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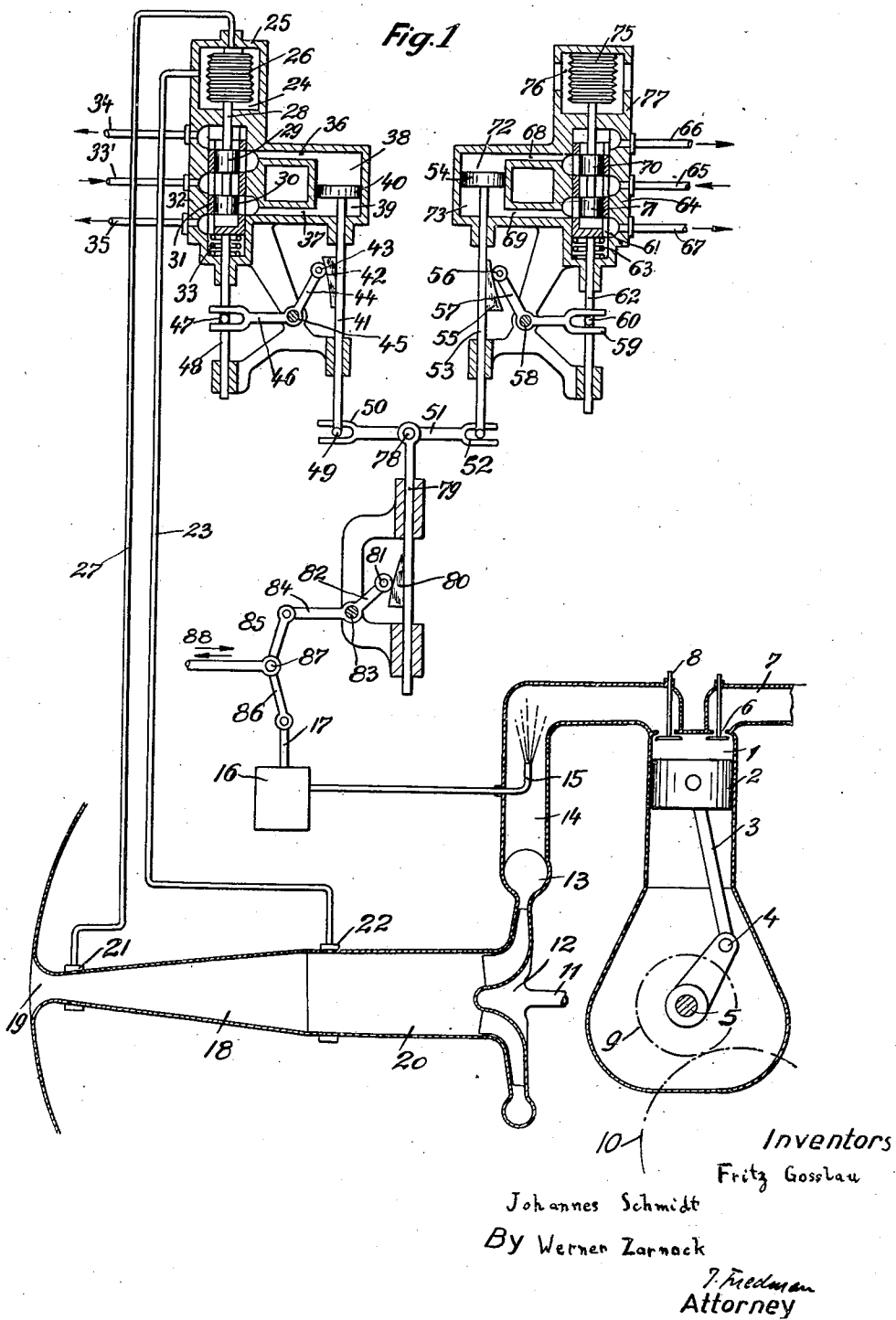
F. GOSSLAU ET AL

2,297,213

CHANGE FORMING DEVICE

Filed Oct. 7, 1938

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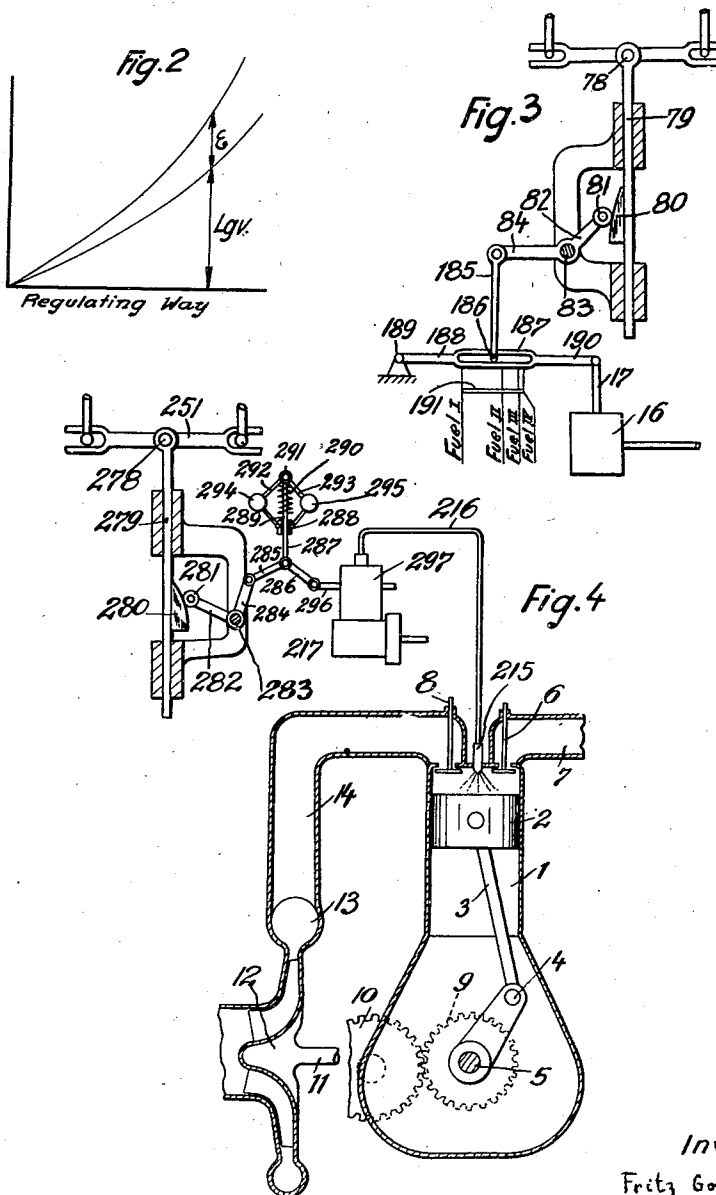
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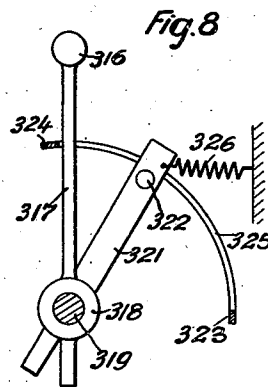
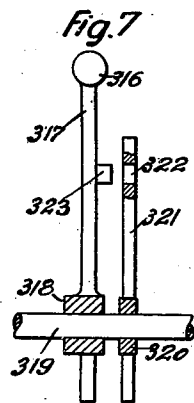
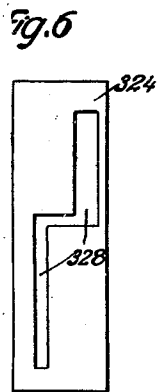
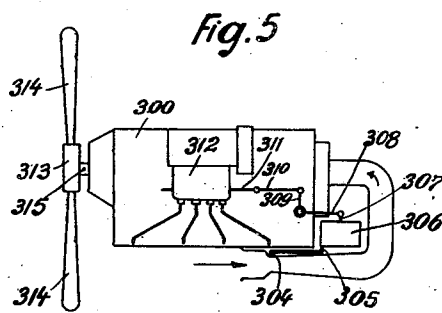
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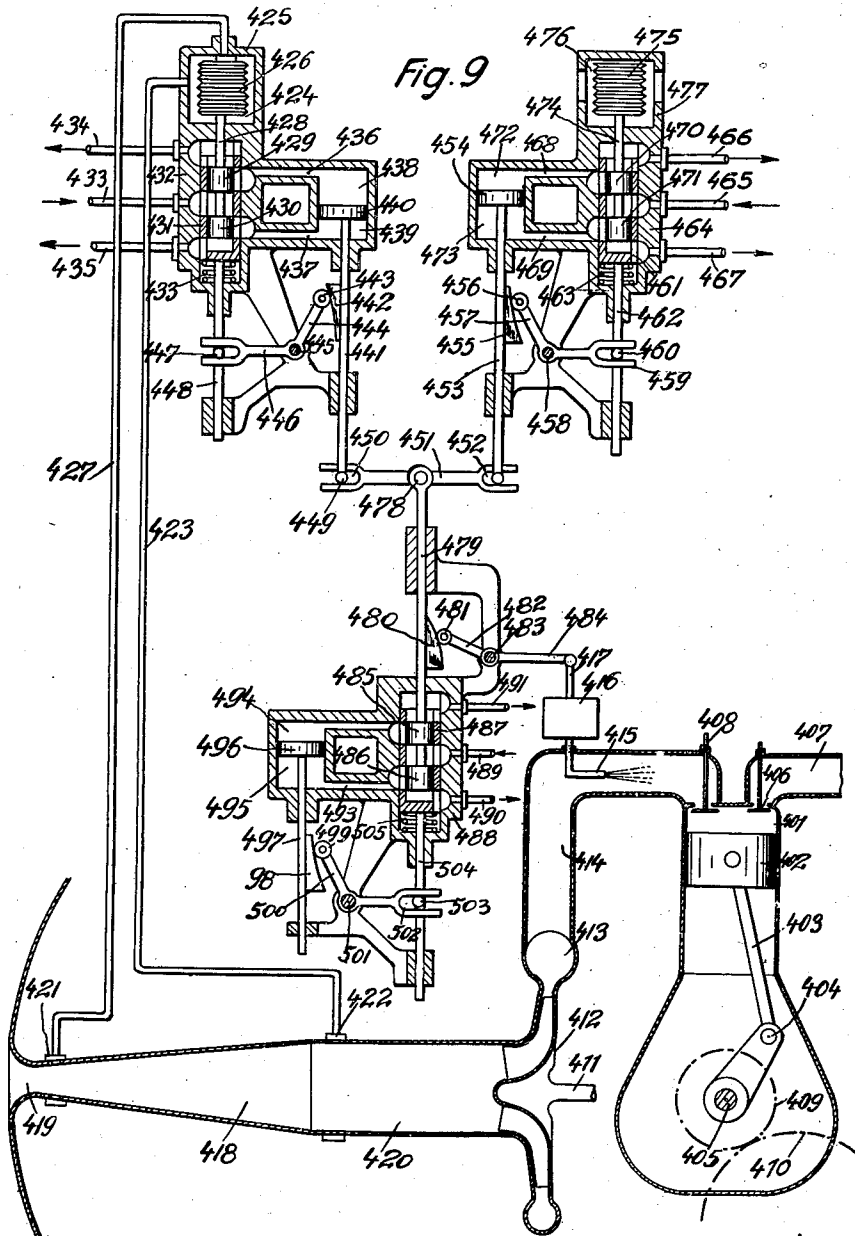
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UNITED STATES PATENT OFFICE

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CHANGE FORMING DEVICE

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15 Claims. (Cl. 123-119)

The present invention relates to a device for regulating internal combustion engines and additional devices, as ignition device, cooling devices, auxiliary motors for the charging device, adjustable or self regulating propellers, regulators for controlling the amount of fuel and the like, connected to the internal combustion engine and forming with the latter a driving unit.

The device according to the invention is adapted to serve various purposes.

For instance, the regulation of those devices the optimum position of which changes in accordance with the motor efficiency is to be automatically effected in dependence on the weight of air fed in the unit of time.

A further object of the invention is to provide a device which allows a particularly favorable utilization of the fuel reserve of the engine. Such a regulating device has, for instance, the advantage that aircrafts provided with such regulators have a range of flight which is greater than with the use of the hitherto known regulating devices.

A still further object of the invention is to provide a regulating device which operates free of objection and particularly at great heights above the earth which is of importance for modern aircraft.

Another object of the invention is to provide a device which seldom or never requires operation of the person controlling the engine, for instance of a pilot.

Still another object of the invention is to provide a regulating device which automatically adjusts definite ratios of mixture of air and fuel and this in particular with the use of the most various kinds of fuel.

The regulating device according to the invention, moreover, is to be adapted also for use in aircrafts provided with regulatable propellers having adjustable blades.

Moreover, the regulating device is for instance to be so constructed that the various regulating actions aimed at may be obtained independent on the state of the air at times.

Other objects of the present invention will be apparent from the following description of the various embodiments of the regulating device.

The hitherto known means for regulating internal combustion engines and additional devices connected thereto generally at the best are satisfactory only for some of the above mentioned requirements.

Now, it has been found that all the above mentioned requirements may be fulfilled in a very

simple manner by providing a device which operates in dependence on the weight of air fed in a unit of time during charging and which controls the internal combustion engine as well as the additional devices in dependence on this weight of air fed in a unit of time.

The regulator according to the invention may be connected to the ignition device of the internal combustion engine for controlling the time of ignition, or to the cooling apparatus of the internal combustion engine for controlling the amount of cooling medium, or to the adjusting members of an adjustable or self regulating propeller coupled to the internal combustion engine for adjusting the pitch of the propeller blades.

A preferred use of the regulating device consists in connecting the measuring instrument, operating in dependence on the weight of the air supplied in a unit of time, to regulating means influencing the quantity of fuel fed in a unit of time.

Eventually, one and the same regulator may simultaneously control the feed of the fuel and the drive of an auxiliary motor for the charging device, of coolers, ignition devices, regulatable propellers clutched to the engine and so on.

It has, furthermore, been found, that for carrying into effect the general inventive idea, consisting in utilizing the measuring of the weight of the air drawn in and dealt with in a unit of time for the regulation of the various devices it is preferable to start from the following mathematical-physical relation: $G=C\sqrt{\Delta p/v}$, wherein G is the weight of the air, C is a dimension constant, Δp is the difference of certain pressures of the air in the suction pipe and v is the state (specific volume) of the air at one of the points of pressure differences.

It is also possible to start from the following relation: $G=C\sqrt{\Delta p \cdot p/R \cdot T}$, wherein G again is the weight of the air, C is a dimension constant, p is the pressure of the air, R is the gas constant, and T is the absolute temperature.

If the regulator is to operate according to the last mentioned mathematical relation it is, for producing the pressure differences, recommendable to use a partially restricted tube, for instance a Venturi nozzle inserted in the suction pipe. The specific volume

$$\frac{R \cdot T}{p}$$

preferably is measured with the aid of a vacuum diaphragm bellows and a temperature feeler, ar-

ranged in the air current, and is then converted into corresponding control movements.

Instead of the Venturi tubes any other well-known measuring instruments may be used. Venturi tubes have the advantage that practically no throttle losses occur.

For practically carrying into effect the above mentioned mathematical-physical relations preferably curve discs, cams or the like are provided, the control surfaces of which are formed according to logarithmic and number value law respectively. By means of such curve discs or cams, the values of the quotient may be converted into values of the sum and into values of differences respectively, so that for instance auxiliary devices provided with balance beams may be used upon the arms of which act the pressures to be superimposed.

A particularly suitable construction of such pressure difference scales consists for instance of two coaxial cylinders each having a piston, one of these pistons in the one cylinder being influenced by air pressure differences and the other of these pistons in the other cylinder being influenced by fuel pressure differences, whereas a rod connecting both pistons actuates a throttle device which changes the effective pressure difference in one or both cylinders.

Further features of the present invention will result from the following description of the various modifications with the aid of the drawings.

In the drawings various modifications are illustrated by way of example partially diagrammatically, and partially with explaining diagrams.

In the drawings:

Fig. 1 shows a construction of a regulator for controlling the fuel spray pump.

Fig. 2 is a diagram relating to the regulation.

Fig. 3 represents a detail of the construction according to Fig. 1 in which a gate is provided for adjusting the arrangement to the use of different fuels.

Fig. 4 shows a portion of a regulator construction in which a centrifugal regulator serving as an additional regulating element is positively driven by the internal combustion engine.

Fig. 5 shows in elevation an internal combustion engine coupled to a propeller having adjustable blades.

Figs. 6, 7, and 8 are details of a special coupling device for the regulator according to Figs. 4 and 5, and

Fig. 9 represents a regulator arrangement which is particularly adapted for regulating the ignition, the position of the flaps controlling the flow of cooling air, the pitch of the propeller and the like, that is to say, which is particularly adapted for the motors of aircraft.

In one of the embodiments the measuring instrument serving as actuator for the fuel regulation is designed and arranged to respond to the weight of air temporarily fed into the internal combustion engine. In this construction of the regulator the pilot is completely relieved, and the device operates automatically and correctly, because for the perfect combustion of a certain quantity of fuel the predetermined required quantity of air is always supplied. Conversely, quite a definite weight of fuel per unit of time is allotted to a weight of air just used by the engine per unit of time.

The weight of flowing gases or air may be measured according to the ordinary methods used in physics and in particular used in the ignition

art. Preferably a Venturi tube is used which is inserted in the suction pipe leading to the internal combustion engine.

For considering the state of the air, for instance its specific volume, preferably a diaphragm chamber containing air or a correspondingly operating barometer or thermo-barometer respectively is used.

When using the above mentioned measuring devices as actuator for the associated power converting members, as for instance hydraulic pistons or the like, logarithmic curve discs form the return drive for the actuators. When such logarithmic curve discs are used, the power pistons move in accordance with the logarithm values.

The control members connected to the two measuring devices, for instance to a Venturi tube and to a barometric box preferably are connected to a common balance beam or another linkage of the same kind which by way of a further curve disc acts upon the fuel regulator. Furthermore, a device may also be provided which may be actuated automatically or by hand and which allows adjustment of grade settings for the various operative conditions, as for instance half load, full load, overload, or a definite number of revolutions also. The adjusting device may for instance substantially consist of a toggle lever system.

An internal combustion engine 1, 2, 3, 4, 5, for instance an aircraft motor, shown in Fig. 1 drives by way of intermediate gearing, not shown, a centrifugal blower 12, 13 serving as charger. To the latter the air flows through a Venturi tube 18, the open end 19 of which faces the relative air current and which flares in the manner of a diffuser from the narrow opening towards the charger and has two pressure tapping points 21, 22. The latter are utilized for measuring the velocity, one of them opening into a chamber 25, the interior space 24 of which contains a diaphragm box 26 formed by a corrugated tube. The interior of box 26 is connected to the other tapping point 21. The difference in pressure at these two tapping points, which occurs when a flow takes place, thus causes an expansion or contraction of the measuring box 26 and consequently the displacement of a control slide 29, 30 which in the usual manner controls pressure oil supply pipes of a power compensation piston 40. The push curve 42 of the power compensation piston 40, which is in the form of a logarithmic curve, acts through a bell crank 46 on a returning sleeve 31 surrounding the control slide 29, 30, which sleeve is loaded by a spring 33 for pressing the bell crank 46 against the push cam 42.

This arrangement produces a motion of the power compensation piston 40 in a logarithmic ratio to the pressure differences of the tapping points 21, 22.

For considering the air condition (specific volume) a diaphragm box 75 formed by a corrugated tube, which is filled with a definite weight of air, is connected to a second power compensation piston 54 by means of a control gear corresponding exactly to that previously described. In this case the push curve is formed according to a negative logarithm.

The second power compensation piston 54 will therefore be moved in the negative logarithmic ratio to the variations in the state of the air.

The two power pistons 40, 54 are connected to a balance beam 51 and a plunger 79 connected to the middle of the same, which thus performs a motion corresponding to half the difference of the

logarithm value of the pressure difference and the logarithm value of the state of the air. Plunger 79 is provided with a further push curve 80 which coacts with a leverage leading to the fuel injection nozzle. The push curve 80 introduces into the calculation the constant and the number value of the formula given above. In the motion transmitting leverage is interposed a toggle lever arrangement 85, 86, the deflection of which can be set to different values by hand or foot by means of the gas lever or also by a centrifugal governor. By this means a general adjustment to a desired flying condition is obtained, on the basis of which the further mixture regulation will then maintain the correct weight ratio of air to fuel.

A modification of the invention serves to solve the following problem:

In connection with the known single lever devices for adjusting aircraft motors it is usual to provide a position of the lever for cruising load corresponding to 80% of the full load at which the motor is driven with an excess of air, i. e. with a poor or weak mixture, and to provide another position for a 100% output, at which the motor operates with a very rich mixture. This arrangement is disadvantageous, because, if the aircraft is flying in great height and the motor, therefore, due to insufficient charging pressure, has 80% of its full efficiency or output only, and also in still greater heights the pilot must adjust the lever to the position corresponding to 100% output, so that in great heights the aircraft can only be driven with a rich mixture, notwithstanding the fact, that in this height a motor of an aircraft during a long flight even with the greatest charging pressure could substantially more economically be driven with a poor mixture.

To obviate these drawbacks the device according to the invention is so constructed, that, as long as the quantity of air drawn in and therefore the motor output or efficiency remains below a predetermined value of the full output, a poor mixture and with increasing output a gradually richer mixture is supplied. The formation of the mixture, therefore, is, according to the invention, no longer dependent on the position of the efficiency lever, but on the quantity of fuel mixture consumed by the motor. In this manner the pilot may choose any desired charging pressure in a height in which the motor at the very best draws in 80% of the total quantity of air only. The pilot will fly in any case with a poor or weak mixture. To allow the pilot of setting a richer mixture in special cases, for instance when fighting, a second lever may be provided in the linkage for influencing the formation of the mixture, or the efficiency lever may be brought into a 110% position in which it allows supply of a richer mixture.

In the modification shown by way of example one cylinder 1 of the motor or any other internal combustion engines only is represented. In cylinder 1 the piston 2 is moved up and down and is connected, by means of a piston rod 3, to the crank 4 of the crankshaft 5. The cylinder 1 is provided with an outlet valve 6 which is connected to a pipe leading to the exhaust 7. Furthermore, an inlet valve 8 is provided. Mounted on the shaft 5 is a gear wheel 9 which engages a gear wheel 10 on the shaft 11. The latter carries the rotor 12 of a centrifugal blower serving as charging device, the fixed casing 13 of which is connected by way of a pipe 14 to the inlet valve 8 and serves to supply combustion air under pres-

sure. A spray nozzle 15 for the fuel extends into the pipe 14. The nozzle 15 is connected to the fuel pump 16, constructed for instance as a geared pump, the construction of which is well-known and therefore need not be described. The quantity of fuel fed by the pump 16 is regulated by a lever 17 acting upon a well-known control valve of the pump which also is not shown in the drawings.

Air flows into the centrifugal blower 12, 13 by means of a Venturi tube 18 open to the relative air current and having a narrow discharge end 19, said Venturi tube flaring in the manner of a diffuser towards the charger as far as the width of the inlet socket 20. Tapping points 21 and 22 are provided at the smallest and at the widest point respectively of the Venturi tube 18. The tapping 22 is connected by way of a pipe 23 with the interior space 24 of a chamber 25. In the interior space 24, closed against the outer atmosphere, a diaphragm box 26 formed by a corrugated tube is arranged the interior of which is, by means of a pipe 27, connected to the tapping 21. The difference of pressure occurring due to the flow of air, at the two tapping points 21 and 22 of the Venturi tube 18 causes expansion and contraction respectively of the diaphragm box 26. Rigidly connected to the diaphragm box 26 is a rod 28, which is actuated by the contraction and expansion movements of diaphragm box 26. Mounted on said rod 28 are two pistons 29, 30 which are shiftably arranged in a sleeve 31 which in turn is movably arranged in a cylinder 32. A spring 33 tends to press the sleeve 31 upwardly. Connected to the cylinder 32 are an inlet pipe 33' and two outlet pipes 34, 35 for pressure oil. The cylinder 32 is furthermore connected, by way of channels 36, 37, to chambers 38, 39, which are arranged above and below the piston 40 respectively. The piston 29 and the piston 30 effect in a well-known manner the supply and the discharge of pressure oil into and out of the chambers 38 and 39 respectively, whereby the piston 40 is moved upwardly or downwardly. Besides from the position of the pistons 29, 30 the admission and discharge of the pressure oil also depends on the position of the sleeve 31 and on the position of the openings provided in this sleeve. A piston rod 41 carrying a cam 42 is connected to the piston 40. The cam 42 is in the form of a logarithmic curve. A roller 43 bearing against the cam 42 is provided at one arm 44 of a bell-crank pivotally mounted on a bolt 45. The end of the other arm 46 of this bell-crank is fork-shaped and engages a pin 47 provided at a rod 48 which is rigidly connected to the sleeve 31. In this manner the piston 40 controls the sleeve 31 in accordance with a logarithmic law. The spring 33 tends to always press the roller 43 against the curve 42.

The lower end of the rod 41 carries a pin 49 engaging a fork 50 of a balance beam 51 and acting upon the latter. Upon the other arm of said balance beam 51, also having a fork-shaped end portion 52, acts a piston rod 53 which is controlled by a piston 54. The piston rod 53 also carries a curve 55 in the form of a logarithmic curve which, however, extends in the reverse direction with regard to the curve 42. Against the curve 55 bears, by means of a roller 56, the one arm 57 of a bell-crank pivoted on the bolt 58, the other fork-shaped arm 59 of which engages a pin 60 of a rod 62 rigidly connected to a sleeve 61. This sleeve is shiftably arranged in a cylinder 64 against the action of a spring 63. The cylin-

der 64 is provided with an inlet pipe 65 and two outlet pipes 66, 67 carrying pressure oil. On the other side of this cylinder the channels 68, 69 are provided which in accordance with the position of the sleeve 61 and of the pistons 70 and 71, slidably arranged in said sleeve, effect the admission and discharge of pressure oil into and out of the chambers 72, 73 arranged above and below the piston 54 respectively. The pistons 70, 71 are fixed to a piston rod 74 which is connected to a diaphragm box 75 formed by a corrugated tube and is controlled by the expansion and contraction movements of this box. Box 75 is closed against the outer atmosphere and contains a definite weight of air, whereas atmospheric pressure prevails in the space 76 of the chamber 77, surrounding the diaphragm box 75, so that expansion and contraction of the box 75 occur in dependence on the state of air prevailing at a given time.

Rod 79 is linked to the center 78 of the balance beam 51. Since the piston 40 due to the control of the sleeve 31 transfers to the balance beam 51 the logarithm value of the pressure difference at the two measuring points 21, 22, while the piston 54 transfers to the balance beam 51 the negative logarithm value of the state of the air, a displacement of the rod 79 results in such a manner that this displacement corresponds to half the difference of the logarithm value of the pressure difference and the logarithm value of the state of air. The rod 79 carries another push curve 80 which introduces into the calculation the constants and the number value of the above mentioned formula.

This curve 80 is, moreover, so formed, that, as long as the amount of air drawn in and, therefore, the motor output remains below a predetermined value, for instance 80% of the full load, a poor mixture is supplied, whereas at a higher output a mixture gradually becoming richer is supplied. Against the curve 80 bears, by means of a roller 81, the one arm 82 of a bell-crank pivoted at 83 the other arm 84 of the bell-crank being connected to a toggle lever. The toggle lever consists of two links 85, 86 at the connecting point of which a lever 88 is connected which may effect different positions of the toggle lever 85, 86. The free end of the link 86 is connected to the lever 17, and thereby influences, in the manner described above, the quantity of fuel delivered by the fuel pump 16. The lever 88 may be actuated by the pilot. This either is effected by connecting this lever 88 to an emergency lever which is pulled by the pilot in special cases, for instance during fighting, only to allow an enrichment of the mixture in great heights also, or by connecting the lever 88 to the efficiency lever in such a manner that by shifting the latter into the 110% position the toggle lever linkage is influenced and thereby an enrichment of the fuel mixture is effected.

The automatic regulation of the adjustment to a poor and rich mixture respectively in dependence on the mixture dealt with in the engine is effected by the formation of the cam 80, whereas the additional arbitrary influencing of the mixture is effected by the lever 88.

In connection with the above mentioned devices for regulating the fuel supply in dependence on the weight of the air, the latter may be represented by the following formula:

$$G = F \cdot \sqrt{2g} \cdot \alpha \cdot \epsilon \cdot \sqrt{\Delta p / v}$$

Whereas the accessory value α has quite an

unimportant influence on the measuring exactness of the Venturi tube and quickly approaches a constant value with increasing height of flight, the indication by the accessory expansion value ϵ of the air flowing through the Venturi tube is disturbed in an increasing degree with increasing height of flight. If a gas, such as air flows through a Venturi tube, it increases its volume when the pressure decreases due to the compressibility of gases. For incompressible liquids the expansion value ϵ is equal to 1. The larger the effective pressure in the Venturi tube with respect to the pressure in front of the Venturi tube, the larger is the change in the expansion value ϵ . Hence ϵ depends upon the density of the air, viz. upon the height of flight of the aircraft. It has been ascertained by tests, that between 0 and 5 kilometers of height the value of ϵ for a definite weight of air was reduced by about 3.5%.

To compensate this fault, the influence of the variable value of ϵ is, according to the invention, taken into consideration and this preferably by the regulator which is controlled by the alteration of the specific weight of the air, this is effected by superimposing the control curve of the return sleeve 61 of this regulator by the curve for the variable value ϵ . Hereby the amplitude of the v -regulator increases with increasing height not only in proportion to the increase of the specific volume of the air, but additionally in proportion to the alteration of the value ϵ .

An example of this modified construction according to the invention is shown in Fig. 1 as well as in Fig. 2 which graphically represents the curve of the magnitude ϵ mentioned above and of the logarithm v in dependence on the way of regulation.

In this construction of the regulator the piston rod 53 carries a curve 55 which according to Fig. 2 consists of a logarithmic curve corresponding to the expansion characteristic of the box 75, whereby a curve, shaped in accordance with the alteration of the expansion accessory value ϵ is superimposed to this characteristic. Here also the curve 55 extends in the reverse sense as the curve 42.

Since the piston 40 due to the control of the sleeve 31 transfers to the balance beam 51 the logarithm value of the pressure difference prevailing at the two measuring points 21, 22, while the piston 54 transfers to the balance beam 51 the negative logarithm value of the state of air under consideration of the value ϵ , a displacement of the rod 79 results in such a manner, that this displacement corresponds to half the difference of the logarithm value of the pressure difference and of the logarithm value of the state of air under consideration of the value ϵ .

The lever 88 again may be actuated by the pilot. This is effected either by connecting the lever 88 to an emergency lever which is pulled by the pilot in special cases, for instance during fighting, only to allow an enrichment of the mixture in greater heights also, or by connecting the lever 88 to the efficiency lever in such a manner, that the shifting of the efficiency lever into the 110% position causes influencing of the toggle lever linkage and thereby an enrichment of the fuel mixture.

The value ϵ depends besides on the height of flight on the load of the motor also. The modification shown and described neglects the alteration which per se is required by the motor load.

Strictly speaking, therefore, this modification is correct for a definite motor output only. Practically, however, an additional correction, corresponding to the motor output, may be obviated, since the correction made is not very great itself and, moreover, is of importance within the limited ranges of cruising output only. If a complicated additional regulation in accordance with the motor output is to be prevented, it may evidently be included in the bargain that certain deviations occur at full load and if the motor runs idle.

Another modification of the present regulator has the advantage, that it may be used for the most different fuels and may very quickly be regulated to the quantity of air required for the particular fuel used. For this purpose, a device for arbitrarily adjusting the quantity of fuel to be supplied is provided at the automatic regulator.

Preferably, this device consists in this that the length of one or more of the lever arms of the regulator linkage is adjustable, one lever of the linkage being provided with a gate in which the pivot point of another lever is arbitrarily shiftable and fixable in any desired position. The arbitrarily adjustable portion of the regulator preferably is connected to an indicating device which indicates on a scale that quantity of fuel which corresponds to the optimum mixing ratio of the fuel in question.

As an example for this device, advantageously the construction shown in Fig. 1 may be used in which between the bell-crank 82, 84 on the one hand and the fuel pump 16, 17 on the other hand an adjustable device, for instance a device as shown in Fig. 3, is inserted. Otherwise the construction of the regulator may be exactly the same as the one shown in Fig. 1.

The rod 79 carries a push curve 80 against which bears, by means of a roller 81, a lever arm 82 pivotally arranged at 83. The other lever arm 84 of this bell-crank acts upon a link 185. The other end of link 185 is provided with a pin 186 which engages a gate 187 in which it may be arbitrarily adjusted and fixed in any desired position. This gate 187 is carried by a lever 188 linked to the casing at 189. The other end 190 of the lever 188 acts upon the lever 17, whereby the quantity of fuel injected by the fuel pump 16 is regulated in a well-known manner.

At the gate 187 a scale 191 is provided upon which the marks for the most favorable adjustment of the air-fuel mixture for different kinds of fuel are provided. So for instance, a mark may be provided for each kind of fuel. Therefore, when changing from one fuel to another it is only necessary to adjust the pivot point 186 of the link 185 in the gate 187 to that mark which designates the fuel now to be used. Then the motor is at once and without time-consuming regulations adapted to operate with the new fuel under the most favorable conditions with regard to the fuel-air mixture.

A further modified construction according to which also the measuring of the weight of the air drawn in and dealt with in the engine in a unit of time is utilized for influencing certain regulator members, is particularly adapted for aircraft motors used to drive propellers and represents an improvement of the following ratios:

In connection with the known devices a definite position of a switch lever is provided for each weight of air on which depends the quantity of fuel supplied. Often the pressure of a pump for injecting fuel, for instance into the mixing cham-

ber, is influenced by the regulator. The regulator then correctly operates as long as the fuel pump, driven by the motor, maintains constant the injection pressure chosen independent on the prevailing number of revolutions of the motor.

Supposing a regulator in which the weight of air measured in each unit of time is utilized as impulse co-operates with a pump feeding in dependence on the number of revolutions and provided with a regulator for the fuel fed, the regulator being provided with an adjustable regulator member and the pump feeding a definite quantity of fuel determined by the number of revolutions and the setting of the regulator member. In this case very unfavorable operating conditions result if an aircraft is to be driven by a motor performing different numbers of revolutions at equal output, i. e. with an equal weight of air.

Such conditions, for instance prevail if an aircraft provided with a so-called non-adjustable propeller changes from horizontal flight to climbing. When climbing, the number of revolutions of the motor is decreased with regard to the number of revolutions of the motor during horizontal flight. This is due to the low pitch of the propeller. Hereby the feed of the pump is reduced for the same position of the regulator rod, so that the correct mixing ratio for the horizontal flight becomes too poor for climbing.

The reverse proportions for instance occur, if the aircraft is pushed or falls. Generally speaking, an undesired change of the mixing ratio occurs with each alteration of velocity of the aircraft and at equal motor output. This is due to the fact, that the mixture regulator acts according to a certain time (hourly weight of air), the pump, however, acts on the individual cycle of operation.

The above described difficulties are obviated according to the invention in a simple manner by providing a special regulator, driven in dependence on the number of revolutions of the motor and so influencing the actual values of the regulation effected by the regulator responding to the quantity of air dealt with in a unit of time, that at all operating conditions the corresponding calculated mixing ratio of air and fuel is warranted. For instance a centrifugal regulator driven by the internal combustion engine is connected by way of its control member to the regulator for the fuel fed by the pump and influenced by the air dealt with in the engine in such a manner, that it influences a valve member controlled by this regulator and provided in the fuel pipe.

According to the invention such a device is so constructed, that the regulating value of the meter for the air fed into the engine may be corrected in dependence on the number of revolutions.

According to another modification of the present invention the regulator influenced in dependence on the number of revolutions of the engine is formed as a regulator for the adjustable propeller, the shaft of which is positively coupled to the drive shaft of the pump feeding the fuel. This regulator automatically adjusts itself to a constant number of revolutions in a manner known per se. The special advantage of this construction consists in this, that, with the use of adjustable propellers provided with regulators for the number of revolutions, it is not necessary to provide a special regulator which for instance corresponding to the construction previously described acts on the control rod for the fuel pump.

With this last described construction with adjustable propeller, the regulator provided for the propeller effects the regulation of the fuel feed aimed at. The fuel pump need to be regulated according to the temporary quantity of the consumed air only, since the number of revolutions of the pump is perfectly constant.

A further modification of the present invention is particularly adapted for aircraft motors with adjustable propellers operating in two ranges of numbers of revolutions. When using such adjustable propellers the difficulty may occur similar to that occurring in connection with fixed propellers, i. e. that the mixing ratio always will be richer at the higher number of revolutions than at the lower number of revolutions. This difficulty may, according to the invention, be overcome by the fact, that the regulator, influenced in dependence on the number of revolutions, is arranged as a regulator for the propeller automatically setting to a plurality of constant number of revolutions and that control means, for instance correspondingly shaped curve discs, are provided which on setting of a range of higher number of revolutions simultaneously and automatically effect an enrichment of the mixture of fuel and air. For example the second range of number of revolutions of the propeller is chosen so much higher than the first range, that the change of the number of revolutions just results in an enrichment from the cruising mixture to the high duty mixture. This construction of the regulating device also is characterized by a particularly great simplicity.

When constructing and using the last described device, the regulator is once set to a definite mixing ratio, as poor as possible which is determined for cruising. At the lower number of revolutions this mixing ratio then remains constant at each position of the so-called pilot lever as far as to the 100% position. Only if the propeller is switched to the higher number of revolutions an enrichment also is positively effected, so that the motor operates with highest efficiency.

Preferably, the switch lever for the propeller is positively coupled to the pilot lever in such a manner, that, on shifting the pilot lever from the 80% position to the 100% position, the propeller also is adjusted to the higher number of revolutions. This modification of the device has the special advantage, that by means of a single lever the enrichment as well as the increase of the number of revolutions may be effected. As for the two states of operation two ignition points only are required. The device may be improved further by the fact that the switching gear of the ignition device also is coupled, preferably in the same manner, to the above described multiple switching lever.

Preferably, the various levers are rotatably mounted upon a common shaft and are movably arranged in a common gate provided for engaging and disengaging the levers.

Preferably, with the present device provided with a regulator for the fuel fed by the fuel pump which may be influenced by pressure differences prevailing in an air measuring device actuated by the motor, the regulator is coupled to a further regulator which may be influenced by alterations of the state of the outer atmosphere, for instance on account of different heights above the earth and which correspondingly controls in such a manner that the regulating movements of the first regulator are compensated.

As an example of the last described regulating

device the construction described in connection with Fig. 1 may again be used, certain regulating members and devices being constructed and arranged in accordance with Fig. 4.

The spraying nozzle 215 is not provided in the air suction pipe leading to the cylinder, but in the cylinder cover. Connected to the nozzle 215 is the supply pipe 216 for the fuel, the other end of which is connected to the outlet socket of the feed pump 207, for instance a geared pump.

By means of a roller 281 a lever arm 282 of a bell-crank pivoted on the bolt 283 bears against the curve 280. The other arm 284 of the bell-crank is fixed to a toggle lever. The latter consists of two links 285, 286 at the connecting point of which a lever 287 acts on which an axially displaceable member 288, for instance in the form of a sleeve, is arranged.

Two weights 294, 295 of a control member formed as a centrifugal regulator bear against the member 288. A spring 290 tending to move the sleeve 288 downwardly bears against a rod 289 fixed to the sleeve 288 and displaceable axially with said sleeve. The spring 290 bears with its other end against a link 291 on which two arms 292, 293 are pivoted which carry the weights 294 and 295 respectively.

As may be seen from the drawings, the weights of the centrifugal governor 287—295 driven by the internal combustion engine 1—5 are swung outwardly at higher number of revolutions of the engine, so that the sleeve 288 is drawn upwardly and therewith the link 287 of the toggle linkage 285, 286 also is moved upwardly, whereby the length of the linkage is shortened. Consequently, a pull is exerted on the regulator rod 296 which tends to withdrawn this rod from the regulator casing 297. The amount of adjustment effected hereby depends on the control movements of the bell-crank 282, 284, influenced by the curve disc 280, besides being dependent on the control movements of the centrifugal governor. According to the invention the various co-operating gear members are so to be dimensioned and arranged, that the feed movement of the regulator rod is compensated again by the last mentioned lever by shortening the toggle lever system acted upon by the centrifugal governor.

In the construction shown in Fig. 5 the motor block of the internal combustion engine is designated with 300. Connected to the rear part 301 of the casing is a pipe 302 the other end of which ends in a Venturi tube 303 or the like, the open mouth of which faces the relative air current which flows into the mouth in the direction of the arrow. Tappings 304 and 305 are provided at the Venturi tube 303 in the same manner as the tappings 21 and 22 described in connection with the construction shown in Fig. 1. Pipes connected to these tappings lead to a regulator 306 which is constructed in a well-known manner and measures the weight of the quantity of combustion air drawn in. A rod 307 projects from the regulator 306 which is, by means of a link, connected to a further rod 308 which in turn is, by a link, connected to a rod 309. Rod 309 is connected by a link to a rod 310 which preferably also acts, by way of a link, upon a rod 311 formed as a regulating rod of the fuel pump 312 and movably arranged in the casing of the latter.

A regulator 313 for the number of revolutions is mounted in the adjustable propeller 314 journaled upon the shaft 315 and driven by the

internal combustion engine 300. The regulator 313 is, according to the invention, so constructed as to change the position of the blades of the propeller in such a manner, that the driving motor always rotates with a constant number of revolutions.

Figs. 6-8, illustrate by way of example the coupling of the pilot lever to the selecting lever for the adjustment of the various ranges of numbers of revolutions of the propeller. 316 is the handle of a pilot lever 317. The two levers 317 and 321 bear, by means of the hubs 318 and 320 respectively, against a common pivot 319. In the lever 321 a recess 322 facing the lever 317 is provided into which a projection 323 of the lever 317 may engage to couple the two levers.

The so-called pilot lever as well as the selecting lever for the number of revolutions of the adjustable propeller are movable in a common slide 324 provided with a slot 325.

As may be seen from Figs. 6 and 8, the pilot lever 316, 317 may be moved in the slide from the point *a* over *b* to *c*, then to *d* and finally to *e*. In the positions *a* and *e* the lever, bears against stops which are formed by the slot of the slide.

a designates the idle running position, *b* and *c* designate the cruising positions arranged at 80% of the nominal output, while *d* is the position for the nominal output and *e* is the position for take off output.

On shifting the pilot lever 316, 317 from the position *c* to the positions *d* and *e* the selecting lever 321 is entrained by the nose 323 which engages into the recess 322. Hereby the selecting lever is moved from the position *c* (see also Fig. 5) which corresponds to the low number of revolutions of the propeller into the positions *d* and *e* which correspond to the high number of revolutions.

If the levers 316, 317 and 321 are not coupled to each other, the selecting lever 321 always is maintained in the position *c*, by means of a spring 326, whereas the pilot lever 316, 317 may be maintained in any desired position.

Another modification of the present device has the advantage that it may be used for controlling the quantity of the fuel and also for controlling auxiliary devices, as for instance the ignition device, the cooling apparatus, the adjustable propeller and so on of the internal combustion engine. The device is so constructed, that the following operating conditions also may be considered.

If for instance an aircraft is flying in a height substantially above the so-called full pressure height, the motor supplies a certain portion of its full efficiency only due to the reduction of the charging pressure. If it is supposed for instance, that the motor only supplies 50% of its full power during the time the pilot lever occupies the 100% position, very unfavorable conditions result in connection with the known device. For instance, the cooling flaps are completely opened, whereas the motor only supplies half of its full power, so that the motor is strongly cooled down and the speed of the aircraft is unnecessarily reduced. Also with regard to the adjustment of the time of ignition faults result, as with the 100% position of the pilot lever the times of ignition favorable for full load are set, whereas due to the great height of the aircraft about 50% of the motor efficiency only may be ob-

tained. The same is true for instance for the adjustment of the pitch of the propeller and the setting of other parts.

To obviate these defects, the regulating device according to the invention is so constructed, that a time of ignition, different from that required for a smaller quantity of air fed, for instance such as corresponding to the cruising efficiency is automatically set, when larger quantities of air corresponding to a great motor efficiency are dealt with in a unit of time.

Also the blades of an adjustable propeller are set and the position of the plates allowing discharge of the cooling air is regulated in such a sense, that above a definite height of flight in which the motor cannot operate with highest efficiency, because the amount of air drawn in in a unit of time is too small, the cooling flaps cannot longer be completely opened.

In the modification shown in Fig. 9 by way of example only one cylinder 401 is represented of the motor or other internal combustion engine used. In cylinder 401 the piston 402 moves up and down which is connected by means of a rod 403 to the crank 404 of a crankshaft 405. An outlet valve 406 of the cylinder 401 is connected to a pipe 407 leading to the exhaust, and an inlet valve 408 also is provided. Mounted upon the shaft 405 is the gear wheel 409 engaging with a gear wheel 410 mounted on the shaft 411. Shaft 411 carries the rotor 412 of a centrifugal blower serving as charger, the fixed casing 413 of which is connected by way of a pipe 414 to the inlet valve 408 and supplies the latter with combustion air under pressure. A nozzle 415 for injecting fuel extends into the pipe 414. Nozzle 415 is connected to the fuel pump 416 which is formed for example as a geared pump 416 the construction of which is known, so that, therefore, this pump need not be described. The quantity fed by the fuel pump 416 is controlled also in a well-known manner by a lever 417 acting upon a control valve of the pump which also is well-known and is, therefore, not shown in the drawings.

Air is supplied to the centrifugal blower 412, 413 by a Venturi tube 418 open to the relative air current the discharge end 419 of which is narrow and flares in the manner of a diffusor towards the charger as far as to the width of the inlet socket 420. At the smallest point as well as at the largest point of the Venturi tube 418 tappings 421 and 422 respectively are provided. The tapping 422 is connected by way of a pipe 423 to the interior space 424 of a chamber 425. In the interior space 424, closed against the outer atmosphere, a diaphragm box 426, formed by a corrugated tube, is arranged the interior of which is connected by a pipe 427 to the tapping 421. The pressure difference, due to the flow of air, occurring at the tappings 421 and 422 of the Venturi tube 418 effects an expansion or contraction of the diaphragm box 426. Rigidly connected to the latter and actuated by its expansion and contraction movements is a rod 428 on which two pistons 429, 430 are mounted. These pistons are displaceably arranged in a sleeve 431 which in turn is displaceably arranged in a cylinder 432. A spring 433 tends to press the sleeve 431 upwardly. In the cylinder 432 an inlet pipe 433' and two outlet pipes 434, 435 for admitting and discharging pressure oil are provided. Moreover, the cylinder 432 is connected to chambers 438, 439 arranged above and below a piston 440 respectively by means of channels 436, 437. The

pistons 429 and 430 in a well-known manner effect admission and discharge of pressure oil into and out of the chambers 438 and 439 respectively, whereby the piston 440 is moved upwardly or downwardly. The admission and discharge of the pressure oil, besides depending on the position of the pistons 429, 430, depends on the position of the sleeve 431 and the openings provided in this sleeve. A piston rod 441 carrying a cam 442 is attached to the piston 440. The cam 442 is formed in the manner of a logarithmic curve. Roller 443 bears against cam 442 and is carried by the one arm 444 of a bell-crank pivotally mounted on a bolt 445. The other arm 446 of the bell-crank is fork-shaped and engages a pin 447, provided on rod 448 rigidly connected to the sleeve 431. In this manner the piston 440 controls the sleeve 431 according to a logarithm law. By means of the spring 433 the roller 443 is always pressed against the curve 442.

The lower end of the rod 441 carries a pin 449 which engages a fork 450 of a balance beam 451 and acts upon the latter. Piston 453 controlled by a piston 454 acts upon the other arm of the balance beam which also is formed with a fork-shaped end 452. The piston rod 453 carries a curve 455 which also is formed in the manner of a logarithm curve which, however, extends in a reverse direction with regard to the curve 442. Bearing against the curve 455 is a roller 456 carried by a lever arm 457 of a bell-crank, pivotally mounted upon the bolt 458 the other fork-shaped arm 459 of which engages a pin 460 which is provided at a rod 462 rigidly connected to a sleeve 461. Against the action of a spring 463 sleeve 461 may be displaced in a cylinder 464 provided with an inlet 465 and two outlets 466 and 467 for pressure oil. On the other side channels 468, 469 are provided which, according to the position of the sleeve 461 and the pistons 470, 471 displaceably arranged in said sleeve, effect the admission and discharge of pressure oil into and out of the chambers 472, 473 above and below the piston 464. The pistons 470, 471 are fixed to a piston rod 474 attached to a diaphragm box 475, formed by a corrugated tube, and are controlled by the expansion and contraction movements of said diaphragm box. Diaphragm box 475 is closed against the outer atmosphere and contains a definite weight of air, whereas atmospheric pressure prevails in the space 476 of the chamber 477 which surrounds the diaphragm box 475, so that the expansion and contraction of the box 475 is effected in dependence on the state of air at a given time.

In the middle of the balance beam 451 a rod 479 is linked to the point 478. As the piston 440 due to the control of the sleeve 431 transfers upon the balance beam 451 the logarithm value of the pressure difference existing at the two measuring points 421, 422, while the piston 444, transfers upon the balance beam 451 the negative logarithm value of the state of air, a displacement of the rod 479 results. This displacement corresponds to half the difference of the logarithm value of the pressure difference and the logarithm value of the state of air. The rod 479 carries a further push curve 480 which introduces into the calculation the constant and the root value of the above mentioned formula. Against curve 480 bears, by means of a roller 481, the one arm 482 of a bell-crank pivoted on the bolt 483, the other arm 484 of which acts upon the lever 417. In this manner the fuel supply is effected in dependence on the actually

consumed weight of air at a given time. Mounted on the rod 479 are two pistons 485, 486 which, in correspondence to the position of the rod 479, are displaced in a sleeve 487 at the times shiftably arranged in a cylinder 488. Pressure oil is admitted to and discharged from the cylinder 488 by way of an inlet pipe 489 and discharge pipes 490, 491. The sleeve 487 is provided with openings which substantially correspond to the openings of the cylinder. By means of two channels 492, 493 the cylinder 488 is connected to the chambers 494, 495 arranged above and below a piston 496 respectively, so that in a manner known per se the position of the pistons 485, 486 as well as the position of the sleeve 487 control the position of the piston 496 at the times. Piston rod 497 carrying a curve 98 is fixed to the piston 496. Roller 499 mounted on an arm 500 of a bell-crank pivoted at 501 bears against curve 98. The other arm 502 of the bell-crank is fork-shaped and engages a pin 503 of a piston rod 504 which bears against the sleeve 487 and displaces the latter against the action of a spring 505. The rod 497 acts upon a lever, not shown in the drawings, which in a manner known per se effects adjustment of the ignition device, adjustment of the cooling flaps or setting of the blades of a variable propeller. One and the same piston 496 may effect the adjustment of all adjustable devices, but separate devices also may be provided for adjusting each individual device.

By the above mentioned device not only the fuel supply, but also the regulation of all devices, the optimum position of which changes in accordance with the motor efficiency, are directly controlled in dependence on the quantity of the fuel mixture consumed by the engine.

What we claim is:

1. In combination with an internal combustion engine, a fuel pump, a charger comprising an air intake, said air intake comprising a Venturi tube, said tube being provided with means to measure the pressure of the air passing through said tube at the narrowest and at the widest part of said tube, means actuated by the pressure difference of said two parts of said tube, said means actuating one of the two arms of pressure balancing means in the logarithmic ratio of said pressure difference the other arm of said pressure balancing means being actuated by the logarithmic value of the variations in the specific volume of the air, said balancing means actuating said fuel pump and thereby controlling the weight of the fuel in dependence upon the weight of the air.

2. In combination with an internal combustion engine, a fuel pump, a charger comprising an air intake, said air intake comprising a Venturi tube, a balance beam comprising two arms, one of said arms being actuated by the logarithmic value of the pressure difference of the air passing through the widest part and through the narrowest part of said Venturi tube, the other of said arms being actuated by the negative logarithmic value of the variations in the specific volume of the air, a rod connected with the fulcrum of said two arms and actuated in accordance with half the difference of the logarithmic value of said pressure difference and the logarithmic value of said specific volume of the air, means to control said fuel pump by means of said rod, whereby the weight of the fuel is controlled in dependence upon the weight of the air.

3. A device as claimed in claim 2 wherein said

control means between said rod and said fuel pump comprises a device being further actuated by the logarithmic value of a constant.

4. A device as claimed in claim 2 wherein said control means between said rod and said fuel pump is further dependent upon a hand operated device for adjusting the fuel air ratio to a predetermined value.

5. A device as claimed in claim 2 wherein the last mentioned arm of said balance beam is further actuated by the expansion value of the air flowing through said Venturi tube in different densities of the air.

6. In combination with an internal combustion engine, a charger comprising an air intake, said air intake comprising a Venturi tube, a balance beam comprising two arms, one of said arms being actuated by means including a cam, said means being controlled by the logarithmic value of the pressure difference in the air passing through the widest part and through the narrowest part of said air intake, the other of said arms being actuated by means including a cam, said means being controlled by the negative logarithmic value of the variations in the specific volume of the air and being further controlled by the negative expansion value of said Venturi tube in different densities of the air, said last mentioned cam being shaped in the form of a curve having superposed the negative logarithmic value of the variations in the specific volume of the air and the negative expansion value of said Venturi tube in different densities of the air, a rod connected with the fulcrum of said two arms and actuated in accordance with half the difference of the logarithmic value of said pressure difference and the logarithmic value of said specific volume of the air and by said negative expansion value, means to control said fuel pump by means of said rod, whereby the weight of the fuel is controlled in dependence upon the weight of the air.

7. In combination with an internal combustion engine, a fuel pump, a charger comprising an air intake, said air intake comprising a Venturi tube, a balance beam comprising two arms, one of said arms being actuated by the logarithmic value of the pressure difference of the air passing through the widest part and through the narrowest part of said Venturi tube, the other of said arms being actuated by the negative logarithmic value of the variations in the specific volume of the air, a rod connected with the fulcrum of said two arms and actuated in accordance with half the difference of the logarithmic value of said pressure difference and the logarithmic value of said specific volume of the air, a device connecting said rod with said fuel pump, said device comprising a lever pivotally and adjustably connected with a second lever one end of which having a fixed fulcrum, the other end of said second lever being pivotally connected with said fuel pump, the distance from the connecting point of said two levers to said fixed fulcrum being adjustable in accordance with the type of fuel used, whereby the weight of the fuel is controlled in dependence upon the weight of the air.

8. A device as claimed in claim 7 wherein said adjustable connection of said two levers is provided with a scale showing the optimum mixing ratios for various types of fuels.

9. In combination with an internal combustion engine, a charger comprising an air intake, means for continuously measuring the weight of the air passing through said air intake, a fuel

pump supplying fuel to said engine, means dependent upon the number of revolutions of said engine, means to simultaneously control said fuel pump in dependence upon the measured weight of the air and further in dependence upon said means dependent upon the number of revolutions of said engine.

10. In combination with an internal combustion engine, a fuel pump, a charger comprising an air intake, said air intake comprising a Venturi tube, a balance beam comprising two arms, one of said arms being actuated by the logarithmic value of the pressure difference of the air passing through the widest part and through the narrowest part of said Venturi tube, the other of said arms being actuated by the negative logarithmic value of the variations in the specific volume of the air, means controlled by the number of revolutions of said engine, said means controlling further means connecting said rod with said fuel pump, whereby the weight of the fuel delivered by said pump depends upon the weight of the air as well as on the number of revolutions of said engine.

11. A device as claimed in claim 10 wherein said means controlled by the number of revolutions of said engine is a centrifugal governor.

12. Method for controlling the fuel supply of internal combustion engines in dependence upon the weight of the air, said method comprising measuring the difference between the static and the dynamic pressure of the air passing through the air intake of said engine, actuating means in the logarithmic ratio of said air pressure difference, actuating other means by the logarithmic value of the variations in the specific volume of the air, balancing said first and said last mentioned means, and controlling the fuel pump of said engine by said two thus balanced means.

13. Method for controlling the fuel supply of internal combustion engines in dependence upon the weight of the air, said method comprising measuring the weight value G of the air substantially in accordance with the formula $G = \text{constant} \cdot \sqrt{\Delta p/v}$ wherein Δp is the pressure difference of the air passing through the air intake and v is the specific volume of the air, and controlling the weight of the fuel in dependence upon the thus measured weight of the air.

14. Method for controlling the fuel supply of internal combustion engines in dependence upon the weight of the air, said method comprising measuring the difference Δp between the static and the dynamic pressure of the air passing through the air intake of said engine, further measuring the specific volume v of the air, influencing a means in accordance with said pressure difference Δp , influencing other means in accordance with said specific volume v , converting the two influences to the weight value G of the air in accordance with the formula

$$G = \text{constant} \cdot \sqrt{\Delta p/v}$$

and controlling the weight of the fuel in dependence upon the thus measured weight of the air.

15. The combination with an internal combustion engine including a fuel pump, of a charger having an air intake, said air intake comprising a Venturi tube, a balance beam including two arms, one of said arms being actuated by the logarithmic value of the pressure difference of the air passing through the widest part and through the narrowest part of said Venturi tube, the other of said arms being actuated by the negative logarithmic value of the variations in

the specific volume of the air, a member connected with the fulcrum of said two arms and actuated in accordance with half the difference of the logarithmic value of said pressure difference and the logarithmic value of the specific volume of the air, and a control mechanism for controlling said fuel pump by means of said member including a lever having a fixed pivot, said lever being operatively connected with said pump, said member being operatively connected with an attacking said lever at a predetermined

point, and means to vary the distance of the point of attack of said member from the fixed pivot of said lever for adjusting the amount of fuel to be fed by said pump in dependence upon the type of fuel used, whereby the weight of the fuel is controlled in dependence upon the weight of the air.

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