
Fig 1. – Annealing lehr.

One company's annealing process

Every glass type is characterised by a different batch composition and consequently, a different temperature-dependent viscosity and expansion coefficient.

During melting, the batch passes continuously from a solid to a liquid state. At forming it is brought back to a solid, passing the various 'plastic' stages and characterised by different viscosities. These define the characteristic points of glass annealing, such as moulding, softening, annealing and strain points and annealing range (the temperatures between softening, annealing and strain points). Through knowledge of the annealing range, temperature limits for each stage have been established.

Residual stress control

In industrial glass production, the annealing process is applied to control the residual stresses of products (***Fig 1***).

It consists of slowly cooling the glass in the annealing lehr to ensure a low and satisfactory residual stress level. The purpose of annealing is to remove the stress and ensure there is only a minimum acceptable amount of stress remaining in the article when it reaches room temperature.

To do this, the lehr must provide heating and cooling zones to carry out the process in three steps:

- To remove any stresses;
- To cool the glass through the annealing range without re-introducing any new stresses; and
- To cool the articles to ambient temperature without breakage.

The main factor, which affects the final stress that remains in an article after annealing is the rate of cooling, per thickness of glass.

In glass annealing three stages or three steps of annealing are considered.

Three stages

In the first step, the glass must be kept at a uniform temperature for a certain amount of time to remove the stresses in the glass. The higher the temperature at which the article is maintained, the shorter the period required to remove the stresses.

In the second stage, the article must be cooled at a rate sufficiently slow through the annealing range to keep any temperature variation through the thickness of the glass to a minimum so the stresses remain at a minimum value.

During the final stage, the article may be cooled as quickly as possible. Any temporary stresses introduced during this stage do not cause breakage (***Fig 2***).

Annealing range cycles are ruled by two essential temperatures as annealing point and strain point. This temperature depends of glass composition. The intermediate region between annealing point and strain point is most critical because that is where residual stresses are created. The cooling rate will be determined by the level of residual stresses needed and by the quality of production. The lower the cooling rate applied, the lower the permanent stresses obtained. Below the strain point the stresses induced by thermal gradients will not be permanent. Quicker cooling rates can be used after strain point temperature, providing that the temporary stresses added to permanent stresses do not exceed the mechanical resistance of the glass.

A glass article submitted to forced convection inside the tunnel of an annealing lehr is on transient heat flow regime. This means temperature at various different points of the glass item varies with time. Vidromecanica can analyse the annealing curves for those interested free of charge (***Figs 3 & 4***).

Vidromecanica is based in Marinha Grande, Portugal and is dedicated to the production of equipment for the glass industry. ■

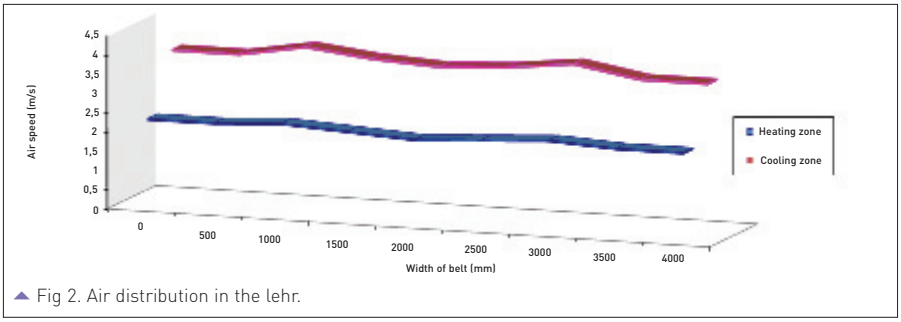

Fig 2. Air distribution in the lehr.


Fig 3. Bottles at the exit of the annealing lehr tunnel.


Fig 4. Annealed glasses.

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