

Aug. 16, 1938.

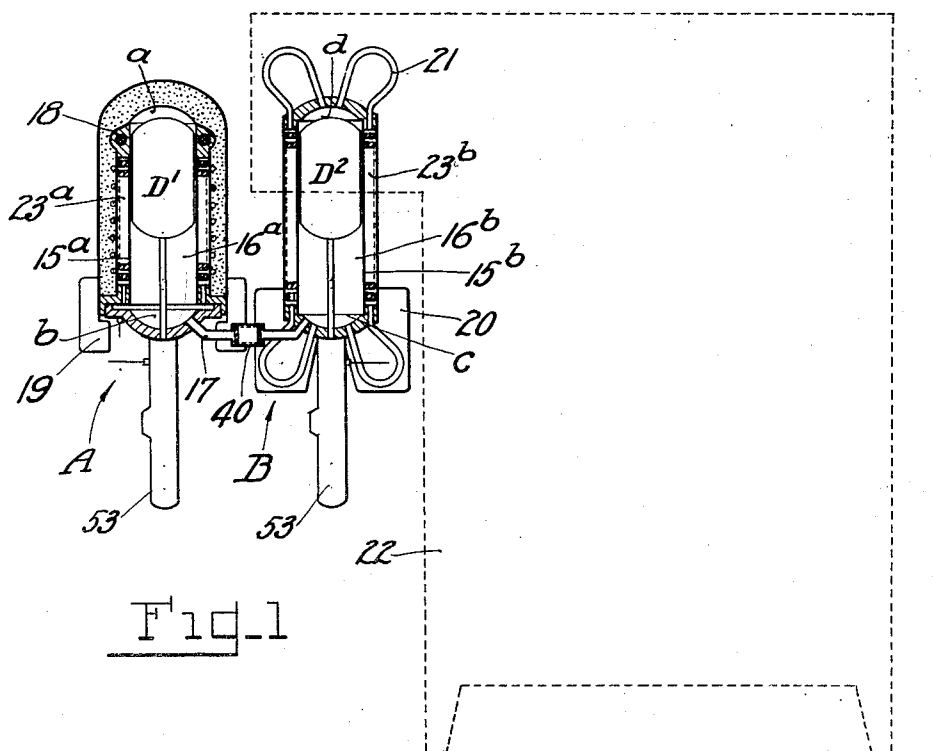
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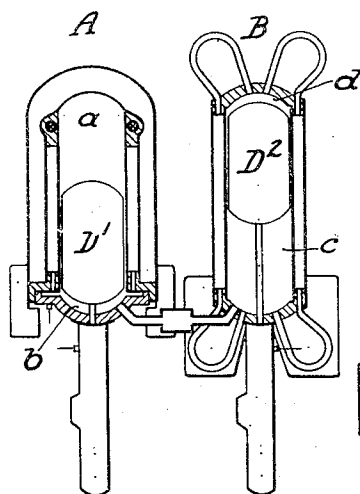
APPARATUS FOR TRANSFERRING HEAT

Filed Oct. 18, 1935

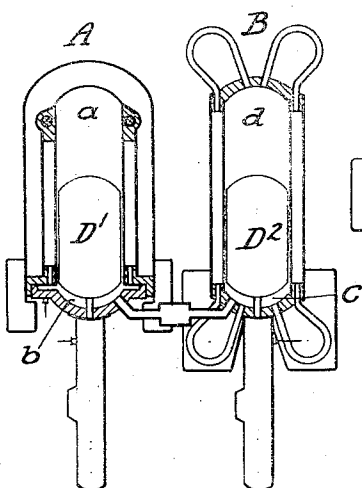
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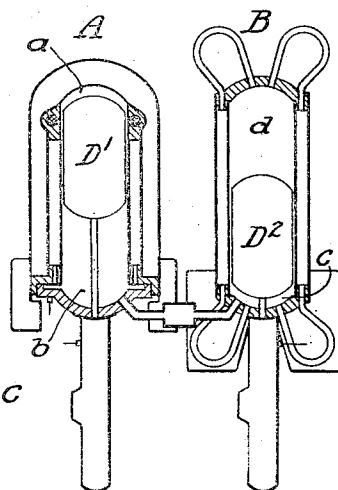
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File 4

INVENTOR:

Vanuatu Bush.

by Mike, Calver & Gray

Attyys.

Aug. 16, 1938.

V. BUSH

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APPARATUS FOR TRANSFERRING HEAT

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FIG. 5

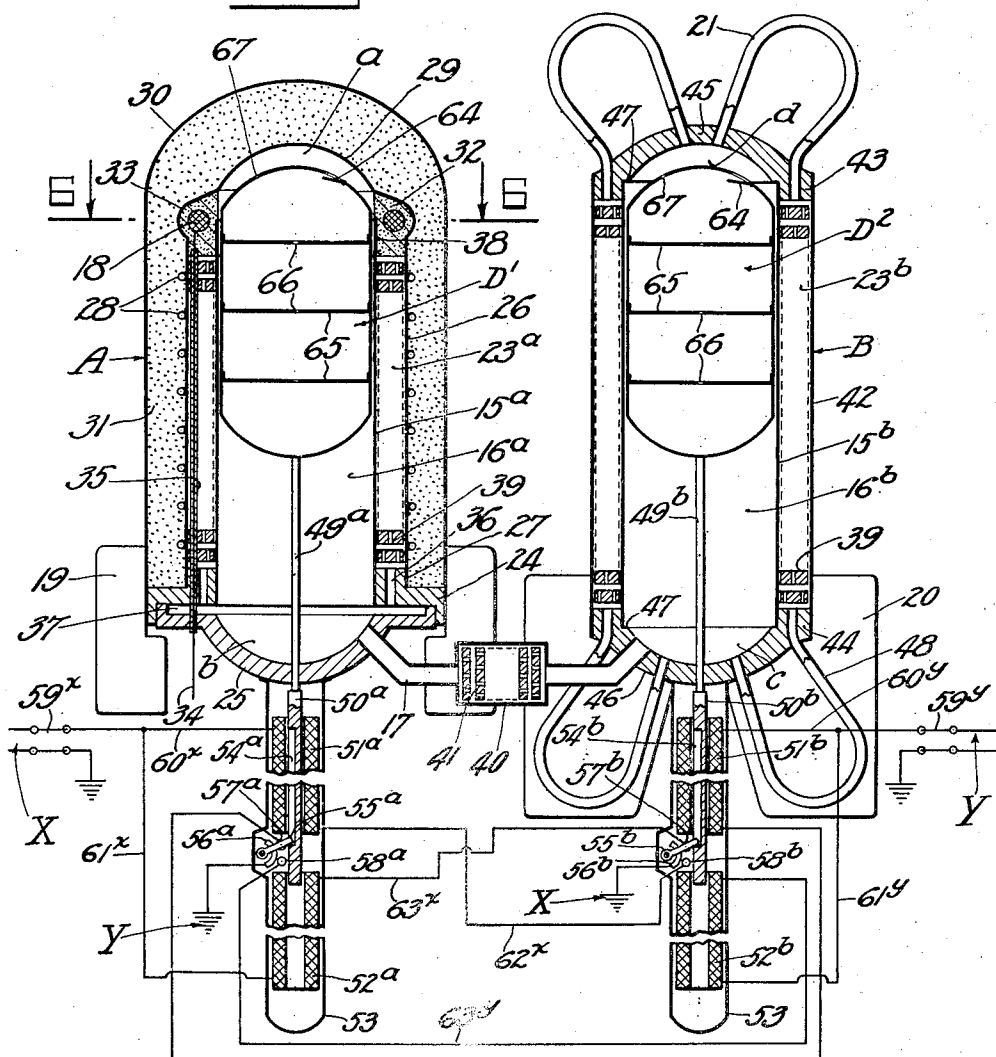


FIG. 6

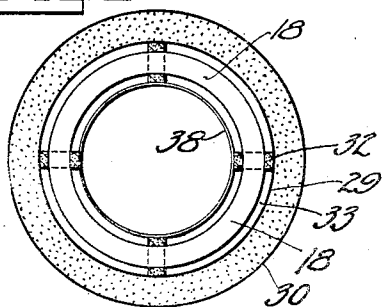
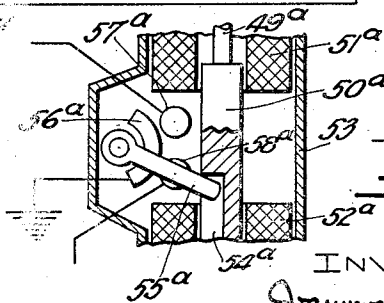


FIG. 7



INVENTOR:
Vanuvar Bush,
 by *Dick, Cohn & Gray,* ATTYS.

Aug. 16, 1938.

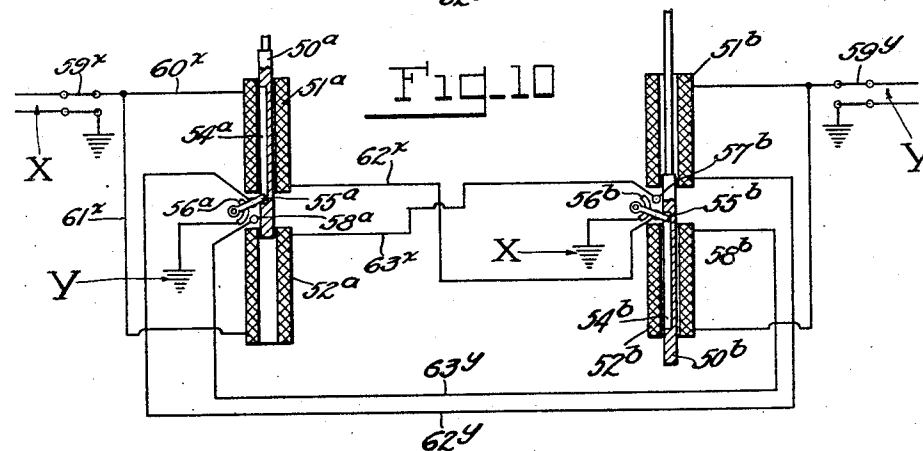
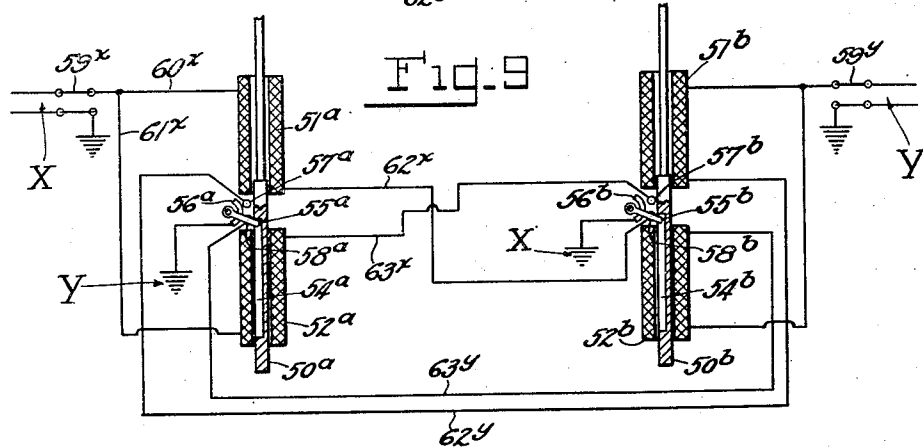
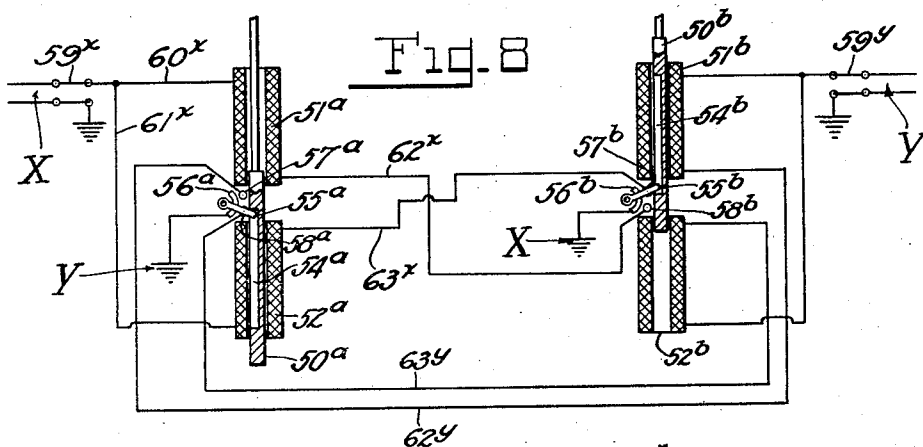
V. BUSH

2,127,286

APPARATUS FOR TRANSFERRING HEAT

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INVENTOR:

Vanuatu Bush.

by Dike, Calver & Gray.

Attys.-

UNITED STATES PATENT OFFICE

2,127,286

APPARATUS FOR TRANSFERRING HEAT

Vannevar Bush, Belmont, Mass., assignor, by
mesne assignments, to Research Corporation,
New York, N. Y., a corporation of New York

Application October 18, 1935, Serial No. 45,553

9 Claims. (Cl. 62—1)

In another application filed July 17, 1935, Serial No. 31,859, I have described a method of and apparatus for directly utilizing heat energy for the purpose of compressing gases without the interposition of mechanical power, this being accomplished by alternating heating and cooling a body of gas at constant volume, thereby causing its pressure alternately to rise and fall, and employing the fluctuations in pressure to transfer quantities of gas from a region of relatively low pressure to a region of relatively high pressure.

The present invention has for its general object to utilize the same or similar principles for the purpose of transferring heat from one region to another of higher thermal potential, that is to say, against the direction of normal heat flow, and includes both a novel method of and novel means for accomplishing this result. An apparatus embodying the invention may, for convenience, be termed a "thermal pump" or "thermal transformer" and, being reversible, may be employed for the purpose of supplying heat to a relatively warm region, as in house heating, or for the purpose of extracting heat from a relatively cold region, as in a refrigerator. In accordance with the invention the flow of heat from a source to a sink, i. e., from the place of its application to that of its dissipation, is caused directly, and without the interposition of mechanical power, to effect a transfer of heat from one region to a second of higher thermal potential. More particularly, the transfer of a relatively small amount of heat over a relatively great temperature range causes directly the transfer of a relatively large amount of heat over a lesser temperature range, and I believe myself to be the first to provide an apparatus for thus transferring more heat than it receives without the intermediary conversion of the supplied heat energy into mechanical power. Although the apparatus includes certain moving parts, these are merely for the control of the thermal cycle and do not operate against any considerable resistance, so that the power required for their operation is relatively small, the energy employed for the accomplishment of the results aimed at being, in accordance with the principle of the invention, heat energy as distinguished from mechanical energy.

The invention is herein considered primarily from the standpoint of its use for refrigerating purposes and will best be understood from the following description of the construction and operation of the apparatus shown in the accompanying drawings, this, however, being chosen for purposes of exemplification merely, as it will

be obvious that the invention, as defined by the claims hereunto appended, may be otherwise embodied and practiced without departure from the spirit and scope thereof, since the wide range of application of the invention for various purposes involves modifications in design in order to best adapt it to those purposes.

In said drawings:

Fig. 1 is a diagrammatic sectional view of an installation of apparatus embodying the invention for refrigeration purposes.

Figs. 2, 3 and 4 are views similar to Fig. 1 showing the parts in different positions assumed thereby during the cycle of operations.

Fig. 5 is a vertical sectional view, partly diagrammatic but on an enlarged scale and more in detail, of the apparatus shown in Fig. 1.

Fig. 6 is a section on the line 6—6 of Fig. 5.

Fig. 7 is an enlarged fragmentary detail view of certain parts of the displacer operating mechanism shown in Fig. 5.

Figs. 8, 9 and 10 are diagrammatic views of the displacer operating mechanism shown in Fig. 5, showing the same in the positions corresponding to Figs. 2, 3 and 4, respectively.

In order that the principles of the invention may be clearly understood, the general arrangement of the apparatus shown and its mode of operation will first be outlined, after which the construction of the several parts will be described more in detail.

Referring to Fig. 1, the apparatus comprises two units A and B which, for convenience, may be termed the power or compressor unit and the refrigerator unit, respectively. Each unit comprises a casing 15a, 15b enclosing a chamber 16a, 16b, the chambers of the two units communicating with one another at their lower ends through a conduit 17, and the whole constituting a closed system containing a fixed or constant volume of gas. The upper end a of the chamber 16a of the unit A is heated, as by an electric heating coil 18. The lower ends b and c of the chambers 16a and 16b of the units A and B, respectively, are cooled, as, for example, by cooling fins 19 and 20, the latter being larger than the former. The upper end d of the chamber 16b of the unit B communicates with refrigerating pipes or coils 21 which, as herein shown, are conveniently located within a refrigerator cabinet 22. Within the chambers 16a and 16b of the units A and B are members D1 and D2, respectively, conveniently called displacers, which are periodically moved in a predetermined sequence from one end to the other of their respective chambers, by

means hereinafter described, to shift the gas in the several chambers from one end to the other thereof. In its passage between the regions *a* and *b* of the unit A, and between the regions *c* and *d* of the unit B, the gas is preferably caused to flow through regenerators 23a, 23b which, as shown, are annular passages surrounding the casings 15a, 15b, containing heat-storing material, and having a thermal gradient along their lengths, the thermal conductivity longitudinally being small. The gas is thus caused to be heated and cooled gradually during its passage, rather than abruptly, with consequent improvement in efficiency.

The cycle of operations is as follows. The parts being in the positions shown in Fig. 1, the displacer D1 moves down into the position shown in Fig. 2, thereby transferring the gas in the chamber 16a of the unit A from the cooled region *b* to the region *a* where it is heated, so that, since the two units are interconnected by the open conduit 17, and since the system is a closed one and the volume of gas contained therein constant, the gas pressure in the whole apparatus, including the unit B, rises. At this time the gas in the unit B is in the region *c* from which a portion of the heat imparted to it incidentally to its compression is ejected by the cooling fins 20. The displacer D2 then moves down into the position shown in Fig. 3, thereby transferring the gas in the chamber 16b of the unit B from the heat ejection region *c* to the refrigerated region *d*, the gas passing from the region *c* to the regenerator 23b through heat exchange pipes 48, hereinafter further described, where the remainder of said heat is ejected. The displacer D1 then moves up into the position shown in Fig. 4, transferring the gas in the chamber 16a of the unit A from the region *a* to the region *b* where it is cooled, so that the pressure in both units falls. The displacer D2 then moves up into the position shown in Fig. 1, thereby returning the gas in the chamber 16b of the unit B from the region *d* to the region *c*, absorbing heat in its passage through the coils 21, and completing the cycle. It will be seen that, considering the unit B, the gas is in the heat ejection region *c* when it is compressed and in the refrigerated region *d* when it is expanded. Consequently the region *d* and the coils 21 communicating therewith will be cooled or refrigerated, and the heat extracted therefrom will be transferred to the region *c* and delivered or ejected from the latter by the cooling fins 20.

Referring to Fig. 5, the casing 15a of the power or compressor unit A comprises a hollow cylinder, preferably of suitable heat insulating material, supported at its lower end on an annular base 24, preferably of copper, to which is soldered or otherwise secured a bottom cap 25, also preferably of copper, which closes the lower end of the chamber 16a. Surrounding the cylinder 15a, but spaced therefrom to provide the annular regenerator passage 23a, is a coaxial hollow cylinder 26 of thin sheet metal, preferably Monel metal or stainless steel, supported at its lower end on an annular shoulder 27 formed on the base 24. The wall of the cylinder 26 is made as thin as practicable in order to hold down thermal conductivity, and is braced or reinforced by rings or hoops 28 to assist in withstanding the internal pressure. The upper end of the chamber 16a is closed by a dome 29 of spun sheet metal similar to that of which the cylinder 26 is composed and welded or otherwise secured to the upper end of said cylinder 26. The entire unit, with the exception of the base

24 and cap 25, is preferably enclosed in an insulating jacket comprising a bell-shaped outer casing or shell 30 secured and sealed at its lower edge to the base 24, and providing, between itself and the outer cylinder or wall 26 and dome 29, a space 31 filled with suitable insulating material, such as lampblack. The cooling fins 19 are soldered to the base 24 and casing 30.

The heating coil 18 comprises an annular helix of a suitable heater alloy and is supported by spaced porcelain or other insulators 32 (see also Fig. 6) in an annular recess 33 formed in the dome 29, the lead wires 34 being brought down through porcelain tubes 35 in the regenerator space 23a and extending through the base 24 and a suitably sealed opening in the cap 25.

The regenerator space 23a connects the regions *a* and *b* at the upper and lower ends respectively of chamber 16a. At its lower end said space communicates, through an annular series of holes 36 in the base 24, with a marginal space 37 in the cap 25, whereby the downwardly flowing gas is caused to impinge upon the cap, thereby facilitating heat transfer. At the upper end of the inner cylinder or casing 15a is provided a thin metal cylinder 38 for directing the gas flowing upwardly from the space or passage 23a into the region *a* into proximity to the heating coil 18. The regenerator space 23a is loosely filled with material capable of giving up and receiving heat rapidly. As shown, this material is in the form of spaced, perforated rings 39, the perforations in adjacent rings being staggered, and the space not filled by the rings being relatively small. The rings 39 adjacent the upper heated region *a* are preferably of copper and those adjacent the lower cooled region *b* of aluminum. In the course of its transfer between the ends *a* and *b* of the chamber 16a, the gas passes through the regenerator space 23a, giving up a portion of its heat to the rings 39 during its downward passage, and absorbing heat from the rings during its upward passage.

The conduit 17 connecting the units A and B is preferably provided with an intermediate regenerator comprising a cylindrical casing 40 connected at its ends in said conduit and containing spaced, perforated, aluminum disks 41 whose action is similar to that of the rings 39. The temperature of the region *b* is preferably higher than that of the region *c*, and there is a certain amount of flow back and forth through the conduit 17 due to the fluctuations in pressure in the respective units. In the course of this flow, the gas gives up a portion of its heat to the disks 41 in passing from the region *b* to the region *c* and absorbs heat from said disks in passing from the region *c* to the region *b*.

The refrigerator unit B is generally similar to the power unit A with certain differences due to the differences in function. The spaced, coaxial, inner and outer casings or cylinders 15b and 42 are both composed of thin sheet metal, preferably Monel metal or stainless steel, and are spaced to provide between them the annular regenerator passage 23b by engagement at their upper and lower ends with opposite sides of annular marginal flanges 43 and 44 on upper and lower caps 45 and 46, preferably of copper. The outer cylinder 42 is soldered at its upper and lower ends respectively to the outer faces of the flanges 43 and 44, while the inner cylinder 15b fits loosely in the caps 45 and 46 in engagement with the inner faces of the flanges 43 and 44 and with its ends abutting annular shoulders 47 on said caps. Except that the rings 39 may all be of aluminum, the

regenerator 23b of this unit is substantially identical with the regenerator 23a of the unit A but communicates at its upper end with the region d through the cooling pipes 21 and at its lower end with the region c through the heat exchange pipes 48. The cooling fins 20 are soldered to the heat exchange pipes 48 and to the cap 46. Consequently the flow of gas between the regions c and d takes place, not only through the regenerator 23b, but also through the pipes 21 and 48.

Suitable mechanism for operating the displacers D1 and D2 in the sequence hereinbefore outlined is shown in Figs. 5, 8, 9 and 10, which show positions of the parts corresponding respectively to Figs. 1, 2, 3 and 4. The displacers D1 and D2 are carried by stems 49a and 49b which extend through openings in the caps 25 and 46 and are provided outside the chambers 16a and 16b with soft iron cores or armatures 50a and 50b which cooperate with pairs of aligned solenoid coils 51a, 52a and 51b, 52b enclosed in casings 53 soldered or otherwise secured to the caps 25 and 46 and having suitable sealed openings for the lead wires. The armatures or plungers 50a and 50b are formed with grooves 54a and 54b which cooperate with the pivoted blades 55a and 55b of controlling switches likewise housed in the casings 53. The switch blades 55a and 55b are adapted to connect contacts 56a and 56b alternatively with contacts 57a, 57b or 58a, 58b, according to whether said blades are in the position shown in Fig. 5 or that shown in Fig. 7. The solenoids 51a, 52a and 51b, 52b are alternatively energized, under the control of the switches 55b and 55a, respectively, by circuits X and Y including main switches 59x and 59y by which the apparatus can be put into or out of operation. The circuit X includes (through suitable grounded terminals) the contact 56b and two branches 60x and 61x leading respectively to the solenoids 51a and 52a the return connections from which are through conductors 62x and 63x leading respectively to the contacts 58b and 57b. Similarly, the circuit Y includes the contact 56a and two branches 60y and 61y leading respectively to the solenoids 51b and 52b the return connections from which are through conductors 62y and 63y leading respectively to the contacts 57a and 58a.

The action of the mechanism last described to perform the cycle of operation hereinbefore outlined as follows: In Fig. 5 the switch blades 55a and 55b are shown in engagement with the contacts 57a and 57b, respectively, thereby closing the circuits X and Y through the solenoids 51b and 52a, the latter acting to hold the displacer D2 in its uppermost position, as shown in said figure and in Fig. 1, and the former acting to move the displacer D1 downwardly into the position shown in Fig. 2. As the displacer D1 approaches the limit of its downward movement, the switch blade 55a is engaged by the upper end of the groove 54a and moved out of engagement with the contact 57a and into engagement with the contact 58a, as shown in Fig. 8, thereby opening the circuit Y through the solenoid 51b and closing it through the solenoid 52b which thereupon acts to move the displacer D2 downwardly into the position shown in Fig. 3. During the downward movement of the displacer D2, the switch blade 55b remains in engagement with the contact 57b, maintaining the circuit X closed through the solenoid 52a which holds the displacer D1 in its lowermost position. As the displacer D2 approaches the limit of its downward movement, the switch blade 55b is engaged by the

upper end of the groove 54b and moved out of engagement with the contact 57b and into engagement with the contact 58b, as shown in Fig. 9, thereby opening the circuit X through the solenoid 52a and closing it through the solenoid 51a, the circuit Y remaining closed through the solenoid 52b. The displacer D2 is therefore held in its lowermost position while the displacer D1 is moved upwardly into the position shown in Fig. 4. As the displacer D1 approaches the limit of its upward movement, the switch blade 55a is engaged by the lower end of the groove 54a and moved out of engagement with the contact 58a and into engagement with the contact 57a, as shown in Fig. 10, thereby opening the circuit Y through the solenoid 52b and closing it through the solenoid 51b, the circuit X remaining closed through the solenoid 51a. The displacer D2 is thereupon moved upwardly, and, as it approaches the limit of its upward movement the switch blade 55b is engaged by the lower end of the groove 54b and moved out of engagement with the contact 58b and into engagement with the contact 57b, thereby restoring the parts to the positions shown in Figs. 1 and 5 and completing the cycle of operations. In order to render the motion smooth, dashpots may be added if desired in such manner as to become operative at each end of the stroke, thereby stopping the motion of the displacers without jar.

The mechanism above described for operating the displacers is merely illustrative of a wide variety of expedients which may be employed for this purpose. For example, the automatic switches 55a and 55b may be replaced by a rotary switch or controller actuated by suitable timing mechanism, or the solenoids may be replaced by small fluid pressure motors, similar to those employed for operating motor vehicle windshield wipers, and controlled either by a rotary valve actuated by timing mechanism or by automatic valves operated in a manner similar to that of the automatic switches, all as more fully pointed out in my prior application Serial No. 31,859 above referred to.

The displacers D1 and D2 above referred to, while resembling pistons, are not pistons in the usual sense. They are of light hollow construction and do not need to fit the cylinders as closely as is usual with pistons employed in the cylinders of power apparatus, since moderate leakage past them does no serious harm, so that they move freely in the cylinders 15a and 15b without friction. The pressures on their opposite ends are substantially balanced, so that the gas imposes no considerable resistance to their movement but flows substantially freely back and forth through the regenerators under their impulse. Consequently, the only force required to operate these displacers is that necessary to overcome gravity and gas friction, both of which are relatively small. The effect of gravity may, if desired, be offset by suitable counterbalancing springs. In order to cut down weight and loss due to thermal conduction, the displacer walls should be thin. Since such a hollow, thin-wall body can stand an internal pressure considerably higher than external, although not the reverse, it is well to fill the displacers with gas to a pressure equal to the maximum which they will encounter. This is easily done by providing them with small check valves 65 (Fig. 5) allowing gas to flow in up to the maximum pressure experienced. Also, in order to cut down convection inside the displacers and radiation from one end to the other, they should

be provided inside with a series of light transverse polished diaphragms or baffles 65 which also serve to brace the structure and which have small perforations 66 therethrough to permit equalization of pressure. The displacer D2 can, if desired, be made of somewhat thicker metal than the displacer D1, since the heat flow losses due to thermal conduction are not as serious in the case of the unit B as in the case of the unit A, the temperature differences between the regions c and d being less than those between the regions a and b.

In each of the units A and B the opposite ends of the chambers 16a, 16b constitute, in effect, two relatively hot and cold regions from one to the other of which portions of the gas are passed alternately in opposite directions through the regenerator by the action of the displacer, this being a simple and effective form which the apparatus may assume in practice, although it will be obvious that the several regions of the closed gas container or system as a whole may be otherwise arranged and the transfer of gas otherwise effected, or that the alternate heating and cooling of the gas in the power unit A may be accomplished otherwise than by its transfer back and forth between separate regions or chambers. Also, from another point of view, in each of the units shown and described the regenerator 30 and the cylinder, connected at opposite ends with each other, constitute, in effect, a gas conduit or closed circuit or path through which the gas is circulated alternately in opposite directions by the displacer, absorbing and discharging heat respectively at different points in the circuit in the course of its circulation; and it will be obvious that such a conduit or circuit can be provided otherwise than by a cylinder and coaxial regenerator and that the alternately reversed circulation of the gas can be effected otherwise than by means of a displacer.

In the apparatus described, the system being permanently closed and, if desired, hermetically sealed, it is desirable to employ as a working medium a fixed monatomic gas, such as argon or helium, since the molecular specific heat of such a gas is less than that of the polyatomic gases. When a gas other than air is used, the displacers are preferably provided with small leak openings 67 to allow the air to be extracted slowly before filling with such gas.

The temperatures and pressures employed are susceptible of considerable variation. Since the system is permanently closed, it is possible and desirable to employ pressures substantially higher than atmospheric and thereby obtain a large output with a given volume. An average pressure of 90 lbs. per square inch with a total range or variation of 25 lbs. per square inch has been found suitable in a small size apparatus although a considerable increase in this pressure may be utilized to advantage. The following temperatures are illustrative:

	° C.
Region a-----	500
65 Region b-----	80
Region c-----	30
Region d-----	0

It will thus be seen that flow of heat between the region a and the region b takes place over the relatively great temperature range of 420° C., while that between the region c and the region d takes place over the relatively small temperature range of 30° C. Consequently, the amount of heat extracted from the region d and eject-

ed from the region c through the cooling fins 20 may be greater than the amount of heat applied to the region a by the heating coil 18 and dissipated from the region b by the cooling fins 19, particularly if the size and design of the apparatus be such that the heat losses are relatively small in proportion to the useful heat supplied.

I claim:

1. A thermal pump comprising two intercommunicating chambers, means for heating one end of one chamber, means for cooling the other end of said chamber, heat exchange means for the opposite ends of the other chamber, displacers in said chambers, and means for periodically moving said displacers in sequence from one end to the other of their respective chambers, said displacers being of thin walled, hollow construction and enclosing a gas at a pressure substantially equal to the maximum external pressure.

2. A thermal pump comprising two chambers, means for heating one end of one chamber, means for cooling the other end of said chamber, heat exchange means for the opposite ends of the other chamber, a regenerator connecting one end of said last named chamber with the cooled end of said first named chamber, displacers in said chambers, and means for periodically moving said displacers in sequence from one end to the other of their respective chambers, said displacers being of thin walled, hollow construction and enclosing a gas at a pressure substantially equal to the maximum external pressure.

3. A thermal pump comprising a permanently closed and hermetically sealed system containing a substantially constant volume of a fixed monatomic gas under a pressure substantially higher than atmospheric, means for alternately heating and cooling a portion of said gas in one part of said system, and means for periodically shifting another portion of said gas between two localized regions in said system, distinct from the part in which said first named portion is heated and cooled, in alternation with the heating and cooling of said first named portion.

4. A thermal pump comprising two intercommunicating chambers having their end portions of generally diverse temperatures, displacers in said chambers, and means for periodically moving said displacers in sequence from one end to the other of their respective chambers, said displacers being of thin walled, hollow construction and enclosing a gas at a pressure substantially equal to the maximum external pressure.

5. A thermal pump comprising two intercommunicating chambers having their end portions of generally diverse temperatures, displacers in said chambers, and means for periodically moving said displacers in sequence from one end to the other of their respective chambers, said displacers being of thin walled, hollow construction and having valve controlled openings permitting admission of gas to but preventing its escape from said displacers.

6. A thermal pump comprising two intercommunicating chambers having their end portions of generally diverse temperatures, displacers in said chambers, and means for periodically moving said displacers in sequence from one end to the other of their respective chambers, said displacers being of thin walled, hollow construction and having valve controlled openings permitting admission of gas to but preventing its escape from said displacers, the entire apparatus being permanently closed and hermetically sealed and con-

taining a gas under a pressure substantially higher than atmospheric.

5 7. A thermal pump comprising two intercommunicating chambers having portions of generally diverse temperatures and means for transferring gas between the several portions of the respective chambers, said chambers containing a fixed monatomic gas.

10 8. A thermal pump comprising two chambers having portions of generally diverse temperatures, a regenerator connecting said chambers, and means for transferring gas between the sev-

eral portions of the respective chambers, said chambers containing a fixed monatomic gas.

9. A thermal apparatus comprising a closed gas containing system containing a fixed monatomic gas under a pressure substantially higher than atmospheric and having a plurality of regions of generally diverse temperatures, regenerators connecting said regions, and means for transferring gas between said regions through said regenerators.

VANNEVAR BUSH.

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