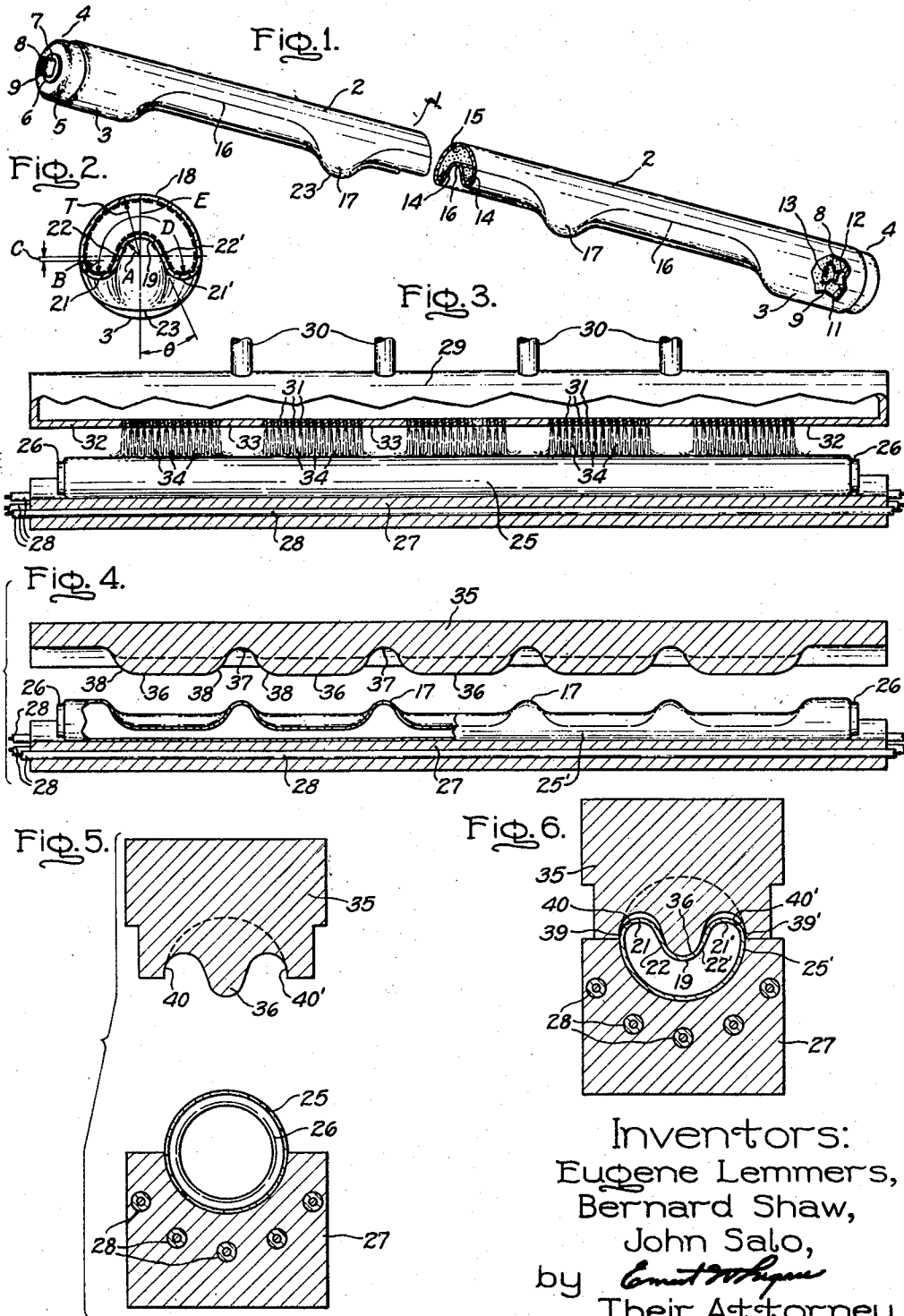


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TUBULAR LAMP ENVELOPES

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TUBULAR LAMP ENVELOPES

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8 Claims. (Cl. 313—109)

This invention relates generally to electric lamps and similar devices having elongated tubular envelopes. It is directed particularly to low-pressure resonance radiation discharge lamps such as fluorescent lamps and to a vitreous envelope of unique form and configuration especially suited therefor.

In copending application Serial No. 577,017, filed April 9, 1956, of Eugene Lemmers entitled, "Tubular Electric Lamps," assigned to the same assignee as the instant application, there are disclosed resonance radiation lamps wherein a high ratio of perimeter to area of the cross section simultaneously with improved implosion resistance is achieved by an envelope having a longitudinally extending transversely re-entrant portion or groove. The cross section of the discharge space in these lamps is in general a sector of an annulus defined by generally concentric walls and bounded by rounded convex edge walls. A resonance radiation lamp having such a cross section, for instance a fluorescent lamp utilizing the resonance radiation of mercury vapor at 2537 Å. to excite a phosphor coated internally on the walls of the envelope to produce visible light, achieves a higher loading and lumen output per unit axial length at a given efficiency than heretofore possible.

Re-entrant groove lamps as described above have other characteristics amongst the most noteworthy of which is that of providing a preferential light output in the sector of the cross section which includes the groove. This comes about as a result of the resonance radiation diffusion process occurring in these lamps wherein a photon or quantum of radiation which originates through the fall of an atom from an excited level to its ground level, is reabsorbed and re-emitted many times before it reaches the surface of the discharge medium and finally escapes. The plasma or region having substantially equal concentrations of electrons and positive ions conforms itself more closely to the re-entrant portion or groove, and the groove receives resonance radiation per unit area at a rate much greater than the mean unit area of the envelope. The resonance radiation is converted by the phosphor which coats the envelope walls into visible radiation or light and as a result, the groove has a much higher brightness than the lamp as a whole. The groove may be as much as 40 percent brighter than the envelope wall on the opposite side, and the quadrant of the cross section of the lamp which includes the groove may show an increase in light output of approximately 50 percent by relation to that obtained under a uniform circular light distribution.

The aforementioned copending Lemmers' application discloses various forms of re-entrant groove lamps including one with a continuous longitudinally extending groove along one side of the envelope, and another with relatively short groove portions spaced apart and alternating on opposite sides of the envelope giving a dimpled or crenelated appearance. The former is preferable from the point of view of ease of manufacture and also of light distribution since by operating the lamp with the

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groove facing downward, maximum illumination will be achieved on the working surface. The latter, on the other hand, has the advantage of inherently higher implosion resistance allowing it to be made in thinner walled tubing but has the disadvantages that it is more difficult to manufacture, and also that it provides re-enforced light components in two directions in accordance with the relative length of the groove sections on opposite sides of the envelope.

Accordingly, the object of the invention is to provide a new and improved re-entrant groove lamp envelope which is relatively easy to manufacture and which has higher implosion resistance than a similar lamp provided with a continuous groove.

Another object of the invention is to provide a re-entrant groove lamp envelope of improved strength and implosion resistance achieving a re-enforced luminous output in a single sector of its cross section.

In accordance with the invention, the tubular elongated envelope of a low-pressure resonance radiation lamp is provided with relatively short discontinuous sections of groove or re-entrant cavities running along one side. In the groove sections proper, the cross section of the discharge space is generally re-entrant and kidney-shaped, for instance a sector of an annulus defined by generally concentric walls and bounded by rounded convex edge walls. In between the cavities or groove sections, there are provided upstanding portions or ribs of generally circular section although possibly flattened slightly on the side corresponding to the groove sections. In general, the envelope has a wavy or undulating appearance along the side having the groove sections. For maximum strength, the distance between the raised portions or ribs which determines the length of the grooved panels is relatively short using the maximum tube diameter as a unit measure, for instance approximately three tube diameters. However if a lesser strength or implosion resistance suffices, the length of the grooved panels may be made greater.

A re-entrant groove lamp as described above has the advantage of much higher strength or implosion resistance than a re-entrant groove lamp with a continuous uninterrupted groove running along one side. It has a re-enforced luminous output in the direction or sector corresponding to the medial plane of the groove sections or cavities. Furthermore, it is relatively easy to manufacture as will become apparent hereinafter.

For a more detailed description of the invention, attention is now directed to the following description and accompanying drawing. The features of the invention believed to be novel will be more particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is a pictorial view of a discharge lamp embodying the invention with discontinuous groove sections extending longitudinally along its underside, portions of the envelope wall being broken out to shorten the figure and to reveal the internal constructions.

Fig. 2 is a cross-sectional view of the lamp of Fig. 1.

Fig. 3 is a side view of a vitreous cylindrical envelope positioned in a mold and being heated prior to forming.

Fig. 4 is a side view partly in section of the envelope formed to discontinuous groove wavy configuration and showing the forming die or plunger raised above it.

Figs. 5 and 6 are cross-sectional views of the lamp in the mold, the former showing the envelope and plunger just prior to forming and the latter at the completion of the forming step.

Referring to Fig. 1, there is shown a fluorescent lamp of the low-pressure, positive column type embodying the invention. The lamp comprises an elongated vitreous envelope 2 having circular or round tube ends 3, 3 which

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are annularly reduced or shouldered at their extremities for securing thereto bases 4, 4. Each base 4 may be of the double recessed contact type described in Patent 2,733,420 Marz, and comprises an annular metal shell 5 to which is secured a disc 6 of an insulating plastic provided with a raised elongated embossment 7. The outward projections of the lead wires 8, 9 extend through a central passage in the disc into the recessed outer face of the embossment to serve as contact terminals.

As shown at the end of the lamp having the cutaway portion, an electrode mount or stem flare 11 is sealed peripherally into each circular tube end and includes a press 12 through which are sealed the current inlead wires 8, 9. The inward projections of the lead wires support the filamentary cathode 13 which may consist of a coiled-coil of tungsten wire provided with an overwind and coated with an activated mixture of alkaline-earth oxides, such as the usual mixture comprising barium and strontium oxides. One of the stem flares is provided with an exhaust tube which is sealed or tipped off in the usual fashion.

The lamp contains an ionizable atmosphere including a starting gas or mixture of one or more of the inert rare gases of group 0 of the periodic table at a low pressure, for instance argon at a pressure of 0.5 to 5 mm. of mercury, and mercury vapor. The droplets of mercury indicated at 14 exceed in amount the quantity vaporized during the operation of the lamp wherein the mercury vapor exerts a partial pressure in the range of 1 to 20 microns for optimum generation of mercury resonance radiation at 2537 Å. A phosphor coating indicated at 15 on the inside of the envelope converts the 2537 Å radiation into visible light.

In accordance with the invention, vitreous envelope 2 is provided with transversely re-entrant longitudinal groove sections or cavities 16. The series of groove sections extends substantially the entire length of the envelope between the rounded tube ends 3, 3. In between the groove sections there are provided raised portions or ribs 17 which separate the grooved sections or panels.

As illustrated in Fig. 2, the cross section of the envelope in the grooved panels between the ribs may be visualized as a flattened tube which has been rolled up transversely into an inverted U-shape. More exactly, the cross section of the discharge space may be described as a sector of an annulus defined by generally concentric walls 18 and 19, and bounded by rounded convex edge walls 21, 21'. Convex outer wall 18 has the minimum curvature, its radius being that of the original round tube from which the instant grooved tube was formed. Concave inner wall 19 has a greater curvature than outer wall 18, its radius of curvature being approximately one-third that of outer wall 18. Convex edge walls 21, 21' are provided with a slightly greater mean curvature than concave inner wall 19. This is done because whereas it is desirable to have the wall-to-wall spacing substantially constant, it is essential to avoid a constriction at the center. If such a constriction were permitted, the discharge would not fill the cross section uniformly and would tend to occupy the space to one side or the other of the constriction. Since molding of glass cannot in any event be performed with perfect accuracy, a practical solution resides in making the radius of curvature of the convex edge walls somewhat less than that of concave inner wall 19, or somewhat less than one-half the maximum wall-to-wall spacing of the concentric outer and inner walls 18, 19. Preferably the groove is provided with more or less straight slanting wall sections 22, 22' interposed between the curvatures of the top of the groove and of the edge walls. The side walls of the groove are thus outwardly divergent, that is, slanted downwardly and outwardly.

At the rib portions 17 which divide the lamp into panels, the cross section of the envelope is convex in alignment with the groove sections in the panels. In

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the illustrated embodiment, the cross section at the rib portions is convex throughout but a slight flattening of the ribs on the side corresponding to the groove sections, that is on the underside as indicated at 23 in Fig. 2, is permissible and may occur as a result of the molding operation. The provision of ribs in accordance with the invention achieves a substantial increase in implosion resistance of the envelope; the ribs serve as bridges or supports which brace the legs of the U-shaped section and reduce the maximum stress in the envelope, particularly in the inner wall 19, thereby strengthening the envelope.

For maximum strength and resistance to implosion of the vitreous envelope, the length of the grooved panels or, in other words, the longitudinal distance between ribs should be relatively short, using the maximum tube diameter as a unit measure, and not in excess of several tube diameters. For instance, the longitudinal distance between ribs may be approximately 3 tube diameters. With shorter spacing between ribs, the increment in strength tapers off rapidly, that is, little further increase in strength is gained from further reduction in spacing. At the same time the mean perimeter to area ratio of the envelope, taking into account the cross section at the ribs as well as in the grooved panel, rapidly decreases. The advantages of the instant re-entrant groove configuration from the point of view of high efficiency and high loading capacity of the lamp are inherently connected with the re-entrant groove cross section having a high ratio of perimeter to area. Accordingly, for practical purposes a longitudinal distance between ribs of approximately 3 tube diameters is the minimum desirable for a practical lamp. Where less than maximum implosion resistance is required as in tubes of smaller diameter or where it is proposed to use an envelope of greater wall thickness, the longitudinal distance between ribs may be allowed to exceed considerably the figure of approximately 3 diameters which has been proposed. For instance, a panel length or distance between ribs of 12 inches in a T17 envelope having an outer diameter of approximately 2½ inches (corresponding to a panel length of approximately 5.6 diameters), provides a substantial increase in implosion resistance by comparison with a lamp of the same size having a continuous groove.

A number of lamps made from T17 tubing of nominal outer diameter 2½ inches and length 48 inches having 5 grooved panels with a longitudinal distance between ribs of approximately 8 inches have shown an increase in implosion resistance of as much as 200 percent over that of similar lamps made with a continuous groove. These lamps made with tubing of .075 inch wall thickness can safely withstand a pressure in excess of 6 atmospheres, that is, 90 pounds per square inch, and some in fact have withstood pressures as high as 150 pounds per square inch.

The dimensions of the foregoing lamps representing a preferred embodiment of the invention, were as follows, reference being made to Fig. 2. The radius of curvature T of outer wall 18 is approximately 1.063 inches measured to the outer surface. The radius of curvature A at 19 in the top of the groove is approximately 0.3125 inch measured to the outer surface of the glass. The radius of curvature B of the edge walls 21, 21' is 0.325 inch measured again to the outer surface of the glass. The center of the radii curvature of the edge walls is located a distance C equal to 0.094 inch below the center of the radius of curvature of the concave inner wall of the groove. The slanting side walls of the groove slope outwardly at an angle θ to the vertical which is in excess of 15° and preferably about 27°. Regarding radii A and B of the groove and of the edge walls, it will be appreciated that when viewed from the inside of the envelope, the radius of the edge wall is actually less than that of the groove by twice the thickness of the glass.

An important factor in the efficiency and loading capacity of re-entrant groove lamps is the degree of

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equivalent flattening, both the efficiency and the loading capacity at a given efficiency increasing therewith. In a simple flattened tube, for instance an oval tube, the degree of flattening is simply the ratio of maximum to minimum internal dimensions of the cross section. By analogy, in a re-entrant groove cross section such as illustrated in Fig. 2, the degree of equivalent flattening may be taken as the ratio of curved annular breadth of the discharge space given by D to the maximum wall-to-wall spacing opposite the groove and given by E. The illustrated cross section is that of one of the grooved panels where D equals approximately 2.97 inches and E equals approximately 0.600 inch, indicating an equivalent flattening of approximately 5:1. However, in the rib portions dividing the grooved panels, the cross section of the lamp is substantially circular and the grooved panels merge therewith with a gradual taper. Since the degree of flattening in the rib portions is substantially 1:1 (cross section substantially circular), the effective or mean equivalent flattening for the lamp as a whole will be intermediate that of the grooved panels and that of the rib portions. The equivalent mean flattening of the illustrated lamp is approximately 3:1. In other words, the illustrated lamp will perform in generally the same fashion as regards efficiency and loading capacity and enhanced lumen output in the sector including the groove as a lamp having a continuous groove of lesser depth proportioned to give an equivalent flattening of 3:1. Of course, the lamp illustrated in Figs. 1 and 2 has a much higher strength and implosion resistance than such other lamp of equivalent electrical characteristics.

A discontinuous grooved lamp in accordance with the invention may be manufactured following the method and procedure outlined in Figs. 3 to 6. The starting point is a cylindrical vitreous tube 25, illustrated in Fig. 3. The tube may be of the size commonly designated 48T17, being a few inches under 48 inches in length in order to make a lighting unit 48 inches long when the based lamp is mounted in suitable lampholders. The tube has an outer diameter of approximately $2\frac{1}{8}$ inches, a wall thickness of .075 inch, and is already provided with finished annularly reduced or shouldered ends 26, 26 to which the flares of the mounts are sealed during subsequent manufacturing operations.

As illustrated in Fig. 3, tube 25 is seated in a semi-cylindrical mold 27 which accommodates the lower half of the cross section of the tube. The tube has previously been heated to a temperature just below the softening point of the glass, for instance approximately 900° F. for a lime glass envelope. Suitable means are also provided to maintain the mold 27 at approximately the same temperature; as illustrated, such means may consist of sheathed electric heating elements 28 running longitudinally through the mold and disposed to surround generally the cavity therein. Vitreous tube 25 is now heated in selected areas to its softening temperature, for instance to approximately 1000° F. The heating may be performed by a gas flame burner 29 to which a combustible gas and air mixture is supplied by conduits 30. Burner 29 extends longitudinally above tube 25 and is provided with downwardly directed gas jets or orifices 31 throughout its length except at 32 over the ends of the tube 25 which are to be maintained cylindrical, and at the locations 33 which correspond to the regions to be maintained substantially circular in cross section in order to form the ribs 17. In the intervening regions which correspond to the grooved panels, the gas jets direct flames 34 downwardly against the vitreous tube in order to heat the glass above its softening point.

The tube 25 in its mold 27 is then located under a vertically reciprocable die or plunger 35 as illustrated in Fig. 4. The plunger 35 is made of stainless steel or other suitable material and is provided with downwardly projecting protuberances 36 separated by cutout portions 37. Means are provided (not shown in the drawing) for heat-

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ing the plunger 35 and for heating the protuberances 36 and especially the corners 38 thereof approximately to the softening temperature of the glass; this may be done by playing localized gas jets on the corners 38 just prior to the molding operation and depending upon the thermal conductivity of the metal of the plunger to heat sufficiently the remainder of the protuberances. By so doing, the corners of the protuberances are heated slightly more than the body portion thereof in order to facilitate stretching the glass of the envelope next to the ribs which are at a lower temperature.

Just prior to the molding operation, the relative positions of cylindrical tube 25 in mold 27 and of plunger 35 are as illustrated in Fig. 5. The plunger is then forced down as illustrated in Fig. 6 and the protuberances 36 contact the upper surface of envelope 25 in the zones where the glass is heated above its softening temperature. This causes the upper surface of the tube to fold inward in the highly heated zones thereby forming re-entrant cavities of the general cross section of a sector of an annulus, the tube 25 being reformed to the configuration 25' illustrated in Figs. 4 and 6 corresponding to envelope 2 of lamp 1 previously discussed. In the central part of the grooved panels, the glass merely folds inwards without any substantial stretching; however, in the corners next to the rib portions, there is some stretching of the glass as a result of the relatively steep angle in the bottom wall of the cavities at those points.

Preferably the envelope is made without causing the die or plunger to contact the glass over the entire portion of the cross section required to be reformed from the previously circular section. As illustrated in Fig. 6, protuberance 36 is shaped so as to achieve contact with the vitreous envelope in the bottom of the groove at 19 but not along the curved edge walls at 21, 21', the glass being allowed to form freely at the convex edge walls. If desired, in order to more accurately control the slope of the divergent side walls 22, 22', protuberance 36 of the plunger may be appropriately shaped to effect contact with the vitreous envelope in those regions. The glass of the tube is not contacted in the regions of the ribs 17 and the final configuration thereof is dependent on maintaining the glass slightly cooler in those regions. The instant free forming process has the advantage of simplicity and economy over other processes such as blowing the glass into a mold. Moreover it tolerates substantial dimensional variations in the size of the original circular sectioned tube, the variations being absorbed in the areas which are free forming.

It is important to maintain the side wall portions at 39, 39' at a temperature slightly below the softening point of the glass in order to prevent squashing or bowing out of those portions beyond the circular outline of the ends of the envelope. This is particularly desirable because, whereas no particular problem is introduced in subsequent manufacture of the lamp by having portions of the envelope wall deformed inwardly from the original cylindrical outline of the tube, subsequent manufacture would be severely complicated if the reformed glass envelope were allowed to project anywhere beyond the original cylindrical outline. This objective is aided by proportioning the skirts 40, 40' of the plunger to correspond to the desired outline of side wall portions 39, 39'.

It will be appreciated from the foregoing that the discontinuous groove or wavy configuration in accordance with the invention, in addition to the advantages from the point of view of the lamp itself into which the envelope is made, namely its structural and electrical characteristics, has the advantage of ease of manufacture since it can be made according to a relatively simple forming process. Moreover, having all re-entrant portions or cavities on the same side of the envelope allows the entire forming operation to be made by a single movement of a plunger with the envelope reposing in a single mold, such representing a substantial manufacturing economy.

While a specific embodiment of the invention has been illustrated and described in detail, it will, of course, be understood that various modifications may be made without departing from the invention. Obviously, the invention admits of modifications with respect to the proportioning of the grooved panels or cavities, in regards not only to depth but also to specific cross section and to panel length or distance between rib portions. The scope of the invention is to be determined by the following claims which are intended to cover any modifications coming within its true spirit and scope.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A vitreous envelope for an evacuated electric device of generally tubular form having discontinuous transversely re-entrant groove sections extending longitudinally along one side and forming panels of grooved re-entrant cross section and having upstanding rib portions interposed between the grooved panels.

2. A vitreous envelope for an evacuated electric device of generally tubular form having discontinuous transversely re-entrant groove sections extending longitudinally along one side and forming panels of the general cross section of a sector of an annulus defined by generally concentric walls and bounded by rounded convex edge walls, and having upstanding convex rib portions interposed between the grooved panels.

3. An elongated vitreous envelope for an evacuated electric device of generally tubular form having longitudinally spaced panels each provided with a longitudinally extending transversely re-entrant groove providing a space of the general cross section of a sector of an annulus defined by generally concentric walls and bounded by rounded convex edge walls, rib portions of generally circular cross section intervening between said grooved panels, the grooves in the panels being formed along the same side of the envelope and being tapered into the rib portions to provide an envelope of generally wavy configuration along one side.

4. An elongated vitreous envelope for an evacuated electric device of generally tubular form provided with relatively short discontinuous transversely re-entrant groove sections extending longitudinally along one side, and having rib portions of generally circular cross section intervening between the groove sections, the cross section of the envelope in the grooved portions being in general a sector of an annulus bounded by a convex outer wall, a concave inner wall, convex edge walls joined to the convex outer wall, and outwardly diverging substantially straight wall sections joining the concave inner wall to the convex edge walls.

5. An elongated vitreous envelope for an evacuated electric device of generally tubular form provided with relatively short discontinuous transversely re-entrant groove sections extending longitudinally along one side, and having rib portions of generally circular cross section intervening between the groove sections, the cross section of the envelope in the grooved portions being in general a sector of an annulus bounded by a convex outer wall of minimum curvature, a concave inner wall of greater curvature, and convex edge walls likewise

of greater curvature than the convex outer wall and joined thereto, and outwardly diverging substantially straight wall sections inclined at an angle of at least 15° to the medial plane of the groove joining the concave inner wall to the convex edge walls, the distance between rib portions being several tube diameters.

6. A low-pressure discharge lamp comprising an elongated vitreous envelope having electrodes sealed into opposite ends and containing an ionizable medium wherein an electric discharge maintains a plasma containing atoms at an excited level which emit quanta of resonance radiation which reach the plasma boundary by the process of resonance radiation diffusion, said envelope being of tubular form and provided with discontinuous groove sections extending longitudinally along one side wherein the cross section of the discharge space is in general a sector of an annulus, and having convex rib portions interposed between said groove sections.

7. A low-pressure positive column fluorescent lamp comprising an elongated vitreous envelope having electrodes sealed into opposite ends and containing an ionizable medium including an inert starting gas at a low pressure and a small quantity of mercury wherein an electric discharge maintains a plasma containing atoms at an excited level which emit quanta of 2537 Å. resonance radiation which reach the plasma boundary by the process of resonance radiation diffusion, said envelope being of tubular form and provided with discontinuous groove sections running along one side forming panels wherein the cross section of the discharge space is in general a sector of an annulus defined by generally concentric walls and bounded by rounded convex edge walls, and having rib portions of generally circular section interposed between said grooved panels, and a phosphor coating on the internal surface of said envelope responsive to said resonance radiation and achieving in the groove sections a substantially higher brightness than over the remainder of the envelope resulting in a light distribution pattern providing a substantial increase in light output in the sector of the cross section including the groove.

8. A low pressure electric discharge lamp comprising an elongated vitreous envelope having electrodes sealed into opposite ends and containing an ionizable medium including an inert starting gas at a low pressure and mercury vapor in equilibrium with an excess thereof, said envelope having an outer wall of generally circular section provided with discontinuous transversely re-entrant groove sections extending longitudinally along one side and forming grooved panels of generally kidney-shaped cross section, said envelope having upstanding rib portions of generally circular cross section interposed between the grooved panels for increasing its implosion resistance.

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