Chapter 4

Manufacture of tempered-glass insulators

4.1 Scope of manufacturing processes

The scope of the glass-insulator maufacturing processes is very much narrower than for porcelain. At present the use of toughened glass is confined to cap-and-pin insulators or those types, such as railway pedestals and multiple-cone posts, which can be assembled from disc-like modules. There is no such thing as a glass longrod, solid post or hollow shell even though, in principle, there is no reason for not applying the tempering or toughening process to such geometries.

In practice, therefore, the manufacture of toughened-glass insulators is confined to the following stages: mixing the ingredients; melting the glass; forming and heat-treating the discs; elimination of defective pieces; attachment of metal fittings. It is evident that such simplicity cries out for long runs of standard pieces, and that, when these conditions are fulfilled, cheap and good insulators may be expected.

In the following descriptions the publications of Hogg and Johnston[11, 12], describing pioneer work in England, and of Dumora, Pargamin and Parraud[58], covering the recent developments in France which have dominated the technology worldwide, have been heavily drawn upon. Reference to the original sources is recommended (Fig. 4.1).

4.2 Preparation of glass

The glass is melted continuously in a large tank furnace holding as much as 1300 tonnes. The raw materials, typically silica (57),limestone (9), Dolomite (11), felspar (4), soda ash (14) and salt cake or sodium sulphate (6), where approximate percentages are in brackets, are intimately mixed and introduced to the 'melting end' of the furnace, on top of the existing melt. The temperature may be as high as 1500°C, to contain which a highly refractory furnace lining of zirconia or similar oxide is needed.

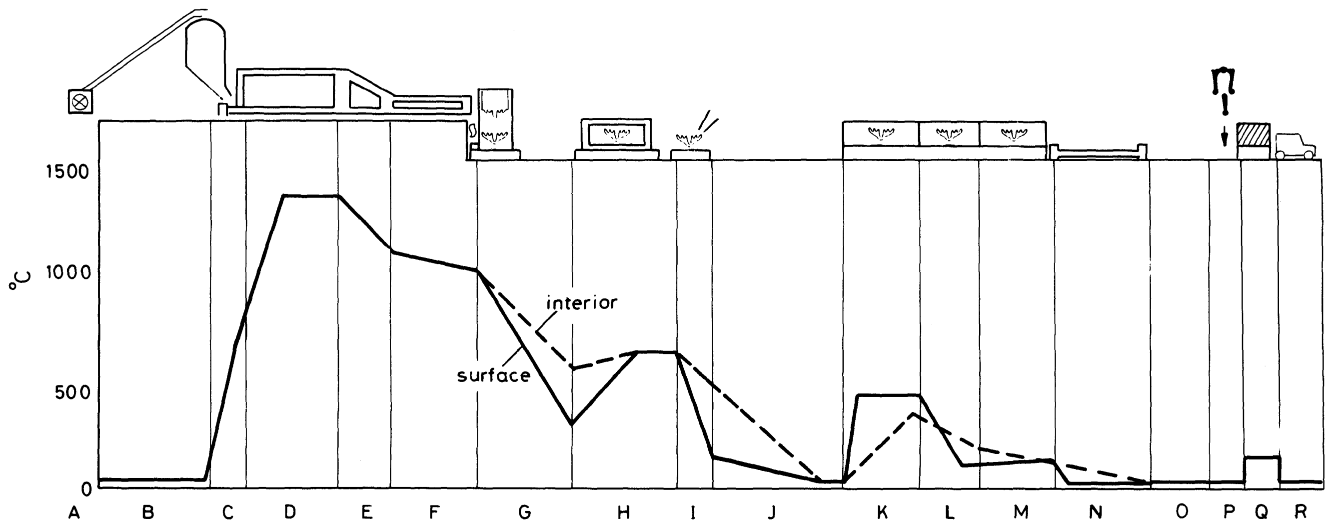

Fig. 4.1 *Manufacture of toughened-glass insulators*

A Preparation and mixing of raw materials
B Holding silo
C Charging furnace
D Melting and homogenisation
E Cooling
F Conditioning: delivery of gobs
G Moulding in chilled forms
H Equalisation of temperature
I Air-blast toughening
J Cooling of bodies
K Cold to hot thermal shock
L Cooling
M Equalisation of temperature
N Hot to cold thermal shock
O Storage
P Assembly of metal fittings
Q Steam cure of aluminous cement
R Packing and despatch

The chemistry of the raw materials under increasing temperature is related to that of porcelain. Loss of surface water is followed by decomposition, yielding oxides of sulphur and carbon as well as chemically bound water, and then by liquefaction as eutectics form between the fresh constituents and those already in the melt. Again as with porcelain, crystallisation may occur from the melt, as of calcium silicate. Oxides of alkalis volatilise and some of the furnace gases dissolve; the resultant bubbles would be undesirable in finished pieces and their removal is expedited by a fining process. This comprises elevation of temperature, to reduce the viscosity of the melt, and sometimes also the addition of specific materials[12].

The mass of the melt is in convective flow, which is desirable in permitting the fining process to eliminate both bubbles and other local inhomogeneities, but hazardous in stripping and circulating solid material from the walls of the tank. Such small fragments of refractory oxide as are entrained into the glass, and pass into the shaping operations, may cause mechanical and electrical weakness in the finished piece.

Before leaving the furnace the glass is brought to the correct temperature to form, at the end of the exit feeder, a calibrated drop or gob of glass. This falls into the mould, which has been coated with release agent.

4.3 Moulding and toughening

The molten gob is forced to flow between the upper and lower parts of the metal mould, which is often multi-piece, permitting complex three-dimensional shapes to be both formed and extracted from the mould. After ejection from the mould the surface of the piece has been cooled by conduction much below the temperature of the interior. A reheat or homogenisation is performed before the toughening, which is by carefully controlled air jets.

As stated in Chapter 2, the temperature after reheat is above that at which the glass acts elastically: the behaviour is that of a highly viscous fluid. The surface is converted to an elastic solid by the chilling air blast. The final distribution of stresses in the glass, once the whole piece has fallen to room temperature, is from a surface compressive stress to an internal tensile stress of about half the surface value (Fig. 2.9). Mean strengths are of the order of 200 MPa, (flexural).

Rejection of wrongly toughened or otherwise failure-prone pieces is done by thermal shock. The disc, at or near room temperature, is placed in a kiln at some 550°C, where it remains until the transient temperature gradient within it has reached a maximum, thus enhancing the internal tension and causing defective pieces to shatter. Some discs are partially stress-relieved at 450°C, to diminish slightly the internal tension following this cold-to-hot shock, but the return of the piece to ambient temperature is always done rapidly, to give a second hot-to-cold thermal shock, again to weed out defective pieces.

Discs are visually inspected for flaws and subjected to dimensional checks before going for assembly with metal fittings. Aluminous rather than Portland cements are favoured for glass insulators; curing of the cement is usually completed in some hours under water. Because the thermal expansibility of insulator glass is fairly close to that of the metallic fittings, there are fewer inherent difficulties with glass than with porcelain, in obtaining good resistance to thermal cycling tests. Loss of mechanical strength at low temperatures has also been claimed to be less for glass than porcelain, for related reasons.