Sept. 3, 1968 P. L. GEIRINGER 3,399,511

JET COMPRESSOR

Filed Feb. 15, 1966

Fig. 3.

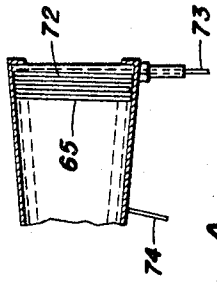


Fig. 4.

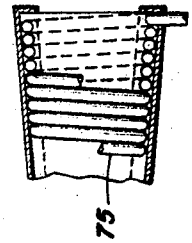
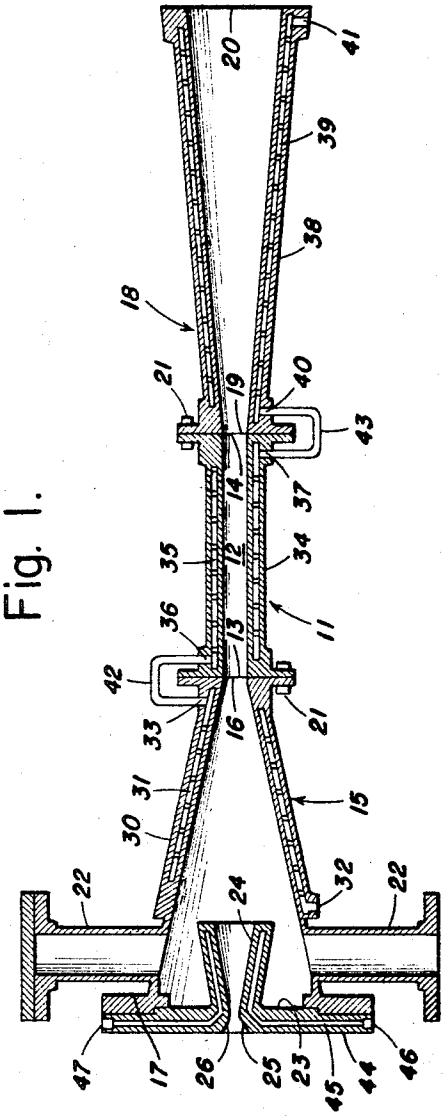


Fig. 1.



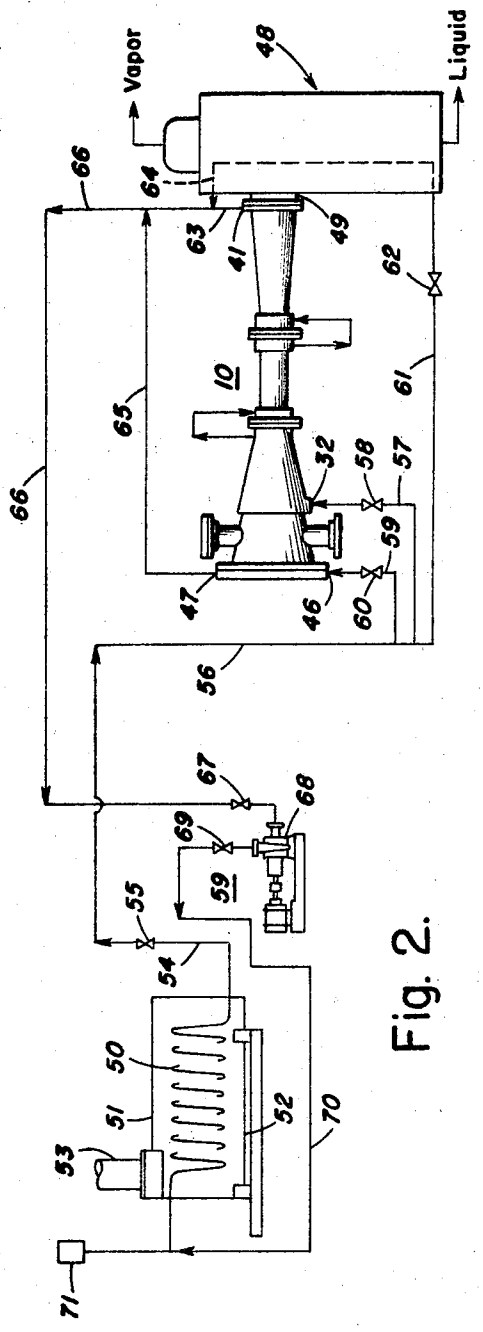


Fig. 2.

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JET COMPRESSOR

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7 Claims. (Cl. 55—36)

This invention relates to a jet compressor, and more specifically relates to a jet compressor utilizing a liquid as the compressing medium and an arrangement for adding heat to such compressor and associated liquid-vapor separator, by circulating a heat transfer fluid having a given temperature level about such compressor and separator.

Jet compressors or ejectors of various types are well known in the art for many years. One problem inherent in the use of such compressors is the reduction of thermodynamic efficiency as a result of heat loss of the fluid streams as such fluid streams pass through the compressor. Such efficiency reduction tends to impair the efficiency of operation of a vapor compression-distillation system in which such a jet compressor is used. This, of course, has the additional undesirable effect of reducing the economy of operation of a particular vapor compression-distillation system.

The present invention contemplates an arrangement for continuously maintaining the temperature of the nozzle and/or the internal surfaces of a jet compressor at a predetermined temperature level to add heat to the fluid streams.

It is the principal object of the present invention to improve the thermodynamic efficiency of operation of a jet compressor utilizing a liquid as the compressing medium.

Another object of the invention is to improve the economy of operation of a jet compressor utilizing a liquid as the compressing medium as well as the liquid-vapor separation associated with the compressor.

Still another object of the invention is to provide an arrangement for continuously adding heat to the nozzle of the compressor to reduce the friction along the surface thereof.

A further object of the invention is to provide a facile arrangement for continuously adding heat to the internal surfaces of such a jet compressor to reduce the friction along the surfaces, and to evaporate water formed on such surfaces.

A still further object of the invention is to provide a method for recirculating a heat transfer fluid to maintain continuously the internal surfaces of a jet compressor at a predetermined temperature level.

Other objects and advantages will become more apparent from the following description taken in conjunction with the accompanying drawing.

A jet compressor known in the art is comprised of a body formed of a cylindrical section, an inlet tapered section, and an outlet tapered section with the cylindrical section being connected to and disposed between the tapered sections; a tapered nozzle positioned in the widest portion of the inlet tapered section for transmitting a fluid stream under pressure therethrough into the body of the compressor in a direction toward the cylindrical section; and a port oriented on the inlet tapered section to permit a second fluid stream to be introduced into the inlet tapered section in proximity to the end of the nozzle emitting the first fluid stream. At the end of the outlet section, the outlet fluid stream has a pressure higher than

the pressure of the second fluid stream. Such a jet compressor has found application in a vapor compression-distillation system, as more fully disclosed in my copending application, Ser. No. 355,963, filed Mar. 30, 1965, where the first fluid stream is high temperature water and the second fluid stream is steam.

In association with a jet compressor of the above-described type, a specific embodiment of the present invention comprises a jacket formed on the external surface of the nozzle of the compressor and includes an opening extending through different positions of the jacket and an inlet and an outlet. Additionally, a plurality of jackets are formed on an external surface of the cylindrical and tapered sections, each jacket is provided with a spiral opening formed therein and provided with an inlet and an outlet. The inlet and outlet of the spiral opening in the jacket formed on the cylindrical section is connected to the outlet and the inlet of the spiral openings, respectively, of the jackets formed on the two tapered sections disposed on opposite sides of said cylindrical section whereby the spiral openings of the cylindrical and tapered sections are connected in series. Further, the liquid-vapor separator associated with the jet compressor is provided with heating means.

A heating system in fluid communication with the inlet and outlet of the nozzle permits a heat transfer fluid to be passed therethrough. The heating system is also in fluid communication with the inlets and outlets of the series connected openings in the jackets formed on the cylindrical and tapered sections. A heat transfer fluid of controlled temperature is circulated through the respective openings in the several jackets. The temperature level and quantity of heat transfer fluid passing through the jackets formed on the cylindrical and tapered sections are controlled to maintain the temperature of such sections above the temperature of the vapor-liquid mixture exiting from the compressor. The temperature level and quantity of heat transfer fluid passing through the jacket formed on the nozzle are controlled to maintain the temperature of the nozzle above the temperature of the water entering the nozzle. In this manner, friction along the surface of the nozzle is decreased thereby increasing the exit velocity of the fluid, and friction along the internal surfaces of the compressor is reduced thereby improving the thermodynamic efficiency of such a jet compressor by from 10 to 15%. When utilized in a vapor compression-distillation system, such a jet compressor substantially improves the economy of operation of such a system.

One modification includes electric wires of a resistance heating type wound on the external surfaces of the cylindrical and tapered sections to replace the afore-mentioned jackets for maintaining the latter surfaces at a required temperature level. Another modification is to replace the jackets with a tube spirally wound on the external surfaces of the cylindrical and tapered surfaces and having its inlet and outlet connected to the controlled heating and pressure system for circulating a heat transfer fluid through the tube for maintaining the surfaces at the required temperature level.

It has been found that modifications can be made to the standard compressor configuration utilizing a liquid as the compressing medium. For instance, the inlet and cylindrical sections may have substantially the same diameter, or the compressor body may have a diverging tendency throughout its length.

A feature of the present invention resides in the facile arrangement for heating the surfaces of a jet compressor

in contact with the stream passing therethrough. Another feature concerns the simplicity of the design of such heating arrangement. Still another feature involves the economy of operation and maintenance of such heating arrangement.

The present invention is readily understood from the following description taken together with the accompanying drawing in which:

FIG. 1 is a cross-sectional view of a specific embodiment of the present invention;

FIG. 2 is a schematic flow diagram of a method for maintaining the flow of a heat transfer fluid to the jet compressor of FIG. 1 and a liquid separator associated with such compressor;

FIG. 3 is a partial schematic diagram of an alternate method for heating the walls of a jet compressor; and

FIG. 4 is a partial schematic illustration of an alternate method for heating the walls of a jet compressor.

Referring to FIG. 1, there is provided a jet compressor, generally indicated as **10**, and including a hollow cylindrical section **11** having an internal opening **12** and flanged ends **13** and **14**; a first conically-shaped hollow section **15** having an internal opening at one flanged end **16** of a diameter generally equal to the diameter of opening **12**, with the opposite end **17** of generally larger diameter; and a second conically-shaped hollow section **18** having an internal opening at one flanged end **19** of a diameter generally equal to the diameter of opening **12**, and at the opposite, an end **20** of larger diameter.

The flanged end **16** of the section **15** is connected to end **13** of the cylindrical section **11** in a conventional manner, as by bolts **21**. The flanged end **19** of the section **18** is similarly connected to section **11**. Ports **22** are provided on the end **17** of the section **15**. One end of the port **22** is in fluid communication with the interior of the section **15**, with the opposite end being connected to a conduit of circular cross-section (not shown). The end **20** of larger diameter of the section **18** is connected to a conduit of circular cross-section (not shown). It is noted that the two conically-shaped sections are disposed in opposite directions relative to the cylindrical section. A tapered nozzle **23** mounted on the end **17** of the section **15** has a diverging end **24** of larger diameter disposed entirely of the larger end **17** of the conically-shaped section **15** and has an end **25** of smaller diameter connected to a conduit of generally circular cross-section (not shown). It is noted that the nozzle **23** includes an opening of a diameter intermediate those of ends **24** and **25**. It is also noted that the openings in end **24** of the nozzle and the first section **15** are flared in opposite directions.

As hereinbefore mentioned, however, the body formed by the sections **11**, **15** and **18** may have a diverging tendency from the end **17** of the section **15** to the ends **20** of the section **18**.

In operation, water at a temperature of from about 450° to 650° F., preferably 530° to 600° F., and at a pressure of from about 500 to 2000 p.s.i.a. is introduced into the end **25** of the nozzle **23**, passes through the intermediate opening **26**, and is expanded during passage through the opening **24** into the first conically-shaped section **15** in a direction toward the cylindrical section **11**. By such expansion, a portion of the water is vaporized. Port **22** is in fluid communication with a source of low pressure vapor such as steam. Water is entrained in the steam and is carried into the conically-shaped section **18** which converts velocity energy of the steam into pressure energy thereby increasing the pressure of the steam. The steam now at a higher pressure may be utilized in a vapor compression-distillation system for purification of water as disclosed in my copending application, supra.

In accordance with the present invention as utilized with the jet compressor explained hereinbefore, means are provided for heating the nozzle constituting such jet compressor and the surfaces of the cylindrical and conically-shaped sections to control the heat input of the internal surfaces in contact with the fluid passing therethrough. The heat input to the cylindrical and conically-shaped sections is selected to maintain the temperature of the internal surfaces thereof above the temperature of the vapor-liquid mixture emerging from section **18**, while the heat input to the nozzle is selected to maintain the temperature thereof at above the temperature of the water introduced into the end **25** of the nozzle **23**. This is accomplished by regulating the temperature of the heat transfer fluid at a given temperature level. By adding heat as hereinbefore described reduces the friction, increases the velocity of the mixture passing through the compressor, reduces water condensation, and lowers the viscosity of the fluid along the walls thereby improving the efficiency and economy of operation of the compressor in a water or liquid distillation system as disclosed in my copending application, supra.

An insulated jacket **30** formed with a spiral internal opening **31** having an inlet **32** and an outlet **33** is disposed on the external surface of the first conically-shaped section **15**. An insulated jacket **34** formed with a spiral internal opening **35** having an inlet **36** and an outlet **37** is mounted on the external surface of the cylindrical section **11**. An insulated jacket **38** formed with a spiral internal opening **39** having an inlet **40** and an outlet **41** is disposed on the external surface of the conically-shaped section **16**. A first tubular fitting **42** connects outlet **33** of jacket **30** to inlet **36** of jacket **34**. A second tubular fitting **43** connects outlet **37** of jacket **34** to inlet **40** of jacket **38** whereby the spiral openings in the respective jackets are connected in series for a purpose that is now fully hereinafter described. It is obvious that the openings in the respective jackets may be arranged in parallel rather than in the series arrangement just mentioned for a purpose that is later pointed out. It is also obvious that the three jackets may be formed integrally to constitute a unitary jacket.

The nozzle **23** is provided with an internal opening **45** having an inlet **46** and an outlet **47**. It is understood that opening **45** is so formed throughout nozzle **23** as to extend over substantially the entire or at least a large portion of the surface of the nozzle **23**.

It is noted that FIG. 1 illustrates the several jackets formed integrally with the external surfaces of the respective cylindrical and conically-shaped sections. It is obvious, however, that such jackets may be designed in the form of discrete equipments applied mechanically to the external surfaces of the cylindrical and conically-shaped sections in a suitable manner if so desired.

Referring to FIG. 2, there is illustrated a thermal liquid heating system for continuously circulating a heat transfer fluid of a type well-known in the art through the openings in the respective jackets and nozzle for adding heat to the surfaces of the several components of the jet compressor described above with regard to FIG. 1. The jet compressor **10** is schematically illustrated in FIG. 2, and for the purpose of the explanation of the latter figure includes inlet **32** and outlet **41** for the series openings in the respective jackets formed on the external surfaces of the cylindrical and conically-shaped sections, and inlet **46** and outlet **47** of the nozzle **23**. In connection with FIG. 2, it is understood that the solid lines delineate conduits for transmitting a heat exchange fluid therein in the directions indicated by the arrows. The jet compressor **10** is in fluid communication with a liquid separator, such as a cyclone separator, generally indicated as **48**, through conduit **49**.

As shown in FIG. 2, a coil **50** is disposed within a boiler **51** suitably heated at area **52** and having a stack **53** for venting products of combustion. The coil **50** as well as the conduit system connected thereto passes a heat transfer fluid of a type well-known in the art and serving a purpose that is later mentioned. The purposes of the boiler is to maintain the temperature level of the heat transfer fluid at a value dependent on the requirements of the compressor. It is obvious that the heat transfer fluid may be heated in other devices familiar to the heat transfer art.

The heat transfer fluid heated to a desired temperature in coil **50** is passed via conduit **54**, control valve **55** and conduit **56**. A portion of the heat transfer fluid in line **56** is passed through line **57** under the control of valve **58** to the inlet **32** of the jackets formed on the cylindrical and conically-shaped sections. Another portion of the heat transfer fluid in line **56** is passed through line **59** under the control of valve **60** to the inlet **46** of the nozzle **17**. The remaining portion of the heat transfer fluid in line **56** is passed through line **61** under the control of valve **62** to the liquid separator **48** to add heat to the upper surfaces of the separator **48** at the point where the thick, fast moving liquid film is formed. After passing through the several jackets, the fluid is withdrawn through outlet **41** through line **63** and combined with the fluid in line **64** withdrawn from the separator **48**. The fluid withdrawn through outlet **47** of the nozzle **23** in line **65** is combined with the fluid in lines **63** and **64** and passed through line **66** under the control of valve **67** to the inlet of pump **68**. The liquid is passed from the pump **68** under the control of valve **69** into conduit **70** and into the coil **50** wherein the heat transfer fluid is reheated. A temperature control **71** is illustrated schematically in FIG. 2 and serves to regulate the quantity of liquid passing through the coil **50** as well as the heat input into the boiler **51**. The liquid-vapor mixture from the compressor **10** is passed into separator **48** and separated into a liquid stream and a vapor stream. The heat transfer fluid passing through separator **48** about the surface wherein a thick, fast moving, water film is formed, is at a temperature higher than the liquid passing over such surface.

A first alternate arrangement for heating the surfaces of the cylindrical and tapered sections is shown in FIG. 3 and this utilizes an electric wire **72** usually, a resistance wire used for heating purposes, wrapped continuously around the peripheries of the external surfaces of the respective sections. External connections **73** and **74** are provided and connected to a suitable source of electric power (not shown). A control system (not shown) but well known in the art, is utilized to control the electric energization of the resistance wire and thereby the heat input to the compressor. The heating wire is embedded in a suitable electric and heating material in accordance with the usual practice in the art.

A second alternate arrangement for heating the external surfaces of the cylindrical and conically-shaped sections is shown in FIG. 4. This includes a tube **75** wound continuously and spirally around the external surfaces of the cylindrical and conically-shaped surfaces and connected to the circulating heat transfer fluid system, such as shown in FIG. 2. In this arrangement, the nozzle described with reference to FIG. 1 could remain connected to the heat transfer fluid system shown in FIG. 2.

It is understood that the invention herein described would function equally as well with a jet ejector or compressor of different wall design in which another high temperature and pressure fluid is supplied at end **25** of nozzle **23**, and another vapor is introduced through port **27** into the compressor.

The following is an example of the invention: 112.5 pounds per hour of water at a temperature of 544.6° F. and at a pressure of 1000 p.s.i.a. is passed through a nozzle **17** into the compressor **10**, 100 pounds per hour of steam at a temperature of 225° F. and a pressure of 17.6 p.s.i.a. is introduced through port **10**. 138 pounds per hour of steam at a temperature of 240° F. and a pressure of 25.0 p.s.i.a. is withdrawn from the compressor **10** together with 74.5 pounds of water. By maintaining the temperature of the wall above the outlet temperature of the steam-water mixture, i.e., 240° F., only 108.9 pounds per hour of water at the above temperature and pressure are required to achieve the same result.

It is understood that the invention herein is described in specific respects for the purpose of this description. It is to be further understood that such respects are merely illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is

1. A process for compressing a vapor with a liquid which comprises:

(a) expanding a high temperature liquid stream through a first diverging zone into a mixing zone;

(b) introducing the vapor into said mixing zone to form a liquid-vapor mixture;

(c) expanding the mixture of step (b) in a second diverging zone;

(d) recovering a vapor-liquid mixture from said second diverging zone at a pressure higher than the pressure of the admixed vapor; and

(e) heating said first diverging zone by circulating a heat transfer fluid thereabout to maintain said first diverging zone at a temperature above the temperature of the liquid expanding in the first diverging zone.

2. A process for compressing a vapor with a liquid which comprises:

(a) expanding a high temperature liquid stream through a first diverging zone into a mixing zone;

(b) introducing the vapor into said mixing zone to form a liquid-vapor mixture;

(c) expanding the mixture of step (b) in a second diverging zone;

(d) recovering a vapor-liquid mixture from said second diverging zone at a pressure higher than the pressure of the admixed vapor;

(e) heating said first diverging zone to maintain said first diverging zone at a temperature above the temperature of the liquid expanding in the first diverging zone; and

(f) heating said mixing zone and said second diverging zone to maintain said mixing zone and said second diverging zone at a temperature above the temperature of the vapor-liquid mixture withdrawn from the second diverging zone.

3. The process as claimed in claim **2** wherein the temperature is maintained in said mixing zone and said second diverging zone by passing a heat transfer fluid about said mixing and second diverging zones.

4. A process for compressing a vapor with a liquid which comprises:

(a) expanding a high temperature liquid stream through a first diverging zone into a mixing zone;

(b) introducing the vapor into said mixing zone to form a liquid-vapor mixture;

(c) expanding the mixture of step (b) in a second diverging zone;

(d) recovering a vapor-liquid mixture from said second diverging zone at a pressure higher than the pressure of the admixed vapor;

(e) heating said first diverging zone to maintain said first diverging zone at a temperature above the temperature of the liquid expanding in the first diverging zone;

(f) separating the mixture withdrawn from the second diverging zone in a separation zone; and

(g) heating said separation zone to maintain said separation zone at a temperature higher than the mixture passing through said separation zone.

5. The process as claimed in claim **4** wherein the temperature in the separation zone is maintained by passing a heat transfer fluid in an indirect heat transfer relationship with said separation zone.

6. A process for compressing steam with water which comprises:

(a) expanding the water at a temperature of between about 450° and 650° F. through a first diverging zone into a mixing zone;

(b) introducing the steam into said mixing zone to form a water-steam mixture;

(c) expanding the mixture of step (b) in a second diverging zone;

(d) recovering a steam-water mixture from said second diverging zone at a pressure higher than the pressure of the admixed vapor; and

(e) heating said first diverging zone to maintain said first diverging zone at a temperature above the temperature of the water expanding in the first diverging zone.

7. The process as claimed in claim 6 wherein the water introduced into the first diverging zone is at a pressure from about 500 to about 2000 p.s.i.a.

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