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GAS PUMPING METHODS AND APPARATUS

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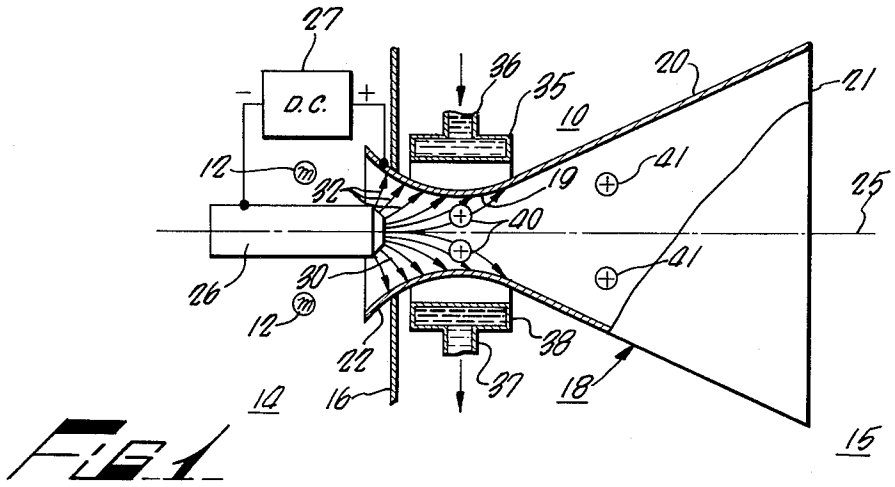


FIG. 1

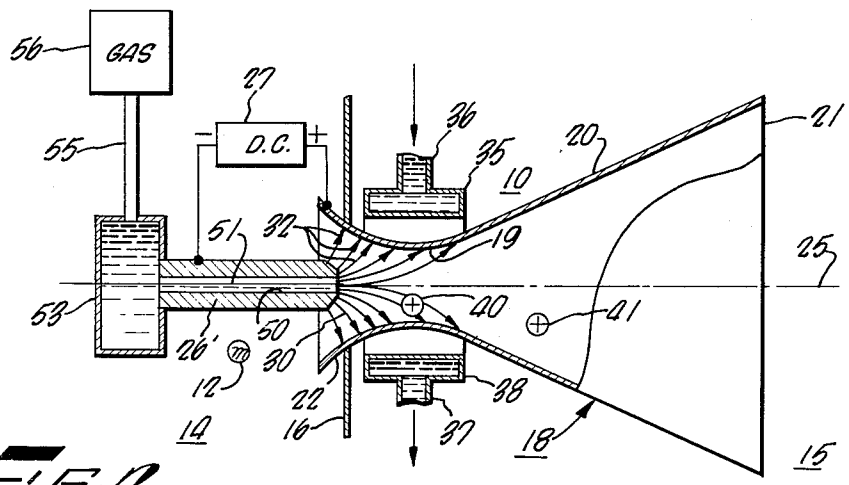


FIG. 2

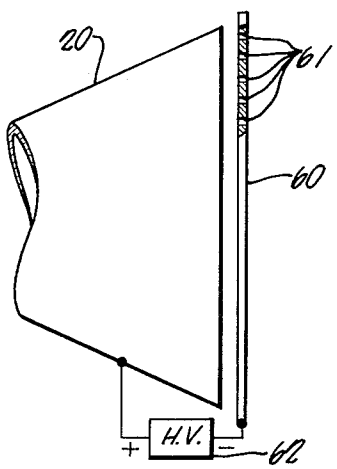


FIG. 3

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GAS PUMPING METHODS AND APPARATUS

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The present invention relates to gas pumping methods and apparatus and, more particularly, to methods and apparatus for moving or evacuating gas molecules from a space by means of an electric arc plasma.

The subject invention provides improved methods and apparatus for moving or evacuating gas molecules from a space without objectionable contamination of the space or the gas.

According to the invention a nozzle is prepared which has a throat region and a divergent portion adjacent the throat region. The throat region is placed into communication with the space to be evacuated. An electric arc plasma is established in the throat region whereby gas molecules are drawn from the space to be evacuated through the throat region and are expelled through the divergent portion of the nozzle. The gas thus drawn from the space to be evacuated will be heated by the electric arc plasma as it passes through the throat region. In the divergent nozzle portion, this heated gas will expand and thus help to reduce the pressure at the nozzle throat. In this manner, the efficiency of the pumping operation is greatly increased.

If desired, a negatively biased, apertured screen may be placed adjacent the open end of the divergent nozzle portion to accelerate the gas ions emerging from the arc plasma and thus further reduce the pressure at the nozzle throat and increase the efficiency of the pumping operation.

A further increase in pumping efficiency is experienced if the nozzle is made to be of the convergent-divergent type, with the convergent nozzle portion being exposed to the space to be evacuated. A larger amount of gas molecules will then be advanced to the arc plasma during operation of the pump.

A large increase in pumping efficiency is also obtained by supplying the arc plasma with an ionizable gas, such as nitrogen, argon and the like, during the pumping operation. This gas is ionized and heated in the arc plasma and leaves the nozzle through its divergent portion, thereby reducing the pressure at the nozzle throat.

The arc plasma is preferably established by striking an electric arc in the throat region of the nozzle. To this end, the throat region may be made of electroconductive material and an electrode may be provided adjacent the throat region. The throat region is then preferably connected to the positive terminal of a direct-current source and the electrode to the negative terminal of this source. An arc is then struck between electrode and nozzle throat. The electrons traveling in this arc from the cathode to the anode, that is from the electrode to the inner wall of the throat region, will entrain the gas molecules present in the region of the electric arc. In this manner, gas molecules are continuously removed from the space to be evacuated, inasmuch as the electrons in the arc travel at high velocity and occur in great number.

It will now be appreciated that the method of the invention has utility not only for evacuating spaces or vessels, but also for moving gasses in a predetermined direction. Thus, the expressions "evacuated" or "space to be evacuated" as used herein should be understood as referring not only to high vacuum evacuation processes, but also to gas pumping operations in general where the object is to move a gas in a predetermined direction.

The apparatus of the invention comprises a nozzle having a throat region adapted to communicate with the space to be evacuated and including a divergent portion communicating with the throat region. The apparatus of the invention includes means for establishing an electric arc plasma in the throat region to draw gas molecules from the space to be evacuated through the throat region and cause the gas molecules to be expelled through the divergent portion.

The throat region may comprise electroconductive material and the means for establishing the arc plasma may include an electrode located adjacent the throat region. Preferably, a direct-current source may be connected with its positive terminal to the throat region and with its negative terminal to the electrode. The direct-current source is dimensioned to maintain an electric arc between the electrode and the throat region, with the electrode serving as a cathode and the throat region as an anode for the electric arc.

The electrode may have a hollow cylindrical configuration and an ionizable pumping gas may be supplied to the electric arc through the hollow electrode. The ionizable pumping gas may, however, also be supplied to the electric arc by means of nozzles arranged in the space between the electrode and the nozzle throat region.

The apparatus of the invention may include an apertured screen located adjacent the open end of the divergent nozzles portion. This screen may be negatively biased with respect to the nozzle, so that ionized gas molecules are accelerated from within the divergent nozzle portion towards the open end thereof. The gas molecules thus accelerated are substantially neutralized at the screen and leave the apparatus through the apertures in the screen.

The invention and its operation and utility will become more readily apparent from the following detailed description of preferred embodiments thereof, illustrated by way of example in the accompanying drawings, in which:

FIG. 1 shows diagrammatically and partially in section a vacuum pump according to the invention;

FIG. 2 shows a first modification of the apparatus illustrated in FIG. 1; and

FIG. 3 shows a detail, partially in section, of a second modification of the apparatus of FIG. 1 or a modification of the apparatus of FIG. 2.

The object of the vacuum pump **10** illustrated in FIG. 1 is to pump gas or gas molecules from a region **14** to a region **15**. A wall **16** has been schematically illustrated between regions **14** and **15** to indicate that these two regions are separated and isolated from each other. In practice, the region **14** may be the inside of a vessel to be evacuated, or of a chamber connected to a vessel to be evacuated, and the region **15** may be a chamber that is pre-evacuated by any suitable conventional means, such as mechanical, oil diffusion or mercury pumps (not shown).

The vacuum pump **10** comprises a nozzle **18** having a throat region **19** and a divergent portion **20**. The divergent portion **20** communicates with the throat region **19** and has a discharge opening **21**. The nozzle **18** also has a convergent portion **22** which, in the instant embodiment, is integral with the throat region **19**. In brief, the nozzle **20** is of the convergent-divergent type. In addition, the nozzle **20** has a symmetrical configuration about longitudinal axis **25**.

An electrode **26** is located on axis **25** and in the vicinity of the throat region **19**. Nozzle **20** is of electroconductive material and has the positive terminal of a direct-current source **27** connected thereto. The negative terminal of source **27** is connected to electrode **26**. While source **27** has been illustrated in the general area of electrode **26** and convergent portion **22**, it will of course be

understood that the source 27, in practice, will be located outside region 14, as well as region 15.

Source 27 is constructed and dimensioned to strike and maintain an arc 30 between electrode 26 and nozzle region 19. To this effect, the source 27 may include a high voltage source for striking an arc and a low voltage source (not shown in detail) for maintaining the arc 30. This low voltage source, which is connected to electrode 26 and nozzle 18 as long as the arc 30 is to be maintained, may, for example, have a voltage of some 50 to 500 volts and a nominal current rating of some 100 to 300 amperes. During the existence of arc 30, electrons will flow from electrode or cathode 26 to throat region or anode 19 and part of convergent portion 22, as has been schematically indicated in the drawings by means of arrows 32.

Electrode 26 is of the non-consumable type to prevent undue contamination of the regions 14 and 15 and of the gas being pumped. For example, electrode 26 may be a tungsten electrode or may be of another one of the conventional high-temperature and consumption resistant electrode materials. The nozzle 18 may, for example, be of stainless steel or other suitable consumption resistant material. The apparatus 10 includes a cooling jacket 35 which encompasses the throat region 19. The cooling jacket 35 has an inlet 36 and an outlet 37 for admission and withdrawal of a suitable cooling medium 38, such as water, to and from the cooling jacket 35. This cooling jacket 25 serves to maintain the nozzle 18 at throat region 19 at reasonable temperatures. If desired, heat-conducting elements (not shown) may be provided between nozzle 18 and jacket 35 or the jacket 35 may be disposed in close proximity to or in contact with nozzle 18 to accomplish a desired cooling effect.

The electrons in the arc 30 will flow in great numbers and at great velocity from electrode 26 to the wall of nozzle throat region 19 and will thus entrain gas molecules present in throat region 19. These molecules will be ionized as schematically indicated at 40, and will thus be driven through convergent nozzle portion 20, as indicated at 41, and the opening 21 thereof. In this manner, gas molecules will be drawn from region 14 and moved to region 15. The electrons traveling within throat region 19 form a dense sheath which prevents backflow or migration of pumped gas molecules into the region 14.

It will now be appreciated that FIG. 1 shows an apparatus for evacuating a space in an efficient and advantageous manner. If desired, this apparatus could also be employed for moving or transferring gasses in a circulation or pumping system.

FIGS. 2 and 3 shows apparatus similar to that of FIG. 1, so that like reference numerals have been employed for like elements.

In the apparatus of FIG. 2, a hollow cylindrical electrode 26' with a longitudinal bore 50 is employed in the place of electrode 26 shown in FIG. 1. During operation of the apparatus an ionizable gas 51, such as nitrogen, argon or the like, is supplied through bore 50 to the arc plasma or arc 30. To this effect, a gas transfer chamber 53 is connected to the electrode 26' so as to be in communication with bore 50. Gas is supplied to transfer chamber 53 by a conduit 55 which is connected to a suitable supply of pressurized gas 56, such as a steel bottle located outside regions 14 and 15. In this manner, the ionizable gas 14 will be supplied to the arc 30 without entering the low-pressure region 14. This gas will be entrained and ionized by the electrons in arc 30 along with the gas molecules pumped from region 14. Subsequently, this gas will also pass through and expand in divergent portion 20 and will thus significantly increase the aspiration of gas molecules from region 14. If desired, a pump (not shown) may be associated with gas supply 56 for recovery of ionizable gas from region 15 and re-use thereof in arc 30.

In the apparatus of FIG. 3, a screen 60 with apertures 61 is located in front of opening 21 of divergent nozzle portion 20. The remaining structure of the apparatus of FIG. 3 may be the same as that shown in FIG. 1 or in FIG. 2, so that only the larger end of divergent nozzle portion 20, a high-voltage source 62, and the screen 60 with apertures 61 have been illustrated in FIG. 3. The screen may be a metal sheet with a large number of apertures or may also consist of wire mesh. The apertured or perforated screen 60 is baised negatively with respect to nozzle 18 by means of the high-voltage source 62 which is connected to screen 60 and nozzle 18 as shown and which, in practice, is preferably located outside region 15. Screen 60 is effective to accelerate the gas molecules within divergent portion 20 towards the opening 21. At screen 60, the gas molecules are neutralized and pass through the apertures 60. In this manner, the aspiration of gas molecules from region 16 is further increased. If desired, the gas supply structure of FIG. 2 may be combined with the screen structure of FIG. 3 to realize maximum pumping efficiency.

While an arcing electrode structure has been shown in the drawings, convention or other types of plasma-producing means could be employed in its place. Various other modifications will be apparent to those skilled in the art.

I claim:

1. Apparatus for evaluating gas molecules from a chamber, comprising a nozzle having a throat region connected to said chamber, and including a divergent electrically conductive nozzle portion connected to the throat region, and means for establishing a continuous electric arc plasma in the throat region to draw gas molecules from said chamber through the throat region and expel the gas molecules through the divergent portion.

2. Apparatus for evacuating gas molecules from a chamber, comprising a nozzle having an electroconductive throat region connected to said chamber, and including a divergent electrically conductive nozzle portion communicating with the throat region, an electrode located at the throat region, and means for establishing a continuous electric arc between the electrode and the throat region and maintaining a flow of electrons from the electrode to the throat region.

3. Apparatus for evacuating gas molecules from a space, comprising a convergent-divergent nozzle having a symmetrical configuration with respect to a longitudinal axis through the nozzle and being connected to said chamber, an electrode located on said axis and projecting into the convergent portion of the nozzle, and means for establishing a continuous electric arc between the electrode and the nozzle and maintaining a flow of electrons in said arc from the electrode to the nozzle.

4. Apparatus for evacuating gas molecules from a chamber, comprising a nozzle having an electroconductive throat region connected to said chamber, and including a divergent portion connected to the throat region, an electrode located at the throat region, means for establishing a continuous electric arc between the electrode and the throat region and maintaining a flow of electrons from the electrode to the throat region, and means for introducing ionizable gas into the electric arc.

5. Apparatus for evacuating gas molecules from a chamber, comprising a convergent-divergent nozzle having a symmetrical configuration with respect to a longitudinal axis through the nozzle and being connected to said chamber, a hollow cylindrical electrode located on said axis adjacent the convergent portion of the nozzle, means for establishing a continuous electric arc between the electrode and the nozzle, and means for supplying ionizable gas through the hollow cylindrical electrode and into said arc.

6. Apparatus for evacuating gas molecules from a chamber, comprising a nozzle having a throat region connected to said chamber, and including an electrically con-

ductive divergent nozzle portion connected to the throat region, means for establishing an electric arc plasma in the throat region to draw gas molecules from said chamber through the throat region and expel the gas molecules through the divergent portion, an apertured screen adjacent said divergent nozzle portion, and means for electrically biasing said screen with respect to said divergent nozzle portion to accelerate gas molecules from said divergent nozzle portion to said screen and through the apertures thereof.

7. Apparatus for evacuating gas molecules from a chamber, comprising a nozzle having an electrically conductive throat region connected to said chamber, and including an electrically conductive divergent portion connected to the throat region, an electrode located at the throat region, means for establishing an electric arc between the electrode and the throat region and maintaining a flow of electrons from the electrode to the throat region, means for introducing ionizable gas into the electric arc, an apertured screen adjacent said divergent portion, and means for electrically biasing said screen with respect to said divergent nozzle portion to accelerate gas molecules from said divergent portion to said screen and through the apertures thereof.

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LAURENCE V. EFNER, *Primary Examiner.*