Oct. 30, 1928. 1,689,970

E. Y. ROBINSON

VACUUM TUBE AND THE LIKE

Filed Oct. 11, 1923 2 Sheets-Sheet 1

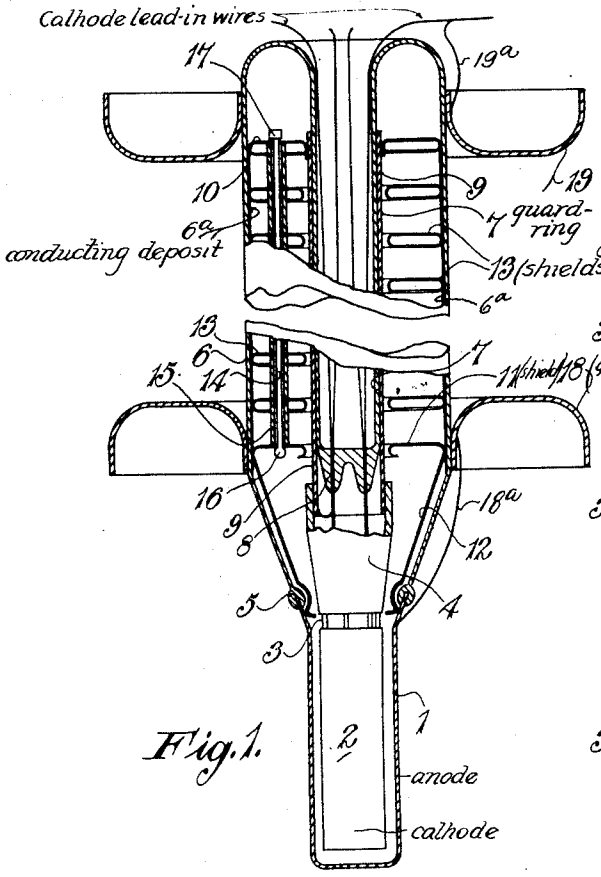


Fig. 1.

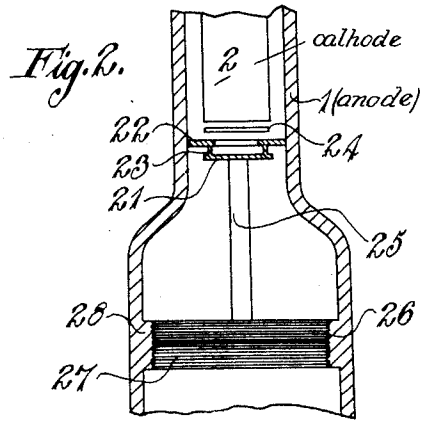


Fig. 2.

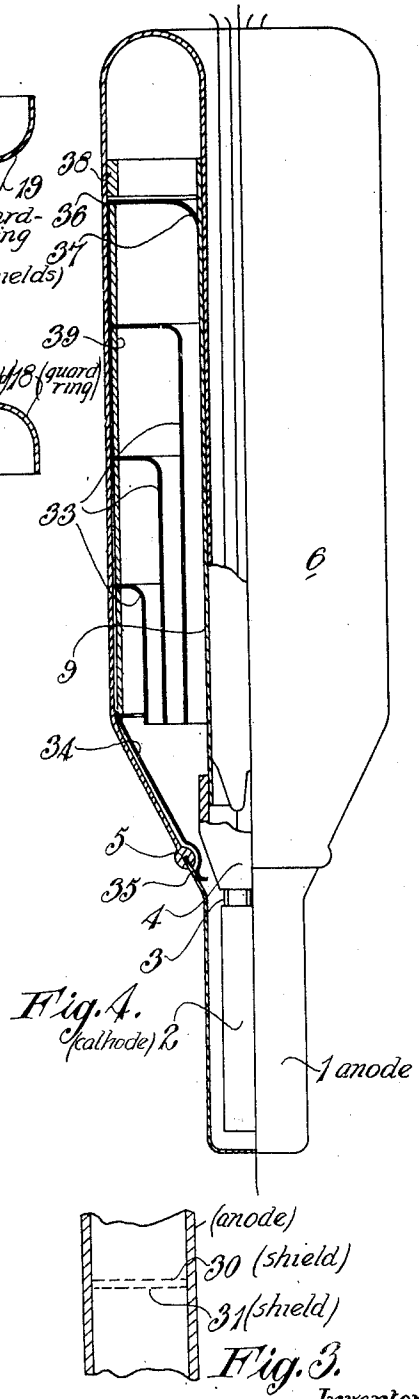


Fig. 4.

Fig. 3.

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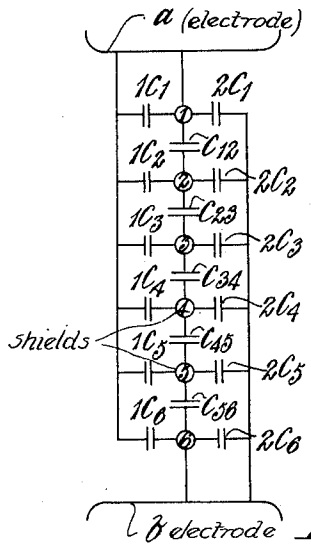


Fig. 5.

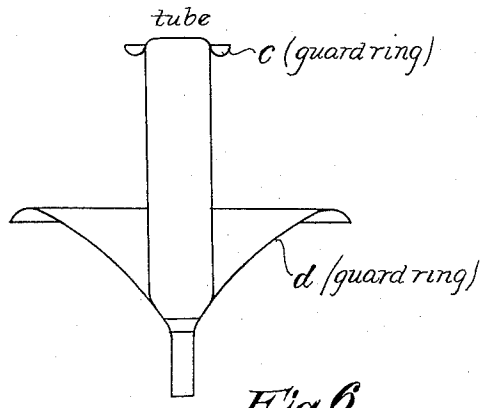


Fig. 6.

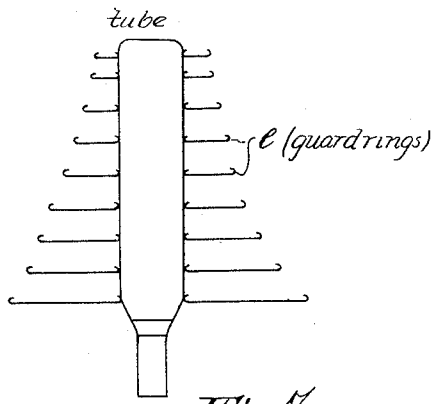


Fig. 7.

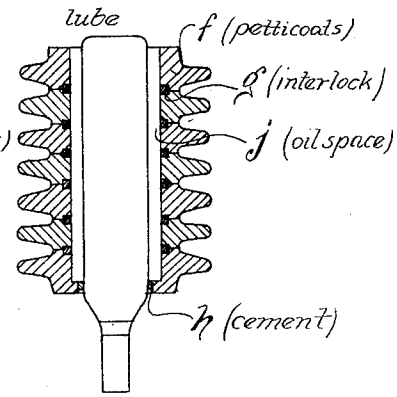


Fig. 8.

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Patented Oct. 30, 1928. 1,689,970

UNITED STATES PATENT OFFICE.

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VACUUM TUBE AND THE LIKE.

Application filed October 11, 1923, Serial No. 667,922, and in Great Britain October 18, 1922.

This invention relates to vacuum electric devices and has particular relation to such devices, for example, as thermionic valves, mercury arcs, gaseous discharge devices, vacuum condensers and the like, in which the vacuum is not perfect, that is to say, gas is present which may be either highly rarefied or else at a relatively high pressure.

The object of the invention is to prevent undesirable gaseous discharges occurring in such devices, for example between the leading in wires. That is to say, the invention is intended to be applied to a vacuum electric device for the prevention of gaseous discharges therein, or alternatively where the device depends for its operation on a gaseous discharge the object of the invention is to prevent undesirable discharges for example between the leading in wires or at the edges of the electrodes thereof.

Considering the case in which two electrodes are immersed in a gas and the discharge between the electrodes is confined to the inter-electrode space by any suitable means such for example as a vitreous container fitting close up to the electrode, the voltage, which may be applied between the electrodes before a glow discharge occurs, increases rapidly as the distance between the electrodes is decreased when the length of the gap is below a certain minimum value, which depends on the nature of the gas and the pressure thereof. It therefore follows that a gaseous discharge between the two electrodes in an evacuated device may be prevented by making the separation between the electrodes sufficiently small. It is necessary, however, to prevent a gaseous discharge of such a nature that the electrons and positive ions of the discharge follow the paths of the fringing electrostatic flux at the edges of the cathodes because such paths are long and only limited in length by the walls of the vacuum container; that is to say, the discharge, if permitted to occur, must be confined to the inter-electrode space. Heretofore, in experiments which have been conducted on this phenomenon, the discharge has been confined to the inter-electrode space by means of suitably disposed insulating material. Such an arrangement suffers from several disadvantages. Firstly the short length of insulating material between the electrodes is highly stressed on its surface and hence many undesirable effects occur. For example, there is surface leakage, the insulating material becomes charged up and secondary emission of electrons from the insulating material takes place. This effect is serious because for the tube to withstand a high voltage the gap between the electrodes must be decreased from the point of view of preventing a gaseous discharge, while from the point of view of preventing breakdown of the insulating material surface the gap must be increased. There is therefore a limitation to the voltage which can be applied to such an arrangement. Secondly the gap outside the evacuated device must be long in order to prevent a flash-over; in consequence of this the stress outside the walls of the insulating container does not correspond to the stress inside the walls, and this results in an undesirable transverse stress.

According to the invention the gap between the electrodes and the like is made short enough to prevent gaseous discharges or, in the case of gaseous discharge devices to prevent undesirable gaseous discharges, and the gap where it is in the proximity of insulating material is made sufficiently long to prevent breakdown of the surface of the material and flash-over outside the tube, and for this purpose shields or screens are employed which are so disposed that they break up the long gap and provide a plurality of gaps which are in series with each other.

In operation the shields become graded by the flow of a small leakage current which is due to the initial ionization present in the gas. Such grading may be supplemented in a manner to be hereinafter described. Assuming that the conditions are such that the shields are uniformly graded, the voltage across each gap is reduced; moreover the length of each gap is decreased so that not only is each individual gap capable of withstanding a higher voltage but the voltage applied across each gap is made less. For example in a tube in which the total voltage across the device is V, if N shields are employed N+1 gaps are created and the voltage across each gap is $\frac{V}{N+1}$. Furthermore as pointed out the breakdown voltage of each gap is increased. Hence by providing a suf-

ficient number of gaps in series it becomes possible to insulate the device for any practical voltage.

As an example of the effectiveness of this arrangement, in the simple case of a glow discharge tube containing electrodes 70 cm. apart and fitting close up to the walls of the tube so that the discharge which occurs is confined to the inter-electrode space and with mercury vapour present at a pressure of 2 bars it was found that the tube breaks down at about 3 to 5 thousand volts. This breakdown voltage remains substantially constant as the separation is decreased down to 6 cm; thereafter it rises with a further decrease of gap. However, this rising portion of the curve is generally masked because the surface of the glass breaks down. With the electrodes at the 70 cm. separation and 20 shields inserted so as to form twenty-one gaps in series the tube withstood 150,000 volts without any signs of breakdown.

In order that the invention may be clearly understood reference will be made to the accompanying drawings in which Fig. 1 illustrates partly in section and partly in elevation a vacuum valve constructed in accordance with the invention; Figs. 2 and 3 are sectional elevations of parts of the arrangements shown in Fig. 1 showing two modifications; Fig. 4 is a view half in section and half in elevation showing another modification of the invention; Fig. 5 is an electrical diagram and Figs. 6, 7 and 8 show various arrangements of guard rings.

Referring to Fig. 1, the vaccum electric device therein illustrated comprises an anode 1 and a cathode 2 having a small gap therebetween which is short enough to prevent gaseous discharge. The anode consists of a closed copper tube which is sealed to the vitreous tube 6 at 5. The seal may be, for example, a plain copper to glass seal or alternatively the metal in the neighbourhood of the seal may have a coefficient of expansion equal to that of the glass employed. The vitreous tube 6 carries a re-entrant tube 7 which carries the metal tube 9 and the seals for the various lead-in wires of the device. The combination of the tubes 1, 6 and 7 forms the exhausted envelope of the vacuum valve. The cathode 2 consists preferably of a tungsten tube heated by suitable means, for example by a thermionic bombardment. The cathode is not shown in detail herein, but it may be constructed, for example, in accordance with one of the cathodes shown and described fully in my prior applications, Serial No. 653,554, filed July 24, 1923, and Serial No. 671,570, filed October 29, 1923. It is supported by the stems 3 which are suitably mounted in a metal holder which is supported from the metal tube 9 said metal tube being arranged to lie on and grip the re-entrant glass tube 7. The end of the tube 9 which is remote from the electrodes is arranged in electrical contact with the shield 10 as shown in the figure. It will be seen that the gap between the electrodes is small and the gap in the proximity of the insulating tube is long. The stress across this long gap is confined between the end shield 11 and the shield 10 by connecting the shield 11 to the anode. In the example shown this is effected by means of the conical tube 12 which is made integral with the shield 11 and is so designed that it shields the seal 5 from electrostatic strain. The cathode supporting stems 3 may be shielded from electrostatic strain by means of the shield 4. The gap between the shields 10 and 11 being long a glow discharge would normally occur. In accordance with this invention this glow discharge is prevented by interposing a plurality of shields such as 13 which break up the gap between 10 and 11 into a plurality of gaps in series with each other. By providing sufficient length of gap between the shields 10 and 11 and the requisite number of shields to prevent glow discharge taking place the tube may be made to withstand a very high voltage. Shields or guard rings such as 18 and 19 may be arranged outside the device and electrically connected to the end shields 10 and 11, as by conductors 18^a and 19^a, in order to make the electrical stress outside the tube correspond to the electrical stress inside the tube and to protect the seals from electrostatic strain. The shields 13 and also the end shields 10 and 11 are conveniently flanged, beaded or the like in order effectively to trap the electrons and also in order to prevent local stresses in the glass or in the residual vapour in the valve which would start a discharge. Sharp edges from which the electrons may be pulled out by high concentration of electrostatic strain are also avoided. A convenient cross section of these shields is illustrated.

In order to assemble the tubes in a simple manner the shields 13, which consist of rings, and the end shields 10 and 11 are rigidly fixed to each other by means of three glass rods 14 and glass spacing washers or tubes 15. The rods 14 are each provided with knobs or enlargements 16 at one end and the shields and washers are firmly fixed by means of metal rings 17 which are tied on to the other ends of the rods. The whole shielding system is then slid into the valve before sealing up the re-entrant tube 7 to the outer tube and is forced down so that the shield 11 makes electrical contact with the anode 1. The re-entrant tube is then sealed to the outer tube.

Referring to Fig. 2 which illustrates a modification of the arrangement shown in Fig. 1 in the vicinity of the bottom end of the cathode, such modification being suitable when the relay is continuously evacuated during operation. The lower end of the anode 1 may be connected to a vacuum pump which

is not shown but may be for example of the mercury vapour type. The cathode 2 is provided with a shield 24 for the purpose of reducing ionization as described in the specification of Serial No. 603,715, filed November 27, 1922. The annulus 22 is attached to the disc 21 by means of the stems such as 23, and this combination provides a shield which effectively prevents the formation of a gaseous discharge and permits gas to be pumped therethrough. The shield is in electrical contact with the anode 1 and is supported by the stem or rod 25 which is itself supported by a ring 26 which is screwed into an extension of the anode at 28. This ring 26 is locked into position by means of the locking ring 27. The rings 26 and 27 are provided with holes or apertures to permit the gas which is being pumped to pass therethrough.

Alternatively the shield at the end of the anode may have a grid like structure or be comprised of a sheet of metal with a number of fine holes therein. Two or more of such shields may be employed having holes which are staggered relatively to each other. Fig. 3 illustrates such a device. The shield 30 is provided with a series of holes which are staggered relatively to the holes in the shield 31.

Referring to Fig. 4 which illustrates another modification of a vacuum valve of the type described with reference to Fig. 1, the anode is shown at 1 and the vitreous tube at 6 as before. The shield 34 protects the seal 5 from electrostatic strain and is in electrical contact with the anode 1. The gap between the shield 34 and the tube 9 is made sufficiently small to prevent the formation of a gaseous discharge. Shields 33 which consist of flanged metal tubes are inserted in the device as shown and are spaced apart by means of glass tubes such as 39. A further shield 36 is arranged in electrical contact with the tube 9 by means of a flexible curtain 37, this construction being adopted to permit the device being easily assembled, and the whole of the shields and glass separating tubes are held firmly in position by being pressed up by means of a clamping ring 38 against the conical shield 34 which itself is held by the conical end portion of the vitreous tube 6. The clamping ring 38 may consist for example of a metal ring expanding internally on to the glass tube 6 and is suitably locked in position.

It will be seen that in accordance with this invention the length of vitreous material between the two electrodes is made long and ionization is prevented in the long path by the arrangement of the shields. It will be noticed that if sufficient shields are employed the distribution of electric field in the device is not greatly altered from the distribution which would occur if no discharge-preventing shields were employed.

It is obvious that the shields which are employed in the evacuated tube will assume some potential, that is to say, the voltage along the tube will be graded or speaking broadly, the shields will be graded. By suitable means this grading of the shields may be made uniform so as to produce the most efficient design of tube and shields from the point of view of preventing gaseous discharge. On constant potentials the grading will automatically become approximately uniform owing to the leakage current flowing in the tube due to ions initially present.

The shields may be graded by suitably adjusting the component electrical admittance between the electrodes and themselves and between each other. The shields may be connected to tappings on a high resistance connected with the two electrodes so that they are charged to a definite potential whereby supplementary grading is obtained. This high resistance may consist of a deposit of conducting material on an interior insulating surface. The deposit may consist of carbon or of gold, tungsten, molybdenum, nickel or any other suitable metal, and may be deposited on the inner wall of the envelope of the vacuum device and the shields arranged to be in electrical contact with the deposit on said wall, as indicated, for example, at 6^a, Fig. 1. It will be seen that the effect is to connect the shields to a definite potential source provided in the case described above by tappings on a resistance connected to the two electrodes of the device. Other suitable methods of obtaining the potential may, however, be employed. It can be arranged that the shields are graded by varying the electrical capacity of the shields to each electrode and to each other. By suitably varying these capacities of the shields a uniform or any other desired grading may be produced. The equivalent circuit diagram is illustrated in Fig. 5 wherein the two electrodes and their guard rings are represented at *a* and *b*. The shields are represented by the circles numbered 1 to 6 inclusive. The capacities of the shields to each other, hereinafter referred to as component capacities, are denoted by the letter "C" with prefix and suffix numerals corresponding with the numbers of the circles. The capacities to the electrode "*a*" are denoted by the prefix 1 and those between the shields and the electrode "*b*" by the prefix 2. The suffix numerals of these two series of component capacities denote the several shields and the corresponding component capacities. The component capacity between adjacent shields is represented by the letter "C" followed by suffixes corresponding to the adjacent shields. The diagram only illustrates the electrical circuit approximately; for accuracy it will be necessary to represent the component capacities between the shields which are not adjacent. However, for the purpose of this description it is sufficient to consider only the capacities referred to above.

By varying these component capacities the grading of the shields may be altered as desired and is preferably made uniform. The component capacities may be given the desired values by suitably proportioning the two guard rings connected to the electrodes and also the dimensions of the shields themselves, although the proportioning of the former is generally the most important. At the same time grading may be simplified by employing a much larger number of shields than is requisite to prevent glow discharge in order that the inter-component capacities may swamp out the other capacities. The shields may also be graded by being capacitatively coupled to guard rings mounted on the outside of the tube as shown in Fig. 7. In Fig. 6 two guard rings *c* and *d* are illustrated which have been found suitable with one specific arrangement of the device. The dimensions of the guard rings even for the same device will vary largely as the electrodes are at a high or low potential with respect to earth. In Fig. 7 guard rings *e* are affixed outside the tubes and by their capacitative coupling to the shields inside assist in further grading the shields uniformly if they themselves are uniformly graded.

Alternatively, a combination of these methods of grading may be employed the grading due to the various methods being similar and the grading being preferably uniform. By this means the grading will remain the same when both direct and alternating potentials are applied to the valve.

It should be noted that at high frequencies it is very essential to grade the shields, since otherwise one gap only would break down, the other gap being free from glow discharge.

The tube may be provided with petticoats on its external surface in order to increase the leakage path outside the tube. Fig. 8 illustrates one convenient arrangement of such petticoats. The tube is constructed as hereinbefore described and glass or porcelain petticoat units such as *f* interlock into each other at *g* and are cemented to each other and to the tube at *h*. The space *j* within the petticoats is filled with oil.

It will be understood that various modifications may be made in the shape and disposition of the parts without departing from the scope of the invention.

I claim as my invention:—

1. In a vacuum electric device having a hermetically sealed envelope, conducting members arranged to be operated at high potential difference for the production within the envelope of a predetermined electric phenomenon between predetermined parts of their surfaces, and a bridge of insulating material holding said members in position, said bridge being of sufficient length to prevent surface discharge across it, the space between said surface parts of the conducting members other than directly between said members being divided into a plurality of gaps in series which are individually of such short length as to prevent ionization in said space.

2. A vacuum electric device comprising an envelope formed at least in part of insulating material and containing an ionizable rarefied atmosphere, conducting members arranged to have a high potential difference applied between them for the production within the envelope of a predetermined electric phenomenon between predetermined parts of their surfaces, said members being mechanically held in position by a bridge of the envelope insulating material of such length that surface discharge thereacross is prevented, and at least one shield dividing the space between other surface parts of said conducting members into a plurality of gaps in series which are individually of such short length that ionization in said space is prevented.

3. A vacuum electric device comprising an envelope formed at least in part of insulating material and containing an ionizable rarefied atmosphere, conducting members adapted to have a high potential difference applied between them and having predetermined parts of their surfaces so closely spaced apart that ionization therebetween is prevented, said members being mechanically held in position by a bridge of the envelope insulating material of such length that surface discharge thereacross is prevented, and at least one shield dividing the space between other surface parts of said conducting members into a plurality of gaps in series which are individually of such short length that ionization in said space is prevented.

4. A vacuum electric device comprising an envelope formed at least in part of insulating material and containing an ionizable rarefied atmosphere, conducting members arranged to have a high potential difference applied between them for the production within the envelope of a predetermined electric phenomenon between predetermined parts of their surfaces, said members being mechanically held in position by a bridge of the envelope insulating material of such length that surface discharge thereacross is prevented, and at least one shield dividing the space between other surface parts of said conducting members into a plurality of gaps in series which are individually of such short length that ionization in said space is prevented, the component electrical admittance to each shield being adjusted so that said gaps receive a substantially uniform electrical grading effect.

5. A vacuum electric device comprising an envelope formed at least in part of insulating material and containing an ionizable rarefied atmosphere, conducting members arranged to have a high potential difference applied

between them for the production within the envelope of a predetermined electric phenomenon between predetermined parts of their surfaces, said members being mechanically held in position by a bridge of the envelope insulating material of such length that surface discharge thereacross is prevented, at least one shield dividing the space between other surface parts of said conducting members into a plurality of gaps in series which are individually of such short length that ionization in said space is prevented, and a high resistance connected between each shield and the conducting members so as to produce a supplementary substantially uniform electrical grading effect along the gaps.

6. A vacuum electric device comprising an envelope formed at least in part of insulating material and containing an ionizable rarefied atmosphere, conducting members arranged to have a high potential difference applied between them for the production within the envelope of a predetermined electric phenomenon between predetermined parts of their surfaces, said members being mechanically held in position by a bridge of the envelope insulating material of such length that surface discharge thereacross is prevented, a plurality of shields dividing the space between other surface parts of said conducting members into a plurality of gaps in series which are individually of such short length that ionization in said space is prevented, and a high resistance consisting of a deposit of conducting material on an interior insulating surface between said conducting members, said shields making tapping connection along said resistance so that the gaps receive a supplementary substantially uniform electrical grading effect.

7. A vacuum electric device comprising an envelope formed at least in part of insulating material and containing an ionizable rarefied atmosphere, conducting members arranged to have a high potential difference applied between them for the production within the envelope of a predetermined electric phenomenon between predetermined parts of their surfaces, said members being mechanically held in position by a bridge of the envelope insulating material of such length that surface discharge thereacross is prevented, at least one shield dividing the space between other surface parts of said conducting members into a plurality of gaps in series which are individually of such short length that ionization in said space is prevented, external members connected with said conducting members, and guard rings electrically connected with said terminals for reducing the transverse stress in the material of the envelope.

8. A vacuum electric device comprising an envelope formed at least in part of insulating material and containing an ionizable rarefied atmosphere, conducting members arranged to have a high potential difference applied between them for the production within the envelope of a predetermined electric phenomenon between predetermined parts of their surfaces, said members being mechanically held in position by a bridge of the envelope insulating material of such length that surface discharge thereacross is prevented, at least one shield dividing the space between other surface parts of said conducting members into a plurality of gaps in series which are individually of such short length that ionization in said space is prevented, external terminals connected with said conducting members with a long leakage path between them, guard rings connected with said terminals, and a plurality of further guard rings between the first mentioned guard rings for reducing the transverse stress in the material of the envelope and assisting in producing a uniform grading of said shields by their capacitative coupling therewith.

In testimony whereof I have hereunto subscribed my name this 27th day of September, 1923.

ERNEST YEOMAN ROBINSON.