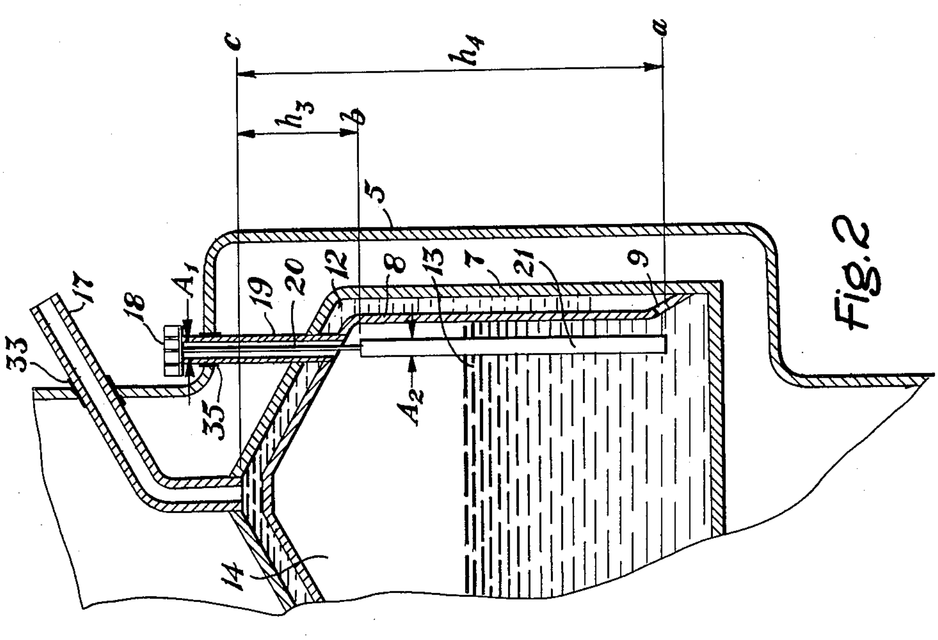
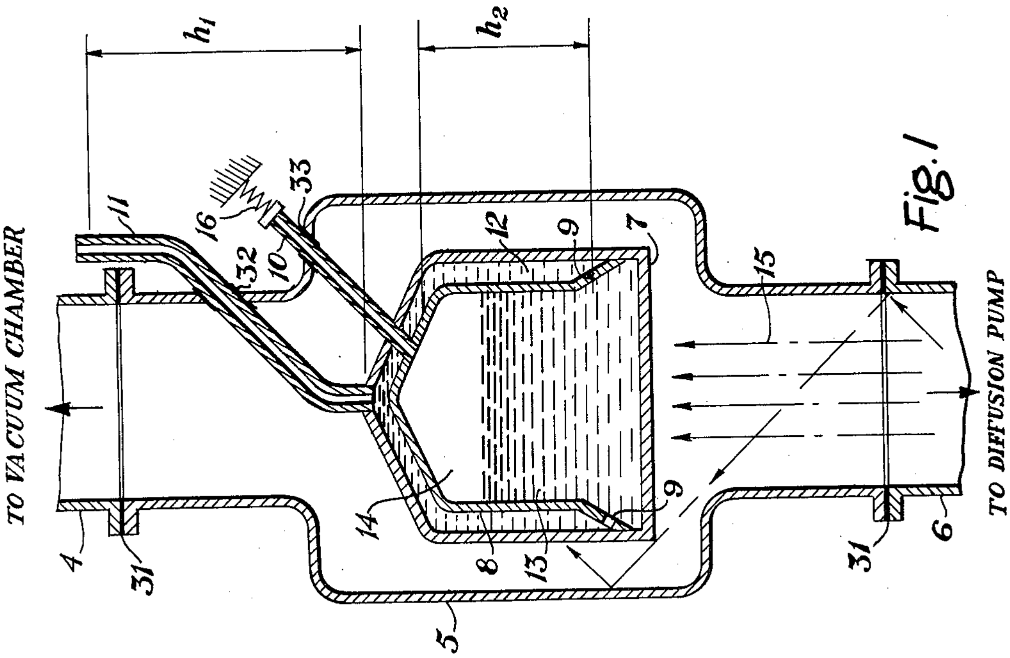
Aug. 18, 1964 K. W. ARNOLD ETAL **3,144,756**

VACUUM SYSTEM COOLING TRAP

Filed July 23, 1962 2 Sheets-Sheet 1





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VACUUM SYSTEM COOLING TRAP

Filed July 23, 1962 2 Sheets-Sheet 2

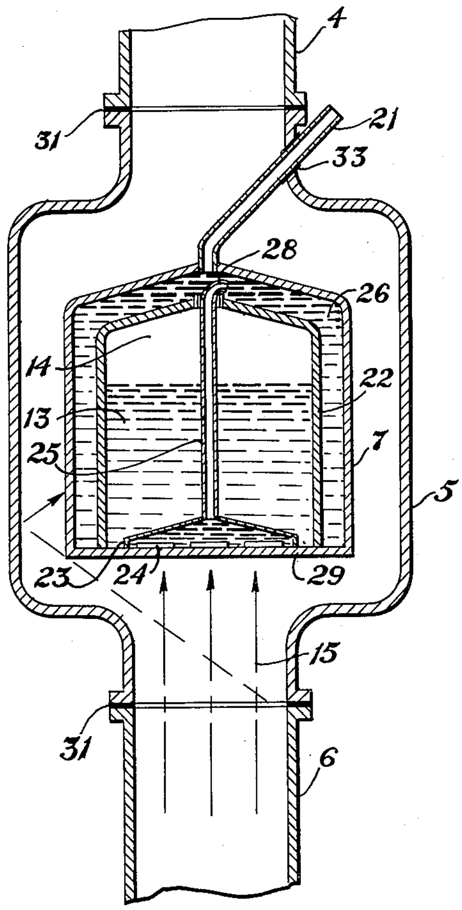

Fig. 3

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VACUUM SYSTEM COOLING TRAP

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This invention relates to vacuum systems employing diffusion pumps and the like, and more particularly to a cooling trap therefor adapted to present a maximum condensation surface to vapors which diffuse onto it from the pump and from the vacuum chamber.

Conventionally, a system to be exhausted, such as a high vacuum tank or particle accelerator, is reduced to a rough vacuum by a rotary displacement mechanical pump which discharges into the atmosphere. High vacuum is then obtained by means of a condensation or diffusion pump. This latter type of pump, in essence, comprises a container of a fluid such as mercury, heavy petroleum oil or chlorinated hydrocarbons. The container is heated sufficiently to vaporize the fluid which streams out of jets in the container walls entraining gas from the system before being condensed by the cooled walls of the pump. Diffusion pumps, however, suffer from back-streaming of the operating fluid and are used with a trap cooled by solid carbon dioxide or liquid nitrogen to minimize this. It is toward the improvement of such traps that this invention is directed. Prior art devices of this type are characterized by a metal container which is disposed in the vacuum system between the diffusion pump and the vacuum tank and filled with liquid nitrogen, air, or helium. The upper interior of such a trap is connected through a conduit to the atmosphere to allow disposal of the liquid as it evaporates. Since it is very desirable that such a trap present a maximum condensation surface to vapor diffusing onto it from the pump, the evaporation of the liquid contained within it limits its effectiveness over any extended period of time. That is, as the liquid evaporates the level in the container drops, thus reducing the total container area in immediate contact with such liquid. Furthermore, conduction through the metal container is of little significance since metals required for vacuum purposes, such as stainless steel, have very poor conductivity characteristics. The problem is still further complicated by the nature of the liquid coolant, which being normally at very low temperatures, precludes the use of elaborate valves and liquid level indicating and actuating devices. Currently available cooling traps then must be constantly attended and refilled or else exhibit declining effectiveness during the use of each container of coolant.

Accordingly, it is a principal object of this invention to provide a new and improved vacuum system cooling trap.

It is another object of this invention to provide a vacuum system cooling trap of the type described adapted to present a constant maximum condensation surface during the utilization time of each container of liquid coolant.

It is another object of this invention to provide, in a cooling trap of the type described, a liquid coolant container that is of simple hydraulic design and that maintains its coolant contiguous to its entire surface area.

It is another object of this invention to provide a cooling trap of the type described that requires a minimum of maintenance.

It is another object of this invention to provide, in a vacuum system cooling trap, a liquid coolant container having a separate compartment adjacent to the walls and top thereof and means for maintaining a maximum amount of coolant therein.

It is another object of this invention to provide, in a vacuum system cooling trap, a liquid coolant container having a separate compartment adjacent the sides and top thereof in combination with a novel self-compensating valve means adapted to maintain coolant therein at a predetermined level.

These together with other objects and features of this invention will become readily apparent from the following detailed description thereof taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a sectional view of one presently preferred embodiment of the invention;

FIGURE 2 is a detail illustrating a novel self-compensating pressure valve adapted to use in such an embodiment;

FIGURE 3 is a sectional view of an alternate embodiment of the invention.

Referring now to FIGURE 1, there is illustrated thereby a cooling trap embodying principles of this invention. Vacuum system housing sections 4 and 6 connect the subject cooling trap to the vacuum chamber (not shown) and to the diffusion pump (not shown) respectively. Section 5, which comprises the housing of the trap is connected therebetween by vacuum seals **31**. Container **7** is positioned within section 5 by any convenient means such as tubular members **10** and **11** or by metal struts, should greater mechanical strength be required. Such struts should, however, be fabricated of a metal that has poor heat conduction characteristics and that is readily outgassed for vacuum use. Container **7** is preferably of stainless steel or other metal that is impervoius to mercury vapor and that is acceptable for vacuum use. The geometric configurations and relationship of housing section 5 and container 7 should be such that mercury (or other pump fluid) molecules arriving from the diffusion pump (indicated by arrows **15**) must strike the cold surface of container **7** at least once. A metal partition **8**, preferably of copper, is provided to establish a compartment **12** within the container that is substantially co-extensive with the sides and top thereof. A plurality of apertures **9** are disposed around the lower portion of metal partition 8 as illustrated. The apex of inner compartment **14** is connected to the atmosphere through conduit **10** and pressure valve **16**. The apex of compartment **12** is connected to the atmosphere through open conduit **11**. Conduits **10** and **11** pass through the vacuum system housing by means of vacuum seals **33** and **32** respectively. Conduit **11** is made sufficiently long (dimension h_1 must be equal to or greater than dimension h_2) so that with pressure valve **16** set to maintain the liquid level in compartment **12** at its maximum, no liquid will be forced to spill over the outer end of said conduit **11** regardless of the amount of liquid in the system.

In operation, the device is fieled with a liquid coolant **13** such as liquid nitrogen for instance. This is done conveniently by pouring the liquid nitrogen into conduit **11** until it appears in conduit **10** at valve **16**. Pressure valve **16** is then placed over the end of conddit **10**. At this point the entire outer surface of the container is very cold and mercury vapor striking it condenses and is thus prevented from passing to the high vacuum chamber. The liquid nitrogen **13**, of course, due to the heat created by impinging mercury molecules slowly vaporizes and the vapor passes to the atmosphere through conduit **11**. In the conventional cold trap, such evaporation of the liquid coolant results in a steadily declining liquid level and a consequently declining cold surface area. In the present invention, however, the vaporized fluid of compartment **14** cannot escape into the atmosphere due to pressure valve **16**, and thus builds up a pressure which forces liquid through apertures **9** to replace liquid of compartment **12** lost by evaporation. The novel container of this invention in this way maintains a constant maximum cold area until substantially all of the liquid coolant has been utilized. Should the pressure in compartment **14** exceed that required to maintain the coolant in compartment **12** at the proper level, pressure valve **16** permits the escape of vapor through conduit **10** in sufficient quantity to prevent any overflow through conduit **11**. A novel pressure valve for use in conjunction with the present invention is illustrated in FIGURE 2. Such a pressure valve is self-compensating and maintains a pressure within the inner chamber adapted to keep the coolant level in outer chamber **12** always at level *c*. Thus, in combination with the unique container structure, it represents another feature of the invention. Having particular reference to FIGURE 2, the valve comprises vertically disposed conduit **19**, compensating rod **21**, rigid connecting member **20**, and valve cap **18**. Valve cap **18** is provided with heat conduction fins to prevent excessive amounts of frost from collecting thereon. It has been determined that the area A_1 of valve cap **18** upon which the pressure of inner compartment **14** acts must be equal to the cross sectional area A_2 of compensating rod **21**. Also, the length of compensating rod **21** should coincide with the liquid level difference between full and empty conditions of inner chamber **14** (h_4 minus h_3, or levels *a* and *b*). With these conditions fixed, it is only necessary to determine the combined weight W of compensating rod **21**, connecting member **20** and valve cap **18**. This is achieved simply in accordance with the relationship $W=h_4P_1A_1$ in which P_1 is the density of the coolant liquid. By way of example, assuming the conditions: $h_4=25$ cm.; $h_3=2.5$ cm.; $A=1$ cm.^{2}, and the coolant being liquid nitrogen of density $P=0.8$; the weight W would equal $25\times1\times0.8$ or 20 grams. The length of the compensating rod would be 22.5 cm. and its volume would be 22.5 cm.^{3}. If 11 grams of the weight is in the compensating rod and the rest in the accessories, the density of the rod must be 11/22.5 or 0.49 gram/cc. It would be convenient to make the compensating rod of aluminum plate 0.5 mm. thick, bent into the form of an air-tight cylinder 22.5 cm. long with a 1 cm.^{2} cross sectional area. Its weight therefore would be 11.0 grams and the rest of the accessories would weigh 9.0 grams. In practice, to ensure stability of the compensating rod it is necessary that the center of mass thereof is below the center of buoyancy. The valve, in operation acts in the following manner. As the liquid in inner compartment **14** recedes from its full capacity (level *b*) to empty (level *a*) increasingly greater pressure is required therein to maintain the liquid in outer compartment **12** at level *c*. Because of the particular weight and geometry of the compensating rod and the buoyancy effects of the liquid, valve cap **18** maintains just the right pressure within inner compartment **14** to support the liquid in outer compartment **12**. As the liquid level in the inner compartment drops there is less buoyancy effect upon the compensating rod and it effectively becomes heavier thus requiring a higher pressure to activate the valve.

Another embodiment of this invention is illustrated by FIGURE 3. In this arrangement liquid is pumped from the inner compartment **14** to the outer compartment **26** by means of tube member **25** in combination with conical member **23** as illustrated. The partition **22** which separates inner and outer compartments in this embodiment does not have apertures in the bottom as does the embodiment of FIGURE 1. Conduit **21** provides an exhaust for evaporated liquid from both compartments and no pressure is required for operation. Conical member **23** has a plurality of openings **24** around the bottom to permit the ready flow of liquid thereunder. In operation, a heat flux generated by the impinging of mercury vapor (indicated by arrows **15**) upon the bottom of the container causes bubbles to form within conical member **23**. These bubbles congregate and move up the sloping side of the conical member to for ma large bubble which forces liquid up tube **25** and into the outer compartment.

It is to be understood that the above-described arrangements are illustrative of the applications of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the scope of the invention.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In a vacuum system cold trap a container for liquid coolant having a partition therein, said partition being substantially parallel to the sides and top of said container and adapted to divide the interior thereof into first and second compartments, said first compartment being contiguous to the sides and top of said container and having means connected to the apex thereof to permit emission of evaporated coolant formed therein, and said second compartment being contiguous to the bottom of said container and comprising a reservoir for said coolant, and means for pumping coolant from said second compartment to said first compartment.

2. A container for liquid coolant as defined in claim 1 wherein said means for pumping coolant comprises, in combination, a conical member, said conical member having its base substantially co-extensive with and residing on the bottom of said second compartment, and a capillary tube, said capillary tube being connected between the apex of said conical member and the apex of said first compartment and adapted to permit the passage therethrough of said coolant.

3. In a vacuum system cold trap, a liquid coolant container having an inner partition adapted to establish a first volume between itself and the top and walls of said container and a second volume between itself and the bottom of said container, said partition having a plurality of apertures therethrough in the vicinity of the bottom of said container, a first vapor escape conduit connecting said first volume to the atmosphere, a second vapor escape conduit connecting said second volume to the atmosphere, and a pressure valve, said pressure valve effecting a closure of said second vapor escape conduit and having a pressure release response adapted to create a vapor pressure within said second volume whereby sufficient liquid coolant is forced through said partition apertures to maintain said first volume in a full condition.

4. In combination with a vacuum system including a high vacuum diffusion pump and a chamber to be evacuated, a cold trap comprising, a housing member, said housing member being an integral part of the vacuum system and constituting a passage between said diffusion pump and said chamber to be evacuated, and a container for liquid coolant affixed within said housing member, said container having an inner partition establishing a first compartment between itself and the top and sides of said container and a second compartment between itself and the bottom of said container, said partition having a plurality of apertures proximate the bottom thereof, a first conduit attached to the top of said container and effecting a communicating relationship between said first compartment and the atmosphere, a second conduit attached to the top of said partition and effecting a communicating relationship between said second compartment and the atmosphere, and a pressure valve, said pressure valve effecting a closure of said second conduit.

References Cited in the file of this patent

UNITED STATES PATENTS

2,039,817	MacMillan	May 5, 1936
2,052,410	Kucher	Aug. 25, 1936
2,293,263	Kornemann	Aug. 18, 1942
2,317,814	Schuchmann	Apr. 27, 1943
2,389,168	Snyder	Nov. 20, 1945
2,462,793	De Groat	Mar. 29, 1949
2,853,859	Thompson	Sept. 30, 1958
2,985,356	Beecher	May 23, 1961
3,009,629	Garin	Nov. 21, 1961
3,057,340	Fritts	Oct. 4, 1962