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(54) A POWER UNIT COMPRISING A SUPERCHARGED INTERNAL COMBUSTION ENGINE

(71) We, ETAT FRANCAIS represented by le Délégué Ministériel pour l'Armements of 4, avenue de la Porte d'Issy, 75966-Paris, (France), do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a power unit comprising an internal combustion engine supercharged by a turbine-compressor unit comprising at least one compressor delivering compressed fresh air to supply the engine, and at least one turbine driving said compressor and actuated by the exhaust gases from the engine.

In such a power unit, it is known to provide a by-pass conduit which is permanently open and enables fresh air delivered by the compressor to pass to the turbine, along with the exhaust gases emerging from the engine; an auxiliary combustion chamber is then generally provided upstream of the turbine, this combustion chamber being supplied with the engine exhaust gases and the fresh air taken from the by-pass pipe.

It is an object of the invention to reduce the work done in discharging exhaust gases, thereby to enable the power of the engine to be increased (by increasing the effective average pressure) and its fuel consumption to be reduced.

It is another object of the invention to enable scavenging of the engine due to a difference of pressure maintained between the intake and the exhaust.

Accordingly, in one aspect, the invention provides a power unit comprising an internal combustion engine supercharged by a turbine-compressor unit whose turbine has an inlet connected to the exhaust of the engine, and comprising a by-pass conduit which is preferably permanently open in operation and which communicates with the outlet of the compressor and with the turbine inlet so that the engine is in parallel air flow relation with the by-pass conduit, said by-pass conduit

having automatically controlled throttle means to develop a pressure drop in the air flow passing through the by-pass conduit which is substantially independent of the rate of flow traversing said by-pass conduit and which is an increasing function of the pressure existing at the compressor outlet.

It will hence be understood that the work of discharging the exhaust gases is reduced, the effective average pressure being increased by a value equal to the difference between the pressure upstream of the throttle means and the pressure downstream of said throttle means.

Moreover, the existence of a difference in pressure maintained between the intake (pressure upstream of the throttle means) and the exhaust (pressure downstream of the throttle means) enables scavenging of the engine.

It is a further object of the invention to adapt the turbine-compressor unit to high supercharging pressures due to operation of the compressor close to the surge line, that is to say with optimum yield.

Accordingly, in another aspect, the invention provides a power unit comprising an internal combustion engine supercharged by a turbine-compressor unit whose compressor operates close to its surge line and whose turbine is connected to receive the exhaust gas of the engine and an air flow delivered by the compressor through a conduit which is permanently open in operation and bypasses the engine, the pressure drop of said air flow being an increasing function of the pressure delivered by the compressor. Preferably, said pressure drop is developed by automatically controlled throttle means in said by-pass conduit.

In an embodiment of the invention, the throttle means comprises a throttle member movable within the by-pass conduit and co-operating with a fixed seat for limiting a throttled air flow section of variable effective cross-sectional area.

The throttle member may be operatively connected to a balancing piston which is sub-

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jected to the pressure which prevails at a point of the by-pass conduit.

Resilient return means may be associated with the throttle member to maintain the throttle means in open condition when atmospheric pressure prevails in the by-pass conduit on both sides of the throttled section.

In a preferred embodiment of the invention, an auxiliary combustion chamber is connected to receive air which has passed through the by-pass conduit and has its outlet connected to the inlet of the turbine, said auxiliary combustion chamber having a fuel inlet, a primary air intake connected to receive fresh air derived from a point of said by-pass located upstream of said throttling means for combustion of the fuel injected into said auxiliary combustion chamber and a secondary air intake adapted to receive air from said by-pass conduit through throttling means providing said pressure drop.

Means may be provided for adjusting the flow rate of the primary air which is responsive to the pressure which prevails at a point of the by-pass conduit which is located upstream or downstream of the throttling means, said adjusting means comprising a first member and a second member movable with respect to each other to adjust the effective cross-sectional area of a passage for said primary air, the first member of the adjusting means being operatively connected to a movable throttle member of said throttle means and the second member of said adjusting means being controlled by the pressure which prevails downstream of said throttle means.

Advantageously, the primary air adjusting means actuates a device for adjusting the flow-rate of fuel injected into the auxiliary combustion chamber so as to maintain a substantially stoichiometric ratio between the flow-rates of primary air and fuel.

It will then be understood that there is established a relationship between the effective cross-sectional area S_p offered to the primary air and the effective cross-sectional area S_s offered to the secondary air.

In fact, if ΔP denotes the pressure difference on each side of the throttling means, and P the pressure existing in the upstream part of the by-pass conduit, the increasing linear function connecting ΔP and P can be written in the following way:

$$\Delta P = \alpha P + \beta,$$

α and β denoting two coefficients.

On the other hand, it can be written that this pressure difference ΔP is proportional to the specific mass m of the fresh air and to the square of its velocity V :

$$\Delta P = kmV^2,$$

k being a constant to a first approximation.

From the two above equations there can then be deduced the value of the velocity V :

$$V = \left(\frac{\alpha P + \beta}{km} \right)^{1/2}.$$

Now the sum of the outlet cross-sections S_p and S_s is connected to the total flow-rate Q of fresh air in the by-pass conduit by the following equation:

$$S_p + S_s = \frac{Q}{mV},$$

with S_p being a function of P , namely $S_p = f(P)$, $f(P)$ being the predetermined relationship connecting the effective cross-sectional area S_p with the pressure P , namely, by replacing the velocity by its value as a function of the pressure:

$$S_p + S_s = Q \left[\frac{m}{k} (\alpha P + \beta) \right]^{-1/2}.$$

Under these conditions, the flow-rate of primary air Q_p only depends on the pressure P , according to the equation:

$$Q_p = f(P) \left[\frac{m}{k} (\alpha P + \beta) \right]^{1/2}.$$

The flow-rate of secondary air Q_s is always equal to the difference between the total flow-rate flowing in the by-pass conduit and the flow-rate of primary air Q_p .

$$Q_s = Q - Q_p.$$

According to a preferred embodiment of the invention, the primary air adjusting means and the fuel flow adjusting device are located in a movable member of the throttle means.

The movable throttle member may be formed with a tubular extension and the primary air adjusting means comprises at least one port formed in said tubular extension and adapted to be covered by a slide valve having an actuation surface subjected to the pressure existing in the downstream or upstream part of the by-pass pipe, and another actuation surface subjected to a counter pressure and to the action of a spring, said slide valve being connected to the adjusting means.

In order that the invention may be readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1, of these drawings, is a diagram-

matic view of a power unit embodying the invention and comprising a super-charged Diesel engine equipped with an auxiliary combustion chamber having a single fresh air intake;

Figure 2 is a diagrammatic view of a power unit embodying the invention and comprising a supercharged Diesel engine equipped with an auxiliary combustion chamber having two fresh air intakes, the said combustion chamber comprising a "return" injector;

Figure 3 is a diagrammatic view of a power unit embodying the invention and comprising a supercharged Diesel engine equipped with an auxiliary combustion chamber having two fresh air intakes, the said combustion chamber comprising a "non-return" injector.

Figure 4 is a partial view of an important element of the power unit of Figure 2 showing a modification thereof; and

Figure 5 is a graph relating to the operation of a power unit embodying the invention.

The power unit shown in Figure 1 comprises a Diesel engine 101 which is supercharged by a turbine-compressor unit 102.

The turbine-compressor unit 102 comprises a compressor 103 delivering compressed air to the engine through a pipe, and a turbine 104 driving said compressor 103 through a shaft 105, the turbine 104 being actuated by exhaust gases from the engine 101.

A permanently open by-pass pipe 106 permits fresh air delivered by the compressor 103 to flow towards the turbine and mix with the exhaust gases emerging from the engine.

A combustion chamber 107 is provided upstream of the turbine 104, this combustion chamber 107 being supplied with the exhaust gases and with fresh air taken from the by-pass pipe 106.

Throttle means 108 defines a variable cross-section at area in the by-pass pipe 106, the means 108 generating between the upstream part of the by-pass pipe 106 (the part connected to the compressor 103) and the downstream part of the by-pass pipe 106 (the part connected to the turbine 104 through the combustion chamber 107) a difference of pressure ΔP which is an increasing function, preferably linear or substantially linear, of the pressure existing in the upstream part.

This linear function may be written:

$$\Delta P = \alpha' P + \beta'$$

α' and β' denoting two coefficients.

In the embodiment of the invention illustrated in Figure 1, the throttle means 108 comprise a throttle member 108a arranged in the by-pass pipe 106 and cooperating with a fixed seat 108e.

The throttle member 108a is borne at one

end of stem 108b the other end of which is fast with a balancing piston 108c sliding in a cylinder, or better, as shown, connected to the by-pass pipe 106 through a deformable wall 108d.

The diameter of the throttle member 108a and the diameter of the piston 108c are such that the said throttle member 108a is balanced,

by the pressure P exerted on its upstream surface and the inner surface of the piston 108c,

by the pressure $P - \Delta P$ exerted on its downstream surface,

and by the atmospheric pressure exerted on the outer surface of the piston 108c.

Resilient return means also act on the throttle member 108a in order to fix the value of the coefficient β' of the relationship

$$\Delta P = \alpha' P + \beta'.$$

The resilient return means may be constituted by a spring 109 and/or by the elasticity of the deformable wall 108d.

To vary the coefficient β' , there may be provided regulating means enabling adjustment of the resultant force applied on the throttle member 108a by the resilient return means; these regulating means can be constituted by a nut 110 modifying the tension of the resilient return means.

This feature is particularly advantageous, since it enables the pressure difference created by the throttle means 108 to be adapted to the power unit of which the supercharged engine forms part. In particular, this pressure difference can be adapted to the load losses which are created by a filtering device 111 situated at the intake of the compressor 103 and/or by a silencer device 112 located at the outlet of the turbine 104.

A viscous damping device, which will be more explicitly considered below, can advantageously act on the throttle member 108a in order to absorb vibration of aerodynamic origin to which said throttle member 108a may be subjected. This viscous damping device is preferably supplied from a source of viscous fluid under variable pressure.

There will now be described more particularly a feature of the invention which is applied in the case where the auxiliary combustion chamber is supplied with fresh air through a primary air intake to introduce fresh air into a combustion zone, and though a secondary air intake to introduce fresh air into a mixing zone.

In this respect, reference will be made first of all to Figures 2 and 3, which show a power unit comprising a Diesel engine 1 which is supercharged by a turbine-compressor unit 2.

The turbine-compressor unit 2 comprises a compressor 3 delivering compressed air to

the engine through a pipe 4, and a turbine 5 driving said compressor 3 by means of a shaft 6, the turbine 5 being actuated by the exhaust gases from the engine 1.

5 A permanently open by-pass pipe 7 permits fresh air delivered by the compressor 3 to be utilised with the exhaust gases emerging from the engine.

10 An auxiliary combustion chamber 2 is provided upstream of the turbine 5, this combustion chamber 8 being supplied with the exhaust gases through a pipe 9, and with fresh air through the by-pass pipe 7.

15 This combustion chamber 8 is in addition supplied with fuel by means of an injector 10 supplied by a pump 11 from a reservoir 12.

20 As regards the supply of the combustion chamber 8 with exhaust gases and with fresh air, said combustion chamber is supplied, by a primary air intake 13 which introduces fresh air into a combustion zone 14.

25 by an exhaust gas intake 15 which introduces the exhaust gases into a mixing zone 16 situated downstream of the combustion zone 14, and by a secondary air intake 17 which introduces fresh air to the abovesaid mixing zone 16.

30 The primary air intake 13 is constituted by a central pipe 18 arranged coaxially with the combustion chamber 8; the exhaust gas intake is constituted by a first annular pipe 19 encircling the central pipe 18; and the secondary air intake 17 is constituted by a second annular pipe 20 encircling the first annular pipe 19.

35 In this embodiment, there is provided: first throttle means 21 defining a variable effective cross-sectional area S_1 for the flow of secondary air, such first throttle means 21 generating between the upstream part of the by-pass pipe 7 (part connected to the compressor 3) and the downstream part of the by-pass pipe 7 (part connected to combustion chamber 8) a pressure difference ΔP which is an increasing function, preferably linear or substantially linear, of the pressure P existing in the upstream part,

50 and second throttle means 22 defining a variable effective cross-sectional area S_2 for the flow of primary air, the means 22 being subjected to the pressure difference ΔP generated by the throttle means 21 and offering to the primary air an effective cross-sectional area which is servocoupled to the pressure $P - \Delta P$ existing in the downstream part of the by-pass pipe 7, this servocoupling being according to a predetermined law.

60 Advantageously the second throttle means 22 also control a regulating device 23 for the flow-rate of fuel which controls the amount of fuel injected into the combustion chamber 8 so as to preserve, for the flow-rates of primary air and of fuel, a ratio

ensuring good stability of combustion, that is to say a relationship as close as possible to stoichiometric proportions.

It will then be understood that the fresh air taken from the by-pass pipe 7 is divided: 70 into primary air coming from the primary air intake 13 and the second throttle means 22 to supply the combustion zone 14 of the combustion chamber 8,

and into secondary air coming from the secondary air intake 17 and the first throttle means 21 to supply the mixing zone 16 of the combustion chamber 8.

The flow-rate of air circulating in the by-pass pipe 7 varies in a ratio of the order of 1 to 10 according as the engine operates at full speed (combustion chamber turned low) or as the engine operates at idling speed (combustion chamber used to the maximum).

80 On the other hand, the flow-rate of fuel which is necessary to ensure operation of the combustion chamber 8 enabling autonomy of the turbine-compressor unit 2 on starting of the engine, and the flow-rate of fuel sufficient to maintain the operation of the combustion chamber 8 turned low, are within a ratio of the order of 30 to 1.

Now the stability of combustion in the combustion chamber will be optimal if the flow-rate of air for combustion, that is to say the flow-rate of air coming from the primary air intake, is in the neighborhood of the flow-rate corresponding to stoichiometric proportions.

As previously explained, the sum of the effective cross-sectional areas $S_1 + S_2$ (respectively offered to the primary and to the secondary air) is hence determined by the values of the delivery pressure P from the compressor, and of the flow-rate Q of fresh air in the by-pass pipe 7.

Under these conditions and to organize the flow-rates of primary and secondary air, it suffices to act on one of these effective cross-sectional areas, the second cross-sectional area then being adjusted automatically; for instance, the effective cross-sectional area S_1 offered to the primary air may be adjusted.

115 The predetermined relationship between the cross-sectional area S_1 offered to the primary air and the delivery pressure $P - \Delta P$ in the downstream part of the by-pass pipe 7 can be selected to fulfil criteria which will be considered again in more detail below with respect to two embodiments of the invention relating respectively to a supply of the combustion chamber by a "return" type injector (Figure 2), and to supply of the combustion chamber by a "nonreturn" type injector (Figure 3). In this specification, the term "non-return injector" is used to mean an injector which is provided with a supply line from a fuel source to the injector only, while the term "return injector" is used to 130

mean an injector which is also provided with a line which returns excess fuel to a fuel reservoir.

In a particularly simple embodiment of the invention from the point of view of its construction, and which can provide two forms of power unit, illustrated respectively in Figures 2 and 3, the first throttle means 21 comprise a movable mechanism which locates the second throttle means 22 and the regulating device for the flow-rate of fuel 23.

To this end, the movable mechanism of the first throttle means 21 can be constituted by a cylinder 24 bearing at one end a throttle member 25 cooperating with a fixed seat 26. The second throttle means 22 can then be constituted by one or several ports 27 formed in the cylinder 24 and by a slide valve 28 covering or uncovering the port or ports 27, the slide valve 28 forming a piston having one surface subjected to the pressure of the primary air and its other surface subjected to the action of a counter pressure P_c and to the action of a spring 29, the slide valve 28 being connected to the regulating device 23 for the flow-rate of fuel.

The covering and uncovering of the one or more ports 27 by the slide valve 28 can be effected by providing said piston with one or several orifices 28a formed in its skirt 28b.

The counter pressure exerted on the slide valve 28 can be equal to atmospheric pressure.

However in certain cases, and to modify the range of regulation, a counter pressure P_c may be selected higher than atmospheric pressure; it is then particularly simple to provide a regulating chamber 30 communicating with the said other surface of the slide valve 28 and communicating also with atmospheric pressure through a throttle orifice 31, this regulating chamber 30 being supplied by air under pressure by means of a flexible pipe 32. This air under pressure escapes continuously from the regulating chamber 30 through the throttle orifice 31 and causes in said regulating chamber 30 an excess pressure, which constitutes the counter pressure P_c .

It is particularly advantageous to connect the flexible pipe 32 opening into the regulating chamber 30 to a pipe from the motor installation in which cooled compressed fresh air flows. There can then be arranged between the engine 1 and its intake cooler R a sampling pipe 52 ending at the flexible pipe 32 after having traversed a needle regulating device 53 enabling adjustment of the counter pressure P_c to a value between atmospheric pressure and the delivery pressure P .

A regulating spring 33 is provided to act on the movable mechanism of the first

throttle means 21, this spring 33 enabling regulation of the parameter β of the linear function $\Delta P = \alpha P + \beta$ giving the pressure difference generated by the abovesaid first throttle means 21. The action of this regulating spring 33 can advantageously be regulated by adjustment of a movable stop 34 against which said spring 33 is supported.

However the first throttle means 21 may be subjected to vibrations of aerodynamic origin, and it is advantageous to provide the movable mechanism of the first throttle means 21 with a viscous damping device 63, shown in Figure 4, in which the same reference numerals denote the same members as in Figure 2. This viscous damping device 63 can be supplied from a source of viscous fluid 64 under variable pressure. The pressure of this source replaces the effect of the spring and its variation replaces the action of the movable stop.

Two embodiments of the regulating device 23 for the flow-rate of fuel are illustrated respectively in Figures 2 and 3.

The embodiment illustrated in Figure 2 corresponds to the use of an injector 10 of the "return" type for supplying the combustion chamber 8. The pump 11 supplies the injector 10 at constant pressure by means of a supply passage 35, and the surplus of fuel, which is not injected into the combustion chamber, passes into a return passage 36 ending, by means of a flexible pipe 37, at the regulating device 23.

This regulating device 23 may comprise a movable member 38 connected by a stem 69 to the slide valve 28 of the second throttle means 22, the regulation being obtained by means of a variable nozzle 39; this variable nozzle can have a continuously variable cross-section (needle progressively engageable in an orifice) or a discontinuously variable cross-section (covering or uncovering of ports).

Preferably the variable nozzle 39 comprises at least one needle 68, with a conical portion progressively engageable in an orifice 70.

The fuel delivered through the flexible pipe 37 enters an intake chamber 40, then is obliged to pass through the variable nozzle 39 before emerging into a recovery chamber 41, whence it re-emerges through a flexible pipe 42 to be sent back to the reservoir 12 through a low pressure passage 43.

Referring to Figure 2, it is noted that, when the pressure which is exerted on the slide valve 28 of the second throttle means 22 increases, the slide valve 28 moves towards the left, which has the effect:

of reducing the effective cross-sectional area of the second throttle means 22, and through this fact reducing the flow-rate of primary air,

and of displacing the movable member 38 with the needle 68 of the device 23.

towards the left and of increasing the other cross-section of the variable nozzle 39, hence of increasing the flow-rate of fuel circulating in the return passage 36, and hence of reducing the flow-rate of fuel injected into the combustion chamber.

Of course, when the pressure which is exerted on the slide valve 28 diminishes, the reverse actions are produced.

10 In Figure 3, the same reference numerals denote the same members as in Figure 2, but the combustion chamber 8 is supplied with fuel by means of an injector 10a, which is of the "nonreturn" type. This injector 15 10a is supplied by a pump 11a from the reservoir 12, through the regulating device 23 for the flow-rate of fuel and a supply channel 35a.

20 The regulating device 23 in Figure 3 can comprise a movable member 38a connected by a rod 69a to the slide valve 28 of the second throttle means 22, the regulation being obtained by means of a variable nozzle 39a which can have a continuously variable cross-section (needle progressively engaging in an orifice) or a discontinuously variable cross-section (covering or uncovering of ports).

30 Preferably this variable nozzle 39a comprises at least one needle 68a, with a conical part progressively engageable in an orifice 70a.

35 The fuel delivered through a flexible pipe 37a enters an intake chamber 40a, then is obliged to pass through the variable nozzle 39a before emerging into a recovery chamber 41a whence it emerges through a flexible pipe 42a to be directed towards the injector 10a through a high pressure passage 43a.

40 To maintain a constant pressure difference on each side of the variable nozzle 39a, a slide valve regulator 44 is provided.

45 This slide valve regulator 44 is constituted by a cylinder 45 in which slides a free piston 46 covering or uncovering a port 47 formed in the wall of the cylinder 45.

This free piston hence defines:

50 a chamber 48 situated on the side of the port 47 and communicating with the intake chamber 40a of the regulating device 23.

and a chamber 49 situated opposite the port 47 and communicating with the recovery chamber 41a of the regulating device 23.

55 The free piston 46 is hence subjected to the difference in pressure existing between the intake chamber 40a and the recovery chamber 41a and to the action of a spring 50 acting contrary to this difference in pressure.

60 The port 47 communicates with a discharge pipe 54 which ends at the fuel reservoir 12.

65 Referring to Figure 3, it is noted that, when the pressure which is exerted on the

slide valve 28 of the second throttle means 22 increases, the slide valve 28 moves towards the left, which has the effect:

of reducing the effective cross-sectional area of the second throttle means 22, and through this fact reducing the flow-rate of primary air,

and of moving the movable member 38a with the needle 68a of the regulating device 23 towards the left and of reducing the outlet cross-section of the variable nozzle 39a, hence of reducing the flow-rate of fuel directed to the injector 10a through the supply passage 35a.

Of course, when the pressure which is exerted on the slide valve 28 diminishes, the reverse actions are produced.

The operation of the slide valve regulator 44 is such that the free piston 46 more or less closes the port 47. The movement of the free piston 46 remaining very slight, the force exerted by the spring 50 on the said free piston 46 is practically constant, and through this fact, the pressure difference between the intake chamber 40a and the recovery chamber 41a is substantially constant whatever the pressure existing in the combustion chamber 8 and whatever the flow-rate of fuel injected.

The valve of this pressure difference is adjusted by the biasing of the spring 50, for which it is possible to provide a movable stop 51 against which said spring 50 is supported.

The flow-rate of fuel through the variable nozzle 39a then depends only on the outlet cross-section, and hence depends only on the supercharging pressure through the position of the piston 28 of the second throttle means 22.

When using one or other of the two embodiments of the invention illustrated in Figures 2 and 4 or in Figure 3, by acting on the geometry of the second throttle means 22 and on the law of the spring 29 acting on the slide valve 28 of the second throttle means 22, it is possible to select the servo-coupling law between the effective cross-sectional area S_p and the pressure downstream $P - \Delta P$, or the difference between this pressure downstream $P - \Delta P$ and the counter pressure P_0 existing in the regulation chamber 30.

To each value of the cross-sectional area S_p there corresponds a value of the flow-rate of primary air Q_p , hence a value of the flow-rate of fuel Q to be introduced into the combustion chamber, this flow-rate of fuel being ensured by the geometry of the variable nozzle.

The desired objective is, to regulate the flow-rate of fuel Q to prevent the supercharging pressure from becoming lower than a preset threshold (assuming that result may be achieved with-

out exceeding the maximum thermal power of the combustion chamber),

to enable starting up of the turbine-compressor unit prior to the engine,

- 5 and to enable a low power operation of the combustion chamber lending itself to rapid resumption of full power without risk of extinction.

- Under these conditions, it is desirable to adopt a relationship for the flow-rate of fuel Q to be introduced into the combustion chamber as a function of the pressure downstream $P-\Delta P$ or of the difference between this downstream pressure $P-\Delta P$ and the counter pressure P_c existing in the regulation chamber 30, such as the relationship illustrated by way of example in the graph of Figure 5 in which the abscissa represents the supercharging pressure P (relative pressure expressed in bars) and the ordinate the flow-rate of fuel Q introduced into the combustion chamber.

- In the absence of counter pressure (the pressure in the regulation chamber 30 being equal to atmospheric pressure), the point of operation of the combustion chamber is moved according to this graph; if this point of operation is stabilized at point K (idling of the engine) it will descend towards the point C when the load on the engine increases up to about 20% of the maximum load and beyond the point of operation is moved between C and D (combustion chamber operating at minimum power).

- The introduction of counter pressure into the regulation chamber 30 enables this graph to be displaced towards higher pressures to increase the value of the pre-set threshold of the supercharging pressure.

- This simple pneumatic displacement of the regulating range can be used advantageously to obtain an excess torque at low speed; it is also possible to profit from the displacement of the regulating zone to accelerate the rise in temperature of the engine (the engine being at idling speed when the combustion chamber is at full power, thermal exchange means being provided between the hot air emerging from the compressor and the cooling fluid for the engine).

- In addition, the introduction of counter pressure which can reach the supercharging pressure enables the production, by the displacement of the regulating zone, of an altimetric compensation; in fact, when atmospheric pressure diminishes, the counter pressure can be given a value equal to the supercharging pressure, which has the effect of opening the second throttle means completely and of supplying the combustion chamber at full power (flow-rate of primary air and flow-rate of fuel reaching their maximum values).

- Due to the invention, the flow-rate of fuel injected into the combustion chamber

8 and the flow-rate of primary air can be controlled at the same time by acting on the geometry of the second throttle means 22 (port 27 and orifice 28a) and on the biasing (and if necessary the adjustment) of the springs 29 and 50. There is thus ensured an air-fuel mixture of the combustion zone 14 in proportions sufficiently close to stoichiometric proportions to obtain, at all operational speeds of the engine, good stability of the combustion process.

WHAT WE CLAIM IS:—

1. A power unit comprising an internal combustion engine supercharged by a turbine-compressor unit whose turbine has an inlet connected to the exhaust of the engine, and comprising a by-pass conduit which is permanently open in operation and which communicates with the outlet of the compressor and with the turbine inlet so that the engine is in parallel air flow relation with the by-pass conduit, said by-pass conduit having automatically controlled throttle means to develop a pressure drop in the air flow passing through the by-pass conduit which is substantially independent of the rate of flow traversing said by-pass conduit and which is an increasing function of the pressure existing at the compressor outlet.

2. A power unit according to claim 1, wherein the increasing function is a linear or substantially linear function.

3. A power unit comprising an internal combustion engine supercharged by a turbine-compressor unit whose compressor operates close to its surge line and whose turbine is connected to receive the exhaust gas of the engine and an air flow delivered by the compressor through a conduit which is permanently open in operation and bypasses the engine, the pressure drop of said air flow being an increasing function of the pressure delivered by the compressor.

4. A power unit according to claim 3, having automatically controlled throttle means in said by-pass conduit to develop said pressure drop.

5. A power unit according to claim 1, 2 or 4, wherein the throttle means comprises a movable throttle member which limits in said by-pass conduit a throttle section whose cross-sectional area is determined by the position of said movable member and wherein the throttling action of said member tends to increase responsive to increase of the pressure which prevails at a point of the by-pass conduit located upstream of said throttled section and to decrease when the difference between the pressures which prevail at points of the by-pass conduit located upstream and downstream of said throttled section decreases.

6. A power unit according to claim 1, 2 or 4, wherein the throttle means comprises



out exceeding the maximum thermal power of the combustion chamber),

to enable starting up of the turbine-compressor unit prior to the engine,

- 5 and to enable a low power operation of the combustion chamber lending itself to rapid resumption of full power without risk of extinction.

- 10 Under these conditions, it is desirable to adopt a relationship for the flow-rate of fuel Q to be introduced into the combustion chamber as a function of the pressure downstream $P-\Delta P$ or of the difference between this downstream pressure $P-\Delta P$ and the counter pressure P_c existing in the regulation chamber 30, such as the relationship illustrated by way of example in the graph of Figure 5 in which the abscissa represents the supercharging pressure P (relative pressure expressed in bars) and the ordinate the flow-rate of fuel Q introduced into the combustion chamber.

- 15 In the absence of counter pressure (the pressure in the regulation chamber 30 being equal to atmospheric pressure), the point of operation of the combustion chamber is moved according to this graph; if this point of operation is stabilized at point K (idling of the engine) it will descend towards the point C when the load on the engine increases up to about 20% of the maximum load and beyond the point of operation is moved between C and D (combustion chamber operating at minimum power).

- 20 The introduction of counter pressure into the regulation chamber 30 enables this graph to be displaced towards higher pressures to increase the value of the pre-set threshold of the supercharging pressure.

- 25 This simple pneumatic displacement of the regulating range can be used advantageously to obtain an excess torque at low speed; it is also possible to profit from the displacement of the regulating zone to accelerate the rise in temperature of the engine (the engine being at idling speed when the combustion chamber is at full power, thermal exchange means being provided between the hot air emerging from the compressor and the cooling fluid for the engine).

- 30 In addition, the introduction of counter pressure which can reach the supercharging pressure enables the production, by the displacement of the regulating zone, of an altimetric compensation; in fact, when atmospheric pressure diminishes, the counter pressure can be given a value equal to the supercharging pressure, which has the effect of opening the second throttle means completely and of supplying the combustion chamber at full power (flow-rate of primary air and flow-rate of fuel reaching their maximum values).

- 35 Due to the invention, the flow-rate of fuel injected into the combustion chamber

8 and the flow-rate of primary air can be controlled at the same time by acting on the geometry of the second throttle means 22 (port 27 and orifice 28a) and on the biasing (and if necessary the adjustment) of the springs 29 and 50. There is thus ensured an air-fuel mixture of the combustion zone 14 in proportions sufficiently close to stoichiometric proportions to obtain, at all operational speeds of the engine, good stability of the combustion process.

WHAT WE CLAIM IS:—

1. A power unit comprising an internal combustion engine supercharged by a turbine-compressor unit whose turbine has an inlet connected to the exhaust of the engine, and comprising a by-pass conduit which is permanently open in operation and which communicates with the outlet of the compressor and with the turbine inlet so that the engine is in parallel air flow relation with the by-pass conduit, said by-pass conduit having automatically controlled throttle means to develop a pressure drop in the air flow passing through the by-pass conduit which is substantially independent of the rate of flow traversing said by-pass conduit and which is an increasing function of the pressure existing at the compressor outlet.

2. A power unit according to claim 1, wherein the increasing function is a linear or substantially linear function.

3. A power unit comprising an internal combustion engine supercharged by a turbine-compressor unit whose compressor operates close to its surge line and whose turbine is connected to receive the exhaust gas of the engine and an air flow delivered by the compressor through a conduit which is permanently open in operation and by-passes the engine, the pressure drop of said air flow being an increasing function of the pressure delivered by the compressor.

4. A power unit according to claim 3, having automatically controlled throttle means in said by-pass conduit to develop said pressure drop.

5. A power unit according to claim 1, 2 or 4, wherein the throttle means comprises a movable throttle member which limits in said by-pass conduit a throttle section whose cross-sectional area is determined by the position of said movable member and wherein the throttling action of said member tends to increase responsive to increase of the pressure which prevails at a point of the by-pass conduit located upstream of said throttled section and to decrease when the difference between the pressures which prevail at points of the by-pass conduit located upstream and downstream of said throttled section decreases.

6. A power unit according to claim 1, 2 or 4, wherein the throttle means comprises



5 a movable throttle member which limits a
throttled section in said by-pass conduit and
said movable member is controlled by
pressure forces exerted on surfaces which are
subjected to the pressures which prevail in
said by-pass conduit upstream and down-
stream of said throttled section, the resultant
surface which is subjected to the pressure
which prevails upstream of the throttled
10 section being smaller than the resultant sur-
face subjected to the pressure which prevails
downstream of the throttled section.

7. A power unit according to claim 1, 2
or 4, wherein the throttle means comprises
15 a throttle member movable within the by-
pass conduit and cooperating with a fixed
seat for limiting a throttled air flow section
of variable effective cross-sectional area.

8. A power unit according to claim 5, 6
20 or 7, wherein said throttle member is
operatively connected to a balancing piston
which is subjected to the pressure which
prevails at a point of the by-pass conduit.

9. A power unit according to anyone of
25 claims 5 to 8, having resilient return means
associated with said throttle member and
which maintains the throttle means in open
condition when atmospheric pressure prevails
in the by-pass conduit on both sides of the
30 throttled section.

10. A power unit according to claim 9,
wherein said resilient return means is adjust-
able.

11. A power unit according to anyone
35 of claims 1, 2 and 4-10, wherein said
throttle means is provided with viscous
damping means.

12. A power unit according to any one
40 of claims 1 to 11, having an auxiliary com-
bustion chamber connected to receive air
which has passed through the by-pass con-
duit and having its outlet connected to the
inlet of the turbine.

13. A power unit according to claim 12,
45 wherein said auxiliary combustion chamber
has a fuel inlet, a primary air intake con-
nected to receive fresh air derived from a
point of said by-pass conduit located up-
stream of said throttling means for combus-
50 tion of the fuel injected into said auxiliary
combustion chamber and a secondary air
intake adapted to receive air from said by-
pass conduit through throttling means pro-
viding said pressure drop.

14. A power unit according to claim 13,
55 having means for adjusting the flow rate of
the primary air which is responsive to the
pressure which prevails at a point of the
by-pass conduit which is located upstream
or downstream of the throttling means.

15. A power unit according to claim 14,
60 wherein said adjusting means comprises a
first member and a second member movable
with respect to each other to adjust the
effective cross-sectional area of a passage

for said primary air, the first member of the
adjusting means being operatively connected
to a movable throttle member of said
throttle means and the second member of
said adjusting means being controlled by the
70 pressure which prevails downstream of said
throttle means.

16. A power unit according to claim 15,
wherein said second member of the primary
air adjusting means is operatively connected
75 by a spring with the first member of said
primary air adjusting means which is fast
with the movable member of the throttling
means.

17. A power unit according to claim 16,
80 wherein said first member of the primary air
adjusting means comprises a tube having a
first opening in its wall and wherein said
second member is a tubular slide valve con-
sisting of a blind tube formed with a second
85 opening adapted to cooperate with said first
opening and slidably received in said tube.

18. A power unit according to any one of
claims 14-17, wherein the primary air
adjusting means actuates a device for adjust-
90 ing the flow-rate of fuel injected into the
auxiliary combustion chamber so as to main-
tain a substantially stoichiometric ratio be-
tween the flow-rates of primary air and fuel.

19. A power unit according to claim 18,
95 wherein the primary air adjusting means and
the fuel flow adjusting device are located in
a movable member of the throttle means.

20. A power unit according to claim 15
or 16, wherein said movable throttle mem-
100 ber is formed with a tubular extension and
the primary air adjusting means comprises
at least one port formed in said tubular
extension and adapted to be covered by a
slide valve having an actuation surface sub-
105 jected to the pressure existing in the down-
stream or upstream part of the by-pass
conduit, and another actuation surface sub-
jected to a counter pressure and to the
action of a spring, said slide valve being con-
110 nected to the adjusting means.

21. A power unit according to claim 20,
wherein said counter pressure is pneumatic.

22. A power unit according to claim 21,
115 wherein said counter pressure is equal to or
greater than atmospheric pressure.

23. A power unit according to claim 21,
wherein said counter pressure is the pressure
in a regulation chamber connected to the
admission of the engine through a needle
120 adjustment device and provided with a
calibrated air leak.

24. A power unit according to claim 18
or 19, in which the auxiliary combustion
125 chamber is supplied by an injector of the
return type, as herein defined, wherein the
means for adjusting the flow rate of fuel
comprises a movable member determining
the effective cross-sectional area of a variable



nozzle as a function of the position of said movable member, said nozzle being arranged on a return path from the injector.

5 25. A power unit according to claim 18 or 19, in which the auxiliary combustion chamber is supplied by an injector of the non return type, as herein defined, wherein the means for adjusting the flow rate of fuel comprises a movable member determining
10 the effective cross-sectional area of a variable nozzle as a function of the position of said movable member, said nozzle being arranged on a passage through which high pressure fuel flows to the injector.

15 26. A power unit according to claim 24 or 25, wherein the variable nozzle comprises a needle with a conical portion adapted to project into an orifice by a variable extent.

20 27. A power unit according to claim 25 or 26, comprising a sliding valve regulator comprising a chamber placed in communication with the pressure of fuel upstream of the fuel flow adjusting device, and a chamber placed in communication with the pressure
25 of fuel downstream of the regulating device, this slide valve regulator covering or uncovering a port placing the first of the two said chambers in communication with a delivery pipe.

30 28. A power unit according to claim 27, wherein the slide valve regulator comprises a piston separating the two said chambers and subjected to the action of a spring acting

in a direction opposite to the difference of pressure existing in the two said chambers. 35

29. A power unit comprising an internal combustion engine supercharged by a turbine-compressor unit whose turbine has an inlet connected to the exhaust of the engine, and comprising a by-pass conduit
40 which communicates with the outlet of the compressor and with the turbine inlet so that the engine is in parallel air flow relation with the by-pass conduit, said by-pass conduit having automatically controlled throttle
45 means to develop a pressure drop in the air flow passing through the by-pass conduit which is substantially independent of the rate of flow traversing said by-pass conduit and which is an increasing function of the
50 pressure existing at the compressor outlet.

30. A power unit constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings. 55

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