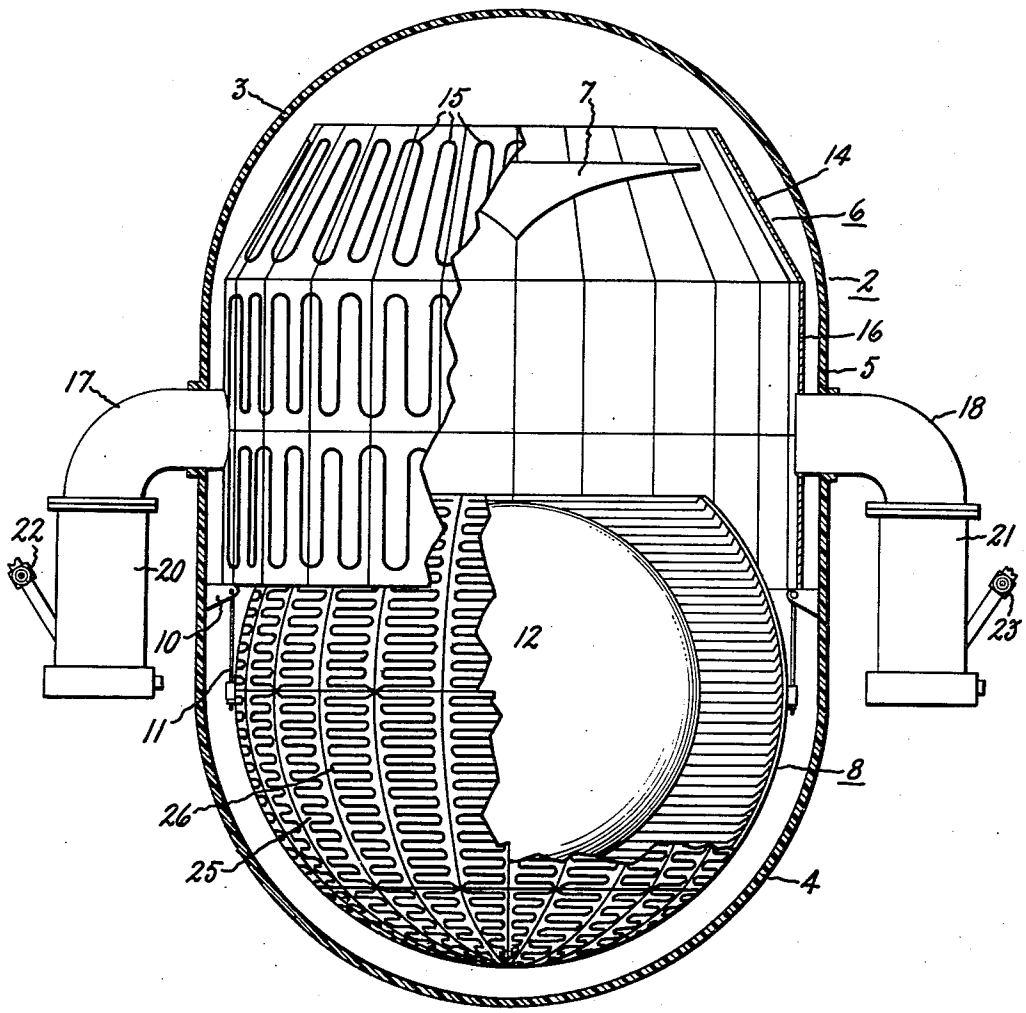
April 28, 1964 N. H. WOOD ETAL 3,130,563

CRYOGENIC APPARATUS

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Fig. 1.



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Fig. 2.

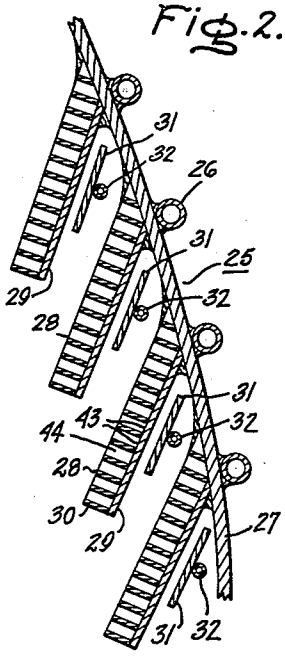


Fig. 4.

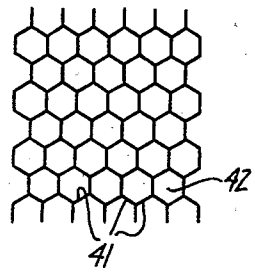
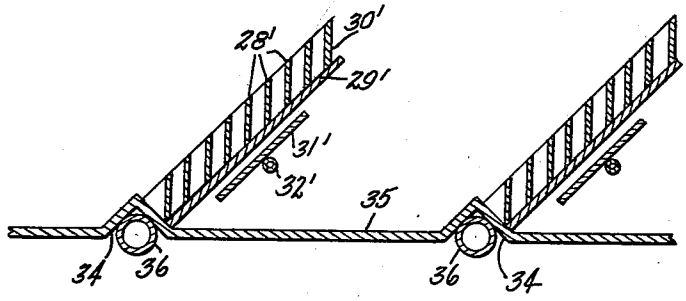


Fig. 3.



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CRYOGENIC APPARATUS

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The present invention relates to improved cryogenic apparatus and, more particularly, to improved cryogenic pumping apparatus for use in space simulating chambers.

In the copending application of Donald J. Santeler, entitled, "Cryogenic Pumping Apparatus," filed September 30, 1960, Serial No. 59,642, and assigned to the assignee of the present application, there is disclosed a cryogenic pumping apparatus for use in space simulating chambers which will substantially permit the duplication of cold "black" space and the pressure conditions existing in the spatial environment. In the Santeler application, it is recognized that molecules being distributed from the surface of a vehicle in space rarely collide with one another and return to the vehicle: To duplicate this effect in a confining chamber, such as a space simulator, it is necessary that the walls of the chamber substantially absorb all the molecules emitted by the space vehicle or the test member. To simulate spatial conditions, pressures less than 1×10^{-5} millimeters of mercury should be maintained and this may be achieved by a three-fold pumping arrangement including mechanical pumping, diffusion pumping, and cryogenic pumping.

Specifically, the Santeler application discloses a cryogenic pumping construction which includes radiant energy absorbing means in the form of a baffle fin which is in heat exchange relation with a refrigerant, such as liquid nitrogen at a temperature of approximately 77° K., to maintain the temperature of the baffle fin less than approximately 100° Kelvin. The baffle fin further shields a condensing fin maintained at a lower temperature, for example, 20° K. This low temperature may be achieved by the use of refrigerants such as gaseous helium and liquid hydrogen. The purpose of this shield construction, as noted in the Santeler application, is to utilize the baffle fin principally for the absorption of radiant energy and to use the condensing fin to pump certain gases. If the baffle fin surface is cooled with liquid nitrogen at 77° K., it cryogenically pumps water, carbon dioxide, and hydrocarbons in addition to absorbing radiant energy. Cryogenic pumping as utilized herein generally denotes the condensation of a gas or vapor on a low temperature surface, the gas substantially remaining on the surface in a liquid or solid state. If liquid hydrogen or gaseous helium is utilized to cool the condensing fin to approximately 20° K., there is cryogenically pumped nitrogen, oxygen, argon, and carbon monoxide which leaves only helium, hydrogen, and neon as unpumped gases. In the event that liquid helium, at approximately 4° K., it utilized in the condensing fin, then only helium in the chamber will not be pumped.

In our copending application entitled, "Improved Cryogenic Pumping Apparatus," filed November 2, 1960, Serial No. 66,820, and assigned to the assignee of the present application, there is disclosed an apparatus having the previously noted advantages of the Santeler construction but also having improved means for assuring rapid and effective cryogenic pumping. This improvement is achieved by providing suitable passages through the baffle fin to permit the passage of certain gases therethrough to the condensing fins. The term "condensing" as utilized herein with reference to the condensing fin denotes the substantial liquification or solidification of certain gases on the condensing fin, these gases not ordinarily condensing on the radiant energy absorbing means, because of their low boiling points.

A study of the previously cited applications discloses a radiant energy source in the chambers for simulating solar radiation. The principal function of the baffle fins is to maintain the blackness of the chamber, that is, to make the walls optically black in a manner that radiant energy when reaching the baffle fins will be absorbed without appreciable reflection. Furthermore, the baffle fins are also "black" to certain molecules, that is, in performing tests of the type described, vast quantities of water vapor may be present and these molecules of water vapor must be pumped, preferably cryogenically, on the surfaces of the baffle fins. After a predetermined time, it is quite possible that the gases that are condensed on the baffle fins form a coating of ice on the surfaces thereof and lose their "black" quality.

The chief object of the present invention is to provide an improved space simulating chamber.

Another object of the invention is to provide improved cryogenic pumping means.

A further object of the present invention is to provide an improved cryogenic pumping member including a baffle fin which will maintain its blackness, i.e., high absorptivity, so that it absorbs radiant energy and cryogenically pumps certain gases, such as water vapor, for long periods of time without substantially reflecting radiant energy and molecules.

These and other objects of our invention may be more readily perceived from the following description.

One of the features of our invention is a cryogenic pumping construction for use in evacuated chambers wherein baffle means utilized mainly to absorb radiant energy and to cryogenically pump certain gases, such as water vapor, carbon dioxide, and certain hydrocarbons, includes a member constituting a heat-conducting path which maintains the temperature of extended surfaces associated therewith at desired levels. The construction assures the optical and molecular blackness of the baffle means by absorbing radiant energy or molecules on initial contact or upon reflection from an adjacent surface.

The attached drawings illustrate preferred embodiments of the invention, in which:

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

FIGURE 2 is a sectional view of a cryogenic member which may be utilized in the apparatus in FIGURE 1;

FIGURE 3 is a sectional view of another embodiment of the cryogenic member illustrated in FIGURE 2; and

FIGURE 4 is an enlarged fragmentary plan view of the baffle member utilized in the cryogenic members illustrated in FIGURES 2 and 3.

In FIGURE 1, a space simulating chamber 2 is illustrated for practicing the present invention. Space simulating chamber 2 may comprise an outer shell including an upper hemispherical shell member 3, a lower hemispherical shell member 4, and a central cylindrical shell member 5 which define the evacuated chamber within which a test member 12 such as a satellite or space vehicle, may be mounted for suitable testing. In the upper portion of the chamber so defined, shield 6 may be suitably suspended for purposes of absorbing radiant energy. Adjacent shield 6 may be mounted a radiation source 7 which is intended to duplicate the radiant energy supplied by the sun in outer space. In the lower portion of the chamber, a substantially spherical cryogenic member 8 may be mounted, the spherical member being supported by rods 11 extending from gusset plates 10. These gusset plates may also support shield 6 within the chamber.

A combination of mechanical, diffusion, and cryogenic pumping means may be utilized to evacuate chamber 2.

The mechanical and diffusion pumping means are located externally of simulating chamber 2 and are connected thereto by means of conduit elbows 17 and 18. These elbows may extend through cylindrical portion 5 of the housing and one end of each may extend through radiant energy absorbing shell 6. The opposite ends of elbows 17 and 18 may be connected to suitable diffusion pumps 20 and 21 which have associated therewith mechanical pumping means 22 and 23. The construction and manner of operation of these diffusion pumps and mechanical pumps are of a conventional nature and may be of the type described in our previously identified patent application.

In FIGURE 2 there is shown an enlarged sectional view of a portion of the cryogenic pumping member 8 illustrated in FIGURE 1. This member comprises a spherical wall portion 27 which is fabricated of a plurality of panels 25 having heat exchange coils 26 (also shown in FIGURE 1) connected thereto. Refrigerants, such as liquid nitrogen, may be circulated through coils 26 to cool all the thermally associated portions of member 8 to maintain them within a given temperature range of from 77° to approximately 100° K. These portions may include baffle fins 28, each of which comprises a plate 29 which constitutes a thermal path from wall member 27 in such a manner that good heat transfer exists throughout the baffle fin construction. The baffle fin may further include honeycomb construction 30 which provides a plurality of surfaces which define recesses, the wall surfaces of which are thermally associated with the refrigerant passing through coils 26.

Condensing fins 31 may be shielded by the baffle fin constructions which are angularly mounted on wall portion 27. In order to suitably refrigerate the condensing fins 31, a refrigerant may be supplied through coils 32 thermally bonded to the condensing fins.

In the embodiment in FIGURE 3, wall member 35 is substantially planar and has suitable corrugated portions 34 into which suitable refrigerant coils 36 may be mounted. These corrugations furthermore may provide mounting areas for baffle fins 28' which comprise a plate 29' which constitutes a heat-conducting path from coil 36 to honeycomb construction 30'. As in the embodiment in FIGURE 2, the baffle fins provide a shielding function for condensing fins 31' which are refrigerated in this embodiment by refrigerant passing through tubes 32'. In this embodiment, the walls of the honeycomb member are oriented at an acute or oblique angle with respect to the backing plate.

In FIGURE 4 there is shown a plan view of a honeycomb construction which may be utilized with the baffle fin constructions illustrated in FIGURES 2 and 3. It can be seen that these baffle fins have honeycomb oriented walls 41 which define a plurality of hexagonal openings 42.

In the operation of baffle fins and condensing fins as illustrated herein and also in the copending Santeler application and our previously identified copending application, the baffle fins absorb radiant energy and also condense certain gases having boiling points higher than the temperature of the baffle fins. The condensing fins condense gases having low boiling points. Preferably liquid nitrogen is utilized to refrigerate the baffle fins and a fluid such as liquid hydrogen or liquid helium is utilized to refrigerate the condensing fins. Under such circumstances, it is desirable to maintain the baffle fins at a temperature of approximately 100° K. or less and the condensing fins at temperatures in the vicinity or range of approximately 20° K.

Depending upon the test, chamber size, and test member, different size fins having different characteristics are required. Clearly, a plain baffle fin having a regular, smooth planar surface has limited condensing area; however, by making the fin of sufficient thickness, the thermal conductivity through the fin may be very good. In the event liquid nitrogen is utilized to cool such a baffle fin, after a predetermined time, if sufficient water vapor is present within the chamber, the surface is coated with a film of ice which may diminish the blackness or absorptivity of the pumping panels, that is, molecules and radiant energy may be reflected from the surface toward the test member.

When utilizing perforated baffle fin constructions as illustrated in our previously identified application, the pumping speed of the construction is extremely good since molecules being pumped by the condensing fins may pass through the passages provided in each baffle fin. The thermal conductive path between the end of the fin and the portion adjacent the refrigerant, however, may be insufficient for a particular application and an excessive temperature difference between the end of the fin and the portion of the fin adjacent the wall and in heat exchange relation with the refrigerant may exist. For example, a temperature difference as great as a few hundred degrees Kelvin may be experienced. Since the area adjacent the refrigerant may be approximately 100° K., having a temperature of 300° K. at the end of the fin will make the fin useless for pumping water vapor and similar gases having lower boiling points. A situation arises wherein the molecules reaching the surface of the baffle fin are reflected and redirected toward the test member thereby making the space simulating chamber unsuitable for use.

The present invention provides a novel baffle fin construction, preferably for shielding a condensing fin to permit cryogenic pumping of certain gases by the condensing fin while the baffle fin effectively absorbs radiant energy and pumps certain higher boiling point gases that are present in the space simulating chamber. The present invention provides a baffle fin with a thermal conducting path, namely, backing plate 29, which constitutes a portion of the baffle fin and this plate has sufficient thickness to permit radiant energy to be absorbed at the end thereof opposite wall 27 at desirably low temperatures. The baffle fins, through the thermal characteristics of the backing plate, remove the heat absorbed and maintain the temperature of the adjacent surfaces at levels of, for example, 100° K.

The honeycomb construction 30 is thermally bonded to the backing plate 29. This honeycomb is fabricated of a good thermal conductor treated to obtain a highly absorptive surface. In addition to being optically black, it is also maintained at the temperature close to the refrigerant temperature in coils 26 by the described action of backing plate 29. For example, a temperature differential across the fin may exist in the order of 35° K. The honeycomb member 30 has a further feature in that the walls 41 define passages 42 through the honeycomb, these passages when connected to the backing plate form with the upper surface 43 of the backing plate recesses 44. It can be readily seen that the temperature of these raised portions extending from the backing plate can be maintained at desired temperatures, or within the desired temperature range, because of the good conductive thermal path to the refrigerant. Furthermore, walls 41 and surface 43 of the backing plate define recesses having a plurality of adjacent surfaces whereby molecules and radiant energy particles pass into these recesses and have an opportunity to be reflected to adjacent surfaces in the event that immediate absorption does not occur. These particles may bounce from one surface to another without being reflected to the test member. The fins in FIGURE 3 function similarly as those described in FIGURE 2, however, under certain circumstances, the angled recesses may be more optically opaque.

In the operation of the space simulating chamber, generally a test member 12 is suspended in the chamber illustrated in FIGURE 1 and is substantially enveloped by cryogenic pumping member 8. Access openings provided in the chamber are sealed and as a result of the action of the mechanical and diffusion pumps, a substantially low pressure may be achieved. This pressure may

be as low as 1×10^{-5} millimeters of mercury. A refrigerant, such as liquid nitrogen, may then be circulated through coils **15** which are in heat exchange relation with shield **6** thereby absorbing radiant energy in the upper portion of the chamber and condensing gas molecules having high boiling points. The random movement of gas molecules continues in the area of the test member accompanied by degassing of the test member resulting in a distribution of gas molecules therefrom. Reflected energy also passes toward cryogenic pumping member **8**, this energy originating from light source **7**. The radiant energy and also molecules in the area of the cryogenic pumping member **8** are absorbed and the cryogenic pumping panels supplement the efforts of the mechanical and diffusion pumping means previously described. Shield **6** and cryogenic pumping member **8** which are both cooled, in a preferred example, by liquid nitrogen constitute a heat sink for radiant energy, and for latent heat of condensation of a gas condensing thereon. Those gases which are not condensed on the baffle fins are reflected therefrom and are permitted to pass into the spaces between the baffle fins where they are condensed on condensing fins **31**. The effectiveness of the baffle fins continues as a result of the extended surface provided by honeycomb portion **30** of each baffle fin. This construction not only provides extended surfaces but as previously noted, upper surfaces **43** of plates **29** provide reflective surfaces whereby in the event that a coating is formed on the surfaces, reflection of molecules or radiant energy culminates in the photon or molecule being absorbed on a subsequent impingement on a condensing surface, such impingement being assured by the close proximity of the walls defining recesses **44** and also by the temperature at which the surfaces which define the recesses are maintained.

The maintenance of these low temperature surfaces which define the recesses is assured by the extremely good thermal conducting path provided by backing plate **29**. The edges of the honeycomb construction are bonded to this backing plate and as previously noted, each backing plate is connected to wall **27** which is in heat exchange relation with refrigerant being circulated through coils **26**. In the preferred embodiment, liquid nitrogen is supplied through these coils and the temperature difference between the refrigerant and the tips of the baffle fin may only be in the range of 35–50° K., assuring that the higher boiling point molecules remaining in the chamber are condensed on the baffle fin surfaces and also assuring that sufficient surface is present so that the coating on the fins does not effectively impede the continuing action of the surfaces.

In the preferred embodiment of the present invention, a baffle fin is provided for shielding a condensing fin utilized for cryogenically pumping extremely low boiling point gas molecules. The baffle fin construction not only provides extended heat exchange surfaces but also assures optical blackness for absorbing radiant energy and also provides molecular blackness for assuring that higher boiling point gas molecules present in the chamber are condensed with minimum reflection of such gas molecules. While a honeycomb construction has been illustrated in the present application, it will be appreciated that other constructions having extended surfaces with closely spaced reflecting surfaces may supply the desired effect.

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

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

1. In a space simulator, means defining a chamber, a pump connected to and adapted to substantially evacuate said chamber, a cryogenic member being located in said chamber and being adapted to substantially envelop a test member in said chamber, said cryogenic member including a wall member, a plurality of baffle fins extending from said wall member and being angularly disposed with respect to said wall member, said wall member and said baffle fins being thermally connected, a plurality of condensing fins being located between said baffle fins and the wall member whereby the condensing fins are substantially shielded from the test member, said baffle fins including a plurality of closely spaced surfaces defining recesses therein.

2. In a space simulator, means defining a chamber, a pump connected to and adapted to substantially evacuate said chamber, a cryogenic member being located in said chamber and being adapted to substantially envelop a test member in said chamber, said cryogenic member including a wall member, a plurality of baffle fins extending from said wall member and being angularly disposed with respect to said wall member, said wall member and baffle fins being thermally connected, a plurality of condensing fins being located between the baffle fins and the wall member whereby the condensing fins are substantially shielded from the test member, said baffle fins comprising a backing plate and a perforated plate thermally connected thereto, said backing plate and the walls of the perforations in the perforated plate defining a plurality of recesses.

3. In a space simulator, means defining a chamber, a pump connected to and adapted to substantially evacuate said chamber, a cryogenic member being located in said chamber and being adapted to substantially envelop a test member in said chamber, said cryogenic member including a wall member, a plurality of baffle fins extending from said wall member and being angularly disposed with respect to said wall member, said wall member and baffle fins being thermally connected, a plurality of condensing fins being located between the baffle fins and the wall member whereby the condensing fins are substantially shielded from the test member, said baffle fins comprising a backing plate and a honeycomb member thermally connected thereto, said backing plate and honeycomb member defining a plurality of recesses.

4. In a space simulator having means defining a chamber and pump means located externally of said chamber for substantially evacuating said chamber; the improvements comprising a heat sink located in said chamber and adapted to substantially envelop a test member, the heat sink including wall members, a plurality of baffle fins extending from some of said wall members, each baffle fin being obliquely disposed with respect to the wall member to which it is attached; means for cooling the heat sink including baffle fins to within a first temperature range, condensing fins mounted between the baffle fins and the wall members, the baffle fins substantially shielding the condensing fins from radiation originating from a test member located in said chamber, means for cooling the condensing fins to a second temperature range lower than said first temperature range; a thermal conductor having a honeycomb configuration thermally connected to portions of the heat sink adapted to be cooled to within said first temperature range and facing the test member.

5. In a space simulator having means defining a chamber and pump means external of said chamber for substantially evacuating said chamber, the improvements comprising a heat sink mounted in said chamber and thermally insulated therefrom, said heat sink adapted to substantially enclose a test member, said heat sink including wall members, baffle fins extending from at least one of said wall members, each such baffle fin being mounted in thermal contact with the wall member and at an oblique angle wtih respect to it, heat exchange means connected to the heat sink adapted to maintain the temperature of the heat sink including wall members and baffle fins substantially within a first temperature range, a thermal conductor having a honeycomb configuration thermally connected to the heat sink to increase the absorptivity of the heat sink to radiant energy, a condensing fin mounted between a baffle fin and the wall member and substantially

thermally insulated therefrom, the baffle fins substantially shielding the condensing fins from radiation originating from a test member located within the heat sink, and heat exchange means for the condensing fins adapted to maintain the temperature of the condensing fins at a second temperature range lower than said first temperature range.

6. A cryogenic member comprising a wall member, a baffle plate having sides connected at an oblique angle to the wall member, heat exchange means connected to the wall member and adapted to maintain the wall member and baffle plate within a first temperature range, a condensing fin mounted between the baffle plate and the wall member, heat exchange means adapted to maintain the condensing fin within a second temperature range substantially lower than first temperature range, and a honeycomb member thermally connected to the baffle plate on the side of the plate opposite that near which the condensing fin is located.

7. A cryogenic member comprising a wall member, a plurality of baffle plates, each baffle plate being connected at an oblique angle to the wall member, heat exchange means connected to the wall member and adapted to maintain the wall member and baffle plates within a first temperature range, a plurality of condensing fins with

each fin being mounted between a baffle plate and the wall member to substantially conceal the condensing fin from radiation substantially normal to the wall member, heat exchange means adapted to maintain the condensing fin within a second temperature range lower than the first temperature range, and a honeycomb member made of a good thermal conductor thermally connected to the baffle plates so that radiation substantially normal to the baffle fins strikes the honeycomb.

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