

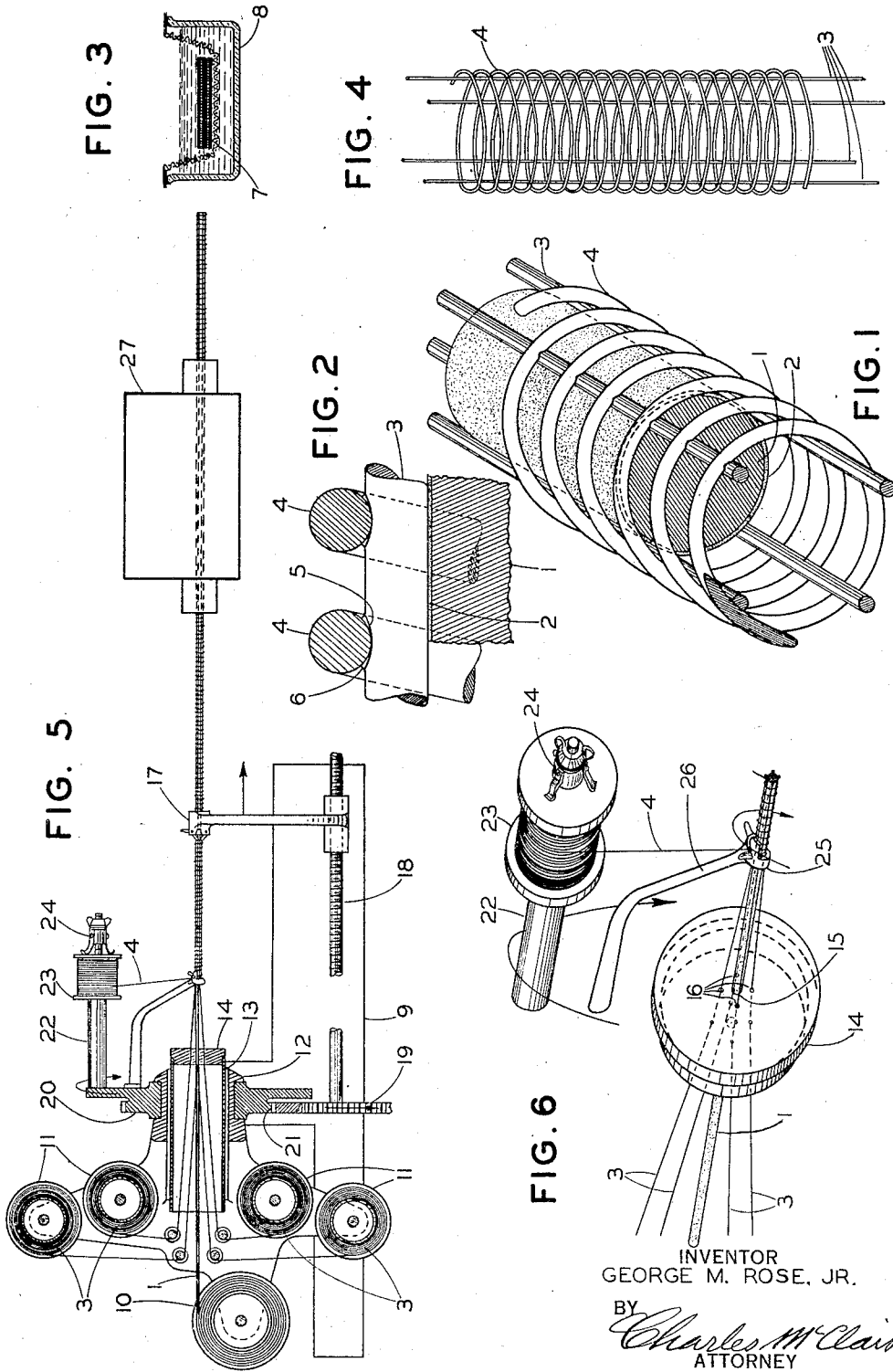
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METHOD OF MAKING GRID ELECTRODES

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## METHOD OF MAKING GRID ELECTRODES

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This invention relates to grid electrodes for electron discharge devices, and more particularly to a method and means for making very small grids of very fine wire.

5 It is well known that the optimum control characteristics of a helical wound grid with side rods cannot be realized in a triode type radio tube if the diameters of the grid side rods are an appreciable fraction of the diameter of the electron  
10 emitting cathode. The same limitation is present in a multi-grid radio tube with respect to the grid closest to the cathode and to a lesser extent with respect to the other associated grids. The usual explanation of this limitation is that the  
15 grid side rods cast "electronic shadows" on the plate, and that these shadows directly or indirectly have deleterious effects upon a number of the electrical characteristics of the tube, for example, the transconductance. These deleterious  
20 effects, which are especially noticeable in miniature types of radio tubes with very close inter-electrode spacings, have been a serious limitation on the development of such tubes. In some types  
25 of miniature tubes the grid side rods are as large as the cathode or the spacing between the different electrodes because of the limitations of the present grid manufacturing processes and equipment. The two well known methods of spot  
30 welding and of peening the grid wire, commonly used for making wound grids, are not commercially feasible when the diameter of the grid side rods is less than 5 mils.

An object of this invention is to provide a method and means for making helical grids in which  
35 the grid turns are spaced by one or more side wires of about the diameter of the grid wire instead of by the usual side rods considerably larger than the grid wire.

Another object of the invention is to provide a  
40 method and means for welding metals in which the pressure contact between different metals in a reducing atmosphere is utilized.

My invention makes commercially feasible the production, by a continuous process if desired, of  
45 a helically wound grid without the usual side rods and in which all the wire exposed to the electron stream is about the same size as the grid wire. Such grids, which are particularly useful in miniature radio tubes, have been made by my invention  
50 of one mil wire and as small as 25 mils in diameter. The methods and means which I have invented are particularly useful in connection with wound grids of very small diameter and made with very fine wire, but are applicable to the  
55 manufacture of all sizes of radio tube grids, and

also to any similar structure which employs welding of metals.

In accordance with my invention a grid wire is formed into a helix with turns wound under tension around one or more grid side wires which  
60 are carried on a metal mandrel during the winding of the helix; the wound assembly including the mandrel passed through a furnace, which preferably has a reducing atmosphere such as hydrogen, to weld each turn of the grid wire helix  
65 to the side wires supported by the mandrel; and the mandrel then reduced in size to permit its removal from the wound grid structure, for example, by treatment in a chemical bath which dissolves some of the mandrel with only negligible  
70 attack on the grid. The mandrel which may to advantage be coated with powdered alundum, maintains the grid of the desired shape and size during the heating of the assembly to a temperature high enough to weld the grid wire to the side  
75 wires but not high enough to melt the wires. The hydrogen seems to facilitate the welding of the grid wire to the side wires at each point of contact, while the alundum coating on the iron mandrel prevents welding of the nickel wires to  
80 the mandrel.

In a preferred embodiment of my invention I use an iron mandrel, such as a wire about 100 mils in diameter, with a coating approximately two or three mils thick of a refractory material,  
85 such as alundum, which will prevent welding of the mandrel. Some nickel side wires about one mil in diameter are laid parallel and lengthwise on the coated iron mandrel with the desired spacing, and tied at one or both ends to the mandrel.  
90 A molybdenum grid wire, about one mil in diameter, is then wound under some tension around the iron mandrel and over the nickel side wires into a helix. The grid assembly produced in this way is then heated in an atmosphere of hydrogen  
95 in a furnace maintained at a temperature of about 1350° C. Usually about five minutes treatment in the furnace will cause the grid wire to be firmly joined or welded to the nickel side wires. As the molybdenum grid wire is quite strong and rigid  
100 at the furnace temperature, and the coefficient of thermal expansion of iron is considerably greater than that of molybdenum, it seems likely that the greater diametrical expansion of the iron mandrel inside the fairly rigid molybdenum helix  
105 during the heating of the assembly may produce between the nickel side wires and the turns of the molybdenum grid wire helix sufficient pressure to facilitate the welding. It has been observed that usually in a welded grid structure made in  
110

this way the molybdenum grid wire appears to be sunk or embedded to some extent in the softer nickel wires at each point of contact.

The welded grid structure after it comes out of the furnace may be placed in cold concentrated hydrochloric acid which attacks the iron mandrel to a much greater extent and much more rapidly than it attacks either the nickel or molybdenum wires. In a few minutes the iron mandrel is sufficiently reduced in diameter to permit its removal from the grid structure without disrupting the latter. If grid wire is used which would be affected by the acid the coated mandrel may be reduced in diameter sufficiently to permit its removal from the wound structure by removing the refractory coating. The alundum coating may be dissolved off the mandrel by using hot caustic, such as sodium hydroxide. The mandrel may be made of iron with a surface coating of chromium oxide which will not weld to the nickel side wires at the furnace temperature. When such a mandrel is used the alundum coating is unnecessary.

For more detailed description of preferred ways of practicing my invention, reference may be had to the following description taken in connection with the accompanying drawing, in which:

Figure 1 is a perspective view of the wound grid assembly before the mandrel has been removed;

Figure 2 is a view, along one of the side wires and with the grid wires in cross-section, of a short section of the fired grid assembly on the mandrel showing the welds between turns of the grid wire and the side wire;

Figure 3 is a sectional view of the chemical bath in which the grid assemblies are treated;

Figure 4 is a front view of a complete grid made in accordance with my invention;

Figure 5 shows diagrammatically a continuous system for making grids in accordance with my invention;

Figure 6 is a perspective view of part of the winding apparatus shown in Figure 1.

In the production of grid electrodes in accordance with my invention the grid is assembled on a metal mandrel which keeps the grid of the right size and shape during welding and is removed only after the grid is practically completed. As best shown in Figure 1, the grid is assembled on an iron mandrel or wire 1 which preferably has on it a thin coating 2 of some refractory material, such as alundum, to prevent the grid sticking to the mandrel. The coating may be produced by spraying the mandrel with a suspension of finely powdered alundum in a binder, such as nitrocellulose binder, or by dipping the mandrel in the suspension. Grid rods or side wires 3, preferably of nickel, are laid lengthwise of the mandrel and parallel to one another and to the mandrel. The number of grid rods 3 and the spacing between them depends on the design of grid. A grid wire 4, preferably of a metal, such as molybdenum, which has considerable strength when hot, and also has coefficient of thermal expansion much lower than that of iron, is wound over the nickel wires 3 on the mandrel into a helix of the desired pitch. Preferably the tension on the grid wire 4 during the winding is great enough to place each turn of the helix on the side wires 3 so firmly that the pitch of the helix is preserved, and in some cases the tension may cause the grid wire to sink slightly into the side wires at the points of contact. As the wound grid assembly is firmly supported on and held in shape

by the iron mandrel 1, the grid wire 4 and the side wires 3 may be of about the same size, and may be very small, for example, 1 mil in diameter. The wound grid assembly is fired in a hydrogen atmosphere at about 1350° C., until the molybdenum grid wire becomes firmly joined or welded to the nickel side wires. Figure 1 shows the grid assembly after firing and still on the mandrel. The type of joint between the molybdenum grid wire and the nickel side wire is indicated in Figure 2, which represents the joint in section and as observed under a high power microscope, the grid wire 4 resting in slight depressions 5 in the side wires, with the metal at the edges of the depressions built up slightly as shown at 6, indicating some kind of welding at the points of contact.

The fired grid assembly shown in Figure 1 is converted into the finished grid shown in Figure 4 by removing the mandrel 1 without distorting the grid. The removal of the mandrel is best accomplished by reducing it in diameter until it will come out of the grid easily. Sometimes the removal of the refractory coating 2 will bring about a sufficient reduction in diameter but usually the most convenient method is to treat the fired grid assembly in an acid bath, as indicated in Figure 3, by putting the grid assemblies in a mesh tray 7 and submerging them in acid in a vessel 8.

My method of making grid electrodes may be carried out in various ways and with various kinds of equipment. A convenient device for making grid electrodes in accordance with my invention and as a continuous process is shown schematically in Figures 5 and 6, illustrating a machine in which the mandrel wire and the nickel side wires are drawn through a winding head by which the side wires are laid lengthwise of the mandrel and the grid wire is wound over them into a helix, thus automatically assembling the grid on the mandrel. The machine comprises a winding head with a base 9 which carries a spool 10 of the iron mandrel wire 1 and four spools 11 of the nickel side wires 3. All of these wires pass simultaneously and side by side through a tubular spindle 12 fixed in the base 9. Supported in the spindle 12 is a removable tubular liner 13 which has at one end a disc or transverse wire guide 14 with a central hole 15 for guiding the mandrel wire 1 and four holes 16 spaced equally about the central hole for guiding the four side wires 3 into place along the mandrel wire 1 as the wires are drawn through the guide 14. The wires are threaded through the guide 14, the ends of the side wires tied to the mandrel wire, and then the wires are drawn through the guide by a drawing device, such as a movable clamp 17 which grips the wires and is moved away from the wire guide 14 by a feed screw 18 driven from a gear 19. As the mandrel wire with the four side wires in place on it leaves the guide 14 the grid wire 4 is wound into a helix around the mandrel and the side wires by means of a rotary carrier 20, rotatably mounted on the tubular spindle 12 and having a gear 21 in mesh with the driving gear 19. The rotary carrier, which is something like the face plate of a lathe, has a projecting stud 22 eccentric to the tubular spindle for carrying a spool 23 of the grid wire 4 which is wound around the wires passing through the wire guide. The grid wire should be wound under tension, and one way of applying the desired tension is by means of a friction tension device 24 mounted on the end of the stud 22 to engage the spool 23. It

is usually advantageous to provide at the point where the grid wire is wound over the side wires a tubular winding guide 25 which surrounds and supports the wires during the winding of each turn of the helix, and which may conveniently be carried on the end of an arm 26 projecting from the carrier.

As the mandrel wire 1 with the side wires 3 lying on it is drawn through the wire guide 14 the rotary carrier 20 turns in synchronism with the feed screw 18, causing the grid wire 4 on the spool 23 to be wound under tension over the mandrel and the side wires into a helix which grips the side wires firmly and holds them in place on the mandrel, while at the same time the side wires engage the turns of the helix so firmly that the pitch of the helix is preserved. The pitch of the helix is determined by the feed screw 18, and the grip of the helix on the side wires depends on the setting of the tension device 24.

The grid assembly produced on the machine is passed through the furnace 27, which may be the usual hydrogen furnace used for cleaning metal parts for radio tubes, and which is usually operated at about 1350° C. About five minutes firing in the furnace will usually secure the turns of the helix to the side wires. The fired assembly is then cut into lengths suitable for grids, and the lengths treated in the chemical bath to remove the mandrel.

Although my invention is useful in making grid electrodes of the usual dimensions, it is particularly useful in making very small grids of very fine wire; for example, I have made in accordance with my invention grids such as above described which have a diameter of about 25 mils and in which both grid wire and side wires are less than 1 mil in diameter. The electronic shadows are negligible with grids of such fine wire, and are much less than usual even with grids made of wire of the usual size, such as 5 mil.

My invention is not limited to the use of molybdenum and nickel, as the grid wire may be molybdenum, tungsten, or other metal having sufficient hot strength, and the side or connecting wires may be nickel, copper, or similar metal.

It is to be understood that the embodiments described hereinabove are merely illustrative and the scope of my invention is limited only by the appended claims.

What is claimed as new is:

1. A method for making grid electrodes comprising winding under tension a metallic conductor around a plurality of elongated conductors positioned side by side on a mandrel to form a grid assembly, heating said mandrel and said assembly in a reducing atmosphere to effect welding at each point of contact of said conductors.

2. A method for making grid electrodes comprising, laying down a plurality of wires upon a metal mandrel, winding a wire around said mandrel and over said plurality of wires to form a grid assembly, heating said mandrel and said grid assembly in a reducing atmosphere to weld said wound wire to said plurality of wires, said mandrel being coated with a material non-weld-

able at the temperature to which the mandrel and grid assembly are heated in the reducing atmosphere and chemically treating said mandrel to permit its removal from said grid assembly.

3. A method of making grid electrodes which comprises making a grid assembly by placing longitudinally on a metal mandrel at least one metallic conductor and winding under tension another metallic conductor around said mandrel and over said first conductor to form a helix enclosing and with its turns in contact with said second conductor, said mandrel having a coefficient of expansion at least as great as the metallic conductor wound under tension heating said grid assembly in a reducing atmosphere until the turns of said helix are welded to said metallic conductor to form a tubular grid and separating said mandrel and said grid.

4. A method of making grid electrodes which comprises making a grid assembly by longitudinally positioning a plurality of nickel wires in contact with and spaced around an insulated iron wire, winding under tension a molybdenum wire in the form of a helix around said nickel wires and said mandrel, firing the grid assembly in a furnace having an atmosphere of hydrogen to a welding temperature until the nickel and molybdenum wires are welded together at each point of contact, subjecting said fired assembly to hydrochloric acid to treat said iron mandrel and permit the separation of said mandrel and said wound assembly.

5. A continuous method for making grids comprising, laying down a plurality of wires upon a metal mandrel, winding a wire which has a lower coefficient of expansion than said mandrel around said plurality of wires to form a grid assembly, advancing said grid assembly through a furnace heated to the welding temperature of said wires, and then through a chemical bath which reacts with said mandrel but has a negligible reaction with said wires.

6. A method for making electron discharge device grids which comprises coating a metal mandrel with a refractory material positioning longitudinally a plurality of metal side rods of approximately the same diameter on the coated metal mandrel, winding a wire of substantially the same diameter as said side rods around said side rods to form a grid assembly, heating said mandrel and grid assembly to weld said side rods to said wound wire, and chemically treating said heated mandrel and grid assembly to remove said mandrel.

7. A method for making electron discharge device grids which comprises positioning longitudinally a plurality of metal side rods of approximately 1 mil in diameter on a metal mandrel, winding a wire of approximately one mil in diameter and having a lower coefficient of expansion than said mandrel around said side rods to form a grid assembly, heating said mandrel and grid assembly to weld said side rods to said wound wire, and chemically treating said heated assembly to remove said mandrel.

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