AGC
BEYOND GLASS™

TECHNICAL SERVICES DOCUMENT TSD-146

Heat Treated Glass Overview

Tempering Process

There are two types of tempering ovens. The first type is a continuous furnace where high volumes of a like size are conveyed straight through a long oven and then cooled. There is also a batch type furnace where multiple sizes of the same type of glass are introduced into an oscillating oven for heating. While the output from a batch type furnace is much less, it is preferred for custom tempering.

In both cases the fundamentals of the tempering process are the same. The glass must be heated to the point where the core glass temperature exceeds the softening point. This temperature is 550 C for most glasses used in our process. After achieving the proper temperature the glass is quenched with high pressure air from both the top and bottom. During quenching a temperature differential is formed between top and bottom surfaces and the glass core. After quenching the glass goes through controlled cooling in order to prevent the surfaces from reheating. The temperature differential formed during quenching causes the glass surfaces to go into compression and the center to go into tension. Glass is 4 times stronger in compression. When the compression layer is fractured the core tension shatters the glass and breaks it into small partials sometimes referred to as dice. Safety glass standards ANSI Z97.1-2009 and CPSC 16CFR1201 require that the dice size must be small enough that the 10 largest dice weigh less than the equivalent of 10 in^2 of the original specimen.

Heat Strengthening Process

Heat strengthened glass goes through the same process as tempered glass only the quench air pressure is greatly reduced. To comply with ASTM C1048-12 the specimen must have a surface compression between 3500 and 7500 psi. The resulting glass will have 2 times the strength of annealed glass. Quench pressures are determined from results gathered through GASP testing.

Pre – Heat Treatment Process Operations for Uncoated Glass

Seaming

- The seaming process is used to remove the glass fissures created during the cutting process. These fissures will cause breakage during the tempering process.
- Seamer operators should inspect incoming glass for proper cutting and edge quality.
- Seamer belts should be 120 - 150 grit and changed periodically to due to excessive wear which will then subsequently cause tempering breakage.
- Glass edges on all four sides, top and bottom must be seamed.

Washing

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- The washing process is used to remove all debris before tempering to prevent adhesion to the glass.
- A good pre-rinse system must be used to flood off slivers or seaming particles to prevent brush scratching.
- Low-E brushes must be used, .006 inch diameter crimped bristles are suggested.
- Tank water should be held between 120 and 140 F and changed daily.
- Detergent may be used but the ph should be nearly neutral, never acidic. No vinegar can be used.
- Pinch rolls in washer and drying section must be smooth and free of contamination.
- All Low-E products must never be stopped in the washer to prevent scratching of the coating.
- Brush height should be adjusted for minimal contact.
- Overflowing of tanks is suggested to reduce washer contamination.
- Supply lines and nozzles must be kept clean and clear to prevent areas of dry brushing.
- The washer should be steam cleaned on a monthly basis (never steam clean brushes).
- Coating must be dry at washer exit to prevent coating deterioration.
- Filters should be used on the air intake.

Logo Placement

- Printing, sand blasting and laser marking are all acceptable forms of logo marking.
- Logos are product specific and must meet ANSI Z97.1-2015, CPSC 16CFR 1201 and SGCC requirements.
- Logos should be in a 2" x 2" landing field and be oriented so it can be read from the base dimension of the final product.

Furnace Loading

- Glass must be loaded so that the base dimension of the final product is the leading or trailing edge of the glass to insure proper orientation of the roller wave distortion.
- Glass should be placed on the load table with 3 inch minimum spacing.
- Bed loads should be maximized whenever possible for the most efficient use of the oven.

Tempering Operations

Furnace – Uncoated Glass

- There must be a dedicated furnace operator for each shift to make furnace adjustments and take all required quality measurements.
- Oven top temperature set-points for uncoated or hard coated glass should not exceed 700 C.
- Bottom temperature set-points should be 5 – 10 degrees lower than top.
- The heating zones may be trimmed to improve temperature uniformity. By trimming a zone you are limiting the percentage of power that can be applied to the heating elements in that area.
- Master control can be used to improve temperature uniformity when running large lites. It slaves the edge elements to the center elements and prevents them from firing until the center temperature matches the edge temperature so that the edges do not get hotter than the center.

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- The exit pyrometer is used to measure the glass exit temperature which is a tool that provides the ability to properly operate the furnace. For coated glass they should be mounted to read the bottom surface.
- Glass exit temperature should be 620 C +/- 10 C.
- Overheating the glass causes excessive distortion.
- Under heating of the glass can result in breakage, chill cracks, or loss of dice size.
- Glass should lay flat on the oven rolls within half the furnace cycle time. If not adjustments to temperature and/or aspirators should be made. The glass will bow away from the hot side when in the oven.
- Ramp heat prevents the elements from firing as the bed load is sent into the oven. It can be useful on producing heavy plate.
- Based on roll quality SO2 may need to be used. Minimal SO2 usage is desirable.
- SO2 should be used on all heavy plate and pattern production.

Typical Heating Times*

Clear Glass	
1/8	**120 seconds**
5/32	**160 seconds**
3/16	**190 seconds**
¼	**220 seconds**
3/8	**320 seconds**
½	**400 seconds**

**The above times are total heating times. The cycle time will be half the time for 2 bay ovens. Heating times will vary slightly based on element efficiency and furnace insulation. These may need to be adjusted based off exit Pyro glass temperature.*

- Furnaces designed with the first ceramic roll outside the exit door wrapped in Kevlar must maintain the Kevlar wrapping in good operating condition. Kevlar sleeve is an acceptable alternative to wrapping.
- Quench room pressure should be held neutral to negative to prevent cooler air from blowing into the furnace.
- Quench heights must be adjusted depending on glass thickness.

Typical Quench and Cooling Pressures

Clear Glass	**Primary Quench**	**Secondary Quench**	**Cooling**
1/8	**40**	**24**	**10 -12**
5/32	**28**	**20**	**10 -12**
3/16	**12**	**10**	**10-12**
1/4		**8**	**10 -12**
3/8		**3**	**4 ramped to 8/10**
1/2		**2**	**4 ramped to 8/10**

These may need to be adjusted based on break dice pattern.

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Pre – Tempering Process Operations for Sputter Coated Low E

Sputter Coated Low E Handling

- All personnel should wear clean approved gloves when handling Low-E.
- Glass should be conveyed with the coated side up .
- Glass should be carried from the edges.
- Suction cups in contact with the coating should be cleaned and free of debris.

Cutting and Edge Deletion

- Coated surface must be up during cutting.
- Cutting oil use should be kept to a minimum .
- Once cut, Low-E should fabricated within 48 hours.
- When restacked for later fabrication, interleaving power should remain on glass.
- Edge deletion is required for commercial end use and temperable Low-E.
- Under specific conditions, edge deletion may take place prior to tempering.
- Edge deletion width should match the width of sealant used to insulate.
- Seamer operators must wear Low-E approved gloves and care should be taken to minimize coating contact.

Furnace Operation for Sputter Coated Low E Tempering

- Because of the properties of all Low-E coatings the ovens must be run cooler and time in the oven increased.
- Oven top temperature set-points will run between 650 and 680 C.
- Excessive temperature can cause damage to the coating.
- Because of the reflectance of the coating, the bottom temperature will need to be lowered 10 to 30 C to prevent excessive bowing during the heating cycle.
- Excessive bowing in the oven can cause bottom surface scaring.
- No use of SO_2 may be used 1 hour prior to running sputter coated low-e.
- Spiral cut rolls are also preferred in the first bay of 2 bay ovens.
- Oscillation speeds can also be adjusted to improve bottom surface quality but also affect roll distortion. Oscillation speeds may be reduced to 150 ipm.
- When in the Low-E mode on TGL ovens, the bottom elements will not fire, the oscillation speed is reduced and the furnace oscillates only over a small area. Because of the short oscillation distance the uncovered rolls get hot and when the low-e time expires, the glass returns to the long oscillation. The bottom of the glass can overheat causing surface damage from bowing.
- Aspiration can improve both heat transfer and bottom surface quality due to their ability to create forced convection, but can also cause damage to the coated surface by reacting with the metals in the films.
- Aspirator designs vary but typically must be run between 40 to 50% of maximum flow on the top. Bottom aspiration must be low enough to prevent bowing.

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- In 2 stage ovens lower amounts of aspiration are needed in the 2nd oven.
- Where available a profile of the aspiration can be used where high flow rates are utilized at the start of the heating process when the coating is less reactive and is lowered as the coating heats up.

Typical Heating Times for Low-E with Compressed Air Aspiration

	Pyrolitic	**ES40,ES36,ESR42 ES31, ES28, ES23**	**ES63,ES25,ES20**
1/8	160 seconds	180 seconds	170 seconds
5/32	190 seconds	240 seconds	230 seconds
3/16	210 seconds	300 seconds	290 seconds
1/4	240 seconds	360 seconds	340 seconds

**The above times are total heating times. The cycle time will be half the time for 2 bay ovens. Heating times will vary slightly based on element efficiency and furnace insulation. These may need to be adjusted based off exit Pyro glass temperature.*

- Quench pressures will be similar to uncoated glass. Additional quench air may need to be diverted to the top to control bow.
- The coating should be inspected in reflection after tempering to view any deterioration of the coating.
- During heating process small micro- scratches that are not visible will expand
- It is always a good idea to inspect the tempered Low-E after subsequent washing to check durability.
- The above problems are all signs of overheating or excessive aspiration.

Heat Strengthening Process

- The same oven set-ups used for tempering can be used for heat strengthening.
- The quench settings will need to be lowered drastically to insure proper surface compression.
- Heat strengthened glass must have surface compression that measures between 3500 and 7500 psi as measured by a Grazing Angle Surface Polarimeter (GASP).
- All furnaces that produce heat strengthened glass must have a GASP to set-up quench and cooling pressures as well as verify surface compression.
- On ¼ inch glass the quench may be turned off and ramp cooling will be required in the cooling section in order to obtain acceptable compression measurement and also to allow the glass to cool sufficiently in order to unload.
- When heat strengthening ¼ inch low-E it may be necessary to add 1 –3 inches of water column air to the top to control bow and the cooling pressure will then need to be lowered.

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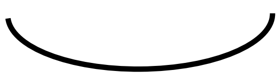
Trouble Shooting for Tempering and Heat Strengthening

Problem	Cause	Possible Solutions
Distortion	Glass is too hot Exit Pyro Temperature above 630 C Rolls may be warped	Lower oven temperature Lower aspiration Reduce cycle time Replace Rolls
Heat Prickle	Glass surface is too hot Poor roll quality	Lower oven temperature Lower aspiration Reduce cycle time Coat rolls with SO2 Replace Rolls
Oil Can Bow	Edges of glass are hotter than center	Trim outside elements Turn on Master Control Increase aspiration in center of light Increase transfer speed
Up Bow 	Glass top surface is cooling after bottom	Increase top quench air Decrease bottom quench air Cool oven top temperature Heat bottom oven temperature
Down Bow 	Glass bottom surface is cooling after top	Increase bottom quench air Decrease top quench air Heat oven top temperature Cool bottom oven temperature
Cold/Chill Cracks	Exit glass temperature is too cold Quench air blowing back into the furnace No Kevlar on first ceramic exit roll outside furnace	Increase cycle time Increase oven temperature Reduce quench room pressure Wrap roll Kevlar sleeve
Large Break Pattern (Big Dice)	Glass temperature and cooling pressure are not proportional	Increase cycle time Increase oven temperature Increase quench air

 TSD-146 August 18, 2016r2

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Bottom Roll Scarring Heat Stain Skunk Stripe	Excessive up bow during heating Poor roll quality	Increase top aspiration Increase top oven temperature Decrease bottom oven temperature Reduce oscillation speed Coat rolls with SO2 Reduce oscillation speed Replace Rolls
Kink	Localized warp in a less than 12 inch span	Level quench rolls Reduce transfer speeds

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