An inovative range of insulation parts, including moulded 3D shaped products with enhanced thermal properties, is available in the market

ABSTRACT

Several new insulation materials based on the 3D moulding technology have been developed, covering all temperature classes according to IEC. The new product range materials are available in all dimensions and thicknesses, offering the design flexibility required for all kinds of transformers without compromising the positive cost-benefit ratio.

KEYWORDS:

3D moulding, hybrid insulation materials, insulation, temperature class

Albert Schweizer GmbH & Co KG, Mannheim and Isotek GmbH, Möckmühl, both well-known in the electrical insulation industry for decades, have started cooperation to develop and manufacture innovative insulation solutions for transformer applications with alternative insulation systems.

Schweizer, in cooperation with Isotek, has developed a new, innovative range of moulded insulating products that comply with all temperature classes as per IEC 60076-14

An innovative range of 3D moulded insulation parts

Products with enhanced thermal properties are available on the market

These products offer OEM´s and end customers vast grades of freedom for designing advanced temperature transformers according to IEC 60076-14 (transformer standard).

Before we start introducing our new product range, please allow us to give a short overview of moulded insulation parts currently available in the market.

Regrettably, it is quite evident that insulating parts and products such as angle rings, snout (chimney) segments and cylinders are at present mainly available made of standard PSP pressboards suited for the thermal class of just 105 °C.

Probably not everyone is aware that in practice, this circumstance is a limiting factor for the transformer industry in designing an extended range of power transformers that could operate at higher temperatures. With regard to the higher thermal classes for 120 °C, 130 °C, 140 °C, 155 °C or 180 °C of the solid insulating product as per IEC 60076-14, this simply means that more complicated formed products for these temperatures do not exist in the market so far.

It goes without saying that the lack of availability of such products prevents a progressive design development of power transformers.

Due to this situation, we – company Schweizer in cooperation with company Isotek, have identified this challenge and set ourselves to develop a new, innovative range of moulded insulating products that comply with all temperature classes as per IEC 60076-14. This even more as by observing the entire energy sector, a change in all branches is recognisable, which is also reflected by increased demand for such innovative insulation products.

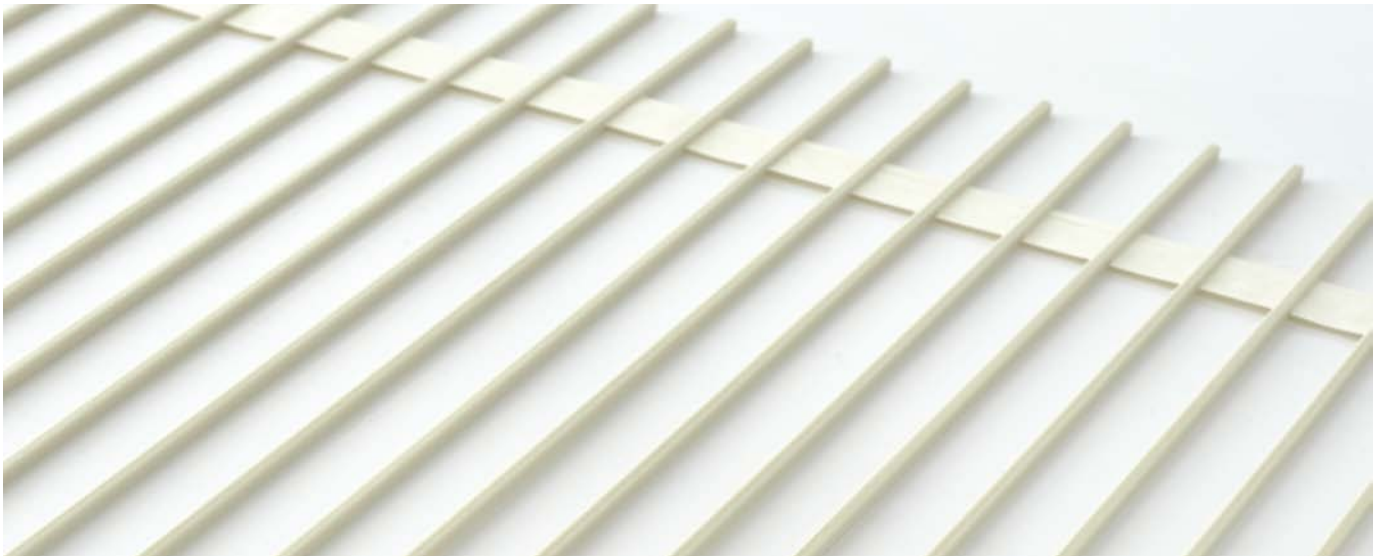
In close cooperation with DuPont, Schweizer has extended the existing NOMEX® Pressboard 993 PSB and 994 PSB product line by a new formable precursor material

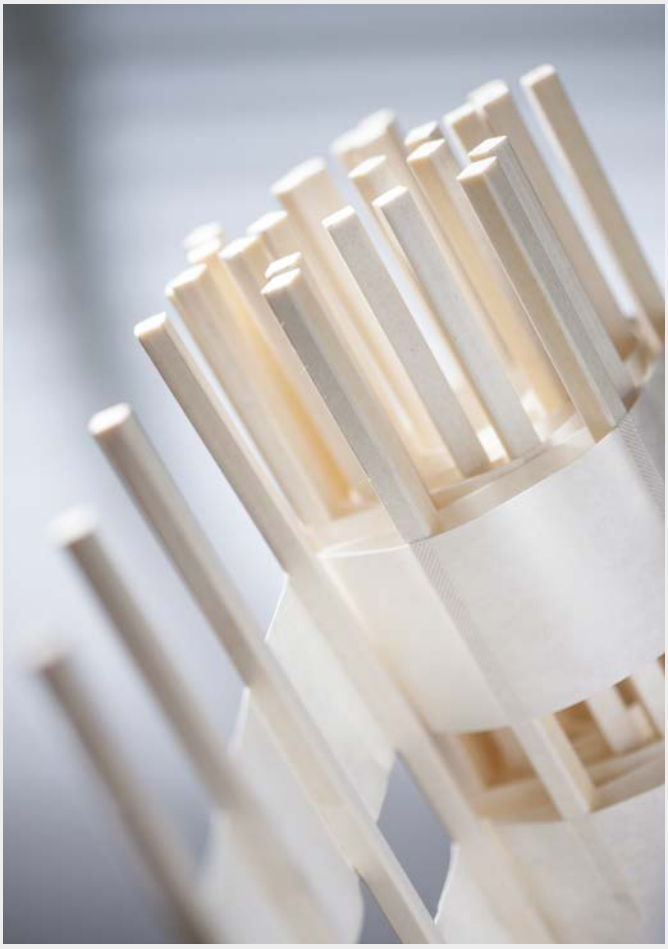
In general, it is evident that energy production, supply and management is becoming more and more complex. Consequently, utilities all over the world and Europe are faced with much higher requirements than in the past. Decentralised energy production, for instance, is a huge challenge and necessitates intelligent systems, which consist of energy storage, grid management, new infrastructure, digitalisation for connecting E-Mobility, Industrial and private consumers in a smart and flexible way. Consequently, new energy management systems specifications of existing transformer designs have to be adjusted to cope with the new requirements.

But what does it mean with regard to power transformer (110 kV – 400 kV) in usual grid operation?

The trend is obvious.

For many intra-urban substations and / or substation-buildings, new power transformers with extended power in MVA are required to deal with the increased requirements to enable safe grid management. These increased power requirements come along with significant load peaks for short whiles (e.g., a few hours per day), challenges which have to be managed by the next generation of power transformers. In standard transformer designs, keeping the existing thermal class of the transformer that needs to be replaced means that the new transformer will have to increase in size. This is where often one problem comes up: space limitations of the existing substation locations! As new power transformers with increased power and size may not fit into existing buildings, they have to be designed





HYBRID INSULATION MATERIALS are a rigid but formable solution that offers OEM´s and transformer end customers more flexibilities in transformers design without losing a positive cost-benefit ratio

with **increased power and the SAME size.** Hence, higher thermal stress has to be accepted. The practical solution can be: implementation of hybrid insulation system concepts under consideration of solid and liquid insulation materials with higher thermal properties! In such a hybrid insulation system, various materials with different chemical structure and thermal capabilities can be combined.

Another application for transformers using high-temperature insulation materials with a power range of approximately 2–10 MVA would definitely be in e-mobility fast-charging stations, wind turbines, energy storage units, and solar parks. End customers of transformers in these kinds of applications are convinced about high-temperature insulating systems for long. The reasons and advantages of these transformers are as follows:

- Improved environmental footprint (by using hybrid insulations combined with ester fluids)
- Overload capacities and / or downsizing transformers without reducing the lifetime
- Improved reliability
- Optimise efficiency and losses per the European ECO-design regulation 548/2014 (Tier 2) or even undercut these values.

Below, IEC 60076-14 guideline for maximum continuous temperature rises for transformers with hybrid insulation systems has served us to identify existing material gaps for developing a larger variation of (moulded) insulating parts in the market. The relevant passages in the below IEC overview table have been marked in red for better visualisation.

As a result and answer to the current market situation, we are pleased to introduce our new extended product portfolio of moulded 3D shaped parts and products as follows:

Parts for solid insulation materials of thermal class 180°C as per IEC 60076-14

In close cooperation with our partner DuPont we extended the existing NOMEX® Pressboard 993 PSB and 994 PSB product line by a new formable precursor material. Based on this new NOMEX® material, we developed processes and equipment for producing a new innovative range of formed parts according to specific customer requirements. With these new ranges of formed parts, completed by winding cylinders (closed or open) made of NOMEX® Pressboard 993 PSB or 994 PSB, press-rings etc., we are able to offer a system solution of insulation parts, which are required for designing **full hybrid insulated windings or high-tempera-**

	Conventional insulation system	Hybrid insulation systems				
		Semi-hybrid insulation winding	Mixed hybrid insulation winding	Full hybrid insulation winding (Hermetical sealed transformers)		
Minimum required solid high-temperature insulation thermal class	105	120	130	130	140	155
Top liquid temperature rise (K)	60	60	60	60	60	60
Average winding temperature rise (K)	65/70	75	65	85	95	105
Hot-spot temperature rise for solid insulation (K)	78	90	100	100	110	125

	Ester liquid			
Minimum required solid high-temperature insulation thermal class	130	140	155	180
Top liquid temperature rise (K)	90	90	90	90
Average winding temperature rise (K)	85	95	105	125
Hot-spot temperature rise for solid insulation (K)	100	110	125	150

ture insulated windings as per IEC 60076-14. A comparable system solution has not been available at the market up to now!

A further aspect will not remain unmentioned: as all the basic materials of our new insulation parts are of NOMEX® Pressboard 993 PSB and 994 PSB (or precursors), OEM's can rely on the quality, mechanical and dielectric properties as well as chemical compatibility of these since decades in liquid immersed (mineral oil, ester and silicone fluids) transformer applications well-established materials. The standard dielectric, mechanical and thermal properties of these products are well known in the market and must not be tested twice.

Parts for solid insulation materials of thermal class 105 °C – 180 °C as per IEC 60076-14

In order to offer OEM´s and transformer end customers more flexibilities in designing innovative transformers without losing a positive cost-benefit ratio out of sight, we have decided to go another step ahead and developed rigid and formable HYBRID INSULATION MATERIALS.

The new TUB.2.1 Pressboard parts are also produced in thicknesses and shapes according to the specific customer requirements / specifications and appropriate for designing the semi hybrid windings

The idea for this hybrid material is simple and smart at the same time and already well known for flexible insulation materials: combining materials of higher thermal properties with materials of conventional thermal properties in different compositions in order to create a part that represents the optimal technical and economical solution.

The material side, which is in direct contact with conductors, is made of pure NOMEX® 993 / 994 or NOMEX® paper of the thermal class: 180 °C.

The material side, which is not in contact with the conductors, is made of conventional PRESS BOARD, IEC 60641-3-1, of the thermal class: 105 °C.

This new product range produced of hybrid pressboard laminate is available as:

- 2-layer laminate = NOMEX® 993 / 994 + conventional PRESS BOARD pressboards

or as

- 3-layer laminate = NOMEX 993 / 994 + conventional PRESS BOARD + NOMEX 993 / 994 pressboards (sandwich system)
- Other combinations possible

The correct selection of 2- or 3-layer hybrid laminate depends on the application in the individual winding design.

This range of insulation parts included moulded parts, are produced according to customer / application requirements for designing **semi- / or mixed hybrid insulated windings.**

In addition, the range of our hybrid insulation parts has the charm that the basic materials, which are NOMEX® Pressboards or NOMEX® Papers and conventional PRESS BOARD, are used and approved by OEM´s for years in transformer applications. However, as the combination of these basic materials as laminate is new in the market, we have arranged several thermal ageing and dielectric tests in cooperation with the Schering Institute in Hannover, to be sure what kind of thickness is required for each layer depending on different temperature and voltages.

For current and forthcoming projects, we would be pleased to share these test results in technical cooperation with OEM transformer designers for the thermal evaluation process in a specific application.

Moulded parts for solid insulation materials of thermal class 120 °C in mineral oil as per IEC 60076-14

Another option in our new product group of parts for applications in liquid-filled transformers is based on a new generation of thermally upgraded cellulose board – named "TU B.2.1 Pressboard". The basic material of B.2.1 Pressboard is a cellulose transformer board, chemically treated with antioxidants in order to reduce the depolymerisation of cellulose in environments with elevated temperatures. With this technique, an increased thermal class of 120 °C in mineral oil can be achieved.

TU Pressboard parts are also produced in thicknesses and shapes according to the specific customer requirements / specifications and appropriate for designing the **semi hybrid windings.**

In this case, the basic material "TU Pressboard" is a new pressboard type in the transformer market that is based on a comparable treatment technology as the thermally upgraded cellulose paper

New products are available in all dimensions and thickness, required for designing full, semi or mixed hybrid insulated windings or for the construction of high-temperature insulation systems

(TUK). The use of these papers is already state of the art in transformers of thermal class 120 °C up to a thickness of 1.0 mm.

Nevertheless, this range of products has to pass OEM's complete technical pre-qualification processes for being used in winding designs. As further support for OEM´s and being meaningful to the main technical points in questions, we executed together with the Schering Institute in Hannover the following thermal ageing, dielectric and mechanical tests in the meanwhile.

For current and projects in the near future, we are always prepared to assist OEM transformer designers with these test results for realising the first individual **semi hybrid winding designs.**

Based on the presented 3 basic insulating material categories, we are able to produce a wide range of insulation parts, including moulded parts for designing high-temperature transformers in all temperature variations as per IEC standard. For providing you with a glimpse of the new product portfolio for moulded parts, please refer to below mentioned table and photos.

In general, the above mentioned new product range is available in all dimensions and thickness, which are required for designing **full, semi or mixed hybrid insulated windings, and further extend beyond that towards the construction of high-temperature insulation systems.**

Being a complete insulation system provider for all kind of hybrid winding designs, we complete our new range of products additionally as follows:

- Spacer, intermediate layer and all kind of spacer mats for all kind of high-temperature transformers are available.
- Adhesive-free clack-band for preparing cooling channels are available with:
  - Guided carrier band made of NOMEX – paper 410 = thermal class: 180 °C combined with:
    - blocks made of NOMEX pressboard 994 = thermal class:180 °C or
    - blocks made of PSP pressboard = thermal class: 105 °C

Additional products for an improved design of magnetic cores in power transformers:

- Pill carpets for preparing cooling channels. The structure of the pill carpet is as follows:
  - NOMEX paper 356 0.13 mm as carrier basis material.
  - ceramic pill glued on NOMEX paper in the height of 4 mm, 5 mm or 6.0 mm

	chimney segments / snouts / other moulded parts	cap - segments	edge protection	cylinder closed and open	cooling tapes	distance -spacer, intermediate layer	support rings	shield rings
pressboard B3.1.A thermal class: 105°C	✓	✓	✓	✓	✓	✓	✓	✓
TU B 2.1. pressboard, thermal class: 120°C in Oil	✓	✓	✓	✓	✓	✓	✓	✓
Hybrid laminate with PSP / Nomex 993/994 pressboards thermal classes: 105°C and 220°C	✓	✓	✓	✓	✓	✓	✓	✓
Nomex pressboards T993 / T993, thermal class: 220°C	✓	✓	✓	✓	✓	✓	✓	✓

Technical advantages compared to rigid laminates are:

- Reduced vibration and noise emission
- Reduced manufacturing cost / time
- Increased short–circuit strength

With the above variety of innovative formed parts, we create new conditions for designing the next generation of high-temperature transformers.

However, it is obvious that without modifications of the existing transformer specifications, it will be hard to develop further projects for these applications. Due to this, we intend to approach end customers such as utilities and industrial transformer owners in this next step for information about these new possibilities. Should you be interested in further information about our new products or like to develop technical cooperation with us, please feel free to contact us at any time.

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