Oct. 18, 1966 G. KLIPPING ETAL 3,279,214

PUMP

Filed Sept. 15, 1964 5 Sheets-Sheet 1

Fig. 1

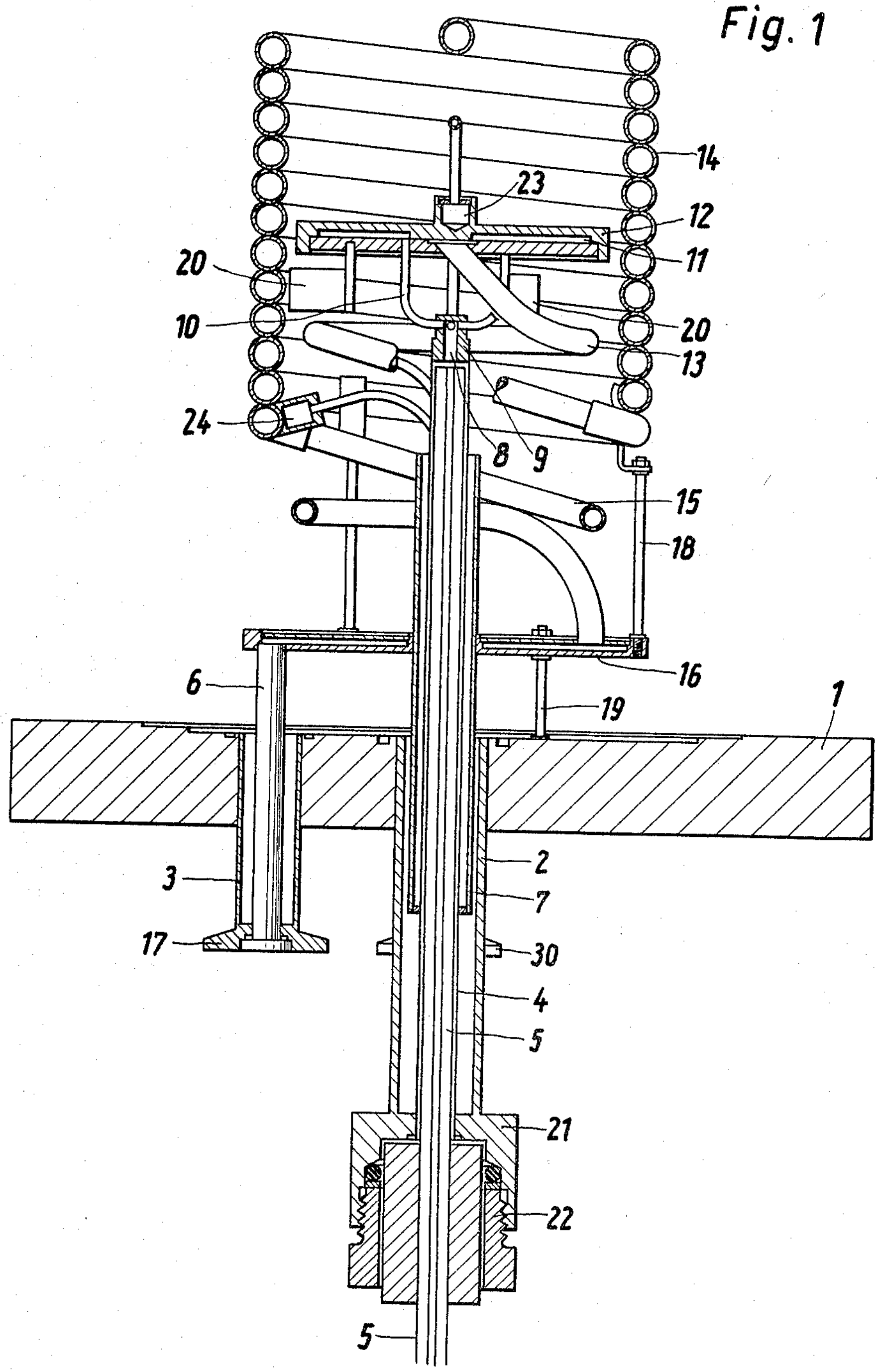

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Fig. 2

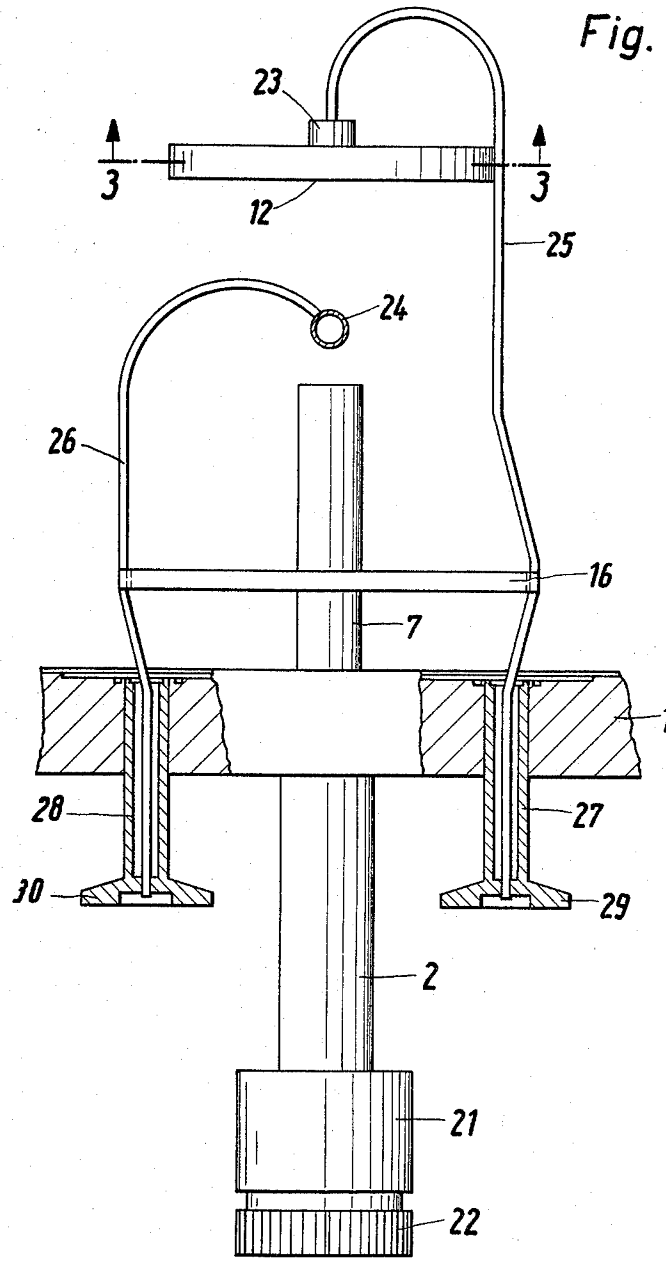

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Fig. 3

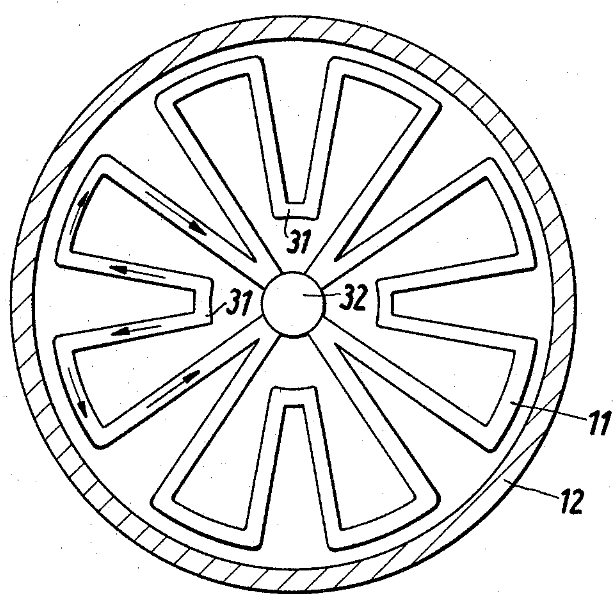

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Fig. 4

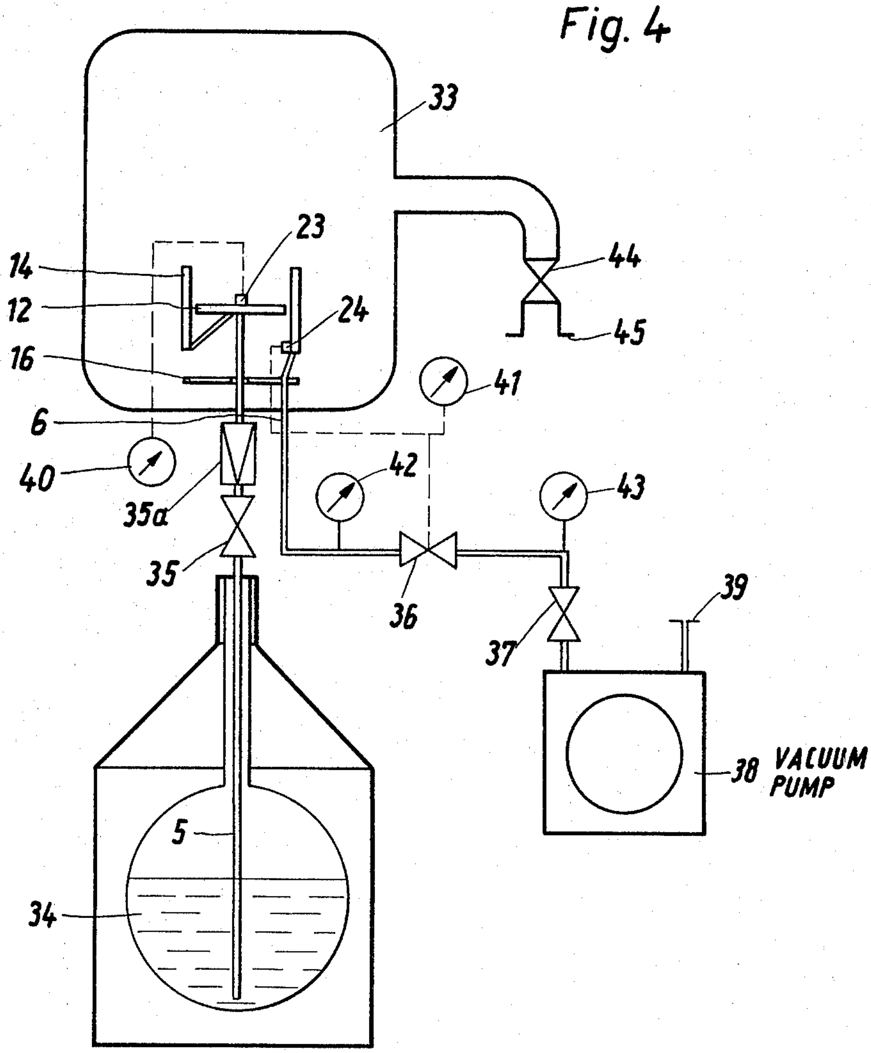

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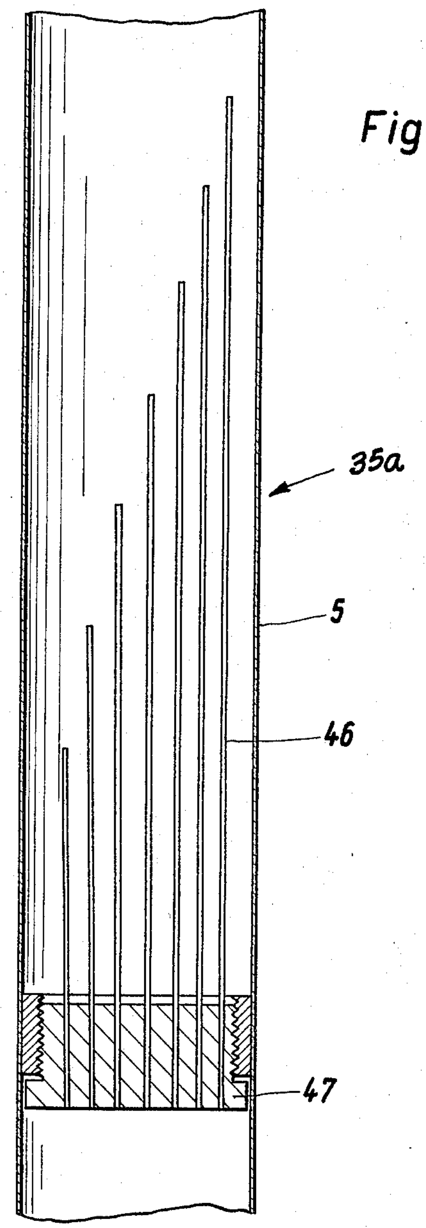
Fig. 5



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PUMP

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20 Claims. (Cl. 62—55.5)

The present invention relates to a device for producing a vacuum with the aid of a condensing element which is cooled to very low temperatures.

So-called cryopumps are used in the art of vacuum engineering whenever high-speed suction is needed. If such high-speed suction is to remove hydrogen, the condensing elements have to be kept at temperatures below 4.2° K., this being the boiling point of liquid helium.

Heretofore, cryopumps have been used only for evacuating large receptacles, e.g., wind tunnels, and only for removing nitrogen or gases having higher boiling points. Conventional cryopumps are connected directly with a refrigeration unit, and the condensing surfaces, which are usually surrounded by a radiation protector cooled by nitrogen, are cooled by means of cold helium gas which flows under the influence of pressure greater than atmospheric. This produces operating temperatures which are substantially above the boiling point of helium, namely, approximately 12 to 14° K.

It has up to now not been found possible to use cryopumps for evacuating hydrogen, because no existing cryopump has been known to operate at sufficiently low temperatures. But for many industrial and scientific purposes, there exists a need for a high-speed pump capable of drawing off hydrogen. One example can be found in ultra-high vacuum engineering where hydrogen often appears, in substantial quantities, as a residual gas. Another example is in plasma physics where, particularly for nuclear experiments, extremely high vacuums and very high rates of suction for hydrogen are needed.

It is, therefore, the primary object of the present invention to provide a cryopump capable of drawing off, at very high speeds, hydrogen and other gases having low boiling points, and, with this object in view, the present invention resides, mainly, in a cryopump which comprises helical tubing forming a hollow cylinder, a hollow header arranged interiorly of the cylinder, conduit means serially connecting the tubing and the header, and means for circulating a coolant through the series-connection formed by the serially connected tubing and header. In a practical embodiment, the cryopump may further include a hollow protective member which is arranged between the cylindrical tubing and a main support on which the cryopump is mounted, this protective member being incorporated in the series-circuit such that the coolant flows therethrough after having passed through the header and tubing.

More particularly, a cryopump according to the present invention comprises a generally horizontally oriented support plate, a first hollow tube extending through the support plate and opening at the upper surface of the support plate, and a second hollow tube also extending through the support plate and opening at the upper surface thereof. A hollow protective plate is mounted on the support plate and is arranged above the upper surface thereof. The helical tubing forming the hollow cylinder is mounted on the protective plate and positioned above it, the axis of the cylindrical tubing being generally vertically oriented. The header, which is located interiorly of the cylinder, is in the form of a plate and is disposed generally at right angles to the cylinder axis, i.e., generally horizontally.

2

The coolant is provided through a riser tube which comprises a valve and a throttling means and extends upwardly through the first-mentioned hollow tube. This riser tube communicates at its top with the interior of the header plate and, besides the conduit means which connect the header and the helical tubing, there are the further conduit means which connect the tubing and the interior of the protective plate. The cryopump also includes an exhaust tube which is in communication with the hollow protective plate and which extends through the second hollow tube passing through the support plate. It will thus be seen that the coolant introduced through the riser is made to circulate first through the hollow header, thereafter through the helical tubing, and thereafter through the protective plate, from which the spent coolant is drawn out through the exhaust tube.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description when taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a sectional elevational view of a cryopump according to the present invention.

FIGURE 2 is a sectional elevational view of the cryopump according to FIGURE 1, taken in a plane at right angles to the plane of FIGURE 1 and showing only certain of the components.

FIGURE 3 is a sectional view through the hollow header plate taken on line 3—3 of FIGURE 2.

FIGURE 4 is a schematic diagram showing a chamber which is to be evacuated, within which chamber is arranged the cryopump according to the present invention. FIGURE 4 shows the actual condensing components of the cryopump, as well as the supply reservoir for the liquid coolant, e.g., helium, and the vacuum pump by means of which the coolant is moved through the cryopump.

FIGURE 5 is a sectional view through the throttling means *35a* of FIGURE 4.

Referring now to the drawings, FIGURE 1 shows the condensing element as comprising a support plate **1** which has set into it two hollow covering tubes **2** and **3** which are open at the top. Arranged within the tube **2** is a tubular jacket **4** which, in turn, surrounds a vacuum riser tube **5**, while the tube **3** has arranged within it an exhaust tube **6**. The covering tubes **2** and **3** for the jacket **4** and the exhaust tube **6** are thus evacuated together with the chamber, receptacle or other space within which the condensing element is mounted by means of the support plate **1**.

The jacket **4** is surrounded, throughout a portion of its length, by a further tube **7** which protects the jacket **4** from radiation, this tube **7** being in heat-exchange contact with the jacket **4**.

Arranged within the upper end of jacket **4** is an end piece **9**, the same being provided with a bore **8** which is in communication with a number of tubes **10** that are set into the end piece **9**. The other ends of the tubes **10** are in communication with a channel system **11** that is provided in a hollow plate or header **12**.

The condensing element further comprises a bifilar helical tubing **14**, forming, generally, a hollow cylinder, adjacent turns of the tubing **14** being in heat-exchange contact with each other. The channeling **11** within the header **12** is connected with the tubing **14** by means of a spirally bent conduit **13** which itself is made of a poor conductor of heat. The tubing **14** is connected, via a further spirally bent exhaust gas conduit **15**, also made of a material which is a poor conductor of heat, with the interior of a generally plate-shaped hollow member **16**, this plate **16** serving as a protective element against heat conduction and radiation. The interior of the plate **16** is in communication, via the exhaust conduit tube **6**, and its end flange 17 as well as a control valve, with a vacuum pump (FIGURE 4).

The actual condensing components, namely, 12, 14, of the condensing element are structurally attached to the protective plate 16 by means of mounting pins 18, the plate 16 being connected to the main support plate 1 by means of further pins 19. The pins 18 and 19 are made of a material which is a poor conductor of heat. Also shown are fins 20, likewise made of a material which is a poor conductor of heat, which serve to position the header 12 centrally with respect to the bifilar helical tubing 14.

The lower ends of the tube 2 and jacket 4 are set into a common end piece 21, the same being provided with a sealing gland or screw 22 by means of which the riser tube 5 can be inserted gas-tightly into the jacket 4. The protective tube 7 is in heat-exchange contact with the plate 16.

A measuring organ 23 of a vapor pressure thermometer is set into the header 12, and a further measuring organ 24 of a further vapor pressure thermometer is attached to the outlet of the helical tubing 14. FIGURE 2 shows the disposition of the conduits 25 and 26 leading to the organs 23 and 24, respectively, these conduits 25 and 26 being likewise made of a poor conductor of heat. The conduits 25 and 26 pass through vacuum packets 27 and 28, respectively, which are set into the support plate 1 and are ending in flanges 29 and 30, respectively, by means of which the vapor pressure thermometers are connected to the measuring and control system (FIGURE 4).

As is apparent from FIGURE 3, which shows the arrangement of the channel system 11 within the header 12, the coolant enters the channels at the points indicated at 31, flows therethrough in the direction shown by the arrows, and leaves the system at 32. Inasmuch as the channeling includes a number of radial branches, and since each of the several inlets of the header communicates with two adjacent radial channels and an outlet whereat two radial channels join, the coolant will be made to flow in counter-current flow through the header, thereby evenly to distribute the temperature throughout the header. As shown in FIGURE 3, the inlets to the header are near the axis of the header, this axis being concentric with the axis of the cylinder formed by the helical tubing 14. Furthermore, the cross section of the interior passage provided by the tubing 14 is greater than the cross section of the channeling in the header.

FIGURE 4 shows a receptacle 33 forming a chamber to be evacuated. Arranged within this chamber is the above-described condensing element, of which the actual condensing components, namely, the header 12 and helical tubing 14 are shown, as is the riser 5 whose lower end dips into a helium reservoir 34. FIGURE 4 also shows a valve 35 and a throttling means 35*a*, for controlling the helium flow through the riser 5. The exhaust tube 6 is connected, via a control valve 36 and, if desired, a throttle valve 37, to a vacuum pump 38. The control valve 36 is thermostatically operated by means of the vapor pressure thermometer 24. The pressure side of vacuum pump 38 is connected, via a connecting flange 39, to the helium recovery system (not shown). FIGURE 4 also shows pressure gauges 40 and 41 which are in communication with the vapor pressure thermometers 23, 24, respectively so that a temperature reading may be obtained. Further pressure gauges 42 and 43 are provided for measuring the pressure in the suction conduit connected to the exhaust tube 6. Finally, FIGURE 4 shows the interior of receptacle 33 as being in communication, via a valve 44, with a suction stud 45 through which the chamber can be pre-evacuated, i.e., evacuated to a pressure which may be considered to be high as compared to the exceedingly low pressure to which the chamber is evacuated by means of the condensing element of the cryopump.

FIGURE 5 shows the throttling means 35*a* which is situated in riser 5. The throttling means 35*a* is formed by a bundle of capillary tubes 46 which have a small diameter and different lengths and which are set into a base piece 47. Capillary tubes 46 and base piece 47 are arranged within riser tube 5. Valve 35 may be situated above or below this throttling means 35*a*.

The above-described arrangement operates as follows: The vacuum pump 38 sucks liquid helium out of the reservoir 34 through the riser 5 and into the condensing component 12 where it is vaporized under normal or reduced pressure so as to effect the desired cooling. More particularly, the coolant flows through the riser 5, valve 35 and throttling means 35*a*, the bores 8 in the end piece 9, and the tubes 10, into the channels 11 in header 12. Thanks to the radial arrangement of the channels as shown in FIGURE 3, the coolant flows radially in counter-current, as a result of which the temperature, as described above, is distributed evenly over the header 12. The coolant leaves the header at the central outlet 32, from whence it flows through the connecting conduit 13, the bifilar tubing 14, the connecting conduit 15, the protective member 16, the exhaust tube 6, the control valve 36, the throttle valve 37 and into the suction pump 38, and thence to the helium recovery system.

The temperature of the components 12, 14 is regulated and maintained constant by means of the valve 35 in combination with the throttlings means 35*a* and the control valve 36 which, as explained above, is itself controlled by the vapor pressure thermometer 24. At the start of the operation, the control valve 36 and valve 35 are open and coolant is sucked through the condensing components 12, 14, thereby cooling the same. As soon as the headers temperature comes near 4.2° K., the flow of liquid through riser 5 has to be reduced by partly closing valve 35, and the pressure within the header must be lowered to the desired low value corresponding to the desired header temperature below 4.2° K. This is done by means of the vacuum pump 38 which has a high suction rate. As soon as the desired pressure for such temperature is reached, the suction of the pump is reduced by means of the control valve 36 so that the desired temperature pressure relationship will be maintained. That means that during operation at a constant header temperature below 4.2° K. the flow of coolant is kept at a rather constant value given by the setting of valve 35 and at the same time the desired low pressure is maintained constant by means of control valve 36. To change the temperature of the condensing elements 12, 14 is is necessary to adjust valve 35 so as to obtain more or less flow of coolant, and to adjust valve 36 so as to maintain a lower or higher pressure within the system. The throttling means 35*a* helps to maintain the temperature at a constant value over long periods of time without having to correct the setting of valve 35. Without throttling means 35*a* it may happen that the temperature rises after some time of operation, so that valve 35 has to be adjusted again and again.

It has been found that temperature fluctuations may be kept very small if the control valve 36 is provided with a by-pass through which the pressure may be lowered to a value which is just short of the desired pressure for the desired corresponding temperature. The control valve itself may then be used to obtain a fine, vernier-type adjustment of the pressure and temperature relationship.

It has been found that, by using the above-described condensing element, the temperature of the header may be reduced to below 4.2° K., while the temperature of the helical tubing 14 surrounding the header 12 is kept to about 20° K. The temperature of the helical tubing 14 may have different values for a given header temperature. The temperature of the helical tubing depends on the flow of coolant, on the amount of cold that is needed to cool the header, and on the size of the outer surface of the helical tubing resp. on the amount of heat transferred to this outer surface by radiation. The operation of the cryopump is most economical with a temperature of about 20° K. for the helical tubing 14, i.e. by means of measuring this temperature it is possible to control the operation with regard to economy.

With the header at 4.2° K. and the helical tubing at about 20° K. hydrogen will be condensed on the header while nitrogen and other gases having higher boiling points are condensed on the helical tubing. Here, the tubing **14** also serves so as partly to protect the header which is cooled to a temperature lower than that to which the helical tubing is cooled.

The protective member **16**, which inhibits heat conduction and which acts as radiation protective shield for a portion of the header **12**, can condense vapors which condense at still higher temperatures.

Thanks to the above arrangement, the coolant is made to flow through a series-connection which causes the liquid helium to flow first through the hollow header **12**, then through the helical tubing **14**, and then through the protective plate **16**, whereafter the spent coolant is drawn out of the cryopump, by the vacuum pump **38**, ultimately to be recovered in a manner known per se. This utilizes the cold of the liquid helium to maximum advantage, in that the coolant first cools the header **12** to a temperature below 4.2° K., there to condense hydrogen. Next, the helical tubing **14**, which serves to protect against radiation the coldest surface of the cryopump and which itself serves as the condensing surface for nitrogen and other gases having a boiling point higher than that of hydrogen is cooled to about 20° K. Thirdly, the coolant cools the protective plate **16** as well as the lead-in conduit for the liquid coolant. In this way, the cryopump described above can be used to remove hydrogen alone or hydrogen as part of a mixture containing other gases having higher boiling points.

A cryopump with a header diameter of 76 mm., a helical tubing diameter of 98 mm., a helical tubing height of 100 mm., a length of each channel in the header of about 75 mm., a cross section of each channel of 3 mm.^{2} (i.e. cross section of all channels about 25 mm.^{2}), an inner cross section of the tube forming the helix of 33 mm.^{2}, a length of the tube forming the helix of 3600 mm., and a suction rate of the vacuum pump of 12 m.^{3}/h. has for example a suction rate of 2500 l./sec. for hydrogen and at the same time 5500 l./sec. for nitrogen.

Thanks to the fact that the entire structure is mounted on a main support, i.e., the plate **1**, the cryopump as a whole can easily be put into whatever space is to be evacuated. This means that the cryopump is versatile enough to allow it to be used wherever needed.

The coolant reservoir **34** per se is, for example, a conventional helium supply tank. Consequently, the cryopump is invulnerable to breakdown to which a liquefying system is susceptible. Furthermore, since the helium tank itself is under atmospheric pressure, the same can readily be replenished, so that the cryopump itself can be operated continuously, without it being necessary to interrupt operation for purposes of refilling the vessel. This means that the cryopumping can be carried on for indefinite periods of time.

It will also be seen from the above that one of the salient features of a cryopump according to the present invention is the fact that the coldest part of the pump, the hollow header **12**, has in each case maximum size relative to the chosen dimensions of the cylindrical tubing **14** which is forming the radiation shield.

Also, thanks to the fact that, as described above, the tubing **14** may be constituted by a bifilar winding and that the adjacent turns of the tubing are in good heat-exchange contact with each other, the temperature distribution will be spread uniformly over the outer surface of the tubing **14**.

Furthermore, the thermometers **23** and **24** arranged, respectively, at the coldest surface, i.e., at the header **12**, and at the point at which the coolant leaves the helical tubing **14**, allow the operation of the cryopump to be regulated and to be monitored at all times.

Furthermore, thanks to the fact that the protective tube **7** for the riser tube **5** is in good heat contact with the jacket **4** and the cooled protective plate **16**, a minimum of heat is conveyed, via radiation and conduction, to the actual condensing surfaces of the cryopump.

Finally, the cryopump is particularly troublefree and economical and needs little service thanks to the facts that a single coolant is circulated throughout the various serially connected parts to be cooled and that the temperature can be maintained automatically at a constant value.

It will be understood that the above description of the present invention is susceptible to various modifications, changes and adaptions, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. In a cryopump, the combination which comprises: helical tubing forming a hollow cylinder; a hollow header in the form of a plate provided with channeling therein arranged interiorly of said cylinder; conduit means serially connecting said tubing and said header; and means for circulating a coolant to the series-connection formed by said serially connected tubing and header.

2. The combination defined in claim **1** wherein said conduit means communicates with said header at a point near the axis of said cylinder.

3. The combination defined in claim **1** wherein said conduit means serially connecting said tubing and said header are made of a material which is a poor conductor of heat.

4. The combination defined in claim **1** wherein said tubing incorporates a plurality of turns which are closely adjacent to each other, the cross section of the interior passage provided by said tubing being greater than the cross section of said channeling in said header.

5. In a cryopump, the combination which comprises: helical tubing forming a hollow cylinder; a hollow header arranged interiorly of said cylinder; conduit means serially connecting said tubing and said header; and means for circulating a coolant through the series-connection formed by said serially connected tubing and header, said header including a plate provided with channeling, said plate having a plurality of inlets with which said circulating means are in communication, said channeling being provided, at each of said inlets, with branches in consequence of which incoming coolant is made to flow through said header in a plurality of directions.

6. In a cryopump, the combination which comprises: helical tubing forming a hollow cylinder; a hollow header arranged interiorly of said cylinder; conduit means serially connecting said tubing and said header; and means for circulating a coolant through the series-connection formed by said serially connected tubing and header, said header including a plate provided with a plurality of channels which extend generally radially with respect to the axis of said hollow cylinder, said plate being provided with a plurality of inlet means each of which communicates with two adjacent radial channels, said header further comprising outlet means whereat two radial channels join, in consequence of which a coolant circulated through said header is made to flow in counter-current flow thereby evenly to distribute the temperature throughout said header.

7. In a cryopump, the combination which comprises: a support; a hollow radiation and heat conduction protective plate mounted on said support; helical tubing forming a hollow cylinder and arranged on said protective plate, said tubing being positioned on that side of said plate which is opposite the side of said plate which faces said support, the axis of said cylinder being generally at right angles to said plate; a hollow header arranged interiorly of said cylinder; first conduit means serially connecting said header and said tubing; second conduit means serially connecting said tubing and said protective plate; and means for circulating a coolant through the series-connection formed by said serially-connected header, tubing and protective plate.

8. The combination defined in claim 7 wherein said circulating means supply coolant first to said header, in consequence of which the coolant traverses said protective plate after having flowed through said header and said helical tubing.

9. The combination defined in claim 8 wherein said first and second conduit means are made of a material which is a poor conductor of heat.

10. The combination defined in claim 8 wherein said circulating means comprise a generally vertically oriented riser tube whose upper end is in communication with said header; a jacket surrounding said riser tube; and a further tube surrounding said jacket throughout at least a portion of its length for protecting the same against heat conduction and radiation, said further tube being in heat-exchange contact with said jacket and with said protective plate.

11. The combination defined in claim 10 wherein said circulating means further comprise sealing means for securing said riser tube and said jacket to each other, and wherein said upper end of said riser tube is approximately at the same level as the upper end of said jacket.

12. The combination defined in claim 7 wherein said protective plate is secured to said support by first pin means and said helical tubing is secured to said protective plate by second pin means, said pin means being made of a material which is a poor conductor of heat.

13. A cryopump comprising, in combination: a generally horizontally oriented support plate; a first hollow tube extending through said support plate and opening at the upper surface of said support plate; a second hollow tube also extending through said support plate and opening at the upper surface thereof; a hollow protective plate mounted on said support plate and arranged above said upper surface thereof; helical tubing forming a hollow cylinder and mounted on said protective plate, said tubing being positioned above said protective plate, the axis of said cylinder being generally vertically oriented; a hollow header plate arranged interiorly of said cylinder and disposed generally at right angles to said cylinder axis; a coolant riser tube comprising a valve and a throttling means and extending upwardly through said first hollow tube, said riser tube communicating at its top with the interior of said header plate; first conduit means for placing said header plate in communication with said helical tubing; second conduit means for placing said helical tubing in communication with said hollow protective plate; and an exhaust tube in communication with said protective plate and extending through said second hollow tube, in consequence of which coolant introduced into said riser tube is made to circulate first through said

hollow header, thereafter through said helical tubing, and thereafter through said protective plate, whereafter the coolant flows through said exhaust tube.

14. In combination with a cryopump as defined in claim 13, a reservoir for a liquid which boils at low temperature, said reservoir being in communication with the lower end of said riser tube; and a vacuum pump in communication with said exhaust tube.

15. The combination defined in claim 14, further comprising valve means arranged in the communication between said vacuum pump and said exhaust tube of said cryopump; and temperature sensitive means responsive to the temperature of said cryopump for controlling said valve means, thereby to regulate the temperature of said cryopump by means of regulating the pressure within the system.

16. The combination defined in claim 14, further comprising valve means arranged in said riser tube for controlling the flow of coolant therethrough.

17. The combination defined in claim 14, further comprising a throttling means arranged within said riser tube for controlling the flow of coolant therethrough.

18. The combination defined in claim 17, wherein said throttling means comprises a bundle of capillary tubes with small diameters and different lengths, this bundle being arranged within said riser tube.

19. In a cryopump, the combination which comprises: bifilar helical tubing forming a hollow cylinder; a hollow header arranged interiorly of said cylinder; conduit means serially connecting said tubing and said header; and means for circulating a coolant through the series-connection formed by said serially connected tubing and header.

20. In a cryopump, the combination which comprises: helical tubing forming a hollow cylinder, adjacent turns of said tubing being in heat-exchange contact with each other; a hollow header arranged interiorly of said cylinder; conduit means serially connecting said tubing and said header; and means for circulating a coolant through the series-connection formed by said serially connected tubing and header.

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