounds and should be compared with a reliable mercury column. The gauges on the market though sufficient for ordinary uses, are seldom accurate enough for this work, and they are liable to change during use. Unfortunately, a comparison of gauges with each other is of little avail since the errors vary irregularly.

The application of the calorimeter is limited to cases which have a small or moderate per cent. of priming. If the priming is

excessive the steam in the calorimeter will fail to be superheated. For any range of pressures the limit may be determined by a calculation similar to that of equation (1), making $(t_s - t_1) = 0$. Thus, with 100 pounds absolute pressure in the boiler and atmospheric pressure in the calorimeter, the steam will fail to be superheated if the priming exceeds four per cent. With lower pressures the limit is smaller and with higher pressures it is larger. If the pressure in the calorimeter is less than that of the atmosphere, for example, if the pipe d communicates with a condenser, the limit will be increased.

The calorimeter described is the first one made and it has been used just enough to show that consistent results can be attained. It is proposed to make others of different sizes and to make further experiments and comparison with other types of calorimeters.

CORRESPONDENCE.

THE IMPROVEMENT OF SABINE PASS.

To the Committee on Publications of the FRANKLIN INSTITUTE :

GENTLEMEN:—Permit me to add the following in reference to the improvement of Sabine Pass, in continuation of the correspondence in your number of May, 1888. Mine, of April 9, 1888, was not written with the purpose of questioning Prof. Haupt's veracity, its object was to correct a statement which, with its context, was entirely incorrect. I made objection to two items in the paragraph alluded to and repeated in Prof. Haupt's reply; the first item being the statement that the west jetty was built first, the second being that this west jetty had made a shoal on its east side.

With reference to the first, you are now informed that the perfect tense "was built" was not used to convey the idea of completeness. But Prof. Haupt quotes extracts from the history to support the expression that the west jetty was built first. He quotes the estimated cost of the entire work, \$3,177,606.50. The details of this estimate, as shown in the reports, gave the cost of the west jetty as \$1,412,493, and the reports further show that when the "work was commenced on the east jetty in March, 1885," only about \$300,000 had been expended in connection with the west jetty—not much more than one-fifth its estimated cost. I submit then that the phrasing "was built" conveyed a most unfair impression of the conditions to readers of the paper in your April number.

I pass on to the second item, viz: that this west jetty made a shoal on its east side.

I gather from the context in the paper in your April issue, that it was