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E. J. WALSH
GRID ELECTRODE STRUCTURE AND MANUFACTURING
METHOD THEREFOR
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2,549,551

FIG. 1

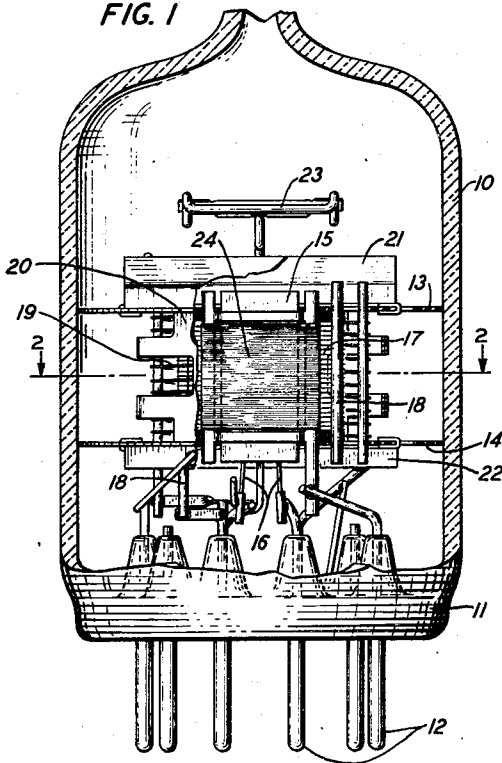


FIG. 2

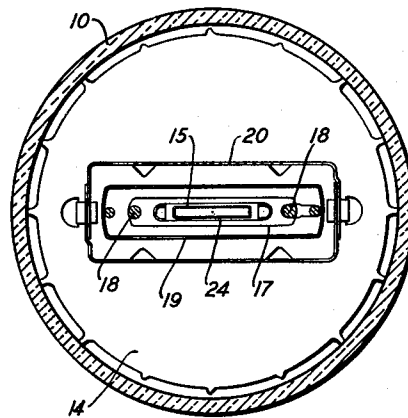


FIG. 3

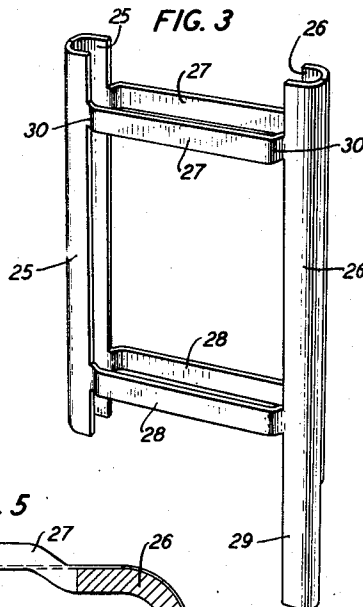


FIG. 4

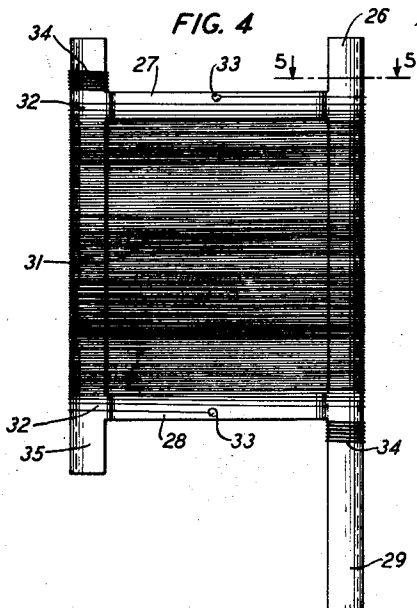
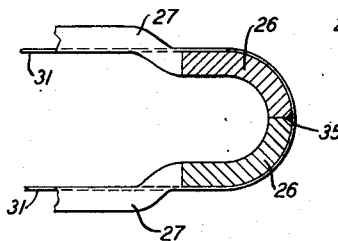


FIG. 5



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GRID ELECTRODE STRUCTURE AND MANUFACTURING METHOD THEREFOR

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8 Claims. (Cl. 250—27.5)

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This invention relates to electronic discharge devices and more particularly to such devices of the micro-midget multi-element type especially useful in ultra-high frequency translating systems.

The static characteristics of electronic discharge devices determine the scope of use and the efficiency of operation in low frequency applications. However, the requirements encountered in the very high and ultra-high frequency ranges, such as the 100 to 500-megacycle range, impose conditions which can only be satisfied by extremely precise mechanical correlation of the elements to produce the essential electrical constants whereby the highest efficiency is attained. The most important characteristic for general use is the transconductance. The transconductance depends on the spacing between the cathode, control grid, and screen grid, the diameter of the grid wire, the spacing thereof, the electrode area and the potentials applied to the electrodes. In order to attain a high transconductance, it is necessary to reduce the diameter of the control-grid lateral wire to a point where the wire is not self-supporting when wound in grid form. Therefore, the fine fragile wire must be wound on a support frame which maintains the collateral relation of grid and cathode constant at very close spacing, for example at of the order of $2\frac{1}{2}$ mils. In addition, the grid laterals must be relatively close together along the length of the grid to secure the desired controlling action upon the electron stream emanating from the cathode.

The attainment of relatively close precision relationship between the cathode surface and the control electrode and the closely spaced lateral turns of the fragile wire of the control electrode practically compels the employment of a sheet metal of highly refractory material as the frame or foundation support for the wire, to insure adequate mounting, freedom from distortion, sufficient rigidity to withstand tensioning of the fine wire during winding, and the maintenance of the laterals in accurate relation without complicated fastening means on the frame structure.

An object of this invention is to facilitate the fabrication of the control electrode assembly in micro-midget electron discharge devices especially suitable for use at very high and ultra-high frequencies.

Another object of the invention is to maintain constant relation between the winding of the con-

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trol electrode and the cooperating cathode surface of the device.

A further object of the invention is to insure the rigidity of the closely spaced lateral windings on a frame type grid structure in the device.

Another object of the invention is to provide an efficacious method of assembly of the control electrode whereby the lateral turns of wire on the frame are definitely secured to the frame structure.

A further object of the invention is to enable fabrication of the control electrode in an expeditious manner to eliminate distortion of the fine wire and efficiently bind the wire on the frame assembly.

These objects are realized, in accordance with features of this invention, by the construction of a control electrode of precise dimensions in which relatively fine wire is wound on a hollow metallic frame of lattice configuration having lateral half sections of rectangular form with arcuate uprights which are joined collaterally along their longitudinal edges to constitute the frame assembly. The uprights are provided with bridging straps or connecting arms bent outwardly adjacent opposite ends to accurately space the upright sections and to form terminations for the wire winding supported on the grid frame structure.

A feature of the invention relates to the sequence of operations performed in fabricating the complete assembly. The two half sections of the frame structure are matched to form a hollow support with the arcuate uprights in abutting relation and the bracing straps in parallel positions transverse to the uprights. The fine wire is wound continuously around the hollow frame over the longitudinal expanse between the straps and also over the straps until the winding is completed. The end turns of wire are temporarily tacked on the frame by affixing a soluble cement over the straps to prevent unwinding of the helical turns of closely spaced wire. After the winding is completed, a fusible metal advantageously in the form of a few turns of gold wire, is applied to diagonally opposed ends of the uprights and the whole assembly is placed in a furnace or oven and heated in a reducing atmosphere to a sufficient temperature to fuse the metal on the ends of the uprights.

During the heating cycle, the fusible metal is reduced to a fluid state and flows by capillary action along the conjoint edges of the uprights to braze the helical turns of wire to the frame and also the half sections of the frame together

whereby the helix of wire is rigidly affixed to the frame structure. As the heating progresses, the temporary cement binder is removed by evaporation and the fused metal forms a permanent binder for the turns of wire on the frame. After the structure has cooled to room temperature in the oven, to avoid oxide contamination the loose extremities of the windings on the bracing straps may be removed.

This arrangement provides an efficient assembly wherein the helical grid winding is rigidly fixed on the frame structure and the two sections of the frame are joined contiguously to form a hollow enclosure of precise dimensions with respect to the major and minor axes so that the required dimensional spacing of the grid laterals with respect to the cathode surface is maintained constant. Furthermore, the heat treatment incident to the melting of the metal is not detrimental to the tension stress of the fine grid wire or the frame parts since these components are highly refractory metals so that the initial tension of the wire which maintains the laterals in close parallel relation is not destroyed or affected.

These and other features and advantages of the invention will be more clearly set forth in the following detailed description of one embodiment of the invention disclosed in the accompanying drawings in which:

Fig. 1 is an elevational view partly in section of a multielement discharge device embodying features of this invention, with the greater portion of the vessel and the internal electrodes broken away to clearly show the position of the control electrode assembly;

Fig. 2 is a cross-section plan view of the device of Fig. 1 taken on the line 2—2;

Fig. 3 is an enlarged perspective view of the frame structure of the control electrode without the helical winding thereon to show the detailed structure of the frame and elemental parts thereof;

Fig. 4 illustrates in an elevation view the control grid assembly after the winding is applied but prior to the final processing and shows the preliminary binder affixing the fine wire to the frame and the position of the brazing material on the uprights of the frame assembly; and

Fig. 5 shows a grossly enlarged portion of the grid assembly in a cross-sectional view taken on the line 5—5 of Fig. 4 and the relationship of the winding and frame in their final integrated form ready to be inserted in the unitary electrode assembly of Fig. 1.

Referring to the drawing, the electronic discharge device of micro-midget dimensions embodying this invention is shown in Fig. 1 to an enlarged scale of about 4:1 to clearly illustrate the components of the unitary electrode assembly mounted within the receptacle. Although the electrode unit, exclusive of mounting projections, occupies less than half of the space in the receptacle, and the mounting includes spacer discs to fit the inner wall of the receptacle, some realization of the microdimensions of the electrode unit may be gained by reducing the dimensions shown by a factor of 4. Then the unit has dimensional limits of approximately one-half inch length, one-half inch width and one-quarter inch thickness. Since the unit includes a multiplicity of individual coaxial electrodes of which the central cathode and surrounding control electrode must be proportionally smaller in two dimensions, namely, width and thickness, it

is evident that extremely precise tolerances must be maintained in the fabrication of these elements to realize the close spacial relation in the unitary assembly.

For example, the control grid structure, to which this invention particularly appertains, has a width of .223 inch $\pm$.001 inch, in a particular embodiment, a length of .333 inch $\pm$.010 inch and an over-all transverse dimension of .0490 inch $\pm$.0006 inch with the minor axis not greater than .0330 inch $\pm$.0006 inch, to attain the uniform collateral relationship of the fine wire laterals supported on the control electrode with respect to the cathode surface of not greater than .0025 inch. Since the fine tungsten wire supported on the control grid may have a diameter within the range of .00022 inch to .00032 inch and the turns per inch may vary between 384 to 326 respectively, for a given amplification factor, it is evident that precision control must be exercised throughout the fabrication of the elements to attain the required dimensional geometry of the elements and satisfy the electrical characteristics desired in the device.

The device, as shown in Fig. 1, includes an evacuated vitreous enclosing vessel 10, of cylindrical configuration having a molded or cast stem 11 sealed to the base end with a plurality of terminal pins 12 projecting from the stem for connection to the electrodes in the unit assembly or mount within the vessel. Since this invention is directed to the construction of the control grid assembly, its method of assembly and spacial relationship with the cathode surface in the unit, the description with respect to the electrode unit will be general in substance. A more detailed description will be found in Patent 2,507,706, issued May 16, 1950, to R. C. Gee and W. Gronros.

The unit or mount includes a pair of spacer insulating discs 13 and 14, advantageously of mica, which support the electrodes in fixed position in the enclosing vessel. These discs are attached to opposite ends of a plurality of electrodes including a central rectangular hollow cathode 15 containing an internal heater element 16, a wire wound screen grid 17 having parallel support posts 18, a wire wound suppressor grid 19 and a sheet metal formed anode 20 surrounding the inner electrodes. In addition suitable metallic shields 21 and 22 are mounted on opposite ends of the unit and attached to the spacer discs, to reduce the capacitance between the control grid 24 and the anode 20. A getter mounting 23 is supported from the top of the unit. Suitable connections extend between the respective electrodes and the terminal pins 12 to couple the individual electrodes in desired arrangements in electrical circuits or functional applications to convert, amplify, control or modulate the signal voltages intended to be applied in the operation of the device.

A precision fabricated control electrode or grid 24 is mounted in close space relationship to the cathode 15 and comprises a fine wire helix, for example of tungsten. Since the very fine tungsten wire which forms a component of the control grid 24 is not sufficiently strong to be self-supporting like the laterals of the other grids in the device, a substantially rigid frame structure is provided to form the foundation or support for the fine wire. This frame structure is clearly shown on an enlarged scale of about 10:1 in Fig. 3 and is formed of a highly refractory metal, such as molybdenum, to withstand the tension

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strain imposed on the fine wire during the winding of the grid. The grid frame preferably is fabricated from sheet metal although it may be formed of tubular stock if a single piece construction is desired. For practical reasons, it is convenient to form the frame support of two similar portions or sections of punched sheet metal of .008 inch thickness, each having a pair of side or upright parallel struts 25 and 26 which are joined by transverse bracing straps or bridging arms 27 and 28 adjacent opposite ends of the strut portions to form a rectangular frame. Each strut is formed into arcuate shape toward the outer periphery so that when both sections are placed in abutting relation to form a hollow body, the combined struts are substantially semi-circular in cross-section with their contacting edges in abutment along the longitudinal median plane of the body, as shown in Fig. 3. One of the struts, for example 26, may be elongated, as shown at 29, to provide an extension for attaching a connecting wire thereto, as shown in the assembly of Fig. 1. By forming the frame structure of rigid metal of highly refractory character, the dimensions of the major and minor axes of the body may be accurately maintained to insure precise lateral relation of the grid winding with respect to the collateral surfaces of the flat cathode 15 in the device. In order to provide adequate clearance from the cathode surface, the straps or arms 27 and 28 may be bent outwardly at 30, as shown in Fig. 3, so that these arms lie in parallel planes spaced more widely than the sides of the curved struts 25 and 26. This dimensional difference is more clearly illustrated in Fig. 5 which shows a portion of the grid frame structure in greatly enlarged proportions of 25:1.

After the frame structure is formed, as heretofore described, with the two sections which comprise the unit frame of the grid in longitudinal abutting relation to form a hollow body, the frame is ready for the winding of the fine wire in helical form with the laterals closely spaced in parallel relation along the major portion of the frame structure. The frame sections are placed in pairs on a suitable winding jig, in series to form a gang of grids so that the winding may be performed as a continuous operation. The winding of the wire is uniform on the frame over the area between the arms 27 and 28 and variable over the intermediate portions of adjacent grids, to reduce loss of wire in the winding operation. Since the fine tungsten wire employed in winding the grid is of very small diameter, of the order of .00022 inch to .00032 inch, and the winding pitch is relatively fine, for example 326 to 384 turns per inch, and the grid may even be wound with smaller diameter wire at the rate of 500 to 600 turns per inch, it is important that precision be exercised in the winding operation to avoid breakage of the wire, due to tensioning, and to insure definite linearity in the adjacent turns of wire to attain absolute constancy of pitch in winding, whereby a high transconductance may be realized in the operation of the device in which the grid is mounted.

In view of the minute diameter of the wire and the close precision in the space relation of the laterals on the frame structure, it is convenient to perform the winding operation on a precision grid winding machine under a powerful microscope, to permit the operator to accurately control the winding operation. Since the fine wire is wound continuously over the frame sections,

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the uniformly spaced laterals must be held in accurate alignment until permanently affixed to the frame. This is achieved by applying the required tension to the wire during the winding operation so that the uniform pitch of the turns is stable on the frame. This requires a strong metal frame to withstand the tension strain applied during the winding so that distortion of the miniature frame does not occur. Molybdenum or other highly refractory metal is particularly suitable for this purpose. Another advantage of the construction involving the metal frame and fine wire with respect to holding the laterals under constant tension during high temperature operation is the fact that the molybdenum frame has a higher coefficient than tungsten whereby the lateral turns of wire on the frame are held taut by the greater expansion of the frame in relation to the lower expansion of the tungsten wire.

A suitable method of tensioning the fine wire is disclosed in the application Serial No. 775,733, filed September 23, 1947, of J. A. Morton.

Fig. 4, which is drawn to the same scale as the grid frame in Fig. 3, shows the fine wire helix 31 wound at a uniform pitch of approximately 360 turns per inch on the major portion of the frame structure between the bridging arms 27 and 28. Since the winding, as heretofore explained, is continuous over a gang of grids in series, the fine wire is wound over the projections of the struts 25 and 26 on adjacent frames in wide turns and as the wire nears the bridge arm 27 or 28, the pitch is reduced to substantially the required uniform pitch desired on the main portion of the frame. However, the instant change from the wide pitch to the desired pitch is not practical so that as the winding progresses near the bridging arm, the pitch is gradually reduced so that the pitch of the initial turns 32 embracing the struts and arms is variable for a short distance. The excess turns of the helical wire winding are located on the bridging straps where they do not enter into the functional operation of the grid assembly.

When the grid helix 31 is completely wound on the frame in the desired pitch to conform to the characteristics of the device in which the grid forms one of the components, the variable pitch turns 32 of the wire in contact with the arms 27 and 28 are fixed thereto, preferably by a spot of reducible cement 33, such as nitrocellulose cement, which tacks the ends of the winding on the respective arms of each grid assembly so that the individual grids may be separated after the winding operation is completed.

The partially complete grid assembly is removed from the winding jig, after severing the stretch wire between adjacent grid frames, and the individual frame structures are prepared for the final operation to permanently affix the fine wire on the frame structure. Since the frame sections are intimately tied together by the surrounding helix of wire extending along the greater length of the structure, the grid assembly may be conveniently handled after removal from the winding jig. The next step is to apply a low melting point metal to oppositely disposed ends of the strut portions 25 and 26, for example, by winding a few turns of .003 inch gold wire or similar low fusing noble metal wire 34, around the projecting portions of the struts relatively close to the junction of the bridging arms to the struts. If desired the frame sections may be pre-

viously gold plated and the wire 31 similarly plated before the winding operation.

When the grid structure is prepared as above described, the wound grid is placed in an electrically heated oven while hydrogen is flowing through the oven and the grid structure is raised to a temperature of approximately 1070° C. for 20 to 30 seconds. This heating step fuses the gold wire 34 which flows by capillary action along the longitudinal joints between the abutting sections of the frame whereby the joints are brazed by a filling of gold 35, as shown in Fig. 5, and the turns of wire 31 are affixed to the arcuate contour of the struts 25 and 26 to rigidly hold the adjacent turns in their uniform pitched relation. The fluid gold metal also flows out onto the lateral wires during the brazing operation. This is an important feature since a gold surface on the wires is desirable to prevent excessive primary emission. During the fusing of the wire to the frame structure, the cement 33 will be evaporated but since the brazing metal 35 intimately embeds the turns of wire 31 to the struts there is no necessity to retain the temporary binder 33 on the ends of the helix applied to the frame. It will be noted from Fig. 5 that the inner surface of the bridging arm is in the same plane as the outer flat surface of the strut so that the arm extends outwardly from the inner plane of the wire helix equivalent to the thickness of the arm. Since there will be a few loose turns of wire extending across the ends of the grid structure over the area of the arms 27 and 28, these excess turns of wire may be removed so that only the uniform pitch winding over the area of the grid between the arms will remain on the frame assembly.

The grid assembly of this invention constitutes a unitary rugged structure in which the frame sections may be accurately proportioned to satisfy precision dimensional limits as to the major and minor axes of the grid so that the grid assembly may be cooperatively mounted in relation to other electrodes in the device to secure the required electrical characteristics. The construction also facilitates the fabrication of the grid assembly whereby the fine wire helix is joined to the frame and the frame sections simultaneously brazed together to provide an integrated structure. This result is attained in an expeditious manner by the capillary flow method of the embedding metal which quickly locks the wire on the frame and prevents loss of tension in the wire, which would result in sagging of the turns of wire on the frame.

While the invention has been disclosed in a particular embodiment and method of operation, it is, of course, understood that various modifications may be made in the materials, shape of grid frame, winding method and processing to achieve the results of this invention and such modifications are intended to be within the scope of the appended claims.

What is claimed is:

1. A frame type grid electrode comprising a pair of upright portions in parallel relation and parallel pairs of bracing straps extending between said uprights adjacent opposite ends thereof, and a helical winding of fine wire embracing said uprights and extending over the area between said straps, said winding having the lateral turns uniformly spaced in parallel relation over the longitudinal area between said straps, said turns being held on said uprights by fusible metal embedding the portions of said laterals on said upright portions.

2. A hollow frame type grid electrode comprising a pair of upright portions of semicircular cross-section in parallel relation and parallel pairs of bracing straps joined to said uprights adjacent opposite ends and extending transversely thereto, said straps being spaced apart a distance greater than the internal dimensions of the open edges of said uprights, and a helical winding of fine wire embracing said uprights and extending over the area between said straps, said winding having the lateral turns uniformly spaced in parallel relation over the longitudinal area between said straps, said turns being held on said uprights by a fusible metal embedding the portions of said turns on the curved parts of said upright portions.

3. A hollow frame type grid electrode comprising a pair of upright portions of semicircular cross-section in parallel relation and parallel pairs of bracing straps integrally joined to said uprights adjacent opposite ends and extending transversely thereto, the inner surfaces of said straps being in alignment with the outer surfaces of said uprights, and a helical winding of fine wire embracing said uprights and extending over the area between said straps, said winding having the lateral turns uniformly spaced in parallel relation over the longitudinal area in line with the outer surfaces of said uprights and the inner surfaces of said straps, said turns being held on said uprights by a fusible metal embedding the portions of said laterals on said upright portions.

4. A hollow frame type grid electrode comprising a pair of half frame sections having arcuate longitudinal upright portions and spaced parallel bracing straps adjacent opposite ends of said portions, said upright portions being placed in abutting relation and forming semicircular pillars coupled together by said bracing straps, and a helical wire winding embracing said upright portions, the turns thereof being held in equally spaced relation by fused metal between said straps.

5. A hollow frame type grid electrode comprising a pair of half frame sections having arcuate longitudinal upright portions and spaced parallel bracing straps adjacent opposite ends of said portions, said upright portions when placed in abutting relation forming semicircular pillars coupled together by said bracing straps, and a helical wire winding embracing said upright portions, said winding lying in parallel planes coincident with the inner surfaces of said straps and the outer surfaces of said upright portions, and a gold brazing metal fusing said wire laterals to said uprights and said half sections being intimately joined together along the conjoint edges in a plane coincident to the axis of said frame.

6. The method of fabricating a hollow grid structure for electronic discharge devices including a rectangular frame member of similar half sections having arcuate upright portions and outwardly bent transverse arms connecting said portions, which comprises matching said sections in pairs with said arcuate portions in abutting relation to form a hollow structure of elongated oval cross-section and said arms in parallel pairs at each end, winding a continuous wire uniformly around said frame between said arms, temporarily fixing the ends of said winding to said arms, applying a low melting point metal to said upright portions out of engagement with said continuous wire, heating said frame assembly to a sufficient temperature to melt said low melting point metal and flow said metal over the suc-

cessive turns of wire in contact with said upright portions, and brazing the abutting edges of said arcuate portions of said uprights together simultaneously at the same time as the bonding of said wire to said upright portions.

7. The method of fabricating a hollow grid structure for electronic discharge devices including a rectangular frame member of similar half sections having arcuate upright portions and outwardly bent transverse arms connecting said portions, which comprises matching said sections in pairs with said arcuate portions in abutting relation to form a hollow structure of elongated oval cross-section and said arms in parallel pairs at each end, winding a continuous helix of fine wire in contact with said abutting upright portions and extending in uniform pitch across the expanse between said portions, cementing the ends of said wire to said arms, winding a plurality of turns of fusible wire around the end of each upright portion on the opposite side of said transverse arms from said fine wire, heating said structure in a non-oxidizing atmosphere, fusing said turns of wire to flow by capillary attraction along the contacting edges of said uprights, removing the cement from the ends of said wire, and brazing said wire to said uprights.

8. The method of fabricating a hollow grid structure for electronic discharge devices including a rectangular metallic frame with curved upright portions and bridging arms at opposite ends connecting said portions, which comprises winding a fine tungsten wire helically about said uprights and arms, affixing the ends of the wire to the center of said arms by cellulose cement,

attaching a few turns of gold wire around diagonally disposed ends of said uprights removed from said fine tungsten wire, heating said structure in a hydrogen filled oven at a temperature of approximately 1070° C., evaporating said cement, fusing said gold wire to flow by capillary action along the abutting surfaces of said upright portions to bond said wire thereto and rigidly braze said half sections together.

EDWARD J. WALSH.

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