Sept. 22, 1964 F. PAGANO **3,149,775**

VACUUM SYSTEM

Filed Dec. 13, 1961

Fig. 1.

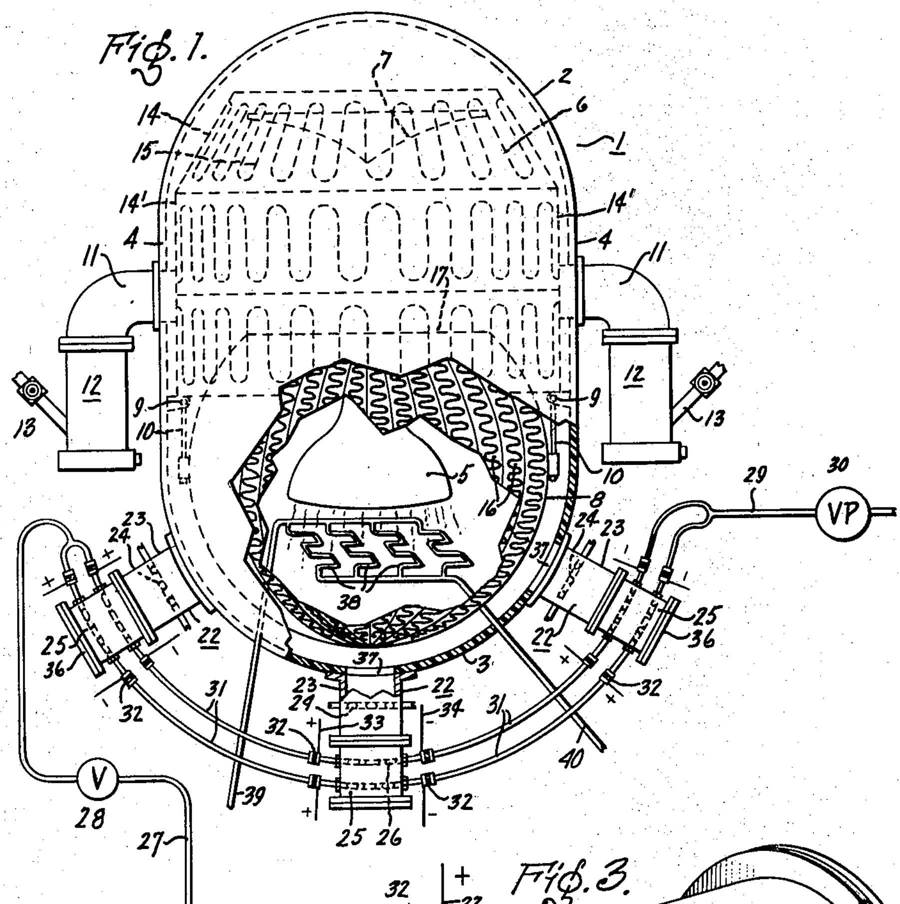


Fig. 2.

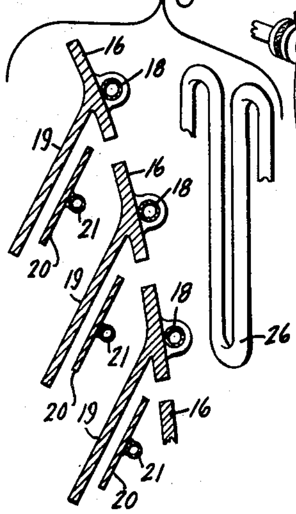
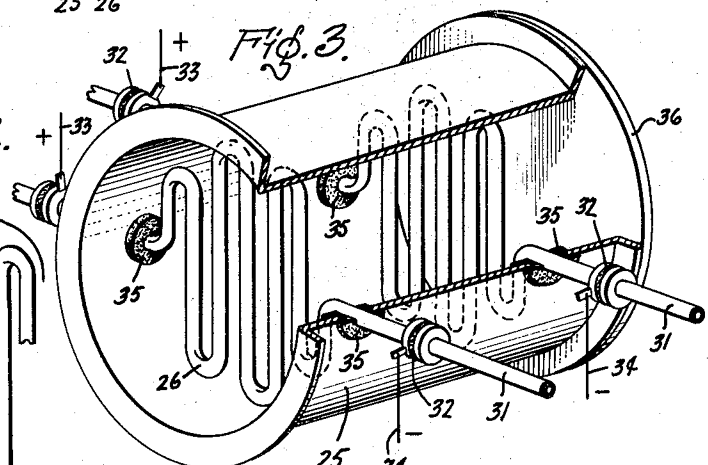


Fig. 3.



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VACUUM SYSTEM

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The present invention relates to vacuum systems of the type in which very low pressures and temperatures are to be maintained and, in particular, to methods and apparatus for removing hydrogen from such systems.

With the impetus toward the successful launching of satellites and vehicles into space, there is a growing need for extensive testing of such vehicles and components thereof under conditions substantially duplicating spatial environment. While it is essential that all information possible be obtained with respect to the operation of a space vehicle in earth orbiting or space travel missions, it is also desirable that this information be obtained rapidly and under conditions which can be controlled more accurately and flexibly and at less expense than sending such vehicles or satellites into space itself.

In the copending application of Donald J. Santeler, Serial No. 59,642, filed September 30, 1960, there is disclosed apparatus for producing low pressure conditions within a space simulating chamber in which mechanical and diffusion type pumps are used for rough evacuation of the chamber and a cryogenic pumping apparatus, consisting of either liquid nitrogen or liquid hydrogen refrigerating apparatus or both, is used to produce the final low pressure. One of the problems encountered in such space simulating apparatus is that of removing hydrogen from the evacuated space. This gas is not readily removed by pumping utilizing cryogenic techniques, since temperatures lower than 4° K. are required to condense hydrogen at the pressure of less than 10^{-7} mm. of mercury desired in space simulating chambers. The problem of removing hydrogen is further intensified in such chamber when they are used for testing engines, such as rocket engines, which exhaust hydrogen containing gases. Under such conditions, it is necessary to remove large amounts of hydrogen to maintain test conditions similar to those which might be encountered in outer space.

In the copending application of Virgil L. Stout and James R. Young, Serial No. 158,460, filed December 11, 1961, there are disclosed methods and apparatus for pumping hydrogen in which a hydrogen permeable member, such as a palladium or palladium alloy diaphragm, is exposed to an oxidizing atmosphere subjected to higher hydrogen pressure so that the diaphragm operates to provide a pumping function and to transfer the hydrogen from a region of low hydrogen pressure to a region having a higher average hydrogen pressure.

The chief object of the present invention is to provide new and improved methods and apparatus for removing hydrogen from a vacuum system operating at very low hydrogen pressures.

Another object of the invention is to provide an arrangement for simulating conditions of space outside the earth's atmosphere by removing not only readily pumped and readily condensable gases, but also hydrogen under conditions such that the gas is transferred from a region of lower pressure to one of higher pressure.

A still further object of the invention is to provide a unique combination of pumping apparatus to simulate conditions in space beyond the earth's atmosphere.

In accordance with an important aspect of my invention, the conditions existing in space beyond the earth's atmosphere are simulated in a chamber by removing gases therefrom using mechanical and cryogenic pumping means and either thereafter or simultaneously removing hydrogen from the chamber by utilizing a material of the type

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through which hydrogen can permeate in atomic form and exposing one surface of the material to the atmosphere in the chamber and exposing the opposite surface of the material to an oxygen containing atmosphere so that hydrogen enters into solution with the material in the surface exposed to the chamber and after passing through the material reacts with oxygen at its opposite surface to form water.

In accordance with another aspect of the invention, the hydrogen contained in gases which are developed in such a chamber when an engine, such as a rocket engine, is tested is rapidly removed by positioning such a hydrogen removing member within the chamber which is exposed to such gases, the member being hollow, and passing an oxygen containing atmosphere through the member.

The attached drawing illustrates preferred embodiments of the invention, in which:

FIGURE 1 is a view in section of a space simulator chamber employing the present invention;

FIGURE 2 is a sectional view illustrating the arrangement of hydrogen removing apparatus with respect to cryogenic pumping apparatus used in the chamber of FIGURE 1; and

FIGURE 3 is a sectional view of a hydrogen pumping apparatus utilizing the apparatus shown in FIGURE 1.

The space simulator 1 illustrated in FIGURE 1 comprises an outer insulated housing, including an upper insulated hemispherical shell 2, a lower hemispherical shell 3, and a central cylindrical shell 4, these elements together defining an evacuated chamber in which a test member, such as the rocket engine 5, is to be tested. A shell 6 located within the evacuated chamber provides means to absorb radiant energy. A suitable reflector 7 is also located in the upper portion of the chamber, and a spherical cryogenic member 8 is mounted in the lower portion of the chamber. Shell 6 is supported within the chamber by means of a plurality of gusset plates 9, and spherical member 8 is supported by rods 10 extending between gusset plates 9 and member 8.

Evacuation of the chamber in accordance with my invention is achieved by a combination of mechanical, diffusion, cryogenic and hydrogen pumping means. The mechanical pumps (not shown) are, preferably, located externally of the simulator chamber 1 and are connected thereto by means of conduits 11 which extend through the cylindrical portion 4 of the housing and radiant energy absorbing shell 6. The diffusion pumps 12, which may be conventional in character, are attached to an opposite end of elbows 11. Pipes or conduits 13, connected to diffusion pumps 12, preferably, are connected to the external mechanical pumps.

The radiant energy absorbing shell 6 comprises a frustoconical shaped portion 14 and a cylindrical portion 14'. These portions, preferably, are fabricated of plate material to form a structure whose lower end surrounds the upper portion of cryogenic pumping member 8. Heat exchange coils 15 are, preferably, fastened and thermally connected to the plates comprising shell 6. A gas, such as liquid nitrogen, may be expanded or evaporated in coils 15. Since it is desirable that a temperature less than 100° K. be maintained within the space simulating chamber, this temperature may be readily achieved by expanding liquid nitrogen in coils 15, the liquid nitrogen upon expansion providing a temperature of approximately 77° K.

The cryogenic pumping member 8 comprises a plurality of panels 16 which are fabricated to form a substantially spherical enclosure having an opening 17 through which a component, such as the rocket engine 5, may be introduced for test purposes. Panels 16 are provided with refrigerant coils 18 through which refrigerant gas, which again may be liquid nitrogen, may be passed.

A portion of the structure of the cryogenic member 8 is illustrated in FIGURE 2. As there shown, the panels 16 have heat exchange coils 18 soldered or otherwise thermally attached in a conventional manner so that gas expanding within the coils 18 is in heat exchange relation with wall 16. A plurality of baffle fins 19 extend from wall 16 and are thermally connected thereto. With this construction, both the wall 16 and the baffle fins 19 are maintained substantially at the temperature of the coils 18 through which the refrigerant is circulated.

I also provide means to condense molecules of gases having boiling points less than the evaporation temperature of nitrogen. For this purpose, condensing fins 20 are positioned below fins 19 and have thermally joined thereto refrigerant or heat exchange coil 21. Condensing fins 20 may be maintained at a temperature of the order, for example, of 20° K. by passing through heat exchange coils 21 liquid helium and allowing the liquid helium to expand in the coils.

In the structure thus far described, any radiant energy heat load is readily exposed to and absorbed by the higher temperature nitrogen refrigerant circuit comprising coils 15 while pumping of nitrogen, oxygen, argon, and carbon monoxide may be performed by the cryogenic pumping action of refrigerant coils 21 and fins 20. One of the remaining problems in order to completely simulate conditions of space outside the earth's atmosphere is to remove the hydrogen gas present in the space chamber and which may be present both in atomic and molecular form. This gas is not readily removed by utilizing cryogenic pumping techniques since temperatures lower than 4° K., the boiling point of liquid helium, are required to condense hydrogen to equilibrium pressures less than 10^{-7} mm. of mercury required to duplicate spatial conditions. In order to remove such hydrogen gas, I provide hydrogen pumping apparatus which comprises one or more tubes 22 located at points on the periphery of the chamber 1 and connected across openings in lower hemispherical shell 3. Each of the tubes 22 comprises a first portion 23 in which may be located a water cooled baffle 24 and a second portion 25 in which are located one or more hydrogen pumping means 26. Hydrogen pumping means 26 are illustrated in FIGURE 3 as a hollow coil of material through which hydrogen can permeate in atomic form. Such a material may comprise, for example, palladium, iron, platinum, or alloys of such materials. One particularly suitable material comprises a palladium alloy consisting of 75% palladium and 25% silver. In such a material, hydrogen enters into solution which the material on one surface thereof and permeates through the material in atomic form to later pass out of solution at the other surface of the material where it reacts with a gas present in the atmosphere at such other surface. When the atmosphere at the exit surface includes oxygen, the hydrogen reacts to form water or water vapor. For this purpose, the coil 26 is formed from a hollow tube and a supply of oxygen, or of an atmosphere containing oxygen, is passed through the coil entering through a conduit 27 from an oxygen supply through a valve 28 and being withdrawn through a conduit 29 and a vacuum pump 30.

As illustrated, in order to expedite the removal of hydrogen from the chamber 11, a plurality of coils 26 may be connected in parallel in each tube 22 and in series through two or more of such tubes. Also, preferably, the coils 26 of the hydrogen permeable material in each tube 22 are joined by tubes or pipes 31 through electrically insulating leak-proof joints 32. Also, each coil of material 26 is electrically heated by means of current passing through wires 33, 34 and supplied from a suitable source of voltage indicated conventionally by the signs plus and minus. In this manner, the temperature of the individual coils 26 is raised preferably to a temperature somewhere

between 100° C. and 500° C. to accelerate the hydrogen pumping action. Alternatively, the temperature of the individual coils 26 may be raised by heating the oxygen, or other oxygen containing atmosphere supplied through conduits 27, to a temperature such that in passing through the tubes 26 it raises the temperatures of such tubes to a desired point. When electric resistance heating is used to raise the temperature of the coils 26, obviously suitable electrical insulating means 35 is supplied at the entry and exit points of the coils 26 through the walls of tube 25. As illustrated in FIGURE 3, the end of tube 25 remote from chamber 1 is closed by a vacuum seal comprising a closure member 36 welded across the end of tube 25.

In the operation of my vacuum system, the chamber 1 is first evacuated by means of a mechanical system, or some equivalent external pumping system, to reduce the pressure in the chamber. Thereafter, both the diffusion pump 12 and the cryogenic pumps comprising coils 15, 18 and coils 21 are made operative by circulating liquid nitrogen through the coils 15, 18 and liquid helium through the coils 21. By these means, gases having boiling points greater than 77° K. are condensed through the operation of the cryogenic pumping coils 15 and 18. Those gases, such as nitrogen, oxygen and argon, having boiling points less than 77° K. at the operating pressures, but higher than 20° K. are condensed through the operation of the cryogenic pumping means comprising coils 21. The remaining hydrogen gas within the chamber is allowed to pass freely through panels 16 through aperatures 37 in such wall and come in contact with the coils 26 of the hydrogen pumping apparatus. To minimize the effect of the heated coils 26 on the panel 16, water cooled baffles 24 in tubes 23 hide the hot coils 26 from refrigerated panel 16 which, in turn, shields the coils from the interior of the chamber itself. On the other hand, any hydrogen gas contained in the chamber, upon passing through openings 37, even though it is at a lower hydrogen pressure than the average hydrogen pressure on the inside of the tube 26, enters into solution with the material of tube 26 since it is in an atmosphere devoid of oxygen. The hydrogen gas permeates through tube 26 to the opposite surface thereof where it reacts with the relatively oxygen rich atmosphere to form water or water vapor. In this fashion, coils 26 comprising the hydrogen pumping apparatus operate to perform a pumping action and to transfer hydrogen from a region of low hydrogen pressure to a region of higher average hydrogen pressure.

In the use of my improved vacuum system for a space simulating chamber, it is frequently desired to test components, such as rocket engine 5, which produce exhaust comprising hydrogen containing gases. During such tests, very large amounts of hydrogen are produced rapidly. In order to quickly remove such excess amounts of beyond the earth's atmosphere as rapidly as possible, I provide additional hydrogen pumping apparatus within the chamber in the vicinity of such a test rocket engine 5. This apparatus comprises a plurality of coils 38 of a material through which hydrogen permeates connected in parallel with each other and in series with conduits 39 and 40 connected, respectively, to a source of oxygen or oxygen containing atmosphere and a vacuum pump. The coils 38 may also be formed of palladium or a palladium alloy and may be heated either by heating the oxygen or oxygen containing gases that pass through conduits 39, 40 and coils 38, or they may be heated by electrical means (not shown) similar to the electrical heating means illustrated in FIGURE 3. Additionally, they may be heated by the exhaust gases themselves to a temperature sufficient to accelerate the hydrogen pumping operation of the coils 38.

An important advantage of my improved vacuum system is that it provides a method and apparatus for rapidly and easily removing hydrogen from a region of low hydrogen pressure to a region of higher average hydrogen pressure. In this way, it can perform a function which is not performed through known cryogenic pumping apparatus. It thus obviates a problem particularly encountered in space simulator chambers where the accumulation of hydrogen, particularly when rockets or similar engines are tested, poses a heretofore unsolved problem. By my combined hydrogen pumping apparatus, conventional mechanical pumping systems, and diffusion and cryogenic pumping apparatus, I provide an arrangement which can more effectively and rapidly simulate conditions beyond the earth's atmosphere.

While in the foregoing I have shown the hydrogen pumping apparatus to be in the form of coils, obviously any other arrangement of surfaces may be employed. Thus, for example, palladium diaphragms may be employed and an oxygen containing atmosphere may be passed on one side of such a diaphragm while the hydrogen to be pumped is presented to the opposite surface of the diaphragm.

While I have described preferred embodiments of my invention, it will be understood that my invention is not limited thereto since it may otherwise be embodied in the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States are:

1. In a space simulating chamber of the type in which the operation of materials and components at low pressures and temperatures is to be examined,
- a pump connected to said chamber to remove gases therefrom,
- cryogenic means located in said chamber for condensing gases therein,
- a first means for removing hydrogen from said chamber positioned along the outer surface thereof and
- a second means for removing hydrogen from said chamber positioned within said chamber and adapted to be exposed to hydrogen containing gases generated within said chamber during operation of a component therein, said first and second means comprising a hydrogen permeable material.

2. The combination of claim 1 in which the means for removing hydrogen comprise palladium.

3. The combination of claim 2 in which the palladium has a first surface exposed to the atmosphere within the chamber and
- an opposite surface over which an atmosphere containing oxygen may be passed.

4. In the combination of claim 2, means for heating said first means to accelerate the pumping of hydrogen from said chamber and means thermally shielding said first means from the interior of said chamber.

5. A space simulating chamber of the type in which the operation of materials and components at low pressures and temperatures is to be examined comprising
- means for reducing pressure in said chamber to a low value,
- cryogenic means located in said chamber for condensing gases therein, and
- means for removing hydrogen from the chamber comprising a tube of palladium containing material positioned to be exposed to hydrogen contained in said chamber,
- means for heating said tube,
- means for passing an oxygen containing atmosphere through said tube whereby hydrogen within said chamber enters into solution with said tube and permeates therethrough to react with such oxygen on the inner surface of said tube, and
- means thermally shielding said tube from the interior of said chamber.

6. In combination, means defining a chamber to be evacuated,
- a pump connected to said chamber to remove gases therefrom,
- cryogenic means located in said chamber for condensing gases therein, and
- means located at the periphery of said chamber for removing hydrogen from said chamber,
- said hydrogen removing means comprising a palladium containing material having a surface exposed to the atmosphere of said chamber,
- means for exposing the opposite surface of said material to a flowing oxygen containing atmosphere,
- means for heating said material to accelerate the removal of hydrogen from the chamber, and
- means thermally shielding said material from the interior of the chamber.

7. A space simulating chamber of the type in which the operation of materials and components at low pressures and temperatures is to be examined comprising
- means for reducing the pressure in said chamber to a low value, and
- means for removing hydrogen from the chamber comprising a palladium member having a first surface exposed to hydrogen and other gases contained in said chamber,
- a second surface exposed to a flowing atmosphere having a hydrogen pressure higher than the hydrogen pressure to be obtained in said chamber,
- said atmosphere containing oxygen,
- means for heating the palladium member to facilitate the removal of hydrogen from said chamber, and
- means thermally sealing said member from the interior of said chamber.

References Cited in the file of this patent

UNITED STATES PATENTS

1,124,347	Snelling	Jan. 12, 1915
1,174,631	Snelling	Mar. 7, 1916
2,570,103	De Groat	Oct. 2, 1951
2,582,885	Rosenblatt	Jan. 15, 1952
2,637,625	Garbo	May 5, 1953
2,749,293	Wahlin	June 5, 1956
2,773,561	Hunter	Dec. 11, 1956
2,939,316	Beecher et al.	June 7, 1960
3,064,364	Schueller	Nov. 20, 1962

OTHER REFERENCES

"1958 Vacuum Symposium Transactions," published by Pergamon Press, Incorporated (New York), 1959 (article by Bailey et al., on pages 262–267 relied on).