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3,217,202

VARIABLE-MU ELECTRON DISCHARGE DEVICE

Filed June 12, 1961

2 Sheets-Sheet 1

Fig. 1.

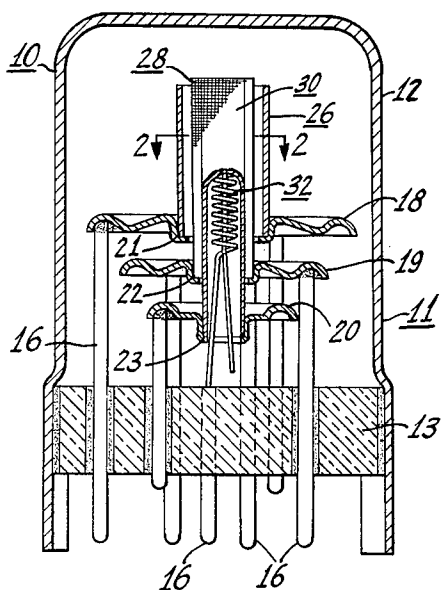


Fig. 3.

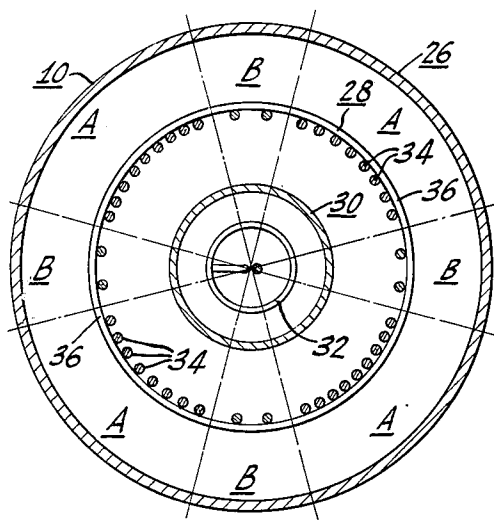
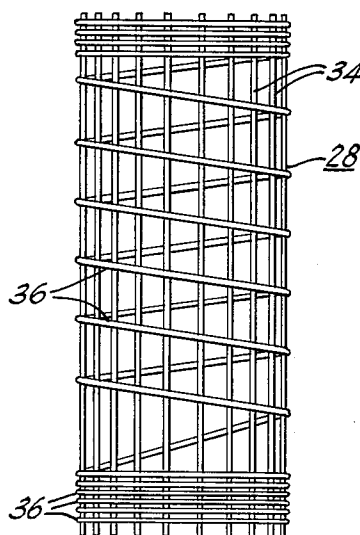


Fig. 2.

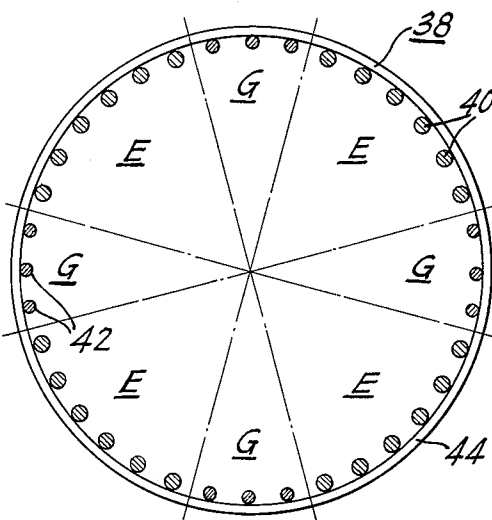


Fig. 4.

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Fig. 5.

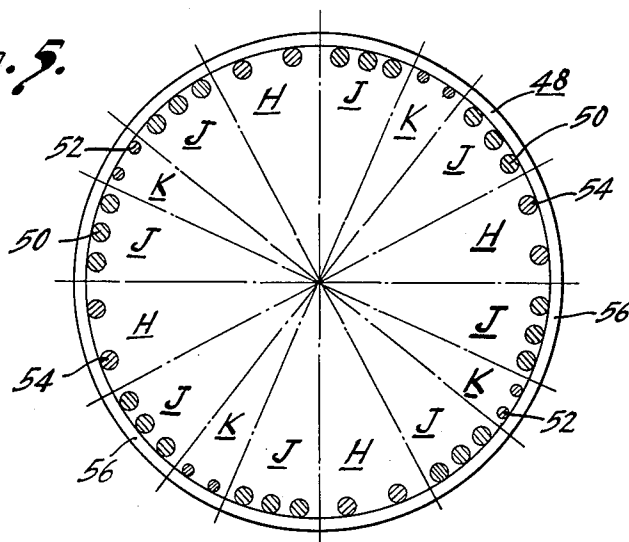
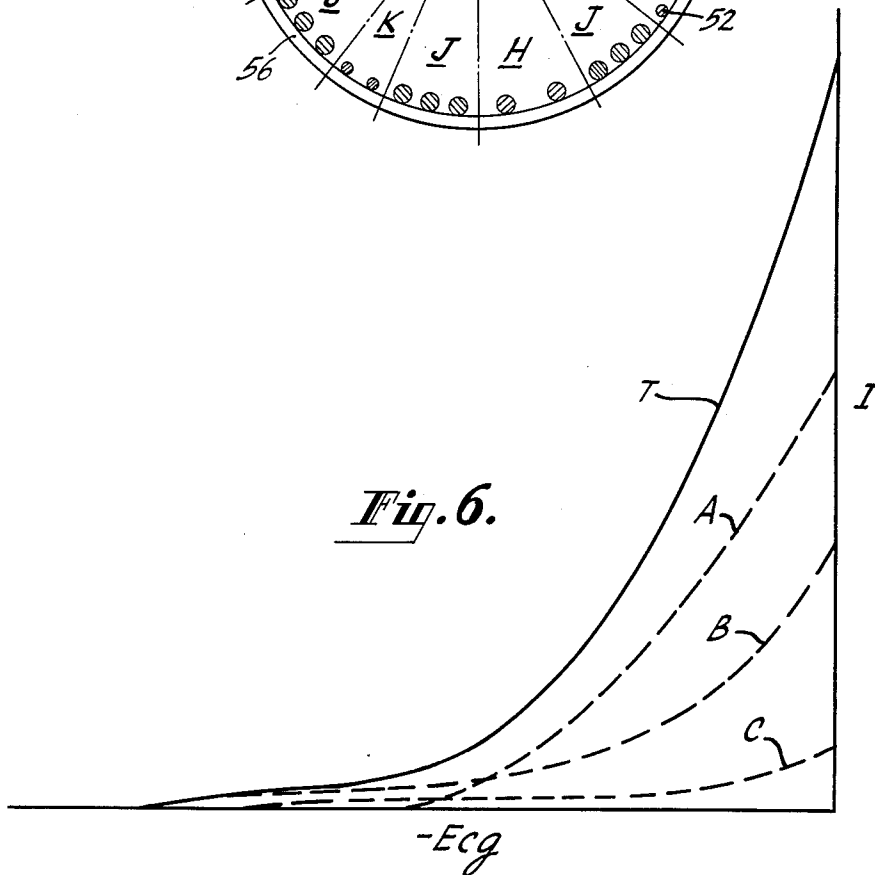


Fig. 6.



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VARIABLE-MU ELECTRON DISCHARGE DEVICE
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This invention relates to electron discharge tubes having variable amplification factor and remote cut-off electrical characteristics, and particularly to improved and novel control grid electrodes for providing such tube characteristics.

By remote cut-off is meant that a relatively large negative control grid voltage is required to cut off the tube current, and by variable amplification factor (mu) is means that the value of mu varies with the control grid voltage, the mu becoming progressively smaller with increased negative voltage. As known, tubes of this type produce significantly less modulation and cross modulation distortion than do sharp cut-off, constant mu tubes. For this reason variable mu, remote cut-off tubes find extensive use in tuner and automatic volume and gain control circuits and the like wherein low signal distortion is desired.

Heretofore, most of the variable mu tube types of the prior art used control grids having a helix of lateral wire wound about two parallel side rods. In such grids, as known, the control of the electron current is provided by the lateral wire turns, the spacing between the turns affecting the mu of the tube. For achieving the variable mu characteristics, the lateral wire was wound with a variable pitch.

The method of fabricating such variable pitch grids usually involves winding the lateral wire about the side rods at a constant rate while pulling the side rods past the lateral wire feed mechanism at a variable rate.

One disadvantage of this method is that once a grid winding lathe has been set up to produce a grid of a particular design it is relatively difficult and time consuming to modify the lathe to produce a grid of a different design. That is, the gearing and cam mechanisms required to produce the desired variable side rod feed are relatively complex and poorly suited for frequent design changes. For engineering tests, for example, wherein it is desired to evaluate new grid designs, the difficulty of changing the grid fabricating apparatus for producing modified grids greatly increases the cost of tube design and development. Moreover, experience has shown that periodic grid design changes are required even for grids used in mass produced tubes having predetermined and fixed electrical characteristics. For a variety of reasons (not completely understood) the average characteristics of batches of tubes made at different times tend to drift from published tube characteristics. To re-center the electrical characteristics of the tubes, grid design changes are often made. Because of the excessive down time required to modify the grid lathes, however, great expense is frequently incurred when design changes are made in such variable mu tubes, because of interruptions in tube production.

A further disadvantage of the use of the prior art grids described is that in some tube types it has been found that the lateral wires have very little control of the electron current whereby the variable pitch lateral wire winding is not effective for providing the desired variable mu tube characteristics. That is, in some tubes wherein the size of the tube electrodes and the spacing therebetween has been reduced to very small values, it is customary to provide more side rods than the two used in other prior art grids. The reason for this is that in such close spaced tubes, it is necessary that the correct spacings between the "active" surfaces of all the elec-

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trodes be maintained to a high degree of accuracy. For the grid constructions of the prior art having but two side rods, it has been found that due to the relatively large unsupported length of the laterals spanning the distance between the side rods it is practically impossible to control the location of the laterals to the desired extent. By providing many and closely spaced side rods and thereby reducing the span of the laterals, this problem is largely avoided. In some instances, however, the number of side rods used is so great and the spacing therebetween so small that the roles of the lateral wire and the side rods are reversed, the side rods providing the control of the electron current, and the lateral wire serving merely to support the side rods. In such instances, as mentioned, it is not practical to use the lateral wires for providing the desired variable mu tube characteristics.

It is an object of this invention to provide a new and novel variable-mu electron tube.

Particularly, it is an object of this invention to provide improved and novel control grid electrodes for use in variable mu electron tubes.

Further objects of this invention are to provide control grid electrodes for use in variable mu electron tubes wherein the grids are of the multi-side rod type, wherein the grid constructions facilitate modification of grid design at grid fabrication, and wherein the variable mu characteristic of electron tubes using the grids is provided by the grid side rods.

For achieving these objects in accordance with this invention a grid electrode is provided which comprises a plurality of longitudinally extending, spaced apart side rods arranged to form a cylindrical structure. A lateral wire is wound around the outside of the structure and secured to the side rods for providing support thereof. For achieving variable mu characteristics when the grid is used within an electron tube, the side rods may be spaced relative to each other according to a predetermined pattern, the spacing between some of the side rods being different than the spacing between other of the side rods. In another construction, the side rods may be arranged with a uniform spacing therebetween, the diameters of the side rods being varied. A still further construction is to arrange side rods of different diameters around the circumference of the grid with varied spacings therebetween. The advantages of these constructions and the ease with which changes with respect thereto may be achieved at grid fabricating will be described hereinafter.

In the drawings:

FIG. 1 shows a longitudinal section of an electron discharge device of a type wherein my invention may be employed;

FIG. 2 is an enlarged view in section taken along line 2-2 of FIG. 1;

FIG. 3 is an elevational view of the grid electrode according to my invention shown in FIG. 2;

FIGS. 4 and 5 are plan views of other grid electrodes made in accordance with my invention; and

FIG. 6 is a graph showing transfer characteristics of the tube shown in FIG. 1, plate current being plotted against negative control grid voltage.

The electron discharge tube 10 shown in FIG. 1 includes an envelope 11 comprising a metal shell 12 closed vacuum-tight by a ceramic header member 13. Extending through and sealed vacuum-tight to the header member are a plurality of terminal leads and supports 16. These leads have mounted at their upper ends flange-like elements 18, 19 and 20 provided with well portions 21, 22 and 23. Each of these flanges is preferably connected to and supported on three equally spaced leads 16. Sup-

ported in coaxial telescoped relation by means of the flange members 18, 19 and 20 are the anode 26, a control grid 28, made according to this invention and shown schematically, and the cathode 30. Cathode 30 is of the indirectly heated type and has a coating thereon of electron emissive material, a heater 32 being provided therein for heating the cathode. All of the parts referred to are secured together to form a rigid tube by means of brazing. The surfaces to be sealed vacuum tight may be first metallized. The seals may be made using brazing rings at the joints between the parts to be brazed. The electrode-to-flange brazes and the flange-to-lead brazes may be similarly made by providing brazing material either in the form of rings of brazing material or brazing material coatings on the flanges and leads. In accordance with one form of my invention, I provide a grid electrode 28 as shown in FIGS. 2 and 3. The grid 28 comprises a plurality of parallel longitudinally extending side rods 34 arranged around the periphery of a circle to form a cylindrical structure. For making the grid structure rigid and self-supporting and for preventing vibration of the side rods 34, a continuous lateral wire 36 is wound in a helix about the outside surface of the grid cylinder and secured to the side rod surface as by brazing. The lateral wire 36 may be wound with a variable pitch, the smallest pitch occurring at the ends of the grid structure for providing a rigid, band-like side rod securing means.

Within the electron tube 10 as shown in FIG. 2, the portions of the grid 28 closest to the cathode 30 are the side rods 34. As known, the greatest control of the electron flow from a cathode is provided by the elements closest thereto. In one embodiment of a type of grid construction shown in FIGS. 2 and 3, 66 side rods 34 having a diameter of 0.72 mil are used, the lateral wire 36 having a diameter of 0.72 mil. The inner diameter of the grid structure is 66 mils and the spacing between the cathode 30 and the cylindrical surface formed by the innermost portions of the side rods 34 is 2 mils. For such grid dimensions and construction, it has been found that almost the entire control of the electron flow is provided by the side rods 34, the lateral wire 36 having relatively little effect thereon.

For providing the desired variable μ tube characteristics, the side rods 34 of the grid 28 may be arranged as shown in FIG. 2, the spacing between the side rods in sectors A being smaller than that in sectors B. The effect of this arrangement on the μ of the electron tube is explained as follows: During operation of an electron tube, electrons are emitted from the entire heated surface of the cathode coated with electron emissive material. The degree of control of the electrons emitted from each segment of the cathode is a function of the geometrical configuration of that portion of the control grid immediately adjacent to or in front of that cathode segment. For segments of cathode 30 having closely spaced side rods 34 adjacent thereto, as in sectors A of FIG. 2, for example, the control of the electron current by the grid is very effective and the μ for these segments is high. Conversely, the μ for those segments of the cathode having more widely spaced side rods adjacent thereto, as in sectors B, are low. In effect, tube 10 comprises a number of small individual tube segments, each tube segment consisting of the cathode segment, the grid segment and the anode segment included in each of the sectors A and B. The μ of each of these individual tube segments is constant and each of the individual tube segments has its own tube electrical characteristics, the characteristics of all the tube segments combining to produce the overall tube characteristics. The various characteristics are illustrated in FIG. 6. The two dashed lines A and B correspond to the tube characteristics of sectors A and B. Dashed line C corresponds to those end areas where the sectors A and B join one another and wherein there is an overlapping of control of the electron current by each sector A and B. The solid line

T represents the measured or actual total tube transfer characteristic which is the summation of lines A, B, and C of the smaller tube segments. As shown in this figure, the point at which the total tube current is cut-off is determined entirely by the cut-off or the μ of sector B. Also, as shown, the total tube current at any grid voltage is the sum of all the currents contributed by the different tube segments at that voltage. The amount of current each segment contributes to the total is a function of the cathode area included in that segment. Thus, in the tube shown in FIG. 2, sectors A include the largest cathode area and hence contribute the greatest current. Therefore, in the design of such a tube, it is possible to fix the shape of the transfer characteristic by allocating proper cathode areas to each tube segment, and to fix the cut-off of the tube by spacing the side rods 34 to provide the proper value of μ in sector B.

The different sectors A and B may be arranged symmetrically around the circumference of the grid with respect to a plane extending through the longitudinal axis of the grid to minimize the effect of eccentric mounting of the electrodes within the tube. The μ 's of the segments are dependent also upon the electrode spacings, and changes in the electrode spacings tend to change the values of the μ 's. The symmetrical arrangement of the sectors A and B minimizes the effect of eccentric electrode orientation since increased spacings on one side of the cathode are counter-balanced by decreased spacings on the other side thereof.

Another form of grid construction which may be made according to my invention is shown in FIG. 4. In this construction the diameter of the side rods about the circumference of the grid 38 is varied. The μ of the cathode segments is a function of the diameter of the side rods adjacent thereto, hence the affect of this construction is similar to that described above for the variable spaced side rods. In one embodiment, the diameter of side rods 40 in sectors E is 0.72 mil, and the diameter of side rods 42 in sectors G is 0.5 mil. The diameter of the lateral wire in helix 44 is 0.72 mil, and the inner diameter of the grid is 66 mils.

A still further form of grid construction which may be made according to this invention is shown in FIG. 5. This grid 48 combines the use of side rods of different diameters and of different spacings. In one embodiment, the diameter of the side rods 50 and 54 in sectors J and H, respectively, is 0.72 mil, the diameter of side rods 52 in sectors K being 0.6 mil. The center to center spacing between side rods 50 and 52 in sectors J and K, respectively, is 2.96 mils, and the center to center spacing between side rods 54 in sectors H is 4.4 mils. The diameter of the lateral wire helix 56 is 0.72 mil, and the inner diameter of the grid is 66 mils.

In grids of the type shown in both FIGS. 4 and 5, the side rods may also be symmetrically arranged around the circumference of the grid of minimizing the effects of eccentric mounting of the electrodes.

In the fabrication of multi-side rod grids of the types shown, the side rods are first laid down along a cylindrical mandrel of a grid lathe and then a lateral wire is wound therearound in a helix. In the grid lathe for winding such grids, the side rods are fed from supply spools and guided onto the mandrel through slots spaced around the circumference of an annular nose piece, the slots controlling the spacing between the side rods. The nose piece contains a central bore through which the mandrel is fed.

The nose piece is readily removable and replaceable from the grid lathe and all that is required to modify the control characteristics of a grid 28 of the type as shown in FIGS. 2 and 3 is to substitute a nose piece of different slot configuration. The pitch of the lateral wire helix need not be changed nor the rate of feed of the mandrel through the nose piece.

Changes in construction of the grid 38 shown in FIG.

4 are affected even more easily. The nose piece slots are much larger than the diameter of the wire fed there-through, the wire being guided by an edge of each slot. Thus all that is required to change the diameters of the side rods of grids of the type shown in FIG. 4 is to change the side rod supply spools on the grid lathe.

Since accurately made nose pieces are somewhat expensive, it is often desirable to utilize a grid combining the constructions shown in FIGS. 3 and 4. That is, the proto-type grid may be of the type as shown in FIG. 3. If adjustments are required either in production or for engineering tests, they may be then achieved simply by changing the diameters of certain of the side rods while using the same nose piece, the result being a grid 48 of the type shown in FIG. 5.

What is claimed is:

1. A variable-mu electron discharge tube having a plurality of electrodes including a tubular cathode and a grid electrode comprising a plurality of parallel side rods arranged to form a round tubular structure coaxial with said cathode and a lateral wire wound around the outside of said structure and secured to said side rods, the spacing between adjacent ones of some of said side rods being different from the spacing between adjacent ones of others of said side rods.

2. A variable-mu electron discharge device having a plurality of electrodes including a grid electrode comprising a plurality of side rods forming a round tubular structure and a lateral wire wound around and secured to said side rods, the diameter of some of said side rods being different from the diameter of others of said side rods.

3. A variable-mu electron discharge device having a plurality of electrodes including a grid electrode comprising a plurality of parallel side rods forming a round tubular structure and a lateral wire wound around and secured to said side rods, the spacing between adjacent ones of some of said side rods being different from the spacing between adjacent ones of others of said side rods, and the diameters of some of said side rods being different from the diameters of others of said side rods.

4. A variable-mu electron discharge device having a plurality of electrodes including a grid electrode comprising a plurality of parallel side rods arranged to form a round tubular structure, and a lateral wire wound around the outside of said structure and secured to said side rods, the spacing between adjacent ones of some of said side rods being different from the spacing between adjacent ones of others of said side rods, and the diameters of some of said side rods being different from the diameters of others of said side rods.

5. A variable-mu electron discharge device having a plurality of electrodes including a grid electrode comprising a plurality of parallel side-rods forming a round tubular structure and a lateral wire helix wrapped around the outside of said structure and secured to said side rods, adjacent ones of said side rods being arranged in groups, the spacing between the side rods of each group being the same, and the spacing between the side rods of certain ones of said groups being different from the spacing between the side rods of others of said groups, and the arrangement of said groups being symmetrical about the circumference of said structure.

6. A variable-mu electron discharge device having a plurality of electrodes including a grid electrode comprising a plurality of parallel side-rods forming a round tubular structure and a lateral wire helix wrapped around the outside of said structure and secured to said side rods, adjacent ones of said side rods being arranged in groups, the diameter of the side rods of each group being the same, and the diameter of the side rods of certain ones of said groups being different from the diameter of the side rods of others of said groups, and the arrangement of said groups being symmetrical about the circumference of said structure.

7. A variable-mu electron discharge device having a plurality of electrodes including a grid electrode comprising a plurality of parallel side-rods lying in the surface of a cylinder, and a lateral wire helix having widely spaced turns in comparison with the spacings between said side rods wrapped around the outside of said cylinder and secured to said side rods, adjacent ones of said side rods being arranged in groups, the spacing between the side rods and the diameter of the side rods of each of said groups being the same, and the spacing between the side rods and the diameter of the side rods of certain ones of said groups being different from the spacing between the side rods of others of said groups, and the arrangement of said groups being symmetrical about the circumference of said structure.

8. A variable-mu electron discharge device having a plurality of electrodes including a round tubular grid electrode comprising a plurality of parallel side rods and a lateral wire wound around and secured to said side rods, the spacing between adjacent ones of some of said side rods being different from the spacing between adjacent ones of others of said side rods, and the diameters of some of said side rods being different from the diameters of others of said side rods, the placement of said side rods being arranged to provide a configuration of side rods which is symmetrical about a plane extending through the longitudinal axis of said grid.

9. A variable-mu electron tube having a plurality of electrodes including a tubular cathode and a control grid surrounding said cathode, said control grid comprising a plurality of spaced apart side-rods providing a round tubular structure, the spacing between adjacent side rods varying about the periphery of said structure, and a lateral wire extending around the outside of said structure and being secured to said side rods for maintaining the relative spacing of said side rods.

10. A variable-mu electron tube having a plurality of electrodes, one of said electrodes being a control grid comprising a plurality of parallel longitudinally extending side-rods forming a round tubular structure, and a variable pitch lateral wire helix wrapped around the outside of said structure and secured to said side rods, the spacing between adjacent side-rods varying about the periphery of said structure according to a preselected pattern, and said pattern being symmetrical about a plane extending through the longitudinal axis of said structure.

11. A variable-mu electron tube having a plurality of electrodes, one of said electrodes being a control grid comprising a plurality of side-rods forming a round tubular structure, and a lateral wire wrapped around the outside of said structure and secured to said side rods, said lateral wire being wound in a variable pitch helix, the pitch of said helix being smaller at the ends of said structure than along the central portion thereof, and the spacing between the turns of said helix along said central portion being relatively large in comparison with the spacings between said side rods, and the spacing between adjacent side-rods varying about the periphery of said structure.

12. A variable-mu electron tube comprising an envelope including a metal shell closed by a ceramic wafer having a plurality of conductors extending therethrough, a plurality of elongated tubular electrodes mounted within said envelope in telescoped relation with each other, said electrodes including an anode, a grid and a cathode, said grid surrounding said cathode and being surrounded in turn by said anode, said grid comprising a plurality of longitudinally extending side rods arranged around the periphery of a circle and a lateral wire helix having widely spaced turns in comparison with the spacings between said side rods wound about the surface formed by the outer portions of said side rods and secured thereto, the spacing between adjacent side rods varying symmetrically about the circumference of said grid, and the

diameter of said side rods varying symmetrically about the grid circumference.

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