REFRIGERATION COMPRESSOR CAPACITY CONTROL SYSTEM

Filed Nov. 14, 1968 3 Sheets-Sheet 1

FIG. 1

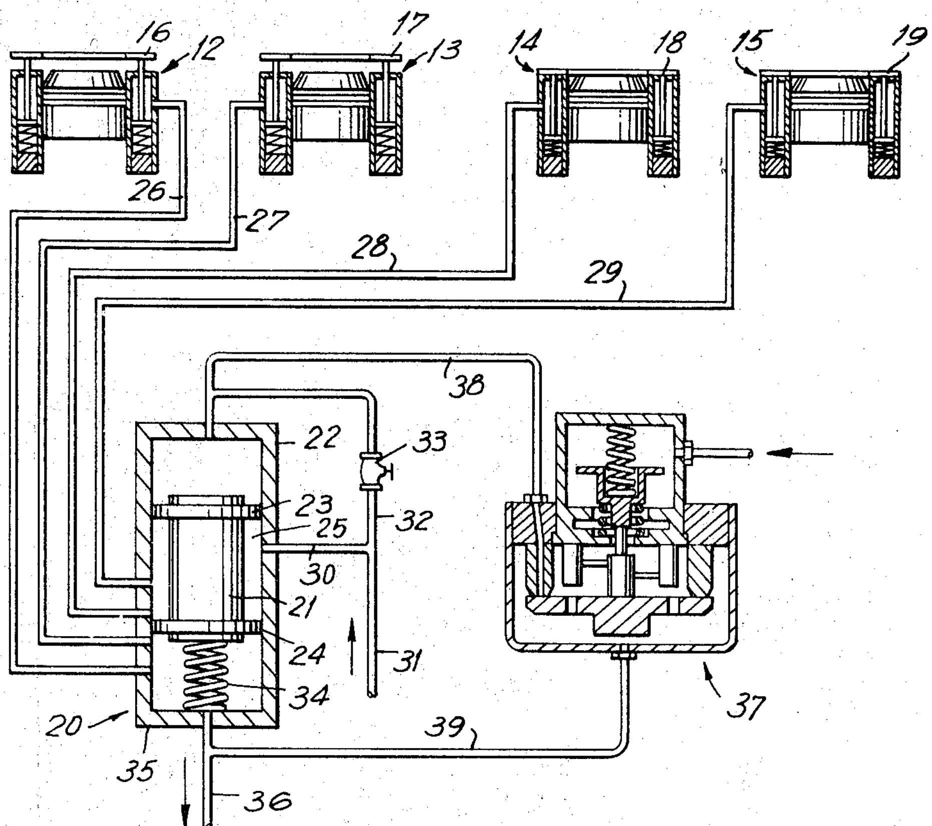


FIG. 2

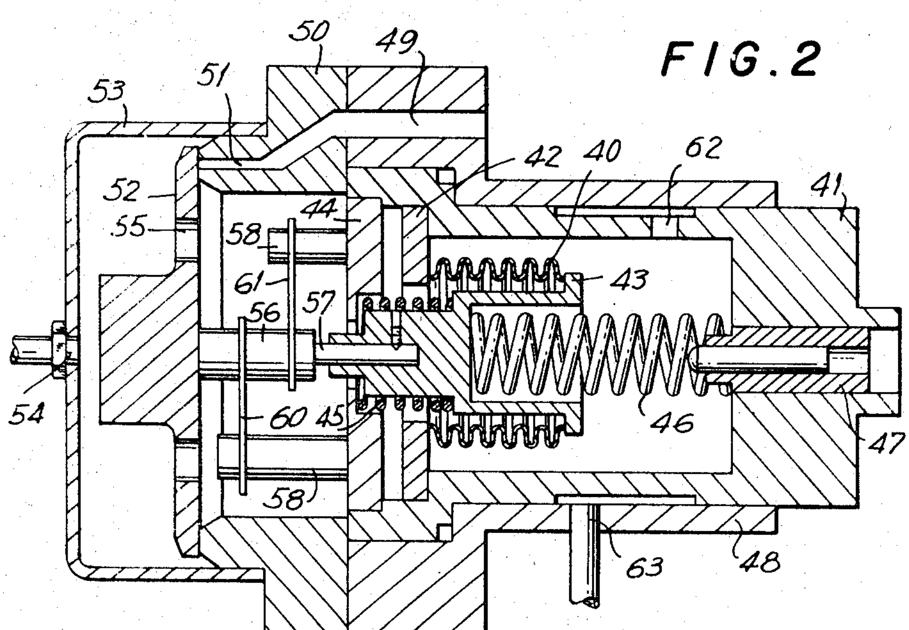


FIG. 3

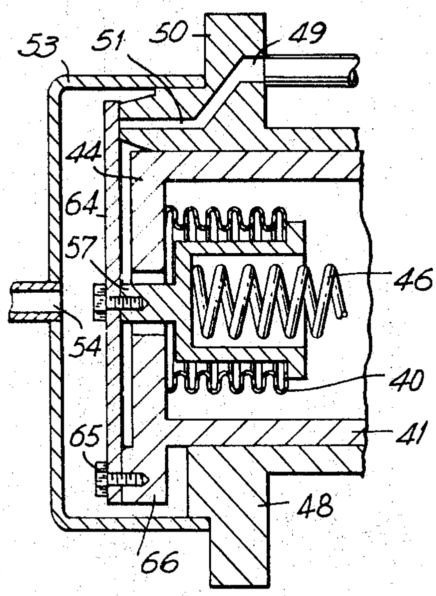


FIG. 4

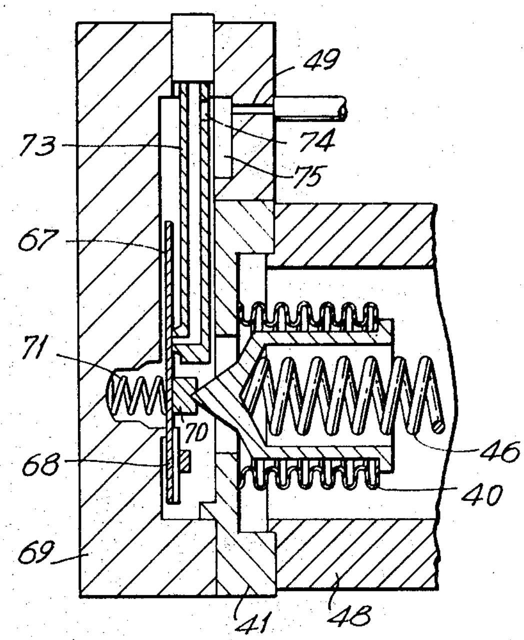


FIG. 9

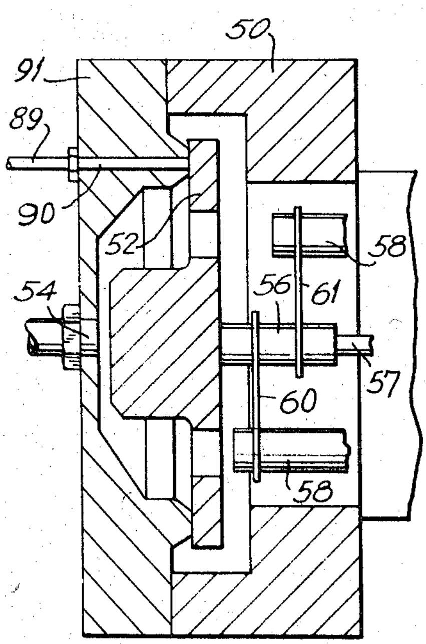
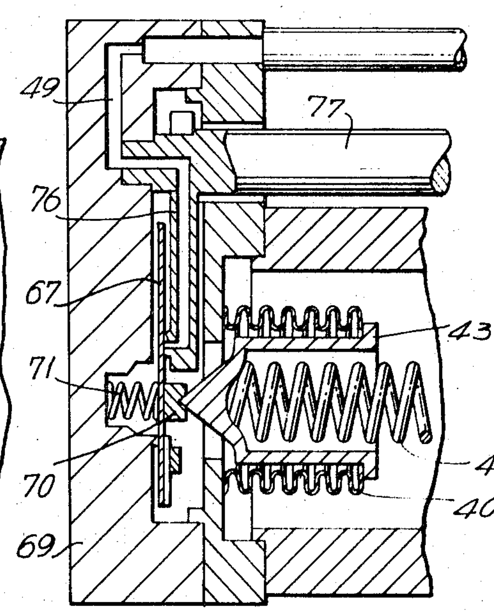
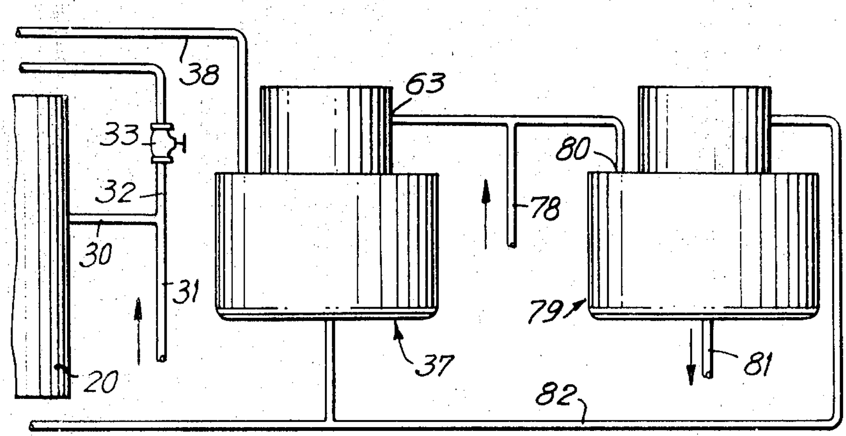


FIG. 5



REFRIGERATION COMPRESSOR CAPACITY CONTROL SYSTEM

FIG. 6



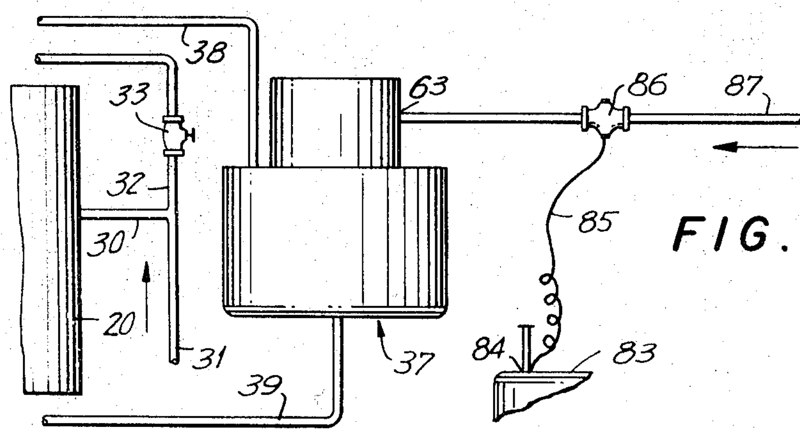
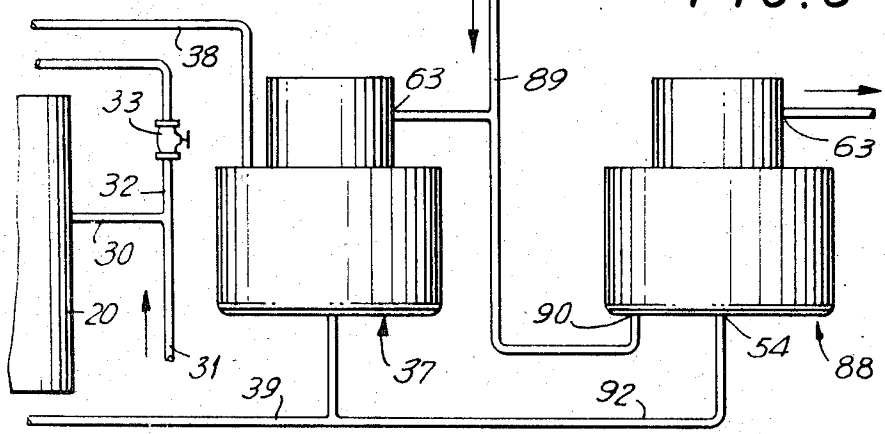


FIG. 7

FIG. 8



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REFRIGERATION COMPRESSOR CAPACITY CONTROL SYSTEM

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Int. Cl. F25b *4/00*
U.S. Cl. 62—196 5 Claims

ABSTRACT OF THE DISCLOSURE

A multi-cylinder refrigeration compressor capacity control system, in which a plurality of compressor unloader mechanisms are operated by means of a capacity control valve having a displaceable valve member the position of which is adjustable in response to the compressor suction pressure in cooperation with an opposed valve actuating pressure. The actuating pressure is varied by means of a pressure control valve in accordance with the required amount of cold, the pressure control valve connecting the compressor suction side to the actuating pressure side of the capacity control valve through a nozzle. A nozzle-closing plate can be positioned in a more or less inclined position by a spring-loaded bellows, and the nozzle and nozzle-closing plate are rotationally adjustable in relation to one another.

In multi-cylinder refrigeration compressors, the number of individual cylinders in service should correspond to the amount of cold required, and to this end an unloader mechanism operates hydraulically on power from the oil pressure of the lubricating system to load and unload the cylinders in response to suction pressure variations. Thus, the unloader mechanism provides automatic capacity control and also permits the compressor to start unloaded. Without oil pressure the unloader mechanism holds suction valves open so that the associated cylinders operate unloaded. Under oil pressure the unloader permits suction to function normally and cylinders to operate at full capacity.

The unloader mechanism comprises two distinct components one of which is a suction valve lifting device for each of the cylinders, and the other component is a capacity control valve which, in response to suction pressure variations, connects a suitable number of the unloader mechanisms to the oil pressure, or to the crankcase. The position of the capacity control valve is determined by the suction pressure in the crankcase on one hand, and by the actuating oil pressure on the other hand, and to adjust the range of cold the oil pressure acting on the capacity control valve can be varied partly by a throttle valve in the oil supply line leading to the control valve, partly by a pressure control valve connected between the throttle valve and the capacity control valve.

The main object of the present invention is to provide a novel and improved pressure control valve for controlling the actuating pressure on the capacity control valve.

Another object is to indicate a capacity control system for continuous adjustment of the controlling range without the need for replacement of springs and/or displacement of lever fulcrums or the like.

A further object of the invention is the provision of a novel pressure control valve including a bellows, the expansion and contraction of which, in response to variation of the crankcase pressure against the action of spring means, serves to open and close a nozzle connected to the control oil pressure applied to the capacity control valve.

A still further object is to improve the continuous operation of the pressure control valve by varying the pressure around the bellows, hereinafter called the pilot pressure.

The invention will be better understood by reference to the drawings in which:

FIG. 1 shows a refrigeration compressor capacity control system embodying the present invention,

FIG. 2 is a sectional view of a first embodiment of a pressure control valve according to the invention, said valve being also useful as a pressure transmitter for controlling the pilot pressure supplied to the pressure control valve,

FIG. 3 shows an alternative embodiment of the pressure control valve according to FIG. 1, in which the nozzle-closing plate is of a different construction,

FIG. 4 shows a further embodiment of the pressure control valve of the invention, in which the discharge opening of the nozzle is radially displaceable,

FIG. 5 is an alternative similar to FIG. 4 with the exception that the nozzle is adjustable along a circular arc,

FIG. 6 shows a portion of the system as shown in FIG. 1, with a pressure transmitter being added,

FIG. 7 is similar to FIG. 6, only the pressure transmitter being replaced by a thermostatic pressure transmitter,

FIG. 8 is similar to FIG. 6, except that the pressure transmitter and its connections are different, and

FIG. 9 is a sectional view of a pressure transmitter as used in the system according to FIG. 8, said pressure transmitter being mainly as the one shown in FIG. 2, only the arrangement of nozzle-closing plate being amended.

In FIG. 1, a capacity control system of a multi-cylinder refrigeration compressor is shown, in which the unloader mechanisms of the compressor cylinders are of any suitable conventional kind. In the embodiment as shown the number of cylinders are four, indicated by **12**, **13**, **14** and **15**, respectively, and the suction valves **16**, **17**, **18** and **19** are in the form of annular valve rings which are arranged to be lifted from their seats on the cylinders by lifter pins. Hydraulic pressure for operation of the unloader mechanisms is supplied from the oil pressure system of the compressor, preferably through a capacity control valve **20**.

The capacity control valve **20** includes a slide valve **21** which is displaceable within a housing **22** and is provided with a pair of annular ribs **23** and **24** adjacent its opposite ends to define a chamber **25**. The axial length of said chamber **25** is sufficient to overlie all the openings of a plurality of conduits **26**, **27**, **28** and **29** connected to the side wall of the valve housing and leading to the respective unloader mechanisms of the compressor cylinders **12**, **13**, **14** and **15**. The openings of conduits **26**, **27**, **28** and **29** are longitudinally spaced in relation to one another so as to enable either of the annular ribs **23** and **24** to be positioned in engagement with the wall between subsequent conduit openings.

On the other side wall of the valve housing **22** an oil pressure supply conduit **30** is connected at a position so as to be in communication with the chamber **25** at all times when the slide valve is moving in either direction.

Thus, oil pressure is supplied to one or more of the conduits **26**, **27**, **28** and **29** leading to the compressor cylinders when the respective conduit is in communication with chamber **25**. As shown, oil pressure is supplied to cylinders **14** and **15** while cylinders **12** and **13** are unloaded.

The supply conduit **30** is connected to the oil lubrication system of the compressor, not shown, through a main supply conduit **31** which is also connected, through a line **32** with a throttle valve **33**, to the top of valve housing **22**, whereby oil pressure upon being reduced in throttle valve **33** serves to urge the slide valve member **21** downwards against the action of a spring **34**. The lower end wall **35** of housing **22** is in communication, through a relief conduit **36**, with the crankcase of the compressor, not shown, so that suction pressure prevails in the interior of the valve housing **22** beneath the slide valve member. As a result, the suction pressure will be connected through conduits **26** and **27** to the unloader mechanisms of cylinders 12 and **13**.

To adjust the range of operation within certain limits, the decreased oil pressure acting through conduit **32** on the top of slide valve member **21**, can be varied by adding to the control system a pressure control valve **37**. Pressure control valve **37** is connected through a line **38** to the top of capacity control valve housing **22**, and through a line **39** to the bottom of said housing **22**.

The present invention concerns the arrangement and construction of the pressure control valve **37** which serves to control the actuating pressure in the capacity control valve **20**. The details of the pressure control valve **37** as shown in FIG. 1 will hereinafter be explained with reference to FIG. 2.

In FIG. 2 a bellows **40** is confined in a bellows housing **41** and with its ends it is hermetically attached to an end plate **42** as well as to a bellows mandrel **43** which is displaceable in the housing, said mandrel extending with one end through the end plate **42** and an end wall **44** of the bellows housing **41**. The bellows mandrel **43** is maintained in position by means of helical springs **45** and **46**, the former abutting against the end wall **44** and the latter against an adjustable stop **47**, which is guided axially in the end of the bellows housing and can be adjusted from without.

The bellows housing **41** is rotatable in an outer housing **48** for a purpose to be subsequently explained. A bore **49** is provided in the outer housing for the admission of a pipe or duct, not shown, which is in connection with the actuating pressure on the capacity control valve of the compressor, said pressure determining the number of compressor cylinders to be engaged. The outer housing **48** is closed with a cover **50**, wherein a nozzle **51** is provided so as to be in connection with the bore **49** and to open out in the edge of the cover, and a nozzle-closing plate **52** is placed over the edge of the cover. A hood **53** fitted on the cover **50** surrounds the nozzle-closing plate, said hood having an aperture **54** which is in connection with the suction side of the compressor, e.g. the crankcase.

The nozzle-closing plate **52** is substantially shaped as a disc, provided with a number of holes **55**, and which in the embodiment shown in FIG. 2 at its center has a projection **56** attached thereto and protruding towards the bellows mandrel, said projection being axially and rotationally in fixed connection with the bellows mandrel **43** through a spindle **57** protruding inwardly into the mandrel, said spindle being secured in the bellows mandrel by means of e.g. a pointed screw. Eccentrically disposed in relation to the projection **56**, and at substantially diametrically opposite sides thereof, are two projections or pins **58** and **59** attached to the end wall **44** of the bellows housing, said projections being connected through two leaf springs **60** and **61**, respectively, to the projection **56** of the nozzle-closing plate at axially spaced places.

Through an opening **62** in the bellows housing and an opening **63** in the outer housing, the space in the bellows housing **41** surrounding the bellows **40** is connected with a source of pilot pressure, which is primarily the atmospheric pressure, when the pressure control valve herein described is used without a pilot pressure governor.

At decreasing compressor load, the suction pressure in the crankcase of the compressor will fall, and through the aperture **54** in the hood **53** and the openings **55** in the nozzle-closing plate, the pressure variation will be transmitted to the interior of the bellows. This causes the bellows to contract, so that the nozzle-closing plate **52** is lifted from the nozzle **51**, and through the bore **49** the pressure acting on the capacity control valve is thereby equalized to a greater or smaller extent corresponding to the degree of opening of the nozzle, so that the sliding control valve changes the number of cylinders engaged.

At a certain adjustment of the desired cooling range by means of the stop **47**, the degree of opening of the nozzle **51** is determined by the angular position of the projections **58** and **59** in relation to the nozzle **51**. When, as shown in FIG. 1, the projections **58** and **59** lie in an axial plane containing the nozzle **51**, the nozzle-closing plate **52** will, when moved to the left, take up an oblique position due to the fact that the attachment points on projection **56** of the springs **60** and **61** will tend to follow curves in opposed direction. Thereby, the plate **52** will be rocked about an axis which is perpendicular to the plane of the drawing at a place diametrically opposite the nozzle and farther away from the projection **56** than is the nozzle. If the plane of the projections **58** and **59** is swung in relation to the plane of the drawing, wherein the nozzle **51** and the projection **56** lie, and this may be effected in the embodiment shown in FIG. 1 by rotating the bellows housing **41**, the nozzle **51** will, for the same rocking of the nozzle-closing plate, be in a position opposite a point of the edge portion of the nozzle-closing plate which has a smaller distance from the nozzle, and thereby its degree of opening will have been reduced.

In the embodiment shown in FIG. 2 the nozzle-closing plate **52** is rotated together with the bellows housing **41** on account of the rotationally fixed connection through the projections and the leaf springs. However, other embodiments are possible according to the invention to provide the resilient oblique positioning of the nozzle-closing plate in relation to the nozzle. For example, according to the invention, the pressure control valve may be altered as shown in FIG. 3 by omitting the leaf springs and making the nozzle-closing plate itself resilient, in which case the nozzle-closing plate is connected to the bellows housing at a point on its marginal edge portion, more particularly the point which in FIG. 1 is nearest to the projection **58**.

In FIG. 3, corresponding parts have the same references as similar parts in FIG. 2. However, the projections are omitted, and the nozzle-closing plate **64** has a point of its marginal portion secured at **65** to a protruding part **66** of the bellows housing **41**. Thus, upon expansion of the bellows **40**, the nozzle-closing plate will be retained at **65** and assume an inclined position. In this embodiment the plate **64** is of elastic material. The part **66** and the point **65** of the plate **64** is rotatable with the bellows housing **41** relative to the stationary nozzle **51** so that the degree of opening of the nozzle will be decreased when turning the plate away from the plane of the drawing.

As will appear from FIG. 4, the nozzle-closing plate needs not be rotatable at all in the case of resilient or elastic material. In FIG. 4, the nozzle-closing plate **67** is secured at **68** to a cover **69** and has a portion **70** which is urged towards the bellows by means of a spring **71**. Thus, the nozzle-closing plate **67** is rotationally stationary in relation to the bellows. However, the nozzle is adjustable in relation to the plate **67** by being formed in an arm **73** which is longitudinally adjustable towards and away from the engagement point **70** between bellows and nozzle-closing plate. The arm **73** is bored and has an aperture **74** in its side wall for communication with a chamber **75** in connection with bore **49**.

The alternative embodiment as shown in FIG. 5 is similiar to that in FIG. 4 except that the nozzle arm **76** is swingable about the axis of an adjustment spindle **77**.

In the pressure control valve heretofore described the degree of contraction of the bellows will be determined by the suction pressure in the interior of the bellows and the atmospheric pressure which is also present in the space defined by the housing **41** around the bellows. Now, a further regulation by means of the pressure control valve can be obtained by replacing the atmospheric pressure around the bellows by a pilot pressure which is controlled in a suitable manner, e.g. in dependence on the suction pressure in the compressor, i.e. corresponding to its load. Such pilot pressure can suitably be provided by means of a pressure transmitter whose construction is identical with the pressure control valve herein described, only the connections being different.

A first arrangement for this purpose is illustrated in FIG. 6, in which compressed air is used for the production of the pilot pressure.

In FIG. 6, the opening **63** in the pressure control valve **37** is connected to a compressed air pipe **78** which is also connected at **80** to the nozzle in a pressure transmitter **79** through a bore corresponding to bore **49** in the pressure control valve **37**.

The aperture in the transmitter which corresponds to aperture **54** in valve **37**, communicates with the atmosphere through a line **81**, while the space surrounding the bellows in the pressure transmitter is connected through a line **82** to the suction side of the compressor. Thus a decreasing suction pressure will keep the nozzle-closing plate in transmitter **79** closed, so that the pilot pressure at **80** rises. The increasing pilot pressure is transmitted through opening **63** to the space surrounding the bellows in the pressure control valve **37** so that the bellows is compressed and the nozzle **51** is opened, thereby causing the capacity control valve **20** to unload one or more compressor cylinders until operational balance has been restored.

An alternative method of controlling the pressure supplied to the capacity control valve **37** is illustrated in FIG. 7. In this arrangement the varying demand for cold is made use of in a different way to adjust the actuating pressure at **63** of the capacity control valve **37**. In the evaporator **83** of the refrigeration plant a feeler **84** is disposed, and the varying temperature of the evaporator is transmitted through the capillary line **85** to a thermostatic valve **86** inserted in a conduit **87** leading to the capacity control valve **37** from the pressure side of the compressor. Thus, the pilot pressure in the capacity control valve **37** is supplied by gaseous coolant.

The gaseous coolant may also be utilized in a different way as the source of pilot pressure in the capacity control valve. In case of utilizing the gaseous coolant to this purpose, it is important that the coolant should not be wasted by allowing it to escape through the aperture **54** of a pressure transmitter to the atmosphere. Consequently, when adapting a pressure control valve **37** according to FIG. 2 as the pressure transmitter **88** in the arrangement as shown in FIG. 8, a few modifications must be made, as will appear from FIG. 9, the rest of the pressure governor remaining as in FIG. 2 with atmospheric pressure transmitted through opening **63** to the space surrounding the bellows.

In FIG. 9, the pressure transmitter is merely distinguished from FIG. 1 in that the nozzle-closing plate **52** opens in the opposite direction. The coolant pressure is supplied through a conduit **89**, as shown in FIG. 8, to serve as the pilot pressure at **63** for the capacity control valve **37**, as well as at a nozzle **90** in the hood **91** of the pressure control transmitter **88**. When the nozzle **90** is opened, the coolant will flow to the suction side of the compressor through the aperture **54** connected through a line **92** to the line **39** leading to the crankcase. When a decreasing suction pressure causes the nozzle-closing plate **52** in the pressure transmitter **88** to close the nozzle **90**, the pilot pressure will rise, and the rising pilot pressure is transmitted to the space surrounding the bellows in the associated pressure control valve **37**, the nozzle of which will be opened, whereby the pressure acting on the capacity control valve **20** is decreased. As a result, one or more compressor cylinders will be unloaded.

Having thus fully described our invention we claim as new and desire to secure by Letters Patent:

1. A multi-cylinder refrigeration compressor capacity control system, which comprises an unloader mechanism for each compressor cylinder, a capacity control valve, conduit means connecting said capacity control valve to either of said unloader mechanisms, a crankcase in said compressor, passage means to communicate said crankcase with said capacity control valve, oil pressure supply means connected to said capacity control valve, a pressure control valve, conduit means connecting said pressure control valve to said capacity control valve and to said oil pressure supply means, passage means between said crankcase of the compressor and said pressure control valve, a bellows within said pressure control valve, a nozzle in said pressure control valve connected to said conduit means connecting said pressure control valve and said capacity control valve, said nozzle opening into the interior of said pressure control valve at a position in communication with the interior of said bellows, a disc-shaped nozzle-closing plate attached to said bellows for axial movement thereof in response to expansion and contraction of said bellows, spring means for biasing said bellows with said nozzle-closing plate in a direction for opening said nozzle against the action of said compressor crankcase pressure and of said oil pressure, and the attachment of said nozzle-closing plate and said bellows being arranged so that, when axially displaced in a direction away from the nozzle, the nozzle-closing plate will be positioned in an inclined plane relative to the axial direction, and furthermore, the distance between the nozzle and the nozzle-closing plate is variable by relative rotation between said plate and said nozzle.

2. A capacity control system according to claim **1**, in which the center of said nozzle-closing plate is axially and rotationally movable with said bellows, and points on said plate spaced from the center thereof are non-rotationally connected through axially yielding spring means to a member rotatable with said bellows.

3. A capacity control system according to claim **1**, in which the center of said nozzle-closing plate is integrally attached to said bellows, said nozzle-closing plate being of resilient and springy material, and a point of said plate adjacent an edge thereof being attached to and rotatable with said bellows or a member rotatable with said bellows.

4. A capacity control system according to claim **1**, in which the nozzle-closing plate is resilient and elastic and is secured to a part of the pressure control valve casing at a point spaced from the point of engagement with the bellows whereby the nozzle-closing plate is capable of being inclined relative to the axial direction of the bellows upon axial expansion of the latter, a spring means being provided opposite said point of engagement to urge the nozzle-closing plate towards the bellows, a hollow nozzle-defining arm being rotationally adjustable in a plane substantially at a right angle to the axial direction of said bellows about a point spaced from said point of engagement between said bellows and said nozzle-closing plate whereby upon rotation of said nozzle-defining arm the distance between the nozzle opening and said point of engagement can be adjusted.

5. A capacity control system according to claim **1**, in which the nozzle-closing plate is resilient and elastic and is secured to a part of the pressure control valve casing at a point spaced from the point of engagement with said bellows whereby the nozzle-closing plate is capable of being inclined relative to the axial direction of the bellows upon axial expansion of the latter, a spring means being provided opposite said point of engagement to urge the nozzle-closing plate towards said bellows, a hollow nozzle-defining arm having a nozzle discharge opening facing said nozzle-closing plate at the same side thereof as is said bellows, said nozzle-defining arm being radially adjustable in a plane perpendicular to the longitudinal axis of said bellows.

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WILLIAM J. WYE, Primary Examiner

U.S. Cl. X.R.

62—510, 117; 230—26