Technology for Low-E tempering

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Abstract

This paper describes the physical nature of convection and radiation combined heating systems in theory and praxis. Different heat transfer factors such as convection, radiation, conduction and contact heat transfer into the glass are discussed. In certain cases also emitted radiation in a glass plate has to be taken in account. These phenomena are coupled together and must be solved simultaneously. Even more complicated the issue becomes with Low-E coatings, because of different characters of glass surfaces. Low-E glass mentioned in this paper is offline coated Super Low-E glass with the emissivity of 0,04 in 21°C.

1. Introduction

The main challenge for glass processors responding to the advanced shapes and product grades favoured by contemporary designers has clearly been technological. Complex products with advanced coatings have triggered entirely new requirements for production machinery and expanded the dimensions of traditional technology. In this market environment several factors contribute to the fast adoption of new products and methods. The continuing move towards better energy efficiency in buildings is providing a strong push for the application of coated glass. Sputtered (off-line) Low-E or solar control coatings are coming standard in countries where climates are cold in winter and warm in summer or sunny the whole year. For glass processors with traditional technology this has meant a need to adopt somewhat slower tempering processes because of longer heating time. At the same time processors are hard pressed to boost their production capacity without compromising the aim for outstanding quality with all glass types.

2. Pre-processing the first consideration

Pre-tempering handling and washing are very important process areas. Considerable care and clean environment in the handling of expensive post-temperable coatings with limited lifetime is required. Small scratches and debris can lead to larger problems down the line in the tempering process. The time between glass removal from the package and tempering should be minimized to reduce problems encountered from dirt and debris, moisture, and excessive handling (see picture 2.).

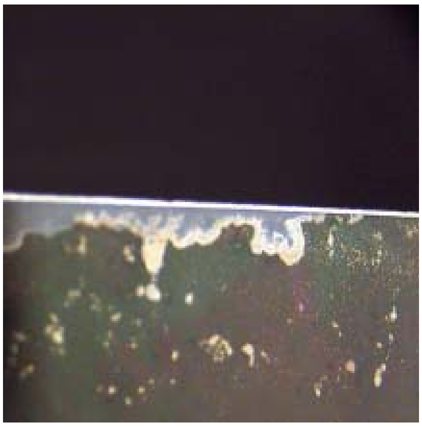
Picture 1.
Structural glazing, Stadttor in Düsseldorf.

3. Prior to tempering

Low-E glass manufacturers recommend that the glass should be tempered in order to avoid glass breakage due to thermal stress. As mentioned above, the post temperable off line coated Low-E products are more sensitive to damage before tempering than after tempering. Special care and attention must be taken at every stage of processing, in particular before and during tempering.

- The cut sizes should be further processed and tempered within the next 8 hours after cutting
- As in the normal case for all tempered glass, notches and holes are made before tempering; no cutting nor edge work may be carried out thereafter.
- Washed panes should be tempered as quickly as possible (maximum 4 hours) after extremely careful and clean washing/drying process.
- All friction or contact with the washed coated side should be avoided.
- No SO 2 in the furnace when tempering soft coated Low-E products.

Tempering edge-deleted glass may introduce edge distortion which will be visible if the glass is to be laminated or applied in structural glazing.



Picture 2.
Damaged Low-E film.

4. Soft coating a special challenge

Excessive overheating conditions in the furnace can have an especially negative influence on soft-coated products. There are concerns about film degradation, the reflected colour may shift towards blue-green instead of the desired neutral-blue that matches the standard product line. Care should be taken to temper Low-E glass in a fashion that is sensitive to the fact that the product is sputtered with Low-E film.

From a general point of view, tempering of soft coated Low-E glass can be carried out using appropriately adjusted furnace settings; this will obviously vary depending upon the type of furnace being used. The sheets should be handled as “cold ”as possible to achieve a flawless coating after tempering; this means that the temperatures and heating times are set so as just to avoid breakage in the quenching/cooling section, and to meet the requirements for safety glass. The sheets are always tempered with the coated side up, i.e. the glass side without coating laying on the furnace rollers.

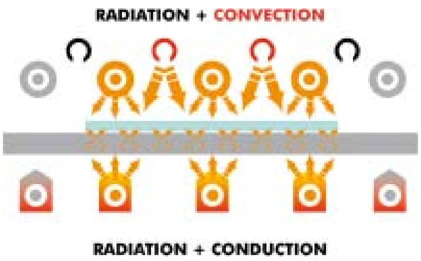
4.1. Radiation furnaces (not recommended for soft coated glass):

Using a standard radiation-only furnace, Low-E glass will tend to bend strongly in the early heating stage due to the different speeds at which the glass surfaces heat up. However, acceptable quality can be achieved at the expense of cycle time by certain furnace types and limited glass size.

4.2. Radiation furnaces with top convection:

As soon as a top convection system with a convection portion is used, the quality and the cycle time improve. The tempering results will be optimum especially for window and architectural glass size with type top convection system mounted in longitudinal direction (see picture 3.). As an example, previously mentioned system has been tested and used in HTF ProE furnace. The following basic settings represent a typical starting value (settings may vary depending on glass size and type):

- Heating time: 58 – 68 seconds /mm of glass thickness
- Set point furnace temperature: 690 to 760 °C
- Top convection level, upper range



Picture 3.

Longitudinal profiled top convection/radiation system (Tamglass patent).

4.3. Traditional high convection furnaces (Closed air circulation):

The traditional high convection furnaces give much faster cycle times as well as improved quality of the end-product when glass size is limited. The basic settings to use are the following (settings may vary depending on glass size and type):

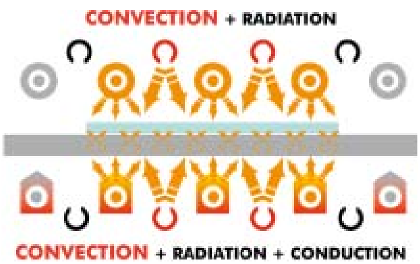
- Heating time: 35 – 45 seconds /mm of glass thickness
- Set point furnace temperature: 650 to 680 °C
- Top convection power high
- Bottom convection power middle

The furnaces require frequent cleaning; any dust (e.g.coming from arrissed edges or from enamelled or screen-printed glass) will increase the likelihood of quality defects like dust bands (see chapter 2.).

4.4. Profiled high convection furnaces (Clean air system):

In the latest profiled high convection furnace the advantages of profiled convection heating methods are combined (see picture 4.). The effective focusing of heat inside the furnace allow tempering architectural size Low-E products. As an example, in ProConvection furnace optimum temperature control is reached utilizing a high convection heating system with convection and radiation profiling. The heating system is thermally closed and the filtered convection air flow passes through a heat recovery process which recycles the energy back to process. The basic settings to use are the following (settings may vary depending on glass size and type):

- Heating time: 35 – 45 seconds /mm of glass thickness
- Set point furnace temperature: 690 to 720 °C
- Top convection level, upper range
- Bottom convection level, middle range



Picture 4.

Profiled high convection heating system (Tamglass patent).

5. Heat transfer in tempering furnace

5.1. Radiation

The heat brought into contact with the glass through the top surface is mostly radiant in traditional tempering furnace. The heating elements are either open, in which case they may also be surface-isolated, or inserted in metallic frames. Due to the high surface temperature of 900–1000 °C, open coil heaters are usually kept at some distance from the glass, 20–100 centimeters, to avoid excessive heat spots below the elements. If they are framed certain advantages result. Heaters can be placed closer to the glass, the heat of the frame is easier to control, heating is better focussed and the temperature may be kept lower (surface temperature abt. 690-720 °C) which is an advantage to avoid Low-E coating burning. The frames are able to store heat and thus the electric peak power demand can be reduced. The control of the frames allows for more heat to be applied in the beginning of the heating cycle, without increasing the total kW value of the heaters, when the glass absorbs more heat. [1]

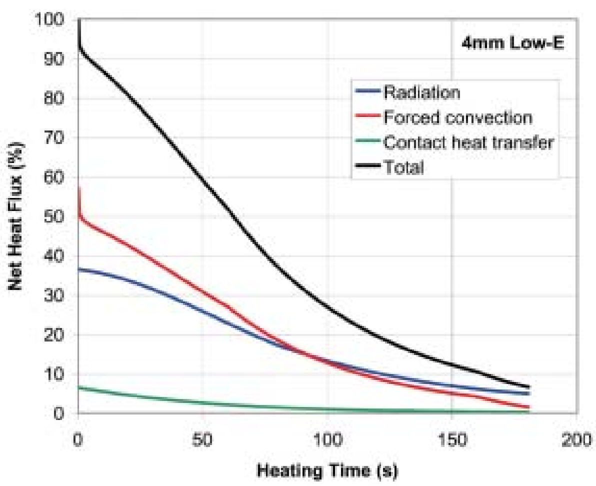
On the bottom several methods of heat transfer apply. The direct radiation from bottom heating elements remains pretty steady even when differing the proportion of direct radiation is limited due to the fact that the roller bed blocks the path of radiation. As a matter of fact most of the radiant heat impinging the bottom surface of the glass is secondary radiation from the rollers that gather heat from the radiant heat source on the bottom (see picture 5.).

5.2. Forced convection

Forced convection heating is the most effective heating method in the case of Low-E and coated glass to date, since the heat exchange rate from the air to the glass surface is practically the same regardless of the nature of coating. Theoretically, by blowing hot air upon glass surfaces inside the furnace, more heat-containing molecules are colliding with the glass surface and exchange heat energy with it.

Picture 5.

Profiled high convection furnace, heat transfer factors.



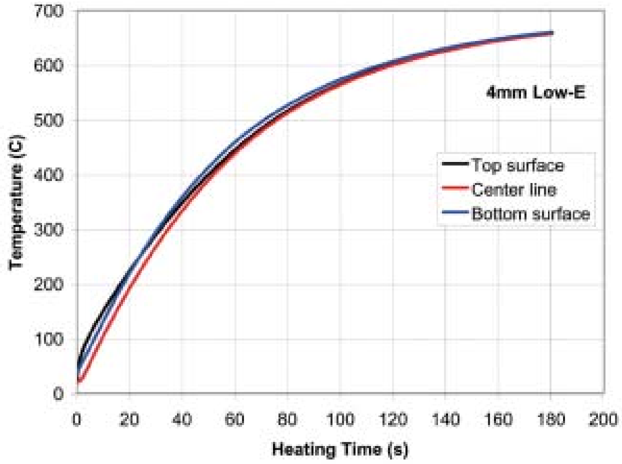
There are two methods to apply forced convection heating on the market. The traditional closed circulation high volume convection method with blowers and nozzle system inside the furnace and the latest profiled high speed convection method with filtered and compressed air jets.

5.3. Free convection

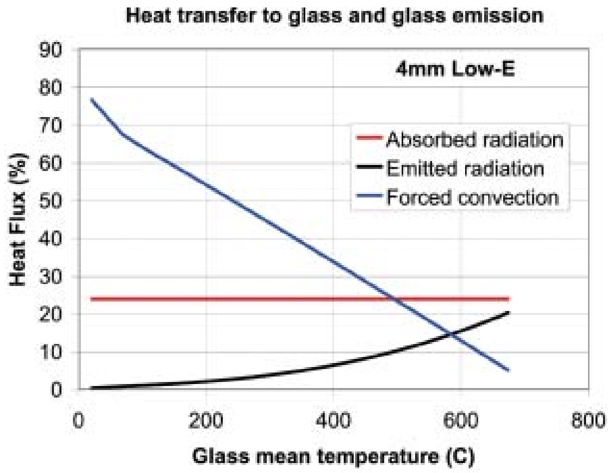
As cold glass hits the rollers, the rollers lose heat i.e. the air, along with everything else on the bottom of the furnace, gets colder. As hotter air below this cold layer naturally tends to travel upwards, a flow of free convection is formed that travels along the surface of the glass and heats the edges of the glass plates. This phenomena is amplified by roller rotation and glass movement in the furnace. Fortunately the effect of free convection is minimized by controlled bottom convection air flow (forced convection) in high convection furnaces.

5.4. Contact heat transfer

The main share of radiation on the bottom of the glass sources from the roller bed. The effect of contact is quite small compared to radiation. There is no practical way of determining the spectrally weighed heat flow from the rollers. Only with exactly controlled bottom heaters excessive thermal changes in roller bed can be avoided. [2]



Picture 6.
Symmetrical heat transfer during the heating cycle.



Picture 7.
Heat transfer to glass and glass emission.

6. Traditional convection technology vs. profiled high convection furnace

It is, however, known from experience that traditional convection concepts do not actually produce the optical quality, especially certain glass types and large glass sizes, than would be expected on theoretical grounds.

The first phenomena in traditional convection heating is the heating environment itself. When glass is bathed in hot air it still receives extra heat by radiation from heat-containing components of the furnace structure and from the ceramic rollers. Both these variables may vary change during the process and therefore cause unbalanced heating conditions in the furnace.

The features of radiant heating become more important when forced convection heating is applied. In such a case, the radiant element of heating is used for overriding the effects of uncontrollable stray radiation from the furnace structure and to maintain roller bed temperature stable.

The second phenomena is how to focus the heat. The glass edges are tending to overheat while the heat flow towards to the middle part of glass remains inadequate. The result is uneven heat distribution in the glass sheet, especially when architectural glass sizes are tempered. This leads to unexpected glass quality with white haze, unstable bow (oilcan effect) or in the worst case, glass breakage in the furnace caused by excessively high temperature differences in glass. Particularly with thicker substances the risk of glass breakage increases.

The edges usually heat up faster than the middle parts of the glass. This is normal because edges have a larger net area which can absorb heat. By means of the heater and convection profiles it is easy to compensate these effects and process large evenly heated glass sheets.

Where convection takes place in a closed circuit and the air coming from the blowers is unfiltered, a third phenomena arises from concentrated dirt particles that may cause quality problems in the form of dust and hot spots on the product. It is obvious that dust and glass particles from the factory air, not forgetting particles from painted glass, will pass into the furnace.

As a base of clean environment the filtered convection air does not contain particles bigger than 1μm. This creates the most ideal environment under hot conditions for soft coated Low-E tempering.

7. Conclusions

The result of tempering process is based on the combination of perfected heating and cooling technology. The Low-E tempering process has to be controlled precisely to maintain symmetrical heat transfer through the gross-section of the glass pane (see picture 6.). The conditions inside the furnace must be the same cycle after the cycle.

The advantage of convection heating is about being able to accelerate the heat transfer into cold glass. Supported by profiled radiation, this allows more speed and flexibility in case of architectural glass size tempering.

Glass breakage is avoided by heating glass slowly at the initial stages, which is something that radiant heating automatically ensures. As a given part of radiation travels through the glass without interacting with it, the glass naturally heats at gradual rate.

Due to the diminished temperature difference between glass and ambient air, the effect of convective heat transfer is minor at the final heating stage of glass (see picture 7.). Now in a more viscous state of glass, close to exit temperature, the most efficient way to heat glass is to apply radiant heat from the bottom (uncoated side of glass).

The heating of glass always takes an equal amount of energy, which is set by the heat capacity of glass. On the other hand quench consumes a given amount of energy regardless of whether the glass is being tempered. During the heating cycle quenching blowers are idling. Shutting blowers down during the process altogether would mean an unjustified power peak when switching them on again. Due to a faster heating cycle the idling time of the blowers is reduced and savings in kWh/m^2 of produced glass are achieved.

For customers this means improved productivity, easier operation and boosted output. In today's competitive market step-by-step improvements in all stages of the process are highly appreciated for their contribution to overall economy and profits (see picture 8.).

References

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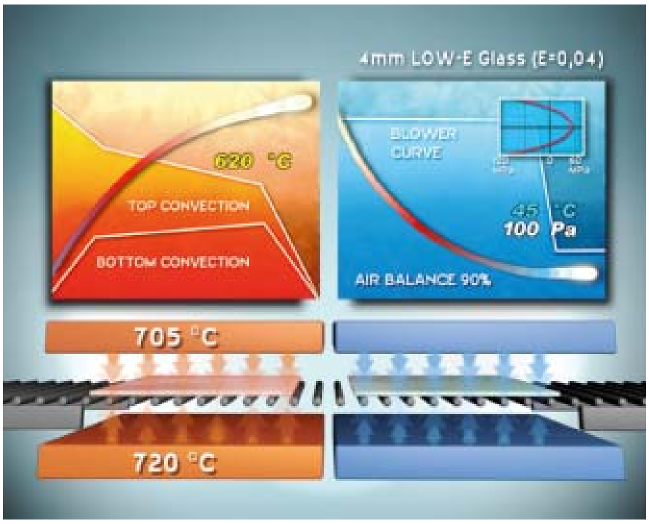

Picture 8.

Profiled high convection furnace, Low-E tempering cycle.

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