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G. F. HAGENBACH ETAL

3,371,499

CRYOSORPTION VACUUM PUMPING SYSTEM

Filed Nov. , 1966

3 Sheets-Sheet 1

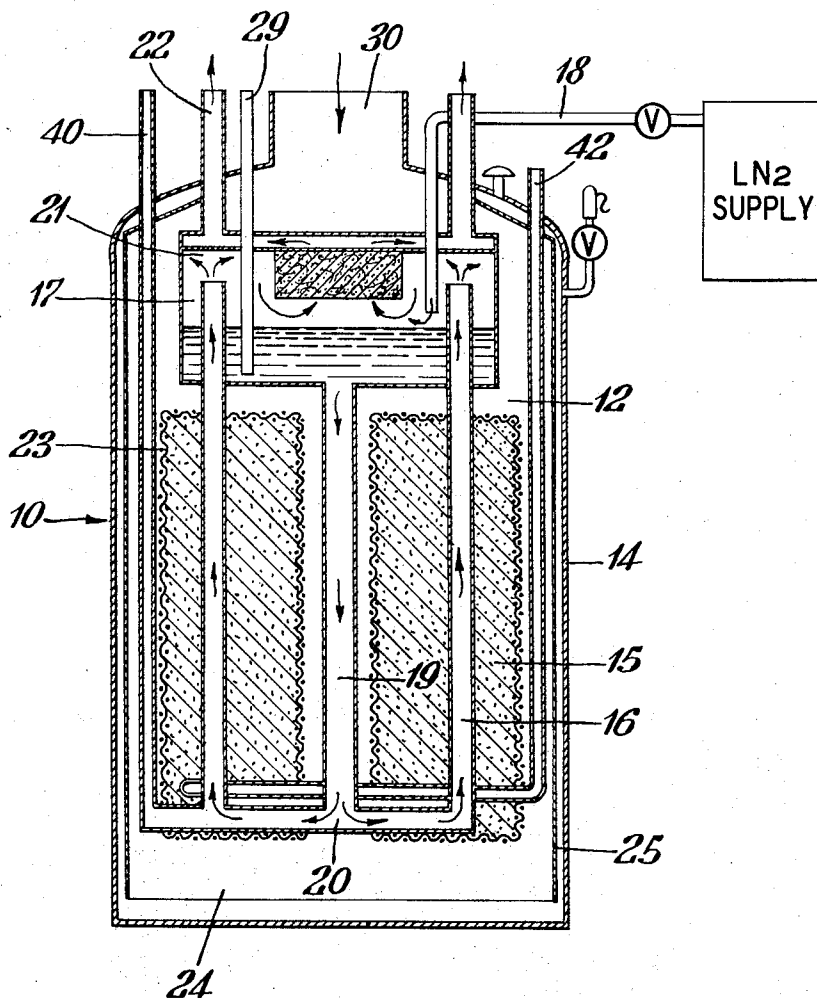


Fig. 1.

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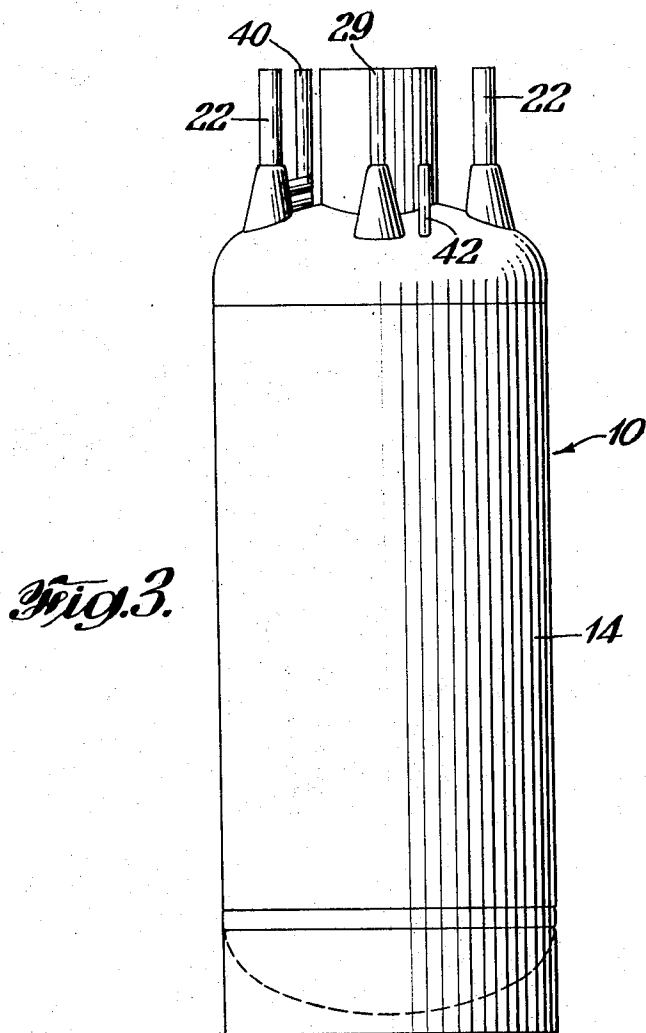
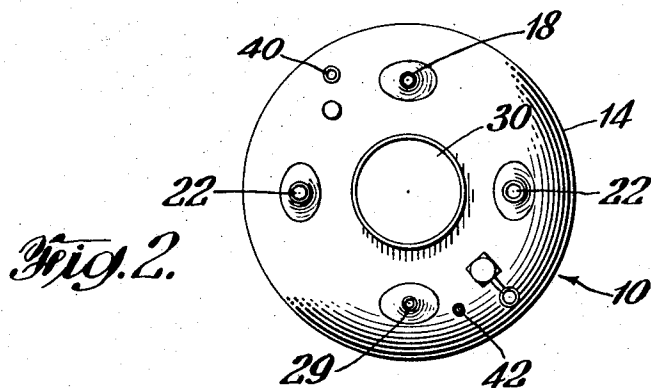
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3 Sheets-Sheet 2



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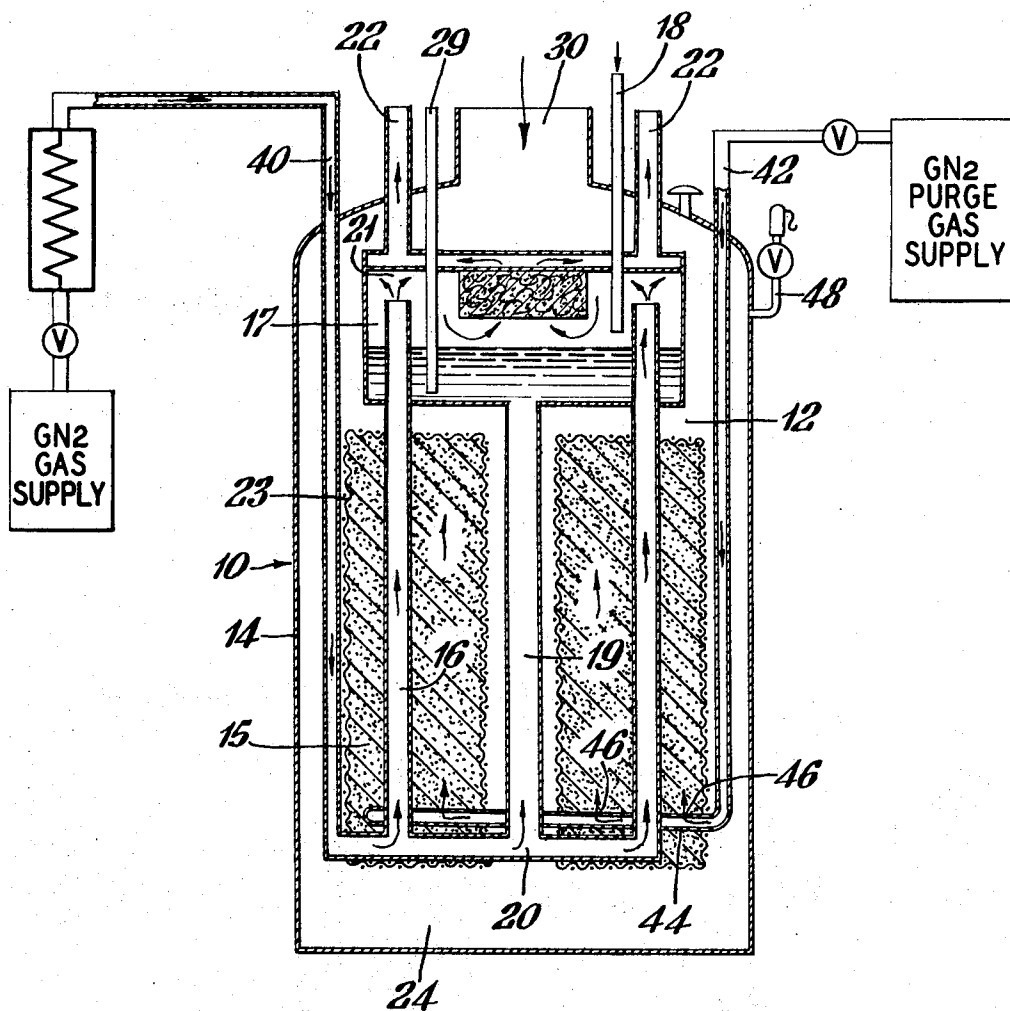
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CRYOSORPTION VACUUM PUMPING SYSTEM

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3 Sheets-Sheet 3



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CRYOSORPTION VACUUM PUMPING SYSTEM
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8 Claims. (Cl. 62—55.5)

This invention relates to cryosorption vacuum pumping systems, and more particularly to large capacity, rough vacuum pumping systems.

The invention provides a cryosorption vacuum pump including adsorbent material having heat transfer means provided with extended surfaces embedded therein. The pump also has a fluid refrigerant conduit in good thermal contact with such extended surfaces, a gas leak-tight casing therefor having a pumping port in communication with said adsorbent material, and a reservoir for liquid refrigerant located wholly within said casing. The pump also comprises means for supplying liquid refrigerant through the wall of said casing to the reservoir, means providing communication for such refrigerant between the reservoir and the fluid conduit, and means for venting vapor from said conduit through the wall of said casing.

The liquid refrigerant is circulated through conduits or tubes having fins providing extended heat transfer surfaces embedded in the adsorbent for cooling it. The adsorbent material enclosed within the leak-tight casing is thermally insulated from the atmosphere by a surrounding self-evacuated space containing a conductive metal shield thermally attached to the effluent vapor conduit. A phase separator chamber is utilized in the upper refrigerant passages to eliminate any refrigerant liquid entrainment losses in the effluent vapor.

The pump structure is simplified by use of a single wall enclosure, and the pump provides for fast pumping speed with reduced refrigerant consumption due to the elimination of entrainment in the vaporized refrigerant.

The cryosorption rough vacuum pumps which have been developed in the past for pumping down vacuum chambers and similar spaces from atmospheric pressure to pressures of 10^{-2} and 10^{-5} torr are either the immersible or the bulk refrigerant-containing type. Specifically, they have consisted essentially of gas-tight enclosure containing an adsorbent material, preferably molecular sieve, with some provision for cooling the adsorbent by heat conduction to the refrigerant, and surrounded by a liquid refrigerant container which may be either separable therefrom or permanently attached thereto. A high vacuum, i.e. low absolute pressure, is achieved in the space being pumped by the adsorption of gases from the space onto the cold adsorbent surfaces.

For a large capacity cryosorption pumps, it is somewhat awkward and undesirable to immerse the adsorbent-containing enclosure into a separate refrigerant container to cool the adsorbent. According to this invention, a large adsorbent pumping system is provided which utilizes nitrogen refrigerant from an external source circulated through multiple internal passages having extended surfaces for cooling the adsorbent material in the pump, instead of either immersing the pump unit within the liquid refrigerant such as for smaller capacity cryosorption pumps, or storing all the refrigerant liquid adjacent but external to the pump casing.

As an important simplification and improvement for large encased type cryosorption pumps, the necessary thermal insulation for the cold adsorbent and refrigerant is preferably provided in part by a surrounding evacuated space within a single wall casing. By this arrangement, the cryosorption pump automatically produces its own surrounding vacuum insulation.

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For improved thermal insulation, one or more thermally-conductive metal radiation shields are preferably provided surrounding most of the adsorbent mass and thermally attached to the evaporation gas conduit of the pump. A further modification to this improved rough vacuum pumping system incorporates an internal phase separator in the effluent vapor stream within the pump casing to reduce or eliminate entrainment losses therefrom.

In the drawings:

FIGURE 1 is a view partly in elevation and partly in vertical cross section of a vacuum pumping system illustrative of the invention;

FIGURE 2 is a top plan view of the pump;

FIGURE 3 is a view in side elevation thereof; and

FIGURE 4 is a view similar to FIG. 1, illustrating the adsorbent reactivation flows.

As shown in FIGURE 1, the invention includes a cryosorption rough vacuum pump 10 of the permanently encased type having an adsorbent-containing pumping chamber 12 enclosed within a single-wall vacuum-tight casing 14. The adsorbent material 15 is cooled by refrigerant liquid, preferably liquid nitrogen, flowing through heat transfer conduits or tubes 16, which extend through the adsorbent bed in pump chamber 12, and are manifolded together in their top and bottom ends. To control and distribute the refrigerant fluid, a liquid reservoir 17 is provided preferably in the upper end of the pumping chamber.

Refrigerant liquid from an external supply is admitted into this reservoir through conduit 18, and then directed through central tube 19 to the lower manifold 20. The refrigerant liquid passes upwardly through tubes 16 having extended heat transfer surfaces or fins and is vaporized, thus cooling the surrounding adsorbent material 15 effectively and uniformly. The liquid is circulated through the tubes, while the resulting evaporation gas emerges through the top portion space 21 of reservoir 17 and passes out through vapor conduit 22, which may be made dual. The adsorbent bed is preferably supported principally by conduits 22, and is retained in a body surrounded by screen material 23. Adequate space is provided for rapid gas conductance to the adsorbent material through an annular space 24 surrounding the adsorbent bed and through a centrally located space within the bed.

As the adsorbent material cools, a vacuum is produced in surrounding space 24 located just inside the single wall casing 14, and this arrangement provides a vacuum-insulated space substantially surrounding the refrigerant cooled adsorbent-containing pumping chamber 12. This arrangement thus provides means for the pump chamber to produce its own surrounding vacuum-insulated space, rather than the pumping chamber being enclosed within a conventional double-wall vacuum-insulated Dewar having a separate vacuum space for insulation purposes.

Also as shown in FIGURE 1, a heat conductive radiation shield 25 of metal is thermally attached to vapor conduit 22 and cooled by the effluent refrigerant gas, and is preferably incorporated into the surrounding vacuum space 24 for further reducing the heat leak into the cold pump chamber. Thus, this invention presents a pump arrangement eliminating the usual companion liquid nitrogen Dewar, thus providing considerable cost reduction for the pumping system.

To solve any problems of entrained liquid in the evaporation gas from this encased type pump, a phase separator 28 is incorporated within the upper portion of the pump casing. This phase separator preferably comprises porous packing material which reduces the velocity of the gas stream through it and promotes condensation

and disengagement of liquid droplets therein, but it could also assume other shapes.

The internal liquid reservoir preferably serves both to provide a uniform refrigerant liquid supply to the heat transfer tubes 16, and also collects the resulting refrigerant vapor and directs it to outlet conduit 22. This liquid reservoir and phase separator feature permits using the maximum cool-down rate for the pump, with consequent fast pumping speed being achieved through efficient use of the refrigerant liquid, i.e., no refrigerant losses by entrainment in the evaporation gas conduit 22. Also, provision may be made for refrigerant liquid level sensing within the liquid reservoir for controlling its filling by inserting a sensing device through probe tube 29.

An actual pump constructed to incorporate the above-described features contains approximately 150 pounds of molecular sieve adsorbent, Type 5A-XW pellets of $\frac{1}{16}$ -inch particle size, and is capable of evacuating volumes of approximately 150 ft.³ from atmospheric pressure to the range of about 10^{-2} torr or lower within about 2 hours. Larger volumes can be evacuated rapidly by using multiples of such cryosorption pumps simultaneously, or by staging them in sequence, or by evacuating the space initially with a clean (unlubricated) mechanical blower followed by cryosorption pumping. Lower pressures of 10^{-4} or 10^{-5} torr can be obtained if the pumped volume is pre-purged with nitrogen or carbon dioxide gas to reduce the concentration of helium, neon, and hydrogen in the space which are only weakly adsorbed on molecular sieve at liquid nitrogen temperatures.

Such pump comprises a cylindrical stainless steel casing about 20" dia. x 50" high structurally designed as a vacuum vessel. It is connected to the space to be evacuated by a 6" dia. pumping port 30 located in the upper head of the pump enclosure 14 and of sufficient length to facilitate attachment thereto, such as by welding. All fluid feed-through connections are also located on the top head of the vertically mounted casing, as illustrated by attached FIGURES 2 and 3. The adsorbent material is installed and/or removed by pouring it through the pumping port 30.

While vertically oriented tubes are usually preferred as shown, such tubes can be oriented in any position including horizontal, and subject only to the requirement of substantially uniform flow of refrigerant through them.

Reactivation of the cryosorption pump is illustrated by FIGURE 4, and is accomplished by directing heated gas from an external source through conduit 40 and thence to the heat transfer tubes 16 to warm the adsorbent bed. At the same time, dry purge gas is introduced through purge conduit 42 and passed to manifold 44 located just below the adsorbent bed 15. The gas is then directed through uniformly spaced orifices 46 upwardly through the adsorbent bed to sweep out the gases evolved from the adsorbent during heating. This vent gas is removed from

the pumping chamber at the upper end through purge gas vent conduit 48.

What is claimed is:

1. A cryosorption vacuum pumping system comprising the combination with a cryosorption vacuum pump including adsorbent material, means having extended heat transfer surfaces embedded therein, said pump also having a fluid refrigerant conduit in thermal contact with said extended surfaces, and a gas leak-tight casing therefor having a pumping port in communication with said adsorbent material; of a reservoir for liquid refrigerant located wholly within said casing, means for supplying liquid refrigerant through the wall of said casing to said reservoir, means providing communication for such refrigerant between the reservoir and said fluid conduit, and means for venting vapor from said conduit through said wall of the casing.

2. A system as defined by claim 1, including a plurality of said fluid conduits arranged vertically in substantial parallelism, said conduits having fins embedded in the adsorbent material.

3. A system as defined by claim 2, including a common reservoir located in the upper portion of the casing.

4. A system as defined by claim 3, including a central liquid refrigerant pipe extending from the bottom of said reservoir to a level below said adsorbent material, and a manifold connecting the lower end of said central pipe to the lower ends of said fluid conduits.

5. A system as defined by claim 2, including a phase separator located between said vapor venting means and the atmosphere.

6. A system as defined by claim 3, including a heat conductive radiation shield of highly conductive metal thermally connected to said vapor venting means, said shield being located adjacent to but spaced from the inner surface of the vertical wall of said casing for minimizing the heat load on the adsorbent material.

7. A system as defined by claim 2, including means for reactivating the adsorbent material.

8. A system as defined by claim 7, including passage means connected to fluid conduits for supplying warm nitrogen gas thereto, which exits from the casing through said vapor venting means, passage means for supplying dry purging gas so as to flow uniformly through said adsorbent material, and means for then venting such purging gas to the atmosphere.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,371,499

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It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 4, beginning with "1. A cryosorption vacuum" cancel all to and including "adsorbent material." in line 21, same column 4 and insert

1. In a cryosorption vacuum pumping system having a cryosorption vacuum pump including adsorbent material, a fluid refrigerant conduit and extended heat transfer surfaces in thermal contact with said refrigerant conduit and embedded in said adsorbent material, and a gas leak-tight casing enclosing said adsorbent material and having a pumping port in gas communication with said adsorbent material: the combination of a reservoir for liquid refrigerant located wholly within said casing, means for supplying liquid refrigerant through the wall of said casing to said reservoir, means providing communication for such refrigerant between the reservoir and one end of said fluid conduit, and means for venting vapor from the other end of said conduit through said wall of the casing.

2. A system as defined by claim 1, including a plurality of said fluid conduits arranged vertically in substantial parallelism and embedded in the adsorbent material.

same column 4, line 37, beginning with "7. A system as" cancel all to and including "the atmosphere." in line 46, same column 4 and insert

7. A system as defined by claim 2, including means for reactivating the adsorbent material comprising heated gas supply means and passage means through the casing wall in gas communication with said heated gas supply means and said fluid conduits for heating thereof, purge gas supply means and passage means through the casing wall in a gas communication with said purge gas supply means and said adsorbent material for purging thereof, and vent means for discharging said purge gas from said casing.

8. In a cryosorption vacuum pumping system having a cryosorption vacuum pump including adsorbent material, a plurality of fluid refrigerant conduits and extended heat transfer fins in thermal conduct with said refrigerant conduits and each embedded in said adsorbent material, and a gas leak-tight casing enclosing said adsorbent material and having a pumping port in gas communication with said adsorbent material: the combination of a liquid refrigerant reservoir in the upper portion of said casing, means for supplying liquid refrigerant through the wall of said casing to said reservoir, a central liquid refrigerant pipe extending from the bottom of said reservoir to a level below said adsorbent material, a manifold connecting the lower end of said central pipe to the lower ends of said fluid conduits, means for venting vapor from the upper ends of said fluid conduits through the casing wall, a heat conductive radiation shield of highly conductive metal thermally connected to the vapor venting means and located adjacent to but spaced from the inner surface of said casing wall for minimizing the heat load on the adsorbent material, and a phase separator located between said vapor venting means and the atmosphere.

Signed and sealed this 23rd day of September 1969.

(SEAL)
Attest:

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Attesting Officer

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