US 20140102408A1

(19) United States
(12) Patent Application Publication
Knob et al.
(10) Pub. No.: US 2014/0102408 A1
(43) Pub. Date: Apr. 17, 2014

(54) MULTI-CYLINDER INTERNAL COMBUSTION ENGINE USING EXHAUST GASES TO INCREASE CYLINDER FILLING

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(21) Appl. No.: **14/123,169**

(22) PCT Filed: **Jun. 4, 2012**

(86) PCT No.: **PCT/CZ2012/000046**

§ 371 (c)(1), (2), (4) Date: **Dec. 6, 2013**

(30) **Foreign Application Priority Data**

Jun. 3, 2011 (CZ) PV2011-333

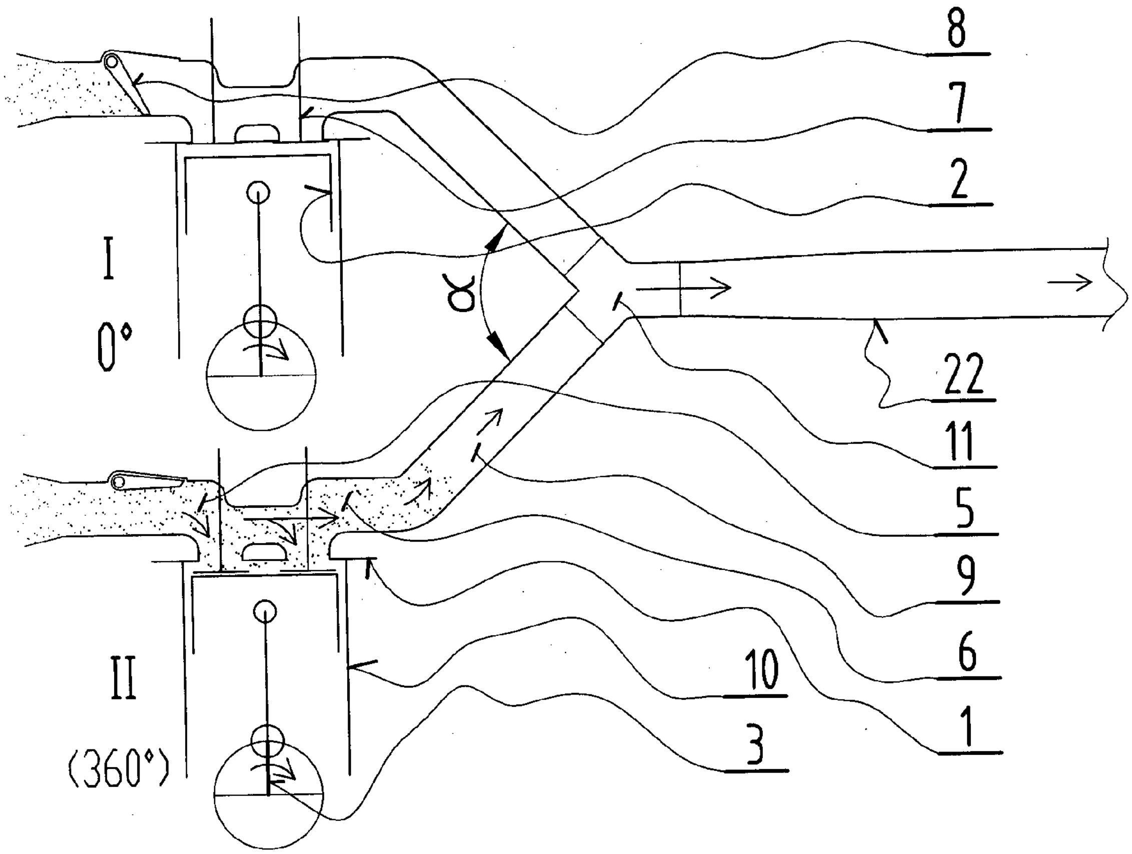
Publication Classification

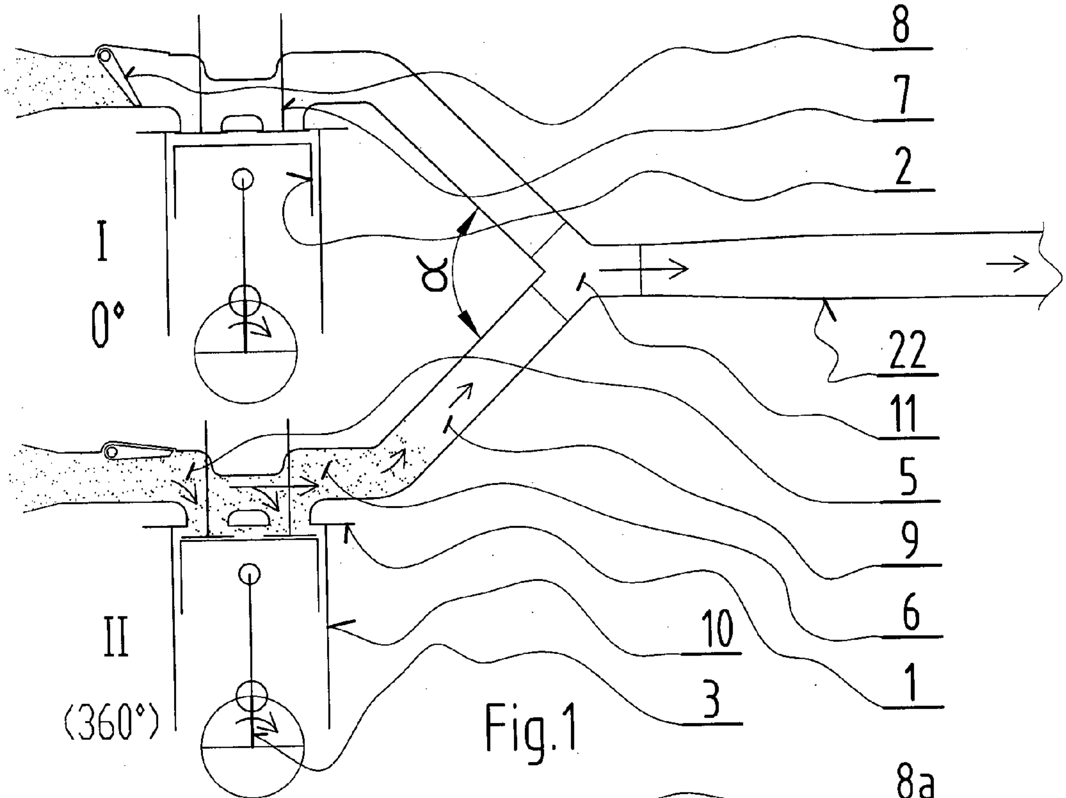
(51) **Int. Cl.**
F01L 1/34 (2006.01)

(52) **U.S. Cl.**
CPC *F01L 1/34* (2013.01)
USPC **123/312**

(57) **ABSTRACT**

Multi-cylinder internal combustion engine using exhaust gases to increase cylinder filling comprises cylinders (**10**) with pistons (**2**), a head (**1**) with lifting valves (**7**) and a crankshaft mechanism (**3**) and is provided with two cylinders (**10**) with mutually shifted four-stroke cycle and/or is provided with three cylinders (**10**) with mutually shifted four-stroke cycle and in the head (**1**) of each cylinder (**10**) there is at least one intake port (**5**) interconnected with at least one exhaust port (**6**) and at least one lifting valve (**7**), while the intake port (**5**) is provided with at least one valve (**8**) and an exhaust branch (**9**) is connected to the exhaust port (**6**) and simultaneously exhaust branches (**9**) of two cylinders (**10**) with mutually shifted cycle are farther joined in a joint (**11**) into one cross-section and/or exhaust branches (**9**) of three cylinders (**10**) with mutually shifted cycle are farther joined in another joint into one cross-section.

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α
22
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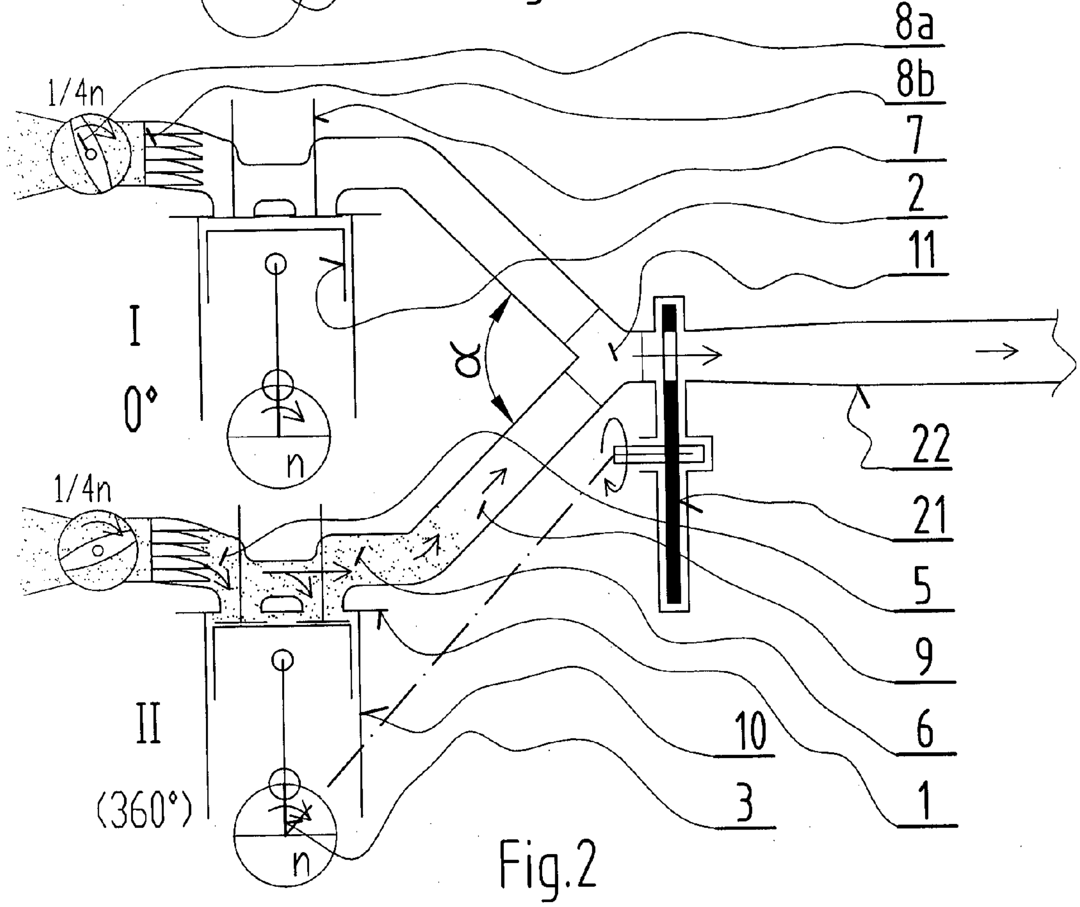
9
6
10
1
II
(360°)
3

Fig.1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8b
1/4n
7
2
11
I
0°
α
n
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21
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5
9
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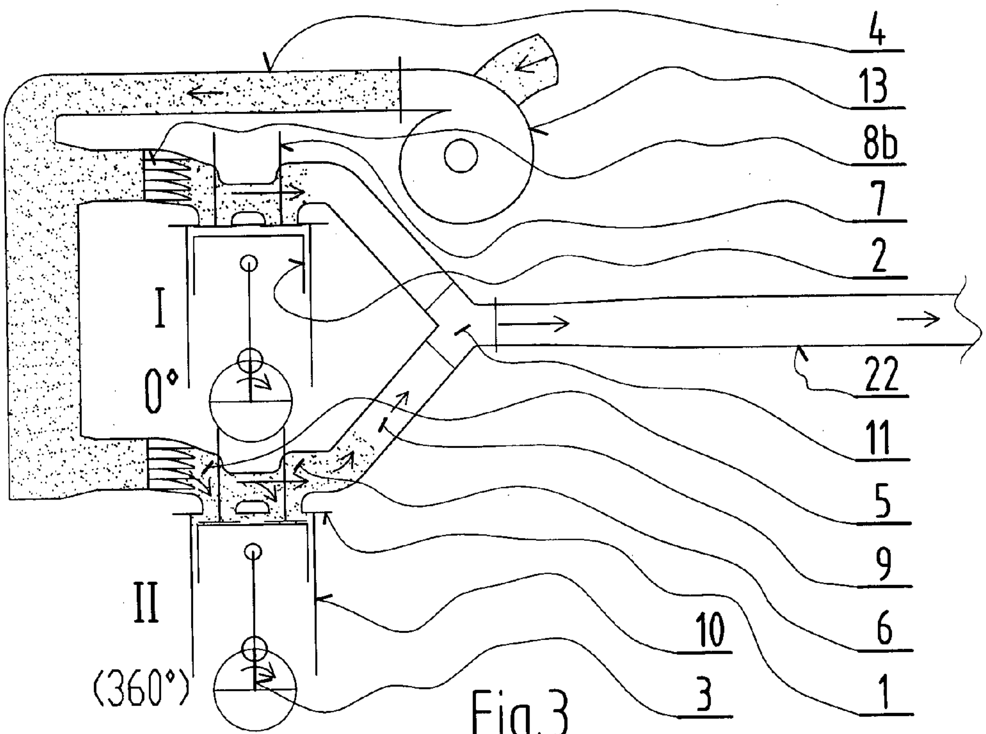
10
II
(360°)
3
1
n

Fig.2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8b
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II
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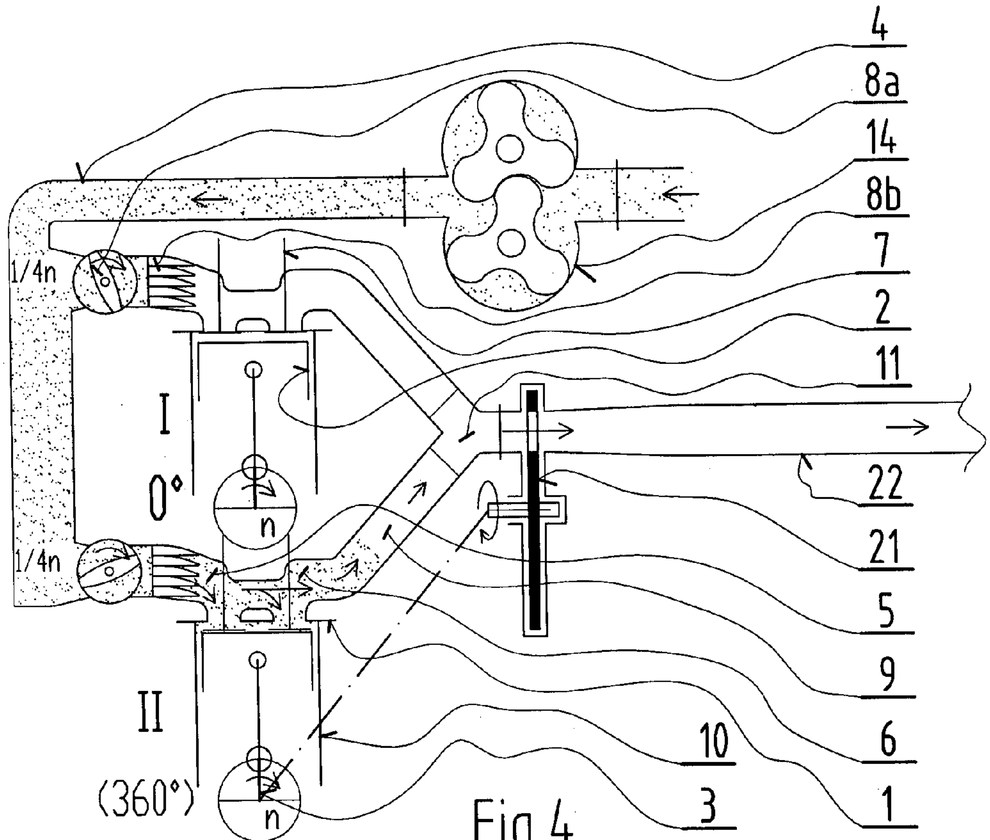
Fig.3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1/4n
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n
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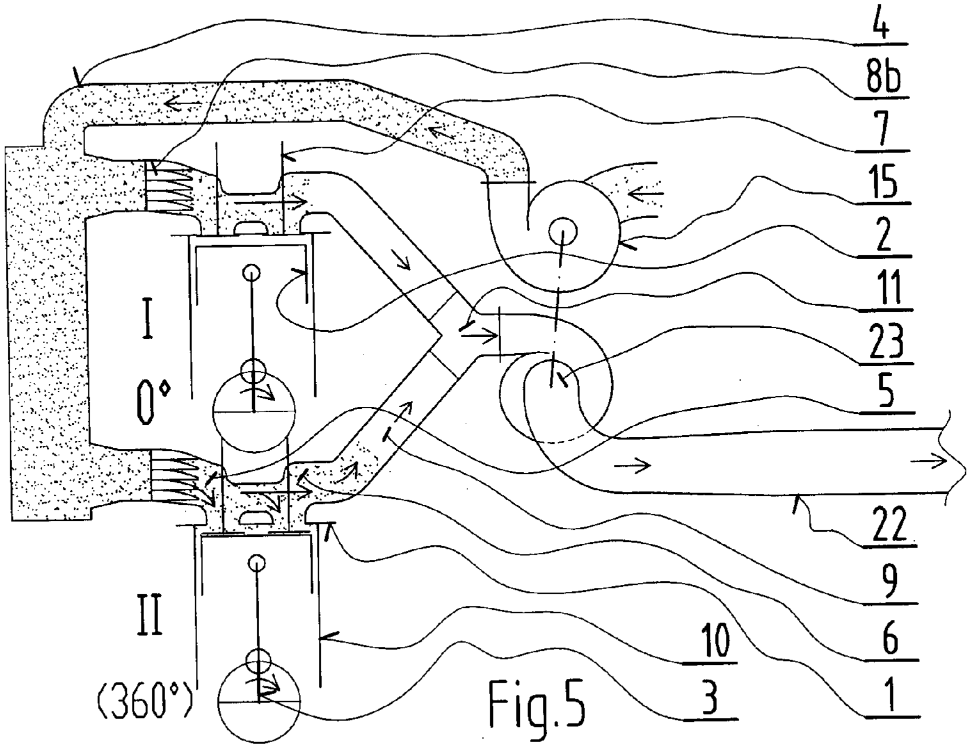
n
3
1

Fig.4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22
9
6
10
1
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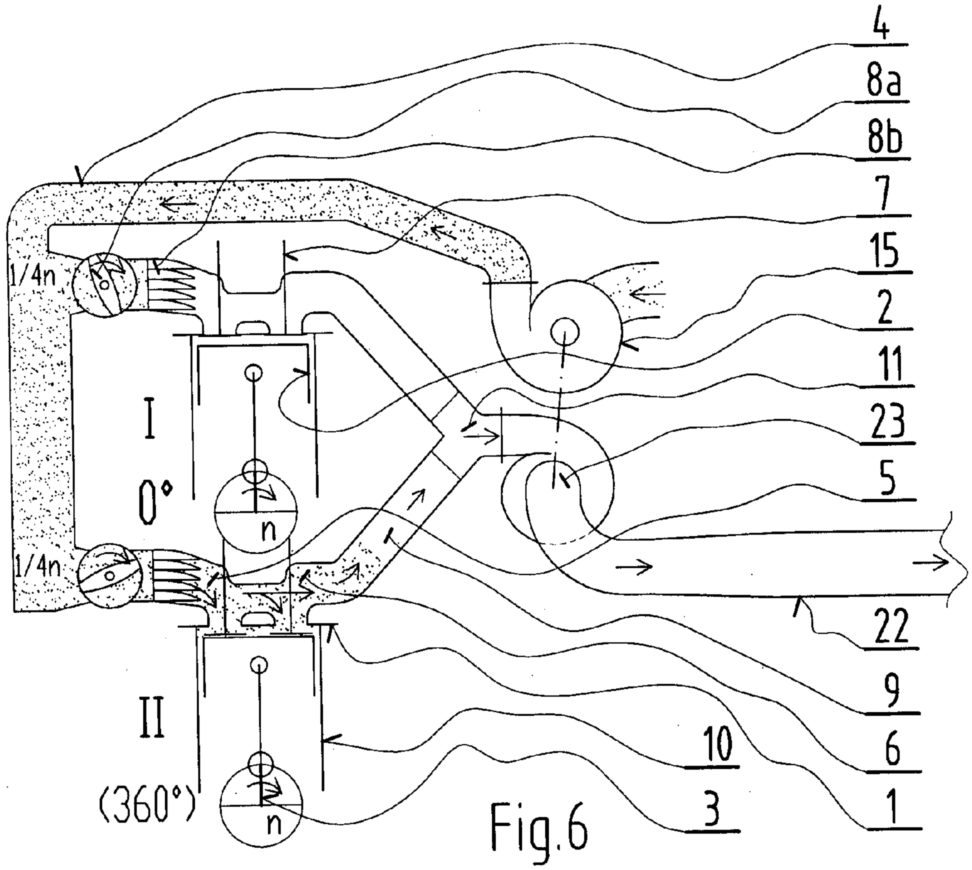
I
0°
II
(360°)

Fig.5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7
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2
11
23
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10
1
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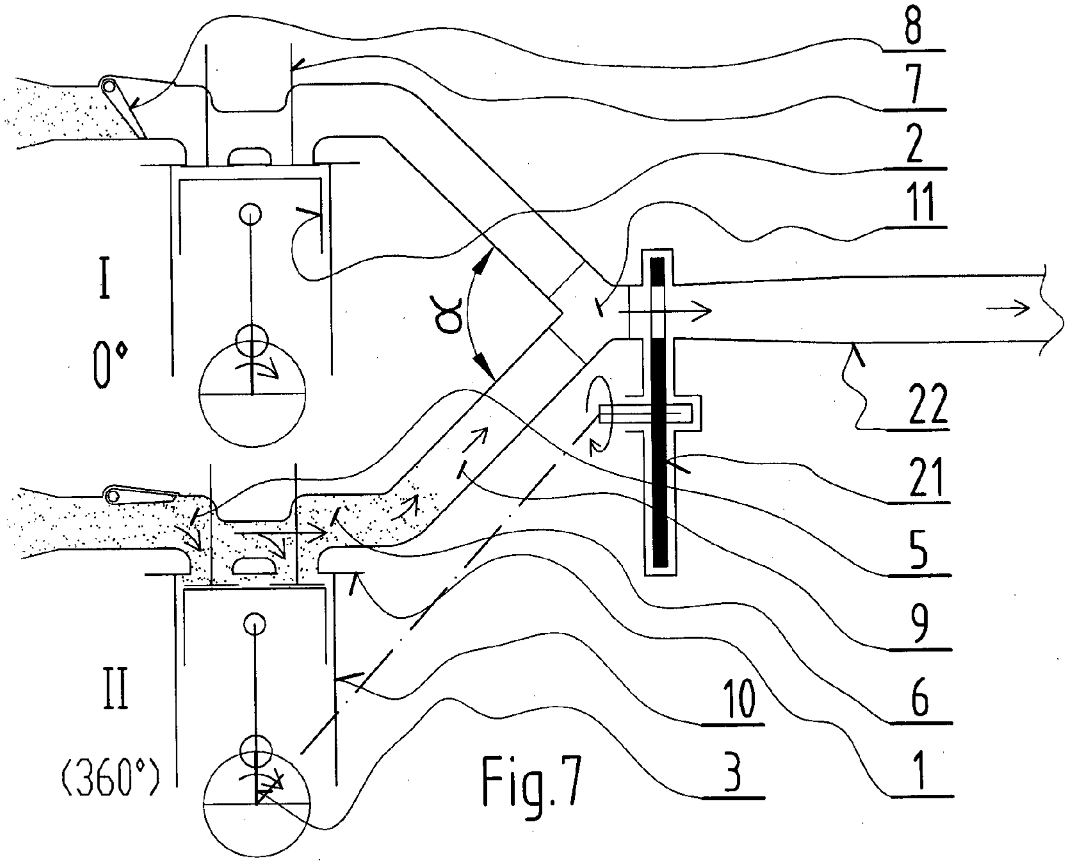
1/4n
1/4n
I
0°
n
II
(360°)
n

Fig.6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22
21
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9
6
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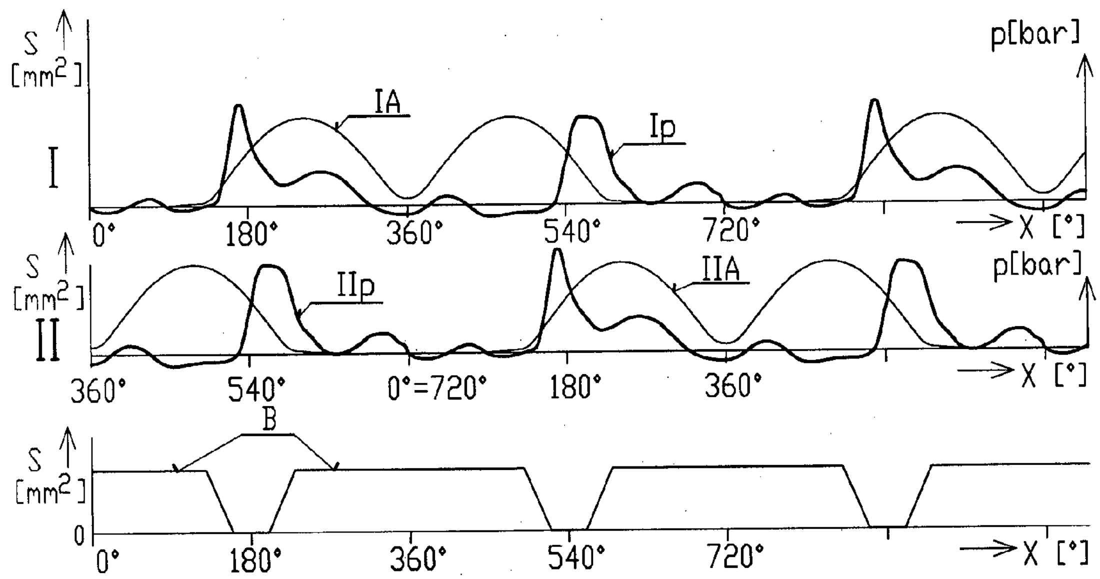
II
(360°)
3
1

Fig.7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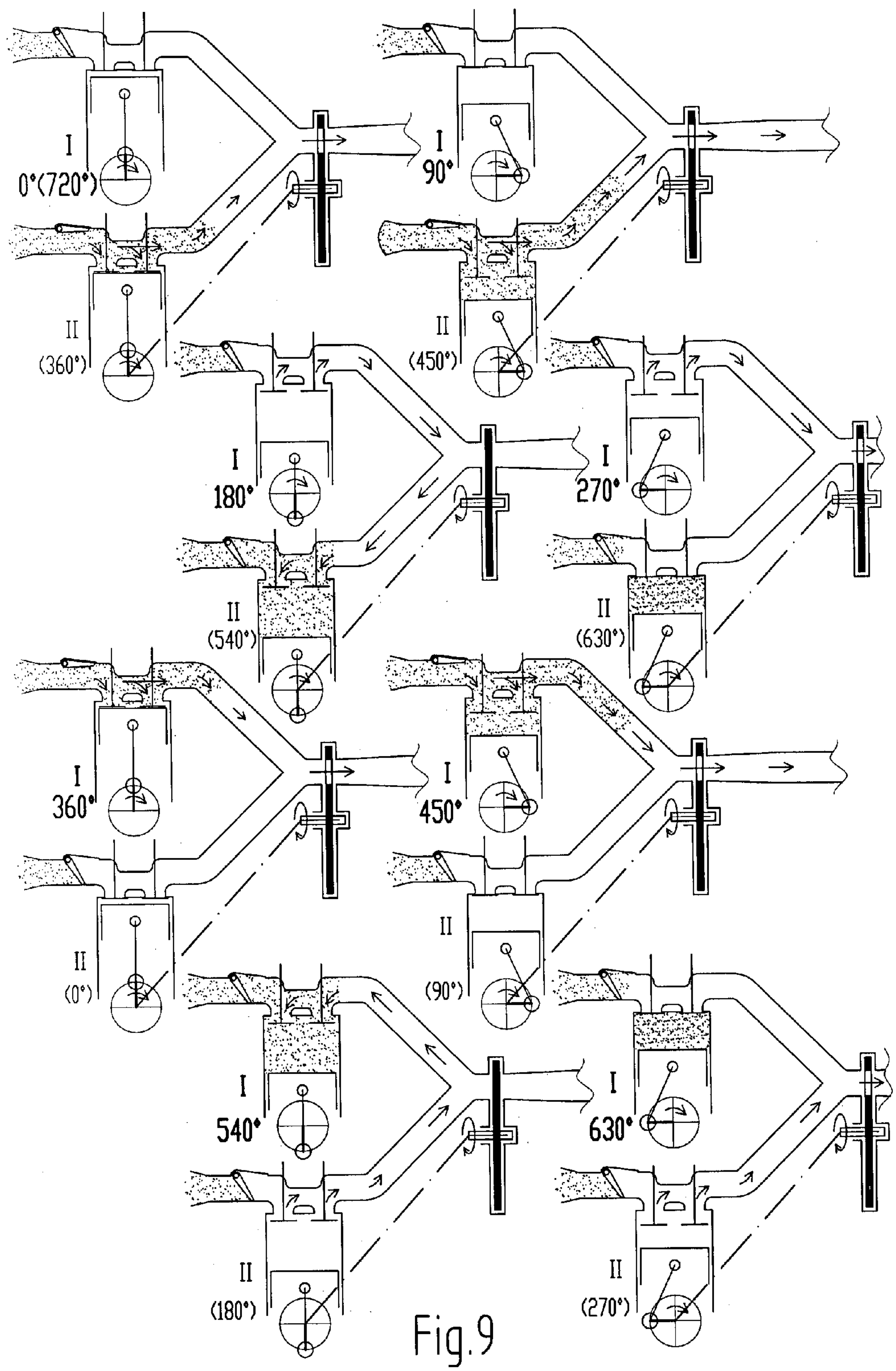
[mm2]
p[bar]
IA
Ip
I
0°
180°
360°
540°
720°
X [°]
S
[mm2]
p[bar]
IIp
IIA
II
360°
540°
0°=720°
180°
360°
X [°]
B
S
[mm2]
0
0°
180°
360°
540°
720°
X [°]

Fig.8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II
(360°)
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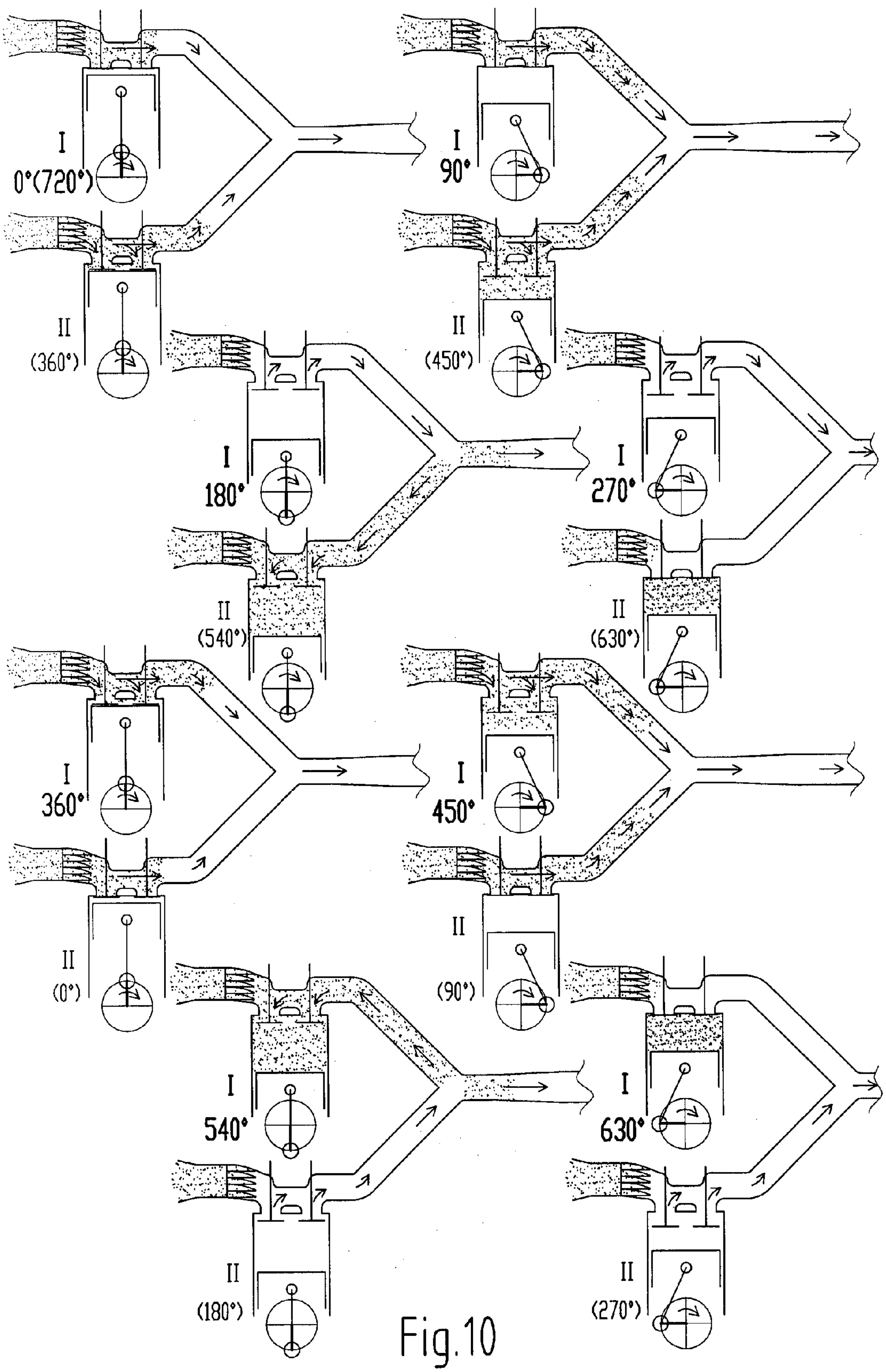
90°
II
(450°)
I
180°
II
(540°)
I
270°
II
(630°)
I
360°
II
(0°)
I
450°
II
(90°)
I
540°
II
(180°)
I
630°
II
(270°)

Fig.9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(450°)
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180°
II
(540°)
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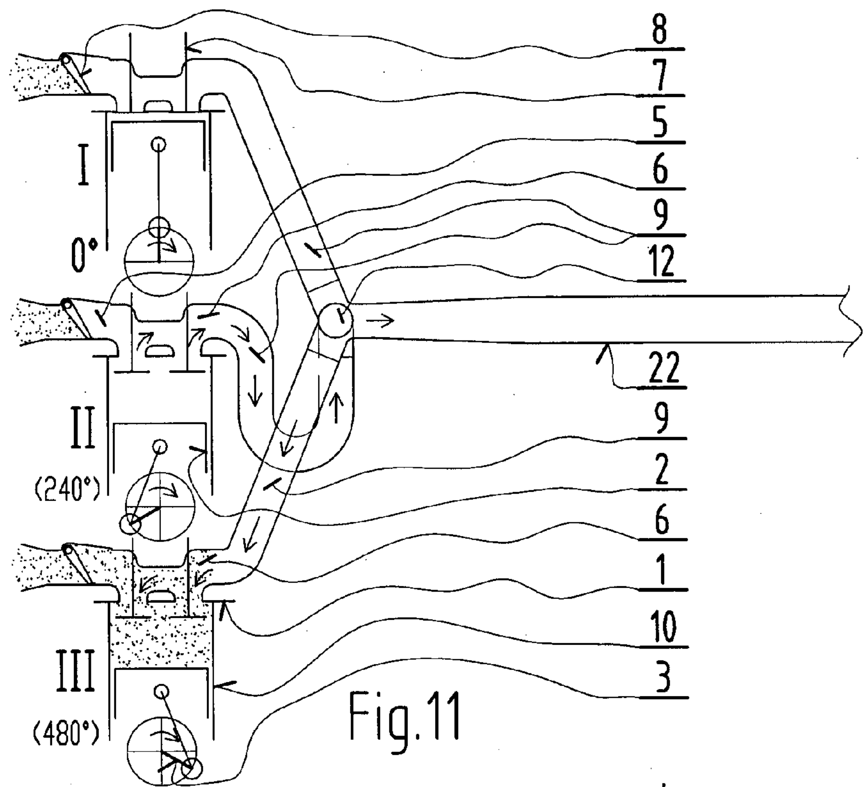
270°
II
(630°)
I
360°
II
(0°)
I
450°
II
(90°)
I
540°
II
(180°)
I
630°
II
(270°)

Fig.10


8
7
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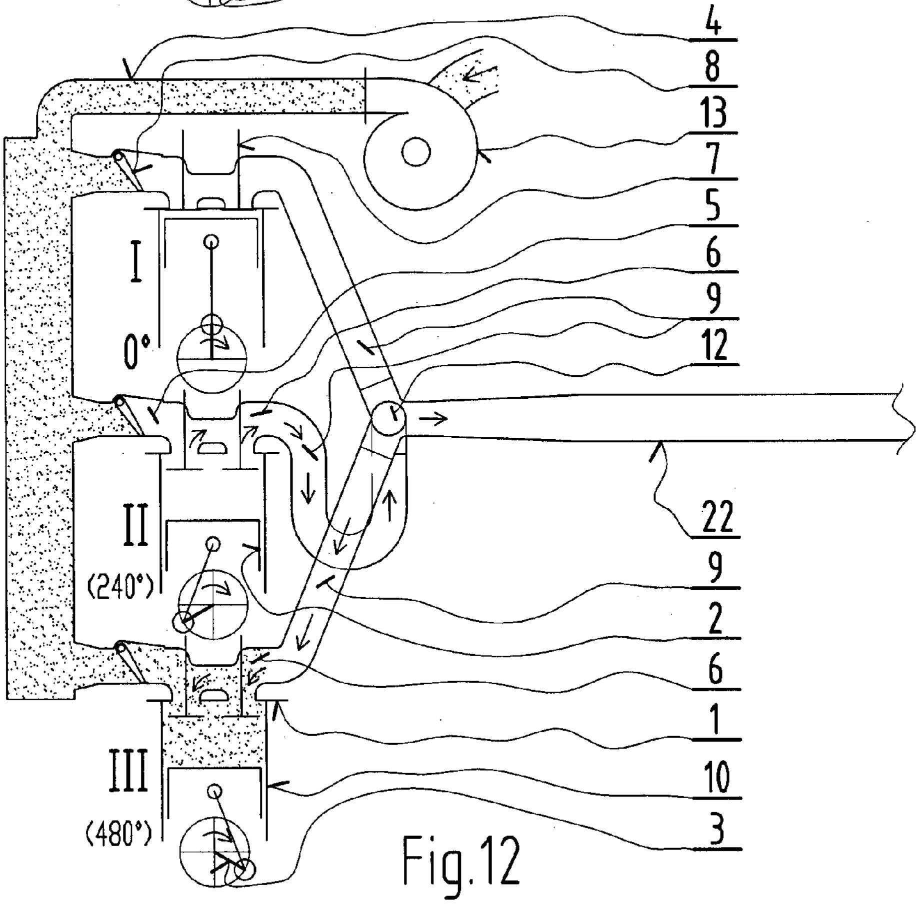
9
12
I
0°
22
II
(240°)
9
2
6
1
10
III
(480°)
3

Fig.11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(240°)
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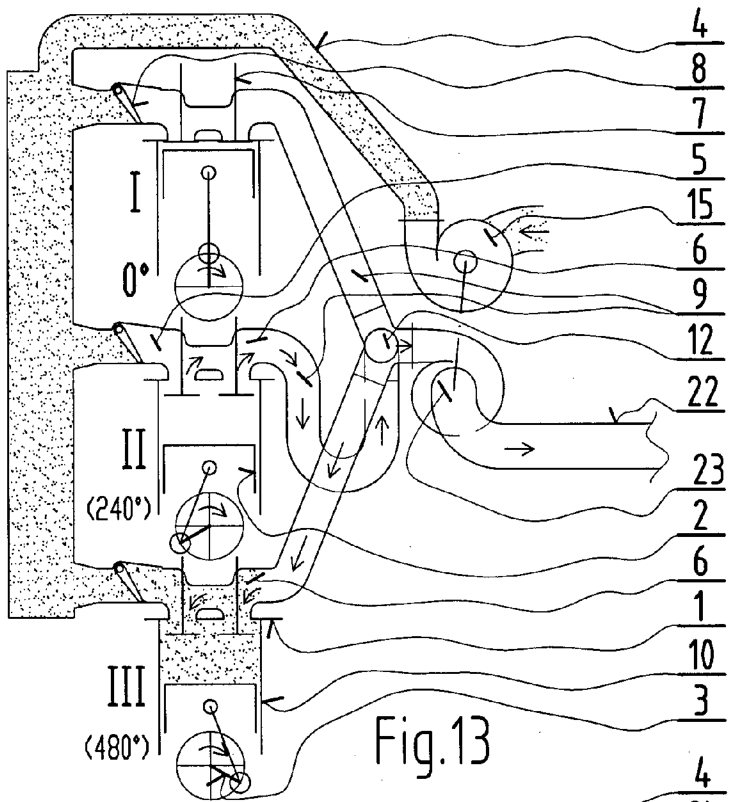
III
(480°)
3

Fig.12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23
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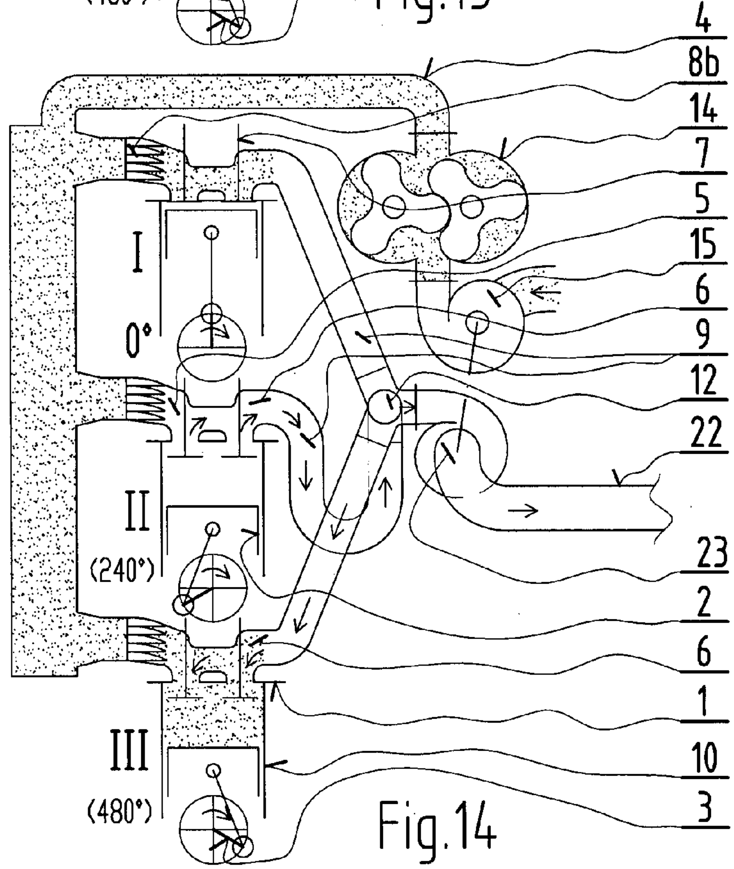
3
I
0°
II
(240°)
III
(480°)

Fig.13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23
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10
3
I
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III
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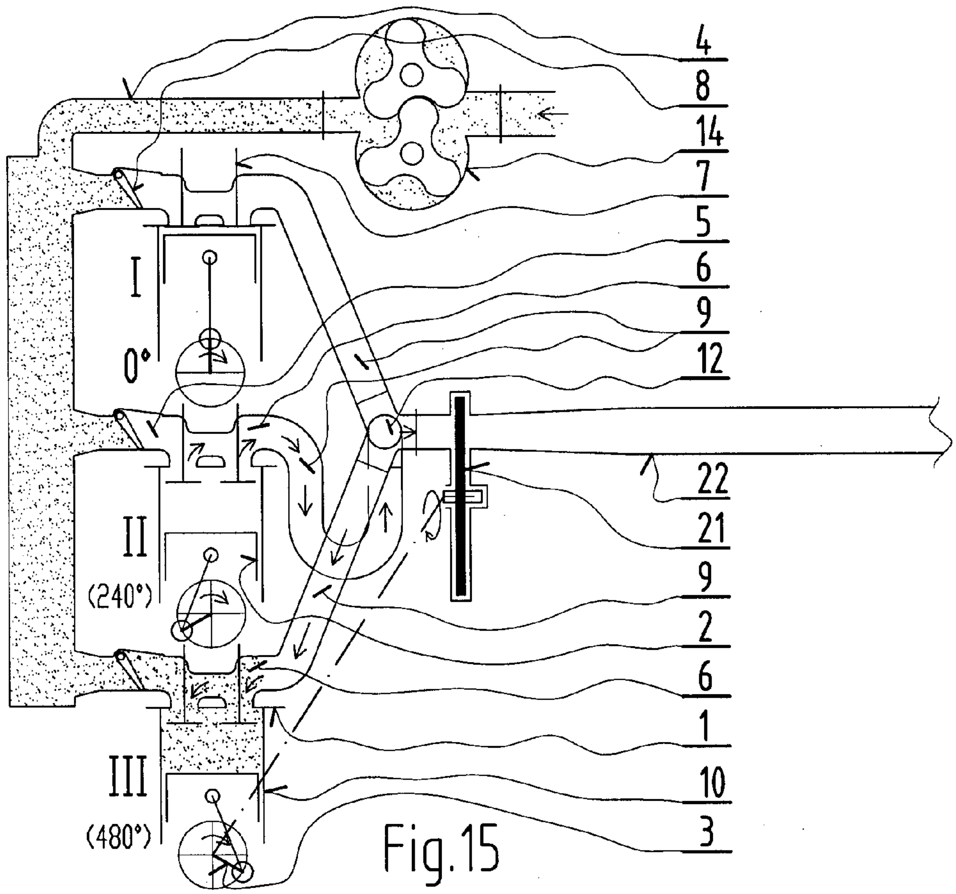
Fig.14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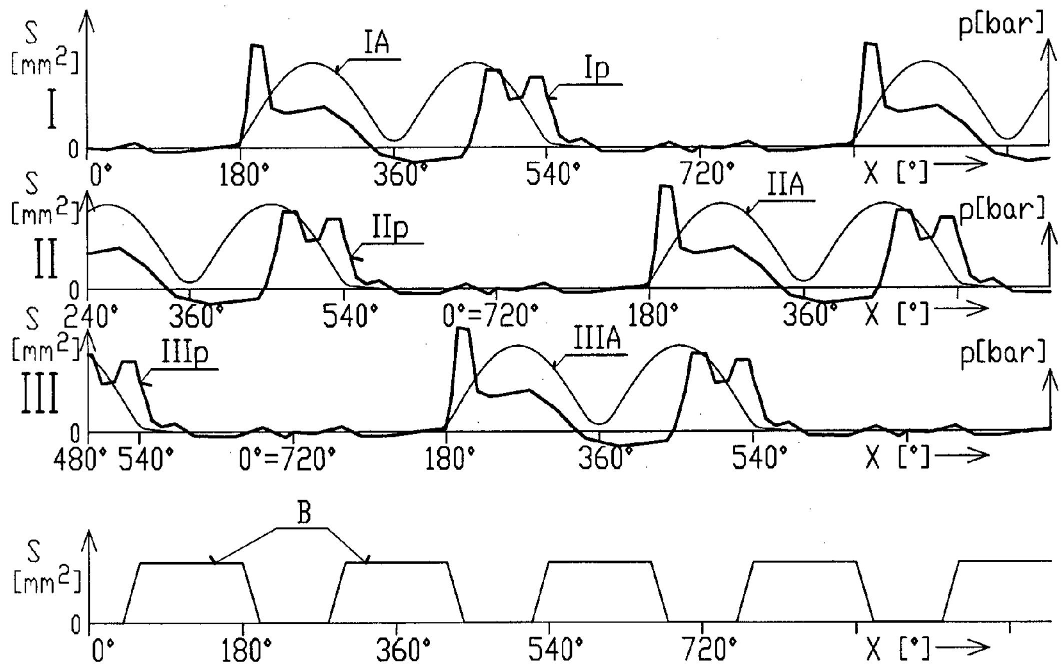
II
(240°)
III
(480°)

Fig.15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IA
Ip
p[bar]
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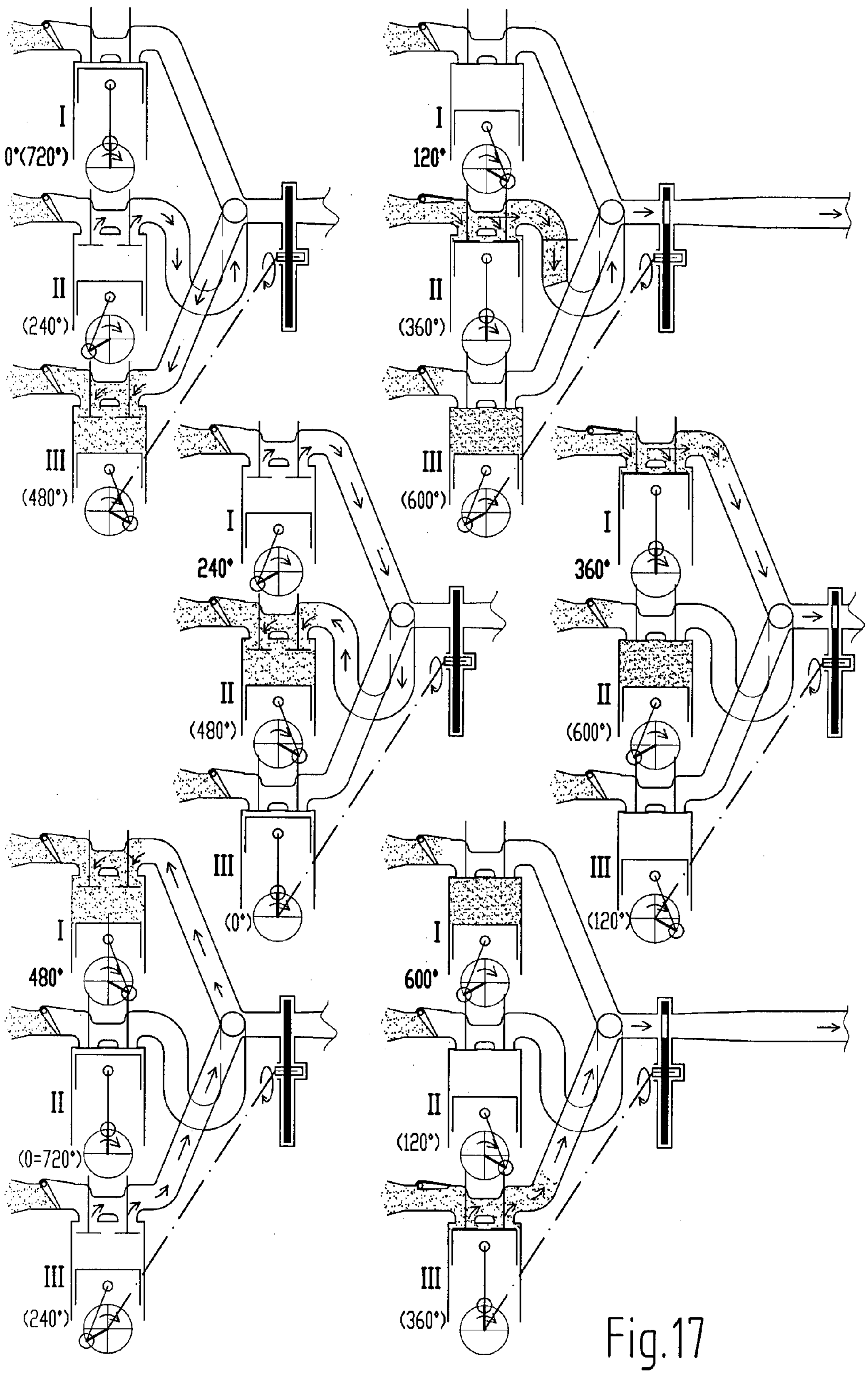
0°
180°
360°
540°
720°
X [°]
II
IIA
IIp
240°
0°=720°
III
IIIA
IIIp
480°
B

Fig.16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(240°)
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III
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(480°)
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(0°)
I
360°
II
(600°)
III
(120°)
I
480°
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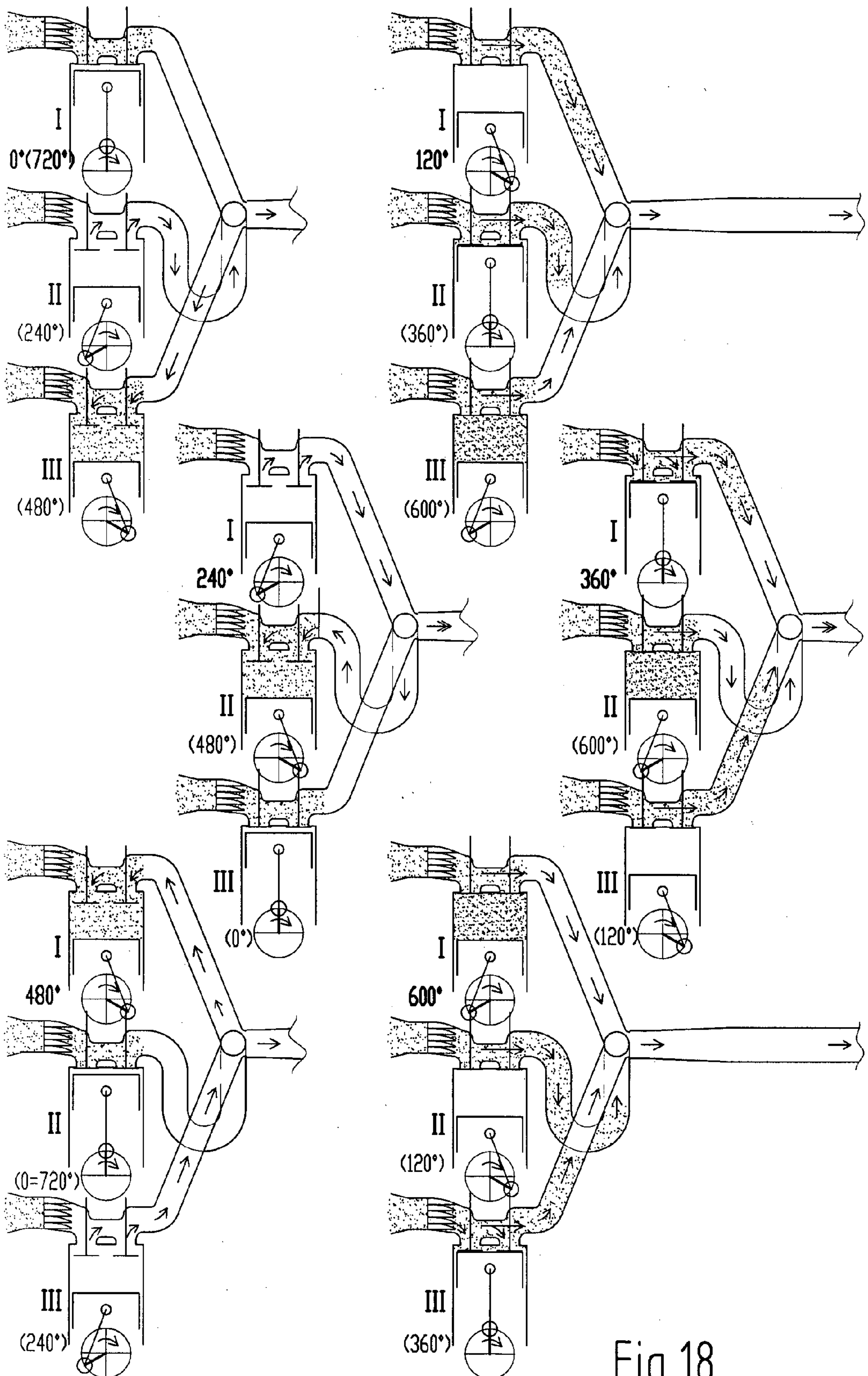
(0=720°)
III
(240°)
I
600°
II
(120°)
III
(360°)

Fig.17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III
(0°)
I
360°
II
(600°)
III
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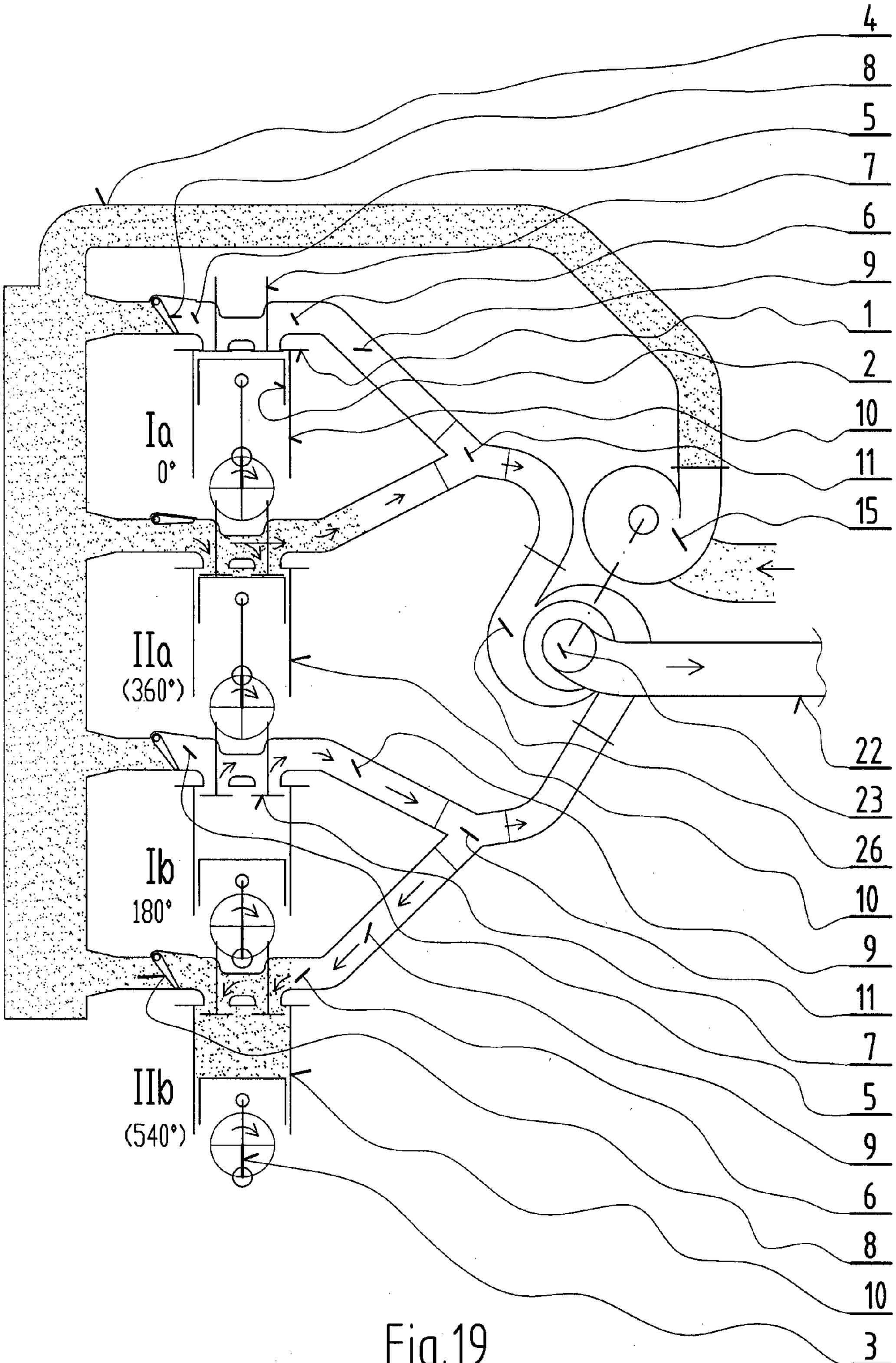
III
(360°)

Fig.18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6
9
1
2
10
11
15
Ia
0°
IIa
(360°)
Ib
180°
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8
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3

Fig.19

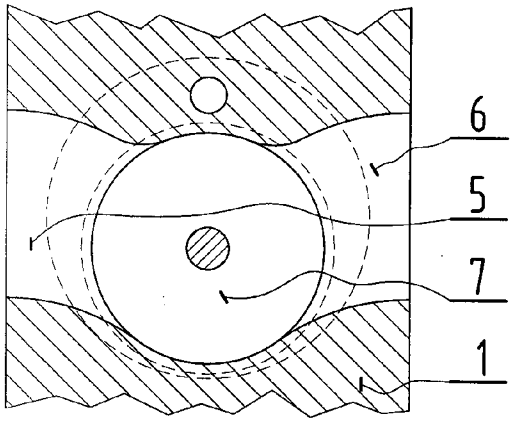

Fig.20

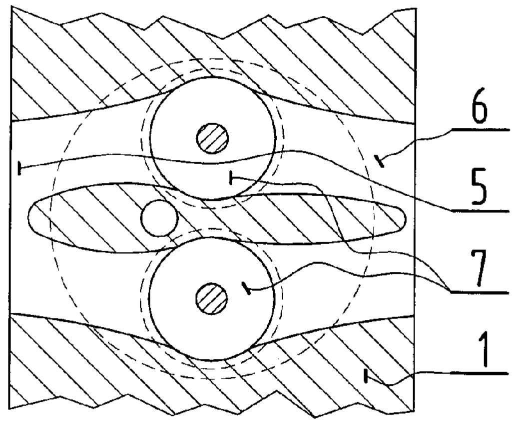

Fig.21

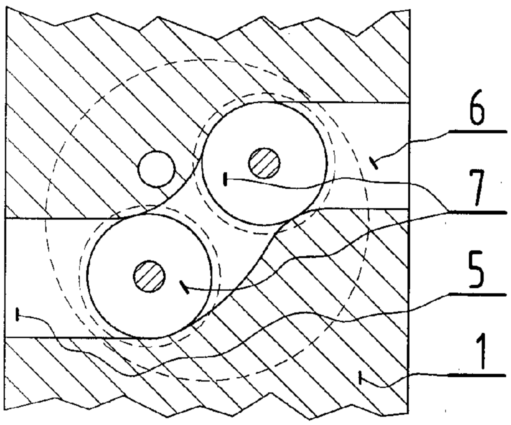

Fig.22

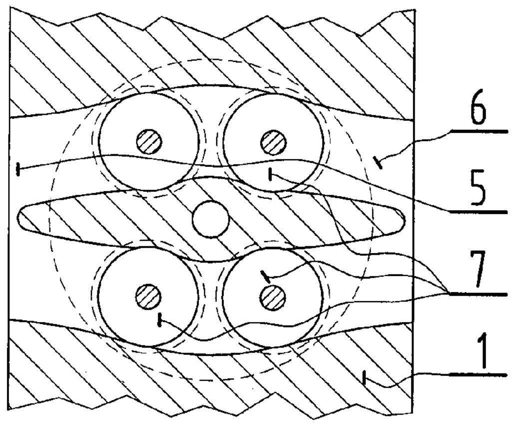

Fig.23

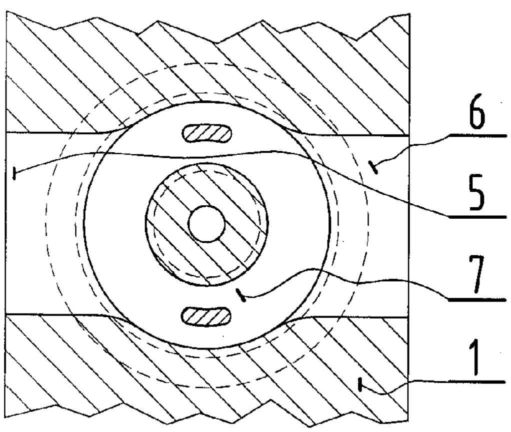

Fig.24

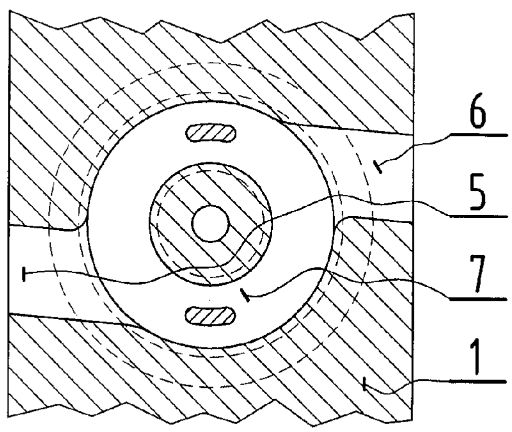

Fig.25

MULTI-CYLINDER INTERNAL COMBUSTION ENGINE USING EXHAUST GASES TO INCREASE CYLINDER FILLING

TECHNICAL FIELD

[0001] This invention relates to an arrangement of a four-stroke multi-cylinder internal combustion engine. It relates particularly to valves in a cylinder head and to an embodiment of an intake and exhaust manifold, so that higher volumetric efficiency of the cylinder as well as higher overall efficiency of the combustion engine is reached, by means of the direct use of a part of energy of exhaust gas pressure waves in the exhaust manifold.

BACKGROUND OF THE INVENTION

[0002] Current modern four-stroke piston engines work usually with a multi-valve gear mechanism in a cylinder head. Intake valves with intake ports are placed in one part of the cylinder head and exhaust valves with exhaust ports are placed in the other part of the cylinder head. It is possible to use energy of exhaust gases for a better cylinder filling, but only to a limited extent. Suitably designed exhaust manifold as well as intake manifold and appropriate valve timing can ensure scavenging of a combustion chamber of the cylinder and set intake gas in motion in the intake port. It results in a small improvement in cylinder filling by intake gas. Further, engine efficiency can be influenced by exhaust manifold, which uses flow momentum of exhaust gases in the manifold and enables easier discharge of exhaust gases out of the cylinder. That leads to a decrease of the pumping work particularly during the exhaust stroke. That is all about direct using of energy of exhaust gases for cylinder filling and for increase of efficiency of current engines. Direct use of energy of exhaust gases by means of Comprex system is not as advantageous as a turbocharger. Supercharging by turbocharger is widely spread way of use of exhaust gas energy. Even in this case, there is a loss of energy by transferring energy of exhaust gases to a turbine. It is caused by a difference between cyclic work of a piston engine and continual work of a turbine. In the past there have been systems that tried to use the pressure wave of exhaust gas directly to improve cylinder filling, for instance by interconnecting intake manifold with exhaust one. Those solutions are described for example in GB592995A, DT2328692A1, JP58104325A, JP61237824A, DE3137454A1, DE3137471A1 and WO0153677A1. Efficiency of their function was not sufficient and they did not break through.

SUMMARY OF THE INVENTION

[0003] Above mentioned deficiencies are removed to a certain extent in a multi-cylinder internal combustion engine with use of exhaust gas pressure to increase cylinder filling. That engine consists of cylinders with pistons, a cylinder head with lifting valves and a crankshaft mechanism. The essence of the engine is the fact that it is equipped with two cylinders that have mutually shifted four-stroke cycle and/or it is equipped with three cylinders that have mutually shifted four-stroke cycle. In the cylinder head of each cylinder is at least one intake port, connected with at least one exhaust port and at least one lifting valve, while the intake port is equipped with at least one valve and an exhaust branch is connected to the exhaust port and simultaneously exhaust branches of both cylinders with mutually shifted 4-stroke cycle are farther joined in a joint into one cross-section and/or exhaust branches of three cylinders with mutually shifted four-stroke cycle are farther joined in another joint into one cross-section.

[0004] Lifting valves have both intake and exhaust function.

[0005] A valve of the intake port is advantageously in the shape of a rotary valve and/or in the shape of a reed valve.

[0006] The valve of the intake port can be equipped with electronic control.

[0007] An intake manifold is advantageously connected to the intake port. This intake manifold is equipped with a centrifugal compressor and/or with a positive displacement compressor that is mechanically connected to the engine and/or equipped with an electric motor.

[0008] There can be placed an exhaust valve and/or an exhaust outlet pipe behind the joint of two exhaust branches and/or behind another joint of three exhaust branches.

[0009] There can be placed a turbine of a turbocharger behind the joint of two exhaust branches and/or behind another joint of three exhaust branches and there is a compressor of the turbocharger in the intake manifold, while the exhaust outlet pipe joins outlet of the turbine of the turbocharger.

[0010] In advantageous embodiment, the multi-cylinder internal combustion engine comprises more cooperating cylinder pairs with mutually shifted four-stroke cycle and with joints of exhaust branches and/or it comprises more cooperating cylinder trios with mutually shifted four-stroke cycle and with other joints of exhaust branches.

[0011] The multi-cylinder internal combustion engine can consist of more cooperating cylinder pairs with mutually shifted four-stroke cycle and with joints of exhaust branches and/or it can consist of more cooperating cylinder trios with mutually shifted four-stroke cycle and with other joints of exhaust branches, while joints and/or other joints are farther connected to separate sections of inlet housing of a turbine of a turbocharger.

[0012] The lifting valve has a valve head in the annular shape in an advantageous embodiment.

[0013] Four-stroke internal combustion engine according to the invention enables an improvement of engine performance parameters, decrease of its specific mass as well as decrease of its specific fuel consumption. That is achieved for two reasons.

[0014] The first important reason for an increase in engine parameters is direct use of a part of exhaust gas energy. That is enabled due to the engine arrangement with interconnected intake and exhaust port in the cylinder head and appropriate tuning of the whole system of a valve gear and engine manifold. Briefly, the difference between operation of the multi-cylinder engine according to the invention and operation of a traditional four-stroke cycle is in intensive scavenging of the cylinder head at the end of the exhaust stroke, taking gas in during the intake stroke also in the exhaust branch besides the cylinder and subsequent refilling of the gas into the cylinder by means of pressure of exhaust gas. Described effect can be achieved only in such an engine with two or three cooperating cylinders of the engine. A part of energy of the exhaust pressure wave is used directly for compressing intake gas into the cylinder and so it is possible to reach significantly higher cylinder filling. That increases mean effective pressure of the engine as well as its efficiency. A naturally aspirated variant of the engine according to the invention in one configuration of valve timing and pipes geometry has excellent parameters in a relatively narrow range of engine speed. That does not have to be disadvantage in case of using this engine at a generator. The absence of a turbocharger and related turbo lag increasing time required for run-up till the full power can be an advantage in this case, in comparison with a traditional engine with similar performance and dimensions. Four-stroke combustion engine according to the invention in turbocharged version achieves characteristic suitable for a common driving cycle with excellent parameters in the whole engine speed range and it is useable in current vehicles.

[0015] The second reason for an increase in engine parameters is the fact that the cylinder head can be equipped with a lifting valve or valves in its entire area and thus the passable area for valve increases. It is better to use all lifting valves simultaneously as intake and exhaust. Decrease in throttling in valves in the cylinder head causes decrease of losses by drawing gas into the cylinder and further the pumping work is decreased, while useable energy of exhaust gases is increased at the same time. The most advantageous is using a lifting valve with a valve head in the annular shape that has both intake and exhaust function. This valve enables to achieve the best flow parameters in intake direction into cylinder, exhaust direction from cylinder as well as in direction of scavenging the cylinder head. The use of shared lifting valves for intake and exhaust that are placed in the entire area of the cylinder head has further advantages. The cylinder head and lifting valves are significantly less thermally stressed due to the changing of intake and exhaust period. There will be no creation of solid sediments due to the lower temperatures on the valve and valve seats and a higher durability of valves, seats and engine heads will be achieved. Possibility of use of internal exhaust gas recirculation in part and full load of the engine can be another advantage. Higher air excess in exhaust gases can be used for its better oxidation. It is possible to decrease emissions of the engine by use of those possibilities and their combinations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] A multi-cylinder internal combustion engine supercharged by exhaust gases according to the invention will be closer clarified in exemplary embodiment with the help of enclosed figures.

[0017] FIG. **1** schematically shows a multi-cylinder combustion engine with two cylinders with a four-stroke cycle that is mutually shifted about 360. There are cyclically working valves in the intake ports and exhaust branches of both cylinders are joined into one exhaust outlet pipe.

[0018] FIG. **2** schematically shows a multi-cylinder internal combustion engine with two cylinders with a four-stroke cycle that is mutually shifted about 360, similarly to the FIG. **1**. The difference is that the intake port is equipped with a rotary valve and a reed valve and there is an exhaust valve in the shape of an exhaust rotary valve behind the joint of exhaust branches.

[0019] FIG. **3** schematically shows a multi-cylinder internal combustion engine with two cylinders with four-stroke cycle that is mutually shifted about 360, similarly to the FIG. **1**. The difference is that the intake port is equipped with a reed valve and there is a centrifugal compressor in the intake port.

[0020] FIG. **4** schematically shows a multi-cylinder internal combustion engine with two cylinders, similarly the FIG. **2**. The difference is that there is a positive displacement compressor in the intake manifold.

[0021] FIG. **5** schematically shows a multi-cylinder internal combustion engine with two cylinders, similar to the FIG. **3**. The difference is that behind the joint of exhaust branches there is a turbine of a turbocharger and a compressor of the turbocharger is situated in the intake manifold.

[0022] FIG. **6** schematically shows a multi-cylinder internal combustion engine with two cylinders with a cycle that is shifted about 360. That engine is equipped with a turbocharger, similarly to the FIG. **5**. The difference is that even a rotary valve is placed in the intake port besides the reed valve.

[0023] FIG. **7** schematically shows a multi-cylinder internal combustion engine with two cylinders with a four-stroke cycle that is mutually shifted about 360, similarly to the FIG. **1**. An exhaust valve is additionally placed behind the joint of exhaust branches.

[0024] FIG. **8** graphically shows dependence of some parameters of a two-cylinder engine according to the FIG. **7**. All curves are dependent on crankshaft angle that is represented by x axis. Curves IA and IIA represent behavior of a cross-sectional area of lifting valves. Curves Ip and IIp represent behavior of pressure in exhaust ports in a cylinder head. Curve B represents behavior of a cross-sectional area of the exhaust valve.

[0025] FIG. **9** shows a multi-cylinder internal combustion engine according to the FIG. **7** in crankshaft angle positions from 0 to 720 in 90 intervals. That demonstrates working of the engine during the entire cycle. Intake gas is represented by gray color. Exhaust gases are not colored.

[0026] FIG. **10** shows a multi-cylinder internal combustion engine with two cylinders with a cycle that is shifted about 360, similarly to the FIG. **7**, in crankshaft angle positions from 0 to 720 in 90 intervals with the difference that in the exhaust manifold there is placed a rotary valve and a reed valve is used in the intake manifold. Intake gas is represented by gray color. Exhaust gases are not colored.

[0027] FIG. **11** schematically shows a multi-cylinder internal combustion engine with three cylinders with a cycle that is mutually shifted about 240. Intake and exhaust ports in a cylinder head are interconnected and lifting valves are shared for both intake into the cylinder and exhaust out of the cylinder. There are cyclically working valves in intake ports and exhaust branches of the three cylinders are joined into one outlet pipe.

[0028] FIG. **12** schematically shows a multi-cylinder internal combustion engine with three cylinders, similarly to the FIG. **11**. A centrifugal blower is additionally placed in the intake manifold.

[0029] FIG. **13** schematically shows a multi-cylinder internal combustion engine with three cylinders, similarly to the FIG. **11**. The difference is that the engine is equipped with a turbocharger.

[0030] FIG. **14** schematically shows a multi-cylinder internal combustion engine with three cylinders with four-stroke cycle that is mutually shifted about 240 and a turbocharger, similarly to the FIG. **13**. The difference is that intake ports are equipped with reed valves and a positive displacement compressor is situated in the intake manifold.

[0031] FIG. **15** schematically shows a multi-cylinder internal combustion engine with three cylinders with four-stroke cycle that is shifted about 240, similarly to the FIG. **11**. The difference is that there is a positive displacement compressor in the intake manifold and an exhaust valve is additionally placed behind the joint of exhaust branches.

[0032] FIG. **16** graphically shows dependency of some parameters of a two-cylinder engine according to the FIG. **15**. All curves are dependent on crankshaft angle that is represented by x axis. Curves IA, IIA and IIIA represent behavior of a cross-sectional area of lifting valves. Curves Ip, IIp and IIIp represent behavior of pressure in exhaust ports in the cylinder head. Curve B represents behavior of cross-sectional area of the exhaust valve.

[0033] FIG. **17** shows an internal combustion engine according to the FIG. **15** in crankshaft angle positions from 0 to 720 in 120 intervals. That demonstrates the working of the engine during the entire cycle. Intake gas is represented by gray color. Exhaust gases are not colored.

[0034] FIG. **18** shows a multi-cylinder internal combustion engine with three cylinders with a cycle shifted about 240, similarly to the FIG. **17**, in crankshaft angle positions from 0 to 720 in 120 intervals. The difference is that there is a reed valve in the intake port and the engine is not equipped with an exhaust valve. Intake gas is represented by gray color. Exhaust gases are not colored.

[0035] FIG. **19** shows a multi-cylinder internal combustion engine with four cylinders on condition that it consists of two pairs of cooperating cylinders. Two outlet pipes going from joints of exhaust branches are connected to separate sections of outlet of turbine housing of a shared turbocharger.

[0036] FIG. **20** shows a cross-sectional view of the cylinder head that is perpendicular to the cylinder axis in the view direction into the cylinder. The figure shows a valve head of the lifting valve and the intake and exhaust port.

[0037] FIG. **21** shows a cross-sectional view of the cylinder head that is perpendicular to the cylinder axis in the view direction into the cylinder. The figure shows valve heads of two lifting valves and the intake and exhaust port.

[0038] FIG. **22** shows a cross-section of the cylinder head that is perpendicular to the cylinder axis in the view direction into the cylinder. The figure shows valve heads of two lifting valves and the intake and exhaust port.

[0039] FIG. **23** shows a cross-section of the cylinder head that is perpendicular to the cylinder axis in the view direction into the cylinder. The figure shows valve heads of four lifting valves and the intake and exhaust port.

[0040] FIG. **24** shows a cross-section of the cylinder head that is perpendicular to the cylinder axis in the view direction into the cylinder. The figure shows a centrally positioned lifting valve with a valve head in the annular shape and the intake and exhaust port.

[0041] FIG. **25** shows a cross-section of the cylinder head that is perpendicular to the cylinder axis in the view direction into the cylinder. The figure shows a centrally placed lifting valve with a valve head in the annular shape and an eccentric intake and exhaust port.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0042] The model multi-cylinder internal combustion engine supercharged by exhaust gases according to the FIG. **1** comprises two cylinders **10** with pistons **2**, a cylinder head **1** with lifting valves **7** and a crankshaft mechanism **3**. Two cylinders **10** have a cycle that is mutually shifted about ½ of four-stroke cycle. There is placed an intake port **5** interconnected to an exhaust port **6** and valves **7** with both intake and exhaust function in the cylinder head **1** of each cylinder **10**. The intake port **5** is equipped with a cyclically working valve **8** and an exhaust branch **9** is connected to the exhaust port **6**. Exhaust branches **9** of both cylinders **10** are joined into one cross-section in a joint **11** and an outlet exhaust pipe **22** goes on from that joint.

[0043] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **2** is based on the embodiment according to the FIG. **1**. A valve **8** is replaced with a rotary valve **8*a*** together with a reed valve **8*b***. There is additionally placed an exhaust valve **21** in the shape of an exhaust rotary valve behind the joint of exhaust branches **9**.

[0044] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **3** is based on the embodiment according to the FIG. **1**. A valve **8** is replaced with a reed valve **8*b***. The engine is equipped with an intake manifold **4**, in which a centrifugal compressor **13** is placed.

[0045] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **4** is based on the embodiment according to the FIG. **2**. The engine is equipped with the intake manifold **4**, in which a positive displacement compressor **14** is placed.

[0046] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **5** is based on the embodiment according to the FIG. **3**. There is a turbine **23** of a turbocharger behind the joint **11** of exhaust branches **9** and a compressor **15** of a turbocharger in the intake manifold **4**.

[0047] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **6** is based on the embodiment according to the FIG. **5**. There are additionally placed rotary valves **8*a*** in intake ports **5**.

[0048] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **7** is based on the embodiment according to the FIG. **1**. There is additionally placed an exhaust valve **21** behind the joint of exhaust branches **9**.

[0049] The model multi-cylinder internal combustion engine supercharged by exhaust gases according to the FIG. **11** comprises three cylinders **10** with pistons **2**, a cylinder head **1** with lifting valves **7** and a crankshaft mechanism **3**. Three cylinders **10** have a cycle that is mutually shifted about ⅓ of four-stroke cycle. There is placed the intake port **5** interconnected to the exhaust port **6** and valves **7** with both intake and exhaust function in the cylinder head **1** of each cylinder **10**. The intake port **5** is equipped with a cyclically working valve **8** and the exhaust branch **9** is connected to the exhaust port **6**. Exhaust branches **9** of all three cylinders **10** are joined into one cross-section in a joint **12** and the outlet exhaust pipe **22** goes on from that joint.

[0050] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **12** is based on the embodiment according to the FIG. **11**. The engine is equipped with an intake manifold **4** that is equipped with a centrifugal compressor **13**.

[0051] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **13** is based on the embodiment according to the FIG. **11**. There is additionally placed a turbine **23** of a turbocharger behind the joint **12** of exhaust branches **9** and a compressor **15** of the turbocharger in the intake manifold **4**.

[0052] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **14** is based on the embodiment according to the FIG. **13**. Valve **8** is replaced with a reed valve **8*b***. There is additionally placed a positive displacement compressor **14** into the intake manifold **4**.

[0053] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **15** is based on the embodiment according to the FIG. **11**. The engine is equipped with the intake manifold **4**, in which the positive displacement compressor **14** is placed and there is additionally placed an exhaust valve **21** behind the joint of exhaust branches **9**.

[0054] The model multi-cylinder internal combustion engine according to the FIG. **19** comprises two cooperating pairs of cylinders **10** in an arrangement according to the FIG. **1**. It is equipped with a shared intake manifold **4**, in which a compressor **15** of a shared turbocharger is placed, and both joints **11** of exhaust branches **9** are connected to separate section of inlet housing **26** of a turbine **23** of a shared turbocharger.

[0055] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **20** is equipped with the head **1** of the cylinder **10**. The head **1** is equipped with a classic lifting valve **7**.

[0056] The embodiment of a multi-cylinder internal combustion engine according to the FIGS. **21** and **22** has the head **1** of the cylinder **10**. The head **1** is equipped with two classic lifting valves **7**.

[0057] The embodiment of a multi-cylinder internal combustion engine according to the FIG. **23** has the head **1** of the cylinder **10**. The head **1** is equipped with two classic lifting valves **7**.

[0058] The embodiment of a multi-cylinder internal combustion engine according to the FIGS. **24** and **25** has the head **1** of the cylinder **10**. The head is equipped with one lifting valve **7**, the head of which is in the annular shape.

[0059] The function of a multi-cylinder internal combustion engine supercharged by exhaust gases is following. A two-cylinder engine works in the four-stroke cycle on condition that the cycle of cylinders **10** is mutually shifted about ½ of the cycle, it means 360. The first cylinder **10** starts usually with ignition and subsequent expansion. The exhaust stroke begins by opening lifting valves **7** in the head **1** of the first cylinder **10** at the end of the expansion, before the bottom dead center. Valve **8** in the intake port **5** is closed and prevents flowing of exhaust gases through the intake port **5**. Pressure wave of exhaust gases travels through the exhaust branch **9** of the first cylinder **10** to the joint **11** and from here it advances through the second exhaust branch **9** to lifting valves **7** of the second cylinder **10**. In the second cylinder **10**, there is just the intake stroke in progress. Valve **8** in the intake port **5** is of the second cylinder **10** is closing and gas that was drawn into the exhaust port **6** and the exhaust branch **9** before is pushed into the second cylinder **10**. Lifting valves **7** of the second cylinder **10** closes afterwards and the compression stroke can start. That causes an improvement in the filling of the second cylinder **10**. The first cylinder **10** finishes the exhaust stroke of the piston **2** and the pressure in the exhaust port **6** decreases at the end of the exhaust stroke. Valve **8** in the intake port **5** of the first cylinder **10** opens and the head **1** is scavenged by gas that is drawn from the intake port **5** into the exhaust port **6** of the first cylinder **10**. As the piston moves during the intake stroke, the gas is drawn into the first cylinder **10** and that gas simultaneously flows into the exhaust branch **9** of the first cylinder **10**, until the exhaust pressure wave from the second cylinder **10** arrives. Valve **8** in the intake port **5** of the first cylinder **10** is subsequently closed and gas previously taken into the exhaust port **6** and the exhaust branch **9** is pushed into the first cylinder **10**. Closing of lifting valves **7** of the first cylinder **10** ensues and the compression stroke can start. That enables an improvement in filling of the first cylinder **10**. The process in the second cylinder is the same as in the first cylinder. The engine in naturally aspirated variant will achieve excellent parameters only in a narrow range of engine speed. The whole system tuning is significantly influenced by all valve timing of all valves, particularly lengths and cross-sectional areas of exhaust branches **9** and outlet pipes **22**. It can be influenced for instance by the angle a that is an angle between inlets entering the joint **11** of exhaust branches **9**. Considerable change of the most advantageous engine speed in naturally aspirated variant is possible to reach only by the change of length of exhaust branches **9** and of the outlet pipe **22**. The work of a valve can be electronically controlled after processing instantaneous data that are read from the engine.

[0060] Two-cylinder engine with the rotary valve **8*a*** and the reed valve **8*b*** in the intake port **5** enables automatic and quick opening and closing of the intake port **5**. The rotary valve **8*a*** prevents gas flowing into the exhaust branch **9** of the cylinder **10** during the compression and expansion in this cylinder **10**. It actually prevents unnecessary high excess of drawing gas in exhaust gases of the engine. If there is the exhaust valve **21** behind the joint **11**, it is possible to increase the amplitude of the exhaust pressure wave. The exhaust valve **21** closes the outlet cross-section of the joint **11** at the time, when the pressure wave of exhaust gases reaches this joint **11**. The cross-section is subsequently opened in order to enable pressure decrease in exhaust branches **9**. FIG. **8** shows behavior of cross-sectional area IA, IIA in lifting valves **7** and pressure Ip, IIp in exhaust ports **6** of the head **1** of both cylinders **10**. It also shows behavior of a cross-sectional area B of the exhaust valve **21**. Behavior of a two-cylinder engine without using the exhaust valve **21** is similar to that case with the exhaust valve **21**. Just the values of pressures Ip and IIp are lower.

[0061] Two-cylinder engine according to the FIG. **3** with the reed valve **8*b*** in the intake port **5** enables automatic and quick opening and closing of the intake port **5**. The reed valve **8*b*** opens whenever the value of the pressure in the exhaust port **6** drops below the value of the pressure in the intake manifold **4**. That enables that the flow of intake gas into the exhaust port **6** is enabled not only during the intake into the cylinder **10**, but also during the compression and expansion in the cylinder **10**. That can be used in case that there is a requirement of increase in amount of drawn gas in exhaust branches **9**. If there is placed a centrifugal compressor **13** in the intake manifold **4**, the filling of cylinders **10** by intake gas will improve and that will cause widening of engine speed range, in which the engine has high parameters.

[0062] Two-cylinder engine according to the FIG. **4** with the positive displacement compressor **14** that is placed in the intake manifold **4** and with the exhaust valve **21** behind the joint **21** enables another improvement in filling of cylinders **10** by intake gas. Influence of dynamic of exhaust gases flow in the outlet pipe **22** on filling of exhaust branches **9** by intake air decreases and that causes another widening of the engine speed range, in which the engine has high parameters.

[0063] In case according to the FIG. **6**, where a two-cylinder engine uses the turbine **23** of a turbocharger behind the joint **11** and the compressor **15** of the turbocharger in the intake manifold, behavior of the engine is similar to the naturally aspirated variant. All pressures in the engine increase. However, it enables to reach excellent parameters of the engine in a wider range of engine speed compared to naturally aspirated versions. In this case, there is no importance of influence of exhaust gases flow dynamic in the outlet exhaust pipe **22**. Inertia of the turbine **23** prevails and the turbine ensures required fluctuation of gas pressure in exhaust branches **9** in a wide range of engine speed. There is advantageous possibility to use the turbine **23** of the turbocharger with regulation.

[0064] Gas exchange process of the cylinder **10** of the three-cylinder engine variant is similar to two-cylinder variant. The process is in four-stroke cycle on condition that the cylinders cycle **10** is mutually shifted about ⅓ of the cycle (240). In the first cylinder **10**, usual ignition and subsequent expansion come. At the end of the expansion, before bottom dead center of the piston **2**, exhaust stroke begins by opening lifting valves **7** in the head **1** of the first cylinder **10**. Valve **8** in the intake port **5** is closed and prevents exhaust gas flow through the intake port **5**. Exhaust gas pressure wave advances through the exhaust branch **9** of the first cylinder **10** to the joint **12** and from there, it goes on through the second and third exhaust branch **9** to lifting valves **7** of the second and third cylinder **10**. There is just the intake stroke in progress in the second cylinder **10**. Valve **8** in the intake port **5** of the second cylinder **10** closes and gas previously taken into the exhaust port **6** and the exhaust branch **9** is pushed into the second cylinder **10**. After that, also lifting valves **7** of the second cylinder **10** close and the compression stroke can start. That enables to reach increase in filling of the second cylinder **10**. There is compression and expansion in progress in the third cylinder **10** and lifting valves **7** and the valve **8** are closed. The first cylinder **10** finishes its exhaust stroke of the piston **2** and pressure in the exhaust port **6** decreases at the end of the exhaust stroke. Valve **8** in the intake port **5** of the first cylinder **10** opens and the head **1** is scavenged by intake gas flowing from the intake port **5** into the exhaust port **6** of the first cylinder **10**. During the intake stroke, piston **2** moves down and gas is taken into the first cylinder **10** and simultaneously the gas is flowing even into the exhaust branch **9** of the first cylinder **10**, until a pressure wave of the exhaust stroke of the third cylinder **10** arrives. Valve **8** in the intake port **5** of the first cylinder **10** closes and gas taken into the exhaust port **6** and the exhaust branch **9** is pushed into the first cylinder **10**. Afterwards, even lifting valves **7** of the first cylinder **10** close and the compression stroke can start. That is how an increase in filling of the first cylinder **10** is reached. Process of the cycle in the second and third cylinder **10** is the same as in the first cylinder **10**.

[0065] It is possible to use a three-cylinder engine in the same variants of engine arrangements as a two-cylinder engine version. For example, with various valves in the intake port **5**, with the centrifugal compressor **13** or with the positive displacement compressor **14** that is placed in the intake manifold **4**. If there is the exhaust valve **21** behind the joint **12**, it is possible to increase the amplitude of the exhaust pressure wave. The exhaust valve **21** closes inlet cross-sectional area of the joint **12** at the time, when an exhaust gas pressure wave reaches this joint **12**. The cross-sectional area is opened afterwards in order to enable decrease of pressure in exhaust branches **9**. In the FIG. **16**, there is behavior of cross-sectional area IA, IIA, IIIA of lifting valves **7** and pressure Ip, IIp, IIIp in exhaust ports **6** of the head lof the three cooperating cylinders **10**. There is also shown behavior of cross-sectional area B of the exhaust valve **21**. Process of work of a three cylinder engine without use of the exhaust valve **21** is similar to that in case with exhaust valves **21**. Just the values of pressures Ip, IIp and IIIp are lower.

[0066] A two-cylinder variant has cooperating cylinders **10**, whose cycles are shifted about ½ cycle, it means 360 and the pressure wave of exhaust gases arrives at the cylinder **10**, in which the intake stroke near the bottom dead center of the piston **2** is in progress. Actually at the end of the intake stroke. The cycle shift of cooperating cylinders **10** at a three-cylinder variant is ⅓, it means 240, the exhaust pressure wave arrives at the cylinder **10**, where the intake stroke is in progress, earlier than in the two-cylinder variant. To enable additional intake of drawing gas into the engine cylinder **10** and the exhaust branch **9** even before the pushing of taken gas into the cylinder **10** by exhaust gas pressure, it is necessary to delay a pressure wave by longer exhaust branches **9** than at a two-cylinder engine. Or it is necessary to increase pressure in the intake manifold **4**, for example by the positive displacement compressor **14**. Angle delay of the exhaust gases pressure wave increases as the engine speed increases. Generally, a multi-cylinder engine of arrangement with two cooperating cylinders **10** is more advantageous rather for lower engine speed and a multi-cylinder engine of arrangement with three cooperating cylinders **10** is advantageous rather for higher engine speed.

[0067] An engine with higher number of cylinders **10** is necessary to be solved as a connection of more pairs or trios of cooperating cylinders **10**. The exhaust system must be lead separately from each pair and trio of cooperating cylinders. Or it is possible to join them at the ends of exhaust outlet pipes **22** in a sufficient distance from the engine, so that there would be no influence of individual exhaust systems.

[0068] Particular case according to the FIG. **19** is, when a common turbocharger is used at a turbocharged engine with more pairs of cooperating cylinders **10**. Outlets of joints **11** must be connected to separate section of common inlet housing **26** of the turbine **23** of the common turbocharger.

[0069] There can be placed any number of lifting valves **7** in the cylinder head **1** according to the FIGS. **20** to **23**. These valves must enable both intake into the cylinder **10** and exhaust out of the cylinder **10**. Therefore it is advantageous to use them all for both intake and exhaust. In addition to all arrangements with classic poppet lifting valves **7**, there is an interesting possibility to use a lifting valve **7** with an annular valve head according to the FIGS. **24** and **25**. In addition to that that it enables to reach the best flow parameters, it is also possible to advantageously form the intake port **5** as well as the exhaust port **6** to achieve swirl of intake gas in the cylinder **10**.

[0070] Briefly, the difference between operation of a multi-cylinder engine according to the invention and operation of a classic four-stroke cycle is in intensive scavenging of the head **1** at the end of the exhaust stroke, intake of gas during the intake stroke not only into the cylinder **10**, but even in the exhaust branch **9** and subsequent pushing of gas from the exhaust branch **9** to the cylinder **10** by pressure of exhaust gases. This effect is enabled by the cylinder head **1** that has the interconnected intake port **5** with an exhaust port **6** and joined exhaust branches **9** of two or three cooperating cylinders **10**. Tuning of the system depends on many parameters. It is possible to achieve described effect only with an engine with two or three cooperating engine cylinders **10**. If the system should be able to achieve required parameters, a quality realization of the head **1** with valves **8** and lifting valves **7** of low flow resistance is necessary. Low flow resistance in the direction of scavenging the head **1** from the intake port **5** into the exhaust port **6** is particularly important. Length and cross-sectional area of exhaust branches **9** and arrangement of their joint **11** or **12** is crucial. Further there are influences of valve timing settings and ways of regulation of a turbocharger. Another difference between an engine according to the invention and an engine with classic four-stroke cycle is possibility of use of natural exhaust gas recirculation in part load as well as full load of the engine. That can be influenced by many regulations, for example by throttling in the intake port **4**.

INDUSTRIAL APPLICABILITY

[0071] Multi-cylinder internal combustion engine according to the invention in naturally aspirated variant is suitable particularly for diesel arrangement for driving a generator, for example as a range extender for electric cars. Variants of an engine according to the invention with a compressor or a turbocharger are suitable as a drive of current vehicles. Spark ignition variant with direct injection could find use on small airplanes market thanks to its high specific power. Possibility of use as gas engines running on natural gas is also promising. It would be advantageous to blow the gas directly into the cylinder of such an engine.

1. A multi-cylinder internal combustion engine using exhaust gases to increase cylinder filling, the engine comprising cylinders with pistons, a head with lifting valves and a crankshaft mechanism wherein the engine is provided with two cylinders with a mutually shifted four-stroke cycle or is provided with three cylinders with a mutually shifted four-stroke cycle and in the head of each cylinder there is at least one intake port that is interconnected with at least one exhaust port and at least one lifting valve, while the intake port is provided with at least one valve and there is an exhaust branch connected to the exhaust port and simultaneously exhaust branches of two cylinders with the mutually shifted four-stroke cycle are further joined in a joint into one cross-section or exhaust branches of three cylinders with the mutually shifted four-stroke cycle are further joined in another joint into one cross-section.

2. The multi-cylinder internal combustion engine according to claim **1** wherein lifting valves have both intake and exhaust function.

3. The multi-cylinder internal combustion engine according to claim **1**, wherein the valve of the intake port is in the form of a rotary valve or in the shape of a reed valve.

4. The multi-cylinder internal combustion engine according claim **1**, wherein the valve of the intake port is provided with an electronic control.

5. The multi-cylinder internal combustion engine according to claim **1**, wherein to the intake port there is connected an intake manifold, which is provided with a centrifugal compressor or a positive displacement compressor that is mechanically connected to the engine or provided with an electric motor.

6. The multi-cylinder internal combustion engine according to claim **1**, wherein an exhaust valve or an exhaust outlet pipe is placed behind the joint of exhaust branches or behind another joint of exhaust branches.

7. The multi-cylinder internal combustion engine according to claim **1**, wherein behind the joint of exhaust branches or behind another joint of exhaust branches there is a turbine of a turbocharger and a compressor of the turbocharger is placed in the intake manifold, while the exhaust outlet pipe is connected to an outlet of the turbine of the turbocharger.

8. The multi-cylinder internal combustion engine according to claim **1**, wherein the engine comprises more cooperating pairs of cylinders that have mutually shifted four-stroke cycle and that are provided with joints of exhaust branches or more cooperating trios of cylinders that have mutually shifted four-stroke cycle and that are provided with other joints of exhaust branches.

9. The multi-cylinder internal combustion engine according to claim **1**, wherein the engine comprises more cooperating pairs of cylinders that have mutually shifted four-stroke cycle and that are provided with joints of exhaust branches or more cooperating trios of cylinders that have mutually shifted four-stroke cycle and that are provided with other joints of exhaust branches, while joints or other joints are further connected to separated sections of an inlet housing of the turbine of shared turbocharger.

10. The multi-cylinder internal combustion engine according to claim **1**, wherein the lifting valve has a valve head of an annular shape.

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