

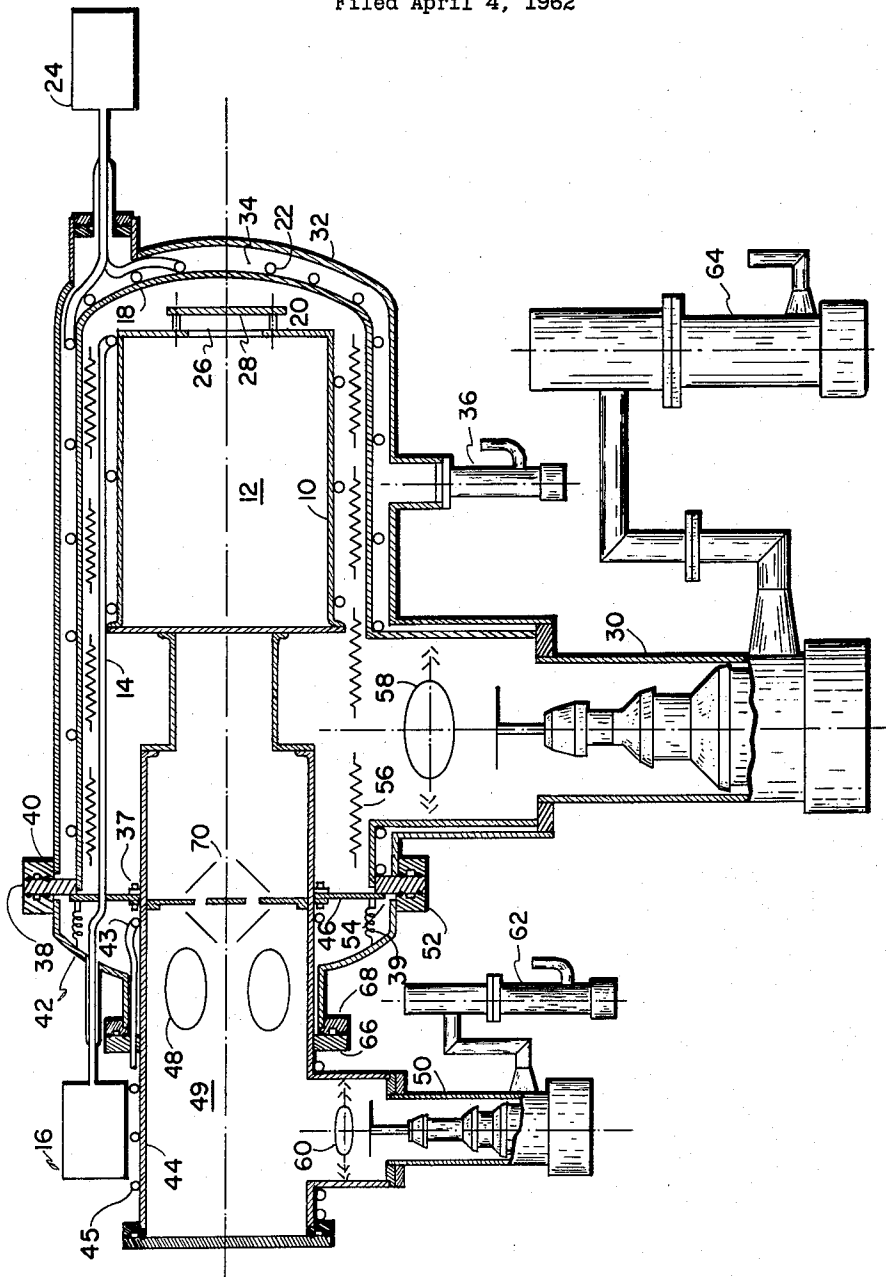
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VACUUM DEVICE

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VACUUM DEVICE

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This invention relates to vacuum facilities and more particularly to extremely high vacuum facilities for maintaining pressures below 10^{-10} torr.

From a practical viewpoint the current limitation of the ultrahigh vacuum art is about 1×10^{-10} torr although a few workers have attained lower pressures in very small volumes constructed of glass. The desirability of providing pressures of at least 2 to 5 decades lower than 10^{-10} torr in large volumes is of considerable importance since a wide variety of surface phenomena could then be investigated. At 1×10^{-10} torr there is less than one hour of time to study the behavior of freshly cleaned surfaces before a significant portion of the surface becomes covered with at least a monolayer of gas. However, at a pressure of 10^{-13} torr, for example, this time is extended into days. Knowledge of the behavior of clean surfaces is not only important as a fundamental interest, but also is important with respect to applications to space vehicles.

Ultimate pressures attainable in vacuum systems depend on the gas load present and on the pumping speed available. When the pumping speeds approach the maximum permitted by the size of the vacuum system the ultimate pressure attainable is then limited by the gas load. The gas load may be minimized in two ways. Much of the gas load results from gas adsorbed on the metallic surfaces or dispersed through the bulk of the metal. The adsorbed gas can be released from the surface in part by baking the metallic surfaces at an elevated temperature. The rate of evolution of the dispersed gases, particularly hydrogen, can be greatly reduced by chilling the walls of the system to cryogenic temperatures.

It is a principal object of the present invention to provide an extremely high vacuum system which will provide pressures of less than 10^{-10} torr.

Still another object of the invention is to provide a vacuum system having volumes of useful size which can be maintained at pressures of less than 10^{-10} torr.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed disclosure and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing which is a diagrammatic schematic sectional view of a preferred embodiment of the invention.

In a preferred embodiment of the invention, by which the above objects are accomplished and the limitations of the prior art overcome, there is provided an inner or working chamber which is to be maintained at a pressure of less than 10^{-10} torr. Associated with the inner chamber is refrigerating means which serves to maintain a major portion of the inner chamber at a temperature below about 20° K. and preferably at a temperature of about 4° K. to 10° K. Cooling of the inner chamber walls to a temperature of below 20° K. comprises an important feature of the present invention since outgassing, particularly of hydrogen, from the walls of the inner chamber will be held to a negligible rate. Additionally ambient gases will be pumped at high speed by

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condensation on the walls of the inner chamber. Surrounding the inner chamber and spaced therefrom is an intermediate chamber. Associated with the walls of the intermediate chamber is a second refrigerating means which serves to cool the wall of the intermediate chamber to a temperature below about 100° K. and preferably to a temperature on the order of 77° K. In the same manner as with the inner chamber cooling of the walls of the intermediate chamber greatly reduces outgassing from the walls by many orders of magnitude and removes ambient gases by condensation on the walls. Adjacent to the forward end of the inner chamber there is provided means for evacuating gases from the intermediate chamber to maintain the intermediate chamber at a pressure on the order of 10^{-10} torr. Referring again to the inner chamber there is provided in the backward end of this chamber an opening which communicates with the intermediate chamber. This opening which communicates with the intermediate chamber permits the inner chamber to be evacuated by the same pumping means which evacuates the intermediate chamber. The location of the opening in the inner chamber comprises another important feature of the present invention. The opening which is in the backward end of the inner chamber is thus at a point remote from the pumping means which is positioned adjacent to the forward end of the inner chamber. Any backstreaming of gases from or through the pump must travel the length of the inner chamber through the space defined by the walls of the inner chamber and the intermediate chamber. Thus the cooled surfaces of the inner chamber and intermediate chamber will act as a cold trap which will condense backstreaming gases and prevent such gases from entering the inner chamber. This serves to maintain a high vacuum within the inner chamber. Adjacent the opening of the inner chamber there is provided a baffle which serves to restrict heat radiation from the intermediate chamber walls to the inner chamber. Around the intermediate chamber and spaced therefrom there next is provided an outer chamber. The outer chamber restrains the atmosphere and is separately evacuated to provide a vacuum tight space around the intermediate chamber. The vacuum tight space formed by the outer chamber serves to reduce the consequence of leaks and provides thermal insulation for the cold intermediate chamber. The outer chamber and intermediate chamber are sealed together at the forward end of the vacuum facility so as to form an integral unit which can easily be removed to provide access to the inner chamber. Any gas leaks from the seal connecting the outer chamber and the intermediate chamber will enter the outer chamber only and be evacuated by the pumping system associated therewith. The forward end of the vacuum chamber preferably comprises an outer transition section and an inner tubular section. The tubular section forms the forward end of the intermediate chamber and also extends into the intermediate chamber to provide support for the inner chamber which can accommodate numerous electrical and instrumentation leads. The outer transition section of the end member is concentric about a portion of the tubular section adjacent the inner chamber. The transition section and the tubular section which form the end member communicate with each other and together form a vacuum tight chamber which is separately evacuated to a low pressure on the order of 10^{-10} torr. An important feature of the present invention is that the end member is constructed and arranged to provide a seal with the intermediate chamber whereby any gases originating from the seal will enter the end member and be removed therefrom and hence will not enter the intermediate chamber. The end section in addition to providing support for the inner chamber can, if desired, provide communication

between the inner chamber and exterior of the vacuum facility. The tubular section of the end member is of advantage in that it forms a tunnel for experimental purposes such as beam experiments. Associated with the walls of the tubular section is refrigerating means which serves to cool the walls of the tubular section to a temperature below about 100° K. and preferably to a temperature on the order of 77° K. Cooling of at least a portion of the walls of the tubular section is important in that it serves to reduce outgassing and also reduces heat transfer to the inner chamber which is supported by the tubular section. Positioned within the intermediate chamber are heating means which serve to heat the walls of the inner chamber, the intermediate chamber, and that portion of the end member which extends within the intermediate chamber to temperatures of up to about 1000° C. to remove adsorbed gases.

Referring now to the drawing there is shown a schematic, diagrammatic, sectional view of one preferred embodiment of the invention. The apparatus comprises a first wall 10 defining an elongated inner chamber 12 which is to be maintained at a pressure below about 10⁻¹⁰ torr. Associated with chamber 12 are cooling coils 14 which provide for circulation of a cooling fluid in heat exchange relationship with wall 10. Preferably gaseous helium from a supply 16 is circulated through coils 14 to cool a major portion of wall 10 to a temperature below about 20° K. and preferably to a temperature of between about 10° K. to 4° K. A second wall 18 spaced from a first wall 10 defines an intermediate chamber 20. Associated with chamber 20 are cooling coils 22 which provide for circulation of a cooling fluid in heat exchange relationship with wall 18. Preferably liquid nitrogen from supply 24 is circulated through coils 22 to cool wall 18 to a temperature below about 100° K., preferably on the order of 77° K. Chamber 12 preferably communicates with chamber 20 through an opening 26 in the rearward end of chamber 12. A baffle 28 is preferably positioned in a line of sight adjacent opening 26. Baffle 28 serves to restrict the radiation of heat from wall 18 directly into the inner chamber 12 but does not prohibit evacuation of gases from chamber 12. A vacuum pump 30 is positioned adjacent to the forward end of the inner chamber 12 and serves to evacuate gases from the intermediate chamber 20 and inner chamber 12 through the opening 26. A third wall 32 spaced from the second wall 18 defines an outer chamber 34 which is separately evacuated by pump 36 to a low pressure. The outer chamber 34 and the intermediate chamber 20 and sealed together by flange joints 38 and 40. Preferably the flanged joints are of the cooled double O ring design as described in the copending application of Farkass, Serial No. 3,674, filed January 20, 1960, now Patent No. 3,058,232. The forward end of the vacuum facility comprises an outer transition section 42 and an inner tubular section 44 which extends into the intermediate chamber and supports the inner chamber 12. The tubular section cooperates with an annular disc 46, which is sealed to the tubular section by bolt means 37 and sealingly held to flange 38 by spring means 39, to form the forward end of the intermediate chamber 20. The outer transition section 42 is concentric about the tubular section 44 and communicates with the interior of the tubular section by means of openings 48. Preferably the transition section 42 is sealed to the tubular section 44 by flanges 66, 68 of cooled double O ring design. The tubular section together with the transition section form a vacuum tight chamber 49 which is separately evacuated by pump 50 to a pressure on the order of 10⁻¹⁰ torr. The transition section is preferably sealed to flange 38 of the intermediate chamber by a cooled double O ring flange 52. An opening 54 is provided between disc 46 and the wall of the transition section 42. Gases originating from the seal of flange 52 or from the atmosphere preferentially enter the transition section through opening 54 and are then removed

by pump 59, thereby preventing the gases from entering the intermediate chamber 20. The portion of the tubular section 44 within the transition section is cooled to a temperature below 100° K. and preferably on the order of 77° K. by circulating liquid nitrogen from a supply (not shown) through coils 43. A liquid nitrogen cooled baffle 70 is provided within the tubular section 44 to restrict heat transfer to the inner chamber 12. The portion of the tubular section 44 which is exposed to the atmosphere is preferably cooled by circulating water through coils 45. The vacuum pumps 30, 36 and 50 are preferably oil diffusion pumps. Preferably pumps 30 and 50 are provided with cold caps and liquid nitrogen cooled baffles (58, 60) and are preferably backed by second diffusion pumps 62 and 64 and by mechanical pumps (not shown). Pump 36 is also preferably backed by a mechanical pump (not shown).

Positioned within the intermediate chamber are heating means 56 which serve to heat the walls of the inner chamber, the intermediate chamber and that portion of the tubular section which extends within the intermediate chamber to a temperature on the order of 200° C. to 1000° C. Preferably the heating means 56 are radiant heaters. The vacuum facility is preferably constructed of stainless steel such as 304 stainless steel. While other suitable metals or alloys can be used, the main requirements are that they provide sufficient strength to withstand the ambient pressures and be capable of being heated to temperatures of up to 1000° C.

In a preferred embodiment of the invention the vacuum-tight space formed by the outer chamber 34 is filled with a thermal insulation material. Thermal insulating materials such as those described in U.S. Patent 3,018,016 to Hnilicka and U.S. Patent 2,900,800 to Loveday are suitable.

In operation of the vacuum facility described above, chambers 12, 18, 34 and 49 will be initially evacuated by mechanical vacuum pumps (not shown). When a pressure of about 10⁻² to 10⁻³ torr is attained, diffusion pumps (50, 62), (30, 64) and 36 will be activated. Heaters 56 will also be activated to heat the intermediate chamber, the inner chamber, and that portion of the tubular section 44 which extends into the intermediate chamber, so as to drive off adsorbed gases and liquids. With the diffusion and mechanical pumps, a pressure on the order of 10⁻⁶ to 10⁻⁹ torr can be obtained at the elevated bake-out temperatures. At this time the heaters will be turned off and liquid nitrogen from supply 24 will be circulated through coils 22 to lower the temperature of the intermediate chamber wall 18 to about 77° K. This temperature is sufficiently low to greatly reduce outgassing and condense water vapor, carbon dioxide residual hydrocarbons and the like. In this manner a pressure of about 10⁻¹⁰ torr will be maintained in the intermediate chamber 20 and the end member chamber 49. Thereafter gaseous helium from supply 16 will be circulated through coils 14 to lower the temperature of the inner chamber wall 10 to about 8° K. This temperature is sufficiently low so that outgassing will be drastically reduced and all gases except hydrogen, neon and helium will be pumped at high speed by condensation on the inner chamber wall. The release of hydrogen from steel will be reduced by many orders of magnitude by lowering the steel temperature to 77° K. The H₂ evolution rate at steel temperatures of 8° K. is sufficiently low to be negligible even at the ultra-high vacuum contemplated. In this manner a pressure on the order of 10⁻¹² to 10⁻¹⁵ torr and lower can be attained in the inner chamber 12.

As the vacuum facility operates, any gas leak from the double O ring seal formed by flanges 38 and 40 will be removed from the outer chamber 34 by pump 36 which will maintain chamber 34 at a pressure on the order of 10⁻⁴ to 10⁻⁵ torr. Thus the outer chamber 34 will act as a guard volume and also provide thermal insulation for the cold intermediate chamber. Backstreaming of vapors from

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oil diffusion pumps 30 and 64 comprise both pump fluid vapor and fluid thermal decomposition products. While the fluid vapors can be removed by condensation on the liquid nitrogen traps 58, thermal decomposition products and other gases which may pass back through the pump may not be condensable at the liquid nitrogen temperature of trap 58. These gases, however, will be substantially removed by the diffusion pump. Any gases which are not removed by the diffusion pump must travel the length of the inner chamber through the space defined by the inner chamber wall 10 and intermediate chamber wall 18 in order to enter the inner chamber. These gases will be condensed and held by the cold walls of the chambers. Heat transfer to the inner chamber which may occur through the tubular section 44 is restricted by cooling the tubular section with liquid nitrogen. Also any gas leak from the cooled double O ring seal formed by flanges 52 and 38 will preferentially enter the transition section 42 through opening 54. The gases will then pass through openings 48 and be removed by pump 50.

While the invention has been described with respect to certain embodiments thereof, numerous modifications thereof can be made within the spirit of the invention. For example, the baffle 28 can be constructed and arranged to be closable when the desired vacuum is attained in the inner chamber.

The specific geometric patterns shown and mentioned are not meant to be used in a limiting sense.

While the invention has been described with respect to the use of gaseous helium and liquid nitrogen, other cryogenic liquids and/or gases which provide the desired cooling can be used.

Since certain changes may be made in the above apparatus and process without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description, or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An ultra high vacuum facility comprising a first wall defining an inner chamber to be maintained at a pressure below about 10^{-10} torr, first refrigerating means for maintaining a majority of said first wall at a temperature below about 20° K., a second wall outside of said first wall for defining an intermediate chamber spaced from said inner chamber, said intermediate chamber being isolated from the atmosphere by at least two sealed walls throughout its whole extent except for pumping ports, a second refrigerating means for maintaining a majority of said second wall at a temperature below about 100° K., means positioned adjacent one end of said inner chamber for evacuating gases from said intermediate chamber to maintain said intermediate chamber at a pressure on the order of 10^{-10} torr, said inner chamber being in communication with the intermediate chamber at the opposite end of said inner chamber, a third wall outside of said second wall and defining an outer chamber spaced from said intermediate chamber and means for evacuating gases from said outer chamber.

2. An ultra high vacuum facility comprising a first wall defining an inner chamber to be maintained at a pressure below about 10^{-10} torr, first refrigerating means for maintaining a majority of said first wall at a temperature between about 4° K. and 10° K., a second wall outside of said first wall for defining an intermediate chamber spaced from said inner chamber, said intermediate chamber being isolated from the atmosphere by at least two sealed walls throughout its whole extent except for pumping ports, a second refrigerating means for maintaining a majority of said second wall at a temperature on the order of 77° K., means positioned adjacent one end of said inner chamber for evacuating gases from said intermediate chamber to maintain said intermediate chamber at a pressure on the order of 10^{-10} torr, said inner chamber being in communication with the intermediate chamber at the opposite end of said inner chamber, a third wall outside

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of said second wall and defining an outer chamber spaced from said intermediate chamber and means for evacuating gases from said outer chamber.

3. An ultra high vacuum facility comprising a first wall defining an inner chamber to be maintained at a pressure below about 10^{-10} torr, first refrigerating means for maintaining a majority of said first wall at a temperature between about 4° K. and 10° K., said first refrigerating means including means for providing a supply of gaseous helium in cooling relationship with the surface of said inner chamber, a second wall outside of said first wall for defining an intermediate chamber spaced from said inner chamber, said intermediate chamber being isolated from the atmosphere by at least two sealed walls throughout its whole extent except for pumping ports, a second refrigerating means for maintaining a majority of said second wall at a temperature on the order of 77° K., said second refrigerating means including means for providing a supply of liquid nitrogen in cooling relationship with the surface of said intermediate chamber, means positioned adjacent one end of said inner chamber for evacuating gases from said intermediate chamber to maintain said intermediate chamber at a pressure on the order of 10^{-10} torr, said inner chamber including an opening providing communication with the intermediate chamber at the opposite end of said inner chamber, a baffle structure positioned adjacent said opening to prevent heat radiation from traversing said opening, a third wall outside of said second wall and defining an outer chamber spaced from said intermediate chamber and means for evacuating gases from said outer chamber.

4. An ultra high vacuum facility comprising a first wall defining an inner chamber to be maintained at a pressure below about 10^{-10} torr, first refrigerating means for maintaining a majority of said first wall at a temperature below about 20° K., a second wall outside of said first wall for defining an intermediate chamber spaced from said inner chamber, said intermediate chamber being isolated from the atmosphere by at least two sealed walls throughout its whole extent except for pumping ports, a second refrigerating means for maintaining a majority of said second wall at a temperature below about 100° K., means positioned adjacent, one end of said inner chamber for evacuating gases from said intermediate chamber to maintain said intermediate chamber at a pressure on the order of 10^{-10} torr, said inner chamber being in communication with the intermediate chamber at the opposite end of said inner chamber, a third wall outside of said second wall and defining an outer chamber spaced from said intermediate chamber, means for evacuating gases from said outer chamber, a first seal means for sealing said outer chamber to said intermediate chamber, an end member forming a vacuum tight chamber adjacent said intermediate chamber, a second seal means adjacent said first seal for sealing said end member to said intermediate chamber, a portion of said end member extending into said intermediate chamber and providing support for said inner chamber and means for evacuating said end member to a pressure on the order of 10^{-10} torr.

5. The apparatus of claim 2 wherein means are included for heating the walls of said inner chamber and intermediate chamber to an elevated temperature to remove adsorbed gases.

6. The apparatus of claim 2 wherein a thermal insulation material is positioned within the space between said intermediate chamber and said outer chamber to provide resistance to heat transfer from said outer chamber to said intermediate chamber.

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