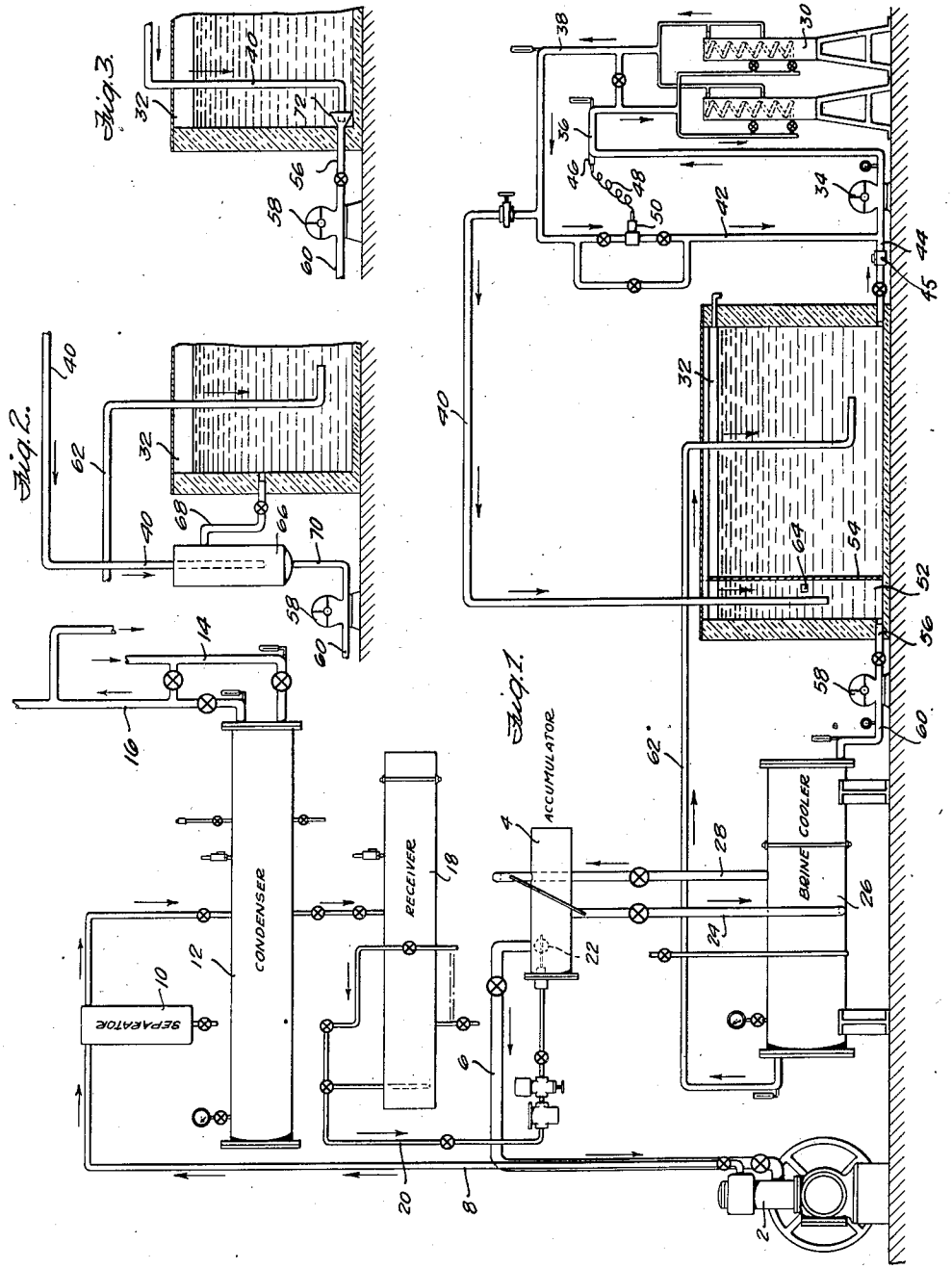
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REFRIGERATION SYSTEM

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REFRIGERATION SYSTEM

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This invention relates to refrigeration systems, and particularly to systems which employ a readily liquefiable gas such as ammonia as the refrigerant and use the refrigerant when condensed to cool brine or other suitable liquid heat transfer and refrigeration storage medium.

A general object of the invention is to improve the overall efficiency of ammonia or other readily liquefiable gas refrigeration systems which use brine or other suitable liquid as a heat transfer and refrigeration storage medium and also to make possible the enlargement of the capacity of existing refrigeration systems of this character without increase in the size of the heat-exchanging and gas compressing parts thereof and without a proportional increase in the power consumption.

In general the capacity of an ammonia refrigeration system is proportional to its back pressure at constant head pressure. In other words, within certain limits and by reason of the greater density of the ammonia taken in on the suction stroke of the compressor, the greater the back pressure the greater the capacity of the apparatus for the same displacement. As an illustration, an 8x8 compressor operating at 327 R. P. M. will have a capacity of approximately 24½ tons per twenty-four hours at 10 pounds back pressure and a capacity of 35¼ tons per twenty-four hours at 20 pounds back pressure.

Furthermore, the horsepower per ton of an ammonia compressor varies with the back pressure and that with an increase in the back pressure the horsepower per ton decreases. Using the above conditions as a basis for the computation of the horsepower per ton, the total horsepower used in producing 24½ tons at 10 pounds back pressure would be 47, while the total horsepower used in producing 35¼ tons at 20 pounds back pressure would be 53.75. This gives an increase in capacity of the same compressor of 43.8% with an increase in power consumption of only 14.3%. Reduced to horsepower per ton, this means that the horsepower per ton at 10 pounds back pressure is 1.93, while at 20 pounds back pressure it is only 1.525, or a saving in power per ton of .405 horsepower or 21%.

The present invention aims particularly so to construct and arrange ammonia or other refrigeration systems, in which brine or other suitable liquid is employed as a heat transfer and refrigeration storage medium, that full advantage may be taken of the thermodynamic relations above set forth.

It has been standard practice, in the design of ammonia refrigeration systems utilizing brine as a heat transfer, heat conveying and refrigeration storage medium, to employ a pump to take the brine from the brine tank, in which it may be at a temperature of anywhere from 0° up to 25° F., and first force the brine through a brine cooler, where it is in heat exchanging relation to the liquid ammonia and in which its temperature is lowered still further, and then through the cooling or heat transfer equipment, where it is in heat exchanging relation to whatever is to be refrigerated, and finally back to the brine tank. Depending upon the temperature of the brine as it is taken from the brine tank and forced through the brine cooler, the amount of heat given up to the liquid ammonia in the brine cooler will vary, but in general it will not be sufficient to cause a very high back pressure on the ammonia compressor.

One of the objects of the present invention, therefore, is so to construct and arrange an ammonia refrigeration apparatus that, while the reserve refrigeration capacity and the adaptability to meet a wide range of load conditions which are provided by the use of a brine storage tank may be available, at the same time the brine will be so circulated through the system as to insure both full use of its heat exchanging capacity and a higher average back pressure on the compressor and thus a higher operating efficiency of the compressor. To this end an important feature of the invention is the employment of two circulating pumps, preferably operating at constant speed, one for effecting the movement of the brine from the brine tank through the cooling or heat exchange equipment, and the other for effecting the movement of the brine from what may be, for convenience, termed a "hot well" through the brine cooler. Another important feature of the invention is the provision of the "hot well" itself.

Another object of the invention is so to arrange the circulation effected by the two pumps aforementioned that, while provision is made for operating both at full capacity and provision is also made for insuring a higher average back pressure on the compressor than in the refrigeration storage systems of the prior art, nevertheless the desired refrigerating conditions can be maintained for whatever is to be refrigerated.

Other objects and important features of the invention will appear from the following description and claims when considered in connection with the accompanying drawing, in which

Figure 1 illustrates a refrigeration system embodying the present invention, some of the parts being shown conventionally;

Figure 2 shows one modified construction and arrangement of the "hot well," and

Figure 3 shows another.

In the illustrative embodiment of the invention, which may use ammonia as the refrigerant, an ammonia compressor is shown conventionally at 2. This ammonia compressor 2 on its suction stroke draws the ammonia gas or vapor from the

upper part of a float-controlled accumulator 4 through a suction line 6 and on its compression stroke forces the ammonia gas or vapor through the pressure line 8 and through an oil drip or separator 10 into the condenser 12, which may be of the shell type, where the compressed ammonia vapor is brought into heat exchanging relation to water circulating from any suitable source of water supply such, for example, as an inlet 14 from a water main and an outlet 16 to the plant line. The condensed ammonia is discharged from the condenser 12 into a storage reservoir 18 from which it may pass through a communicating pipe 20 to the accumulator 4 having a float level control 22, which operates, whenever the level in the accumulator falls below a predetermined point, to open connections to the reservoir 18 to restore the level.

From the accumulator 4 the liquid ammonia passes through the down pipe 24 to the brine cooler 26, which may also be of the shell type and in which the liquid ammonia is brought into heat-exchanging relation to the brine to be cooled, the mixture of liquid ammonia and ammonia vapor or gas then returning to the accumulator 4 through the up pipe 28 from which it is discharged into the top of the accumulator 4, the liquid dropping into and mixing with the mass of liquid in the accumulator 4 and the ammonia gas or vapor remaining above the surface of the liquid in position to be drawn into the suction pipe 6 on the suction stroke of the compressor 2.

From the foregoing description it will be seen that the higher the operating temperature level in the brine cooler 26 the greater will be the pressure on the ammonia gas or vapor above the liquid level in the accumulator 4 and thus the greater the back pressure on the compressor 2. To insure such high temperature operating level in the brine cooler 26 and thus a back pressure of considerable amount upon the compressor 2, while maintaining the desired refrigerating temperature and operating the circulating mechanism at its full capacity, is one of the objects of the present invention.

The brine for cooling the refrigerator 30 is taken from a brine tank 32 by a pump 34 which forces it through the refrigerator 30, the brine entering the refrigerator 30 through the pipe 36 which branches to the several coils of the refrigerator. From the refrigerator coils other branch pipes conduct the brine to a return pipe 38 which connects both with a pipe 40 leading to the "hot well," hereinafter to be described, and with a pipe 42 which may be used when desirable to re-introduce a part of the heated brine into the intake 44 leading from the brine tank 32 to the pump 34. Whether or not any of the heated brine is to be mixed with the brine going from the brine tank 32 to the pump 34 is determined by the temperature of the brine in the pipe 36 and by the desired refrigerating temperature. A thermostat 46, located in the pipe 36, has a connection 48 to a valve 50 in the pipe 42. If the brine in the pipe 36 be colder than is desirable for the particular refrigerating operation, then the thermostat 46, having been set for the desired operating conditions, opens the valve 50 sufficiently to allow a mixing of the heated brine with the brine from the tank 32 in order to bring the temperature of the brine in the pipe 36 to the desired level.

In order to effect a partial separation of the heated brine, coming from the refrigerator, from the colder brine in the tank 32 and at the same time to provide uninterrupted full capacity circulation of brine by the pump 58 through the brine cooler 26, the pipe 40 in Figure 1 of the drawing is led into a compartment 52 separated from the main part of the brine tank 32 by walls 54, this compartment 52 being one form of the so-called "hot well" of the present invention and being shown as located in the near left hand corner of the brine tank 32, shown in section in Fig. 1. From the compartment 52 an intake 56 leads to the additional brine circulating pump 58 which circulates the brine through the brine cooler 26, the pump 58 being connected to the cooler 26 by a pipe 60 and the brine discharged from the cooler 26 being conducted back through a pipe 62 to the main part of the brine tank 32 where it is introduced near the bottom of the tank.

From the foregoing description it will be seen that in some cases all of the brine that is forced through the refrigerator 30 by the pump 34 will not be conducted through the pipe 40 into the "hot well" 52 but that part of it will be diverted through the branch 42. In order, therefore, not to interfere with the circulation of brine through the brine cooler 26 and to insure full capacity operation of the pump 58, a connection is made between the "hot well" 52 and the main part of the brine tank 32, such, for example, as an opening or openings 64, to permit colder brine from the tank, sufficient to insure proper supply to the pump 58, to mix with the heated brine which comes from the refrigerating coils of the refrigerator into the "hot well" 52 through the pipe 40. However, to insure that the heated brine which comes in through the pipe 40 will be drawn into the pump suction, the outlet of the pipe 40 in the "hot well" 52 is brought down pretty well toward the intake 56. Moreover, the openings 64 should be at a level above the discharge end of the pipe 62 and high enough above the bottom of the tank 32 so that the brine coming into the "hot well" 52 through them will be from the warmer upper portions of that in the tank. These openings 64 also provide brine for the operation of the pump 58 when the pump 34 is not running, that is when there is no refrigeration load.

It will be understood, of course, that the "hot well" of the present invention need not necessarily be a compartment in the brine tank and that it can equally well be a separate tank outside the brine tank, as shown in Figure 2.

In Figure 2, a tank 66 is shown as arranged outside the brine tank 32 but connected thereto by a pipe 68 which enters the tank 66 preferably below the upper level of the brine in the tank 32 but above the outlet of the pipe 40, so that the brine drawn from the tank 66 by the pump 58 through the connection 70 will be made up as far as possible of the heated brine coming from the refrigerating equipment through the pipe 40, when the pump 34 is operating.

From the foregoing description the theory of operation and the economies effected by the improved refrigeration system will readily be understood. In a refrigeration system of this general type, that is, one employing a brine tank and a brine cooler, there will, under ordinary conditions of operation, be a definite temperature relation of the ammonia to the average temperature of the brine going into the brine cooler. This relation will change slightly with change in back pressure because of the fact that more work is

being done by the system at higher back pressure than at lower back pressure.

However, with constant pump capacity the temperature drop in the brine in passing through a brine cooler, such, for example, as the brine cooler **26** of the shell type hereinabove referred to, will increase slightly with increase in back pressure and decrease slightly with a drop in back pressure. An increase in the temperature of the brine passing through the brine cooler **26** will cause an increase in the ammonia temperature with a corresponding increase in back pressure. Although the temperature of the ammonia will not be directly proportional to the brine temperature throughout a wide temperature range, for the purposes of comparison of the advantages of this invention with prior practice it will be near enough to say that an increase of 1° in the initial temperature of the brine will mean an increase of 1° in the temperature of the ammonia multiplied by the rates of capacity at increased back pressures over the initial capacity.

The efficiency of the "hot well" of the present invention depends to some extent upon the relative amounts of brine circulated by the two pumps. For example, if the brine cooler pump **58** has a capacity of twice the pump **34**, which circulates the brine through the refrigerating equipment, the increase in the temperature of the brine entering the brine cooler **26** will be less than if the two pumps **54** and **34** were of equal capacity.

In the practice of the present invention the relation of the circulation capacities of the two pumps will vary according to the application, type of load and the relation of the capacity of the actual refrigeration load to the capacity of the machine. As an example, a refrigeration system embodying the present invention has been installed, in which the ratio of circulation of brine by the brine cooler pump **58** to the circulation by the refrigeration equipment pump **34** is 1½ to 1 in a plant in which the maximum load is 2½ times the operating machine capacity, while at another installation embodying the present invention the circulation effected by the pump **34** varies from a relation of 1 to 1½ in respect to the circulation effected by the brine cooler pump **58**, at one time, to a relation of 1 to 1 at another time.

Experience has also shown that the economies effected by the improved refrigeration system are still more marked the longer the refrigeration load lasts. This is illustrated somewhat in the following table which shows the temperature and pressure characteristics of the improved system in an existing installation:

		Brine tank temperature	Temperature of brine in shell cooler	Temperature of brine out shell cooler	Back pressure	NH_3F	Time
		Degrees	*Degrees*	*Degrees*	*Pounds*	*Degrees*	
(1)	Compressor operating without plant load	9	9	7	14	−2.20	6:15
(2)	At start of receiving	9	17	13	15	−.1	6:30
(3)	After ¾ hr. operation on load	13	21.5	18	20	6	7:40
(4)	When brine tank warmed half of total rise	14	22	18	22	7.9+	7:50
(5)	At finish	19	27	23	24	9	8:50

Referring to the foregoing table, the economies effected by the improved refrigeration system can readily be perceived. For example, the readings under condition 1, that is, when the compressor is operating without plant load in a milk-receiving station, before the farmers have started to deliver their milk to the station, shows how an ordinary brine tank ammonia refrigeration system operates without the "hot well" of the present invention, there being in condition 1 no "hot well" action.

The readings for condition 2 show the immediate effect which the "hot well" exerts when refrigeration load is applied. The readings under 3 show the effect after three quarters of an hour of operation with substantially constant application of refrigeration load. The readings under 4 show substantially the average condition of the run, while the readings under 5 show the maximum benefit of the "hot well" at the end of the run.

It is to be noted that the refrigeration system embodying the present invention from which the above table of readings was made embodied also the automatic brine recirculation control, including the by-pass pipe **42**, the thermostat **46** and the thermostatically controlled valve **50**, for maintaining substantially constant refrigeration conditions and that only the overflow, that is, that part of the heated brine flowing through the pipe **38** which was not by-passed again to the pump **34**, was carried on through the pipe **40** into the "hot well." In some systems embodying the present invention the by-pass **42** is not employed and all of the brine from the refrigeration coils is returned to the "hot well."

Referring again to the above table and taking the readings under 4 as the average condition, it will be noted that the brine enters the cooler **26** at a temperature of 22°, whereas the temperature of the brine in the tank **32** is 14°. This gives an increase of the temperature of the brine entering the cooler **26** by reason of the use of the "hot well" over the temperature of the brine, had it been taken directly from the brine tank, of 8° F. It will also be noted that with this average condition the back pressure is 22 lbs. gauge and the ammonia temperature 7.9° F.

In order to make comparison with the ordinary brine tank refrigeration system, that is, a brine tank system operating without a "hot well," we may by computation determine the approximate conditions as to ammonia temperature and back pressure in such a system with the same brine tank temperature. In doing so, two things must be taken into consideration, namely, first the actual temperature difference in the ammonia in the two systems and, secondly, the fact that the capacity of the compressor for the same displacement will decrease with a decrease in back pressure.

Taking all of these things into consideration, the actual ammonia temperature for an average brine tank temperature of 14° F. in the ordinary brine tank systems operating on the same refrigeration load may be estimated to be approximately −2.20° F. This corresponds to a back pressure of 14 lbs.

The H. P. per ton at 14 lbs. back pressure is 1.75. The H. P. per ton at 22 lbs. back pressure is 1.496. It will thus be seen that for the average

condition shown in the table above, that is, the condition showing 22 lbs. back pressure, the ratio of H. P. consumption to that of an ordinary brine system having an average back pressure of 14 lbs. will be 1.496/1.75=85%+. The improved refrigeration system of the present invention in the illustrative example will thus show a saving in power of approximately 15%.

From the foregoing table another economy effected by the system can also be seen. This is the fact that the compressor is put to work immediately. This means fewer hours of operation of the same compressor at the same speed.

Other indirect savings not included in the 15% H. P. saving referred to above are also effected, one being the fact that the "hot well" pump **58** will operate fewer hours. For instance, in the illustrative example given above it is estimated that, without the "hot well," the compressor would have operated at least an additional 1½ hours to take care of the increased amount of work resulting from the increased capacity due to the use of the "hot well" over the amount of work which would have been done by the standard system.

Further to illustrate this point, if an ammonia compressor operating at constant speed has a capacity of 20 tons at 15 lbs. back pressure, this same machine, operating at 22 lbs. back pressure, will have a capacity of 24.7 tons. Assuming, then, a total load of 158 ton hrs., the time of operation would be 158/20 or 7.9 hrs. at 15 lbs. back pressure and 20 ton rate. The time of operation of the same machine, with a 24.7 ton rate at 22 lbs. back pressure, would be 158/24.7 or 6.4 hrs. The difference in the operating time would, therefore, be 7.9 hrs.—6.4 hrs., or 1.5 hrs.

Another indirect saving is effected by the use of two pumps. In brine tank refrigeration systems such as used in milk-receiving plants of usual capacity and employing only one pump, a 15 H. P. motor is utilized to operate the pump and this motor is operated throughout the entire operation of the compressor which, as just stated, would be approximately 1½ hours more than with the "hot well" system. Although, with the two pumps of the refrigeration system of the present invention, the same total H. P. would be required, it would be distributed as follows:

10 H. P. on the pump **34** which circulates the brine through the refrigerator coils, and
5 H. P. on the pump **58** which circulates the brine through the brine cooler.

As shown by the table given above, the refrigeration load lasts only about 2½ hours and thus the pump **34** would be driven by its 10 H. P. motor for only 2½ hours. The pump **58**, however, which circulates the brine through the brine cooler **26** operates necessarily for the same period of time as the compressor, which is from 5 to 8 hours on the average. This means a saving in power applied to brine circulation of from 2½ to 5½ hours on a 10 H. P. motor.

Still another indirect saving comes from the increased capacity of the compressor at the higher back pressure whereby less refrigeration storage or total advance cooling of the brine in the brine tank is required. With the smaller refrigeration storage the final brine temperature in the brine tank will be higher for the same amount of refrigeration load and will therefore create a higher final back pressure. In other words, the machine will have a tendency to keep out of the low back pressure or less economical operating range.

Although in the preferred embodiment of the invention the "hot well" effect is produced by providing either a compartment in the main brine tank or a separate container for the hot brine, it will be understood that an approximation to the same result may be obtained by omitting the partition **54** and carrying the outlet of the pipe **40** down even closer to the intake to the pipe **56** leading to the pump **58**, thus insuring that at least a substantial portion of the brine withdrawn from the tank **32** by the pump **58** will be the hot brine introduced through the pipe **40**. Such an arrangement is intended to be included also in the expression "hot well" and, in one embodiment, is shown in Figure 3, where the intake to the pump **58** is shown as provided with a bell mouth **72** into which the discharge end of the pipe **40** projects. This provides both for proper direction of the hot brine into the pump intake and also for the entrance of make-up brine from the tank **32** to supply any deficiency, particularly when a part of the hot brine is being by-passed back through the refrigeration equipment. In some cases the bell mouth **72** may not be necessary to secure the desired direction of the hot brine to the pump intake.

It is to be noted that the recirculation of thermostatically selected proportions of the partially heated brine, for controlling the temperature of the refrigerating equipment, is effected in the illustrative embodiment of the present invention by the same pump that forces the brine through the refrigerating equipment, this being one of the novel features of the present invention. In order to insure the desired operation under certain pressure conditions, as, for example, when starting with very cold brine, so that substantially all of the heated brine is recirculated, a check valve **45**, opening in the direction of flow from the tank **32** to the pump **34**, may be so located in the pipe **44**, between the junction of the by-pass **42** with the pipe **44** and the tank **32**, as to prevent any tendency of a rise in pressure of the brine in the by-pass **42** to drive a part of this heated brine back into the tank **32**. The desired pressure relations may obviously also be obtained and maintained in other ways well known to the art.

What is claimed as new is:

1. In a liquefied gas refrigerating system, the combination with a storage tank for a heat transfer and refrigeration storage medium, a cooler for said medium in which it is brought into heat-exchanging relation to a liquefied refrigerant and then discharged into said tank, a compressor and a condenser for the vaporized refrigerant from said cooler, refrigerating equipment in which said medium is brought into heat-exchanging relation to whatever is to be refrigerated and a pump for effecting movement of said medium through said refrigerating equipment, of a container for receiving the medium after it is discharged from said refrigerating equipment, a second pump between said container and said cooler for effecting circulation of the medium from said container through said cooler and back to said tank, means for by-passing a portion of the medium, after it has passed through the refrigerating equipment, directly into the intake of the first-mentioned pump, and connections between said tank and said container for providing any necessary make-up in the medium supplied to said second pump required either by its greater capacity or to replace heated medium by-passed to the first pump.

2. In a liquefied gas refrigerating system, the combination with a storage tank for a heat transfer and refrigeration storage medium, a cooler for said medium having connections to said tank whereby the medium may be brought into heat-exchanging relation to a liquefied gas refrigerant in said cooler and then discharged into said tank, a compressor and a condenser for the vaporized refrigerant from said cooler, and refrigerating equipment connected to said tank, of a pump in said refrigerating equipment connections for effecting circulation of said medium through said refrigerating equipment from the tank, means for varying the amount of said medium withdrawn from said tank by said pump and correspondingly the amount to be discharged from the refrigerating equipment into the tank in accordance with the temperature requirements of said refrigerating equipment, a second pump in the connections between said tank and said cooler constructed and arranged to produce a substantially constant flow of medium through said cooler and back to said tank, and means for substantially immediately directing the heated medium discharged from said refrigerating equipment into the intake of said second pump.

3. A refrigerating system according to claim 2 in which the directing means comprises a container having a make-up connection with the tank.

4. A refrigerating system according to claim 2 in which said means for varying the amount of medium withdrawn from the tank comprises a by-pass running from the discharge end of the refrigerating equipment to the intake of the first pump, said by-pass having a valve therein controlled by the temperature of the medium that is about to enter said refrigerating equipment.

5. A refrigerating system according to claim 2 in which each of the pumps is a constant speed pump and in which each is supplied with medium for full capacity operation at the given speed.

6. A process of effecting refrigeration in a system having therein a storage tank for a heat transfer and refrigeration storage medium, a compressor for a liquefiable gas and a heat exchanger through which said medium and said liquefied gas circulate in heat-exchanging relation to each other, said process consisting in effecting a substantially uniform flow of said medium through refrigerating equipment, reintroducing into that part of the stream of medium which flows from the tank to the refrigerating equipment a sufficient quantity of the heated medium leaving said refrigerating equipment to maintain the desired refrigerating temperature with said uniform flow, separately effecting a substantially uniform flow of the medium between the tank and the heat exchanger and substantially directly introducing into the stream of medium flowing through said heat exchanger that part of the heated medium discharged from the refrigerating equipment which is not directly recirculated.

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