

Nov. 9, 1948.

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2,453,584

REFRIGERATING CONTROL APPARATUS

Filed June 8, 1944

2 Sheets-Sheet 2

Fig. 2.

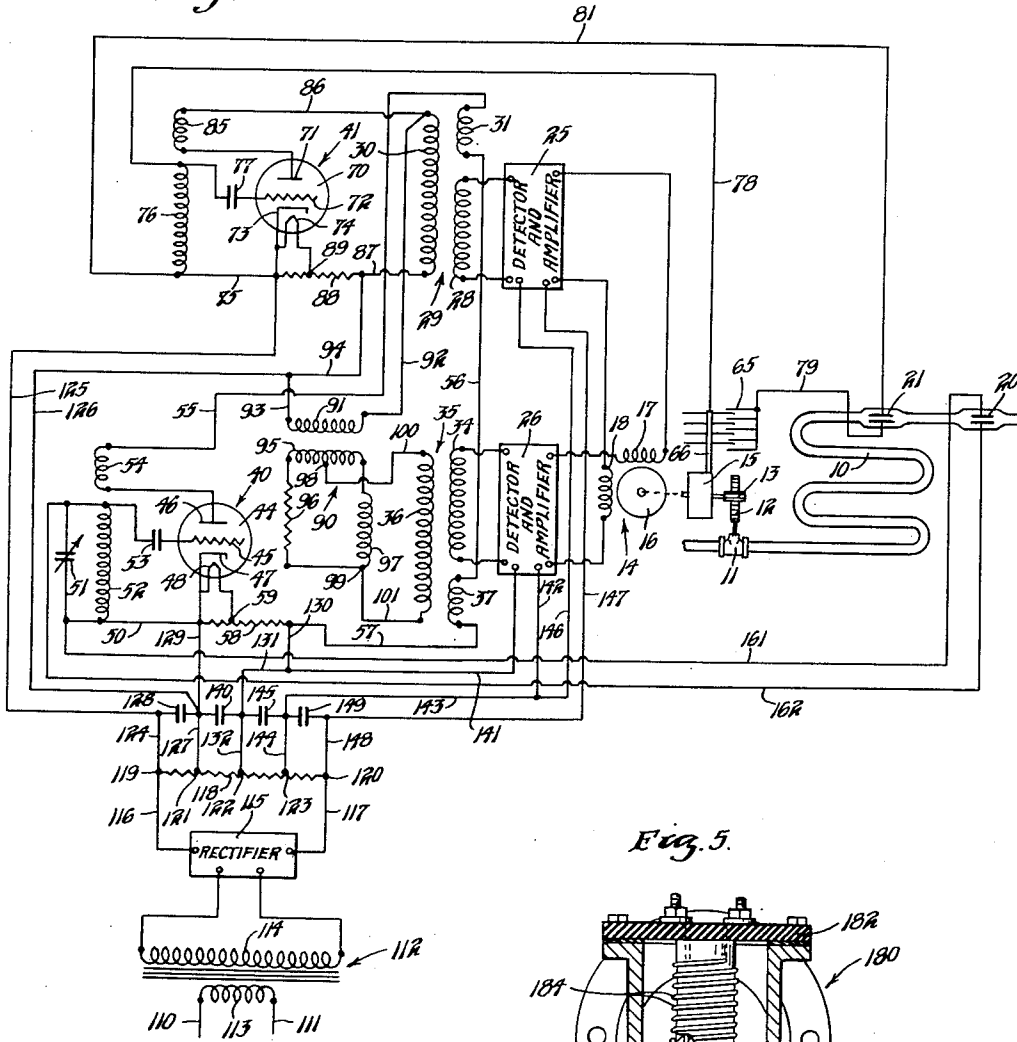
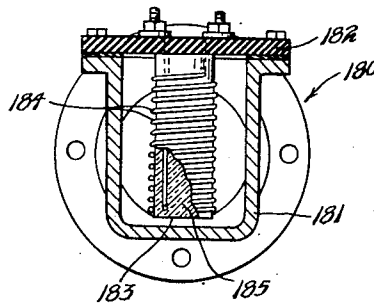


Fig. 5.



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UNITED STATES PATENT OFFICE

2,453,584

REFRIGERATING CONTROL APPARATUS

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Application June 8, 1944, Serial No. 539,299

19 Claims. (Cl. 62-8)

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The present invention relates to electronic means for controlling the flow of refrigerant in a refrigerant evaporator.

In a refrigerating system, the refrigerant evaporator is the device by which the cooling abilities of the refrigerating system are made available. All of the useful absorption of heat in the system takes place in the evaporator, the heat absorbed being transferred to the refrigerant within said evaporator. The ability of an evaporator to absorb heat is largely dependent upon the amount of liquid refrigerant within same, the evaporating liquid refrigerant absorbing heat much more rapidly than gaseous refrigerant. As the refrigerant absorbs heat, it is vaporized, so normally the refrigerant within the evaporator is partially liquid and partially vapor. To maintain the capacity of the evaporator to absorb heat at a high level, it is desirable to keep as much liquid refrigerant in the evaporator as possible; however, the problem of maintaining the most effective amount of liquid refrigerant within an evaporator is complicated by the requirement that all of the refrigerant leaving the evaporator must be vaporized, for it is imperative that no liquid refrigerant enter the compressor. Liquid refrigerant, being comparatively incompressible, cannot be safely handled by the normal refrigerating compressor.

It is a purpose of the present invention to provide means controlling the flow of refrigerant to an evaporator in a manner calculated to provide maximum absorption of heat in said evaporator and still insure the passage of only gaseous refrigerant from said evaporator.

It is known that refrigerants have certain electrical impedance values when in the liquid state and very different values when in the gaseous state. Further, the impedance value of a mixture of gaseous and liquid refrigerant will lie between the above values and will depend upon the refrigerant quality, or percent of gaseous refrigerant; quality being herein used in its thermodynamic sense.

It is thus an object of this invention to control the flow of refrigerant to an evaporator in response to the quality of the refrigerant within said evaporator, said quality being determined by the electrical impedance of said refrigerant.

In the present invention, the flow of refrigerant to the evaporator is controlled by a motorized valve, the motor of said valve being reversibly operated in response to the electrical impedance of the refrigerant issuing from the evaporator. Should the proportion of liquid refrigerant pass-

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ing a predetermined point exceed a desired ratio, the valve is operated toward closed position, and should the proportion of liquid refrigerant diminish below the desired amount, the valve is operated toward open position. The speed of operation of the motor valve is determined by the amount of variation of the liquid refrigerant quality from that desired.

It is therefore an object of this invention to control the flow of refrigerant to an evaporator by a motor valve operated in response to the electrical impedance of the refrigerant flowing in the system.

It is a further object to control the flow of refrigerant to an evaporator in response to the variations in electrical impedance at spaced points near the outlet of said evaporator.

It is also an object to control a refrigerating system in response to the electrostatic capacity of means influenced by the flow of refrigerant in the evaporator.

Additionally, it is an object to control a refrigerating system in response to changes in inductance of means influenced by the flow of refrigerant in the evaporator.

Further, it is an object to control a refrigerating system in response to changes in resistance due to a conductive refrigerant coating with suitable means disposed in the path of flow of the refrigerant in the evaporator.

It is an object of this invention to provide means which will keep an evaporator operating to maximum capacity over a wide range of conditions.

It is also an object to provide means whereby the operation of the control means may be readily adjusted to achieve the desired maximum capacity. Not only is the adjustment easily made in the present system, but also the system may be readily adjusted for use with various refrigerants without substitution of parts.

In the present system, the valve controlling the flow of refrigerant to the evaporator is adjusted at a rate depending upon the variations from the quality desired at the outlet of the evaporator and, if the variations be considerable, the adjustment is made very rapidly; if the variations be slight, the adjustment is made slowly. Because the speed of response is automatically based on the amount of variation, it is feasible to adjust the evaporator capacity to a higher level than may be safely done with less responsive control devices.

It is therefore an object of this invention to

provide control means for a refrigerator evaporator which is more responsive than the devices heretofore used.

It is a further object to control the flow of refrigerant to an evaporator in response to the electrical impedance of the refrigerant flowing near the outlet of said evaporator in such manner that the speed of response of said control is dependent on the amount of variation of said electrical impedance.

It is an object to control the flow of refrigerant in an evaporator in such manner that the impedance of such refrigerant at a location spaced from the outlet will be a predetermined value, the flow of refrigerant being varied if the impedance value falls below said predetermined value and the flow being oppositely varied if the impedance value rises above said predetermined value.

The present system is operated by electrical circuits, consequently other control conditions can be included by the use of modifying electrical control circuits, this being done by introducing controlling impedances.

It is thus an object of this invention to provide control means for a refrigeration system wherein said control means may be modified to consider supplementary control conditions by introducing simple and readily available electrical control equipment.

These and other objects will become apparent upon a study of the following specification and the related drawings wherein:

Figure 1 is a schematic view and wiring diagram of the present system.

Figure 2 is a view similar to Figure 1 but showing a modified control system.

Figure 3 is an elevation view of a control unit such as used in the above systems.

Figure 4 is a section taken on the line 4—4 of Figure 3.

Figure 5 is a section similar to that of Figure 4 of a modified control unit.

In the drawings, Figures 1 and 2 differ only by slight modifications, and like parts have been given similar numbers. In said figures, 10 represents a refrigerator evaporator which may be supplied with liquid refrigerant by any suitable system, such as a conventional compressor operated condensing unit, which may supply liquid refrigerant under pressure to evaporator 10 and withdraw the lower pressure gaseous refrigerant from same. The refrigerant flow through evaporator 10 is controlled by expansion valve 11, said valve including an operating rack 12 adapted to be reciprocated by pinion 13. Valve 11 is operated by a reversible motor 14 driving pinion 13 through gear box 15. Motor 14 includes a rotor 16 and field windings 17 and 18, each of said windings being supplied with a separate source of current. The speed of motor 14 depends on the frequency of the currents supplied to said windings and the direction of rotation of the motor depends on the phase relation between the currents flowing in the windings. If the current in winding 17 leads that in winding 18, rotor 16 will operate in one direction, whereas if the current in winding 18 leads that in winding 17, the rotor will rotate in the opposite direction. It is noted that motor 14 and the means supplying current to same is similar to that described in my Patent 2,303,654, issued December 1, 1942, and that the present invention does not include the circuit per se of said patent. The patented circuit is but one of many that may be used to

carry out the present invention, said patented circuit being considered a preferred one.

The essence of the present invention, as it relates to refrigerating systems, lies in energizing the circuits controlling the action of said motor in response to the electrical impedance of the refrigerant flowing in the outlet portions of the evaporator. As is well known, in a refrigerating system, liquid refrigerant under pressure is fed to an expansion valve which controls the flow of refrigerant and tends to maintain a reduced pressure in the evaporator. At the first pressure drop through the expansion valve, a portion of the liquid refrigerant evaporates and thus reduces the temperature of the remaining liquid refrigerant. The refrigerant then flows through the evaporator as a mixture of liquid and gaseous refrigerant. However, heat is absorbed by the evaporator because of its low temperature level and the evaporation of liquid caused by the inflow of heat reduces the proportion of liquid refrigerant and increases the proportion of gaseous refrigerant as said material flows through the evaporator. Ideally, for maximum refrigerating ability of the evaporator, refrigerant is fed into said evaporator by the expansion valve at such a rate that the heat absorbed by said evaporator is just sufficient to vaporize all of the refrigerant supplied before it leaves said evaporator to be compressed and reliquified. In practice, for safety, the refrigerant is usually permitted to absorb more than enough heat to vaporize same, the excess heat, or super heat, assuring that no liquid refrigerant will be taken into the compressor and damage same. It is thus noted that the quality of refrigerant passing through an evaporator constantly increases as heat is added to same, quality here referring to the percentage of dry gas of the mixture.

In addition to its other characteristics, the electrical impedance of refrigerant varies as said material is changed from a liquid to a gas. For instance, the dielectric constant of liquid ammonia is about 22 whereas gaseous ammonia has a value of 1.007. The electrical resistance of refrigerant also varies as it is changed in state, but in different degree. I make use of these changes in electrical impedance in the present instance by providing capacity, inductance or resistance control units for the aforementioned systems.

In the examples of Figures 1 and 2, capacitor means 20 is located at the outlet of evaporator 10 and capacitor 21 is located at a point in the evaporator upstream of 20, capacitors being used as the preferred control units. The location of 21 is so chosen that the refrigerant passing same under a full load condition will have a predetermined quality, say, for instance, 96% dry gas. Four per cent of the refrigerant will then still be in the liquid state and these liquid particles, it being known that the liquid in the latter part of a refrigerator evaporator is carried along as a mist of finely divided particles, will have an appreciable effect on the electrical capacity of capacitor 21. As the refrigerant passing capacitor 20 is completely vaporized, its capacity will remain reasonably constant, pressure variations causing only slight changes of capacity. However, if the refrigerant reaching said capacitor 20 is not completely vaporized, its capacity will be appreciably increased, the basic capacity of 20 being determined on a dry gas basis. The capacity changes affected in capacitors 20 and 21 by the variations in quality of the flowing refrig-

erant causes expansion valve 11 to be controlled in response thereto by the following circuit means.

As before noted, expansion valve 11 is operated by motor 14, which responds to the frequency and phase relation of the currents impressed on windings 17 and 18 of said motor. The current for winding 17 is supplied by the outlet terminals of detector and amplifier unit 25, while winding 18 is supplied by detector and amplifier unit 26. Unit 25 is energized by secondary 28 of air core transformer 29, said transformer 29 including two primary windings, 30 and 31. Unit 26 is supplied current by secondary 34 of transformer 35, said transformer 35 also including two primaries, 36 and 37.

An oscillator circuit indicated generally as 40 supplies high frequency current to primary windings 31 and 37 of transformers 29 and 35 respectively. A second oscillator circuit indicated generally as 41 supplies high frequency current to primary windings 30 and 36 of said transformers.

Oscillator circuit 40 is rather conventional and includes a suitable discharge device 44, shown as a triode, comprising a control element or grid 45, an anode 46, a cathode 47, and a heater filament 48. The input circuit of device 44 follows cathode 47, wire 50, a variable condenser 51 and an inductance 52 in parallel therewith, a coupling condenser 53, and control element 45. The output circuit of triode 44 may be traced from anode 46 through an inductance 54, a conductor 55, primary winding 31 of transformer 29, conductor 56, primary winding 37 of transformer 35, conductor 57, and a voltage dividing resistor 58 to cathode 47.

Inductances 52 and 54 are coupled to provide a feed-back from the output circuit to the input circuit. The heater filament 48 is connected between cathode 47 and a tap 59 on said voltage dividing resistor 58. The frequency of this oscillator circuit may be adjusted to any desired value by adjusting variable condenser 51. This oscillator circuit is intended to furnish a base, or standard, frequency and, when adjusted to a suitable value, may be left without further adjustment. However, it may be desired to also control expansion valve 11 in response to box temperature or the like, in addition to the impedance value of the refrigerant in the evaporator. To modify the present system to accomplish this result, a thermostat 60 may control capacitor 61, connected in parallel with condenser 51. The operation of this condenser will become clear as the description proceeds.

Oscillator circuit 41 is generally similar to that of 40 except that variable condenser 51 is replaced by capacitors 20, 21, and follow-up capacitor 65. Follow-up capacitor 65 is adjusted by shaft 66 from gear box 15 simultaneously with the adjustment of valve 11.

Oscillator circuit 41 comprises an electrical discharge device 70 of a type similar to 44. Device 70 comprises an anode 71, a control element 72, a cathode 73, and a heater filament 74. The input circuit of device 70 may be traced from cathode 73 through a conductor 75, an inductance 76, and a coupling condenser 77 to control electrode 72. The input circuit also includes conductor 78 connected to the top of inductance 76 and extending to capacitor 65, conductor 79, to capacitor 21, conductor 80, capacitor 20, and conductor 81 to the other end of inductance 76. The output circuit of device 70 may be traced as follows: anode 71, inductance 85, conductor 86, primary winding 30 of transformer 29, conductor 87, and a voltage dividing resistor 88 to cathode 73.

The heater filament 74 is connected between cathode 73 and a suitable tap 89 of the voltage dividing resistor 88. The inductance 85 is suitably associated with inductance 76 to provide a feed-back from the output circuit to the input circuit of the device 70.

An input winding 91 of a phase shifting bridge, generally indicated as 90, is connected in parallel with primary winding 30 of transformer 29. This connection may be traced from the upper end of transformer primary 30 through a conductor 92, input winding 91, and conductors 93 and 94 to the right hand terminal of resistor 88. The phase shifting bridge 90 is of a conventional type having a secondary winding 95 associated with the input winding 91. Connected in series across the terminals of the winding 95 are resistor 96 and an impedance 97. The output terminals of the phase shifting bridge 90, comprising a tap 98 located centrally of the secondary winding 95, and common terminals 99 of the resistor 96 and impedance 97, are connected through conductors 100 and 101, respectively, to the terminals of primary winding 36 of transformer 35.

Current is supplied to the control system from lines 110 and 111 through a transformer 112 comprising a line voltage primary 113 and a high voltage secondary 114. The terminals of the secondary 114 are connected to the input terminals of a rectifier schematically indicated at 115. The output terminals of 115 are connected through conductors 116 and 117 to a voltage dividing resistor 118. Resistor 118 is provided with terminals 119 and 120 and intermediate taps 121, 122, and 123. Oscillator circuit 41 is supplied with energy from the resistor 118 through a circuit which may be traced from terminal 119 through conductors 124 and 125, resistor 88, conductors 94, 126, and 127 to tap 121. A filtering condenser 128 is connected between conductors 124 and 127. Oscillator circuit 40 is supplied with energy through a similar circuit which may be traced from tap 121 through conductors 127 and 129, resistor 58, conductors 130, 131 and 132 to tap 122. A filtering condenser 140 is connected between lines 127 and 132.

The detector and amplifier 26 is supplied with power through a circuit which may be traced from tap 122 through conductors 132, 131, 141, detector and amplifier 26, conductors 142, 143, and 144 to tap 123. A filtering condenser 145 is connected between conductors 132 and 144. Detector and amplifier 25 is supplied with power through a circuit which may be traced from tap 123 through conductors 144, 143, 146, detector and amplifier 25, and conductors 147 and 148 to terminal 120. A filtering condenser 149 is connected between conductors 144 and 148.

It may, in some installations, be considered desirable to operate oscillator circuit 40 at a variable frequency in response to change of impedance of the vaporized refrigerant at the outlet of the evaporator. This may be accomplished by connecting capacitor 20, Figure 2, in parallel with condenser 51. Oscillator circuit 41 is generally similar to that of 40 except that variable condenser 51 is replaced by capacitor 21 and follow-up capacitor 65, said follow-up capacitor 65 being adjusted by shaft 66 from gear box 15 and adjustable simultaneously with valve 11.

As before noted, the system of Figure 2 is quite similar to that of Figure 1 and like numerals have been applied to like parts. In Figure 2, however, only capacitor 21 has been put in series with follow-up capacitor 65, while capacitor 20

is connected in parallel with condenser 51 by conductors 161 and 162. Thus follow-up capacitor 65 is operated to rebalance capacitor 21 and the basic frequency of oscillator 40 is varied by capacitor 20, the capacity of 20 being varied to a small extent by fluctuations in pressure of the gaseous refrigerant. This variation in capacity may be very small, but by varying the basic frequency in response to same, the effectiveness of the system may be somewhat improved when the conditions of operation are quite variable.

Capacitor 20 may be of such capacity relative to 21 that the system may be held to a uniform number of degrees of superheat over a wide range of conditions. Preferably, however, the capacitors should be of such capacity that the system will control to a lessened number of degrees of superheat as the suction pressure is reduced. This tends to give greater evaporator capacity for cooling to low temperatures, which is highly desirable.

In Figure 3 is shown an elevation view and Figure 4 shows a cross section of capacitor 21; however, it also represents capacitor 20 for both may be alike. Obviously, the capacitor shown is merely an example, for any suitable form may be used, including a plurality of parallel plates, concentric tubes, and any other known and suitable form of capacitor wherein the dielectric may comprise flowing refrigerant. In addition, a concentric tube within and insulated from an evaporator tube may be used for one plate of a capacitor, the evaporator tube being used for the other plate. In Figures 3 and 4, capacitor 21 comprises a body portion 170, cover portion 171, plate 172 having attached thereto terminal 173, and plate 174 is provided with terminal 175. Body portion 170 is suitably connected to the evaporator 10 so that the flow of refrigerant is through said body and between and around plates 172 and 174. Any suitable material may be used for body 170 and cover 171, suitable electrical insulating material being suggested for said cover. The plates 172 and 174 are preferably metal and may be given a thin insulating coating of lacquer to prevent their discharge by particles of carbon, etc., that may reach same.

While the present system of control has been disclosed as being based on the change of dielectric constant of flowing refrigerant in response to change in quality, and the slight change in said constant due to pressure and temperature changes, it is also contemplated that the electrical resistance of the flowing refrigerant may be used to control the frequency of the present oscillator. Electrical resistance also varies greatly with the changes in quality of the flowing refrigerant and may vary slightly due to temperature and pressure changes.

Control units such as 180, shown in Figure 5, may be substituted for capacitors 20 and 21 to provide control of oscillators 40 and 41 in response to electrical resistance changes of the flowing refrigerant. Device 180 comprises a suitable body portion 181, a cap or cover portion 182, and inductance means 183. Means 183 comprises an inductance winding 184 of bare wire on a suitable support 185, said wire preferably being of copper, or other good conducting material. The support 185 is preferably made of vitreous material and may be solid, hollow, or comprise a skeleton framework.

With units 180 substituted for capacitors 20 and 21 and exposed to the flow of a suitable conductive refrigerant, the inductance of the units

will depend on the quality of the refrigerant passing over same. When the refrigerant is in the gaseous state, it has little effect on inductance means 183 but when liquid particles of refrigerant reach the bare windings 184, the liquid tends to provide a shunt path across the windings and thus lessen the inductance of the windings. The change in current through the windings varies the inductance of the circuit and causes a change in frequency of the respective oscillator, as in the preferred arrangement. Either capacitor follow-up means, as shown, may be used with the units 180, or variable inductance means, not shown, may be substituted therefor.

By making the winding 184 of wire having high electrical resistance, the resistance of unit 180 will vary considerably with changes in quality of the refrigerant flow. As in the preceding example, liquid refrigerant contacting the windings will tend to provide a shunt circuit across the resistor and thus decrease the resistance value of same. While units 180 wound with resistance wire may be substituted for capacitors 20 and 21 in the present circuits, better results may be had by using said elements in conjunction with resistance tuned oscillators.

While changes in quality of the flowing refrigerant may result in changes of resistance, inductance, or capacity of suitable control elements, capacity control represents the preferred embodiment because of the greater reliability of the capacity changes and the ease of tuning oscillators by capacitors.

Operation

As pointed out previously, and as more fully explained in my Patent 2,303,654, valve controlling motor 14 is operated in one direction or another depending on whether the current supplied to winding 17 or 18 leads that of the other winding and the speed of rotation of the motor depends upon the frequency of the currents impressed on said windings. Briefly summarizing the operation of the present circuit, it is noted that oscillators 40 and 41 produce high frequency currents in the range of several kilocycles. Oscillator 40 supplies current to primary windings 31 and 37 of transformers 29 and 35, respectively. Oscillator 41 supplies high frequency current to primaries 30 and 36 of said transformers, it being noted that the current supplied to primary 36 is reversed in phase from that supplied to primary 30 by phase reversing bridge 90. It is noted then, that each of transformers 29 and 35 have two sources of primary current and that secondaries 28 and 34 of transformers 29 and 35, respectively, will be supplied with high frequency current from said primaries, a portion of the high frequency current supplied to secondary 34 being displaced in phase 90° from that supplied to secondary 28 by virtues of the aforesaid phase reversing bridge 90. It is further apparent that if the frequencies of the current supplied to windings 31 and 30 of transformer 29, or to windings 37 and 36 of transformer 35, are different, then a beat frequency will also be produced. This beat frequency will depend upon the amount of variation of one frequency from the other. The present circuit is so adjusted that, within the control ranges, the beat frequencies produced will be of a usable sort. Detector and amplifier units 25 and 26 are suitable to detect and amplify only the low beat frequencies and will filter out the high frequency current. The beat frequencies thus supplied by transformers 29 and 35 to de-

tor and amplifier units 25 and 26, respectively, will be detected and amplified to a sufficient extent to power motor 14. As pointed out in said patent, supplying a usable low frequency alternating current to split phase motor 14 in such manner that the current supplied to one winding leads that supplied to another winding, provides proper conditions to cause rotation of said motor. Further, if the current supplied to said one winding lags instead of leads that of said other winding, opposite rotation of said motor is produced. Further, the speed of rotation of the motor depends upon the frequency of said beat frequency current. In this brief summary, it is shown how motor 14 may be operated at variable speeds and in reversible directions. For further and more detailed explanation of the operation of said motor by the present heterodyne circuit, reference is made to my previously mentioned patent.

Having briefly outlined the operation of motor 14, it is noted that armature 16 of said motor is connected through gear box 15 with pinion 13, said pinion 13 reciprocating rack 12 which operates expansion valve 11 of the present refrigerating system. Assuming that the refrigerating system is operating, the present control system is preferably adjusted by manually adjusting said valve 11 until a predetermined number of degrees superheat is obtained in the refrigerant leaving the evaporator 10. This superheat may be easily determined by observation of the pressure and temperature of the refrigerant at said exit. With the valve 11 manually adjusted to provide the predetermined number of degrees superheat at the exit of the evaporator, follow-up condenser 65 is manually adjusted to an intermediate position and oscillators 40 and 41 are energized. The frequency of oscillator 41 will depend upon the capacity of follow-up capacitor 65 and capacitors 21 and 20. The frequency of oscillator 40 is then adjusted to the same value by manually adjustable condenser 51, thermostatic device 60 being ignored for the time being. With oscillators 40 and 41 adjusted to similar frequencies, no beat frequencies are produced in the transformers and no operation can take place at said motor 14. Motor 14 is now operatively connected to valve 11 and the system may operate in the manner desired. As previously pointed out, the refrigerant flowing through evaporator 10 is constantly varying in quality, that is, the percentage of liquid in the refrigerant constantly diminishes after leaving valve 11 until at a point near the exit of said evaporator, all of the liquid has disappeared and the total quantity of the refrigerant is gaseous. Capacitors 20 and 21 are so located that only gaseous refrigerant should pass between the plates of 20 and a predetermined and relatively high quality of refrigerant passes between the plates of 21.

Assuming that 96% of the refrigerant passing capacitor 21 is gaseous, it is then observed that stable conditions have been established in this system with capacitor 65 at a mid point of its range, 4% liquid refrigerant passing capacitor 21 and all of the refrigerant passing capacitor 20 vaporized. Should the percentage of liquid refrigerant passing between the plates of 21 increase, the capacity of same will be increased, the frequency of oscillator 41 will be varied and the resulting beat frequency will operate motor 14 to simultaneously adjust valve 11 and follow-up capacitor 65. Both valve 11 and capacitor 65 will then be adjusted by said motor to restore the previous conditions of the system; in other words,

valve 11 will reduce the flow through same and capacitor 65 will be moved to lower its capacity.

Should the refrigerant passing between the plates of 21 increase in quality until only 3% liquid refrigerant is passing same, the capacity of capacitor 21 will be reduced and the frequency of oscillation of 41 will be oppositely varied from that previously described. A beat frequency will again be supplied motor 14 but differing in phase relation from that previously described; hence, motor 14 will rotate in an opposite direction and will move valve 11 to increase the flow of refrigerant through same and move capacitor 65 to increase its capacity.

It is thus noted that a control system is herein provided which controls the flow of refrigerant through an evaporator in response to changes in quality, or electrical impedance, of the refrigerant in an effective manner. Because of the very considerable difference in dielectric constant value, and electrical resistance, of gaseous and liquid refrigerant, the present system is very sensitive to changes in refrigerant quality and, as the speed of response of the present system directly varies with the magnitude of variation from control conditions, the present system accurately and quickly responds to variations in refrigerant loads and provides uniformly and highly effective control of a refrigerant system under widely differing conditions.

As previously noted, the present system need only be adjusted in the aforesaid manner to handle any one of the conventional refrigerants. Obviously, while the system has been described as passing 4% liquid refrigerant between the plates of capacitor 21, this value is chosen only for illustration and said capacitor 21 may be located and the system adjusted to provide any suitable percentage of liquid refrigerant passing through this capacitor. Further, two capacitors have been shown in the evaporator but one or more additional capacitors may be connected in series with said capacitors 20 and 21 and located in said evaporator intermediate same. Further, especially in systems having a long suction pipe, and suction systems having considerable heat capacity, operation may be feasible with only a single capacitor through which refrigerant flows, the system then being adjusted to pass only a very small predetermined quantity of liquid refrigerant or, preferably, all gaseous refrigerant. Because of the responsiveness of the present controlling device, control conditions are restored quickly enough that should a small amount of liquid refrigerant leave the evaporator, the heat capacity of the suction system may vaporize said refrigerant before it reaches the compressor for, as before noted, the quick restoring of control conditions would insure that only a very small amount of liquid refrigerant would ever pass by the aforesaid single condenser. However, for practical operation, the two capacitor arrangement shown is preferred.

The operation of the system with devices such as 180 substituted for capacitors 20 and 21 is the same as that described, the oscillator being varied in frequency by inductance or resistance changes instead of capacity changes. While the initial adjustments of the equipment may involve different values than when capacitors are used, the adjustments are of minor nature and understood by those skilled in the art.

This system has been described as being adapted to maintain maximum refrigerating capacity at the evaporator. However, in some instances it may be desirable to further modify this

control in response to box temperature, or other conditions. To accomplish this result, the frequency of oscillator 40 may be varied in response to said control condition it being noted, however, that the response must always be in such a direction as to lower the capacity of the evaporator. It is obvious that if the evaporator is adjusted normally to operate at maximum capacity, no further increase in its capacity can safely be made. The only feasible adjustment of the control must then be to lower its capacity. This is often desirable, however, especially under conditions of light loading wherein it is desired to reduce the capacity of the evaporator to minimize short cycling. In the present instance this modified control may be effected by connecting thermostatic device 60, which comprises a variable condenser 61 operated in response to temperature variations, in parallel or series with manually adjustable condenser 51. If the system is adjusted so that an increase in frequency of oscillator 41 operates to reduce the flow through valve 11, then device 60 must operate to vary the frequency of oscillator 40 in such manner as to reduce the frequency of oscillator 40, to thereby give the comparative effect of oscillator 41 being increased in frequency. Reducing the frequency of oscillator 40 and thus reducing the flow of refrigerant through valve 11 in response to thermostatic device 60 tends to reduce the capacity of said evaporator 10 and thereby improves the operation of the system for conditions of light loading. The auxiliary control 60 is shown as a thermostatic device but it is considered that it may just as well be a humidity responsive device, or the like. In addition instead of a capacitor, a variable inductance means may be used for tuning oscillator 40.

Another feasible variation in the present system contemplates varying the frequency of oscillator 40 over a relatively small range in response to the variations in dielectric constants of the gaseous refrigerant due to the changes in temperature and pressure of said gaseous refrigerant. This modification is that illustrated in Figure 2 where capacitor 20, instead of being in series with capacitor 21, is connected by wires 161 and 162 in parallel with manually adjustable condenser 51. The frequency of oscillator 41 then is controlled only by capacitor 21 and follow-up capacitor 65 in the manner previously described. The control exercised by capacitor 20 may be of less magnitude than that of capacitor 21 for it is apparent that the essential control of the system must be exercised by capacitor 21. However, by varying the base or standard frequency of oscillator 40 in response to variation in the dielectric constant value of the gaseous refrigerant under variable conditions of pressure and temperature, the predetermined number of degrees superheat which the system may be adjusted to maintain, may be more precisely held or may be varied in a desired manner. If capacitor 20 be made with comparably smaller capacity than 21, then it will be less affected by pressure changes than 21. With a lowering of suction pressure, the base frequency controlled by 20 will vary less than will the control frequency governed by capacitor 21, hence a higher percentage of liquid refrigerant must pass between the plates of 21 to restore a balanced circuit. This is equivalent to operating with less superheat and is a desirable mode of operation as suction pressures are lowered.

The examples above given describe an im-

proved refrigeration control system wherein the impedance values of the refrigerants used comprise the control conditions to which the system responds. As previously noted, my invention is not limited to the particular circuit shown and it is obvious that many variations of this system are feasible. The scope of this invention is therefore to be determined only by the appended claims wherein I claim as my invention:

1. Control means for a refrigerating system of the sort wherein refrigerant is circulated through an evaporator including; valve means for controlling the flow of refrigerant through such an evaporator, reversible motor means for operating said valve means, said motor means being variable in speed, means for responding to the electrical impedance value of the refrigerant at the outlet of the evaporator, and means including said responsive means for controlling said motor means to move said valve means toward closed position upon an increase of said value and to move said valve means toward open position upon a decrease of said value, the speed of operation of said motor means being dependent upon the variation of said impedance from a predetermined quantity.

2. Control means for a refrigerating system of the sort wherein refrigerant is circulated through an evaporator including; valve means for controlling the flow of refrigerant to said evaporator, motor means for actuating said valve means, said motor means having two phase windings, spaced capacitor means associated with said evaporator, one of said capacitor means being located in the outlet of said evaporator, another capacitor means being located near the approximate beginning of the desired dry gas space of the evaporator, said capacitor means being constructed and arranged so that the circulated refrigerant becomes the dielectric for said capacitor means, the electrical capacity of said capacitors varying due to changes of quality of said refrigerant, and means to operate said motor means in response to said capacity comprising a source of alternating electrical current of substantially constant frequency, a second source of alternating electrical current, means for varying the frequency of said second source in response to the capacity of said capacitor means, means for splitting the output current of one of said sources into two components displaced in phase, a first coupling means for combining one of said components with the output current of the other source so as to produce a first beat frequency current, a second coupling means for combining the other of said components with the output current of the other source so as to produce a second beat frequency current displaced in phase from said first beat frequency current, and connections between said first and second coupling means and the windings of said motor means for supplying said motor means with said beat frequency current to operate said valve means.

3. Control apparatus for a refrigerating system of the sort wherein refrigerant is circulated through an evaporator comprising, in combination, expansion valve means for controlling refrigerant flow through said evaporator, means for operating said valve means comprising a motor connected thereto, said motor having a two phase winding, first electrical impedance means associated with said evaporator for responding to the dielectric value of the circulating refrigerant at spaced positions, at least one of said positions being within said evaporator, means for energiz-

ing said motor in response to the value of said impedance means including a first source of alternating current of substantially constant standard frequency, second source of alternating current normally operating at said standard frequency, said impedance means being associated with said second source for regulating the frequency thereof, means for splitting the output current of said one of said sources into two components displaced in phase, a first coupling means for combining one of said components with the output current of the other source so as to produce a first beat frequency current, a second coupling means for combining the other of said components with the output current of the other source so as to produce a second beat frequency current displaced in phase from said first beat frequency current, connections between said first and second coupling means and the windings of said motor for supplying said motor with said beat frequency current, and a second impedance means variable by operation of said motor in a sense opposite to the variation of said first impedance means, said second impedance means being driven to restore said second source to its normal operating frequency and said valve means being driven simultaneously to restore the dielectric value of the refrigerant passing said first impedance means toward its desired value.

4. A refrigerating control system comprising, in combination, an expansion valve for controlling refrigerant flow, a motor for operating said valve, electrostatic capacitor means responsive to refrigerant quality at the outlet portion of said evaporator, and means for operating said motor in response to said refrigerant quality comprising a source of alternating electrical current of substantially constant frequency, a second source of alternating electrical current, the frequency of said second source being varied by the electrostatic capacity of said capacitor means, coupling means for combining the currents from said sources so as to produce a beat frequency current, a connection between said motor and said coupling means for supplying said motor with said beat frequency current, and second means for varying the frequency of said second source, said second means being operated by said motor in a sense opposite to said first mentioned means, said motor operating said valve to change the flow of refrigerant in a manner to restore the desired conditions of quality at the capacitor means.

5. Control apparatus for a refrigeration system of the sort wherein refrigerant is circulated through an evaporator comprising, in combination, valve means for controlling refrigerant flow through said evaporator, motor means for operating said valve, said motor means having two phase windings, means for operating said motor means including a source of alternating electrical current of normally constant frequency, a second source of alternating current, impedance means located near the beginning of a desired dry gas portion of the evaporator for varying the frequency of said second source in response to changes of quality and pressure of the circulated refrigerant, second impedance means located near the outlet of said evaporator and the end of said dry gas portion, said second impedance means normally controlling the frequency of first source over a comparatively narrow range in response to the dielectric value of the refrigerant, coupling means for combining the currents from said sources so as to produce beat frequency current, a connection between said coupling means and

said motor means for supplying said motor means with said beat frequency current, and a second means for varying the frequency of said second source, said second means being operated by said motor means in a sense opposite to said first mentioned means.

6. A refrigeration control device comprising, in combination, fluid conduit means constructed and arranged for connection into a circulating refrigerant circuit, and electrical impedance means disposed within said conduit means and arranged to be exposed to any refrigerant that may pass through the said conduit means, said impedance means being of such a sort that its impedance value will be varied by the presence of liquid refrigerant.

7. In a refrigerating system, valve means for controlling the flow of refrigerant through the evaporator of said system, a reversible and variable speed motor for operating said valve means, and means for operating said motor in response to variations in dielectric constant value of the flowing refrigerant in an outlet portion of the evaporator in such manner that an increase in dielectric constant value above a predetermined value results in the motor driving the valve means toward closed position, a decrease in said dielectric constant value below said predetermined value causes the motor to drive the valve means toward open position, the motor speed being influenced by the magnitude of the variation of the dielectric constant value from said predetermined value.

8. In a refrigerating system of the sort having an evaporator and wherein refrigerant is circulated through said evaporator, flow control means for regulating the flow of refrigerant through said evaporator, reactance means exposed to the flowing refrigerant in said evaporator, the reactance values of said reactance means varying in response to electrical characteristics of the flowing refrigerant, and electrical means including an amplifier controlled by said reactance means for controlling the operation of said flow control means.

9. In a refrigerating system, an evaporator, flow control means connected in controlling relation to said evaporator, power means for operating said flow control means, and electrical control means for controlling said power means including control elements having electrical impedance values, said elements being arranged within said evaporator so that refrigerant flowing through said evaporator will impinge on said elements.

10. Refrigeration control means comprising, in combination, a body having a refrigerant passage therethrough, a control element disposed in said passage, and insulating means for holding said element in proper position in said passage and electrically insulating same from said body, said element comprising capacitor means arranged to use refrigerant as its dielectric material.

11. In a refrigerating system of the sort wherein refrigerant is circulated through an evaporator, said refrigerant normally varying in quality from a minimum of gaseous refrigerant at the inlet of said evaporator to all gaseous refrigerant adjacent the outlet of said evaporator, flow control means for regulating the circulation of said refrigerant, and electrically responsive means for controlling said flow control means, said electrically responsive means being arranged in the outlet portion of said evaporator and capable of

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responding to the presence of liquid refrigerant by a change in electrical characteristics.

12. A refrigeration control device comprising, in combination, fluid conduit means constructed and arranged for connection into a circulating refrigerant circuit, electrical capacitor means disposed within said conduit means, said capacitor means comprising a plurality of spaced metallic plates arranged substantially in alignment with said conduit means so that material such as refrigerant flowing through said conduit means may act as the dielectric material for the said capacitor means, means for insulating at least one of said plates from said conduit means, and electrical conductor means secured to at least said one plate and insulated from said conduit means.

13. Apparatus for controlling a refrigerating system of the sort wherein refrigerant is circulated through conduit means including an evaporator having an outlet portion, comprising flow control means for regulating the rate of circulation of said refrigerant, power means for operating said flow control means, electrical impedance means disposed in the path of refrigerant flow in said conduit means near the outlet portion of said evaporator, and means including an electrical circuit for connecting said impedance means in controlling relation to said power means.

14. Apparatus for controlling a refrigerating system of the sort wherein refrigerant is circulated through conduit means including an evaporator having an outlet portion, comprising flow control means for regulating the rate of circulation of said refrigerant, power means for operating said flow control means, spaced electrical impedance means disposed in the path of refrigerant flow in said conduit means, one of said impedance means being located near the outlet portion of said evaporator and the other of said impedance means being in said evaporator upstream of said one impedance means, and means including an electrical circuit for connecting said impedance means in controlling relation to said power means.

15. Apparatus for a refrigerating system comprising an evaporator having an inlet and an outlet connected by a fluid passageway, an electrical impedance means located in said passageway near said outlet, and a second similar electrical impedance means located in said passageway between the first named impedance means and said inlet, said second impedance means being within but near the end of the portion of said passageway intended to contain unvaporized refrigerant.

16. In a refrigerating system of the sort wherein refrigerant is circulated through an evaporator, electrical capacitance means responsive to varying percentages of liquid refrigerant in said evaporator, regulating means for controlling the rate of circulation of said refrigerant, and electric means connecting said electrical capacitance means in controlling relation to said regulating means in a manner to reduce the rate of circulation as the percentage of liquid refrigerant increases and to increase said rate as said percentage decreases.

17. In control apparatus for a refrigerating system of the sort wherein refrigerant is circulated through an evaporator, means for controlling the rate of circulation of said refrigerant,

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electrical impedance means arranged to be contacted by the circulating refrigerant in said evaporator, said impedance means being variable in impedance value as the quality of said circulating refrigerant varies, and means including an electrical circuit for connecting said impedance means in controlling relation to said rate controlling means.

18. In a refrigeration control device, a body member having a fluid passage therethrough, said body member being constructed and arranged for connection into a circulating refrigerant circuit, said passage having end portions and an intermediate portion, said portions being in substantial alignment and said end portions having like diameters, an electrical impedance means disposed in said intermediate portion of said passage and arranged to be uniformly contacted by refrigerant flowing through said passage, said impedance means being of such a sort that its impedance value will be varied by the presence of liquid refrigerant, the greatest dimension of the effective portion of said impedance means in a direction transverse to the axis of said passage being approximately equal to the like dimensions of the end portions of said passage, and means for making electrical connections to said impedance means.

19. In a refrigeration control device, a body member having a fluid passage therethrough, said body member being constructed and arranged for connection into a circulating refrigerant circuit, said passage having end portions and an intermediate portion, said portions being in substantial alignment and said end portions having like diameters, an electrical impedance means having a winding disposed across the intermediate portion of said passage, said impedance means being of such a sort that its impedance value may be appreciably changed upon contact by a liquid refrigerant, said impedance means having a core member with a longitudinal axis, said core member being arranged so that said longitudinal axis is transverse of said passage, the dimension of the effective portion of said impedance means along said longitudinal axis being approximately that of the diameter of said end portions, and means for making electrical connections to said impedance means.

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