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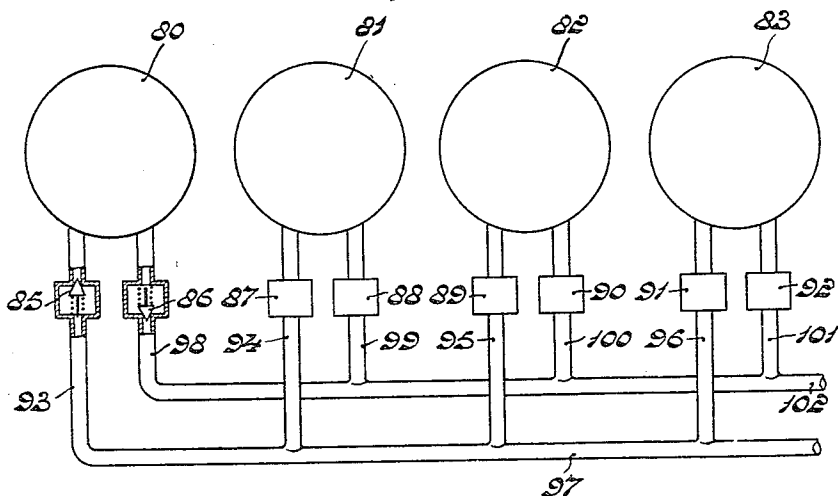
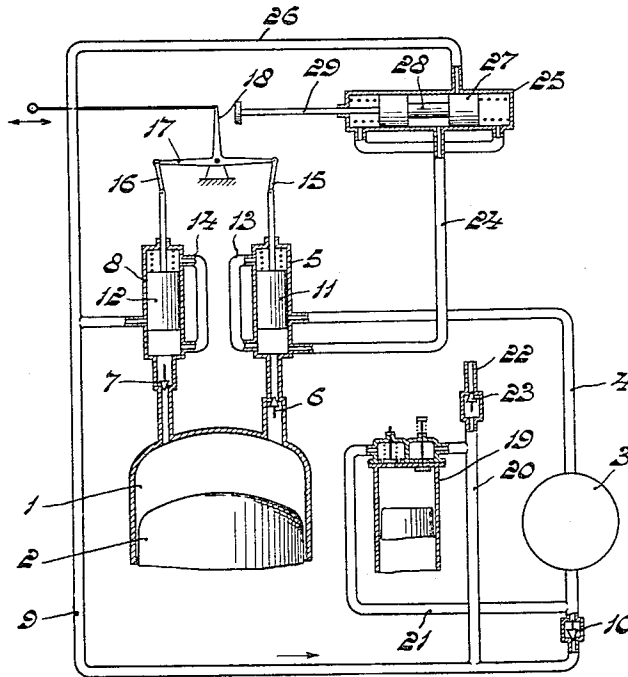


Fig. 2.

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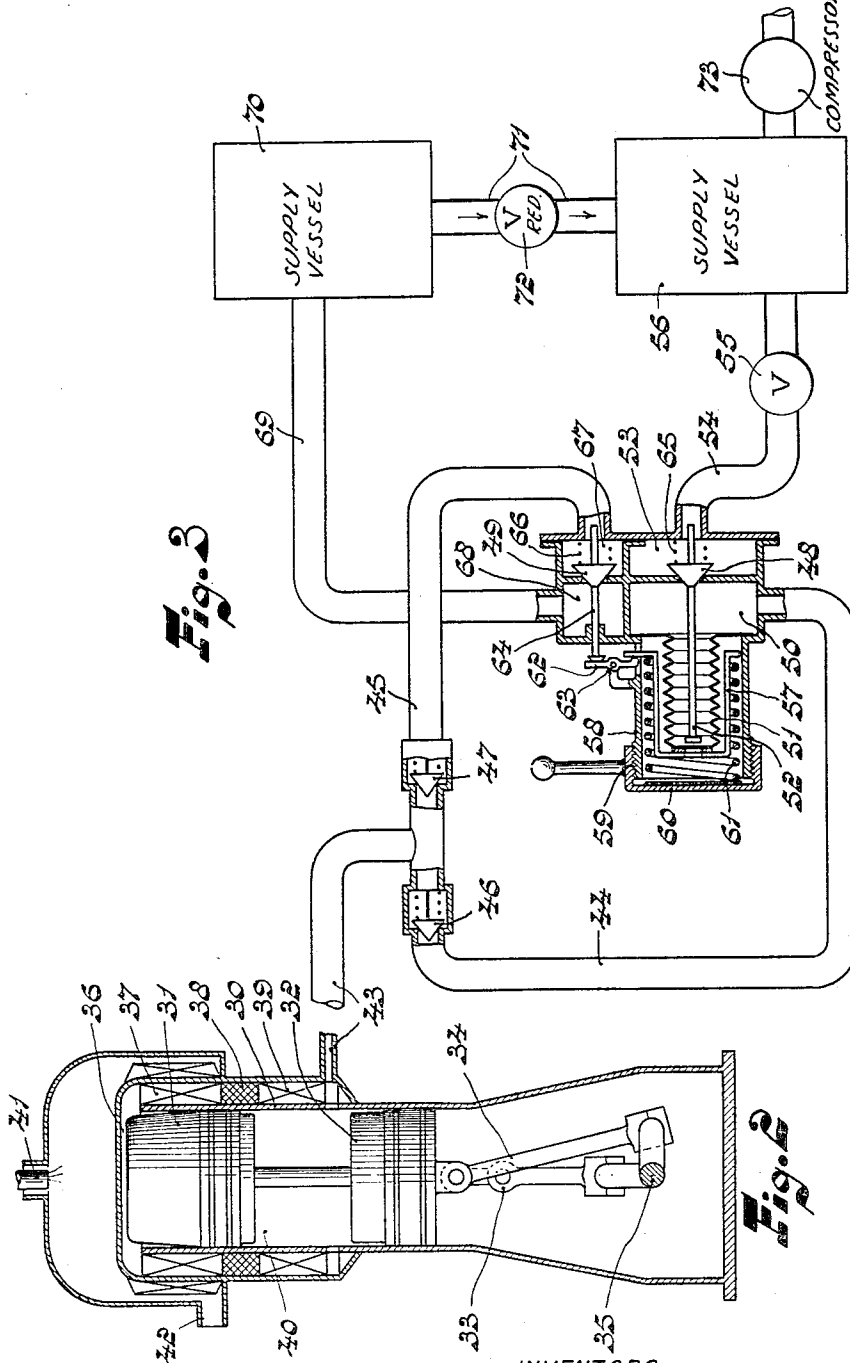
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HOT-GAS RECIPROCATING ENGINE

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2 Sheets-Sheet 2



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HOT-GAS RECIPROCATING ENGINE

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8 Claims. (Cl. 60—24)

This invention relates to hot-gas reciprocating engines comprising a device for supplying working medium to a chamber of the engine, the device having a supply vessel for the medium to be supplied. The term "hot-gas reciprocating engine" is to be understood to include a refrigerator working on the reversed hot-gas reciprocating engine principle or a heat pump. In known hot-gas reciprocating engines, the working medium is supplied and/or discharged at a constant pressure. This constant pressure may be equal to or greater than the lowest pressure occurring during a cycle; thus, for example, it may be equal to the highest pressure occurring during a cycle.

It has now been found that it is advantageous to supply gaseous medium at substantially the lowest pressure occurring during a cycle, medium that may be required to be discharged being discharged at substantially the highest pressure occurring during a cycle.

According to the invention, a hot-gas reciprocating engine comprising a device for supplying working medium to a working chamber of the engine, the device containing a supply vessel for medium to be supplied, is characterized in that the supply vessel communicates with a working chamber of the engine by means of a supply pipe containing a reducing device and a back-pressure valve, the back-pressure valve being arranged between the reducing device and the working chamber so as to permit the flow of medium only from the supply vessel to the working chamber, the engine comprising a discharge pipe also connected to a working chamber of the engine and which contains a back-pressure valve and a reducing device, the back-pressure valve being arranged between the working chamber and the reducing device so as to permit only discharge of medium from the working chamber.

The construction according to the invention ensures quick and effective control of the hot-gas reciprocating engine, low leakage losses and a structurally simple device.

The reducing device may be constructed in a number of ways. Thus, for example a valve, a slide or a lock may be used to constitute the reducing device.

The discharge pipe may communicate with the supply vessel via the second reducing device. This enables the medium which is supplied to the working chamber to be returned to the supply vessel so that the high pressure working medium when being discharged from the working chamber of the machine does not become lost.

The hot-gas reciprocating engine according to the invention may comprise a plurality of working chambers in which equal cyclic processes are performed. Such an engine is referred to as a multi-cycle engine. In this case one supply device will be sufficient for all the cyclic processes and a plurality of working chambers for the engine may be connected in parallel both with the supply pipe and the discharge pipe for working medium, each working chamber having its own set of back pressure valves.

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The pressure level of the working medium in the working chamber of an engine can be varied by varying the pressure levels which are obtained by means of the reducing device. Thus, the two or each set of two reducing devices may be coupled together. In this case, it may be useful to provide both or each set of reducing devices with a common gauge which directly or indirectly registers the mean pressure in the working chamber of the engine. This gauge may be used to indicate the condition of the machine or may be used as an operating mechanism for the reducing devices.

The control range may be increased if, between the supply vessel and the reducing device of the discharge pipe, a pipe is connected in parallel therewith and containing a compressor connected to enable medium flowing to the supply vessel to be compressed.

The device for supplying working medium can also be used for starting the hot-gas reciprocating engine in which case a large quantity of air is required so that the pressure level in the supply vessel would be greatly reduced. To overcome this difficulty if a compressor is provided, the air used in starting can be replenished if the compressor is capable of drawing in atmospheric air.

The control of the hot-gas reciprocating engine may be required to be effected quickly. For this purpose the supply pipe and the discharge pipe may be connected directly to one another by means of a pipe containing a reducing device. Said direct connection may be controlled by means of the engine regulator.

The invention will now be described with reference to the accompanying diagrammatic drawings, given by way of example and showing three embodiments thereof, as follows:

Fig. 1 shows one hot-gas reciprocating engine according to the invention,

Figs. 2 and 3, a second hot-gas reciprocating engine according to the invention, and

Fig. 4 shows a multi-cylinder hot-gas reciprocating engine according to the invention.

Referring now to Fig. 1, the volume of a working chamber 1 of a hot-gas reciprocating engine, the construction of which is shown in greater detail in Fig. 2, is varied by means of a piston 2. A supply vessel 3 which contains working medium, communicates with the working chamber 1 by means of a pipe 4, a reducing device 5 and a back-pressure valve 6. The working chamber 1 also communicates with the supply vessel 3 via a back-pressure valve 7, a reducing device 8, a pipe 9 and a back-pressure valve 10. The reducing devices 5 and 8 constitute sliding throttle valves and comprise slide valves 11 and 12, respectively, which enable the pressure of the medium to be reduced. In order that the resetting forces of these slide valves may be as small as possible, the spaces below the slide valves are connected to the spaces above the slide valves by means of short-circuit channels 13 and 14, respectively. The two reducing devices are coupled together by means of a rod mechanism 15, 16 and 17 so that resetting an associated lever 18, if desired with the use of a regulator, has the effect of resetting the two reducing devices 5 and 8 at the same time.

A compressor 19 is connected in parallel with the back-pressure valve 10 and part of the pipe 9 by means of pipes 20 and 21 and is adapted to draw in atmospheric air via a pipe 22 and a back-pressure valve 23.

A quick-control device constituted by a pipe 24, a reducing valve 25 and a pipe 26, is shown in Fig. 1. The reducing device 25 constitutes a sliding throttle valve which differs from the sliding throttle valves 5 and 8 in that its slide valve 27 comprises a part 28 having a smaller diameter, which results in the formation of an annular channel and enables the pipe 26 to be connected directly with

the pipe 24. The sliding throttle valve 25 can be controlled by the regulator by means of the rod system 29.

The control system operates as follows. If during the use of the hot-gas reciprocating engine working medium leaks away from the working spaces, including chamber 1, or if the engine is required to deliver a higher output, working medium is supplied to the working chamber from the supply vessel 3 via the pipe 4, the reducing device 5 and the back-pressure valve 6. The pressure of the medium which is supplied to the working chamber is controlled by means of the reducing device 5. During those instants at which the pressure in the working chamber is lower than the pressure in the pipe near the back-pressure valve 6, working medium flows into the working chamber. If, however, the pressure in the working chamber 1 increases, for example during compression, thus becoming higher than the pressure in the pipe near the back-pressure valve 6, this back-pressure valve is closed so as to prevent working medium from flowing back through valve 6 to the supply vessel 3. The cyclic process in the working chamber of the machine consequently builds up to a value such that the minimum pressure during the cycle is equal to the pressure of the supply medium after passing through the reducing valve 5.

The highest pressure occurring during a cycle will always be available in the discharge pipe near the back-pressure valve 7. The pressure of the medium in this discharge pipe can be reduced by means of the reducing device 8 so as to correspond to the pressure in the supply vessel 3, it being thus possible for the working medium to be supplied to the supply vessel 3 via the pipe 9 and the back-pressure valve 10.

However, if the hot-gas reciprocating engine is required to deliver a lower output, and hence a smaller amount of working medium is required to participate in the cyclic operation, then, after shifting the sliding valve 12 of the device 8 such that the pressure in the chamber near the back-pressure valve 7 is reduced, working medium will be fed out from the working chamber 1 to the supply vessel 3 via the back-pressure valve 7, the reducing device 8, the pipe 9 and the back-pressure valve 10. Due to the coupling of the slide valves 11 and 12 by means of the rod mechanism 15, 16, 17, a decrease in the reduction by the reducing valve 8 will result in an increase in the reduction by the reducing valve 5. The pressure levels in the working chamber thus alter to values corresponding to the new maximum and minimum pressures so determined.

When the hot-gas reciprocating engine is required to be started, the volume of the supply vessel 3 will generally be insufficient for the amount of air required for starting the engine. However, in order to enable starting with the use of the supply vessel 3 provision is made of the compressor 19, which forces atmospheric air via the pipe 22, the back-pressure valve 23, the compressor 19 and the pipe 21 into the supply vessel 3. The compressor 19 is also used for increasing the control range, since the pressure of the medium contained in the pipe 9 can be raised by means of the said compressor so that the pressure level in the supply vessel 3 can also be raised.

If the pressure of the working medium in the machine is required to be lowered quickly, pipes 24 and 26 can be connected directly so that the maximum pressure of the cycle is reduced. This emergency control may be effected via the rod 29 by a regulator (not shown).

The hot-gas reciprocating engine shown in Fig. 2 comprises a cylinder 30 in which a displacer 31 and a piston 32 are reciprocated. The displacer 31 and the piston 32 are linked to a common crank shaft 35 by connecting-rod mechanisms 33 and 34, respectively. The space 36 above the displacer communicates with the space 40 comprised between the displacer and the piston by means of a heater 37, a regenerator 38 and a cooler 39. The space 36 is the hot chamber and the space 40 is the cold chamber of the hot-gas reciprocating engine. The heater 37

and the hot chamber 36 have terminal energy supplied to them by a burner 41 the combustion gases of which flow along the heater and are discharged at 42.

In order to vary the output or to compensate leakage losses the hot-gas reciprocating engine comprises a control system connected to a pipe 43.

Fig. 3 shows on a larger scale the system connected to this pipe 43. The pipe divides into a pipe 44 and a pipe 45, each enclosing a back-pressure valve 46 and 47, respectively, arranged to permit working medium to flow from the pipe 44 through the pipe 43 to the working chamber of the engine and to permit working medium to flow through the back-pressure valve 47 to the pipe 45.

The pipe 44 and the pipe 45 communicate with a reducing valve 48 and 49, respectively. The reducing valves 48 and 49 are coupled together. The reducing device also comprises a space 50 which is bounded by bellows 51. The reducing valve 48 comprises a rod 52 which at its end bears against the top of the bellows. The space 53 below the reducing valve 48 communicates with a supply vessel 56 by means of a pipe 54 which contains a cock or valve 55. The bellows 51 is provided at the top with a brace 57 which is adapted to reciprocate with the bellows 51 within a casing 58 provided at one end with a screw-thread 59 for threaded engagement with a lid 60 by means of which a spring 61, which bears on the brace 57, can be stressed more or less and by which the bellows 51 can be compressed more or less. The brace 57 is acted upon by a lever 62 which is pivoted at a fixed point 63. The other end of the lever 62 enables the valve 49 to be opened and closed by means of a valve spindle 64. The valves 48 and 49 are urged to their closed positions by springs 65 and 66 respectively.

The pipe 45 provides connection to space 67 in the reducing device below the reducing valve 49. Space 68 above the reducing valve 49 communicates with a supply vessel 70 via a pipe 69. The said supply vessel 70 communicates with a supply vessel 56 by means of a pipe 71 which comprises a reducing device 72. The system described above constitutes a closed unit but since working medium is liable to leak away from the hot-gas reciprocating engine so that working medium becomes lost in course of time, the supply vessel is provided with a compressor 73 by means of which working medium can be fed to the supply vessel 56.

The device operates as follows. If the output of the hot-gas reciprocating engine is required to be increased the average pressure in the hot-gas reciprocating engine is required to be raised and more working medium is required to be supplied. For this purpose the screw lid 60 is turned so as to compress the spring 61 and slightly open the valve 48. As a result, working medium is supplied from the supply vessel 56 via the opened cock 55 and the pipe 54 to the space 50. This results in an increase in pressure in the space 50 and hence also in the pipes 44 and 43. The minimum pressure of the working medium in the working chamber of the engine is also increased and eventually becomes equal to the pressure in the pipe 43. The increase in pressure in the chamber 50 lasts until the force due to the difference in pressures within and without the bellows 51 increased by the spring pressure of the spring 61 is equal to the force of the spring 61. In this case, the valve 48 again closes and the cycle in the working chamber of the machine is at a higher average pressure. The increase of the minimum pressure has the effect of also increasing the maximum pressure but working medium is prevented from escaping since the valve 49 is closed and remains closed.

If, however, the output of the hot-gas reciprocating engine is required to be lowered by reduction of the pressure level in the cycle, the screw lid 60 can be turned so as to reduce the spring pressure of the spring 61. The bellows 51 tends to expand and to withdraw from the valve spindle 52. This results in the lever 62 being pivoted about the point 63 and the valve 49 being opened

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by means of the valve spindle 64 against the pressure of the spring 66. Working medium thus escapes via the spaces 67 and 68 and the pipe 69 to the supply vessel 70. This results in a decrease of the maximum pressure of the cycle and since the compression ratio remains un-
 5 varied the minimum pressure is also reduced with the effect of reducing the pressure in the pipe 44 and hence in the space 50. The bellows are thus again shifted to the right under the action of the spring 61 so that the pressure on the valve 49 is also decreased. This con-
 10 tinues until the valve 49 again closes and the pressure level of the cycle has again been adjusted.

The control system may be used with a multi-cylinder engine as shown in Fig. 4. The multicylinder engine comprises four working chambers 80, 81, 82 and 83,
 15 respectively, each working chamber comprising its own set of back-pressure valves, namely 85, 86, 87, 88, 89, 90 and 91, 92, respectively. The pipes 93, 94, 95 and 96 in which the back-pressure valves 85, 87, 89 and 91,
 20 respectively, are contained, connect to a common pipe 97 which is the supply pipe for working medium and corresponds to the pipe 44 shown in Fig. 3.

The pipes 98, 99, 100 and 101 contain back-pressure valves 86, 88, 90 and 92, respectively. The pipes connect to a common pipe 102, which is the discharge pipe for the working medium and corresponds to the pipe 45
 25 shown in Fig. 3. The system is otherwise exactly similar to that shown in Fig. 3 and operates in a similar manner.

What we claim is:

1. A device for regulating the amount of working medium in the working chamber of a hot-gas engine comprising at least one supply vessel containing said working medium, supply pipe means for connecting said supply vessel to said working chamber, a first reducing device and a first back pressure valve in said supply pipe, said first
 30 back pressure valve being arranged between said first reducing device and said work chamber in order to permit the flow of medium only from said supply vessel to said working chamber, a conduit means including a discharge pipe connecting said working chamber to said supply vessel, a second reducing device and a second back pressure
 35 valve in said discharge pipe, said second back pressure valve being arranged between said working chamber and said second reducing device in order to permit only the discharge of medium from said working chamber to said supply vessel.

2. A device for regulating the amount of working medium in the working chamber of a hot-gas engine comprising a supply vessel containing said working medium, supply pipe means for connecting said supply vessel to
 40 said working chamber, a first reducing device and a first back pressure valve in said supply pipe, said first back pressure valve being arranged between said first reducing device and said work chamber in order to permit the flow of medium only from said supply vessel to said working chamber, a discharge pipe connected to said
 45 working chamber, a second reducing device and a second back pressure valve in said discharge pipe, said second back pressure valve being arranged between said working chamber and said second reducing device in order to permit only the discharge of medium from said working chamber, and coupling means for coupling said first
 50 and second reducing devices together.

3. A device for regulating the amount of working medium in the working chamber of a hot-gas engine comprising a supply vessel containing said working medium, supply pipe means for connecting said supply vessel to
 55 said working chamber, a first reducing device and a first back pressure valve in said supply pipe, said first back pressure valve being arranged between said first reducing device and said work chamber in order to permit the flow of medium only from said supply vessel to said working chamber, a discharge pipe connected to said working
 60 chamber, a second reducing device and a second back pressure valve in said discharge pipe, said second back pressure valve being arranged between said working chamber and said second reducing device in order to permit only the discharge of medium from said working chamber, and coupling means for coupling said
 65 first and second reducing devices together whereby the movement of at least one of the closure elements in one reducing device will cause an opposite movement of one of the closure elements in the other reducing device.

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chamber, a second reducing device and a second back pressure valve in said discharge pipe, said second back pressure valve being arranged between said working chamber and said second reducing device in order to
 70 permit only the discharge of medium from said working chamber, and conduit means for connecting said discharge pipe to said supply vessel through said second reducing device.

4. A device as set forth in claim 3 further comprising a compressor and pipe means for connecting said compressor to said conduit means in parallel with both said supply vessel and discharge pipe whereby said working medium flowing to said supply vessel is compressed.

5. A device as set forth in claim 3 further comprising a third reducing device, and means communicating said supply pipe with said discharge pipe including said first
 15 reducing device, and third reducing device and pipe means.

6. A device for regulating the amount of working medium in the working chamber of a hot-gas engine comprising a supply vessel containing said working medium, supply pipe means for connecting said supply vessel to said working chamber, a first reducing device and a first back pressure valve in said supply pipe, said first back pressure
 20 valve being arranged between said first reducing device and said work chamber in order to permit the flow of medium only from said supply vessel to said working chamber, a discharge pipe connected to said working chamber, a second reducing device and a second back pressure valve in said discharge pipe, said second
 25 back pressure valve being arranged between said working chamber and said second reducing device in order to permit only the discharge of medium from said working chamber, conduit means for connecting said discharge pipe to said supply vessel through said second reducing device, a third reducing device, and means communicating said supply pipe with said discharge pipe including
 30 said first reducing device, said third reducing device and pipe means.

7. A device for regulating the amount of working medium in the working chambers of a multi-cylinder hot-gas engine comprising a supply vessel containing said working medium, supply pipe means for connecting said supply vessel to each of said working chambers, discharge
 35 pipe means in each of said working chambers and connected to said supply vessel for discharging working medium to said supply vessel, each of said supply pipes and said discharge pipes having a back-pressure valve and common pipe means for coupling each working chamber
 40 to each other working chamber.

8. A device for regulating the amount of working medium in the working chamber of a hot-gas engine comprising a supply vessel containing said working medium, supply pipe means for connecting said supply vessel to
 45 said working chamber, a first reducing device having at least one closure element and a first back pressure valve in said supply pipe, said first back pressure valve being arranged between said first reducing device and said work chamber in order to permit the flow of medium only from
 50 said supply vessel to said working chamber, a discharge pipe connected to said working chamber, a second reducing device having at least one closure element and a second back pressure valve in said discharge pipe, said second back pressure valve being arranged between said working chamber and said second reducing device in order to permit only the discharge of medium from said working chamber, and coupling means for coupling said
 55 first and second reducing devices together whereby the movement of at least one of the closure elements in one reducing device will cause an opposite movement of one of the closure elements in the other reducing device.

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