New Plant Targets Growing Market for Composite Hollow Core Insulators

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The growing market for composite hollow core insulators has just grown a lot more competitive. This past May, TE Connectivity (TE) unveiled its new Kunshan insulator plant, the world's newest such facility. Located near Shanghai, this factory signals TE's renewed commitment to its line of composite hollow core insulators – a field it entered in 2001 when it acquired this business and rebranded it under the name Axicom.

INMR travels to Kunshan to meet TE managers closely involved in this project and takes readers on an exclusive tour of this futuristic production plant.

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Tubes wound in single piece at Kunshan will reach 12 m in length.

"This factory represents the single largest investment ever made by TE´s Energy business unit (TE Energy) in this segment," states Transmission Market Director, Robert Strobl, to emphasize the strategic importance of the new Kunshan factory. "It also marks the end of a process that began in 2011 when we first conducted due diligence to examine our alternatives in China, from joint venture to fully-owned production site."

Strobl goes on to explain that the eventual decision to construct a state-of-the-art factory of such a scale was based on a number of market factors. Perhaps foremost among these is the growing tendency within China and elsewhere to employ composite insulators in place of porcelain, especially with rising system voltage. In fact, the recent commissioning of a 750 kV substation totally outfitted with composite insulation (see INMR Q3, 2015) marked a 'watershed' event for the Chinese power industry since it now allows the grid operator to compare life cycle costs and operating performance of this technology versus traditional porcelain.

Another consideration supporting an investment of this magnitude, according to Strobl, was the goal of establishing a production center situated close to key customers across the region – especially given the costs of shipping large insulators here from a TE factory located halfway across the globe. "We needed to have local production," he says, "to better support multinational OEMs in their operations here and elsewhere across Asia."

Steve Dewdney was closely involved in all aspects of planning and start-up of the new plant in his former role as Project Manager and is now Product Manager for its insulator line. He explains that although the new facility breaks new ground in several areas, key elements of its production technology mirror those used for years at Axicom's plant in Wohlen, Switzerland. "Although our capabilities in Kunshan have been expanded to allow us to make tubes up to 12 meters long without any need to join pieces," he reports, "we utilize exactly the same filament winding technology and also the same production tools."

"Customers these days are concerned about challenging service environments and they want to be certain that the insulators they install will perform for at least 40 years."

Yet there are also some profound differences between the two plants.

While the Swiss factory offers insulators made with liquid silicone rubber (LSR) housings, those being produced in Kunshan utilize high temperature vulcanized (HTV) silicone . This changeover

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Dewdney. Decision to changeover to HTV silicone housings was based on local market preferences and cost factors.

Insulators produced in Kunshan are equipped with alternating sheds that have an improved angle to offer a higher creepage factor.

in material is significant since it impacts key elements of the production process, including type of injection machinery used and critical process parameters such as pressure and temperature. It also influences the stage at which flanges can be attached. "The Chinese market strongly prefers HTV," explains Dewdney. "There are cost advantages as well that determined our final choice of housing material and which will help us to better compete locally."

One point of departure from the norm in the Chinese market, however, is TE's decision not to compound their own HTV silicone, as done by most domestic insulator suppliers. Instead, the decision was made to source this material from the local operations of a European-based chemicals giant. "We evaluated the issue of housing material in great detail," reports Dewdney, "and came to the decision not to mix in-house but rely instead on a proven HTV formulation used for years on our line of HV arresters. That means we already have a lot of experience with this material and how it performs. We also feel that outsourcing the silicone material from a specialist in that business will be seen as an advantage by customers from the perspective of assured uniform quality from one shipment to the next."

Apart from choice of housing material, shed geometry is also key to performance and here Strobl states that it was decided to standardize design as much as possible to reduce complexity and make it "fit for purpose". In this regard, insulators produced in Kunshan are equipped with alternating sheds that have an improved angle in order to offer a higher creepage factor. In fact, Strobl points out that all insulators from the new factory conform to IEC 60815 Part 3 for high pollution and this was done to ensure they would always perform well, even in the severe environments found across parts of China and elsewhere around the world.

For example, Dewdney indicates that the new HTV insulators have been tested under artificial pollution, heavy rain and temperature extremes from -60 to +105°C. "We have gone well beyond the requirements of IEC 61462," he says, "since we believe this standard sets a fairly low level. Customers these days are concerned about challenging service environments and they want to be certain that the insulators they install will perform well for at least 40 years."

Dewdney also notes that insulators from Kunshan have passed 5000 hour tests under clean fog and 10,000 hour tests under UV – both carried out with the goal of ensuring they would last well beyond normal requirements. Another benefit of the new housing design, adds Strobl, is that if applied in clean environments, these insulators can have correspondingly shorter lengths while offering the same performance as longer insulators from other suppliers.

HTV silicone insulators from Kunshan designed to offer creepage factor of 4.2 versus the 3.8 used for insulators produced in Wohlen.

One of the main factors that differentiates the hollow core insulators being produced in Kunshan from those of local competitors is tube thickness. Dewdney and Strobl explain that TE's winding technology results in tubes that are significantly thinner than those offered by major domestic suppliers. Thinner tubes require smaller flanges and together result in a finished insulator having the same mechanical performance while being from 25 to 30% lighter. Says Strobl, "our thinner tubes allow us to outperform competitors in a number of applications such as in seismic areas and for wall bushings and live tank breakers. Therefore, it was never really a choice for us to source tubes locally versus making them in-house. They represent one of our core technologies and controlling it ourselves allows us to make whatever design changes are needed on the tube."

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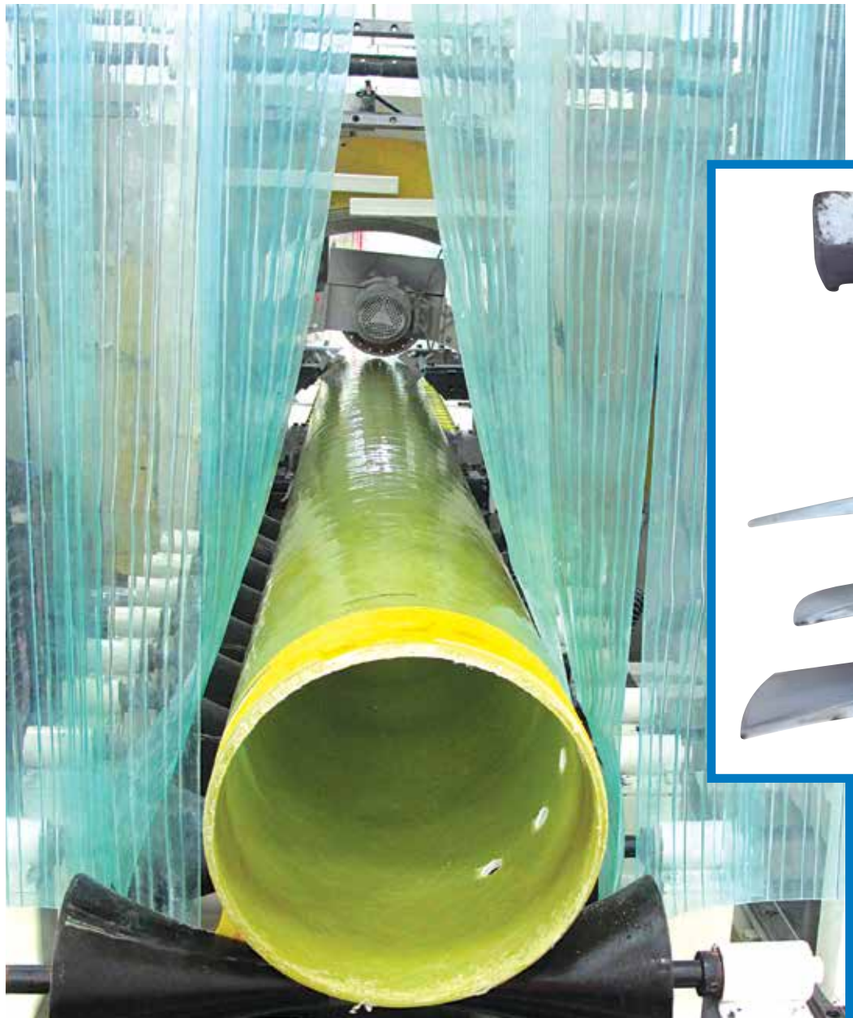
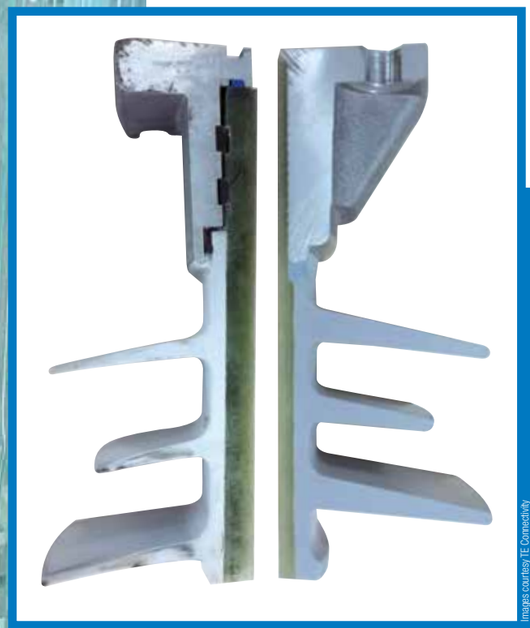
At the same time, thinner tubes need to be protected against the risk of being damaged under the high pressures needed to mold onto them a viscous material such as HTV silicone. Dewdney explains that this challenge, which was never an issue when molding on LSR housings at low pressure, was overcome by employing special storage mandrels during injection. These mandrels, usually shorter than those used in the tube winding process, support the tube dur-





Images courtesy TE Connectivity

Tubes cut using overhead saw to maximize precision of cutting. Comparison of thickness of tube produced in Kunshan (right) with major local competitor.

Photo: INMR ©

Insulator exits molding cycle with mandrels ready to be removed.

ing the molding cycle and are slid out once the insulator exits the mold.

Finally, Dewdney emphasizes that the entire injection molding process in Kunshan has been analyzed carefully with the goal of optimizing it in every way possible. Two of the three machines currently on the factory floor are step-molding units, intended to produce larger dimension pieces in a series of successive injection shots. The third is used for single shot molding of shorter insulators for lower transmission voltages.

These machines were purchased locally and installed early in 2013 at the second TE Energy Kunshan plant which focuses on MV and HV cable accessories. Over that period and in parallel with construction of the new plant, the entire molding process was reviewed by a team of production specialists in order to gain experience and refine every step. The machines were then specially adapted in ways to meet all the key criteria identified and moved into the new facility once it was completed.

"For example", says Dewdney "customers demand good adhesion and sheds that are perfectly straight, not 'wavy', with no air bubbles or sinkage marks. At the same time, we also wanted a product that comes out of the molding process with almost no excess material

Thinner tubes require smaller flanges and together result in a finished insulator having the same mechanical performance while being from 25 to 30% lighter.

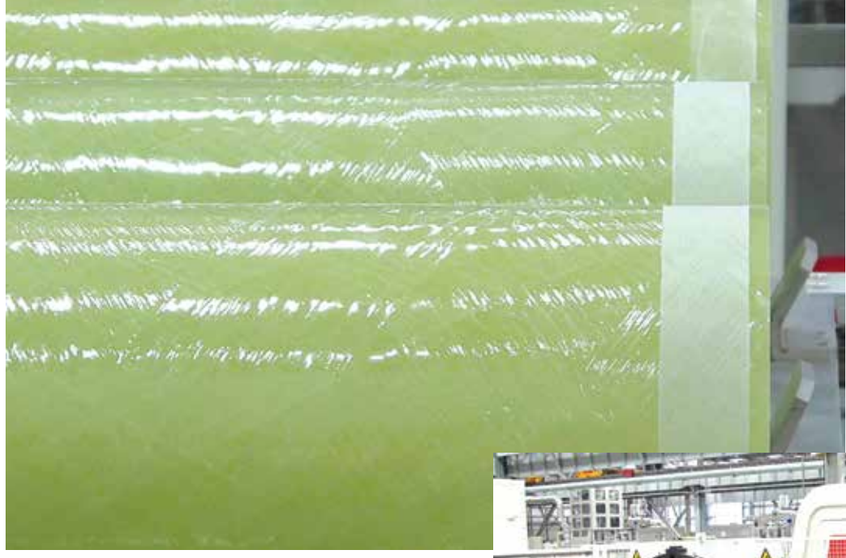
Photo: INMR ©

Single shot molding machine specially adapted to meet required process criteria.

that not only represents scrap but also needs subsequent finishing. IEC allows flash of up to 1 mm while, according to Dewdney, the new plant has set a target of half that limit. "We decided to make added investments at the front end of the molding cycle to ensure all pieces come out defect-free. That meant we had to develop superior quality molds made with higher strength steel than normally used by the industry." Another benefit of superior molds, he notes, is that they will last many years and not become distorted from repeated use under high injection pressures – something that could eventually lead to shed misalignment and excessive flash.

In addition, to guarantee that the high-pressure molding process proceeds each time within the precise limits required, special sealing grooves are machined beforehand onto the tubes. These grooves fit into corresponding seal rings in the mold. Says Dewdney, "we engineered this to guarantee an air tight cavity each time, with assured high pressure inside the mold. This leads to good filling and no risk of air bubbles."

A final but important distinction between production in Kunshan versus what is done at TE's plant in Wohlen relates to attachment of flanges. In the process with LSR housings, flanges are attached before the injection molding cycle whereas with HTV silicone attachment of flanges is performed after the insulators exit the mold. According to Dewdney, the fit between flange and tube is a critical area determining future performance of a hollow core insulator



Special sealing grooves machined onto tubes ensure perfect seal within mold cavity.

and therefore is among the most closely monitored steps during manufacturing.

The process in Kunshan, referred to as 'press fit', begins with the flanges cleaned ultrasonically after which they are heated and clamped onto platens. Glue is applied and they are clamped onto the tube under high force. "The flange shrinks down to the tube as it cools," explains Dewdney, "and we get the 'bite' that guarantees mechanical performance." This process is then followed by another curing cycle for the glue.

A small gap up to 5 mm is left intentionally to ensure that there is always a perfect seal between the HTV material, the flange and the tube. This space is then filled with a high quality, long-lasting RTV silicone material in the last step of production. Says Dewdney, "we identified what we see as a potential weakness in the 'O' ring design used by some local suppliers. This, we feel, can lead to moisture entering this critical area of the insulator."

Futuristic Yet Compact Plant

A walk through the new Kunshan plant helps clarify some of the key points raised by Dewdney and Strobl and also serves to quickly differentiate this facility from most others in this industry. Aside from its futuristic appearance, ultra-clean floor space and compact production flow, Dewdney indicates that every element of the manufactur-

Attachment of flanges. Intentional small gap between housing and flange is filled with RTV material.

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Ni. Interchange of quality staff between Kunshan and Wohlen allowed migration of knowledge both ways.

that staff from Kunshan spent weeks at the facility in Switzerland training in every aspect of quality assurance.

Operation Manager, Tony Ni, explains that there are four levels of quality inspections at the plant – from those focused on incoming materials, to those conducted on items in-process to those performed on all finished insulators. In the materials testing laboratory, for example, tests are performed on samples cut from every tube after it exits the filament winding process. A muffer oven heats these to several hundred °C to burn away the resin and allow the fiberglass content to be measured.

Photo: INMR ©

Discs removed from sample tubes used to monitor glass transition temperature (T_g).

Tests are also carried out on incoming metal parts such as conductor rods to evaluate breaking strength while the viscosity of the resin used in filament winding is also monitored closely. Ni says that one of the benefits of being part of TE is having access to the company's large materials laboratory in Shanghai and also the opportunity to share planning and quality control functions with other divisions.

The manufacturing process for composite hollow core insulators begins with production of tubes, which in Kunshan is performed on one of two winding machines located in a humidity-controlled area of the plant. The wound tubes are then cured for several hours, after which they are checked for dimensional accuracy and transferred to trimming and machining.

Currently, maximum tube length produced in Kunshan is 10.5 m but this is expected to reach 12 m using existing machinery, which has the capability to support sizes from 83 mm up to 1100 mm inner tube diameter. The market now requires hollow core insulators up to ±800 kV DC utilizing a single tube. However Dewdney points out that the plant will also be able to supply units for projects up to 1200 kV AC, as are already being discussed within China. "It is very much a project driven business," he says, "and therefore we have to be able to react quickly. At the same time, we need to make the transition to higher and higher voltages logically so that we will be in the best position to supply these new applications as they come up."

The injection molding machinery at Kunshan is regarded as highly proprietary and confidential since it has been customized in many respects to make the equipment perform optimally. As plant volume ramps up, Ni expects that possibly another 2 or 3 such machines will be needed.

The last element in production involves HV testing the finished insulators and for this purpose a 1600 m² testing area with a ca 30 m high fully shielded high voltage laboratory has been built on-site and equipped with 1.35 MV AC transformers and a 3.2 MV impulse generator. Says Quality Manager, Andrew Wei, "this facility gives us a lot of opportunities for in-house testing of insulators up to 1000 kV, cable terminations up to 500 kV and bushings up to 550 kV."

Tubes checked for dimensional accuracy after curing before being transferred to be trimmed and machined.

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Cantilever and internal pressure tests performed on finished insulators.

TE maintains key performance indicators (KPIs) such as number of customer complaints or speed of response to these. There is also a program called TE Operating Advantage (TEOA) where one of the goals is streamlining production and ensuring continual improvements in productivity. For example, Strobl says that the new Kunshan plant will be expected to realize productivity gains of from 3 to 5 percent each year. "Our target in terms of quality output and low scrap rate will be to be the highest class for both sites, Kunshan as well as Wohlen," remarks Dewdney. Another element of TEOA is what is promised to customers, which in the case of the new plant is more than 95 percent when it comes to shipping to schedule.

The total world market for hollow core insulators is currently estimated at around half a billion US dollars and Strobl says it has undergone a dramatic shift over the past years. Once 90% dominated by porcelain, these days fully one-quarter is accounted for by composite types and this proportion is now growing rapidly as end users start to focus more closely on life cycle costs and less on only initial acquisition cost.

Strobl predicts sales will grow rapidly over the next 3 to 5 years, divided about equally between local and export markets. The first year volume has been dictated in large part by the lead-time needed to meet all qualification audits and approvals from OEM customers and local power authorities. Once these have all been completed, sales are forecast to increase to a target of the plant's full capacity.

Kunshan's high voltage laboratory allows most products to be tested in-house.

Photo: INMR ©

View towards single shot molding machine at Kunshan.

Looking back at what has been achieved so far in the Kunshan factory, Strobl remarks "with this new plant, we think we have prepared ourselves for the future. Relying only on our Swiss plant would have made this increasingly difficult. Now, with the combination of the two, we can leverage our capacity to better meet customer needs. We have one plant in China able to supply larger quantities and sizes while our other plant in Switzerland can focus on more specialized applications." ☒