April 28, 1942. H. F. PARKER 2,280,845

AIR COMPRESSOR SYSTEM

Filed Jan. 29, 1938

2 Sheets-Sheet 1

FIG. 1.

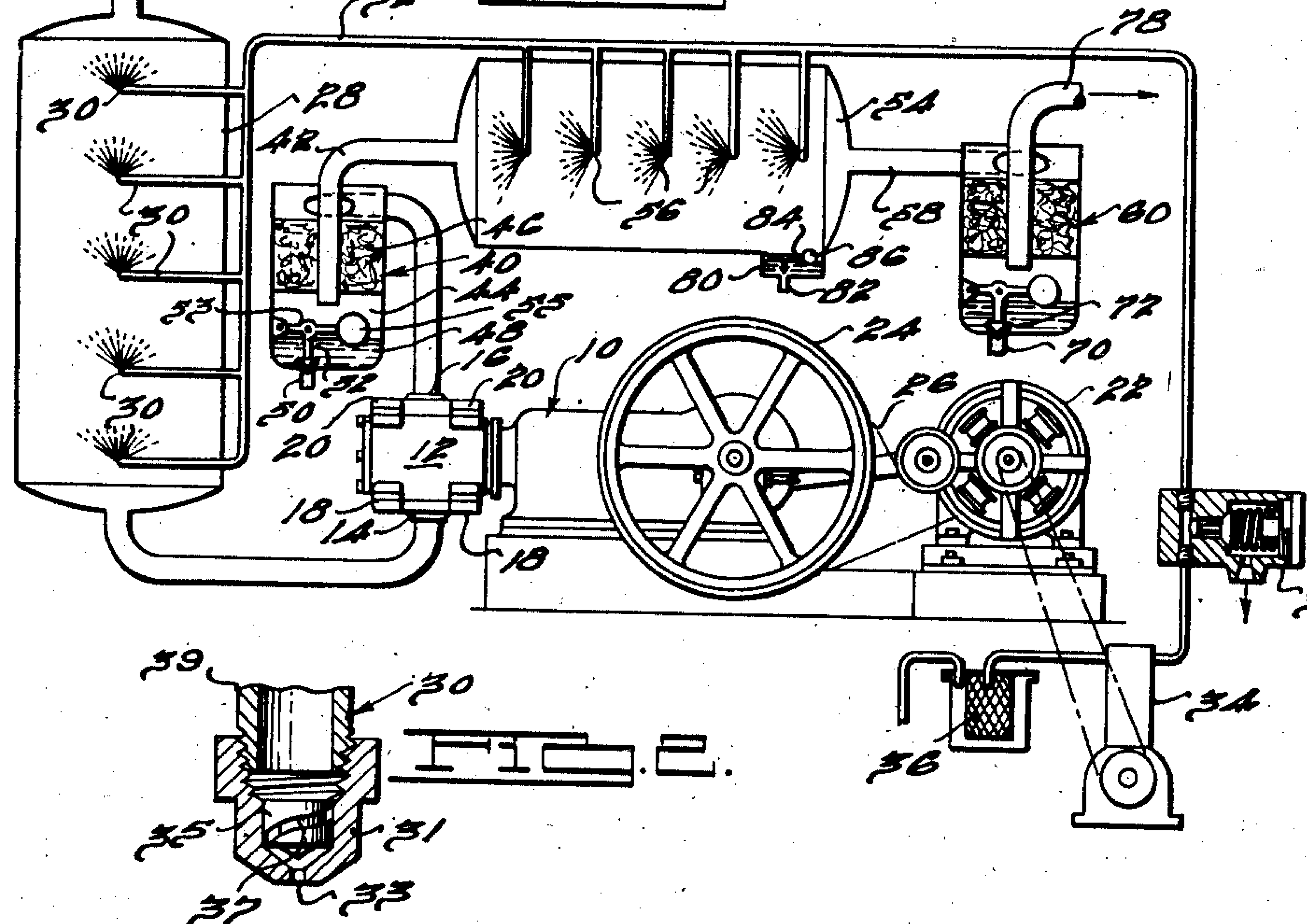

FIG. 2.

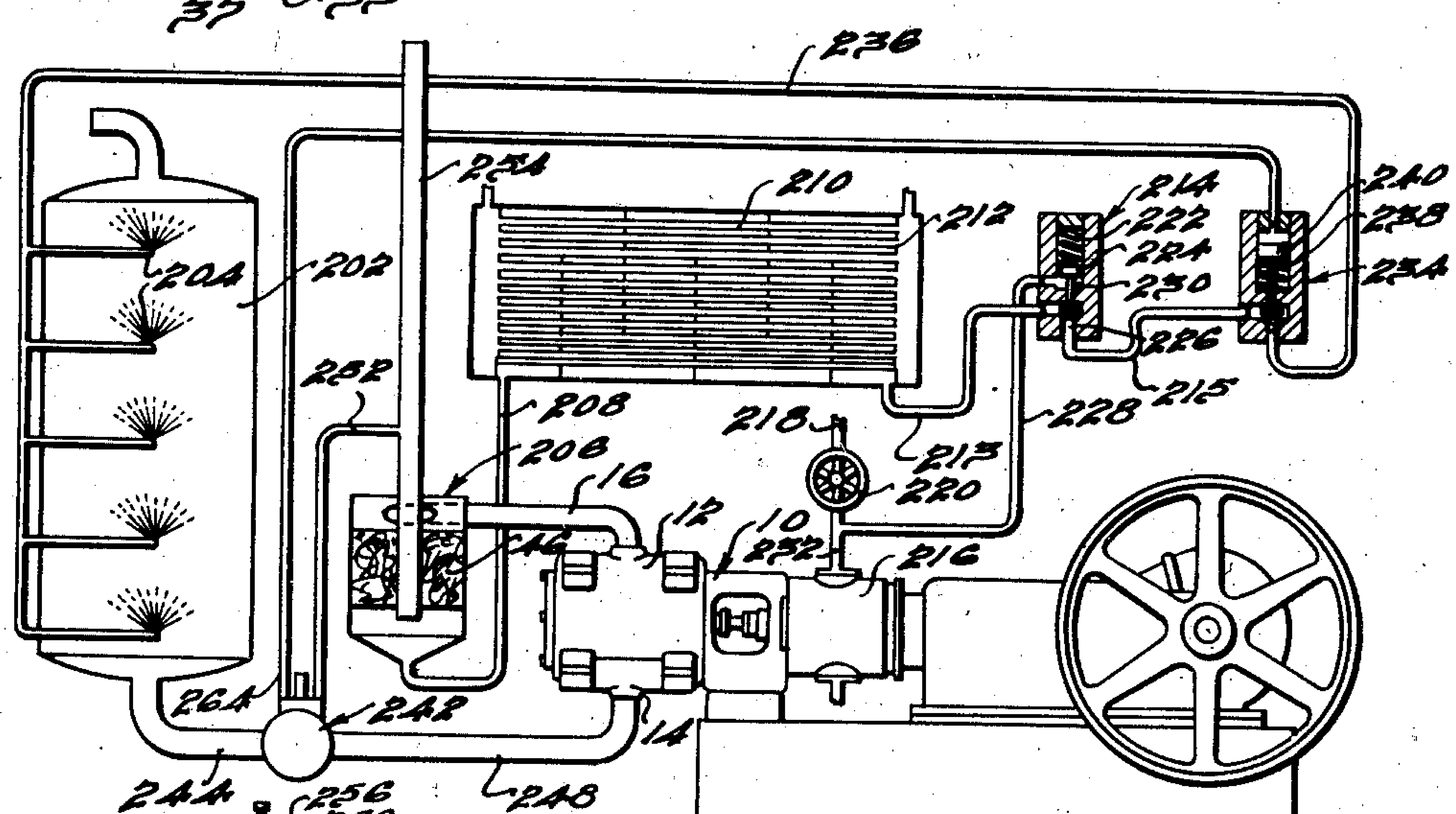

FIG. 3.

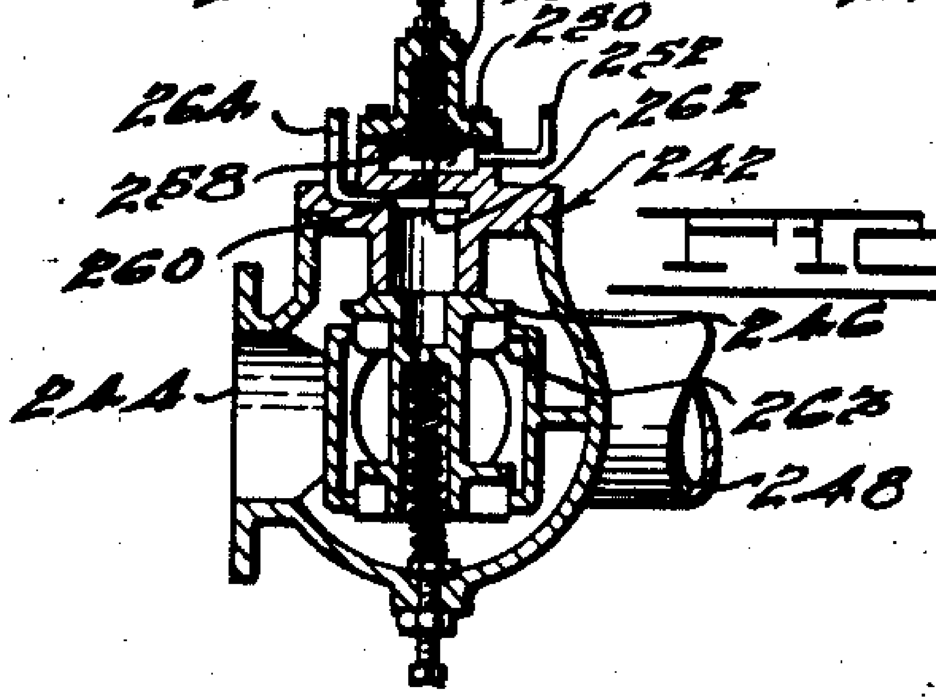

FIG. 4.

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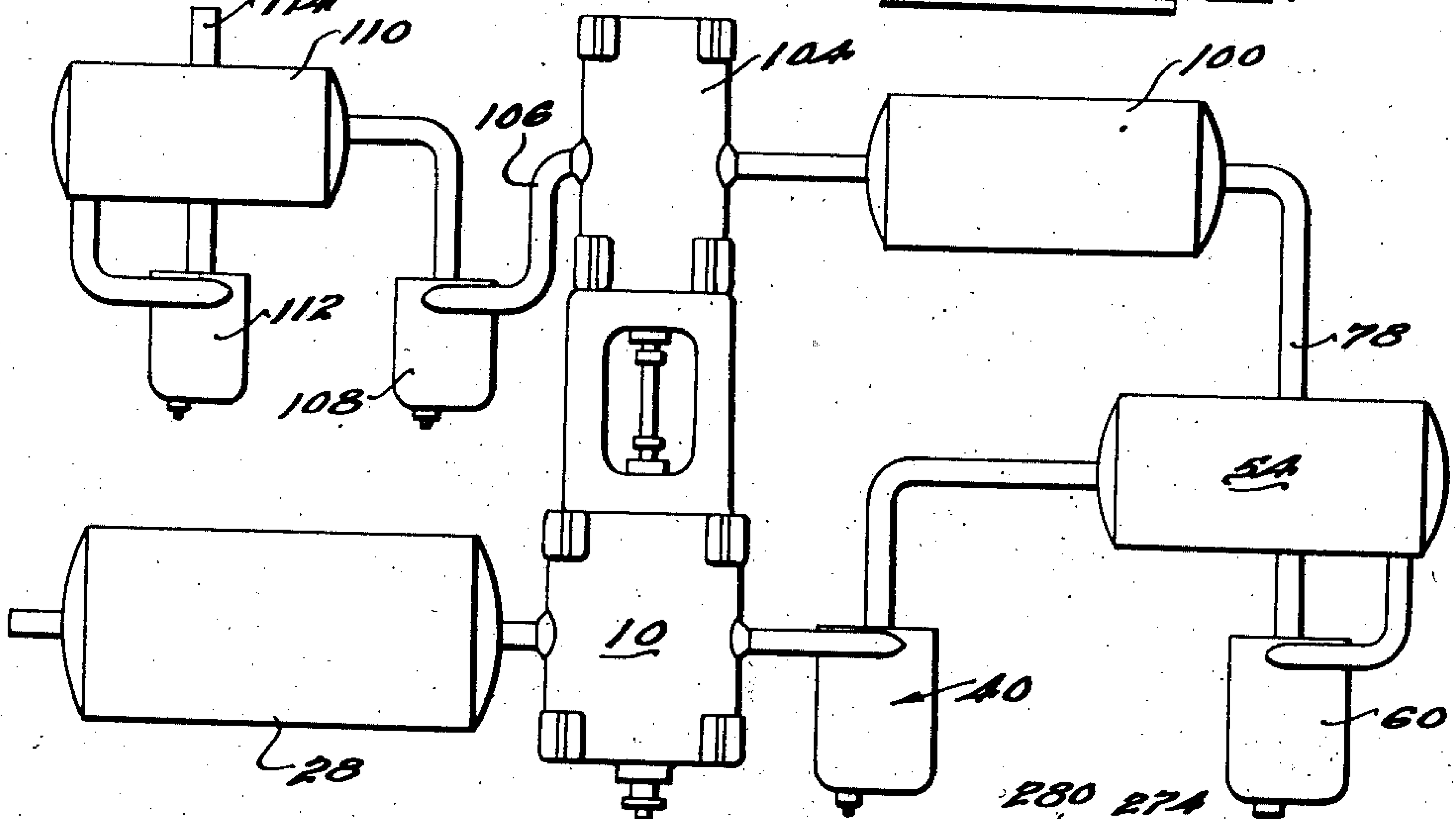
2 Sheets-Sheet 2

FIG. 5.



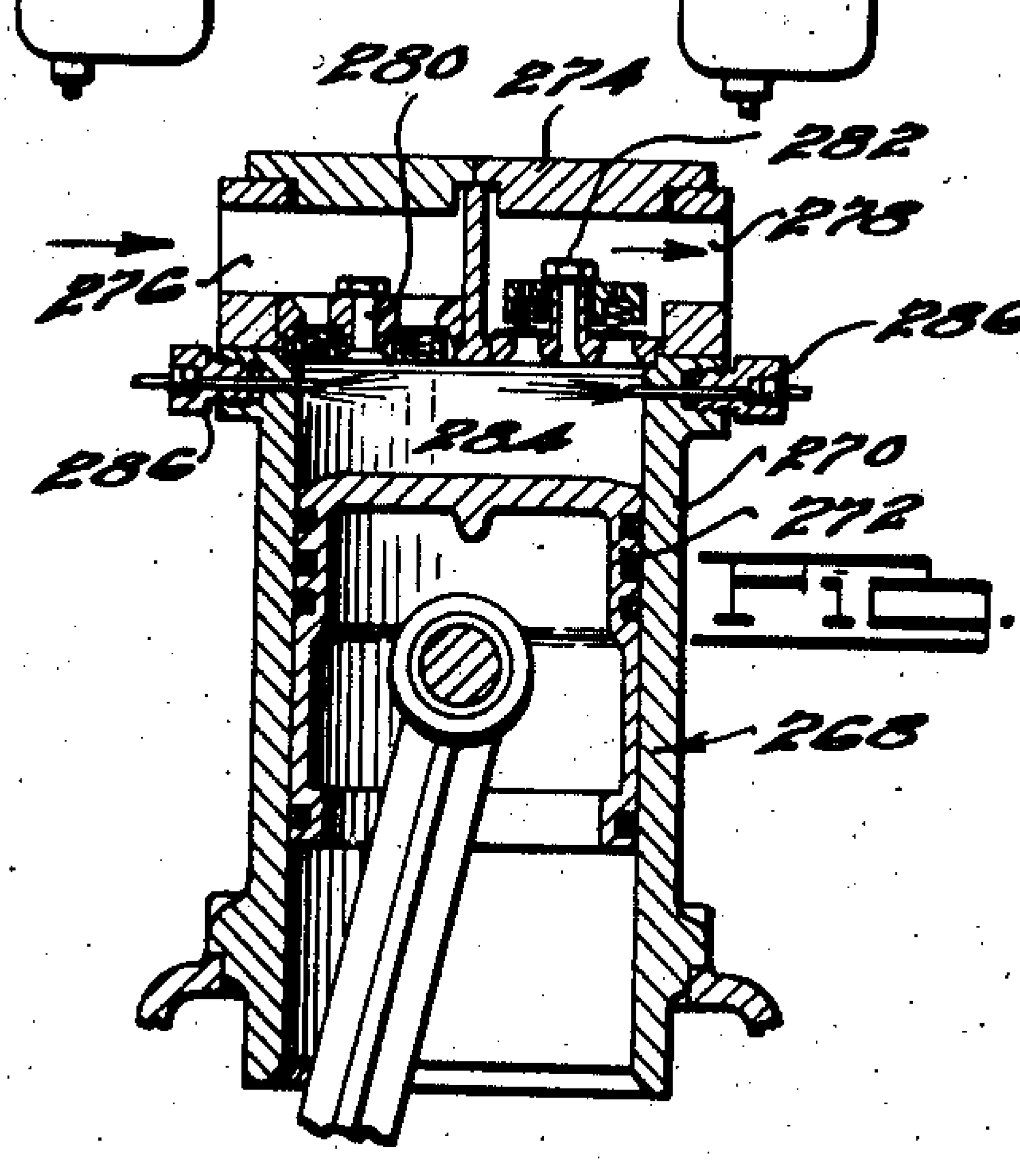
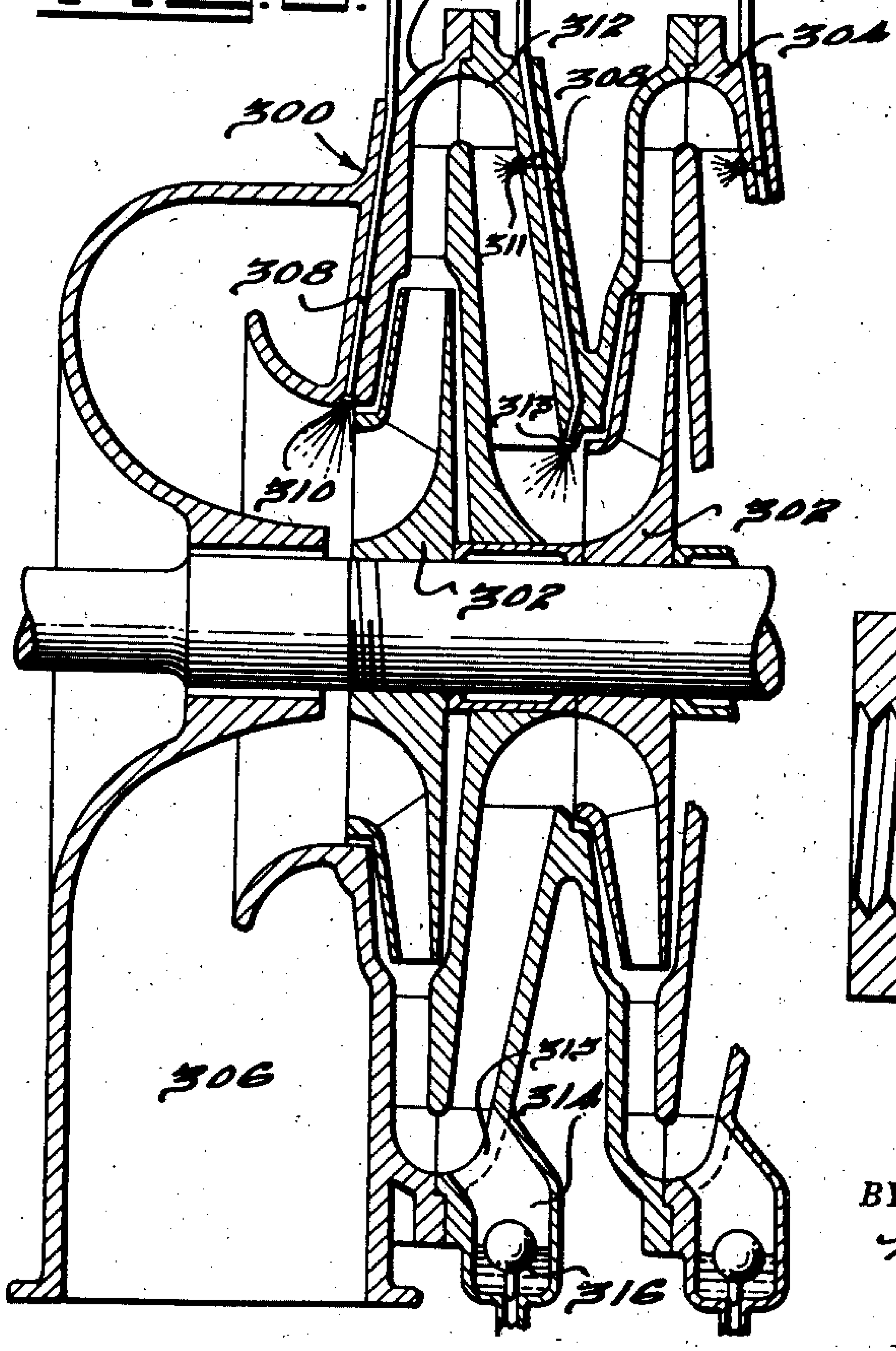


FIG. 6

FIG. 8.



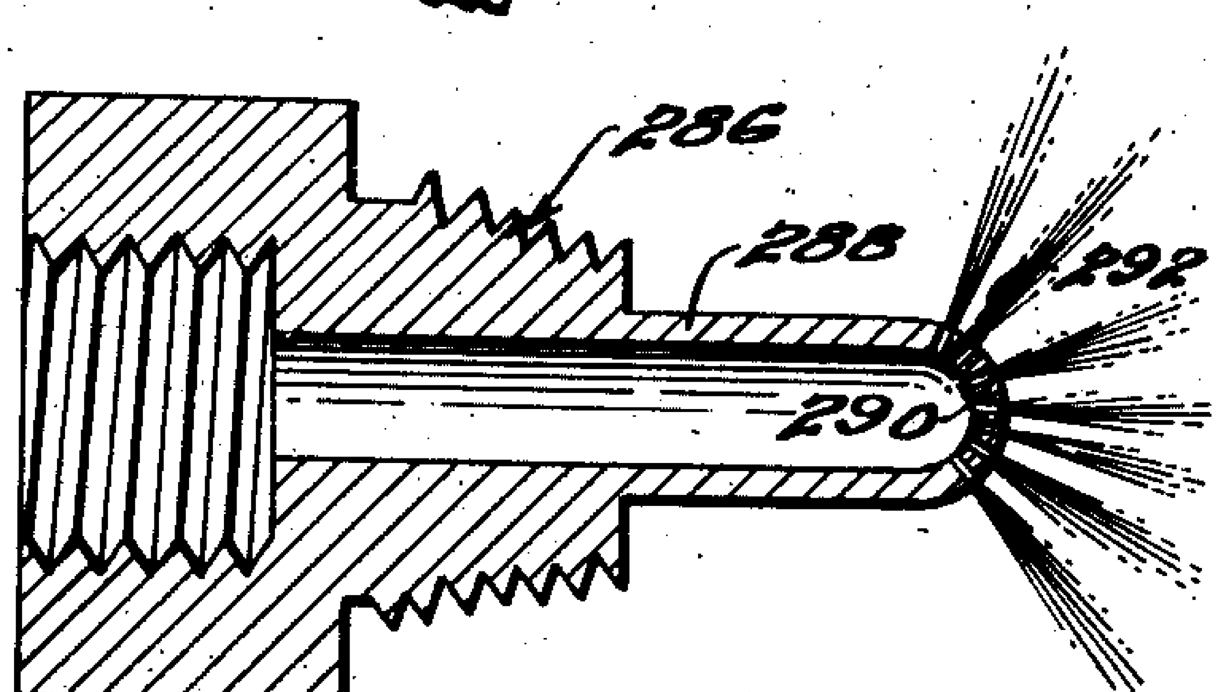


FIG. 7.

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AIR COMPRESSOR SYSTEM

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Application January 29, 1938, Serial No. 187,704

11 Claims. (Cl. 230—208)

The present invention relates to methods of and apparatus for compressing air and other gases. A principal object of the invention is to reduce the temperature rise that accompanies adiabatic compression, thereby approaching the isothermal cycle more closely than has heretofore been practicable and reducing the power consumption necessary for a given output.

Further principal objects of the invention are, to increase the speed of operation of compressors, thereby reducing their weight, bulk, initial cost and cost of installation; to increase the output of existing compressors by safely increasing the operating speeds thereof; to reduce the number of stages of compression, in compressing to very high pressures, without sacrifice in efficiency; to eliminate deposits of carbon and gum upon valves and other parts of the system; to reduce the quantity of cooling water necessary for a given final temperature of the compressed gas; to simplify the casting of compressor cylinders by dispensing with water cooling jackets; and to reduce the cost of pre-coolers, inter-coolers, and after-coolers by making possible the use of heat exchangers of the wet type and at the same time delivering the compressed air in at least as dry a state as has heretofore been customary.

The above objects, as well as other and more detailed objects which appear in the following description and in the appended claims, are attained, in a broad sense, by introducing into the gas to be compressed a non-compressible heat absorbing and heat carrying medium, and then, after compression, in separating and removing this medium, and with it the greater part of the heat of compression, from the compressed gas. The preferred medium is cold water, although in certain cases other liquids such as oil may be used. The liquid is passed through atomizing means whereby it is broken up into a finely divided mist-like form, and is thereafter intimately mixed with the air or other gas to be compressed. By breaking up the liquid into globules sufficiently small to remain suspended in the air, the ratio of surface to volume is made very large, and the time required for a given heat exchange between air and water very short, i. e. measurable in thousandths of a second.

The resulting system will be recognized as being of the wet type, and, in one sense, the present invention may be characterized as rendering the wet-compression principle, with its recognized thermodynamic advantages, applicable to modern high speed compressor requirements.

As mentioned above, the present invention contemplates injecting the cooling medium into the system in a thoroughly atomized state, and, before proceeding to a description of the herein disclosed embodiments of the invention, the following data is of interest as bearing upon the magnitude of the change brought about by effective atomization in place of the spray injection previously used.

Attention is first invited to the quantities involved in compressing one thousand cubic feet of air initially 50% saturated with moisture at 60° F. to eight atmospheres absolute (103 lbs. per square inch gauge). With adiabatic compression, the temperature rise in this case is 430° F. giving a final temperature of 490°. It may be supposed that a quantity of water equal in weight to the air be intimately mixed with the air in a form fine enough to maintain substantial temperature equilibrium during compression. This quantity is arbitrarily assumed, and more or less water may be used depending upon whether lower final temperatures are desired or a smaller consumption of cooling water. The weight of 1,000 cubic feet of air under the above conditions is 75.70 pounds. The same weight of water occupies 1.22 cubic feet, which represents one part in 820 of the uncompressed mixture or less than one per cent of the final volume. The first effect of the injection of water is to saturate the air. This requires the conversion of .4 pound of water into vapor, leaving approximately 75 pounds which remain in the liquid state throughout compression. Assuming the value of .25 for the specific heat of the air and vapor, the compression is accompanied by the generation of 8060 B. t. u.'s of heat. This heat is now imparted to the mixture of air and water, and results in a rise in temperature of 86° F. The final temperature of the air is thus 146° F. in place of 490°.

The above may be expressed in another way by stating that, while the horsepower loss which accompanies adiabatic compression is 27.4%, this loss is reduced by this invention, in the above case, to 5.5%. In actual practice the above theoretical loss for "dry" compressors is reduced by water jacketing the cylinder, but there nevertheless remains a net advantage of 10% to 15% in efficiency in favor of the present improvement.

The quantity of water used in the above example, i. e. 75 pounds, represents .90 gallon per 100 cubic feet of free air, which is substantially the same as that required for water jacketing a single stage compressor of conventional type. The use of the same quantity of water in an after-cooler of the type described hereinafter will bring the final temperature of the compressed air down to about 17° F. above the initial temperature of air and water. In conventional practice with after-coolers used in conjunction with "dry" compressors, four or five times this quantity of cooling water is necessary.

In previous attempts to remove the heat of compression by injection of water, the water has simply been sprayed into the cylinder on the compression stroke. Spray injection merely breaks up the body of water into particles comparable with drops, and since a considerable proportion of these particles re-coalesce into sheets of water within the cylinder, it is usually found that spray injection reduces the average volume of the particles to somewhat less than the diameter of a drop, or to a diameter of approximately .10 inch.

An effective atomizing nozzle is capable of reducing a liquid to particles having a diameter of less than .001 inch. In the matter of heat absorption, moreover, the advantage of the small particles varies inversely as the square of the diameter, so that an atomized particle possesses an advantage over the spray particle discussed above of the order of ten thousand to one.

Heat transfer is a function of temperature difference; of time; of surface area; and of depth of penetration. Comparing now a body of a given volume with the same quantity of material divided into bodies of half the diameter, eight such bodies are required. The surface area in the first case is πr^2, while that in the second case is $8\pi(r/2)^2$, or $2\pi r^2$, showing that, for a given volume, surface area increases directly as decrease in diameter. It is obvious, in a globule or sphere, that the necessary distance of penetration decreases directly as the radius, so that, for a given temperature difference, the time required for heat exchange from the air to the water particles is reduced as a function of the square of the particle diameter, or, in the case discussed above, to one ten-thousandth of the former time. With an improvement of this order possible, an ample margin is available to increase speeds, if desired, ten or twenty times over the previous practice in "wet" compression and still effect a close approximation to complete heat transfer.

In previous attempts to practice wet compression, difficulty has been experienced with lubrication. This has been due to the actual presence of bodies of water within the cylinder, which washed off the lubricant from the walls. In the present invention, the lubrication requirements are comparable with those of a steam cylinder. As is well known this calls for the use of more lubricant than an air compressor cylinder, but a quantity which is still entirely reasonable. This necessary extra oil could not be added in a cylinder operating on dry compression as it would result in carbonization or gumming of the valves. In the present invention, however, the final temperature is so low that no such trouble is encountered.

The present invention further contemplates a continuous injection, as distinguished from an intermittent injection. By using continuous injection, the rate of injection of water is comparable with that of the oil injection in a Diesel engine, in which injection takes place only during about thirty degrees of crankshaft angle. The weight of oil injected in the case of the Diesel is about one fifteenth of the air used, which is injected during about one-twelfth of a revolution. Since intermittent injection involves build up and shut down periods in addition to that of full injection, a continuous injector need only have a capacity of about one-third that of an injector timed for the compression stroke only.

The invention is illustrated in the following drawings, in which:

Figure 1 is a view in side elevation of a single stage compressor system embodying the invention;

Fig. 2 is a view in section of an atomizing nozzle which is preferably utilized in the system of Fig. 1;

Fig. 3 is a view in side elevation of a modified form of the invention, in which the cooling medium is recirculated;

Fig. 4 is a view in section of an unloader valve preferably utilized in the system of Fig. 3;

Fig. 5 is a view in side elevation of a two stage compressor system embodying the invention;

Fig. 6 is a fragmentary view of a modification of the invention;

Fig. 7 is a view in section of an atomizing nozzle preferably used in the system of Fig. 6; and,

Fig. 8 is a view in vertical section of a further modification of the invention.

Referring now to Fig. 1, an air compressor of the reciprocating type is shown at **10**. This comprises a cylinder **12** of the double acting type having an air intake at **14** and an air outlet at **16**. Automatic intake valves, which may be of any of the well known types, are indicated at **18**, and exhaust valves at **20**. The piston (not shown) in the cylinder **12** is operated by the electric motor **22** which drives the flywheel **24** through belt **26**. The compressor, as thus far described, may be identical with or comparable to compressors now in use.

Before being inducted into intake **14**, in accordance with the present invention, the entering air is passed through the mixing chamber **28**, which is provided with a plurality of atomizing nozzles **30**. During the passage of the air or other fluid through the chamber **28**, it is subjected to the atomized liquid, and a thorough mixing of the air and cooling liquid results. The term "atomizing" is used in the present specification and claims to mean the breaking up of a liquid into very fine mist-like particles. Also the terms "mixture," "mixing" and the like are used in the present specification and claims in the technical senses thereof to refer to a complex of two or more ingredients, which, however thoroughly co-mingled, retain their indentites and are separable from each other. By way of example, a suitable nozzle is shown in Fig. 2 as comprising a shell **31** having a small orifice **33**, and a core **35**, pressed into the shell. The core has a helical passage **37** cut in its cylindrical outer surface. Water entering by the inlet pipe **39** is given a rotary motion by the helix, so that when forced through the orifice **33** it spreads out into a cone and breaks up into minute particles. Water is supplied to these nozzles by the pipe **32**, under pressure developed by the pump **34**. As shown, pump **34** is of the multi-cylinder type, capable of developing a continuous, uniform pressure, and is driven by the motor **22** which drives the compressor. Accordingly, when the motor **22** and the compressor are stopped, the supply of water to the atomizing nozzles is stopped also.

The pump **34** draws cold water from any suitable source, and is provided with a filter **36** and a pressure limiting relief valve **38**. When water at a temperature below atmospheric is available, the mixing chamber 28 becomes in addition a pre-cooler, and provides all the advantages of that device without a separate unit.

The air and water mixture is drawn into cylinder 12 through intake valves 18, is compressed, and then discharged through exhaust valves 20 and outlet pipe 16 to the separator unit 40. Preferably the air enters this at the top, tangentially. The body of the separator, surrounding the outlet pipe 42, which extends into the lower chamber 44, is filled with very fine copper "wool," i. e., very fine turnings 46, or other material adapted to provide a labyrinthine passage for the mixture. The mist-like particles of water strike the surfaces of the wool, adhere to them, coalesce into drops, and fall into the collecting sump 48 at the bottom of chamber 44. The air, however, being less dense, moves on through the labyrinthine passages into chamber 44 and out by way of outlet pipe 42. Sump 48 is provided with a water outlet 50 controlled by needle valve 52. The upper end of valve 52 is attached to an arm 53, one end of which is pivoted to the separator casing and the other end of which carries the float 55. Water collects in sump 48 until it begins to lift float 55 whereupon valve 52 is lifted and further water is discharged through outlet 50, without permitting the escape of any air or the loss of pressure.

The compressed air, freed from entrained moisture in the liquid phase, may now be delivered to a receiver and to the devices to be operated by it. It may be expected, however, to be saturated with water vapor at a temperature probably about 140° F. Since this air will cool considerably before reaching the devices to be operated by it, it may deposit water in the pipes and other parts of the system with undesirable results. This condition is usually alleviated by an after-cooler, of the surface condenser type. In the present case an after-cooler of this type may be used, especially when applying the invention to an existing compressor where a surface cooler is already in use. Preferably, however, in place of the conventional after-cooler, a mixing chamber is used similar to that previously described. This is shown at 54, and is equipped with sprays 56, which are supplied through pipe 32. Sprays 56 may be and preferably are duplicates of the previously described sprays 30. With this new after-cooler, the temperature of the air may readily be brought down to within ten degrees of that of the water, with the use of materially less water than is necessary with a conventional after-cooler.

The cooled mixture of air and water globules now passes by pipe 58 to separator 60, which as shown, is similar to separator 40. The final air, free from entrained moisture in either vapor or liquid phase, is discharged through pipe 78 for delivery, and the cooling water is released by needle valve 72 through outlet 70. Mixing chamber 54 is also provided with a sump shown at 80, and a drain 82, controlled by needle valve 84 and float 86 to dispose of liquid which may strike the sides of the chamber and collect in the sump.

In the modification shown in Fig. 3, oil is used as a cooling medium, and is cooled and re-circulated. Modified valve means are used for controlling the supply of liquid to the atomizers. Air entering the mixing chamber 202 encounters mist-like sprays of finely divided oil, delivered by the atomizing nozzles 204, which may be and preferably are constructed as described with reference to nozzles 30. The air and oil mixture is inducted into cylinder 12 as before by intake pipe 14, and is discharged by outlet pipe 16 into separator 206. This is cssentially like separator 40 except that the needle valve 52 and its float control are omitted. The separated oil, carrying most of the heat of compression, is then passed by way of the pipe 208 into the heat exchanger 210. This is provided with a nest of tubes 212 through which cold water is circulated. The heat added to the oil in the compressor is thereby transferred to the water, and the oil, under the high pressure existing in the separator 206, is returned to the sprays 204 through pipes 213, 215 and 236, for re-atomization and mixture with fresh air.

Provision is made for shutting off the flow of oil from separator 206 and for controlling the delivery to the nozzles 204, so that oil will be delivered for mixing only when air is being inducted into the compressor. This control comprises first a shut off valve 214, which in turn is controlled by steam pressure, the motive power in the case illustrated being steam supplied to the cylinder 216 from steam pressure line 218, under control of hand throttle 220.

Valve 214 is normally shut by spring 222 acting against the upper side of piston 224 to force valve element 226 onto its seat. Pipe 228 connects the chamber 230 beneath piston 224 to steam line 232, between throttle 220 and cylinder 216. When the throttle is opened, pressure is admitted not only to the cylinder 216 but also to the chamber 230 beneath piston 224, forcing the piston upwardly against spring 222 and opening valve element 226. When throttle 220 is closed, pressure is shut off from line 232 and from chamber 230, and spring 222 re-seats valve 226 and shuts off the line from separator 206.

It is common practice to equip an air compressor with an unloader valve which is designed to permit the driving engine and the compressor piston to remain in motion under frictional load only, the air load being removed by the operation of the valve. In compressors so equipped and embodying the present invention, it is necessary, or at least desirable, to shut off the supply of liquid to the atomizers in the mixing chamber when the unloader is in operaiton. With this in view, valve 234 is incorporated in delivery line 236 to atomizers 204. This valve is normally held open by the action of spring 238 against piston 240.

An unloader valve which is of generally conventional construction, but modified in accordance with the requirements of the present invention, is shown at 242. This is normally open, air flowing from pipe 244 past balanced disc valve 246 to pipe 248 and compressor intake 14. Chamber 250 is connected by pipe 252 with compressor delivery pipe 254 and is subject to the pressure on the high side of the system. A spring 256 acts on diaphragm 258 and is adjusted so that it just balances the pressure on the diaphragm at the maximum pressure desired in the system. When the delivery pressure exceeds this figure, the diaphragm is lifted, opening needle valve 260 and admitting pressure to chamber 262, thereby forcing valve 246 onto its seat 263 and shutting off the supply of intake air to the compressor. Chamber 262 is connected by pipe 264 with the upper side of piston 240, so that when valve 246 is closed, pressure acts on piston 240 and closes valve 234 also, shutting off the supply of liquid to nozzles 204.

It will be understood, of course, that this combination of an unloader valve such as 242, and a cooperating valve 234 may be used with the form of the invention shown in Fig. 1. In such case, the valve 234 will be placed in line 32, and valve 242 will be placed in line 14. Water will then be shut off from sprays 30 and 56, being discharged instead through relief valve 38.

Fig. 5 illustrates a method of applying the invention to a two stage compressor. All parts relating to the first stage of compression may be the same as those shown in Fig. 1, and are indicated by corresponding numerals. The after-cooler 54, however, in this case becomes an inter-cooler and the cool moisture free air in pipe 78, instead of being delivered into the equipment to be operated, is passed into a third mixing chamber 100. This is equipped with atomizing nozzles, similar to nozzles 30. As a result, a mixture of air and minute water globules is inducted into the high pressure cylinder 104 whence it is discharged at a higher pressure by way of outlet 106 into a third separator 108. In separator 108 the water, carrying most of the heat of compression, is removed from the air, which is then passed into a fourth and final mixing chamber 110 corresponding in structure and in function to chamber 54 of Fig. 1. The air then proceeds through a final separator 112 and is delivered in a cool, moisture free state by outlet 114 for storage or use as may be desired.

From the foregoing description, it will be appreciated that the embodiments shown in Figs. 1, 3 and 5 can be characterized as utilizing an ante-chamber, provided with one or more atomizing nozzles, in which the air or other gas to be compressed is mixed with a cooling medium, preferably oil or water, which is injected into the air or other gas in a very finely divided or atomized state. Due to the enlarged size of the ante-chamber, the movement of the air or other gas particles therethrough is relatively slow, so that ample time is afforded for the atomized cooling medium to be thoroughly and uniformly mixed therewith.

As previously mentioned, although a part of the atomized cooling medium passes into the vapor state, either before or during its passage through the compressor 12, by far the major portion of the atomized cooling medium remains in the liquid phase during its passage through the system. The retention of the cooling medium in the liquid phase is of substantial importance, since it will be appreciated that the heat generated in the compressor may be much more efficiently transferred to the cooling medium in the liquid phase than would be the case if it were in the vapor phase.

As a consequence of the complete mixture, in the ante-chamber, of the air or gas to be compressed, with a suitable quantity of atomized cooling medium preponderantly in the liquid phase, the heat of compression generated in the compressor very rapidly transfers to the cooling medium, so that the temperature of the mixture as it leaves the compressor is very substantially lower than would otherwise be the case.

The above described embodiments are further characterized in that means are provided to abstract the cooling medium from the compressed air or gas and preferably additional means are provided to cool the compressed air or gas and remove any of the cooling medium previously present therein in the vapor phase.

In certain instances, because of space requirements, it is found desirable to eliminate the separate ante-chambers such as 28 of Fig. 1, and in such event the arrangement of Fig. 6 may be used, which is characterized by the provision of a continuous injection of atomized particles, preferably water particles, directly into the cylinder itself.

Referring particularly to Fig. 6, a compressor of generally conventional construction comprises the cylinder casing 270, within which the piston 272 is reciprocable. The head 274 is formed to provide an inlet chamber 276, and an outlet chamber 278. Conventional valves 280 and 282 control communication, respectively, between the inlet 276 and the chamber space 284, and between the outlet 278 and the chamber space 284.

In accordance with the present invention, atomized valves 286 are provided and extend through the cylinder casing 270 at a point adjacent the upper end thereof. The atomizing valves 286 may be and preferably are continuously supplied with the selected cooling medium in the manner described with reference to either Fig. 1 or Fig. 3.

In practicing the embodiment shown in Fig. 6, it is preferred to construct the atomizing nozzles 286 in accordance with the showing of Fig. 7. In Fig. 7 a nozzle 286 is illustrated as being provided with a tip 288 having a thin walled spherical head 290 through which a number of very fine holes 292, of the order of .010'' in diameter, are drilled. Each nozzle is adapted for operation at pressures of the order of about 1000 pounds per square inch, whereas pressures of the order of about 100 pounds per square inch usually suffice for the nozzle structure shown in detail in Fig. 2. It is preferred that all of the holes 292 be drilled in the same plane, and in fitting injector 286 into the cylinder 270, this plane is arranged parallel with the cylinder head. The atomized particles are thus injected into a relatively shallow zone parallel to and adjacent the cylinder head. A minimum percentage of the particles thus strike the cylinder walls or piston head, while a maximum mixing effect is secured due to the fact that, in entering and in leaving, the air is required to pass through the zone of the particles.

It will be appreciated that the operation of the arrangement shown in Fig. 6, as applied to either a single stage system such as shown in Figs. 1 and 3, or to a multistage system such as shown in Fig. 5, may duplicate the operation of the previously described embodiments, with the exceptions noted above, namely, that the ante-chambers of the earlier embodiments are eliminated and instead the cooling medium is injected directly in the cylinder. The embodiment of Fig. 6 thus retains all of the advantages incident to the continuous injection of an atomized cooling medium and, while the advantages incident to the use of an ante-chamber for mixing purposes are sacrificed, this sacrifice is offset in part by a saving in the space requirements of the system as a whole.

The arrangement shown in Fig. 8, illustrates the adaptation of the invention to a centrifugal compressor. In Fig. 8, a centrifugal compressor 300 is provided with a series of similar impellers 302, conventionally arranged within the compressor casing 304. The air or other gas to be compressed is admitted through the usual inlet 306, and it will be appreciated that the final air or other gas is discharged through a conveniently arranged outlet (not shown) at the other end of the compressor.

In accordance with the present invention, means are provided to successively introduce suitable quantities of cooling medium into the compressor, for mixing with the air or other gas, and for successively abstracting the cooling medium from the air or other gas. Preferably, the arrangement is such that the air or other gas is supplied with a quantity of cooling medium once for each stage of the compressor, and such that the just mentioned quantity of cooling medium is abstracted from the air or other gas before the latter enters the next successive stage of the compressor. Each stage of the compressor is thus preferably provided with injecting mechanism and separating mechanism.

In the relation particularly shown in the drawing, the first stage **300a** of the compressor is provided with an injecting nozzle **310**, of suitable construction to thoroughly and effectively atomize a cooling medium. The nozzle **310** is disposed to open into the compressor casing relatively near the axis thereof, and the cooling medium introduced therethrough thus mixes with the incoming air or other gas just prior to the time that the latter enters the corresponding impeller **302**.

The air or other gas being compressed is conventionally acted upon by the impeller **302** associated with the first stage, whereas the cooling medium, being substantially heavier, is thrown outwardly by centrifugal force and strikes the outer peripheral surface **312** of the compressor casing, at which point it coalesces into a film of water. This film of water is swept around to the lower side of the compressor casing and drains therefrom through a pssage **315** into a sump **314**. Sump **314** is provided with a float controlled valve **316** through which the collected cooling medium is removed from the compresser, either for disposal, or for recirculation, as in the case of the system of Fig. 3.

In accordance with the present invention, as stated generally above, the cooling medium associated with the second stage of the compressor may be introduced therein at any time after the abstraction of the cooling medium associated with the first stage, and preferably before the air or other gas enters the impeller associated with the second stage. Accordingly, the second stage of the compressor is provided with a pair of nozzles **311** and **313**, which may duplicate in construction the previously described nozzle **310**. Where both nozzles **311** and **313** are utilized, it is preferred that they be of slightly smaller capacity than the single nozzle **310**. The nozzle **311** opens into the compressor casing relatively near the outer peripheral surface **312** of the latter and the nozzle **313** opens into the compressor casing at a point corresponding to the position of the nozzle **310**.

With the just stated arrangement, it will be appreciated that as the air or other gas passes the outer peripheral surface **312** of the compressor, at which time the first charge of cooling medium is abstracted therefrom, and starts moving radially inwardly toward the impeller **302** associated with the second stage, it is subjected to the successive actions of the nozzles **311** and **313**, and is thereby supplied with a new charge of cooling medium. The cooling medium thus supplied, in advance of the passage of the air or other gas through the second stage, is abstracted therefrom in the previously described manner, and it will be understood that the successive stages of the compressor are also preferably supplied with nozzle arrangements corresponding to the nozzles **311** and **313**.

It will be understood that in the broader aspects of the invention, the nozzle **311** may be dispensed with and the nozzle **313** relied upon to inject all of the cooling medium for the second stage, and alternatively that the nozzle **313** may be dispensed with and the nozzle **311** relied upon entirely. It will further be appreciated that, if desired, groups of nozzles, such as **310**, **311**, and **313**, may be provided for the respective stages, and be distributed circumferentially around the compressor.

All of the nozzles **310**, **311**, and **313** are illustrated as being supplied with cooling medium through a supply line **308** having branches corresponding to the successive stages. The line **308** may be supplied with cooling medium in either the manner described above with reference to Fig. 1 or the manner described in connection with Fig. 3.

It will be appreciated that if desired, a plurality of passages **315** may be provided for each stage of the compressor, instead of the single passage **315** shown in Fig. 8, the preferred arrangement being one in which the several passages **315** drain into a common sump **314**, but open into the compressor casing at a plurality of points spaced circumferentially therearound.

From the foregoing, it will be appreciated that the general operation of the system of Fig. 8 may duplicate the general operation described with reference to the embodiment of Figs. 1, 3, and 5 for single or multi-stage systems, respectively, except that the injection of the liquid occurs within the compressor rather than in an ante-chamber.

Although only several specific embodiments of the invention have been described in detail, it will be appreciated that various changes in the method of practicing the invention, and that various modifications in the form, number, and arrangement of the parts may be made without departing from the scope of the invention.

What is claimed is:

1. A multistage compressor system comprising means for effecting first and second stages of compression, means for mixing an atomized liquid with the gas to be compressed prior to the completion of the first stage of the compression of said gas, means for eliminating said atomized liquid after the completion of said first stage, a second means for mixing an atomized liquid with said gas after said first elimination, a second elimination means effective after said second mixing operation and prior to the commencement of the second stage of compression, means for effecting a third mixing operation prior to the completion of said second stage of compression, and a third elimination means effective subsequent to the completion of said second stage of compression.

2. In combination, a compressor and operating means therefor, means for supplying a fluid to the compressor for compression thereby, continuously acting means for forming a mixture of the fluid and a cooling medium in atomized form prior to its discharge from the compressor, start and stop control means for said compressor, and means controlled by said start and stop control means for controlling said mixing means.

3. In combination, a compressor and operating means therefor, means for supplying a fluid to the compressor for compression thereby, continuously acting means for forming a mixture of the fluid and a cooling medium in atomized form prior to its discharge from the compressor, an

unloader valve mechanism associated with said compressor, and valve means controlled by said unloader valve mechanism for controlling said mixing means.

4. In combination, a compressor of the centrifugal type formed to provide a plurality of stages and having an impeller associated with each of said stages, and means including at least one atomizing nozzle associated with each stage of compression and effective to continuously inject a cooling medium in atomized form into said compressor, said nozzles being arranged to inject said cooling medium into the gas being compressed prior to the time that said gas reaches the corresponding impeller.

5. In a process for compressing a fluid, the steps of subjecting the fluid to the action of a compressor, continuously mixing with the fluid prior to its discharge from the compressor a cooling medium in atomized form capable of suspension in the fluid and in such quantity that a substantial part thereof remains in said compressed fluid in a liquid state, separating said cooling medium from said fluid after compression thereof, extracting heat from said cooling medium after said separation, and remixing said cooling medium with further supplies of said fluid.

6. In combination, a compressor and operating means therefor, means for supplying a fluid to the compressor for compression thereby, continuously acting means for injecting into the fluid prior to its discharge from the compressor a cooling medium in atomized form capable of suspension in the fluid and in such quantity that a substantial part thereof remains in said compressed fluid in a liquid state, means for separating the cooling medium from the fluid after the compression thereof, and an after-cooler associated with the system for reducing the temperature of the separated fluid.

7. In combination, a compressor and operating means therefor, means for supplying a fluid to the compressor for compression thereby, continuously acting means for injecting into the fluid prior to its discharge from the compressor a cooling medium in atomized form capable of suspension in the fluid and in such quantity that a substantial part thereof remains in said compressed fluid in a liquid state, means for separating the cooling medium from the fluid after the compression thereof, means for extracting heat from said separated cooling medium, and means for returning said cooling medium to said injecting means.

8. In combination, a compressor for a fluid formed to provide a cylinder and having a piston movable therein, means including at least one atomizing nozzle for continuously injecting into said cylinder during the operation of said piston a cooling medium in atomized form capable of suspension in said fluid and in such quantity that a substantial part of said medium remains in the compressed fluid in a liquid state, and separating means associated with said compressor for separating said cooling medium from the compressed gas after the discharge thereof from the compressor.

9. In combination, a compressor for a fluid formed to provide a compressor space and compressor element movable therein, means including at least one atomizing nozzle for continuously injecting into said space during the operation of said element, a cooling medium in atomized form capable of suspension in said fluid and in such quantity that a substantial part of said medium remains in the compressed fluid in a liquid state, and separating means associated with said compressor for separating said cooling medium from the compressed gas after the discharge thereof from the compressor.

10. In combination, a compressor and operating means therefor, means for supplying fluid to the compressor for compression thereby, and means including an antechamber and a plurality of atomizing nozzles associated therewith for injecting into the fluid, before the admission of the fluid to the compressor, a cooling medium in atomized form capable of suspension in the fluid.

11. In combination, a compressor and operating means therefor, said compressor having a compression space and means for supplying fluid to the compressor for compression thereby comprising an anterchamber separate from but communicating with said space through which fluid to be compressed is introduced into said space, and means including atomizing means associated with said antechamber for introducing into the fluid, while in said antechamber and prior to its admission into said space, a cooling medium in atomized form capable of suspension in the fluid.

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