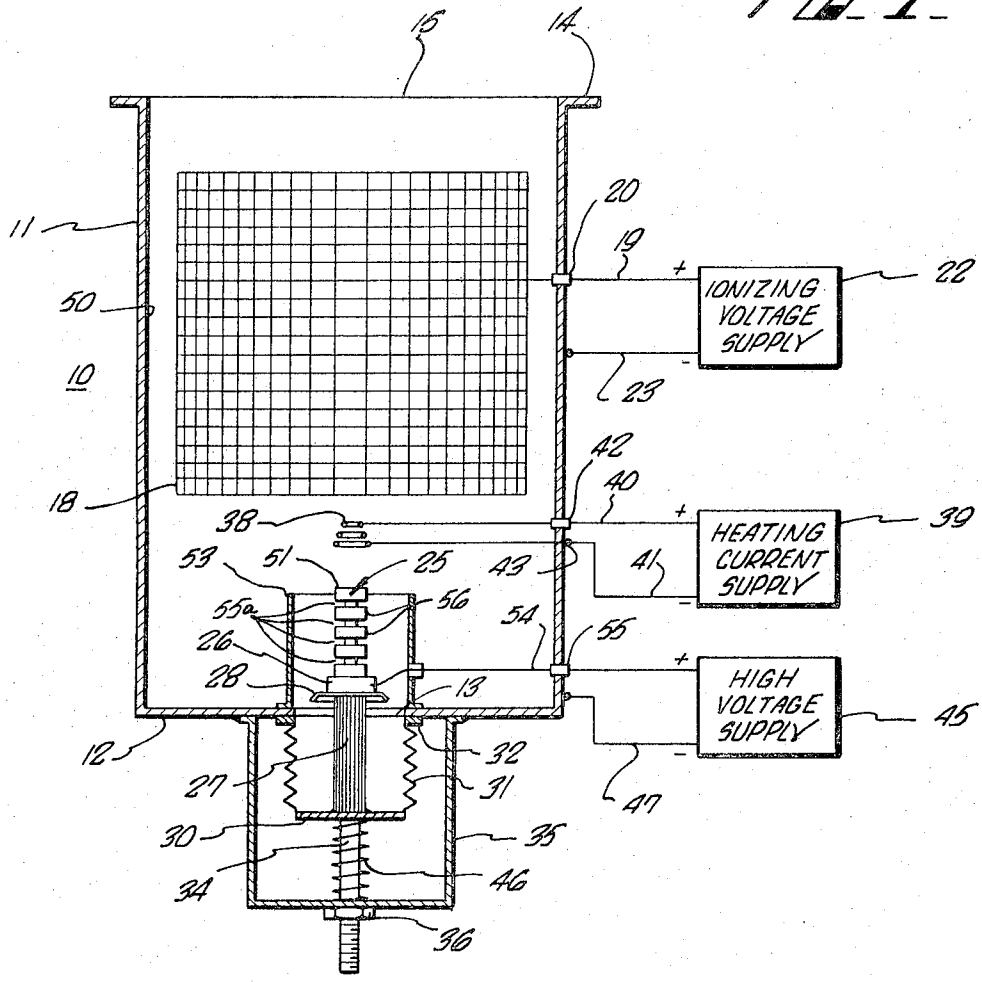
Oct. 1, 1968 A. R. HAMILTON 3,404,255
SOURCE OF VAPORIZABLE MATERIAL FOR BOMBARDMENT THEREOF BY AN ELECTRON BOMBARDING MEANS
Filed June 23, 1965 2 Sheets-Sheet 1

FIG. 1



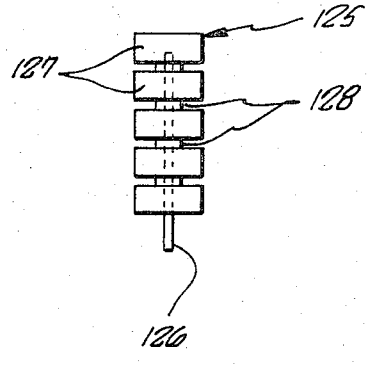


FIG. 2

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FIG 3

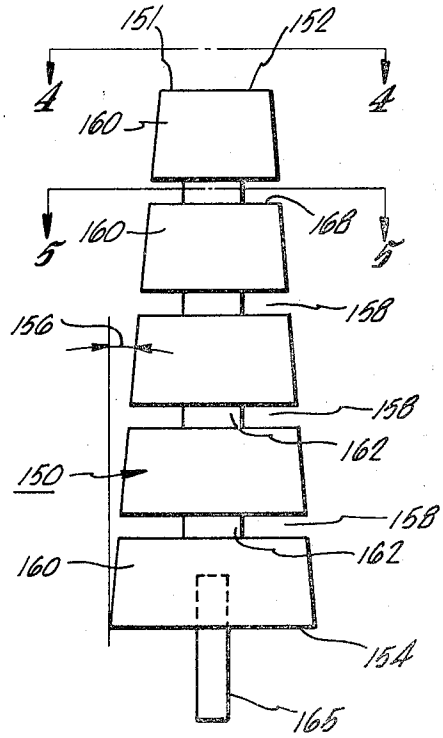


FIG 5

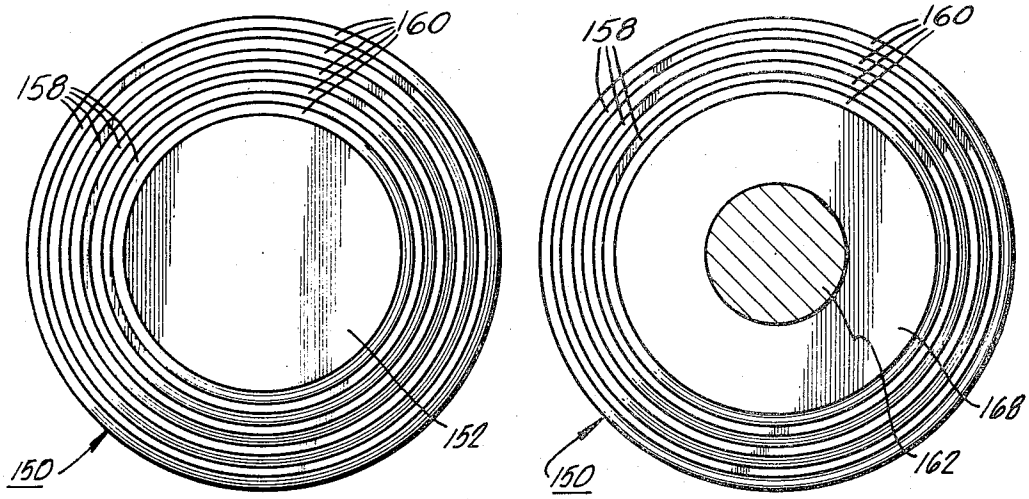


FIG 4

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3,404,255

SOURCE OF VAPORIZABLE MATERIAL FOR BOMBARDMENT THEREOF BY AN ELECTRON BOMBARDING MEANS

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Continuation-in-part of application Ser. No. 387,407, Aug. 4, 1964. This application June 23, 1965, Ser. No. 470,314

16 Claims. (Cl. 219—121)

ABSTRACT OF THE DISCLOSURE

A source of vaporizable material which employs either a rod of vaporizable material having a plurality of mutually spaced annular grooves distributed therealong or a rod having a plurality of mutually spaced pellets of vaporizable material stacked on a supporting pin. The rod of vaporizable material may include a progressively increasing cross-sectional area as seen from a top surface to a bottom surface. An electron bombarding means is spaced from a free end of the vaporizable rod to cause vaporization of material from the free end of the rod. An adjustment means is provided for adjusting the position of the rod to control the spacing between the free end of the rod and the electron bombarding means.

The present invention relates to apparatus and equipment for vaporizing material and, more particularly, to a source of vaporizable material.

This application is a continuation in part of my prior patent application Ser. No. 387,407, filed Aug. 4, 1964, for "Source of Vaporized Material," now abandoned.

Sources of vaporizable material are well known. They are, for example, used in vacuum pumps for providing getter material inside the pump housing, and in vacuum coating apparatus for depositing various materials on articles. Thus, the expression "vaporizable material" as used herein is meant to cover at least vaporizable getter material, as well as vaporizable materials of the type used in vacuum coating processes.

A proposed type of vaporizable material source comprises a rod made of the material to be vaporized and mounted to have a free end. This type of source includes means for heating the rod at its free end to vaporize material therefrom. In a preferred form of this type of source, the heating means include means, such as an electron gun or an electron-emitting filament, for bombarding the free end of the rod with electrons that bring about a vaporization of material from the rod. As the vaporization process progresses, the rod is successively consumed from the free end thereof.

One advantage of this type of vaporizable material source is that it is operative for several hours or days without having to be replenished with fresh material during that time and without requiring intricate material feeder mechanisms for its operation.

On the other hand, this type of source has been found to be subject to heat losses through conduction of heat along the rod and radiation of heat laterally from the rod. This not only leads to a waste of heating power, but requires the heating power to be repeatedly varied as the longitudinal and the lateral surface area dimensions of the rod are progressively diminished by the vaporization of material. In the absence of such repeated variation, the evaporation rate is non-uniform as the vaporization process proceeds.

It is the principal object of the invention to diminish these disadvantages.

According to one aspect of the invention, the rod material to be vaporized defines a plurality of mutually spaced annular grooves distributed along the rod for impeding flow of heat therealong. Preferably, the grooves extend substantially perpendicularly to the general direction of heat flow along the rod.

In this manner, the power requirements of the means for heating the free end of the rod and the power rating of the equipment for energizing these means are significantly reduced. The life of these means is at the same time increased, and there is less heat dissipation from the source, so that the walls of the apparatus in which the source is used will operate at lower temperatures and can be located closer to the source than before. The reduction of heat conduction along the rod leads further to more equalized power requirements for vaporizing material as the dimensions of the rod are progressively diminished and to more equalized evaporation rates.

According to another aspect of the invention, the rod is tapered substantially along its entire length in the direction of its free end so that the area heated for the vaporization of material increases progressively as the length and the lateral surface area of the rod are successively decreased by the vaporization of material from the rod.

The feature of having the vaporization area increase as the latter dimensions decrease leads to a substantial equalization of the power requirement for vaporization over the useful life of the rod and to a corresponding equalization of the rate of evaporation of material from the rod, since the available heat energy is progressively distributed over a larger vaporization area as the heat dissipation from the overall surface of the rod decreases during the operation of the source. This will become more readily apparent as the description proceeds.

If desired, the two aspects of the invention so far described may be combined by providing the tapered rod just mentioned with the mutually spaced annular heat impedance grooves defined above. The result is a highly advantageous source of vaporizable material which is characterized by particularly moderate and equalized power requirements and a substantially constant evaporation rate.

The term "rod of material to be vaporized" as used herein is meant to refer not only to cylindrical but also to non-cylindrical bodies.

The invention 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 is a longitudinal section of a getter-ion vacuum pump including a source of vaporizable material in accordance with a first embodiment of the invention;

FIG. 2 is an elevation on an enlarged scale of a source of vaporizable material in accordance with a second embodiment of the invention;

FIG. 3 is an elevation on a yet more enlarged scale of a source of vaporizable material in accordance with a third embodiment of the invention;

FIG. 4 is a top view on a still more enlarged scale along the line **4—4**, of the source of vaporizable material illustrated in FIG. 3; and

FIG. 5 is a top view on the same scale as in FIG. 4 of a section, along the line **5—5**, through the source of vaporizable material illustrated in FIG. 3.

The pump shown in the drawing comprises a housing **10** having a substantially cylindrical side wall **11**, a bottom **12** with an aperture **13**, and a flange **14** encompassing an inlet opening **15**. A substantially cylindrical anode grid **18** is located inside the housing **10**. A lead **19**, which extends through an insulating bushing **20** in housing wall **11**, connects anode **18** to the positive terminal of an ionizing high voltage supply **22**. The negative terminal of supply **22** is connected to housing wall **11** by a lead **23**.

A rod **25** of getter material to be vaporized, such as titanium, is located in the lower region of housing **10**. The rod **25** is mounted on a support **26** which, in turn, is mounted on an insulating strut **27**. A shield disc **28** is interposed between support **26** and strut **27**. The strut **27** is connected on the bottom **30** of a bellows **31**, which has a flange **32** sealably attached to housing bottom **12** around the aperture **13** thereof. The bottom **30** of bellows **31** has a threaded bolt **34** attached thereto. The bolt **34** extends through an aperture (not shown) in a yoke **35** that is attached to housing bottom **12**. A nut **36** is threaded on bolt **34** at the lower surface of yoke **35** and a spring **46** biases the bellows bottom **30** away from the lower part of yoke **35**.

An electron-emitting filament **38** is located above the rod **25** and is connected to a heating current supply **39** by a lead **40** which extends through an insulating bushing **42** in housing wall **11**, and a lead **41** which extends through housing wall **11** and is connected thereto at **42**, so that the filament **38** is biased negatively with respect to the rod **25**. A wire **47** connects the negative terminal of a high voltage supply **45** to housing wall **11** and thus to point **43** and filament **38**. A wire **54** extends through a bushing **55** in housing wall **11** and connects the support **26** and thus the rod **25** to the positive terminal of the high voltage of supply **45**.

The pump shown in the drawing is connected at flange **14** and inlet opening **15** to a space or vessel to be evacuated (not shown). This space or vessel may be pre-evacuated by a conventional roughing pump (not shown). Gas molecules entering the pump housing **10** are ionized by action of electrons traveling from the filament **38** to the anode **18** under the influence of the electric potential of the ionizing voltage supply **22**. This ionization process is well known in the art. The ionized gas molecules are attracted by and deposit themselves on the inner surface **50** of housing wall **11** which thus serves as a molecule collector surface.

This pumping action is assisted and enhanced by operation of the getter material source including the rod **25** and filament **38**. To this effect, the nut **36** is first adjusted until the free end **51** of rod **25** has a desired initial spacing from filament **38**. The supply **39** is then switched on to send a heating current through filament **38** and the high voltage supply **45** is switched on to bias filament **38** negatively with respect to the rod **25**. In this manner, the free end **51** of rod **25** is bombarded with electrons which heat the free rod end and vaporize material therefrom. A hollow cylindrical shield **53** is mounted to encompass the rod **25** and to be electrically connected to the negative terminal of high voltage supply **45**, so that shield **53** aids in the direction and focusing of electrons from filament **38** onto the free end **51** of rod **25**. In addition, the shield **53** serves as a means for reducing heat dissipation from rod **25**.

According to the invention, the getter rod **25** is provided with a plurality of mutually spaced annular grooves **55***a* which extend perpendicularly or transversely to the general direction of heat flow from the free rod end **51** through the rod. In this manner, the rod **25** is subdivided into a plurality of spaced cylindrical pellets **56** of getter material. The grooves **55***a* extend from the lateral surface of rod **25** to the vicinity of the longitudinal center axis of rod **25**, so as to leave just sufficient material between adjacent pellets **56** to keep the pellets mechanically supported during the getter vaporization process. The grooves **55***a* impede the flow of heat along rod **25** or from getter pellet to getter pellet. The heat developed by electron bombardment of the free end **51** of rod **25** is thus largely retained at this free end, so that the vaporization of getter material takes place thereat most effectively. As the rod **25** wears down or as the getter pellets **56** are successively consumed due to getter vaporization therefrom, the desired distance between rod **25** and filament **38** is readjusted by turning the nut **36**. During this wearing down of the rod, the grooves **55***a*, which impede heat dissipation along the rod, lead to more equalized power requirements for the vaporization of successive pellets.

The getter material that is vaporized from rod **25** enters the free space in pump housing **10** and deposits itself on the inner surface **50** of housing wall **11** where it aids in the entrapment of gas molecules. If desired, the anode **18** may be located from the rod **25** by a distance larger than as shown in the drawing, so that the vaporized getter material will primarily deposit itself on a portion of the inner surface **50** of housing wall **11** that is located below anode **18**. In this case, the action of the vaporized getter material is separate from the action of the gas molecule ionizing system including anode **18**. If desired, a filament (not shown) which is separate from the filament **38** may, in a conventional fashion, be provided for releasing ionizing electrons to the anode **18**.

The rod **25** as shown in FIG. 1 may be prepared by machining the grooves **55***a* into a rod of getter material, so as to leave the getter pellets **56** and the short sections of material therebetween.

FIG. 2 shows the result of a different method. The rod **125** shown in FIG. 2 has a pin **126** of a suitable material, such as tantalum, molybdenum or tungsten. A series of getter pellets **127** of a suitable material, such as titanium, are stacked on pin **126** and are maintained in mutually spaced relationship by washers **128**, which may be of titanium, tantalum, molybdenum or another suitable material. The rod **125** may be used in lieu of the above-mentioned rod **25**.

In this case it is desirable to use for the filament **38** a conventional circular filament configuration (not shown) such that the pin **126** will pass through the center of the filament circle. By suitable sizing and positioning the filament with respect to the getter rod, the number of electrons bombarding the free end of the getter rod will not be appreciably diminished by the presence of the pin.

An alternate method is to allow the pin **126** to approach the filament **38** where it will be subjected to electron bombardment sufficiently intensive to cause the pin **126** to vaporize.

FIGS. 3, 4 and 5 illustrate a source of vaporizable material which is characterized by particularly equalized power requirements throughout the useful life of the source.

The source in accordance with these figures comprises a rod **150** of a material to be vaporized. The rod has a top surface **151** at its free end **152**, and a bottom **154** opposite the free end. The rod **150** is tapered from the bottom **154** to the free end **152**. Because of this tapering, the rod increases progressively in cross-sectional area from the top surface **151** to the bottom **154**. In the illustrated embodiment, the lateral tapering angle **156** is 5½° with respect to the vertical, which I found suitable for the subject purposes. Other angles may also be employed.

In the tapered rod illustrated in FIGS. 3 to 5, annular grooves **158** have been cut into the body of the rod **150**, so as to divide this rod into a plurality of aligned and space pellets **160**. The grooves **158** are cut so as to leave small supporting posts **162** of the material to be vaporized between the pellets **160**.

The tapered and grooved rod **150** of FIGS. 3 to 5 may be substituted for the rod **25** in the pump shown in FIG. 1. In the illustrated embodiment, the rod **150** has a pin **165** for connection to the support **26** of FIG. 1.

With the rod **150** inserted in the apparatus of FIG. 1 and the heating current supply **39** and high voltage supply **45** energized, electrons released by the filament **38** will predominantly bombard and heat the top surface **152** at the free end **151** of the rod. The rod **150** will gradually wear in the direction of the bottom **154** as material is vaporized from the top. Since the rod is tapered as shown, the area presented to electron bombardment increases as material is vaporized and the rod is worn down.

This is particularly well apparent from FIG. 5 which

shows the surface **168** located below the top pellet shown in FIG. 3. This surface **168** is larger in area than the top surface **152**. In FIG. 5, the surface **168** includes the cross-sectional area of the post section **162** which is vaporized upon consumption of the top pellet shown in FIG. 3.

The area presented to electron bombardment will, of course continue to increase as further material is vaporized below the surface **168**. As indicated above, the reason for this deliberate increase in vaporization area is to equalize the heat energy requirements of the source of vaporized material, and to provide more equalized vaporization rates with a given magnitude of heating power. Initially, the rod has an overall surface of a given area from which heat will be dissipated. These heat losses are reduced as the overall surface area of the rod decreases with the progressing vaporization of material from the rod. An uncompensated decrease of these heat losses leads to an increase in the evaporation rate which can reach undesirable proportions unless the heat source is checked.

By having the area which is subjected to heating increase as the vaporization of material proceeds, a substantial compensation is provided for the above mentioned decline in heat losses, since progressively increasing vaporization areas will tend to acquire gradually lower temperatures with a given source of heating power.

The principle inherent in the embodiment of FIGS. 3 to 5 can also be expressed as providing for a gradual spreading of the available heat energy over a larger evaporation area as a function of a progressive decline in heat losses. The result is a more constant rate of evaporation from the rod with a heat source of a given power.

The advantageous effect is enhanced by the grooves **158** illustrated in FIG. 3, since these grooves impede heat flow along the rod and thus tend to maintain the available heat energy at the location of vaporization. It will, however, be understood that the advantageous effect just mentioned iis also present in the absence of the grooves **158**. Accordingly, the invention extends also to tapered getter rods of the type shown in FIGS. 3 to 5 but having no grooves of the type of grooves **158**.

If a grooved arrangement is desired, the tapered pellets **160** shown in FIG. 3 may be manufactured separately and may be arranged on the above mentioned pin **126** shown in FIG. 2 with intervening washers **128** to preserve the spacing, as illustrated in FIG. 2. When the pellets **160** are thus positioned on the pin **126**, each pellet below the top pellet will have a mean diameter which is larger than the mean diameter of the next higher pellet, in the same manner as in the embodiment of FIGS. 3 to 5.

Those skilled in the art will recognize that a good approximation is obtained with a string of cylindrical pellets arranged in the manner of the pellets **160** in FIG. 3, provided each cylindrical pellet below the top pellet has a diameter which is larger than the diameter of the next higher pellet. In other words, the pellets **160** in the embodiment of FIGS. 3 to 5 may be cylindrical instead of tapered, as long as each pellet below the top pellet has a larger cross-sectional area than the next higher pellet. This approximation to a strictly tapered configuration is sometimes easier to manufacture and yields often sufficiently satisfactory results.

While specific embodiments of the invention have been shown, it will be recognized that many modifications within the scope of the invention are possible. Thus, the free end of the getter rod herein described may also be bombarded with electrons that emanate from an electron gun, rather than a heated filament. The subject invention may also be employed in getter-ion pumps of a different structure than that shown. Moreover, the invention and its various aspects may be employed in vacuum coating apparatus, as has been mentioned initially.

Other modifications within the scope of the invention will be apparent to those skilled in the art.

I claim:

1. A source of vaporizable material, comprising a rod being of material to be vaporized and having a free end, and means for heating the rod at said free end to vaporize material therefrom, the rod defining a plurality of mutually spaced annular grooves distributed along the rod for impeding flow of heat therealong.

2. A source of vaporizable material, comprising a substantially cylindrical rod being of material to be vaporized and having a free end, and means for heating the rod at said free end to vaporize material therefrom, the rod defining a plurality of mutually spaced annular grooves extending substantially at right angles to the longitudinal axis of the rod and extending from the outer lateral surface of the rod to the vicinity of said longitudinal axis to impede flow of heat along the rod.

3. A source of vaporizable material, comprising a rod being of material to be vaporized and having a free end, means for heating the rod at said free end to vaporize material therefrom, the rod defining a plurality of mutually spaced annular grooves distributed along the rod for impeding flow of heat therealong, and a heat shield being spaced from and laterally surrounding the rod.

4. A source of vaporizable material, comprising a substantially cylindrical rod being of material to be vaporized and having a free end, and means for heating the rod at said free end to vaporize material therefrom, the rod defining a plurality of mutually spaced annular grooves extending substantially at right angles to the longitudinal axis of the rod and extending from the outer lateral surface of the rod to the vicinity of said longitudinal axis to impede flow of heat along the rod, and a heat shield being spaced from and concentrically surrounding said rod at a region below said free end thereof.

5. A source of vaporizable material, comprising a rod being of material to be vaporized and having a free end, and means for bombarding the rod with electrons at said free end thereof to cause vaporization of material from the free end of the rod, the rod defining a plurality of mutually spaced annular grooves distributed along the rod for impeding flow of heat therealong.

6. A source of vaporizable material, comprising a rod being of material to be vaporized and having a free end, and means for bombarding the rod with electrons at said free end thereof to cause vaporization of material from the free end of the rod, the rod defining a plurality of mutually spaced annular grooves distributed along the rod for impeding flow of heat therealong, and a substantially hollow cylindrical, negatively biased shield of electrically conductive material being spaced from and laterally surrounding the rod for reducing heat dissipation from the rod and focusing electrons onto the rod.

7. A source of vaporizable material, comprising a rod being of a material to be vaporized and having a free end, means spaced from the free end of the rod for bombarding the rod with electrons at said free end thereof to cause vaporization of material from the free end of the rod, the rod defining a plurality of mutually spaced annular grooves distributed along the rod for impeding flow of heat therealong, and means for adjusting the position of the rod to control the spacing between the free end of the rod and said electron bombarding means.

8. A source of vaporizable material, comprising a supporting pin and a series of pellets of material to be vaporized stacked on the supporting pin in mutually spaced relationship.

9. A source of vaporizable material, comprising a supporting pin, a series of pellets of material to be vaporized stacked on the supporting pin, and a washer between each adjacent pair of pellets for spacing the pellets of said adjacent pair.

10. A source of vaporizable material, comprising a rod being of a material to be vaporized and having a free end, and means for heating an area of the rod at said free end to vaporize material therefrom, the rod defining a plurality of mutually spaced annular grooves distributed along the rod for impeding flow of heat therealong, and the rod being tapered toward said free end whereby the

area heated by said means increases as material is vaporized from the rod.

11. A source of vaporizable material, comprising a rod being of a material to be vaporized and having a free end, and means for heating an area of the rod at said free end to vaporize material therefrom, the rod being tapered toward said free end substantially along its entire length whereby the area heated by said means increases as material is vaporized from the rod.

12. A source of vaporizable material, comprising a frustoconical rod of material to be vaporized having a top surface and a bottom opposite the top surface and increasing progressively in cross-sectional area from the top surface to the bottom, and means for bombarding the rod with electrons at the top surface to vaporize material therefrom, and for progressively bombarding the increasing cross-sectional areas as material is vaporized from the rod.

13. A source of vaporizable material, comprising a frustoconical rod of material to be vaporized having a top surface and a bottom opposite the top surface and increasing progressively in cross-sectional area from the top surface to the bottom, said rod defining a plurality of annular grooves extending parallel to said top surface and being spaced from each other between said top surface and said bottom to impede in the flow of heat in the direction of said bottom, and means for bombarding the rod with electrons at the top surface to vaporize material therefrom, and for progressively bombarding the increasing cross-sectional areas as material is vaporized from the rod.

14. A source as claimed in claim **13**, including means for adjusting the position of the rod relative to the electron bombarding means.

15. A source of vaporizable material, comprising a series of aligned, interconnected and mutually spaced frustoconical pellets of material to be vaporized.

16. A source of vaporizable material, comprising a substantially cylindrical top pellet of material to be vaporized, and a plurality of substantially cylindrical additional pellets of material to be vaporized, said additional pellets being connected to and located below the top pellet, being aligned with the top pellet and being spaced from the top pellet and spaced from each other, and each of said additional pellets having a mean diameter which is larger than the mean diameter of the next higher pellet.

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