CONTROL APPARATUS FOR REFRIGERATION SYSTEM

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This invention relates to refrigeration systems and control apparatus for such systems.

Refrigeration systems are often employed to regulate the temperature of refrigerated zones in cold rooms or cold boxes that are located within heated buildings. In such a refrigeration system, an evaporator coil is mounted within the cold room while a condenser is mounted outside the building. Very commonly, a compressor is arranged outside the building somewhat adjacent the condenser. The low-pressure or suction side of the compressor is connected to a pipe which leads to the discharge end of the evaporator, while the exhaust side of the compressor leads to the inlet of the condenser. The outlet of the condenser leads through a pipe to an expansion valve at the inlet end of the evaporator.

In such a refrigeration system, the compressor is operated periodically whenever the temperature in the cold room reaches a predetermined upper limit and operation is discontinued when the temperature reaches a predetermined lower limit. In practice, in most commercial refrigeration systems of this type, a pressure-sensitive switch communicating with the low-pressure side of the compressor is employed to start and stop the compressor. Such a switch does not operate directly in response to the temperature of the cold room, but responds to the pressure in the pipe that leads from the evaporator to the compressor. Such a pressure switch is provided with means for determining a cut-in pressure and a cut-out pressure. When the pressure on the low-pressure side of the compressor reaches the cut-in pressure a motor which drives the compressor is operated, starting the compressor. And when the pressure on the low-pressure side of the compressor subsequently falls to a cut-out pressure the motor is de-energized and stopped. Each time the compressor is started the pressure begins to fall, and each time it is stopped the pressure begins to rise. This process is repeated periodically, maintaining the pressure in the evaporator coils between the limits established by the cut-in pressure and the cut-out pressure and regulating the temperature of the cold room.

Customarily, the value of the cut-in pressure is set during the warm period of the year at such a value as to maintain the temperature in the cold box at a reasonably safe value suitable for refrigerating the material that is to be preserved in the cold room. But when cold weather approaches, the ambient temperature, that is the temperature of the air or atmosphere external to the building into which the compressor, the pressure switch and part of the pipe is exposed, often falls to such a value that the vapor pressure of the refrigerant at that temperature falls below the cut-in pressure. Unless provisions are taken to adjust the cut-in pressure, refrigerant condenses in the low-pressure pipe at a point therein external to the building and the temperature in the cold room rises indefinitely because the pressure is never able to reach a sufficiently high value equal to the cut-in pressure sufficient to cause the motor to operate the compressor. In the past when cold weather approaches, a service man has been called upon to adjust the setting of the cut-in pressure of the pressure switch. This is, of course, an expensive procedure since, if cold weather suddenly occurs without anticipation and no adjustment of the cut-in pressure setting has been made, the temperature of the cold room may rise suddenly to such an extent that any material, such as meats and the like, stored therein is spoiled. This too is expensive.

One object of the invention is to provide an improved control device for such a refrigeration system for maintaining the temperature in the refrigerated zone at a safe value even when the temperature of the air to which the pressure switch is exposed falls to a point at which the vapor pressure of the refrigerant is less than the normal cut-in pressure of the pressure switch.

Another object of the invention is to provide an improved control mechanism for such a refrigeration system which is responsive to ambient temperature as well as to the pressure of the vapor with the evaporator.

It is still a further object of this invention to provide an improved control apparatus for starting and stopping an electric motor connected to a refrigerating compressor, the starting instant of the motor being controlled both by the maximum pressure in the evaporator and also by the ambient temperature at least when the air temperature drops below a predetermined value.

Still another object of this invention is to provide an improved control apparatus for a refrigeration apparatus, including hermetically sealed bellows connected to the low pressure side of the compressor for operating an electric switch to energize and deenergize the compressor motor in response to adjustable cut-in and cut-out pressures on the low pressure side of the compressor, and also including a temperature sensitive element for adjusting said cut-in pressure automatically in response to a change in temperature of the air exterior of the zone refrigerated by the apparatus.

Yet another object of the invention is to provide a refrigeration apparatus control means capable of maintaining a safe storage temperature within the refrigerated compartment placed in a heated building independent of the temperature of the air outside of such building.

It is also an object of this invention to provide a control element for a refrigeration apparatus, such element being capable of actuating the apparatus at a lower "cut-in" pressure than the normal cut-in pressure when the ambient temperature falls below a predetermined value.

Yet another object of this invention is to provide a refrigeration apparatus controlled by an electric switch responsive to "cut-in" and "cut-out" pressures corresponding to the maximum and minimum pressures encountered on the low pressure side of the apparatus, such switch being also automatically responsive to the temperature of ambient air exterior of the refrigerated zone, at least when the ambient temperature falls below a predetermined point, the switch being located outside of such zone, so as to avoid any time lag between the temperature of the exterior zone and the actuation of such switch in response to the drop in ambient temperature.

It is also an object of this invention to provide a control element for a refrigeration apparatus in which the refrigerated compartment is located in a heated building, and the compressor and motor are located exterior of the building, the control element being mounted adjacent to the compressor-motor unit and being responsive...
to the maximum and minimum pressures on the low pressure side of the refrigeration systems, and being also responsive to the ambient temperature of the air, and being emotionally filled with some such temperature drops below that value which is apt to produce excessive heating of the refrigerated compartment.

Further objects of the invention will appear from the following description and from the drawings, which are intended for the purpose of illustration only, and in which:

Figure 1 is a schematic diagram of a refrigeration system embodying this invention; Fig. 2 is a perspective view of the control unit; Fig. 3 is a front view of the control unit with the side cover removed; Fig. 4 is a side view of the same control unit taken along line 4—4 illustrated in Fig. 3; Fig. 5 is an additional side view of the control unit taken along line 5—5 illustrated in Fig. 3; Fig. 6 is an additional side view of one portion of the control unit illustrated in Fig. 3.

Referring to Figure 1, there is illustrated a refrigeration system including a compressor 10 connected through a shaft 11 to an electric motor 12. The motor is connected to a power line 13. In one of the conductors of the power line there is a manually operated switch 14 and a switch 15 which is mechanically actuated through means 16 and 40 by a control unit 17. The control unit 17 is connected through the inside of a small pipe 19 to one of the conductors of the power line. The switch 15a connects compressor 10 to an oil strainer and gauge valve housing 20. The oil strainer and gauge valve housing 20, which is normally mounted on a compressor unit, is connected by a low-pressure pipe 21 to evaporator coils 22 in a cold box 23. The evaporator coils 22 are connected through a pipe 24 to an expansion valve 25. The expansion valve 25 is connected through a pipe 26 to a condenser 27 which in turn is connected to compressor 10 through a pipe 28. Condenser 27 may have additional pipes, such as pipes 29 and 30, connected to the condenser for supplying some cooling medium such as water. Condenser 27 therefore is a conventional heat exchanger wherein the compressed refrigeration fluid is cooled to some lower temperature. Mounted on top of the evaporator coils is a conventional thermostat power element 32 which is connected through a small pipe 34 to bellows 35 mounted on top of the expansion valve 25.

According to this invention, the control unit 17 is provided to respond to the pressure of vapor standing in the evaporator coils 22 and pipe 24 and also to the ambient or atmospheric temperature so as to regulate the temperature of the refrigerated zone within the cold room or cold box 23.

With the exception of the control unit 17 and connections 16 and 40 between the control unit 17 and switch 14, Fig. 1 discloses a standard refrigeration system. Compressor 10 is operated by the electric motor 12; the compressor refrigeration fluid, such as "Freon 12," is discharged through pipe 28 into condenser 27 where it is cooled. The refrigerant then is conveyed through pipe 26 to the expansion valve 25. The expansion valve 25 discharges the compressed refrigeration fluid at the desired rate into the evaporator coils 22 where the refrigerant is evaporated thereby lowering the temperature within the evaporator coils 22. The thermostatic power element 32 is connected through pipe 34 to the bellows 35 of the expansion valve 25 and normally controls the opening and closing of this expansion valve. The power element 32, pipe 34 and bellows 35 comprise a closed system filled with some suitable refrigeration fluid, such as "Freon 12," for closing and opening valve 25 in response to the pressure within the element.

The evaporator coils 22 and the expansion valve 25, as well as the cold box or refrigerated room 23, are located within a heated building 36. The condenser 27, compressor 10, motor 12 and control unit 17 are mounted externally of the building 36, usually at ground level. The expansion valve 25 is of a conventional type which normally closes automatically shortly after the compressor stops and remains closed until shortly after the compressor is started again.

In the specific condenser employed, a pressure responsive device connected to the vapor space of the condenser tank is employed to control a valve in the water line 29, so as to maintain the pressure of the refrigerant in the condenser substantially constant. In this way the temperature of the refrigerant in the high pressure region of the refrigeration system is maintained constant at a corresponding value even though the temperature of the water flowing in the pipes 29 and 30 varies somewhat. Thus, if for any reason the temperature of the cooling water increases, thereby tending to heat the vapor in the condenser 27, a corresponding rise in the pressure of the vapor increases the opening of the valve thereby reducing the temperature and also reducing the pressure of the vapor in a corresponding way. This pressure responsive device therefore acts to regulate the temperature of the refrigerant being returned to the expansion valve.

The control unit 17 has means 16 for energizing electric motor 12 by closing switch 15. The control means 16 includes a pressure operated bellows which is connected by means of the pipe 19 to the suction side, of compressor 10. When the pressure in the evaporator coil 22 and pipes 21 and 19 rises to a predetermined maximum or "cut-in" value, the bellows actuates switch 15 through connection 40 and closes the circuit of the electric motor 12. The electric motor then operates the compressor 10 until the pressure in the evaporator coils 22 reaches a predetermined minimum or "cut-out" value. At this point, the bellows opens switch 15 stopping the operation of compressor 10.

The pressure in the evaporator coils 22 increases to the predetermined maximum value when the temperature within the refrigerated room rises a corresponding amount. The cut-in pressure may be of the order of 34 lbs. per square inch.

As previously mentioned, the refrigerated room 23 is located in the building 36 and the compressor 10, the condenser 27, the motor 12, and the control unit 17 are located outside of the building 36. For this reason, the refrigerated room constantly receives heat from the air within the building which usually is maintained within a comfortable range, the latter being of the order of 65° F. to 80° F. The ambient temperature of the air outside building 36 varies in accordance with the time of any given day, usually being higher in daytime than at night; the ambient temperature also has wide seasonal fluctuations, generally being highest in the summer and lowest in the winter.

The cut-in pressure is generally adjusted to a value such as about 34 lbs. per square inch to prevent air temperature in the refrigerated room 23 from reaching any temperature higher than about 35° F. or 36° F., when the outside temperature is at the highest temperature that is encountered in the location where the refrigeration system is installed. These maximum outside temperatures may reach as high as 125° F. during the summer season. The cut-out pressure is selected so as to maintain the minimum temperature in the box 23 at approximately 30° F. This minimum temperature is selected primarily by the minimum temperature limit permissible in the box without freezing or spoiling the food or other articles.

Generally the maximum and minimum temperatures within the refrigerator room are so controlled as to maintain the average temperature of the air in the refrigerator room just above the freezing point, i. e. around 33° F.
This average temperature of 33° F., is maintained by adjusting the cut-in and cut-out pressure settings for the bellows 22 which surround the evaporator coils 20 and enters the pipe 21. Accordingly the refrigerating cycle under such circumstances functions in a normal manner.

When the outside temperature drops below about 37° F., the refrigerant, after it leaves evaporator coils 22, begins to condense in that part of the system which is located outside of building 36, condensing both in pipes 21, 18, and 19, in the strainer housing 20, and also in the compressor 10 itself. Such condensation of the refrigerant continues to reduce the pressure of the refrigerant in the pipe 21 and in the evaporator coils 22 with the result that the pressure control bellows 42 cannot respond to a rise in the temperature of the air in the refrigeration room 23 above a safe limit. Under such circumstances, a control unit 17 of the usual type will not respond to any rise in the temperature of the air within the refrigerated room. Furthermore, if refrigerant does condense in the compressor 10, then upon restarting, oil is pumped through the crankcase endangering the bearings and other parts of the compressor.

According to the present invention, the control unit 17 is provided with temperature responsive means which is sensitive to the temperature of the air exterior of building 36. The temperature responsive means comprises a bimetallic element which operates 12 in such a way as to reduce the cut-in pressure when the outside temperature drops below a predetermined high value such as 37° F.

The reduction of the cut-in pressure is of such amount as to maintain the cut-in pressure less than the vapor pressure of the refrigerant at ambient temperature. In this way, condensation of refrigerant is prevented and the compressor operates at a suitable cut-in pressure for preventing the temperature in the refrigerated room 23 from exceeding a safe limit. Similar results may be accomplished by installing a temperature sensitive element or bimetallic element within the refrigerated room and allowing this temperature sensitive element to control the operation of motor 12. An installation of this kind, however, requires, firstly, the installation of the bimetallic element within the refrigerated zone and, secondly, the installation of appropriate wiring between the bimetallic element and the control unit 17.

A control unit embodying the present invention is illustrated in detail in Figs. 2 to 7 inclusive. The unit will be described as though mounted with respect to a vertical plane in the manner shown in the drawings. Except for the incorporation of a bimetallic element designed in accordance with the invention, the construction and operation of the control unit 17 are the same as those described for the control unit 17 illustrated in the patent to Ranco Inc., of Columbus, Ohio. Even though control unit 17 is of standard design except for the bimetallic element, its construction and operation are described in detail because of the fact that the present invention differs from the prior art in this respect.

The control unit 17 is mounted on a U-shaped frame 200 provided with a U-shaped cover 201 held in close position by a cover screw 203, see Fig. 2. Attached to the bottom of frame 200 is low pressure bellows 204 mounted in a bellows cup 205 which is attached to frame 200 by set screws 206. A cone-shaped pin 207, having a flange 208, is centrally mounted on top of the bellows with the flange 208 resting on top of the bellows. The lower end of pin 207 is directed upwardly and is seated in a downwardly concave cone-shaped seal 209 provided in a range spring plate 210, see Fig. 6, which is pivoted at one end on a shaft 211 mounted in two brackets 212 and 213 attached to frame 200. A range spring 214 is mounted on top of plate 210 and it is held in a fixed upright position by means of a range adjusting screw 215 which is rotatably mounted on frame 200 by means of a bushing 216. The lower end of screw 215 threaded engages an upper plate 218 mounted on top of spring 214. Plate 218 is provided with a range indicator arm 220 which indicates the range setting of spring 214 on a range scale 222. This setting can be adjusted by turning a range knob 224 mounted on the upper end of the set screw 215 which determines the degree of compression imparted to spring 214 and the pressure exerted by this spring on bellows 204 through pin 207 which holds plate 210 above frame 200 so that plate 210 is free to rotate on shaft 211 in response to any change in pressure in bellows 204. Mounted on plate 210 is a bellows lever arm 226 and a toggle actuating arm 227 stamped out of one piece of metal, see Fig. 7. Arms 226 and 227 are mounted on plate 210 by means of a shaft, or pin, 228 which interconnects the two arms in a rotative relationship with respect to each other. A torsion spring 230 is mounted on pin 228, one end of the spring engaging and pressing against the arms 226 and 227 while the other end engages pin 211, thus exerting a pressure on the lever arms 226 and 227 tending to turn the arms in a clockwise direction as viewed in Figs. 3 and 6. This pressure holds the arms in an engaged position with a set-screw 232 which is used for adjusting the angular position of the arms with respect to plate 210, the set screw 232 being mounted on a set screw arm 234 which is an integral part of plate 210.

Arm 236 is provided with a finger 236 having a hole 235 for hooking the end of a toggle spring 237, the other end of which is hooked onto a toggle yoke 238. Yoke 238 holds a toggle 240 in a pivoted relationship with respect to a toggle bracket 242 mounted on frame 200. The toggle bracket is provided with two V-shaped recesses 243 and 244 which act as pivot points for two knife-edge toggle arms 245 and 246. The lower end of the toggle 240 is provided with two electrical contacts 247 and 248 which are used for closing contacts 249 and 250 connected to conductors 251 and 252.

The pressure responsive control system also includes means for adjusting the cut-out pressure, or the minimum pressure exerted by the refrigerant on bellows 204, at which the toggle switch opens contacts 249 and 250. This adjustment device includes a differential lever arm 254 pivotally mounted on frame 200 by means of a pin 255, a differential spring 256, a differential indicator 257, and a differential adjustment screw 258 having a head 259, see Fig. 4. By turning head 259, it is possible to vary the tension of spring 256 which exerts an upward pull on the lever arm 254 and plate 210 through a tongue 260 projecting through a slot 261 provided in arm 254. Since the range spring 214 is much stronger than the differential spring 256, plate 210 always rests on pin 207 and spring 256 merely exerts a differential upward pull on plate 210 through the lever arm 254 and tongue 260. When the refrigerant pressure is low, tongue 260 is in its lowest position as illustrated in Fig. 4, with tongue 260 pressing downwardly on the bottom surface of the plate 262 of slot 261, and arm 254 resting against frame 200.

When the refrigerant pressure rises, the bellows 204 expands and raises plate 210 and arm 254, the raising of arm 254 by bellows 204 to raise plate 210 against the downward pressure exerted by the range spring 214 being assisted by spring 256. Such upward travel of the lever arm 254 continues until a tooth 264 on the arm 254 engages or
strikes a stop 265 which constitutes an integral part of frame 200. At this point the upward travel of arm 254 stops, and as the refrigerant pressure increases still further, the tongue 260 and plate 210 continue to rise and to compress the range spring 214 still further. Such upward travel continues until the bellows lever arm 227 and the toggle acting arm 226 swing the toggle switch 240 over to the closed position, thus starting motor 12 and compressor 19, causing the pressure of the refrigerant in the evaporator coil 22 to be reduced gradually.

The lever 12 of the pressure control remains in its position until the bellows 204 and the range spring 214 swing the toggle switch back to its open position which is accomplished by the counterclockwise rotation of the arms 226 and 227. Such rotation of the arm 227 releases the toggle 240 to permit it to snap away from the contacts under the influence of the force furnished by the spring 237, the lower end of which travels with the arm 227. Such travel places the position of the finger 236 to the left of the knife edges 246 and their points of contact with the bracket 242, as viewed in Fig. 6. Accordingly, spring 237 exerts a force on the U-shaped member 238 which can be resolved into two components, one component being that part which is balanced out by the equal and opposite force exerted on the toggle 240 by the bracket 242 through the knife edges 246, and the second force component being a horizontal component which pulls contacts 247 and 248 away from the contacts 249 and 250 thus opening the switch.

Toggle 240 is also provided with a U-shaped plate 255, as shown in Figs. 6 and 7, which is mounted on the plate 240 by means of two pressed-in flanges 266 and 267. This plate is provided with a U-shaped projection 265 and knife-edge seats 269 and 270 which are used for obtaining a pivot-type engagement between the members 238 and the plate 255, as illustrated in Figs. 3, 5 and 6. This permits the lower end 272 to produce a snap action against the plate 240, because the cross-section of this member has a dimension 273 which is greater than the thickness of the plate 240. The U-shaped member 250 is provided for limiting the amount of travel of the entire toggle switch assembly in the counterclockwise direction when the spring 237 opens the switch. At the completion of this cycle, the U-shaped member 238 strikes plate 240, which limits the travel of the toggle switch assembly away from the contacts 249 and 250.

The operation of the control system, which the control unit controls in response to the pressure on the low pressure side of the refrigeration system, is as follows: From prior experience and knowledge of the refrigeration systems and the anticipated rise in temperature in the refrigerated room 23, which is determined by the position of the refrigeration room within building 36 and the insulating qualities of room 23 with respect to building 36, an experienced operator generally knows that the maximum cut-in pressure should be of the order of 34 lbs. per square inch for the summer cycle of the refrigeration system. The summer period, or the summer cycle of the refrigeration system, is selected as the season for which the maximum cut-in pressure should be adjusted because it is obvious that it is during this season that the temperatures within the building 36 are the highest and therefore the rate of flow of hot air from building 36 into the refrigeration room 23 will be at its maximum value.

This setting should be adjusted to be at its maximum value for 34 lbs. per square inch, which represents the maximum cut-in pressure. This adjustment is obtained by manipulating the knob 224, and releasing the set-screw 215 in turn adjusting the pressure produced by spring 214 on plate 210. This plate presses on pin 257, flange 208 of which presses directly on the flat or upper portion of the pressure bellows 204. As a rule this adjustment is obtained by connecting a pressure gage to the oil strainer in gauge valve housing 20 illustrated in Fig. 1. Since adjustment of this type is well known in the art, they need no additional description.

The adjustment of the set-screw 215 is known as the range adjustment because it not only determines the cut-in pressure, but it also determines the cut-out pressure since any adjustment of the set-screw 215 also produces a corresponding change in tension of the differential spring 256. The range adjustment, as a rule, is made first and after a proper cut-in pressure is obtained it is then followed by the adjustment of the tension of the differential spring 256. The tension of the differential spring 256 is obtained by adjusting the setting of the set-screw 259. Since the two springs oppose each other, it follows that the higher or larger is the tension exerted by spring 256 on the differential arm 254, the lower will be the cut-out pressure. With "Freon 12", this cut-out pressure is adjusted to approximately 14 lbs. per square inch, which roughly corresponds to a temperature of the order of 100 degrees F. in the evaporator coils. This rise and fall of the temperature of the evaporator coils between 10° F. and 35° F. produces an average air temperature of approximately 33° F. in the refrigeration room, thus preventing freezing.

When the pressure in the evaporator coils drops to 14 lbs. per square inch, this same low pressure is communicated to the control bellows 204, with the result that pin 207 is lowered. Accordingly, plate 210 and the differential lever arm 254 both travel in the downward direction until arm 254 comes near to frame 200. It should be remembered that plate 210 is provided with the tongue 260 which presses on the lever arm 254 in the manner illustrated in Fig. 4, because spring 214 is much stronger than the differential spring 256. Therefore, when the pressure in the bellows 204 is sufficiently low, spring 214 depresses the bottom plate 210 and tongue 260 until it engages the differential lever arm in the manner illustrated in Fig. 4, and thereafter spring 214 moves plate 210 as well as the lever arm 254 downwardly until the lever arm 254 approaches close to the frame 200 in the manner illustrated in Figs. 3, 4, and 5.

Before the lever arm 254 and plate 210 assume this position, the toggle switch arms 255 and 256 rotate around shaft 251 and of the refrigerator in the direction with the result that the toggle switch 240 opens.

Such opening of the toggle switch 240 disconnects the electric motor 12 from the power source 13 with the result that the compressor as well as the electric motor comes to rest. Since the building 36 is maintained at the comfort zone, there is a heat transfer from the building into the refrigerated zone with the result that the pressure in the evaporator coils 22 gradually begins to rise until it reaches a pressure of about 34 lbs. per square inch which is the cut-in pressure. At this time, bellows 204 again energizes the toggle switch 240 and the cycle repeats itself.

This normal functioning of the refrigerating cycle continues as long as the outside temperature, or the temperature of the air exterior of building 36, does not drop below about 37° F. However, when the outside temperature reaches this low level, the refrigerator begins to come into operation in the plate 19, pin 188, and even the set-screw 215 of the pressure control mechanism. Although the outside temperature may be quite low, since the temperature of building 36 is controlled by some other means, and is maintained at a comfort level of 65° F. to 80° F., it follows that the temperature of room 23 will gradually rise and eventually the temperature will reach a level of 37° F. This rise in the temperature in room 23 will have some effect on the pressure of the refrigerant; however, such influence will be relatively negligible when it occurs.
duce the condensation of the refrigerant. Therefore, conditions may be reached when room 23 will have a temperature which is higher than the safe temperature and pressure range of the refrigerant. In such a case, it is to be noted that the control unit 17 will be unable to start the electric motor 12. According to this invention, a temperature responsive element is mounted outside building 36 and is incorporated within the control unit 17. In the specific embodiment of the invention, the temperature responsive element is in the form of a bimetallic strip that aids the pressure responsive bellows to urge the toggle switch from its cut-out position to its cut-in position when the ambient temperature drops below 37°F. In Figs. 3 to 7, there is illustrated a bimetallic element 280 which is connected at its lower end to the plate 210. This bimetallic element normally is in the position away from the toggle switch 240—255 when the outside temperatures are above 37°F. However, when the outside temperature drops down to 37°F. or below 37°F., the bimetallic element presses on switch 240—255, thereby altering the cut-in pressure.

The horizontal force applied by the bimetallic element to the switch 240—255 increases as the ambient temperature decreases below 37°F. The strength of the bimetallic element and the force that it applies to the toggle switch as the temperature is reduced below 37°F. are so established that the cut-in pressure is maintained below the vapor pressure corresponding to the ambient temperature and also at such a value that the average temperature of the refrigerated room 23 is still maintained above about 33°F. Suppose for example that the ambient temperature falls to 20°F. At this temperature the vapor pressure of "Freon 12" is about 21 lbs. per square inch. If it were not for the inclusion of the bimetallic element 280 vapor would condense in the pipes 18, 19 and 21 and the pressure in the evaporator coil 22 would never exceed 21 lbs. per square inch and the motor 12 would not become energized. However, by selecting a bimetallic element of suitable characteristics, this element applies a sufficiently great force to the switch arm 240 to reduce the cut-in pressure to a value of say 18 lbs. per square inch. This value lies beneath the vapor pressure of 21 lbs. per square inch, but it is still above the vapor pressure corresponding to the cut-out pressure. It will be noted that the toggle switch, in effect, is arranged to swing between a cut-out position in which contacts 240—255 are open and a cut-in position in which contacts 240—255 are closed. The toggle switch swings back and forth between these positions past a neutral position or region as the pressure rises and falls in the low pressure pipe 21. The bimetallic strip engages the toggle switch urging it from the cut-out position to the cut-in position at all times while the toggle switch is in the cut-out position or is swinging from the cut-out position past the neutral region, but remains out of contact with the toggle switch while the toggle switch is in its cut-in position or is swinging from its cut-in position past the neutral position. By virtue of this fact, the bimetallic element modifies the cut-in pressure without however modifying the cut-out pressure. Thus, in the specific embodiment of the invention described, the cut-in pressure is varied as an inverse function of the ambient temperature over a range between a relatively high temperature at which the bimetallic element first contacts the toggle switch to a relatively low temperature at which the vapor pressure of the refrigerant is equal to the cut-out pressure. This relatively high temperature is equal to or slightly above the temperature at which the vapor pressure of the refrigerant equals the maximum cut-in pressure at which the pressure switch is to be operated. This temperature is also slightly below the maximum temperature to which the refrigerant is to be heated in the evaporator coils. It is to be noted that in the temperature range over which the bimetallic element is effective, the differential pressure range between the cut-in pressure and the cut-out pressure is reduced, since the cut-in pressure is reduced but the cut-out pressure remains essentially unchanged. The exact characteristics of the bimetallic element employed will depend upon the specific characteristics and dimensions of the various springs and mechanical elements of the control unit. The determination of suitable dimensions and other constants of the bimetallic element are well within the skill of the art and may now readily be designed by a person skilled in the art having the principles of the invention before him.

Though in the specific embodiment of the invention described, it is assumed that the bimetallic element commences to modify the cut-in pressure only when the ambient temperature falls below 37°F., it will be understood that the ambient temperature at which the bimetallic element commences to take hold may be somewhat higher than 37°F. In any event, it will be understood that the actual cut-in pressure will be less than the pressure indicated on the face of the dial 222 when the ambient temperature is below the temperature at which the bimetallic element commences to add its force to the force of the toggle spring 257 to aid in the closing of contacts 248 and 256.

Furthermore, though only one type of temperature responsive element has been specifically illustrated and described, it will be understood that other types of temperature responsive elements may be employed to vary the cut-in pressure of the control unit. Furthermore, it will be understood that other bimetallic elements may be employed. For example, the toggle switch operating arms 226 and 227 might be made of bimetallic plates, so as to modify the cut-in pressure as a function of ambient temperature. However, in this case, the cut-out pressure, as well as the cut-in pressure, will vary with ambient temperature.

In view of the foregoing disclosure, it will be understood that the invention is not limited to the specific embodiment thereof illustrated and described herein in detail, but that it may be embodied in other forms within the scope of the appended claims.

The invention claimed is:

1. A control device for a refrigeration system, said device including pressure-responsive means responsive to high and low refrigerant pressures on the high-pressure side of such system for starting and stopping, respectively, the operation of said system, a temperature-responsive element cooperating with said pressure-responsive means to reduce the high pressure at which said system starts, without, however, reducing the low pressure at which said system stops when the temperature of the ambient air surrounding said control device drops to a value otherwise rending said pressure-responsive means ineffective for starting said system, said pressure-responsive means including bellows connected to said system, a range spring normally exerting a pressure on said bellows, a differential spring acting in the opposite direction to said range spring, a common element interconnecting said range and differential springs, an electric switch closed and opened by said common element in response to said high and low pressures, respectively, said temperature-responsive element being loaded with one end on said common element and having the other end free to aid said common element to close said switch when said temperature drops to said above-mentioned value without, however, opposing the opening of said switch.

2. In a control unit for controlling the operation of a motor driven compressor of a refrigeration system in response to cut-in and cut-out pressures of the high-pressure side of said compressor, the improvement comprising the combination of an electrical toggle switch actuated by pressure responsive means adapted for connection to said low pressure side, and temperature responsive means having a movable part responsive to the tempera-
ture of the ambient air to which said compressor is exposed, said movable part aiding said pressure responsive means to close said toggle switch without however opposing the opening of said switch after it has been cut-in at a cut-in pressure which is reduced as said temperature is reduced within a temperature range below a predetermined temperature.

3. In a control unit for controlling the operation of a motor driven compressor of a refrigeration system in response to cut-in and cut-out pressures on the low pressure side of said compressor, the improvement comprising the combination of an electrical toggle switch activated by pressure responsive means adapted for connection to said low pressure side, and temperature responsive means having a movable part responsive to the temperature of the ambient air to which said compressor is exposed, said movable part engaging said toggle switch when said compressor is not operating but not when said compressor is operating and when so engaged being urged toward said toggle switch by a force which increases as said temperature is reduced within a range below a predetermined temperature, said movable part aiding said pressure responsive means to close said toggle switch at a cut-in pressure which is reduced as said temperature is reduced within said range without however opposing the opening of said switch.

4. In a control unit for controlling the operation of a motor driven compressor of a refrigeration system in response to cut-in and cut-out pressures on the low pressure side of said compressor, the improvement comprising the combination of an electrical toggle switch activated by pressure responsive means adapted for connection to said low pressure side, means including a spring actuated by said pressure responsive means to start said compressor when the pressure on said side reaches a cut-in pressure and to stop said compressor when said pressure falls to a cut-out pressure, and temperature responsive means having a movable part responsive to the temperature of the ambient air to which said compressor is exposed, said movable part urging said toggle switch from cut-out condition to cut-in condition by a force which aids said spring without however resisting the movement of said toggle switch from cut-in condition to cut-out condition, which force increases as said temperature is reduced within a range below a predetermined temperature, whereby the cut-in pressure is reduced as said temperature is reduced within said range without however reducing said cut-out pressure.

5. In a control unit for controlling the operation of a motor driven compressor of a refrigeration system in response to cut-in and cut-out pressures on the low pressure side of said compressor, the improvement comprising the combination of an electrical toggle switch activated by pressure responsive means adapted for connection to said low pressure side, means including a spring actuated by said pressure responsive means to start said compressor when the pressure on said side reaches a cut-in pressure and to stop said compressor when said pressure falls to a cut-out pressure, said toggle switch being swingable between a cut-in position and a cut-out position on opposite sides of a neutral region, and temperature responsive means having a movable part responsive to the temperature of the ambient air to which said compressor is exposed, said movable part being operable in a temperature range below a predetermined temperature to engage said toggle switch while said toggle switch is swinging from said cut-out position past said cut-in position but not while said toggle switch is swinging from said cut-in position to said cut-out position, said movable part while engaging said toggle switch urging said toggle switch toward said cut-in position by a force which aids said spring, which force increases as said temperature is reduced within a range below a predetermined temperature, whereby said cut-in pressure is reduced and said cut-out pressure remains unaffected as said temperature is reduced within said range.

6. In a control unit for a refrigeration system having a refrigerated zone within a building maintained at a human-comfort temperature level with the evaporator coils positioned within the refrigerated zone and having a compressor and control element positioned outside of said building and connected to said evaporator coils by means of a low-pressure pipe, the combination of an electric switch for controlling the operation of said compressor, a pressure responsive element adapted for connection to said pipe to respond to pressure therein, first means interconnecting said pressure responsive element for starting said compressor when the pressure in said pipe increases to a predetermined cut-in level, and means responsive to a drop in the temperature of the air external to said building to a predetermined low temperature for starting said compressor when the pressure in said pipe increases to a predetermined cut-out level, and means responsive to a drop in the temperature of the air external to said building to a predetermined low temperature for stopping said compressor when the pressure in said pipe decreases to a predetermined cut-out level, and means responsive to a drop in the temperature of the air external to said building to a predetermined low temperature for stopping said compressor when the pressure in said pipe decreases to a predetermined cut-out level, and means responsive to a drop in the temperature of the air external to said building to a predetermined low temperature for stopping said compressor when the pressure in said pipe decreases to a predetermined cut-out level.

7. In a control unit for a refrigeration system having a refrigerated zone located within a building maintained at a human-comfort temperature level with the evaporator coils positioned within the refrigerated zone and having a compressor and control element positioned outside of said building and connected to said evaporator coils by means of a low-pressure pipe, the combination of a control element for controlling the operation of said compressor, a pressure responsive means adapted for connection to said pipe to respond to pressure therein, said pressure responsive means actuating said control element to stop said compressor when the pressure in said pipe is reduced to a predetermined cut-out level, and to start said compressor when the pressure in said pipe increases to a predetermined cut-out level, and means responsive to a drop in the temperature of the air external to said building for regulating said predetermined cut-out level as an inverse function of said air temperature to maintain said predetermined cut-in pressure below the point at which refrigerant would condense in the part of said pipe exposed to the air at said temperature without however affecting the cut-out level.

8. In a control unit for a refrigeration system having a refrigerated zone located within a building maintained at a human-comfort temperature level with the evaporator coils positioned within the refrigerated zone and having a compressor and control element positioned outside of said building and connected to said evaporator coils by means of a low-pressure pipe, the combination of a control element for controlling the operation of said compressor, a pressure-responsive means connected to respond to pressure in said pipe, said pressure-responsive means actuating said control element to stop said compressor when the pressure in said pipe is reduced to a predetermined cut-out level and to start said compressor when the pressure in said pipe increases to a predetermined cut-in level, and means responsive to a drop in the temperature of the air external to said building from a predetermined cut-in level above a predetermined temperature to a predetermined low temperature for reducing said cut-in level and for simultaneously reducing the difference between said cut-in level and said cut-out level.

9. In a control unit for controlling the operation of a motor-driven compressor of a refrigeration system in response to cut-in and cut-out pressures on the low pressure side of said compressor, the improvement comprising said cut-out switch, said cut-in switch, and means responsive to a drop in the pressure on said side to operate said switch means and by a cut-out pressure on said side to restore
said switch means, thereby starting and stopping said compressor respectively, said switch means including range-establishing means for determining the difference between said cut-in pressure and said cut-out pressure, and a temperature-responsive means controlled by the ambient temperature to which said compressor is exposed for reducing the cut-in pressure and for simultaneously reducing said pressure difference when the value of such ambient temperature is reduced from one, relatively high, value to another, relatively low, value.

10. In combination: a control unit; and an external motor-driven compressor of a refrigeration system connected with and controlled by said unit in response to cut-in and cut-out pressures on the low pressure side of said compressor, the control unit including electrical switch means activated by pressure-responsive means adapted for connection to said low pressure side, said pressure-responsive means being controlled to operate said switch means when the pressure on said side attains a cut-out pressure, said switch means including range-establishing means for determining the difference between said cut-in pressure and said cut-out pressure above a predetermined ambient temperature to which said compressor is exposed, and a temperature-responsive element disposed in the ambient atmosphere of said compressor and controlled by the ambient temperature for reducing the cut-in pressure and for simultaneously reducing said pressure difference as such ambient temperature is reduced in a range of temperatures below said predetermined temperature.

11. In a refrigeration control: a bearing plate member actuable by a pressure-actuated bellows; a range spring working on said plate member; a differential spring cooperating with said plate member; a toggle-actuated device having a toggle element working under the influence of said spring plate member and said bellows, and operable to close electric contacts of a compressor circuit; and a bimetallic temperature-responsive element connected at one end with said plate member and positioned at its other end to bear against said toggle at low ambient temperatures to assist toggle movement to close said contacts where ambient temperatures decrease.

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