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[54] **SECONDARY AIR SUPPLY SYSTEM FOR AN INTERNAL COMBUSTION ENGINE**

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[51] **Int. Cl.** **F01n 3/10**, F16k 15/02

[58] **Field of Search** 60/293, 289, 290, 307; 417/456, 458, 566; 137/512.3; 251/174, 170; 418/15

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[57] **ABSTRACT**

A secondary air supply system for use with an internal combustion engine includes an air supply system comprising an air pump adapted to be intermittently operated and an air supply conduit extending from the air pump to an air manifold communicated with exhaust ports of respective engine cylinders. First and second check valves are provided in series in the air conduit so as to prevent back flow of the exhaust gas toward the air pump. The first check valve is positioned adjacent the air pump and characterized by its high blocking performance while the second check valve is characterized by its high heat-resistant and corrosion-resistant properties.

5 Claims, 8 Drawing Figures

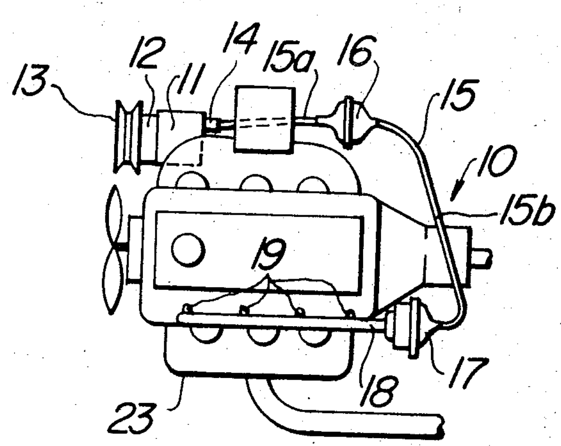


FIG. 1

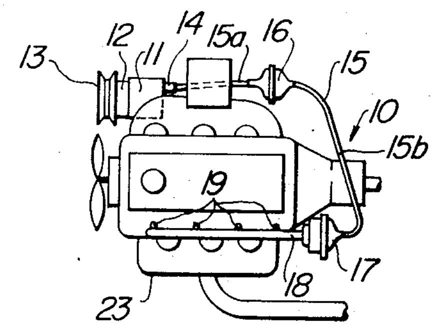


FIG. 2

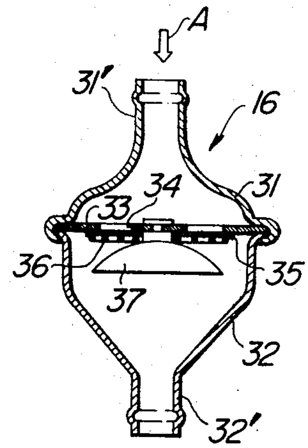


FIG. 3

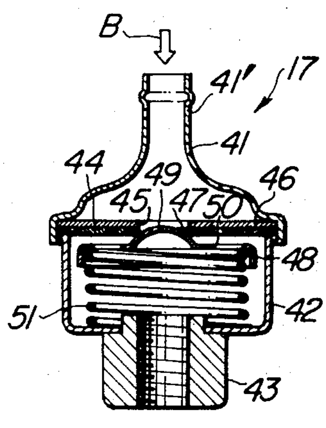


FIG. 4

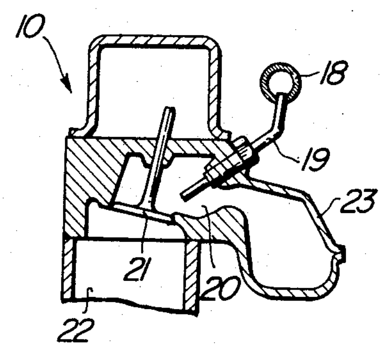


FIG. 5

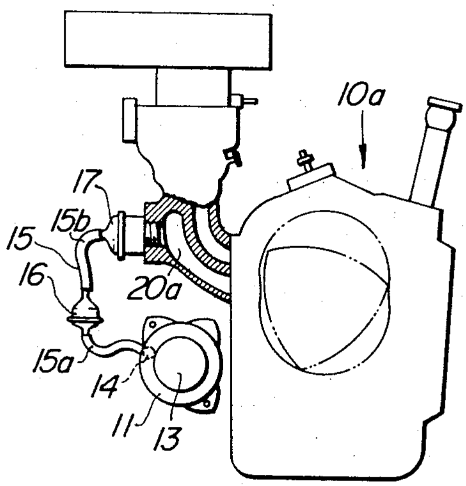


FIG. 6

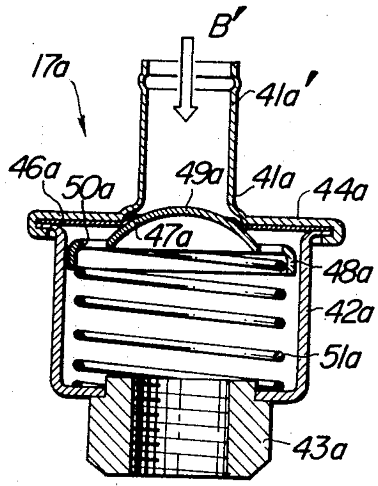


FIG. 7

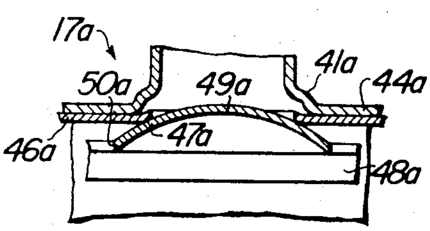
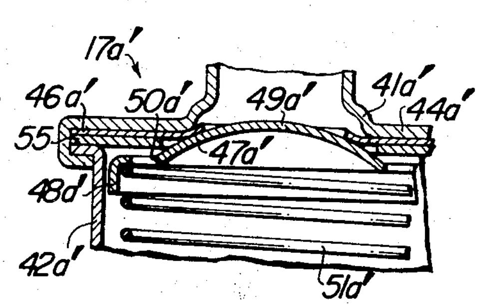


FIG. 8



SECONDARY AIR SUPPLY SYSTEM FOR AN INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a secondary air supply system for purifying the exhaust gas from an internal combustion engine and, particularly, to an improvement in secondary air supply system having means for preventing back flow of exhaust gas toward a secondary air supply source.

2. Description of Prior Art

In an internal combustion engine such as an internal gasoline engine, it has been heretofore known to supply secondary air into the exhaust system of the engine downstream of the exhaust valves thereof so as to purify the exhaust gas from the engine by oxidizing the unburnt gaseous components, such as hydrocarbon and carbon monoxide contained in the exhaust gas. An air supply source for the purpose has been an air pump which is driven by the engine or by an electric motor. In the case where the air pump is designed to be continuously operated during the operation of the engine, a check valve is provided in the secondary air supply system so as to protect the air pump from an accidental back flow of exhaust gas in the event that the operation of the air pump is discontinued due to a breakage of a drive belt for the pump or a trouble in the electric motor for the pump. In such event, the check valve is merely required to block back flow of the exhaust gas for a short time, i.e., until the drive for the air pump is repaired. The check valve is not exposed to the exhaust gas at a high temperature when the air pump is operated because secondary air flows through the valve to protect the valve from the exhaust gas. Thus, those in the art have not been required to make the elements or components of the check valve for materials which withstand extremely high temperature.

However, in a prior art secondary air supply system in which an air pump is designed to be intermittently operated by an electric motor or from an engine crank pulley through a magnet clutch and a drive belt and in which the air pump is not operated when no secondary air is needed, i.e., when the engine is running at more than a predetermined rotational speed, there often occurs a case wherein the air pump is not in operation during the operation of the engine. In such a case, when leakage occurs in the check valve to permit back flow of the exhaust gas through the check valve to the air pump, the latter suffers from corrosion caused by harmful gaseous components and vaporized water contained in the exhaust gas with a disadvantageous result that the air pump is damaged in short time. With the secondary air supply system of the type concerned, no satisfactory result can be expected from the check valve designed for use in a secondary air supply system of the type in which the air pump is continuously operated and the check valve is required to block back flow of exhaust gas only during the repair of the drive for the air pump.

A check valve for use with a secondary air supply system in which an air pump is intermittently operated is required to be operable not only with as minimum resistance as possible against the flow of secondary air from the air pump so as to minimize the load on the pump but also with high blocking or sealing performance relative to the back flow of exhaust gas. In addition, the check valve of the class concerned is also required to have high heat-resistant and corrosion-resistant properties because the valve is exposed to corrosive exhaust gas at a high temperature when the air pump is not in operation. With a secondary air supply system of so-called "air injection type" in which the secondary air is supplied into engine exhaust ports downstream of exhaust valves, the check valve is required to have an extremely high temperature-resistant property because, with this type of secondary air supply system, the check valve is exposed to the exhaust gas at an extremely high temperature.

One type of check valve which has been designed in an attempt to satisfy the above-discussed requirements includes valve parts made of a heat-resistant and corrosion-resistant material such as fluorinated rubber or fluorine-contained rubber. While this type of check valve is satisfactory with respect to minimized resistance of the valve parts to the flow of secondary air through the check valve and sealing or blocking performance of the valve against the exhaust gas, the check valve is not satisfactory with respect to its heat-resistant property and is damaged by heat in a relatively short time. Another type of check valve includes a valve member made of a stainless steel sheet and a valve seat made of an asbestine material. The other type of check valve is satisfactory with respect to the heat-resistant property but fails to satisfactorily operate to efficiently block the back flow of exhaust gas. With the other type of the check valve, use of a higher pressure to close the valve so as to improve the sealing or blocking performance disadvantageously results in an increase in the resistance of the valve member to the flow of secondary air through the check valve. With respect to the heat-resistant property, metal is an appropriate material for the valve parts of the check valve. However, the use of valve parts of a metal encounters a problem that solid particles, such as soot, contained in the exhaust gas are deposited on the mating surface of valve member and seat with resultant leakage therebetween and corrosion of the inner components of the air pump caused by corrosive gaseous components and vaporized water contained in the exhaust gas which flows back through the check valve to the pump. Thus, no satisfactory check valve has been provided up to date for a secondary air supply system of the type in which the air pump is interruptedly operated to supply secondary air.

SUMMARY OF THE INVENTION

It is an object of the present invention to eliminate the disadvantages and problems discussed above.

It is another object of the present invention to provide an improved secondary air supply system for an internal combustion engine in which secondary air supplied from an air pump is allowed to flow with minimized resistance within the system and in which the air pump is efficiently protected from being exposed to the exhaust gas from the engine.

According to the present invention, there is provided a secondary air supply system for use with an internal combustion engine having an exhaust system in which means are provided for purifying the exhaust gas from the engine, said air supply system including an air pump adapted to be intermittently operated and an air conduit interconnecting said exhaust purifying means and said air pump, wherein first and second check valves are provided in series in the path of flow between said air pump and said exhaust gas purifying means so as to prevent back flow of exhaust gas through said air conduit toward said air pump, said first chect valve being characterized by its high blocking performance and positioned adjacent said air pump, said second check valve being characterized by its high heat-resistant property.

The first check valve may preferably include a first valve member made of an elastic material, a first valve seat and a first biasing means normally urging said first valve member into sealing contact with the first valve seat. The arrangement may preferably be such that the first valve member is easily opened against the first biasing means by the air supplied by the air pump when the latter is operated to thereby permit the air to pass through the first check valve. The second check valve may preferably include a second valve member made of a heat-resistant and corrosion-resistant metal, a second valve seat made of a heat-resistant and corrosion-resistant material and a second biasing means normally biasing the second valve member into sealing engagement with the second valve seat. Preferably, the second valve member may have a spherical convex valve portion while the second valve seat may preferably be made of a heat-resistant and corrosion-resistant sheet metal which is resiliently deformable into intimate sealing contact with the spherical valve portion of the second valve member when the same is moved into engagement with the second valve seat. Alternatively, the second valve seat may be made of a heat-resistant and corrosion-resistant sheet material the main component of which may be asbestine or graphitic fiber.

The above and other objects, features and advantages of the present invention will be made apparent by the following description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagrammatical top plan view of a reciprocating internal combustion engine equipped with a secondary air supply system according to the present invention;

FIG. **2** is an axial sectional view of a first or seal type check valve used in the secondary air supply system shown in FIG. **1**;

FIG. **3** is an axial sectional view of a second or heat-resistant type check valve used in the secondary air supply system shown in FIG. **1**;

FIG. **4** is an enlarged fragmentary sectional view of the engine of FIG. **1** showing an air nozzle of the system extending into the exhaust port of a cylinder of the engine;

FIG. **5** is a diagrammatical end view of a rotary engine equipped with the secondary air supply system according to the invention;

FIG. **6** is an axial sectional view of a modified heat-resistant type check valve;

FIG. **7** is an enlarged fragmentary sectional view of the valve of FIG. **6** showing the valve member and valve seat thereof; and

FIG. **8** is an axial sectional view of a further modified heat-resistant type check valve with some parts thereof being cut away.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring first to FIGS. **1** and **4** of the drawings, there is shown a reciprocating internal combustion engine generally indicated by **10** and having an exhaust system including an exhaust manifold **23** and exhaust pipe. An air pump **12** is rigidly mounted on one side of the engine and is adapted to be intermittently driven through a magnet clutch **12** by pulley **13** which in turn is driven by a crank pulley, not shown, of the engine **10** through an approporiate torque transmitting means such as a V-belt not shown. The pump **11** has an air delivery pipe **14** connected to an end of a secondary air supply conduit **15** comprising conduit portions **15*a*** and **15*b*** connected in series. A first check valve **16** is provided between the conduit portions **15*a*** and **15*b***. The conduit **15** is connected at the other end to a second check valve **17** to which an air manifold **18** is connected. The air manifold **18** has a plurality of air nozzles **19** each extending into an exhaust port **20** of a cylinder **22** of the engine **10** so as to inject air into the port **20** downstream of an exhaust valve **21** for the cylinder. The exhaust port **20** is in communication with the exhaust manifold **23.**

Referring to FIG. **2**, the first check valve **16** comprises a housing formed of two generally cup-shaped parts **31** and **32** secured together at their large diameter ends. The housing part **31** has an outer or reduced end portion **31′** to which the portion **15*a*** of the conduit **15** is connected. Similarly, the other housing part **32** has an outer or reduced end portion **32′** which is connected to the portion **15*b*** of the conduit **15.** A substantially flat disc-like valve seat **33** is sandwiched at the marginal area between the inner ends of the housing parts **31** and **32.** The valve seat **33** is provided with a plurality of valve openings **34** formed therein and arranged in a circumferential row. A substantially flat disc-like valve member **35** made of a corrosion-resistant elastic material such as fluorinated rubber or fluorine-contained rubber is urged against the valve seat **33** by means of a coil spring **36** having its turns normally extending substantially in a flat plane. The coil spring **36** is suspended from the valve seat **33** by means of a support **37** having a spherical convex portion and a stem portion which is connected to the valve seat. This arrangement is such that, when air is supplied from the pump **11** as shown by an arrow A in FIG. **2**, the valve member **35** is easily opened from the valve seat **33** by virtue of downward deformation of the valve member **35** against the coil spring **36** caused by the air flow A. The valve member **35** and the coil spring **36** are so designed as to have a very small resistant force against the passage of the air through the valve **16.**

Referring to FIG. **3**, the second check valve **17** comprises a housing formed of two housing parts **41** and **42** secured together at their large-diameter ends. The housing part **41** is generally cup-shaped and has a reduced end **41′** to which other end of the conduit portion **15*b*** is connected. The other housing part **42** has a generally drum-like shape having an outer end connected with a coupling **43** through which the valve **17** is connected to the air maniflod **19.**

Disc-like support plate **44** and valve seat **46** are laminated together and sandwiched at their edge portions between the inner ends of the housing parts **41** and **42.** Ths support plate **44** is advantageously made of a sheet of stainless steel while the valve seat **46** is made of a heat-resistant and corrosion-resistant sheet material the main component of which may be asbestine of graphitic fiber. The support sheet **44** and the valve seat **46** have axially aligned central openings **45** and **47.** A generally disc-like valve member **48** is normally urged against the valve seat **46** by means of a coil spring **51** extending between the valve member **48** and the outer end of the housing part **42.** The valve member **48** is advantageously made of a sheet of a heat-resistant and corrosion-resistant metal such as stainless steel and is provided with a central spherical convex portion **49** and a plurality of apertures or holes **50** formed in the valve member and arranged in a circumferential row around the convex portion **49.** The coil spring **51** is advantageously made of stainless steel. It will be noted that the spring **51** biases the valve member **48** upwardly so that the upper surface of the convex portion **49** is urged into sealing engagement with the peripheral edge of the opening **47** in the valve seat. The spring force of the coil spring **51** is so determined that the flow of air fed from the air pump **11,** as shown by an arrow B, displaces the valve member **48** against the spring **51** and passes through the valve **17.**

In operation, when the magnet clutch **12** is energized to drivingly couple the air pump **11** and the pulley **13,** the pump operates to supply secondary air through the conduit portion **15***a* into the first check valve **16** in which the air is forced in the direction indicated by the arrow A (FIG. **2**) into the openings **34** and moves the marginal area of the valve member **35** away from the valve seat **33** against the coil spring **36** so that the air passes through the first check valve **16** into the conduit portion **15***b*. The air is then fed into the second check valve **17** in the direction indicated by the arrow B shown in FIG. **3.** In the valve **17,** the air is forced through the openings **45** and **47** to move the valve member **48** away from the valve seat **46** against the spring **51** so that the air passes through the valve **17** into the air manifold **18** from which the air is distributed to the air nozzles **19** only one of which is shown in FIG, **4.** The air is fed through the nozzle **19** into the exhaust port **20** in which the air is mixed with the exhaust gas at a high temperature to oxidize a quantity of unburnt gaseous components included in the exhaust gas for thereby convert the same into a substantially harmless gas.

When the gas exhausted from the engine contains relatively small amount of unburnt gaseous components and a large engine output is required as is in the case where the vehicle on which the engine is mounted is operated at more than a predetermined high speed, the magnet clutch **12** will be deenergized to discontinue the operation of the air pump **11.** In such event, the exhaust gas at a high temperature flows from the exhaust port **20** through the air nozzles **19** and the air manifold **18** into the second check valve **17.** However, because no secondary air is supplied into the second check valve **17** in the direction of the arrow B, the valve member **48** is urged against the valve seat **46** by the coil spring **51** to close the valve **17.** The exhaust gas in the check valve **17** acts on the valve member **48** in the direction opposite to the direction of the arrow B to exert an additional force on the valve member **48** with a result that the valve member is further strongly urged against the valve seat **46.**

If, for some reason or accidentally, the exhaust gas should flow past the second check valve **17** through the conduit portion **15***b* to the first check valve **16,** the exhaust gas applies a pressure, in addition to the pressure by the coil spring **36,** to the deformable valve member

35 with a result that the latter is advantageously urged into sealing engagement with the valve seat **33** to close the valve opening **34** for thereby substantially completely blocking the back flow of the exhaust gas. Thus, no exhaust gas flows to the air pump **11.** It is to be understood that the exhaust gas will be at a high temperature within the second check valve **17.** However, the exhaust gas will be cooled as it flows through the conduit portion **15***b* and, when the exhaust gas arrives at the first check valve **15,** the gas will be so cooled that the first check valve **15** is not required to have a heat-resistant property. The first check valve, therefore, can have a variation in its design, i.e., the structure of the valve and the materials from which the valve parts are made. For this reason, the first check valve can be designed to have a structure which is characterized by a high sealing or blocking performance.

In the embodiment described above, the first check valve is provided in the air conduit **15.** The first check valve, however, may alternatively be incorporated into the air delivery pipe **14** of the air pump **11.** Moreover, the first check valve **16** may alternatively be used in combination with another valve of different kind, such as a bypass valve or relief valve.

With the described and illustrated embodiment, secondary air is injected into exhaust ports **20** of respective engine cylinders. The secondary air supply system of the present invention, however, may also be used with an engine which is equipped with another kind of exhaust gas purifying device, such as catalytic converter or afterburner, to which secondary air is supplied through a supply port either in the exhaust manifold of the engine or in the engine pipe. In such use, the first check valve will be disposed adjacent the air pump and the second check valve will be connected in series relative to the first check valve and positioned adjacent the supply port.

When it is required by a particular engine design that the air conduit **15** has an extremely small length, the conduit portion **15***b* between the first and second check valves **16** and **17** may advantageously be formed of a tubing of a metal having a high heat conductivity so that the exhaust gas entering into the conduit portion **15***b* is rapidly cooled before the gas reaches the first check valve.

The unit of air pump **11,** magnet clutch **12** and pulley **13** may be replaced by an electrically powered air pump of a design which is intermittently operable in accordance with the requirement for secondary air.

The secondary air supply system according to the present invention is also applicable to a rotary engine **10***a* as shown in FIG. **5** in which similar parts are indicated by similar reference numerals. The rotary engine **10***a* has a secondary air supply cavity **20***a* leading to an air nozzle or nozzles not shown. The arrangement of the secondary air supply system shown in FIG. **5** is substantially identical with the embodiment described with reference to FIGS. **1** to **4** except that the second check valve **17** is directly communicated with the secondary air supply cavity **20***a* in the rotary engine **10***a*.

FIG. **6** shows a modification of the second check valve. The modified second check valve is generally indicated by **17***a* and comprises a housing formed of two parts **41***a* and **42***a*. Those portions of the valve **17***a* which are similar to the corresponding portions of the check valve **17** of the described embodiment of the invention are indicated by similar reference numerals followed by a character *a*. The valve **17***a* is substantially similar to the valve **17** with the exception that housing part **41***a* has an annular flat portion **44***a* which acts as a support plate for a valve seat **46***a* and that the latter is made of a sheet of a heat-resistant and corrosion-resistant metal. The valve seat **46***a* is formed therein with a central valve opening having a circumferential edge portion **47***a* which is deformable into intimate sealing engagement with a spherical convex portion **49***a* of a valve member **48***a* when the latter is urged against the valve seat **46***a*. Of course the valve member **48***a* can be disengaged from the valve seat **46***a* against the pressure by a coil spring **51***a* when secondary air is supplied from the air pump **11** in a direction indicated by an arrow B' in FIG. **6**.

The modified check valve **17***a* is advantageous over the check valve **17** in that the valve seat **46***a* of the check valve **17***a* is made of a heat-resistant and corrosion-resistant metal which is highly resiliently deformable at a high temperature and thus is kept in intimate sealing contact with the valve member **48***a* even if the valve seat **46***a* is subjected to a high temperature by the exhaust gas from the exhaust ports **20** of the engine. The check valve **17***a* provides another advantage that, because the valve member **48***a* is brought into face-to-face contact with the valve seat edge portion **47***a* of small area and because the edge portion **47***a* is resiliently deformed at each time when the valve member **48***a* is moved into contact with the valve seat **46***a*, the check valve **17***a* is free from deposition, on the contact surfaces of the valve seat **46***a* and valve member **48***a*, of solid particles contained in the exhaust gas. Thus, the check valve **17***a* can have a prolonged operative life through which the valve member **48***a* can have an intimate sealing contact with the valve seat **46***a* without any solid particles therebetween.

As an example, the housing parts **41***a* and **42***a* of the check valve **17***a* have a wall thickness of 1 mm. The valve member **48***a* is 0.6 mm in thickness. The valve seat **46***a* has a thickness ranging from 0.1 to 0.2 mm.

In the case where the valve seat **46***a* is made of an extremely thin sheet metal, the valve seat tends to be so extremely displaced at its central portion from the support plate **44***a* by the supplied air that the displaced central portion is positioned close to the valve member **48***a* which has been opened, to disadvantageously provide an increased resistance to the flow of the secondary air through the check valve **17***a*. FIG. **8** shows a further modified second check valve **17***a'* which has been designed to eliminate the disadvantageous tendency accompanied with the check valve shown in FIGS. **6** and **7**.

The check valve shown in FIG. **8** is substantially similar to the check valve **17***a* with an exception that an additional support plate **55** is provided for a valve seat **46***a'* so that the latter is prevented from being unduely displaced by secondary air supplied from the air pump. The additional support plate **55** has a central opening having such a size that the peripheral edge of the opening is not contacted by a convex spherical valve portion **49***a'* of a valve member **48***a'* when the latter is urged against a valve seat **46***a'*. Those parts of the check valve

17*a'* similar to the corresponding parts of the check valve **17***a* are indicated by similar reference numerals. In the structure shown in FIG. **8**, the support plates **44***a'* and **55** and the valve seat **46***a'* are secured together in such a manner that the peripheral edge portion of the support plate **44***a'* is curled around an outwardly extending annular flange at the top of the housing part **42***a'* with the valve seat **46***a'* and the additional support plate **55** being sandwiched at their outer edge portions between the support plate **44***a'* and the annular flange. The additional support plate **55** may alternatively be secured to the valve seat **46***a'* and the supporting plate **44***a'* by means of spot-welding or rivetting.

What is claimed:

1. A secondary air supply system for use with an internal combustion engine having an exhaust system with means for purifying the engine exhaust gas comprising:

an intermittently operated air pump,

an air conduit interconnecting said air pump and exhaust purifying means,

a first check valve having a high blocking performance provided in said conduit adjacent said pump including a first valve member of elastic material, a first valve seat with portions of said first valve member opposing the valve seat and a first biasing means normally urging said first valve member into sealing engagement with said first valve seat, the air flow from said air pump deforming said first valve member against said biasing means to permit flow and back flow of exhaust gas deforming said valve member into sealing relation with said valve seat,

a second check valve having a high heat resistance provided in said conduit adjacent said purifying means including a second valve member made of heat-resistant and corrosion-resistant metal, a second valve seat made of heat-resistant and corrosion-resistant material and a second biasing means normally urging said second valve member and sealing engagement with said second valve seat said second valve member and second valve seat having a higher heat resistance and a lower blocking performance than said first valve member and first valve seat, respectively.

2. A system as in claim **1**, further including means for intermittently operating said air pump.

3. A system as in claim **1** wherein said first biasing means is a coil spring with its turns extending substantially in a flat plane.

4. A system as in claim **1** wherein said second valve member has a spherical valve portion which is moved into and out of sealing engagement with the peripheral edge of the opening in said second valve seat.

5. A secondary air supply system according to claim **1** wherein said second valve seat is made of a heat-resistant and corrosion-resistant sheet metal which is resiliently deformable into intimate sealing contact with said valve portion of said second valve member when the same is moved into engagement with said second valve seat.

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