

[54] **THERMODYNAMIC RECIPROCATING
MACHINE WITH CONTROLLED FUEL/AIR
SUPPLY**

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[22] Filed: **Feb. 16, 1972**

[21] Appl. No.: **226,913**

[30] **Foreign Application Priority Data**

Mar. 4, 1971 Netherlands 7102862

[52] U.S. Cl. **60/39.27, 60/39.28 T, 60/39.29,
60/39.63, 200/83 A**

[51] Int. Cl. **F02g 3/02**

[58] **Field of Search**..... 60/39.27, 24 D, 39.28 R,
60/39.28 T, 39.29, 39.63

[56]

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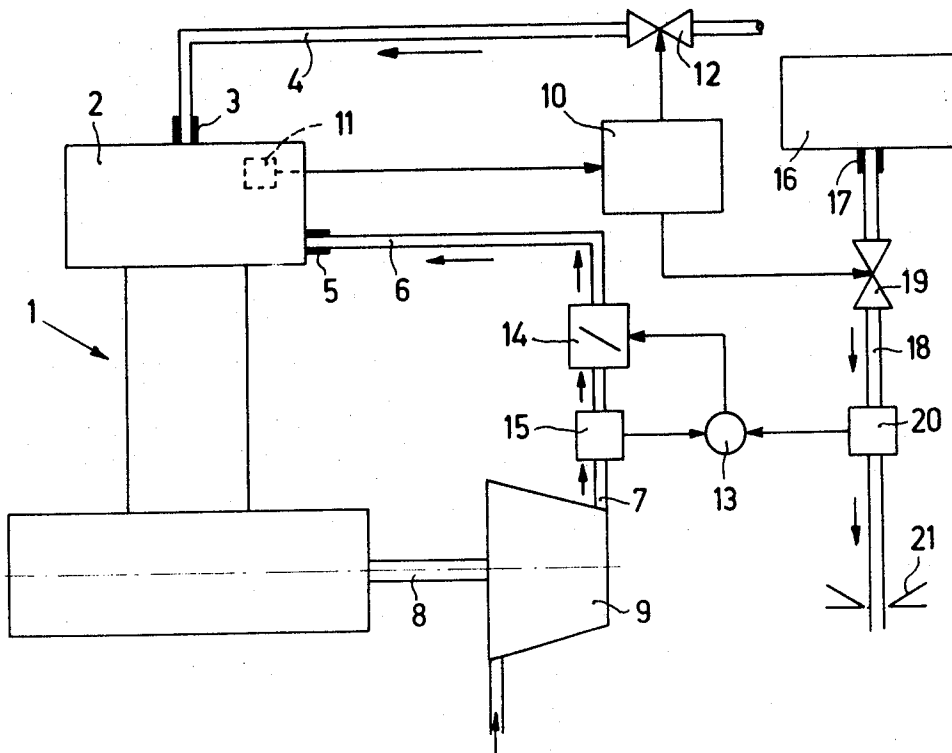
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ABSTRACT

A thermodynamic reciprocating engine in combination with a carburetor having inlets and control apparatus responsive to air and fuel flow for providing optimum operation.

5 Claims, 3 Drawing Figures



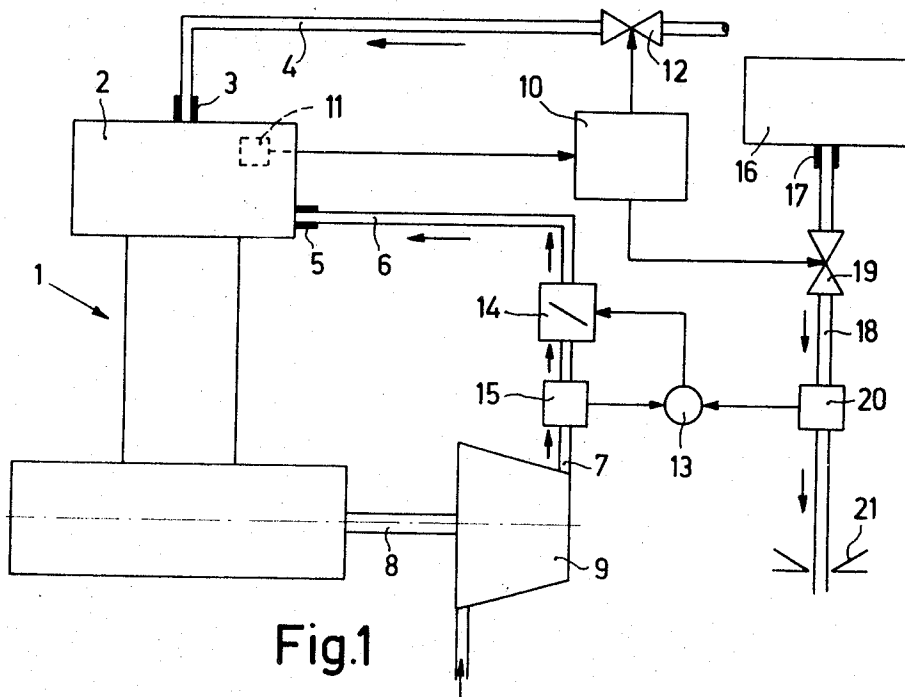


Fig.1

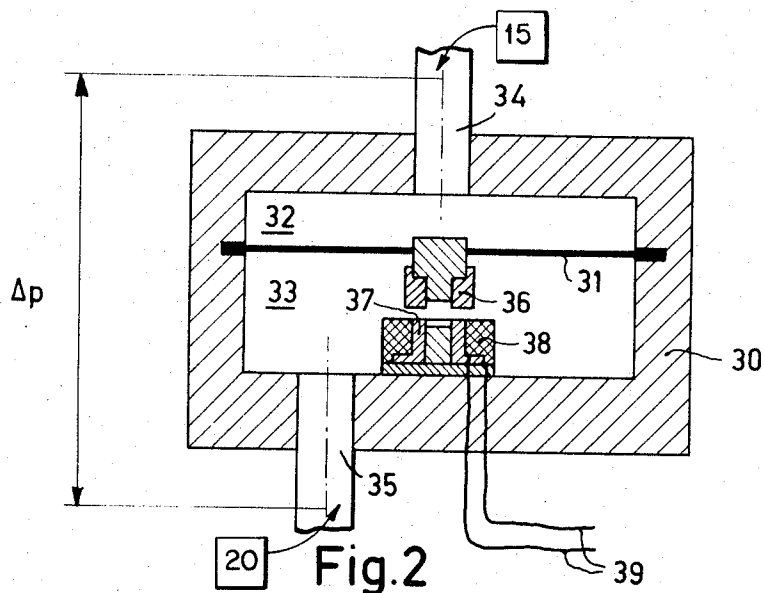
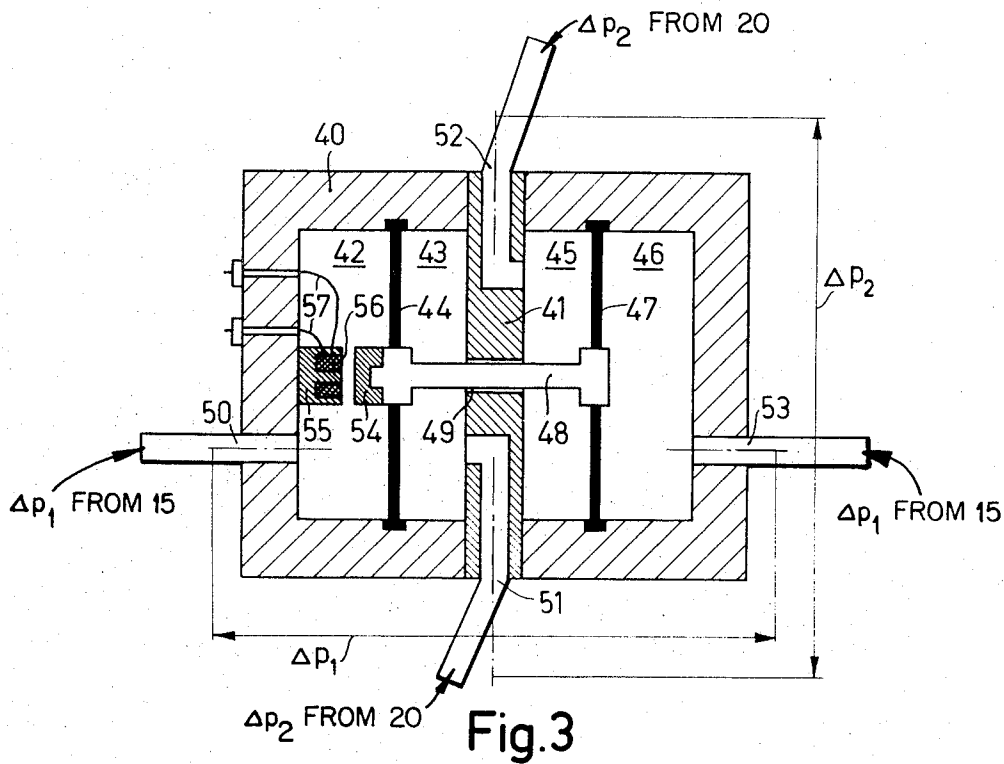


Fig.2



THERMODYNAMIC RECIPROCATING MACHINE WITH CONTROLLED FUEL/AIR SUPPLY

The invention relates to a thermodynamic reciprocating machine comprising a burner device having a fuel inlet as well as an inlet for air of combustion with which a duct of air of combustion communicates, which latter communicates with the outlet of a device for supplying air of combustion coupled to a shaft of the machine, in which a control apparatus reacting to at least one parameter of the machine is present for controlling a fuel flow to the fuel inlet and in which the quantity of air of combustion to be supplied is controlled in proportion to the supplied quantity of fuel by means of a control member which operates a control mechanism in the duct for air of combustion, in which duct a flow restricting element is present which provides a signal proportional to the speed of the flow of air of combustion through the said duct, which signal influences the control member.

In thermodynamic reciprocating machines it is known to couple a fan for the supply of air to the burner device directly to the shaft of the machine so that the number of revolutions of the fan is determined only by the number of revolutions of the machine.

This is often done in machines of high powers in which the comparatively high power required for driving the fans is directly supplied by the machines themselves.

The control apparatus which controls the fuel supply to the burner device can react to one or several parameters. For example, it may react only to the heater temperature of the machine (British Patent Specification 895,869), to both the heater temperature and to the average pressure of the working medium in the machine (British Patent Specification 655,935) or, for example, to the said average pressure in combination with the number of revolutions of the machine (British Patent Specification 691,785, Dutch Patent Specification 68,679).

Control in a thermodynamic reciprocating machine of the quantity of air of combustion to be supplied to the burner device in proportion to the quantity of fuel supplied is known from the said British Patent Specification 895,896. In this known machine, pressure differential gauges are arranged in the fuel duct and the duct for the supply of air of combustion, which gauges influence, independently of each other but in opposite senses, the same control member of a hydraulic system which controls the position of a throttle valve as a control mechanism in the duct for air of combustion in accordance with the flow of fuel. Since the flows of fuel to the burner device are comparatively small, measurement of said flows with a pressure differential gauge is hardly possible in a reliable manner. The pressure drop across measuring plates in small fuel flows depends upon temperature because in that case the flow through said plates is not turbulent but laminar.

As a result of this the ratio air-fuel can easily differ from the desirable value. The use of a pressure differential gauge in the fuel duct therefore exhibits drawbacks.

In thermodynamic reciprocating machines in which the fan is coupled to a shaft of the machine and in which the supply of air of combustion is controlled in direct dependence upon the fuel supply, it is a problem — since the use of a fuel pressure differential gauge is

avoided for the above-mentioned reasons — to adapt the control of air with a given fan characteristic (yield versus number of revolutions) to the fuel control in such manner that irrespective of the number of revolutions of the fan the correct air-fuel ratio is always obtained.

The use of complicated and expensive electronic circuits (for example diode networks) which derive a suitable control signal for the flow of air of combustion from each control signal for the fuel flow, is then substantially unavoidable.

Since the choice of the fan depends upon the type of machine (both as regards power and application) in question, and each type of fan has its own characteristic, this means that for each type of machine with associated type of fan an air-fuel control system is necessary which has been developed especially for this type. In addition to the condition that a satisfactory solution is not possible in all cases, it is undesirable for practical and economic reasons that each type of machine with associated type of fan should need a separate air-fuel control system and that the same number of control systems as the number of machine types should be necessary.

It is the object of the present invention to mitigate the said drawbacks.

For that purpose, the thermodynamic reciprocating machine according to the invention is characterized in that a device is present for supplying a pressure medium under a constant pressure and having a medium outlet with which a medium outlet duct communicates, the medium outlet duct, taken from the medium outlet, comprising successively a control element, a further flow restricting element and a fixed restriction, the control apparatus also operating the control element for controlling the flow of medium through the medium outlet duct in proportion to the flow of fuel controlled by said apparatus, the further flow restricting element providing a further signal which is proportional to the speed of the flow of medium and which influences the control member in a sense opposite to the signal originating from the flow restricting element.

In the present case, the flow of air of combustion is not controlled directly but indirectly, via the medium flow as an auxiliary flow, in proportion to the flow of fuel. The medium flow may be large in comparison with the fuel flow so that the further flow restricting element provides a comparatively large signal representing the medium flow in a reliable manner.

The control apparatus ensures that the flow of medium is varied in proportion to the fuel flow, for which purpose the characteristic of the fuel control element and that of the medium control element are adapted to each other.

The control apparatus may have a universal construction and application.

Since the flow of air of combustion is directly compared with and controlled in accordance with likewise a flow, the medium flow in a separate medium control system, no special measures are required to obtain the desirable proportionality between the flows of air of combustion and medium. The characteristic of the fan substantially plays no part of importance any longer.

The medium control system may have a universal construction; the elements from which this circuit is constructed may be the same for all the cases occurring in practice.

Measurement of small flows of fuel with all the difficulties involved is no longer necessary.

In this manner a universal air-fuel control system of an inexpensive and simple construction is obtained for thermodynamic reciprocating machines having their fan coupled to a shaft of the machine, irrespective of the type of machine and fan characteristic. The required adaptation of the air control to the fuel control occurs once and is generally solved in designing the control system, and is incorporated in said system.

As regards the flow restricting element and the further flow restricting element, respectively, there is a great possibility in choice.

To be considered are, for example, Pitot tubes Venturi tubes, measuring plates which all provide a pressure differential as a signal. This pressure differential may directly influence the control member, for example, in the manner as described in the British Patent Specification 895,869. The pressure differential may also be converted, for example, into an electric signal in a pressure converter and the resulting signal be applied to an electric comparison element which reacts as a control member to the difference between two electric signals representing the flow of air of combustion and the medium flow, respectively.

Furthermore, for example, pressure sensors may be used which sense the overall pressure (static pressure plus dynamic pressure) and supply a pressure signal which again directly influences the control member or is first converted into another signal, for example an electric signal.

To be considered are also anemometers, for example hot wire flow meters, the latter providing an electric signal directly.

Of course, the flow restricting element and the further flow restricting element in the same control system need not be the same type of element, that is to say the flow restricting element may be, for example, a Venturi, while the further flow restricting element is a Pitot tube, a measuring plate, an overall pressure sensor and so on, provided the signal characteristics correspond mutually.

As a flow restricting element in the duct for air of combustion is to be preferred an element which provides a pressure differential (dynamic pressure gauge) over an element which provides one pressure signal (static pressure plus dynamic pressure). The reason for this is that the pressure in the burner device may vary in certain circumstances so that the static pressure in the duct for air of combustion communicating therewith may also vary. In the case of measurements on the basis of pressure differentials, the influences of the variations of the static pressure in the duct for air of combustion on the determination of the flow of air of combustion is eliminated.

In order that the invention may be readily carried into effect, it will now be described in greater detail, by way of example, with reference to the accompanying diagrammatic drawings which are not drawn to scale.

FIG. 1 shows a thermodynamic reciprocating machine having a fan coupled to a shaft of the machine and comprising an air-fuel control system.

FIG. 2 shows an embodiment of a pressure differential converter in which a difference in two pressures supplied to it are converted into an electric signal.

FIG. 3 shows an embodiment of a combined pressure differential comparison and converting element in

which two pressure differentials (four pressure signals) supplied thereto are compared and the difference therebetween is converted into an electric signal.

Reference numeral 1 in FIG. 1 denotes a thermodynamic reciprocating machine comprising a burner device 2 having a fuel inlet 3 with which a fuel duct 4 communicates and comprising an inlet 5 for air of combustion with which a duct 6 for air of combustion communicates which communicates with the outlet 7 of a fan 9 coupled to a shaft 8 of the machine 1. A control apparatus 10 which reacts to the electric signal originating from a temperature-sensitive element 11 and which element senses the temperature of a heater of the machine not shown operates an electromagnetic valve 12 in the fuel duct 4. By means of said valve a fuel flow to the burner device 2 is controlled in accordance with the heater temperature. When the heater temperature increases, for example by reduction of the power derived from the machine, the control apparatus 10 ensures that the valve 12 is closed more so that less fuel flows to the burner device 2. Conversely, when the heater temperature decreases, the control apparatus 10 ensures that the valve 12 is opened more so that more fuel is passed. Fuel may be supplied in the manner as described, for example, in the British Patent Specification 895,869.

A control member 13 operates a control mechanism 14, for example a throttle valve, in the duct for air of combustion. The control member controls in accordance with the difference signal between the signals originating from a flow restricting element 15 present in the duct 6 for air of combustion and from a further flow restricting element 20, which elements each supply a signal which is proportional to the flow rate through the relevant duct. A device 16 is present which supplies a pressure medium under a constant pressure and in this case consists of a compressor for atomized air which normally is already present to supply the air which is guided along the atomizers of the fuel burners so as to obtain a good nebulisation of the fuel. The compressor 16 comprises an outlet 17 with which an outlet duct 18 communicates. Incorporated in the outlet duct 18 are an electromagnetic valve 19 as a control element for the air flow through the outlet duct, the further flow restricting element 20 which, as already stated, influences the control member 13, and a fixed restriction 21.

The control apparatus 10 operates both the valve 12 in the fuel duct 4 and the electromagnetic valve 19.

The characteristics of electromagnetic valves 12 and 19 are matched mutually, as well as the characteristics of the flow restricting element 15 and the further flow restricting element 20. Otherwise, as already stated in the preamble, the flow restricting element and the further flow restricting element may be different types of instruments, while other instruments are to be considered, for example, Pitot tubes, Venturis, measuring plates with which pressure differentials proportional to the flow rate are produced, pressure sensors which measure the overall pressure or anemometers such as electric anemometers which provide an electric signal which is a measure of the flow.

The control member 13 may be a hydraulic control member which is controlled hydraulically by pressure and pressure differential signals, respectively, originating from elements 15 and 20. It may also be an electric comparison element which compares electric signals

originating directly from elements 15 and 20 (anemometers) or originating therefrom indirectly (pressure differential) signals converted into electric signals) and operates the control mechanism 14 on the basis of the difference signal.

Conversion of a pressure differential into a corresponding electric signal may be carried out, for example, in a converter as shown in FIG. 2 to be described hereinafter.

When the elements 15 and 20 supply pressure differentials while control mechanism 14 is controlled electrically, a combined unit may be used as is shown in FIG. 3 to be described hereinafter.

The operation of the control system shown in FIG. 1 is further as follows.

During operation, air of combustion is supplied to the burner device 2 by the fan 9 coupled to the shaft 8 of the machine 1 while fuel is supplied to the said burner device via fuel duct 4, in a manner not shown.

Compressor 16 supplies a flow of air of a sufficiently high pressure relative to the atmospheric pressure, which flows away to the atmosphere via outlet duct 18. In a certain fixed position of the valve 19 a constant air flow flows through the duct 18 and the pressure between said valve and the fixed restriction 21 is also constant with the exception of a possible influence of variations in the ambient pressure hereon. When the latter is disturbing, the element 20 may be of the type which provides a pressure differential. The influence of ambient pressure variations is then eliminated in an analogous manner to the influence of pressure variations in the burner device of the duct for air of combustion.

When the heater temperature decreases, this results in a variation in the electric signal supplied by the temperature-sensitive element 11 in such manner that the control apparatus 10 further opens both the valve 12 and the valve 19 and that both the fuel flow in the fuel duct 4 and the air flow through the outlet duct 18 increase to the same extent. As a result of this, the signal produced by the further flow restricting element 20 also varies, increases in value, which has for its result that the control member 13 further opens the control mechanism 14 and more air of combustion flows to the burner device 2.

Owing to the larger flow of air of combustion, the value of the signal produced by the flow restricting element 15 will also increase in the first instance as a result of which the control member 13 is forced to slightly close again the control mechanism 14 which in turn results in a reduction of the signal produced by the flow restricting element 15 as a result of which the control mechanism 14 is again opened slightly further, and so on. By suitable mutual matching of the relevant components of the control system, however, such an oscillation effect is prevented and the equilibrium condition is rapidly reached. When the heater temperature increases, the control system operates in the opposite direction from in the case of a decrease of the heater temperature, that is to say, the control apparatus 10 in that case closes the valves 12 and 19 further so that the flow of air through the outlet duct 19 decreases to the same extent as the fuel flow through the fuel duct 4.

The valve of the signal supplied by the further flow restricting element 20 also decreases, which has for its result that the control member 13 closes the control mechanism 14 further and less air of combustion is passed.

Instead of as is shown in the figure, the control mechanism 14 may also be provided in other places, for example, between the fan 9 and the flow restricting element 15 or on the inlet side of the fan. When the number of revolutions of the machine and hence the number of revolutions of the fan vary, the signal supplied by the flow restricting element 15 will also vary due to the varied fan yield. In that case the control member 13 will further open or close the control mechanism 14 so that upon variation of the number of revolutions of the fan the quantity of air of combustion passed to the burner device 2 remains unchanged irrespective of the fan characteristic. The control system described is simple and compact of construction, may have a universal construction and application for all types of thermodynamic reciprocating machines having a fan coupled to a shaft of the machine, irrespective of the type of fan. Of course, all kinds of other devices are possible which supply a pressure medium under a constant pressure, for example, a medium storage container. Not only gases but also liquids are to be considered as media. Medium which has flowed through the outlet duct need not necessarily be dissipated to the atmosphere but may be caught, if desirable, and then be returned to the device.

Reference numeral 30 in FIG. 2 denotes a housing in which a diaphragm 31 is arranged which is secured to the housing and which separates a chamber 32 from a chamber 33. Chamber 32 is accessible via an inlet 34, chamber 33 via an inlet 35.

The diaphragm 31 supports a magnetic element 36 which faces a soft iron core 37 with induction coil 38 arranged inside the chamber 33. Electric conductors 39 are connected to the induction coil and are passed out through the wall of the housing 30.

When the magnetic element 36 moves in the direction of the core 37, an electric signal is produced in the induction coil 38 the value of which signal is proportional to the distance over which the magnetic element 36 moves.

The two different pressures which are supplied by the flow restricting element 15 or the further flow restricting element 20, constructed, for example, as Venturis, may be applied to the inlets 34 and 35.

When the flow of air of combustion and medium, respectively, through the outlet duct varies, and hence the pressure differential produced, the electric signal of the induction coil 38 varies proportionally thereto since the pressure differential across the diaphragm 31 varies so that said diaphragm moves towards the core 37 or away from it.

FIG. 3 shows a housing 40 having a partition 41 which divides the space inside the housing into two subspaces. One sub-space consists of two chambers 42 and 43 separated from each other by a diaphragm 44, the other subspace consisting of two chambers 45 and 46 separated from each other by a diaphragm 47.

Diaphragms 44 and 47 are connected at one end to the housing 40 and at the other end to a common rod 48 which can reciprocate in the axial direction and is passed through the partition 41 through an aperture 49.

Chambers 42, 43, 45, 46 each comprise an inlet 50, 51, 52 and 53, respectively. At its one end the rod 48 comprises a magnetic element 54 which faces a soft iron core 55 with induction coil 56 arranged inside the chamber 42 and to which electric conductors 57 are connected which are passed to the exterior through the

wall of the housing 40. When the rod 48 again moves in the direction of the assembly core 55/induction coil 56, an electric signal is induced in the coil 56 in this case also the value of which is proportional to the distance over which the rod 48 has moved.

By supplying the pressure differential Δp_1 to the chambers 42 and 46 which represents the flow of air of combustion, and by supplying the pressure differential Δp_2 which represents the medium flow in the outlet duct to the chambers 43 and 45, an equilibrium condition is obtained in which the rod 48 assumes a given position with a corresponding electric signal on the induction coil 56. The forces on the rod and the result of the pressure differentials prevailing across the diaphragms 44 and 47 then make equilibrium with the forces on the said rod as a result of the tension forces in the diaphragms.

When the pressure differential Δp_2 varies, the equilibrium of forces is disturbed and the rod 48 assumes a new position in which a new equilibrium of forces is achieved. Induction coil 56 then supplies a new electric signal corresponding to the new position.

The control mechanism 14 in the duct 6 for air of combustion of FIG. 1 can be directly controlled by the signal supplied by the induction coil 56.

The same medium is present in the chambers 43 and 45. Any medium leakage from the higher to the lower pressure chamber therefore provides no complications, while the pressure differential between the chambers is hardly influenced by small leakage.

What is claimed is:

1. In a thermodynamic engine including a burner for combustion of fuel and air, with a fuel inlet fed by a fuel duct, an air inlet fed by an air duct, a flow valve in each of said ducts, a heater heated by the burner, a temperature sensing element indicating heater temperature, a device for supplying air to said air duct, drive means from said engine to said device, the improvement in combination therewith of control apparatus responsive to at least one parameter of the engine for controlling said fuel flow and for controlling said air flow to be proportionate to said fuel flow, comprising, an air flow re-

stricting element in the air duct intermediate said air supply device and the air flow valve responsive to air flow therethrough and providing a corresponding 1st signal, a source of constant pressure fluid medium, an outlet duct for said medium flow, a main valve controlling flow through said outlet duct, a second flow restricting element in said outlet duct downstream of said main valve for providing a second flow signal, a fixed restriction in said outlet duct downstream of said second flow-restricting element, a control apparatus responsive to signals from said temperature sensing element for opening wider said fuel duct valve and said main valve in said medium outlet duct when temperature is low, and vice versus, a control member receiving said first and second flow signals respectively from said flow restricting elements in said air flow and fluid medium flow ducts, for determining the difference between said signals, and producing a resulting control signal to said air flow valve.

2. Apparatus according to claim 1 wherein said air-flow element and fluid medium flow restricting element register the fluid pressure of the fluid flow in the corresponding ducts.

3. Apparatus according to claim 1 wherein said fluid medium is a gas.

4. Apparatus according to claim 1 wherein said fluid medium is a liquid.

5. Apparatus according to claim 1 wherein said control member comprises a housing with first and second ports, a diaphragm within the housing dividing same into first and second chambers, an electromagnetic transducer having one fixed and one moving part, one of these parts secured to said diaphragm and the other to the housing in the first chamber, the first and second ports communicating with said flow-restricting elements respectively of the medium flow and air flow ducts, whereby the diaphragm registers the pressure differential between said elements and the electromagnetic transducer is actuated by the diaphragm and produces a corresponding electrical signal to said flow valve in the air flow duct.

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