March 23, 1937. W. NOBLE 2,074,803

AIR COMPRESSOR

Original Filed Feb. 28, 1934 2 Sheets-Sheet 1

Fig. 1.

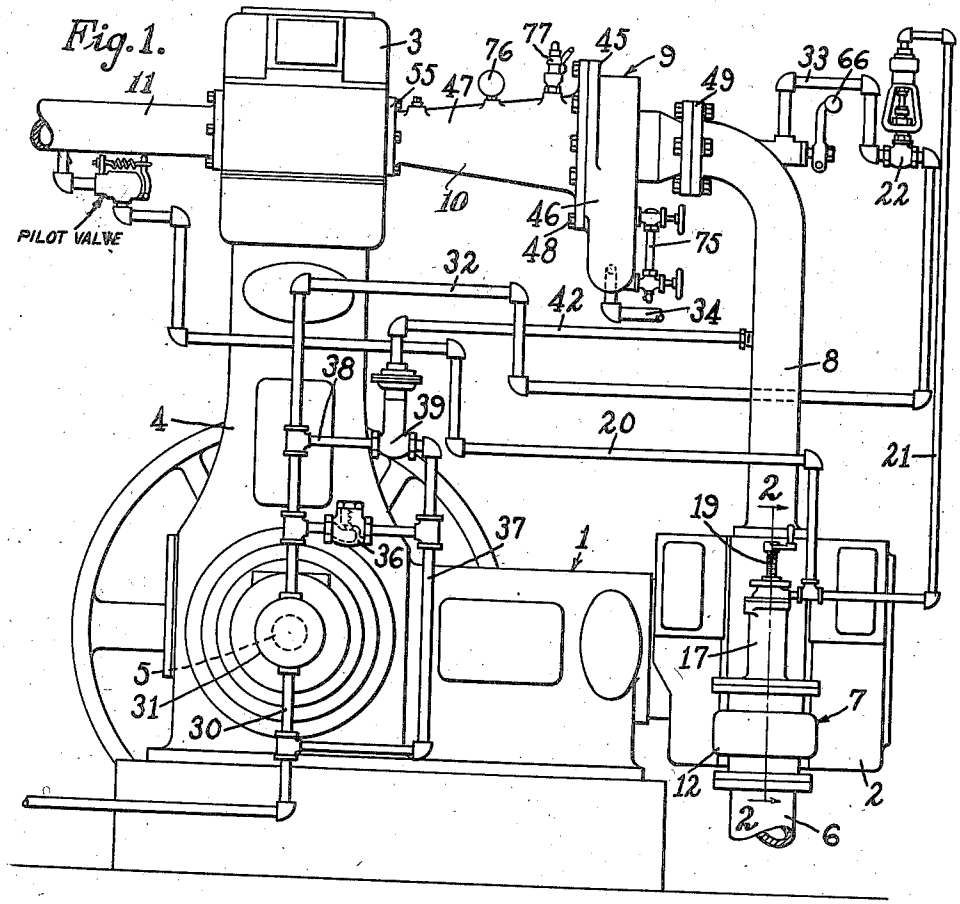


Fig. 2.

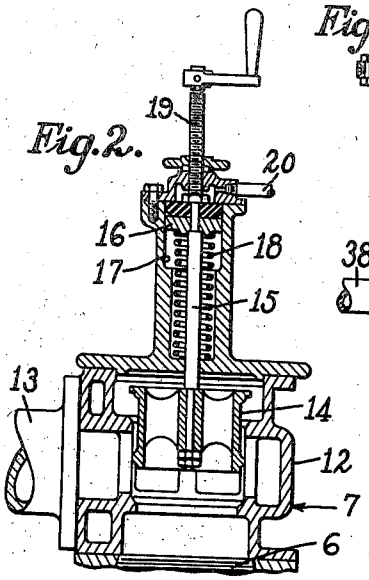


Fig. 4.

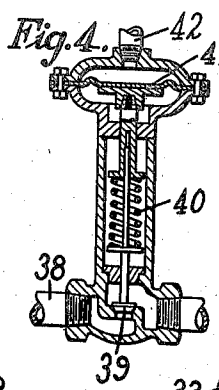
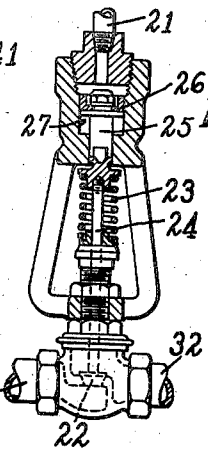


Fig. 3.



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Fig.5.

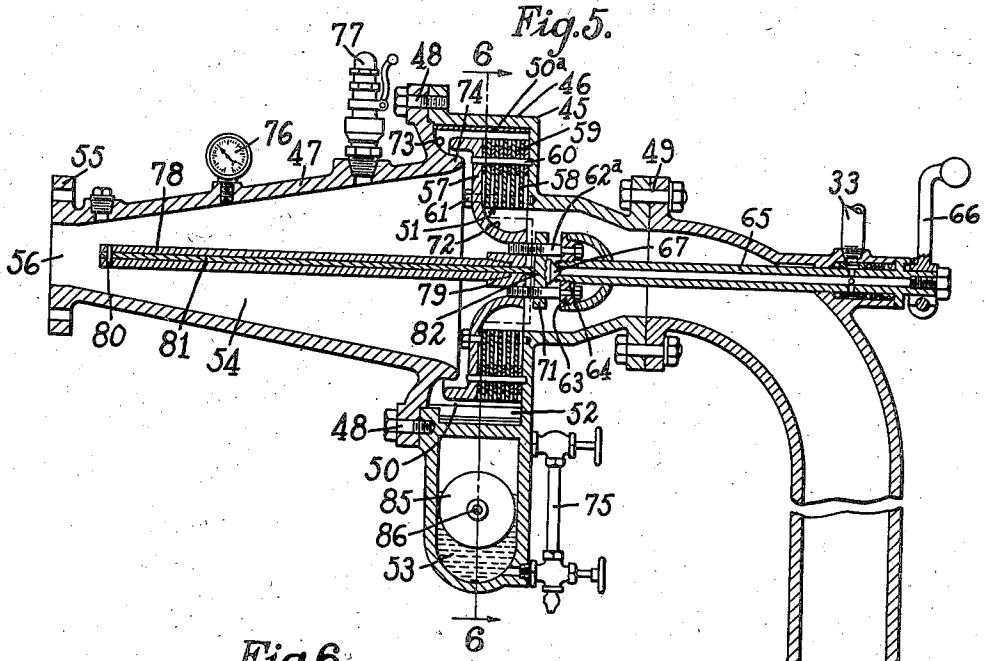


Fig.6.

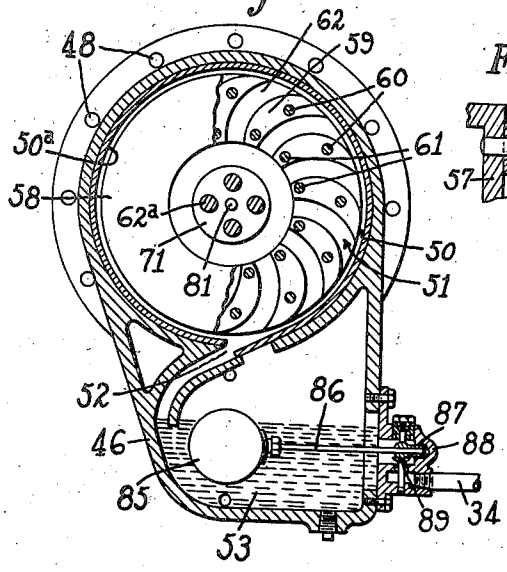


Fig.7.

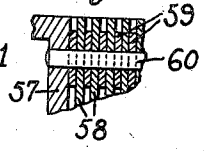


Fig.8.

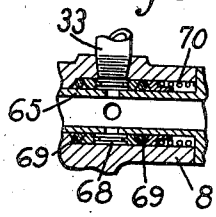
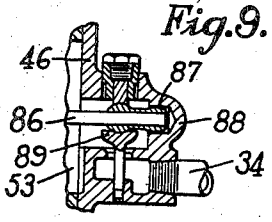


Fig.9.



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UNITED STATES PATENT OFFICE

2,074,803

AIR COMPRESSOR

Warren Noble, Michigan City, Ind., assignor to Sullivan Machinery Company, a corporation of Massachusetts

Original application February 28, 1934, Serial No. 713,333. Divided and this application November 16, 1934, Serial No. 753,361

15 Claims. (Cl. 230—182)

This invention relates to air compressors and more particularly to compound air compressors having an improved intercooling means.

An object of this invention is to provide an improved multi-stage compressor having improved intercooling means of the direct mixture type, that is to say, the type in which the air to be cooled and the cooling agent are directly intermingled and then separated prior to the time when the air enters the next higher stage of the compressor. Another object of the invention is to provide an improved compressor intercooler having improved controlling means whereby damage to the compressor due to the passage into any stage of the compressor of liquid admitted to the intercooler may be avoided. A further object is to provide an improved compressor having an improved cooling system involving the direct inter-mixture of the cooling liquid and the partially compressed air, having improved cooling liquid supply and controlling means governed by automatic means in accordance with the loaded or unloaded condition of the compressor, and controlled in addition in accordance with pressure conditions. A still further object of the invention is to provide an improved air compressor which constitutes not only an efficient means for compressing air, but also means for washing the air as it traverses the compressor and is compressed therein. These and other objects and advantages will, however, hereinafter more fully appear.

In the accompanying drawings there is shown for purposes of illustration one form which the invention may assume in practice, and in these drawings:

Fig. 1 is a side elevation of a fluid compressor or pump having embodied therein improved intercooling apparatus and controlling means therefor, in accordance with the illustrative embodiment of my invention;

Fig. 2 is a detail sectional view taken substantially on line 2—2 of Fig. 1 and showing the intake unloading means for the low pressure cylinder;

Fig. 3 is a detail sectional view showing an automatic controlling valve for the cooling liquid supply, operative to interrupt such supply on unloading;

Fig. 4 is a sectional view through an automatic by-pass valve for regulating the supply of the cooling liquid;

Fig. 5 is an enlarged vertical sectional view showing the internal construction of the improved intercooler;

Fig. 6 is a cross sectional view taken substantially on line 6—6 of Fig. 5;

Fig. 7 is a fragmentary sectional view showing details of construction of the separating discs;

Fig. 8 is a detail sectional view showing the packing gland for the cooling fluid inlet;

Fig. 9 is a fragmentary sectional view showing in detail the construction of the liquid drain control valve.

The mode of operation of my improved intercooling apparatus may be readily understood by considering the conditions which prevail at times when a fog stands over a river or the like, and there occurs a short shower. The rain washes the fog from the air and thereby removes the water vapor, which is entrained with the raindrops.

Referring to the drawings, it will be noted that a fluid compressor or pump generally designated 1, and herein of what is termed the angle-compound type, comprises a low pressure cylinder 2 and a high pressure cylinder 3. The cylinders are mounted upon a suitable frame 4, and each contains a piston (not shown) actuated from the common compressor crankshaft 5. The low pressure cylinder has an intake pipe 6, controlled by an intake unloading mechanism generally designated 7, for supplying air to it; and a discharge pipe 8 leads from the discharge side of the low pressure cylinder to the intercooling apparatus which is generally designated 9. The latter is herein arranged in the angular space between the low and high pressure cylinders, and a discharge connection 10 from the intercooler leads to the intake of the high pressure cylinder, and after further compression in the high pressure cylinder compressed fluid is discharged through a pipe 11. The unloading mechanism 7 is of the total-intake-closure type, and comprises a casing 12 to which fluid is admitted directly from the atmosphere through the intake pipe 6, and the air at atmospheric pressure passes from this casing through a pipe 13 to the low pressure cylinder inlet space under the control of the double seat valve 14 which is adapted to be actuated through a stem 15 by piston 16 reciprocable in a cylinder 17 supported on top of the casing 12. Valve 14 is normally held in open or loading position by a spring 18, and when the valve is in this position fluid may be drawn in freely to the intake of the low pressure cylinder 2. The unloader valve is closed to effect unloading by the action of pressure fluid upon the piston 16 in the cylinder 17, and the amount of opening movement of the valve

14 is controlled by an adjustable stop 19. For the purpose of controlling the pressure supply to the cylinder 17, there is provided unloading mechanism including a usual pilot valve mechanism marked "Pilot Valve" (details not shown) which may be any of the well-known types, as, for instance, the R. Conrader valve, which operates in a well-known manner in response to predetermined high discharge line pressure to establish a connection between the discharge line and the unloader cylinder 17 by way of a pipe 20 leading from the discharge pipe 11 to the upper end of the cylinder 17, as shown in Fig. 2. When the discharge line pressure drops below a desired minimum, the pilot valve operates to vent the line 20 and permit the spring 18 to reopen the valve 14. Also connected to the pipe line 20 is a pipe line 21 which supplies pressure fluid to an automatic control valve for the cooling liquid supplied to the intercooler, in a manner to be presently described, to effect interruption of the liquid supply to the intercooler during unloading. This water control valve, as shown in Fig. 3, comprises an end seating valve 22 of usual design and normally held open by a coiled spring 23 acting on a plunger 24 connected to the valve element. Secured to the upper end of this plunger is a piston rod 25 of a piston 26, the latter being reciprocably mounted in a cylinder 27, with whose upper end the pipe line 21 communicates so that when pressure fluid is supplied to the pipe line 20, it also passes through pipe 21, and thereby acts on the piston 26 and moves the latter downwardly, and thereby closes valve 22 to interrupt liquid flow.

To repeat somewhat, it will thus be seen that when the compressor discharge pressure reaches a predetermined minimum the pilot valve mechanism operates to interrupt fluid supply to and to vent the line leading from the unloader cylinder 17, and thereby also to vent the line 21 connected to the automatic cooling liquid control valve 22, these operations respectively resulting in the opening of the intake valve to reload the compressor, and opening of the valve 22 so that, as will later be explained, cooling liquid may be supplied to the intercooler. When the pressure in the pressure discharge line reaches a predetermined maximum, the pilot valve mechanism operates to supply pressure fluid through the pipe line 20 to the unloader cylinder 17, thereby causing the piston 16 to close the valve 14 and effect unloading, and at the same time pressure fluid passing through the pipe 20 flows on through the pipe 21 and acts on the piston 26 and closes the valve 22, thereby insuring interruption of liquid supply to the intercooler promptly upon unloading. Since the unloading mechanism and water control valve heretofore mentioned are of well-known design and do not per se enter into this invention, further detailed description thereof is unnecessary.

The cooling liquid for the intercooler 9 is conducted from any suitable source through a pipe line 30 to a pump 31 of suitable design, driven by the compressor crank shaft 5, and the cooling liquid is forced by the pump under relatively high pressure through a pipe line 32 to the automatic liquid control valve 22 and from the other side of the latter passes through a pipe line 33 to the intercooler. When city water pressure is available, the pump 31 may be eliminated and the pipe line 32 connected to the city water supply, provided the latter is at a high enough pressure. The cooling liquid after use in the intercooler 9 is discharged from the latter through a pipe line 34, but may be led off to any desired point for discharge.

When the cooling water supply is effected by the pump 31 it is necessary to maintain an appropriate pressure, which must exceed by a substantial amount the pressure at the discharge side of the low pressure cylinder, in order to create and maintain an effective liquid screen. For safety purposes a spring-loaded by-pass check valve 36 is arranged to communicate with a connection 37 leading back to the intake side of the pump. A second by-pass connection is also provided at 38 between the pump discharge and intake controlled by a valve 39, which is adapted to be held seated by a spring 40. Spring 40 is not substantially tensioned during the normal unloaded operation of the compressor and, therefore, permits the pump 31 to operate without material loss of power when no liquid is required to be supplied to the intercooler. However, when liquid must be supplied to the intercooler, means including a diaphragm 41 subjected to pressure through a line 42 leading from the low pressure cylinder discharge line 8, imposes a pressure upon the spring 40 and thus upon the valve 39, this arrangement permitting flow over to the suction side of the pump, past the valve 39 only when the pressure in the line 32 very substantially exceeds the amount desired in the intercooler, a condition not likely to occur. The valve 36 may advantageously be set to open at a lower pressure than the pressure required to open the valve 39 when pressure in the pipe 8 during loaded operation of the compressor acts upon the diaphragm 41. In other words, 36 is the normal pressure limit controlling means.

Now referring to the structure of the improved intercooler per se, it will be noted that the same comprises a casing 45 herein composed of two parts 46 and 47 bolted together at 48, and a bolted flanged connection 49 connects the casing to the discharge pipe 8 of the low pressure cylinder 2 of the compressor. The portion 46 of the intercooler casing has formed therein a circular chamber 50 in which an improved cooling and separator unit generally designated 51 is arranged; and discharge from the unit 51 passes through a bottom opening 52 to a cooling liquid discharge chamber 53, at the bottom of which the discharge pipe line 34 is connected. Chamber 50 is preferably lined with a non-corrosive liner 50*a*, preferably of stainless steel, and provided with an extremely smooth, highly polished inner-surface water race, and one end of this liner is bent downwardly to form a discharge opening 52. Section 47 has a fluid discharge passage 54, communicating with the intake of the high pressure cylinder of the compressor, casing section 47 being bolted to the high pressure cylinder by means of a flange and bolt connection 55. The passage 54 tapers onwardly from the cooling and separator unit 50 and communicates with the high pressure cylinder intake through a relatively restricted passage 56, the compressed fluid, after separation from the cooling liquid within the chamber 50, discharging through the opening 54 to the high pressure cylinder intake; and the liquid separated from the compressed fluid drains down into the chamber 53 from which it is discharged, as hereinafter described, through the discharge pipe 34. Secured to the casing section 46 is the separator unit comprising a separator plate 57, supporting a series of discs 58 spaced apart from

each other and from the separator plate by a series of thin spirally arranged vanes **59**, the component elements being positioned relative to each other by pins **60** and clamped in place by screws **61**. Between adjacent plates the space is broken up into a series of curved passages **62** between vanes, these passages having relatively large surface areas as compared with their flow areas, and these passages are formed to accelerate fluid flow therethrough. Through these passages the mingled air and water pass with a whirling motion which both increases the washing action and effects an efficient separation on the centrifugal principle, a separation which is completed in the chamber surrounding the unit described. Rods **62***a* threadedly secured to the hub of the separator plate **57** support a plate **63** having adjustably secured thereto as by threads **64** a cooling liquid supply pipe **65**. The supply pipe has at its outer extremity a handle **66** whereby the same may be rotated, and thus, by reason of its threaded connection with the plate **63**, can be moved axially with respect to the controlling valve or plug **67**, which, when the parts are in the position shown in Fig. 5, maintains the inner end of the liquid supply pipe closed. Movement of the pipe **65** axially in and out with respect to the valve **67** effects regulation of the flow of cooling liquid through the pipe. The cooling liquid supply pipe **33** communicates with the supply pipe **65** through the packing ring **68** and packing collar **69**—**69** held in sealing engagement by coiled spring **70** so that a fluid tight seal is provided between the pipe **33** and pipe **65** irrespective of the adjusted position of the latter. Valve **67** is formed on a liquid deflector or spray plate **71**, slidably supported on the elements **62***a* and positioned as hereinafter described, and when the pipe **65** is moved axially to provide an opening between the inner end thereof and the valve **67**, cooled liquid flows from the pipe **33** through the pipe **65**, and as it is discharged from the latter and conically deflected by the valve **67** it impinges against the disc **71** and is deflected laterally in the form of a spray (a sheet of spray) across the stream of compressed fluid flowing from the low pressure cylinder discharge pipe **8** of the compressor, the cooling liquid commingling with and traversed by the compressed fluid, cooling the latter; and the commingled liquid and compressed fluid is guided by the curved deflecting surface **72**, formed on the hub of the separator plate **57**, into and then through the arcuate or spiral passages **62** formed between the separator discs **58**, so that the commingled liquid and compressed air are whirled about the interior wall of the chamber **50** of the intercooler casing, thereby effecting cooling of the air and separation of the compressed fluid, from which its burden of water vapor has been separated, from the cooling liquid. Any excess liquid with the fluid discharged from the low pressure cylinder is of course at the same time removed by this centrifugal separating action, and moreover the air is washed of any impurities, the separated cooling liquid is drained into the liquid drain chamber **53** while the compressed fluid, then cooled, flows past a deflecting surface **73** formed on the inner wall of the casing section **47** and past an annular liquid retaining and flow forming lip **74** to the discharge opening **54**, from which the cooled fluid is discharged through the opening **56** to the intake of the high pressure cylinder of the compressor. A water gauge having a usual sight glass **75** is provided for enabling observation of the level of the separated cooling liquid in the liquid discharge chamber **53**, while the pressure of the fluid in the discharge space **54** communicating with the intake to the high pressure cylinder may have its pressure observed by a pressure gauge **76**. A suitable safety valve **77**, as is common on connections between the stages of compound compressors, is duly provided to preclude the building up of the pressure in chamber **54** to an excessive height.

Improved means is provided for automatically controlling the regulating valve **67** for the cooling liquid conducted to the valve **67** by the supply pipe **65**, so that automatic variation in the quantity of liquid supplied may be effected in accordance with the temperature of the cooled compressed fluid in the discharge space **54** of the intercooler. This mechanism comprises a hollow thermostatic element **78** arranged centrally within the chamber **54** and secured at **79** to the hub of the separator plate **57**. To the free end of this thermostatic element **78** is connected at **80** a thermostat plunger rod **81**, which lies within the thermostatic element **78** and is connected at **82** to the cooling liquid regulating valve **67** and plate **71**. Tube **78** and rod **81** are, of course, made of elements having different coefficients of expansion, and the coefficient of expansion of the tube is the higher of the two. Accordingly, as the temperature of the compressed fluid in the space **54** rises the thermostatic couple acts to move the valve **67** away from the discharge end of the supply pipe **65**, and thereby to admit a larger quantity of cooling liquid to the intercooler. If, on the other hand, the temperature of the compressed fluid in the discharge passage **54** becomes too low, the thermostatic couple operates to move the regulating valve **67** toward the discharge end of the supply pipe **65**, and thereby to diminish or cut off the flow of cooling liquid to the intercooler.

To control the liquid level in the chamber **53** a trap having a float **85** is attached to the side of the intercooler casing. The float **85** is supported on a lever **86** which engages the valve **89** and controls the flow of the discharged cooling liquid from the chamber **53** to the discharge pipe **34**. Lever **86** is pivoted at **87** within a casing **88** attached to the side of the intercooler casing.

As a result of this invention, it will be noted that there is provided an improved compressor having an improved intercooler which effectually removes excess water vapor from the air discharged from the low pressure cylinder, and also washes the fluid being handled by the compressor. It will be further noted that the improved intercooler arrangement, though providing for a direct inter-mixture of the cooling liquid with the compressed fluid, is provided with automatic controlling means precluding the carrying of solid water over into the high pressure cylinder or the running of solid water back into the low pressure cylinder, and is also provided with improved controlling means operative to interrupt the supply of cooling liquid when none is needed, and to provide at a time when air flow is not present additional insurance against possible escape of liquid back towards the low pressure cylinder, by completely shutting off the liquid supply.

This application is a division of my application Ser. No. 713,333, filed February 28, 1934.

While there is in this application specifically described one form which the invention may assume in practice, it will be understood that this form of the same is shown for purposes of illus-

tration, and that the invention may be modified and embodied in various other forms without departing from its spirit or the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent is:

1. The combination with a fluid compressor having fluid compressing means including a fluid compressing cylinder and discharge means for the compressed fluid, of a heat exchange device for receiving the fluid from said cylinder, means for delivering cooling liquid under pressure to said heat exchange device for cooling the compressed fluid, and pressure controlled means for controlling the supply of liquid flowing to said heat exchange device including by-pass means controlled by the pressure in said compressor discharge means.

2. In a compressor, in combination, a fluid compressing cylinder, a heat exchange device for receiving the fluid from said cylinder, a cylinder receiving fluid from said heat exchange device, means operated by the compressor crank shaft for delivering cooling liquid under pressure to said heat exchange device, means controlled by the discharge pressure of said compressor for controlling the load on said first mentioned cylinder, and means controlled by the pressure at the discharge of said first mentioned cylinder for controlling the supply of cooling liquid for said heat exchange device.

3. In a compound compressor, in combination, a low pressure cylinder, a high pressure cylinder, a direct mixture intercooler between said cylinders, a liquid supply pump operated by said compressor for delivering liquid to the intercooler, unloading means for said compressor, and means for interrupting liquid supply to the intercooler upon unloading of the compressor and for thereupon relieving the load upon said pump.

4. In a compound compressor, in combination, a low pressure cylinder, a high pressure cylinder, a direct mixture intercooler between said cylinders, a liquid supply pump operated by said compressor for delivering liquid to the intercooler, unloading means for said compressor, and means for interrupting liquid supply to the intercooler upon unloading of the compressor and for opening a bypass from the discharge to the intake of said pump.

5. In combination, in a compound compressor, a low pressure cylinder, a high pressure cylinder, a pump rotated with said compressor, an intercooler between said cylinders, said pump supplying cooling liquid to said intercooler, unloading means for said compressor, and means for interrupting liquid delivery from said pump to said intercooler and providing a low pressure discharge for said liquid automatically when said compressor is operated unloaded.

6. In combination, in a compressor, a low pressure cylinder, a higher pressure cylinder, a direct mixture intercooler between the cylinders, liquid supply means governed by the pumping operation of the compressor, compressor unloading means and means for effecting a discharge of the cooling liquid automatically to another point than said intercooler upon unloading of the compressor.

7. The combination with a fluid compressor having fluid compressing means including a fluid compressing cylinder and discharge means for the compressed fluid, of a heat exchange device into which the fluid compressing cylinder discharges including means for injecting a cooling liquid directly into the fluid stream, and means controlled by the discharge pressure in said compressor discharge means for controlling the load on the compressor and the flow of cooling liquid into the fluid stream.

8. The combination with a fluid compressor having fluid compressing means including a fluid compressing cylinder and discharge means for the compressed fluid, of a heat exchange device into which the fluid compressing cylinder discharges including means for injecting a cooling liquid directly into the fluid stream, means controlled by the discharge pressure in said compressor discharge means for controlling the load on the compressor and the flow of cooling liquid into the fluid stream, and means governed by loaded operation of the compressor for controlling further the flow of cooling liquid into the fluid stream.

9. In combination, in a multi-stage air compressor, a low pressure cylinder, a high pressure cylinder, and an intercooler arranged between said low pressure cylinder and said high pressure cylinder and interconnected between the same, said intercooler having provision for the direct intermixture of the air flowing between the cylinders with a cooling liquid and means for governing the quantity of said cooling liquid in accordance with high pressure cylinder intake temperature.

10. In combination, in a multi-stage air compressor, a low pressure cylinder, a high pressure cylinder, and an intercooler arranged between said low pressure cylinder and said high pressure cylinder and interconnected between the same, said intercooler having provision for the direct intermixture of the air flowing between the cylinders with a cooling liquid, and the subsequent separation of said liquid from the air prior to the entry of the latter to the higher pressure cylinder, and means for governing the quantity of said cooling liquid in accordance with high pressure cylinder intake temperature.

11. The combination with a fluid compressor having a fluid compressing cylinder and compressor unloading means, of means for cooling the compressed fluid discharged from the compressor cylinder by injecting a cooling liquid directly into the fluid stream, a liquid supply pump operated by the compressor for supplying a cooling liquid under pressure to said injecting means, and means for interrupting the liquid supply to said injecting means upon unloading of the compressor.

12. In a fluid compressor having unloading means, in combination, a fluid compressing cylinder, a direct mixture intercooler for receiving the fluid from said cylinder, a liquid supply pump operated by said compressor for supplying a cooling liquid to said intercooler, and means for interrupting liquid supply to said intercooler upon unloading of the compressor and opening a bypass from the discharge to the intake of said pump.

13. In a fluid compressor having unloading means, in combination, a fluid compressing cylinder, an intercooler for receiving the fluid from said cylinder, a pump driven with the compressor for supplying a cooling liquid to said intercooler, and means for interrupting liquid delivery from said pump to said intercooler and providing a low pressure discharge for said liquid automatically when said compressor is operated unloaded.

14. In a fluid compressor having unloading means, in combination, a fluid compressing cylinder, a direct mixture intercooler for receiving

the fluid from said cylinder, liquid supply means governed by the pumping operation of said compressor for supplying a cooling liquid to said intercooler, and means for effecting discharge of the liquid automatically to another point than the intercooler upon unloading of the compressor.

15. In a fluid compressor, in combination, a fluid compressing cylinder, a heat exchange device for receiving and cooling the fluid from said cylinder, means for delivering cooling liquid under pressure to said heat exchange device, and means controlled by the discharge pressure from said cylinder for controlling said liquid delivering means.

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