THE MANUFACTURE OF GLASS.*

SCIENTIFIC DEVELOPMENTS IN THE GLASS INDUSTRY.

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THE manufacture of glass involves first the chemical process of producing glass from the proper raw materials, and secondly the mechanical art of fashioning the molten glass into the multitude of articles for which the market calls. The mechanical aspect of the industry was early developed to a high state of perfection. It is only within comparatively recent times, on the other hand, that the chemistry of glass making has been worked out with scientific method. The need for such a development first made itself felt with special force in connection with the manufacture of optical instruments, and it is largely this circumstance which caused the famous Jena Glass Works to undertake the systematic study of the physical and chemical properties of glass.

The influence of the composition of glass on its properties is best brought out by a graphic representation. Thus in Fig. 1, distances measured off to the right, along the axis of the abscissæ, represent the composition of a soda glass, while the corresponding ordinates represent temperatures. The curve drawn out in a full line shows the upper limiting temperature of devitrification. This means that a soda glass of a given composition remains glassy provided it is not cooled below that point on the curve, which corresponds to the particular composition of the glass. Thus for example a glass containing about 75 per cent of silica (SiO_2) and 25 per cent of soda (Na_2O) can be cooled to nearly 700 deg. C. without devitrifying. The significance of this curve is obvious when we consider that in working the glass it must be brought down to a temperature at which it possesses a sufficient degree of tenacity. The dotted line on Fig. 1 indicates points of equal tenacity. It will be seen that at temperatures corresponding to this particular tenacity, glasses of certain compositions are below the temperature required to keep them from devitrifying. They cannot therefore safely be cooled down to this degree of tenacity. Others, in a small region extending about from 71 to 76 per cent SiO_2 , are above that temperature, and will therefore remain glassy if cooled till they have the tenacity corresponding to the dotted line.

The pure soda glasses can not be used for the general purposes to which "glass" is put, as they are water-soluble. The second diagram shows some of the properties of a lime-soda glass, such as we have for example in window glass. In this diagram the ordinates represent the proportion of soda (Na_2O), and the abscissæ proportion of lime (CaO). It is understood throughout that the proportion of silica (SiO_2) is 100. The lines drawn out in full are lines of equal stability, the numerals 2, 3, 5 representing increasing degrees of instability. The dotted lines correspond to equal temperatures of devitrification. The compositions suitable for window glass are those comprised within the field bounded below by one of these dotted lines, and above by one of the full lines. For if we step outside this region, either the temperature of devitrification is too high, so that the glass cannot be cooled down to a working temperature, or else the glass is too unstable.

In addition to lime and soda, many glasses contain also alumina or boron trioxide. The effect of these constituents is to increase the stability of the glass. In the case of alumina this is probably due to the formation of double silicates of the type of felspar. The beneficial influence of the boric oxide is probably due to another cause: this body functions as an acid, setting free silica.

As has already been pointed out, the physical and chemical investigations at the Jena Glass Works were in the first place aimed chiefly for the production of new optical glasses. All the glasses known in the earlier days were somewhat similar in their optical properties. That is to say, while their refractive index and dispersive power varied within certain limits, they ran parallel throughout, so that if the known glasses were arranged in order of increasing refractive index, this would at the same time place them in the order of their dispersive powers. Glasses were needed which should not conform to this order, and it was found that especially barium and zinc possessed in a high degree the property of imparting to glass a high refractive index, accompanied by a comparatively low dispersive power.

Another problem was to prepare crown and flint glass which would give as nearly as possible similarly proportioned spectra. The flint glasses then known

gave a spectrum which was much more drawn out in the blue than that produced by crown glass. The remedy was found in the addition of boric oxide, which foreshortens the blue end of the flint-glass spectrum.

Another class of optical glasses are the colored glasses. The principal problem in the preparation of these is to produce as nearly as possible ideal color filters. Such a glass must absorb as completely as

FIG. 1.

possible some particular portion of the spectrum, while transmitting the remainder. The materials added to give the requisite color are the oxides, sulphides and selenides of certain metals, or in certain cases the metal itself in a highly divided state. The color imparted by such additions depends in part on the composition of the glass in which they are dissolved.

A problem of the same character is the preparation of glasses which transmit very short wave lengths of light. It is well known that quartz and boric acid have the property of being transparent to ultra-violet rays. The presence of metallic oxides more or less completely destroys this property, the extent to which this takes place depending on the nature of the metal, thus sodium has a stronger effect than potassium,

FIG. 2.

while lead glasses are particularly opaque to short wave lengths. However, by carefully observing certain precautions, it is possible to prepare silicate glasses of much greater transparency to ultra-violet light than common glass. A special product of this character made by the Jena works and marketed under the name of "uviolet glass" has found application

especially in astro-photography and in the manufacture of the uviolet mercury lamp. This latter, as our readers may remember, is used for medical purposes in the treatment of skin diseases, and in certain chemical industries, especially in the production of linseed oil products.

Another property of glass which is of great importance in connection with certain of its applications is its behavior toward changes of temperature. If a hot glass article, while still soft, is allowed to cool quickly, inequalities in density are produced within the mass of glass, giving rise to internal strains. A glass tube, for this reason, is always under a peripheral compressing strain, while the inside is under tension. The consequence of this is a high resistance to mechanical injury on the outside, while any scratch on the inside, especially in the case of thick walled tubes, almost inevitably leads to the cracking of the tube. Such tubes in which the outer wall is under a compressing strain and the inner wall under tension nevertheless possess certain advantages over tubes free from strain. For if such a tube is heated from within to a temperature considerably exceeding that of its surroundings, the thermal expansion of the inner layers must first neutralize the existing tension before the tube can acquire any tangential expansion strain tending to burst the tube. Such a tube can therefore withstand considerably higher differences of temperature between its inner and outer surface than a tube initially free from strain. The same advantage is gained where the tube is to be subjected to pressure from within, as in water gages for boilers. For this purpose tubes free from strain cannot be used at all. The sensitiveness of the inner wall may be prevented by making the tube of two layers having a different coefficient of expansion with temperature. Tubes of this kind are largely employed for boiler gages.

A glass having a very low coefficient of expansion will cool without acquiring any appreciable strain. Such a glass is particularly well adapted to resist sudden temperature changes and is used for example in making chimneys for incandescent gaslight. Another purpose for which glass possessing special properties is required is the construction of thermometers. One of the errors to which thermometers are subject is the apparent lowering of the freezing point if the latter is observed soon after the thermometer has been used to measure a high temperature. Experiments showed that the simultaneous presence of potash and soda is particularly responsible for a large error of this character. Finally, the brand known as Jena normal thermometer glass 16 III was evolved, and this is now regularly manufactured in uniform quality. It is commonly formed with a red streak to render it readily distinguishable. Its coefficient of expansion is so nearly alike to that of platinum that the metal can be fused into it, making a gas-tight joint. Another special thermometer glass is the boron glass 59 III, which is particularly well adapted for high temperature thermometers ranging up to 500 deg. C. This glass is even superior to the first mentioned, having a lower coefficient of expansion. This, however, brings with it the disadvantage that a gas-tight joint with platinum cannot be made through it by fusion.

In conclusion it may be said that the principal characteristic of the advances made at the Jena works during the last twenty-five years consist in the production of special glass adapted for definite purposes. This was rendered possible only by greatly increasing the variety of types of glass prepared and by the utilization of elements which previously had not been employed in glass making. Nevertheless, had the demand been exclusively for glasses for scientific purposes, this would never have been sufficient to enable the manufacturer to meet the requirements and at the same time secure a margin of profit. The commercial possibility of the developments which have taken place necessarily rested on their exploitation for general technical purposes, as for example in the manufacture of the Jena incandescent gas-light chimneys.

Patina.—The modern bluish imitation patina on lamps, etc., can easily be produced by means of a varnish paint prepared by stirring together copper carbonate and a very light colored spirit varnish (sand-arac or shellac solution). Verdigris alone, used in the same way, gives a pale green patina; mixed with copper carbonate, it gives the medium tones.

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