Oct. 31, 1967 L. C. MINNEMAN ET AL 3,350,154

REINFORCED CATHODE-RAY TUBE AND FACE PLATE THEREFOR

Original Filed Dec. 18, 1964 4 Sheets-Sheet 1

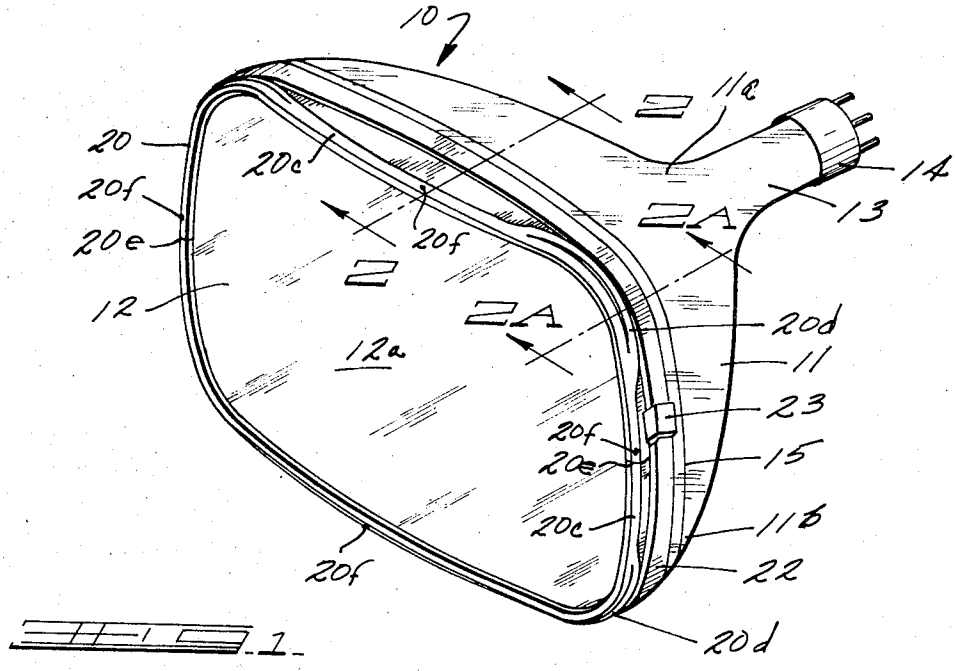


FIG. 1

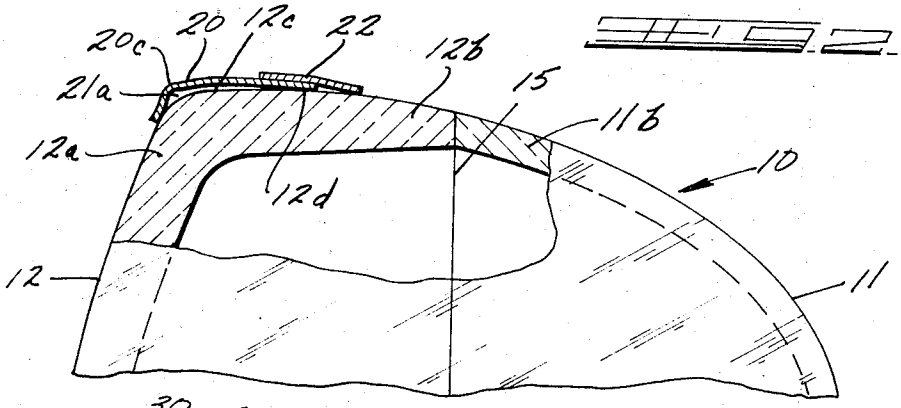


FIG. 2

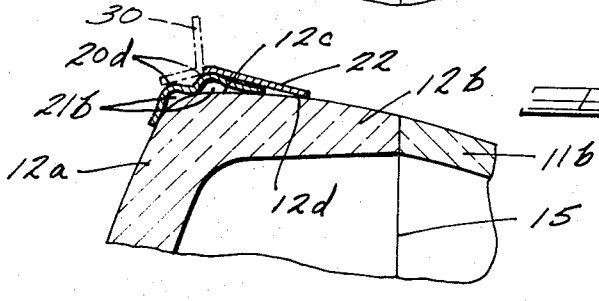


FIG. 2A

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Original Filed Dec. 18, 1964 4 Sheets-Sheet 2

FIG. 3

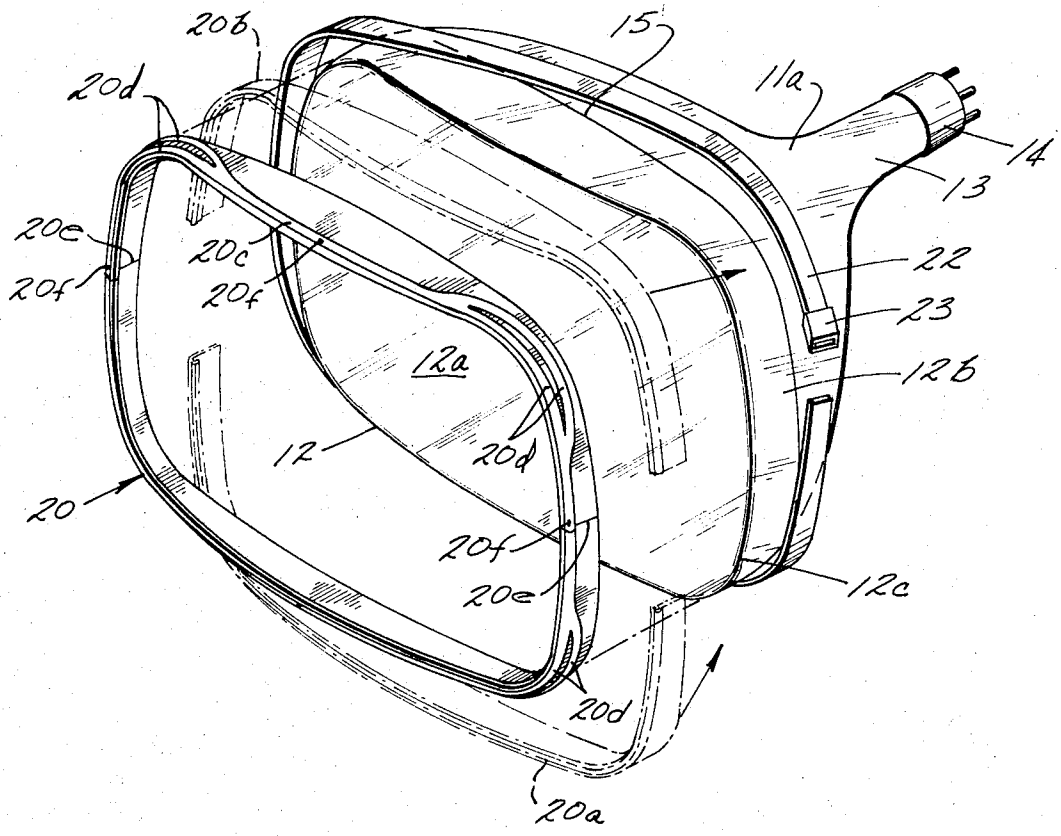


FIG. 4

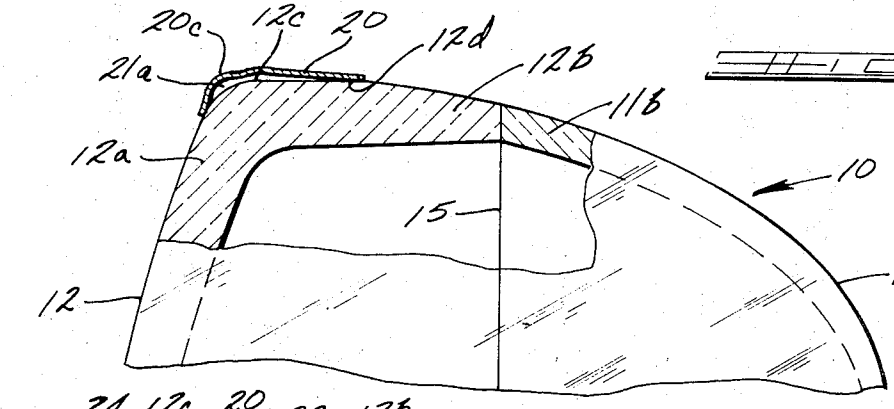
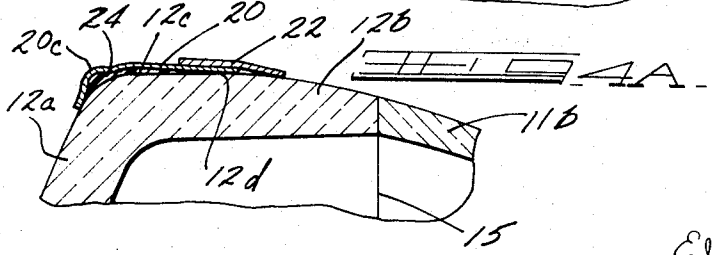


FIG. 4A



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Original Filed Dec. 18, 1964 4 Sheets-Sheet 3

FIG. 5

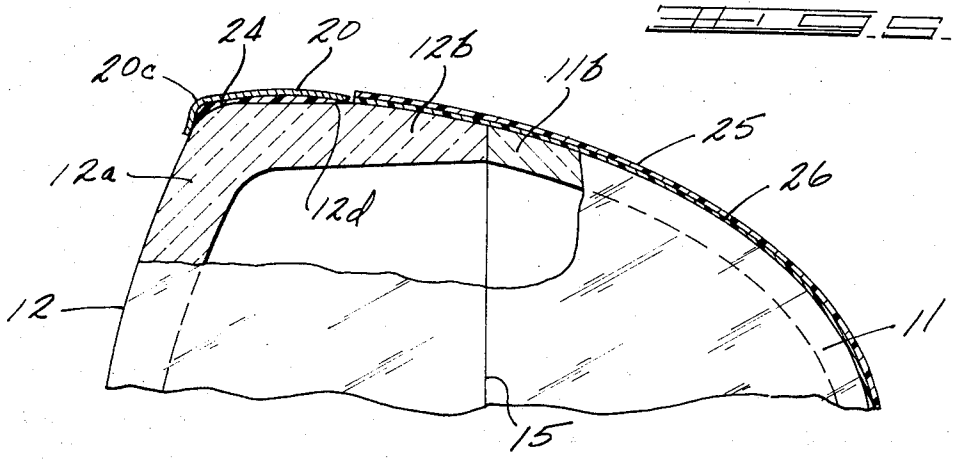


FIG. 6

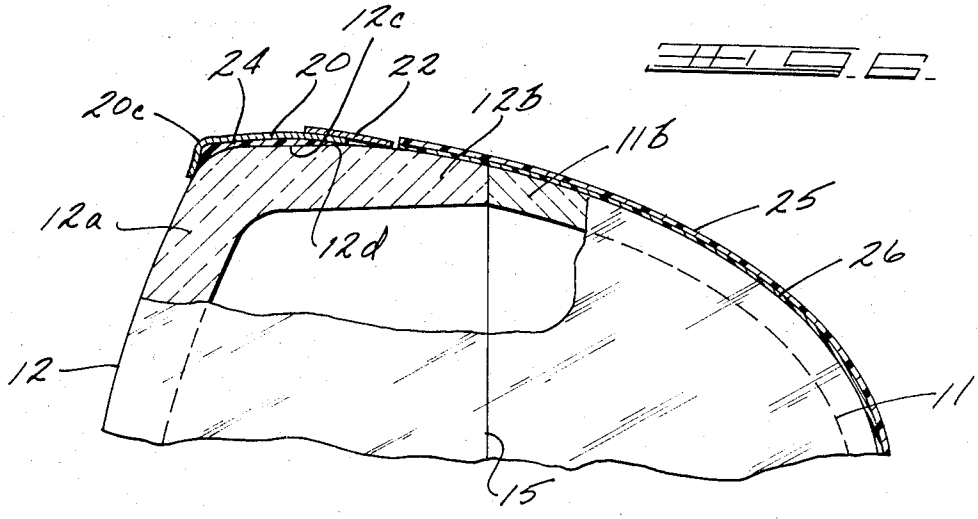
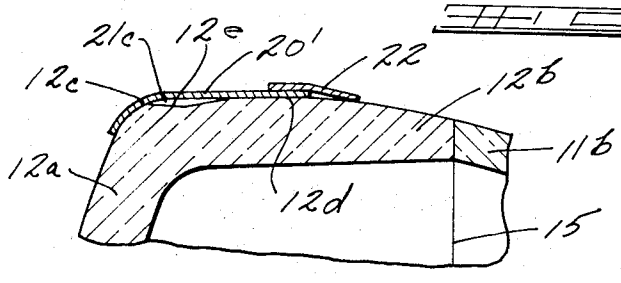


FIG. 7



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Oct. 31, 1967 L. C. MINNEMAN ET AL 3,350,154

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Original Filed Dec. 18, 1964 4 Sheets-Sheet 4

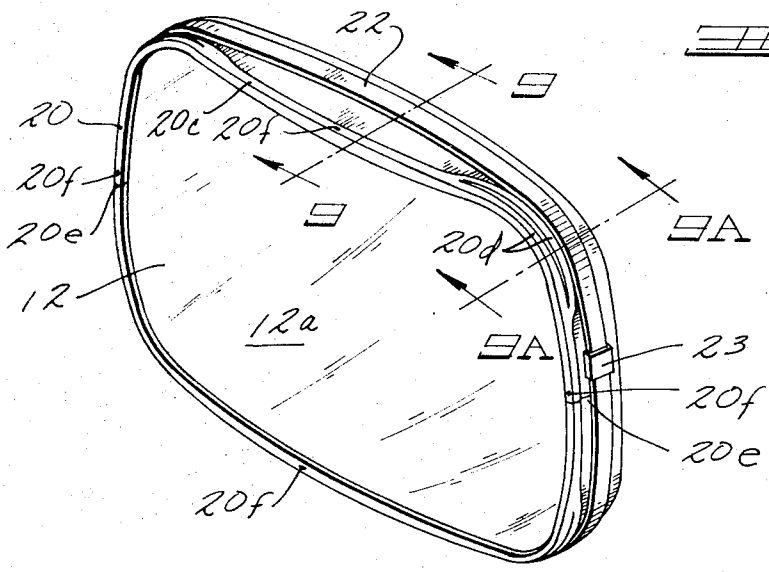


FIG. 8

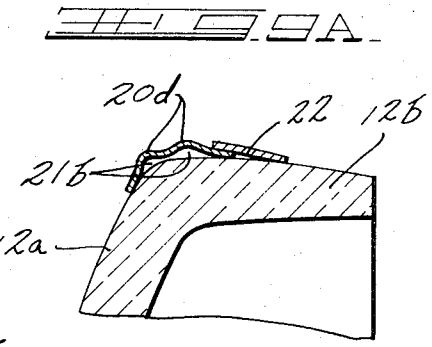


FIG. 9A

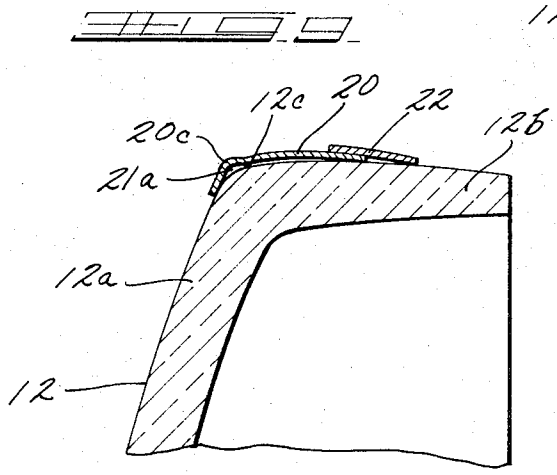


FIG. 9

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United States Patent Office 3,350,154
Patented Oct. 31, 1967

3,350,154

REINFORCED CATHODE-RAY TUBE AND FACE PLATE THEREFOR

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Original application Dec. 18, 1964, Ser. No. 422,063, now Patent No. 3,314,566, dated Apr. 18, 1967. Divided and this application Nov. 14, 1966, Ser. No. 606,484
14 Claims. (Cl. 316—19)

This application is a division of application Ser. No. 422,063, filed Dec. 18, 1964, now Patent No. 3,314,566, granted Apr. 18, 1967, which, in turn, is a continuation-in-part of application Ser. No. 285,696, filed June 5, 1963, now abandoned.

This invention primarily relates to television and, more particularly, to the prevention of fracture and to the control of implosive-explosive effects in sealed and vacuumized cathode-ray image tubes such as for television reception.

More specifically, the invention relates to improved types of direct-viewing cathode-ray image tubes as well as other vacuumized tubes having glass envelopes of appreciable dimensions and methods of fabricating such tube envelopes to eliminate breakage and to control devacuation thereof upon accidental or spontaneous breakage either in processing, shipping, installation or while in service.

In the manufacture of television picture tubes having essentially all-glass envelopes, each tube is evacuated to a high degree of vacuum with the resultant effect of creating high external pressures over extensive surface areas of the tube. Relative dimensions of these tubes are such that substantial surface pressures are exerted on the glass sidewalls and particularly on viewing and sealed portions. Such pressures cause vacuumized tubes to be highly subject to destructive implosive-explosive effects upon breakage or fracture of the glass envelope and sudden uncontrolled devacuation thereof. Therefore, the tube envelope and its various sealed areas are normally designed to safely withstand such high pressures without breakage during processing, shipment and installation as well as during long-term service.

Conventional television picture tubes are subject to variation in internal-external pressure conditions during initial fabrication of the tube and during reprocessing certain tubes found to contain malfunctions. Varying the pressure differential during evacuation, devacuation and re-evacuation, for example, may introduce excessive stresses into the tube envelope, particularly at their areas of maximum cross-sectional dimensions, such as where hollow funnel and face plate members are circumferentially joined at a seal line either by direct fusion or by annular band of relatively low-melting glass sealing composition. Tensive stresses can and do occur in exterior surface portions of the envelope at or adjacent the seal line, which stresses must be controlled or avoided. Such stresses present localized areas subject to damage such as by scratches or abrasion which may result in envelope breakage. The envelope must be designed having sidewalls and seal construction to withstand such abrasive damage.

Previously in the installation of television picture tubes in various types of receivers, a transparent implosion plate usually consisting of a tempered glass panel has been mounted adjacent and fully coextensive with the tube viewing portion. Alternately, a contoured transparent implosion plate is bonded to the tube viewing area as an integral component part of the tube to resist implosive-explosive effects. However, in both types of tube construction and mounting, whether the tube be unlaminated

with a separate protective panel or laminated with an integral implosion plate, the tubes may still be subject to destructive implosion, either spontaneously or by thermal or physical shock.

In such implosions the glass of the envelope funnel sidewalls may break violently in such manner as to destroy the component parts of the receiver by fragments being projected forcefully in random directions. The implosion panel serves to restrain glass fragmentation in a forward direction as well as to absorb frontal impacts delivered to the tube viewing area. However, in all cases either the separate or integral implosion plate adds substantially to the cost of the tube per se or its mounting in a receiver cabinet. Further, the implosion plate having substantial dimensions and wall thickness adds to the overall weight and dimensions of the receiver, and in combination with the tube face plate must provide proper light-transmitting characteristics while protecting viewing areas against implosion.

Obviously, in conventional types of essentially all-glass cathode-ray picture tubes for television reception, only the viewing area has been previously protected against implosion when the tube is properly installed. The body portion of the tube envelope remains subject to damage either in processing, installation, or when the receiver is serviced. The frontal implosion panel does not serve in any way to prevent damage to the tube body portion but merely protects against deleterious effects from or in a forward direction. The implosion panel must have light-transmitting properties of near-optical clarity and no visual defects can be tolerated in either this panel or the tube face plate. Near-optical perfection and strength requirements in these several members necessitate special precautions in their forming and handling. The present invention obviates the need for the conventional twin-panel system and optical matching of these component parts.

Accordingly, it is an object of the present invention to provide a reinforced direct-viewing vacuum tube envelope which is damage-resistant and capable of controlling sudden devacuation without serious fragmentation of its sidewalls under widely-varying adverse conditions.

Another object of this invention is to provide an improved type of reinforced glass vacuum tube envelope which is capable of withstanding tube fabricating processes, the envelope having resistance to fracture and inherent control over its sudden devacuation wherever and however caused, the completed tube being adapted to further reinforcement at the periphery of its viewing area and capable of functioning in a normal manner.

Another object of this invention is to provide a novel implosion-proof cathode-ray image tube envelope which is capable of being fabricated into a completed tube having integral heat-resistant reinforcing means to resist thermal damage and implosive-explosive effects, said reinforcing means extending over non-viewing exterior surfaces adjacent its viewing area to eliminate exterior surface damage thereat and to prevent violent devacuation of the envelope.

An additional object of the present invention is to provide a face plate having heat-resistant reinforcing means extending over non-viewing surfaces adjacent the viewing area, said reinforcing means being capable of withstanding thermal cycling during tube making process and facilitating the addition of heat-destructable components to the completed tube in supplemental operations.

Another object of this invention is to provide resistance to fracture and breakage in a hollow glass envelope utilized in the formation of large-size vacuum tubes and the like, wherein said envelope possesses heat-resistant integral means to control and minimize sidewall frag-

mentation upon rapid devacuation due to spontaneous or accidental breakage.

A further object of this invention is to provide a direct-viewing implosion-resistant television picture tube envelope, the forwardmost non-viewing external surfaces adjacent the envelope viewing area having implosion and fracture preventing elements disposed annularly thereover to minimize sidewall fragmentation upon envelope breakage.

A further object of this invention is to provide a method of fabricating an electron-discharge tube envelope having integral reinforcing components surrounding peripheral sidewalls of essentially maximum cross-sectional dimensions of the envelope, said reinforcing components being capable of withstanding thermal cycling during tube-making processes and facilitating the addition of heat-destructable components to the completed tube in supplemental operations.

A still further object of this invention is to provide a new article of manufacture and method of fabricating same to provide a primarily-glass electrical discharge tube envelope having heat-resistant elements surrounding a non-viewing frontal region of substantial dimensions whereby upon breakage the envelope is permitted to controllably devacuate without deleterious fragmentation of its sidewalls.

The specific nature of this invention as well as other objects and advantages thereof will become apparent to those skilled in the art from the following detailed description taken in conjunction with the annexed sheets of drawings on which, by way of preferred example only, are illustrated the preferred embodiments of this invention.

In the accompanying drawings:

FIGURE 1 is a perspective view of a cathode-ray television picture tube fabricated in accordance with the present invention;

FIGURE 2 is an enlarged fragmentary view partly in vertical section of the tube envelope taken along the line 2—2 of FIGURE 1;

FIGURE 2*a* is a view similar to FIGURE 2 taken along the line **2***a*—**2***a* of FIGURE 1;

FIGURE 3 is an exploded view illustrating the individual components utilized to fabricate the embodiment shown in FIGURE 1;

FIGURE 4 is an enlarged fragmentary view similar to FIGURE 2 illustrating a modification of the invention;

FIGURE 4*a* is a view similar to FIGURE 2 illustrating the same embodiment with the band sealant in place;

FIGURES 5 and 6 are views similar to FIGURE 4*a* illustrating several additional modifications of the invention;

FIGURE 7 is a view similar to FIGURES 2 and 4 illustrating a still further embodiment of the invention.

FIGURES 8, 9 and 9*a* are views similar to FIGURES 1, 2 and 2*a* showing a face plate fabricated in accordance with the present invention prior to the joinder of the face plate to the funnel member.

The present invention is described hereinbelow as specifically applied to the manufacture of a television cathode-ray picture tube, however, it will be apparent to those skilled in the art that the invention is equally applicable to the manufacture of many different types of evacuated tube envelope particularly all-glass envelopes having substantial dimensions which are subject to implosion and concomitant explosion on sudden devacuation.

The term "devacuation" as used herein is intended to mean the converse of "evacuation" as in the case where a vacuumized vessel experiences an internal pressure change toward atmospheric pressure upon loss of vacuum. The rate of change may occur rapidly or over an extended period of time wherein the evacuated space interiorly of the envelope returns to atmospheric pressure.

The present invention provides an impact-resistant and implosion-proof system which is capable of being incorporated into existing types and shapes of cathode-ray tube envelopes without serious alterations or modifications of present tube fabricating procedures. Certain elements of the invention are combined with the selected type of glass bulb or envelope using materials and methods which are capable of supplementing envelope fabricating processes. Only minor additions to the system are required subsequent to conventional tube fabricating processes. As used herein, the term "bulb" is applicable to the tube envelope "per se," while the term "tube" refers to the envelope hermetically-sealed in evacuated condition with its additional electrical and image-producing components properly installed in operative arrangement.

Briefly stated, the invention involves the application of a high-tensile strength contoured annular band which is snugly mounted around a perimetrical region of the tube face plate surrounding its non-viewing exterior surfaces of substantially maximum cross-sectional dimensions. The annular band has internal surfaces which are precisely complemental for forwardmost non-viewing exterior surfaces of the envelope and is mounted transversely of its axis. An intermediate circumferential space is provided between the contoured band and the envelope exterior surfaces preferably at a non-viewing region adjacent the transitional zone where the periphery of the tube viewing area joins a surrounding perimetrical and axially-extending sidewall. A second annular band is placed around the tube envelope surrounding and at least partially overlapping a rearward annular portion of the first-applied contoured band. The second band also encompasses and surrounds envelope sidewalls disposed adjacent and rearwardly of the first band. Both bands are preferably disposed entirely forwardly of the annular seal line region where face plate and funnel members of the envelope are circumferentially joined. By virtue of such location the bands may be applied either before or after face plate and funnel member are joined to form the bulb. This is especially significant in the manufacture of color television tubes where present technology dictates that the face plate and funnel members be shipped separately to the tube fabricator who installes the electrical and image-producing components and then joins the face plate to the funnel member. As is well known in the art of fabricating color television tubes, these members are joined and sealed by an annular band of relatively low-melting glass sealing composition.

The several annular bands are heat-resistant and capable of withstanding conventional thermal bake-out and evacuation cycles of cathode-ray tube making processes. After the tube is fully fabricated into final form, an annular layer of adhesive material such as synthetic resin is introduced into an intermediate circumferential space to provide a continuous perimetrical bonding layer. A single contoured annular band having proper physical characteristics such as thin-walled high-tensile strength metal can also be employed to perform functions of the several individual bands as desired or required. The forwardmost band has an annular contour which is precisely complemental to major surrounded envelope exterior surfaces where applied. This band is preferably endless in character and applied to the envelope in continuous tension by expansion and contraction of the band. The circumferential space is provided adjacent the frontal edge of the single band and subsequently filled with a bonding medium.

In a preferred embodiment of the present invention as shown in FIGURE 1, a glass cathode-ray tube envelope **10** is normally comprised of a funnel member **11**, face plate **12** and neck tubulation **13** which are joined to form a unitary hollow glass article. The terminating end of neck tubulation **13** is normally sealed by one or more electron-beam emitting guns retained within an end cap member **14**. Funnel member **11** is usually frusto-conical or frusto-pyramidal (FIGURE 1) in shape with its small end **11***a*

sealed to neck **13** and its large end **11***b* sealed to face plate **12**. Electromagnetic beam deflecting coils (not shown) are normally mounted at the yoke area where neck **13** and funnel small end **11***a* are joined to provide electron beam deflection and proper scanning of the tube screen.

Face plate **12** consists of a concave-convex viewing portion **12***a* bounded by a depending peripheral side panel or flange **12***b* (FIGURE 2). Face plate flange **12***b* and large end **11***b* of the funnel member terminate in annular sealing surfaces of generally complemental planar contour. Sealing surfaces are joined at seal line **15** either by direct fusion of the glass or by an interposed annular layer of solidified low-melting glass sealing composition which is selected as being compatible with the thermal and physical characteristics of the parent glass parts. The basic shape of the envelope viewing area **12***a* may be either rectangular (FIGURE 1) or circular (not shown) in plan as conventionally known in the art with the sealing surfaces being substantially planar for forming a vacuum-tight durable joint. However, the present invention is applicable to all conventional types of cathode-ray tube envelopes regardless of their contours or dimensions.

As stated, the invention consists of applying certain heat-resistant reinforcing elements to external non-viewing surfaces of the tube envelope prior to subjecting the envelope or bulb to a tube fabricating process, it being understood that such reinforcing elements may be applied either before or after the face plate is joined to the funnel member. The initially-applied reinforcing elements are capable of withstanding temperatures of the order of about 450° C. for a sufficient length of time to conduct bake-out and evacuation cycles in fabricating the completed tube without degradation of these elements. The bulb after being fabricated into this form exhibits certain characteristics for controlling devacuation on breakage, however, as described hereinbelow one or more additional elements is applied to the envelope subsequent to its conversion into a completed tube to further safeguard the same. The components initially applied to the bulb to provide implosion and fracture resistance must be capable of withstanding required break-out cycling temperatures and pressures of the tube-making process while the components subsequently applied to the tube need not be capable of withstanding such severe environments.

Method of fabrication

A glass face plate **12** of an all-glass cathode-ray image tube envelope or bulb **10** having an open-neck tubulation **13** excluding end cap **14** is taken for further fabrication and reinforcement in accordance with the following method. As shown in FIGURE 3 illustrating the embodiment wherein the reinforcement is applied to an assembled bulb, a peripheral rim band **20** which is preferably comprised of two similar metallic half-sections **20***a* and **20***b* is taken for mounting on the face plate corner area **12***c*. Alternately, a unitary annular band having prescribed circumferential dimensions is employed. Each of the two half-sections **20***a* and **20***b* is contoured to have internal surfaces which are closely complemental to the geometry of about one-half the external surfaces of face plate annular corner **12***c*. Corner surfaces **12***c* are formed by the transition zone between the periphery of viewing panel **12***a* and surrounding perimetrical flange **12***b*. Each half-section has a U-shaped configuration and a circumferential extent slightly greater than one-half the periphery of face plate corner surfaces **12***c*. The pair of similar bands preferably overlap in telescoping arrangement on opposing sides of the face plate such as on the short axis side of the rectangular envelope. The pair of bands are premeasured to determine their precise circumferential extent in mounted relation. In one embodiment the pair of half-sections are fitted around the complementally-contoured corner surfaces **12***c* of the face plate with their end portions in juxtaposed overlapping relation. Half-sections **20***a* and **20***b* overlap on the short-axis opposing sides of the face plate at line **20***e*. The bands are marked at the overlapped region while snugly disposed around the face plate in telescoped relation and then are removed therefrom. The overlapped portions of the removed half-sections are then shortened a prescribed distance such as 0.160 inch on each side at line **20***e* for a 23 diagonal inch rectangular bulb. The several sections are then joined into a unitary annular band such as by spot-welding at each side. With a plurality of envelopes having precise exterior surface contours at their frontal region, one-piece bands having the requisite slightly lesser circumferential dimensions are utilized.

A forward portion of rectangular rim band **20** has an exteriorly-projecting annular beaded region **20***c* formed on its opposing sides to provide a circumferentially-disposed recess **21***a* intermediate the band and corner surfaces **12***c*. As shown in FIGURE 2, annular space **21***a* extends throughout the extent of long and short-axis sides of the face plate. The exteriorly-projecting beaded region **20***c* defining the recess **21***a* feathers at the corner regions of the face plate into two parallel beaded regions **20***d* defining a pair of spaces or channels **21***b*. Thus, a pair of spaces or channels **21***b* connecting with space **21***a* are provided at the corner regions intermediate the band and face plate corner surfaces **12***c*. Such construction insures that sufficient space exists between the sidewall and the beaded regions **20***d* to permit the introduction of a sufficient quantity of adhesive material to insure firm bonding between the band and the peripheral sidewall in this critical area. The circumferential space is located anywhere between frontal and rear edges of the contoured band and preferably slightly rearwardly of the corner radius on the long-axis sides and closely adjacent the corner radius on the short-axis sides and at the corners of a rectangular face plate when viewed in plan.

With annular band **20** formed as described having a circumferential extent slightly less than face plate annular corner surfaces **12***c*, the band is heated into expanded condition such as by surrounding it with a high-frequency electrical heating coil. Band **20** is comprised of relatively thin-walled high-tensile strength metal such as carbon steel having an aluminum metal coating thereover to minimize or prevent oxidation on moderate heating. With the band in expanded condition it is capable of being fitted over corner surfaces **12***c* and allowed to cool therein into shrunken condition. The band in cooled form at ambient temperatures is then placed in tension to introduce compressive stresses into the glass sidewalls therebeneath. Band **20** preferably is placed in tension in the range of 300 to 400 pounds such that it tends to approach its yield strength at the corner regions of the bulb due to minimal cross-sectional dimensions thereat. Band **20** has a frontal edge configuration which conforms snugly to the non-viewing periphery of the viewing area **12***a* and parallels the so-called "screen line" of viewing area **12***a*. This frontal edge is preferably spaced about $\frac{5}{16}$ inch from the screen line for a 23 inch tube. The rearward edge of band **20** extends adjacent and parallel to the mold match line **12***d* of the face plate.

A series of access openings or apertures **20***f* are provided at spaced-apart locations in band **20** such as at the mid-point of the long and short-axis sides. These apertures may be provided in band **20** when fabricated or may be formed in its beaded region **20***c* after the band is properly applied to the envelope. The plurality of apertures serve to facilitate the introduction of an adhesive or bonding material into annular spaces **21***a* and **21***b* to permanently bond band **20** to exterior surfaces **20***c*.

As shown in FIGURES 1, 2 and 2*a*, immediately subsequent to mounting band **20** in tension surrounding envelope exterior surfaces **12***c*, tension band **22** such as one comprised of thin-walled heat-resistant metallic material is applied to the envelope band **20**. Band **22** preferably is comprised of tempered carbon steel strapping having a coating of aluminum metal thereover. Band **22** encompasses and surrounds a rearward portion of band **20** as

well as an adjacent exterior surface of the envelope. Band **22** is mounted to straddle mold match line **12***d* of the face plate and both bands **20** and **22** are mounted forwardly of seal line **15**. Band **22** preferably consists of a discontinuous element having its ends joined by a clip member **23** or joined at a localized region by spot-welding.

In a preferred embodiment, tension band **22** overlaps rim band **20** by about one-half inch and consists of a flexible strap of substantially uniform cross-section. A tensioning device such as an air wrench is employed to draw band **22** into permanent tension with the ends of the bands passed through clip member **23** which is crimped to form a permanent connection of the band ends. Band **22** may also be comprised of an endless ring member which may be shrunk onto the rim band and adjacent envelope surfaces. Band **22** is preferably placed in tension ranging from about 800 to 1500 pounds tension for a 23 inch tube. FIGURES 2 and 2*a* illustrate in sectional views the disposition of the several bands at long side and corner areas of the envelope. FIGURE 3 illustrates the several bands individually in an exploded view prior to their mounting on the envelope.

FIGURES 1, 2 and 2*a* illustrate a tube envelope having the metallic reinforcing elements surrounding a non-viewing frontal region of the envelope. Both bands are mounted in a transverse place substantially parallel to seal line **15** and forwardly thereof and, as shown in the drawings, rim band **20** has a greater width on its long axis sides than on its short axis sides. Normally, this member has its narrowest width at the corner regions due to conventional face plate contours. The envelope having the several bands mounted thereon is capable of providing abrasion resistance to the envelope exterior surfaces where mounted as well as providing substantial implosion resistance against breakage due to impacts of the order of about five foot-pounds delivered to any region of the tube face. The all-glass envelope in this condition is capable of being taken to a tube fabricating process and withstanding all thermal bake-out and evacuation cycling without deleterious effects on its metallic reinforcing members.

As shown in FIGURE 4, only a single annular rim band **20** is utilized to surround the face plate corner surfaces **12***c*. In this case band **20** has a configuration similar to that shown and described in FIGURES 1 and 2 and provides an open annulus **21***a* and **21***b* at the transitional zone between the viewing panel **12***a* and perimetrical flange **12***b*. Band **20** may also have a longer axial extent rearwardly to surround and encompass greater surface areas of sidewall portion **12***b*. However, where only a single band is employed, the circumferential open space is provided in generally the same area as described hereinabove.

The subject envelopes when evacuated are capable of controlled evacuation on breakage of the envelope. The tubes can be subjected to nominal impact damage which may or may not be perceptible at normal viewing distances. The described elements are capable of safeguarding the envelope against destructive implosive-explosive effects on breakage due to moderate adverse effects. However, further reinforcement thereof is highly desirable in order to make the envelope resistant to both high and low impact damage as well as breakage caused by any and all sources.

Tube envelopes fabricated as shown in FIGURES 2 or 4 are then subjected to a tube fabricating process in order to install the working components of the completed tube. This involves the application of one or more luminescent screen materials to the internal surface of viewing area **12***a*, a conductive coating over non-viewing internal surfaces of the envelope, the installation of the cathode-ray emitting gun or guns and evacuation of the envelope, all of which operations are conventionally known in the art and do not comprise a part of the present invention. The tube is then finally formed with all of its internal and external working components properly installed in operative alignment following which it is subjected to bake-out temperatures and evacuation.

The completed tube is then subjected to the application of one or more additional elements in accordance with this invention with ambient conditions existing externally of the tube. As stated, an organic adhesive capable of integrally bonding glass-to-metal surfaces is introduced into this space subsequent to the tube-making process as described hereinbelow.

A completed cathode-ray picture tube capable of recreating transmitted electronic images is taken for further reinforcement of the envelope in accordance with the following procedure. The series of access openings **21***f* such as at the mid-point on the long and short axis sides of the envelope are utilized to introduce an adhesive bonding material such as epoxy resin into the interconnecting annular spaces **21***a* and **21***b*. Either an individual pressurized gun or a manifold having an aligned series of discharge orifices is employed to introduce the synthetic resinous material interiorly of the circumferential space. A continuous annular layer **24** of synthetic resin, such as epoxy or polyester resin, as shown in FIGURES 4*a*, 5 and 6, is introduced into the open annulus. Good adherence of annular bonding layer **24** to both the glass and surrounding rim band surfaces is particularly important. A preferred material consists of Union Carbide Epoxy Resin, Product No. EXRL–0231–A, this particular resin system having a relatively high viscosity when previously mixed with two parts Union Carbide Hardener, Product No. EXRL–0231–B per one part of a resin. The subject resin is a thixotropic resin system manufactured by Union Carbide Company for sealing glass-to-glass and glass-to-metal members. The epoxy system is comprised of liquid epoxide resin which can be cross-linked by a liquid hardener into a tough, resistant solid having excellent dimensional stability and strength. The reactive resin system forms a stable, durable adhesive bond between glass and metal. An epoxy resin which is particularly well suited for this purpose is Union Carbide Epoxy No. EBLM 7652 which is also a thixotropic paste having a relatively high viscosity when mixed two parts Union Carbide Hardener No. ABLM 8653 per three parts resin. This resin system has an elongation at rupture of 1 percent and will cure at room temperature in three to four hours or at 200° F. in ten minutes. Other liquid epoxy resins which are relatively thick and capable of being pumped under pressure can also be employed. The synthetic resin system is capable of bonding chemically to the glass surfaces on reaction, the final rigid layer having a considerable strength for rupture resistance. If desired, a high-temperature resistant bonding agent can be similarly employed.

As shown in FIGURES 5 and 6, annular layer **24** essentially fills the previously open annulus **21***a* and **21***b* and extends in a circumferential pattern throughout the peripheral extent of corner surface **12***c*. FIGURE 6 shows both bands **20** and **22** disposed in place and maintained in tension as described hereinabove with continuous bonding layer **24** filling the intermediate space between band **20** and exterior surfaces **12***c*. FIGURE 5 illustrates only a single rim band **20** in place with a similar annular layer **24** of bonding material therebeneath. As shown in both views, a surrounding layer **25** of glass fiber cloth impregnated with an intermediate layer of synthetic resin **26** such as epoxy resin is employed to surround the funnel. The layer **25** of interwoven and adhered material may be applied over extensive major exterior surfaces of the funnel member extending forwardly to adjacent mold match line **12***d* and metal bands **20** and **22**. The supplemental layer of woven material such as glass fiber cloth may or may not be applied as required, depending upon the shape and size of the envelope and the desired level of damage resistance desired. The application of adhered interwoven material **25** to the funnel strengthens the envelope against most severe impacts, however, elimination of this element permits the banded bulb to resist

low and moderate damage levels in an acceptable manner.

FIGURE 7 illustrates another form of the invention in which non-viewing exterior surfaces of the glass face plate have an annular recess **12***e* formed in an area adjacent corner radius **12***c*. Contoured band **20'** has a smoothly-curved internal surface devoid of an exteriorly-projecting beaded portion to snugly surround corner surfaces **13***c* and mold match region **12***d*. Thus, with band **20'** disposed in place and in continuous tension, an open annulus **21***c* is provided within which is disposed an annular layer of adhesive material. The tension band **22** contacts and surrounds the rearward portion of band **20'** to reinforce the same.

One of the tension bands such as contoured rim band **20** or **20'** may have a series of spaced-apart lug members **30** (as shown in broken outline in FIGURE 2A) mounted thereon in exteriorly-projecting relation. The lug members are preferably L-shaped in cross-section and located at the four corners of the face plate when viewed in plan to facilitate retention of the tube in a receiver cabinet. Lug members **30** also serve to provide a seat for tension band **22** to permit its expedient mounting in a plane transversely of the envelope axis parallel to the rim band. FIGURES 8, 9 and 9*a* illustrate a form of the invention in which the reinforcing elements, either the single rim band **20** or the rim band **20** and tension band **22**, are applied to the face plate **12** prior to the joining of the face plate to the funnel member **11**.

The above-described reinforcing elements which consist of a pair of circumferential bands provide a system of reinforcement which will withstand prolonged exposure to 450° C. without deterioration of the system. The use of heat-resistant aluminized steel bands is preferred to minimize or prevent oxidation of these elements on heating. The rim band is sweated on to apply approximately 300 to 400 pounds tension and the second tension band applies an additional 800 or more pounds tension to the envelope. The endless rim band is shortened by about .0320 inch for a conventional 23 diagonal inch tube. The glass sidewalls therebeneath are thus placed in considerable compression.

The combination of 0.021 inch thick sweated rim band and a three-quarter inch wide 0.035 inch thick tension band was applied to a twenty-three inch tube envelope having the construction shown in FIGURES 1, 2 and 2*a*. In this case no adhesive was used to bond the rim band to the glass exterior surfaces. A total of 46 bulbs were impact-tested at various foot-pound impact levels in different positions on the face. Of this test group 29 were subjected to five foot-pound impacts which produced small fissures in the face and resulted in about 100 to 200 times less glass being thrown forwardly as compared with a plain unreinforced cathode-ray television tube envelope of the same type. Of seventeen 15 foot-pound impacts, six caused cave-in type devacuation which resulted in approximately five times less glass being thrown forwardly as compared with a plain cathode-ray television tube envelope of the same type. Without an annular layer of resin to obtain firm adhesion of the rim band, some fragments of glass are thrown forwardly at the 15 foot-pound impact level and above. The subject bulb is resistant to violent devacuation due to thermal shock and guillotine tests.

With an epoxy resin injected into the annular space beneath the contoured rim band to provide a well-cemented rim band construction, a total of 120 bulbs were tested and evaluated at all positions. Impact forces were varied from five to 50 foot-pounds. Twenty-five five foot-pound impacts produced small fissures in the face with only small slivers of glass falling off the face section. This same test applied to plain television tubes of the same type results in hundreds of times more glass being thrown forwardly. Sixty-five bulbs were tested with 15 foot-pound impacts which caused 30 cave-in devacuations, and produced 20 times less glass being thrown forwardly for the cave-ins than a plain television tube of the same type would throw when subjected to the same test. Twelve 25 foot-pound impacts at center position resulted in approximately 1,000 times less glass being thrown forwardly as compared to a plain television tube of the same type under the same conditions. Thirty-five and fifty foot-pound impacts delivered in the center portion were conducted. Three out of eleven 50 foot-pound impacts caused safe cave-in devacuation with approximately five to ten times less glass being thrown forwardly as compared to a plain television tube of the same type under similar conditions. The remaining eight tubes tested resulted in virtually no glass being thrown forwardly. The system performs very well when subjected to thermal shock and guillotine-type tests.

The subject system controls devacuation caused by five foot-pound impacts delivered at any region of the face. With the addition of the epoxy resin adhesive in bonding relation, the system is perfectly safe when tested with 15 foot-pound impacts delivered at any position except when struck closely adjacent the rim band at a corner location. Additional testing of 24 bulbs with 25 to 50 foot-pound impacts delivered at the center position resulted in safe devacuation. The corner impacts were considered to cause destruction of the system due to probable release of the tension in one or both bands. When tension is maintained in both bands during breakage, safe devacuation from any cause with minimal glass throw is observed.

Cathode-ray tubes fabricated in accordance with the above-described invention possess significant weight advantages due to their being direct-viewing with no separate or integral implosion panel being required. The subject tubes are wholly capable of controlled devacuation on breakage of the envelope whether subjected to nominal or severe impact damage or other adverse effects such as thermal shock. The subject tube envelopes are able to control their devacuation on sudden or accidental breakage and attendant release of vacuum under virtually all forms of destructive damage. The non-viewing periphery of the face plate viewing area is completely restrained against movement either laterally or radially on envelope breakage, however caused, by the surrounding reinforcing elements. On cavitation of the face plate from any fracture source, fragments of the viewing area are driven with less force in a rearward direction by atmospheric pressure to strike and impinge upon internal surfaces of the funnel member. The face plate fragments may or may not cause breakage of the funnel from internal impingement due to retardation of impact forces achieved by retention of the face plate perimeter. The reinforced peripheral corner and adjacent flange of the face plate are positively maintained completely intact in breakage and crack propagation through this region is markedly reduced or eliminated. The space intermediate the rim band being filled with reacted adherent rupture-resistant material functions to maintain the envelope sidewall regions therebeneath in integral form. Although cracks or fissures may be created in the envelope sidewalls at the area of centrally maximum cross-sectional dimensions reinforced against movement due to breakage originating at any region, collapse of the envelope is delayed or retarded so that air cannot rush into the interior void to cause rapid and destructive fragmentation. Thus, retardation of air rushing into the vacuumized interior from the face plate or funnel areas is achieved to prevent violent devacuation of the envelope. In most cases fracture of the face plate usually results in minimal fragments being drawn inwardly with virtually their complete containment within the funnel. Where the funnel is broken, fragments thereof which impinge the interior surfaces of the face plate may cause breakage thereof. However, the throw of fragments is greatly retarded or eliminated.

Various modifications may be resorted to within the spirit and scope of the appended claims.

We claim:

1. The method of fabricating an implosion-resistant cathode-ray tube envelope having a substantially funnel-shaped hollow body portion and a light-transmitting viewing portion enclosing its larger end, said method comprising the steps of forming an endless reinforcing band of thin-walled high-tensile strength material having a complemental contour and circumferential extent slightly less than a forwardmost non-viewing region of substantially maximum cross-sectional dimensions of said envelope, expanding said band into an enlarged condition, mounting said band in close proximity circumferentially around said forwardmost non-viewing region, contracting said band therearound, and forming an open annulus intermediate said band and the envelope sidewalls therebeneath having at least one exteriorly-opening aperture.

2. The method in accordance with claim 1 including the steps of introducing a synthetic resin adhesive material into said open annulus to substantially fill the same subsequent to positioning and contracting said endless band and bonding said band and the envelope sidewalls therebeneath into an integral structure.

3. The method in accordance with claim 1 including the step of positioning a second reinforcing band around said envelope in at least partially overlapping relation with respect to said first endless reinforcing band and placing said second band in continuous tension.

4. The method in accordance with claim 1 including the step of providing an annular recess in the inner surface of said first endless reinforcing band to constitute said open annulus.

5. The method in accordance with claim 1 including the step of adhering an annular coating of rupture-resistant high-tensile strength material over extensive non-viewing exterior surfaces of said envelope body portion.

6. The method in accordance with claim 1 including the steps of fabricating said tube envelope into a complete image tube, evacuating the same and subsequently introducing a continuous annular layer of adhesive material in said open annulus to bond said first reinforcing band to said forwardmost envelope sidewalls therebeneath.

7. The method of fabricating a direct-viewing implosion-resistant cathode-ray tube envelope having a substantially funnel-shaped hollow glass body portion and a light-transmitting glass viewing portion enclosing its larger end, said glass viewing portion having an integral peripheral sidewall region of substantially maximum cross-sectional dimensions of said envelope sealed to the larger end of said body portion along a circumferential seal line, said method comprising the steps of forming an endless reinforcing band of thin-walled high-tensile strength metal from a pair of similar U-shaped half-sections, said band being complementally contoured and having a circumferential extent slightly less than the forwardmost non-viewing peripheral sidewall region of maximum cross-sectional dimensions of said envelope at ambient temperatures, expanding said band by heating and positioning the same in juxtaposed relation around said forwardmost non-viewing peripheral sidewall region, contracting said band around said sidewall region on cooling to introduce compressive stresses into the latter, and forming a circumferential space intermediate said band and the envelope sidewalls therebeneath having at least one exteriorly-opening aperture therein.

8. The method in accordance with claim 7 including the step of introducing a continuous annular layer of synthetic resin bonding material into said circumferential space to adhere said reinforcing band to said peripheral sidewall region.

9. The method in accordance with claim 7 including the steps of mounting a second reinforcing band in partially overlapping relation rearwardly of said first band and maintaining said second band in continuous tension, both said first and second bands being mounted entirely forwardly of said seal line.

10. The method in accordance with claim 7 including the step of adhering an annular coating of interwoven glass fibers and synthetic plastic resin over extensive surface areas of said envelope body portion.

11. The method in accordance with claim 7 including the steps of providing a series of exteriorly-opening apertures in said first reinforcing band, injecting flowable synthetic resin adhesive material under pressure into said open annulus through said apertures and curing said adhesive material in situ to bond said band to said envelope non-viewing forward region.

12. The method of fabricating a face plate for an implosion-resistant cathode-ray tube envelope, said method comprising the steps of forming an endless reinforcing band of thin-walled high-tensile strength material having a complemental contour and circumferential extent slightly less than a forwardmost non-viewing region of substantially maximum cross-sectional dimensions of said face plate, expanding said band into an enlarged condition, mounting said band in close proximity circumferentially around said forwardmost non-viewing region, contracting said band therearound, and forming an open annulus intermediate said band and the face plate sidewalls therebeneath having at least one exteriorly-opening aperture.

13. The method in accordance with claim 12 including the step of positioning a second reinforcing band around said envelope in at least partially overlapping relation with respect to said first endless reinforcing band and placing said second band in continuous tension.

14. The method in accordance with claim 12 including the step of providing an annular recess in the inner surface of said first endless reinforcing band to constitute said open annulus.

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