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METHOD AND DEVICE FOR REGULATING THE RATIO OF MIXTURE OF GASES

Filed Nov. 29, 1941

Serial No. 421,060

2 Sheets-Sheet 1

Fig.1

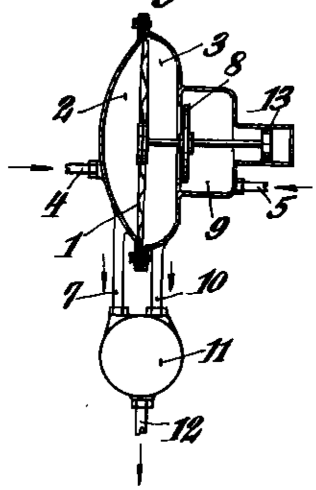


Fig.4

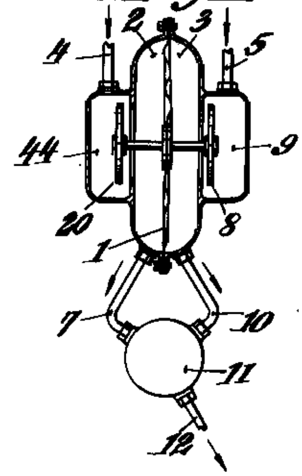


Fig.2

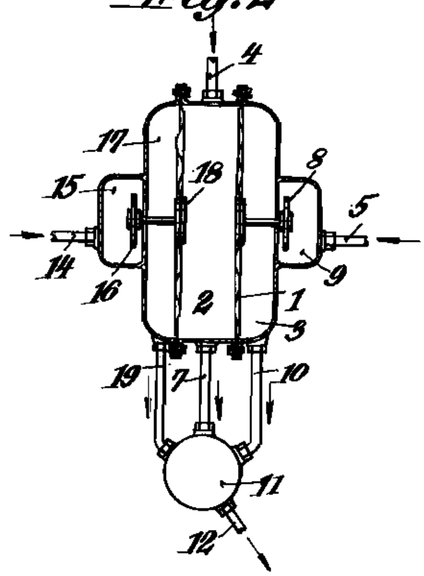
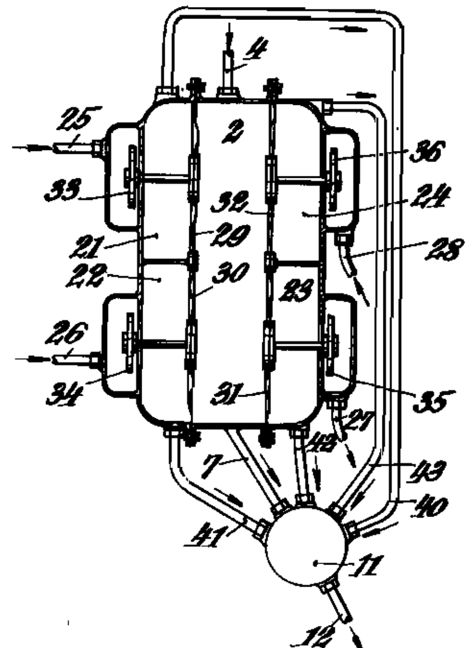


Fig.3



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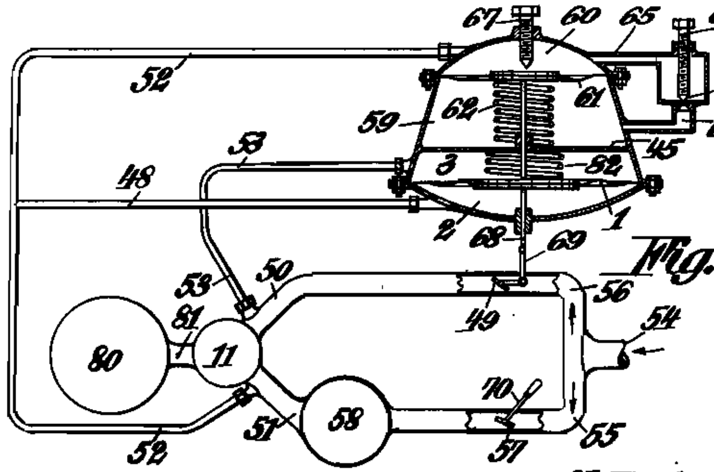

Fig.5

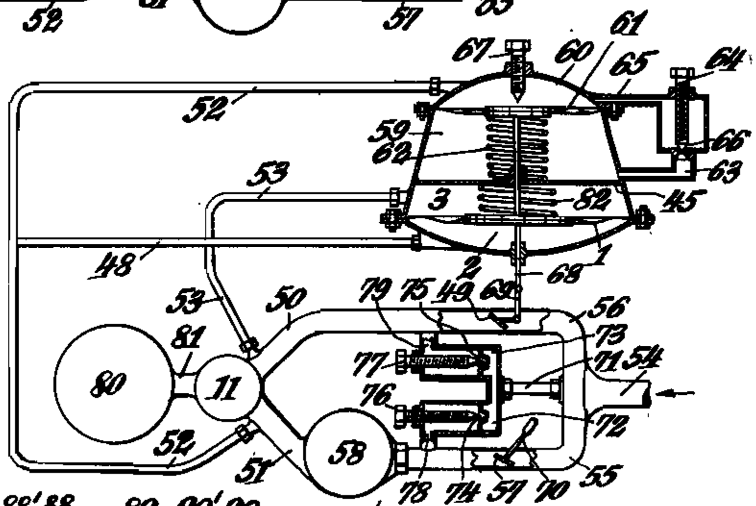

Fig.6

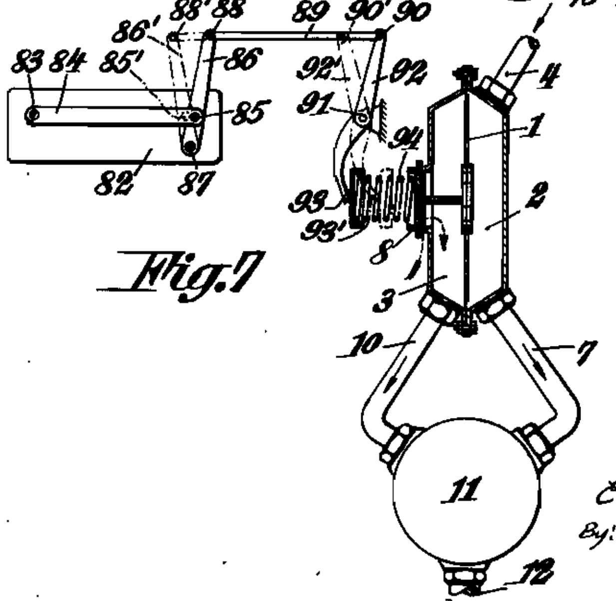

Fig.7

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METHOD AND DEVICE FOR REGULATING THE RATIO OF MIXTURE OF GASES

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The invention relates to methods and devices for regulating or controlling the ratio of mixture of two or more gases and consists in essence in making the pressures of the gases to be mixed automatically dependent on each other or on a comparison pressure.

In practice it often occurs that the ratio of mixture has to be regulated in such a manner that the ratio of mixture remains constant or is adjusted according to certain requirements. Up to now the ratio of mixture of gases was regulated always by modifying or adjusting the outlet cross section. It is well-known, however, that the volume of a gas flowing through an aperture depends on the cross section of the aperture as well as on the pressure gradient. Therefore, if the pressures of the gases change before the point of mixture, a regulation by adjusting the cross section becomes unreliable and even often unserviceable. This drawback is overcome by the invention by way of making the pressures of the gases before mixing dependent on each other so that the pressure gradient of the gases is involved in this method or used therefor, respectively.

The invention is especially suitable in connection with the operation of internal combustion engines working with a mixture of gases as for instance blast furnace gas, waste gas, lighting gas etc. with air, and particularly for internal combustion engines with a gas generator. For, with internal combustion engines it is of great importance for maintaining a high output that the required ratio of mixture of gas and air is maintained exactly. Especially with engines supplied from gas generators the regulation accordance to the invention is of great importance because, in view of the varying resistance to flow through the generator, gas purifier etc., the pressure of the generator gas varies considerably before the mixing chamber. these variations being dangerous to the working of the motor or impairing the output of the motor.

If, for instance, during prolonged working or with an inferior fuel the gas purifier is choked up whereby the resistance to flow is increased, the motor sucks in too much air in proportion to the gas whereby under certain conditions the mixture can become even inexplosive. Especially for internal combustion engines, therefore, the invention may be used to regulate the ratio of gas and air in accordance with the requirements so that a good output of the motor is warranted under all conditions of use.

According to the invention the regulation can be effected in such a manner that the pressures of the gases to be mixed will be balanced automatically against each other and the ratio of mixture determined by the cross section of the outflow, this cross section in case of need being adjustable. The pressures of the gases to be mixed may be regulated automatically in a direct manner so that the ratio of volumes of the gases flowing towards the mixing point will be determined by the ratio of the pressure gradients feeding the gases. Therefore, the pressure of a gas can be used for regulating the pressure of the other gases to be mixed whereby all pressures can be kept constant or the ratio between the gas pressures adjusted as desired.

If the volumes of the gases to be mixed are equal, the pressures of these gases can be regulated in such a manner that the same are equal or balanced, whereby the gases flow through apertures having equal cross sections. If, however, the volumes of the gases to be mixed are unequal, this proportion can be taken into account by the size of the outflow openings or by adjusting ratio of pressures or by both methods. In any case, however, according to the invention the pressure of the gases before mixing must be involved in the regulation. According to the invention, the ratio of mixture may also be varied in accordance with the requirements for instance by varying the ratio of the pressures of the gases to be mixed or the ratio of the pressure gradients feeding the gases in a predetermined manner. This may be effected by balancing the pressures of the gases to be mixed in such a manner that the ratio of mixture for instance in case of differing gas consumption or different heights of pressure will be changed by the influence of an additional power which takes part in the resulting balance conditions. Such a method of regulation corresponds to the requirement that with internal combustion engines the mixture should contain more gas with less number of revolutions and with the running light. Likewise, if the quality of the generator gas grows worse with decreasing gas consumption this circumstance is taken into consideration.

The variation of the volume of the mixture in accordance with the differing quantity of mixture required can be effected according to the invention in such a manner that only the pressure of one of the gases is varied by throttling arbitrarily while the pressure of the other gases is adjusted automatically in dependency of the pressure which is varied arbitrarily.

In adjusting the ratio of mixture also changes in the composition of one or more gases of the mixture can be taken into account in such a manner that one of the gases becoming worse, the volume of this gas will be increased automatically if compared with the volume of the other gases to be mixed. Such a change can take place by a variation of the temperature or quality (calorific power) of the gas. Therefore, according to the invention the ratio of mixture can be varied automatically in accordance with the changes occurring with one or more of the gases to be mixed.

Especially in the use of generator gas for internal combustion engines the drawback occurs that the calorific power of the generation gas varies considerably with the load or the gas consumption, respectively. This drawback has the effect that the motor receives a mixture varying under different loads even if the same ratio of mixture is maintained. If the calorific power of the generator gas decreases too much, under certain circumstances the mixture becomes so bad that the working of the motor, will be in danger. On the other hand the gas cannot be fully utilized with the consumption of gas corresponding to best calorific power if the ratio of mixture of air and gas is adjusted corresponding to an average value of the gas quality. In any event the degree of efficiency of the plant decreases.

The invention also serves the purpose to avoid this drawback, by taking into account that the temperature of the gas leaving the generator is a measure for calorific power of the gas. The less the temperature of the outflowing gas, the higher is the calorific power because the rate of efficiency of the generator is higher in this case. The higher the temperature of the gas, however, the less is the calorific power because the higher gas temperature involves a higher content of carbon dioxide and a smaller content of hydrogen. Therefore, according to the invention the ratio of mixture of generator gas and air is adjusted in correspondence with the quality of the generator gas by a device operating in dependency of the temperature of the gas leaving the generator in such a manner that with an increase of the temperature effected by a decrease of the calorific power the volume of the gas is increased and/or the volume of the air is decreased, and vice versa.

Therefore, the invention permits of keeping the heat capacity constant, the requirement of varying the heat capacity of the mixture with different loads or number of revolutions, respectively, of the motor being taken into account. Therefore, the invention is of great advantage especially with internal combustion engines supplied with gas from gas generators.

A device for carrying out the method according to the invention in essence comprises an apparatus having pressure-sensitive means for instance diaphragms, pistons or the like, the pressures of the gases to be mixed or the comparison pressure acting upon such means, these means being connected with the mechanisms controlling the gas supply, the regulating pressure acting on one side of these diaphragms or the like and the pressure to be regulated acting on the other side. If more than two gases are mixed, the pressure of each gas will be balanced against the pressure of the arbitrarily regulated gas by means of a separate diaphragm. The supply of the gases may take place directly through the regulating device.

According to the invention the adjustment of the ratio of mixture in accordance with the temperature or the quality of the gas can be effected for instance by the action of a temperature-sensitive device on a spring or the like acting upon the pressure-sensitive device (diaphragm or the like) or by way of a variation or throttling, respectively, of the outflow cross section or sections.

In the drawings different forms of execution of a device according to the invention are shown in a diagrammatic manner. Figs. 1 and 4 show different devices for the regulation of the ratio of mixture of two gases whilst Figs. 2 and 3 show devices for regulating the ratio of mixture for three and five gases, respectively. Figs. 5 and 6 illustrate two forms of execution relating to a plant comprising a gas motor and a gas generator. Figs. 7 relates to an embodiment of the invention in which the ratio of mixture is regulated in dependency of the temperature or the calorific power, respectively, of a gas.

Fig. 1 shows an embodiment of the invention for the regulation of the ratio of mixture formed by two gases, for instance air and fuel gas. One of the two gases, for instance air flows in through the pipe 5 in the direction of the arrow into the chamber 9 which is connected with the chamber 3 by a valve 8. From this chamber 3 the air flows through the pipe 10 into the mixing chamber 11. The chamber 3 is separated from the chamber 2 by a diaphragm 1 which serves for regulating the pressures. The fuel gas enters into the chamber 2 through the pipe 4 and flows through the pipe 7 into the mixing chamber 11 from which the mixture of gas and air flows to the motor cylinder through the pipe 12.

By the valve 8 controlled by the diaphragm 1 the same pressure is maintained in the two pipes 7 and 10 leading into the mixing chamber, and the chambers 2 and 3. The regulation takes place in the following manner: If the air pressure in the chamber 3 is higher than the gas pressure in the chamber 2, the diaphragm 1 moves to the left and closes the valve 8 so that the air pressure in the chamber 3 decreases until the diaphragm 1 shifts the valve 8 in such a position that the pressures in the chamber 2 and 3 become equal. Advantageously, a cataract 13 is arranged in order to damp the movement of the valve 8, the damping being dependent on the tightness of the sealing of the damping piston 13 on the cross section of an opening (not shown in the drawing).

Fig. 2 shows an embodiment of a device for regulating a mixture of three gases e. g. a mixture of air with two different gases for instance generator gas and lighting gas. The air enters the chamber 9 through a pipe 5 and flows through the valve 8 into the chamber 3 which is separated from the chamber 2 by diaphragm 1. From chamber 3 the air flows into the mixing chamber 11 through the pipe 10. The generator gas enters the chamber 2 through the pipe 4 and flows through the pipe 7 into the mixing chamber 11. The lighting gas enters the chamber 15 through the pipe 14 and flows into the chamber 17 through the valve 16, the chamber being separated from the chamber 2 by the diaphragm 18. The lighting gas flows through the pipe 19 into the mixing chamber 11. The operation of this device is the same as with a device shown in Fig. 1 with the difference that the device shown in Fig. 2 is double acting and the pressure of the generator gas in the chamber 2 controls not only the air pressure in chamber 3 but also the lighting gas pressure in chamber 17, the valve 19 regulating the pressure in chamber 17 under the influence of diaphragm 18 in such a way that this pressure is equal to the pressure in chamber 2. Therefore, in the chambers 2, 3 and 17 the pressure is the same.

The walls of chamber 2 may consist of several diaphragms so that a mixture composed of any desired number of gas components can be regulated.

Fig. 3 shows an embodiment of the invention for the regulation of a mixture of five gases. For instance, the regulating gas may be generator gas and the regulated gases may be air, lighting gas, blast furnace gas and water gas (hydrogen).

Regulation takes place by the pressure in the chamber 2. The regulating gas flows into the chamber 2 through the pipe 4 and from this chamber through the pipe 7 into the mixing chamber 11. The regulated gases flow through the pipes 25, 26, 27 and 28, respectively, and the valves 33, 34, 35 and 36, respectively, into the chambers 21, 22, 23 and 24, respectively. The valves are controlled by the diaphragms 29, 30, 31 and 32, respectively, in the same manner as described with regard to Fig. 1 so that the pressure in all the chambers 2, 21, 22, 23 and 24, respectively, will be equal. Therefore, the gases flow through the pipes 7, 40, 41, 42 and 43, respectively, under equal pressure into the mixing chamber 11.

In order to enable quick regulation with small movements of the diaphragms the regulating pressure can be regulated itself. Fig. 4 shows an embodiment of such a device. According to this embodiment two valves 8 and 20 are connected with the diaphragm 1 in such a manner that these valves are operated by the diaphragm in opposite directions. Therefore, also the gas flowing in through the pipe 4 first enters the chamber 44 from which it flows regulated by a valve 20 into the chamber 2 and then through the pipe 7 into the mixing chamber 11. In this manner the pressures in the chambers 2 and 3 are balanced much more rapidly because when the diaphragm moves to the right, valve 8 opens and valve 20 closes while in the opposite direction to the left valve 8 closes and valve 20 is opened at the same time. This opposite movement lasts until the pressures are balanced.

The pressure-sensitive means for effecting the regulation are shown in the drawing as diaphragms. However, also, other means as for instance pistons or the like may be used.

In the embodiments shown in the drawing the regulation effects equality of the pressures. If equal volumes of gases are to be mixed, the cross sections of the openings leading to the mixing chamber are equal. If unequal gas volumes are to be mixed, this can be effected by choosing different cross sections of these openings, and the same could be made adjustable at will. However, the arrangement could be made also in such a manner that the pressures of the gases would be maintained unequal so that already by the ratio of the pressures the ratio of mixture would be determined.

The arrangement could be made also in such a manner that the pressure of one of the gases will be kept equal to the sum of the pressures of a plurality of gases so that the pressure of the other gas or the other gases will be increased automatically if one or more gases are failing. This for instance will occur when the available gas volume is temporarily insufficient and equilibrium shall be obtained by a gas used auxiliarily. This may, for instance, occur with internal combustion engines fed by generators if at the start the generation of gas is not sufficient. In such a case the invention enables in a simple manner additional use of a gas for instance fed by gas bottles.

Furthermore, the invention permits variation of the composition of the mixture in a predetermined manner. For instance, this is necessary with a gas motor in which with small loads and low numbers of revolutions of the motor a mixture more rich in gas is advantageous if compared with full loads and high number of revolutions. This can be obtained by the invention for instance by loading the diaphragm 1 (Fig. 1) by a compression spring arranged in chamber 3. In this case the diaphragm 1 will be in equilibrium only when the gas pressure in chamber 2 becomes equal to the sum of the spring pressure and the air pressure in chamber 3. Therefore, the air pressure in chamber 3 always is smaller than the gas pressure in chamber 2 in accordance with the spring pressure, and this of course has the more effect with smaller loads i. e. with less absolute pressure. This has the consequence that with smaller loads less air flows into the mixing chamber. The desired variation of the composition of the mixture can be obtained by corresponding spring pressures whereby the suction pipe pressures and the pressures in the mixing chamber occurring during running without load and under full load will be taken into consideration.

Such an embodiment of the invention has special advantages for plants comprising gas generators and gas motors. Figs. 5 and 6 show diagrammatically the arrangement of such a machine unit.

The motor 80 is connected with the mixing chamber 11 by a suction pipe 81, the gas and the air flowing through the pipes 51 and 50, respectively, to the mixing chamber. The gas is generated by the generator 58 into which the air to be gasified flows in through the conduit 55. A throttle valve 57 which can be actuated arbitrarily is arranged before the gas generator 58. The quantity of mixture which enters the motor and accordingly also the output and number of revolutions of the motor are altered by changing the position of the throttle valve 57 by means of a lever 78 which may be operated by hand or by foot. The gas flows from the generator through conduit 51 into the mixing chamber 11. The air required for producing the mixture flows through the pipes 56 and 50 and is controlled or regulated by the throttle valve 49. The conduits 55 and 56 are combined with one another so as to constitute a common or joint conduit 54. The throttle valve 49 which is arranged in the conduit 56 and regulates the volume of air is operated by the diaphragm 1 through the lever arrangement 68, 89 in dependency of the pressure in the chambers 2 and 3. The chamber 2 is connected with the conduit 51 through the conduit 48, 52 while the chamber 3 is in connection with the pipe 30 through the conduit 53.

This device is operated in the following manner: By varying the position of the throttle valve 57 arranged before the generator the pressure in the gas generator 58 and in the conduit 51 may be altered. When the throttle valve is entirely opened the maximum volume of air enters the gas generator and the generator gas will be developed nearly at atmospheric pressure. However, when the motor is to be adjusted for a smaller output, the throttle valve 57 is closed more or less and the gas flows into the mixing chamber at a smaller pressure. Therefore, the pressure in the conduit 50 will be higher than the pressure in the conduit 51. As a consequence, the pressure in the chamber 3 connected with the air conduit 50 through the conduit 53 will be higher than the pressure in the chamber 2 connected with the gas conduit 51 through the conduit 52, 48. Therefore, the diaphragm 1 moves down and holds by means of the lever arrangement 68, 69 the throttle valve 49 closed until the pressures in chamber 2 and chamber 3 are equalized or balanced. As, however, also the spring 82 is acting on the diaphragm 1, the condition of equilibrium will only be reached when the gas pressure in chamber 2 equals the sum of the air pressure in chamber 3 and the pressure of the spring 82. This spring 82 will be necessary in case the composition of the mixture has to be varied at smaller loads of the motor (with the throttle valve 57 being more or less closed) in such a manner that a richer mixture is obtained. The force of this spring ought to be the greater the more the composition of the mixture is required to differ.

In order to render the working of the motor sufficiently elastic, it is necessary that the number of revolutions per unit of time of the motor, which runs with a more or less closed throttle valve, is almost discontinuously increased by opening the throttle valve. For this purpose the mixture of gas and air should be richer in gas after the opening of the throttle valve i. e. during the acceleration of the motor than under normal conditions. This may be effected by having the opening of the throttle valve 49 in the air conduit lagging behind the opening of the throttle valve 57 in the gas conduit 55. This lag of the opening of the air throttle valve may be accomplished in different manners.

In order to effect this lag of the opening of the throttle valve, in the embodiment shown in Fig. 5 the air throttle valve 49 is influenced not only by the diaphragm 1, i. e. by the pressure difference between the pressures in the chambers 2 and 3, but also by a second diaphragm 61 separating the chamber above the wall 45 in two parts 59 and 60. The upper chamber 60 is connected with the gas conduit 51 through the conduit 52 and has the same pressure as the conduit 51. The chambers 60 and 59 are connected with one another through a small aperture 66 constituting a cataract and through the conduits 65 and 63. The cross section of the aperture 66 can be regulated by means of the screw 64.

Now, if the motor runs at a constant load for some time, the same pressure will be generated in the chambers 59 and 60. If however the pressure in the conduit 51 and accordingly also in the chamber 60 has been increased rapidly by a quick opening of the throttle valve 57, a downward pressure is exerted upon the diaphragm 61 against the action of the spring 82 till the pressures in the chamber 60 and 59 are balanced, through the cataract 66. By this downward pressure the opening of the throttle valve 49 is lagged. During this period the gas content of the mixture increases and the motor works under a higher load with acceleration. The adjusting screw 67 serves the purpose to limit the opening movement of the throttle valve 49.

In the neighbourhood of the running without load the composition of the mixture is very sensitive with regard to pressure variations and the relation between the composition of the mixture and the gas pressure follows a different rule than with higher loads. In Fig. 6 a device for the regulation of the running without load is shown.

The device shown in Fig. 6 corresponds in essence to the example shown in Fig. 5 and therefore the same reference numerals are used. However, the admission of air to the mixing chamber 11 and to the generator 58 takes place not only by way of the conduits 58 and 55 and the throttle valves 49 and 57, but also through the conduit 71—73—78 and an aperture 75, and through the conduit 71—72—78 and an aperture 74, thus shunting the throttle valves 57 and 49, respectively. The apertures 74 and 75, respectively, can be adjusted by screws 76 and 77, respectively. In view of the fact that the apertures 74, 75 are comparatively small, only a little portion of the air will flow through these apertures when the throttle valves 49, 57 are opened, the main part flowing through the conduit 55 and 56, respectively. If however the throttle valve 57 is closed, this resulting automatically in closing also the throttle valve 49, the volumes of air flowing through the conduits 55, 58 will decrease and therefore an increasing part of the total air volume flows through the conduit 71 and through the adjustable apertures 74, 75. When the throttle valve 57 and, therefore, also the throttle valve 59 is closed completely, the quality of the mixture or the ratio of air and gas is determined solely by the cross section of the apertures 74, 75. The cross sections of these apertures can be adjusted by means of the screws 76, 77 in such a manner that only the volume of air necessary for no-load running will flow into the generator and into the mixing chamber respectively, when the throttle valves 49, 57 are closed. Fig. 7 shows an embodiment of the invention in which variations of the temperature or of the caloric power are involved in the regulating process. In this embodiment a device sensitive to variations in temperature is exposed to the action of the gas which acts upon the device regulating the gas pressure.

In the embodiment shown in Fig. 7 the temperature-sensitive device consists for instance of two parts having different heat expansion, a base plate 82 and a bar 84. The base plate 82 is connected with the conduit through which the gas flows out of the generator in such a manner that the base plate takes up the temperature of the conduit. The bar 84 is pivotally mounted at 83 on this base platĕ, the other end of the bar being hinged at 85 to a lever 86 which is pivotally mounted on the base plate 82 at 87. The other end 88 of this lever 86 is connected to a bar 89 which at 90 acts upon a two armed-lever 92 pivotally mounted at 91. The other end 93 of the two-armed lever 92 cooperates with a spring 94 bearing upon the valve 8 which is acted upon by the diaphragm 1. The arrangement is analogous to that shown in Fig. 1. Through the conduit 4 the gas flows into the chamber 2 and from this chamber through the conduit 7 into the mixing chamber 11, the air flowing through the valve 6 into the chamber 3 and through the conduit 10 into the mixing chamber 11. From the mixing chamber the mixture flows through the conduit 12 to the motor. The air pressure in the chamber 3 is determined by the gas pressure in the chamber 2 on the right-hand side of the diaphragm 1 and by the pressure of the spring 94 on the left-hand side of the diaphragm because the air pressure must be equal to the difference of these two counteracting pressures. If the spring pressure increases, the air pressure lowers whereby the mixture becomes richer in gas. This, as has been mentioned already, is necessary when the caloric power of the gas decreases i. e. when the gas leaves the generator at high temperature.

If for instance the base plate **82** is made of aluminium and the bar **48** of steel owing to the greater thermal expansion of aluminium the end **85** of the bar **84** gets into the position **85'** when the temperature raises. The lever **86**, the end **88**, the bar **88** and the two-armed lever **92**, therefore, will get into the position **86'—88'—90'—93'** shown by dot-and-dash lines whereby the spring will be compressed. The power by which the air pressure in the chamber **3** has to keep up the equilibrium decreases because with unvaried gas pressure and greater spring power the resulting pressure against which the air pressure must be balanced decreases so that the air volume flowing to the motor diminishes. If, however, the temperature of the gas decreases, the pressure of the spring **94** diminishes and, therefore, the air pressure increases by the unequal deformation of the base plate **82** and the lever **84**. In view of this change more air flows into the mixing chamber **11** and this is desirable with regard to a better quality of the gas.

Instead of the base plate **82** and the lever **84** also another regulating device responsive to temperature variations may be used as for instance boxes filled with gas or liquid. If the regulation is effected by a gas or a liquid, the resilient box containing this medium must be exposed to the temperature of the gas leaving the generator and must be connected with a regulating device in such a manner that a dilatation of the box compresses the spring **94**.

The temperature-responsive device may also act in any other suitable manner upon the regulation of the mixture. In the embodiment shown in Fig. 7 the temperature-responsive device varies the ratio of pressure between air and fuel gas, but it could control also for instance the outflow cross sections of air and fuel gas.

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