Aug. 2, 1938. J. KIRGAN 2,125,347

REFRIGERATING APPARATUS

Filed June 29, 1936

FIG-2.

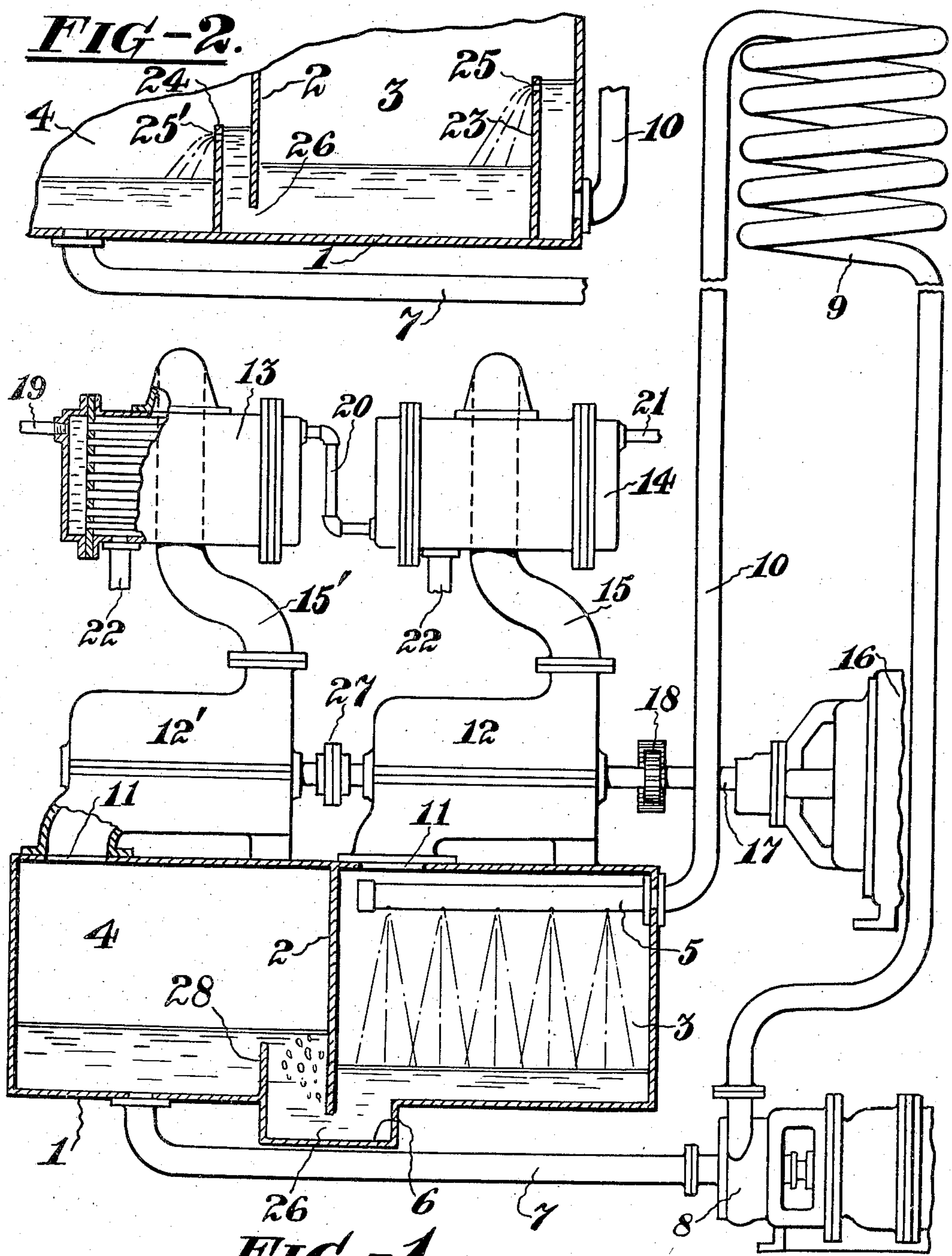

FIG.-1.

INVENTOR.
John Kirgan.
BY
HIS ATTORNEY.

Patented Aug. 2, 1938

2,125,347

UNITED STATES PATENT OFFICE

2,125,347

REFRIGERATING APPARATUS

John Kirgan, Easton, Pa., assignor to Ingersoll-Rand Company, Jersey City, N. J., a corporation of New Jersey

Application June 29, 1936, Serial No. 87,876

2 Claims. (Cl. 62—115)

This invention relates to refrigerating apparatus, and more particularly to refrigerating apparatus of the type wherein a refrigerant is chilled by partial vaporization.

It is an object of the invention to economize in the cost of refrigeration.

It is another object of this invention to provide an evaporator wherein a refrigerant may be progressively chilled by subjecting it to successively lower pressures as it flows through the evaporator, thereby to effect a material reduction in the power consumed.

It is another object of the invention to provide an evaporator so constructed that its height is no greater than that required by a single evaporating chamber, the present evaporator having a plurality of horizontally disposed chambers so connected that the liquid refrigerant flows successively through all the chambers.

It is a further object of this construction to enable the pressure differential between successive evaporator chambers to cause the liquid refrigerant to flow between such chambers and to enable such flowing refrigerant to establish liquid seals between the chambers without the aid of additional apparatus.

Still another object of the invention is to provide a suitable evacuator for each evaporator chamber, the several evacuators being coupled and driven by a single motor to obviate variations between the operating characteristics of the several evacuators and to render these characteristics dependent only upon the total load on the evacuators and upon the refrigerating load.

An additional object of the present construction is to effect the greatest possible economy in the consumption of power for removing vapor from the evaporator and in the consumption of condensing medium for liquefying such vapor. To this end the vapors from each chamber are condensed separately and at progressively lower pressures, the highest condensing pressure being associated with the evaporator chamber having the highest pressure, and the progressively lower pressures being accordingly associated. For liquefying the vapors, a condensing medium passes successively through the condensing sections from the section of lowest pressure to that of highest pressure.

Other objects will be in part obvious and in part pointed out hereinafter.

On the drawing, Figure 1 shows one form of the apparatus in which the invention is incorporated, and

Figure 2 is a fragmentary view showing a modification of the evaporator structure. The same numerals identify similar parts throughout. Referring now to the drawing and particularly to Figure 1, the numeral 1 indicates an evaporator in the form of a closed vessel having bottom, top and side walls, and within which a number of partitions 2, one of which is herein shown, depend from the top wall and terminate short of the bottom wall to divide the vessel into a number of separate chambers, two of which are shown at 3 and 4. Below each of these partitions 2, a portion 6 of the bottom wall of the evaporator is depressed to form a transverse trough or well 6, and each partition 2 extends down into the well but terminates short of the bottom thereof to form a passage 26 connecting the adjacent chambers 3 and 4.

Extending into one of the chambers is an inlet header 5 containing openings through which a liquid refrigerant may be sprayed, for example, into the right hand chamber 3 as shown in Figure 1. An evacuator 12 acts to maintain a high vacuum in the chamber 3 and some of the entering liquid refrigerant immediately flashes into vapor, extracting heat from the remainder and chilling it. The unvaporized chilled refrigerant falls to the bottom of chamber 3 and fills the well 6 passing through the passage 26, around a baffle 28 and into the succeeding chamber 4. A still higher vacuum is maintained in this chamber by the evacuator 12′ and a further reduction in refrigerant temperature is effected. For the purpose of illustration I have shown but two cooling stages, but more stages may of course be utilized.

The cooled liquid is withdrawn from the final chamber 4 by a motor-driven pump 8 through a pipe 7 to be delivered to a cooling coil 9 where a refrigerating effect is desired. From this cooling coil the used refrigerant may again return to the evaporator by way of a pipe 10 connected to the header 5. Ordinarily sufficient liquid refrigerant will be present within the evaporator chambers to fill the troughs 6 and rise above the bottom of any partition 2 to establish a liquid seal between adjacent chambers thereby assuring that the pressure differential between such chambers is maintained.

In the modification shown in Figure 2, the inlet header 5 of Figure 1 is replaced by a weir or other overflow means 23 adjacent a wall of the chamber 3. The pipe 10 delivers the liquid refrigerant to the well contained between the weir and the wall from whence it flows over the top of the weir 23 or through a series of openings 25 in the side of the weir into the chamber 3. Each succeeding chamber is, in this instance provided with a weir 24 somewhat shorter than the weir 23 adjacent the partition 2 separating such a chamber 4 from the preceding chamber 3. The weir 24 and the partition 2 form an additional well communicating with the preceding chamber by a passage 26 and liquid flows from the chamber 3 over the weir 24 or through openings 25′ in the side of this weir into the succeeding chamber 4. With either of the evaporator constructions shown, the flow of refrigerant from one chamber to the next is caused by the pressure differential between the two chambers and a liquid seal between the chambers is established by the flowing refrigerant without any additional equipment being required.

As shown in Figure 1, the pressure differential between adjacent chambers manifests itself by a higher liquid level in the chamber 4 than in the chamber 3, and liquid refrigerant passing through the passage 26 creates some turbulence in the refrigerant as it enters the chamber 4 to hasten the vaporization thereof. Within the chamber (or chambers) 4 and forming a continuation of a side of the trough 6, I have placed a short upright baffle 28 which is submerged in the liquid in the chamber 4. The purpose of this baffle is to prevent liquid from flowing directly to the outlet pipe 7 without coming near the surface of the liquid in the chamber 4. Such a construction greatly aids in creating turbulence in the liquid entering the chamber.

In Figure 2 the pressure differential is shown by the difference between the level in the chamber 3 and the level in the inlet well for chamber 4. In this instance the water entering any chamber is sprayed onto the surface of the liquid therein and evaporation is thus aided. So long as refrigerant is removed from the chamber 4 by the pump 8 liquid will continuously pass from one chamber to the next without appreciably rising above a given level in either chamber. On the other hand, suitable controlling devices may of course be applied to prevent the liquid level from rising beyond a predetermined level in the chambers should some accident occur. In either evaporator construction the chambers may thus be horizontally disposed with respect to each other and the overall height of the evaporator becomes no greater than that required for a single evaporator chamber.

Turning again to Figure 1, each evaporator chamber has an outlet 11 at its top through which the vapor of the refrigerant is extracted. Each of these outlets leads to the intake of an evacuator which in practice both withdraws the vapor and maintains the proper vacuum in the chamber to which the evacuator is connected. As indicated in the drawing, the evacuators are preferably centrifugal compressors contained in the housings 12 and 12′. These compressors increase the pressure of the vapor formed in the chambers 3 and 4 and transmit it to separate condensers 14 and 13 through discharge flues 15 and 15′. The compressors may be operated at high speed by a motor 16 through a shaft 17, connected if necessary to the motor by the step-up gearing indicated at 18.

The two condensers may be cooled by any suitable medium, such as water, supplied by a pipe 19 to the condenser 13 connected to the evacuator for the chamber 4 for example, and from this condenser the cooling medium may be conducted by a pipe 20 into the other condenser 14 and be carried away therefrom by a pipe 21. These condensers are preferably provided with interior tubes through which the cooling medium flows, the vapor of the refrigerant being liquefied by contact with these tubes and the condensed vapor being thereafter withdrawn by way of the pipes 22 to be conducted back into the evaporator or elsewhere. Each condenser will of course be provided with a suitable evacuating device (not shown) for maintaining the desired degree of vacuum therein, and the pipes 19 and 21 may be provided with valve mechanisms if desired.

Because the refrigerant entering the second chamber 4 is at a lower temperature than when it entered the chamber 3, the absolute pressure in the chamber 4 will be somewhat less than the absolute pressure in the chamber 3. The refrigerant entering the chamber 3 undergoes the first reduction in temperature and the vapor formed in this chamber is then forced into the condenser 14 by the evacuator 12 connected to this chamber. The cooling water in this condenser will be somewhat higher in temperature than the water for the other condenser 13 which receives the cooling medium first. Consequently the evacuator 12 for the chamber 3 must work against a slightly higher back pressure than the evacuator 12′ for chamber 4. But the suction pressure on the compressor 12 is also somewhat higher than the suction pressure on the other compressor 12′, and the result is that the ratio of compression developed by one compressor is approximately the same as that of the other.

For example, the water entering the chamber 3 may be about 54° and the absolute pressure therein may be about 0.39 inch of mercury. The water in this chamber may be reduced to 47° and at this temperature it flows into the chamber 4 where the pressure is, say, 0.25 inch of mercury. Here the second reduction may carry the water temperature down to about 40°. The cooling medium for the condenser 13 connected to the pipe 19 may have an inlet temperature of about 70° and be warmed to about 83° before it flows into the next condenser 14. Leaving this second condenser 14 the cooling medium may be at about 97°. The pressure in the first condenser may then be about 1.24 inches of mercury and in the second condenser about 1.95 inches of mercury. It will be seen, therefore, that the compression-ratio of each compressor will be about 5 to 1 and although this ratio will vary with the refrigerating load, the equality between the several ratios remains. I have found that by an arrangement of this sort a large saving of condenser water is obtainable.

For example, with a single stage evaporator of 100 tons output, the condenser water may be 222 gallons per minute, while with a two-stage evaporator system as shown in the drawing and operating according to the above figures, the consumption of condenser water may be reduced to 100 gallons per minute, which is less than half. I have also found that the consumption of power by the evacuators may be considerably reduced by utilizing series vaporization and series condensing in conjunction with one another, for, as brought out earlier, all vapor is herein pumped at the same low ratio of compression, whereas if all condensing is effected at a common condenser pressure, the greater part of the vapor must be pumped at compression-ratios considerably in excess of the present low ratio, and at these higher ratios more energy would of course be utilized for operating the evacuators. Thus the cost of operation may be greatly cut down, while at the same time a large reduction in temperature of the water entering the evaporator is rendered possible.

In practice, the compressors are preferably identical and run at the same speed, and to this end the shafts of the compressors are coupled as at 27, to be driven in unison by the motor 16. Such operation obviates the liability of one compressor to temporarily run at greater speed than another and assume more than its share of the load, and of course thereby aids in removing fluctuations in condenser operation. In other words, by operating the evacuators in unison by a single driving means a form of equilibrium is produced between the compressors and between the evaporator chambers, such that the load on any one compressor is maintained at a substantially fixed proportion of the total load on the evacuators as governed by the condenser and evaporator conditions.

Such a system is adapted to work well, both at full load and at part load. As is well known, when a centrifugal compressor is used in a refrigerating system of this sort, and run at constant speed, the compressor is self-regulating and the power for operating same is automatically reduced when the load thereon is reduced. Further the load on any compressor remains stable over a considerable part of the load range and instability does not manifest itself until a very light load is reached. To prevent instability of compressor load at even the lightest loads, suitable controlling apparatus may of course be employed.

The apparatus is, therefore, well adapted to accomplish the objects in view, and while I have shown and described certain embodiments of the invention, it is to be understood that I may make various changes in shape or mode of procedure without exceeding the scope or spirit of the invention as limited by the prior art and as defined by the hereinafter appended claims.

I claim:

1. In a refrigerating system, an evaporator having a plurality of chambers wherein a refrigerant is chilled, said chambers being arranged to cause the refrigerant to pass successively through the chambers, an evacuator for each chamber, motor means common to all of the evacuators for driving same in unison, a separate condenser for the discharge of each evacuator, and means for passing a cooling medium serially through the several condensers.

2. In a refrigerating system, an evaporator having bottom, top and side walls, a plurality of partitions depending from the top wall and terminating short of the bottom wall to form a plurality of chambers in the evaporator, an inlet for liquid to one of said chambers, an outlet for liquid from another of said chambers, said outlet being so disposed that the refrigerant must pass successively through all of the chambers to reach the outlet, said liquid in its passage forming seals between the various chambers, an evacuator for each chamber to remove vapor therefrom and to maintain progressively lower pressures in said chambers, the liquid being caused to flow from one chamber to the next by the pressure differential maintained therebetween, and condenser means to which the evacuators discharge.

JOHN KIRGAN.