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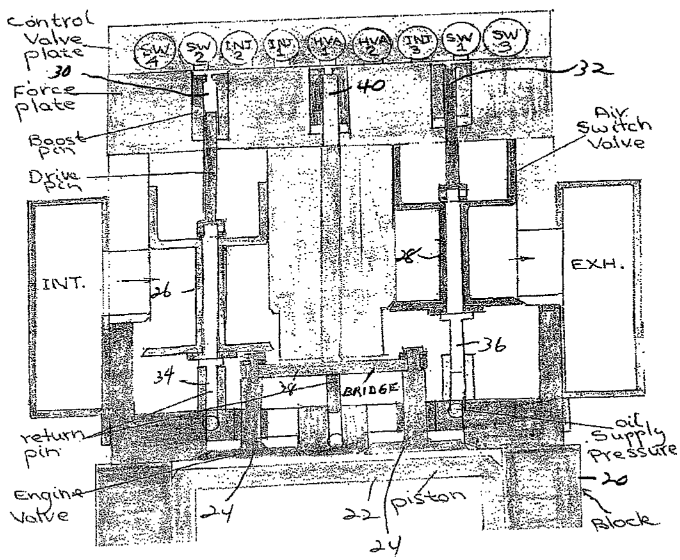
(54) **Title:** METHODS AND APPARATUS TO USE ENGINE VALVES AS BOTH INTAKE AND EXHAUST VALVES



(57) **Abstract:** Methods and apparatus to selectively use engine valves as both intake and exhaust valves and to selectively operate the engine as a 2 cycle or as a 4 cycle engine. In a disclosed embodiment, the intake valves and the exhaust valves are manifolded together through a small manifold, with the manifold being connectable to the intake manifold or the exhaust manifold through two-way valves. In preferably a camless engine, the engine valves may be controlled to operate the intake valves as intake valves only or to operate as both intake valves and exhaust valves, and to operate the exhaust valves as exhaust valves only or to operate the exhaust valves as both intake valves and exhaust valves. Exemplary embodiments are disclosed.

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METHODS AND APPARATUS TO USE ENGINE VALVES AS BOTH INTAKE AND EXHAUST VALVES

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Patent Application No. 60/775,387 filed February 21, 2006.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of the operation and control of engine valves in piston engines.

2. Prior Art

The present invention is based on the fact that at higher engine speeds and higher power outputs, engines have more difficulty breathing, that is, their volumetric efficiency goes down. Typically modern engines may include, by way of example, two intake valves and two exhaust valves per cylinder to attempt to increase the volumetric efficiency. However, there is a limit as to how much this can achieve, as all four valves must generally fall within a circle of a diameter approximately equal to the piston diameter.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic cross-section through an engine head illustrating one embodiment of the present invention.

Figure 2 is an embodiment similar to that of Figure 1, but using return springs for the air switch valves.

Figure 3 is a top schematic view of the exemplary assembly of Figure 1.

Figure 4 is a cross section of an embodiment using poppet valves for the air switch valves, and corresponds to a cross section taken along line A-A of Figure 3.

Figure 5 is another cross section of the embodiment of Figure 4, though corresponding to a cross section taken along line B-B of Figure 3.

Figure 6 is a schematic diagram for a V-6 engine incorporating the present invention.

Figure 7 is a block diagram schematically illustrating the incorporation of the present invention in a multi-cylinder engine.

Figure 8 is a block diagram of a multi-cylinder engine incorporating an embodiment of the present invention, together with a fuel injector per cylinder, and a multi-cylinder engine controller.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention are intended to be used on diesel engines, though this is not a limitation of the invention, as the invention is also applicable to gasoline engines, or engines intended to operate on other fuels. Also, while the present invention is preferably to be used on turbocharged engines, this too is not a limitation of the invention, as the present invention is also applicable to non-turbocharged engines. Further, the preferred embodiments are intended to be used on engines having multiple intake and multiple exhaust valves, as is characteristic of most modern engines, though this too is a preference, not a limitation of the invention.

The present invention is intended to increase the volumetric efficiency of engines, in the exemplary embodiments disclosed herein, engines having two intake valves and two exhaust valves per cylinder, by selectively using all four valves, the two intake and the two exhaust valves, as both the intake valves and as the exhaust valves for that cylinder. For this purpose, much larger valves external to each combustion chamber are used to switch the coupling of the valves (intake and exhaust) between an intake manifold and an exhaust manifold. Thus the intake valves may be coupled as intake valves or exhaust valves, depending on whether it is an intake stroke or an exhaust stroke. Similarly, the exhaust valves may be coupled between the exhaust manifold and the intake manifold, depending on whether they are then currently functioning as exhaust valves or intake valves. Because these external valves can be large, they can be made to have low flow resistance, with the net result providing much better intake and exhaust breathing for the engine.

The preferred embodiments of the invention are intended to be used in what are referred to as camless engines, wherein the timing and operation of the engine valves may be electronically controlled (see for instance, U.S. Patent No. 6,739,293 entitled Hydraulic Valve Actuation Systems and Methods, the disclosure of which is hereby incorporated herein by reference). While the preferred embodiments use electronically controlled hydraulic valve actuation, other types of camless engine engine valve operation could equally as well be used. Because of that degree of control, an engine such as a diesel engine may be operated as a four cycle engine, or for higher power output, switched to two cycle operation, as desired. Consequently, in a typical application of the present invention, a diesel engine may be operated as a conventional four stroke engine using two intake valves and two exhaust valves at idle and at low engine outputs, at higher engine speeds and outputs, perhaps operated with all valves functioning as both intake and exhaust valves as described, and at still higher engine outputs operating as a two stroke engine, again with all valves functioning as both intake and exhaust valves as described. This is merely one example of the combinations of operating modes possible with the present invention.

Figure 1 presents a schematic cross-section through an engine head showing a block 20, a piston 22 and two engine valves 24. These two engine valves could be either two intake valves or two exhaust valves on the respective cylinder, with two such assemblies being used per cylinder in this example. Two two-way air switch valves 26 and 28 are shown, operated by electronically controlled hydraulic actuators 30 and 32 at the top of the Figure, with return pins 34 and 36 at the bottom being always subjected to hydraulic pressure for return of the air switch valves to the upper position when the hydraulic actuators 30 and/or 32 at the top of the air switch valves 26 and 28 are not pressurized. At the left side is the intake manifold INT and on the right side is the exhaust manifold EXH. These manifolds would be common to all cylinders of a multi-cylinder engine.

In Figure 1, the right-hand air switch valve 28 is in its upper position, preventing flow from the engine valves 24, when open, to the exhaust manifold EXH. At the same time, the air switch valve 26 at the left of the Figure is in its lower position, allowing flow past the engine valves 24, when open, from the intake manifold INT to the cylinder. Thus the two engine valves 24 shown, with the air switch valves 26 and 28 in the position illustrated, function as intake valves. However, if the air switch valves 26 and 28 are reversed in position, the two engine valves 24 shown would function as exhaust valves.

The hydraulic control valves for the hydraulically controlled engine valves and switch valves in this embodiment are shown schematically at the top of Figure 1. Hydraulic control valve HVA1 controls the two engine valves 24 for the cylinder shown, with hydraulic control valve HVA2 controlling the other two engine valves for that cylinder, not shown. Hydraulic control valves SW1 and SW2 control the switch valves 26 and 28 for the two engine valves 24 for the cylinder shown, with hydraulic control valves SW3 and SW4 controlling the other two switch valves for the other two engine valves for that cylinder, not shown. Also in this embodiment, an intensifier-type fuel injector may be used, such as one having direct needle control, and a selection of one, a second, or both intensifier actuation piston areas to provide respective intensified fuel pressures for injection, as controlled by control valves INJ1, INJ2 and INJ3. Figure 2 is an embodiment similar to that of Figure 1, but using return springs 42 for the air switch valves 26 and 28.

A top schematic view of the exemplary assembly of Figure 1 is illustrated in Figure 3. Two engine valves 24 are operated in unison by a single actuator 40 (Figures 1 and 2) controlled by control valve HVA1 as a result of the BRIDGE shown in Figure 1 and as illustrated in Figure 3 as vertical dashed lines extending between two engine valves 24. The larger circles are the associated air switch valves 26 and 28. While in Figure 1 the air switch valves 26 and 28 are shown as a form of spool/poppet valve, any type of valve of adequate speed could be used. In that regard, note that these valves are not subjected to substantial pressure differentials, and accordingly, relatively simple valves of various configurations could be used, including but not limited to rotary valves. Also, while two, two way valves are shown, a three-way valve could be used if desired.

Figures 4 and 5 show schematic cross sections of an embodiment using poppet valves 26′ and 28′ for the air switch valves. These cross sections correspond to cross sections taken along lines A-A and B-B of Figure 3. This embodiment uses hydraulic return for both the engine valves 24 and the air switch valves 26′ and 28′. Obviously however, the present invention is not limited to any form of engine valve return, or any form of air switch valves or operation thereof, provided they accommodate the desired air flow area at least as large as the combined engine valves themselves, and more preferably at least twice or three times the air flow area of the combined engine valves. It is also not limited to any form of engine valve actuation, provided the required control of engine valve operation and timing are available.

Figure 6 is a diagram illustrating an embodiment on a V-6 engine. In this embodiment, a turbocharger Turbo having a TURBINE driven from each exhaust manifold and driving an intake air COMPRESSOR is shown. Also shown is another Compressor driven by a hydraulic motor, augmented by a hydraulic accumulator. Obviously many variations of engine inlet air implementations will be apparent to those skilled in the art.

Now referring to Figure 7, a multi-cylinder engine is schematically illustrated. Each cylinder of the engine includes valves INV and EXV normally functioning as intake and exhaust valves, respectively, by setting the respective air switch valves to the appropriate position and leaving them there. However when desired, both intake valves INV and exhaust valves EXV for any, and usually all cylinders, can be used as both intake valves and as exhaust valves whenever desired. The fuel injectors normally used on such engines are not shown for clarity. There are of course small internal manifolds IM between the air switch valves and the engine intake valves INV and the engine exhaust valves EXH, though preferably these manifold volumes are kept relatively small.

Figure 8 is a block diagram of a multi-cylinder engine incorporating an embodiment of the present invention, together with a fuel injector per cylinder, and a multi-cylinder engine controller. Normally the controller will respond to various inputs for control of engine valve timing, the associated switch valves and injectors based on various inputs, such as crankshaft angle and speed (measured or calculated from the changing crankshaft angle) and power setting, as well as other parameters such as intake manifold pressure, air temperature, engine temperature, etc. Note also, of course, the present invention may be used for engine compression braking, in the embodiment disclosed, using all four engine valves per cylinder to vent each cylinder when the piston is at or near top dead center. This venting may be to the exhaust manifold, or to the intake manifold to recover some of the energy of compression when braking.

While in the preferred embodiments, when desired, all valves are used for both intake and exhaust, note that one could always use the intake valves for intake and switch only the exhaust valves between functioning as exhaust and intake valves, or vice versa, thereby eliminating the need for switching valves on the engine intake valves or the engine exhaust valves, respectively. The advantage, particularly with respect to increasing the volumetric efficiency on intake, is two-fold. First, less energy is lost by the pressure drop through the intake valves, and secondly, more air is ingested, allowing injection of greater amounts of fuel to obtain greater engine output. Thus both efficiency and maximum power output are increased.

Thus the present invention has a number of aspects, which aspects may be practiced alone or in various combinations or sub-combinations, as desired. Also while certain preferred embodiments of the present invention have been disclosed and described herein for purposes of exemplary illustration and not for purposes of limitation, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A piston engine comprising:

at least one intake valve and at least one exhaust valve per piston engine cylinder; and,

a flow control valve system for controllably coupling the at least one intake valve to an intake manifold or to an exhaust manifold, and for controllably coupling the at least one exhaust valve to an exhaust manifold or to an intake manifold;

the at least one intake valve and at least one exhaust valve per piston engine cylinder being actuated by camless actuators.

2. The piston engine of claim 1 wherein the flow control system comprises two, two-way valves per cylinder.

3. The piston engine of claim 2 wherein for each intake valve, a first two-way valve controllably couples the intake valve to the intake manifold or blocks the coupling of the intake valve to the intake manifold, and for each exhaust valve, a second two-way valve controllably couples the exhaust valve to the exhaust manifold or blocks the coupling of the intake valve to the exhaust manifold, the at least one intake valve and the at least one exhaust valve being manifolded together.

4. The piston engine of claim 3 wherein a first two-way valve controllably couples the at least one intake valve to the intake manifold or blocks the coupling of the at least one intake valve to the intake manifold, and a second two-way valve controllably couples the at least one exhaust valve to

the exhaust manifold or blocks the coupling of the at least one intake valve to the exhaust manifold, the at least one intake valve and the at least one exhaust valve being manifolded together.

5. The piston engine of claim 1 further comprising a control system for controlling the camless actuators and the flow control valve system to operate the engine as a four cycle engine or as a two cycle engine.

6. The piston engine of claim 1 further comprising a control system for controlling the camless actuators and the flow control valve system to operate the engine using the intake valves for intake and the exhaust valves for exhaust, and to operate the engine using the intake valves for both intake exhaust and the exhaust valves for both intake and exhaust.

7. The piston engine of claim 1 wherein the flow control system couples the intake valves to the intake manifold or blocks the coupling of the intake valves to the intake manifold, and couples the exhaust valves to the exhaust manifold or blocks the coupling of the exhaust valves to the exhaust manifold, the at least one intake valve and the at least one exhaust valve being manifolded together.

8. The piston engine of claim 1 wherein the piston engine is a camless engine further comprising:

a control system for each cylinder to control the intake and exhaust valves so that;

at times, the piston engine operates as a 4 cycle engine using the at least one intake valve as intake valves and the at least one exhaust valve as exhaust valves; and at other times, the piston engine operates as a 4 cycle engine using all the intake and exhaust valves as intake valves and all intake and exhaust valves as exhaust valves.

9. The piston engine of claim 8 further comprising at still other times, the control system controls the intake and exhaust valves so that the piston engine operates as a 2 cycle engine.

10. The piston engine of claim 9 wherein the piston engine sometimes operates as a 2 cycle engine using all the intake and exhaust valves as intake valves and all intake and exhaust valves as exhaust valves.

11. A method of operating a camless piston engine having at least one intake valve and at least one exhaust valve per cylinder comprising:

for each cylinder;

at times, operating the piston engine as a 4 cycle engine using the at least one intake valve as intake valves and the at least one exhaust valve as exhaust valves; and

at other times, operating the piston engine as a 4 cycle engine using all the intake and exhaust valves as intake valves and all intake and exhaust valves as exhaust valves.

12. The method of claim 11 further comprising at still other times, operating the piston engine as a 2 cycle engine.

13. The method of claim 12 wherein the piston engine is sometimes operated as a 2 cycle engine using all the intake and exhaust valves as intake valves and all intake and exhaust valves as exhaust valves.

14. In a piston engine, the improvement comprising:

at least one intake valve and at least one exhaust valve per piston engine cylinder; and,

a flow control system for each cylinder for controllably coupling the at least one intake valve to an intake manifold or to an exhaust manifold, and for controllably coupling the at least one exhaust valve to an exhaust manifold or to an intake manifold.

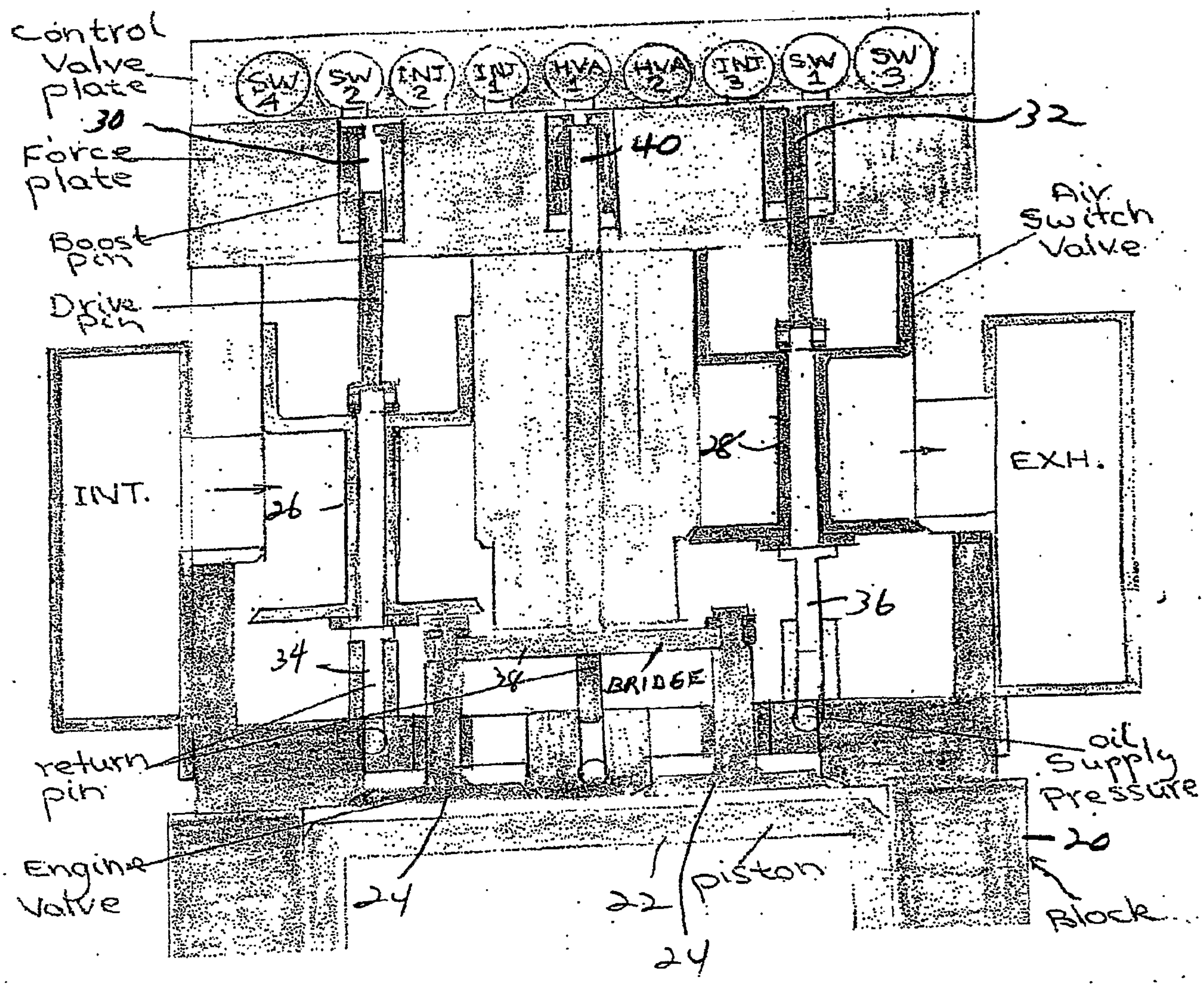
15. The improvement of claim 14 wherein the flow control system comprises one two-way valve per intake valve and one two-way valve per exhaust valve.

16. The improvement of claim 15 wherein for each intake valve, a first two-way valve controllably couples the intake valve to the intake manifold or blocks the coupling of the intake valve to the intake manifold, and for each exhaust valve, a second two-way valve controllably couples the exhaust valve to the exhaust manifold or blocks the coupling of the exhaust valve to the exhaust manifold, the at least one intake valve and the at least one exhaust valve being manifolded together.

17. The improvement of claim 15 wherein the piston engine includes multiple intake valves and multiple exhaust valves, the flow control system having an air flow area at least as large as the combined intake and exhaust valve air flow area when coupling the intake and exhaust valves to an intake manifold, and when coupling the intake and the exhaust valves to an exhaust manifold.

18. The improvement of claim 14 wherein the flow control system couples the intake valves to the intake manifold or blocks the coupling of the intake valves to the

intake manifold, and couples the exhaust valves to the exhaust manifold or blocks the coupling of the exhaust valves to the exhaust manifold, the at least one intake valve and the at least one exhaust valve being manifolded together.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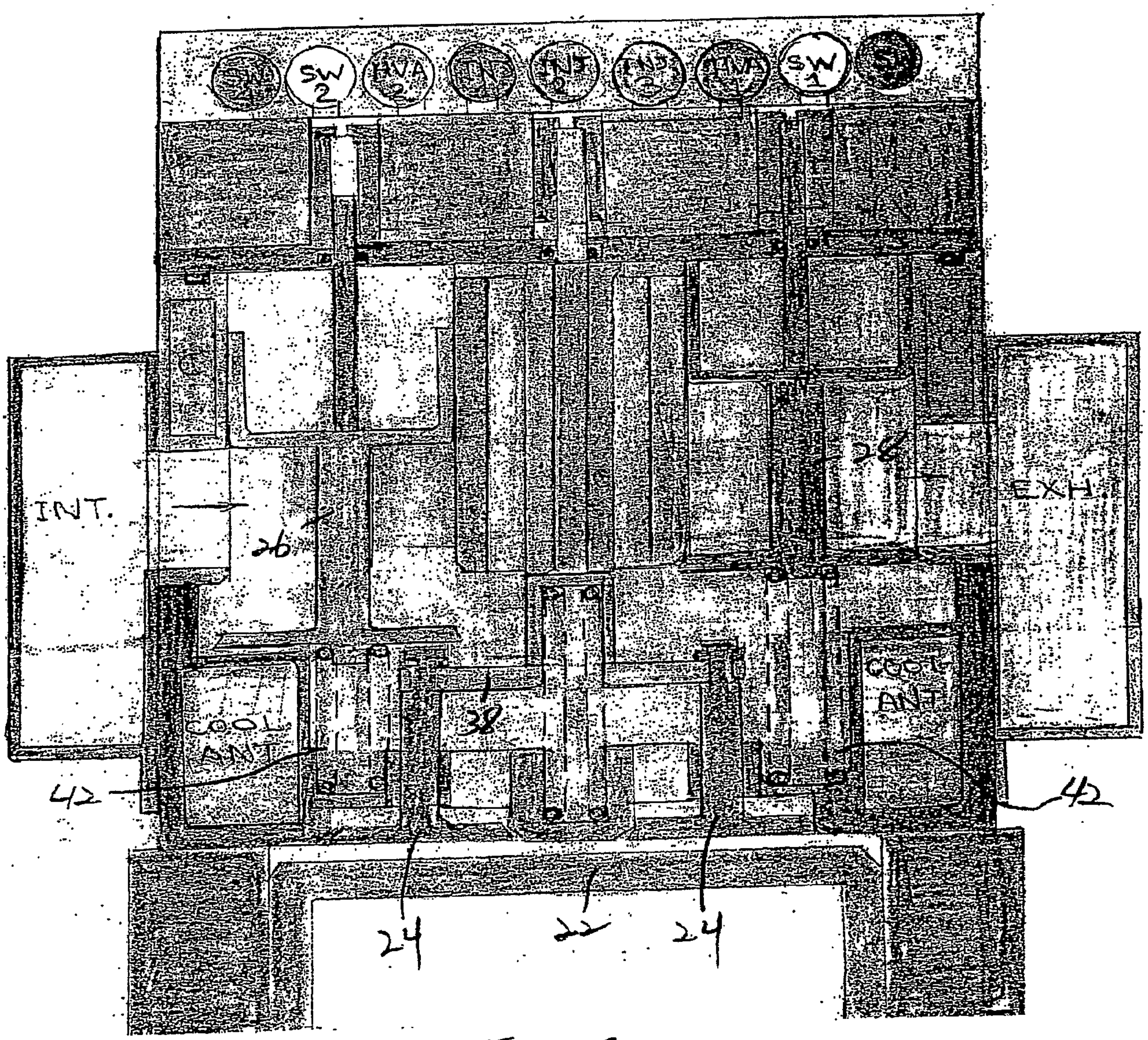
SW 2
INJ 2
INJ 1
HVA 1
HVA 2
INJ 3
SW 1
SW 3
30
32
40
Force plate
Boost pin
Air Switch Valve
Drive pin
INT.
EXH.
26
28
36
34
38
BRIDGE
return pin
oil Supply Pressure
Engine Valve
24
22
piston
24
20
Block

Fig. 1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HVA 2
INT 2
SW 1
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EXH.
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COOL ANT
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24
22
24

Fig. 2

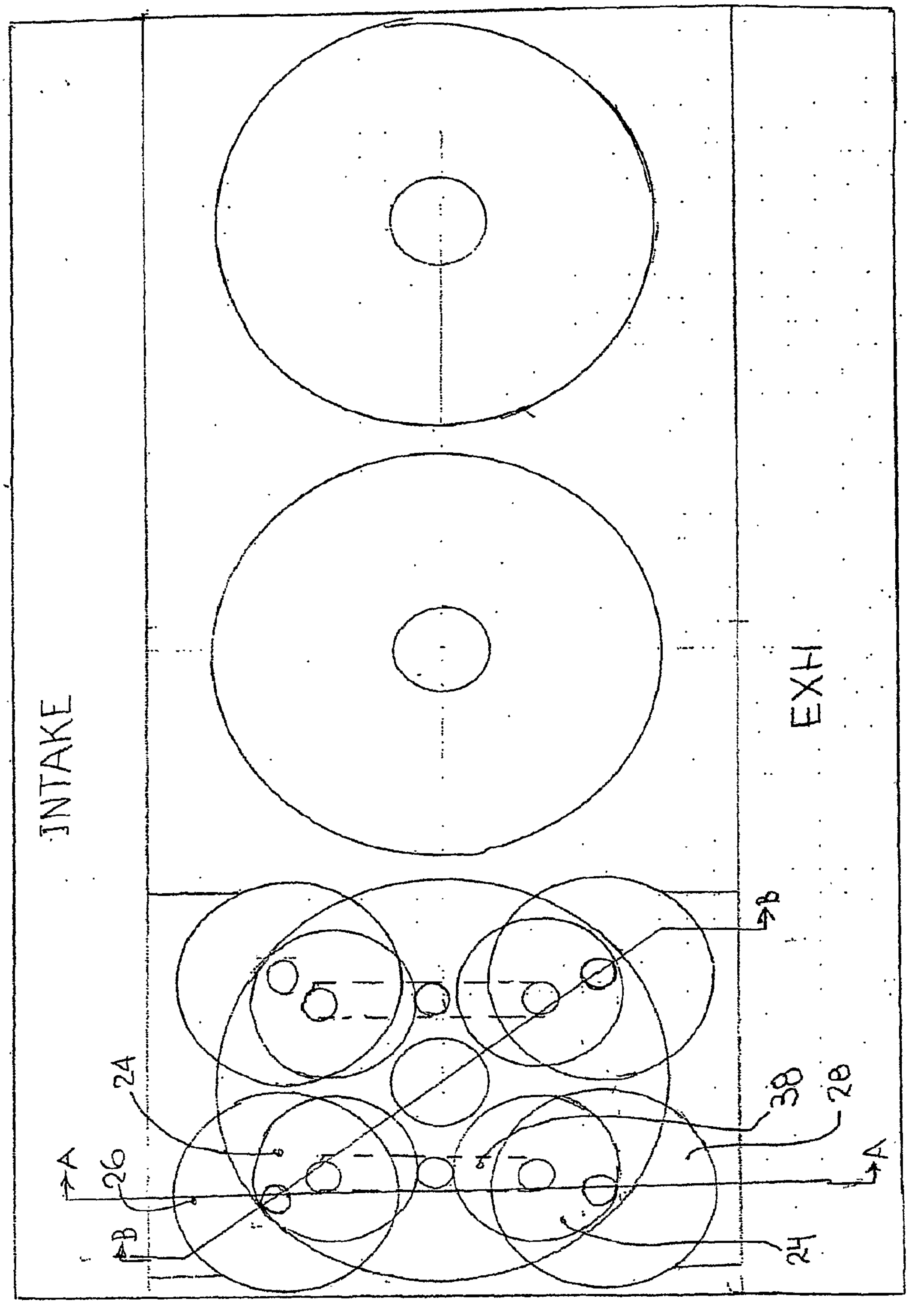
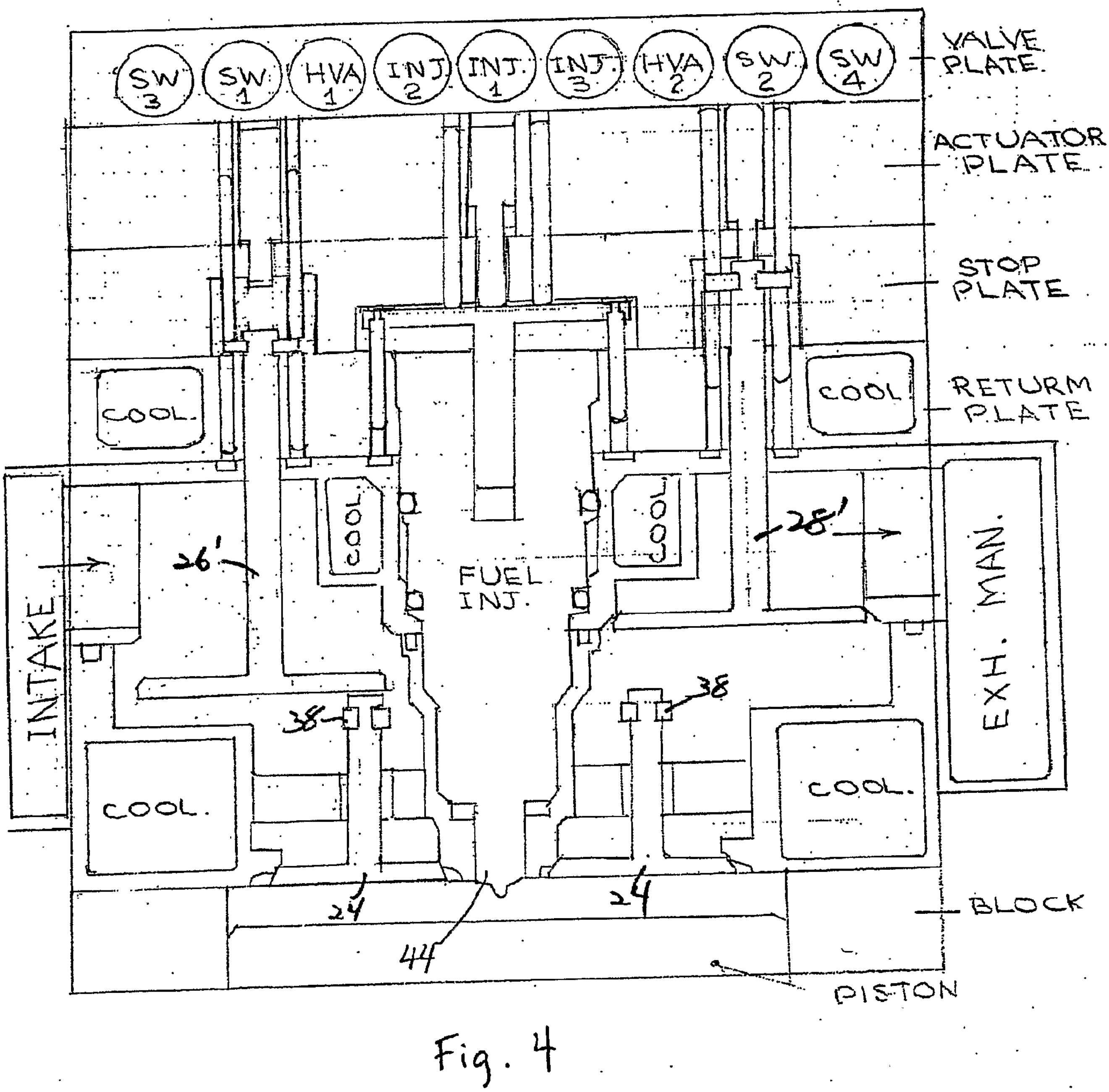


Fig. 3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HVA 1
INJ 2
INJ 1
INJ 3
HVA 2
SW 2
SW 4
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ACTUATOR PLATE
STOP PLATE
RETURN PLATE
COOL.
COOL
COOL
COOL
COOL.
COOL.
FUEL INJ.
INTAKE
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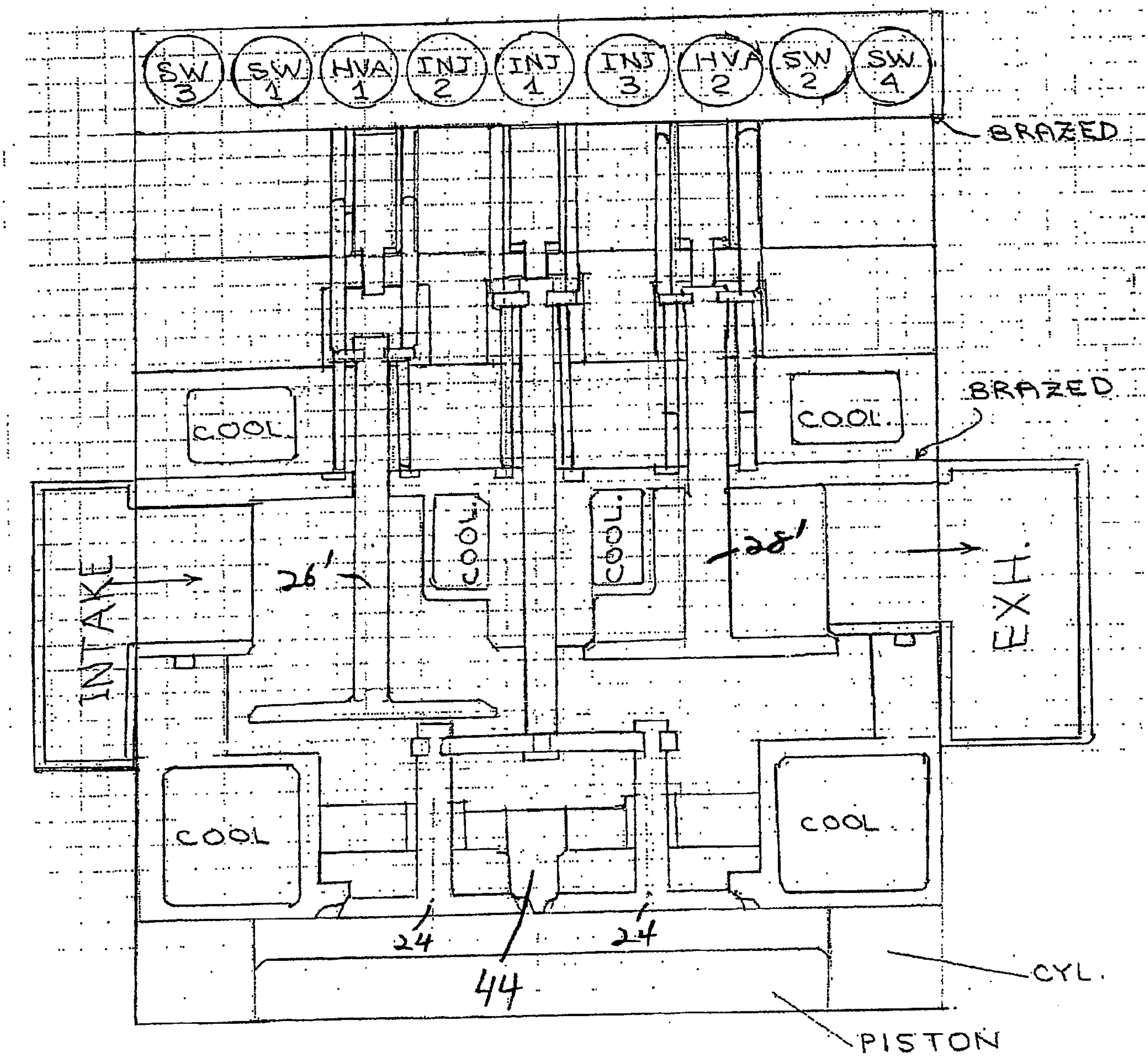
28'
EXH. MAN.
38
38
24
24
44
BLOCK
PISTON

Fig. 4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HVA 1
INJ 2
INJ 1
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COOL
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INTAKE
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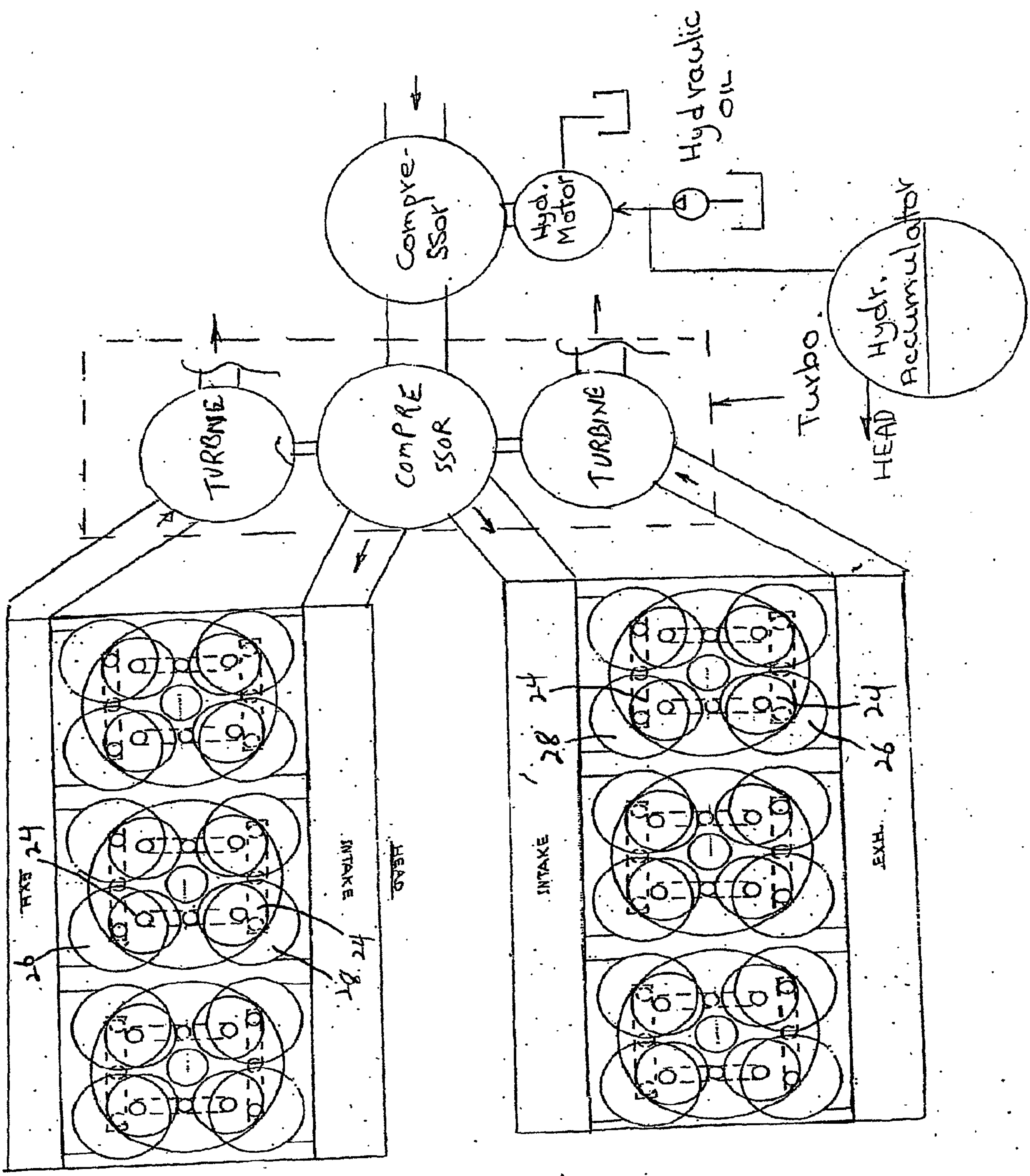
28'
EXH.
COOL
COOL
24
44
24
CYL.
PISTON

Fig. 5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Compressor
Hyd. Motor
Hydr. Accumulator
Turbo
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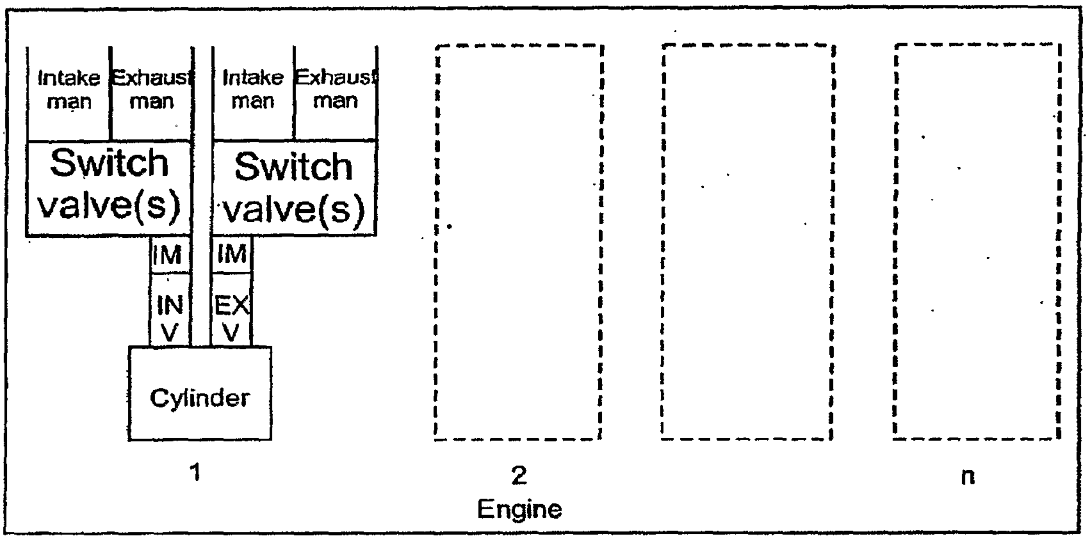
TURBINE
COMPRESSOR
TURBINE
24
26
28
INTAKE
HEAD
INTAKE
EXH.

Fig. 6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Exhaust man
Switch valve(s)
IM
IN V
EX V
Cylinder
1
2
n
Engine

Fig. 7

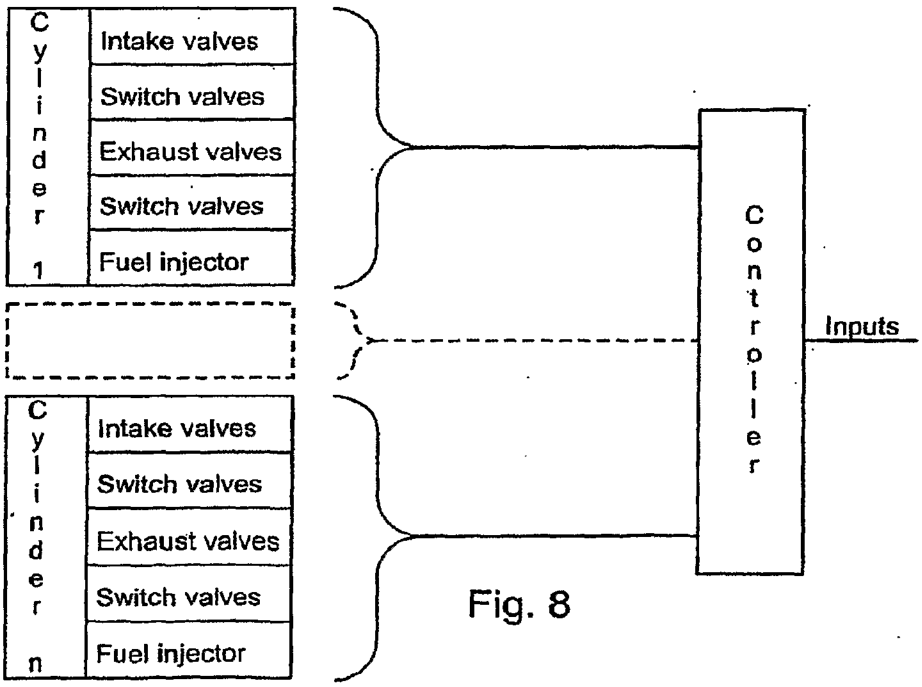
Cylinder 1
Intake valves
Switch valves
Exhaust valves
Switch valves
Fuel injector
Cylinder n
Controller
Inputs

Fig. 8