

Sept. 8, 1959

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2,903,547

VAPORIZING ELEMENT CONNECTOR AND METHOD

Filed Aug. 21, 1957

6 Sheets-Sheet 1

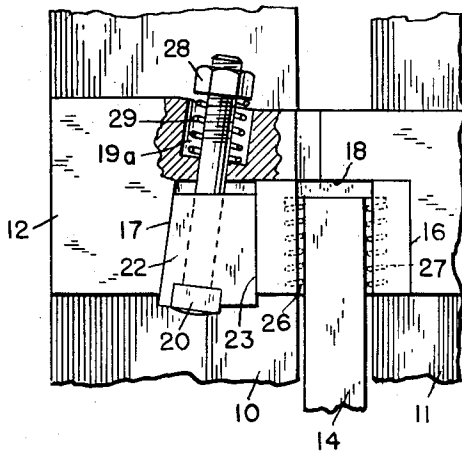


FIG. 4.

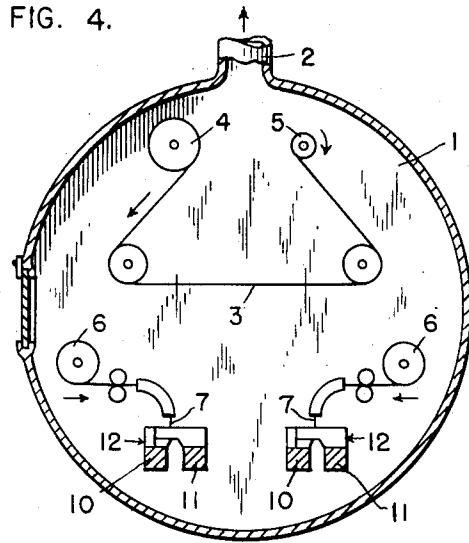


FIG. 1.

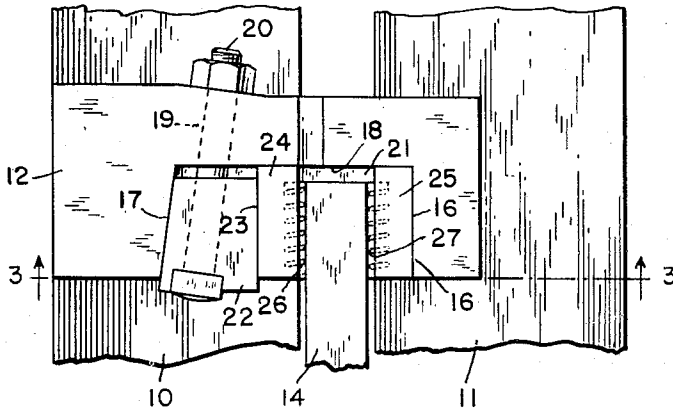


FIG. 2.

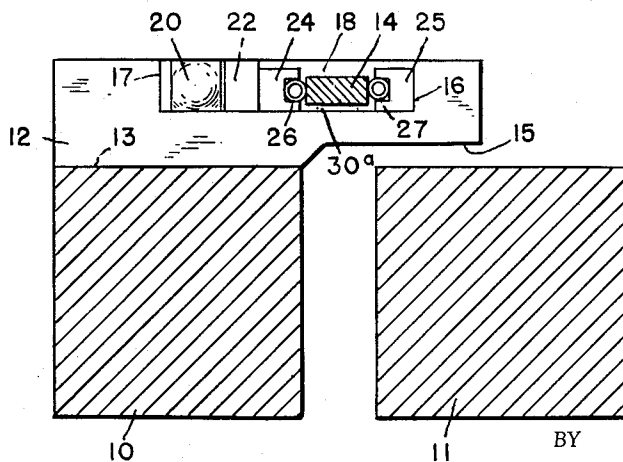


FIG. 3.

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FIG. 5.

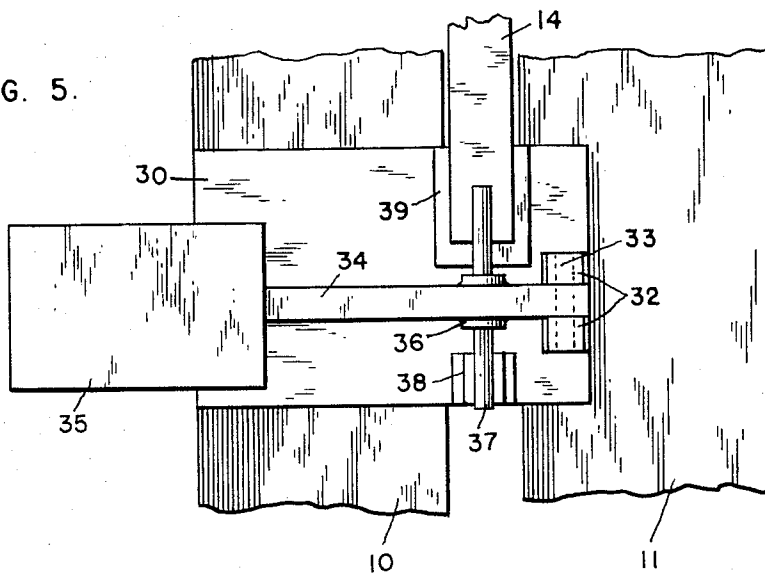
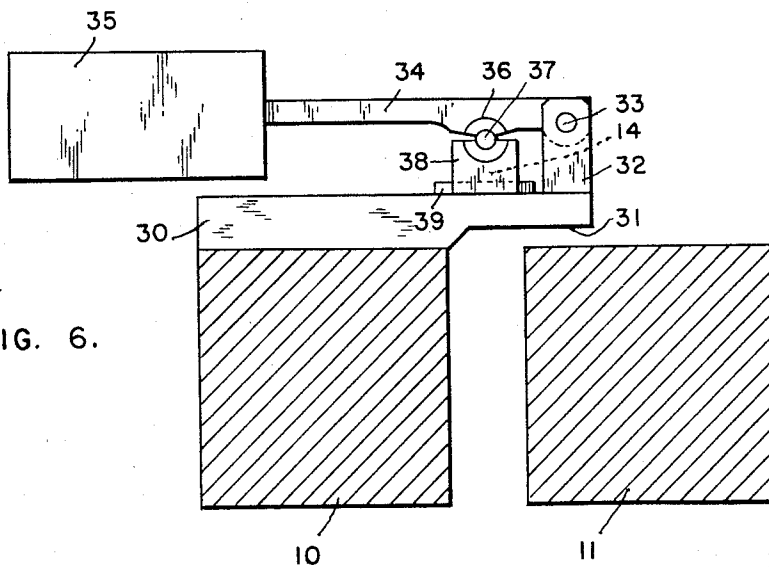


FIG. 6.



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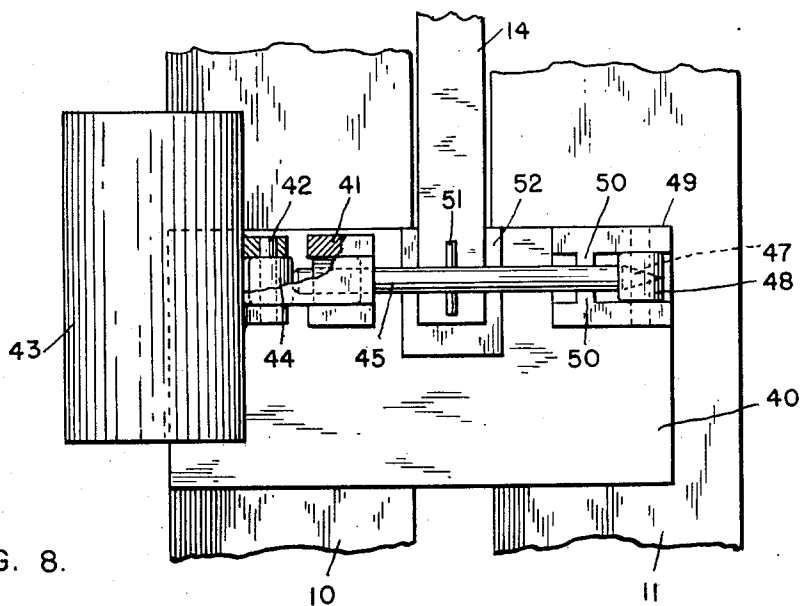


FIG. 8.

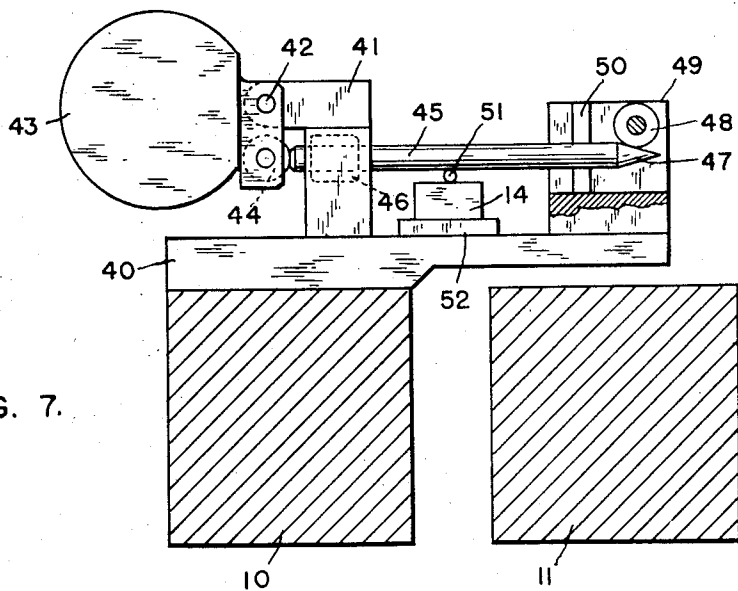


FIG. 7.

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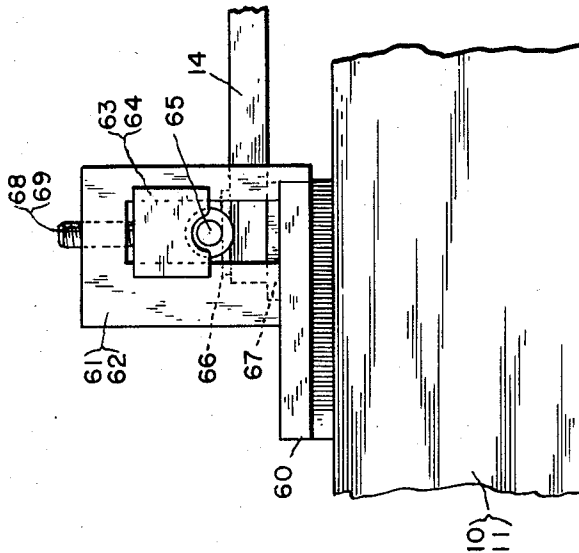


FIG. 10.

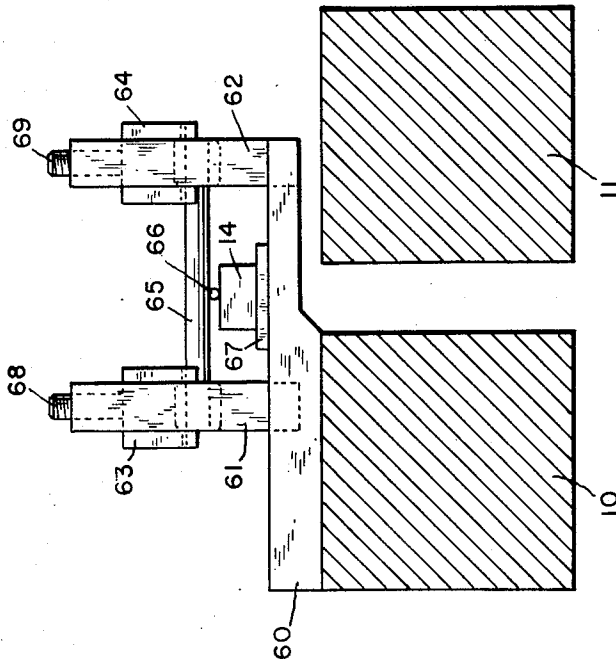


FIG. 9.

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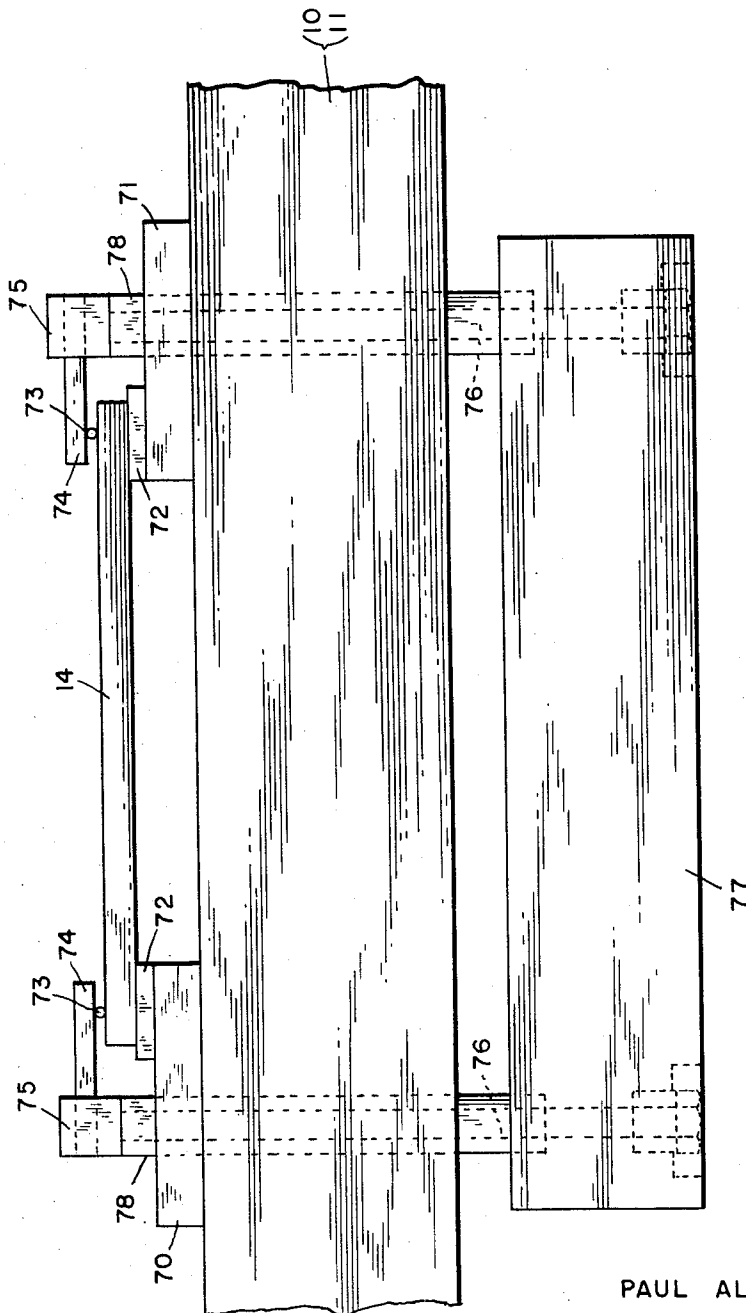


FIG. 11.

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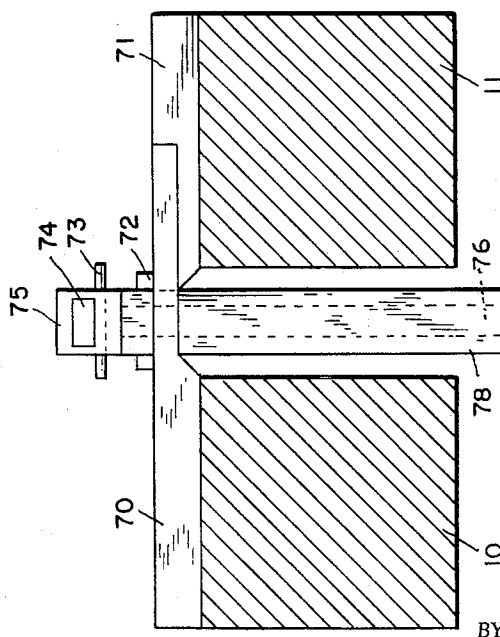
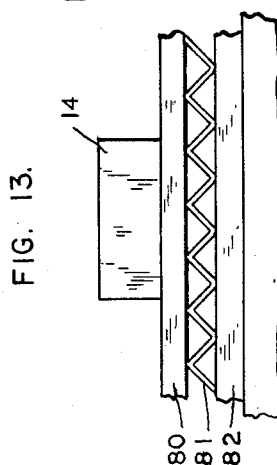
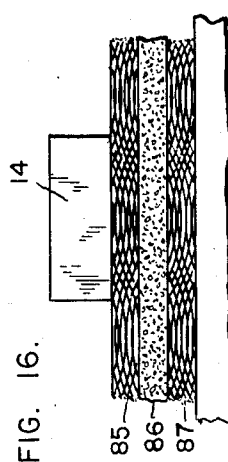
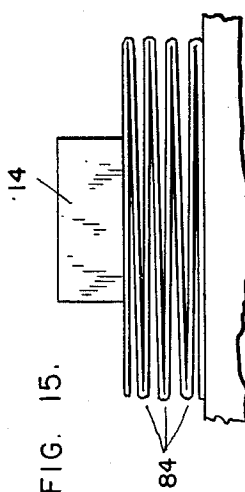
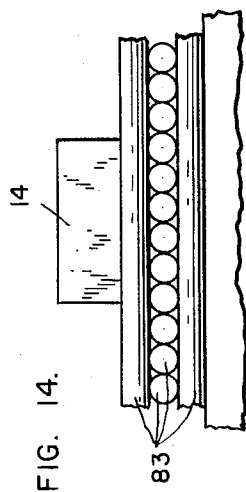
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VAPORIZING ELEMENT CONNECTOR AND METHOD

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6 Sheets-Sheet 6



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2,903,547

VAPORIZING ELEMENT CONNECTOR
AND METHOD

Paul Alexander, Princeton, N.J., assignor to Continental Can Company, Inc., New York, N.Y., a corporation of New York

Application August 21, 1957, Serial No. 679,383

19 Claims. (Cl. 219—19)

This invention relates to the art of vapor deposition of materials in vacuum, and is more particularly concerned with the support and electrical connection of vaporizing elements and a method of employing the same.

The vaporizing element is employed for the purpose of raising the deposition material to a high temperature, i.e. to above its vaporization or sublimation temperature at the low pressure or vacuum employed during the deposition operation. Such elements can be heated by conduction of electrical current therethrough, wherewith the electrical resistance cause the development of heat in the element.

It is known to make these elements of substances such as carbon or tungsten, possibly with protective coatings of materials resistant to the solvent or chemical action of the deposition material. When the deposition material is aluminum, for example, aluminum carbide is formed at the interface of contact of the molten metal with the carbon, and such corrosion reduces the cross-section of the carbon. When tungsten is employed a like corrosion occurs by dissolution. In such cases of corrosion, it is necessary to adjust the voltage being applied to the element, in order to assure an amperage which will give an I^2R heating effect appropriate to maintain the deposit material at the requisite temperature for evaporation. In large scale operations, several heating and vaporizing elements are employed; and therewith individual variations of the elements make it difficult to operate each element at an optimum condition for its service.

When coatings of less-soluble or less-reactive materials are employed, e.g. as set out in my prior patents and patent applications, the degradation of the elements is delayed so that hours of continuous service of elements in vacuum deposition is possible. Such elements are more brittle than simple carbon or tungsten elements, and great care is needed in mounting and connecting them for the electrical current flow therethrough.

This need of care in mounting is even greater with refractory carbides of many elements and with non-carbon heating elements of refractory borides, nitrides or silicides. This is true for such components of the transitional metal elements of groups IV, V, and VI of the periodic system, which are commonly referred to as "hard metals." These elements are brittle at room temperatures and at the temperatures of 1400 to 1500 degrees C. which are employed during vacuum deposition of metals; noting that such temperatures are still low as compared with the melting points of the compounds; and heat shock and irregular heating can cause breakage during the initial heating up to operating temperature and during the operation period.

It has been found that a satisfactory mounting and connection can be effected by employing supports which include mounting devices which retain form and resiliency up to the operating temperature and which present a multiplicity of points of mechanical and electrical engagement with the element, along with devices for pre-

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senting and maintaining the mounting devices in position.

An illustrative form of practice of this invention is shown on the accompanying drawing, in which:

Fig. 1 is a conventionalized upright sectional view of a vacuum chamber for metal evaporation and deposition, having vaporizing element connectors, according to this invention.

Fig. 2 is a plan view of a structure according to this invention;

Fig. 3 is an upright section substantially on line 3—3 of Fig. 2;

Fig. 4 is a view corresponding to Fig. 2, of a second form of construction;

Figs. 5 and 6 show a third form of construction, and correspond respectively to Figs. 2 and 3;

Fig. 7 is an upright end view as in Fig. 3 of a fourth form of construction with parts broken away;

Fig. 8 is a plan view of the structure in Fig. 7, with parts broken away;

Fig. 9 is an end elevation of a fifth form of construction;

Fig. 10 is a side elevation of the structure in Fig. 9;

Fig. 11 is a side elevation of a sixth form;

Fig. 12 is an end elevation of the structure in Fig. 11;

Figs. 13 to 16 show forms of conductive pads for the structures of Figs. 5 to 11.

Fig. 1 shows a conventionalized form of vacuum chamber for metal evaporation and deposit upon a substrate. The chamber 1 has a conduit connection 2 to a vacuum pumping system. The illustrative substrate is a web 3 which is unwound from a supply roll 4, passed across the chamber above the vaporizer elements, and then rewound on a driven take-up roll 5. Pairs of copper bus bars 10, 11 extend horizontally along the chamber, the bars of each pair being of opposite potentials during the operation. Mounting blocks 12 for vaporizer elements are provided for contact with and support upon the bus bars 10, 11; and are present in pairs, with one block of each pair resting on one bus bar, and the other block on the other bus bar. These bus bars are of large section for passage of high amperage currents without excessive loss by electrical resistance and illustratively have flat tops so that the element mountings can be seated by gravity thereon, and moved therealong if necessary for producing vapor in such local concentrations that a uniform or a predetermined varied depth of coating can be deposited on the substrate. The blocks 12 are illustratively in pairs, with each block of a pair in contact with a respective bus bar 10 or 11; and the pair provide mounting for a vaporizer element, as described hereinafter. Supply rolls 6 of the material to be vaporized and deposited, such as aluminum in wire form, deliver the material 7 to the vaporizer elements.

The mounting for only one end of a vaporizer element is shown in several of the figures of drawing, it being understood that a duplicate structure can be employed at the other end.

A copper end terminal block 12 is thus illustratively seated in Figs. 2 and 3 at its bottom surface 13 on the bus bar 10 for mounting one end of the vaporizer element 14 shown as having this end of rectangular section. A part of the bottom of the block 12 is cut away to provide a surface 15 which is spaced from the top of the other bus bar 11. A part of the upper surface of the block 12 is also cut away to provide a recess having one end wall 16 essentially parallel to the direction of the element 14, and a second end wall 17 at an angle thereto: the rear wall 18 of this recess has an opening 19 through which is passed a clamping bolt 20. The floor 21 of the recess supports a wedging piece 22 which bears against the recess surface 17 and has at its opposite side a surface 23 which is illustrated as parallel to the

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surface 16: the bolt 20 passes through the wedging piece 22.

Two copper channel pieces 24 and 25 rest on the recess floor and present channel grooves toward the element 14. Two coil springs 26 and 27, e.g. of tungsten wire, are supported in the channel grooves and bear against the sides of the element 14.

The parts can be assembled outside of the vacuum chamber. The pieces 22, 24 and 25 are put in place with the bolt 20 engaged and the wedge piece 22 well spaced from the wall 18. The springs 26, 27 are inserted and the element 14 placed in position: a temporary spacer, shown by dotted lines at 30a, can be used to support the element 14 above the floor 21. It will be noted that the element 14 is also spaced from the end wall 18. The bolt 20 is now tightened until the wedging action of the piece 22 moves the channel piece 24 and its spring 26 tightly against the element 14, and this element 14 in turn presses tightly against the spring 27, with the reaction of the latter spring being taken up by the engagement of the channel piece 25 against the wall 16. The temporary spacer 30a can now be removed; and the element 14 is now supported and mounted on the block 12 with permissive relative movement. A like mounting can be provided at the other end of the element 14.

When the structure is to be placed in service, with the vacuum chamber open, it is placed with the block 12 on one bus bar, and the corresponding block at the other end upon the other bus bar. The freedom for self-adjusting movement of the element 14 is tested: and further minor adjustment of the bolt 20 effected if found desirable. The evacuated vacuum chamber is closed, sealed and electrical current is supplied to the bus bars. This current flows from the bus bar 10, for example, to the block 12 and thence into the wedge piece 22 and the channel pieces 24, 25 and through the springs 26, 27 into the vaporizer element 14. The pressure produced by the wedging piece 22 has caused to turn the springs to yield individually into contact with the surfaces of the element 14, so that this element is being supported at many points and in resilient fashion: and current flow also occurs at many points so that no single point is being highly heated with accompanying local thermal expansion and heat shock to the element. As the element becomes heated, it can expand in all directions. Horizontal transverse expansion between the channel pieces is accepted by the springs 26, 27. Horizontal longitudinal expansion is permitted by movement of the spring turns individually noting that the end of the element 14 is spaced from the wall 18. Perpendicular expansion is permitted by the spacing of the element 14 from the floor 21 and the absence of constraint at its top surface. At the other end of the heater or vaporizer element 14, current flow occurs in like manner through like parts and from the block 12 thereat to the bus bar 11.

When the deposit operation is interrupted, for opening the vacuum chamber, the electrical current is shut off, and the parts cool. Thermal contraction occurs, and is permitted by the springs, noting that the element 14 is being supported by the spring turns, and that heat radiation can occur from the surface of its ends so that the ends are not being held at high temperature while intermediate portions of the element have fallen to much lower temperatures.

In the form shown in Fig. 4, a continuing stress is employed to maintain mechanical and electrical contact. Here, the parts are as described for Figs. 2 and 3. In addition, a cavity 19a is provided around the bolt 20 for receiving a coil spring 29 of material which maintains its resiliency at the temperature of operation, for example beryllium copper alloy. This compression spring 29 acts between the bottom of the cavity 19a and the nut 28 of the bolt, to maintain a tension on this bolt, and thus tends to draw the wedge block 22 along the

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surface 17 and thus maintain mechanical and electrical connections at the element 14. It has been found that the structure of Figs. 2 and 3 operates satisfactorily even after a number of successive heatings and coolings: in cases where the angle of the wedging surface 17 is high relative to the sides of the vaporizing element, or when the pads of Figs. 13 to 16 are substituted for the springs 26, 27, it is advantageous to have the continuing stress afforded for example by a spring 29. With the structure of Fig. 4, it was found that after fourteen runs, with cycles of heating before a run and cooling thereafter, a gradual deformation of the coils 26, 27 was noted but the change of contact resistance was slight, and the ends of the vaporizer element were only slightly cooler and without effect on the operation.

In the form shown in Figs. 5 and 6, the bus bars 10, 11 support blocks 30, of which one is shown. These blocks are cut away at their bottoms to a surface 31 spaced above the opposite bus bar. Upright ears 32 support a pivot 33 which passes through a lever 34 having a mass 35 on its free end to serve for maintaining pressure upon the electrically contacting parts. Intermediate its length, the lever 34 has a half-socket member 36 with a downwardly open groove which receives the pressure pin 37. A post 38 secured to the block 30 has a groove in its top to receive one end of the pin 37. The other end of the pin rests on the vaporizer element 14. A conductive pad 39, as described in detail hereinafter, is provided beneath the element 14, resting on the block 12.

In operation, the assembly of blocks 30 and associated parts including the element 14 is placed on the bus bars 10, 11; and the chamber is closed, evacuated, and the electrical current supplied to the bus bars. The assembly rests on the bus bars, with proper areas in contact for transmission of the current to and from the blocks 30. At the start, the assembly is cold. When the current is applied, it flows from one bus bar to its contacting block 30, thence through the compressible pad 39 thereon, and to the respective end of the element 14; thence passing along the element 14, and through the pad 39 of the other block 30, through this other block and thence to the other bus bar. The current initially meets greater resistance in the pads 39 than in the element 14, and hence the pads heat more rapidly and lose a part of their supporting strength. The pressure produced by the masses 35 cause the pins 37 to force the element 14 downwardly, compressing the pads and flattening them, wherewith their resistances drop, and the ratio of resistance between the pads and the element 14 changes, so that a greater heating effect is applied in the element. The compression of the pads also assures accurate and extensive mechanical support to the element over a large area thereof at each end.

In the form of construction shown in Figs. 7 and 8, the bus bars 10, 11 are employed as before. A conductive block 40 is shaped at its bottom to rest on one bus bar and be spaced from the other, as before. An upright post 41 secured to the block 40 supports pivot 42 on which is mounted a crank lever having a mass 43 and a roller 44 mounted below and eccentric to the pivot 42, and adapted to press endwise on a plunger 45 which is mounted in loose slide bearing 46 for permitting sliding and rocking of the plunger, and mounted on the post 41. The other end 47 of the plunger 45 is conical and can move beneath a roller 48 rotatably supported on a second post 49 fixed to the block 40. The plunger 45 is in a slot provided in the top of the post 49, and is guided by ribs 50 so that it moves in an upright plane. Beneath the plunger 45 is provided a pressure pin 51 which rests on top of the vaporizing element 14. The element 14 in turn rests upon a pad 52 as employed with Figs. 5 and 6.

The electrical operation of this structure is as with Figs. 5 and 6. As the current enters the assembly, the

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resistance of the pads 52 is initially high, and then decreases as the material thereof becomes hot and is compressed by the downward pressure of pin 51. The mass 43 acts to force the roller 44 toward the right in Fig. 7, thus moving the plunger 45 relatively endwise so that its conical end 47 is forced downward by the roller 48, and therewith the pressure is delivered to the pressure rod 51.

In the form according to Figs. 9 and 10 the bus bars 10, 11 are as before, and each copper end block 60 rests on one bus bar and is spaced as before from the other. Two posts 61, 62 are secured to the block 60 and have upright slots for receiving the vertical and movable blocks 63, 64 which have grooves at their bottoms for engaging a transverse rod 65 and therethrough delivering pressure to the pressure pin 66 which rests on the corresponding end of the vaporizing element 14. The end of the element 14 in turn rests upon a pad 67 as before. A screw 68, or 69 is threaded in the top of each post 61, 62 for exerting pressure upon the respective sliding blocks 63, 64.

In operation, the assembly of the two blocks 60 and the heater element 14, and the associated parts, is made and then the assembly is placed upon the bus bars 10, 11. The posts 61, 62 and the blocks 63, 64 are preferably made of materials having different coefficients of heat expansion, with the blocks 63, 64 thus elongating more than the post 61, 62, and thus exerting pressure through the rod 65 and upon the pin 66 throughout the heating period, for exerting compression upon the pad 67. Therefore, the operation is as described in Figs. 5 to 8.

In the form of construction according to Figs. 11 and 12, a single device is employed for exerting pressure at both ends of the vaporizing element.

Here, the bus bars 10, 11 support the copper blocks 70, 71 which rests respectively thereon. Pads 72 of compressible conductive material are placed on the blocks 70, 71 as before and the vaporizing element 14 rests on these pads. Pressure pins 73 rest on the respective ends of the elements 14 and are pushed downward by the fingers 74 secured in the upper ends 75 of tension rods 76. A large mass 77 is supported by the lower ends of rods 76, noting that this mass may be of insulating material or insulatively supported so that it does not provide a short circuit from one end of the vaporizing element 14 to the other. The operation of this structure is as described above.

In the forms having top pressure pins such as 37, 51, 66, 73, it will be noted that these pins can be made with small contact areas with the vaporizing element, as their functions are mechanical only; and that they can be electrically insulated from the bus bars if desired, for example by making the posts or receiving sockets in Figs. 5 to 10 of refractory insulating material or by providing the insulating sleeves 78 in Figs. 11 and 12.

The material used for the pads 39, 52, 67 and 72 may be as shown in Figs. 13 and 16.

In Fig. 13, sheets of heat-resistant conductive materials, such as tungsten, are crimped to a zig-zag form and three such crimped sheets 80, 81 and 82 are then superposed at successive right angles to one another between the supporting block and the element 14. During the initial heating, the ridges engage the block and heater element and conform thereto. As the material becomes heated and somewhat more yielding, the crimped or corrugated form yields and is compressed so that the total thickness of the pad is lessened and the electrical resistance therewith decreases at a rate much greater than the thermal rise of resistance in the material used.

In the form of Fig. 14, a number of coils 83 of heat resistant conductive materials such as tungsten wire are provided in three layers successively at right angles to one another. Upon initial assembly these coils make contact with the heater element 14 at a great number

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of placed points, with assured mechanical and electrical contact; and during the increase of heating, the coils become compressed so that the contact occurs over greater areas of the heater element and block, and greater areas than the pad assembly, wherewith the electrical resistance drops.

In the form according to Fig. 15, a sheet of heat resistant conductive material is folded upon itself, with a horizontal dimension of each fold greater than that of the vaporizing element 14. This folded assembly 84 is then placed on the block and the vaporizing element 14 mounted thereon. During initial heating there is a long conductive path provided by the folded pad 84, of greater electrical resistance than that of the vaporizing element 14; but as the pad 84 is heated and under the pressure effect by the above described structures, the pad 84 is compressed so that its folds come into contact with one another and thus decrease the electrical resistance until it becomes less than that through the vaporizing element 14.

In the form of construction according to Fig. 16, interwoven or felted wires or strips of heat resistant electrically conductive matter, such as lengths of tungsten wire are plaited or woven to form layers of materials 85, 86, 87 which are arranged at angles to one another between the block and the vaporizer element 14. This woven or felted mass presents a large number of contact points when the heating begins, with respect to the block, the vaporizing element 14, and each other, but the resistance is relatively high. During the heating and under the action of the continuing pressures afforded by the structures described, the pad is compressed so that there is less distance of conduction along the individual filament, and more points of contact are developed, until the electrical resistance has been lowered below that of the vaporizing element 14.

It will be noted that in the several forms, electrically conducted materials can be employed which remain resilient even at the temperatures of vacuum deposition of metals, so that although they yield under the pressure effects, the elastic limit of the materials still assures a resilient response and maintenance of contact over large areas of the vaporizing element 14, even with changes of temperature as may occur during the controlled operation of the deposition equipment.

In each of the forms, the assembly assures a gradual temperature gradient between the element and the base blocks, during the heating and cooling stages, rather than a sharp and high temperature drop between an end of the element and a solid mass with which it is in contact.

In the form of Figs. 2 and 3, the conductivity of the coils 26, 27 may be greater than that along the vaporizer element itself, so that the coils do not become visibly hot as the unit is being brought into service. The heat transfer to and from the coils, and to the copper blocks, is so small that the coils do not carry a large amount of heat away from the vaporizer element to the blocks, and hence the ends of the vaporizer element heat quickly and remain hot. When the coils are short and have few turns, the ends of the vaporizer element heat more rapidly than mid-points of its length, but very soon the whole element reaches an optically determined uniform temperature. In the course of a long operation, or after several operations with intervening cooling and reheating, the coil resistance may become reduced, probably by deposition thereon of aluminum from the vapor atmosphere: but this has not been found harmful nor to cause breakage, because the temperature gradient from the element to the blocks remain gradual. With the structure of Figs. 2 and 3, during cooling after one deposition operation, the element 14 is usually somewhat loose between the springs 26, 27, due to a minor permanent deformation of these springs during the prior heating up and deposition operation. This usually is

not visible upon examining the coils, but has an advantage during the cooling, as it eliminates any danger of breakage of the element during its contraction. It is preferred to turn the nut of the bolt 20 before the structure is again heated, to compensate for this minor effect. In the structure of Fig. 4, the springs 29 automatically assure a sufficient pressure upon the springs so that a proper mechanical and electrical engagement is attained.

In other forms, the resistance of the vaporizing element 14 can be low initially, as compared with the contact pads or springs, wherewith the heating of the element is gradual and heat shock is eliminated. In particular, the transmission of heat from the pads to the ends of the vaporizing element assures that the element may be heated with greater uniformity, even though the radiation effect is greater at the ends than along the length of the element. This initial heating of the contact pads or springs means that much of the electrical energy is being consumed therein. However, as the springs or pads are stressed or deformed into contact with the vaporizing element, and the length of current path through the springs or pads is decreased as these yield, ultimately the resistance therein is lowered to such a value that the major portion of the electrical current is being usefully employed in the vaporizing elements 14. In practice, it is noted at the beginning that the springs or pads become visibly hot in the red and yellow ranges of temperature, before the intermediate parts of the vaporizing element 14 are raised above the visually black condition. As the heating progresses, the ends of the heater elements pass to a visually radiant condition, at about the same rate as the intermediate parts of the heater. When the desired operating temperature has been attained, as observed visually or by a pyrometer, aluminum metal wire 7 (Fig. 1) may be fed to the top of the vaporizing element 14 from the supply reels 6, so that the aluminum metal melts and spreads out on top of this element and is vaporized therefrom. The heat required for this melting and vaporization causes the center of the element to fall slightly in temperature, and the rate of delivery of the aluminum wire is preferably controlled so that this fall of temperature is very slight.

In all forms, the pads or spring coils make a large number of point or line contacts with the element, and this secures adequate electrical contact for the high current employed and prevents the development of unduly high contact resistance at any one point which might result in a rapid heating up of a small area of the element which would cause breakage. At the same time, these point or line contacts provide a limited heat contact area, because the total area of these points or lines is small; therefore, there is only a slight cooling of the ends of the elements, thus they become hot from end to end. Accurate line-up of the elements is not necessary, because the pads or coils conform to the surfaces of the contact ends and provide adequate electrical contact even if the surfaces of the element and of the contact blocks are not perfectly true. It has always been a serious problem to provide an accurate line-up of parts, when a rigid clamp is employed with rigid elements, even with accurate grinding of the element ends and the cooperative surfaces of the block, noting that such grinding substantially increases the costs of the vaporizing elements.

It is obvious that the invention is not limited to the specific form of the invention, but that it may be practiced in many ways within the scope of the appended claims.

What is claimed is:

1. A mounting and electrically conducting structure for a rigid heating element which exhibits expansion along an axis when heated, comprising a supporting block having an electrically conductive surface portion, an electrical current supply connection to the block, a conductive

resilient and yielding member engaged with said surface and presenting a multiplicity of mechanical and electrical points of engagement with a side of the element adjacent an end thereof, and means for producing a pressure from the block upon the said member transversely relative to said axis and thence upon the element at said points for supporting the element free of contact with the block and whereby during thermal expansion of the element the member maintains electrical contact between the element and the block at said points without inhibiting mechanical relative movement of parts of the element.

2. A mounting and electrically conducting structure for a rigid heater element which exhibits expansion along a horizontal axis when heated, comprising a supporting block having an electrically conductive surface portion, a coherent conductive resilient member presenting a multiplicity of mechanical and electrical points of engagement with a side of the element, said member having parts adjacent said points resiliently yieldable along the direction of said axis, and means on the support for pressing said member toward said axis and into resilient engagement of said points with the element for supporting the element free of said block, whereby a conductive path is established from the element to said surface portion and axially spaced parts of the element may move relative to one another with resilient movement of parts of said member adjacent said points.

3. A mounting and electrically conducting structure for a rigid heating element which exhibits expansion along an axis when heated, comprising a supporting block having an electrically conductive surface portion, an electrical current supply connection to the block, a conductive resilient and yielding member engaged with said surface and presenting a multiplicity of mechanical and electrical points of engagement with a side of the element adjacent an end thereof, and means connected to the block for producing a pressure upon the said member transversely relative to said axis and thence upon the element at said points and cooperating with said member for supporting the element free of contact with the block and whereby during heating and thermal expansion of the element the member maintains electrical contact between the element and the block without inhibiting mechanical relative movement of parts of the element.

4. A mounting and electrically conducting structure for a rigid heating element which exhibits expansion along an axis when heated, comprising a supporting block having an electrically conductive surface portion, an electrical current supply connection to the block, a conductive resilient coil spring engaged with said surface and presenting a multiplicity of mechanical and electrical points of engagement with a side of the element adjacent an end thereof, and means for producing a pressure from the block upon the said coil spring transversely relative to said axis and thence upon the element at said points for supporting the element free of contact with the block and whereby during thermal expansion of the element the coil spring maintains electrical contact between the element and the block without inhibiting mechanical relative movement of parts of the element.

5. A structure as in claim 4, in which the block has a surface directed at an angle to the direction of the coil spring, a wedge member is provided in contact with said angled surface, and a device is provided as part of said means for moving the wedge member along said surface and thereby pressing the coil spring against the element.

6. A mounting and electrically conducting structure for a rigid heating element, comprising a conductive support block, an electrically conductive coil spring having turns thereof engaged with the element, the block having a surface directed at an angle to the direction of the coil spring, a wedge member in contact with said angled surface, and means on the block for acting upon the spring to force it against the heating element, said means including a bolt engaging the block and the wedge member

for moving the wedge member along said surface and thereby pressing the coil spring against the element.

7. A mounting and electrically conducting structure for a rigid heating element, comprising a conductive support block, an electrically conductive coil spring having turns thereof engaged with the element, the block having a surface directed at an angle to the direction of the coil spring, a wedge member in contact with said angled surface, and means on the block for acting upon the spring to force it against the heating element, said means including a second spring effective to move the wedge member along the said angled surface and thereby pressing the coil spring against the element.

8. A mounting and electrically conducting structure for a rigid heating element having an end with substantially parallel side surfaces, comprising a conductive support block, electrically conductive coil springs having turns thereof engageable with said side surfaces at a multiplicity of points at each side thereof, and means on the block effective to press the turns of both coil springs against the sides of the heating element whereby to resiliently support the said end of the heating element out of contact with the said block and said means for permitting relative movement of the heating element with respect to the block upon expansion during heating.

9. A mounting and electrically conducting structure for a rigid heating element subject to thermal expansion along its length, comprising a conductive supporting block, an electrical current supply connection to the block, a pad member of conductive heat resistant material located upon the supporting blocks for engaging a side surface of the element adjacent an end thereof and conducting electricity thereto at a multiplicity of points, said pad being yieldable along the direction of the length of the element and also being yieldable transversely to such length under pressure from the element whereby its electrical resistance is decreased, and means for exerting pressure against the opposite side surface of the element.

10. A mounting and electrically conducting structure for a rigid heating element, comprising a conductive support, a pad member of conductive heat resistant material located upon the support for engaging a surface of the element and conducting electricity thereto at a multiplicity of points, said pad being yieldable under pressure from the element whereby its electrical resistance is decreased, a weighted lever pivoted on the support, and a device actuated by said lever to press against the element.

11. A structure as in claim 10, in which the device includes a pin resting upon the element.

12. A structure as in claim 10, in which the device includes a rod movable transversely of the element and having an angled portion, and a member on the support engaged with said portion, the lever being effective for moving the rod in the direction of its length, whereby the rod is caused by said engaged member to rock and thereby press toward the element.

13. A mounting and electrically conducting structure for a rigid heating element, comprising a conductive support, a pad member of conductive heat resistant material located upon the support for engaging a surface of the element and conducting electricity thereto at a multiplicity of points, said pad being yieldable under pressure from the element whereby its electrical resistance is decreased, a rod extending transversely of the element, and means on the support for pressing the rod toward the element.

14. A mounting and electrically conducting structure for a rigid heating element, comprising a conductive sup-

port, a pad member of conductive heat resistant material located upon the support for engaging a surface of the element and conducting electricity thereto at a multiplicity of points, said pad being yieldable under pressure from the element whereby its electrical resistance is decreased, a weight, a pin engaged with the surface of the element opposite said pad, and a connection whereby the weight presses the pin against the element.

15. A mounting and electrically conductive structure for a rigid heating element subject to thermal expansion, along its length, comprising a conductive support, resiliently yieldable conductive means effective to permit endwise movement of the element relative to the support and located between the support and parts of a side of the element adjacent an end thereof, and means engaged with an opposite side of the element for pressing said parts of the element against the said conductive means, said conductive means having initially high electrical resistance and being reactive during heating and by the pressure of said pressing means to have a lower electrical resistance at high temperature.

16. A mounting and electrically conductive structure for a rigid heating element subject to thermal expansion along its length, comprising a conductive support, a conductive member effective to permit endwise movement of the element relative to the support and located between the support and parts of a side of the element, adjacent an end thereof, said member having a multiplicity of points of engagement with the element and long paths of heat transmission from the element to the support and being yieldable whereby said points on the element can move relative to the points on the support when the element is heated while maintaining long paths of such heat transmission, and means for maintaining the member in electrical contact with both the support and the element.

17. A structure as in claim 16, in which the member is of metal which retains resiliency at the temperature of operation and is comprised of a plurality of parts having spaced contacts with one another whereby to provide the said long paths.

18. A structure as in claim 17, in which the member is made of metal wire, with the wire having points of contact with the element, said points being spaced along the wire by portions of the wire which are not in contact with the element.

19. The method of operating a heating element subject to thermal expansion along its length, which comprises supporting parts of a side of the element adjacent an end thereof upon a resiliently yielding pad of conductive material having multiplicities of points of contact with the element, the pads being effective to permit relative longitudinal expansion movement, the pads initially having higher electrical resistance than the element, pressing the element against the pad for effecting a reduction of resistance of the pad when the pad and element are heated, and conducting electrical current to the element through the pad whereby to effect heating of the pad and the element.

References Cited in the file of this patent

UNITED STATES PATENTS

1,645,091	Chapman	Oct. 11, 1927
1,742,286	Shaw	Jan. 7, 1930
1,969,132	Heyroth	Aug. 7, 1934
2,104,555	Cousteix	Jan. 4, 1938
2,679,545	Kistler	May 25, 1954
2,703,834	Charbonneau	Mar. 8, 1955