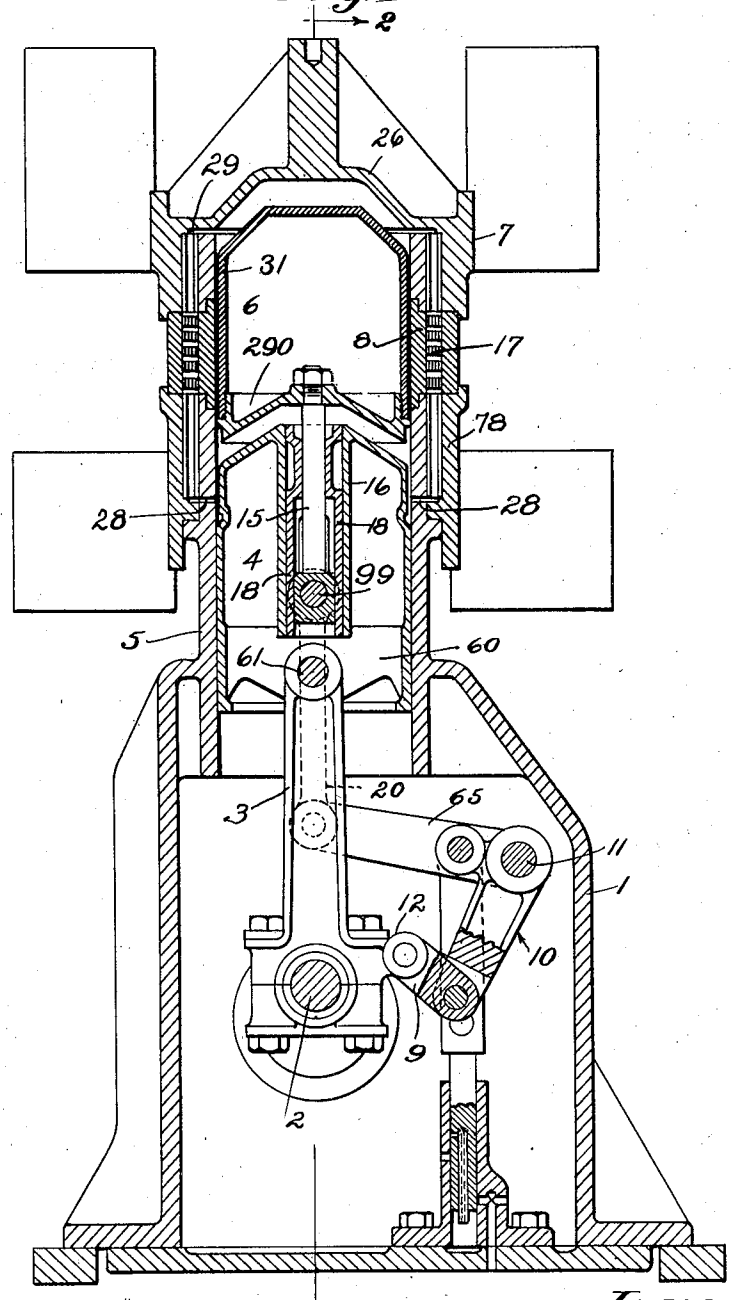
Oct. 8, 1929. I. LUNDGAARD 1,730,580

REFRIGERATING MACHINE

Filed Aug. 5, 1926 5 Sheets-Sheet 1

Fig. 1



Inventor
Ivar Lundgaard
by Roberts, Cushman & Woodberry.
Att'ys

Oct. 8, 1929. I. LUNDGAARD 1,730,580

REFRIGERATING MACHINE

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Fig. 3

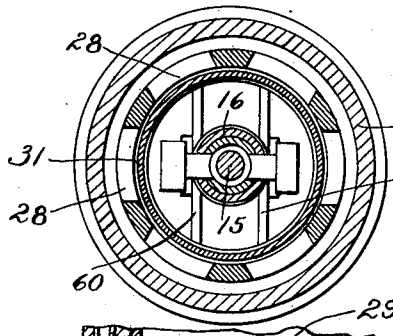
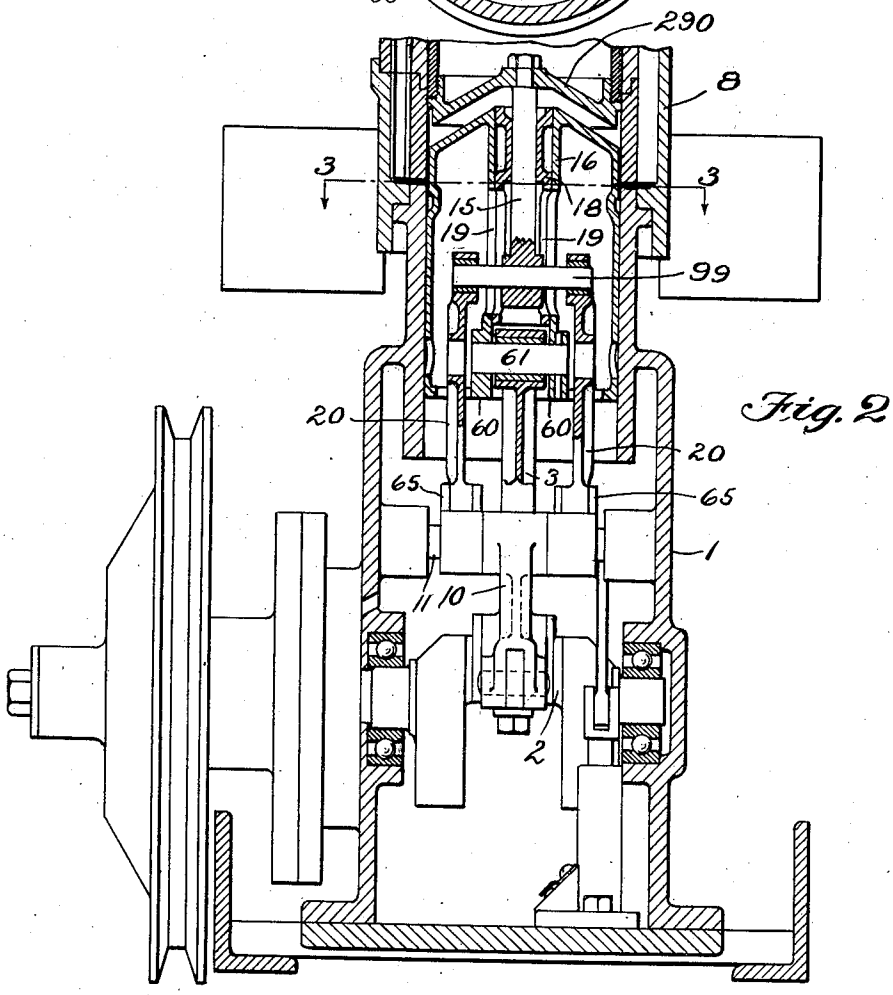


Fig. 2



Inventor
Ivar Lundgaard
by Roberts, Cushman & Woodberry.
Att'ys

Oct. 8, 1929. I. LUNDGAARD 1,730,580

REFRIGERATING MACHINE

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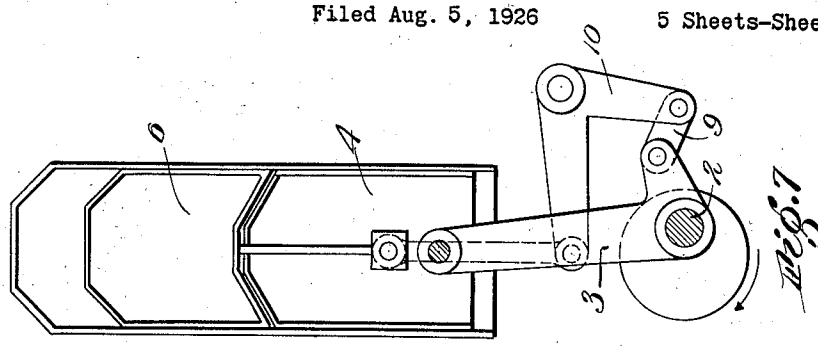


Fig. 7

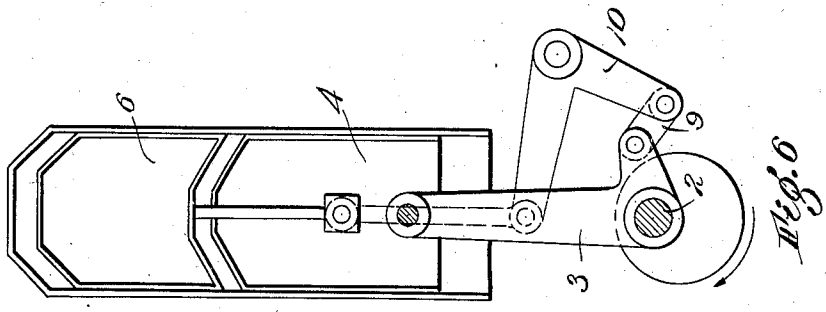


Fig. 6

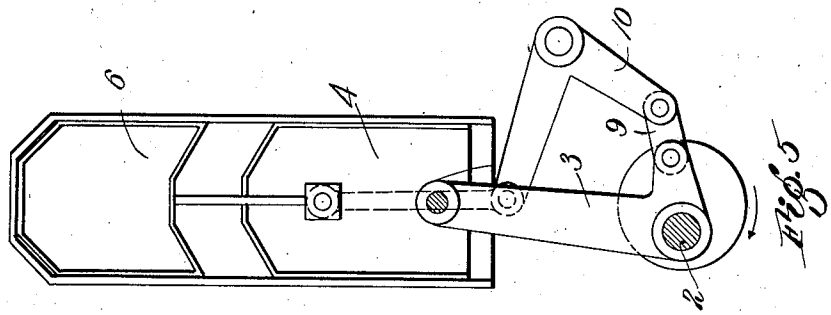


Fig. 5

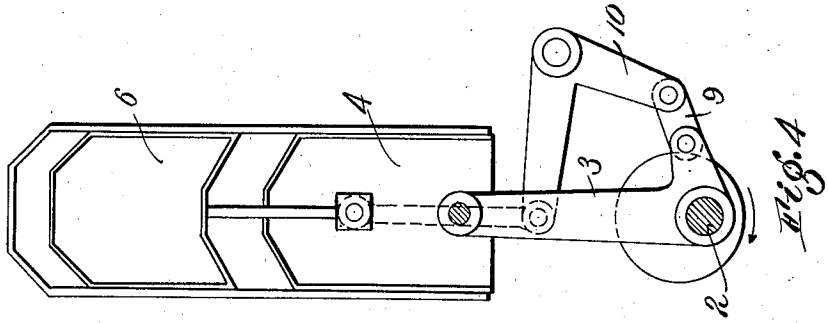


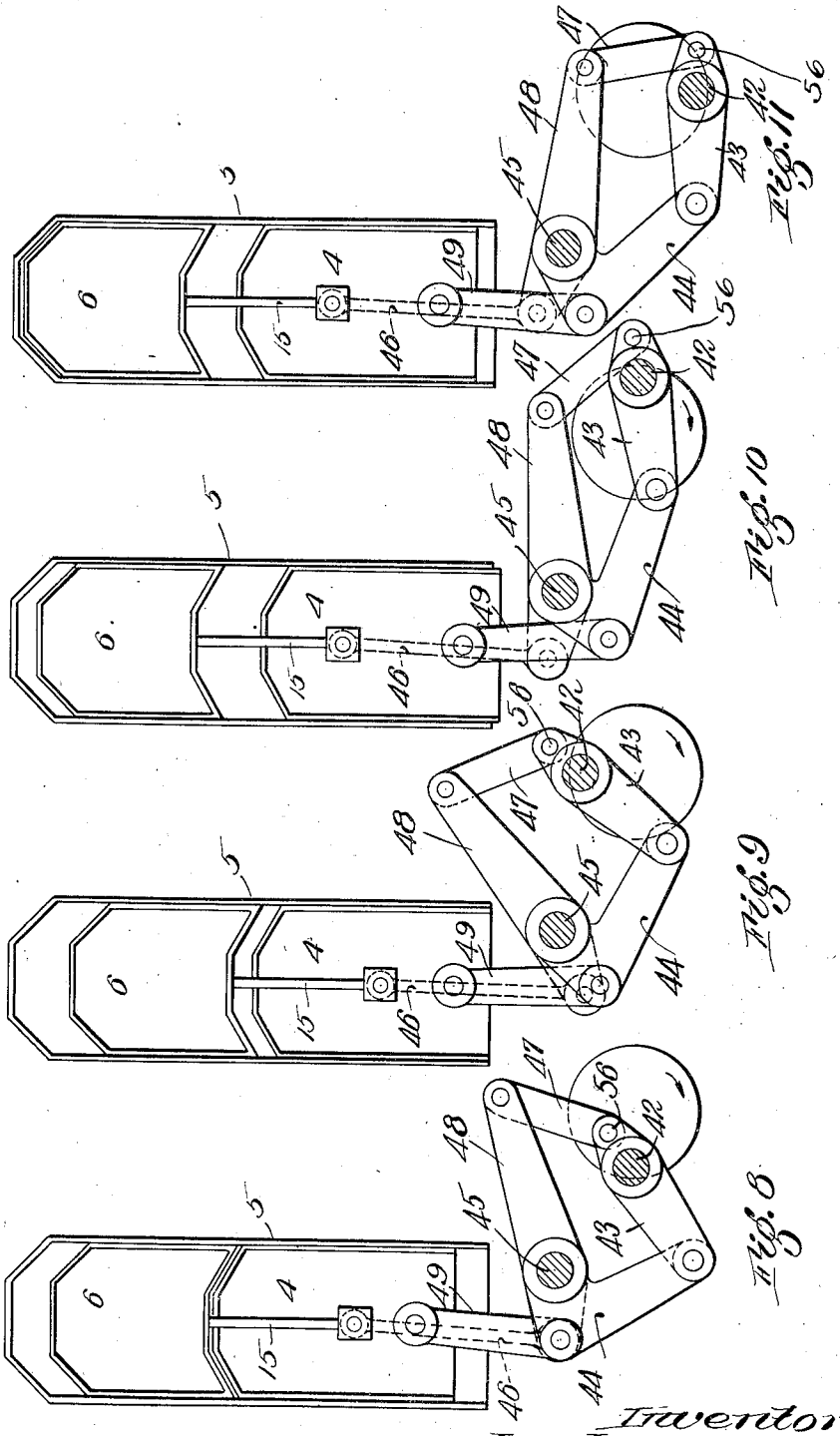
Fig. 4

Inventor
Ivar Lundgaard
By Roberts, Cushman & Woodbury.
Attys.

Oct. 8, 1929. I. LUNDGAARD 1,730,580

REFRIGERATING MACHINE

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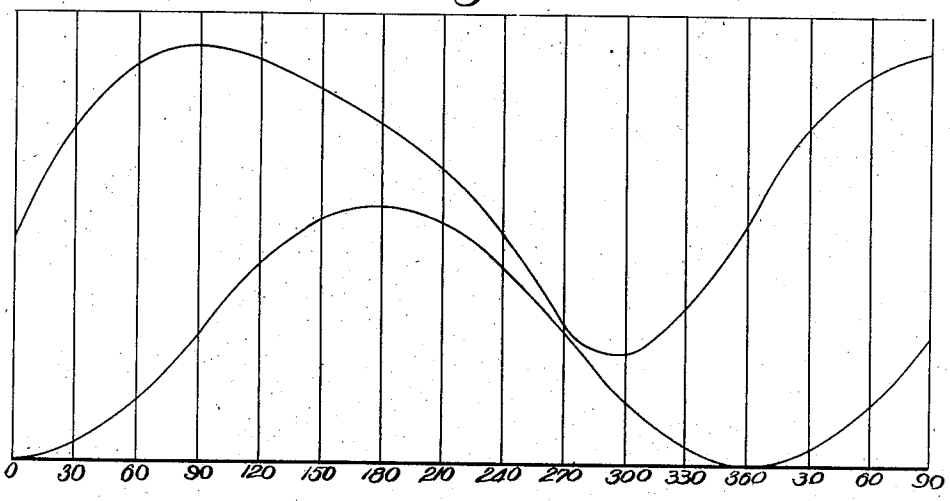
Inventor
Ivar Lundgaard
by Roberts Cushman & Woodberry
Attys

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REFRIGERATING MACHINE

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Fig. 12



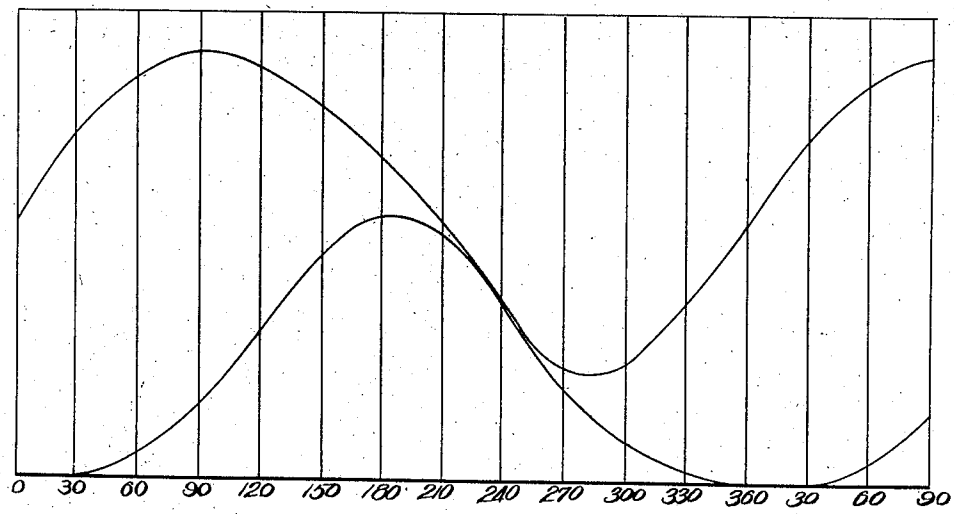


Fig. 13

Inventor
Ivar Lundgaard
by Roberts, Cushman & Woodberry.
Attys.

Patented Oct. 8, 1929 1,730,580

UNITED STATES PATENT OFFICE

IVAR LUNDGAARD, OF WORCESTER, MASSACHUSETTS, ASSIGNOR TO DEVON MANUFACTURING COMPANY, OF BOSTON, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS

REFRIGERATING MACHINE

Application filed August 5, 1926. Serial No. 127,292.

This invention relates to a refrigerating machine designed to use air or other gaseous mediating fluid in a closed thermo-dynamic cycle.

My United States Patent No. 1,240,862 issued September 25, 1917, disclosed an air refrigerating machine of the general type upon which the present invention is an improvement. This machine was provided with a cylinder equipped with a compression piston and with a shifted piston for transferring the mediating gas back and forth between a compression chamber and an expansion chamber through heat exchangers and a regenerator or heat interchanger. My United States Patent No. 1,553,546, issued September 15, 1925, disclosed an improved cyclic arrangement in an air refrigerating machine of this general type, whereby the mediating fluid might be transferred from the compression chamber to the expansion chamber, or vice versa, at substantially constant pressure, the relative piston movements being arranged to compensate for the fall in temperature and the consequent decrease in gaseous pressure due to the transfer of the mediating fluid from the hot to the cold end of the machine, or vice versa. The present invention also in some respects pertains to the improved cycle first disclosed by my Patent No. 1,553,546 and in general may be said to disclose improved mechanism and structural details which are suited to provide a thermo-dynamic efficiency comparable to that obtained from the refrigerating apparatus described in the last-named patent and at the same time to provide a more satisfactory and more reliable machine.

One object of the present invention concerns the provision of a machine of the type disclosed in the above identified patents, in which both the shifter and the compression pistons may be actuated by cranks or orbit-generating pivots and connecting rods together with suitable cooperating linkage but without necessity of depending upon cams, push rods, springs and the like, such as have been disclosed in my previous patents. Among the advantages to be derived by the substitution of orbit-generating pivots and cooperating connecting rods for the cam and follower mechanisms is the decrease in noise and vibration, which is an important consideration in household machinery of this type. Further, the type of mechanism disclosed herein may be made more dependable, the possibility of breakage or fatigue in the spring or related mechanism being obviated, and the improved machine is better adapted to low cost quantity production, the necessity of accurately grinding cams and preparing related parts to stand relatively high shocks being avoided. Another advantage of the construction disclosed herein is the fact that the crank case may be comparatively compact in comparison with the type of crank casing necessary for a mechanically efficient mechanism, according to my former designs.

In addition to the above objects and advantages, it is a purpose of my present invention to provide a structural arrangement whereby the two pistons may be maintained in accurate alignment and yet heat insulating material may be located between the cold end and the hot end of the machine to check the flow of heat, improved means also being provided for actuating the shifter piston through an element reciprocable in the head of the compression piston.

The above and further objects and advantages of the invention will become apparent to those skilled in the art upon a reading of the subjoined description and claims in conjunction with the accompanying drawings, in which:

Fig. 1 is a vertical transverse section through a portion of my improved machine;

Fig. 2 is a similar section taken on line 2—2 in Fig 1;

Fig. 3 is a section on line 3—3 in Fig. 2;

Figs. 4, 5, 6 and 7 are diagrammatic views of the relative positions of the pistons at various points in the thermo-dynamic cycle;

Figs. 8, 9, 10 and 11 are similar views illustrating another type of piston actuating mechanism;

Fig. 12 is a diagram illustrating the relative movements of the pistons during the cycle; and

Fig. 13 is a similar diagram illustrating the

piston movements of the mechanism illustrated in Figs. 8 to 11.

In order to obtain an efficient thermodynamic cycle in a closed refrigerating machine of this type and yet to approach conditions of uniform torque and obviate comparatively high and low pressures which do not materially aid the efficiency of the device, it is desirable to provide for relative movements of the pistons substantially in the manner disclosed in my prior Patent No. 1,553,546. As fully explained in that patent, it is desirable to continue the movement of the compression piston upwardly while the air is being transferred to the expansion or cold end of the machine. It is then desirable to have the shifter move downwardly while the compression piston is passing its upmost position and then to have the two pistons move downwardly together substantially in contacting relation, so that during expansion practically all the mediating fluid is contained in the expansion chamber or in this chamber and the air ducts. It is furthermore desirable to have the shifter piston begin its upward movement near the mid-stroke of the compression piston and to have the compression piston move slowly downward while the shifter is moving upward relatively fast, in order first to transfer the air from the expansion to the compression chamber, and second to impose a further expansion upon the air, thus increasing its volume to an amount greater than that at the end of the expansion stroke in the expansion chamber, but maintaining its pressure substantially equal to that occurring at the end of the expansion stroke, or, in other words, compensating for the increased pressure transmitted to the air by the warm walls of the compression chamber and related parts when it is shifted to that end of the machine. Thereafter, the bulk of the air will be contained between the pistons in the compression chamber and upward movement of the compression piston will be initiated as the shifter approaches its topmost position. Obviously it is possible by the use of a cam to vary the relative movement of these pistons in accordance with the desirable thermo-dynamic cycle disclosed in Patent No. 1,553,546. However, the use of a cam having a profile which will move the pistons in exact accordance with such an ideal thermo-dynamic cycle will result in noise, vibration and excessive racking or strain of mechanical parts. It is therefore desirable only to approximate the cycle disclosed in the earlier patent and it has been found possible to provide a satisfactory approximation of this cycle by using crank elements having circular or substantially elliptical orbits and to dispense with the cams, springs, etc.

Provided a crank follows a circular orbit at uniform speed and its connecting rod is of such a length approaching the infinite that its angularity may be neglected, the motion of the upper end of the connecting rod and the piston would be harmonic. Provided, however, the connecting rod is relatively short and therefore the mean angularity thereof is relatively large, the rod upper end will move relatively faster at the vicinity of its upper dead point than at the vicinity of its lower dead point, or, in other words, the piston will have moved more than half way down in the first quarter stroke from the upper dead center position. When the line connecting the upper and lower dead points of the connecting rod lies at one side of the diameter of the orbit generated by the connecting rod lower end moving at uniform speed, the piston movement will be unsymmetrical or, in other words, its stroke in one direction or its movement between one pair of dead centers will be comparatively fast and its stroke in the other direction between the succeeding pair of dead centers will be comparatively slow in continued alternation. Both of the above factors may be involved whether the connecting rod end follows an orbit which is a circle or an elliptical path. It is, however, desirable in certain cases to provide a distorted elliptical path in order to accentuate the effect of the angularity of the connecting rod. In order to obtain an elliptical path of almost any desired form, it is only necessary to locate a pivot upon a portion of the connecting rod between its crank end and its opposite end, since every portion of the rod between its two ends generates a more or less elliptical orbit.

In obtaining a relative piston movement substantially conforming to the cyclic arrangement disclosed in my previous patent I may make use of the three factors or principles named above and impose the variations in connecting rod movement resulting from these factors upon each other in a suitable manner to approximate the relative movements disclosed in the earlier patent and to provide an efficient thermo-dynamic cycle which may be effected by mechanism which will not be characterized by objectionable vibration or racking.

Referring more particularly to Figs. 1 and 2, which illustrate one embodiment of the invention, the refrigerating machine is provided with a crank case 1 and has an upstanding cylinder 5. It is to be understood that one or more cylinders may be used as is desirable in view of the size of the machine and various other mechanical considerations, the structural arrangement in each case being similar for each cylinder. The metal cylinder 5 is provided with a suitable head 26 between which and the main body of the cylinder is interposed a ring 78 of heat insulating material disposed about the cylinder 5 as well as suitable heat exchangers 7 and 8 with a regenerator 17 disposed therebetween

and located between the ring of insulating material and an outer ring of similar material. Suitable ports 28 are provided in the cylinder wall 5 at the lower part of heat exchanger 8, the metal portion of the cylinder wall extending upwardly above the ports for the extent of the heat exchanger, and a suitable annular opening 29 is disposed about heat exchanger 78 at the head of the cylinder. Ports 28, heat exchanger 8, regenerator 17, heat exchanger 7 and annular opening 29 comprise a duct for the passage of mediating fluid, such as air, between the expansion and compression chambers of the machine which are respectively between the upper or shifter piston 6 and the cylinder head and between the shifter 6 and the compression piston 4.

The shifter piston 6 comprises a lower metal member 290 adapted to bear upon the upper part of the metal cylinder wall above the ports 28 and a shell 31 of heat insulating material extending upwardly from the metal member 290 and comprising the body of the piston. The member 290 is adapted to close the lower end of the piston 6 and to retain a body of dead air therein to augment the heat insulating effect of the piston. The piston 4 comprises a metal casting provided with a cross member 60 consisting of a pair of struts extending between opposite inner surfaces of the piston and supporting a wrist pin 61 at their mid-portions, the upper end of the connecting rod 3 being engaged with the wrist pin therebetween. Extending from the head of piston 4 to the member 60 is a suitable collar or boss 16 which receives a bushing 18 of suitable bearing metal. The members 16 and 18 have vertically disposed slots at their opposite sides which are designated by the numeral 19. Depending from the bottom 290 of piston 6 is a rod 15 which is adapted to slide in the bushing 18 and to engage a suitable cross pin 99 at its lower extremity. The cross pin 99 may conveniently be disposed in a block adapted to slide in an enlarged portion of the bushing 18. Pin 99 projects outwardly through the slots at either side of the boss 16 and is engaged by a pair of links 20 which are driven by suitable actuating mechanism in the crank case. In order to permit the flow of mediating fluid through the ports 28, but yet properly restrict the size of the compression chamber, the upper portion of piston 4 is slightly reduced in diameter to provide an appreciable distance between the upper end of the piston and the adjacent cylinder wall.

The improved piston actuating mechanism which comprises a feature of the present invention is driven from a crank shaft 2 of the conventional form upon which is mounted a connecting rod 3 which actuates the piston 4 through the wrist pin 99 in the conventional manner. Mechanism for moving the shifter 6 in proper synchronized relation to the compression piston 4 comprises pivot 12 fixed to one side of the big end of connecting rod 3, a short connecting rod or link 9 connecting the pivot 12 with a bell crank 10 which is pivoted on a suitable rod 11 parallel with the crank shaft and provided with arms 65 pivotally engaging links 20 which are connected to either end of the cross pin 99.

The pistons will move in a manner disclosed more particularly by the curves of Fig. 12. For example, at the beginning of the compression stroke, the compression piston 4 will be at or just leaving bottom dead center and will move rather slowly while the shifter piston will be approaching its upmost point (Fig. 4) and the compression piston will continue to move upwardly while the shifter piston lingers at or near its topmost position (Fig. 5). Such a relative movement of the pistons is made possible by the fact that the pivot 12 follows an orbit of distorted elliptical form and by that fact that during this portion of the cycle the natural retardation of shifter piston 6 due to the angularity of the short connecting rod or link 9 is accentuated by the shape of this orbit, or, in other words, since this portion of the path of the pivot 12 closely approaches a circle drawn about the opposite end of the link as a center. As the compression piston 4 nears the top of its stroke, the shifter starts downwardly at first slowly (Fig. 6) and then rather rapidly due to the shape of its orbit; in the meantime, due to the angularity of the connecting rod 3 and to the fact that its upper dead center coincides with the convex portion of the orbit of crank 2, the shifter moves down until it is almost in contact with the compression piston (Fig. 7).

The movement of the pistons thus far described results in the compression of mediating fluid when it is practically all in the compression chamber and in the passages about the cylinder walls and compression of the fluid continues as it is moved into the expansion chamber, such a movement compensating from the decreased pressure which results from the cooling of the gas as it flows to the cooled end of the chamber. When the compression piston has reached the top of its path, the accelerating downward movement of the shifter aids the further expansion and transfer of gas. Downward movement of the two pistons substantially in contact results in expansion of the gas taking place while it is practically all either in the expansion chamber or in the passages surrounding the cylinder. At about the mid-stroke of piston 4 the shifter piston approaches its bottom position and its movement is restricted while the continuing downward movement of the piston 4 serves to accentuate the flow of mediating gas back into the compression end of the machine; such a movement combined with the restricted

movement of the shifter piston compensating for the expansion of the gas which will normally occur when it is returned to the hot end of the machine. By the time piston 4 has reached its lower position, the shifter has moved upwardly at a comparatively rapid rate in order to return the remainder of the gas to the compression end of the machine to repeat the cycle, this upward movement shifting most of the air to the compression chamber.

In considering means to provide for the relative movement of pistons in substantially the manner indicated without necessity for depending upon cams, springs and the like, it is to be recognized that substantially the same efficiency may be obtained from machines wherein the pistons occupy the same relative positions in succession, although the relative speeds of different parts of the cycle may vary, or in other words, different parts of the cycle may occupy different proportions of the whole cyclic period in different cases. Such a principle is illustrated by the operation of the mechanism disclosed in Figs. 8 to 11, the relative movement of the pistons of which is indicated by the diagram of Fig. 13. From an examination of the last named figure it is evident that the relative positions of the pistons at various parts of the cycle correspond to similar positions in Fig. 12; but that certain portions of the travel of the pistons take place more quickly in one cycle than in the other. This variation in speed between different portions of the cycle, however, has a negligible effect upon the thermal efficiency of the device when operating at normal speeds.

Referring more particularly to the assembly illustrated in Figs. 8 to 11, it may be seen that the crank shaft 42 is offset considerably to one side of the axis of the vertical cylinder 5. The crank shaft is provided with a short connecting rod 43, the outer end of which is articulated to one end of a bell crank 44, the other end of which is pivoted upon the fixed member 45. The intermediate portion of the bell crank actuates the lower end of the connecting rod 49 of compression piston 4. The crank end of connecting rod 43 is provided with a pivot 56 itself articulated to link 47 which pivotally engages a rocker 48, the latter having a forked end which is connected to links 46 engaging the lower end of the connecting rod 15 of piston 6 in the general manner disclosed in Figs. 1, 2, and 3.

The connecting rod 43 has its dead center positions placed at one side of the diameter or the orbit of the actuating crank, so that the curve generated by the piston movement as plotted in Fig. 13 is unsymmetrical, or in other words, so that its stroke in one direction is considerably faster than in the other direction when its orbit generating crank is moving at a uniform speed. A similar effect may be provided for the bell crank 48 by the position of its pivot and connecting rod. Since both of the connecting rods are comparatively short the mean angularity thereof is comparatively large, and the speed of piston movement when the connecting rods are at the opposite dead points will vary considerably. By suitably disposing and dimensioning of parts substantially in the manner disclosed in the accompanying drawings, the paths followed by the pistons during the cycle will be as indicated in Fig. 13, and the relative movement of pistons will result in the compression, expansion and return of the gas to its original state in substantially the same way as disclosed in connection with the mechanism illustrated in Fig. 1, the fact that certain operations such as the shifting of the gas from the expansion to the compression chamber requires relatively longer in one cycle than in the other not materially affecting the efficiency of the device.

While I have disclosed herewith two mechanisms making use of orbit generating pivots or cranks to provide relative movement of pistons in order to approximate ideal thermodynamic conditions in a machine of this type, and yet to provide reasonably smooth torque, quiet and reliable operation and to dispense with the need of cams, springs or similar mechanisms which entail shock and vibration in their operation and are dependent upon the use of springs which are liable to break or to show fatigue under continued usage; it is to be understood that many other equivalent arrangements of cranks and similar linkages based upon the use of orbit generating pivots may be provided to function in substantially a similar manner by making use of some or all of the variable factors noted above which serve to vary the movement of a crank operated piston from an exact harmonic motion, although the crank member is moved at a constant speed, and such constructions are regarded as within the purview of my invention.

I claim:

1. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, said chambers being in a common cylinder and said pistons having overlapping paths of movement, a pair of synchronized orbit generating pivots, one end of a connecting rod engaging each pivot, means connecting the other end of one rod to the compression piston and the other end of the other rod to the shifter piston, said orbits, connecting rods, and means being so disposed and synchronized that the piston and shifter will move downwardly substantially together during a portion of their down stroke and

will be spaced during another portion of their travel.

2. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and an unobstructed duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and the other end of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that the motion of one piston will correspond closely to that of the other piston during the expansion stroke.

3. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and an unobstructed duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and the other end of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that the latter half of the expansion stroke of the shifter occurs toward the earlier part of a similar movement of the compression piston and the speeds of the pistons will be substantially equal during a substantial part of this portion of the cycle.

4. In refrigerating apparatus for using a gaseous mediating fluid having a single acting piston reciprocating in a compression chamber, a single acting shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, one end of a corresponding connecting rod engaging each pivot, means connecting the other end of one rod to the compression piston, means connecting the other end of the other rod to the shifter piston, the orbit generating pivots and the path of travel of the connecting rods being so arranged that the initial expansion movement of the compression piston substantially conforms with the movement of the shifter during the latter part of its expansion stroke.

5. In a refrigerating machine having a compression piston and a shifter piston reciprocable in a single cylinder, said pistons having overlapping paths of movement, a pair of synchronized orbit generating pivots, one end of a corresponding connecting rod engaging each pivot, means connecting the other end of one rod to the compression piston and the other end of the other rod to the shifter piston, the compression and expansion chambers being located in a single cylinder, and a duct connecting said chambers, the connecting rod for actuating one of the pistons having its dead point positions both to one side of a diameter passing through the axis of the orbit.

6. In a refrigerating machine having two pistons reciprocable in a single cylinder, said pistons having overlapping paths of movement, a pair of synchronized orbit generating pivots, one end of a corresponding connecting rod engaging each pivot, means connecting the other end of one rod to one piston and the other end of the other rod to the other piston, and a duct connecting the chambers in which said pistons reciprocate, the path of one orbit generating pivot and of its connecting rod being so disposed that the corresponding piston will move more rapidly in alternate motions between dead point positions while the corresponding pivot is moving along its path at substantially uniform speed.

7. In a refrigerating apparatus for using a gaseous mediating fluid having a piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, one end of a corresponding connecting rod engaging each pivot, means connecting the other end of one rod to the piston and the other end of the other rod to the shifter piston, and a duct connecting the chambers in which said pistons reciprocate, the path of one orbit generating pivot and the dead points of its connecting rod being so disposed that a substantially larger part of the orbit is covered by the pivot during the movement in one direction of the connecting rod end between dead points than during such movement in the opposite direction.

8. In a refrigerating machine having two pistons reciprocable in a single cylinder, said pistons having overlapping paths of movement, a pair of synchronized orbit generating pivots, one end of a corresponding connecting rod engaging each pivot, means connecting the other end of each rod to a piston, and a duct connecting the chambers in which said pistons reciprocate, the path of one orbit generating pivot and the dead points of its connecting rod being so disposed that a substantially larger part of the orbit must be covered by the pivot during the movement in one direction of the connecting rod end between dead points than during such movement in the opposite direction, the other orbit and connecting rod being so arranged that successive movements of the rod between succeeding dead point positions coincide with movement of the pivot over substantially equal parts of the orbit.

9. In a refrigerating machine having two pistons reciprocable in a single cylinder, said

pistons having overlapping paths of movement, a pair of synchronized orbit generating pivots, one end of a corresponding connecting rod engaging each pivot, means connecting the other end of each rod to a piston, and a duct connecting the chambers in which said pistons reciprocate, the path of one orbit generating pivot and the dead points of its connecting rod being so disposed that a substantially larger part of the orbit is covered by the pivot during the movement in one direction of the connecting rod end between dead points than during such movement in the opposite direction, the shape of said orbit and the distance between the pivot end and the other end of the connecting rod being so arranged that the piston will pause at the dead point at the end of the period of rapid movement for a substantially longer period of time than at the opposite dead point.

10. In refrigerating apparatus using a gaseous refrigerant and comprising two pistons reciprocable in a single cylinder and actuated by mechanism in a crank case, a depending boss in the head of the piston nearer the crank case, slots in the opposite sides of said boss, a reciprocating pin slidable in said slots, a reciprocating rod within the boss and secured to the pin and to the upper piston, and a duct connecting the space between the pistons with the space above the upper piston.

11. In refrigerating apparatus using a gaseous refrigerant and comprising two pistons reciprocable in a single cylinder and actuated by mechanism in a crank case, a connecting rod engaging a transverse bracket extending between opposite portions of the lower piston skirt to actuate the lower piston, a pair of links at either side of the rod and bracket, a cross pin slidably mounted above said wrist pin in an extension of the lower piston head, the ends of said links being connected to said pin, and means connecting the upper piston and said cross pin, and a duct connecting the space between the pistons with the space above the upper piston.

12. In refrigerating apparatus using a gaseous refrigerant and comprising two pistons reciprocable in a single cylinder and actuated by mechanism in a crank case, a connecting rod engaging a transverse bracket extending between opposite portions of the inner piston skirt to actuate the inner piston, a pair of links at either side of the rod and bracket, the ends of said links being connected by a cross pin slidably mounted above said wrist pin and connected to a rod extending from the remote piston, an opening in the head of said inner piston to accommodate said rod and permit its reciprocation in relation thereto, and a duct connecting the space between the pistons with the space beyond the outer piston.

13. In refrigerating apparatus using a gaseous refrigerant and comprising two pistons reciprocable in a single cylinder and actuated by mechanism in a crank case, a connecting rod engaging a transverse bracket extending between opposite portions of the inner piston skirt to actuate the inner piston, a pair of links at either side of the rod and bracket, the ends of said links being connected by a cross pin slidably mounted above said wrist pin and connecting to a rod having an axis coincidental with the vertical axis of the inner piston, the head of said inner piston having a downwardly extending boss to compose a guide for said rod, and a duct connecting the space between the pistons with the space beyond the outer piston.

14. In refrigerating apparatus using a gaseous refrigerant and comprising two pistons reciprocable in a single cylinder and actuated by mechanism in a crank case, a connecting rod pivotally connected to a transverse pivot extending between opposite portions of the skirt of the inner piston, an actuating link at either side of said pivotal connection, each of said links being connected to means passing through the head of the inner piston for actuating the upper piston, and a duct connecting the space between the pistons with the space above the upper piston.

15. In refrigerating apparatus using a gaseous refrigerant and comprising two pistons reciprocable in a single cylinder and actuated by mechanism in a crank case, a connecting rod pivotally connected to the inner piston, said pivotal connection being intersected by the vertical axis of the inner piston, a link extending upwardly at one side of said pivotal axis and connected to means which passes through the head of the inner piston and connected to the upper piston, and a duct connecting the space between the pistons with the space above the upper piston.

16. A refrigerating machine comprising a cylinder with two pistons reciprocating therein, a duct connecting the space between the pistons with a space between one piston and the end of the cylinder, ports in the cylinder wall registering with said first named space and connecting with said duct, the piston nearer the cylinder head having a body of heat insulating material and a lower portion of metal, the metal of said cylinder wall being extended upwardly from said ports to comprise a bearing for the lower metal portion of said last-named piston and terminating substantially adjacent the limit of movement of said metal portion, a section of the cylinder wall above the termination of said metal wall being composed of heat insulating material, whereby the upper piston is guided by the same cylinder wall as the lower piston and wear of the bearings and noise are minimized.

17. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression cham-

ber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that one piston will follow the other in arriving at both top and bottom dead center, but so that the interval between corresponding dead centers in one case is less than the said interval in the case of the opposite dead centers.

18. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that one piston will follow the other in arriving at both top and bottom dead center, each piston being arranged to move slower at one end of its stroke than at the other end thereof.

19. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that one piston will follow the other in arriving at both top and bottom dead centers, each piston being arranged to move slower at one end of its stroke than at the other end thereof, said period of slower movement in the case of the two pistons being at opposite ends of their strokes.

20. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that the shifter piston will be moving at its slowest rate when near its dead point remote from the orbit of its pivot.

21. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that the shifter piston will be moving at a slower speed when near its dead point remote from the orbit of its pivot than at the opposite end of its stroke, and will have a more rapid movement during its stroke approaching said dead point than during its stroke leaving said dead point.

22. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that the strokes of one piston will follow these of the other in a corresponding direction, the strokes of one piston in opposite directions requiring substantially uniform periods, while the strokes of the other piston require relatively longer and shorter periods in alternate succession.

23. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that the strokes of one piston will follow that of the other in a corresponding direction, the strokes of one piston in opposite directions requiring a substantially uniform period of time, while the strokes of the other piston require relatively longer and shorter periods in alternate succession, the speed of the latter piston being substantially greater near one of its dead points than when near its other dead point.

24. In refrigerating apparatus for using a gaseous mediating fluid having a compression piston reciprocating in a compression chamber, a shifter piston reciprocating in an expansion chamber, and a duct between the

chambers, a pair of synchronized orbit generating pivots, a pair of connecting rods, each of which has an end engaging one of the pivots, means connecting the other end of one rod to the compression piston and of the other rod to the shifter piston, the orbit generating pivots being so disposed and synchronized that the strokes of one piston will follow that of the other in corresponding directions, the strokes of one piston in opposite directions requiring substantially equal periods of time, while the strokes of the other piston require relatively longer and shorter periods in alternate succession, the speed of the latter piston being substantially greater near the dead point at the beginning of its relatively rapid stroke than at the dead point near the end of said stroke.

25. In refrigerating apparatus for using gaseous mediating fluid having a compression piston and a shifter piston reciprocating in a single cylinder and having overlapping paths of movement, means adapted to provide suitable movement of said pistons and relative movement therebetween, said means comprising a single crank throw and connecting rods positively actuated thereby and connected to the respective pistons, and a duct connecting the space between said pistons with the space between one piston and the cylinder head.

26. In refrigerating apparatus for using gaseous mediating fluid having a compression piston and a shifter piston reciprocating in a single cylinder, means adapted to provide suitable movement of said pistons and relative movement therebetween, said means comprising a single crank, a connecting rod imparting movement directly from said crank to a piston, a second connecting rod engaging a bell crank, said bell crank being connected to the other piston by suitable links, and a duct connecting the space between said pistons with the space between one piston and the cylinder head.

27. In refrigerating apparatus for using gaseous mediating fluid having a compression piston and a shifter piston reciprocating in a single cylinder, means adapted to provide suitable movement of said pistons and relative movement therebetween, said means comprising a single crank, a connecting rod imparting movement directly from said crank to one piston, a second connecting rod pivotally engaging a bell crank which is connected to a piston by suitable links, said last named connecting rod having a pivotal connection with a portion of the first named rod between its ends whereby said connection may follow a path of substantially elliptical form, and a duct connecting the space between said pistons with the space between one piston and the cylinder head.

28. In refrigerating apparatus for using gaseous mediating fluid having a compression piston and a shifter piston reciprocating in a single cylinder, means adapted to provide suitable movement of said pistons and relative movement therebetween, said means comprising a single crank throw and rods connected thereto positively to move the respective pistons over corresponding portions of their strokes at different relative speeds, and a duct connecting the space between said pistons with the space between one piston and the cylinder head.

29. In refrigerating apparatus for using gaseous mediating fluid having a compression piston and a shifter piston reciprocating in a single cylinder, means adapted to provide suitable movement of said pistons, said means comprising a single crank and a pair of connecting rods pivotally connected thereto, one of said rods actuating its piston through a bell crank and suitable linkage, and a duct connecting the space between said pistons with the space between one piston and the cylinder head.

30. In refrigerating apparatus for using gaseous mediating fluid having a compression piston and a shifter piston reciprocating in a single cylinder, means adapted to provide suitable movement of said pistons, said means comprising a single crank and a pair of connecting rods pivotally connected thereto, one of said rods being pivoted to the crank shaft and the other rod being pivoted to the first rod, and a duct connecting the space between said pistons with the space between one piston and the cylinder head.

31. In refrigerating apparatus for using gaseous mediating fluid having a compression piston and a shifter piston reciprocating in a single cylinder, means comprising two connecting rods adapted to provide suitable movement of said pistons, one of said rods being pivoted to the crank shaft and the other rod being pivoted to the first rod, said last named rod being comparatively short and having a dead point along the flattest part of the orbit of its pivot, whereby its remote end may linger near its corresponding dead point position for a considerable interval, and a duct connecting the space between said pistons with the space between one piston and the cylinder head.

Signed by me at Boston, Massachusetts, this 2nd day of August, 1926.

IVAR LUNDGAARD.