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STEAM JET REFRIGERATION APPARATUS

Filed April 24, 1936 2 Sheets-Sheet 1

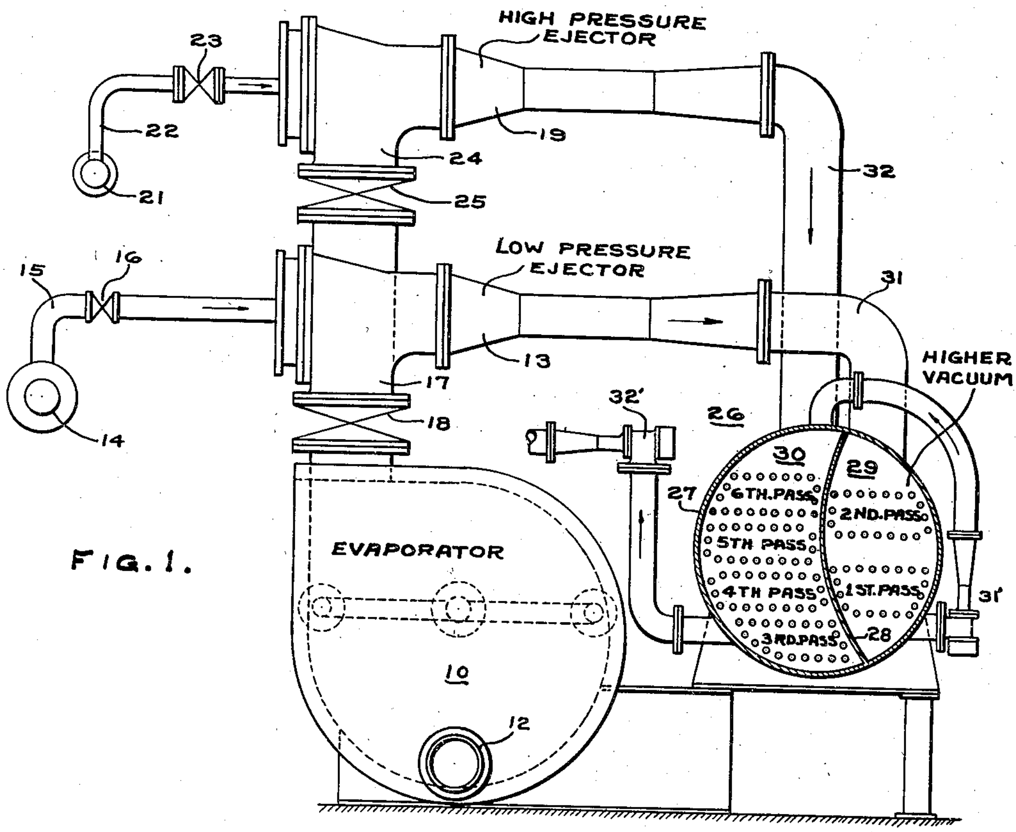

FIG. 1.

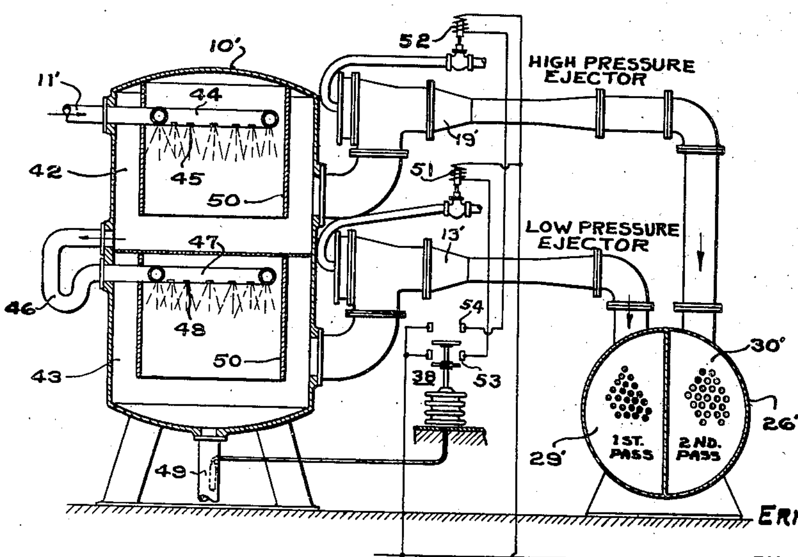

FIG. 3.

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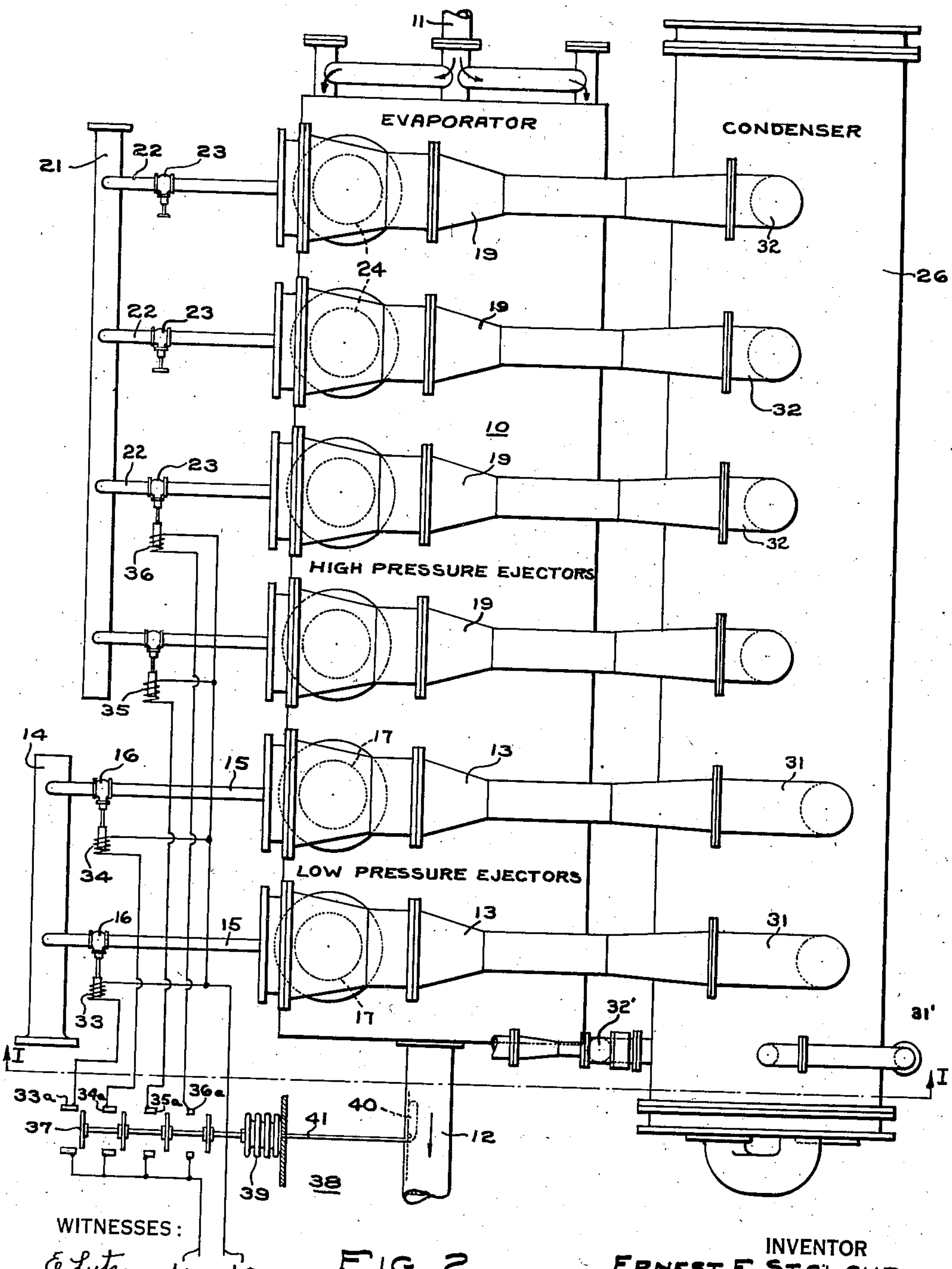

FIG. 2.

WITNESSES:

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STEAM JET REFRIGERATION APPARATUS

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6 Claims. (Cl. 62—152)

My invention relates to vapor jet refrigerating apparatus, more particularly to an installation in which a supply of low pressure steam is available and in which a source of high pressure steam is provided for supplementing the low pressure supply, and it has for an object to provide improved apparatus.

A particular object is to provide apparatus of improved economy of operation.

In accordance with my invention, I provide an evaporator, one or more ejectors using steam of relatively low pressure, one or more ejectors using steam of relatively high pressure, and means for condensing the vapor exhausted from the ejectors. The latter is divided into a plurality of condensing chambers through which cooling water is circulated in series, a higher vacuum being thereby effected in the first condensing chamber. The low pressure ejectors are arranged to exhaust into the first condensing chamber in which the higher vacuum is maintained, and the high pressure ejectors are arranged to exhaust into the second condensing chamber. Thus the better vacuum is utilized to provide most economical operation of the low pressure ejectors. This is desirable as the low pressure steam supplied to such ejectors is usually waste steam, such as exhaust from auxiliaries, and it is economical to use such steam as far as possible. Also, the higher vacuum provides a better heat drop or pressure drop for the low pressure steam.

These and other objects are effected by my invention, as will be seen from the following description and claims taken in connection with the accompanying drawings, and forming a part of this application, in which:

Fig. 1 is an end elevation of the apparatus, partly in section, as seen along the line I—I of Fig. 2;

Fig. 2 is a plan view thereof; and,

Fig. 3 is a diagrammatic view of a second embodiment.

Referring in detail to the embodiment shown in Figs. 1 and 2, the apparatus includes an evaporator **10** through which water or other fluid to be cooled is circulated. The evaporator may be of any suitable type known in the art, having either a single chamber or a plurality of chambers through which the water may be circulated either in parallel or in series. In the embodiment of Figs. 1 and 2, the evaporator **10** is shown as comprising a single chamber, and it is provided with an inlet connection **11** and an outlet connection **12** for the circulation of water therethrough.

The present invention is applicable to an installation in which there is available a variable or limited supply of motive fluid of relatively low pressure, for example, steam exhausted from auxiliaries at a pressure of 2 lbs. per square inch, which exhaust would otherwise be wasted. There are provided two ejectors **13** which are constructed and designed for operation with such low pressure steam, which is delivered thereto through a main conduit **14** and branch conduits **15**, the latter having valves **16**. The suction inlets of the ejectors **13** are connected to the evaporator at **17**, valves **18** being preferably interposed in such connections.

In order to supplement the action of the low pressure ejectors **13**, a number of ejectors **19** are provided, which are designed and constructed for economical operation with motive fluid of higher pressure from a suitable available source. The high pressure motive fluid, usually steam, is conveyed through a main conduit **21** and branch conduits **22** having valves **23**. The suction inlets **24**, of the ejectors **19** are connected to the evaporator, preferably through valves **25**.

A condenser **26** is provided for condensing the exhaust from the ejectors, both the expended motive fluid and the compressed vapor withdrawn from the evaporator. The condenser may be of any suitable type, for example, of the type having water cooled tubes arranged in a plurality of passes, which type is well known in the art. It comprises a shell **27** having a partition **28** dividing the same into first and second chambers **29** and **30**, respectively. The tubes are arranged so that the circulating fluid first passes through tubes in the chamber **29** and then through tubes in the chamber **30**. For example, the first two passes may be in the chamber **29** and four more passes may be arranged in the chamber **30**. As the cooling fluid passes first through the chamber **29**, it maintains a lower pressure therein than in the chamber **30**. In accordance with the present invention, the outlets of the low pressure ejectors **13** connected through conduits **31** to the low pressure chamber **29**, and the high pressure ejectors **19** are connected through conduits **32** to the higher pressure chamber **30**.

Suitable air removal apparatus is provided, for example, an ejector **31'** removes air and noncondensible vapor from the chamber **29** and exhausts the same into a higher pressure chamber **30**, and another ejector **32'**, which may comprise a plurality of stages, is connected to the chamber **30** for removing air and uncondensed vapor therefrom. The suction inlets of the ejectors **31'** and **32'** are connected to the chambers at suitable points, preferably remote from the inlets through which the exhaust from the ejectors is admitted. Suitable provision for supplying motive fluid to this ejector, is, of course, provided. Suitable provision is made for removing condensate from the chambers 29 and 30, as is well understood in the art.

Automatic control mechanism may be provided for varying the number of ejectors in operation. In Fig. 2, there is shown such an automatic control mechanism for the two low pressure ejectors 13 and for two of the high pressure ejectors 19, the remaining high pressure ejectors being manually controlled. The control mechanism comprises solenoids 33 and 34 for actuating the steam admission valves 16 of the low pressure ejectors 13 and solenoids 35 and 36 for operating the steam admission valves 23 of two of the high pressure ejectors 19. The solenoids 33 to 36 are connected to contacts 33*a* to 36*a* respectively. The latter are adapted to be successively engaged by the bridging members 37 of a thermostatic switch device 38. The latter comprises a bellows 39 for actuating said bridging members 37, a thermostatic bulb 40 disposed in the chilled water outlet connection 12, containing an expansible fluid, and a tube 41 connecting said bulb and bellows.

Operation

The operation will first be described assuming all ejectors to be operating. Low pressure steam is supplied to the low pressure ejectors 13 and high pressure steam is supplied to the high pressure ejectors 19. Water to be cooled is circulated through the evaporator in any suitable known manner, being admitted through the inlet connections 11 and withdrawn through the outlet connection 12. The ejectors withdraw vapor from the evaporator, thereby reducing the pressure therein. Such pressure reduction effects vaporization of a portion of the water with consequent cooling of the remaining portion. The vapor withdrawn from the vaporator, together with the expanded motive fluid, is discharged by the ejectors into the condenser 26, the low pressure ejectors 13 discharging into the chamber 29 and the high pressure ejectors 19 discharging into the chamber 30.

The condenser is cooled by means of a supply of cold water which is circulated, in any suitable known manner, first through the first and second tube passes in the chamber 29 and then through the third to the sixth tube passes in the chamber 30. Inasmuch as the water in the tubes in the chamber 30 has absorbed heat from the chamber 29, its temperature is higher than that of the water in the tubes in the chamber 29. Accordingly, a higher vacuum, or lower absolute pressure is maintained in the chamber 29 than in the chamber 30. The provision of the best vacuum for the low pressure ejectors 13 provides the maximum heat drop or pressure drop of the low pressure steam supplied to said ejectors for motivating the steam. The ejectors 19 are provided with higher pressure steam, which is better able to exhaust against the higher absolute pressure in the chamber 30.

During a great portion of the operation of the apparatus, only a limited number of ejectors need be operated. Inasmuch as the low pressure steam is usually steam that is otherwise wasted, the low pressure ejectors 13 are first placed in operation and then, as greater cooling action is required, the high pressure ejectors 19 are brought into operation. This may be done manually or, when automatic control is provided as in the illustrated embodiment, it is automatically effected in the following manner:

When the temperature of the water flowing through the outlet connection 12 is so low as to indicate that no cooling is required, the bridging members 37 of the thermostatic switch device 38 are moved to the right to disengage all of the contacts. Accordingly, all of the solenoids are deenergized and the steam admission valves are closed. As the cooling load increases, indicated by rise in temperature of the water flowing through the outlet connection 12, the fluid in the thermostatic bulb 40 expands, causing the bellows 39 to move the bridging members 37 to the left. The latter are arranged relative to the contacts 33*a* to 36*a*, as will be readily seen from Fig. 2, so as to engage said contacts in the order named. Thus, in response to a light load the solenoid 33 will open the steam admission valve 16 of the first low pressure ejector 13, and upon further increase, the solenoid 34 will open the steam admission valve of the other low pressure ejector 13. When the refrigerating load increases beyond the capacity of the two low pressure ejectors, then the solenoid 35 will open the steam admission valve of the first high pressure ejector 19 and upon still further increase, the solenoid 36 will open the steam admission valve of a second high pressure ejector 19. Upon decrease in refrigerating load, the ejectors are closed in reverse order.

The remaining high pressure ejectors 19 are provided with manually operated steam admission valves 23, and may be used to carry base load, the automatically controlled ejectors providing for the variations in cooling load in a manner well known in the art.

It will thus be seen that the low pressure steam is first used as far as possible and that the high pressure steam is used only when necessary. During a large portion of the operating period, the refrigerating load will be sufficiently low so that the same is carried mainly or entirely by low pressure steam.

It will also be noted that the best vacuum is provided for the low pressure ejectors which are operated the greatest portion of the time and which utilize steam that would otherwise be wasted.

In Fig. 3, I show my invention applied to apparatus in which cooling of the water or other liquid to be cooled is effected in a plurality of stages, the evaporator 10′ being divided into chambers 42 and 43. The water to be cooled is admitted through a conduit 11′ and admitted into the chamber 42 through a pipe 44 having spray openings 45 therein. The water collects in the bottom of the chamber 42 and flows by gravity through a conduit 46, formed to provide a loop seal, into an annular pipe 47 in the chamber 43, which conduit has spray openings 48 therein. From the chamber 43, the cooled water is withdrawn through an outlet connection 49.

An ejector 19′, designed and constructed for operation with high pressure motive fluid has its suction inlet connected to the chamber 42. An ejector 13′, designed and constructed to operate with motive fluid of lower pressure has its suction inlet connected to the chamber 43. Baffles 50 may be provided in the chambers 42 and 43 adjacent the connections with ejectors, to minimize entrainment of solid particles of water.

The low pressure ejector 13′ and the high pressure ejector 19' discharge into chambers 29' and 30' of a condenser 26'. This condenser is also arranged so that cooling fluid flows first through the chamber 29' and then through the chamber 30', thereby maintaining a higher vacuum in the chamber 29'.

In the operation of this embodiment, a portion of the cooling of the water is effected in the chamber 42, the vapor being withdrawn therefrom by the high pressure ejector 19'. The remaining portion of the cooling is effected in the chamber 43, the vapor being withdrawn with the low pressure ejector 13'. Inasmuch as the temperature of the water is lower in the chamber 43, a lower pressure, or higher vacuum, is maintained therein.

At partial load, the high pressure ejector 19' may be shut down and only the low pressure ejector 13' operated. This may be effected by automatic control mechanism similar to that shown in Fig. 2 and including solenoids 51 and 52 controlling the motive steam supply to the ejectors 13' and 19', respectively, and in turn controlled by contacts 53 and 54, respectively. A thermostat switch device 38, similar to that shown in Fig. 2, engages the contact 53 to effect operation of the low pressure ejector 13', only upon light load, and engages both contacts to effect operation of both ejectors upon a greater load.

It will be understood that I have described, for the most part, only such parts of the apparatus as directly concern the invention and that other suitable known features, which are applicable in an obvious manner, may be applied. For example, the valves 18 and 25 controlling the communication between the evaporator and the suction inlets of the ejectors are opened in any suitable manner at such times as the ejecting action of the associated ejectors is established. Also, the ejectors may embody starting nozzles, in which case suitable known forms of control therefor may be employed. It will also be apparent that the number of low pressure ejectors and the number of high pressure ejectors will be such as are most suitable for the particular conditions encountered in each installation.

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:

1. In vapor jet refrigerating apparatus, the combination of evaporator means, first and second ejectors for withdrawing vapor from said evaporating means to effect cooling by evaporation of liquid therein, said first and said second ejector being designed and constructed for operation with motive fluid of relatively low pressure and motive fluid of relatively high pressure, respectively, condensing means comprising first and second condensing chambers for condensing the vapor exhausted by said first and second ejectors, respectively, and means for conveying cooling water through said first and second condensing chambers in series in the order named, whereby the first ejector utilizing motive fluid of low pressure exhausts into a region of lower pressure than the second ejector.

2. In vapor jet refrigerating apparatus, the combination of evaporator means, first and second ejectors for withdrawing vapor from said evaporator means, said first and said second ejector being designed and constructed for operation with motive fluid of relatively low pressure and motive fluid of relatively high pressure, respectively, means for supplying motive vapor of relatively low pressure and motive fluid of relatively high pressure to said first and second ejectors, respectively, means providing first and second condensing chambers connected to said first and second ejectors, respectively, and means for circulating cooling fluid in heat exchange relation with said first and second condensing chambers in series in the order named and for maintaining a lower pressure in said first chamber than in the second chamber, whereby the first ejector utilizing motive fluid of low pressure exhausts into a region of lower pressure.

3. In vapor jet refrigerating apparatus, the combination of evaporator means, first and second ejectors for withdrawing vapor from said evaporator means, said first and said second ejector being designed and constructed for operation with motive fluid of relatively low pressure and motive fluid of relatively high pressure, respectively, means for supplying motive vapor of relatively low pressure and motive fluid of relatively high pressure to said first and second ejectors, respectively, means providing first and second condensing chambers connected to said first and second ejectors, respectively, means for conveying cooling fluid in heat exchange relation with said first and second chambers in series in the order named, whereby a lower pressure is maintained in said first chamber connected to said first ejector utilizing motive fluid of low pressure, and means for rendering said first and second ejectors operative successively in response to successive increases in refrigerating load, respectively.

4. In vapor jet refrigerating apparatus, the combination of evaporator means, first and second ejectors for withdrawing vapor from said evaporator means, said first and said second ejector being designed and constructed for operation with motive fluid of relatively low pressure and motive fluid of relatively high pressure, respectively, means for supplying motive vapor of relatively low pressure and motive fluid of relatively high pressure to said first and second ejectors, respectively, means providing first and second condensing chambers connected to said first and second ejectors, respectively, means for conveying cooling fluid in heat exchange relation with said first and second chambers in series in the order named, whereby a lower pressure is maintained in said first chamber connected to said first ejector utilizing motive fluid of low pressure, and means for rendering said first ejector operative in response to a predetermined refrigerating load and said second ejector operative in response to a greater refrigerating load.

5. In vapor jet refrigerating apparatus, the combination of first and second evaporator chambers, means for conveying liquid to be cooled through said first and second chambers in series in the order named to effect cooling thereof in successive stages, a first ejector designed and constructed for operation with motive fluid of relatively low pressure for withdrawing vapor from said second evaporator chamber, a second ejector designed and constructed for operation with motive fluid of relatively high pressure for withdrawing vapor from said first evaporator chamber, condensing means comprising first and sec-

ond condensing chambers for condensing the vapor exhausted by said first and second ejectors, respectively, and means for conveying cooling water through said first and second condensing chambers in series in the order named, whereby the first ejector utilizing motive fluid of low pressure exhausts into a region of lower pressure than the second ejector.

6. The method of refrigeration comprising supplying motive fluid of relatively low pressure to a first ejector and motive fluid of higher pressure to a second ejector, utilizing said ejectors to remove vapor from evaporator means to effect cooling by evaporation of liquid therein, discharging the exhaust fluid from said first and second ejectors into first and second condensing chambers, respectively, and conveying cooling fluid into heat exchange relation first with the exhaust fluid in said first condensing chamber and then into heat exchange relation with the exhaust fluid in said second condensing chamber, whereby said first ejector utilizing low pressure motive fluid exhausts into a region of lower pressure in the first condensing chamber.

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