Feb. 21, 1967 N. F. FYLER 3,305,334

METHOD OF MAKING A GLASS SHEET HAVING A PLURALITY OF SPACED WIRES THEREIN

Original Filed March 22, 1960 2 Sheets-Sheet 1

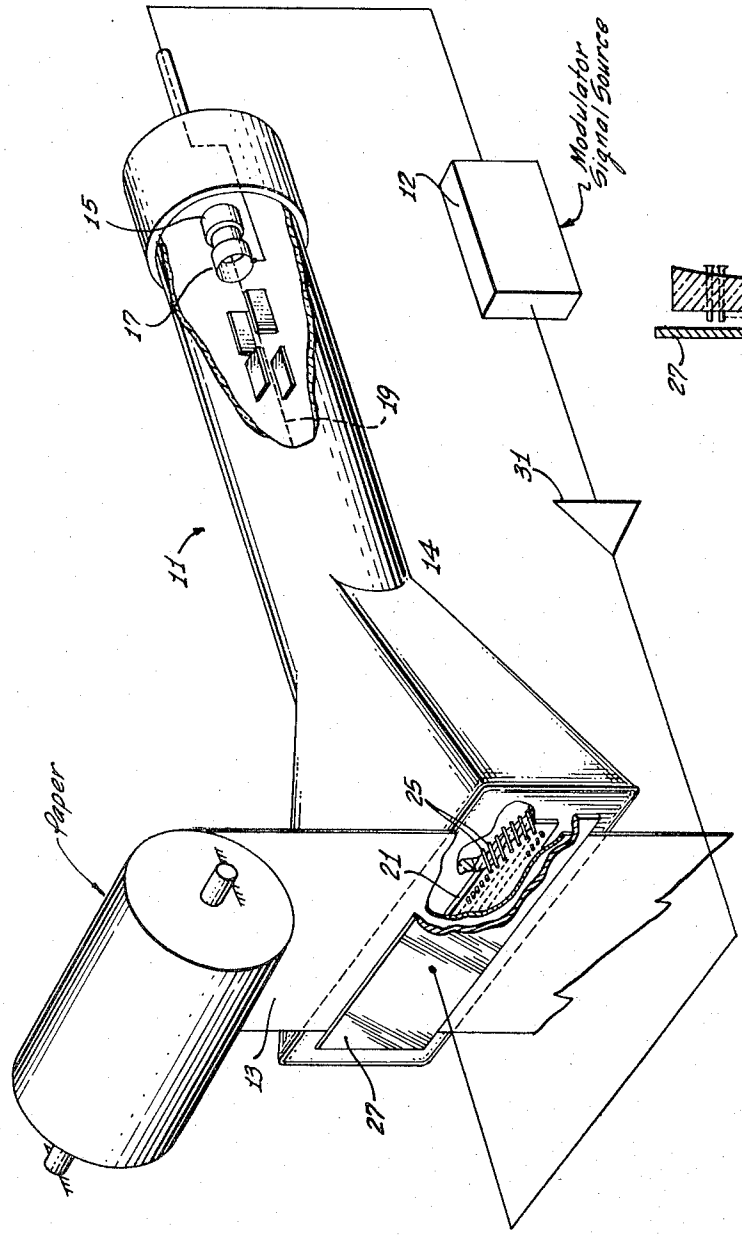


Fig. 1

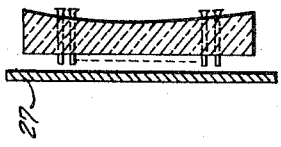


Fig. 2

INVENTOR:
Norman F. Fyler

By Alfred B. Levine
Attorney

Feb. 21, 1967 N. F. FYLER 3,305,334

METHOD OF MAKING A GLASS SHEET HAVING A PLURALITY OF SPACED WIRES THEREIN

Original Filed March 22, 1960 2 Sheets-Sheet 2

Fig. 3

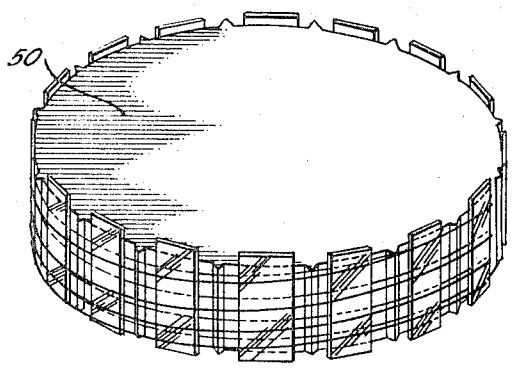


Fig. 4

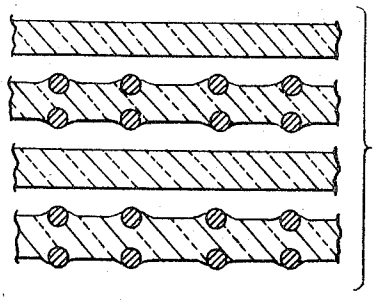


Fig. 5

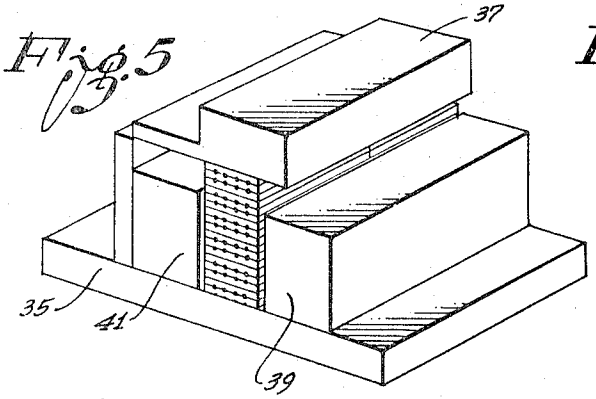


Fig. 6

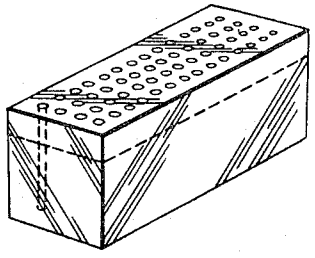


Fig. 8

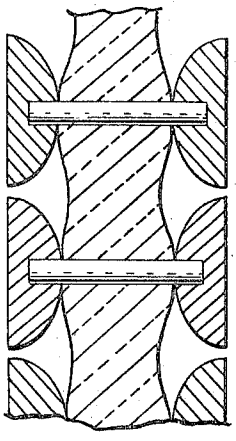
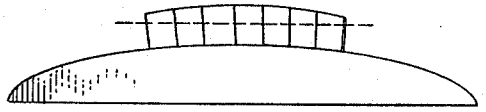


Fig. 7



INVENTOR:
Norman F. Fyler

By Alfred B. Levine
Attorney

United States Patent Office 3,305,334 Patented Feb. 21, 1967

3,305,334

METHOD OF MAKING A GLASS SHEET HAVING A PLURALITY OF SPACED WIRES THEREIN

Norman F. Fyler, Menlo Park, Calif., assignor to Litton Precision Products, Inc., a corporation of Delaware

Original application Mar. 22, 1960, Ser. No. 16,734, now Patent No. 3,193,907. Divided and this application Oct. 6, 1964, Ser. No. 401,866

3 Claims. (Cl. 65—42)

This application is a division of application Serial Number 16,734, filed March 22, 1960 and now U.S. Patent No. 3,193,907.

The present invention relates to a high speed cathode-ray direct writing tube and more particularly to an improved method of making the face plate structures for a high speed cathode ray direct writing tube.

In modern high speed electronic computer applications as well as in modern communication systems, there is a constant need for high speed visual intelligible display of coded information. In the prior art, many mechanical and electromechanical printing devices have been utilized for this purpose. However, all of these devices have substantial inherent inertia which severely limits the speed of operation of the devices.

In order to avoid the foregoing described speed limitations inherent in the mechanical and electromechanical types of printing devices, the prior art has developed a cathode ray xerographic printing system which converts coded electron beam or cathode ray information into visual images by means of a phosphor screen positioned on the face of the cathode ray tube. The visual image produced by the phosphor is, in turn, converted to a charge pattern which is transferred to a dielectric recording material. The recording material is then dusted with a pigmented powder which adheres to the charged areas on the recording medium. Hence, the visual image presented on the face of the cathode ray tube is printed on the recording material. While this type of printing device possesses a substantially faster printing rate than the mechanical and electromechanical devices heretofore mentioned, the device is not capable of obtaining the speeds desired in many applications since the electron beam information must be converted first to a visual image, then reconverted again to a voltage pattern, and finally to a charge pattern on the recording material, each of these conversions, of course, decreasing efficiency and requiring a finite period of time. Further, as would be expected, this form of device requires a substantial number of components and thus is cumbersome and expensive to manufacture.

In order to provide a printing system having a printing rate in excess of that which can be achieved by xerographic methods, the prior art has also attempted to develop a specialized type of cathode ray tube including a face plate having a plurality of conducting wires embedded therein traversing the face of the tube, the conductive wires being insulated from one another and having their ends flush with the sides of the face plate. In theory at least the face plate permits the coded electron beam to be converted directly to a charge pattern which can be deposited on a recorded medium, a backing plate maintained at ground potential being positioned contiguous with the remote side of the record medium and adjacent the face plate of the tube for maintaining a uniform potential behind the record medium so that the charge deposited thereon in response to each charged conductor corresponds to the magnitude of the charge on each conductor.

While a prototype cathode ray tube printing system of the foregoing type has been built which can achieve speeds which approach the speeds desired in present day computation and communication equipment, it still does not completely fulfill the desired speed requirements. Further, the system has proved to be extremely difficult to mechanize. For example, the individual wire conductors traversing the face plate must be uniformly spaced and must be sealed to the insulating material vacuum tight, while the face plate itself must be affixed to the remainder of the tube envelope with a vacuum tight seal. In addition, for the system to print properly a dielectric material such as paper must pass adjacent the face plate in such a manner that it is always in contact with the exterior ends of all the wire conductors which are flush with the mosaic surface. However, because of the impossibility of producing an absolute planar exterior mosaic face many of the exterior ends of the wire conductors are not in contact with the dielectric material as it passes over the wires. As a result a clear image is not printed inasmuch as the electrostatic field established at the ends of the wire conductors attenuates rapidly even at rather small distances from the ends of the wires. Therefore, a distorted charge pattern is produced on those portions of the recording material not in contact with the ends of the charged wires, and the printing quality is inferior. In addition, the electron beam bombardment of the wire conductors tends to cause secondary emission of electrons within the tube which rain upon other wire conductors which have not been bombarded by the electron beam. Therefore, these wires also have a charge placed thereon which further reduces the clarity of the printed image.

It should also be noted that since the wire conductors must be placed a relatively substantial distance apart in order that the insulating material therebetween be of sufficient strength to resist the pressures exerted thereon as a result of the tube vacuum without cracking or developing leaks, a substantial portion of the electron beam will fall or impinge upon the insulating material rather than on the ends of the wire conductors. It is clear that the impinging of substantial portions of the electron beam on the insulating material rather than on the ends of the wire conductors extends the time necessary to build up a sufficient charge on the wire conductors to adequately charge the record material. Therefore, the overall speed of the cathode-ray writing tube is substantially limited.

However, the most important limitation of the cathode ray writing tube of the prior art is that it is impossible to do half tone writing with the tube. In other words, only high contrast marks can be printed on the record medium. While this limitation may be of little importance in applications where it is desired to print only alphabetic or numeric characters, it renders the system incapable of reproducing or printing high quality pictures or photographs. Thus, the prior at cathode ray writing tube cannot be used in applications requiring such uses.

As is apparent from the foregoing discussion, while the prior art cathode ray writing tubes can print at a faster rate than mechanical printers, they still suffer from numerous limitations which seriously limit their usefulness. For example, they are extremely difficult and expensive to mechanize. Further, despite the fact that the printing speed of the cathode ray writing tube is substantially improved, it is still substantially less than that required in a good number of present day applications. In addition, cathode ray writing tubes of the prior art cannot be used in applications requiring the printing of half tones or, in other words, where complete gray tone printing is required.

The abovementioned application, Serial Number 16,734, overcomes the foregoing enumerated and other limitations of the prior art devices by providing a mosaic face plate of novel design for use in mechanizing an improved high speed writing system capable of half tone printing as well

as full contrast printing. The present invention further provides a method of constructing a mosaic face plate which can be easily fabricated, the face plate having sufficient strength to withstand the pressures exerted thereon by the pressure differentials between the extrior and the interior surfaces of the tube. In addition, in accordance with the present invention the conductive wires are affixed to the tube envelope with a highly reliable vacuum seal.

In accordance with the method of the invention, the mosaic target structure may be fabricated by placing a plurality of fine wires on a sheet of vitreous insulating material, applying tension to the wires, heating the vitreous material, and embedding the wires in the vitreous sheet. In accordance with another step of the present invention, the thin sheets of vitreous material are stacked one upon the other and are fused into a solid mass by application of heat and pressure to create a matrix array. Thereafter the fine wires may be made to project out from the surface of the insulating material by the additional step of etching the insulator back from the ends of the fine wires and flaring the projecting ends through a plating process whereby the ends of the wires are built up in size by metal deposits.

It is therefore an object of the present invention to provide a mosaic face plate for use with a direct writing cathode ray tube which permits full gray scale printing.

It is another object of the present invention to provide a mosaic face plate having a plurality of fine conductive wires embedded in and traversing an insulating body, the wires being affixed to the insulating body in a vacuum tight manner.

It is still another object of the present invention to provide a method of fabricating the mosaic face plate of the present invention.

The novel features which are believed to be characteristic of the invention, both as to its organization and methods of operation and fabrication, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and are not intended as a definition of the limits invention.

FIGURE 1 is an isometric view, partly in section, of a high speed cathode ray direct writing tube in accordance with the invention;

FIGURE 2 is a side elevational view of the mosaic face plate of the tube shown in FIGURE 1;

FIGURE 3 is a three-dimensional view of a fretted drum illustrating one of the steps in the method of fabricating a mosaic face plate in accordance with the present invention;

FIGURE 4 is a side elevational view of a stack of insulating sheets used in fabricating a mosaic face plate of the invention;

FIGURE 5 is an isometric view of a jig used in one method of fabricating the mosaic face plate;

FIGURE 6 is an isometric view of a mosaic face plate of the present invention illustrating the mosaic face plate after it has been molded but prior to finishing;

FIGURE 7 is a side view depicting one manner in which the face plate may be curved prior to incorporation of the tube; and

FIGURE 8 is a side view of a portion of an alternative form which the mosaic face plate may take.

Referring now to the drawings wherein like or corresponding parts are designated by the same reference character throughout the several views, there is shown in FIGURE 1 a high speed direct printing cathode ray tube **11** which is operable in response to a code modulated signal generated by a modulated signal source **12** to produce visually the coded information by printing on an insulating material **13**, such as paper.

As shown in FIGURE 1, tube **11** includes an envelope **14** which encloses an electron beam generator comprising a cathode **15** and a control grid **17** for producing an electron beam **19**, and, in addition, two pairs of deflection plates operable for deflecting the electron beam to impinge at predetermined points upon a mosaic face plate **21** affixed to the front portion of tube envelope **14**. As further shown in FIGURE 1, the code modulated signal from modulated signal source **12** is applied to grid **17** for selectively generating electron beam **19** having an intensity corresponding to the modulated signal. The deflection plates are, of course, energizable from a source, not shown, to deflect the electron beam to scan the complete surface of mosaic **21** whereby the electron beam selectively bombards the surface of the mosaic in accordance with the modulated signal.

As indicated in FIGURE 1, mosaic target **21** includes an insulator having a plurality of fine conductive wires **25** embedded therein and traversing the face plate. When the ends of conductors **25** inside the envelope, hereinafter referred to as the interior ends, are bombarded by electron beam **19**, an electrostatic charge is developed on the interior ends and this charge is transported to the exterior ends of the conductors. As shown in FIGURE 1, dielectric paper **13** is moved at a constant rate past the exterior ends of conductors **25**, and is backed by a conductive backing plate **27** which is positioned contiguous with the remote side of paper **13** and adjacent face plate **21**. As will be apparent to one skilled in the art, the charged exterior ends of conductors **25** generate an electrostatic field which induces a charge on those portions of paper **13** which pass adjacent the charged conductors. Hence, the charge pattern produced on the face plate conductors is transferred to paper **13**.

It will be recognized that the charged pattern induced on the surface of paper **13** can be developed or processed to produce a visual image in a number of ways. For example, a pigmented powder or dust can be automatically or manually sprinkled over the surface of paper **13** whereby the pigmented particles will adhere to the charged areas. To further insure that the particles adhering to the charged areas on paper **13** remain affixed to the paper, the paper can be heated and a thin molten layer of wax can be applied to the paper surface. Upon cooling and hardening the wax will thus mechanically affix the pigmented particles to the paper and a permanent printed image will be produced on paper **13** corresponding to the code modulated signal.

Referring now more particularly to mosaic face plate **21**, attention is directed to FIGURE 2 wherein there is shown a side elevational view of the mosaic structure and backing plate **27**. As indicated in FIGURE 2, the exterior surface of face plate **21** is substantially planar while the interior surface of the face plate is curved, the interior side of the face plate being curved, of course, so that it can better resist the pressures exerted on the face plate due to the lack of internal air pressure resulting from the tube vacuum. As is shown in FIGURE 2, the ends of conductors **25** on both the interior and exterior sides of the face plate project out from the surfaces of the face plate a predetermined distance. Further, as shown in FIGURE 2, the interstitial spacing of the conductors is substantially greater than the wire diameters in order that there be sufficient insulating material between the embedded conductors so that the insulating material can resist the pressure differentials exerted thereon without developing vacuum leaks.

Each of the projecting interior ends of the conductors is outwardly flared so that the perimeters of the interior ends of each of the conductors almost touches the perimeters of the ends of the adjacent conductors in order to prevent the electron beam from impinging on the space

that would exist between the interior projecting ends of the conductors were they to have the mean or average cross-sectional area of the conductors. Hence, the interior surface of the face plate is shielded from bombardment by the electron beam and concomitantly substantially all the electron beam impinges upon the selected wire conductors thereby decreasing the time necessary for the conductors to develop charges of sufficient magnitude to print on paper **13**. Accordingly, the speed of operation of the printing system is substantially greater than that of prior art devices.

Directing attention now to the physical properties of the insulating material which generally comprises the body of the face plate, the insulating material should have a low dielectric constant and minimum hysteresis effects. Furthermore, the dielectric material should be complementary in its physical characteristics with those of the metal conductors especially with respect to the coefficient of thermal expansion, which should be substantially the same. In addition, the insulating material should be so chosen that a true molecular seal can be achieved between metallic conductors **25** and the insulating material.

Among the materials suitable for use as the insulating material are ceramic or glazed materials. For example, a lead-potash glass, No. 8871, manufactured by the Corning Glass Company, has been used on a number of occasions as the insulating material of the face plate with satisfactory results.

Continuing with the description of FIGURE 1, the operation of backing plate **27** in conjunction with face plate **21** to enhance full gray scale printing will now be discussed. As has been hereinbefore mentioned, the interstitial spacing between the conductors is a number of times greater than the size of the conductors. Hence, the resultant charge pattern produced by an individual wire conductor can be made to vary in size from a condition where the pattern is somewhat smaller than the wire itself to where the image is substantially larger than the interstitial spacing between the wires. Of course, the size of the image corresponds to the charge positioned on the exterior end of each individual conductor so that the greater the range of variation of charge magnitude that can be obtained on the exterior ends of the wires, the greater will be the range variation in the size of the individual image pattern produced on paper **13**.

In prior art printing tubes the structure equivalent to backing plate **27** has been maintained at a fixed potential, such as ground potential. However, with a fixed potential on backing plate **27** it has been found that it is impossible to achieve the full range of variation of charge magnitude on the exterior ends of the conductors necessary to obtain the full range of image sizes needed for full gray scale printing. For example, if the potential on the backing plate is determined in such a manner that the system is capable of printing images somewhat smaller than the wire conductors, it has been found that the potential will not be of sufficient magnitude to insure that the charge deposited on the interior ends of the conductors by a high intensity electron beam will be transported to the exterior ends of the conductors with sufficient speed to print the enlarged size image corresponding to high intensity electron beam. Moreover, it has been found that excessive secondary emission is experienced when charge is not transported from the interior ends of the conductor to the exterior ends with promptness. Hence, the clarity of the printing is impaired.

As shown in FIGURE 1, the modulated signal which controls the intensity of the electron beam is applied to the backing plate through a noninverting amplifier **31**. Therefore, when a small intensity electron beam is generated and it is desired to produce an image somewhat smaller than the diameter of the conductive wire, the voltage applied to backing plate **27** is reduced. However, when a large intensity electron beam is generated and it is desired to produce an image pattern substantially larger than the spacing between conductors the voltage applied to backing plate **27** is substantial so that the prompt transportation of the charge from the interior ends of the conductors to the exterior ends is insured. Hence, the full range of tones from slight gray to high contrast black can be printed with a system mechanized in accordance with the teachings of the present invention. Further, since the movement of charge along the conductors is faster than in prior art devices, the printing speed of the system is substantially increased.

In view of the foregoing, it is clear that the unique geometry of the conductors and the face plate not only permits full tone printing but decreases the time necessary to build up a sufficient charge on the exterior ends of the conductors to print an image on paper **13** whereby the overall printing speed of the present invention is substantially greater than that of prior art devices. Further, in conjunction with the foregoing features the application of a modulated voltage to backing plate **27** further increases the clarity of the printed image as well as inceasing the printing speed and the overall tonal range capability of the system.

Referring now to the method of the present invention for fabricating face plate **21** of the invention, a number of thin sheets of vitreous insulating material are thoroughly cleaned to remove therefrom foreign materials such as grease, adherent oxides, and dusty chemical residues. Furthermore, a roll of fine conductive wire is also thoroughly cleaned to remove all foreign matter therefrom. The exact manner of cleaning will vary somewhat depending upon the nature of the contaminants and the basic atmosphere to which the raw materials have been exposed. Electropolishing has been found to be a satisfactory method of cleaning the wire if, preparatory to the electropolishing, standard degreasing procedures are used. In the case of the vitreous sheets, if glass, for example, is used, a simple fluid bath is usually satisfactory.

It should be noted that both the vitreous sheets and the wire are cleaned because foreign materials tend to prevent the proper oxide conditions from being achieved as well as preventing the proper intimate contact between the sheet and the conductors. Thus, if the materials are not cleaned, the metallic oxides in the vitreous sheet would be reduced and voids or bubbles would be formed in the mosaic structure.

As indicated in FIGURE 3, the cleaned fine wire is wrapped in a helix around a fretted drum **50** and then cut. Next, as shown in FIGURE 3, one sheet of vitreous material is positioned on top of the wire between each pair of frets on drum **50**. Then the remaining wire is wrapped in a helix around the fretted drum on top of the sheets of vitreous material whereby the sheets are affixed to the drum.

In the foregoing described manner a "sandwich" consisting of two layers of wire imprisoning individual insulating sheets is formed between each of the frets on the drum. It should be noted that the drum should be constructed of a material having a higher coefficient of expansion than the wire and the insulating material comprising the sheets. More particularly, the diameter of the drum and the coefficient of expansion thereof should be so selected that when the drum, wire, and vitreous sheets are heated, the wire is stretched almost to the yield point so that during the critical interval wherein the wire and the vitreous material of the sheets are intersealed, the individual wires are taut and in a true cylindrical condition.

In accordance with the next step in fabricating the mosaic, the drum with the sandwiches thereon is placed in an air atmosphere oven, heated to a predetermined temperature range which is sufficient for fusing the metal and the vitreous insulating material. After fusion, or in other words, after the metal-to-vitreous sealing, the drum is allowed to cool gradually to room temperature and the metal and vitreous material sandwiches are

stripped from the drum. Next, the individual sandwiches are separated by cutting the wires interconnecting them, and they are stacked alternately with sheets of vitreous material not having wires embedded therein, as shown in FIGURE 4.

The stack of vitreous sheets shown in FIGURE 4 is next invested or wrapped in thin aluminum foil. As shown in FIGURE 5, the invested package is placed in a forming jig **35** which includes a hinged weighted top **37** which tends to compress the package in the direction indicated in FIGURE 5 and a pair of restraining bars **39** and **41** which tend to apply a limited amount of restraint to the sides of the package adjacent the bars.

Continuing with the discussion of the invention, jig **35** is placed in an air atmosphere oven which is gradually heated until the vitreous material becomes soft whereby the package is compacted. In this regard, jig **35** is operable to apply pressure to two surfaces of the invested package and restraint to two other surfaces whereby a compact resultant of uniformly distributed wire in a homogeneous base of insulating material is obtained. It should be noted that if too much restraint is exerted on the package, a nonuniform distribution of wire will result. Further, if inadequate pressure is applied, air trapped between the vitreous sheets will not bleed out of the structure and voids in the insulating structure will occur which will ultimately lead to vacuum leaks. In addition, it should be pointed out that an excess of pressure or an excess of restraint or no restraint and no pressure will produce a poor geometric configuration. After the package has been compacted it is allowed to gradually cool to room temperature and, as indicated in FIGURE 6, the package is sliced to produce a rectangular portion having a predetermined width.

Continuing with the description of the process of the invention, it should be noted that while the subsequent steps in fabricating the face plate can be performed in any order, the order herein now described has been found to produce quite satisfactory results. In accordance with this order, one of the sides of the sliced portion having wire embedded therein is etched with an etching solution so that the vitreous material is removed away from the ends of the wire conductors embedded therein whereby the ends project out from the insulating material. The etched face should then be rinsed thoroughly with a pacifying solution to arrest the corrosive action of the etching solution.

The mosaic thus produced is then curved by heating and placing the mosaic on a cylindrical mold as shown in FIGURE 7. After the cylindrical shape has been achieved, the outer or exterior surface is then made planar by cutting the spherical surface away, as indicated by the dash line in FIGURE 7. The planar surface of the mosaic is then etched away in the same manner heretofore described so that the ends of the conductors associated therewith project out from the exterior mosaic surface.

In order to achieve the outward flare on the interior ends of the conductors, the projecting ends of the conductors associated with the curved surface of the mosaic are placed in a plating solution and built up in size by plating. After the plating operation has continued for a period of time sufficient to increase the projecting ends of the wire sufficiently in size, they are milled so that the ends have the general configuration shown in FIGURE 2.

The completed mosaic face plate is then sealed to the rest of the tube envelope by use of a vitreous material having a melting point lower than that of the face plate. In this regard it should be noted that it is preferable to place a supplemental layer of the low melting point vitreous material on the inner and outer surfaces of the mosaic face plate before sealing it to the tube envelope to insure the vacuum tightness of the fit.

It is to be understood that the above described arrangements are only illustrative of the application of the present invention. Numerous other applications may be devised by those skilled in the art without departing from the spirit and scope of the invention. Accordingly, it is understood that the present invention is limited only by the spirit and scope of the appended claims.

What is claimed as new is:

1. The method of forming a sheet of glass having a plurality of spaced wires therein, comprising the steps of: winding a first plurality of spaced turns of wire having a first coefficient of expansion about a support having at least one flat supporting surface portion and a second coefficient of expansion greater than the said first coefficient of expansion to form a first traverse row of wires, placing a first sheet of glass on the flat surface portion abutting said first traverse row of wires, winding a second plurality of spaced turns of said wire about the support containing said supported glass sheet to form a second traverse row of wires abutting the outside of said glass sheet, applying heat to said support, glass sheet and wires in common for embedding the wire on each side of said sheet of glass while additionally enhancing the tension holding the rows of wire properly spaced and taut by the greater expansion of the support relative to the expansion of the wire, severing the ends of the rows of wire at the ends of the glass sheet to allow removal of the first glass sheet, removing the glass sheet with embedded wires from the said support, and removing the excess wire from about the support.

2. The method as defined by claim **1** including the additional steps of winding a third plurality of spaced turns of wire having a first coefficient of expansion about a support having at least one flat supporting surface portion and a second coefficient of expansion greater than the said first coefficient of expansion to form a third traverse row of wires, placing a second sheet of glass on the said flat surface portion abutting said third traverse row of wires, winding a fourth plurality of spaced turns of said wire about the support containing said supported glass sheet to form a fourth traverse row of wires abutting the outside of said glass sheet, applying heat to said support, glass sheet and wires in common for embedding the wire on each side of said sheet of glass while additionally enhancing the tension holding the rows of wire spaced and parallel and taut by the greater expansion of the support relative to the expansion of the wire, severing the ends of the rows of wire at the ends of first glass sheet, removing the glass sheet with embedded wires from the support and removing the excess wire from about the support, and sandwiching a third sheet of glass between the first and second sheets of glass.

3. The method as described in claim **2** including the additional steps of forcing the first and second and third glass sheets together, restraining the expansive movement of the sides of the glass sheets while simultaneously applying heat to the sheets to fuse the three sheets of glass together into one mass and bleed air out of the sheets and spaces therebetween.

References Cited by the Examiner

UNITED STATES PATENTS

936,663	10/1909	Quertinmont	65—147 X
2,526,704	10/1950	Bair	65—59 X
2,825,184	3/1958	Charlotte	29—25.17

OTHER REFERENCES

A.P.C. of Serial No. 125,892, Wempe, April 1943, U.S. application published under Alien Property Custodian Act.

DONALL H. SYLVESTER, *Primary Examiner.*

G. R. MYERS, *Assistant Examiner.*