

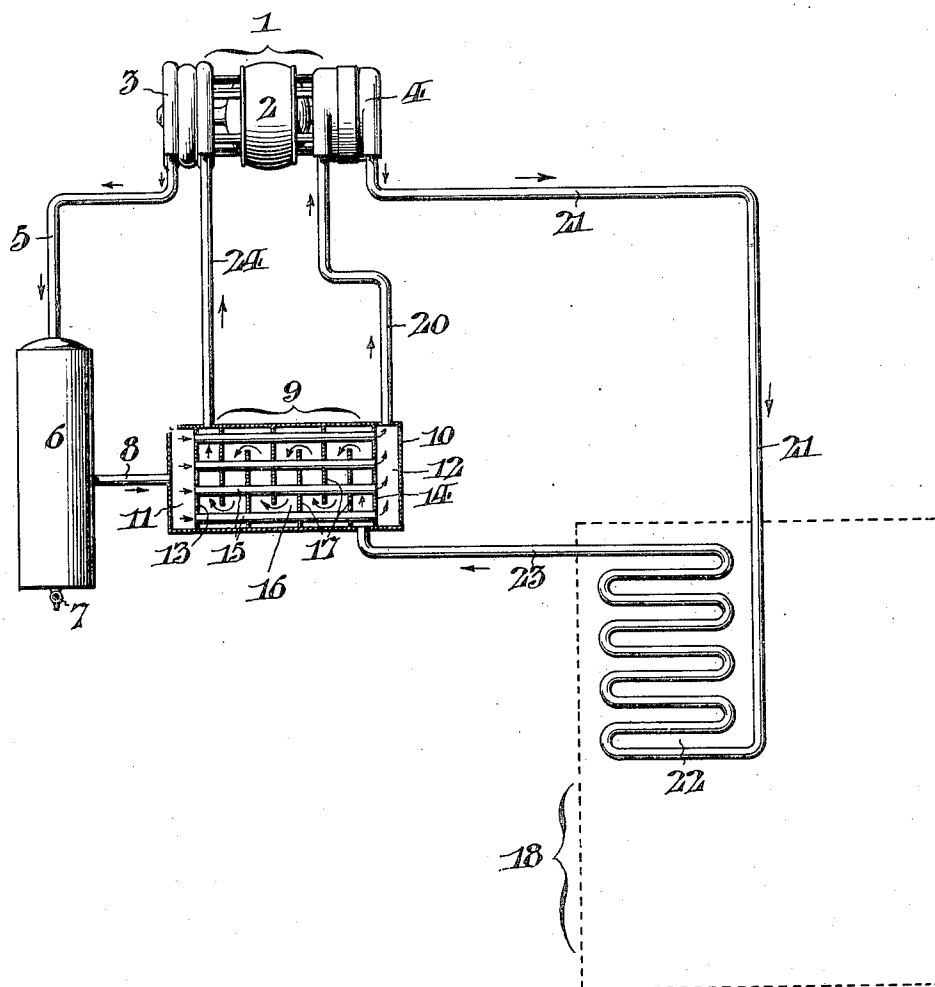
Dec. 26, 1922.

C. E. BONINE.
REFRIGERATION
FILED MAY 3, 1920

1,440,000

3 SHEETS-SHEET 1

FIG. I.



WITNESSES:

John C. Berger
James H. Bell

INVENTOR:

Charles E. Bonine,

BY *James H. Bell*
ATTORNEYS.

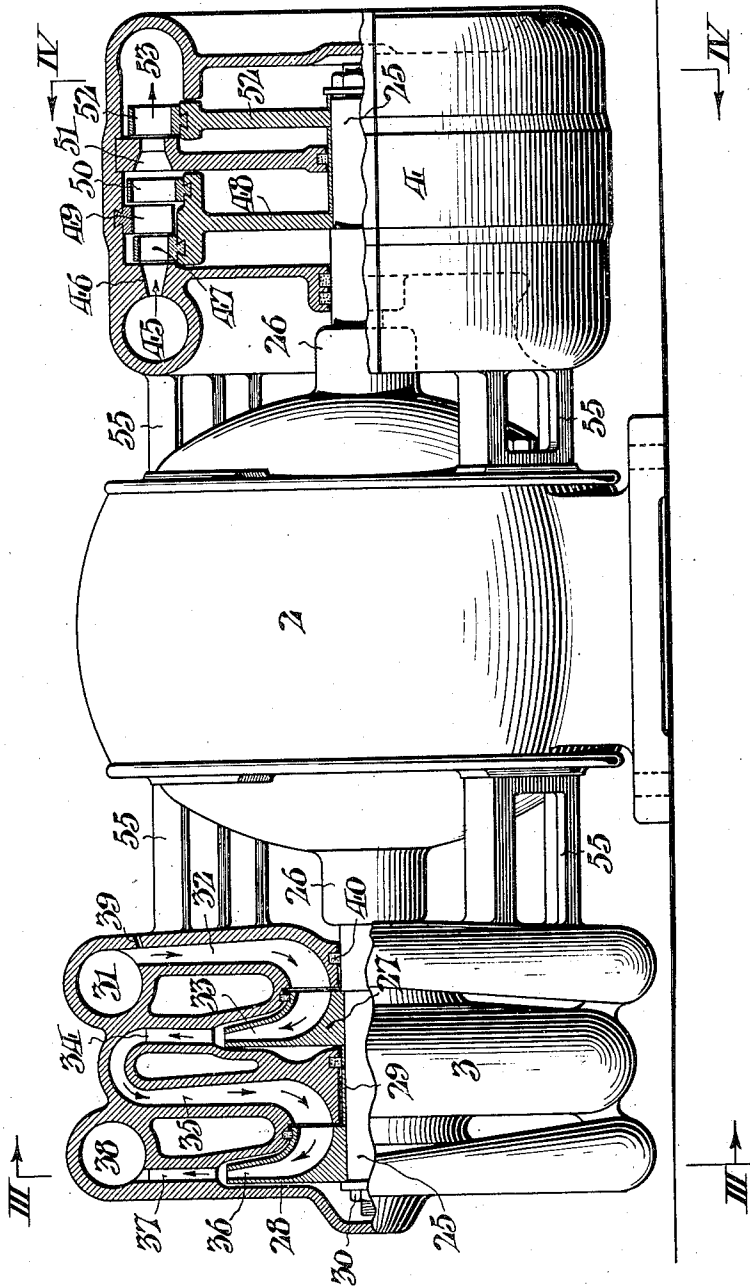
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3 SHEETS-SHEET 2

FIG. II.



INVENTOR:

Charles E. Bonine,

by *James & Fay*

ATTORNEYS.

WITNESSES:

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James H. Bell

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3 SHEETS-SHEET 3

FIG. III.

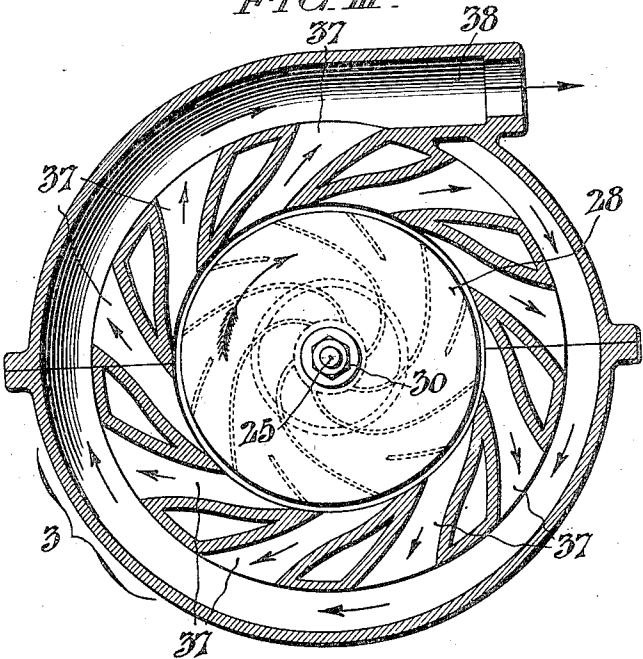
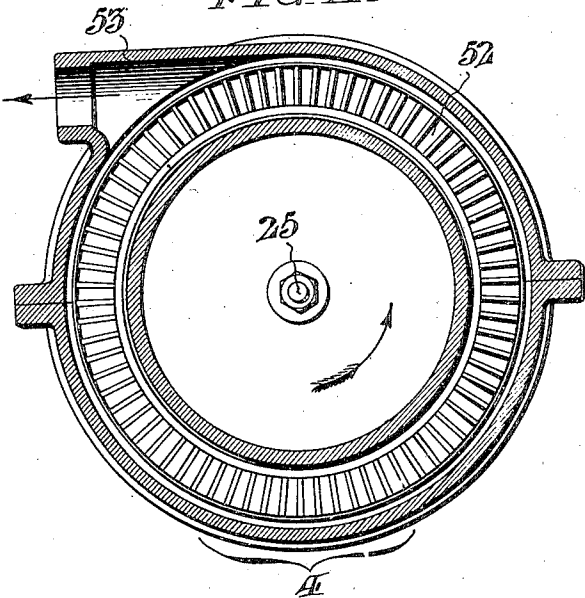


FIG. IV.



WITNESSES:

John C. Bergman
James H. Bell

INVENTOR:

Charles E. Bonine,

BY

Julius F. Long
ATTORNEYS.

Patented Dec. 26, 1922.

1,440,000

UNITED STATES PATENT OFFICE.

CHARLES E. BONINE, OF MELROSE PARK, PENNSYLVANIA.

REFRIGERATION.

Application filed May 3, 1920. Serial No. 378,467.

To all whom it may concern:

Be it known that I, CHARLES E. BONINE, a citizen of the United States, residing in Melrose Park, in the township of Cheltenham, in the county of Montgomery and State of Pennsylvania, have invented certain new and useful Improvements in Refrigeration, whereof the following is a specification, reference being had to the accompanying drawings.

My invention relates to refrigeration, and especially to systems and processes in which a refrigerating or working medium (preferably air or other elastic fluid) is given the capacity for absorbing heat (which constitutes refrigerating power) by compressing it, abstracting heat from it,—as by cooling with some extrinsic medium or agency,—and expanding it and thereby reducing its temperature below whatever temperature is to be brought about or maintained in the object or region to be refrigerated. Such refrigerating systems are advantageously operated by circulation of a body of working medium or fluid in a closed circuit and cycle of successive stages of compression, extrinsic cooling, expansion, and refrigerating activity,—the same body of medium thus traversing the entire circuit of the apparatus and repeating the complete cycle of stages or operations over and over again.

The aim of my invention is to improve upon such processes and systems of refrigeration in such wise as to permit the extrinsic cooling operation to be effected at relatively wide ranges of temperature (even when it is desired to attain very low temperatures of refrigeration), to allow the compression and expansion to be effected with great economy and convenience, and to simplify the apparatus and equipment required as much as possible. My invention, furthermore, enables the apparatus to be made compact, simple, rugged, and inexpensive in construction and arrangement; convenient and easy to operate and repair; and free from derangement. Hence it is especially applicable to household plants or equipments, where only slight and unskilled attention to operation and upkeep will ordinarily be given.

How these and other advantages can be realized in connection with my invention will be apparent from the description herein-after of the best methods, operations and apparatus for the purpose at present known

to me, while its scope and essentials will be understood from my claims. It will be seen that while I have disclosed compressing and expanding devices of multi-stage centrifugal and turbine types which are especially advantageous, yet these and other particular features and details of the apparatus shown are not essential to the invention, since in some of its broader aspects it can be carried out with many other types and forms of apparatus.

In the drawings, Fig. I is a somewhat diagrammatic general view of a refrigerating system suitable for the purposes of my invention, one of the pieces of apparatus being shown in mid-section.

Fig. II is an enlarged elevation of a compression and expansion unit appearing in Fig. I, certain portions being shown in longitudinal mid-section.

Figs. III and IV show transverse sections through the compressor and expander portions of the apparatus illustrated in Fig. II, taken as indicated by the lines III—III and IV—IV on Fig. II, and looking in the direction of the arrows.

The closed circulatory system illustrated in Fig. I includes a compression and expansion operating unit comprehensively indicated by the numeral 1, a cooling device 6, a heat interchanging apparatus comprehensively indicated by the numeral 9, and a cold room or refrigerating apparatus conventionally represented in dotted lines, and comprehensively indicated by the numeral 18. The operating unit 1 shown consists of a unitary structure comprising a motor 2 receiving power from an external source, a compressor 3 for compressing the working medium, and a motor 4 which serves for and is operated by expansion of the compressed medium to restore its refrigerating power. The compressor 3 is driven by the motors 2 and 4 in co-operation, through a drive element common to all three of these machines. The cooling device 6 is shown as an upright cylindrical storage tank receiving the compressed medium at its top through piping 5 from the compressor 3, and delivering to the heat interchanger 9 through piping 8 that enters the tank a suitable distance above its bottom. The comparative arrest of the medium in the tank 6 permits precipitation and separation off of any moisture suspended therein or condensing therefrom, and a drain cock 7 in the bottom of the tank allows the

accumulated water to be drawn off from time to time.

The heat interchanger 9 consists of a cylindrical casing 10 having in its opposite ends inlet and discharge chambers 11 and 12 formed by tube-sheets 13 and 14, and connected by a number of tubes 15. In the central compartment 16, between the tube-sheets, are alternating, staggered, upper and lower transverse baffles 17. The compressed medium delivered from the pipe 8 enters the chamber 11, passes through the tubes 16 to the chamber 12, and is thence delivered to the motor 4 through the piping 20. The expanding medium that has been exhausted and delivered from the motor 4 through the piping 21 to the cooling coil 22 or the like of the refrigerating apparatus 18 returns from its refrigerating activity therein through the piping 23 and 24 to the compressor 3. On its way, this returning medium passes through the compartment 16 of the interchanger 9, traversing a serpentine course through this compartment back and forth around and amongst the tubes 16, and in a general direction counter to the flow of compressed medium through the tubes 15. Thus an interchange of heat is effected between the medium intermediate the cooling and expansion stages of its cycle and the medium returning from its refrigerating activity to the compression stage.

Referring, now, to Figs. II, III, and IV, it will be seen that the three machines composing the operating unit 1 are of rotary type, with a common rotary shaft 25 as their drive element, and a unitary casing and frame structure. The base of this structure is that of the frame of the centrally arranged motor 2 (here shown as an electric one), which carries the shaft bearings 26, 26. The casing of the compressor 3 and the fluid motor 4 are secured to the motor frame at opposite sides, as by means of bolts taking into openwork bracket extensions 55 on said casings. The open air spaces intervening between the electric motor 2 and the compressor 3 and the fluid motor 4 at opposite sides thereof prevent or minimize the interchange of heat between said electric motor 2 and either of said other devices 3 and 4, or between said devices 3 and 4 themselves.

The rotary compressor 3 is of multi-stage centrifugal type, with centrifugal rotor elements 27 and 28 spaced apart on the reduced end of the shaft 25 by means of a sleeve 29, and secured by a nut 30. From the compressor inlet channel 31, the working medium enters the first compression stage, passing inward through stationary passages 32 and sidewise into the moving vane-channels or passage 33 of the rotor section 27. The medium or fluid discharged peripherally at high velocity from the rotor 27

passes through the stationary vane or nozzle passages 34 in the casing, which are so shaped as to utilize the velocity of the fluid in compressing it. The partially compressed fluid now enters the second compression stage, traverses stationary and moving passages 35, 36, and 37 in the casing (see Fig. III) and in the rotor section 28 (all similar to the corresponding passages in the first stage), and is in like manner further compressed. The fluid is finally collected in an annular outlet chamber 38 of gradually increasing cross-section that surrounds the nozzle-passages 37 (and is similar to the inlet channel 31), and is discharged into the piping 5 at the desired pressure, and at a temperature corresponding to that at the inlet 11 and to the work of compression done upon it. The nozzle passages 34 and 37 are preferably designed to effect the compression in a practically adiabatic manner, so as to minimize the temperature increase and the work of compression.

When air is used as refrigerating medium and the system is operated at comparatively low pressure, the "make up" supply of medium required in starting and to compensate for leakage losses may be admitted and drawn into the system, during operation, through one or more openings 39 in the casing wall at the inlet or suction side of the compressor. Makeup air may also be obtained through the clearance around the shaft 25, by omitting the packing ring 40 ordinarily employed at the suction side of the machine.

The rotary expansion motor 4 is shown as of multi-stage axial flow turbine type. The working medium entering through the inlet 45 is discharged through inclined stationary expansion nozzles 46 against the first row of moving blades or buckets 47 carried by the rotor disk 48 of the first stage. The fluid issuing from the buckets 47 passes through a row of stationary reguide buckets 49 mounted on the turbine casing, and then enters and traverses the second row of moving buckets 50, carried by said rotor disk 48. The nozzle and bucket passages 46, 47, 49 and 50 may be of such progressively increasing size as to develop and utilize the velocity of the fluid obtainable by expansion fractionally, as shown, and may be of either impact or reaction types. The fluid is next discharged through the inclined stationary expansion nozzles 51 in the interstage diaphragm against the row of buckets 52 on the rotor disk of the second stage, its pressure being thus further converted into velocity and utilized to assist in driving the compressor 3. The fluid finally issues from the turbine outlet 53, and enters the piping 21 in an expanded condition, and at a low temperature corresponding to that when it

entered the turbine and to the expansion it has undergone, so that its former refrigerating power when it enters the refrigerating apparatus 18 is restored. Preferably, the turbine is designed (as indicated) so as to effect the expansion as nearly adiabatically as possible, in order that the maximum power output may be obtained and that the final temperature may be as low as possible.

10 It will be seen that the system as a whole is as simple as possible, and that the operating unit, likewise, has a minimum of parts, and has only two bearings to be lubricated. Owing to the utilization of the energy obtainable from the expansion of the working fluid to assist in driving the compressor 3, the net power consumption of the system is reduced to a minimum. The interchange of heat between the relatively warm compressed medium on its way from the cooler 6 to the expander 4 and the relatively cold medium returning to the compressor 3 is doubly advantageous. It results in a low minimum temperature for the medium after expansion, and hence in maximum refrigerating power; and it results in a relatively high temperature for the medium in the cooler 6, so as to permit cooling at a relatively high temperature range and thus promotes maximum abstraction of heat from it by the agency employed, such as the surrounding atmosphere. Thus the high heat level of the refrigerating cycle is, as it were, "jacked up", by forcing down the low heat level, and vice versa.

40 I am aware that it has been previously proposed, in U. S. patent to Allen, No. 231,886, Sept. 1, 1880, to use an engine driven by the expanding refrigerating medium to assist in the work of compression. The system shown in that patent is, however, so complicated and subject to such other dis-

advantages as to be of quite limited utility, and under many conditions quite impracticable.

Having thus described my invention, I claim:

1. A refrigeration compressing and expanding unit comprising, on a common shaft, and in a unitary casing and frame 50 structure, a rotary compressor device for compressing the working medium; a rotary fluid motor device for expanding the medium thus compressed to restore its refrigerating power; and additional motor device 55 receiving power from an external source and cooperating with the first-mentioned motor to drive said compressor; and a base for said unit with one of said devices mounted directly thereon and carrying the others 60 through their attachment to that so mounted.

2. A refrigeration compressing and expanding unit comprising a base for the unit and a motor receiving power from an external source mounted directly thereon; a 65 rotary compressor for compressing the working medium attached to said motor by openwork, with an intervening air space, and thereby carried from said base; a rotary fluid motor for expanding the medium 70 thus compressed to restore its refrigerating power cooperating with the aforesaid motor to drive said compressor, and attached to the aforesaid motor by openwork, with an intervening air space, and thereby carried 75 from said base; and a common shaft for said compressor and said motors.

In testimony whereof, I have hereunto signed my name at Philadelphia, Pennsylvania, this 29th day of April 1920.

CHARLES E. BONINE.

Witnesses:

JAMES H. BELL,
E. L. FULLERTON.