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Sablev et al.

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[45] **Feb. 19, 1974**

[54] **APPARATUS FOR METAL EVAPORATION COATING**

[76] Inventors: **Leonid Pavlovich Sablev**, ulitsa Entuziastov, 3, kv. 51; **Nikolai Petrovich Atamansky**, bulvar Mira, 2, kv. 8; **Valentin Nikolaevich Gorbunov**, ulitsa Vesnina, 7, kv. 19; **Jury Ivanovich Dolotov**, bulvar Mira, 2, kv. 50; **Vadim Nikolaevich Lutseenko**, prospekt Kurchatova, 13, kv. 21; **Valentin Mitrofanovich Lunev**, ulitsa Entuziastov, 5, kv. 37; **Valdislav Vasilievich Usov**, prospekt Kurchatova, 27, kv. 34, all of Kharkov, U.S.S.R.

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[51] **Int. Cl.** .. **C23c 15/00,** C23c 11/00, C23c 13/12

[58] **Field of Search** .... 204/192, 298; 219/121 R; 313/157, 197, 173; 117/93.1 R; 93/1 CD; 118/49.1

[56] **References Cited**

UNITED STATES PATENTS

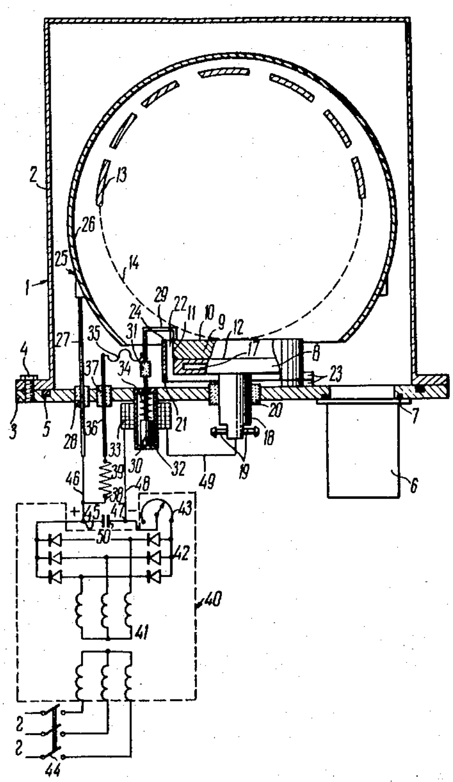
3,661,758	5/1972	Jackson et al.	204/298
3,719,582	3/1973	Hansen et al.	204/298
3,625,848	12/1971	Snaper	204/298
2,972,695	2/1961	Wroe	313/157

Primary Examiner—John H. Mack
Assistant Examiner—D. R. Valentine
Attorney, Agent, or Firm—Holman & Stern

[57] **ABSTRACT**

An apparatus for metal evaporation coating, comprising an evacuated chamber, an anode made as an envelope of arbitrary shape, a cathode made of the metal being evaporated, the evaporation surface of said cathode facing the space defined by said envelope, a trigger electrode generating a cathode spot on the cathode, means for retaining the cathode spot on the cathode in the form of a shield, and an electric arc supply.

7 Claims, 9 Drawing Figures



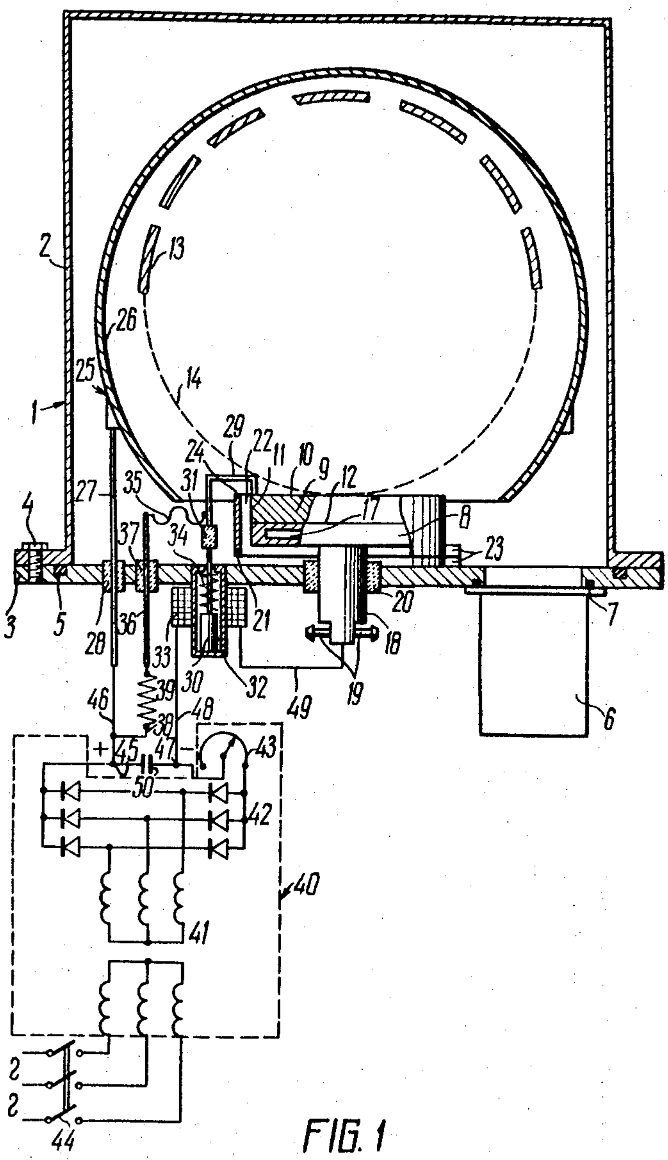

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FIG. 1

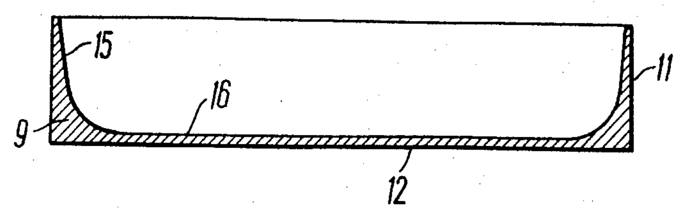
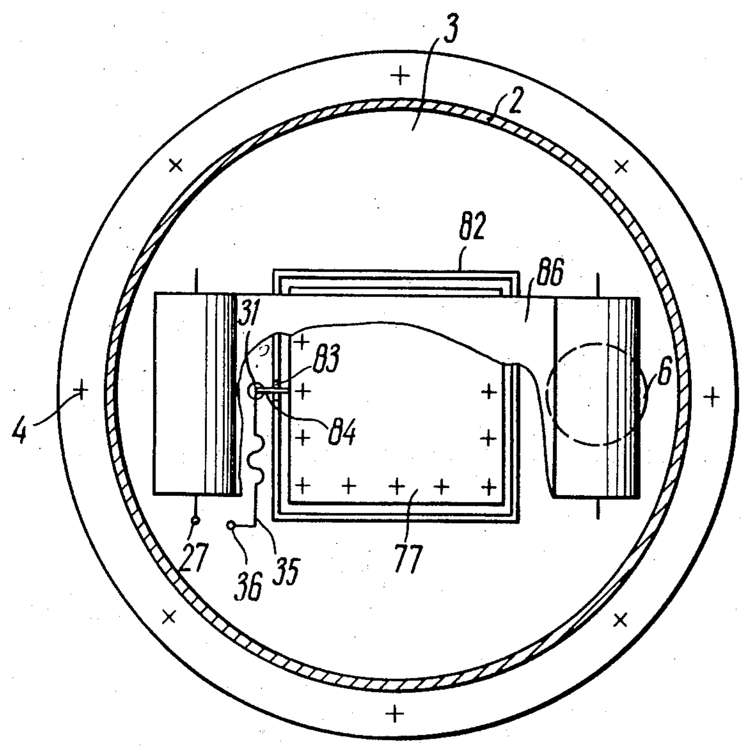


FIG. 2



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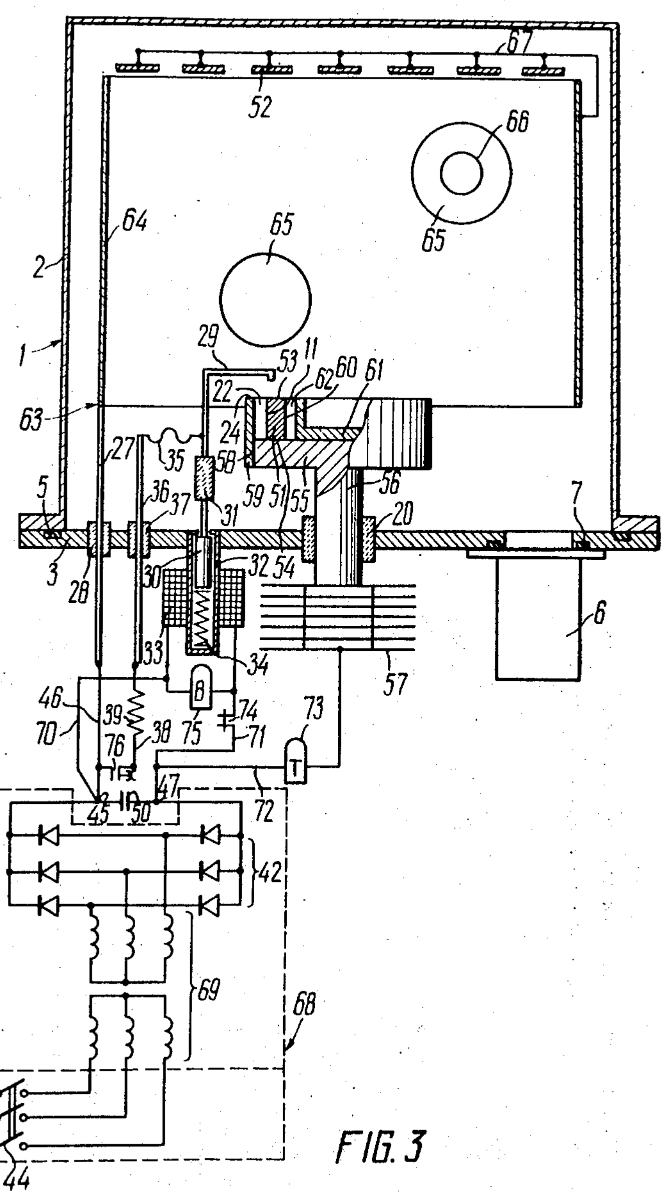
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FIG. 3

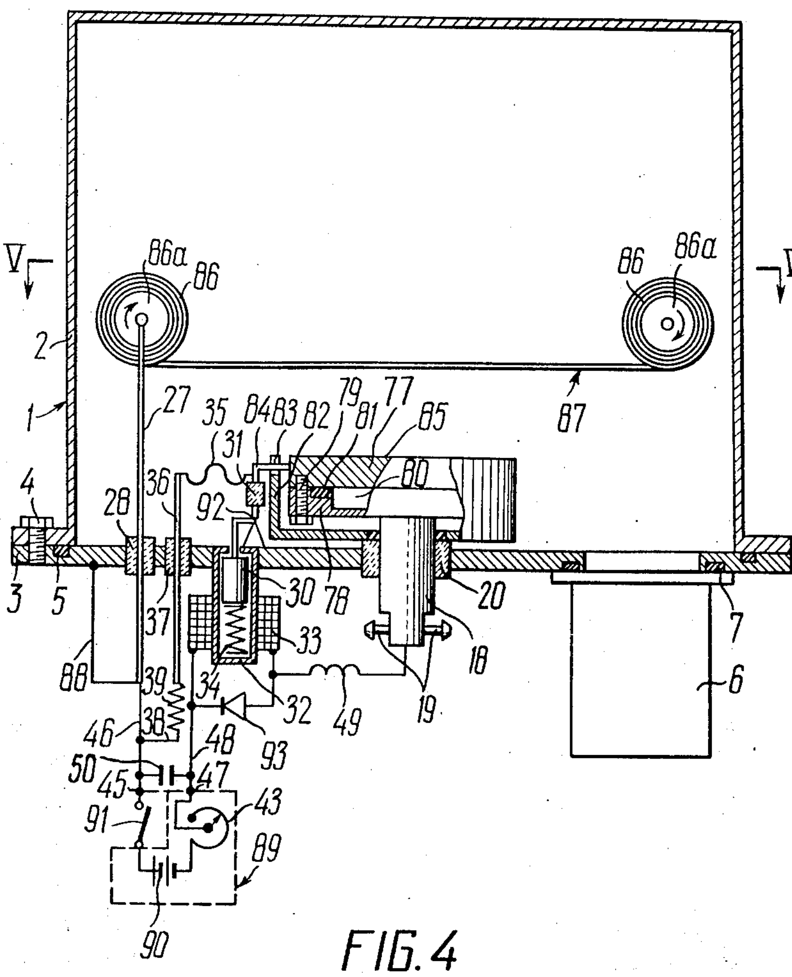
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FIG. 4

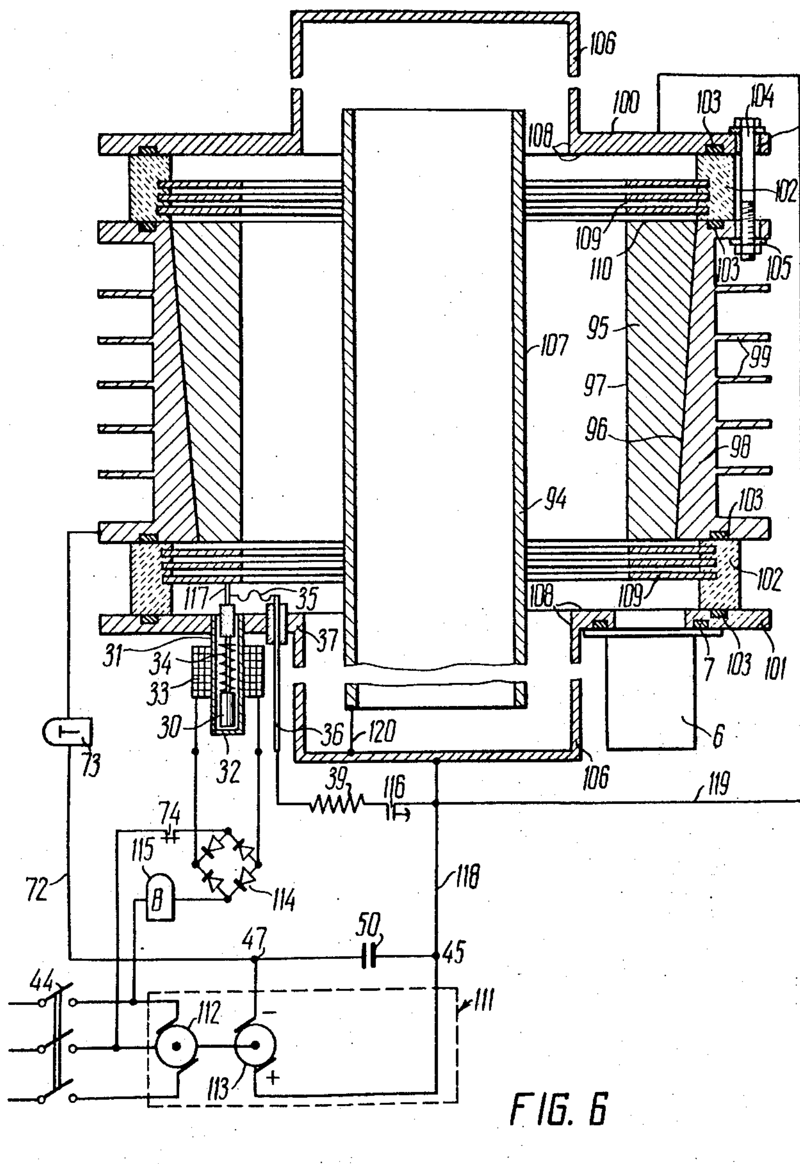
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FIG. 6

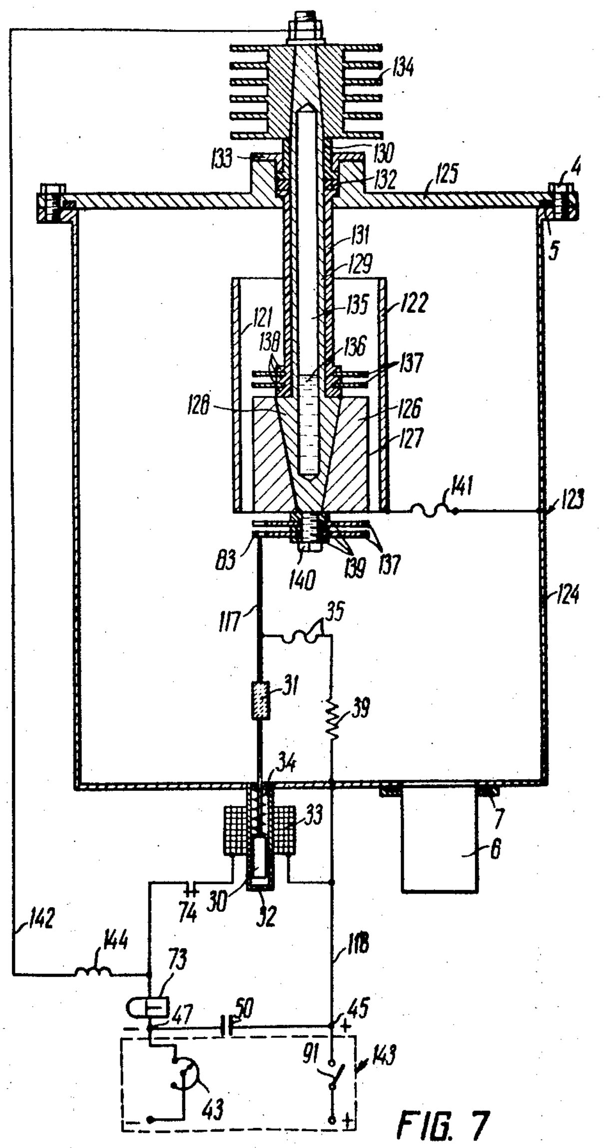
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FIG. 7

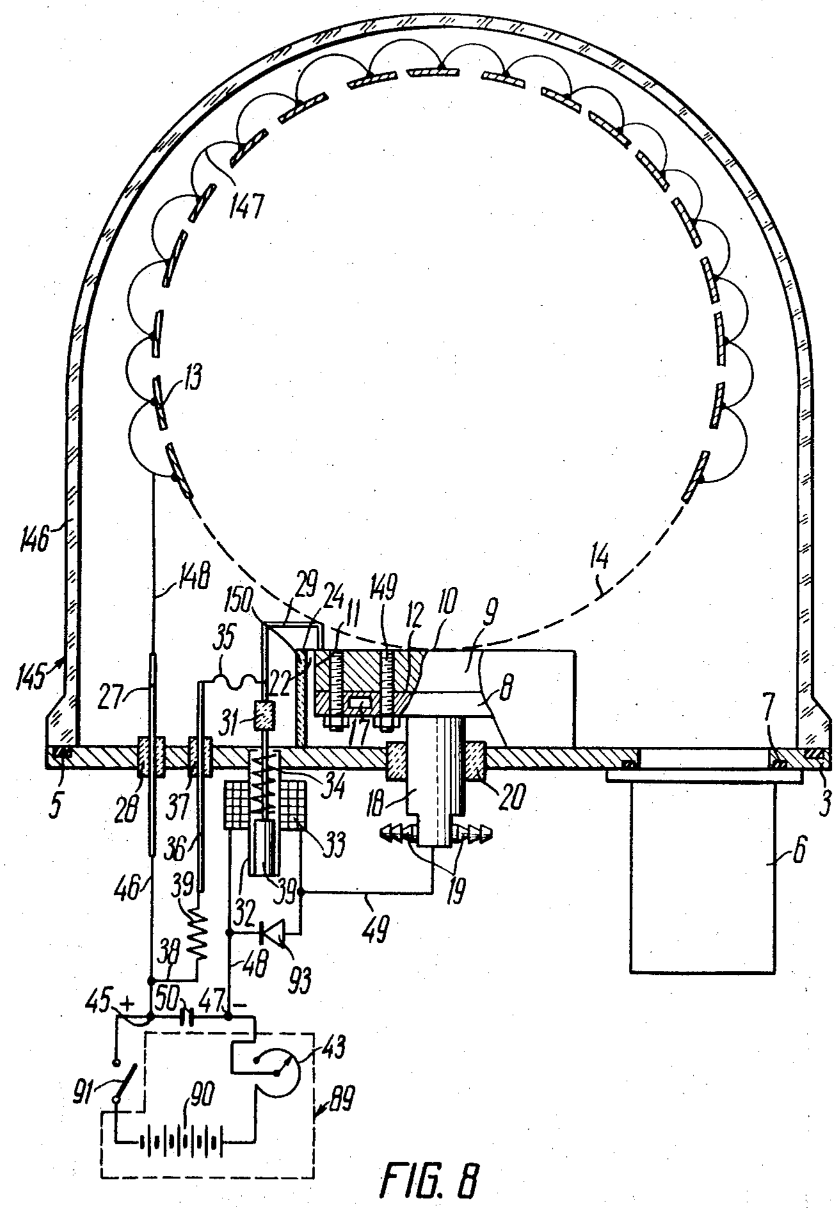
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FIG. 8

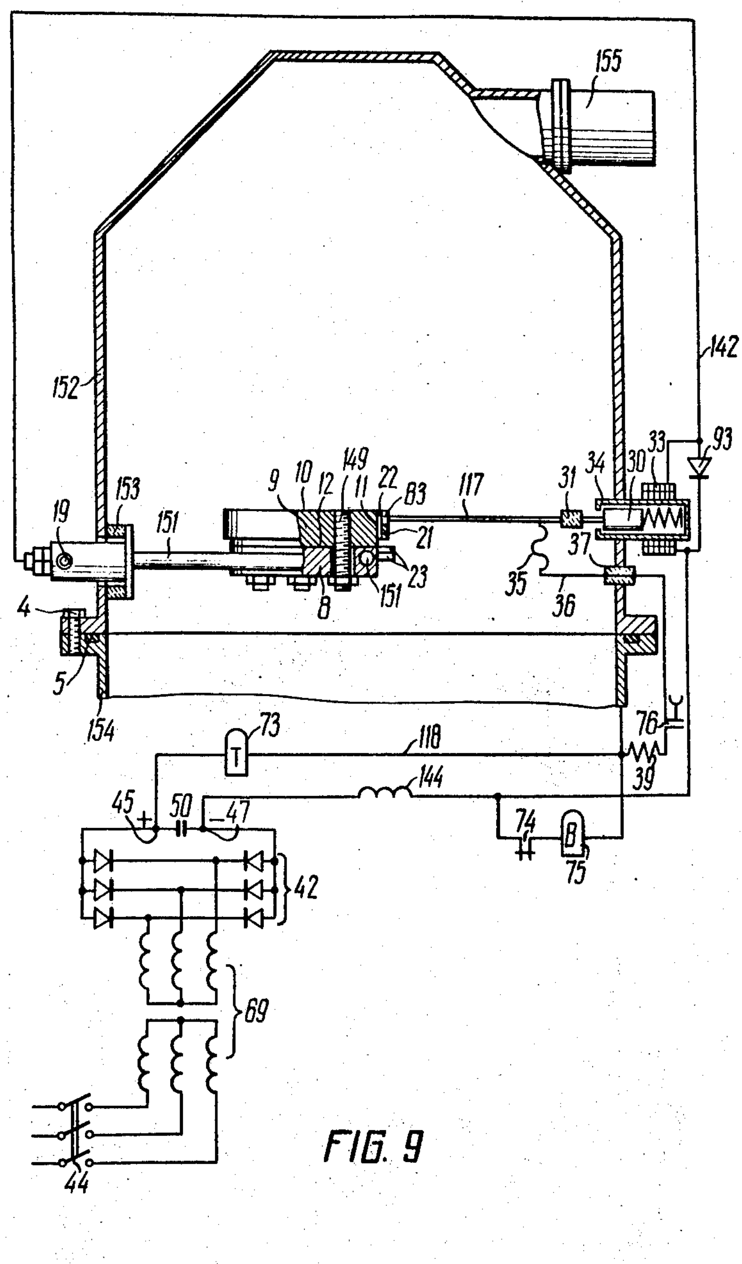
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FIG. 9

APPARATUS FOR METAL EVAPORATION COATING

The present invention relates to apparatus designed for applying metal coatings through the deposition of metal evaporated by an electric arc in vacuum.

Known at present are several types of apparatus employed for metal evaporation coating. Most extensively used are apparatus provided with a refractory crucible in which the metal being evaporated is placed. The heating of metal to the melting and evaporation point is effected in these apparatus in various ways (for example, by ohmic, induction, electron beam, arc and other techniques).

In these apparatus, only low-melting metals featuring high vapour pressure can be deposited, which react with the crucible material at the evaporation point.

Crucible evaporation of refractory metals such as tungsten, molybdenum, niobium, tantalum and a number of others is practically impossible.

Also, in crucible-type apparatus the coating becomes contaminated with the crucible material.

In order to obtain pure coatings and refractory-metal coatings, extensive use is made of apparatus in which the metal proper being evaporated serves as the crucible. In these apparatus, a liquid bath is provided with the aid of an electron gun on the surface of metal being evaporated, from which bath the evaporation takes place. All metals without exception can be evaporated in such apparatus.

The disadvantage of said known apparatus consists in the necessity of using an electric gun whose operation requires high voltage and high vacuum in the working space.

Recently, the electric arc has come into use in apparatus for vacuum deposition. The electric arc is characterized by the formation of a cathode spot on the cathode surface. Cathode spot is a small region on the cathode surface through which the arc current flows.

Current density in the cathode spot reaches values of from 10^5 to 10^7 amp/sq.cm, with a voltage decrease of from 10 to 20 volts. Quite naturally, such a concentration of energy makes for an intensive evaporation of metal in the cathode spot region. In vacuum, the arc burns in the vapours of the evaporated metal. The cathode spot of the vacuum arc displaces chaotically on the cathode surface. With an increase of the arc current, the cathode spot is divided into two, three and more independent cathode spots chaotically moving on the cathode surface independently of each other.

In the case of extinction of one cathode spot for some reason, the remaining cathode spots split to keep constant their total number on the cathode surface.

Current transfer in the cathode-anode space of the arc is effected with the aid of metal plasma generated in the cathode region of the arc discharge.

There are known apparatus for evaporation coating, in which the arc discharge is effected between the vibrating electrodes manufactured from the metal being evaporated.

The disadvantages of the apparatus of the latter type include a low stock of the metal being evaporated and the presence in the evaporated metal flow of large particles formed at the moment of disconnection of the contacting surfaces, which affects the quality of coating.

A low coefficient of utilizaing the evaporated metal (not more than 16 per cent) is another disadvantage of the known apparatus of this type.

There is also known an apparatus for applying coatings through the deposition of metal evaporated by electric arc in vacuum (see U.S. Pat. No.2,972,695 of Feb. 21, 1961), comprising an evacuated chamber which accommodates an anode and a cathode that are made from the metal being evaporated, the cathode being arranged on a cooling bed (the cooling bed is a device providing for the supply of electric current to the cathode manufactured from the metal being evaporated and for the removal of heat evolved in the cathode during the arc burning) and facing the anode with its evaporation surface (the cathode evaporation surface is the surface of the cathode manufactured from the metal being evaporated on which the electric arc cathode spot displaced in the course of the apparatus operation), a trigger electrode serving to generate the electric arc cathode spot on the cathode evaporation surface, means for retaining the cathode spot on the cathode evaporation surface, and the arc supply source. The retention of the cathode spot on the evaporation surface of the cooled solid cathode is effected in the apparatus with the aid of a magnet whose lines of force are oriented in the required manner with respect to the cathode evaporation surface. The anode and cathode of the apparatus are made from the metal being evaporated. The anode is arranged in the immediate vicinity of the cathode. The arc is ignited following the evacuation of the apparatus chamber to a pressure below 1.10^{-3} mm Hg by a momentary contact of the trigger electrode, electrically connected to the anode, with the cathode surface.

The main disadvantage of the latter apparatus consists in a low coefficient of utilization of the evaporated metal. As is known, in apparatus wherein the evaporation of metal is effected by means of electric arc the most intensive flow of the evaporated metal is directed square to the evaporation surface. However, in this apparatus the feed of the evaporated metal flow to the article being coated is effected in a direction parallel to the cathode evaporation surface, that is, in the direction of the least intensity of the flow of evaporated metal.

In addition, a considerable part of the metal flow stays on the walls of the steam pipe through which the metal is fed to the article being coated. For attaining a high deposition efficiency, apparatus featuring large overall dimensions and high power capacity are to be used.

Still another disadvantage of the known apparatus lies in the presence of the magnet and in the necessity of imparting a specific shape to the cathode, which brings about a complication of the overall design of the apparatus.

Due to the electric connection of the trigger electrode to the anode, heavy current flows in the circuit of the former at the moment of its contact with the cathode, which results in the welding of the trigger electrode to the cathode surface and its rapid wear.

The last-described apparatus has found no commercial application in vacuum-deposition technology.

It is an object of the present invention to develop an apparatus for metal evaporation coating that will provide for a multiple increase of the coefficient of utilization of the metal being evaporated.

Another object of this invention is to develop an apparatus for metal evaporation coating that will provide a substantial increase in the deposition efficiency without increasing the overall dimensions of the apparatus.

Still another object of the present invention is to develop an apparatus for metal evaporation coating that will provide for a reduction of electric energy consumption per unit mass of the deposited metal.

These and other objects can be accomplished through the disclosure of an apparatus designed for applying coatings by the deposition of metal evaporated by an electric arc in vacuum, comprising an evacuated chamber which accommodates an anode, a cathode made of the metal being evaporated and disposed on a cooling bed with a current conductor, a trigger electrode generating the electric arc cathode spot on the cathode evaporation surface, means for retaining the cathode spot on the cathode evaporation surface, and an electric arc supply source. According to the present invention, the apparatus for evaporation coating has an anode which is essentially an envelope of arbitrary shape. The cathode evaporation surface faces the space defined by said envelope, while the means for retaining the cathode spot on the cathode evaporation surface is made as a shield serving to limit the cathode evaporation surface and to close at least a part of its non-evaporation surface adjoining the cathode evaporation surface, the shield being arranged so close to the cathode surface as to preclude the transition of the cathode spot to the non-evaporation surface.

It is preferred that the arbitrarily shaped envelope be provided with openings. This ensures a convenient arrangement of the articles being coated and measuring instruments for measuring, for example, the thickness of films, etc., as well as for the evacuation of the envelope.

It is likewise preferred that the inner walls of the evacuated chamber be used as the envelope.

Such a structural arrangement of the apparatus helps render the latter most simple of design and also inexpensive.

It is desirable, especially in apparatus whose evacuated chambers are manufactured from dielectric materials such as quartz, glass or ceramics, that electrically conductive articles being coated be electrically connected to the positive pole of the arc power supply source.

This provides for the utilization of deposition apparatus featuring a glass evacuated chamber, presently available commercially, for applying coating with the aid of electric arc.

It is also desirable that the electrically conductive articles being coated be electrically connected to the anode envelope. This helps improve the stability of the arc burning.

It is preferred that the cathode made of metal being evaporated be in the shape of a flat disk. This helps obtain uniform coatings on articles arranged on the inner surface of an imaginary sphere tangent to the cathode evaporation surface and coaxial with the cathode, especially so if the sphere radius exceeds by several times that of the cathode.

It is likewise advisable that the cathode made of metal being evaporated be shaped as a ring. This helps obtain more uniform coatings over large surfaces of flat articles being coated arranged parallel with the evaporation surface of the cathode.

It is also preferred that the cathode made of metal being evaporated be shaped as a cylinder from whose cylindrical side surface evaporation takes place. This helps obtain coatings on the inner surfaces of pipes.

In addition, it is preferred that the cathode made of metal being evaporated be shaped as a hollow cylinder from whose inner cylindrical surface evaporation takes place. This helps obtain coatings on outer cylindrical surfaces without rotating the latter relative to the cathode.

It is feasible that the cathode be soldered to the cooling bed. This is convenient when securing cathodes made of materials featuring low mechanical strength, such as zinc, lead, tin, etc., and makes for a considerable increase of the amount of evaporated metal without affecting the stability of the arc burning.

It is likewise preferred that the means adapted for fastening the cathode to the cooling bed be manufactured from the material of the cathode. This helps eliminate the possibility of the arc concentration on the fastening means which could bring about the deterioration of the latter.

It is also advisable that the fastening means be mounted flush with the cathode evaporation surface, thus helping maintain the stability of the arc burning despite a great number of fastening means employed.

It is preferred that the thermal contact between the cooling bed and the cathode be effected over a conical surface. In this manner, an insignificant axial force is capable of establishing a reliable thermal contact between the cathode and cooling bed making, thereby, for an increase of the arc combustion current.

It is also preferred that the cathode be packed over the perimeter of its contact with the cooling bed, and that between the remaining portion of the cooling bed surface and the cathode, in the cooling bed, provision be made for a space adapted for the circulation therein of cooling liquid. This makes for a sharp increase in the deposition efficiency due to an increase of the arc current.

It is further preferred that the shield limiting the cathode evaporation surface be arranged so as to protect said shield from the metal evaporated from the cathode evaporation surface. This helps ensure a normal functioning of the apparatus until an almost full evaporation of the cathode, due to maintaining a gap between the non-evaporation surface of the cathode and the shield in the course of the deposition of coatings.

It is practicable to manufacture the shield from an electrically conductive material and, therefore, make use of materials that can be readily treated.

It is also practicable to manufacture the shield from a material featuring high permeability, thus improving the stability of the arc burning.

It is feasible that the shield be electrically connected to the cathode when evaporating metals featuring high vapour pressure, whereby the design of the apparatus can be made considerably simpler.

It is preferred that the shield be electrically insulated from the cathode and anode. Thus, the shield can be manufactured from any material, and the possibility of the transition of the electric arc cathode spot onto the screen in the course of the apparatus operation can be precluded.

It is practicable that the whole of the non-evaporation surface of the cathode be covered with the shield. This helps preclude the possibility of the arc burning on the cooling bed and current conductor during the apparatus operation at high pressures (of the order of 10^{-1} to 10^{-3} mm Hg).

It is likewise preferred that the whole of the non-evaporation surface of the cathode be covered with several shields insulated from each other and arranged in series one after another with respect to the non-evaporation surface. This helps preclude the possibility of the arc burning on the cooling bed and current conductor through the shield under conditions of high pressure (of the order of 10^{-1} to 10^{-3} mm Hg) in the evacuated chamber.

It is desirable that the number of shields be such that the arc burning voltage between the cathode non-evaporation surface and the anode across the shield exceeds that of the power supply source. This helps preclude the arc burning on the cathode non-evaporation surface and on the surfaces of the cooling bed and current conductor adjoining the cathode during the evaporation of refractory metals such as tungsten, molybdenum, niobium, etc.

It is likewise practicable that the shield be manufactured from an electric insulating material which ensures the most reliable protection of the cathode non-evaporation surface and of the surfaces of the cooling bed and current conductor adjoining the cathode from the arc burning on said surface at any voltage of the supply source.

It is expedient that in the shield on the side of the cathode evaporation surface provision be made for a slot adapted for the passage of the trigger electrode therethrough. As a result, the trigger electrode can be disposed on the side of the non-evaporation surface of the cathode to be protected from the cathode material evaporated during the apparatus operation.

It is also preferred that the trigger electrode be insulated from the anode and that a resistor be incorporated in the circuit of the trigger electrode. This helps decrease the current flow through the circuit of the trigger electrode during its contact with the cathode and, thereby, reduce the wear of the trigger electrode.

It is likewise preferred that a contact of an electrical commutation device be incorporated in the circuit of the trigger electrode. This makes for switching-on the current in the circuit of the trigger electrode following its contact with the cathode surface, thereby precluding the possibility of the trigger electrode welding to the cathode. This also makes for breaking the circuit of the trigger electrode after the arc excitation between the cathode and anode, precluding the melting of the trigger electrode in the case of the apparatus operation under conditions of high pressure (on the order of from 10^{-1} to 10^{-3} mm Hg).

It is practicable that the coil of an electromagnet serving to control the trigger electrode be incorporated in the arc current circuit. This makes, along with the automatization of the arc ignition, for the reduction of the number of elements in the electric circuit and for an increase of the speed of response of the latter.

It is also practicable that the electromagnet winding be shunted. This helps decrease the value of current flow directly across the winding of the electromagnet and, thereby, reduces its dimensions.

It is preferred that a semiconductor diode be used as the shunt, which helps expand the range of variation of the rate of metal evaporation (arc current) in the apparatus.

It is also preferred that a high-frequency choke be incorporated in the arc current circuit, thus making for an increased stability of the arc burning and a simultaneous decrease of the electric arc supply source voltage.

It is feasible that a capacitor be provided on the output terminals of the arc supply source. This helps protect the arc supply source from a breakdown by a high-voltage pulse generated at the amount of extinction of the electric arc cathode spot.

It is likewise feasible that the current conductor for the supply of current to the cooling bed serve simultaneously for heat transfer from the latter, for which purpose the current conductor should be connected to a radiator located outside the evacuated chamber. As a result, the apparatus needs no water cooling.

The present invention has resulted in the development of an apparatus designed for evaporation coating which helps increase by several times the coefficient of utilization of the metal being evaporated, decrease the electric energy consumption per unit mass of the deposited metal, as well as to sharply increase the deposition efficiency without increasing the overall dimensions of the apparatus, while maintaining a high reliability of the apparatus operation.

The present invention will become more apparent upon considering the following detailed description of the preferred embodiment thereof taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates an apparatus designed for evaporation coating, in accordance with the present invention, in which the anode is made as a hollow spherical envelope;

FIG. 2 illustrates a disk-shaped cathode made from the metal being evaporated, shown after a prolonged evaporation period;

FIG. 3 illustrates a modified version of the apparatus for evaporation coating as shown in FIG. 1, featuring a cathode having the shape of a flat ring;

FIG. 4 illustrates a modified version of the apparatus of FIG. 1 designed for evaporation coating of resilient metallic bands;

FIG. 5 is a section taken on the line V—V of FIG. 4;

FIG. 6 illustrates a modified version of the apparatus for evaporation coating as shown in FIG. 1, featuring a cathode shaped as a tube;

FIG. 7 illustrates a modified version of the apparatus for evaporation coating as shown in FIG. 1, featuring a cathode having a cylindrical shape;

FIG. 8 illustrates a modified version of the apparatus for evaporation coating as shown in FIG. 1, wherein the articles being coated serve as the anode; and

FIG. 9 illustrates a modified version of the apparatus according to the present invention to be used as an electric-arc sorption high-vacuum pump.

Referring now to FIG. 1 of the drawings, the apparatus designed for applying coatings through the deposition of metal evaporated by an electric arc in vacuum has the following structural arrangement:

A vacuum chamber 1, comprising a housing 2 and a lid 3 connected to each other by means of bolts 4 and packed with a rubber packing 5, is evacuated to the required working pressure by means of a vacuum-producing system 6 attached to the lid 3 by bolts (not shown in the drawings) and packed with a rubber packing 7.

The vaccum-producing system 6 includes a vacuum lock, as well as diffusion steam-oil and preevacuation pumps, that are not shown in FIG. 1.

Mounted on a cooling bed 8 inside the evacuated chamber 1 is a cathode 9 made of the metal being evaporated.

The cathode 9 is shaped as a flat disk whose one end surface 10 serves as its evaporation surface, while its cylindrical side surface 11 and the other end surface 12 make up its non-evaporation surface.

Shaping the cathode 9 as a flat disk is very convenient for applying coatings on articles 13 being evaporation-coated which are placed on a special appliance (not shown in the drawings) so that the surfaces of the articles 13 being coated will be tangent to the surface of an imaginary sphere 14 coaxial with the disk and tangent to the evaporation surface 10 of the cathode 9. In this case, the most uniform coatings may be obtained, especially so if the radius of the cathode 9 is several times smaller than that of the imaginary sphere 14.

This should be attributed to the cosine law of the intensity distribution of the flow of metal evaporated from a flat small-sized source, in this particular case, the electric arc cathode spot which moves chaotically on the evaporation surface 10 of the cathode 9.

For some metals, especially, low-melting ones, the law of cosine distribution of intensity of the evaporated metal flow holds in a space defined by a solid angle of 90° with a vertex in the electric arc cathode spot.

The cathode 9 is soldered by its end surface 12 to the cooling bed 8 throughout the whole plane of its contact. Soldering the cathode 9 made of metal being evaporated is very convenient for securing it to the cooling bed 8 in case brittle and low-strength metals are to be evaporated, such as lead, tin, zinc, chrome, etc.

The present inventors have observed that the stability of arc burning depends upon the temperature of the evaporation surface 10 of the cathode 9, the lowering of this temperature bringing about a greater stability of the arc burning. In addition, a low temperature of the cathode evaporation surface 10 results in the decrease of the amount of large spatters and particles of metal in the flow of metal vapour condensed on the articles 13 being coated.

In the course of the arc burning on the cathode 9 there evolves about 30 per cent of the arc discharge energy which is to be removed from the cathode via the cooling bed 8.

Therefore, with a view to reducing the thermal resistance between the cathode and the cooling bed, the cathode is soldered to the latter over the whole surface of their contact.

Following a prolonged operation of the apparatus (see FIG. 1), the evaporation surface of the cathode 9 assumes the shape of a hole having walls 15 and a bottom 16 (FIG. 2).

The thickness of the cathode 9, in view of conditions of the stable arc burning at low currents, cannot exceed the cathode diameter for, after a prolonged evaporation of the cathode, the walls 15 (see FIG. 2) shield the flow of metal plasma from the electric arc cathode spot to the anode, which affects the stability of the arc burning.

In order to gain a high deposition efficiency, the thickness of the cathode 9 should be selected such that there should be no considerable excess of the temperature of the cathode evaporation surface 10 over the temperature of the cooling bed. Based on this condition, the selected thickness of the cathode is different for various metals at different arc currents, that is, the higher the thermal conductivity of the metal being evaporated or the lower the arc current, the greater the cathode thickness.

On the basis of these requirements, it is recommended that the thickness of the cathode be selected within the range of from 20 to 50 per cent of the cathode diameter, depending upon the type of metal being evaporated and the required deposition efficiency.

The cooling bed 8 serves for the removal of heat transferred to the bed from the cathode 9, as well as for a uniform distribution of the arc current throughout the evaporation surface of the cathode 9.

Consequently, the cooling bed 8 should possess adequate thermal and electric conductivity. In the apparatus according to FIG. 1 it is made of copper. The cooling bed is provided with a space 17 for the circulation of water supplied through openings (not shown in the drawings) in a current conductor 18. The cooling bed 8 is fastened on the current conductor 18. The supply of water to the current conductor 18 is effected with the aid of rubber pipes (not shown in the drawings) set on nipples 19.

The current conductor 18 together with the cathode 9 and the cooling bed 8 are fastened with the aid of a ceramic insulator 20 on the lid of the evacuated chamber. The insulator 20 serves for the electrical uncoupling of the current conductor 18 from the lid 3 of the evacuated chamber, and as a vacuum seal.

During the apparatus operation, means should be provided to preclude the transition of the electric arc cathode spot from the evaporation surface of the cathode 9 to the non-evaporation surface thereof, the latter surface being made up of the cylindrical side surface 11 and the end surface 12, as well as of the surfaces of the bed 8 and current conductor 18 adjoining the cathode. This problem has been solved in the present invention through the provision of a shield 21 adapted to close the cylindrical side surface of the cathode 9 and the surface of the cooling bed 8. The shield 21 is made as a hollow cylinder whose inner surface is concentric with the cylindrical surface of the cathode and cooling bed and is positioned with a gap 22 of 2 to 3 mm. The shield 21 is mounted on the lid 3 of the evacuated chamber 1 and electrically uncoupled from said lid with the aid of an insulator 23.

If, in the course of the apparatus operation, the electric arc cathode spot gets in the gap 22 between the shield 21 and non-evaporation surface, it is extinguished. Should the value of the arc current at this moment be such that one or several more electric arc cathode spots are present on the cathode evaporation surface 10, said cathode spots split instantaneously to keep constant the total number of the cathode spots due to the arc current.

The shield 21 is placed with its upper edge 24 level with the evaporation surface 10 of the cathode 9.

If the edge 24 of the shield 21 is higher than the evaporation surface of the cathode 9, the evaporated metal will deposit on the screen in the course of the apparatus operation, which will finally bring about the decrease of the gap 22 between the non-evaporation surface and the shield 21 and, as a result, the transfer of the cathode spot to the shield 21. If the edge 24 of the shield 21 is below the level of the cathode evaporation surface 10, part of the cathode cylindrical surface 11 that is not closed by the shield 21 will become evaporation surface from which metal will evaporate, which will likewise result in the short-circuiting of the gap 22.

From structural considerations, the thickness of the shield is chosen to be 2 – 3 mm. The material of the shield is magnetically soft steel, for the present inventors have observed that the use of a shield made from a non-magnetic material has an adverse effect upon the stability of the arc burning.

The cathode evaporation surface 10 faces an anode 25 which is essentially a hollow spherical envelope 26 set on a metal rod 27 which is electrically uncoupled from the lid of the evacuated chamber by means of an insulator 28. The rod 27 serves at the same time for supplying electric current to the anode 25.

The electric current transfer in the space between the cathode and anode during the apparatus operation is effected by the electrons of metal plasma generated in the cathode spot of an arc discharge. The present inventors have observed that the most stable burning of the arc takes place provided the total flow of metal plasma participates in the current transfer.

In the scope of the present invention this is attained due to the fact that the holoow spherical envelope 26 faced by the evaporation surface 10 of the cathode fully embraces said latter surface.

The present inventors have also found that neither shape nor dimensions of the envelope affect the arc burning stability and the voltage across the cathode and anode.

Thus, when testing spherical envelopes having radii of 100, 200, 300 and 1,000 mm, the external parameters of the arc, i.e., the voltage across the cathode and anode and the minimum current of the stable burning of the arc, remained unchanged (The minimum current of the stable arc burning is taken by us to be a value of current at which the average time of the arc burning on the cathode evaporation surface without extinction is equal to five minutes).

The shape of envelope embracing the cathode evaporation surface is also due to the necessity of protecting the inner surface of the evacuated chamber 1 from being contaminated by the evaporated metal.

A trigger electrode 29 is fastened to an electromagnet armature 30 with the aid of an insulator 31. The armature 30 is placed inside a pipe 32 of non-magnetic material, outside of which pipe an electromagnet coil 33 is arranged. A return spring 34 is provided inside the pipe 32.

The trigger electrode 29 is connected with the aid of flexible wire 35 to a rod 36 electrically uncoupled from the lid 3 by means of an insulator 37. A resistor 39 is incorporated in a circuit 38 connecting the trigger electrode 29 with the anode 25.

The resistor 39 is essential for limiting the value of current in the trigger electrode circuit at the moment of ignition. The absence of the resistor 39 brings about a rapid wear of the trigger electrode 29, for the value of current in the circuit of the trigger electrode at the moment of ignition becomes equal to the value of short-circuit current of the arc supply source 40.

The value of the resistor 39 is selected such that the current flowing in the circuit 38 of the trigger electrode 29 at the moment of contacting the evaporation surface 10 of the cathode 9 is equal to approximately 20 – 25 per cent of the minimum current of the stable burning of the arc. This results in a considerable reduction of the probability of the trigger electrode 29 welding to the evaporation surface 10 of the cathode 9 and in a reliable ignition of the arc.

The arc supply source 40 includes a three-phase reducing transformer 41, a three-phase full-wave rectifier 42 and a rheostat 43. The arc supply source 40 is connected with the a.c. mains by means of a switch 44. The use of an arc-type rectifier is only possible provided the instantaneous value of voltage across the rectifier output is always higher than that across the apparatus electrodes in the course of operation.

This is due to the fact that the arc extinction in vacuum takes place upon the disappearance of current in the arc circuit for a period of time exceeding 10^{-7} sec.

A positive terminal 45 of the supply source 40 is connected by a wire 46 to the rod 27 of the anode 25, and a negative terminal 47 is connected through the electromagnet coil by wires 48 and 49 to the current conductor 18 of the cathode 9. A capacitor 50 is placed between the terminals 45 and 47.

The apparatus shown in FIG. 1 operates in the following sequence.

After a working pressure below 1.10^{-3} mm Hg (preferably, from 1.10^{-5} to 1.10^{-6} mm Hg) has been reached in the evacuated chamber 1 with the aid of the vacuum-producing system 6, the switch 44 operates to connect the arc supply source 40 to the a.c. mains. A voltage of from 40 to 70 volts is generated on the output terminals 45 and 47 of the arc supply source 40. In the circuit incorporating the terminal 45, wire 38, resistor 39, rod 36, flexible wire 35, trigger electrode 29, cathode 9, cooling bed 8, current conductor 18, wire 49, electromagnet coil 33, wire 48, terminal 47 there is generated electric current whose value depends upon the value of resistance of the resistor 39.

The electromagnet armature 30, overcoming the resistance of the return spring 34, is attracted by the electromagnet coil 33 and moves the trigger electrode 29 away from the evaporation surface 10 of the cathode 9.

Formed on the evaporation surface 10 of the cathode 9 is an electric arc cathode spot which is initially under the end of the trigger electrode 29 and, following the withdrawal of the trigger electrode 29, starts moving chaotically over the whole of the evaporation surface 10 of the cathode 9, and the current starts flowing in the circuit incorporating the terminal 45, wire 46, rod 27, envelope 26, cathode 9, cooling bed 8, current conductor 18, wire 49, electromagnet winding 33, wire 48, and terminal 47.

The flow of current on the space defined by the envelope 26 (anode) and the cathode 9 is due to metal plasma generated in the envelope by the electric arc cathode spot. The value of the latter current depends upon the value of resistance of the rheostat 43 of the supply source 40 and is selected so as to provide for the stable burning of the arc (the lower limit) and for the required evaporation rate whose value is proportional to the arc current.

The metal evaporated from the evaporation surface **10** of the cathode **9** by the electric arc cathode spot precipitates on the articles **13** being coated and on the inner surface of the envelope **26.**

If one of the cathode spots gets in the gap **22** provided between the non-evaporation surface **11** of the cathode **9** and the inner surface of the shield **21,** it is extinguished, while the other cathode spots remaining on the evaporation surface **10** of the cathode **9** split because of an increase of voltage across the anode **25** and cathode **9** due to a reduced voltage decrease on the rheostat **43.** In the case of arc extinction for some reason, current in the circuit of the electromagnet winding **33** ceases to flow and the spring **34** acts to lower the electromagnet armature **30** together with the trigger electrode **29** until the contact with the surface **10** of the cathode **9.** The arc is excited automatically in the same sequence as during the initial triggering of the apparatus.

In the course of the apparatus operation, high voltage pulses occur on the cathode and anode. This is due to the fact that it takes about 10^{-7} sec for the extinction of the cathode spot elementary cell, whereas the supply source **40** and the circuit of the arc current possess adequate inductance. These pulses are capable of rendering the arc supply source 40 in-operative. In order to avoid this, the output terminals **45** and **47** of the arc supply source **40** are shunted by the capacitor **50** whose stored energy, at a voltage permissible for the arc supply source **40,** is equal to the energy of the electromagnetic field of the supply source and the arc current circuit.

On gaining the required thickness of coating on the articles **13** being coated, the arc is switched off with the aid of the switch **44.**

FIG. **3** illustrates another embodiment of the apparatus for evaporation coating according to the present invention. The apparatus is designed for applying uniform coatings of metals featuring high vapour pressure (e.g., lead, cadmium, zinc, etc.) on flat-shaped articles. A uniform coating on a flat surface is formed due to the fact that the apparatus cathode **51** of the metal being evaporated has the shape of a flat ring, while articles **52** being coated are arranged in parallel relationship to a circular evaporation surface **53** of the cathode **51.** The cathode **51** is soldered with its circular surface **54** to a cooling bed **55.** The thickness of the cathode **51** sufficient to ensure a stable burning of the arc should not exceed the width of the ring in a radial direction (in view of the previously-discussed reasons).

The cooling bed **55** is manufactured of copper and made integral with a current conductor **56.** The cathode of the metal being evaporated is cooled with the aid of a radiator **57** arranged on the lower end of the current conductor **56.** In order to reduce the thermal resistance between the cooling bed **55** and radiator **57,** the current conductor **56** is made solid, without any internal cavities. The use of a radiator for the removal of heat from the cathode helps simplify the design and increase the operation reliability of the apparatus (no water cooling system is required).

Pressed on the side surface **58** of the copper bed is a ring **59** of a magnetically soft metal serving as a shield. The gap **22** between the inner surface of the shield **59** and the cylindrical side surface **11** of the cathode **51** from the metal being evaporated is 1 – 3 mm.

A cylindrical surface **60** of the cathode **51** from the metal being evaporated is covered with a shield **61** of a magnetically soft material mounted on the cooling bed **55** with a gap **62** equal to 1 – 3 mm.

In the apparatus described herein, the shields **59** and **61** are electrically connected with the cathode. This makes for a simpler design of the apparatus, however, such a structural solution is only suitable for the case of evaporating metals featuring high vapour pressure.

The apparatus anode **63** is essentially a cylindrical envelope **64** arranged coaxially with the cathode. Provided on the side surface of the cylindrical envelope are a series of openings **65** serving for the accommodation thereinside of sensing elements **66** of instruments adapted to regulate the parameters of the deposition process. In case the total area of the openings provided in the envelope is greater than the area of the remaining portion of the envelope and the openings are arranged in the path of the maximum flow of metal plasma, there is observed a decreased stability of the arc burning which is to be compensated for by increasing the arc current. In such apparatus, the arc burns for a prolonged time at greater currents than in the apparatus featuring a solid envelope.

The electrically conductive articles **52** being coated are arranged opposite the cathode of the metal being evaporated on a special means (not shown in the drawings) and are electrically connected to the envelope **64** by means of a wire **67.** No deterioration of the stability of the arc burning takes place, for the articles perform part of the anode function.

The envelope **64** is attached to the lid of the evacuated chamber in a manner similar to that described in connection with the apparatus shown in FIG. **1.**

The arc supply source **68** comprises a reducing transformer **69,** which has a drooping extrinsic voltage-current characteristic due to high magnetic leakage, and the rectifier **42.** The arc current in such a source is controlled by varying the electromagnetic coupling between the primary and secondary windings of the transformer **69.**

The electromagnet winding **35** is connected with the aid of wires **70** and **71** to the terminals **45** and **47** of the arc supply source **68.** Connected to an electric circuit **72,** serving to connect the terminal **47** with the current conductor **56,** is a winding **73** of a current relay whose contact **74** is incorporated in the circuit **71.** Arranged in parallel with the electromagnet coil **33** is a time relay **75** whose contact **76** is incorporated in the circuit **38** serving to connect the trigger electrode **29** with the anode **63.**

The apparatus of the present invention, as shown in FIG. **3,** operates in the following manner: After a working pressure has been gained in the evacuated chamber **1** with the aid of the vacuum-producing system **6,** the switch **44** is actuated. Direct current flows in the electromagnet winding **33,** which brings about the drawing in of the electromagnet armature **30** until the trigger electrode **29** contacts the evaporation surface **53** of the cathode **51.** The time relay **75** operates with a delay equal to 0.3 – 0.5 sec following the contact of the trigger electrode **29** with the evaporation surface **53** of the cathode **51** and closes its contact **76** in the circuit **38** of the trigger electrode **29.** The current generated in the circuit incorporating the terminal **45**, contact **76**, wire **38**, resistor **39**, rod **36**, flexible wire **35**, trigger electrode **29**, cathode **51**, cooling bed **55**, current conductor **56**, wire **72**, current relay **73** and terminal **47** causes the operation of the current relay **73** and its contact **74** in the circuit **71**.

The electromagnet winding **33** is cut off and the spring **34** acts upon the trigger electrode **29** to cause the latter to withdraw from the evaporation surface of the cathode **51** following 0.3 – 0.5 sec after the operation of the contact **74** of the current relay **73**, the contact **76** of the time relay **75** is released. The incorporation of the contact **76** of the time relay **75** in the circuit of the trigger electrode **29** helps recuce the probability of the trigger electrode **29** welding to the cathode **51** due to pre-closing the circuit trigger electrode **29**-cathode **51** followed by energizing the circuit of the trigger electrode by means of the contact **76** of the time relay **75**. In addition, the present inventors have observed that, in the course of the apparatus operation, a high (on the order of from 10^{-1} to 10^{-3} mm Hg) pressure in the evacuated chamber **1** is accompanied by the arc burning between the cathode **51** and the end of the trigger electrode **29**, which causes the trigger electrode **29** to melt. In order to avoid this, the contact **76** of the time relay **75** serves to deenergize the circuit of the trigger electrode **29** following the arc excitation between the cathode **51** and the anode **63**.

Otherwise, the operation of the apparatus shown in FIG. **3** is similar to that of the apparatus described in connection with FIG. **1**.

FIGS. **4** and **5** illustrate a modified version of the apparatus according to the present invention designed for a high-efficiency application of coatings on moving band-like materials. For obtaining a uniform coating, a cathode **77** manufactured from the metal being evaporated is shaped as a flat rectangle. The cathode **77** is attached to a cooling bed **78** by means of bolts **79**. The cooling bed **78** is provided with a space **80** for the supply of water thereinto. Sealing the cooling bed **78** and the cathode **77** of the metal being evaporated is effected with the aid of a rubber packing **81** laid in a groove close to the outer perimeter of the cathode **77**. In case a high intensity of the deposition process is desired, the arc current should be increased. When so doing, the removal of heat from the cathode surface should naturally be increased. Therefore, the cathode is packed over the perimeter of its contact with the cooling bed, while between the remaining portion of the coding bed and the cathode provision is made for a space (made in the cathode or in the cooling bed) adapted for the circulation therein of a cooling liquid. In this embodiment of the present invention, the removal of heat is effected directly from the cathode obviating the need for any intermediate bodies (such as the cooling bed). The hermetic sealing of the cathode can also be effected by soldering the cathode and the cooling bed over the perimeter of their relative contact. The whole of the non-evaporation surface is closed with a metal shield **82**. The shield is provided with a slot **83** through which a trigger electrode **84** passes towards the surface of the cathode **77**. During the apparatus operation within a high-pressure range (on the order of from 10^{-2} to 10^{-4} mm Hg), high-voltage pulses generated at the moment of arc extinction are capable of causing a gas breakdown between the cooling bed and the anode. If the shield closes the whole of the non-evaporation surface of the cathode **77** and the surface of the cooling bed **78** adjoining the latter, there exist better conditions for the occurrence of a gas breakdown on the cathode evaporation surface **85** rather than on the non-evaporation surface, as a result of which the arc burning mainly takes place on the cathode evaporation surface **85**. A metal band **86** is wound on drums **86***a* which can be set to rotation as indicated by arrows (drum-rotating mechanisms are not shown in the drawings). Serving as the apparatus anode are the inner walls of the evacuated chamber and surface **87** of the metal band electrically coupled to the evacuated chamber by a wire **88**. Should it be possible to connect the positive terminal of the arc supply source **89** to the evacuated chamber **1**, the inner walls of the evacuated chamber alone can perform the anode function. In this case, the apparatus design will be simpler for there will be no need for the envelope and structural element required for installing the latter inside the evacuated chamber.

The arc supply source **89** comprises a storage battery **90** and the rheostat **43**. Voltage is set on by means of a switch **91**. The trigger electrode **84** is fastened with the aid of the insulator **31** to a pivoted bracket **92**. The solenoid coil **33** is shunted by means of a diode **93**. This helps extend the range of the arc current due to passing excess current through the diode **93** which has a logarithmic characteristic in a forward direction, that is, with the arc current increase by a factor of, say, **10**, the voltage across the diode and, consequently, the current in the coil **33**, increases only by a factor of two.

The operation of the apparatus is similar to that of the apparatus described in connection with FIG. **1**.

Shown in FIG. **6** is still another modified version of the apparatus for metal evaporation coating, which is designed for applying uniform coatings of metals featuring high vapour pressure (such as niobium, molybdenum, tantalum) onto the outer surface of a pipe **94** or of other cylindrical bodies.

A cathode **95** manufactured from the metal being evaporated is essentially a tube whose outer surface **96** features a conicity on the order of 2° – 3°.

The inner cylindrical surface **97** is the cathode evaporation surface. The uniformity of coating is attained due to the fact that the cathode **95** made from the metal being evaporated encircles the pipe surface being coated. Given the chaotic displacement of the cathode spot over the cathode evaporation surface **97**, a uniform coating is obtained if the pipe displacement rate is much lower than the rate of the cathode spot travel (the cathode spot travels at a rate of hundreds of centimeters per second). Serving as the cooling bed for the cathode **95** of metal being evaporated is the evacuated chamber housing **98**. The inner surface of the evacuated chamber housing features the same conicity as that of the surface **96** of the cathode **95** made from the metal being evaporated. The thermal contact of the cathode with the housing **98** is gained as a result of pressing the cathode **95** in the axial direction, whereby the latter is wedged in the housing **98**. The outer surface of the housing **98** is fashioned as a radiator **99** adapted for better removal of heat from the cathode. End face lids **100** and **101** of the evacuated chamber are electrically uncoupled from the housing **98** with the aid of insulators **102**. The chamber is hermetically sealed with the aid of rubber packings **103** arranged in corresponding grooves provided in the lids **100** and **101** and in the housing **98** of the evacuated chamber. The lids are pressed against the evacuated chamber housing with the aid of bolt **104.** The latter bolts are passed through dielectric sleeves **105** so as not to disturb the insulation between the lids and the housing of the evacuated chamber. the lids of the evacuated chamber are made integral with cylindrical casings **106** which accommodate the pipe **94.** The pipe is displaced along the chamber axis by means of a mechanism which is not shown conventionally in FIG. **6.**

The function of the apparatus anode is served by the outer surface **107** of the pipe **94** being coated and the inner surface **108** of the lids **100** and **101** of the evacuated chamber. For limiting the cathode evaporation surface **97,** use is made of several circular shields **109** arranged in grooves provided in the insulator **102.** The shields **109** are insulated from the electrodes of the apparatus and from each other and shield the whole of the non-evaporation surface **110.**

The number of the shields should be such that the arc burning voltage between the non-evaporation surface **110** and the anode across the shields exceed that of the arc supply source **111.** In this case, voltage surges under unfavourable circumstances (high pressure in the evacuated chamber, contaminated shields) may cause a high-voltage gas breakdown between the anode and the cathode across the shields. However, during the transition of the discharge from the high-voltage stage to the low-voltage arc stage the discharge cannot exist in the foregoing direction, for the voltage provided by the power supply source is not sufficient for maintaining the discharge. In the apparatus described herein, the arc discharge can only be maintained between the cathode evaporation surface and the anode.

The electric arc power supply source **111** comprises an asynchronous motor **112** and a welding generator **II3** having a drooping extrinsic voltage-current characteristic. Since constant voltage pulsations in the arc supply source **111** are less than those in rectifiers, the minimum current of stable arc burning in this apparatus is less than that in the apparatus described in connection with FIGS. **1** and **3.**

The current relay **73** is incorporated in the circuit **72** serving to connect the terminal **47** with the housing **98.** The electromagnet winding **33** is fed from a rectifier **114** series-connected with a time relay **115** and the contact **74** of the current relay **73.** A contact **116** of the time relay **115,** which closes with a delay of 0.3 – 0.5 sec after energizing the winding of the relay **115,** is cut in the circuit of a trigger electrode **117** in series with a resistor **39.**

The terminal **45** of the arc supply source **111** is connected by a wire **118** to the cylindrical casing **I06** connected, in turn, by a wire **119** to the lid **100.**

The article **94** being coated is connected by a wire **119** to the cylindrical casing **106.** The incorporation of the contact **74** in the a.c. circuit helps reduce the wear of said contact.

The principle of operation of this apparatus is similar to that of the apparatus described hereinabove.

FIG. **7** illustrates an apparatus for applying uniform coatings onto the inner surface **12I** of a pipe **122.** The pipe **122** is placed in an evacuated chamber **123** comprising a housing **124** and a lid **125.** A cylindrical cathode **126** made from the metal being evaporated is introduced inside the pipe. A cylindrical surface **127** of the cathode made from the metal being evaporated is the evaporation surface. The pipe **122** is displaced in the course of deposition. If the rate of the pipe displacement is lower than the rate of travel of the cathode spot, a uniform coating is gained on the inner surface of the pipe. Provided in the centre of the cathode **126** made from the metal being evaporated is a conical opening (with a conicity of 2° – 3°) adapted to receive the conical portion of a cooling bed **128.** The cooling bed **128** is made integral with a current conductor **129.** The current conductor, passing through an opening provided in the lid **125** of the evacuated chamber **123,** is secured and packed with the aid of dielectric sleeves **130, 131,** rubber packing **132** and a flange **133.** Set on the atmospheric portion of the current conductor **129** is a radiator **134** adapted for the removal of heat from the cathode **126** manufactured from the metal being evaporated. In the body of the current conductor **129** and cooling bed **128** provision is made of a closed space **135** partly filled with a low-boiling liquid **I36.** The heat transfer from the cathode **126** made from the metal being evaporated is effected by the vapours of the boiling liquid which rise to the upper portion of the space **135** to condense and to yield the heat to the radiator **134.** The condensed liquid flows down to the lower portion of the space **135.** The whole of the non-evaporation surface of the cathode **126** is covered with four shields **137** of a magnetically soft metal and dielectric sleeve **I3I.** The shields **137** are secured to insulators **138** and **139.** The insulator **139** is attached to the cooling bed **128** by a bolt **140.** The pipe **122** is electrically connected by means of flexible wire **14I** to the evacuated chamber **123** and serves, together with the latter as the anode of the apparatus.

In this particular version of the apparatus of the invention, the resistor **39** is mounted inside the evacuated chamber **123,** which eliminates the need for an insulator providing the electrical outlet for the trigger electrode **117.** In addition, a high-frequency choke **144** is incorporated in a circuit **142** serving to connect the negative pole of the arc supply source **143** with the current conductor **129.**

The incorporation of the choke in the arc current circuit **142** helps reduce the voltage drop across the rheostat **43** and, thereby, reduce the voltage in the d.c. mains from which the arc supply source **143** is supplied.

This occurs due to the fact that during the extinction of the elementary cell of the electric arc cathode spot, which takes place over a period of time of from 10^{-5} to 10^{-7} sec, on the choke **144** there occur voltage surges proportional to the current of the elementary cell of the electric arc cathode spot, said current varying for different metals in the limits of from 0.08 amp for mercury to 0.8 amp for titanium.

This voltage surge is conducive to the formation of a new elementary cell of the cathode spot due to the split of the other elementary cells, which is the same as the voltage rise across the cathode due to a reduction of the voltage drop across the rheostat **43.**

Since the extinction time of the elementary cell of electric arc cathode spot is 10⅛^5 to 10^{-7} sec, this time should be sufficient for the choke to increase the voltage and transmit it to the cathode **126.** It is therefore recommended that the choke **144** be made of the air-type, without a magnetic coil, which makes for the manufacture of a choke featuring the required operating ferquency in the range of from 0.1 to 10 mc.

The principle of operation of the apparatus is similar to that of the apparatus described hereinabove.

FIG. **8** illustrates yet another modified version of the apparatus according to the present invention, in which the anode function is served by the surfaces of the articles **13** being coated arranged on a special appliance (not shown in the drawings) over the surface of the imaginary sphere **14.** An evacuated chamber **145** of the apparatus comprises a dielectric hood **146** made of glass and having a metal lid **3.** Sealing of the lid **3,** and the hood **146** is ensured by means of the rubber packing **5.** The articles **13** being coated are electrically connected to each other by a wire **147** and to the current conductor in the lid 3 of the evacuated chamber by a wire **148.** The current conductor **27** is connected by the wire **46** to the positive terminal **45** of the arc supply source **89.** The greater the surface being coated of the articles which faces the evaporation surface **10** of the cathode **9,** the more stable is the arc burning. The article should placed in the path of the maximum flow of plasma in a solid angle of about 90° whose vertex is in the centre of the evaporation surface **10** of the cathode **9.** The cathode made from the metal being evaporated is secured to the cooling bed **8** with the aid of fasteners **149** (such as pins, bolts, rivets, etc.). This helps reduce the time required for replacing the spent cathode from the metal being evaporated (as compared, for instance, with an apparatus design in which the cathode is soldered to the cooling bed). In order to avoid the contamination of the coating metal with the material of the fasteners, as well as the fixation of the cathode spot on the fasteners, it is expedient that the fasteners be manufactured from the metal being evaporated. While so doing, reliable thermal and electrical contacts can be ensured by arranging the fasteners so as to provide for uniform pressing over the whole surface of the cathode made from the metal being evaporated and the cooling bed adjoining said surface. It is likewise preferred that the fasteners be mounted flush with the cathode evaporation surface. In this case, during the initial start-up of the apparatus the gaps between the fasteners and the cathode are filled, whereupon the cathode and the fasteners are sputtered uniformly as a single piece. If a fastener is not mounted flush with the working surface of the cathode, openings are formed in places where the fasteners are located following some sputtering of the cathode. The cathode spot is likely to get into these openings and become extinguished, which brings about the instability of the arc burning. A great amount of such openings on the cathode evaporation surface may cause a marked violation of the stability of the arc burning.

The cathode evaporation surface **10** is limited with the aid of a shield **150** manufactured from a heat-resistant insulating material featuring a low vapour pressure (such as alundum, quartz, etc.) arranged with a gap of **1** to **3** mm relative to the cathode non-evaporation surface. The ceramic shield closes the whole of the non-evaporation surface of the cathode. The provision of the ceramic shield fully eliminates the possiblity of the arc burning on the cathode non-evaporation surface.

The operation of the apparatus is similar to that described in connection with the apparatus shown in FIG. **4.**

FIG. **9** illustrates an apparatus designed for use as a sorption high-vacuum pump. The cathode **9** manufactured from the metal being evaporated (such as titanium) is shaped as a flat disk and secured to the cooling bed **8** by means of pins **149** made from the metal being evaporated. The cathode is cooled by water passing through pipe **151.** The pipe **151** passes through the cylindrical wall of a housing **152,** which serves as the anode of the apparatus, and is electrically disconnected from said housing **152** by means of an insulator **153.** The shield **21** on the insulators **23** is secured to the cooling bed **8.** The active metal (titanium) is sputtered on the inner surface of the housing **152** where sorption pumping of active gases (such as nitrogen, oxygen, hydrogen, carbon oxide and dioxide, etc.) takes place. Inert gases (argon, neon, helium) are not pumped out by the sputtered metal. For pumping them out use is made of a diffusion pump **155.** The efficiency of the diffusion pump with respect to inert gases corresponds to 1 – 2 per cent of the sorption pump efficiency with respect to nitrogen. The housing **152** is connected with its inlet flange to a volume **154** being evacuated. The arc is ignited in the pump by the trigger electrode **117** passing through the slot **83** in the shield **21.** The high-vacuum sorption pump helps develop a high rate of pumping both at high (on the order of from 1.10^{-3} to 1.10^{-5} mm Hg) and low (below 1.10^{-5} mm Hg) pressures. The minimum current of the stable arc burning when using ordinary commercial titanium is about 120 amp. The arc supply source voltage is 30 volts. Titanium is consumed at a rate of 14 grams per hour at a continuous operation of the pump. This is sufficient for pumping out nitrogen at a rate of 40,000 to 50,000 litres per second, with the pressure of 2.10^{-5} mm Hg (extreme pressure obtained when pumping volumes below 1.10^{-7} mm Hg). Heavy hydrocarbons are absent in the spectrum of residual gases. Hydrogen is the basic gas component in the spectrum. The present inventors have observed that in the plasma of arc discharge there takes place the decomposition of hydrocarbon molecules into constituent elements (hydrogen and carbon) that are actively pumped out by the pump.

The principle of the apparatus operation is similar to that of the apparatus described above.

The present invention has resulted in the development of an apparatus for evaporation coating which features the following advantages over prior art apparatus.

The apparatus of the present invention makes for an 80 to 90 per cent utilization of the evaporated metal;

it provides for use of one and the same structure of the cooling bed for fastening all the metals being evaporated;

it makes for a larger stock of the metal being evaporated, from 100 grams to 100 kg and more.

As distinct from apparatus featuring crucible evaporation of metal, the design of the present invention provides for a service life of the apparatus of up to 10^4 hours, with an intermediate replacement of the metal being evaporated.

Unlike apparatus employing electron-beam evaporation of metal, the apparatus according to the present invention provides for starting the evaporation of metal at a pressure of 1.10^{-1} mm Hg.

The apparatus design according to the invention provides for arranging the metal being evaporated in any position in space relative the articles being coated.

The apparatus according to the present invention can be used as a high-vacuum sorption pump featuring high efficiency (over 100,000 litres per second at a pressure of 1.10^{-5} mm Hg with respect to active gases) at a starting pressure of 1.10^{-1} mm Hg.

An atmospheric breakthrough into the evacuated chamber presents no hazard for the apparatus according to the present invention, for the metal being evaporated is under low temperature and cannot oxidize.

The simplicity of design of the apparatus according to the invention provides for its high reliability in operation.

What we claim is:

1. Apparatus for applying coatings through deposition of metal, comprising: an evacuated chamber; a cooled cathode located in said chamber, said cathode being made of a solid metal to be evaporated, one portion of the surface of the cathode being an evaporation surface; an anode in the form of an envelope located in said chamber opposite the evaporation surface of said cathode so that said evaporation surface faces the space defined by said envelope; means for generating an electric arc between the evaporation surface of said cathode and said envelope, the metal of said cathode being evaporated by the cathode spot of said electric arc moving in a random manner over the evaporation surface of said cathode; and means for extinguishing the cathode spot when the cathode spot moves from the evaporation surface of said cathode to a surface of said cathode other than the evaporation surface.

2. The apparatus of claim **1,** wherein said cooled cathode is made in the form of a disk, said envelope has the shape of a hollow sphere having an opening accommodating said disk, said means for generating an electric arc is made in the form of a movable trigger electrode which is connected electrically to said envelope after a mechanical contact has been achieved between said trigger electrode and said cooled cathode.

3. The apparatus of claim **1,** wherein said evacuated chamber has the shape of a bell, with said cathode being arranged coaxially with said evacuated chamber and insulated electrically from said evacuated chamber, said cathode having the shape of a flat cylindrical disk with one flat end portion constituting the evaporation surface, the evaporation surface facing a space defined by said evacuated chamber, said means for extinguishing the cathode spot being made in the form of a metal ring arranged coaxially with, and spaced from, the cylindrical surface of said cathode, the end of said ring corresponding to the evaporation surface being located at the same level as said evaporation surface, said ring having a cut-out at the side of said flat surface through which said means for generating an electric arc, made in the form of a movable trigger electrode, may approach said cooled cathode.

4. The apparatus of claim **1,** wherein said cathode is made in the form of a cylindrical ring having a flat surface which serves as the evaporation surface, while the inner and outer cylindrical surfaces of said ring are not subject to evaporation, said envelope being made in the form of a cylinder arranged coaxially with said ring, and said means for extinguishing said cathode spot being made in the form of rings arranged coaxially with, and speced from, said inner and outer cylindrical surfaces.

5. The apparatus of claim **1** wherein the means for extinguishing the cathode spot includes a shield attached to the evacuated chamber and extending around the cathode so as to screen off at least a portion of the surface of the cathode which is not to be evaporated, the shield being arranged so that a gap is formed between the shield and the cathode surface which is not to be evaporated, the gap being sufficiently large to result in the cathode spot being extinguished when the cathode spot moves into said gap.

6. The apparatus of claim **5,** wherein said shield is made of an electrically conductive material and is connected electrically to said cooled cathode.

7. The apparatus of claim **5,** wherein said shield is made of an electrically conductive material and is insulated electrically from said cooled cathode.

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