



Manufacturing Quality of Toughened Glass Insulators

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What does “Quality” mean, and what should it provide with respect to (TGI) Toughened Glass Insulators?

Quality can be defined as the measure of superiority of a product or service as compared to similar products or services and as a degree of excellence. For the electrical industry we benchmark quality using defined national (i.e. ANSI, IEEE, ASTM, etc.) standards. While meeting industry standards is critical, most recognize that standards represent minimum performance standards for material to function in its application. For this reason, many customers and manufactures and look to further differentiate product quality with enhanced specifications. Quality is also about manufacturing the product. Manufactures use standards and continual process improvement methodologies to improve both processes and the product quality with focus on process controls, repeatability, and work toward zero defect. Ultimately, we want quality to represent product capability, longevity, and compliance to industry standards and customer specifications.

The manufacturing of Toughened Glass can be considered as two steps, manufacturing the glass shell, and then assembly of that shell with metal fittings. The production of glass requires specialized equipment and very few carry out manufacturing of both insulating shell and fittings under one roof. So, we will focus on the quality related to manufacturing of the toughened glass shell and final assembly of the insulator as separate steps.

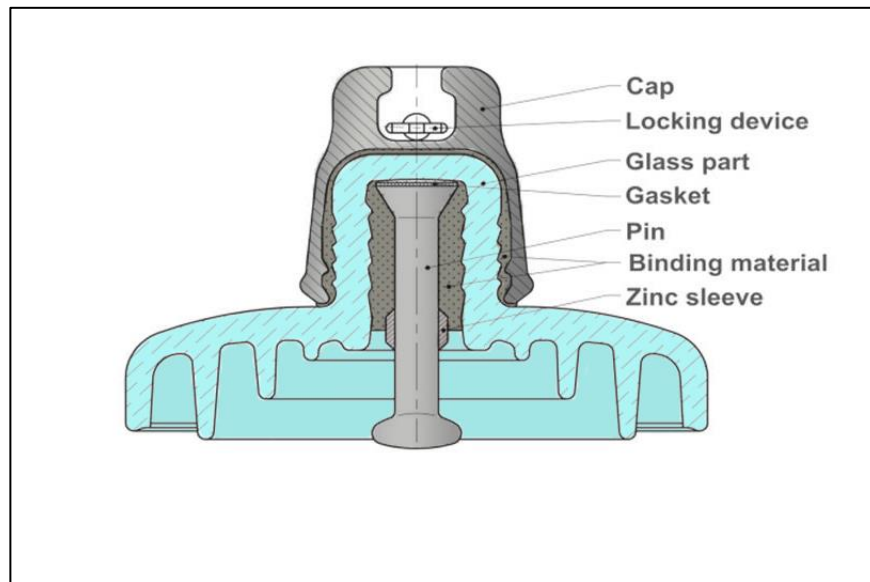


Fig. 2 – Toughened Glass cut-away showing the shell, cap & pin, and cement.

Hardware components of TGI

- Cap – top fitting is ductile iron socket fitting, galvanized, and assembled with a stainless-steel locking pin
- Pin – bottom fitting is forged steel ball connection, galvanize, and coated with bituminous tar. A sacrificial zinc collar can be added for extended service performance
(Note: Clevis / tongue fittings are sometimes used on lower voltages)

The toughened glass shell is the insulator. While the fitting assembly and cementing are important, it is important for the shell to remain intact for its service life. Once assembled the occurrence of shell breakage not caused by an external event should be very rare. The expectation within the industry is that less than 1 per 10,000 installed units per year should occur. Spontaneous shattering of the glass shell is one aspect of manufacturing that the factory should strive to minimize.

Raw Glass & Furnace - The manufacturing of the glass shell starts with the raw materials, combining key ingredients including silica, alumina, sodium carbonate, sodium sulfate, limestone, potash, dolomite and cullet (sometimes referred to as seed glass – is recycled glass from the manufacturing process). The mix of material is specific to each manufacturer as well as to account for the natural minor variations of elements mined or used in the furnace. These natural variations in minerals account for the slight differences in the shade of the glass insulating shell. Typically, furnaces are very large-scale affairs that exceed 100 tones capacity. For consistency it is important to maintain the temperature and regularly monitor the chemistry of the both the furnace output as well as mix of raw material being fed into it. The furnace is the first potential source of inclusions (imperfections in the glass that can cause shattering). Over time refractory bricks will begin to sluff off material into the glass. Periodically furnaces must be shut down and relined.

Shell Forming – on an automated press, a precise amount of molten glass is inserted into the mold cavity and pressed to form the shell (see figure 3). The dimensions for each shell, height, and diameter, are defined by standards, but the geometry and shell profile can differ from one supplier to the next.

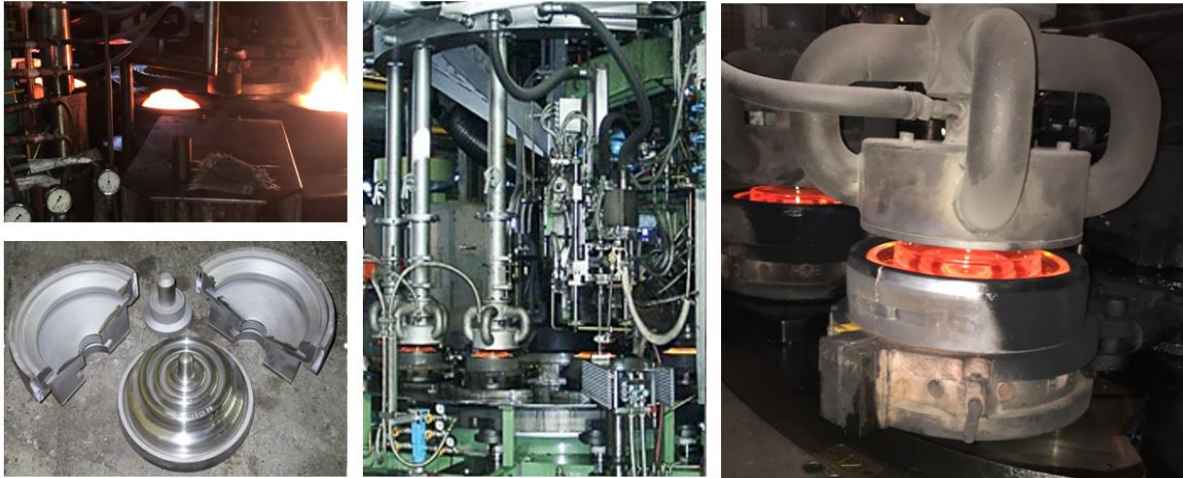


Fig. 3 – shell forming

Any product markings on the shell are from the tooling and will vary by supplier. Since the shell is the insulator, it should have the markings, not the cap (which may be assembled in a different factory).



Fig. 4 – Product marking on the shell

MPS Shell markings include...

- M&E Rating (see figure 4)
- Product ID
- Cavity #
- Date Code
- Factory ID

Questions to ask the supplier...

- 1) Where is the shell manufactured?
- 2) Does the Shell include a Factory ID?
- 3) Is the Insulator manufactured complete in the same factory?

Go see the factory, the process, and the Quality Assurance program used at that factory.

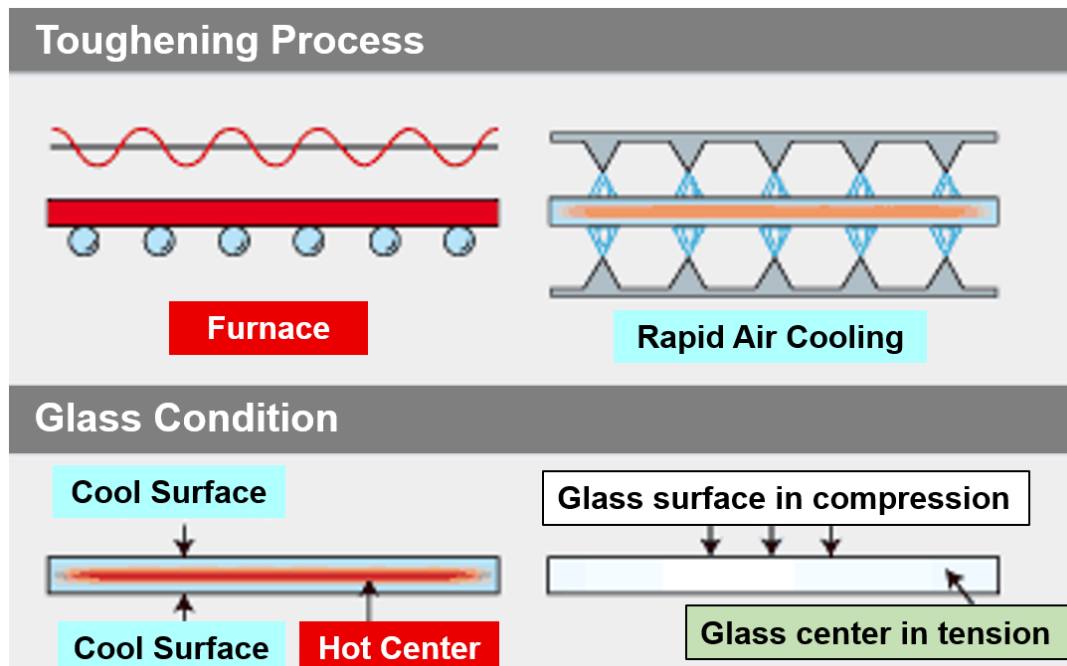
Toughening Process – after forming, the shell goes through the toughening process. Each shell is transferred from the press to the toughening line, passing through a homogenization furnace to keep the glass at a constant high temperature (figure 6). The toughening of the glass is accomplished by rapidly cooling the hot glass using compressed air at key locations on the shell to achieve uniform cooling (figure 7). This results in the glass having a hot center temperature, and a cool outer surface. The structure of the glass after toughening is that the center of the glass is in tension, and the surface is in compression. The toughening process increases the mechanical and electrical resistance and durability of the glass insulating parts. High quality results require a highly automated and controlled material handling process.



Fig. 6 – Homogenization Furnace



Fig. 7 – Rapid air cooling



Thermal Cycle – after toughening, the shells are transferred to the thermal cycle, where the shells are thermal shocked to extract potentially defective shells. The shells are heated up to a temperature of 300 C (figure 8), then dropped into cold water, reducing the glass temperature -120 C (figure 9). Insufficiently toughened glass shells will collapse because of the thermal shock. Every shell made is thermal tested once, and if required, the process can be cycled a second time. The thermal cycle is essentially a quality check, any shell that pops is “No Go”, the shells that survive the thermal shock are “Go”. Glass shells that collapse during the thermal cycles are recycled. The glass fragments are collected and added back to the process in the form of cullet (or seed glass).



Fig. 8 – Thermal Cycle – heated up to 300 C



Fig. 9 – Thermal Shock – water cooled -120 C

Operation of the furnace is a 24/7 process and is faster than the assembly process, so completed shells are held in stock until ready for assembly. The manufacturing process now turns from fabrication to assembly.



Fig. 10 – Completed Insulator Shell

Assembly of the Toughened Glass Insulators

Cap & Pin Assembly



Fig. 11 – Cap socket fitting

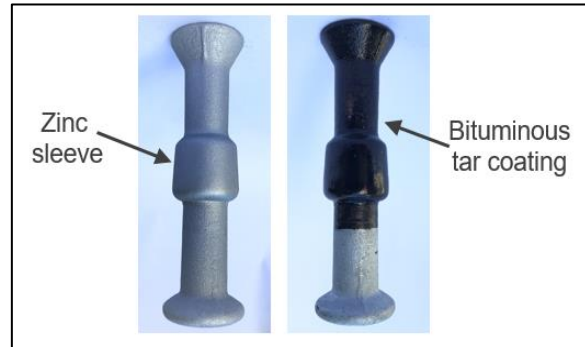


Fig. 12 – Pin ball fitting [before and after coating]

- 1) The pin is coated with Bituminous Tar
- 2) The Gasket is inserted into the Cap
- 3) The glass shells are cemented into the cap; the pin and zinc sleeve are cemented into the shell with alumina cement. Here again automation is utilized to get a measured amount of cement and to achieve precise length tolerance.
- 4) The cemented assembly is then cured, cycling through an hour-long bath in 70 C water.

After curing, every toughened glass insulator is subjected to electrical and mechanical routine testing as well as visual check.

- Routine electrical test – continuous flash-over for 4 minutes
- Routine mechanical test – held at 50% of SML rating for >3 sec.

Sampling tests are then carried out on the assembled lot of insulators. This includes verification of all critical dimensions, socket/ball gauge compliance, verification of locking system, galvanizing check, M&E test and impulse puncture test.



Fig. 13 – Electrical Flash-over Test

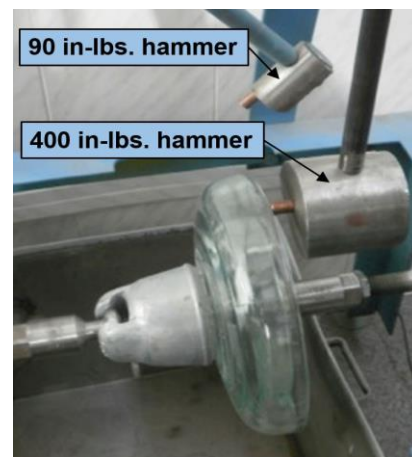


Fig. 14 – Impact Test

90 in-lbs. hammer used on Porcelain

400 in-lbs. hammer used on Toughened Glass

Validation & Test Reports

The insulators are subject to Design or Qualification testing per industry standards, including ANSI C29-2B, IEC 60383, CSA-411-1-16, and GOST 6490-93. The customer can add additional test criteria to their specification to qualify the performance of the insulator above and beyond these standards.

The Test Reports for each insulator design should be specific to the factory the insulator is manufactured. If a supplier has two factories that make the same insulator type, then the supplier should have Design / Qualification reports for each insulator specific to the plant the insulator was made in. For product assembled at an alternate factory location, the test reports for these products should include reference to which factory the shell was made in. If the toughened glass shells come from two different factories, then that should also dictate separate test reports (specific to the factory the shell is made in). The following are examples of what test reports are required in relation to which factory the insulator is made in.

When considering “Quality” of a Toughened Glass insulator, the evaluation and qualification process should be thorough and include every aspect of the manufacturing process. There should be extra attention on where the toughened glass shell is manufactured and how the process is maintained to prevent potentially defective shells from being used in production of the finished insulator. While the assembly of the cap and pin is important, the quality of the toughened glass shell will have greater impact on long term performance of the insulator. Test reports should be specific to the factory the insulator is made in, but should also reference where the TG shell is manufactured. This would require specific factory markings be included on the toughened glass shell.

At a minimum, the toughened glass should have markings molded into the body of the shell, including M&E rating, lot code reference, and factory ID. These markings should be legible and permanent. The factory ID of where the insulator is assembled should be marked on the cap of the insulator. These should also be legible and permanent. Even when made in the same factory, having markings on both the shell and cap helps identify when the shell was made, and when it was assembled. Adding factory ID markings to the shell is quite simple, with little impact to the cost of the product, and it brings with it a higher level of quality assurance for the insulators.

The various standards (ANSI, IEC, CSA) do not specifically call out for factory ID on the shell, but maybe they should?



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