Window and Glazing Topics – Float glass

TANGRAM TECHNOLOGY Consulting Engineers

Tangram Technology Ltd.

33 Gaping Lane, Hitchin, Herts., SG5 2DF

Phone: 01462 437 686

E-mail: sales@tangram.co.uk

Web Pages: www.tangram.co.uk

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1. Introduction

Float glass is produced by floating a continuous stream of molten glass onto a bath of molten tin. The molten glass spreads onto the surface of the metal and produces a high quality, consistently level sheet of glass that is later heat polished. The glass has no wave or distortion and is now the standard method for glass production and over 90% of the world production of flat glass is float glass.

The float glass process was developed by Sir Alastair Pilkington and patented by Pilkington in 1959 and the detailed history of the development is process is described by Sir Alastair Pilkington in his review lecture to the Royal Society of London in 1969 (Pilkington, L.A.B. *Proc. Roy. Soc.* London 1969, **A314**, 1-25).

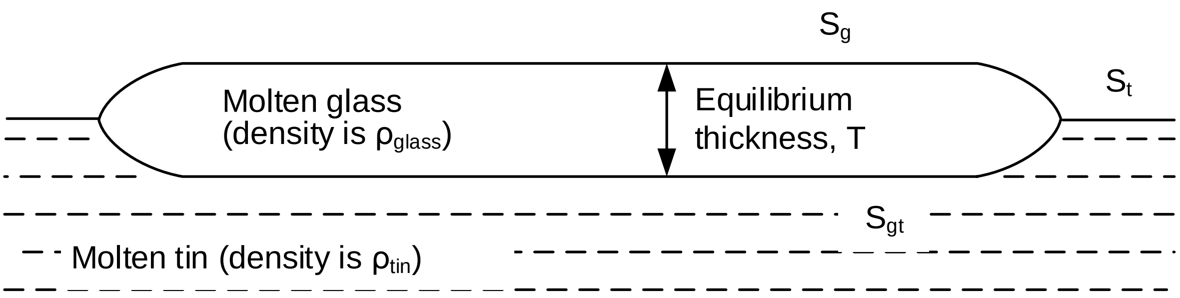
2. The float glass process

The basic science

If molten glass is poured onto a bath of clean molten tin, the glass will spread out in the same way that oil will spread out if poured onto a bath of water. In this situation, gravity and surface tension will result in the top and bottom surfaces of the glass becoming approximately flat and parallel.

The molten glass does not spread out indefinitely over the surface of the molten tin. Despite the influence of gravity, it is restrained by surface tension effects between the glass and the tin. The resulting equilibrium between the gravity and the surface tensions defines the equilibrium thickness of the molten glass (T).

The resulting pool of molten glass has the shape shown below:



Vertical section through a pool of molten glass floating on molten tin

The equilibrium thickness (T) is given by the relation:

$$T^2 = (S_g + S_{gt} + S_t) \times \frac{2\rho_t}{g\rho_g(\rho_t - \rho_g)}$$

where S_g, S_{gt}, and S_t are the values of surface tension at the three interfaces shown in the diagram.

For standard soda-lime-silica glass under a protective atmosphere and on clean tin the equilibrium thickness is approximately 7 mm.

The best detailed explanation of the physics involved in the float glass process is described by Charnock (Charnock, H. *Physics Bulletin* 1970, **21**, 153-156).

The raw materials

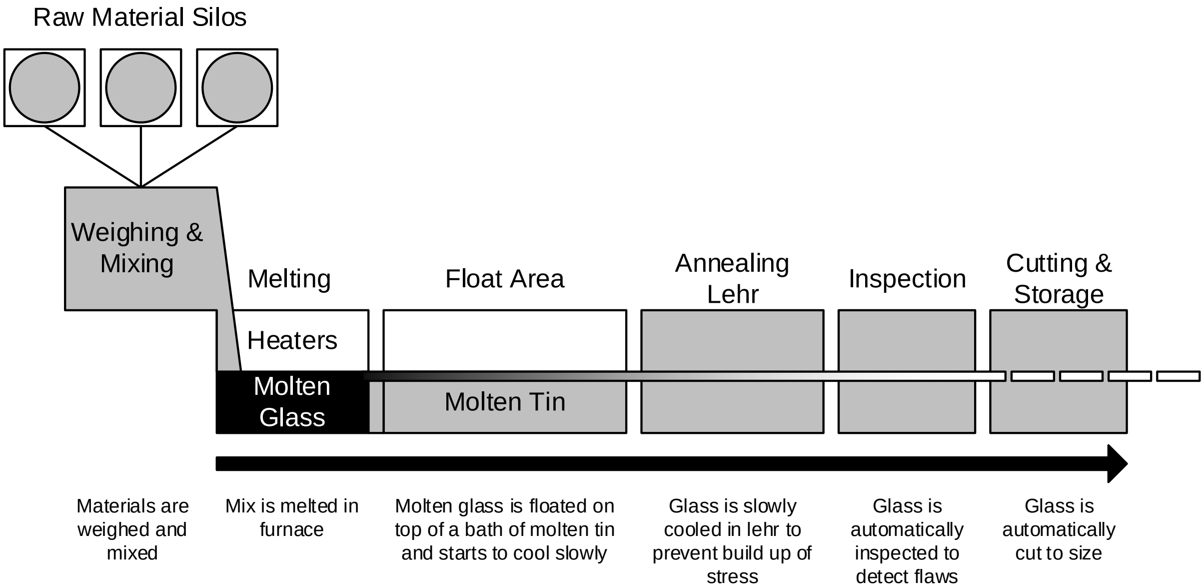
The basic raw material composition for standard soda-lime-silica float glass is:

Raw Material	%
Sand	72.6
Soda Ash	13.0

Limestone	8.4
Dolomite	4.0
Alumina	1.0
Others	1.0

The production process

This basic science was developed over a long period by Pilkington into the full-scale continuous process that is illustrated below.



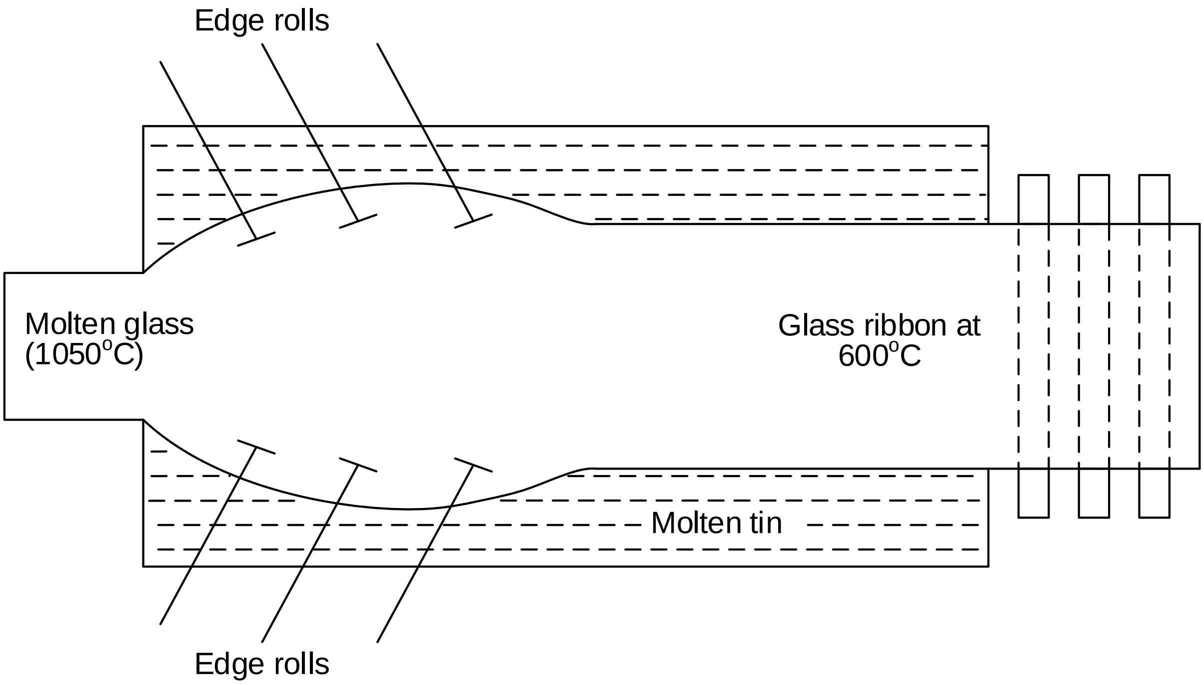
The basic float glass process

The batch of raw materials is automatically weighed and mixed and then continuously added to the melting furnace where it is taken to around 1050^{o}C using gas fired burners. The mix then flows over a ‘dam’ where the continuous stream of molten glass flows onto the bath of molten tin. The stream of glass is pulled along the top of the molten tin by haul-off conveyors at the end of the float area which transport the glass into the annealing lehr.

At the start of the float area the molten glass spreads outwards with flat top and bottom surfaces and the thickness decreases towards the equilibrium thickness (T). The thickness can then be further controlled by the stretching effect of the conveyors as it cools until it reaches 600^{o}C when it exits the float area and enters the annealing lehr.

Whilst the equilibrium thickness is approximately 7 mm the process has been developed to allow the thickness to be controlled between 0.4 mm and 25 mm.

For thin sheets, the exit conveyor speed can be increased to draw the glass down to thinner thicknesses. This drawing down will also result in a decrease in the sheet width and to prevent unacceptable sheet width decreases edge rolls are used. Edge rolls grip the outer top edge of the glass and not only reduce decrease in width but also help to reduce the thickness even further.



Using edge rolls to reduce the thickness of the glass produced

For thick sheets, the spread of the molten glass is limited by using non-wetted longitudinal guides. The glass temperature allows the spread to remain uniform and is reduced until the ribbon can leave the guides without changing dimensions

3. Low-E coatings

Much of the architectural glass produced is now coated with low-e (for low emissivity) coatings to enable the production of more energy efficient windows. As with any advanced technology, there are several different production methods and the products have different properties.

The two basic methods of producing low-e coatings are sputtering and pyrolytic deposition:

Sputtering - soft coat and off-line coating

Sputtering uses a vacuum chamber to put several layers of coating on the basic glass and the total thickness of the coatings is around ten thousand times thinner than a human hair. Sputtered coatings are referred to as 'soft coats' and must be protected from humidity and contact. The sputtered coatings are very soft but inside a sealed unit, they will easily last for the life of the unit.

These sputtered 'soft coat' products can have emissivities ranging from 0.05 to 0.1 compared to uncoated glass that has a typical emissivity of 0.89. This means that 'soft coat' products will reflect between 95 and 90% of the long-wavelength radiant energy from the surface where uncoated glass will only reflect 11% of the radiant energy received by the surface.

Pyrolytic deposition - hard coat and on-line coating

Pyrolytic coating deposits a metallic oxide directly onto the glass surface whilst it is still hot. The low-e coating is effectively 'baked-on' to the surface and the resulting low-e coating is very hard and durable. The pyrolytic coatings are often referred to as 'hard coats'. Pyrolytic coatings can be up to 20 times thicker than sputtered coatings (they are still 500 times thinner than a human hair) and the baking process makes them much harder and resistant to wear.

Pyrolytic 'hard coats' have a low emissivity but this is higher than those achieved for soft coats. Hard coat products have emissivities ranging from 0.15 to 0.2.

The ability to apply 'hard coats' whilst the glass is still hot means that hard coated products are cheaper than soft coated products.