PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

Improvements in High-pressure Metal-vapour Electric Discharge Devices

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British Company, and VICTOR JAMES FRANCIS, a British Subject, and MARCELLO PIRANI, a German Citizen, both of Research Laboratories of The General Electric Company Limited, Wembley, Middlesex, do hereby declare the nature of this invention to be as follows:—

This invention relates to high-pressure metal-vapour electric discharge (H.P.M.V). devices of the type having a pair of main starting electrodes and a pair of running electrodes, at least one of the said starting electrodes being spaced apart from both said running electrodes, so constructed and arranged that during the run up one end at least of the discharge transfers itself automatically from a said starting to a said running electrode.

The use of separate starting and running electrodes is disclosed in Patent Specification No. (Application No. 9156/36) and is elaborated in Application Nos. 1594/37 and 3485/37. It is there explained, for example, that the starting and running electrodes, though spaced apart, may be mechanically integral; and that, when the surface of an electrode is mentioned as affecting the discharge, that part alone of the surface is referred to, on which the discharge actually terminates.

In all the said applications it is provided that the running electrode, being of refractory metal, shall be free from any store of thermionically active material. This provision was inserted in the belief that any material substantially more active thermionically than a refractory metal would be so much more volatile than such metal that its presence on the running electrode would lead to the evil that the use of separate starting electrode is intended to cure, namely transference of material from the electrodes to the envelope.

This belief has now proved to be unfounded. Thoria, though less active thermionically than the alkaline earths, is definitely more thermionically active than tungsten; but, it is not (like the alkaline earths) so much more volatile than tungsten that its presence on the running electrodes necessarily leads to the said evil.

Here a word of explanation must be interpolated. Thoria itself is almost completely inactive thermionically, just as are the alkaline earths themselves. Its and their thermionic activity is known to be due to the presence of a film on the surface developed in the process of use or of some special process of formation; this film probably consists of the metal reduced from the oxides, thorium or the alkaline earth metal. When thoria is mentioned what is really meant is the surface film developed from it, which may transfer itself from the thoria to a neighbouring surface. Since it is usual to call "alkaline earth" the corresponding film that develops on the alkaline earths, this procedure should cause no confusion.

However, even if the presence of thermionically active material on the running electrode will not lead to the aforesaid evil, it remains to be considered whether it will do any good or lead to any other evil. The answer depends on what is meant by thermionically active; some attention must be given to this matter.

In a highly evacuated device the statement that X is more active thermionically than Y usually means that, if X and Y are held at the same temperature in the range relevant to the device, the saturated thermionic emission from X is greater than that from Y. In practice this usually implies that the work function of X is less than that of Y, although (since A in Richardson's equation is not an absolute constant) this is not theoretically necessary. But when the surface concerned is acting as an electrode of a high pressure discharge, it is not possible to determine experimentally either the saturated emission from it or the work function. Further it not permissible to assume that the state of the surface (and therefore the thermionic properties) is the same as that of the surface of a similar body in a

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vacuum. Accordingly, even if the temperature of the surface could be measured accurately, it would not be possible to decide which of two surfaces acting as such electrodes is the more active thermionically in the fundamental sense based on saturated emission or on work function.

On the other hand there are two properties observable in such circumstances which are known to be both closely correlated with thermionic activity in the fundamental sense and with each other. One of these is the ease with which the surface acts as the cathode of a gas discharge; if two geometrically similar surfaces are offered to a discharge as cathodes on which it may terminate, and if one of these surfaces is known to be much more active thermionically than the other in the fundamental sense, then the discharge will usually (if not always) terminate on the more active surface. The other concerns the heating of the cathode; if two discharges, otherwise similar, terminate on cathode surfaces of which one is known to be much more thermionically active than the other in the fundamental sense, then the more active surface will usually (if not always) receive less heat from the discharge than the less active.

It is clearly desirable that the running electrode should be thermionically active in this last sense. For since the object of the running electrodes is to reduce loss of material from the electrodes, and since high temperature is a primary cause of such loss, anything that will reduce the heating of the electrodes is desirable.

As regard ease of starting, the position is not quite so simple. If the thermionically active material on the running electrodes made it is as easy for the discharge to start on the running electrodes as on the starting electrodes, it would make the provision of starting electrodes unnecessary. But so long as it is less thermionically active in this sense than the material on the starting electrodes, the starting electrodes are still desirable. It may then have some slightly beneficial effect in making easier the transference of the discharge from the starting to the running electrodes.

The relation between alkaline earths, thoria and tungsten can now be restated more accurately thus. Thoria is less active thermionically than the alkaline earths in respect of ease of starting, and also much less volatile; it is more active thermionically than tungsten in respect of heating. In virtue of these facts the use of thoria on the running electrodes may be desirable. It may be true that thoria is less thermionically active than the alkaline earths in respect of heating and more thermionically active than tungsten in respect of starting; but these facts are relatively unimportant.

According to the invention in a H.P.M.V. device of the type specified, each running electrode which acts as cathode during the full operation of the device is supplied with thoria during that operation, whereby it is more thermionically active than tungsten in respect of heating and each main starting electrode spaced apart from a running electrode is provided with a store of material more active thermionically than thoria in respect of ease of starting.

The term "supplied with thoria" means that the part of the running electrode on which the discharge terminates need not be actually coated with thoria. For example, the running electrode may be composed of the known thoriated tungsten; or it may have thoria so closely adjacent to it that thoria diffuses on to it. Such a supply of active material by diffusion is well known when the thermionically active material is an alkaline earth; it is also possible when the material is thoria, although thoria may diffuse more slowly.

Finally, a matter which relates generally to running and starting electrodes may be mentioned. If the distance between starting and running electrodes or their difference in respect of ease of starting is not sufficient to ensure complete transference of the discharge, a partial transference may occur. The discharge when fed by A.C. may terminate at the same end on a running electrode when this end is anode and on a starting electrode when this end is cathode, so that the discharge in alternative half cycles follows different paths. This state of affairs may or may not be desirable, according to circumstances; but it is permissible according to the invention.

Dated the 20th day of May, 1937.
For the Applicants:
NORMAN R. CAMPBELL.

COMPLETE SPECIFICATION

Improvements in High-pressure Metal-vapour Electric Discharge Devices

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British Company, and VICTOR JAMES FRANCIS, a British Subject, and MARCELLO PIRANI, a German Citizen, both of Research Laboratories of The General Electric Company Limited, Wembley, Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to high-pressure metal-vapour electric discharge (H.P.M.V.) devices of the type having, at one end at least of the discharge path, a running electrode with which is associated a starting electrode, these electrodes being so constructed and arranged that during the run up the end of the discharge transfers itself automatically from the said starting to the said running electrode.

The use of separate starting and running electrodes is discussed in Patent Specifications Nos. 444,545, 472,658. It is there explained how the danger of cold spots behind the electrodes have hindered the use of starting and running electrodes; how starting electrodes are to be distinguished from auxiliary electrodes that initiate a subsidiary discharge; that the starting and running electrodes, though spaced apart, may be mechanically integral; and that, when the surface of an electrode is mentioned as affecting the discharge, that part alone of the surface is referred to, on which the discharge actually terminates.

In all the said discussions it is stated or indicated that the running electrode, being of refractory metal, should be free from any store of thermionically active material. This provision was inserted in the belief that any material substantially more active thermionically than a refractory metal would be so much more volatile than such metal that its presence on the running electrode would lead to the evils that the use of separate starting electrodes is intended to cure, resulting from transference of material from the electrodes to the envelope.

This belief has now proved to be unfounded. Thoria, though less active thermionically than the alkaline earths, is definitely more thermionically active than tungsten; but, it is not (like the alkaline earths) so much more volatile than tungsten and so liable to attack a vitreous envelope that its presence on the running electrodes necessarily leads to the said evils.

Here a word of explanation must be interpolated. Thoria itself is almost completely inactive thermionically, just as are the alkaline earths themselves. Its and their thermionic activity is known to be due to the presence of a film on the surface developed in the process of use or of some special process of formation; this film probably consists of the metal reduced from the oxides, thorium or the alkaline earth metal. When the thermionic properties of thoria are mentioned what is really meant is the properties of the surface film developed from it, which may transfer itself from the thoria to a neighbouring surface. Since it is usual to call "alkaline earth" the corresponding film that develops from the alkaline earths, this procedure should cause no confusion.

However, even if the presence of thermionically active material on the running electrode will not lead to the aforesaid evils, it remains to be considered whether it will do any good or lead to any other evil. The answer depends on what is meant by thermionically active; some attention must be given to this matter.

In a highly evacuated device the statement that X is more active thermionically than Y usually means that, if X and Y are held at the same temperature in the range relevant to the device, the saturated thermionic emission from X is greater than that from Y. In practice this usually implies that the work function of X is less than that of Y, although (since A in Richardson's equation is not an absolute constant) this is not theoretically necessary. But when the surface concerned is acting as an electrode of a high pressure discharge, it is not possible to determine experimentally either the saturated emission from it or the work function. Further it is not permissible to assume that the state of the surface (and therefore the thermionic properties) is the same as that of the surface of a similar body in a vacuum. Accordingly, even if the temperature of the surface could be measured accurately, it would not be possible to decide which of two surfaces acting as such electrodes is the more

active thermionically in the fundamental sense based on saturated emission or on work function.

On the other hand there are two properties observable in such circumstances which are known to be both closely correlated with thermionic activity in the aforesaid sense and with each other. One of these is the ease with which the surface acts as the cathode of a gas discharge; if two geometrically similar surfaces are offered to a discharge as cathodes on which it may terminate, and if one of these surfaces is known to be much more active thermionically than the other in the aforesaid sense, then the discharge will usually (if not always) terminate on the more active surface. The other concerns the heating of the cathode; if two discharges, otherwise similar, terminate on cathode surfaces, from which the same electronic current is drawn, of which one is known to be much more thermionically active than the other in the aforesaid sense, then the more active surface will usually (if not always) receive less heat from the discharge than the less active. The same is probably true of heating of the anode.

It is clearly desirable that the running electrode should be thermionically active in this last sense. For since the object of the running electrodes is to reduce loss of material from the electrodes, and since high temperature is a primary cause of such loss, anything that will reduce the temperature of the electrodes on which a given discharge terminates is desirable.

As regards ease of starting, the position is not so simple. If the thermionically active material on the running electrodes made it as easy for the discharge to start on the running electrodes as on the starting electrodes, starting electrodes would be unnecessary, at least in respect of their primary function. But so long as it is less thermionically active in this sense than the material on the starting electrodes, starting electrodes may still perform that function. The thermionically active material may then be beneficial in making easier the transference of the discharge from the starting to the running electrodes; for easier transference means that the distance between starting and running electrodes may be reduced, so that it is easier to avoid cold spots behind the electrodes.

The relation between alkaline earths, thoria and tungsten can now be restated more accurately thus. Thoria is less active thermionically than the alkaline earths in respect of ease of starting, and also much less volatile; it is more active thermionically than tungsten both in respect of heating and in respect of ease of starting. In virtue of these facts the use of thoria on the running electrodes may be desirable. It may be true that thoria is less thermionically active than the alkaline earths in respect of heating; but this fact is relatively unimportant.

According to the invention in a H.P.M.V. device of the type specified, at least one running electrode is so provided with a store of thoria that it is supplied with thoria during the full operation of the device, whereby it is more active thermionically than tungsten in respect of heating, and/or in respect of ease of starting, and/or in respect of the ease of transference of the discharge during the run-up, and the starting electrode associated with the said running electrode is provided with a store of material more active thermionically than thoria in respect of ease of starting.

If, as is usual, the H.P.M.V. device is to be operated on A.C., then both running electrodes are preferably provided with a store of thoria. If it is to be operated on D.C., the anode need not be associated with a main starting electrode, but it may still be usefully provided with a store of thoria to reduce the heating. Further, a matter which relates generally to running and starting electrodes may be mentioned. If the distance between starting and running electrodes is not sufficient to ensure complete transference of the discharge, a partial transference may occur. The discharge when fed by A.C. may terminate at the same end on a running electrode when this end is anode and on the associated starting electrode when this end is cathode, so that the discharge in alternative half cycles follows different paths. This state of affairs is not desirable, and is not permissible according to the invention; during full operation on A.C. the running electrode must act as cathode as well as anode.

The term " provided with a store of thoria " does not necessarily imply that the part of the running electrode on which the discharge terminates is actually coated with thoria. It may have thoria so closely adjacent to it that thoria diffuses or is distilled on to it. The supply of active material by diffusion and distillation is well known when the thermionically active material is an alkaline earth; it is also possible when the material is thoria, although thoria may diffuse more slowly.

Three embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, each of which represents a pair of associated running and starting elec-

trodes. The kind of H.P.M.V. lamp for which each pair is suitable will be stated.

In the embodiment of Figure 1, the running electrode 1 consists of 3½ turns of a close-wound helix of tungsten wire 0.35 mm. in diameter wound on a mandrel 1 mm. in diameter. These turns are coated with a suspension made by ball-milling for 100 hours a mixture of 100 gm. ThO_2 with 125 gm. of water and adding, just before use, 10 to 15 gm. of tungsten powder passing 200 mesh.

The starting electrode 2 consists of a rod of alkaline earth silicate 3 enclosed in an inner helix 4 enclosed in turn in an outer helix 5. The rod 3 is 1 mm. in diameter and 2 mm. long; the inner helix 4 is close-wound of 0.15 mm. tungsten wire on a mandrel 1 mm. in diameter. The outer helix, which is continuous with the helix 1, has 6 turns of 0.35 mm. wire on a mandrel 1.5 mm. in diameter.

The electrode is suitable for a 125 watt lamp with a quartz tubular envelope of 8 mm. bore, operating with 145 volts across an arc length of 30 mm. The utmost precautions must be taken in pumping to degas the envelope and the electrodes. Since there is only one lead to each electrode, the electrodes should be degassed by heating the envelope externally, both when the envelope is evacuated and when it is filled with hydrogen and by subsequent bombardment. During this treatment the electrode should reach so high a temperature that the tungsten and thoria sinter together.

In the embodiment of Figure 2, the running electrode is the tungsten rod 6 coated with thoria on its exposed surface. The rod is 1 mm. in diameter and 5 mm. long, 2 mm. being exposed. The rod is heated in hydrogen and the exposed part coated with the thoria-tungsten suspension aforementioned. It is then sintered in wet hydrogen for 30 minutes at 1500° C. The unexposed portion is then introduced into the helix 7, which is 7 mm. long and wound of 0.4 mm. tungsten wire on a 1 mm. mandrel. The rest of this helix is filled by a helix 8 wound of 0.2 mm. tungsten wire on a 0.6 mm. mandrel, enclosing a rod 9 of alkaline earth silicate. An outer helix 10 wound of 0.4 mm. tungsten wire on a 1.75 mm. mandrel extends from the back of the helix 7 to about half-way along the rod 6; it serves as the starting electrode. The pitches of all the helices are between 100% and 120%. The back end of helix 10 is welded to the leading-in-wire.

This electrode is suitable as the lower electrode of a 250 watt lamp with a tubular quartz envelope of 13 mm. bore, adapted to operate with 160 volts across a vertical arc 35 mm. long. It would be suitable for the upper electrode of such a lamp if the exposed part of the rod 6 were somewhat longer. The treatment of the electrode during pumping should be similar to that described with reference to the previous embodiment; but, since the sintering has been carried out, there is no need for further sintering.

In the embodiment of Figure 3, the helix 11 consists of 9 turns of 0.4 mm. tungsten wire wound with a pitch of 150% on a 2 mm. mandrel. The front two turns are covered with a helix 12 of 0.3 mm. tungsten wire close-wound on a 0.4 mm. mandrel. These turns are coated with the thoria-tungsten suspension aforementioned, and form the running electrode. The remaining turns enclose a rod 13 of alkaline earth silicate, 2 mm. in diameter, whose front end extends to within about 1 mm. of the front end of the helix 11. Both ends 14 and 15 of this helix are attached to leading-in-wires, so that the electrode can be degassed by passing current through the helix. It is preferable, as before to heat the electrode in hydrogen; partly in order to sinter the tungsten and thoria together.

This electrode is suitable for a 250 watt lamp with an envelope of refractory glass 26 mm. in bore, adapted to operate with 150 volts across an arc length of 120 mm.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is:—

1. A high pressure metal-vapour electric discharge (H.P.M.V.) device of the type specified wherein at least one running electrode is so provided with a store of thoria that it is supplied with thoria during the full operation of the device, whereby it is more active thermionically than tungsten in respect of heating, and/or in respect of care of starting, and/or in respect of ease of transference of the discharge during the run-up, and the starting electrode associated with the said running electrode is provided with a store of material more active thermionically than thoria in respect of ease of starting.

2. A H.P.M.V. device according to Claim 1 wherein the store of thoria is a mixture of thoria and tungsten powder.

3. A H.P.M.V. device according to Claim 1 wherein the said running and starting electrodes are mechanically integral.

4. A H.P.M.V. device comprising a pair of associated running and starting electrodes constructed substantially as hereinbefore described with reference to

trodes. The kind of H.P.M.V. lamp for which each pair is suitable will be stated.

In the embodiment of Figure 1, the running electrode 1 consists of 3½ turns of a close-wound helix of tungsten wire 0.35 mm. in diameter wound on a mandrel 1 mm. in diameter. These turns are coated with a suspension made by ball-milling for 100 hours a mixture of 100gm. ThO_2 with 125 gm. of water and adding, just before use, 10 to 15 gm. of tungsten powder passing 200 mesh.

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In the embodiment of Figure 2, the running electrode is the tungsten rod 6 coated with thoria on its exposed surface. The rod is 1 mm. in diameter and 5 mm. long, 2 mm. being exposed. The rod is heated in hydrogen and the exposed part coated with the thoria-tungsten suspension aforementioned. It is then sintered in wet hydrogen for 30 minutes at 1500° C. The unexposed portion is then introduced into the helix 7, which is 7 mm. long and wound of 0.4 mm. tungsten wire on a 1 mm. mandrel. The rest of this helix is filled by a helix 8 wound of 0.2 mm. tungsten wire on a 0.6 mm. mandrel, enclosing a rod 9 of alkaline earth silicate. An outer helix 10 wound of 0.4 mm. tungsten wire on a 1.75 mm. mandrel extends from the back of the helix 7 to about half-way along the rod 6; it serves as the starting electrode. The pitches of all the helices are between 100% and 120%. The back end of helix 10 is welded to the leading-in-wire.

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This electrode is suitable for a 250 watt lamp with an envelope of refractory glass 26 mm. in bore, adapted to operate with 150 volts across an arc length of 120 mm.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is:—

1. A high pressure metal-vapour electric discharge (H.P.M.V.) device of the type specified wherein at least one running electrode is so provided with a store of thoria that it is supplied with thoria during the full operation of the device, whereby it is more active thermionically than tungsten in respect of heating, and/or in respect of care of starting, and/or in respect of ease of transference of the discharge during the run-up, and the starting electrode associated with the said running electrode is provided with a store of material more active thermionically than thoria in respect of ease of starting.

2. A H.P.M.V. device according to Claim 1 wherein the store of thoria is a mixture of thoria and tungsten powder.

3. A H.P.M.V. device according to Claim 1 wherein the said running and starting electrodes are mechanically integral.

4. A H.P.M.V. device comprising a pair of associated running and starting electrodes constructed substantially as hereinbefore described with reference to

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Figure 1, 2, or 3 of the accompanying drawings.

5. A H.P.M.V. lamp according to Claim 4 wherein the envelope and the arc length are substantially as hereinbefore described in connection with Figure 1, 2, or 3 respectively.

Dated the 30th day of March, 1938.

NORMAN R. CAMPBELL,
For the Applicants.

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