Feb. 17, 1953

H. J. DAILEY

2,629,065

OVERWOUND FILAMENT

Filed May 14, 1948

Fig. 1.

Fig. 2.

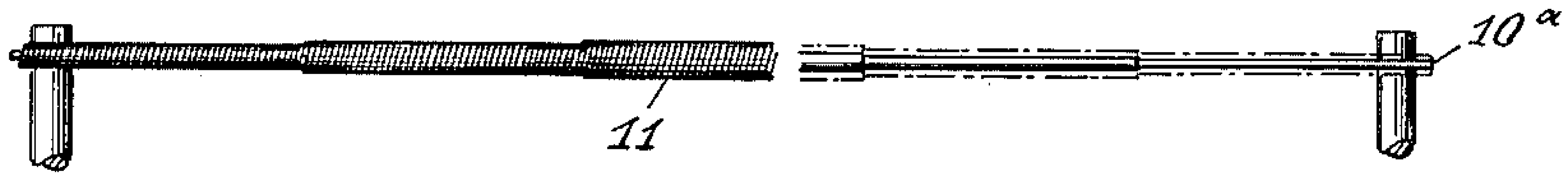


Fig. 3.

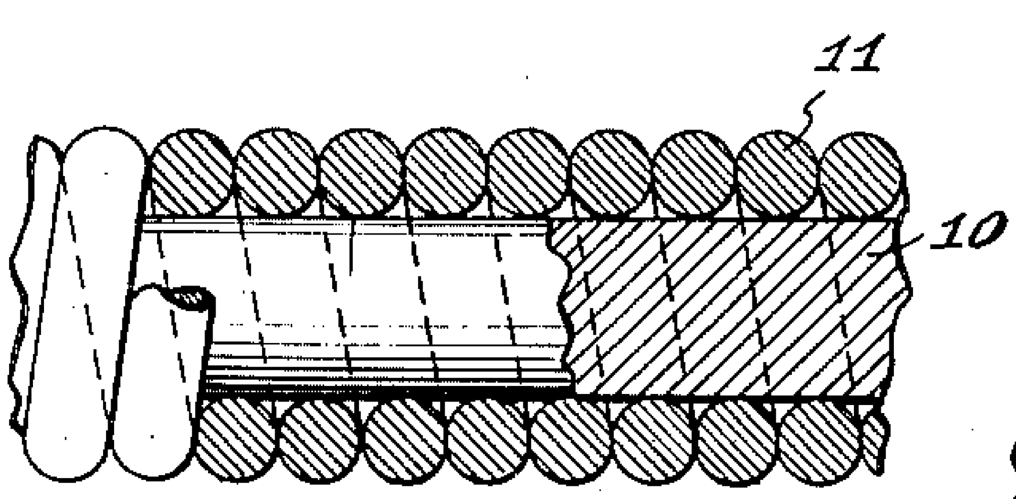


Fig. 4.

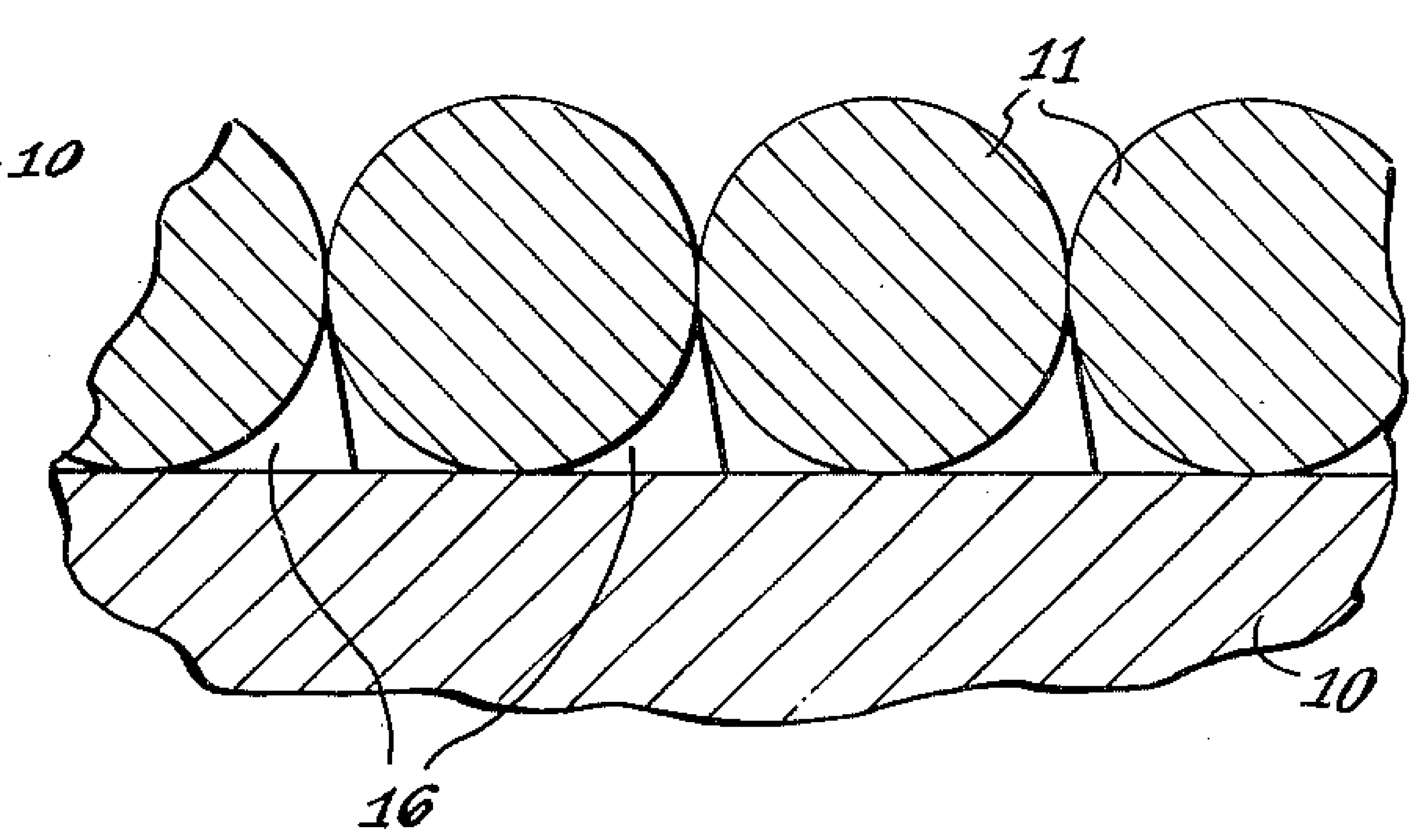


Fig. 6.

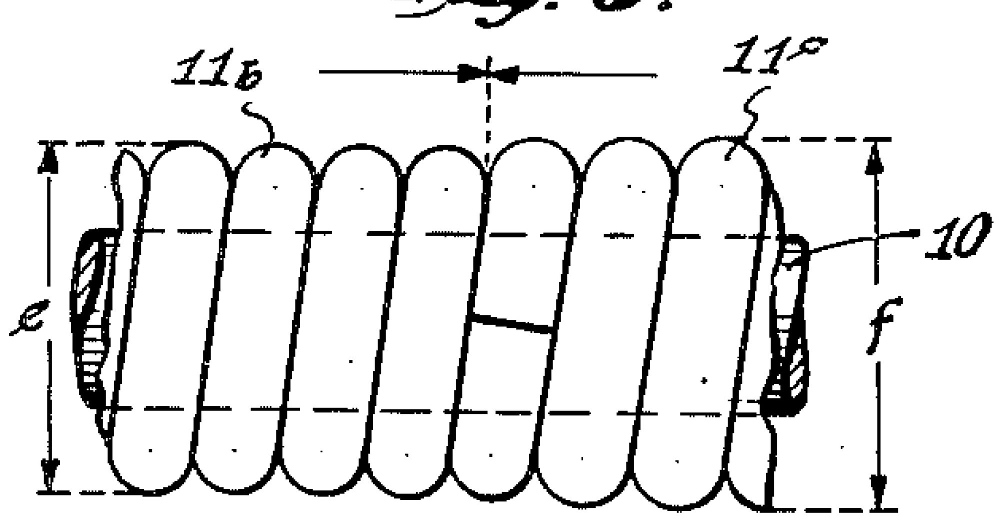


Fig. 5.

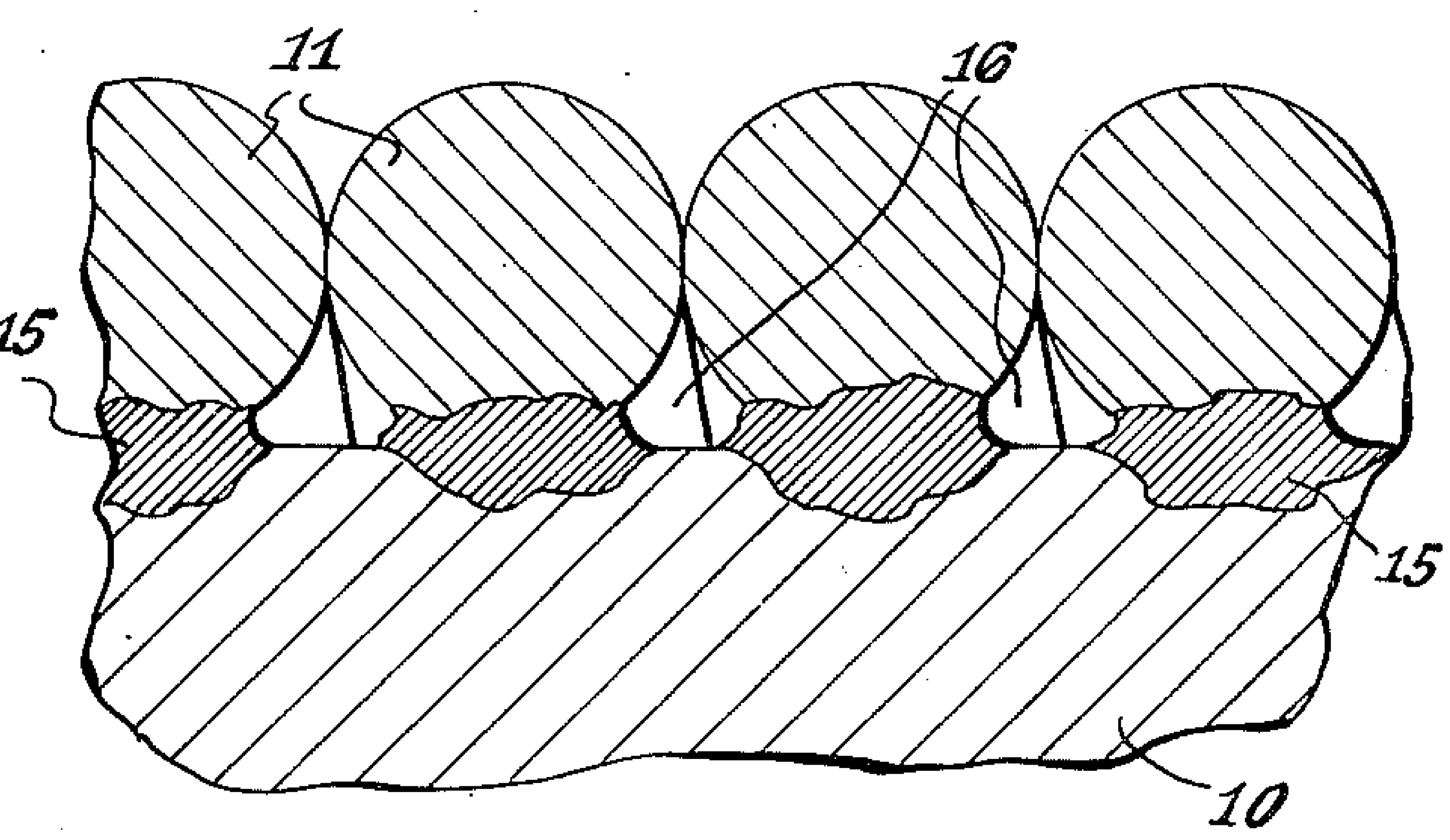
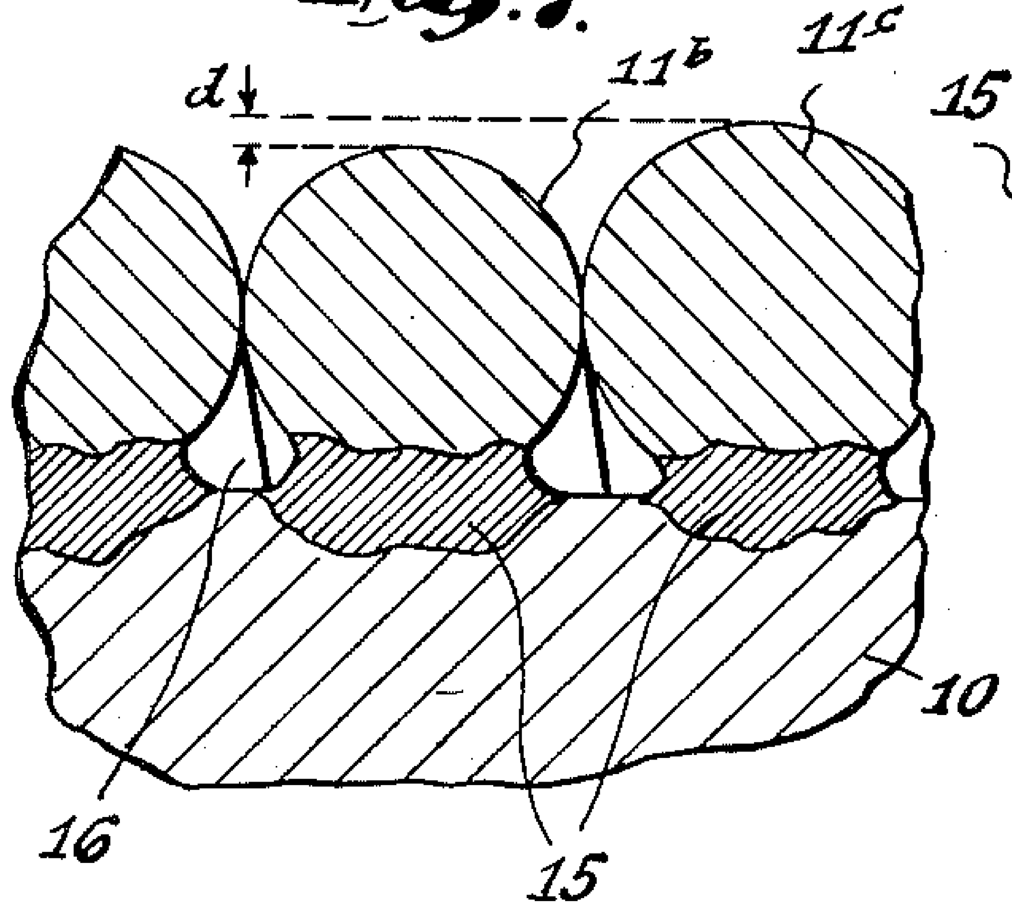


Fig. 7.



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OVERWOUND FILAMENT

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4 Claims. (Cl. 313—343)

1

This invention relates to overwound filaments for use particularly as cathodes for electron discharge devices.

It is known that the basic defect of the ordinary tungsten cathode is the rapid burning up thereof, especially at a mid-part of the same. It is an unavoidable circumstance that end portions of a cathode will be cooled by heat conduction therefrom by the lead-in connections whereas the mid-portion of the cathode does not correspondingly suffer from this reduction in operating temperature. Due to the temperature existing at the mid-portion of the usual filament or cathode being higher than at the end portions in development of the desired average cathode temperature, the rate of evaporation of the emissive material is much greater at the mid-portion than at the end portions of the cathode and the mid-portion consequently begins to grow thinner, which operates to increase its resistance and to make it even hotter and to erode even more rapidly. The cathode therefore suffers from the vicious cycle of becoming thinner and hotter at its mid-portion during use until it finally erodes to the point of uselessness or breakage.

In designing power tubes for high powers and long life, the questions of filament or cathode power and longevity are very important considerations. The highest practical emission efficiency for conventional pure tungsten filaments of prior art construction is approximately six to seven milliamperes per watt of filament power. The limitation on temperature and higher emission efficiencies of the prior art single strand surface exposed tungsten filament is the relatively high evaporation rate from the exposed surface, the effect of which is referred to above.

An object of the present invention is to provide a tungsten filament wherein evaporation is substantially prevented.

Another object of the invention is to obtain a greater than double electron emission per watt of filament power over conventional tungsten filaments.

Furthermore, an object of the invention is to provide a filament which is equally usable in high power, high voltage electron discharge devices or tubes and which, when so used, has longer life and increased emissivity over prior art conventional filaments.

Yet another object of the invention is to provide an emissive wrapping on a tungsten core in such manner that heating current suffers

2

substantially no change due to evaporation occurring in the wrapping, and in which evaporation will not materially reduce tube life.

Again, an object of the invention is to retain the benefits of sturdiness of tungsten wire for filament use.

A further object of the invention is to obtain rapid heat interchange from the tungsten core of my improved filament to the emissive wrapping thereon and a consequential lowering of necessary operating temperature for the said core.

Still further objects of the invention will appear to those skilled in the art to which the same appertains as the description proceeds, both by direct recitation thereof and by implication from the context.

In the accompanying drawing in which like numerals of reference indicate similar parts throughout the several views:

Figures 1 and 2 are side elevations of two forms of filaments embodying my invention;

Figure 3 is a longitudinal section of a portion of a filament showing the invention in its simplest form and before alloying heat has been applied;

Figure 4 is an enlarged view in section of a part of the showing of Figure 3, but before alloying has been effected;

Figure 5 is a sectional view similar to Figure 4, but after alloying has been effected;

Figure 6 is an elevation of a portion of a filament of modified construction utilizing overwindings of different diameters; and

Figure 7 is an enlarged longitudinal section of a portion of the filament of Figure 6.

In the specific embodiment of the invention illustrated in said drawing, and devoting attention initially to Figures 1, 3, 4, and 5, the reference numeral 10 designates a filamentary metallic core of material which becomes incandescent by flow of electrical current therethrough. An acceptable example is tungsten wire of 0.011 inch diameter for operation with current in the range of 4 to 6 amperes. Wound tightly upon this core 10 is a helical coil 11 the convolutions of which are in tangential engagement each with the next adjacent one, thereby obtaining a closed coil which preferably extends along the core at least for the length thereof where emission is desired, and for which purpose the said coil is preferably a material which is electron emissive when heated. It is preferable to employ different materials for core and coil and to select an emissive metal for the coil which is more resistive at the operating temperature than the metal of the core. Thus, tantalum or an alloy of tungsten and tantalum are given as satisfactory examples for coil materials to be used in conjunction with the example given above of tungsten core. Furthermore, the diameter of the coil wire is preferably less than the diameter of the core, so example of a satisfactory coil wire may be given for use with the mentioned tungsten core, of tantalum wire having a diameter of 0.002 inch. The most economical mode of manufacture is to wind the tantalum wire directly upon the tungsten coil in long lengths and cut off such length thereof as needed for any particular filament.

The severed length of the overwound core is attached in place upon the supporting posts or lead-in wires 14 of the electron discharge tube or device, and a current is then applied thereto for rendering the core highly incandescent to a degree of temperature approximating 2400° K. to 3000° K. which will obtain an alloying or welding unification of the convolute portions of the coil where in engagement with the core due to the tight winding of the coil on the core. This alloying or welding is indicated in Figure 5 as accomplished at 15. There is no alloying or welding of the convolutions to each other since the tangential engagement of the convolutions with each over is at a distance from the incandescent core.

The alloying of the coil to the core is evidenced in a gradual change in filament characteristics over an approximate period of forty-eight hours of applied current to the filament. For instance, where an initial current of about 4.8 amperes is used to heat the core to incandescence, the current drawn as alloying progresses will rise and will reach approximately 5.1 amperes in the period mentioned, showing that the alloying has been accomplished. Alloying of the coil to the core will cause the core to operate at a lower temperature. At the desired operating temperature of 2400° K. of the tantalum coil, its resistivity is 92.85 x 10^{-6} ohm-centimeters. Throughout the temperature range of 2400° K. to 2600° K., and beyond, the resistivity of tungsten is less than that of tantalum and as the resistance is

$$r=p\frac{l}{A}$$

where A stands for cross sectional area and l for length; the resistance r of the wrap is greater since l of the wrap is greater and A of the core is greater. Consequently the tungsten core carries most of the heating current both for the reasons noted, and because of the resistance presented by mere surface contact at the tangential engagement of the several convolutions of the coil with each other. It has been found with the materials, currents, and temperatures described above, the temperature difference in the tantalum and tungsten is appreciably less than 5° C., thus showing that a degree of alloying is desirable.

The highest practical emission efficiency for a pure tungsten filament is approximately 6–7 milliamperes per watt of filament power. The limitation, to use of a tungsten filament with higher temperature and correspondingly higher emission, resides in the relative high evaporation rate or erosion of the tungsten at temperatures of 2500° K. and above. The evaporation reduces the cross section of the wire, thus causing hot spots and early burnouts at the points of reduced

cross section in the prior art filaments. According to the present invention, however, the coil or wrapping of tantalum traps products of tungsten evaporation within the closed spaces 16 formed by the convolutions so that the vapor pressure due to the evaporation that occurs is confined to those spaces and operates to deter or prevent further evaporation. Since the wrapping or coil carries little of the heating current, evaporation of material from the coil or erosion of the coil at its outer or exposed portions will not affect the heating current. With a coil or wrapping of tantalum operated at approximately 2400° K., the electron emission per watt of filament power is substantially 20 milliamperes per watt or roughly three times that of a prior art pure tungsten filament.

In order to equalize temperature of operation of the filament throughout its length to compensate for the cooling effect of the lead-in connections and/or heating due to electron bombardment at the mid-portion of cathode, it is within the scope of the present invention to provide a core 10*a* as shown in Figure 2 of increasing diameter toward the mid-portion of the length thereof. Such a core may be of tungsten and otherwise be of the character of core previously described. Likewise, said core 10*a* may be over-wound or wrapped with a coil of tantalum wire alloy of tungsten and tantalum, or other emissive material or materials as heretofore described, with the convolutions tightly wound upon the core and in tangential engagement with each other.

Furthermore, if so desired, compensation for greater erosion or vaporization of the emissive material near the middle of the cathode than toward its ends, may be obtained by applying a coil the wire of which varies in diameter and has greatest diameter at the mid-portion of the length of the cathode. Thus in Figures 6 and 7, core 10 is closely over-wound with a wrapping or coil of which one series of convolutions 11*b* are of wire of one diameter and from the end thereof another series of convolutions 11*c* of wire of larger diameter by a desired amount *d* continues to form the mid-portion of the cathode, so the outside diameter *e* at an end portion of the cathode increases to diameter *f* nearer the middle of the cathode. Tangential engagement of the convolutions and other characteristics of material, location, alloying and the like, heretofore described, likewise apply with respect to the showing of core and coil of these two figures. In all constructions the inventive concept is present of closely wound convolutions of the over-wound coil and alloying of the said convolutions with the core.

I claim:

1. A cathode comprising a metallic cylindrical core adapted to be heated by flow of current therethrough, and an overwound coil of wire on said core, said coil being of different chemical constituency from said core and having a continuous-spiral portion of its convolutions in contact with and alloyed directly to said core substantially throughout the length of said continuous-spiral portion, and said cathode having a greater outside diameter at its middle than at its ends.

2. A cathode comprising a metallic cylindrical core adapted to be heated by flow of current therethrough, said core having a greater outside diameter at its middle than at its ends, and an over-wound coil of wire of different chemical

constituency from and on said core, said coil having a continuous-spiral portion of its convolutions in contact with and alloyed directly to said core substantially throughout the length of said continuous-spiral portion.

3. A cathode comprising a metallic cylindrical core adapted to be heated by flow of current therethrough, said core having a greater outside diameter at its middle than at its ends, and an over-wound coil of wire on said core, the wire of said coil having substantially uniform diameter throughout its length and the convolutions of said coil having greater diameter midway of the length of said coil than at the ends thereof in conformity with the diameters of the core where the coil is over-wound.

4. A cathode comprising a metallic cylindrical core adapted to be heated by flow of current therethrough, and an overwound coil of wire of different chemical constituency from and on said core the convolutions whereof are in contact with and alloyed directly to said core, and the convolutions midway of the length of said coil being formed of wire of greater diameter than the wire forming the convolutions at the ends of said coil.

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