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Panhard

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[54] **POST-COMBUSTION DEVICES FOR INTERNAL COMBUSTION ENGINES**

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[51] **Int. Cl.**............................**F02b 75/10,** F01n 3/10

[58] **Field of Search**..............60/30 R, 290, 294, 298; 23/277 C

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[57] **ABSTRACT**

The device comprises a post-combustion chamber bounded by a casing and connected to the engine exhaust pipe, a blower driven by the engine for sending additional air into the post-combustion chamber and a heat-exchanger for pre-heating the additional air by the exhaust gases from the post-combustion chamber. The pos-combustion chamber and the heat-exchanger are constituted by three co-axial cylinders, the assembly being arranged so that the exhaust gases are introduced into the axis and at the center of the post-combustion chamber, the outer cylinder and the intermediate cylinder defining a peripheral zone in which the additional air circulates. The intermediate cylinder and the inner cylinder define an intermediate zone in which the exhaust gases from the combustion chamber circulate in countercurrent to the additional air. The device is useful for two-stroke, four-stroke and rotary piston engines.

10 Claims, 4 Drawing Figures

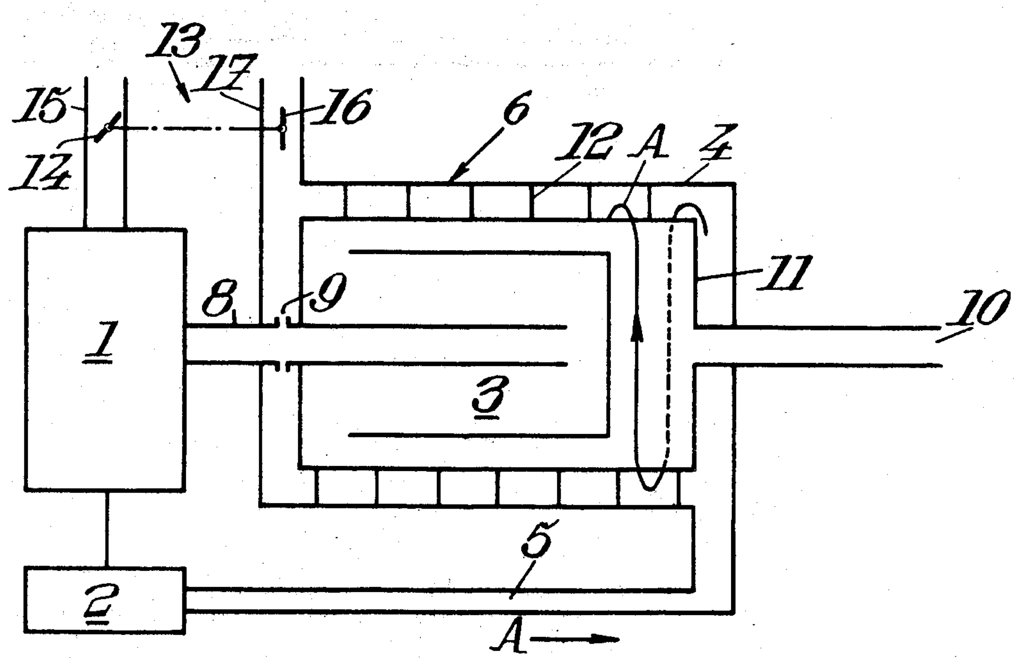
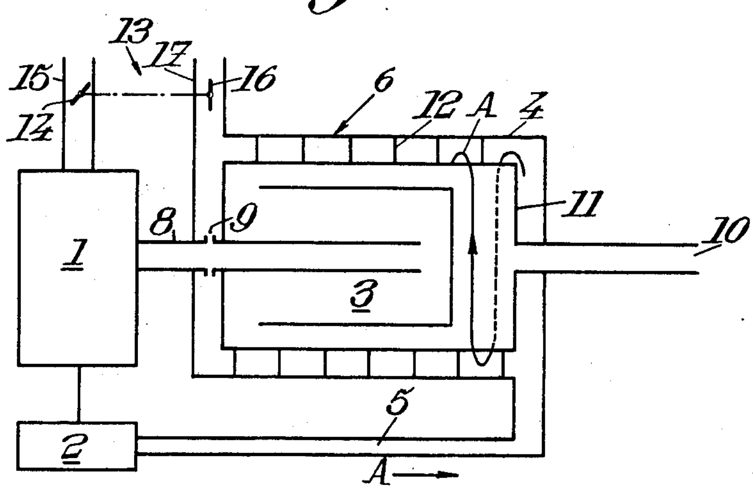


Fig. 1.



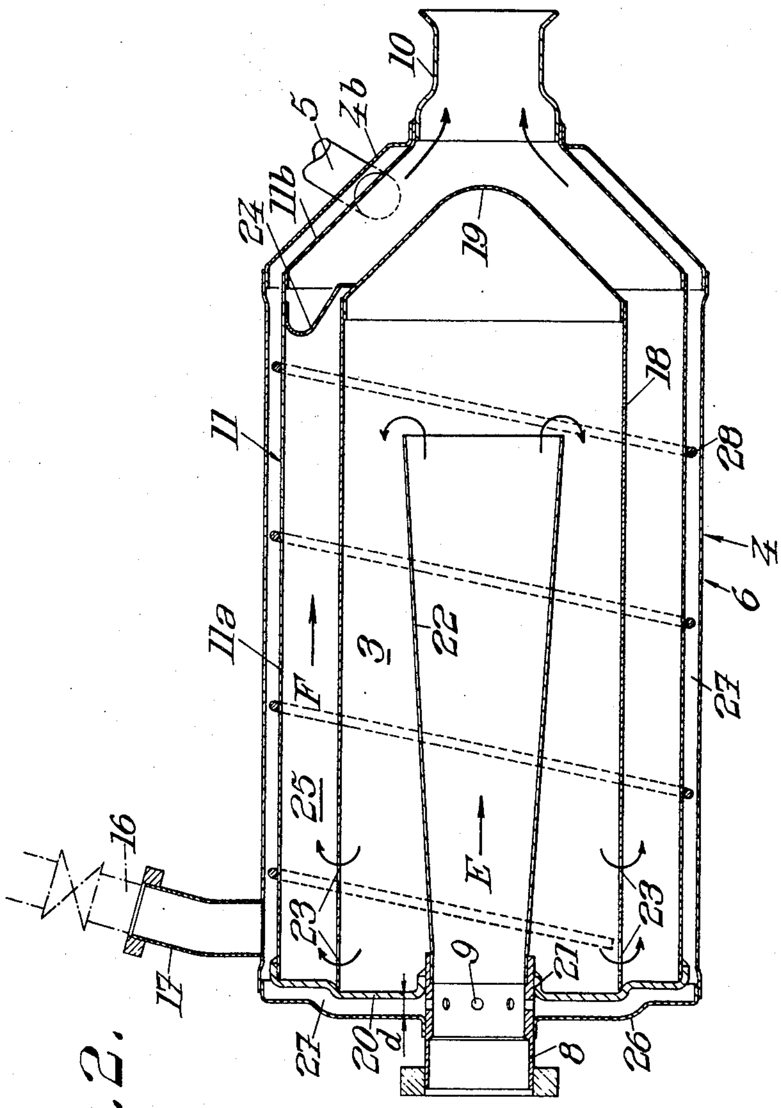

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Fig. 2.

Fig. 3.

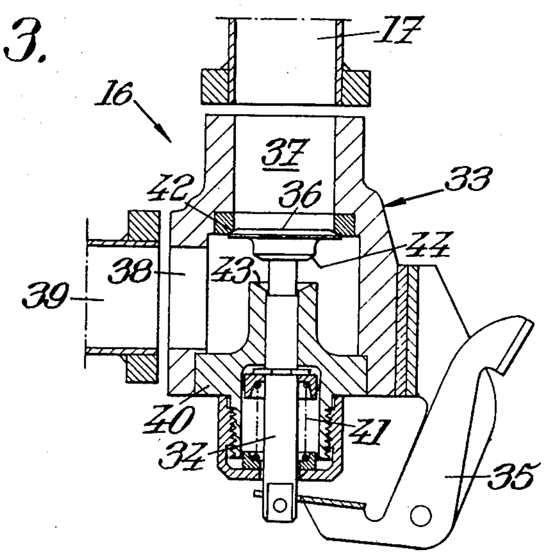
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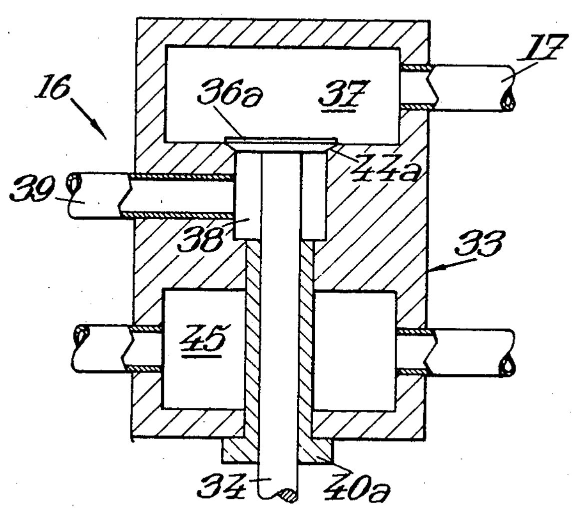
Fig. 4.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POST-COMBUSTION DEVICES FOR INTERNAL COMBUSTION ENGINES

The invention relates to post-combustion devices for burning combustible gases contained in the exhaust gas of an internal combustion engine of the type which comprise:

a post-combustion chamber limited by a casing and linked to the exhaust piping of the engine,

means for introducing additional air into the post combustion chamber,

a heat exchanger for pre-heating the additional air by exhaust gas from the post-combustion chamber, the heat exchanger surrounding the said chamber for post-combustion and being such that the circulation of the additional air is done in a peripheral zone in counter-current to the exhaust gases which circulate in an intermediary zone between the said periphery zone and the casing of the combustion chamber.

The invention concerns more particularly, because it is in this case that its application seems likely to have the most interest, but not exclusively, amongst these devices for post-combustion, to those for internal combustion engines in which, in the course of the cycle, there is a simultaneous opening of admission and of exhaust, especially two-stroke engines, four-stroke Diesel engines and rotary piston engines.

It has already been proposed to eliminate or to reduce the undesirable constituents of the exhaust gas of internal combustion engines by burning these constituents, especially carbon monoxide, with the aid of additional air mixed with these exhaust gases, upstream of the post-combustion chamber. However, the efficiency of devices of the type described above, known to this day, is not entirely satisfactory and very often a spark plug is necessary to ignite the mixture of combustible gas and of additional air in the post-combustion chamber.

It is an object of the invention is to make the post-combustion devices of the type described above sufficiently efficient for the spark plug in the post-combustion chamber to be unnecessary.

Furthermore, the proportion of undesirable constituents such as carbon monoxide or unburnt hydrocarbons, contained in the exhaust gas from the engine, is high enough at slow speeds of rotation of the engine but relatively weak at higher speeds of rotation to which correspond the higher levels of power of the engine. For these powerful levels of operation, the temperature of the exhaust gas before post combustion is already high; in these conditions, after post combustion of a part of the undesirable constituents, even if the latter are not great in quantity, the temperature of the exhaust gas after post-combustion becomes too high and risks putting the exhaust manifold into a dangerous state.

It is another object of the invention to remedy this drawback.

According to the invention, a post-combustion device for burning combustible gases contained in the exhaust gas of an internal combustion engine of the type described above, is characterized by the fact that, on one hand, the means for introducing the additional air comprise a blower adapted to be driven by the engine and to deliver a flow of air in excess and on the other hand, the assembly of the post combustion chamber and of the heat exchanger is constituted by three coaxial cylinders, that is an interior cylinder forming the casing of the post-combustion chamber and linked to the exhaust piping of the engine in such a way that the exhaust gases of the latter are introduced into the center and into the axis of this cylinder, an intermediary cylinder forming, with the interior cylinder, an annular space which constitutes the abovesaid intermediary zone and communicates, at one end situated on the side of the exhaust piping of the engine, with the post-combustion chamber by openings provided in the internal cylinder and, at its other end, with a piping for the escape of the burnt gases from the post-combustion chamber, an external cylinder defining with the intermediary cylinder the abovesaid peripheral zone, which communicates, on one hand, with an intake piping for additional air and, on the other hand, with the exhaust pipe of the engine by holes provided in the latter and situated axially between two covers substantially flat and perpendicular to the common axis of the cylinders, the said covers being traversed by the exhaust pipe of the engine and being able to shut, at one end, on one hand the intermediary cylinder and the interior cylinder and, on the other hand, the external cylinder, the axial distance between the covers being just sufficient in order that the holes might issue between the said covers, the said peripheral zone comprising a partition rolled in a helix adapted to increase the distance traveled by the additional air in this zone, the assembly being arranged in such a way that the abovesaid intermediary zone separates the peripheral zone from the combustion chamber along the whole of the axial length of this latter.

The post-combustion device comprises means sensitive to the speed and/or to the load of the engine to prevent the air delivered by the blower which has cooled the exhaust gas of the post-combustion chamber and this chamber, from being introduced into the said post combustion chamber when the speed of rotation of the engine and/or the load have values higher than the given limit to which correspond a given limit of power of the engine, in such a way that the post-combustion ceases when the motor delivers a power higher than the limit of power chosen.

The invention consists, apart from the features described hereabove, in certain other features which are used preferably at the same time and about which more will be said explicitly in the detailed description which follows, given with reference to the annexed drawings.

FIG. 1 of these drawings represents schematically an internal combustion engine which is equipped with a post combustion device constructed according to the invention.

FIG. 2 shows longitudinally in detail the post-combustion chamber and the exchanger of the device in FIG. 1.

FIG. 3 represents, in section, a valve belonging to the above-mentioned means sensitive to the speed and to the load of the engine.

FIG. 4, finally, represents, also in section, a variation of the valve of FIG. 3.

As shown on FIG. 1, a internal combustion motor 1 drives a blower 2, or a compressor, which drives additional air into a post-combustion chamber 3.

The post-combustion chamber is lodged in an external casing **4** linked to the blower by a piping **5**. The air circulates in this piping and in the casing **4** according to the arrows A.

Before penetrating into the post-combustion chamber **3**, the air which flows from the blower is heated by a heat-exchanger **6** in which pass the exhaust gases when they have left the post-combustion chamber **3**.

An intermediary casing **11** is disposed between the external casing **4** and the walls of the chamber **3**, and a partition **12** is rolled in a helix between the casings **4** and **11**.

As one can see in FIG. **1**, the air which leaves the exchanger **6** is obliged, by the partition **12**, to follow a sinuous journey between the casing **4** and the walls of the post-combustion chamber **3**. It can then penetrate into the piping **8**, linking the exhaust of the engine **1** to the chamber **3**, due to the orifices **9** pierced in the said piping **8**.

A piping **10** constitutes the exit from the post combustion chamber **3**.

The partition **12** obliges the air coming from the blower **2** to turn several times around the cylindrical surface of the wall **11** before penetrating into the post-combustion chamber **3**. The wall **11**, which is internally, in contact with the exhaust gases of the post-combustion chamber, transmits a part of the heat of these gases to the air flowing from the blower **2**. The heat-exchanger **6**, in this case, is therefore constituted by the assembly of the two casings **4** and **11** and of the partition **12**.

The functioning of a engine equipped with such a device results clearly from the foregoing description. The exhaust gases from the engine arrive through the pipe **8** and mix, at the position of the orifices **9**, with the air flowing from the blower **2**. A part of the undesirable constituents burns in the post-combustion chamber **3**. The exhaust gases from the post-combustion chamber heat the air flowing from the blower, then are evacuated by the piping **10**.

However, if one lets the post-combustion function for speeds of engine rotation relatively high and for maximal engine power, there is a risk of provoking a deterioration of the post-combustion device because of the temperatures, which are too high, of the exhaust gases. Now, the post-combustion becomes unnecessary for, on one hand, at the maximal power of the engine, the amount of undesirable constituents in the exhaust gases is lower than at low power and on the other hand, the maximal power is not in general, attained until outside crowded areas, such that an elimination of undesirable constituents which is not as good, becomes less troublesome.

The post-combustion device comprises means **13** sensitive to the speed and/or to the load of the engine to prevent air flowing from the blower **2**, and which has cooled the exhaust gases and the post-combustion chamber **3**, from being introduced into the said post-combustion chamber when the speed of rotation of the engine and/or the load have values higher than a given limit to which corresponds a chosen power limit which has the effect of stopping post-combustion for engine powers higher than the chosen power limit.

According to one embodiment represented in FIG. **1**, the means **13** are linked to the position of the accelerator lever of the vehicle, that is to say in practice, linked to the position of the throttle valve **14** situated in the intake pipe **15** of the engine.

In another embodiment (not represented) the means **13** are linked to the flow pressure of the blower **2**, which flow pressure depends on the speed of engine rotation of the engine **1**.

The means **13** comprise a throttle member constituted by a valve **16** able to open or shut a pipe **17** of which one end can be linked to the silencer (not shown) and of which the other issues into the casing **4**. The air flowing from the blower **2** can be thus directed towards the atmosphere by the exhaust tube or towards the post-combustion chamber **3** according to whether the valve **16** is open or shut, that is to say according to whether the power which is available on the drive shaft of the engine is high or low. The power limit above which the post-combustion can cease is comprised advantageously between a quarter and two-thirds of the maximal power of the engine.

Referring to FIG. **2**, one sees that the walls of the chamber of the post-combustion are constituted by those of a cylinder **18** of which the shape is such that the relationship of the length of the cylinder to its diameter is relatively small.

An end of the cylinder **18** is shut by a conical cap **19** whilst the other end is shut by a cover **20** in the form of a circular disc, appreciably flat and perpendicular to the axis of the cylinder **18**.

The cover **20** comprises in its center a circular opening **21** in which is housed the end of the pipe **8** or a connection to this pipe. This latter, it is recalled links the exhaust of the engine to the chamber **3**. It is as short a possible and is, preferably, blanketed, which allows maximum reduction of the heat losses of the exhaust gases between the engine and the post-combustion chamber **3**.

The pipe **8** is prolonged coaxially inside the chamber **3**, by a divergent frustoconic element **22**, which extends appreciably over three-quarters of the length of the chamber and issues towards the cap **19**. The diameter of the divergent member **22** increases from the pipe **8** towards the interior of the chamber **3**.

Openings **23** are formed in the wall of the cylinder **18** in the region of the cover **20**.

The intermediate casing **11** is constituted by a cylinder **11***a*, coaxial to the cylinder **18** and ends, on the side of the cap **19**, by a frustoconic wall **11***b* of which the end of small diameter is connected to the exhaust pipe **10**.

A lug **24** ensures a liaison between the cap **19** and the cylinder **11***a*.

The end of the casing **11** opposite the wall **11***b* is shut by the cover **20**.

An annular space **25**, or intermediate zone, is thus defined between the cylinders **18** and **11***a*, which space communicates with the chamber **3** by the openings **23** and with the exhaust tube by the intermediary of the piping **10**.

This annular space **25** is traversed through, in the direction of the arrow F, by the exhaust gases of the post-combustion chamber.

The casing **4** is constituted by a cylinder coaxial to the casing **11** and is separated from it radially, towards the exterior, by a very small distance. The end of the casing **4** situated in the region of the piping **10** ends by a tronconic wall **4b** which rejoins the wall **11b**. The other hand of the casing **4** is shut by a cover **26** slightly separated, towards the exterior, from the cover **20**, the cover **26** being appreciably flat and at right angles to the axis of the cylinder **18**.

A peripheral zone **27** of small thickness is limited by the casings **11** and **4**, by the frustoconic walls **4b** and **11b** and by the covers **20** and **26**.

The orifices **9** of the piping **8** are spread out regularly on a circumference and issue into the zone **27**, between the covers **20** and **26**. The distance *d* following the axis of the cylinder **18** between these covers is just sufficient for the orifices or the holes **9** to be able to issue between the said covers.

Preferably, the diameter of the pipe **8** at the level of the orifices **9** is minimal in such a way that the exhaust gases of the engine which direct themselves towards the chamber **3** form a convergent-divergent stream and produce an effect of vacuum at the level of the neck, that is to say at the level of the orifices **9**.

It should be noted that the exhaust gases from the engine are introduced at the center and in the axis of the cylinder **18**.

The piping **5**, leading the air flowing from the blower, crosses the wall **4b** and issues into the peripheral zone **27**, in the region of the connection of the walls **4b** and **11b**.

The conduit **17** issues into the peripheral zone **27** in the region of the cover **26**. It will be noticed that the annular space **25** separates the peripheral zone **27** from the combustion chamber **3** along the whole of the axial length of the latter.

The partition **12**, disposed between the casings **11** and **4** is advantageously constituted by thread of cylindrical section **28** of which the diameter is appreciably equal to the distance separating the cylindrical walls of the casings **11** and **4**. This thread is rolled into a helix over an axial distance appreciably equal to the distance separating the cover **20** from the base of the cover **19**.

The assembly of the post-combustion chamber and of the casings **11** and **4** which constitute the heat-exchanger **6** is made of metal and the different elements are preferably assembled by soldering.

The valve **16** able to open the conduit **17** towards the silencer when the power developed by the engine is sufficient, is shown schematically in mixed line.

The operation of the post-combustion chamber and of the heat-exchanger of FIG. **2** is as follows.

The exhaust gases from the engine arrive by the pipe **8** and the divergent element **22** into the chamber **3**, as indicated by an arrow E.

If the power of the engine is less than the predetermined limit, the valve **16** is shut and the air flowing from the blower **2**, which arrives by the pipe **5**, runs through the zone **27** and crosses the holes **9** in order to mix itself with the exhaust gases of the engine of which the undesirable constituents burn, completely or partly, in the chamber **3**.

The gases escape from the chamber **3** by the openings **23** and circulate in the space **25** according to the direction of the arrow F heating, in the process, through the casing **11**, the air flowing from the blower. It will be noticed that, in the zone **27**, the air moves longitudinally in counter-current to the exhaust gases of the post-combustion chamber.

If the power of the engine is equal to or exceeds the above-mentioned limit which is predetermined, the valve **16** opens and the air which flows through and from the blower, after having cooled the casing **11** and taken away the heat from the exhaust gases of the post-combustion chamber, escapes towards the silencer by the piping **17**.

The quantity of air which flows from the blower is in excess in relation to that which is just sufficient to burn theoretically the undesirable constituents, in such a way that there subsists, after post-combustion, an excess of free oxygen of the order of 3 percent by volume.

The assembly is arranged in such a way that the heat-exchangers between the exhaust gases and the additional air are sufficient to take the additional air when it arrives at the holes **9**, to a temperature close to that of the post-combustion gases, which is of the order of 900° C, and in any case higher than 600° C.

The combustion reaction of carbon monoxide:

$$CO + \frac{1}{2} O_2 \rightleftarrows CO_2$$

is a reaction of equilibrium which is moved in the direction of an augmentation of CO_2 when the oxygen is in excess, which is thus favorable to the diminution of the amount of carbon monoxide.

It will be noted that there exists a compromise to be found for the flow of additional air, for a flow which is not sufficient does not permit the obtaining of excess of oxygen favorable to the combustion of carbon monoxide and of unburnt elements, and a flow which is too strong can lead to a drop of temperature which is finally detrimental. For these reasons, the content of oxygen of the exhaust gases of the post-combustion chamber must be somewhere between 1 percent and 8 percent, and preferably close to 3 percent, by volume.

When the power of the engine exceeds the fixed limit, the cooling of the combustion chamber and of the exhaust gases by the additional air is particularly advantageous because it allows a better holding-up of the materials and the welds, by diminishing the thermal stresses.

As regards the valve **16** (FIGS. **3, 4**), it comprises advantageously a body **33**, a sliding valve stem **34**, of which the movement can be controlled mechanically by the aid of a lever **35** connected, on one hand, to an end of the stem **34** and, on the other hand, by liaison means such as link-rods, to the throttle valve of the gases or to the accelerator control.

The other end of the stem **34** carries a valve **36** (FIG. **3**) or **36a** (FIG. **4**) which can isolate or make to communicate, according to whether it is shut or open, two chambers **37** and **38** provided in the body **33** and which are connected respectively to the conduit **17** and to a pipe **39** connected to the silencer.

The stem **34** slides in a guide **40** (FIG. **3**) or **40a** (FIG. **4**) carried by the body of the valve **33**.

Elastic return means **41**, represented solely in FIG. **3**, are provided to maintain shut the valve **36**, outside of any external action. When the valve is maintained in its rest position by the said means, as represented on FIGS. **3** and **4**, the chambers **37** and **38** are isolated from one another.

According to a first embodiment (FIG. 3), the valve **36** can co-operate with two seats **42, 43**. The seat **42** is provided on the body of the valve **33** and can serve as a support to a complementary surface arranged on the edges of the face of the valve **36** opposite the stem **34**. The seat **43** is provided at the end of the guide **40** turned towards the valve **36** and can serve as support to a complementary surface **44** arranged on the edges of the surface of the valve **36** turned towards the stem **34**.

In this way, at the time of the opening of the valve **36**, the surface **44** comes into contact with the seat **43**, which assures a good air-tightness between the valve and the guide **40** and prevents the hot air coming from the conduit **17** from escaping between the stem **34** and the guide **40**.

According to a variation (FIG. **4**), the guide **40***a* has a cylindrical elongated form and traverses a chamber **45** provided in the body **33**.

This chamber **45** is transversed by the additional air before heating of the latter in such a manner that a cooling of the guide **40***a* of the stem **34** and of the body **33** is assured, which improves the holding-up of the valve **16**. It will be noticed that, in this variation, a sole seat **44***a* is provided on the body **33** for the valve **36***a*.

There is obtained finally a post-combustion device which is efficient, of simple construction and whose condition and resistance are very good since the throttle, constituted by the valve **16** allow, at high power, to stop the post-combustion by lack of additional air, which limits the temperature of the exit gases. Furthermore, again at high power levels, the air flowing from the blower cools, in the heat exhanger **6**, the exhaust gases, which lowers their temperature of exit and assures a better holding-up of the device.

The post-combustion device is constructed in such a way that any cooling of the exhaust gases of the engine before their post-combustion is eliminated. This is due, in particular to the fact that any exchange of heat between the exhaust gases of the engine and the additional air before they mix is avoided.

The pre-heating of the additional air is due solely to the exhaust gases of the post-combustion chamber and the efficiency of the thermal exchanges is such that the additional air, in mixing with the exhaust gases of the engine, does not cool them in practice. There results a very good post-combustion which does not necessitate the presence of a spark plug in the post-combustion chamber **3**.

Furthermore, advantage is taken of the fact that the additional air is well pre-heated in order to make the blower deliver an excess of air relative to the carbon monoxide to be burnt. This excess of air does not in practice cool the exhaust gases from the engine and allows the obtaining of a complete combustion of the carbon monoxide and of the hydrocarbons.

The thermal inertia of the combustion device is minimal and allows a rapid putting into action of the latter.

The exhaust gases of an internal combustion engine equipped with such a device have a content of carbon monoxide which passes from a value comprised between 0.5 and 4 percent by volume, before post-combustion, to a value somewhere between 0 and 0.05 percent by volume, after post-combustion. The concentration of unburnt hydrocarbons in the exhaust gases which, measured according to the procedure of infrared absorption is comprised, before post-combustion, between 100 and 4,000 p.p.m. (parts per million), is, after post-combustion, lower than 15 p.p.m.

As it goes without saying, and as there results furthermore already from what has preceded, the invention is not limited in any way to that of its embodiments, neither to those embodiments of its diverse parts, which have been more particularly envisaged; it embraces, on the contrary, all variations.

I claim:

1. Post-combustion device for burning combustible gases contained in the exhaust gases of an internal combustion engine, comprising

a post-combustion chamber devoid of a spark producing means and bounded by a casing,

means for introducing additional air into the post-combustion chamber,

a heat-exhanger adapted to pre-heat the additional air by exhaust gases from the post-combustion chamber, the heat-exchanger surrounding the said post-combustion chamber and being such that the circulation of additional air is effected in a peripheral zone in countercurrent to the exhaust gases which flow in an intermediate zone comprised between the said peripheral zone and the casing of the combustion chamber, the means for introducing the additional air comprising a blower adapted to be driven by the engine and to deliver a flow of additional air in excess, and the assembly of the post-combustion chamber and the heat-exchanger being constituted by three coaxial cylinders namely an inner cylinder forming the casing of the post-combustion chamber and adapted to be connected to the exhaust pipe of the engine in such a way that the exhaust gases of the latter are introduced at the center and in the axis of said inner cylinder, an intermediate cylinder forming with the inner cylinder an annular space which constitutes said intermediate zone and communicates, at an end situated at the side of the engine exhaust pipe, with the post-combustion chamber by openings provided in the inner cylinder and, at its other end, with a pipe for the escape of the burnt gases from the post-combustion chamber, an outer cylinder defining with the intermediate cylinder the abovesaid peripheral zone, which communicates, on one hand, with an inlet pipe for additional air and, on the other hand, with the exhaust pipe of the engine through holes provided in the latter and situated axially between two end-enclosing covers substantially flat and at right angles to the common axis of the cylinders, said covers being traversed by the exhaust pipe of the engine and being adapted to shut, at one end, on one hand the intermediate cylinder and the inner cylinder and, on the other hand, the outer cylinder, the axial distance between the covers being just sufficient for the holes to open between the said covers, said peripheral zone including a partition rolled in a helix, adapted to increase the path traversed by the additional air in said peripheral zone, the assembly being arranged in such a way that said intermediate zone separates the peripheral zone from the combustion chamber over the whole of the axial length of the latter, and sensing means sensitive to at least one of (a) the speed and (b) the load of the engine comprising by-pass means located between the heat exchanger and the atmosphere to prevent the air delivered by the blower, which has cooled the exhaust gases from the post combustion chamber from being introduced into said post-combustion chamber when at least one of (a) and (b) has a value higher than a given limit to which corresponds a chosen power limit, in such a way that the post-combustion ceases when the engine delivers a power higher than said chosen power limit.

2. Post-combustion device according to claim **1**, wherein the sensing means are connected to the position of the accelerator control of the engine.

3. Post-combustion device according to claim **1**, wherein the sensing means are linked to the delivery pressure of the blower.

4. Post-combustion device according to claim **1**, wherein the limit of power of the engine above which the sensing means are adapted to stop the post-combustion, is comprised between a quarter and two-thirds of the maximal power of the engine.

5. Post-combustion device according to claim **1**, comprising a divergent frustoconical element coaxial with the post-combustion chamber and constituting an extension in the latter chamber, of the engine exhaust pipe, the diameter of the divergent element increasing from the pipe towards the interior of the post-combustion chamber.

6. Post-combustion device according to claim **1**, wherein the heat-exchanger is arranged in such a way that the temperature of the additional air at the exit of this exchanger is higher than 600° C.

7. Post-combustion device according to claim **1**, wherein the partition of the peripheral zone is constituted by a thread of cylindrical section.

8. Post-combustion device according to claim **1**, wherein the flow of additional air delivered by the blower is such that the amount of oxygen in the exhaust gases at the exit from the post-combustion chamber is comprised between 1 percent and 8 percent by volume.

9. Post-combustion device according to claim **2**, wherein the sensing means comprise a sliding valve provided with a valve flap carried by a stem and adapted to cooperate, on one hand, with a first seat when the valve flap is shut and, on the other hand, with a second seat carried by a guide of the stem of the said valve flap when the valve is open, the cooperation of the valve flap and of the seat being adapted to reduce the escapes of additional preheated air between the stem and the guide.

10. Post-combustion device according to claim **1**, wherein the sensing means comprise a sliding valve provided with a valve flap carried by a stem, which stem is adapted to slide in a guide which crosses a cavity in which the additional cold air, circulated by the blower, is adapted to circulate in such a way that the guide and the stem are cooled.

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