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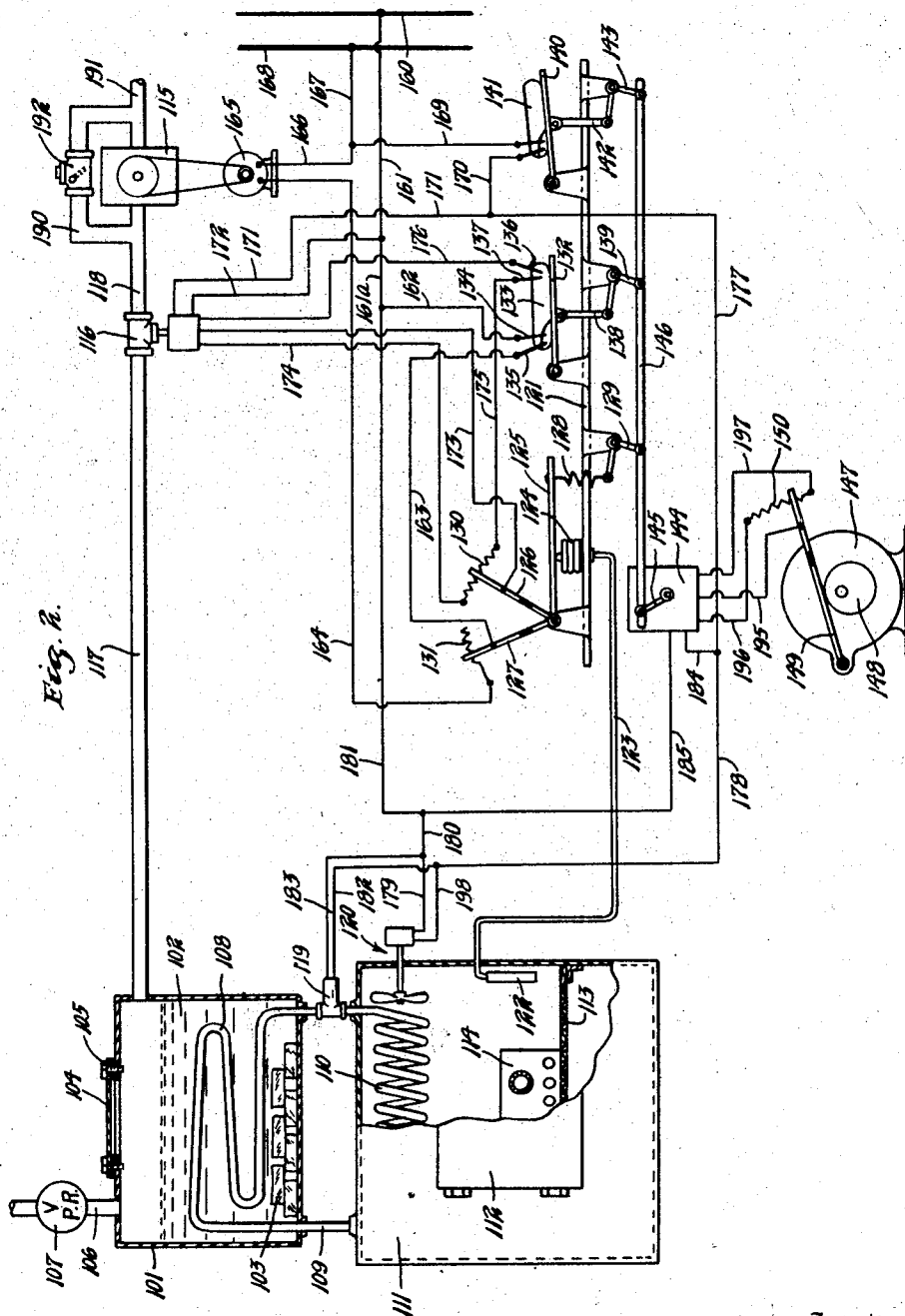
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LOW TEMPERATURE TEST CHAMBER

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LOW-TEMPERATURE TEST CHAMBER

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The present invention relates to a low temperature refrigeration system for test chambers and the like.

Means have long been available for reaching very low temperatures. One of the simplest means of refrigerating to a very low temperature is to pack the objects to be cooled in solid carbon dioxide, the carbon dioxide vaporizing at about -109° F. More complicated means of obtaining low temperatures have comprised multiple stage refrigeration systems using compressors and other suitable equipment; systems of this sort being most commonly used for low temperature work. In addition, when properly controlled, the plural stage refrigeration system gives good results at various control points within a rather wide range of temperature. The multiple stage refrigeration system, has however, the disadvantage of complexity and cost. For small laboratories and for infrequent use, the cost of a plural stage refrigeration system is often too high to justify its use.

The present invention is directed towards providing a low temperature refrigeration system which is relatively simple in nature and inexpensive. It must be granted that a system of the sort to be described is not particularly desirable for continuous operation nor is it as economical per unit of refrigeration as conventional systems. However, the present invention appears to provide a solution for those instances wherein infrequent operation is required, in which a refrigeration system is desired that is low in cost, will provide effective results, and wherein operating costs are reasonable.

It is therefore an object of this invention to provide a refrigeration system capable of attaining very low temperatures.

It is a further object of this invention to provide a low temperature refrigeration system which may be controlled at any temperature within an extensive range.

It is a present object to provide a refrigeration system utilizing a volatile refrigerant and using power only to control the pressures existing on said refrigerant.

It is a further object to control a refrigeration system using a volatile refrigerant by automatically controlling the conditions under which said refrigerant may evaporate.

It is a further object to provide a refrigeration system in which solid carbon dioxide is a refrigerant and in which the capacity of the refrigerant for cooling may be increased by immersing same in alcohol.

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It is an object to provide a refrigerating system wherein volatile material is used as a refrigerant and in which the capacity of the material may be increased by immersing same in a suitable liquid.

It is another object of this invention to provide a low temperature refrigeration system in which a heat exchange means is cooled by a volatile refrigerant evaporating under controlled pressure conditions, the pressures being varied as desired over a wide range.

It is another object of this invention to provide a controllable low temperature open circuit refrigeration system in which the refrigerant is a volatile solid.

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

Figure 1 is a schematic showing of the present system, parts of the pressure vessel and well being broken away;

Figure 2 is a schematic showing of a modified form of the invention, parts being in section and parts being broken away; and

Figure 3 is an elevational view, parts being in section and parts being broken away, of a modified heat exchange means which may be used in the structure of Figure 2.

In Figure 1, pressure vessel 10 is fitted with lid 11 which is clamped in place by securing means 12. Lid 11 includes a well 13 in the central portion of said lid and which forms the cooling chamber in the present example. Well 13 may be fitted with lid 14 having suitable openings therein to receive such instruments as thermometer 15 and temperature controller 16, to be calibrated. To increase the heat conductivity from the walls of said well to the instruments contained within same, a heat conducting fluid such as alcohol may be contained in said well. Further, agitating means, not shown, may be used to keep said alcohol stirred and provided uniform temperatures within the well, and other agitating means, not shown, may be provided for bath 25, to be described.

A conduit 17 connects to the upper portion of said pressure vessel 10 and leads to a modulating motor valve 20, said valve controlling flow through pipe 17 and connecting said pipe 17 to pipe 19. Pipe 19 connects to vacuum pump 18 and by-pass 63, said pump discharging through pipe 65; said by-pass also connecting to pipe 65. By-pass 63 includes check valve 64 which is arranged to permit flow only when the pressure in pipe 19 exceeds that in pipe 65 and is used to permit

gases to flow around the pump when same is not being operated. Pipe 17 also connects with pipe 21 having therein pressure relief valve 22, which protects the system from excessive pressure. Vacuum pump 18 is driven by electric motor 23.

Refrigeration is provided within pressure vessel 10 by a charge of immersed solid carbon dioxide 24, or other refrigerant, contained within a bath 25 of alcohol, or the like, said refrigeration being principally due to the evaporation or sublimation of said carbon dioxide. The evaporation of the carbon dioxide and the resulting refrigerating effect is controlled by a thermostatic device 26 comprising a temperature responsive bulb 27 connected by capillary tube 28 to bellows 29. Bellows 29 bears against pivoted lever 30 which operates arms 31 and 32, the action of bellows 29 on arm 30 being resisted by a tension spring 33. Adjustable screw means 34 is provided for adjusting the tension of said spring 33. Arm 32 carries mercury switch 35, which controls the operation of motor 23. Arm 31 has a contact portion which sweeps over potentiometer coil 36 to control modulating motor valve 20. Adjusting screw 34, in addition to adjusting the tension of spring 33, also coacts with pivoted arm 37 which is maintained in contact with said adjusting means 34 by tension spring 33. Pivoted arm 37 has a bracket portion 39 which carries mercury switch 40. Mercury switch 40 contains terminals 41 and 42, in the control circuit of modulating valve 20; and terminals 43 and 44 in the control circuit of motor 23, the bridging of the pairs of terminals by the mercury of the switch permitting energizing of the respective circuits.

Obviously, the structural details shown of pressure vessel 10, well 13, and the objects contained within said well 13, are to be considered illustrative only. Further, pressure relief valve 22 may be directly attached to pressure vessel 10 or lid 11, and vacuum pump 18 and valve 20 may be interchanged, if desired, or valve 20 may be on a separate branch from conduit 17. The insulation normally used for equipment of this sort is, of course, contemplated, but it has been omitted from this figure and the others to simplify the showings.

While solid carbon dioxide is the preferable refrigerant for this system, it is contemplated that other solid or liquid refrigerants may be used, such as liquid ammonia, sulphur dioxide, halogenated hydrocarbons of the paraffin series such as the Freons, and others. Alcohol has been given as a preferred material for the bath in well 13 and for bath 25 but obviously other non-freezing liquids may be used, such as ethylene glycol, light petroleum fractions, etc.

If desired, and especially when vacuum pump 18 is not of the positive displacement type, terminals 41 and 42 may be eliminated and valve 20 may be operated throughout the operating range of the system, said valve serving to regulate the capacity of the vacuum pump when same is running. When using a pump of this sort, by-pass 63 may not be needed.

The relation and function of the various parts above recited will be discussed in the following operation schedule.

Operation of Figure 1

To place the above described system in operation, the control point of thermostatic device 26 should be adjusted to about -109° (with carbon dioxide refrigerant), lid 11 removed from vessel 10, and said vessel charged by placing solid

carbon dioxide 24, or other refrigerant, in the bottom of same, said carbon dioxide being covered with alcohol, or other suitable liquid 25, to a suitable depth. Lid 11 is then replaced and securely clamped in sealed relation to said vessel 10. Well 13 is filled to a suitable level with alcohol, or the like, and thermometer 15 and the device to be tested or calibrated is inserted within said well and immersed in said alcohol, lid 14 then being placed in position.

Thermostatic control means 26 is then adjusted to a suitable control point. As before mentioned, vessel 10 was charged at atmospheric pressure; hence the alcohol bath within said vessel would tend to reach about -109° F. Assuming that the control point is to be -150° , the adjustment is made by loosening adjusting screw 34. Loosening adjusting screw 34 is accomplished by turning said screw inwardly and releasing tension on spring 33. Turning adjusting screw 34 inwardly also coacts with pivoted arm 37 and bracket portion 39 to tip said bracket portion 39 downwardly and thus make contact between terminals 43 and 44 of mercury switch 40. Further, loosening adjusting screw 34 permits arm 32 to pivot counter-clockwise and thus complete a circuit within mercury switch 35.

With contacts made between terminals 43 and 44 and in mercury switch 35, motor 23 is started as follows: line 50, wire 51, terminals 43 and 44, wire 52, mercury switch 35, wire 53, motor 23, wire 54, and line 55. Motor 23 is thus started, and vacuum pump 18, driven by same, reduces the pressure exerted on bath 25 and the immersed carbon dioxide 24 in pressure vessel 10, thus permitting said carbon dioxide to vaporize at a lower temperature. As carbon dioxide 24 vaporizes at the reduced pressure, and lowers the temperature of bath 25 and the immersed well 13, the pressure exerted by bellows 29 is lessened. When the predetermined control point is reached, and the pressure exerted by bellows 29 is overcome by spring 33, arm 32 is rotated clockwise and contact is broken in switch 35, thus stopping motor 23 and vacuum pump 18. Motor 23 will again be started when the rising temperature in bath 25 causes bellows 29 to expand and rotate arm 32 counter-clockwise, thus making contact within mercury switch 35.

It will be thus seen that control points below about -109° are attained by maintaining suitable reduced pressures over bath 25 and the immersed carbon dioxide 24, said reduced pressure being kept at proper levels by on and off control of motor 23. When bracket portion 39 of pivoted arm 37 is tilted downwardly, and contact is made between terminals 43 and 44, contact is broken between terminals 41 and 42, thus biasing valve 20 open as will be seen.

The motor of modulating valve 20 is operated by current supplied through the circuit: line 50, wire 56, motor valve 20, wire 57 and line 55. The motor is controlled by the circuit: arm member 31, wire 58, motor valve 20, wire 59, coil 36, wire 60, terminals 41 and 42, wire 61 and motor valve 20. It will thus be noted that with contacts broken between terminals 41 and 42, one control side of said modulating valve is opened and all of its control current must flow in the other branch of the control circuit thereby causing the valve to be biased toward an extreme position; in this case its open position.

To show the control of the system with control points above -109° , assume the control point to be -20° . Thermostatic device 26 is adjusted

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for a control point of -20° by tightening adjusting screw 34, thereby increasing the tension of spring 33. Tightening adjusting screw 34 results in said screw being backed out of its support member, thereby allowing pivoted arm 37 and its related bracket 39 to rotate counter-clockwise due to action of spring 38. Counter-clockwise rotation of bracket 39 tends to tilt mercury switch 40 upwardly and contact is broken between terminals 43 and 44, thus preventing operation of motor 23. At the same time, however, contact is made between terminals 41 and 42, and modulating valve 20 is placed under control of arm 31 and potentiometer coil 36.

To attain a control point of -20° F., it is necessary that the carbon dioxide be vaporized under pressures exceeding those of atmospheric, hence it is the function of modulating valve 20 to throttle the outlet of the vaporized gases from pressure vessel 10 in such manner that a suitable pressure may be built up in said vessel to thus control vaporization within same.

Assuming for the moment, that the temperatures within vessel 10 are below the control point, the pressure exerted by bellows 29 will be less than that required to successfully oppose the action of spring 33, and arm 31 will be rotated in a clockwise direction, thus moving it downwardly on potentiometer coil 36. In the downward position of arm 31 on coil 36, valve 20 is closed, thus prohibiting the escape of gases from pressure vessel 10 and permitting pressure to build up therein. As the pressure and temperature within said pressure vessel increases up to the desired point, the pressure exerted by bellows 29 is increased. When the pressure exerted by bellows 29 is sufficient to overcome, at least partially, the pressures exerted by spring 33, arm 31 is rotated upwardly across coil 36 and valve 20 is partially opened. The opening of valve 20 will tend to reduce pressures in vessel 10 and thus reduce temperatures, said temperature reduction resulting in less pressure by bellows 29 and counter-clockwise movement of arm 31, thereby again tending to close said valve 20. Valve 20 is thus throttled to maintain a predetermined pressure and temperature within the vessel. As previously mentioned, thermostat bulb 27 may be placed within well 13, if desired, thus making the control dependent upon the temperature within said well 13 rather than that of the bath in vessel 10.

When terminals 41 and 42 are not used and the modulating valve is operated throughout the range of the system, the control circuits are the same as shown with the exception that wires 61 and 60 are joined. The system functions the same as described at pressures above atmospheric; but at pressures below atmospheric, the throttling action of said valve may supplement or replace the on and off control exercised by mercury switch 35. Valve 20 exercises control over pump 18 by throttling its suction. Should the positions of the valve and pump be reversed, the discharge would be throttled.

Figures 2 and 3

Figure 2 shows a modified form of the present invention. This figure shows a pressure vessel 101 containing therein an alcohol bath 102 and immersed carbon dioxide 103, it being noted that these materials are given as examples only, other materials being contemplated, as in the preceding example. The alcohol and carbon dioxide are charged into the vessel through removable closure 104, said closure being held in place by fas-

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tening means 105. Dangerous pressures are avoided by conduit means 106 and pressure relief valve 107. Immersed within bath 102 is coil 108 of heat exchange means 109, said heat exchange means 109 including coil 110, contained within test chamber 111, said coil 110 being connected in sealed relation with coil 108. Heat exchanger 109 is charged with a fill of a suitable refrigerant, such as one of the Freon group, in such manner that coil 110 will normally contain some liquid refrigerant.

Test chamber 111 may comprise a suitable door 112 and a rack 113 to hold the devices to be tested. A radio 114 is shown on rack 113 as a device to be tested under low temperatures, but obviously this is only an illustration.

The rate of vaporization of carbon dioxide 103 and the resulting refrigerating effect of same, is determined by the pressure imposed on bath 102 and refrigerant 103. Pressures within vessel 101 are influenced by a modulating valve 116 and a vacuum pump 115, said valve being connected to vessel 101 by conduit 117 and discharging through conduit 118 into vacuum pump 115 and by-pass 190, said by-pass and pump discharging to exhaust pipe 191. By-pass 190 includes check valve 192 which permits flow around pump 115 only when the pressure in pipe 118 is higher than that in pipe 191. As in the previous example, the use of a pump permitting free passage of gases when said pump is not being run would make the by-pass unnecessary.

The circulation of heat exchange fluid between coils 108 and 110 is controlled by solenoid valve 119, and the cooled medium of test chamber 111 is circulated over coil 110 by a fan means 120.

The operations of vacuum pump 115, modulating valve 116, solenoid valve 119, and fan 120 are all controlled by a thermostatic device 121. Thermostatic device 121 comprises a volatile fluid filled bulb 122 located within test chamber 111, and connected by a capillary tube 123 to bellows 124. Bellows 124 coact with arm member 125 to cause pivotal movement thereof, said arm 125 having associated therewith arms 126 and 127. The action of bellows 124 on arm 125 is resisted by tension spring 123 attached at one end to said arm 125 and at the other end to one arm of bell-crank lever 129. Arm 126 coacts with potentiometer coil 130 and arm 127 coacts with resistance 131. Device 121 also includes pivoted switch support 132 having thereon mercury switch 133, said mercury switch 133 having at one end terminals 134 and 135, and having at the other end thereof, terminals 136 and 137. Switch support 132 is connected by link 138 to bell-crank 139. Said device 121 also includes pivoted switch support 140 having thereon mercury switch 141, said switch support 140 being connected by link 142 to one arm of bell-crank 143. Modulating motor 144, which adjusts device 121, includes a pivotal operating lever 145, said pivotal operating lever being connected by link or connecting rod means 146 to bell-cranks 129, 139 and 143. Modulating motor 144, as well as the motor of modulating valve 116, is similar to that described in Patent 2,028,110, issued to D. G. Taylor. The position of arm 145 of modulating motor 144 is determined by timer 147 which comprises a scheduling cam 148 coacting with a pivoted arm 149, said arm 149 sweeping over potentiometer coil 150 to thereby control said motor 144.

As in the previous example, modulating valve 116 may be operated in conjunction with vacuum pump 115 to supplement or replace the

rheostat control of said pump. Valve 116 may be made operative throughout the range of the system by connecting wires 175 and 176.

In Figure 3, modified means are shown for transferring heat from test chamber 111 to bath 102 comprising heat exchange coil 155, located within chamber 111 and connected at one end to pump 156 and perforated inlet pipe 157, and connected at its other end to perforated outlet pipe 158. Inlet pipe 157 and outlet pipe 158, as shown, are located within vessel 101 and immersed in bath 102. The fluid of bath 102 enters pipe 157 and is caused to circulate by pump 156, through said coil 155 and out through perforated pipe 158, said material 102 flowing across refrigerating material 103 as it leaves pipe 158 and flows towards pipe 157. Pump 156 is preferably driven by electric motor means and is controlled by the same circuit as solenoid valve 119 of Figure 2. Obviously, the direction of circulation may be reversed, if desired.

Operation of Figures 2 and 3

To operate the structure as outlined in Figure 2, the control point should be adjusted to about -109° . The manner in which the control point may be adjusted and the operation of the control will be brought out presently. With the control point adjusted to about -109° , valve 116 is open and vacuum pump 115 is not operating. Closure 104 is removed from vessel 101 and a charge of solid carbon dioxide 103, or other refrigerant used, is placed within said vessel. After charging the vessel with carbon dioxide, the carbon dioxide and coil 108 are covered by alcohol, or other liquid, closure 104 then being replaced and tightly secured by fastening means 105. The system is now ready for operation and the control point may be adjusted as desired. In the system as disclosed, the control point may be established, or may be varied in a predetermined manner by timer means 147 which includes schedule cam 148, adjusted by suitable means and operable by the mechanism of 147, and pivoted arm 149, it being the purpose of the timing and scheduling mechanism to operate the refrigeration system in a manner duplicating predetermined conditions. For instance, if it be desired to duplicate the conditions of temperature of an aircraft flying in the sub-stratosphere, the mechanism may be so adjusted as to change the temperature in the test chamber in the same sequence as the temperature is changed by said aircraft in flight. Obviously, the mechanism may be adjusted to maintain the temperature at any control point within its range.

For the purpose of illustration, assume that it is desired to test the characteristics of radio 114 from -120° to -10° within a period of thirty minutes. Cam 148 will be so adjusted relative to pivoted arm 149 that said arm will be in a position to establish a control point of -120° . The cam is made of such contour and rotated when started at sufficient speed to rotate arm 149 counter-clockwise across coil 150 sufficiently to raise the control point to -10° within the time period of thirty minutes. Modulating motor 144 is so related to the timing mechanism and its potentiometer coil 150, that arm 145 is at the extreme left position when arm 149 is at the clockwise extreme of coil 150, and arm 145 is at the extreme right position when arm 149 is at the extreme counter-clockwise end of coil 150.

Assuming that the position of arm 149 on coil 150 is such as to maintain a control point of

-120° F., arm 145 is in the left portion of its travel, and bell cranks 129, 139 and 143 have been rotated in a clockwise direction. The rotation of bell crank 129 has served to loosen the adjustment of spring 128 thereby permitting arm 125 to rotate counter-clockwise, thus moving arms 126 and 127 counter-clockwise. Rotation of bell crank 139 has caused the tilting of mercury switch 133 in such manner that contact is made between terminals 134 and 135 and contact is broken between terminals 136 and 137. The rotation of bell crank 143 has tilted mercury switch 141 in such manner as to make contact between its terminals; therefore valve 116 is open, vacuum pump 115 is operating, valve 119 is open, and fan 120 is operating, as shown, by the following circuits: The circuit placing vacuum pump 115 in operation is as follows: line 160, wire 161, wire 161a, wire 162, terminal 134, terminal 135, wire 163, arm 127, resistance 131, wire 164, motor 165, wire 166, wire 167, and line 168.

As determined by the following circuits, valve 116 is open: The motor of valve 116 is supplied with current by line 168, wire 167, wire 169, mercury switch 141, wire 170, wire 171, modulating motor valve 116, wire 172, wire 161, and line 160; thus operating current is supplied to modulating motor valve 116. The control circuit for motor valve 116 is as follows: arm 126, wire 173, motor valve 116, wire 174, coil 130, wire 175, terminal 137, terminal 136, wire 176 and motor valve 116. However, as no contact is made between terminals 136 and 137, no current flows through one side of the control circuit of said valve, hence all the current flows through the other branch of the control circuit and the valve is modulated to an extreme position, in this case, wide open.

Valve 119 is open and fan 120 is operating by the following circuit: line 168, wire 167, wire 169, mercury switch 141, wire 170, wire 177, wire 178, wire 198, fan 120, wire 179, wire 180, wire 181, wire 161a, wire 161, and line 160. Valve 119 is connected in parallel with fan 120 by wires 182 and 183 and is opened upon being energized.

The operating current for modulating motor 144 is furnished by the circuit: line 168, wire 167, wire 169, mercury switch 141, wire 170, wire 177, wire 184, modulating motor 144, wire 185, wire 181, wire 161a, wire 161, and line 160. Modulating motor 144 is controlled by the circuit: arm 149, wire 195, motor 144, wire 196, potentiometer coil 150, wire 197 and motor 144. As previously mentioned, clockwise movement of arm 149 drives arm 145 of motor 144 in a counter-clockwise direction.

With the parts in the position shown, vacuum pump 115 is operating at a fairly high speed due to the comparatively small amount of resistance in its control circuit, valve 116 is fully open, as before noted, valve 119 is open, and fan 120 is operating. The operation of vacuum pump 115 lowers the pressure imposed on bath 102 and carbon dioxide 103, thus permitting said carbon dioxide to vaporize readily and at low temperatures. The low temperatures attained by the bath 102 are imposed on coil 108 and thereby reduce the temperature and pressure of the heat exchange refrigerants therein correspondingly. Liquid forming in coil 108 by condensation runs into coil 110 by gravity, wherein, due to the heat supplied from chamber 111 to said coil, said refrigerant is vaporized and rises into said coil 108 to be again liquified by the chilled bath. The temperature of coil 110 will tend to closely approximate that of bath 102, for its temperature is due

to the pressure of the refrigerant within it. The pressure of the refrigerant within coil 110 will be determined by the condensing effect of coil 108 brought about by the low temperature of the surrounding bath 102.

Fan 120 is not a necessary part of the present system but is useful in circulating cooled medium within chamber 111 and thereby increases the effectiveness of cooling coil 110. It is the purpose of valve 119 to trap as much liquid refrigerant in coil 108 as is possible when there is no demand for refrigeration and the system is turned off. During all operating conditions, however, said valve 119 is open as previously described.

Should the action of vacuum pump 115 reduce the temperature more than is desired, the effect of such reduction will be to lessen the pressure exerted by bellows 124 and to cause retraction of same, thereby permitting clockwise movement of arm 125 and arm 127. Clockwise movement of arm 127 causes more resistance of coil 131 to be added to the control circuit of motor 165 thereby slowing same and reducing the pumping action of the vacuum pump. Should the action of the vacuum pump be insufficient to lower the temperature as desired, the resulting higher temperature increases the pressure on bellows 124 and causes counter-clockwise rotation of arm 125 and arm 127, the counter-clockwise rotation of arm 127 diminishing the resistance of coil 131 and thereby speeding the action of motor 165.

As the scheduling cam 148 is rotated and the control point is raised by moving arm 149 counter-clockwise, arm 145 is moved to the right and bell cranks 129, 139 and 143 are rotated counter-clockwise. The counter-clockwise movement of the bell crank 129 increases the tension on spring 128 and tends to cause clockwise movement of arm 125. The counter-clockwise movement of bell crank 139 changes the slant of mercury switch 133 so that contact is broken between terminals 134 and 135 at a control point of about -109°F. and operation of motor 165 is stopped. At the same time, contact is made between terminals 136 and 137 and modulating valve 116 is placed under control of its potentiometer circuit. Counter-clockwise movement of bell crank 143 has altered the slant of mercury switch 141 but has not broken contact between its terminals, switch 141 being so arranged as to maintain contact throughout the operating range of the system, said switch serving to disconnect the control means from the current supply when the system is not being operated.

To show the controlling circuits in effect at control points above about -109°F. , assume a control point of -70°F. , with a control point of -70° , motor 165 is not operated due to breaking of the contact between terminals 134 and 135 of mercury switch 133 as previously described. With contact made between terminals 136 and 137, modulating valve 116 is now operative by the circuit previously described. The circuit is so arranged that clockwise movement of arm 126 tends to close valve 116 and counter-clockwise movement of said arm tends to open said valve. By throttling valve 116, a pressure may be maintained over bath 102 and refrigerant 103 which controls the evaporating temperature of the refrigerant in the manner desired. If the pressure is lowered unduly by too wide a valve opening, the evaporation is increased, thus resulting in lower temperatures, and causing a relaxing of the pressure of bellows 124 and a movement of

arm 126 tending to close the valve to again re-establish the necessary pressure, it being noted that a control point of -70°F. requires a pressure above atmospheric when carbon dioxide is the refrigerant. Likewise, the maintenance of too high a pressure in the vessel will cause excessively high temperatures to be maintained, and will cause an expansion of bellows 124, a counter-clockwise movement of arm 126, and an opening of said valve to relieve said pressure.

When valve 116 is operated throughout the range of the system, it controls pressures above atmospheric in the manner described. At pressures below atmospheric, it may be used to control the capacity of pump 115 by throttling its suction. This throttling control may, as before noted, either supplement or replace the rheostat control described. To use valve 116 continuously, wires 175 and 176 are joined, and if the rheostat control is to be replaced, wires 163 and 164 are joined, permitting the elimination of arm 127 and resistance 131. The control circuits are otherwise as shown and the function of the system as a whole remains unchanged.

As in the previous example, conduit 106 and pressure relief valve 107 are provided to prevent the accumulation of dangerous pressures within vessel 101 and other parts.

With the structure of Fig. 2 modified as suggested by Fig. 3, the control action is precisely as before with the exception that the current flowing through wires 182 and 183, instead of opening valve 119, serves to energize electrically driven pump 156 and thereby circulate chilled alcohol bath means 102 through pipe 157, pump 156, coil 155, and pipe 158.

A single charge of refrigerant is usually sufficient for most test purposes but it is also contemplated that suitable charging means may be used to introduce charges of refrigerant into the chamber while the system is being operated, and thus prolong the operating period.

Solid carbon dioxide has been given as the preferred refrigerant in the above examples of the present invention because it is easily handled and is cheap and readily available. However, as previously noted, other solid or liquid refrigerants may be used, most of the common refrigerants being readily available in liquid form. As some of the more common refrigerants, such as ammonia, have irritating fumes, they should preferably be introduced into the chamber by piping, not shown.

Obviously, disposal of the discharged gases from the present system offers much less of a problem when carbon dioxide is used. Carbon dioxide has further merit in increasing the safety of the system. When volatile and inflammable baths, such as alcohol, petroleum fractions, etc., are used, a portion of these materials may be evaporated and discharged with the refrigerant. However, the carbon dioxide, being in much greater quantity, dilutes the fumes from the bath and renders them relatively unflammable.

It is considered that the above examples have taught the construction and operation of a controllable low temperature refrigeration system ideally suited for those installations wherein relatively low cost of equipment and moderate cost of operation are important and wherein infrequent operation of the equipment does not justify the added costs of more elaborate systems.

The examples above described of the present invention are considered to be illustrative only and are not intended to limit the structure or the

system to the details described. It is obvious, that upon an inspection of the present disclosure, many modifications of the present invention will become apparent to one skilled in the art. It is the intent, therefore, that the scope of the present invention be determined by the appended claims.

I claim as my invention:

1. In a refrigerating system capable of operating over a range of temperature for utilizing a refrigerant having a vapor pressure above atmospheric pressure at the upper end of said temperature range and below atmospheric pressure at the lower end of said range, means for controlling the vapor pressure of said refrigerant including throttling valve means and pumping means, adjustable condition responsive means, and means for connecting said condition responsive means in controlling relation to said valve means for maintaining a refrigerant temperature in said upper range or in controlling relation to said pumping means for maintaining a refrigerant temperature in said lower range.

2. In a refrigerating system, a pressure vessel for containing a charge of volatile refrigerant of a sort wherein the vapor pressure of said refrigerant is above atmospheric pressure at higher refrigerating temperatures and below atmospheric pressure at lower refrigerating temperatures, means for regulating the pressure within said vessel comprising valve means and fluid pumping means, temperature responsive means, means for adjusting the control point of said temperature responsive means, adjustable energy control means permitting operation of either said valve means or said pumping means, and means simultaneously adjusting said control point and said energy control means in such manner as to permit operation of said valve for said higher refrigerating temperatures and to permit operation of said pump for said lower refrigerating temperatures.

3. In a low temperature refrigerating system, comprising an enclosed pressure vessel for containing a liquid having a low freezing point and a refrigerant having a boiling point above said freezing point disposed within said liquid, a coil of a closed circuit circulating fluid heat exchange means within said vessel and arranged to be in heat exchange relation with said liquid, another coil of said heat exchange means being within a space to be refrigerated, control means, said control means comprising a throttling valve, a fluid translating device, and means having an adjustable control point responsive to the temperature of the space to be refrigerated, said temperature responsive means controlling said throttling valve when control point temperature is above a predetermined level and controlling said fluid translating device when the control point temperature is below said predetermined level.

4. Control means for an expendable refrigerant refrigerating system comprising, in combination, modulating means arranged to control the operation of a throttle valve, control means capable of controlling a fluid translating device, additional controlling means including means supplementing said modulating control means for said valve and means supplementing said control means for said translating device, condition responsive means operable to actuate said modulating means and said control means in a manner to maintain said condition at a predetermined control point, and adjusting means, said

adjusting means simultaneously adjusting said condition responsive means to a given control point and adjusting said additional controlling means to selectively permit operation of said throttle valve or said translating means.

5. A low temperature refrigeration system comprising an enclosed pressure vessel for containing a liquid having a low freezing point and a refrigerant having a boiling point above said freezing point disposed within said liquid; heat exchange means disposed in a space to be cooled, said heat exchange means having inlet and outlet connections within said vessel disposed for circulation of said liquid; means for circulating said liquid through said heat exchange means; control means, said control means comprising a throttling valve, a fluid translating device, and means responsive to the temperature of the space being refrigerated, said temperature responsive means having an adjustable control point, said temperature responsive means controlling said throttling valve when control point temperature is above a predetermined level and controlling said fluid translating device when the control point temperature is below said predetermined level, said control means causing circulation of said liquid throughout the operating range of said system.

6. In a refrigerating system, an enclosed pressure vessel for containing a liquid having a low freezing point and a volatile refrigerant having a low boiling point immersed within said liquid, a cooling chest having means arranged to be in heat exchange relation with said liquid, means for regulating the evaporation of said volatile refrigerant comprising fluid translating means, throttling valve means, means responsive to the temperature within said chest, said temperature responsive means controlling the action of the fluid translating device and said modulating valve and having an adjustable control point, and means for varying the control point of the temperature responsive means in a predetermined manner.

7. In a low temperature refrigerating system, an enclosed pressure vessel for containing a liquid having a low freezing point and a refrigerant having a boiling point above said freezing point disposed within said liquid, a coil of a closed circuit circulating fluid heat exchange means within said vessel and arranged to be in heat exchange relation with said liquid, another coil of said heat exchange means being within a space to be refrigerated, control means, said control means comprising a throttling valve, a fluid translating device, and a means having an adjustable control point responsive to the temperature of the space to be refrigerated, said temperature responsive means controlling said throttling valve when the control point temperature is above a predetermined value and controlling said throttling valve and fluid translating device when the control point temperature is below said predetermined value.

8. In a refrigerating system, an enclosed pressure vessel for containing a volatile refrigerant means, temperature responsive means, said temperature responsive means having an adjustable control point, modulating motor means for adjusting said control point, means for controlling said modulating motor, and means for varying the pressure within said vessel, said pressure varying means being operated in response to said temperature responsive means.

9. A low temperature refrigeration system

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comprising an enclosed pressure vessel for containing a liquid having a low freezing point and a refrigerant having a boiling point above said freezing point disposed within said liquid, means arranged to be in heat exchange relation with said liquid, means for varying the pressure in said vessel, control means, said control means comprising temperature responsive means for controlling the action of said pressure varying means, and timing means, said timing means varying the control point of said temperature responsive means in a predetermined manner.

10. Control means for an expendable refrigerant refrigerating system comprising, in combination, modulating means arranged to control the operation of a throttle valve, control means capable of controlling a fluid translating device, additional controlling means including means supplementing said modulating control means for said valve and means supplementing said control means for said translating device, means responsive to a condition indicative of a need for operation of the refrigerating system operable to actuate said modulating means and said control means in a manner to maintain said condition at a predetermined control point, and adjusting means, said adjusting means simultaneously adjusting said condition responsive means to a given control point and adjusting said additional controlling means to selectively permit operation of said throttle valve or said translating means.

11. Control means for an expendable refrigerant refrigerating system having throttle valve means and fluid translating means for controlling the flow of exhaust refrigerant comprising in combination, modulating means arranged to control the operation of said throttle valve means, control means capable of controlling said fluid translating device, additional controlling means including means supplementing said modulating control means for said valve and means

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supplementing said control means for said translating device, means responsive to a condition indicative of a need for operation of said refrigerating system operable to actuate said modulating means and said control means in a manner to maintain said condition at a predetermined control point, and adjusting means, said adjusting means simultaneously adjusting said condition responsive means to a given control point and adjusting said additional controlling means to selectively permit operation of said throttle valve or said translating means.

12. In control means for a refrigerating system of the sort wherein a charge of refrigerant is placed within an enclosed receptacle and the pressure within said receptacle is controlled by a throttling valve means and pumping means, in combination, means responsive to a condition indicative of a need for operation of the system, means controlled by said condition responsive means for controlling the said throttling valve means for higher values of said condition, and means controlled by the same condition responsive means for controlling said translating means for lower values of said condition.

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