3, is then incandesced by a passage of current to a temperature of about 3000° K. which causes rapid vaporization of the metal, thereby producing a gas-free conducting deposit or coating 11 which has been shown on the inner surface of the envelop. Conductors 12, 13 sealed into the envelop make contact with this coating and enable it to be used as an anode for an electrical discharge. A device having a gas-free film anode and the method of its preparation has been described and claimed by me in a co-pending application, Serial No. 843,569, filed June 6, 1914. The method of producing high vacua by vaporizing tungsten is claimed by me in a co-pending application, Serial No. 838,768, filed May 15, 1914. Pressures much below .001 micron of mercury may be attained thereby. The cathode conductor 2 is prepared by introducing a thorium compound, such as the nitrate of thorium to the oxid of the refractory metal before reduction, or by adding either thorium nitrate or thoria to the metal powder after reduction but before consolidation of the metal by sintering and mechanical working to the solid metal state has taken place as described, for example, with reference to thoriated tungsten in U. S. Patent No. 1,082,933. The proportion of thoria in the unsintered metal usually varies from about ½ to 10% but in some cases may be even greater. The proportion of thorium compound in the cathode within the above limits makes little difference in the maximum electron emission that may be obtained under the best conditions but with a greater proportion of thorium compound the desired active condition of the filament may be reached and maintained with greater ease than with a lesser amount.

The thoriated cathode 2 is now heated to about 2900° K. for about one minute. The treatment of the filament at a temperature of 2900° has no marked effect on the subsequent electron emission of the cathode when at lower temperature but appears to be desirable for purifying the surface of the cathode. The cathode is then incandesced within the range of about 2000° to 2400° K. and by this temperature treatment some change is produced in the cathode which enormously increases its electron-emitting property under the condition described. The greatest activity is obtained between about 2200° to 2300° K. and the treatment at this temperature is usually continued for about one minute, but even outside of this range a marked change is produced. Apparently a concentration of metallic thorium or of some other oxidizable thorium material takes place on the surface of the filament. The filament 2 may now be used as a cathode at a temperature below this forming temperature.

With a filament thus prepared I have obtained at a temperature of about 1300° to 1380° K. substantially the same electron emission per sq. cm. as with a pure tungsten filament at about 2000° K., that is, about three milliamperes per sq. cm. Preferably a thoriated cathode is operated around 1700° to 1800° K., at which temperatures its life is indefinitely long.

Subsequently heating the filament to a higher temperature, for example, to 2800° K., causes some change, apparently a distillation of the film of thorium from the surface, as the electron emitting power of the cathode falls to the same order of magnitude as pure metal. When the cathode after being thus heated is re-subjected to a temperature of 2200° to 2300° K., the active condition is restored.

A similar heat treatment of pure tungsten has no effect on its electron emissivity at incandescence. The active thorium material may be transferred by distillation to an adjacent surface. For example, if the filament 3 consisting of pure tungsten has not been completely destroyed during the preparation of the apparatus, the heating of the cathode to a temperature above 2300° after the preparation of the surface film results in the distillation of some of the thorium material to conductor 3 so that when the conductor 3 is used as a cathode with respect to the anode 11, it is found that its electron emission has been greatly increased.

One of the most striking proofs that the active surface film is not due to the effect of the thoria as in the Wehnelt cathode is furnished by the effect of a minute trace of oxygen on the behavior of the cathode. If in some manner a trace of oxygen is admitted, the electron emission immediately falls as low or even lower than the low value observed when a cathode of pure tungsten is slightly oxidized. In other words, the electron emission becomes very much lower than that of the unoxidized metal. When subsequent to oxidation a trace of hydrocarbon vapor is admitted, the electron emission suddenly rises as though reduction were taking place. If the carbon is in excess, the electron emissivity immediately drops to a low value as though a carbid were formed with the excess of carbon. In an application Serial No. 58,377 filed by me on October 28, 1915, I have more fully described and also claimed a thoriated cathode device containing reducing material.

Cathodes containing only a small amount of thorium compound are deleteriously affected by disintegration of the surface produced by positive ion bombardment and in this respect may be extremely sensitive. In this case, it is necessary when using voltages high enough to cause ionization of residual gases to carry the vacuum far beyond the