The Dynamics of Ceramic Rollers And Operating and Maintenance Practices to Produce Quality Tempered Glass

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4 = Precision ceramic rollers 5 = Plant cleanliness 6 = Quality glass

Abstract

Heat treating glass in horizontal tempering furnaces is a dynamic process influenced by the systems, controls, and engineering quality of the furnace. Additionally, the quality and stability of the ceramic furnace rollers, maintenance programs, plant cleanliness, and glass fabricating practices are critical and significant to glass quality and productivity. The introduction of new value-added and high performance glass coupled with new and tighter glass specifications requires comprehensive understanding and strict control of the tempering process. This includes the proper use and maintenance of precision fused silica ceramic rollers.

High Performance IG Units With Reflective and Low-E Glass
Photo Courtesy of Pilkington North America

Introduction

The glass tempering industry has undergone constant evolution, but nothing as challenging as the opportunities facing this industry today. There have been many significant developments for heat treating glass including vertical tong tempering and the evolution to horizontal roller hearths, continuous furnaces to oscillating systems, the introduction of fused silica ceramic rollers, aspiration systems, and convection furnaces to name a few. This evolution has always been market driven and in response to demands for increased capacity, flexibility, availability, and glass quality. Today these market expectations continue and are coupled with the challenges to produce evolving energy efficient solar products, glass with new reflective coatings, conductive coatings, hydrophobic and hydrophilic glass, thinner glass, ultra-clear glass, and bent glass. Compounding these challenges, specifications are also tightening.

Producing high quality distortion free tempered glass fundamentally requires good process control and good housekeeping. While the principals have not changed, the ongoing evolution of architectural and automotive glass requires a thorough understanding of the fundamentals and dynamics of the horizontal heat treating process. As glass products evolve, the tempering process is also evolving. This includes enhanced furnace systems, assurance that the rollers remain straight and true at tempering temperatures, and extra attention to plant cleanliness and fabricating practices.

New Products and Tighter Specifications

New product development and quality demands are driving the changes in the tempered glass industry. Energy efficiency is a key to development as consumers and utilities search for ways to reduce costs. Low-emissivity glass offers tangible results. Europe has led the move to solar reflective products and the recent energy concerns in The United States has established a renewed awareness in the Americas. The market demand for solar reflective glazing will drive the primary glass producers and the fabricators. But this is not as simple as offering energy efficient and solar reflective glass. Virtually every product has it's own unique properties requiring strict attention to detail during the tempering process.

At the same time that new products are being brought to market, glass specifications are tightening. The American Society for Testing and Materials is in the process of revising *ASTM C 1036, The Standard Specification for Flat Glass*, and *ASTM C 1048, The Standard Specification for Heat Treated Flat Glass, Kind HS, Kind FT, Coated and Uncoated Glass*. It is critical that glass fabricators and temperers understand and comply with these specifications.

Distortion in Tempered Glass

Distortion in flat glass is a quality issue, and roll wave distortion is one form of distortion predominately found in horizontally tempered glass. The Roll Wave Sub-committee within the Tempering Division of the Glass Association of North America (GANA) has been actively addressing roll wave distortion. The committee has released *Document GANA TD 01 03-00, Standard Test Method for In-Plant Measurement of Roll Wave in Heat-Treated Architectural Glass*. This document covers definitions, summary of the test method, the significance and use, apparatus, equipment calibration, and the test procedure. A flat gauge or three-point gauge with a dial indicator or linear variable differential transformer (LVDT) is used to measure roll wave distortion *"Figures 1 & 2"*.

Another document, *Glass Information Bulletin GANA TD01 01-01, Quantifying Roll Distortion in Heat-Treated Architectural Glass*, is in draft form and has been released to the membership for review and comment. This document includes proposed Standard Specifications of allowable roll wave distortion for various glass thickness. GANA will be proposing specifications for roll wave distortion in heat-treated architectural glass for inclusion in ASTM C 1048.

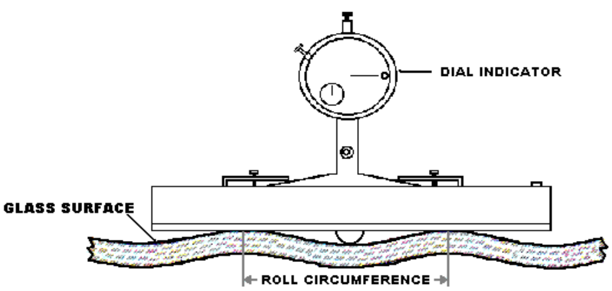

Figure 1 Flat Bottom Gauge For Measuring Roll Wave

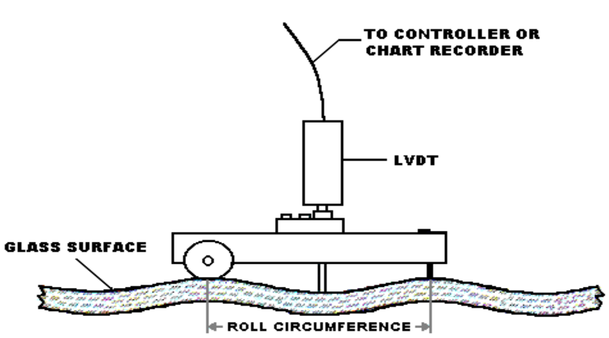

Figure 2 Three Point Gauge For Measuring Roll Wave

Formula for Roll Wave Distortion

Historically roll distortion has been in terms of peak-to-valley depth and reported in millimeters or thousandths of an inch. The Roll Wave Sub-committee determined that peak-to-peak spacing also has a major affect on distortion. This roll wave distortion is measured as an optical power expressed in millidiopters (mdpt) and is reported as D, distortion or an RW Factor. The lower the RW Factor or millidiopter value, the less visible the optical distortion. The formula for calculating the RW Factor is as follows:

RW Factor, $D = 4\pi^2 W/L^2 \times 10^6$

Where D = distortion (mdpt), W = peak-to-valley depth, and L = average peak-to-peak wavelength excluding the distance equal to one roll circumference at each end.

The calculations in units is as follows:
L and W in millimeters, D in mdpt: $D_{mpdt} = 40\ W_{mm} / L^2_{mm} \times 10^6$
L and W in inches, D in mdpt: $D_{mpdt} = 1.6\ W_{in.} / L^2_{in.} \times 10^6$

Examples of roll wave distortion viewed in the reflected image are shown *Figures 3 & 4*. Figure 3

Figure 3 Roller Wave Distortion – Reflected Image RW Factor = 13.00 mdpt (approx.) Photo Courtesy of S.W. Joehlin, Inc.

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*Figure 4 **R**oller Wave Distortion – Reflected Image RW Factor = 66.00 mdpt (approx.) Photo Courtesy of S.W. Joehlin, Inc.*

is considered acceptable within the proposed roll wave distortion specification while Figure 4 is outside of the acceptable RW Factor.

Ceramic Rollers and Roll Wave Distortion

As glass specifications are tightened and new specs are implemented, particularly Roll Wave Distortion, the interface between the glass and the rollers becomes even more critical. Some of the known possibilities for creating roll wave distortion include overheating the glass and allowing it to sag between the rollers, an uneven roller bed allowing the glass to undulate through the furnace, the relationship between roller spacing and glass temperature, and roller eccentricity. This eccentricity may result from the end cap attachment, loosening of the end caps during operation, and poor quality ceramic resulting in excessive hot TIR.

Roller Straightness – TIR

Roller TIR (total indicated run-out) is important, and hot TIR is critical to avoid inducing roll wave distortion. The ceramic must be homogenous and amorphous. If the roller structure is inconsistent or if it has a significant amount of cristobalite phase (the crystalline form of silica), it is likely to bow or spring at operating temperatures. Good cold TIR does not always guarantee good hot TIR. It is important to know how to measure TIR and how to identify warped rollers in the furnace.

End Cap Attachment and Selection

End cap attachment is critical to maintaining straight rollers. A good fit between the roller and the end cap is necessary to avoid wobble, but they cannot be too tight or the stress can cause the ceramic to shear off at the point of attachment. Properly assembled, silicon bonded end caps function very effectively at lower temperatures (approx. 176°C / 350°F) when the end caps are located outside of the furnace. Some roller designs require end caps with an additional mechanical key. These keys serve as backups when the end caps may be subjected to higher temperatures causing the silicon bond to fail. Also available are patented bimetallic mechanically attached end caps that operate effectively at high temperatures (600°C / 1100°F). The end caps should be selected and matched to the furnace and to the application environment.

Precision Rollers To Produce Quality Glass

Glass tempering furnaces are precision-engineered systems designed to produce quality heat-treated glass. These systems are especially important and sensitive when tempering high performance, energy efficient glass. Altering the design parameters of the furnace can seriously affect the operating system and ultimately the glass quality and tempering productivity.

The ceramic rollers are also precision engineered and fabricated to extremely tight specifications and tolerances under ISO 9001 Quality Assurance Standards. The surface finish is diamond machined to a smooth and flat finish. Diameter tolerances are typically held to ± 0.05mm (± .002") or tighter. The TIR is usually specified at 0.25mm (.010") maximum and often supplied to 0.10mm (.004") typically. Premium quality tempered glass requires premium quality rollers. This can only be achieved when high purity, thermally stable blanks are machined to precise specifications.

Roller Maintenance

Maintenance of the rollers is important to maintain the quality and to optimize life and performance. The rollers may be washed with water. Mildly abrasive synthetic pads such as 3M's Scotch Brite™ are effective, but never use soaps or detergents! The rollers should be thoroughly dried before heating to avoid forming steam, which may lead to roller failure. As a last resort, light sanding of the roller surface may be done with very fine grit sandpaper. Wiping the rollers with tack cloth to remove any fine dust or debris is recommended.

Roller Refinishing and Regrinding

A good preventive maintenance program can extend the life and performance of the rollers, and avoid the expense of refinishing and the risk of regrinding. The rollers should be inspected before refinishing or regrinding. Rollers with high TIR will usually bow again when returned to temperature, and if the end caps are loose, they often need to be replaced.

Refinishing involves removing approximately 0.08mm (.003") from the roller diameter. This may restore the surface finish of the roller and remove build up and debris. Refinishing has little effect on roller speed and the pass line through the furnace.

Regrinding often involves removing up to 1.27mm (.050") from the roller diameter which can result in significant changes to the roller and to roller performance. Most rollers have finer grains at the outside surface with coarser grains and larger porosity towards the center. Regrinding can expose this coarser fraction leading to accelerated build up and unpredictable physical changes to the roller in the furnace. Spring back or bow may develop, and changes in roller speed and the pass line are significant *"Tables 1 & 2"*. The risks for developing scuff and roll wave distortion are very high. Regrinding also requires adjustments to the drive to match the level and speed of the transfer conveyor and the quench rollers. Under any circumstance, regrinding should be approached with care. When tempering the high performance, energy efficient glass the risks and the need to alter the engineered parameters of the furnace will likely exceed any possible cost benefit of regrinding.

Table 1

EFFECT OF ROLLER DIAMETER CHANGE ON ROLLER SPEED

63.5mm (2.500") DIAMETER @ 165.5 RPM = 1300 in/min

DIA. REDUCTION	LINEAR SPEED @ 165.5 RPM
- 0.13mm (.005")	1297.4 in./min
- 0.25mm (.010")	1294.8 in./min
- 1.27mm (.050")	1274.0 in./min

95.25mm (3.750") DIAMETER @ 110.3 RPM = 1300 in/min

DIA. REDUCTION	LINEAR SPEED @ 110.3 RPM
- 0.13mm (.005")	1298.3 in./min
- 0.25mm (.010")	1296.5 in./min
- 1.27mm (.050")	1282.7 in./min

Table 2

EFFECT OF ROLLER DIAMETER CHANGE ON PASS LINE

Chain & Sprocket or Pulley Driven on Journals

DIA. REDUCTION	VERTICAL DROP OF PASS LINE
- 0.13mm (.005")	0.06mm (.0025")
- 0.25mm (.010")	0.13mm (.005")
- 1.27mm (.050")	0.64mm (.025")

Direct Drive on Belts, Chains, or O-Ring Drives

DIA. REDUCTION	VERTICAL DROP OF PASS LINE
- 0.13mm (.005")	0.13mm (.005")
- 0.25mm (.010")	0.25mm (.010")
- 1.27mm (.050")	1.27mm (.050")

Plant Cleanliness and Fabrication Practices

The importance of good housekeeping and good fabrication practices have been well documented and are thoroughly reviewed in previous articles and available through in- plant seminars offered by Vesuvius. There are many sources of dirt, dust, and debris that can result in various conditions on the glass surface. Often these conditions appear as random markings, scuff, or white haze "*Figures 5 & 6"*.

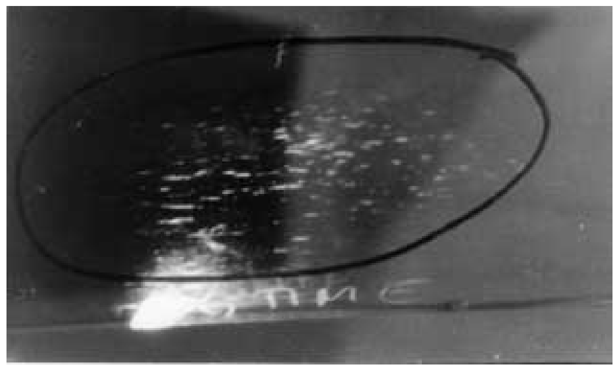

Figure 5 Tempered Glass with Microscopic Bottom Surface Marking

Figure 6 Tempered Glass with Microscopic Bottom Surface Marking

Plant dust including debris from furnace insulation and roll seals must be controlled. Glass dust and separation media must be removed from the glass just prior to tempering. Effective use of the glass washer and following the recommended operating and maintenance schedules is important to surface quality. It is recommended that the exposed conveyor rolls be cleaned daily to avoid

Figure 7 Tempred Glass with Bottom Surface Markin @ 50x Microscopic Paint Debris

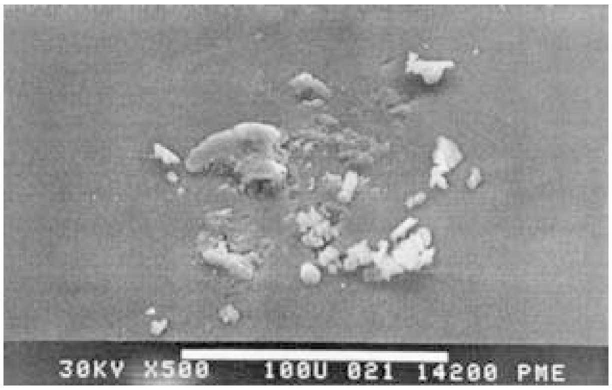

Figure 8 Tempered Glass with Bottom Surface Marking @ 500x Microscopic Glass Dust

picking up dust. Paint must be contained and the edges of the glass must be clean to avoid dripping paint onto the rollers which will ultimately track back onto the glass *"Figure 7"*.

Good fabricating techniques are important so that edge work is complete, smooth, and free of chips or protrusions that may break away during the tempering process. Glass dust and debris deposited on the furnace rollers can be picked up by the glass *"Figure 8"*. Good housekeeping and good fabricating practices will pay back by reducing the roller maintenance and cleaning cycle, consistent glass quality, and increased productivity.

Summary

The glass tempering process is dynamic and the ceramic rollers play an integral role in producing high quality tempered glass. The industry is introducing new high performance energy efficient glass, tightening glass specifications, and the development of roll wave distortion specifications is imminent. As a result, ceramic roller quality is absolutely critical and there is no compromise for good fabricating practices, housekeeping, and maintenance programs.

For more information on Roll Wave Distortion and activities of GANA, contact Mr. Greg Carney, GANA Technical Director at Phone 910.596.2209, Fax 910.592.9261, or E-mail cgcarney@aol.com. For more information on fused silica rollers, in-plant seminars, glass surface analysis, and technical support contact Mr. Ren Bartoe at Vesuvius, Phone 724.843.8300 x230, Fax 724-843-5644, or E-mail Ren_Bartoe@vesuvius.com.

Ren Bartoe is Product Line Manager, Americas for Vesuvius and has 25 years of experience in the glass tempering and float glass industries. He is also the chairman of the Roller Wave Sub-committee of GANA and active on numerous committees.