This invention relates to an improved refrigeration system of the type shown in United States Patent No. 2,174,302, granted September 26, 1939.

Such systems usually employ water as a refrigerant and mercury as a propellant, and while water and mercury are immiscible under ordinary conditions, under certain operating conditions fine particles of mercury become suspended in the water to form a mud-like sludge, as is more fully explained in the above-mentioned patent. Such sludge tends to impede circulation and provision must be made to minimize its formation, to remove and break up accumulations of such sludge, and to return the mercury component to the boiler or propellant circuit without impairing the operating efficiency of the refrigerating system.

To this end the system shown in the above-mentioned patent has proved successful, but it will be noted that the arrangement is relatively complicated, bulky and expensive. Moreover, since such systems are also used to provide a supply of hot water, provision must be made to transfer the heat of condensation of the propellant and refrigerant fluids to a suitable water supply, as shown for example in United States Patent No. 2,174,302, granted September 26, 1939.

It is, of course, highly desirable to operate such systems so as to maintain a high refrigeration efficiency and heat transfer, and yet prevent the objectionable accumulation of mercury sludge.

The principal objects of the present invention are to simplify the above systems and to provide an improved multiple stage ejector having efficient and reliable means for eliminating sludge and for transferring or dissipating heat, and which is relatively inexpensive to manufacture and install.

Another object is to minimize the amount of propellant passing from the first stage to the second stage ejector.

Further objects relate to various features of construction and will be apparent from a consideration of the following description and the accompanying drawings wherein:

Fig. 1 is a diagrammatic view of a refrigerating system embodying the present invention;

Fig. 2 is a longitudinal section view through the multiple stage ejector;

Fig. 3 is an end elevation of the ejector;

Fig. 4 is an enlarged section on the line 4—4 of Fig. 2;

Fig. 5 is a fragmentary elevation with parts broken away, of the outer end of the first stage ejector; and

Fig. 6 is a fragmentary sectional view of the outer ends of the ejectors of modified construction.

Referring to Fig. 1, the refrigerating system shown therein comprises a boiler 1 having a suitable heater such as a gas burner assembly 2 and a draft-inducing flue 3, only a portion of which is shown. Mercury vapor passes from the boiler 1 through a riser 5 to the branches 5a and 5b which are connected respectively to the interconnected first and second stage aspirators 6a and 6b of my improved multiple stage ejector. The first stage aspirator 6a is connected by a vapor duct 8 to the cooler or evaporator 11 which contains a body of aqueous refrigerant containing a suitable antifreeze agent. Vapor is drawn through the duct 8 to the mixing chamber of the first stage aspirator (heretofore more fully described) and the mixed propellant mercury vapor and the refrigerant vapors are passed through the aspirator where the refrigerant is compressed and the mercury is condensed.

The condensed mercury flows from the first stage aspirator into a drain 14 while the compressed vapor passes to the second stage aspirator 6b into which a second stream of mercury vapor flows from the line 5b, this latter propellant stream causing a further compression of the refrigerant vapor in the second stage aspirator. A drain 27 receives the condensed mercury from the second stage aspirator and the two drains 14 and 27 converge at 28. The compressed refrigerant passes upwardly from the second stage aspirator through duct 29 to the refrigerant condenser 30. The condenser 30 may be of any suitable form and is here shown as being disposed within a water tank or reservoir T, as in Patent No. 2,174,302, granted September 26, 1939.

A chamber or drum 32 is preferably located at the end of the condenser 30 which is remote from the inlet of the pipe 29 and one end of a pipe 39 communicates with the chamber 32 so as to receive noncondensable gases therefrom. The lower portion of this chamber is connected with a drain or refrigerant return pipe 34 through which the condensed refrigerant passes on its way back to the cooler 11.

The lower end of the pipe 34 is connected to an inclined tube 48, the upper end of which has a vertical continuation 42 which extends above the level of the liquid L in the cooler 11. The pipe section 42 has a connection with a downwardly extending pipe 43, the lower end of which is connected with a drain duct 44 communicating with the lower part of the cooler 11. The lower part of the cooler 11 is formed with walls which incline downwardly toward the drain 44 so that accumulations of mercury sludge in the cooler 11 may pass directly into the drain 44.

The lower part of the duct 44 provides a shallow
The duct 44 has a relatively large diameter to permit the movement of the heavy sludge through and the drum 50 extends downwardly a substantial distance below its connection with the trap defined by the duct 44. The upper part of the drum 50 is connected by vapor duct 51 to the low-pressure portion of the system, i.e., the upper part of the cooler 11. An upwardly inclined duct 52 extends from the lower part of the drum 50 and is connected at 53 with the vapor duct 51. Below the connection 53 is a spill-over duct 55, the lower part of which provides a trap 56 connected to a mercury return 57 which is connected with the boiler 1.

When sludge accumulates in the cooler 11, it forms a mud-like deposit on the lower walls of the cooler and since the cooler is provided with downwardly sloping walls, this heavy, mud-like deposit can drain into the drum 50. Since the drum 50 is connected to the low-pressure portion of the system and is in a relatively warm location, the more volatile element of the heavy sludge, i.e., the aqueous refrigerant, is evaporated and drawn into the first-stage mixing chamber through the duct 58, while the mercury residue flows into the line 52 and thence into the spill-over 55 to the mercury return 57. Since the drum 50 extends a substantial distance below the spill-over connection into the line 55, any sludge in the lower part of the drum is subjected to a substantial liquid head which results in a tendency to squeeze refrigerant out of the sludge so that the mercury may coalesce.

The connection 28 between the drains 14 and 27 communicates with a small drum or chamber 60 to which the lower end of the inclined pipe 40 is also connected, while an upwardly inclined duct 61 extends from this chamber 60 to a chamber 64 constituting a part of the purger assembly 63. The chamber 64 receives noncondensable gases through the pipe 39 and a drop tube 65 of restricted internal diameter extends downwardly therefrom. Globules of condensed mercury spilling over from the duct 61 entrain bubbles of the noncondensable gases in the tube 65, compressing the gases as they move downwardly through the tube. The lower end of the tube 65 is immersed in a body of mercury in the well 67, the upper surface of this liquid propellant being exposed to atmosphere. A return duct 69 is circumcised about the tube 65 and is connected to the mercury-return pipe 57, there being a very small pressure-equalizing vent between the upper part of the duct 69 and chamber 64. A deflector 68 prevents gas from rising into the duct 69 from the lower end of the drop tube 65.

The arrangement of the spill-over connection between the tube 61 and chamber 64 determines the level of the mercury in the trap defined by the lower parts of the ducts 34 and 42. The condensed mercury received from the drains 14 and 27 passes into the chamber 60 and from the latter may pass to the spill-over connection and thence to the purger. From the purger the mercury flows through the pipe 57 back to the boiler 1, the height of the mercury in the pipes 57 and 69 being sufficient to balance the boiler pressure.

During normal operation of the system the trap 70 defined by the pipes 61 and 40 is constantly receiving condensed mercury from the drains 14 and 27, and the spill-over connection between pipe 61 and chamber 64 definitely limits the height of mercury in the pipe 27. Thus, a mercury column of constant height is automatically maintained in the leg 71 of the trap, since the vapor spaces above the mercury in the pipe 27 and in the pipe 39 both lead into the condenser 36, and are therefore at the same pressure. These mercury columns are balanced by the mercury in pipe 40 which fills pipe 48 up to its intersection with pipe 34, plus condensed refrigerant liquid in pipe 34. Mercury rises in the vertical pipe 42 to a sufficient height to balance the pressure difference between the condenser 36 and the evaporator 11. The condensed refrigerant rises in pipe 34 until sufficient head is built up to allow some of the liquid to pass into pipe 42 and rise through the mercury therein, and then pass into the evaporator via pipes 43 and 44. The liquid heads in the branches 34 and 42 are provided by bodies of condensed mercury and aqueous refrigerant, as explained more fully in Patent No. 2,174,330, granted to Lynn F. Whitney, September 26, 1939, to which reference may be had for a more complete description of the operation of the system.

In accordance with the present invention, the first-stage aspirator 103 and associated parts provide an interconnected assembly which, as shown in Figs. 2 to 4, comprises an elongate housing of cylindrical shape and formed in two sections, one the inner section 108 having a closed rear end 109 and the outer section 108a having an opened rear end 112 which receives the first-stage aspirator 103. The floor or bottom wall 114 of the first section of the housing slopes slightly from the front toward the rear so that condensate accumulating therein runs toward the rear of the trap.
5 The ejector or aspirator 102c is generally similar to the aspirator 103 and comprises an elongate diffuser 139 having an inner end in spaced alignment with a nozzle 131 which projects through an opening in a cap 132 connected to the branch line 50 of riser 5. A sleeve 133 extends about the space or mixing chamber between the nozzle and diffuser, and this sleeve is formed with spaced perforations or inlet so as to provide a communication between the mixing chamber and an annular intake chamber 138 only by the cap 132 and sleeve 133. The intake chamber is connected to duct 124 so that compressed vapors from the first stage ejector are conducted into the intake chamber of the second stage ejector. Each of the perforations in sleeve 133 is considerably smaller than the inlet opening, communicating with duct 124, but their combined area is substantially greater.

A jacket 134 surrounds the inner section of the diffuser and defines a cooling chamber 135. A second casing 156 surrounds an outer section of the diffuser and defines a discharge chamber 137.

A series of baffles 138 fit about the inner end of the diffuser within the chamber 137 and their peripheries are shaped so as to permit propellant condensate to run toward the closed end of the casing. The floor of this casing adjacent to its closed end is formed with a drain opening 140 to which the line 27 is connected and the opposite end of the chamber 137 beyond the innermost baffles is provided with a vapor discharge opening 141 to which the vapor line 29 is connected. The inlet chamber 139 is also provided with a drain opening 142 connected by line 143 with the propellant drain 14 so that condensed particles of mercury or propellant may be returned to the system. The line 143 preferably is formed with a trap 143a which is filled with mercury so as to prevent any flow of refrigerant vapor and mercury from the discharge end of the first stage ejector through line 143 to inlet chamber 139.

In order to permit the apparatus to have as an over-all height as possible, it is desirable that the outlet 122 be above the outlet 140, preferably at least by an amount corresponding to the height of a mercury column equal to the difference between the maximum condenser pressure that can be obtained in the operation of the apparatus and the pressure that occurs at the outlet of the first stage diffuser when the machine is operating at the maximum condenser pressure. The particular arrangement herein shown permits the attainment of this objective.

The inner end of the diffuser within the jacket 134 carries a series of heat-dissipating fins 143 and the upper part of this chamber is provided with an enlarged opening 146 directly connected with the duct 126. The chambers 121 and 135 are filled with alcohol or other similar liquid which receives heat from the gases passing through the diffusers and the hot vapor conducted by the pipe 125 to a condenser 150 located in a hot water supply tank T, as shown in Fig. 1.

The tank T is provided with a connection 155 leading to the condenser 150 by means of which the cooling circuit may be initially evacuated so that the alcohol therein may vaporize at relatively low temperature (around 176° F.) when the temperature of the water around the condenser 150 is 170° F. The tank T is also provided with an inlet line 156 for receiving incoming water from the supply main, and a hot water supply line 151 is connected with the upper part of the tank, as in Patent No. 2,174,302, granted September 26, 1939, to which reference may be had for a more complete description of this part of the system.

In operation, mercury vapor discharged from the nozzle 112 aspirates water vapor through the duct 8 and carries it through the diffuser 110, compressing it and discharging the compressed hot vapor into the interior of the housing 108. A substantial amount of heat is absorbed by the alcohol in the jacket 116, and any condensed mercury falls to the bottom of the housing 100 and eventually passes into the drain pipe 14. The compressed water vapor and any uncondensed mercury is drawn through pipe 124 into the second stage aspirator and carried through the diffuser 130 which results in further compressing the water vapor which, after passing about the baffles 138, is discharged into the duct 29. The condensed mercury accumulating in the bottom of the chambers 120 and 130 is returned to the system through pipes 14 and 21, respectively. Heat from the second stage aspirator is absorbed by the alcohol in the section 134 and circulates upwardly through the jacket 116 and duct 128 into the condenser 150 where alcohol vapors are condensed and thus give up their heat to the water in the tank T, as is more fully described in Patent No. 2,174,302.

An important objective, as above noted, is the prevention to the greatest practical extent of the formation of mercury sludge, particularly in the condenser, refrigerant return line and associated parts. Although the mechanism accountable for the formation of mercury sludge is not definitely known, one explanatory theory is that mercury particles carried by the mixed vapors discharged from the ejectors may carry electric charges which cause the particles on encountering liquid water in the condenser to form a relatively stable emulsion or sludge, unless such charges are removed or dissipated by contact with hot metal surfaces. In any case it has been found that by passing the hot vapors over heated metallic surfaces, such as a series of baffles disposed about the diffuser of the ejector, the formation of mercury sludge in condenser and return line is virtually eliminated.

In order to obtain improved pumping efficiency, the mercury vapor passing through the diffusers should be condensed so that the fluid entering the inlet chamber 139 will contain a minimum amount of mercury vapor and minute particles of condensed mercury. The boiling of the alcohol in the chambers 121 and 135, which respectively surround the first and second stage diffusers, serves to cool the diffuser walls and furthermore cooperates with the cooling fins 119 in condensing the major portion of mercury vapor remaining in the fluid stream leaving the outlet of the diffuser 110. Hence, the fluid entering the inlet chamber 128 of the second stage ejector contains only a very small amount of uncondensed mercury vapor.

Moreover, the 180° change in the direction of the fluid stream discharged from the end of the diffuser 110 in its travel to the inlet chamber 139 allows minute particles of condensed mercury to impinge upon the wall 101 and as a consequence such particles fall to the bottom of the chamber 120 and pass into the return pipe 14.
and thereby are eliminated from the fluid conducted to the inlet chamber 138.

The fluid leaving the discharge or outlet of the second stage diffuser 130 is quite hot, as are also the fins 138 disposed about the diffuser 130. Since the hot fluid must pass about the fins 138 before being discharged through the opening 141 on its way to the condenser 30, it is maintained at an elevated temperature; and it will be noted that the baffles are preferably so designed and arranged that the fluid before being discharged through the opening 141 passes through a tortuous channel defined by the fins 138 and thus the hot fluid comes in contact with a heated metallic surface which is believed to be effective in eliminating any static charge which may be carried by the mercury particles. Hence, even though minute particles of condensed mercury may be entrained with the vapors passing through the duct 25, virtually no snudge is formed when the water vapor and condenser.

Certain modifications of the above described system are permissible or desirable. For example, the fins 119 on the jacket 118, as shown in Fig. 2, may be made more effective in condensing mercury vapor and removing particles of condensate from said jacket: and the stream of vapor passing between them if their construction is slightly altered as shown in Fig. 5. In this modification the outer or free end portions of the fins 119a are cut and bent to form oppositely extending parts projecting obliquely from the central parts of the fins, thereby to provide a greater chance for the mercury to come in contact therewith.

Another desirable modification is shown in Fig. 6, wherein semi-oval baffles 158 and 159 are positioned in spaced relation to the discharge end of the diffusers 110 and 130, respectively, so as to deflect the mercury particles downwardly and then redirect the fluid stream rearwardly. The baffle 158 may be spot-welded to the walls of the housing 101 as indicated by the numeral 160, and similarly the baffle 159 may be spot-welded to the end 130 of the housing 130 and the wall of housing 136 as indicated by numeral 161. In either case the lower ends of these baffles are formed with openings or spaced from the bottom wall portion of the respective housings so as to provide passageways 163 through which condensed mercury may flow directly to the return 14 and 21, respectively.

While I have shown and described one desirable embodiment of the invention, it is to be understood that this disclosure is for the purpose of illustration and that various changes and modifications may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

I claim:

1. In an ejector, an elongate diffuser, baffle elements carried by the outer face of the discharge end portion of said diffuser, a cooling jacket surrounding the intake end portion of said diffuser, said cooling jacket having a port arranged to permit circulation of cooling fluid into said diffuser and a vapor discharge port adjacent to the inner end of said baffle elements and disposed above the level of said discharge port.

2. In an ejector an elongate diffuser, baffle elements carried by the outer face of the discharge end portion of said diffuser, a cooling jacket surrounding the intake end portion of said diffuser, said cooling jacket having a port arranged to permit circulation of cooling fluid into and out of said jacket, a casing surrounding said discharge end port and defining with said baffle elements a tortuous path of travel for fluid discharged from said diffuser, the lower parts of said baffle elements being spaced from said casing so as to define a path of travel along the lower wall portion of said casing, a condensate discharge port below the level of the discharge end of said diffuser and arranged to communicate with said port, and a vapor discharge port adjacent to the inner end of said baffle elements and disposed above the level of said discharge port.

3. In a refrigeration system of the type having a refrigerant fluid circuit including a vapor duct and a condenser duct, a propellant fluid circuit including a pressure source and a return to said source, and a cooling fluid circuit, a multiple stage ejector comprising a first stage ejector including a diffuser having its intake connected with said vapor duct and a nozzle connected with said pressure source, a housing surrounding the outer end portion of said diffuser, said casing enclosing said diffuser and said condenser, a second stage ejector including a diffuser having a vapor intake communicating with the intake end portion of the second stage diffuser, a conduit connecting the cooling jacket with said cooling fluid circuit, a housing surrounding the discharge end portion of said second stage diffuser, said housing having a vapor discharge port spaced from the discharge end of said diffuser and a condensate discharge port below the level of the discharge end of said diffuser, a vapor discharge line connecting the vapor discharge port with said condenser duct, a pipe line connecting the condensate discharge port with a return to said source, and baffle elements interposed between said vapor discharge port and said discharge end of said diffuser.

4. In a refrigeration system of the type having a refrigerant fluid circuit including a vapor duct and a condenser duct, a propellant fluid circuit including a pressure source and a return to said source, and a cooling fluid circuit, a multiple stage ejector whereof the first stage comprises a diffuser having its intake connected with said vapor duct and a nozzle connected with said pressure source, a cooling jacket surrounding at least a part of the outer surface of said diffuser, a housing surrounding the outer end portion of said jacket and projecting therefrom so as to provide a chamber into which said diffuser discharges, a second stage ejector including a diffuser having a vapor intake communicating with said housing at a point remote from the discharge end of said first stage diffuser, a cooling jacket surrounding the intake end portion of said second stage diffuser, conduits connecting the cooling jackets with said condenser duct, a housing surrounding the discharge end portion of said second stage diffuser so as to provide a second chamber into which it may discharge, said second chamber having a vapor discharge port inwardly of and above the level of the discharge end of said diffuser and a condensate discharge port adjacent to but below the level of the discharge end of said diffuser, baffle means about said discharge end portion between said vapor
discharge port and said condensate discharge port, a discharge line connecting said vapor discharge port with said condenser duct, and a pipe line connecting a return to said source with said condensate discharge port.

HENRY A. BURGRABE.

REFERENCES CITED

The following references are of record in the file of this patent:

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,118,971</td>
<td>Barker</td>
<td>Nov. 10, 1914</td>
</tr>
<tr>
<td>1,972,704</td>
<td>Crosthwait, Jr.</td>
<td>Sept. 4, 1934</td>
</tr>
<tr>
<td>2,008,350</td>
<td>Dardin et al.</td>
<td>July 16, 1935</td>
</tr>
<tr>
<td>2,142,806</td>
<td>Schumbohm</td>
<td>Jan. 3, 1939</td>
</tr>
<tr>
<td>2,174,302</td>
<td>Whitney</td>
<td>Sept. 26, 1939</td>
</tr>
<tr>
<td>2,180,447</td>
<td>Whitney</td>
<td>Nov. 21, 1939</td>
</tr>
<tr>
<td>2,190,123</td>
<td>Whitney</td>
<td>Apr. 30, 1940</td>
</tr>
<tr>
<td>2,380,447</td>
<td>Pearce</td>
<td>Apr. 21, 1942</td>
</tr>
<tr>
<td>2,436,693</td>
<td>Hickman</td>
<td>Feb. 14, 1948</td>
</tr>
<tr>
<td>2,486,019</td>
<td>Goddard</td>
<td>Oct. 25, 1949</td>
</tr>
</tbody>
</table>