United States Patent

Hoffman et al.

[15] **3,702,110**

[45] **Nov. 7, 1972**

[54] **CLOSED CYCLE ENGINE SYSTEM**

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[22] Filed: **Nov. 30, 1970**

[21] Appl. No.: **93,677**

[52] **U.S. Cl.** ....**123/119 A,** 60/29 R, 60/31, 60/39.29, 60/39.5, 60/39.51 R, 60/39.52

[51] **Int. Cl.** **F02b 29/00**

[58] **Field of Search**..........60/39.05, 29, 31, 39, 39.5, 60/39.51, 39.52, 39.3, 39.53, 39.66

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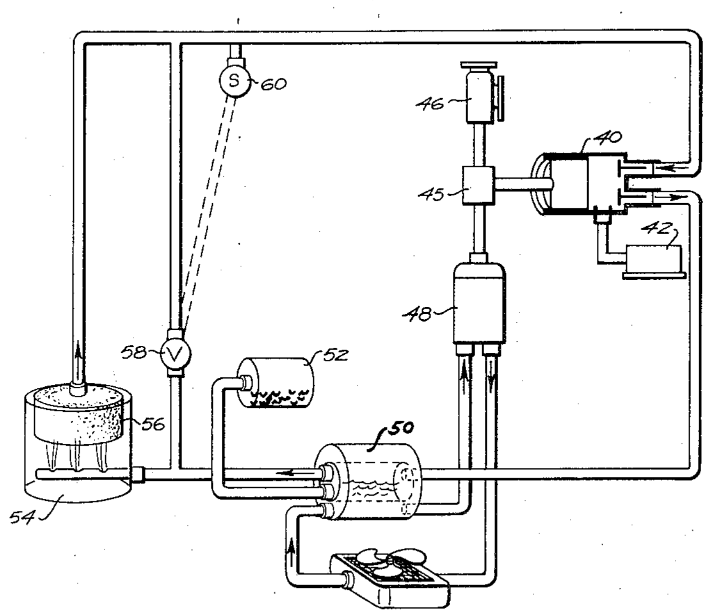
[57] **ABSTRACT**

Disclosed is an engine, preferably of the diesel type, operating in a closed cycle system in which there is generated a mixture of gaseous oxygen and water vapor for its "breathing." The generation of this mixture uses the engine exhaust products, which comprises mainly, carbon dioxide, oxygen and water vapor. This synthetic "air" combusts with the diesel fuel to drive, for instance, an electrical generator. The system incorporates units connected to the engine exhaust which employ the carbon dioxide to produce new oxygen, condense the water vapor and recycle the unused oxygen, and a further provision for control of the oxygen production.

15 Claims, 3 Drawing Figures



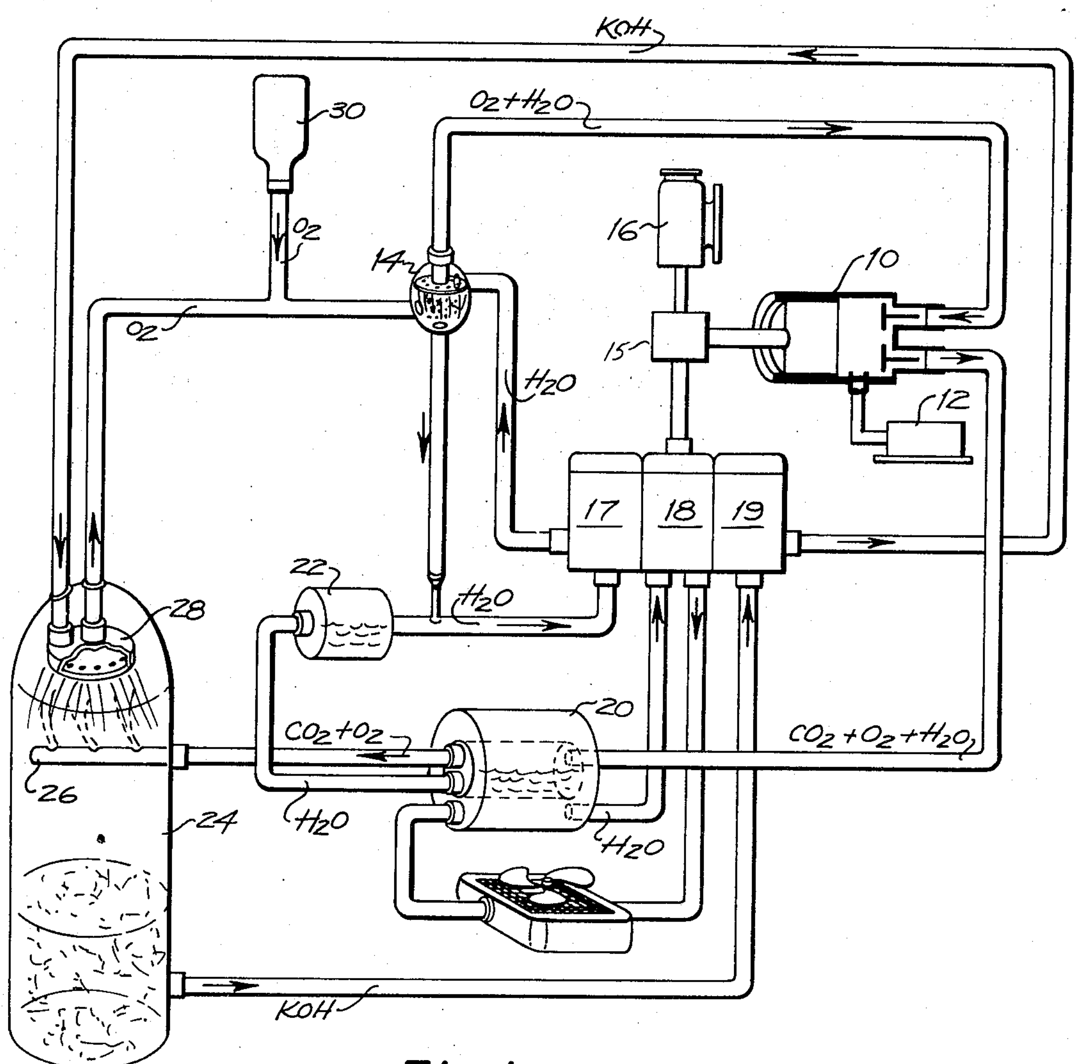


Fig. 1
PRIOR ART

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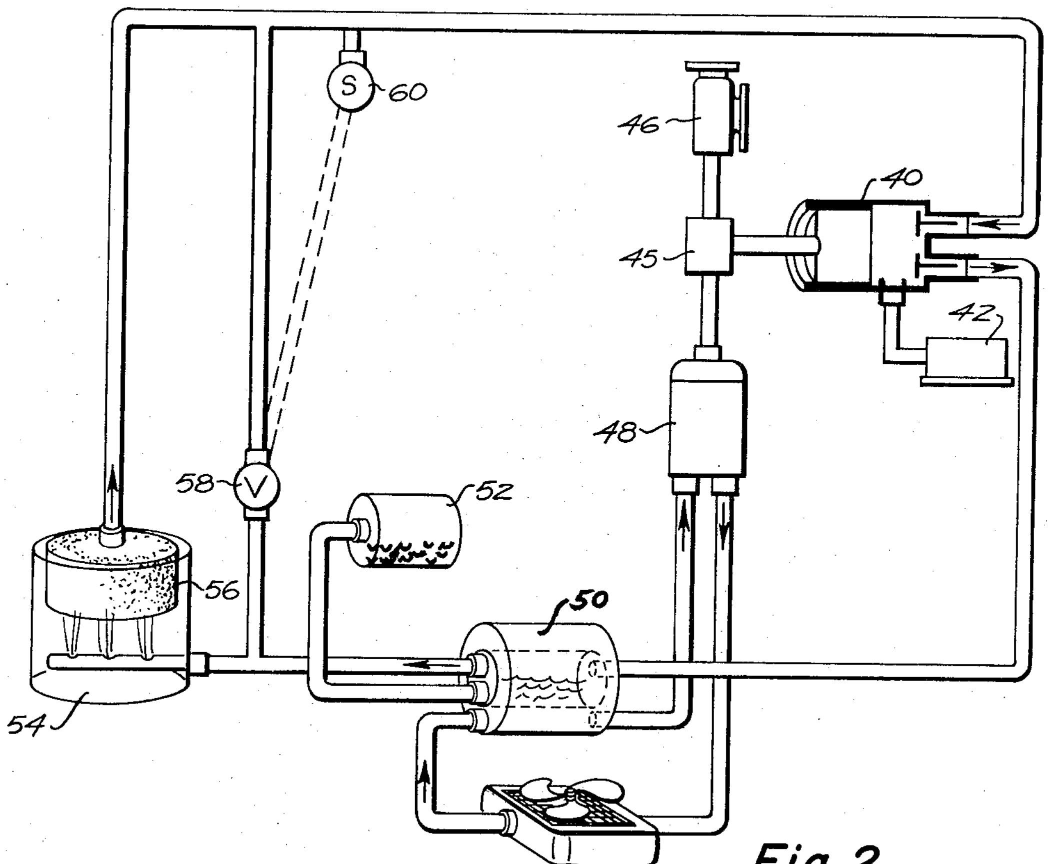

Fig. 2

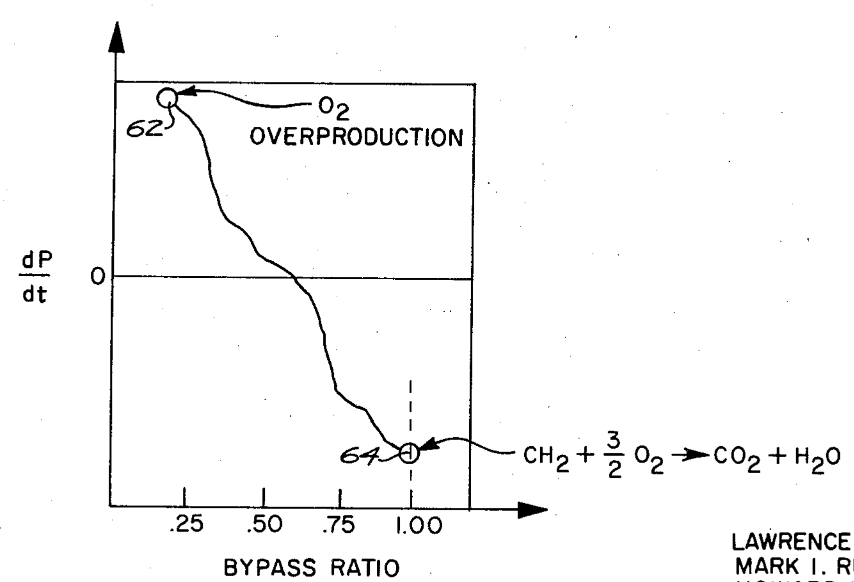

Fig. 3

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CLOSED CYCLE ENGINE SYSTEM

BACKGROUND OF THE INVENTION

The diesel engine is widely respected as the most practical source of power for most terrestrial surface applications such as trucks, rail and marine transportation. Further application of this engine to undersea, underground and contaminated environments is highly desirable since it is low in cost, excellent in performance and reliability and available in a wide variety of power levels.

Until very recently, attempts extensive in expense, frequency and time have not resulted in the development of a simple, efficient and practical way to operate the diesel in an enclosed system. The best that was known to the art is a system for submarine engines which returns the exhaust gases to the input while it adds oxygen from stored tanks; the induction working fluid thus is oxygenated carbon dioxide. The exhaust is cooled, thereby condensing out the water vapor from the combustion and, to obtain a constant operating pressure and material balance in the loop, the excess oxygen, water and carbon dioxide are pumped out of the vessel against the sea pressure.

What is considered an appreciable advance in this art is divulged in a copending application for patent Ser. No. 851,586, filed on Aug. 20, 1969, now U.S. Pat. No. 3,658,043. As described therein, the diesel engine exhaust passes to a cooler-condenser in which the water vapor is condensed and the oxygen and carbon dioxide mixture is conveyed to a unit wherein the carbon dioxide is absorbed by a potassium hydroxide solution to generate the bicarbonate and new oxygen. The oxygen, supplemented as necessary, is humidified by a lung which uses the condensed water and is then returned to the engine input.

The arrangement of this system was based upon certain observations made during extensive tests of diesel engines:

1. combustion gas analysis data indicate that "lean" (4 to 6 oxygen to fuel ratio) operation evolves only oxygen, carbon dioxide and, in the case of air-breathing operation, the inert constituent nitrogen;
2. an engine will operate efficiently on water vapor-oxygen mixtures as a substitute for air;
3. in proper proportions, the water vapor will serve the same purpose as the nitrogen with regard to limiting combustion temperature;
4. under the above operation, the exhaust comprises mainly steam, which may be condensed to allow isolation of other exhaust constituents;
5. the psychrometric properties of the water vapor-oxygen mixture may be used to maintain automatically the oxygen to-fuel ratio within limits for producing an exhaust compatible with closing the cycle.

BRIEF SUMMARY OF THE INVENTION

The present invention is submitted as a further advance in the art directed to achieving further compactness, light weight and simplified operation; it is based on the realization that the alkali metal superoxides, such as sodium or potassium superoxide, NaO_2 or KO_2, have the ability to liberate oxygen as well as to absorb carbon dioxide, in a ratio very close to the oxygen-combusted to carbon dioxide-emitted ratio of the diesel engine. The invention uses this concept in providing a bed of KO_2 solid granules in a thin walled canister having openings at its ends for gas throughflow. Cooled engine exhaust, after condensation of most of its water content, flows through the canister and chemical reaction therein produces potassium carbonate (K_2CO_3) in granular form and gaseous oxygen in a continuous basis. It has been found that, when allowed to operate at relatively high temperatures (e.g.q 120° F to 150° F), the KO_2 bed remains firm and dry, pressure drop in the system is very low, in the steady state, little oxygen needs to be added to the loop, and both pressure regulation and oxygen-concentration regulation are feasible (and therefore incorporated).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of the system of Ser. No. 851,586;

FIG. 2 is a diagram of the system of the present invention; and

FIG. 3 is a graph showing the operation of the bypass regulation circuit of the system of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 comprises a simplified diagram of the aforementioned closed cycle engine, which briefly, consists, in its preferred embodiment, of diesel engine **10** supplied with fuel from tank **12** and "air" from lung **14**. Engine **10** drives through gearbox **15**, electrical generator **16** or some other power converter and pumps **18** and **19**, and exhausts into heat sink **20**. The input to engine **10** is thus the active ingredient of the fuel, chemically idealized as CH_2, and moisturized oxygen from lung **14**, which react in accordance with:

$$CH_2 + 3/2\,(O_2) \rightarrow CO_2 + H_2O.$$

The exhaust of engine **10** is thus made up mainly of carbon dioxide, water and unused oxygen and trace materials; the water is condensed by sink **20** into tank **22** from which it enters pump **17** and lung **14** and the carbon dioxide-oxygen mixture enters absorption tank **24** by way of outlets in pipe **26** where it is sprayed by a caustic solution, preferably potassium hydroxide solution, issuing from spray head **28**. Chemical reaction in tank **24** may be represented by:

$$2\,KOH + CO_2 \rightarrow K_2\,CO_3 + H_2O$$

and thus the entering oxygen merely passes through tank **24** to re-enter lung **14**, together with an auxiliary supply from tank **30**. The excess KOH solution is also circulated by pump **19** to head **28**.

In effect, FIG. 1 shows the following circuits:

1. engine circuit, including fuel tank **12**, engine **10**, heat sink **20** and oxygen supplies, tanks **24** and **30**;
2. water circuit, including heat sink **20**, tank **22**, pump **17** and lung **14**;
3. KOH circuit, including tank **24**, pump **19** and spray head **28**.

In operation, lung **14** takes in oxygen, passes it through a water spray for humidification, and passes it on to the intake of engine **10**. The water spray in lung **14** is provided by circulation of coolant water between lung **14** and engine **10** by pump **17**. The partial evaporation of the water which takes place in lung **14** to humidify the oxygen, also cools the circulating water and hence engine **10** by evaporation.

Engine exhaust is piped to heat sink **20** where the water vapor is condensed by cooling. The condensed water is drained into tank **22** which in turn supplies make-up water to the water circuit. The exhaust gas enters absorption tank **24** where the carbon dioxide is absorbed, forming potassium carbonate solution. The remaining gas (unused oxygen) passes out where it is then piped back to lung **14** for re-circulation.

In the foregoing system, it is the function of the caustic spray to absorb, by chemical action, the engine exhaust carbon dioxide so that the system might operate in a "closed" mode, and it is the function of lung **14** to humidify the oxygen so that combustion in engine **10** may occur at a reduced temperature acceptable to engine **10**, namely, about 2,500° to 3,000° F; also, in this system, the input oxygen needed to supplement the recirculated oxygen is supplied by an external source, here, tank **30**.

FIG. **2** presents a closed cycle engine system characterized by considerable departure from that of FIG. **1**.

Here, as before, fuel tank **42** supplies fuel to engine **40**, which operates generator **46** through gearbox **45**, and engine exhaust is cooled by heat sink **50**, coolant in the jacket of which is circulated by pump **48**, also driven by engine **40** through gearbox **45**. Condensate water from the exhaust is collected in tank **52** for disposal and the carbon dioxide-oxygen mixture flows partly to canister **54**, which contains a bed of potassium super-oxide, KO_2 and partly to the intake of engine **40**.

It has been found that a metallic superoxide such as KO_2, in this type of system, is capable of performing the two functions of absorbing the carbon dioxide and generating oxygen ideally as follows:

$$4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$$

and, further, that the oxygen generation and CO_2 absorption, under most conditions of operation, are closely matched to the oxygen intake and CO_2 release of engine **40**. As a consequence, under ordinary circumstances, it has been found unnecessary to supply to engine **40** any additional external oxygen or other breathing component; accordingly, the humidified oxygen output of canister **54** is fed as shown, directly into engine **40**.

With regard to canister **54**, granules of solid KO_2 are packed in wire mesh container **56**, and it is provided with a conduit entrance opening near its bottom and a conduit exit at its top so that the exhaust gas may enter and generated oxygen may be emitted. The reaction results in a K_2CO_3 product also in a granule form which remains in container **56** and, periodically, is replaced by a container of fresh KO_2.

Experience with the above system has shown that it is feasible to control the rate of oxygen generation, especially by varying the exhaust flow through canister **54**, at practically no pressure loss in the system, particularly under high temperature operation.

Accordingly, bypass valve **58**, installed at the output of heat sink **50** operates to shunt the exhaust around canister **54** and back into engine **40** in response to control from pressure sensor **60**; thus, when sensor **60** recognizes an oxygen pressure level beyond a prescribed level, it operates to open valve **58** so that exhaust directed to canister **54** is reduced. As a result, no "lung" is required in this preferred embodiment since valve **58** operates to provide inherently for a dilution of the oxygen concentration of the gas flowing to the intake of engine **40**.

It should be obvious to those skilled in this art that, alternatively, valve **58** may be operated according to oxygen concentration, if so desired, by substituting for control by sensor **60**, control through one of the known oxygen analyzers available on the market.

However, regardless of which method of oxygen generation is employed, it will be found that the system behavior in this respect will, in a general way, accord with FIG. **3**. This graph depicts the operation of valve **58** with regard to response to oxygen pressures variation, shown as the ordinate and the effect thereof, shown as the ratio of vapor by-passed around canister **54** to that admitted to canister **54**, along the abscissa. Point **62** on the curve represents a condition of oxygen overproduction which causes substantial opening of valve **58** (bypassing canister **54**) whereas point **64** on the curve represents a condition of "choking" which causes valve **58** to close, thereby admitting all the exhaust from heat sink **50** to canister **54**.

In the further development of this invention, it has been discovered that a mode of operation is possible for which control of the generation of oxygen is not required, i.e., it eliminates the need for valve **58** despite the fact that any of the known methods of supplying external oxygen (the KOH-CO_2 reaction of FIG. **1**, the KO_2-CO_2 reaction of FIG. **2**, a liquid oxygen supply, etc., or any combination of these may be used.

This operating mode is based on the precharging of the system with a mixture of gases: oxygen, water vapor and an inert gas such as argon, and operating it as a completely closed system in which the oxygen supply is controlled by sensor **60** to admit fresh oxygen only where pressure or analysis indicates that it is lacking. The precharge mixture constituency and ratio may be selected to suit specific conditions of environment and the requirements of adequate dilution of the oxygen in the combustion reaction and suppression of reaction of the oxygen with lubricants.

What is claimed is:

1. Apparatus for supplying breathing fluid to an engine having an intake comprising:

means to cool the engine exhaust, to condense water vapor therefrom, and to dispose of the resulting liquid;

means to react with the carbon dioxide in the exhaust from said cooling means to generate oxygen; and

means to supply said generated oxygen to said engine.

2. Apparatus according to claim **1** and further including

means to selectively combine the exhaust from said cooling means and said generated oxygen from said reactor; and

means to supply the output of said combining means to the intake of said engine.

3. The apparatus of claim **1** wherein said cooler includes

a pump operated by the engine and adapted to have coolant circulated thereto.

4. The apparatus of claim 1 wherein said reactor includes
a supply of superoxide and
means to stream the exhaust through said supply.

5. The apparatus of claim 4 wherein said superoxide supply comprises
a bed of potassium superoxide pellets and
a mesh basket for containing said bed.

6. The apparatus of claim 5 wherein said bed and the exhaust combine in accordance with the equation

$$4\,KO_2 + 2\,CO_2 \rightarrow 2\,K_2CO_3 + 3O_2\,.$$

7. The apparatus of claim 2 wherein said combining means comprises
a conduit forming a stream of exhaust gases bypassing said reactor to said engine intake.

8. The apparatus of claim 2 and
a sensor to determine appropriate generation of input in the engine intake and
means responsive to said sensor to adjust the operation of said reactor.

9. The apparatus of claim 2 wherein said sensor is installed in said supply means.

10. The apparatus of claim 2 wherein said sensor is pressure-responsive.

11. The apparatus of claim 2 wherein said sensor is oxygen-quantity responsive.

12. The apparatus of claim 2 wherein said adjust means comprises a valve.

13. The apparatus of claim 2 wherein said valve is installed between said cooler and said reactor such that said reactor may be bypassed by the engine exhaust.

14. The apparatus of claim 2 wherein said adjust means controls said reactor for continuous although variable oxygen generation.

15. The apparatus of claim 1 wherein
said engine and said means are connected in a circuit closed to ambient influence.

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