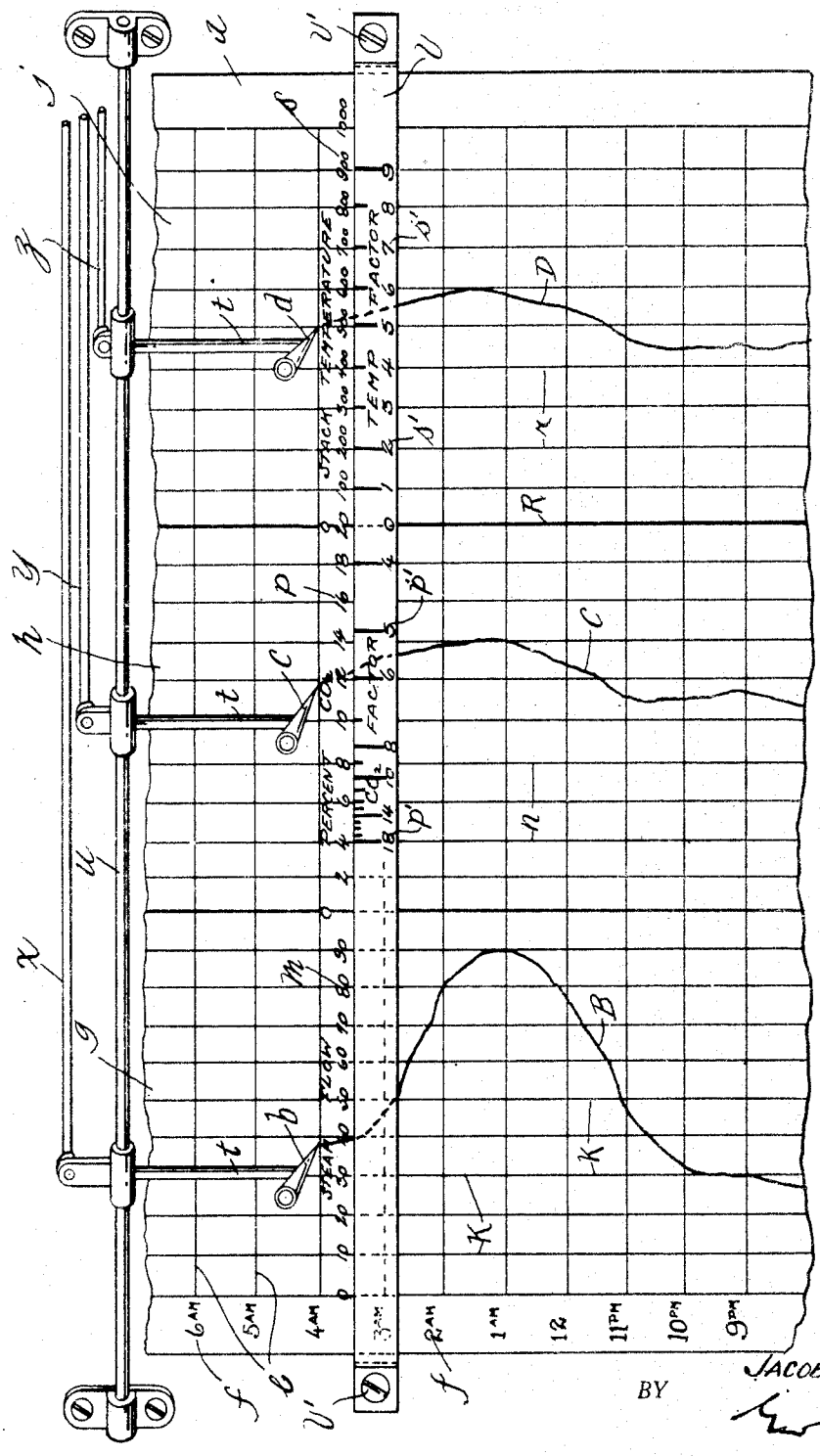
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FURNACE EFFICIENCY METER

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FURNACE EFFICIENCY METER.

Original application filed May 1, 1926, Serial No. 105,957. Divided and this application filed January 12, 1927. Serial No. 160,721.

This application is a division of my pending application Serial #105,957, filed May 1st, 1926, and relates especially to the apparatus shown in said pending application. One object of the present invention is to provide means by which the operator may at all times be appraised of the conditions existing in the apparatus so that if he observes that any of them are at variance with those which have been predetermined as being most advantageous, they may be corrected, thus causing the apparatus always to function with maximum efficiency even though the capacities at which it is operating change from time to time. For illustration, taken the case of a steam generating plant in which fuel is employed to generate the heat. Ordinarily the demands upon the boiler will vary from time to time. My apparatus is designed to make it possible for the operator in charge of the boiler room to so control the conditions of operation as to produce maximum efficiency at the various capacities at which the boiler is called upon to operate. The steam flow, that is, the rate at which the boiler must produce steam, depends, in the case of a factory, upon the amount of power required, or in the case of a heating plant, on the amount of heat which must be supplied. This factor of steam flow, therefore, while variable, is not, practically speaking, under the control of the man in charge of the boiler room but is dependent upon exigencies beyond his control, such as power or heat requirements. Consequently, the steam flow or boiler capacity is the given or predetermined factor, and one purpose of the invention is to provide a method and means for keeping the operator advised as to the capacity at which the boiler is operating and also keep him advised as to other correlative conditions or factors so that he may be able to modify them in such manner as to obtain maximum efficiency. Another object of the invention is to provide means by which the operator may readily compute the efficiency at which the boiler is operating at any given moment. Another object is to provide means by which a permanent record of the various conditions or factors may be made and the efficiency computed.

Boiler efficiency is obtained in practice by determining the loss of heat due to improper combustion of fuel in the furnace and improper absorption of heat in the boiler.

In ordinary boiler room operation most of the loss is the heat carried away through the stack by the heated gases. Improper combustion caused by feeding too much air increases the weight of gas per pound of fuel so that more pounds are heated from room to stack temperature for each pound of fuel. Besides, such improper combustion causes a reduction in the furnace temperature which in itself reduces the possible transfer of heat to the boiler. Improper absorption or transfer of heat to the boiler increases the temperature of the escaping gases. The product of the two forms the so-called stack losses, which have been found in all cases to be indicative of the total loss of heat through the boiler.

Let L signify the percent loss in the boiler, and W and T the weight and temperature of the escaping gases respectively.

Then

$$L=KWT \quad (1)$$

K being a constant determined by the conditions of each given case.

Of the two variables involved in the heat loss, T can be obtained directly by measuring the temperature of the gases. Properly speaking, the temperature that should be considered is the difference between the room temperature and the temperature of the flue gases at the last pass in the boiler or at the base of the stack, but a scale may be readily prepared to read direct in degrees above the room temperature and T will therefore be understood as representing the difference in temperature or the rise above room temperature.

The value of W cannot be obtained directly but it has been found by experience based on numerous tests and experiments that the percent of carbon dioxide in the flue gases is a direct index of the amount of air used for the combustion of the fuel (it being understood, of course, that in the practical operation of a steam boiler a greater amount of air than that theoretically required for complete combustion is always supplied, such excess

resulting in the proportionate reduction of the CO_2 contents in the flue gases). Consequently the amount of CO_2 in the gases indicates the weight of the gases passing through the stack per pound of fuel. Hence we may write

$$W=f/P \quad (2)$$

That is, the weight of gases per pound of fuel is a function of P where P represents the percent of CO_2 in the products of combustion or stack gases, and f is a constant which depends upon the character of the fuel employed.

Experience teaches also, as a result of numerous tests, that the relation between W and P is very definite for all fuels. The relation is reciprocal, that is, W increases uniformly as P decreases. The demonstration will be simplified by substituting $\frac{K'}{P}$ for KW, this substitution being close enough for practical purposes although in the actual construction of my apparatus the scale may be made according to the more accurately determined relation of W to P.

Making the substitution in Equation (1) we have

$$L=K'\frac{T}{P} \quad (3)$$

To illustrate the application of this equation; let it be assumed that a given fuel, say western bituminous screenings, having a heat value of 11,000 B. t. u. per pounds, requires a minimum weight of 8.4 pounds of air per pound of fuel for perfect combustion resulting in a maximum of 18.4 per cent of CO_2.

In practice. it is first necessary to obtain the characteristics of the particular boiler for which the instrument is to be used and for this purpose a test is run on the performance of the boiler. Let is be assumed that the test shows that when T is equal to 500 degrees F., and P is equal to 10 percent CO_2, the boiler has an overall efficiency of 64 percent. Subtracting this efficiency from 100 percent it is found that L, the loss, is equal to 36 percent.

With a knowledge of these conditions we solve for the value of K' from Equation (3). For convenience we let T represent units of temperature, 100 degrees F. each. Then

$$36=K'\frac{5}{10}=.5\,K',$$

or

$$K'=\frac{36}{.5}=72,$$

and

$$L=\frac{72}{P}T$$

Thus the loss may be computed at any time by observing the temperature and the percent of CO_2 and this formula will hold substantially true for various capacities or rates of steam flow of the particular installation under observation.

To give a concrete illustration of the method and operation of the apparatus, reference may be had to the accompanying diagram in which a record strip a is caused to travel beneath styli b, c, and d. In the present case, the strip is assumed to travel downward and as mechanism for causing record strips to travel are well known such mechanism need not be described here. The sheet has cross rulings e which indicate the various hours of the day, these hours being denoted by appropriate markings f here shown in a column at the left margin of the strip. The strip is divided into three sections arranged side by side, the section g at the left representing steam flow, the section h at the middle representing the percent of CO_2 and the section j at the right representing the stack temperature, or more properly speaking, the difference between the stack temperature and the temperature of the boiler room.

The steam flow section g has vertical rulings or ordinates k spaced equally and representing units of steam flow. These units are indicated by a row of numerals m which in the present illustration progress from left to right in increments of ten. These units are selected arbitrarily and the operator may, if he wishes, translate these units into actual pounds of steam generated per hour.

The CO_2 section h has vertical rulings or ordinates n spaced equally and representing the percentage of CO_2. These percentages are indicated by a row of numerals p which in the present illustration progress from left to right in increments of two.

The stack temperature section j at the right has vertical rulings r that are spaced equally and represent stack temperatures. These temperatures are indicated by a row of numerals s which progress from left to right in increments of one hundred.

Said rows m, p and s of numerals may be printed directly upon the record strip at intervals or they may marked on a stationary portion of the apparatus in such position that the vertical lines or ordinates k, n, r will pass under them in juxtaposition thereto.

The styli b, c, d may be supported and operated by any appropriate type of mechanism so long as they are moved in accordance with the variation of the factors which they represent. In the present case, which is largely diagrammatic, the styli are supported upon rods t slidable upon a guide bar u and controlled by rods x, y, z which are moved by suitable devices in accordance with the variable factors of steam flow, percentage of CO_2 and stack temperature. For example, the rod x may be operated by a steam flow-meter, which is a known instrument, and the rod y may be operated by a gas analyzer

which will indicate the percentage of CO_2, such instruments also being known. The rod z may be operated by a pyrometer which is also a known instrument.

The styli b, c and d trace graphs B, C, D respectively on the record strip and from the considerations above stated it will be evident that the loss will be least and the efficiency greatest in proportion as the graph C moves toward the right and the graph D moves toward the left. Thus by merely noting the positions of the graphs or styli with respect to the line of reference R, which is at the right end of scale p and the left end of scale s, an approximate idea of the loss may be obtained. In other words, as the right end of scale p and the left end of scale s are coincident, an approximation may be obtained by noting the distance between the two graphs.

But my device in its developed form goes further than this and is so constructed that the observer may by making a simple multiplication of two numerals calculate the efficiency at which the boiler is operating. The mechanism more intimately concerned with this characteristic will now be described.

The bridge v is mounted in front of the record strip and held stationary by screws v' or other suitable fastening means. In the form illustrated it consists of glass, celluloid or other transparent material, although this is not essential. On this bridge in juxtaposition to scale s there is marked a scale s' in which the numerals represent units of temperature. The integers in the present illustration run from 0 to 9, progress from left to right, and each unit represents 100 degrees of stack temperature. This scale represents the temperature factor T of Equation No. (3) and it will be noted that it progresses in the same direction as the scale s and that the zero point is a line R.

On the bridge v in juxtaposition to scale p there is marked a scale p' in which the numerals progress in the opposite direction from scale p. These numerals are marked to represent the values of $\frac{K'}{P}$ in Equation No. (3). Thus the scale p' bears a reciprocal relation to the scale p in the same manner that the factor W bears to the factor P as hereinabove explained. The scale p' in reality represents the W factor, although as this is determined according to my method from the CO_2 factor in the flue gases, in the parlance of the boiler room the scale p' is more apt to be referred to as the "CO_2 factor" and is so marked in the diagram. In the form illustrated scale p' runs from 4 to 18 with the graduations gradually decreasing in extent toward the higher portion of the scale.

The scales p', s' as stated are calibrated according to Equation No. (3) so that by multiplying the readings on these two scales together the product will give the percent loss in the efficiency of the boiler. The result is that my instrument provides means by which the heat losses may be obtained by simply multiplying together the readings on the two scales p', s' and the efficiency may be readily obtained by subtracting this loss from unity or 100 per cent.

From the foregoing it will be evident that the device illustrated constitutes a boiler efficiency meter and embodies in a single instrument means for indicating or recording three variable factors, viz, steam flow, stack temperature and percentage of the carbon dioxide in the stack gases, the latter factor in my device being interpretable in terms of the weight of flue gases per pound of fuel. Thus the operator may be appraised at all times of the actual conditions of operation, and he is afforded simple and reliable means by which he may, by an easy computation, calculate the efficiency at which the boiler is operating.

According to the arrangement illustrated, the graphs C and D approach each other as the efficiency increases and recede from each other as it decreases, but it will be understood, of course, that this arrangement may be reversed without departing from the spirit of the invention, for by reversing the scales p', s' and reversing the movement of the indicators c and d the efficiency will be greatest when the graphs C, D are farthest apart and least when they are closest together. The present arrangement, however, is preferred, for according to it the zero points may be located on a common line (in the present case line R) and the instrument will present a more graphic and readily understood picture in the mind of the operator.

The words "stack gases" in the specification and the claims are intended and will be understood to mean the products of combustion whether before or after they enter the stack proper.

I claim:—

1. A furnace efficiency meter comprising an indicator movable in accordance with the temperature of the stack gases and an indicator movable in accordance with the percentage of carbon dioxide in the stack gases, said indicators being so positioned that the temperature indicator moves away from the CO_2 indicator as the temperatures increase and toward it as the temperatures decrease and the CO_2 indicator moves toward the temperature indicator as the percentage of CO_2 increases and moves away as it decreases.

2. A device of the class described comprising a plurality of independently movable indicators which are mutually approachable as the stack temperatures decrease and the percentage of carbon dioxide in the stack gases increase, and means for indicating the indi-

vidual distances of said indicators from a common reference point located between them.

3. A furnace efficiency meter having indicated thereon a base point of reference, an indicator movable toward and from said base point in proportion to the temperature of the stack gases, and a second indicator movable toward and from said base point in proportion to the weight of the flue gases per pound of fuel passing through the stack.

4. A furnace efficiency meter comprising an indicator movable in proportion to the temperature of the stack gases, an indicator movable in proportion to the percentage of carbon dioxide in the stack gases, and a scale in juxtaposition to the last mentioned indicator and reversed with respect to the movement thereof whereby the indicator will show an increased value on the scale as the percentage of carbon dioxide decreases and a decreased value as the percentage increases.

5. A furnace efficiency meter comprising an indicator movable in proportion to the percentage of carbon dioxide in the stack gases, and a scale of factors in juxtaposition to said indicator and reversed with respect to the movement thereof whereby the indicator will show an increased value on the scale as the percentage of carbon dioxide decreases, and a decreased value as the percentage increases, a second indicator for indicating the temperature of the stack gases, and a scale of factors in juxtaposition to the second indicator, said scales being calibrated to give the loss of efficiency when the two factors are multiplied together.

6. A furnace efficiency meter comprising two scales, one reading directly in proportion to the temperature of the stack gases, and the other reading inversely proportional to the percentage of carbon dioxide in the flue gases, an indicator co-operating with the temperature scale and movable directly proportional to the temperature of the stack gases, and a second indicator co-operating with the second scale and movable in direct proportion to the percentage of carbon dioxide in the flue gases, said scales being in line with each other and coordinated, whereby by multiplying the two readings the product will equal the loss of efficiency of operation of the boiler.

In testimony whereof, I affix my signature.

JACOB M. SPITZGLASS.