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Hakansson

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[54] **VARYING THE POWER OUTPUT OF STIRLING CYCLE ENGINES**

[76] Inventor: **Sven Anders Samuel Hakansson,** Karolingatan 10, 212 34 Malmo, Sweden

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[51] **Int. Cl.** **F02g 1/04,** F02g 1/06

[58] **Field of Search** 60/24

[56] **References Cited**

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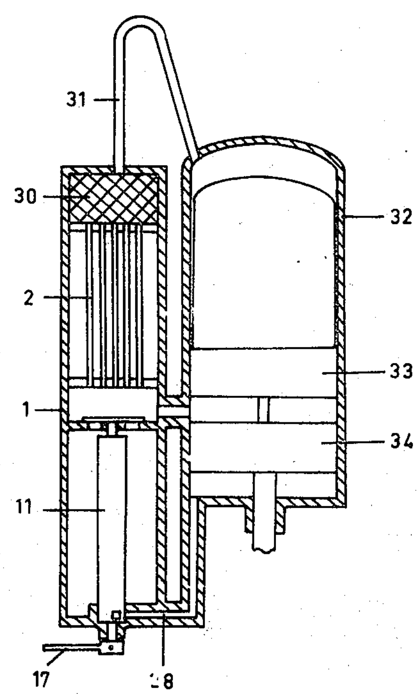
Primary Examiner—Martin P. Schwadron
Assistant Examiner—Allen M. Ostrager
Attorney—Laurence R. Brown

[57] **ABSTRACT**

Means provides the varying of mean pressure of the gaseous working medium in a multiple chamber reservoir at a higher temperature position in each engine cylinder connected to the lower temperature portion of the engine cylinder with valve regulating means governing the following of pressures of gas in the various stages and the cooler portion of the engine cylinder.

5 Claims, 10 Drawing Figures



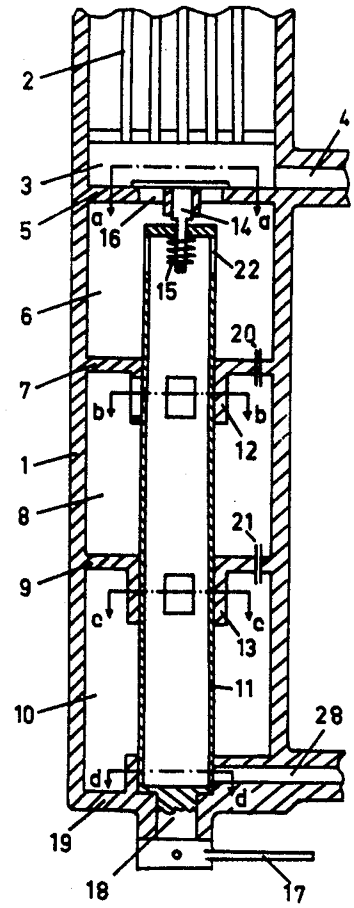
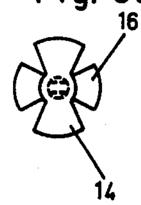


Fig. 1

Fig. 2a

Fig. 3a



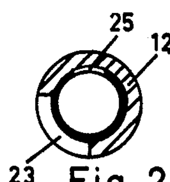


Fig. 2b

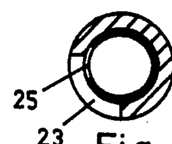


Fig. 3b

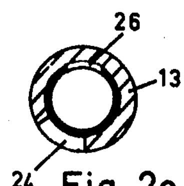


Fig. 2c

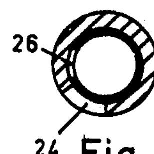
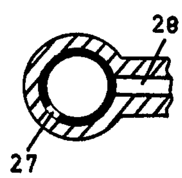


Fig. 3c



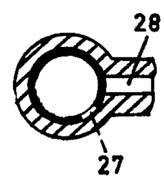


Fig. 2d

Fig. 3d

INVENTOR.
SVEN A.S. HÅKANSSON
BY Laurence R. Brown
Attorney

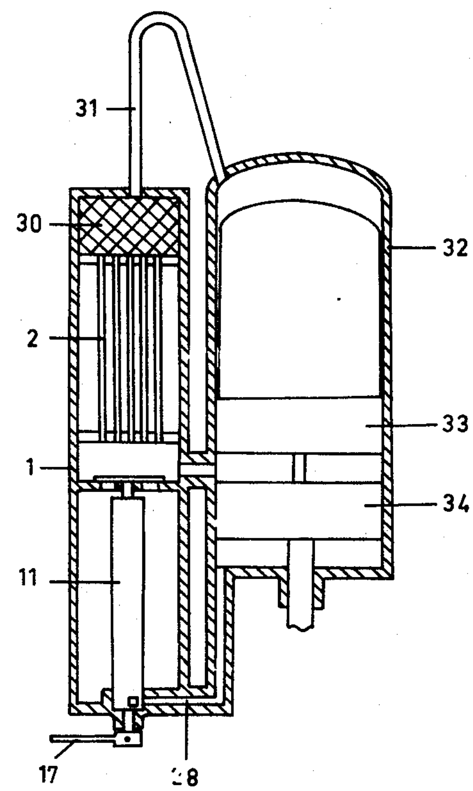


Fig. 4

INVENTOR.
SVEN A. S. HÅKANSSON
BY Laurence R. Brown
Attorney

VARYING THE POWER OUTPUT OF STIRLING CYCLE ENGINES

This invention relates to a device of the kind (hereinafter called "the kind defined") used for varying the power output of a Stirling cycle engine by varying the mean pressure of the gaseous working medium, the said device comprising for each engine cylinder a reservoir, connection means for connecting the reservoir to the cooler part of the engine cylinder containing low temperature gaseous medium, and regulating means for governing the said connection means.

Known devices of the kind defined have the drawback that a continuous stepless variation between minimum and maximum output only can be obtained by choking the connection between the reservoir and the respective engine cylinder, and this involves a highly reduced degree of efficiency when the engine is required to produce only a part of its maximum possible power output. However, devices of the kind defined allow very rapid changes in engine power output. They are also cheap in manufacture and reliable in operation and are consequently desirable for use in connection with Stirling cycle engines to be used in the automotive industry.

The present invention is therefore intended to provide a device of the kind defined which will offer a higher degree of efficiency than that hitherto obtainable with the said known devices.

According to the present invention there is provided a device of the kind defined characterised in that the said connection means comprises a non-return valve always allowing the gaseous working medium in the whole reservoir to pass to the cooler part of the engine cylinder containing low temperature gas.

The invention is defined in the appended claims, and how it may be performed is described in more detail with reference to the accompanying drawings, in which

FIG. 1 is a diagrammatic view in axial section through a device according to the invention,

FIGS. 2 *a*, *b*, *c* and *d* show the positions of four valve members in sections *a—a*, *b—b*, *c—c*, and *d—d* of FIG. 1 respectively the positions of the valves giving maximum load to the engine.

FIGS. 3 *a*, *b*, *c* and *d* show the same valves in their positions corresponding to half load to the engine, and

FIG. 4 schematically shows some parts of a multicylinder Stirling cycle engine provided with a device according to the invention.

FIG. 1 shows a cylindrical housing 1 containing a cooler 2 and a space 3 below the cooler 2, the said space 3 being connected to a compression chamber (not shown in FIG. 1) by a channel 4.

A first wall 5 separates the space 3 from a first chamber 6. A second wall 7 separates the chamber 6 from a second chamber 8, and a third wall 9 separates the chamber 8 from a third chamber 10.

A valve tube 11 extends co-axially and centrally through the three chambers 6, 8 and 10, and fits tightly against tubular flanges 12, 13 on the walls 7 and 9 respectively. At the top of the tube 11 a butterfly valve member 14 is arranged to be axially movable and downwardly actuated by a helical compression spring 15 which tends to establish contact between the valve member 14 and the first wall 5 but allows upward movements of the valve member 14 and passage of medium through an opening 16 in the wall 5 in case the pressure inside the chamber 6 is higher than in the

space 3. The butterfly valve member 14 is angularly locked to the valve tube 11 which is movable in rotation about its longitudinal axis by an arm 17 fastened to a solid extension 18 of the tube 11 passing through the bottom 19 of the cylinder 1.

Choke passages 20 and 21 are provided in the second wall 7 and the third wall 9 respectively.

In case the butterfly valve 14 is closed — as shown in FIG. 2 *a* — the pressure variations in the space 3 (which is connected to a compression chamber via the channel 4) will allow gaseous working medium in the chamber 6 to pass into the space 3 during any period in which there is a higher pressure in the chamber 6. Thus after a relatively short period the pressure in the first chamber 6 as well as the pressure in the second and third chambers 8 and 10 will correspond to the minimum pressure occurring in the space 3. This situation corresponds to maximum output of the Stirling cycle engine — provided that no other output determining factor is changed.

The valve tube 11 and the flanges 12, 13 are provided with openings in their respective axially overlapping sections, as will be seen most clearly in FIGS. 2 and 3, sections *b*, *c*, and *d*. The interior of the tube 11 is always in connection with the first chamber 6 via openings 22. As shown in FIG. 2 an opening 23 in the flange 12 is of angularly greater extent than an opening 24 in the flange 13. The corresponding openings 25 and 26 in the valve tube 11 are of equal size and are of the same angular position. As viewed in section *d* an opening 27 in the valve tube 11 may communicate with a passage 28 in case the valve tube 11 is turned about 120° in the counter-clockwise direction from the position shown in FIG. 2.

As shown in FIG. 3 an angular displacement of the tube 11 of about 90° in the counter-clockwise direction will cause a full opening of the butterfly valve 14 and a nearly full overlapping of the openings 25, 23.

This will cause an easy communication between the space 3 and the first and second chambers 6 and 8. The pressure variations in the chambers 6 and 8 will thus follow the variations in pressure occurring in the space 3. The pressure in the third chamber 10 will correspond to the mean value of the pressure in the chamber 8 because of the choke connection 21.

Basically the operation of the device is as follows:

In case the butterfly valve 14 is closed maximum output and efficiency is obtained. Minimum pressure prevails in all chambers 6, 8 and 10.

In case the arm 17 is turned to rotate the tube 11 slightly the butterfly valve 14 will open gradually. This will cause a rise in pressure in all chambers 6, 8 and 10 until the mean pressure of the space 3 is obtained in all these chambers. This will cause a decrease in output, but also a decrease in efficiency. A further opening of the butterfly valve 14 will allow a varying pressure in the chamber 6 substantially completely following the pressure variations in the space 3.

A further angular movement of the arm 17 to rotate the tube 11 in the opening direction will cause a full opening of the butterfly valve 14 followed by a gradual opening of the connecion between the chambers 6 and 8. The resistance offered by a partly opened connection to a further chamber will cause a decrease in efficiency, but the fully opened connections offer a very slight resistance and thus a decrease in engine power output can be achieved in combination with a minor decrease in efficiency.

FIG. 4 shows schematically and in vertical section the use of a device according to the invention as applied to a single-cylinder Stirling engine.

The cylindrical housing **1** contains a cooler **2**, and a heat-exchanger **30** connected at its top to heater tubes **31** (only one of which is shown). The heater tubes **31** are connected to the top of the engine cylinder **32** containing a displacer piston **33** and a working piston **34**.

The passage **28** shown in FIG. **1** is also shown in FIG. **4** and leads to the space below the working piston **34**. Thus in case the arm **17** is turned to rotate the tube **11** fully in the engine-throttling direction the spaces on both sides of the working piston **34** are short-circuited via the valve tube **11** and will cause a complete stop of the engine.

In case of a multi-cylinder Stirling cycle engine a similar short-circuiting will be obtained by connecting the passage **28** from the unit belonging to one cylinder to the corresponding passage **28** of the unit belonging to the following cylinder in the engine.

From the above description it will be readily appreciated that the illustrated device is of the kind defined and that the valve **14** constitutes an adjustable valve which can be set to act as a non-return valve which always allows the working medium from the whole of the reservoir comprising the chamber **6, 8,** and **10** to pass to the cooler **2** and through the channel **4** to the cooler part of the engine cylinder **32**.

What is claimed is:

1. In a Stirling cycle engine having a gaseous working medium and at least one cylinder with a cooler part of the cylinder with a low temperature gaseous medium, a device for varying the power output by varying the mean pressure of the gaseous working medium, the said device comprising for each engine cylinder a reservoir for containing said gaseou working medium, gas flow connection means for connecting the reservoir to the cooler part of the engine cylinder containing low temperature gaseous medium, and regulating means for governing the said connection means comprising a non-return valve always allowing the gaseous working medium in the reservoir to pass to the cooler part of the engine cylinder containing low temperature gas wherein the reservoir consists of a number of separate chambers connected in series, the first chamber being connected to the said cooler part of the engine cylinder by said non-return valve, valve means connected to govern the flow of the gaseous medium between the said cooler part of the engine cylinder and the number of chambers including movable means being mechanically coupled to open connections successively to the series of chambers in the order away from the cooler part of the engine cylinder and to shut off the connections in the opposite order.

2. A device according to claim **1**, in which the connection between the cooler part of the engine cylinder and the first chamber of the reservoir comprises a combination of a butterfly valve and a non-return valve.

3. A device according to claim **1**, characterized in that a choke passage is present between each chamber of the reservoir.

4. A device according to claim **1** in a multi-cylinder engine, characterized in that the valves include means interconnecting all the reservoirs when the regulating means are moved to positions beyond those corresponding to the opening of the passages between all the chambers.

5. In a Stirling cycle engine having a gaseous working medium, a reservoir for receiving said medium and a cylinder compressing said medium, a device for varying the power output by varying the mean presure of the gaseous working medium between said compression cylinder and said reservoir, comprising in combination, a single valve extending into said reservoir and having an element adjustable between a position preventing and a position permitting flow in both directions between said cylinder and said reservoir and means on said valve operable in said position preventing flow of said medium to prevent flow only in the direction between said cylinder and said reservoir while permitting a flow of said medium in the direction from the reservoir to said compression cylinder.

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