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GAS REFRIGERATOR

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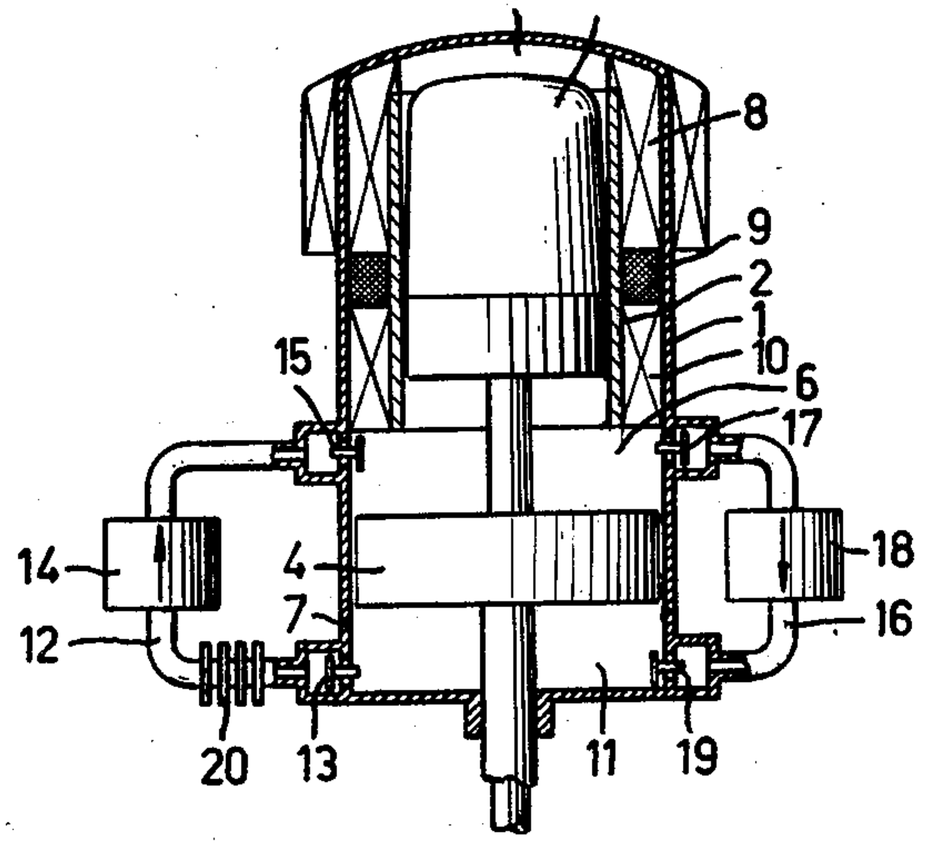

FIG 1

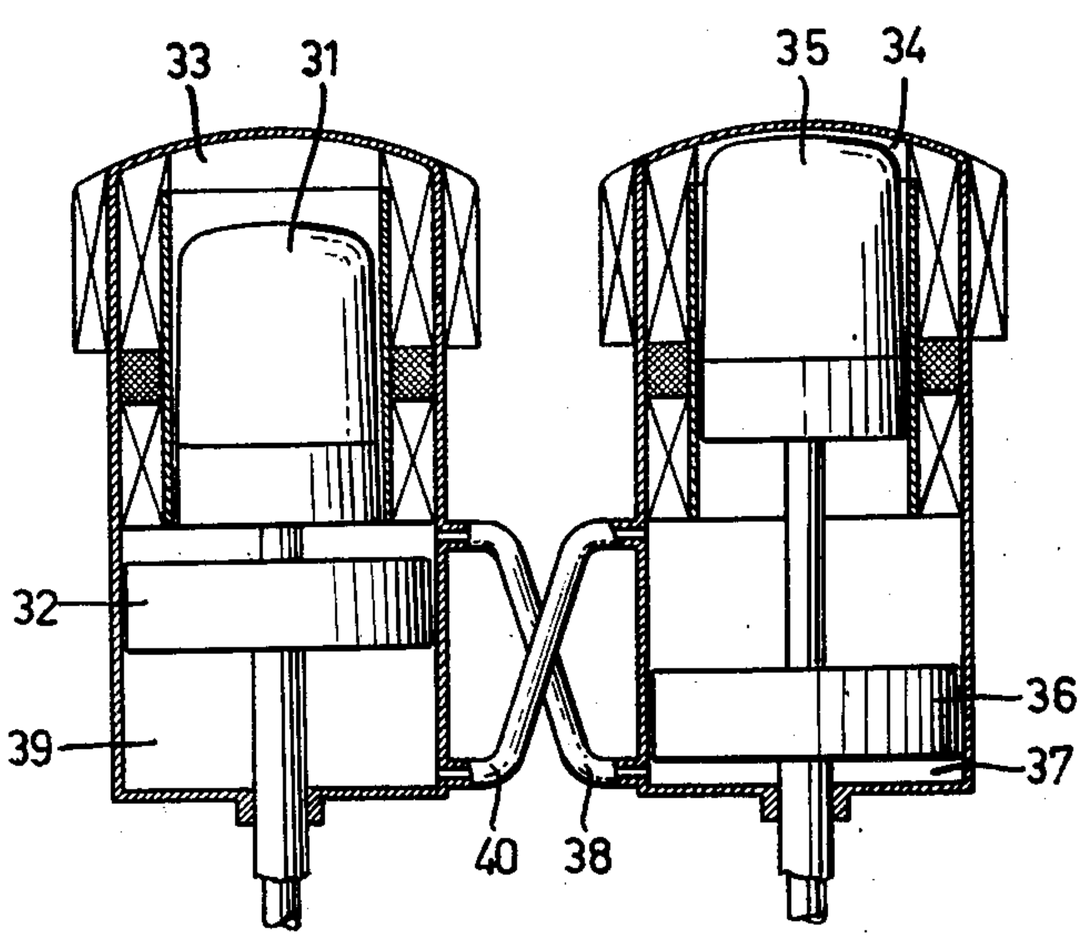

FIG.2

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GAS REFRIGERATOR

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The invention relates to a gas refrigerator having one or more cycles traversed by a working medium and two piston-shaped members for each cycle. During operation of the refrigerator, one of these piston-shaped members has a lower average temperature than the other. This gas refrigerator is characterized in that each of the piston-shaped members having the higher average temperature is constructed as a double-acting member and, with its surface remote from the associated working space, varies the volume of an auxiliary space likewise containing working medium. In addition, in this refrigerator means are available to admit, during the compression in the working spaces, working medium from the auxiliary spaces in question to the associated working spaces and to allow working medium to escape, during the expansion in the working spaces, from these latter spaces to the associated auxiliary spaces.

In this manner, a structurally simple refrigerator is obtained in which, with a suitable load of the gear of the refrigerator and without many technical complications, the compression spaces are extended considerably as compared with those of the commonly used gas refrigerators. This facilitates the obtaining of low temperatures by means of such a gas refrigerator.

In an embodiment of the refrigerator according to the invention having only one cycle, channels with controlled stop members are provided between the spaces situated on either side of the double-acting piston. As a rule, also so-called receivers will be provided in those channels.

Another embodiment of a gas refrigerator according to the invention having two cycles is characterized in that, whereas the movements of the piston-shaped members which are associated with one cycle show a phase difference with the movements of the piston-shaped members which are associated with the other cycle, the side of the double-acting pistons associated with each of the two cycles and remote from the working spaces varies the volume of an auxiliary space which contains working medium in which in each auxiliary space the piston in question performs its compression and expansion stroke respectively substantially in phase with the compression and expansion which takes place in the working space with which the auxiliary space is connected.

In such a machine no stop members need be present between the working spaces and the auxiliary spaces, which members have to be closed and opened during each cycle occurring in the refrigerator.

This advantage also holds good for a special embodiment of this latter type of the gas refrigerator according to the invention, in which embodiment the movement of the piston-shaped members of the one cycle show a phase difference of approximately 180° with the movements of the piston-shaped members of the other cycle.

By a gas refrigerator is to be understood in this connection a driven piston machine which for each cycle is provided with a first space of variable volume, which space is in open connection with a second space which also has a variable volume and in which a higher average temperature prevails than in the first space. In such a machine a regenerator is available in the connection between the two spaces, while a gaseous working medium may flow to and fro between the spaces via the regenerator so as to transport heat from a lower temperature level

to a higher temperature level. If the lower temperature level is for example —200° C. and the higher level for example +20° C., the machine is a refrigerator. If the lower level is for example +15° C. and the higher level for example +400° C., the machine, in which consequently the "refrigerator cycle" is carried out, is a so-called heat pump.

In order that the invention may be readily carried into effect, two embodiments thereof will now be described, by way of example, with reference to the accompanying drawing, in which

FIG. 1 shows a first embodiment of a gas refrigerator according to the invention having only one cycle,

FIG. 2 shows an embodiment of that refrigerator constructed with two cycles and of which the movements of the piston-shaped members of the one cycle show a phase difference of 180° with the movements of the piston-shaped members of the other cycle.

For the sake of simplicity, the gears are not shown in the drawing; the rods of the two piston-shaped members are connected to the gear in a manner commonly used in gas refrigerators.

The embodiment of the refrigerator shown in FIG. 1 has a housing **1** commonly used in gas refrigerators in which a can-shaped member **2** is provided coaxially. The refrigerator contains the piston-shaped members **3** and **4** which show a certain phase difference in their up and down motions in the manner which is normal in this type of gas refrigerators. For the sake of simplicity the piston-shaped member **3** which during operation of the machine has the lower average temperature will be termed "displacer" and the piston-shaped member **4** which during operation of the machine has the higher average temperature will be termed "piston." The working space of the machine is filled with a gaseous medium, for example hydrogen or helium.

The said phase difference is chosen so that when the piston **4** makes its forward or expansion stroke, the medium is contained principally in the freezing space **5** of variable volume. If on the other hand this piston makes its backward or compression stroke, the working medium is contained principally in the cooled space **6** of variable volume. The displacer **3** can be moved up and down in the can-shaped member **2**. The piston **4** moves in the guide box **7**. The freezing space **5** is connected to the cooled space **6** via the heat exchange **8** which is termed freezer, the regenerator **9**, and the second heat exchanger **10** which is the so-called cooler. So far, the gas refrigerator described does not in principle differ from those known so far.

In the embodiment shown in FIG. 1, the piston **4** is constructed as a double-acting piston. This piston influences, with its lower side, the volume of an additional space **11** of variable volume, which space is the so-called auxiliary space. This auxiliary space is connected to the cooled space **6** via a duct **12** in which comprises an outlet valve **13**, a receiver **14** and a controlled valve or slide **15** are arranged. Through the duct **12**, medium can flow only from the auxiliary space in the direction of the arrows shown to the cooled space **6**.

The cooled space **6** in its turn is connected to the auxiliary space **11** through the tube **16** comprising a controlled valve or slide **17**, a receiver **18**, and a suction valve **19**. Through this tube, medium can flow only from the cooled space in the direction of the arrows to the auxiliary space.

It will be clear from FIG. 1 that the piston **4** in its descending stroke, which consequently is the expansion stroke for the gas refrigerator cycle, compresses the medium present in the auxiliary space **11** and forces it into the receiver **14** via the outlet valve **13**. So the receiver **14** forms a storage vessel which contains compressed

working medium. By opening the controlled valve 15 during the compression stroke of the refrigerator cycle of the piston 4, it is achieved that additionally compressed working medium is supplied to the working space of the gas refrigerator.

In addition, in the descending stroke of the piston 4, in which consequently expansion occurs in the gas refrigerator, the controlled valve or slide 17 is opened so that for the expansion of the gas not only the working space proper of the machine is available but also the space available in the receiver 18. This means that the expansion in the refrigerator cycle can be continued to a lower final pressure than when the receiver 18 would not be available. This means in addition that at the freezer 8 a lower final temperature occurs. Finally, the valve 19 opens automatically in the ascending stroke of the piston 4 so that then the gas present in the receiver may flow into the auxiliary space 11.

In this manner the advantage is obtained that without additional load of the gear a larger compression and expansion ratio may be obtained than when the said additional space would not be available. Finally, in the tube 12 a cooler 20 is provided which serves for cooling as much as possible the compressed gas flowing from the auxiliary space 11.

It will be clear that the valves 13, 15, 17 and 19 and the receivers 14 and 18 are necessary in the embodiment shown. At every moment, the condition changes to which the working medium is exposed as the upper and lower sides of the piston 4 differ in phase by 180°. If above the piston 4 an expansion of the working medium takes place, the medium below the piston 4 is compressed at that instant and conversely.

The embodiment of the refrigerator according to the invention having two cycles as shown in FIG. 2, differs from that shown in FIG. 1 in that the displacer 31 and the piston 32 which move in the cylinder 33 have a phase difference in their movements of 180° with respect to the displacer 35 and the piston 36 which move in the cylinder 34. The cranks (not shown) on the crankshaft of this machine are at an angle with each other of 180°. The result is that when the piston 32 makes its descending or expansion stroke, the piston 36 makes its ascending or compression stroke, all this with respect to the refrigerator cycles occurring above these pistons. In this manner a permanently opened connection 38 may be provided between the working space of the refrigerator cycle which

occurs in the cylinder 33 and the auxiliary space 37 which is present in the cylinder 34 below the piston 36. The same holds true for the working space for the refrigerator cycle in the cylinder 34 above the piston 36 and the auxiliary space 39 below the piston 32 in the cylinder 33. In this manner, a permanently opened connection 40 may be provided also between these spaces. All this construction leads to an extremely simple refrigerator having two cycles in which consequently also an additional compression and expansion of the working medium which performs a cycle in the two cylinders, takes place.

What is claimed is:

1. A cold gas refrigerator having two cycles comprising two cylinders each having a pair of piston-shaped members mounted for reciprocation therein, one of which is double-acting, the piston-shaped members in one of said cylinders having a predetermined phase difference with the movements of said piston-shaped members in the other of said cylinders, a main working space between the piston-shaped members in each cylinder, an auxiliary working space on the side of said double-acting member remote from said main working space, conduit means connecting the main working space in one of said cylinders to the auxiliary working space in the other of said cylinders, the side of said double-acting piston associated with each of said two cycles remote from said main working spaces in each cylinder functions to vary the volume of said auxiliary working space containing working medium and to force working medium through one of said conduit means to a main working space in another cylinder, said piston operating its compression and expansion stroke in said auxiliary working space substantially in phase with the expansion and compression which takes place in the main working space with which said auxiliary working space is connected through said conduit means.

2. A cold-gas refrigerator having two cycles as claimed in claim 1 wherein the movements of the piston-shaped members in one of said cylinders are approximately 180° out of phase with the movements of the piston-shaped members in said other cylinder.

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