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REFRIGERANT ENGINE AND WORK DEVICE

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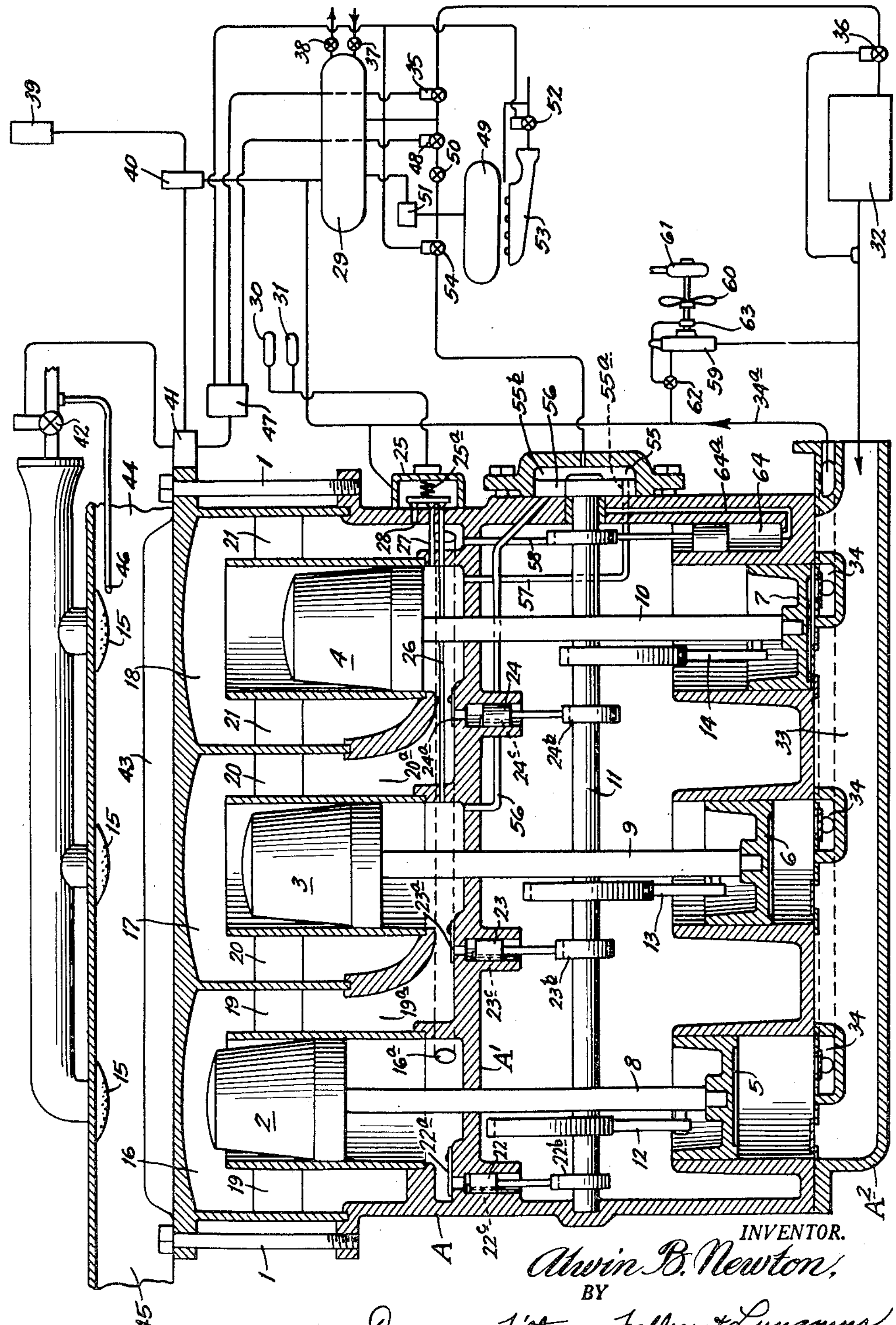

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REFRIGERANT ENGINE AND WORK DEVICE

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This invention relates to a refrigerant engine and work device. The invention is particularly useful in a combined hermetic refrigerant engine and compressor having an automatic starting and capacity control, and also with a refrigerant which is highly effective in the engine and compressor structure.

An object of the invention is to provide a refrigerant engine and work device in which refrigerant is employed as a motive force for the engine and as a material acted on in the work device and in which the refrigerant is employed in the power and work chambers of the device. A further object is to provide a completely automatic and self-powered system independent of electrical energy for either refrigeration, air conditioning, or heat pump operation and employing refrigerant in the power and work portions of the apparatus. A still further object is to provide, in a combined refrigerant engine and work device, means for providing a successive rise in temperature as a starting means and also providing in the run-down cycle of the apparatus condensed refrigerant for starting the engine. Yet another object is to provide in such apparatus means for limiting the pressure in the power piston chambers and means for operating the refrigeration cycle at less power input. A still further object is to provide control means responsive to temperature or other conditions for bringing about the bleeding of refrigerant from the power cylinders, etc. Yet a further object is to provide in such a mechanism control means whereby refrigerant may operate above the critical temperature of the refrigerant during the hot portion of the cycle and below the critical temperature during the cold portion of the cycle through the joint control of pressure and temperature reached in the cycle.

Another object is to provide in such a structure means for employing refrigerant in the power side of the system in such a manner that the refrigerant is in the form of gas in one part of the operation and in the form of liquid in another part of the operation. A further object is to provide, in a system of the character described, a refrigerant gas having properties peculiarly adapted to the hot portion of the cycle and in the refrigeration system. A still further object is to employ in such a system carbon dioxide which combines the characteristics needed to make a good thermocompressor which are similar to those required to make a good hot gas engine with the characteristics needed to be a good refrigerant. Other specific objects and advantages will appear as the specification proceeds.

The invention is shown, in an illustrative embodiment, by the accompanying drawing, in which a portion of the apparatus is shown in section and the remainder in a diagrammatic layout. Much of the apparatus is conventional, and the diagrammatic showing is believed to be sufficient.

In the illustration given, A designates a casing providing a large chamber which is divided into an upper power chamber and a lower work chamber by the transverse partition wall A^1. Extending below the bottom

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wall of the casing is a conduit part A^2 for forming a suction manifold. The upper portion of the casing is formed in two parts, which may be secured together by bolts 1. Within the casing are two sets of pistons, one of which provides power in the upper chamber, and the other of which provides a work chamber as, for example, a chamber for the compressing of refrigerant. Power is supplied by the pistons 2, 3 and 4, whereas, in the illustration given, refrigerant is compressed by the pistons numbered 5, 6 and 7. Each of the pistons operates in a chamber formed by casing walls, as illustrated in the drawing. The pairs of pistons 2 and 5, 3 and 6, and 4 and 7, are each interconnected by connecting rods 8, 9 and 10, respectively. Power is thus transmitted directly from a power piston to a compressor piston. In addition, each connecting rod is connected to a crank-shaft 11 on which are located eccentrics (or cranks) which by means of connecting rods 12, 13 and 14 provide for the transmission of power from one set of pistons to another and for their proper cycle relationship.

The power-producing cycle is similar in operation to the more or less conventional hot air engine except that it employs a hot refrigerant gas. Heat is applied by means of burners 15 to the heads of each cylinder 16, 17 and 18. Below the heated area regenerator sections 19, 20 and 21 are provided, together with cross connections or passages 19*a* and 20*a* so that the upper space above each piston is cross connected to a lower space below an adjacent piston in the following order: 2 to 3, 3 to 4, and 4 to 2. The chamber 18 is connected to chamber 16 by means of the conduit 16*a*. The engine operates on a comparable cycle, therefore, to hot air engines, with the exception that refrigerant under pressure is used in place of air as the power-producing medium.

In the illustration given, I have set forth three power pistons and three compressor pistons, but it will be understood that any number may be employed in the practice of the invention.

Associated with each combination cylinder space is a small, low capacity piston driven through the medium of an eccentric on the main crank-shaft or rock shaft 11. These pistons are located in cylinders so that refrigerant from the refrigeration portion of the system may be pumped into the engine portion. They may employ a limited compression ratio which will automatically limit the increase in pressure in the engine section as compared to the refrigeration section. The pistons are designated by numbers 22, 23 and 24. Above the pistons 22, 23 and 24 are passages connecting the piston chambers with the spaces below regenerator sections 21, 19 and 20, respectively through the valve means 22*a*, 23*a* and 24*a* which are effective in permitting refrigerant to flow into the engine section but preventing refrigerant from returning to the lower or refrigerant portion of the structure. Each piston is equipped with a conventional suction valve (designated 22*c*, 23*c*, and 24*c*, respectively) which permits the flow of refrigerant from the lower or refrigerant chamber into the piston chamber, while preventing return flow into the refrigerant chamber. In the drawing, the eccentrics for operating the pistons 22, 23 and 24 are indicated by the numerals 22*b*, 23*b* and 24*b*.

The limited compression ratio of the pistons 22, 23 and 24 may be used to limit the power of the engine by means of limiting the pressure in the power piston chambers. However, it is sometimes advantageous to operate the refrigeration cycle at less power input, and furthermore, an alternate manner of limiting the maximum power may be employed as follows:

A pressure-limiting device 25, normally urged inwardly by a spring 25*a*, is associated with bleed tubes 26, 27 and 28 so as to close the same, or at a given pressure in the power chamber, to release refrigerant so that refrigerant is bled out of the tubes into the water-cooled condenser 29 of the refrigeration system. The pressure at which this action occurs may be varied, as, for example, by use of a temperature-responsive bulb 30 which is responsive to the temperature in the refrigerated or air conditioned space, and additionally, if desired, by an outside temperature-responsive bulb 31 which serves to increase the capacity during periods of warm weather or decrease it during periods of cool weather. Other means of effecting the bleed pressure may also be employed such, for example, as a reduction of suction pressure being arranged to cause a reduction in pressure within chambers 16, 17 and 18.

The refrigeration system itself is substantially conventional, consisting of evaporator 32, suction manifold 33, discharge manifold 34 communicating through conduit indicated by line 34*a* with the condenser 29, liquid valve 35 and expansion valve 36. Water in and out of the water-cooled condenser may be supplied by pipes indicated by lines 37 and 38, respectively, but any other means for bringing about condensation may be employed.

The system may be started and stopped by means of a conventional thermostat 39 which operates through limit controls such as 40 responding to high refrigerant temperature and 41 responding to high engine temperature. Assuming that a demand for cooling has existed for some time, thermostat 39 will maintain valve 42 in an open position, allowing fuel to enter the burner 15 and heat the engine chambers 16, 17 and 18. To further such heating, fins, as indicated by the numeral 43, may be employed. The flue gases may be expelled through one or more flues 44, 45, etc. Furthermore, the gas may be lighted and controlled safety-wise by a conventional pilot, as at 46.

Provision is made for re-starting the engine after shutdown, and this provision is associated with the action at the time of shutting down. When the thermostat 39 is satisfied, it closes valve 42 and simultaneously, by means of a combination relay and timer 47, closes valve 35 and opens valve 48. The liquid refrigerant is then diverted from the expansion valve 36 into auxiliary receiver 49 during the cool-down or coasting period of the engine. The refrigerant enters through check valve 50 (the use of which is optional), and receiver 49 may be supplied with a relief device 51 so that in the event excessive pressure is developed, the refrigerant will relieve or flow back into the water-cooled condenser 29 in sufficient quantity to remove the pressure hazard.

When the thermostat again calls for an operation of the equipment, it opens valve 42 to ignite the main gas burners 15. It also opens auxiliary gas valve 52 to ignite burner 53, thus applying heat to auxiliary receiver 49. Valve 54 is also opened at the same time so as to apply the higher pressure refrigerant to chamber 55. In chamber 55 is a disc 56 rotatably mounted on the main crankshaft 11 and provided with a valve passage 55*a* selectively registering with tubes 56, 57 and 58 and communicating also with the space 55*b*. This disk acts as a valve for permitting successive flow of refrigerant into the tubes for starting the operation of the pistons as the transverse opening 55*a* is brought sequentially into registry with the tubes. The rise of pressure brought about by the flow of highly heated refrigerant through the tubes starts the movement of the pistons, which is immediately augmented by the rise in pressure in the next appropriate space as well as by the heat input from the main burner 15. The combination relay-timer 47 soon closes valve 52 and somewhat later closes valve 54, and the engine then continues to operate under the heat input of the main burner 15. Alternately, the speed of rotation of the engine may be used to close valve 52 and valve 54 rather than the timing action of a relay such as 47.

Certain other pieces of equipment, such as fans and pumps, may frequently have to be operated in conjunction with refrigerant apparatus. This can be done by the main engine in the obvious manner of providing a shaft seal for the crank-shaft 11 and appropriate driving means external to the engine for fans, pumps, etc. However, an alternate method is shown in which a turbine or positive displacement engine 59 drives apparatus such as fan 60 or pump 61. This engine 59 obtains its energy from the high pressure refrigerant line 34*a* through valve 62, shown controlled by a governor 63. This means for driving such auxiliary mechanism is provided without the necessity of using electrical connections of any kind, and even though this is accomplished in the refrigeration portion of the cycle, the low cost of fuels used for direct firing permits this action without excessively burdening the system with cost of operation.

When heating instead of cooling is required, the entire cycle may be reversed without loss of any of its features such as capacity control, automatic starting, etc., by obtaining heat from a heat source in evaporator 32 and using the heat rejected in the condenser water or other condenser cooling medium as at 38 as well as the heat rejected at 44 and 45 for the heating process. The engine and compressor arrangement may obviously take other forms such as those employing a conventional crankshaft, connecting rod and piston, and, if desired, pressure lubrication may be provided as by oil pump 64 feeding lubricant through line 64*a* and other lines (not shown) to bearing surfaces.

In the operation of the foregoing structure, the use of a refrigerant instead of a noncondensable gas, such as air, permits one to take advantage of a partial condensation cycle. This is accomplished by adjusting the pressure levels in the chambers 16, 17 and 18, as controlled by the controller 25, to a point in which some of the refrigerant condenses as it passes through regenerator 19, 20 or 21 into the corresponding cold space below. This causes a marked further reduction in volume while raising the mean effective pressure. As the combined remaining gas and liquid refrigerant is forced back through the regenerator, the liquid is re-evaporated as the liquefied refrigerant comes into intimate contact with the heat-exchanger. By control of the pressure in the chambers 16, 17 and 18, it is thus possible to operate above the critical temperature of the refrigerant during the hot portion of the cycle and below the critical temperature during the cold portion of the cycle, in each set of chambers. This would make a different transition from the liquid to gaseous stage, but gives a greater mean effective pressure in a somewhat similar manner to a cycle which did not happen to cross the critical pressure line. This can be attained by joint control of the pressure and temperature reached in the cycle.

A number of refrigerants can be satisfactorily employed. Among them are the following: Freon–4 (CF_4), ethan (C_2H_6), nitrous oxide (N_2O), Freon–13 ($CClF_3$), propylene (C_3H_6), propane (C_3H_8), Freon–22 ($CHClF_2$), and Freon–12 (CCl_2F_2). I have discovered that optimum results in the performance of the device herein described are obtainable through the employment of carbon dioxide as the working fluid and refrigerant. Carbon dioxide is peculiarly adapted for operation in the engine and compressor system above described. Carbon dioxide has sufficient stability at the elevated temperatures in the hot end of the cylinder while always being at a temperature and pressure above the critical point, at the same time being effective as a refrigerant in the operation of the refrigeration system. For these reasons and others, carbon dioxide appears to be unique as the combined refrigerant and energy-producing gas in the thermo compressor of hot gas systems. Carbon dioxide may be effectively employed for operation in the power cycle on both sides of the critical pressure. In fact, with sufficient cooling of the bottom end of the cylinder, there can be easily a zone of condensation which will limit the high pressure attainable by heating gases in the hot end of the cylinder, whereby some of the energy would be transferred directly from heat input at one end to condenser refrigerant in the other end of the cylinder. Putting the matter in another way, the carbon dioxide compresses itself in the thermocompressor and then expands through an expansion valve in the evaporator without ever being subjected to an external power cycle, and in this operation the carbon dioxide has peculiarly excellent characteristics and is unique.

While, in the foregoing specification, I have set forth specific structures and steps in considerable detail for the purpose of illustrating the invention, it will be understood that such details of structure and procedure may be varied widely by those skilled in the art without departing from the spirit of my invention.

I claim:

1. In a refrigerant engine and compressor in which the refrigerant is employed as the motive fluid in the engine and the material acted on in the compressor, a casing providing an engine chamber and a compressor chamber, a plurality of interconnected piston and cylinder units in said engine chamber, each of said units being equipped with regenerator means intermediate the length thereof, means for heating said casing adjacent one end of said units, piston and cylinder means in said compressor chamber, said piston and cylinder means being coupled to a condenser, expansion valve, and evaporator to form a refrigeration system, a crankshaft mounted for rotation in said casing and coupled to said piston and cylinder means, a plurality of flow passages communicating said engine and compressor chambers, each of said passages being equipped with one-way pump means connected to said crankshaft for causing flow of refrigerant from said compressor chamber to said engine chamber.

2. The structure of claim 1, in which conduit means communicate the other end of each of said units with said condenser, and pressure-relieving valve means in said conduit means.

3. The structure of claim 1, in which conduit means

communicate the other end of each of said units with means in said refrigeration system for supplying high pressure refrigerant, means in said conduit means for sequentially communicating said high pressure refrigerant supply means with individual units.

4. The structure of claim 3 in which the said sequentially communicating means is coupled to said crankshaft.

5. In a refrigerant engine and compressor, a casing providing an engine chamber and a compressor chamber, a plurality of pistons in each of said chambers and connected by shafts whereby the operation of an engine piston moves a compressor piston, a refrigerant in the chamber of the engine and the chamber of the compressor, means for heating the refrigerant for driving the engine pistons and thereby the compressor pistons, means for directing refrigerant from the said compressor chamber into the said engine chamber, means for collecting condensed refrigerant from the compressor during the run-down cycle of the engine, means for heating the said collected refrigerant, and means for supplying the refrigerant engine, to start the pistons thereof, with heated refrigerant in a controlled and sequential manner.

6. The structure of claim 5, in which the said pistons are coupled to a crankshaft mounted for rotation in said casing and said supply means includes a valve-equipped disk mounted on said crankshaft, said valve being in selective communication with the cylinders of said engine pistons.

7. The structure of claim 5, in which means are provided in said casing for bleeding refrigerant from the engine chamber into a refrigerant system to control the pressure within the engine chamber.

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