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SHUMAN'S PROCESS AND APPARATUS FOR EMBEDDING WIRE NETTING IN GLASS.

[*Being the report of the Institute by its Committee on Science and the Arts,
adopted November 1, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, November 1, 1893.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, by its Committee on Science and the Arts, investigating Shuman's process and apparatus for embedding wire netting in glass, finds as follows :

The object of this invention is to strengthen, or reinforce, sheets of glass of various dimensions intended to be used for roof lights, partitions, vault and pavement lights, port and deck lights, etc., by inserting a metallic netting into the body of the glass sheets at the time they are rolled

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with the view of protecting the glass against fracture and of preventing fragments of fractured sheets from detaching themselves in case of accident.

The present mode of protecting glass skylights is to suspend copper wire netting immediately beneath the glass, the wire being fastened to a framework holding the glass. In situations exposed to smoke, corroding gases and other destructive influences, as in railway stations, chemical works, etc., this practice is attended with serious objections, for the reason that, in such situations, even copper and brass wire will become corroded and will then be worthless as a protection against the fall of large fragments of glass, should the skylights become broken.

The enormous extent to which wire netting is used thus to protect skylights was strikingly illustrated at the late World's Columbian Exhibition in Chicago, where 1,045,000 square feet of wire netting was placed under the glass roofs of four of the main exhibition buildings.

The use of wire netting in such a manner that it cannot be corroded and, at the same time, will reinforce and strengthen the glass (which, in the old practice, the netting does not do), would obviously be a great step in advance and one which should commend itself to architects and engineers, and the advantages of embedding the wire in the glass itself to accomplish these objects are so manifest that further comment would seem unnecessary.

In examining the prior state of the art of producing sheets of glass with metallic enclosures for the purpose of strengthening and guarding the same, the following references, bearing more or less directly on the subject, have been found and consulted.

The first invention, showing wire netting embedded in glass, is the British patent, No. 1,528, of 1855, granted to Newton for fire- and burglar-proof glass. This patent describes the depositing of a quantity of molten glass into a mould, then placing on the glass a sheet of wire gauze, then placing upon the wire another quantity of molten glass, and finally pressing the mass into a sheet. The wire is prevented from projecting beyond the glass by constructing the mould in

two parts and mounting the wire between the parts; it is claimed that several sheets of wire cloth can be thus introduced into the glass.

The British patent of Hyatt, No. 1,482, of 1871, describes a method of making glass with wire embedded in it, by casting the glass on both sides of the wire work. Hyatt proposes to bend or undulate the wire by coiling it in the form of a helix, so as to allow for expansion and contraction to avoid fracture.

The British patent granted to Lake as a communication from Becoulet and Bellet, of Paris, France, No. 9,226, of 1876, describes the following method:

"A layer of fused glass of one-half the thickness required is spread upon a table, a net work of iron wire, previously polished, is placed upon the glass, another layer of glass is placed on the wire, over which a roll is passed."

The British patent granted to John Armstrong, No. 5,701, of 1887, describes a machine for embedding wire in glass. "The ordinary table and roll is used, and in front of the roll is a guide roller, under which the wire is passed from a reel. The wire is fixed at one end of the table and brought under both rolls; the wire is pressed against the incandescent glass and partly enters it, the hot glass coming through the meshes to the upper side. The roll passes over the glass and wire, squeezing the glass out to the required thickness.

The following United States patents, Nos. 229,907, 229,928 and 222,768, of 1879, granted to Arbogast, for glass insulated electric conductors and methods of making the same, and No. 355,486, of 1887, to Thompson, for wire-embedded enamelled ware, need no special mention.

German patent No. 46,287, of 1888, to Armin Tenner, and published March 18, 1889, is next in order. This patent discloses a process similar in many respects to the early British patent of 1855.

The process is as follows: "A mass of molten glass sufficient for making one-half the thickness of the plate desired is poured into a suitable mould and then rolled or pressed; then the metal inlay is introduced, consisting preferably of wire gauze; then sufficient glass is poured on to make the

desired thickness and the whole rolled or pressed and finally tempered."

The German patent of Sievert, No. 60,560, of 1891 (published February 5, 1892), follows Tenner, but describes a different method, to-wit :

"A platen is used of the shape corresponding to the size of the sheet to be made. The bottom of this platen is provided with a pattern. A pattern can be formed in strips, corrugations, facets and eyes of all kinds, so that the upper edge of this pattern forms the bed for the metal inlay to be enclosed in the glass. The metal inlay is distributed on the upper edge of the pattern, and then by pouring in the liquid glass, and, if necessary, afterwards rolling, pressing and cooling off, the glass plate is produced ; then on the pouring in and penetrating of the liquid glass into the depressed pattern of the mould the metal inlay will be raised, as experiments have shown, so as to be within the mass of glass."

British patent, No. 11,039, was granted to Sievert in 1891 (published April 30, 1892), for the same process described in the German patent of 1891, with additional matter, as follows, as a modification, viz :

"A mould with a smooth bottom may be employed and the design or pattern may be formed on the lower surface of the presser or plunger which is adapted to enter the mould and press down the molten glass. In this case the wire gauze is fixed by means of pieces of string or other suitable material underneath the lower surface of the plunger, so that the gauze rests against the edges of the design and is pressed into the mould, the pieces of string immediately breaking or being burnt by the heat of the molten glass. The glass enters into the cavities of the design or pattern and acts to press the metal inclosure so far down that the latter is actually inclosed in or surrounded by the glass."

It is also stated in the specification that the glass may be pressed down by pressure or rolling so as to receive an even surface.

The Shuman patents, Nos. 483,020 and 483,021, of Sep-

PLATE 4.—Rolling the sheet; pouring the ladle of glass on table. (American Wire Glass Manufacturing Company, Tacony, Phila.)

PLATE 5.—Carrying off the rolled sheet from the table. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

tember 20, 1892, are next in order, and, as far as can be found, are the only patents granted in the United States for embedding wire netting in glass.

From the preceding sketch, it is made evident, that the idea of inserting a wire netting into sheets of glass while the glass is in a plastic condition, is by no means a new one, although its development on the commercial scale, until very recently, has not been successful.

The first attempts to put the idea into practice appear to have been made in England, some twenty years ago, by Thaddeus Hyatt, whose British patent, No. 1,482, of 1871, is referred to above, and concerning which we give the following additional details :

A section of wire netting is securely clamped in a frame of cast iron of a thickness equal to that of the glass sheet to be made. This frame is then laid upon a flat table, and sufficient glass to form a sheet poured into it. By means of a hydraulic press, part of the glass is forced through the meshes with the view of getting the glass on both sides of the netting; or, in other words, placing the netting as near as possible in the centre of the glass sheet. While this seems very simple in theory, Hyatt appears to have encountered great difficulty in forcing the glass through the meshes when a fine netting was used. To obviate this difficulty, a square or round hole was made in the centre of the section of wire netting in order to facilitate the flow of glass underneath.

The netting was thus necessarily subjected to a severe strain in forcing the glass through the meshes, and, since the metal becomes red hot by its contact with the molten glass, it will evidently stretch and sag when pressure is applied to it, thus making it impossible to keep the netting even approximately in the centre of the glass sheet. Another objection to this method is that the dimensions of the glass sheet are limited to the size of the face of the plunger of the hydraulic press. Hyatt's process was apparently found to be impracticable, and, so far as can be determined, his product never became a commercial commodity.

The patent of Armstrong (British patent, No. 5,701, of 1887) appears to come nearer to the practical solution of the problem than any which preceded those of Shuman.

In Armstrong's case a clever attempt is made to realize practically the plan of pressing a wire netting, by means of a heavy roller, into the body of a sheet of glass, and then covering the wire up in the glass by the pressure of a second roller following the first one. The mechanism by which it was attempted to carry out this idea, though embodying the elements of a useful invention, was seriously defective, and the inventor does not appear to have made any effort to improve it.

Concerning the subsequent inventions of Tenner and Sievert, it may best serve the purpose of setting forth the marked differences between them and the Shuman process, to give, in as much detail as possible, an account of the methods of procedure described therein.

In Tenner's German patent (No. 46,287, of 1888), a sheet of glass, one-half the thickness of the sheet desired, is first rolled out with a smooth roll on a flat table, in the ordinary way; then a sheet of wire netting, which has previously been made red hot, is laid upon it; another sheet of glass, one-half the thickness of the plate desired, is then rolled or pressed over the wire netting, and the whole is then subjected to hydraulic pressure, and finally annealed in the usual manner.

With this method, it is said, great difficulty has been experienced in making sheets of any considerable size; that is, of more than two feet square. It is also stated to be expensive to operate.

In Sievert's German patent (No. 60,560, of 1892), the mould in which the glass sheet is to be cast is provided with corrugations, or ridges, the upper edges of which serve as points of support to metallic bodies to be enclosed. After placing the metallic objects in position the melted glass is poured into the mould, whereupon the entering glass lifts the metallic object sufficiently, so that after the sheet is finished the metallic body will be incorporated approximately in the body of the glass sheet. This method, there-

fore, is in some sense an improvement on the method of Tenner, since it is unnecessary to produce two layers of glass, and to unite the one with the other.

In Tenner's process, the manner of incorporating the metallic netting, etc., by laying the metal upon one sheet of glass, then rolling or pressing a second sheet upon it, is liable to cause severe strains in the finished glass, and for this reason the statement that the plan is limited to the production of sheets of small size, would appear to be well founded.

Hyatt and Sievert, it will be recalled, cast the glass in a mould and incorporated the metal with the glass in one operation, and, in this respect, they represent an improvement on the process of Tenner. It is apparent, nevertheless, that in all the processes antedating Shuman's, excepting that described by Armstrong, the size of sheets produced must be limited by the difficulty of making moulds of large size.

According to a publication which appeared in the *Paris Revue Industrielle* (April 8, 1893), under the title "*Les Vitres Armées*" (Guarded Glass), the idea of embodying a metallic trellis work (*treillage métallique*), or wire netting, with the glass, is of French origin. We quote as follows:

"An application for a patent was made ten years ago by a large mirror manufacturer in the Rue de Deux-Ecus in Paris, and experiments were successfully made in the glass works of Messrs. Appert Brothers, of Clinchy, and also in the foundries of Jeumont. The results thus obtained proved that the idea, however simple and practical it might appear, was devoid of practical results; the metallic netting suddenly assuming such a high temperature bends and twists and is with great difficulty kept in the mass of glass."

The article alleges, further, that the amount of labor required to manufacture this glass renders it so very expensive that it cannot compete with the modern process of making ordinary roofing glass. Another objection alleged in the article, is that it is absolutely necessary to know beforehand the dimensions of the required sheets, for when once made it becomes almost impossible to cut them.

Neither the French patent above referred to, nor any other reference to it, could be found, and consequently no idea of the method employed can be formed. Numerous attempts have been made in this country to incorporate a wire netting in molten or plastic glass, but here also no record exists, or could be found, of any such attempts that had met with success prior to those of Shuman.

By the Shuman process the wire netting is inserted into the glass whilst a sheet is being rolled, the wire being heated, just before its incorporation, to a temperature near the melting point of glass. The wire netting thus incorporated with the glass forms part of the sheet itself and it cannot by any means short of violence be detached or removed therefrom. Of course, such a sheet may become cracked and portions detached from and expose the wire; but even in such case, there are so many points of attachment that it would hardly be probable that sufficient corrosion could take place to seriously weaken the wire and damage the sheet, no matter how many fine cracks it might contain through which the corrosive influences could work their way to attack the metal.

The inventions of Shuman form the subject of two letters-patent of the United States, herein referred to, one covering the details of the machine, and the other the features of the process. In the following description, reference will be made to both of these specifications without special distinction, as it will be convenient to regard them for the purpose of this investigation as a single invention.

The following description of the method of manufacture, freely collated from the Shuman patents, will be understood by reference to the accompanying sheet of sectional views (*Plate 1*) of a thirty-inch glass-rolling machine, showing the same in plan, longitudinal and transverse sections, and by an inspection of the several reproductions made from photographs taken in the works of the American Wire Glass Manufacturing Company, at Tacony, Philadelphia. (See *Plates 2 to 9*.)

The sheet of drawings (*Plate 1*) represents the table upon which the glass is rolled, and which is arranged so

PLATE 6.—Pushing the rolled sheet from tray into the annealing oven. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

PLATE 7.—View of interior of works, showing portions of annealing ovens, glass furnaces, rolling platforms, etc. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

-AMERICAN WIRE

GLASS MFG CO

Plate I. — 30" Glass Rolling Machine.

Tacony, Illa. Dec 4, 1893.

Roller Through Rod
Weld from rollers and one the size.

that it may be heated from below by large gas jets, prior to beginning work. The table is made preferably of cast iron, and is provided on each side with ribs of sufficient height to allow for the rolling of the glass, and on the outer edges are rails upon which the rolls travel. On each side are rails, supporting the carriage before and after its travel. These rails are mounted in any suitable manner and are in line with the rails of the table.

The carriage is provided with four rolls, a front smoothing roll, a ribbed roll and two following smoothing rolls. It is moved across the table by power transmitted by means of a sprocket wheel and link belt. The front roll is intended to smooth out the molten glass after it is poured out upon the table and prepares it for the reception of the wire netting.

An inclined chute, for feeding the wire netting to the glass as this is spread by the front roll, is shown in connection with the carriage, arranged at the proper angle, and has a trigger, or other stop, at its lower end to detain the sheet of wire netting placed thereon until the proper time to discharge it upon the glass. The sheet of wire netting is preferably heated to the proper degree, so that it will not chill the glass when it is placed thereon. Directly back of the chute is a roll independently mounted in the carriage and having on its periphery a series of annular ribs (see plan) so arranged in reference to the table, as to press the wire netting into the molten glass. The ribs may be so arranged that although all the wire is incorporated in the molten glass some portions thereof will be pressed more deeply than others, thus corrugating the wire within the glass, if this be desired.

A smoothing roll directly behind the ribbed roll then passes over the glass and closes up the openings made by the ribbed roll and wire, completing the rolling of the glass. A second smoothing roll is preferably employed, as shown in the drawings, in order to correct the tendency of the rolled sheet, while still in the plastic state, to curl up over the first rear smoothing roll.

The finished glass is then removed and placed in an annealing furnace (see *Plates 5 and 6*). After the glass has

been annealed any glass or wire projecting over the edges of the sheet is cut off, after which the glass is ready for the market. The wire is preferably cut to the proper size prior to its application to the glass. The three smoothing rolls support the carriage, the ribbed roll being so mounted therein that it is free to rise or fall independently of the carriage. Thus, by raising this roll when the carriage is returning it will be clear of the glass. In order properly to handle the glass, the smoothing rolls are made hollow, and the heads are perforated to admit a gas pipe with jets for heating the rolls before beginning work. The rolls when thus brought to the proper temperature will not chill the glass during the process of rolling.

In operating the process a sufficient quantity of glass is poured upon the table at a point immediately in front of the first roll (*Plate 4*). As the carriage is moved forward, the roll smooths out the molten glass to the proper thickness, after which the wire netting is delivered upon the molten glass and pressed into it by the following ribbed roll. The next following smoothing roll closes the openings and corrugations made by the netting and ribbed roll. By this means a sheet of glass is produced with strips of wire, or a sheet of wire netting embedded therein. By having at certain distances, a series of annular grooves upon the ribbed roll, it is possible to corrugate the wire within the sheet. The heated wire being pliable, it will yield only at the points where it receives pressure, and may, accordingly, be made to follow a waving, or any other desired, course in the sheet, as the outline of the periphery of the ribbed roll shall determine. Thus the wire is, so to speak, woven within the glass in such manner as to tie both wire and glass together.

The glass after it has been rolled is carefully annealed in a furnace of the usual construction (*Plate 6*). The wire embedded in the glass not only strengthens the sheet, but also prevents the particles of glass from breaking entirely away from the main sheet, while, on the other hand, the glass protects the wire against corrosion.

From the foregoing abstract, it will appear that the radically novel feature of Shuman's apparatus is the ribbed or

grooved roll, by which the wire netting is pressed to a predetermined depth into the glass whilst the sheet is being rolled, and, at the same time, is permanently fixed in position by the following smoothing rolls; and the scope of the process may be defined as rolling out a sheet of glass, pressing into it a metallic fabric, and finishing the sheet by pressure of a heavy roll or rolls, whereby the metallic fabric is permanently embedded therein; these steps constituting practically a single operation.

The pressure of the rolls in the later machines is about fifty pounds to the square inch; the distance from centre to centre of the ribs or grooves in the ribbed roll is one inch. It has been found that with grooves of this size, any wire mesh between one-fourth inch and three inches can readily be embedded. These sizes of mesh represent the extremes of the sizes employed. A smaller mesh would require a groove of different size.

The average temperature of the fused glass is about 3,000° F. It is stated that the glass may be rolled at about 2,200° F., although the higher temperature is evidently the better one.

The inventions of Mr. Shuman are in practical operation on an extensive scale at the works of the American Wire Glass Manufacturing Company, at Tacony, Philadelphia.

The works cover an area of one and one-half acres, and the plant at present consists of one main building, 300 x 100 feet, and two auxiliary buildings, each 20 x 150 feet. The glass melting plant is an eight-pot Siemens regenerative furnace of the latest design and capable of melting ten tons of glass per day. The fuel used is gaseous, furnished by three Wellman gas producers. There are twelve annealing ovens of the Belgian type for tempering the glass sheets immediately after the wire has been inserted, and to these the glass is carried in a tray. These annealing ovens are heated by the Aërated Fuel Company's system using crude petroleum.

The steam plant consists of one fifty horse-power Babcock and Willcox, and one fifty horse-power upright, boiler. All mixing and handling of glass is done by machinery.

There are three sizes of rolling machines at present installed; two, capable of rolling sheets up to 24 x 84 inches; two, capable of rolling up to 30 x 84, and one machine capable of producing sheets as large as 54 x 144 inches.

Machinery has been introduced for handling the product wherever it could advantageously be applied. Thus, all the waste material is removed by tramways, and all cars and wagons are loaded from overhead tracks. The waste ends and imperfect sheets are utilized by separating the glass from the wire by means of special bending rolls. The glass broken off is returned to the furnace and the wire, wherever practicable, utilized for other sheets. With the experience now gained in the operation of the plant, it is stated that the percentage of defective sheets made is so small that it does not enter as a factor in the cost of production.

The rapidity with which sheets are made varies with the thickness. With three-sixteenths inch, the time of rolling is eighteen seconds; with one-fourth inch, twenty-five seconds; with three-eighths inch and over, thirty-five seconds. The capacity of the plant is 5,000 square feet per day of all sizes, and it is stated that the demand for the product has been large enough to keep the works fully occupied.

With its present facilities, which, it has been stated, will be extended as the requirements of business demand, the company is now engaged in the manufacture of wired-glass sheets of any required dimensions up to 4 x 10 feet and from $\frac{3}{16}$ to 1 inch in thickness. It is manifest that there must be a limit beyond which it would not be prudent to increase the dimensions of sheets on account of their weight, and the risk of cracking in handling and transportation. The usual dimensions for skylight and roofing glass range from 10 x 20 to 30 x 84 inches. Sheets larger than 48 x 144 inches, therefore, will rarely be called for.

The objection that has been urged against the process because of the difficulty of cutting the sheets to desired dimensions is a real one, but to a great extent has been overcome. In the operation of cutting, the sheets are first scratched with the diamond, then broken across the cut,

PLATE 8.—View of interior of works, showing operations of cutting and trimming. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

PLATE 9.—Showing the appearance of a finished sheet of wired glass. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

when the ductility of the embedded wire readily permits, by bending slightly to and fro, a sufficient separation of the edges of the cut to allow a thin-bladed saw to be inserted, by which the wires are cut through with comparative ease. In nearly all cases, however, the demands of the trade are for standard sizes, which require no cutting beyond that necessary to trim the edges.

The rolling machines, it should be explained, are adjustable, in length, breadth and thickness, up to their maximum range, to correspond with the dimensions of the sheets to be produced. Thus, on the same machine, wired-glass sheets of any thickness, width and length, within certain limits, may be produced, by adjusting the strips on the table for the regulation of the width, and the collars on the grooved roll for thickness: the length is regulated by that of the sheet of wire to be embedded and the quantity of glass poured upon the table.

By this adjustability of the rolling machines, it will be seen that the necessity of having a separate machine for each size of plate to be made is done away with, and that the problem of rolling sheets of any desired dimensions is practically solved.

Another point of interest which is worthy of notice, in connection with the operative features of the Shuman process, is the preliminary preparation of the wire for the production of the higher grades of wired glass. This consists in first removing the oil or grease from the wire by treatment with a cheap solvent (such as benzine), then passing the wire under a swiftly revolving roll, provided with bristles, and finally beneath flannel buffing wheels, whereby the wire is thoroughly cleansed and polished. For the best grades of wired glass, a specially annealed steel wire is used, which, after the cleansing treatment, presents a white and brilliant surface.

The following claims of merit, made on behalf of the new product, appear to be substantiated, viz: When used for the skylights in railway sheds, the much greater strength of wired glass permits the use of thinner and larger sheets, thus reducing the weights in the roof. It is hail-proof, and

proof against vibration. The copper wire netting which is now required beneath such skylights to protect persons below from injury by the accidental falling out of glass, may be dispensed with, thus saving not only the cost of the guard, but also the cost of renewing such netting when weakened by corrosion. The increased strength of wired glass will enable it to support with safety great weights of snow, which occasionally prove destructive to skylights of the ordinary kind; and, even should it become cracked by reason of rough usage or by accident, the tension of the wires will hold the fractured portions together, and the efficiency of the sheet will not be notably impaired.

Worthy of mention also is the fact that the common skylight guarded with wire tacked on beneath is so difficult to clean that this important item is practically neglected, with the result that the glass in time becomes greatly obscured by accumulations of soot and dirt.

It is probable that there would be much less likelihood of the occurrence of fatal or minor accidents caused by persons falling through skylights of wired glass when it is properly set in its frame; also, stones and heavy articles falling on such glass will often be arrested; and, on account of the time and trouble entailed in cutting through it with the diamond and severing the wires, it would interpose a much more serious obstacle to thieves, than the plain, unguarded glass. These qualities commend the new product for use in show windows where articles of value are exposed. It is proposed for windows in warehouses and stables, machine shops, railroad shops, and it is also suggested as advantageous for partitions in buildings. For deck, port and cabin lights in vessels, the same reasons should ensure its serviceability.

Finally, it is suggested that in the form of large sheets of extra thickness, strengthened by one or more enclosures of wire netting, and properly supported in an iron frame, wired glass would afford an advantageous substitute for the round bull's eye and other small patterns at present largely used for pavement and vault lights. The wired glass could not only be made sufficiently strong for such service, but

would also admit much more light per square foot of area than the forms of lights in common use.

These claims appear to be well founded.

The members of the committee of investigation, having had the opportunity of examining this invention in the course of its practical development on the commercial scale at the Tacony Works, are fully satisfied that the mechanical elements of the problem have been admirably worked out; that the present mode of manufacture is simple, efficient and rapid; and that the quality of the product is good. In conclusion, they find that the process and machine of Mr. Shuman, not only represent a marked advance upon all previous efforts in the class of inventions to which they relate, but also that they meet for the first time in this branch of the arts, the requirements of a practically operative method and means of manufacture.

For the reasons herein stated, and because of the undoubted advantages of wired glass for those uses for which it is adapted, the Institute recommends the award to the inventor, Frank Shuman, of the John Scott Legacy Premium and Medal, for his machine and process for producing wired glass.

JOSEPH M. WILSON, *President.*

WM. H. WAHL, *Secretary.*

Approved, November 1, 1893.

H. R. HEYL,

Chairman of the Committee on Science and the Arts.