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METHOD OF AND DEVICE FOR AUTOMATICALLY ASCERTAINING THE HEATING VALUE OF GASES WITH REFERENCE TO A CERTAIN NORMAL CONDITION

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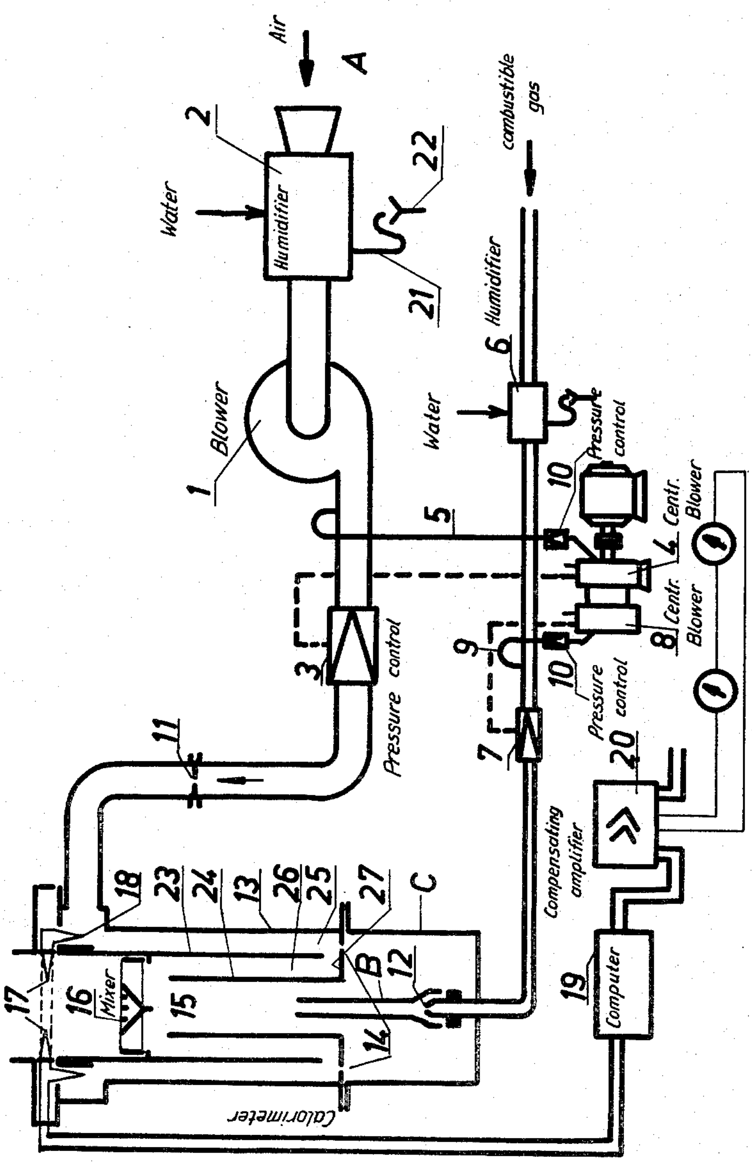

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# METHOD OF AND DEVICE FOR AUTOMATICALLY ASCERTAINING THE HEATING VALUE OF GASES WITH REFERENCE TO A CERTAIN NORMAL CONDITION

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The present invention relates to a method of and device for automatically ascertaining the heating value of gases with regard to a certain normal condition. More specifically, the present invention concerns the automatic and continuous ascertainment of the heating value or combustion heat of combustible gases while employing for instance air or water as heat carrier, the ascertained heating value being referred to a comparable normal condition. By heating value is meant the lower heating value, whereas the upper heating value is designated as combustion heat.

The heretofore known automatic calorimeters for measuring the heating value with air as heat carrier have certain drawbacks with regard to maintaining the volume relationship of gas to air precisely constant and also with regard to the condition of these two substances so that a precise measurement could not be obtained.

Devices are known in the art according to which gas and air are charged with an undefined content of moisture, and there are also known devices with which the employed gas and air are saturated with steam without, however, correspondingly considering the steam content which varies with the temperature and which with the air water mixture changes the specific heat.

A well known calorimeter which does not measure the heating value but the combustion heat operates with mechanically driven volume meters for maintaining constant the relationship of gas to air and which humidifies both substances with steam up to the saturation point. This known device, however, lacks means for considering or taking into account the fact that with different temperatures a different specific heat of the steam air mixture is encountered so that the said device can furnish a precise measurement of the combustion heat per Nm.$^3$ (normal cubic meters; definition see below at Formula 5) gas at a certain reference temperature only. Deviation from this reference temperature must by necessity cause measuring errors unless a correction is effected by hand.

According to another heretofore known calorimeter, neither a humidification of gas and air up to the saturation point is effected nor a computation of the heating value to a normal condition. The said known device is equipped with means to compensate for variations in the density of the gas, this compensation being effected by the buoyancy varying in conformity with the density variations of the gas in a vertical pipe in connection with a choke mechanism. This arrangement, however, has the drawback that it easily results in faulty measurements in view of the fact that the low gas pressures in front of the main nozzle to the burner and the compensation nozzle to the vertical or stand pipe are easily affected by pressure variations in the room or by draft air.

Furthermore, a method has become known which is intended to overcome the last mentioned drawbacks. This method, however, does likewise not take into consideration the influence which the steam content of the air, which varies at varying temperatures, exerts upon the measured value which consideration, however, is indispensable for a precise measurement of the heating



value. In addition thereto, with this device due to the prevailing differences in the temperature between air entrance and exhaust air mixture exit and the lower air admixture inherent thereto, the steam produced by the combustion of hydrogen in the combustible gas exerts a non-negligible influence upon the measured value.

It is, therefore, an object of the present invention to provide a device for and method of automatically ascertaining the heating value of gases referred to a certain normal condition, which will overcome the above mentioned drawbacks.

It is another object of this invention to provide a device for and method of automatically ascertaining the heating value of gases referred to a certain normal condition, which will make it possible precisely to maintain constant the ratio or volume of gas to air and also will take into consideration the steam contained in the gas or air at the saturation point thereof.

These and other objects and advantages of the invention will appear more clearly from the following specification in connection with the accompanying drawing diagrammatically illustrating a device according to the present invention for carrying out the method according to the present invention.

More specifically, according to the present invention gas and air are prior to their entry into the combustion and mixing chamber in steam-saturated condition and at a corresponding pressure higher than atmospheric pressure separately fed into known pressure control devices which control the pressure of gas and air with regard to pressure values proportional to their specific weights. Pressure control devices of the type involved are described for instance in the German periodical "Gaswärme" vol. 5 (1956), pages 100 to 110. To this end, branch currents of said two substances gas and air are branched off from the pressure controls and are expanded to atmospheric pressure or to a higher constant pressure. These branch currents are separately conducted to the entrance of two centrifugal blowers operating at the same or proportionally the same speeds. Such centrifugal blowers are known for instance in connection with the dynamic measuring of specific weights. The said two separate currents are then in said centrifugal blowers compressed to pressures proportional to their specific weights and higher than atmospheric pressure. Centrifugal blowers of the type involved are described for instance in the German periodical "Das Gas- und Wasserfach" vol. 97 (1956), pages 461 to 465. The compression is effected in conformity with the formula

$$p=c_1\times\gamma \quad (1)$$

In this formula $p$ stands for pressure, $c_1$ is a blower constant or blower factor, and $\gamma$ stands for the specific weight in grams per cubic centimeters.

The outlet pressures of the blowers, when conveyed as control pressures to pressure governors corresponding to the measuring devices, will with said pressure governors bring about control pressures of the same or proportional magnitude which as pressures in front of restrictors or metering orifices or calibrated nozzles maintain an always uniform flow ratio of gas and air. The flow through a nozzle or restrictor, as is well known, can be expressed by the formula:

$$V=F\times\alpha\times\epsilon\sqrt{\frac{2g\times h}{\gamma}} \quad (2)$$

In this formula V is the quantity of flow in cubic centimeters per second; F represents the opening cross section of the nozzle or restrictor in square centimeters; $\alpha$ is a flow constant which takes into consideration the friction and the constriction of the gas jet; $\epsilon$ is the expansion factor considering the influence of the pressure drop at the throttling point upon the flow; $g$ is acceleration due to gravity; $h$ is the effective head in grams per cubic centimeter.

If the constant factors in the above formula are combined and replaced by $c_2$, the above formula may be written as:

$$V=c_2\times\sqrt{\frac{h}{\gamma}} \quad (3)$$

With $h=p=c_1\times\gamma$ (see Formula 1) there will be obtained

$$V=c_2\times\sqrt{c_1}=c \quad (4)$$

This means that a constant flow is obtained as long as the blower constant $c_1$ remains constant. The blower constant $c_1$ can, however, change only in view of variations in the speed in which instance the blower constant of both blowers would vary at the same ratio because the said two blowers rotate at the same or at proportionally the same speeds. While in this way changes in the through flow would be possible, the through flow ratio would in each instance remain constant.

The method of the dynamic specific weight compensation has over the static method with buoyancy pipe the advantage that it can operate at considerably higher pressures above atmospheric pressure whereby room pressure variations will exert a far less influence upon the measuring precision while the gas jet at the burner nozzle will be able automatically to draw in a portion of the combustion air with premixture whereby a better combustion of gases at a high heating value will be obtained.

With pressure governors, devices as for instance counter weights or springs, will compensate the influences exerted upon the control pressure by the weight of the measuring or control members of the governor. This method may be employed for measuring the heating value as well as for measuring the combustion heat if the waste gas and cooling air are held separate from each other and if the waste gas is cooled back to the ambient temperature.

The specific weight dependent control of the gas pressure by a centrifugal blower may also advantageously be employed with continuously measuring calorimeters employing water as heat carrier, if a centrifugal blower rotating at constant speed is employed for controlling the pressure governor preceding the burner, for automatically holding constant the gas flow at the burner nozzle. Variations in the specific weight of the gas will be in this way made ineffective and will not any longer affect the measuring precision. The gas and air streams metered by the applied pressure and the selectively applicable restrictors or calibrated nozzles will flow further to the heat exchanger where a small portion of the air is branched off as combustion air and is conveyed preferably to a one flame burner as primary or secondary air. While the employment of a one-flame burner is preferred, it may be added that also the employment of multi-flame burners is possible. The by far major portion of the air will at the combustion chamber exit intermix with the hot waste gases and will be heated up to an extent depending on the magnitude of the heating value. A mixer arranged above the combustion chamber exit and provided with radial deviating blades speeds up the uniform intermixing of waste gases and cooling air. The temperature difference between air inlet and waste gas air mixture outlet is taken into consideration by correspondingly arranged thermoelements, and in said thermoelements a thermo tension is produced which is proportional to the temperature difference. This thermovoltage is for any desired reference temperature to be established taken as measurement for the heating value per Nm.³ gas.

The heating value per Nm.³ gas can be calculated according to the formula

$$H_{uo}=L\times\Delta t\ (c_{pL}+k.G_D.c_{pD})\ \text{kcal./Nm.}^3 \quad (5)$$

kcal. is the measuring unit of the heat quantity 1 kcal. (kilocalorie)=1000 cal. (calories).



Nm.³ means normal cubic meter; 1 Nm.³ gas=1 m.³ dry gas at a temperature of 0° C. and at a pressure of 760 Torr.

Torr. is the customary physical measuring unit for the pressure employed in connection with air pressure measurements by means of a mercury barometer.

1 Torr.=1 mm. Hg (1 millimeter Hg=1 millimeter mercury column).

In this formula

$H_{uo}$ indicates the heating value in kcal./Nm.³ gas.

L indicates the air through flow in Nm.³ referred to 1 Nm.³ gas (dry).

The $\Delta t$ indicates the temperature difference in degrees centigrade between air entrance and waste gas=air mixture exit.

$c_{pL}$ indicates the specific heat of the air in kcal./Nm.³° C.

$c_{pD}$ indicates the specific heat of the steam in kcal./kg.° C.

$G_D$ indicates the steam weight in kg./m.³ air at the respective condition and saturation.

$k$ is a factor for converting the steam weight from kg./m.³ of humid air into kg./Nm.³ of dry air.

However, since, as will be evident from the values $k$ and $G_D$ in Formula 5, the specific heat of the steam saturated air changes with the temperature and to a minor extent also with the pressure, and since a calorimeter must precisely measure also at various conditions, it is necessary to measure these effects by an auxiliary device responsive to changes in temperature and the barometric pressure. It is for this reason that the thermovoltage produced as starting value in the calorimeter is conveyed to a so-called computer. Such computer corrects the thermovoltage and computes the same to a value which is independent of said influences, which value is by means of an electrical measuring instrument indicated or registered as heating value per Nm.³ gas, or may also be conveyed to a governor as measuring value. This conversion or computation may be effected by means of heretofore known computers which operate, for instance, according to the principle described in German Patents 459,743 and 640,894 for reducing the heating value to a certain normal condition. The devices of said German patents may, when adapted to the calorimeter according to the present invention, be employed as computer for said calorimeter. A computer which has proved particularly advantageous for use in connection with the present invention is described in my copending patent application Serial No. 151,980 filed of even date herewith, now Patent No. 3,153,340.

Referring now to the drawing in detail, the embodiment of a device according to the present invention comprises a blower 1 which draws air through a humidifier 2 where the air is saturated with steam. More specifically, the air passes in the direction of the arrow A into the humidifier 2 where the humidification may be effected, for instance, by water flowing into the humidifier 2 from above. The water not absorbed by the air is discharged into a discharge pipe 21 which is, in a manner known per se, provided with a gooseneck to act as a gas block, which means that the liquid in the gooseneck prevents the passage of air or gas through the discharge pipe. From the discharge pipe 21 the water is freely discharged into a pipe 22 so that a suction effect in pipe 22 cannot draw liquid out of the gooseneck and thereby destroy the gas lock. Thus, humidified air drawn in by the blower 1 is, at the required pressure, conveyed to a pressure control 3 which is controlled by a blower 4 in such a way that the pressure of the air passing through control 3 will always be equal or proportional to the outlet pressure of the blower 4. A branched-off current of air passes through conduit 5, expanded to atmospheric pressure at a control 10 to the inlet of blower 4 and by the latter is compressed to a pressure which is proportional to the specific weight of the air and higher than the atmospheric pressure. This pressure is conveyed to control 3. Parallel thereto, the gas passes at the required pressure throug the humidifier 6 which works according to the same principle as humidifier 2, and after being saturated with steam, passes to the pressure control 7, which latter, similar to the air pressure control 3, is controlled by the outlet pressure of a blower 8 coupled to the blower 4 and which controls the gas pressure to the same or a proportional high pressure. A branched-off current of the gas passes to blower 8 through conduit 9 and the control 10 which controls the pressure so as to be equal to atmospheric pressure. The blower 8 compresses the gas to a pressure proportional to the specific weight of the gas and higher than atmospheric pressure. The speed of blowers 4 and 8 is held constant, for instance by the frequency of the alternating current network, whereas the speed ratio between said two blowers may be held constant by means of a rigid coupling through the intervention of a shaft or a transmission. At the thus controlled pressure, the air flows to the restrictor 11 where it is metered and similarly, also, the gas at the burner nozzle 12.

The burner nozzle 12 is centrally introduced into the calorimeter vessel C which is formed by the cylinder 13 closed at its bottom. In the specific instance described the heat carrier, air, enters the calorimeter vessel C at the upper end thereof. The upper portion of the calorimeter vessel has concentrically arranged therein two pipes 23 and 24 which form two annular chambers 25 and 26 which chambers communicate with each other at the lower ends thereof. The bottom of the chamber confined by pipe 24 and cylinder 13 is formed by an annular plate 27 provided with air apertures 14. A fraction of the air passes through apertures 14 as combustion air to a burner B which is centrally located above the burner nozzle 12. The by far major portion of the supplied air passes first downwardly through the annular chamber 25 and then upwardly through the annular chamber 26 and above the pipe 24 mixes in mixer 16 with the hot waste gases which emanate from the combustion chamber 15 confined by pipe 24. The mixer 16 will accelerate and complete the intermixture of gas and air by imparting upon the waste gas air mixture a swirl or twist. Corresponding mixers of any known type may be employed for this purpose. Thereupon, the heated and homogeneous waste gas air mixture passes by the thermoelement soldering points 17 or thermocouples. The comparative soldering points are located in the entering air stream so that in the thermoelements, a thermovoltage will be produced which corresponds to the temperature differences between the soldering points 17 and 18. This thermovoltage is computed by the computer 19 into a voltage which is proportional to the heating value per $Nm.^3$, and this last mentioned voltage is, by means of an electronic compensating amplifier 20, converted by a currentless measurement into a proportional measuring current, which latter flows through a connecting conductor to electric measuring instruments or controls gauged in heating values per $Nm.^3$.

The method according to the present invention is also applicable for determining the heating value of dry combustible gases, if the air employed for the combustion or, as the case may be, as heat carrier, is likewise dry. The method according to the invention will then, while omitting the saturator for gas and air, work in the described manner while compensating for variations in the specific weight. In this instance, the temperature difference measured by the thermoelements corresponds directly to the heating value of the gases, and the conversion necessary for considering the steam content varying in conformity with pressure and temperature, will be superfluous.

It is, of course, to be understood that the present invention is, by no means, limited to the particular arrangement and method described above but also comprises any modifications within the scope of the appended claims.

What I claim is:

1. A method of continuously and automatically ascertaining the heating value and combustion heat of a combustible gas while employing a gaseous heat carrier in connection therewith, which comprises the steps of: separately branching off a minor portion from each of a main flow of said combustible gas and a main flow of said gaseous heat carrier, reducing the pressure of each of said branched off portions of said combustible gas and said gaseous heat carrier to the same predetermined lower pressure, thereafter separately centrifugally compressing said branched off portions of said combustible gas and said gaseous heat carrier, respectively, to respective pressures above atmospheric pressure and which pressures are proportional to the specific weight of said combustible gas and said gaseous heat carrier, respectively, and adjusting the main flow of said combustible gas and of said gaseous heat carrier respectively, to a calorimeter in accordance with the respective pressures of the compressed branched off portions of said combustible gas and said gaseous heat carrier.

2. A method according to claim 1, which includes the step of separately humidifying the main flow of combustible gas and the main flow of said gaseous heat carrier respectively, and prior to the said branching off therefrom of the said minor portions thereof.

3. In a device for ascertaining in an automatic and continuous manner the heating value and combustion heat of a combustible gas while employing a fluid heat carrier in connection therewith: a calorimeter including a burner, first main conduit means for conveying a fluid heat carrier to said calorimeter, first pressure control means interposed in said first main conduit means, first centrifugal blower means, first branch conduit means having a diameter less than that of said first main conduit means and branching off from said first main conduit means ahead of said first pressure control means and leading to the suction side of said first centrifugal blower means, first additional conduit means leading from the pressure side of said first centrifugal blower means to said first pressure control means, second main conduit means for conveying a combustible gas to said calorimeter, second pressure control means interposed in said second main conduit means, second centrifugal blower means, second branch conduit means having a diameter less than that of said second main conduit means and branching off from the latter and leading to the suction side of said second centrifugal blower means, second additional conduit means leading from the pressure side of said second centrifugal blower means to said second pressure control means, and conduit means leading from said second pressure control means to said burner.

4. An arrangement according to claim 3, which includes restrictor means interposed in said first main conduit means between said first pressure control means and said calorimeter.

5. An arrangement according to claim 3, in which said first and second branch conduit means have interposed therein additional pressure control means for adjusting the medium passing therethrough to atmospheric pressure.

6. In a device for ascertaining in an automatic and continuous manner the heating value and combustion heat of a combustible gas while employing a fluid heat carrier in connection therewith: a calorimeter comprising a cylindrical vessel having a burner located in the central portion thereof and also comprising passage means for guiding cooling air employed as combusting means and heat carrier, said passage means defining a combustion chamber for receiving waste gas and cooling air, first main conduit means for conveying a fluid heat carrier to said calorimeter, first pressure control means interposed in said first main conduit means, first centrifugal blower means, first branch conduit means having a diameter less than that of said first main conduit means and branching off from said first main conduit means ahead of said first pressure control means and leading to the

suction side of said first centrifugal blower means, first additional conduit means leading from the pressure side of said first centrifugal blower means to said first pressure control means, second main conduit means for conveying a combustible gas to said calorimeter, second pressure control means interposed in said second main conduit means, second centrifugal blower means, second branch conduit means having a diameter less than that of said second main conduit means and branching off from the latter and leading to the suction side of said second centrifugal blower means, second additional conduit means leading from the pressure side of said second centrifugal blower means to said second pressure control means, conduit means leading from said second pressure control means to said burner, and mixer means arranged above said combustion chamber for intensively intermixing said waste gas and said cooling air in said combustion chamber.

7. An arrangement according to claim 3, in which said first main conduit means and said second main conduit means have respectively interposed therein first and second humidifier means respectively preceding said first and second branch conduit means when looking in the direction of flow of said heat carrier and said combustible gas respectively.



8. An arrangement according to claim 3, in which said calorimeter is provided with thermocouple means therein having terminals, computer means electrically connected to said terminals for converting the electric metering value at said terminals into a value independent of the physical condition of said combustible gas and said heat carrier based on a certain normal condition, and means for conveying the thus established value to electric metering instruments.

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