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HOT-GAS PISTON ENGINE

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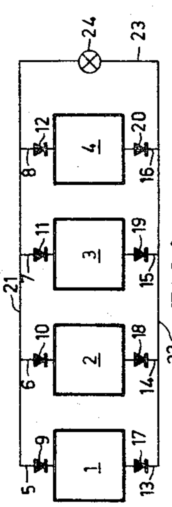

FIG.1

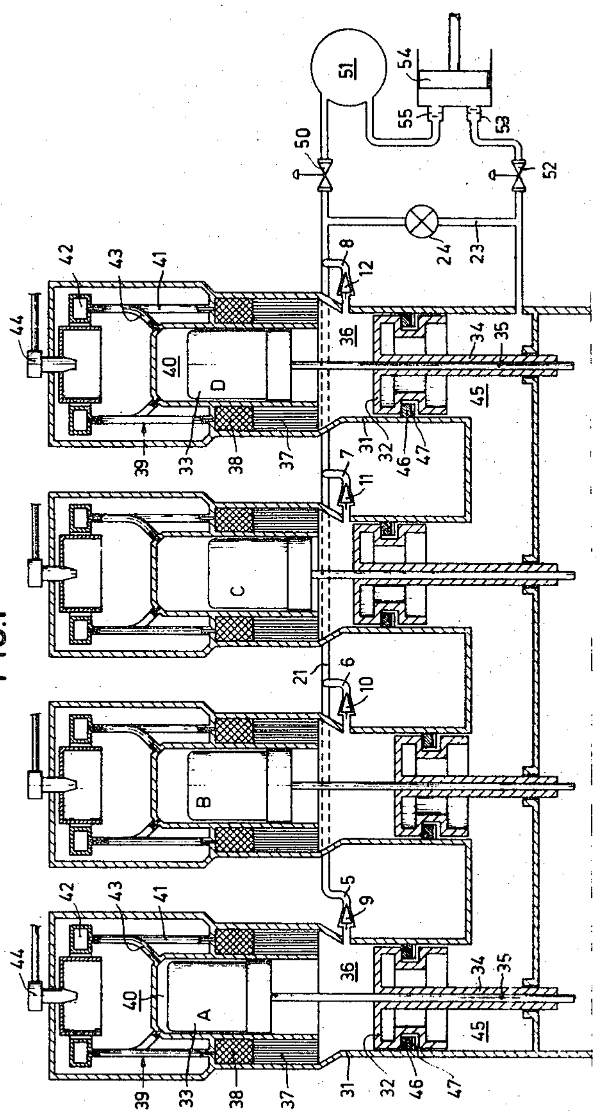

FIG.2

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HOT-GAS PISTON ENGINE

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ABSTRACT OF THE DISCLOSURE

A hot-gas engine with a duct system and a single valve means for controlling the flow of fluid medium into and out of a plurality of working spaces to regulate the average pressure therein, and the corresponding power output.

The invention relates to a hot-gas piston engine comprising one or more working spaces, each space having connected to it, (a) a first duct with a nonreturn valve opening towards the working space, and (b) a second duct with a nonreturn valve inhibiting a flow of medium towards the working space. The sides of the first ducts remote from the associated working spaces are all connected to a first common duct, and the sides of the second ducts remote from the associated working spaces are all connected to a second common duct.

In known hot-gas piston engines the first ducts and the first common duct serve to supply the working medium to the relevant working spaces, whereas the second ducts and the second common duct serve to remove the medium from these working spaces. The power of the hot-gas engine can be controlled by regulating the supply and removal of medium, with the medium generally removed with the aid of a compressor. Since the dimensions of this compressor must not be unduly large, the removal of medium and hence reduction of the power supplied can only proceed comparatively slowly. However, under certain circumstances, it is necessary to instantaneously reduce the power of the hot-gas piston engine from a certain high value to a certain low value.

In addition to the above-mentioned control, by means of supply and removal of the medium to and from the working spaces, it is known to use to this end the so-called bypass control so that the power decreases very rapidly. Here the working space is connected to a space of substantially the same average pressure. A stream of gas passing back and forth then occurs in this connection, with the result that the pressure volume diagram undergoes a phase shift and the torque becomes smaller. In a mono-cylinder engine the working space may be connected to the buffer space. In a multi-cylinder engine having an even number of cylinders it will be possible to connect together two cylinders situated side by side so that an engine having 2.*n* cylinders includes *n* connection cocks. In an engine having an odd number of cylinders each cylinder will have to be provided with a cock capable of connecting the relevant working spaces to the buffer spaces.

A drawback of this control in multi-cylinder engines is the large number of bypass cocks required, especially in engines having an odd number of cylinders. Furthermore, the possibility of placing the relevant bypass cocks is rather limited for the purpose of limiting additional useless space in the connection ducts. A further difficulty is the very accurate adjustment of the open position of the connection cocks in such manner that all cocks open simultaneously.

Opening not simultaneously results in an irregular running of the engine.

An object of the invention is to provide a hot-gas piston engine in which all above-mentioned drawbacks are obviated. To this end the hot-gas piston engine according to the invention is characterized in that the first and second common ducts are connected together by a connection duct including a shutter which is continuously adjustable between its closed position and its entirely open position.

The engine according to the invention thus includes only one adjustable shutter by means of which the power can be controlled centrally. When this shutter is opened a unidirectional gas stream arises; from the working space into the second common duct through the shutter to the first common duct and thence through the nonreturn valve back into the cylinder. As a result a distortion of the pressure volume diagram occurs resulting in a reduction of output. In this manner shutters are highly economized, the problem of the additional useless space does not substantially arise, while all working spaces are simultaneously controlled since only one cock is present and an irregular running of the engine cannot occur. In addition the shutter can be placed in arbitrary positions which considerably simplifies the constructions. An advantageous side effect is that the first and second common ducts may be used simultaneously for the supply and removal of working medium to and from the engine.

An advantageous embodiment of the hot-gas piston engine according to the invention has each working space bounded by a piston adapted to reciprocate in the cylinder, a buffer space present on the side of the piston remote from the working space, and all buffer spaces communicating with one another. The second duct of each working space is formed by the gap between piston and cylinder wall, the relevant nonreturn valve being formed by one or more piston rings which rings or the wall of the groove cooperating therewith are so constructed that their sides facing the buffer space cannot engage in a sealing manner the wall of the groove cooperating with this side and accommodating this ring; and the second common duct is formed by the buffer space.

In order that the invention may be readily carried into effect, it will now be described in detail by way of example, with reference to the accompanying diagrammatic drawings, which show two embodiments of hot-gas piston engines constructed as hot-gas motors.

The reference numerals **1, 2, 3** and **4** in FIG. 1 indicate working spaces of hot-gas engines. Each working space is connected to a first duct **5, 6, 7** and **8**. Non-return valves **9, 10, 11** and **12** opening towards the working space are provided in these first ducts. Furthermore, second ducts **13, 14, 15** and **16** are connected to the working spaces which ducts include non-return valves **17, 18, 19** and **20** which inhibit flow of medium towards the relevant working spaces. The sides of the first ducts **5, 6, 7** and **8** remote from the relevant working spaces are connected to a first common duct **21**, while the sides of the second ducts **13, 14, 15** and **16** remote from the relevant working spaces are connected to a second common duct **22**. The first and second common ducts are connected together by means of a connection duct **23**, including an adjustable shutter **24**. If a certain average pressure prevails in the working spaces **1, 2, 3** and **4** the hot-gas motor will provide a certain output. On closed position of the adjustable shutter **24**, the minimum pressure which occurs in the working spaces **1, 2. 3** and **4** will prevail in the common duct **21**, while the maximum pressure which occurs in the working space will prevail in the second common duct **22**. If the output of the motor must become smaller this can be achieved by opening the adjustable shutter

24 to a greater or smaller extent. As a result a flow of medium will occur from the working spaces **1**, **2**, **3** and **4**, through the non-return valves **17**, **18**, **19** and **20** to the second common duct **22** and through the adjustable shutter **24** to the first common duct **21** and thence through the nonreturn valves **9**, **10**, **11** and **12** again to the working spaces **1**, **2**, **3**, and **4**. Due to this circulation of the medium the pressure volume diagram which occurs in the working spaces **1**, **2**, **3** and **4** will be distorted in such manner that the output of the hot-gas motor decreases. This decrease of output is thus obtained by operating only one shutter **24** so that all working spaces are controlled simultaneously to the same extent. If the motor further comprises a device for supplying and removing medium to and from the motor, the first and second common ducts **21** and **22** may also serve as supply and drain ducts.

FIG. 2 shows not to scale a hot-gas motor which comprises four units A, B, C and D, in which a hot-gas engine cycle is accomplished. Each unit includes a cylinder **31** in which a piston **32** and a displacer **33** can reciprocate. The piston **32** and the displacer **33** are connected by means of a piston rod **34** and a displacer rod **35** to a driving mechanism not shown which can move this piston and displacer with phase shift. A compression space **36** is located between the piston **32** and the displacer **33** which compression space is connected through a cooler **37**, a regenerator **38** and a heater **39** to an expansion space **40** above the displacer **33**. The heater **39** is constructed of a number of pipes **41** which are connected to the regenerator **38** at one end and to a ring duct **42** at the other end, and a number of pipes which are connected to the duct **42** at one end and to the expansion space **40** at the other end. Heat is supplied to this heater with the aid of a burner **44**. A buffer space **45** is located below the piston **32**, the buffer spaces of all units A. B, C and D communicating freely with one another. The seal between the piston **32** and the cylinder **31** is formed by a piston ring **46** which is provided with grooves **47** at its side facing the buffer space **45**. These grooves prevent the piston ring **46** from engaging in a sealing manner the wall of the groove facing said side and accommodating the piston ring **46**. This means that the piston ring passes medium towards the buffer space. The piston ring **46** thus operates as a non-return valve which opposes flow of medium towards the compression space **36**. The piston rings **46** are thus comparable with the non-return valves **17**, **18**, **19** and **20** of the hot-gas motor of FIG. 1, in which the buffer space **45** is now comparable with the second common duct **22**. Furthermore, the first ducts **5**, **6**, **7** and **8** and the non-return valves **9**, **10**, **11** and **12** incorporated therein are connected to the compression space **36** of the different units. The sides of these first ducts remote from the working spaces are again connected to the common duct **21**. The buffer space **45** and the first common duct **21** are connected together by means of a connection duct **23** including a shutter **24**. The first common duct **21** is connected through an adjustable shutter **50** to a supply vessel **51** which contains working medium under pressure. The buffer space **45** is furthermore connected through an adjustable shutter **52** to the suction side **53** of a compressor **54**. The exhaust **55** of the compressor is connected to the supply vessel **51**. When the adjustable shutters **50** and **52** and the shutters **24** are closed, a certain average pressure will prevail in the working spaces of the units A, B, C, and D the motor supplying a certain power. Furthermore the maximum pressure which occurs in the working space will prevail in the buffer space **45** because the piston ring **46** passes medium towards said space, while the minimum pressure which occurs in this working space will prevail in the common duct **21**. If the power must rapidly be adjusted to a lower value, this can be effected by opening the adjustable shutter **52** and the shutter **24** simultaneously. By opening the adjustable shutter **24**, medium will again be circulated from the working spaces of the units A, B, C and D through the piston rings **46** to the buffer space **45** and through the shutter **24** in the third common duct **23** to the common duct **21** and thence back into the working spaces again. As a result the power supplied decreases. The compressor **54** pumps medium towards the supply vessel **51** through the adjustable shutter **52**. As a result the average pressure in the working space of the units A, B, C and D will decrease so that a reduction of power occurs. The shutter **24** is brought to its closed position simultaneously with the reduction of the average pressure. A situation is then eventually reached at which the average pressure in the working space again corresponds to the power desired. At that moment the shutter **24** and the shutter **52** are closed again. If on the other hand it is desired to obtain an increase in power supplied, shutter **50** must be opened, so that high-pressure medium can flow from the supply vessel **51** through the common duct **21** and the non-return valves **9**, **10**, **11** and **12** into the relevant working spaces. As a result, an increase of the average pressure is obtained and hence an increase of the power supplied by the motor.

What is claimed is:

1. In a hot-gas engine operable with a source of pressurized fluid, the engine having a piston reciprocally movable within a cylinder, the piston's ends bounded by a working space and a buffer space respectively, a first one-way valve permitting flow from the source only into working space and a second one-way valve permitting flow only out of the working space into the buffer space, the piston having an annular groove and a piston ring therein which cooperate with the adjacent cylinder wall forming said second valve, duct means interconnecting the source with the first and second valves, and third continuously adjustable valve means in said duct means intermediate said source and first and second valves, whereby the average pressure of the fluid in the working space is regulated.

2. Apparatus according to claim **1** comprising a plurality of said piston and cylinder combinations including first and second valves in each, said duct means comprising a first common duct interconnecting said first valves and a second common duct interconnecting said second valves, and a third common duct interconnecting said first and second common ducts.

3. Apparatus according to claim **2** wherein said third valve means comprises an adjustable valve in said third common duct.

4. Apparatus according to claim **2** wherein said source comprises a fluid storage chamber and a compressor discharging into the chamber, the compressor inlet and chamber outlet communicating respectively with said second and first common ducts, the adjustable valve means comprising a third valve in the third common duct, and fourth and fifth valves immediately adjacent the compressor inlet and chamber outlet respectively.

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