Feb. 18, 1964 W. H. BENNETT 3,121,329

SIMULATION OF REENTRY CONDITIONS

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FIG. 1

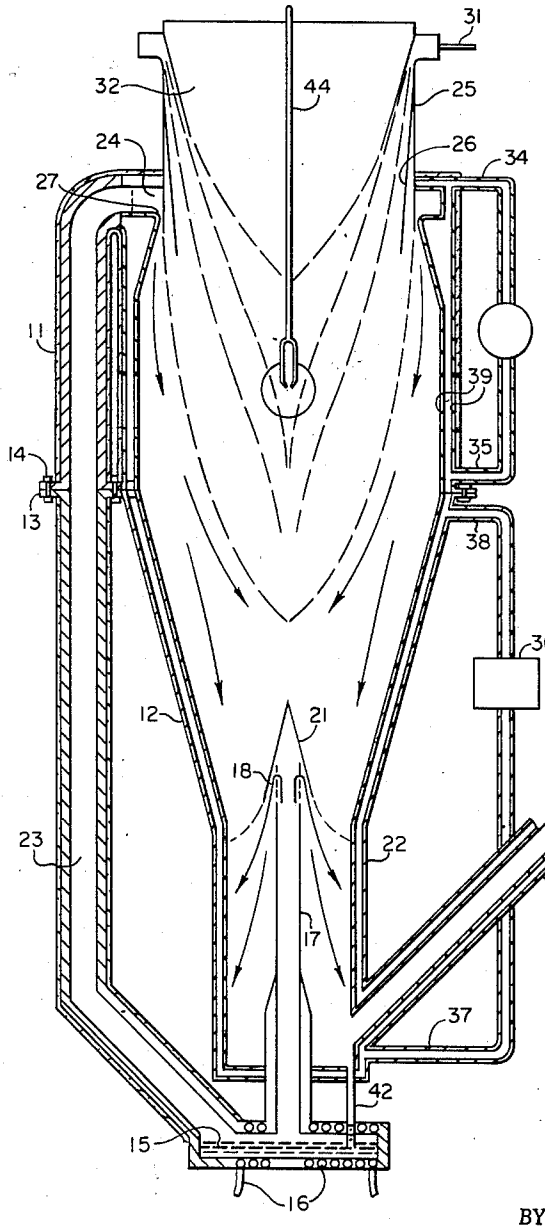


FIG. 8

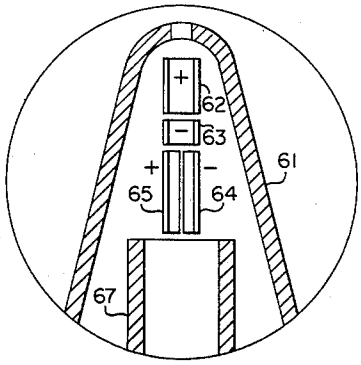
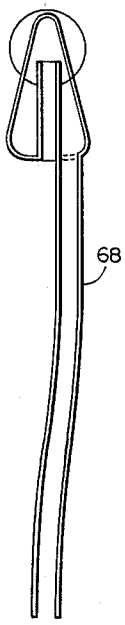


FIG. 9



INVENTOR
WILLARD H. BENNETT
Melvin L. Crane, agent
BY Richard C. Reed
ATTORNEY

Feb. 18, 1964 W. H. BENNETT 3,121,329

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FIG. 5

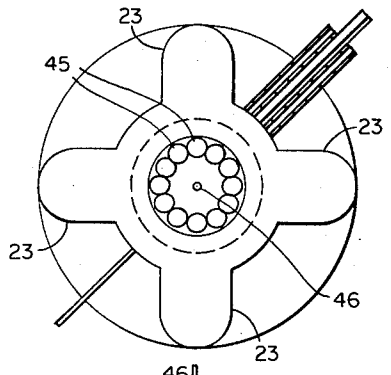
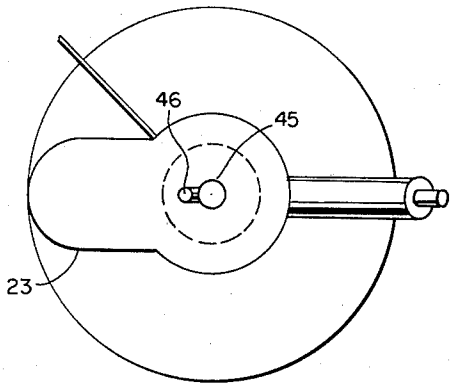


FIG. 3



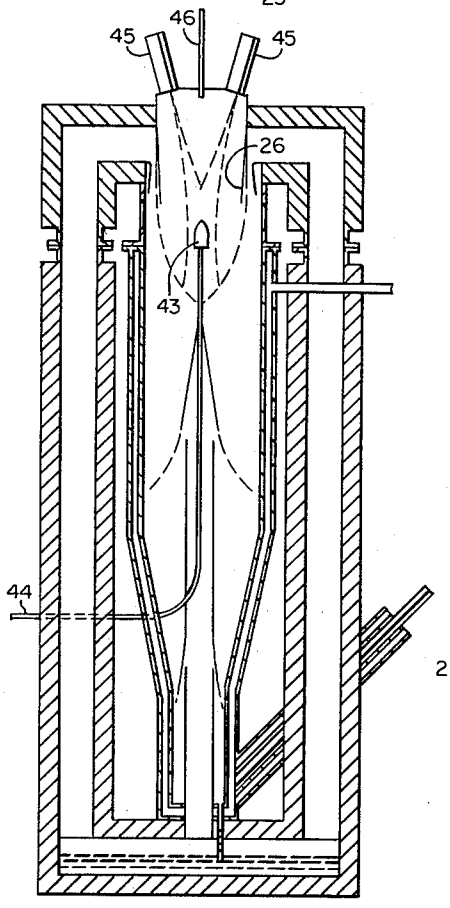
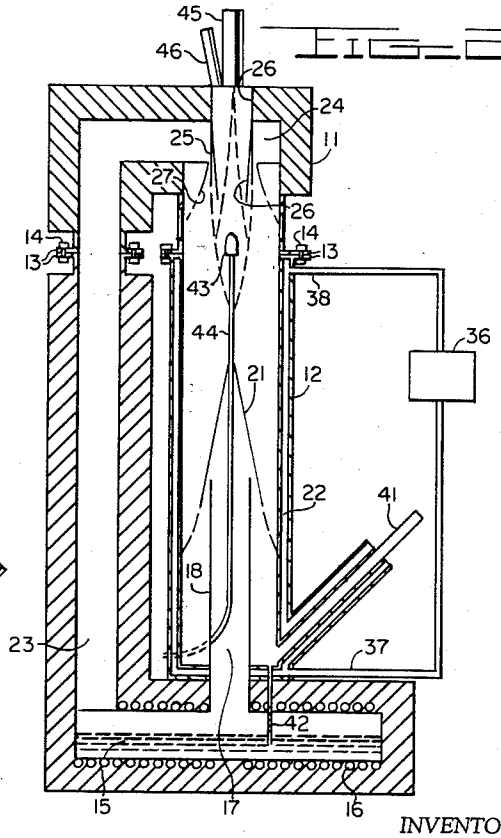


FIG. 4

FIG. 2



INVENTOR
WILLARD H. BENNETT
Melvin L. Crane agent
BY Richard C. Sleet
ATTORNEY

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FIG. 7

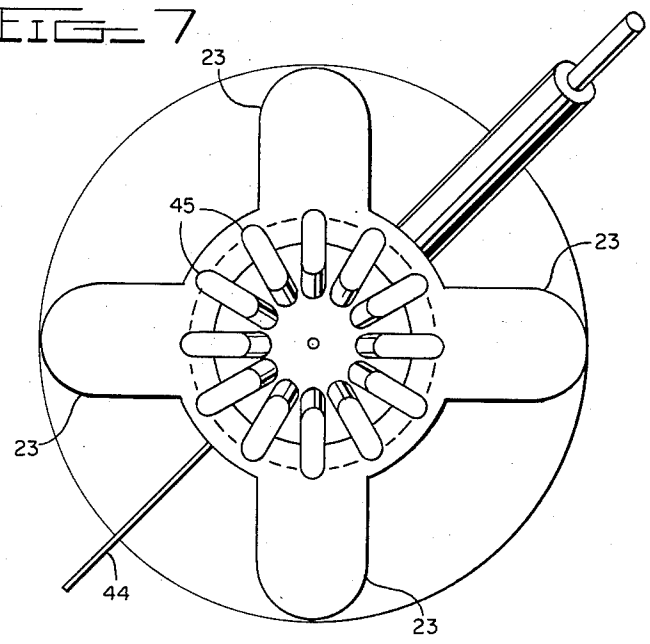
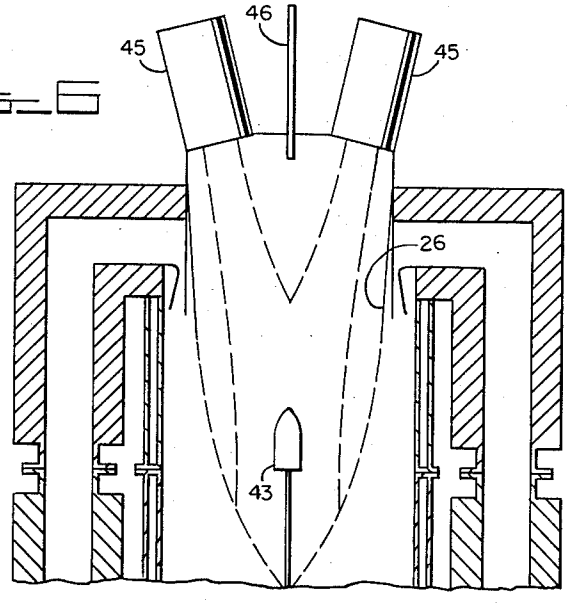


FIG. 6



INVENTOR
WILLARD H. BENNETT
Melvin L. Crane, agent
BY Richard C. Reed
ATTORNEY

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3,121,329

SIMULATION OF REENTRY CONDITIONS

Willard H. Bennett, 174 Chesapeake St. SW., Washington, D.C.

Filed Mar. 13, 1961, Ser. No. 95,444
14 Claims. (Cl. 73—147)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to space condition simulating devices and more particularly to a device for producing and maintaining conditions resembling those of space environment and reentry into the earth's atmosphere.

Heretofore attempts have been made to provide space reentry simulating conditions by various methods such as the use of shock waves and similar heat producing devices; the use of large capacity diffusion pumps of conventional design for evacuating large tanks in which a high vacuum is maintained; by use of a cryogenic pump in which the residual gas of a large tank is pumped by freezing the gas on louvres which are cooled by passing liquid helium through them; and in another type, a jet of nitrogen or air is driven at high pressure past a high power rotating electric arc discharge and expanded into a wind tunnel which may or may not be pumped. These devices or methods have their drawbacks. The conventional diffusion pump is limited by the pumping speed and the rate at which the test device evolves gases; the cryogenic pump can be used for only short periods and is limited by the coating of frozen gases on the louvres; and the electric arc methods primarily simulate reentry by forcing hot gases over the nose of a test device in which the velocities are much less than the velocity of a reentry device.

The present invention overcomes the above shortcomings by providing apparatus that will produce streams of partially ionized gas at the speeds characteristic of orbiting satellites within an evacuated space simulating environmental conditions of the upper atmosphere and outer space.

It is therefore an object of the present invention to provide a device for simulating the environmental conditions encountered by objects such as rockets or satellites in outer space or in the upper atmosphere.

Another object of this invention is to provide a device capable of producing a pumping speed and gas-handling capacity to simulate outer space and upper atmospheric conditions.

Still another object is to provide a device capable of sufficiently pumping ions or ionized gases evolved from a test device to prevent generation of spurious electric fields.

Other objects and many advantages of this invention will become apparent upon a careful consideration of the following detailed description when taken together with the accompanying drawings, in which:

FIG. 1 illustrates a cross-sectional view of a suitable device for carrying out the invention;

FIGS. 2, 4 and 6 illustrate modifications of the device shown by FIG. 1;

FIGS. 3, 5 and 7 illustrate top views of the devices shown by illustration in FIGS. 2, 4 and 6; and

FIGS. 8 and 9 illustrate a probe suitable for probing the ionized gas streams of the various devices.

The teaching of the present invention is carried out through the use of a diffusion pump in combination with means for producing a high velocity jet of molecules,

atoms and ions together with space-charged neutralizing electrons. The diffusion pump includes a high stage annular jet or an annular array of jets at the top of a diffusion chamber which is supplied vapor from a boiler at the bottom of the chamber through a separate tubular arrangement which parallels the axis of the pump chamber. Vapor from the boiler also ascends a central tube within the chamber below the high stage and enters an annular jet at the top of the tube from which the vapor issues downwards into a space between the central tube and the wall of the chamber to form a low stage. The chamber wall in the vicinity of the high stage section may be heated by any suitable means to keep the vapors hot and in the area of the low stage, the wall may be cooled to condense the vapor whence it is returned to the boiler reservoir as a liquid. Two or more low stage pumps can be assembled in series in the chamber and separate diffusion or fore-pumps can be connected to the pump outlet near the bottom of the chamber to provide backing pumps. Hydrogen or nitrogen gas and ions from a suitable source are injected through the top of the chamber and directed toward a test object positioned axially within the chamber near the top thereof in the vicinity of the high stage diffusion pump.

Now referring to the drawings, there is shown by illustration in FIG. 1, a cross-sectional view of a suitable device for carrying out the invention. The device includes a housing having an upper section **11** and a lower section **12** with matching flanges **13** which are secured together by any suitable means such as bolts **14**. When the upper and lower sections are secured together the housing forms a diffusion pump having a high vacuum stage and at least one low vacuum stage. The lower section of the housing includes a reservoir boiler **15** which is heated by any suitable means such as heating coils **16**. The boiler supplies vapor to the low stage through an axially disposed tube **17** that meets the top of the reservoir through which vapor ascends and enters an annular jet **18** at the top of the tube formed by a conical cap **21** that extends downward over the tube **17** and spaced therefrom to provide an opening or jet through which the vapor passes. The vapor as shown by heavy black arrows in FIG. 1 represents a moving wall of high velocity medium and issues downwardly into the spacing between the tube **17** and the cylindrical wall **22** of the housing. A tubular passage **23** joins with the top of the reservoir at the bottom of the housing and extends parallel to the axis of the diffusion pump chamber to supply vapor to the high stage pump. The tubular passage **23** joins a circular vapor reservoir or cavity **24** at the top of the housing to supply vapor as shown by the light broken lines in FIG. 1 to the high stage pump. The high stage pump is formed by a cylindrical member **25** that passes through an opening **26** in the housing at the top of the vapor reservoir, through the vapor reservoir and through an opening **27** in the lower side of the vapor reservoir and extends into the diffusion pump compartment of the housing coaxially with the axis thereof. The opening **27** in the lower side of the reservoir has a diameter greater than the cylindrical member **25** to provide an annular jet for the high stage. The opening **27** is rounded on the vapor reservoir side and has a wall surface extending downwardly which diverges away from the cylindrical member **25** inserted into the housing through the top. The opening in the lower side of the vapor reservoir diverges downwardly with respect to the cylindrical member to provide an increasing spacing between the opening wall and the cylindrical member **25** to permit an annular jet about the cylindrical member through which gaseous vapors issue downwardly through the pump chamber. The cylindrical member **25** has a fender **26** secured to

the inner surface thereof that extends downward beyond the lower end of the cylindrical member and has a slightly smaller diameter at the lower end, the purpose of which will be explained later. For the purposes of admitting hydrogen, nitrogen or any other desired gas into the chamber through the cylindrical member **25**, a connection can be made with any suitable means such as with a tubular member **31** connected to the cylindrical member at the top thereof. An annular gas jet is formed in the top of the cylindrical member by an annular passage between the cylindrical member wall and a cap **32** that extends into the cylindrical member. The cap **32** has walls that converge downwardly away from the wall of the cylindrical member to provide a pumping action on the gases entering through inlet tube **31**. The gas enters into an annular space at the top of the cylindrical member **25** which acts as a gas reservoir to supply the gas to the annular gas jet pump at the top of the cylindrical member.

It is desired to provide means for maintaining a high temperature in the vicinity of the high stage and for cooling the wall surfaces of the housing in the vicinity of the low stage; therefore, the housing upper and lower sections are made with double walls. The upper portion is maintained at a high temperature by a supply of hot water, steam or hot air entering through inlet **34** and passing out through outlet **35**. The bottom section of the housing is cooled by a coolant, such as from a refrigeration compressor **36**, passing through inlet **37** and outlet **38**. The upper section of the housing is provided with a double glass window **39** for the purpose of viewing the test object. The bottom section of the housing is provided with an arm **41** which connects with the pump chamber to which additional diffusion pumps or forepumps **40** can be connected to aid in maintaining the desired pumping speed in the diffusion pump chamber; also, these additional pumps can be used to pre-evacuate the pumping housing prior to operation of the device to simulate conditions acting on orbiting satellites. The arm **41** is also cooled to condense any vapors that may be pumped into the arm during operation. For the purpose of returning the fluid made by the condensing vapor in the pumping chamber from the pumping chamber to the reservoir there is provided a passage **42** in the bottom of the pumping chamber that extends to the top of the reservoir.

A holder is provided for positioning a test device in the pumping chamber. The test device is positioned along the axis just below the lower end of fender **26** and slightly above the converging pumping vapor flow path that issues from the high vacuum stage pump. For the purpose of recording certain effects on the test vehicle, electrical lead lines can be connected to the test vehicle and brought into the pumping chamber through tube **44** which is brought in from the top and extends along the axis through the cylindrical member **25** such that it will have the least effect on the pumping action.

In operation, the test object is connected to the proper electrical leads leading to the test instruments and positioned within the pumping chamber in the proper position. The upper section is secured in place to the lower section, the gas inlet line is connected to a source of desired gas which is forced into the area bounded by the cylindrical member **25**. The refrigeration unit or any other suitable means is connected to the lower section and actuated to cool the lower section while the upper section is heated by any suitable means connected thereto. The additional forepumps or diffusion pumps connected to the outlet are started in operation to evacuate the chamber and the heater in the base of the device is actuated to vaporize the liquid in the reservoir such as mercury. When the mercury is vaporized, the mercury vapors will flow through the tube or tubes into the vapor reservoir for the high stage pump at the top of the housing where the vapor issues downwardly into the chamber through a confined area between the walls and the centrally located annular member extending from the top of the housing into the chamber which forms an annular pumping jet. The vapor also passes upward through the centrally located tube **17** and issues downwardly from the conical shaped member **21** positioned over the tube in which the combination forms an annular pumping jet. The vapor from the jet flows between the centrally located tube and the chamber wall to the outlet.

Air exhaustion is effected by the diffusion of the air molecules above the annular jets which flow downward into the vapor streams and are traveling in the same direction at comparable speeds. Once the air molecules are entrained in the vapor stream, the air molecules cannot diffuse back upwards in the face of the downward streaming vapor molecules, but are driven downwards and compressed towards the outlet leading to the backing pumps.

The mercury vapors issuing from the vapor reservoir through the high vacuum stage pass through a confined area which increases the velocity of the vapor with reduced pressure due to the small annular opening. As the vapors pass by the central member of the high stage pump the velocity will be less and the pressure greater. The vapor molecules will follow a path between the chamber wall and the centrally located annular member and the annular vapor jet will converge at a point on the axis just below the position of the test vehicle. The vapors with entrained air molecules will then flow on downward by the action of the low stage pump and the backing pumps connected to the outlet. The annular jet forms a vapor wall which prevents the gas injected at the top from hitting the walls of the chamber in the vicinity of the test object. The pumping action of the high stage pump forces the gases through the chamber about the test object to create about the test object the conditions of the upper atmosphere within which a satellite would travel. The annular jet issuing about the cylindrical member in the top of the housing has a stagnation layer along the lower end of the member, thus molecules of pump vapor could turn from the lower edge of the cylindrical member into the space surrounding the test object. For this purpose, fender **26** has been secured to the inner surface of the cylindrical member and extends below the lower edge thereof to prevent any back flow of the vapor jet. The lower end of the fender is kept out of the main flow of gases and only blocks any back flow gases which may try to enter the test area. The gas flowing through the cylindrical member will also aid in carrying the back flow back into the main stream. The chamber in the vicinity of the high stage is kept at a high temperature to prevent condensation of the vapor in that area, however, the lower section of the housing is maintained in a cold stage for the purpose of condensing the vapors. The vapor from both the high and low stages will flow downwardly and the vapors will strike the cold surface and will condense. Some of the vapors may enter into the outlet tube therefore the outlet tube is cooled to condense the vapor which may enter the outlet tube. The condensed vapor then drops to the bottom of the pump chamber as mercury and is returned to the reservoir through the opening **42** in the bottom of the pump chamber. The operation of the high and low vacuum stages with the aid of the backing pumps maintain a high vacuum in the chamber about the test device.

The above is only one of several forms of annular pumps which may be used. Another makes use of an annular array of jets in place of the annular jet, with the fender extending below the lower edge of the jet tubes.

FIG. 2 is a modification of the device illustrated in FIG. 1 which makes use of essentially the same structural housing and pumping chamber with the cover modified to include an ion source **45** and the electrical lead lines to the test object are brought in from the bottom of the device extending along the axis and passing through the low stage pump. In this modification, gases may be

fed into the chamber through a tube 46 adjacent to the ion source entrance.

FIG. 3 is a top view of FIG. 2 which illustrates the general configuration of the device.

FIGS. 4 and 6 are modifications of the device illustrated by FIGS. 1 and 2 and comprise basically the same structure with exception that the device has four vapor tubes 23 to the vapor reservoir for the high vacuum stage pump instead of only one and the device has a plurality of ion injection devices assembled in a circle about the axis such that the ion streams are directed toward the test vehicle. The devices are also illustrated with two low stage pumps and a tube connected to an opening through the cover along axis for the injection of hydrogen or nitrogen.

FIGS. 5 and 7 illustrate the top view of the structure illustrated by FIGS. 4 and 6 where the main difference in the two devices is represented by the ion propulsion devices connected to the cover for admitting ion jets into the chamber above the test object and directed toward the object. FIG. 4 illustrates ion propulsion devices which admit the ion jets through small openings in the cover whereas FIG. 6 illustrates larger ion propulsion devices which admit the ions through a slit in the cover. The slit will permit a greater flow of ions into the chamber. The different modifications illustrate different ion injection arrangements and with an increase in ionic injection the pumping action must also be increased to provide proper operation of the device in simulating upper atmospheric or space conditions on an orbiting satellite or upon reentry.

In order to simulate the conditions of space or reentry conditions the device is operated as described for the device of FIG. 1 with the addition that a source of ions injected into the evacuated area along with a suitable gas such as hydrogen or nitrogen. A suitable ion source for this purpose is disclosed and described in a publication ORNL–2926 by the Oak Ridge National Laboratory dated June 9, 1960. However, any high current kind of source may be used. The gas is admitted into the chamber through the cover at a velocity such that, at the pressure of admittance, the molecular mean free path of the gas is appreciably shorter than the distance from the gas source to the test vehicle. High velocity ions from an ion source are projected into the gas where the momentum of the high velocity ions will be shared with the gas with the result that a high speed electrically neutral gas jet will be produced and forced toward the test object at a speed equal to that of an orbiting satellite. The high velocity gas jet will hit the test object and will be forced over the entire area by the downward motion. The gas jet will then mix with the vapors of the high stage pump and will be carried off through the pump chamber mixed with the pumping vapor.

As an example of operation with an ion source the test object is positioned about 50 centimeters from a source of nitrogen positive ions projected through the cover into the cylindrical member at about 5000 volts into nitrogen gas at a density such that the ions will make between four and five collisions in traveling from the ion source to the test vehicle in the nitrogen gas at the reduced pressure which the nitrogen gas will have in the highly energized high velocity jet stream generated by the ion stream. The velocity of a 5000 volt molecular nitrogen ion is about 1.86×10^7 centimeters per second and the velocity of an orbiting object is about 8×10^5 centimeters per second. Thus, the momentum of each ion must be distributed among about 25 nitrogen molecules for the velocity of the gas in the downward stream to reach the orbital speed of an object. The collisions of the high energy nitrogen ions with the nitrogen gas molecules will produce a high degree of ionization and optical excitation in the nitrogen gas in addition to a large increase in kinetic temperature due to the large increase in mean momenta in directions transverse to the direction of the stream. The increase in kinetic temperature in the stream produces adiabatic expansion of the stream with a corresponding reduction of density in the stream. For each 5000 volt nitrogen ion to redistribute its down-stream momentum among 25 molecules in a 50 centimeter stream the mean free path in the stream should be 10.8 centimeters. This is the molecular mean free path in nitrogen at a density of 2.2×10^{13} molecules per cubic centimeter, therefore assuming the average kinetic temperature in the stream to be 3000° K. the pressure of the nitrogen at a density of 2.2×10^{13} molecules per cubic centimeter is 0.02 millimeter. Other ion energies between 100 volts and 100,000 volts can be used with appropriately adjustable gas pressures to give any jet speed desired.

As an example of operation of the device with an ion source and with hydrogen, hydrogen gas is admitted into the upper part of the chamber at a pressure sufficient for the mean free path of the ions to be short compared with the distance to the test object. Ten hydrogen ion jets each producing one ampere of 100 kilovolts molecular ions delivers 6×10^{19} ions per second. Each such ion must share its forward momentum with 400 molecules in order that the average forward velocity of the composite gas jet will be 8×10^5 centimeters per second which is the velocity of an orbiting object at reentry. The number of molecules per cubic centimeter in a jet with a cross-section of 1000 sq. centimeters will be 1.5×10^{13} which is the density of a gas at a pressure of one-half micron, the pressure of the surrounding hydrogen.

If desired, an ion probe may be positioned at the position 43 that the object will be placed to probe the ion flow. For this purpose, an ion probe as illustrated by FIGS. 8 and 9 may be used. The probe comprises a shell 61 which has an opening of about two millimeters at the forward end to admit ions. Immediately behind the opening, a cylindrical electrode 62 is positioned and has a sawtooth or zig-zag retarding potential varying between 0 and about 25 volts positive relative to the shell to retard positive ions passing through the electrode. Another cylindrical electrode 63 is positioned in alignment with electrode 62 to which a potential of about 50 volts negative relative to the shell is applied for the purpose of repelling all electrons. In axial alignment with cylinders 62 and 63, a split cylinder having electrodes 64 and 65 to which a negative potential of about 10 volts is applied to electrode 64 while electrode 65 is held at the potential of the shell. The difference in potential between the two halves of the split cylinder serves to sweep into the negative half 64 all positive ions passing down through the cylinders 62 and 63 while the neutral gas is allowed to pass through. The current collected by the negative electrode 64 is measured through a full feedback amplifier based at the negative potential of the collector electrode 64. Aligned with the cylinders at the rear of the shell is located a conduit 67 and an opening for permitting the gas that passes through the probe to escape from the shell. The probe is supported in position by an offset pipe 68 connected to the shell which also provides a means through which the electrical leads are fed to the respective electrodes. The lead to the negative electrode 64 is shielded against any interference from the other electrical lines. During the probing operation, when a high velocity low density gas containing ionized atoms and molecules is passing down through the ion probe, while the retarding potential on the cylinder 61 is being swept, the increase of the positive potential on the cylinder 61 turns back and cuts off from the collector electrode 64 those species of ions with successively increasing ionic masses. For example, if the oncoming gas is partially ionized nitrogen, atomic nitrogen ions entering the probe with a velocity of 8×10^5 centimeters per second will be turned back with a potential of about 4.6 volts and molecular ions at the same velocity will be turned back at about 9.2 volts. It has been determined

that if the nitrogen ions in the high velocity stream are moving at about 8×10^5 centimeters and the stream has a temperature of about 2000° C. in the vicinity of the probe, the mean thermal velocity of the electrons will be about 3×10^7 centimeters per second which greatly exceeds the velocity of the gas stream. More electrons than ions will be collected on the ion probe leaving behind some positive charge in the oncoming stream which accelerates the positive ions into the ion probe with an energy which is in excess of the kinetic energy of the ions due to the gas stream velocity. Due to this acceleration an additional voltage ΔV must be applied to the 4.6 volts on the electrode for atomic nitrogen and to the 9.2 volts per molecular nitrogen to cut off each species of ion respectively.

A close approximation of the thermal energy, speed, and equivalent temperature of each species of ion can be obtained from the shape of the cut off for that species of ion. The gas temperature calculated from the excess retarding potential, ΔV, can be compared with the calculated from the energy spreads. Other means can be used to make a rough measurement of the gas stream velocity by measuring the Doppler shifts of spectral lines photographed through a spectrometer directed through a viewing port located in the simulating device in the vicinity of the ion source. Observations transverse to the direction of the jet should be made to determine the degree of spreading of the jet at various ion currents and gas densities.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing, a chamber means in said housing, an opening in said chamber for inserting a device to be investigated, a cover means for closing said opening, an annular jet nozzle in the upper end of said chamber adapted to direct a gaseous fluid flow outwardly of, along and below said device to be investigated, a boiler reservoir in the bottom portion of said housing for holding a liquid, heating means positioned relative to said reservoir for vaporizing said liquid, means connected between said reservoir and said annular jet nozzle for supplying vapor from said boiler to said annular jet nozzle, means for admitting a gaseous medium into the chamber through said cover and directing said gaseous medium toward said device to be investigated.

2. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing, a chamber means in said housing, an opening in said chamber for inserting a device to be investigated, a cover means for closing said opening, an annular jet nozzle in the upper end of said chamber adapted to direct a gaseous fluid flow outwardly of, along and below said device to be investigated, a baffle means associated with said annular jet nozzle to prevent any gaseous back flow in the area of said object, a boiler reservoir in the bottom portion of said housing for holding a liquid, heating means positioned relative to said reservoir for vaporizing said liquid, means connected between said reservoir and said annular jet nozzle for supplying vapor from said boiler to said annular jet nozzle, means for admitting a gaseous medium into the chamber through said cover and directing said gaseous medium from above said annular jet nozzle toward said device to be investigated.

3. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing, a chamber means in said housing, an opening in said chamber for inserting a device to be investigated, a cover means for closing said opening, an annular jet nozzle in the upper end of said chamber adapted to direct a gaseous fluid flow outwardly of, along and below said device to be investigated, said annular jet nozzle formed by the wall of the housing at the upper end and a cylindrical member inserted into said chamber, a baffle secured to said cylindrical member and extending beyond the lower end thereof to prevent any back flow of gases into the area bounded by said cylindrical member, a boiler reservoir in the bottom portion of said housing for holding a liquid, heating means positioned relative to said reservoir for vaporizing said liquid, means connected between said reservoir and said annular jet nozzle for supplying vapor from said boiler to said annular jet nozzle, means for admitting a gaseous medium into the chamber through said cover and directing said gaseous medium from above said annular jet nozzle toward said device to be investigated.

4. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing, a chamber means in said housing, an opening in said chamber for inserting a device to be investigated, a cover means for closing said opening, an annular jet nozzle in the upper end of said chamber adapted to direct a gaseous fluid flow along and below said device to be investigated, a boiler reservoir in the bottom portion of said housing for holding a liquid, heating means positioned relative to said reservoir for vaporizing said liquid, means connected between said reservoir and said annular jet for supplying vapor from said boiler to said annular jet nozzle, means for admitting a gaseous medium into the chamber through said cover, means for injecting high energy ions into said chamber through said cover and means for pumping said vapors and said gaseous medium through said chamber.

5. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing, a chamber means in said housing, an opening in the top of said chamber for inserting and positioning an object to be investigated, a cover means for closing said opening, means for admitting a gaseous medium through said cover into said chamber, means for injecting high velocity ions into said chamber and into said gaseous medium, a high stage annular evacuating pump means positioned near the top of said housing and centered about said gaseous medium and said ions injected into said chamber, a boiler reservoir in the bottom of said housing for holding a liquid medium, heating means positioned relative to said reservoir for vaporizing said liquid, means connected between said reservoir and said high stage pump for supplying vapors from said reservoir to said high stage pump, and means for pumping said vapors and gases through said chamber.

6. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing having an upper and a lower section, a pumping chamber in said housing, an opening in the upper section of said housing through which an object to be investigated may be inserted, an annular member secured to said housing about said opening and extending into said chamber, an annular spacing between the upper wall surface and said annular member extending into said chamber, said annular member and said wall surface forming a high vacuum stage in the upper section of said housing, a reservoir boiler in the bottom of said lower section of said housing for holding a liquid medium, heating means positioned relative to said reservoir for vaporizing said liquid medium, means connecting with said reservoir and said high vacuum stage for supplying vapors from said reservoir to said high stage pump, a cover for closing said opening in said upper section, means for admitting a gaseous medium

into said chamber through said cover and into said chamber bounded by said annular member, means for injecting high velocity ions through said cover into said chamber bounded by said annular member, and means for pumping said vapors and said gaseous medium through said chamber.

7. A device as claimed in claim 6 which includes an annular baffle secured to said annular member to prevent gaseous back flow into the area bounded by said annular member.

8. A device as claimed in claim 7 wherein the upper housing section is heated and said lower section is cooled to condense the vapors passing through said chamber.

9. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing having an upper section and a lower section connected together in axial alignment to form a pumping chamber in said housing, an inlet in the upper section and an outlet in said lower section of said housing, said upper section including a high vacuum stage pump, said lower section including at least one low vacuum pump, an annular member secured in said top section about said inlet and extending downwardly into said chamber, said annular member and the wall surface of said chamber forming an annular jet nozzle about said annular member diverging toward the bottom of said chamber, a reservoir boiler in the bottom of said lower section of said housing for holding a liquid medium, heating means positioned relative to said reservoir for vaporizing said liquid medium in said reservoir, a tubular means connected between said reservoir and said high vacuum pump, a cover for closing said opening in said upper housing section, means connected with said cover for admitting a gaseous medium into the area bounded by said annular member, and means for admitting high velocity ions into said gaseous medium within said chamber, and means for continuously evacuating said chamber.

10. A device as claimed in claim 9 which includes an annular baffle secured to said annular member to prevent gaseous back flow into the area bounded by said annular member.

11. A device as claimed in claim 10 wherein the upper housing section is heated and said lower section is cooled to condense the vapors passing through said chamber.

12. A device for simulating the physical conditions encountered by an object orbiting in space upon reentry into the earth's atmosphere which comprises a housing having upper and lower sections connected together in axial alignment to include a pumping chamber, an inlet in said upper section axially disposed relative to said chamber, an outlet in the lower section connected with said chamber, an annular cavity in said housing in axial alignment with said chamber and opening into said chamber at the bottom thereof, an annular member connected to the upper wall of said cavity about said inlet and extending downwardly through said cavity and into said chamber with a spacing between the lower wall of the cavity and said annular member, said chamber wall forming a diverging spacing relative to said annular member to form an annular high vacuum pumping stage within the spacing between the annular member and the wall surface, a reservoir boiler in the bottom of said lower section for holding a liquid medium, heating means for vaporizing said liquid medium in said reservoir, a tubular means connected with said reservoir and extending parallel to the axis of said chamber and connecting with said annular cavity in said upper housing section to supply vapor from said reservoir to said high vacuum pump, a cover for closing said inlet into said upper housing section, means connected with said cover for admitting a gaseous medium into said area bounded by said annular member, means for injecting high velocity ions into said gaseous medium, means in said chamber for securing an object to be investigated along the axis of said chamber just below the bottom of said annular member and just above the path taken by vapors flowing through said high vacuum pumping stage, and means for continually evacuating said chamber.

13. A device as claimed in claim 12 which includes an annular baffle secured to said annular member to prevent gaseous back flow into the area bounded by said annular member.

14. A device as claimed in claim 12 wherein the upper housing section is heated and said lower section is cooled to condense the vapors passing through said chamber.

References Cited in the file of this patent

UNITED STATES PATENTS

2,933,233	Gerow et al.	Apr. 19, 1960
2,992,345	Hansen	July 11, 1961
3,044,301	Bennett	July 17, 1962

FOREIGN PATENTS

1,198,069	France	June 8, 1959
848,623	Great Britain	Sept. 21, 1960