July 5, 1949. M. SELIGMAN ET AL 2,475,556

REFRIGERATION SYSTEM, INCLUDING VALVE CONTROLS

Filed June 3, 1944

2 Sheets-Sheet 1

Fig. 1.

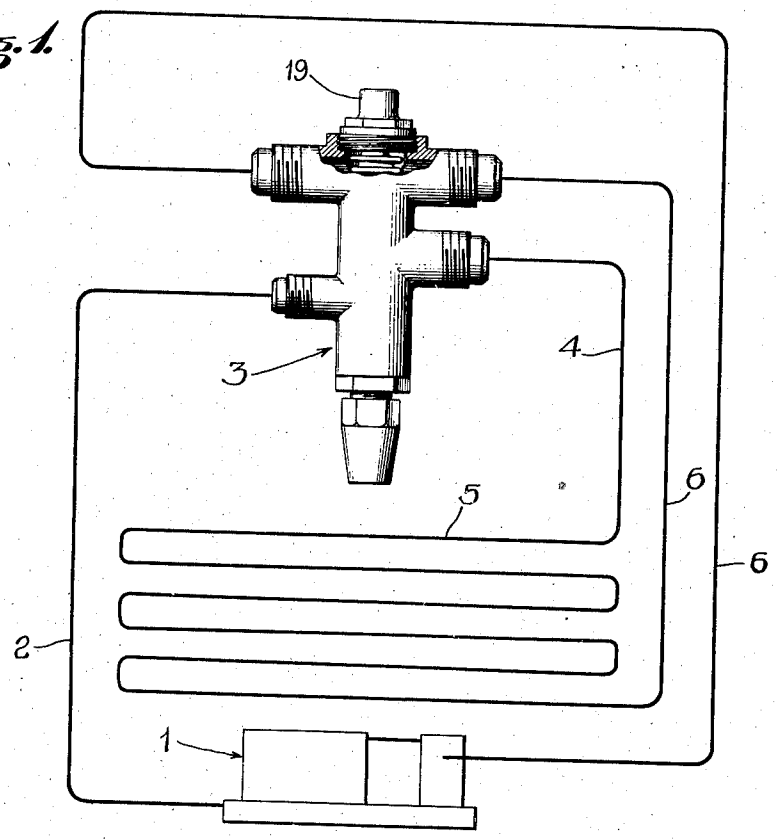


Fig. 3.

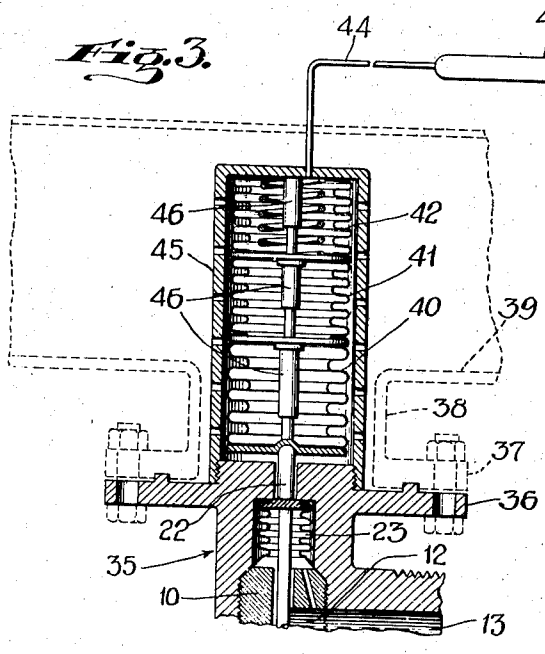
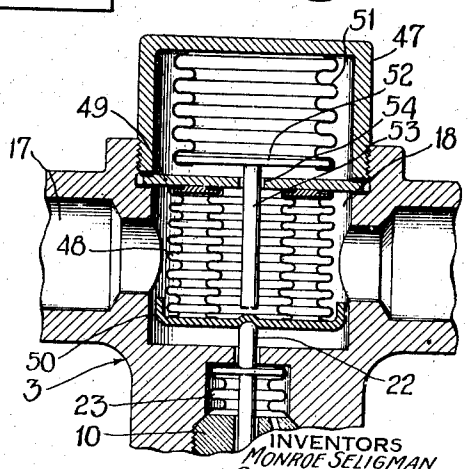


Fig. 4.



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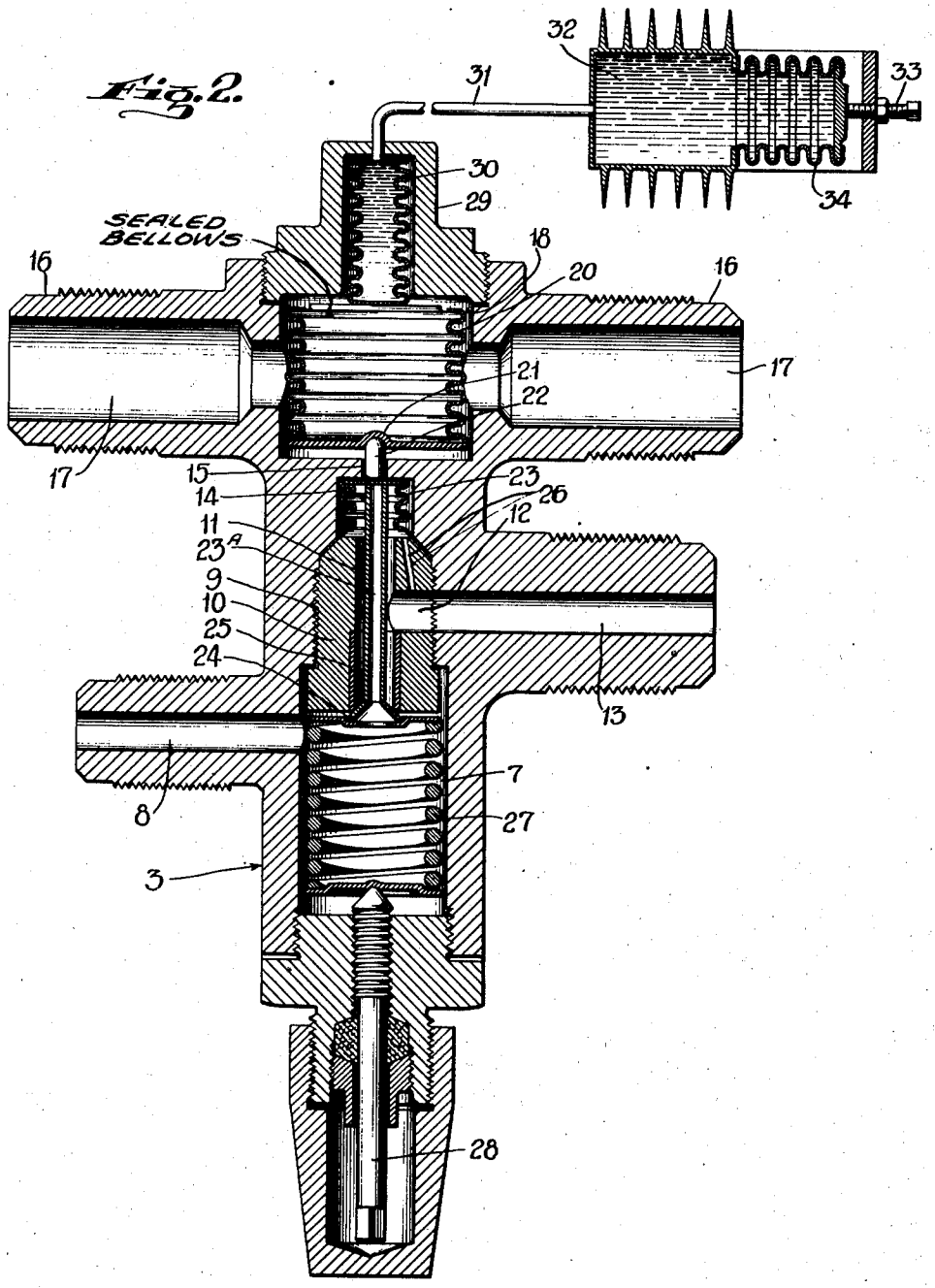
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Fig. 2.



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REFRIGERATION SYSTEM, INCLUDING VALVE CONTROLS

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15 Claims. (Cl. 62—8)

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The present invention relates to refrigeration systems in general, whether applied to the maintenance of conditions appropriate in frozen food cabinets, cold storage rooms, air conditioning, or otherwise, and has for its principal objects the elimination of certain disadvantages inherent in such systems as heretofore employed, and the provision of a system of control and apparatus which is more efficient in its automatic response to varying conditions of operation and which embodies certain principles and methods susceptible to use, alone or in combination, to meet a wide variety of needs.

As is well understood, refrigeration systems ordinarily include a vapor condenser of the compression or absorption type, to condense a refrigerant vapor into its liquid state; a refrigerant control valve to meter the quantity of refrigerant for system requirements; an evaporator to conduct heat to the refrigerant so that the refrigerant again becomes a vapor; and a return vapor line to conduct the refrigerant vapor back to the compressor or other vapor liquefier.

These known systems have certain serious disadvantages which are largely the result of the following characteristics: first, that the refrigerant valves, while theoretically organized so as to be controlled primarily by temperature variations of the super-heated vapor return line, are, in fact, relatively insensitive thereto, i. e. both literally and in the sense that the usual types of control respond too readily to factors other than the actual temperature within the vapor return line; secondly, such controls are relatively insensitive, except indirectly, to the pressure in the super-heated vapor return line; and, thirdly, that the valve controls are incapable of accommodating themselves automatically, and, in fact, require manual adjustment, to compensate for variations in the conditions under which the system may operate.

Take, for example, the case of a compression type system as ordinarily applied to a food dispensing or storage refrigerator. In such systems the refrigerant valve is customarily controlled by a remote thermal bulb strapped to the outside of the vapor return line, and, on occasion, ice may form around the bulb and keep the control valve closed when the system requires it to be open. Again, warm air entering through door openings or heat conducted through the superheated vapor return line from the outside may open the valve when the system requires it to be closed. Also, it is common to have these valves over-feed and then under-feed the system because of the time lag introduced between the remote bulb and the valve proper. Under-feeding results in reducing system capacity making for inefficient operation. Over-feeding is dangerous to both the compressor and motor. On certain types of valves the body can become colder than the bulb and cause a complete loss of control. Any of the above can be responsible for unstable storage conditions in addition to high maintenance and operating costs, and while various devices have been proposed and used in an attempt to minimize these shortcomings, either system efficiency or valve life has been sacrificed.

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Take also, for example, the case of a commonly used air-conditioning system consisting of a vapor condenser, evaporator, refrigerant control valve, space temperature controller for starting and stopping the system, and a fan for delivering the cooled air to the conditioned space. This type of system is usually of a capacity and design to meet the cooling needs of a given space for the heaviest loads and the hottest day of the season. However, changes in load may take place many times during any one day and consequently the system will be forced to stop and start at frequent intervals and usually with short running periods. This condition is not at all satisfactory since the temperature of the cooled air entering the conditioned space, due to the design of the system, will be far below the comfort level, and during the off period of the system the relative humidity will increase above the comfort level. In addition frequent starting and stopping is uneconomical from the standpoint of cost of operation and system maintenance.

Various automatic controls have been devised for the purpose of overcoming some of the disadvantages above mentioned but they, too, in some instances are not entirely satisfactory and in all cases their complexity and high cost are such as to militate against their widespread adoption and use.

According to the present invention, an improved system of control is provided, characterized, among other things, by the fact that the refrigerant flow is regulated by a power element which may be controlled in direct accordance with both the vapor temperature and vapor pressure obtaining at a predetermined point in the system, as in the low pressure super-heated vapor return line. It may be stated at this juncture that the term "power element" as used herein is not to be confused with the known, fixed capacity bulb as heretofore employed in the control of refrigerant valves. The term is used as a conven-

ient abbreviation to denote a housing or container which is charged with a suitable thermally responsive fluid medium but which is itself also expansible, so that the element is directly responsive to the surrounding pressure as well as temperature conditions to which it is subjected. Preferably, because it has special advantages in such form, the power element consists of an expansible bellows, but as will be recognized hereafter, many of the advantages of the invention can be otherwise achieved, as by the use of a power element incorporating a flexible diaphragm.

Also, the present invention contemplates a much simplified and highly effective system of refrigeration control readily adaptable to automatic modulation of the basic operation of the refrigerant valve in accordance with the requirements of a wide variety of load conditions and varying factors such as are encountered in different applications of such systems.

Other objects and advantages of the invention will be apparent from the ensuing description, taken in connection with the accompanying drawings which illustrate several applications of the invention.

In these drawings, which are in part diagrammatic, Fig. 1 illustrates a refrigeration system of a relatively low capacity type having a simple form of the invention applied thereto, Fig. 2 is an enlarged section view of the valve of Fig. 1 but incorporating also one form of the automatic modulation feature of the invention, and Figs. 3 and 4 are broken out sectional views illustrating other arrangements of automatic valve controls adaptable to various special conditions as hereinafter described.

Referring to Fig. 1, primary elements of the system will be recognized as including a condensing unit generally designated 1, which may be of any efficient type, a liquid refrigerant line 2 leading to a refrigerant control valve generally designated 3, a low pressure liquid and vapor line 4 leading to an evaporator 5 and a vapor return line 6 leading back to the condensing unit 1 as presently described.

As respects its mechanical function of metering the refrigerant, the valve may be variously constructed, but for the purpose of illustrating the several aspects of the invention in preferred form, a valve structure having various novel and advantageous features of construction is illustrated. As shown in Fig. 2, the body of the valve includes a chamber or bore 7 to which the refrigerant is admitted from line 2 through port 8. An upper, reduced section of bore 7 is threaded at 9 to receive a plug 10, having a central passage 11 communicating with a lateral bore 12, which provides an outlet to port 13 to the line 4 to the evaporator. Immediately above plug 10 is a further reduced bore 14 the upper or end wall of which has a central opening 15.

In accordance with this preferred form of the invention, the upper end of the valve body is provided with laterally projecting coupling portions 16 which may be threaded or otherwise appropriately formed for ready connection directly in the vapor return line 6. The transverse bore 17 provides a vapor flow passage extending clear through the housing, and, intermediate the ends of the bore 17 is a vertical bore or chamber 18 the upper, open end of which (in the Fig. 1 form) is closed as by a plug 19. The alternative type of closure shown in Fig. 2 is described below in connection with another application of the invention.

Within chamber 18 is located the power element above referred to. As shown and preferred, it comprises a sealed bellows 20 which is suspended or freely located within the chamber directly in the vapor flow through bore 17. As will presently appear, this power element may be constructed in multiple compartment form and variously charged, but in the simplest type of installation contemplated in Fig. 1 comprises a single bellows charged with the liquid or vapor of the same refrigerant as is circulated within the system. The bellows substantially fills chamber 18 except, of course, for clearance adequate to avoid unduly impeding the vapor flow, and, preferably, avoiding also any contact with the adjacent metal of the valve body. At its upper end the bellows 20 of Fig. 1 abuts the closure plug 19.

The lower face of bellows 20 is cupped, as at 21, to center it on a thrust pin 22 located in opening 15. The lower end of the pin seats on the upper end of a small sealing bellows 23, the lower, flared end of which is clamped by plug 10. The upper end wall of the sealing bellows also abuts or is secured to the upper end of the hollow stem 23a of a refrigerant valve, the head 24 of which seats against an insert 25 in plug 10. A pressure equalizing or vent passage 26 connects the interior of the sealing bellows with lateral bore 12.

The valve head 24 is biased towards closed position by a spring 27, the pressure of which may be adjusted in any conventional manner, as by spindle 28.

As the result of the foregoing or equivalent construction, it will be apparent that the refrigerant flow, as determined by valve head 24, is controlled directly, and with great sensitivity, in accordance with both the vapor temperature and vapor pressure conditions obtaining at a particular point in the system, specifically, at a point in the suction vapor or return line 6. The basic instrumentality of control, namely, the power element, being wholly within the vapor return line, is obviously insensitive to all extraneous thermal conditions which are of such character or duration as not to materially affect the actual demands of the evaporator. Being also virtually insulated from the body of the valve itself, the bellows is sensitive, for all practical purposes, exclusively to the temperature and pressure in the vapor return line. In this connection it will be recognized that provided the sealing bellows 23 (the interior of which is subject to evaporator inlet line pressure) is of small size, relative to that of the power element, its controlling effect on the valve stem is negligible. In this connection it may also be noted that the sealing bellows is screened or shielded from the vapor flow in line 17, whereby condensation of suction vapor on its colder surface is avoided; also that vent 26 serves to relieve any tendency of the inrush of refrigerant to expand the sealing bellows and thereby change the valve setting as dictated by the power element.

Thus, either temperature increase or pressure reduction in the vapor return line is immediately reflected in the expansion of the power element, resulting in the opening of the valve to permit the flow of additional refrigerant to the evaporator; and, conversely, either temperature decrease or pressure increase in the vapor return line is promptly reflected in the contraction of the power element and closing of the valve by spring 27, which, as will be understood,

will have been appropriately set by means of adjusting spindle 28 to suit the particular condition required to be maintained.

It will be noted that in this preferred arrangement the valve opens towards the direction from which the high pressure refrigerant enters bore 11, or in a direction opposite to that of the refrigerant flow. Also that chamber 7 constitutes a reservoir for liquid refrigerant and that such refrigerant has access to the hollow interior of valve stem 23A, thereby, by reason of its relatively high temperature, tending to keep the valve head and seat quite free from frosting or icing.

While the system above described is highly effective in the various respects noted, the particular super-heated vapor condition which is maintained is dependent upon the setting, and is invariable without manual adjustment, of spindle 28 and spring 27. However, a further feature of the invention resides in the fact that the described system can be readily adapted for further automatic control of a character to modify the action of the power element without manual readjustment of the spindle and spring setting.

For this purpose the plug 19 of Fig. 1 can be removed and substituted by a housing 29, as shown in Fig. 2. In this housing is mounted an auxiliary bellows 30, the interior of which is connected by capillary tube 31 with a bulb 32, the bellows, tube and bulb being filled, as for instance, with the same refrigerant, in liquid form, as circulates within the system, or with some other medium appropriate to the condition involved. This auxiliary bellows constitutes, in effect, an adjustable back stop for the main power element, engaging the opposite side or end thereof from the valve actuating means, and operates to superimpose on the refrigerant valve a thermal control responsive to whatever temperature change the bulb 32 is subjected to, depending upon its location to meet the needs of the particular system. For instance, if it is desired to maintain a constant air temperature in an air outlet from the evaporator, notwithstanding variations in the temperature of air flowing to the evaporator, bulb 32 would be located in such air outlet. Then, in response to temperature decrease in the outlet, the refrigerant in the bulb contracts, and, acting through the capillary, contracts the auxiliary bellows, thereby permitting spring 27 to close (or decrease the opening of) the refrigerant valve. When the air temperature condition has been corrected, the bulb liquid expands and the several parts are restored to the previous positions. As will be understood, the net effect is that of varying the evaporator capacity.

Suitable adjustment means may be provided to vary the response of the auxiliary bellows to different bulb temperatures, as diagrammatically indicated by adjustment screw 33 bearing on a bellows section 34 incorporated in bulb 32. Any conventional means may also be provided to protect the auxiliary bulb against excessive pressures.

There is thus provided what may be termed a modulating device, which functions independently of the power element, i. e. while it physically acts through the power element as a transmission member, it operates to control the refrigerant valve in accordance with the variable conditions to which it is itself subjected and without regard to the functioning (expansion and contraction) of the power element. Whereas the function of the power element is, within reasonable limits, to maintain a substantially constant super-heat condition in the vapor return line, the function of the modulating device is to vary the super-heat according to load.

As will now be recognized, the described system lends itself to a wide variety of types of control effective to meet numerous special situations where, as in the particular illustration above described, it is desirable to modify the action of the power element and valve in accordance with certain conditions extraneous to the refrigerant circulation system. Also, the modulating device can take the form of any suitable remote control, as for instance, of any of the known pneumatic types, presently used in other relationships.

In Fig. 3 of the drawing is indicated a further illustrative form of the invention diagrammatically shown as it might be applied to a larger capacity system for which the above-described complete valve unit might be inappropriate. In this application the valve body 35 may be of the same construction as above described (including the sealing bellows 23, pin 22, etc. shown in Fig. 3) excepting only that the upper end of the body is flanged, as at 36, to adapt it to be secured to the flange 37 of a short, lateral branch 38 of a large vapor return line 39. As will be understood, this vapor return is simply of a larger bore than can conveniently be accommodated within the valve body as in the Fig. 2 valve unit. As before, however, the power element is intended to be mounted wholly within the vapor line and to function as above described.

By way of illustrating another of the sundry arrangements to which the control lends itself, a dual power element is shown consisting of a divided bellows or two superimposed bellows 40 and 41. These two power elements may, for example, be differently charged, say, one as a limited vapor charged bellows and the other as a part liquid charged bellows, thereby achieving the advantages of both types in the one assembly. Also, as shown in the drawing, a modulating bellows 42 of the character above described may also be superimposed on the two power elements, and subject to control by a remote bulb 43 to which it is connected by capillary 44. All three bellows are indicated as being mounted in a cage 45 threaded on the upper end of the valve body 35. Any well known or suitable bellows travel limit mechanism such as diagrammatically indicated at 46 may be employed.

As above set forth, the function of the illustrative form of modulating device described above in the given example, viz. the maintenance of a constant air temperature in an air outlet from an evaporator, is to vary the superheat according to load changes. However, the invention is also adaptable to supplemental automatic control of a character to maintain a constant super-heat over a very wide range of refrigerant temperatures.

This is achieved as special conditions may require, by means of what may be designated a compensating device, preferably an air or gas filled, sealed bellows, which, like the power element is also subject to vapor return line pressures and which operates to off-set the otherwise excessive valve-spring pressure at and below any predetermined temperatures or pressures. Such

an arrangement is illustrated in Fig. 4 which will be briefly described.

The parts corresponding to those already described with reference to Figs. 1 and 2 are correspondingly numbered, and it will be seen that in lieu of the top closure plug 19 of Fig. 1 or the housing 29 of Fig. 2, a housing 47 is screwed into the top of the valve body. The power element in this instance is a so-called doughnut type, sealed bellows 48 which is suspended from or backed by a plate 49 which is clamped in position by housing 47. In its normal action the power element bears against a floating plate 50 which centers on pin 22. Without more, of course, this bellows 48 would function precisely like the bellows 29 already described. But within housing 47 and suspended from or backed by its top wall is a compensating bellows 51 and from the lower wall 52 of this bellows depends a thrust rod 53 which passes freely through a hole 54 in plate 49, so that the interior of housing 47, and hence bellows 51, is subject to the vapor return line pressure. The bellows 51 is gas filled at a predetermined pressure. In the drawing the lower end of rod 53 is shown as terminating short of the upper side of plate 50 and it will be understood that this is the normal condition which obtains when the vapor line pressure exceeds the predetermined pressure at which bellows 51 is filled. When the vapor line pressure falls below such predetermined pressure the lower end of rod 53 engages the back of plate 50 and thereby acts against the valve spring to supplement the action of element 48.

It will be apparent that, by selection of an effective area and sealing pressure of the compensating bellows appropriate to the refrigerant employed in the system and the particular superheat to be maintained in the vapor return line, the compensator can be caused to apply compensating or off-setting pressure to that of the valve spring whenever the vapor line temperature or pressure falls below selected limits.

In the light of the foregoing description, the following is claimed:

1. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator and a vapor return line, of means for controlling the refrigerant flow from the liquid line to the evaporator in accordance with the temperature and pressure conditions at a point in the vapor return line, and means for modifying the action of said first means in accordance with the temperature conditions at another point in the system.

2. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator, a vapor return line, and a valve to control the refrigerant flow from the liquid line to the evaporator, of a power element subject to the temperature and pressure conditions in the vapor return line, valve actuating means controlled by the power element, and means for modifying the action of said element.

3. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator, a vapor return line, and a valve to control the refrigerant flow from the liquid line to the evaporator, of a power element subject to the temperature and pressure conditions in the vapor return line, valve actuating means engaging one side of the power element and responsive to the expansion and contraction thereof, and an adjustable back stop device engaging the other side of the power element.

4. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator, a vapor return line, and a valve to control the refrigerant flow from the liquid line to the evaporator, of a power element subject to the temperature and pressure conditions in the vapor return line, valve actuating means engaging one side of the power element and responsive to the expansion and contraction thereof, and a thermally controlled back stop engaging the other side of the power element.

5. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator and a vapor return line, of a dual-compartment power element subject to the temperature and pressure conditions in the vapor return line, the compartments of the power element being differently charged, and means operated by the power element to control the refrigerant flow from the liquid line to the evaporator.

6. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator and a vapor return line, of two immediately-adjacent, differently charged bellows type power elements subject to the temperature and pressure conditions in the vapor return line, and means responsive to the combined action of said power elements to control the refrigerant flow from the liquid line to the evaporator.

7. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator and a vapor return line, of a power element subject to the temperature and pressure conditions in the vapor return line, means operated by the power element to control the refrigerant flow from the liquid line to the evaporator, and an externally controlled power element connected to and adapted to modify the action of said first-mentioned power element.

8. In a refrigerating system, the combination with a liquid refrigerant line, an evaporator and a vapor return line, of a power element subject to the temperature and pressure conditions in the vapor return line, means operated by the power element to control the refrigerant flow from the liquid line to the evaporator, a second and differently charged power element also subject to the temperature and pressure conditions in the vapor return line, said second power element being normally disengaged from said means, the effective area and charge of said second element being correlated to activate the same to engage said means in response to predetermined conditions in the vapor return line.

9. In an apparatus of the character described, the combination of an elongated valve body having adjacent the upper end thereof a chamber opening toward such upper end of the body and in the lower end of the body a chamber opening toward such lower end, removable closure means for each chamber, lateral inlet and outlet ports in the body communicating with the upper chamber, and lateral inlet and outlet ports communicating with the lower chamber, an actuating member slidably mounted in the valve body between the two chambers, a power element located in the upper chamber and operatively associated with the upper end of the actuating member, a valve in the lower chamber controlling flow between the second-mentioned inlet and outlet ports and operatively associated with the lower end of the actuating member, and means for sealing the chambers from one another.

10. The combination of claim 9 in which the power element is loosely seated on the actuating

member and is freely removable through the open end of the upper chamber upon removal of the closure for such chamber.

11. A valve structure of the character including a vapor flow passage incorporating a chamber and a power element in said chamber, a refrigerant flow passage and a valve controlling refrigerant flow through said passage, characterized by the provision of a rigid wall portion bounding the chamber on one side thereof, said wall having a restricted opening therein, and an actuator for said valve extending through said opening for engagement by the said power element.

12. A valve structure of the character including a vapor flow passage incorporating a chamber and a power element in said chamber, a refrigerant flow passage and a valve controlling refrigerant flow through said passage, characterized by the provision of a rigid wall portion bounding the chamber on one side thereof, said wall having a restricted opening therein, and an actuator for said valve comprising a thrust pin seated in and substantially filling said aperture, with freedom for movement therein, said pin extending into the said chamber for engagement by the power element.

13. A valve structure of the character including a vapor flow passage incorporating a chamber and a power element in said chamber, a refrigerant flow passage and a valve controlling refrigerant flow through said passage, characterized by the provision of a rigid wall portion bounding the chamber on one side thereof, said wall having a restricted opening therein, a sealing bellows obstructing flow between the said chamber and the said refrigerant passage by way of said opening and an actuator for said valve extending through said opening for engagement by the said power element.

14. A valve structure of the character including a vapor flow passage incorporating a chamber and a power element in said chamber, a refrigerant flow passage and a valve controlling refrigerant flow through said passage, characterized by the provision of a rigid wall portion bounding the chamber on one side thereof, said wall having a restricted opening therein, a sealing bellows obstructing flow between the said chamber and the said refrigerant passage by way of said opening and located on the side of said wall remote from the said chamber and an actuator for said valve extending through said opening for engagement by the said power element.

15. A valve structure of the character including a vapor flow passage incorporating a chamber and a power element in said chamber, a refrigerant flow passage and a valve controlling refrigerant flow through said passage, characterized by the provision of a rigid wall portion bounding the chamber on one side thereof, a sealing chamber on the side of the wall remote from the power element chamber, said wall having a restricted opening connecting the two chambers, an actuator for said valve extending through said opening for engagement by the said power element, and sealing means in said sealing chamber obstructing refrigerant flow between the said flow passages, said sealing means having a substantially smaller effective area than the said power element.

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