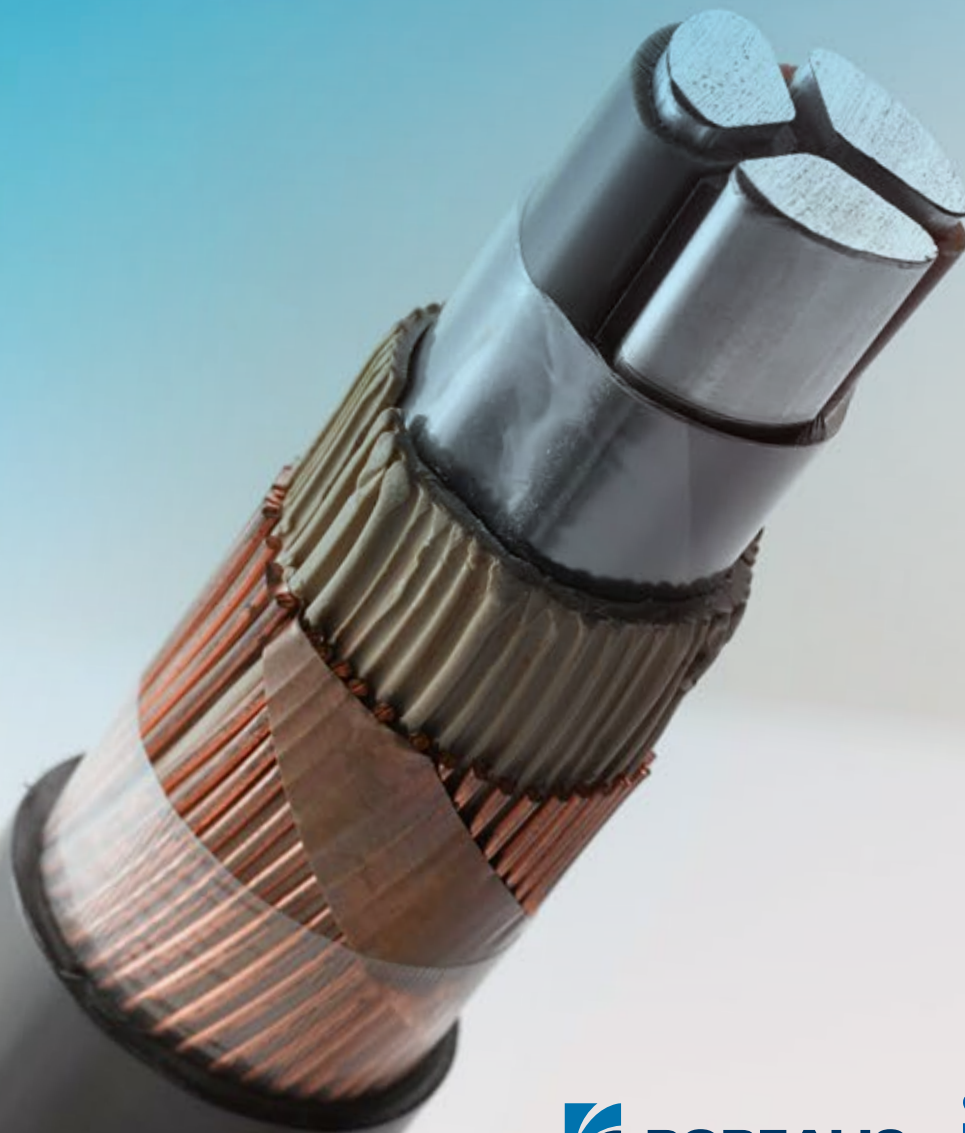

Visico™/Ambicat™ for cost effective production of high performance Low Voltage cables



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Low voltage overhead covered aluminum conductor



Low Voltage energy cable with sector shaped solid aluminium conductors

Insulation for Low Voltage cables

Quality of manufacturing is essential to the in-service reliability of energy cable insulation systems. Key is to select the material and manufacturing technique best suited to the applications to be served and which can deliver the required performance cost effectively.

For Low Voltage cable, crosslinked polyethylene (XLPE) offers significant advantages and is the pre-eminent choice for insulation. The intrinsic properties of XLPE make cable design, manufacturing, installation and operation highly cost effective. Its high temperature rating, which provides the capability to accept a temporary network overload without cable damage, good mechanical properties also

at low temperatures, good stress cracking and chemical resistance is complemented by low weight and cost effective cable manufacturing. In addition, the material's proven long life and high reliability in service is driving the selection of Low Voltage cable insulation from PVC to XLPE.

Today, moisture curable XLPE has become the material of choice for the vast majority of XLPE insulated Low Voltage cables and with the development of its proprietary Visico/Ambicat insulation system, Borealis and Borouge have taken the lead in assisting cable makers towards cost effective production of high performance Low Voltage cables.

State-of-the-art insulation technology

Visico/Ambicat is an ethylene (vinylsilane) copolymer-based system for moisture crosslinking. Used worldwide for the production of cables, pipes, films, injection moulded articles and floor coverings, its main application is as insulation for 1 kV underground, industrial and overhead cables. Other important insulation applications in which it finds a fit are mains, telephone and automotive wires, as well as track resistant floor heating and fire safety cables.

Developed with the clear objective of decreasing the overall complexity and cost of producing high quality Low Voltage cables, Visico/Ambicat is a state-of-the-art insulation system that brings significant cable making benefits. The Visico/Ambicat system is designed to eliminate common production line problems and interruptions and provide a faster, longer running process from conductor to finished cable.

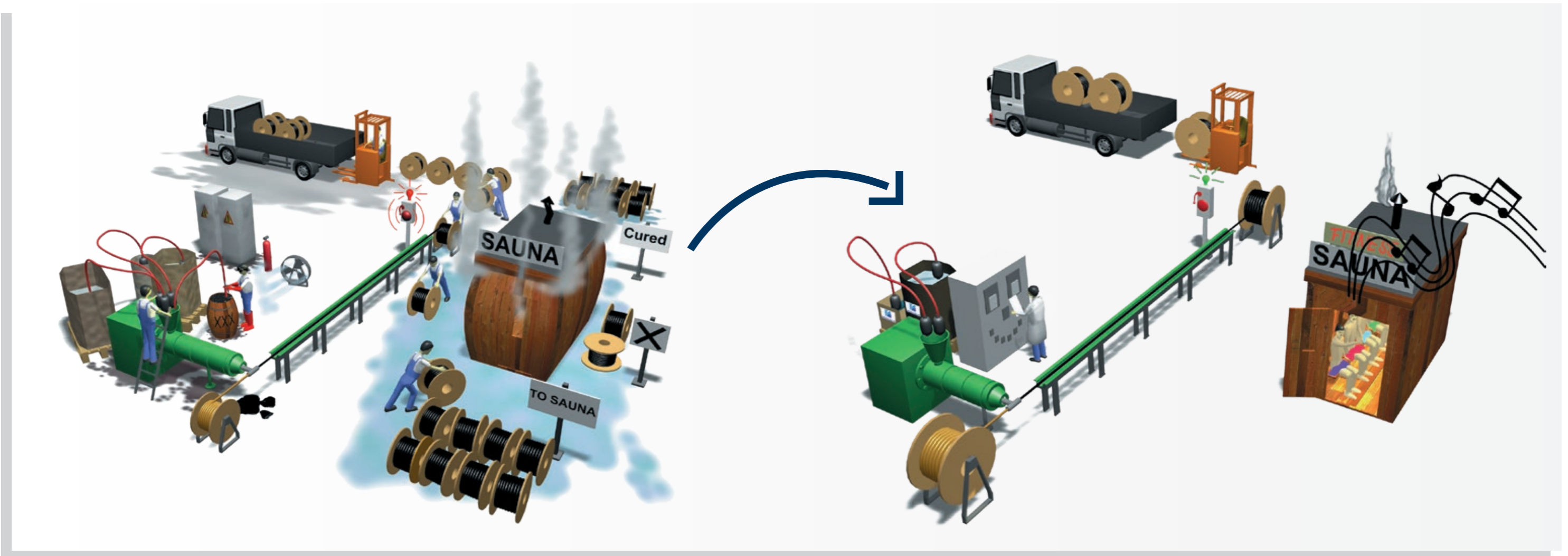


Figure 1: Visico/Ambicat on the shop floor Visico/Ambicat reduces complexity in cable manufacturing

Advanced moisture crosslinking system

Whereas traditional moisture crosslinking methods such as Sioplas and Monosil require chemical grafting of the silane onto the polymer chain, the Visico/Ambicat system builds on silane copolymer technology in which the silane is introduced into the polymer chain as the polymer is produced in the reactor.

The development of a material system based on this technology was a breakthrough that resulted in solutions whereby standard PE extruders as well as PVC extruders could be used, where storage stability could be improved to a level of only insignificant restrictions and where the overall cost structure was clearly enhanced.

Also of importance was the possibility to control the quality of the silane copolymer before it is transferred

to the extrusion process. This is a major improvement compared to the Monosil process where final quality, resulting from the grafting process, is possible to control only after the cable core is made.

The speed of crosslinking is governed by the efficiency of the catalyst, temperature and moisture diffusion. In earlier techniques the crosslinking step is made by exposing a cable to high temperature and moisture. This is achieved by storing the cable core reels in special chambers or saunas, until completion of the crosslinking reaction.

The most recent development of catalyst technology makes it possible to carry out the crosslinking process at ambient conditions without the need for saunas. This solution is called Ambicat (Ambient cure catalyst).

Another limitation of earlier techniques was the propensity for the premature crosslinking (scorching) of material in the cable extruder. This limited effective production time by necessitating frequent stops for extruder cleaning, thus reducing productivity and increasing costs.

The problem of scorching, which can lead to cable defects, has been solved by Borealis by including a special scorch retardant technology in the Visico/Ambicat system, thereby making it possible to significantly extend extrusion process time.

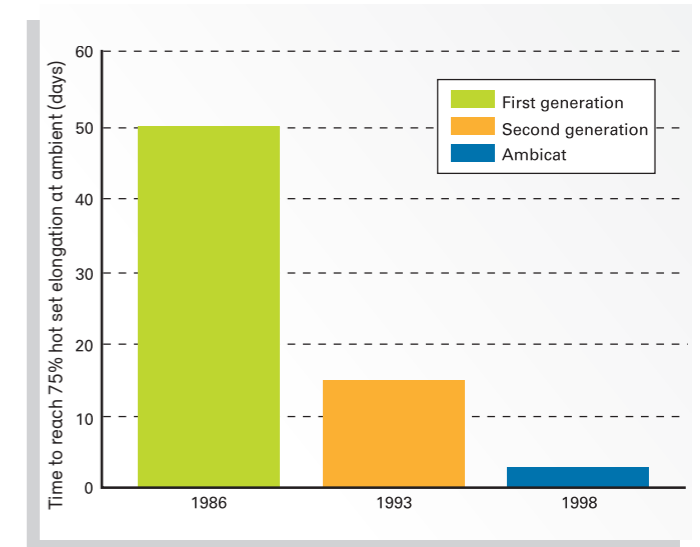
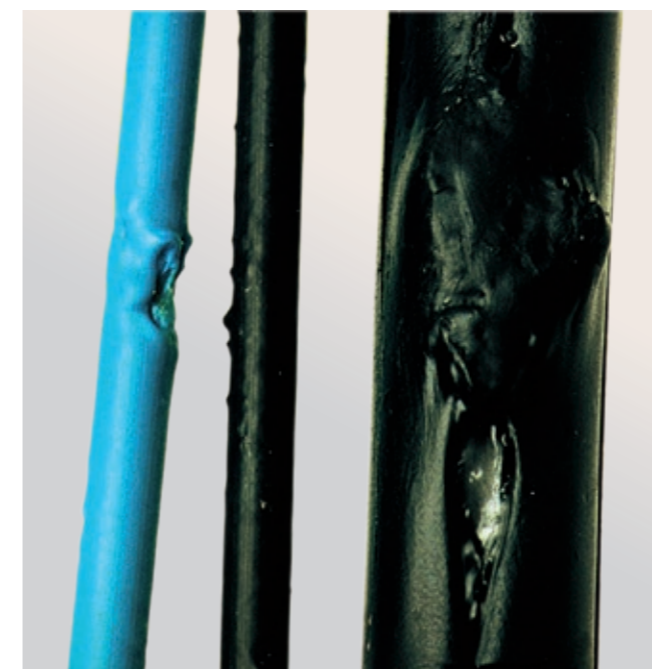


Figure 2: Development of Visico curing rate (Tape 1.8 mm thickness)



Visico mains cable



Scorch defects in cables



Visico insulated low voltage cable with HFFR bedding and sheathing compound

Visico™/Ambicat™ – a cost effective ‘total solution’

Visico™ and Ambicat™ bring a unique combination of benefits in cable production.

Higher productivity or reduction of working capital

Because the silane is already incorporated in the polymer system, Visico can typically be processed with substantially increased output on a cable extruder than, for example, Monosil. The inclusion of a scorch retardant additive allows continuous production for up to one month without the need to stop the run for extruder cleaning. This leads to significantly higher productivity, which reduces the fixed cost per produced length of cable and gives the opportunity to fulfil more orders when production unit capacity would otherwise be constrained – alternatively it allows for more tool changes. This enables the cable maker to produce smaller batches which can lead to reduction of working capital.

The Ambicat catalyst facilitates curing of the cables at room temperature without the need of water bath or sauna. Hence, the crosslinking step no longer adds time to the production process. With optimised production set-up, cable cores can even be jacketed directly after insulation extrusion and still achieve the necessary crosslinking.

Reduced downtime and less scrap

As the system includes an effective scorch retardant system, the extruder and screw can be run significantly longer without the need for cleaning. Even stops for tool change or change of colour are problem-free and bleeding of material can be avoided. Moreover, the feeding of the material system into the cable extruder is easy and high quality is obtained with minimum scrap at line start up. Waste and downtime are therefore minimised, making an important contribution to reduced costs and increased overall output.

More reliable cable quality

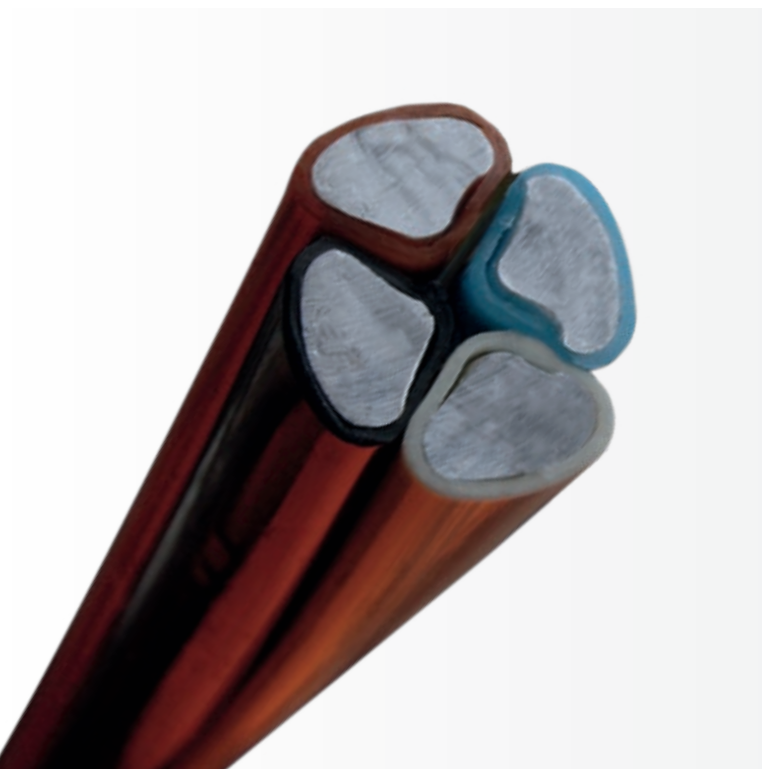
The manufacturing of Visico and Ambicat in large-scale production units secures robust and consistent processing performance. The system is delivered fully quality controlled according to strict specifications and its excellent storage stability does not require additional quality checks before use.

Greater simplicity

As only two components, which are in pellet form, have to be stored and handled, logistics are simplified and related potential errors minimised. Furthermore, as only these two components have to be fed into the extruder, minimum manpower is needed to operate and monitor the extrusion process.

No extra investment

Visico/Ambicat can be run on a variety of standard extruders. No investments in special extruders are necessary and, for example, it is possible to replace PVC with Visico/Ambicat using existing machinery.



Low voltage energy cable

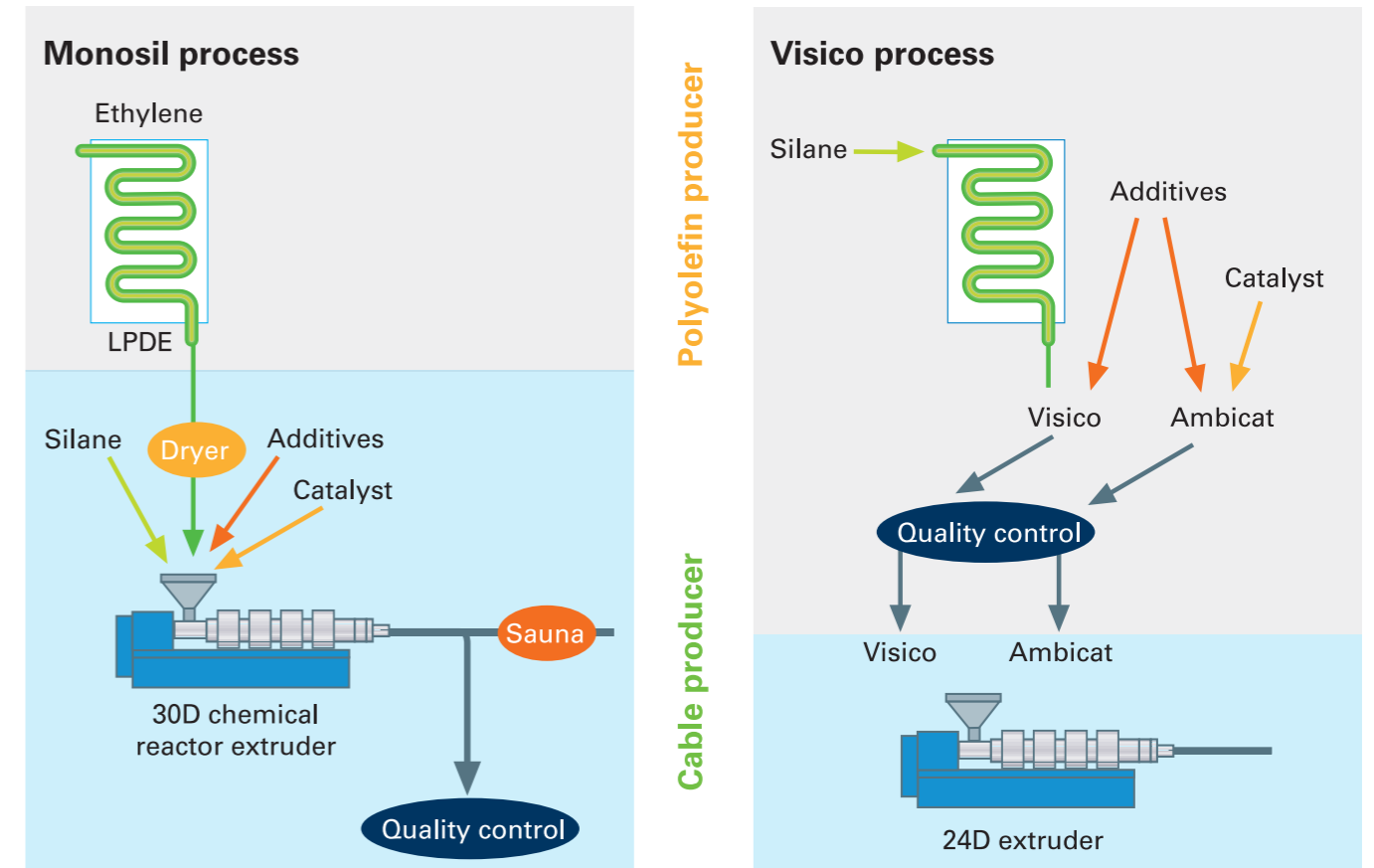


Figure 3: Quality control

Confidence through experience

With the industry’s focus on achieving the optimum balance between cost and high reliability of installed Low Voltage networks, Visico/Ambicat technology is well recognised as a state-of-the-art material system that delivers productivity and performance benefits for Low Voltage cable producers and end users.

Low environmental impact

The physical handling of Visico/Ambicat is easy and safe. All components are incorporated in the pellets and therefore there are no flammable liquids or harmful additives to be handled. The catalyst, based on organic acid, is environmentally friendly unlike traditional tin organic technology. Moreover, because neither predrying of the pellets nor crosslinking at elevated temperatures is required, the resulting energy saving helps in further reducing the environmental burden.

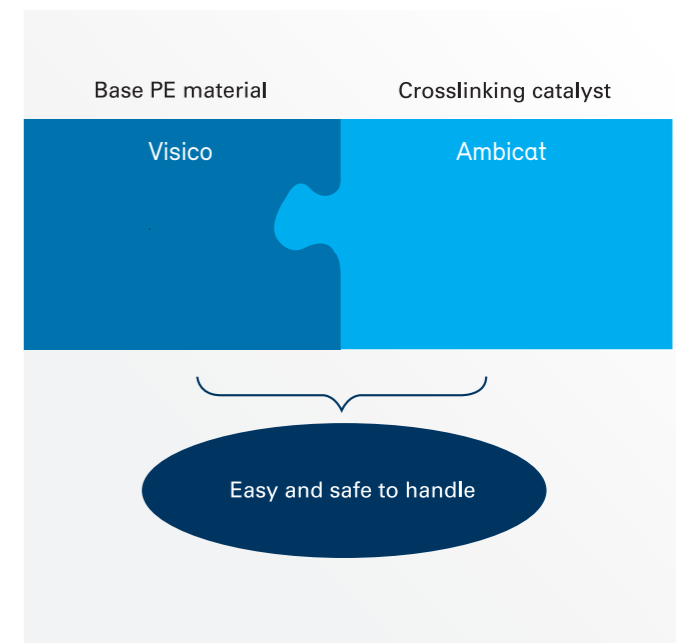


Figure 4: Visico/Ambicat simplicity

Material systems for Low Voltage cables

The Visico/Ambicat product portfolio is based on Visico base polymers and the Ambicat catalyst masterbatches that contain additives for proper thermal stability, as well as carbon black for UV protection. Depending on specification requirements the addition of catalyst masterbatches ranges from 5% to 9%.

Base polymer	Visico™ LE4423 Natural Low Density Visico™ LE4427 Black Low Density Visico™ LE4421 Natural Low Density Visico™ ME4425 Natural Medium Density
Catalyst Masterbatch	Ambicat™ LE4476 Natural Ambicat™ LE4472 Black

Table 1: Material systems for LV cables

A technical overview of Visico™/Ambicat™

Storage stability

The Ambicat catalyst masterbatches can be stored in unopened original packaging for up to 15 months and Visico 18 months at 10–30°C, without deterioration of material quality, after production. As both Visico and Ambicat are sensitive to moisture, they are delivered with low moisture content, ready to be used. Pre-drying should not be carried out as it will destroy the drying agent that has been added to prevent the material from absorbing moisture.

An opened bag of Ambicat catalyst master batch must be used within one week and it is recommended to reseal bags between uses.

Extrusion

Processing Visico is similar to processing conventional thermoplastic polyethylene with a similar viscosity. The only difference is that the catalyst must be added. Conventional polyethylene or PVC extruders can be used.



Adjustment of extruder die

Visico can be processed across a wide range of temperature settings. For appropriate mixing and homogenisation of the melt a flat temperature setting of 165–170°C is recommended, without screw cooling, for most types of extruders.

For special extruders with limited homogenisation properties, including short extruders such as L/D =18 and screws with low compression, an 80–100 mesh filter is recommended. Poor homogenisation will result in a melt without viscous elasticity and cables with irregular shaped lumps distributed throughout the insulation.

Visico/Ambicat contains a scorch retardant additive, which makes continuous processing possible for periods of up to one month without scorch defects in the insulation. Flame is not needed, as the die drool build-up is very small.

Extrusion temperature sensitivity is indicated in Figure 5, where the drop in viscosity as a function of the extruder exit temperature is compared with the corresponding sensitivity of grafted materials.

The Visico/Ambicat system shows virtually no viscosity changes. Even when extruded at very high temperatures it behaves more like thermoplastic material. Furthermore, Visico/Ambicat is markedly insensitive to residence time, as shown in Figure 6. This material characteristic allows for frequent stops and starts for tool changes or other production interruptions.

Orientation

As silane crosslinking takes place below melting temperature, stresses frozen into the insulation may remain and result in poor mechanical properties. It is even possible that breakage of fully crosslinked samples might occur during the hot set test. These stresses can be minimised by preheating the conductor (typically 80°C – 100°C) as this considerably improves mechanical properties. In the absence of preheating possibilities, the use of tube-on die and, preferably, a hot water cooling bath usually lead to improved mechanical properties. In practice the effect of orientation on mechanical properties is much greater for smaller cables.

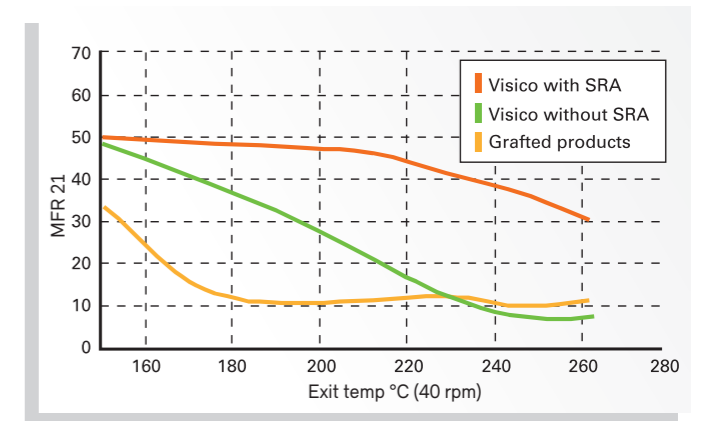


Figure 5: MFR evolution as function of extrusion temperature – indication of scorch sensitivity

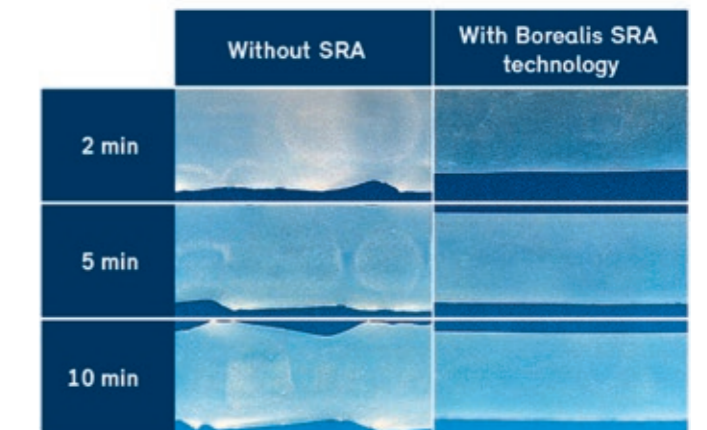


Figure 6: Effect of scorch retardant additive at extruder stop and start Tape extrusion experiment Melt temperature 200°C

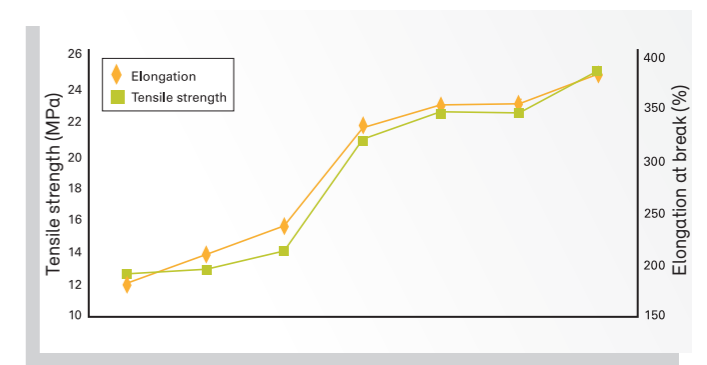


Figure 7: Effect of conductor preheating on mechanical properties, Visico LE4423 + 5% Ambicat LE4476

Crosslinking

Crosslinking takes place when the cables are subjected to moisture in a separate processing step. The conventional method is to cure cable reels in saunas or hot water baths. However, with the Visico/Ambicat system curing at ambient conditions is feasible.

Time needed to cure the complete cross section of insulation is dependent on the following factors:

- Catalyst activity
- Relative humidity
- Temperature
- Insulation thickness
- Reel size

Tables 2–4 illustrate the effect of humidity, temperature and insulation thickness. Crosslinking is expressed as hot

set elongation according to IEC 60811-507 (200°C, 0.2 MPa) where 100% elongation is taken as the comparative value as this level typically is the maximum acceptable in industrial production.

Also shown in tables 2–4 is that Ambicat makes it possible to crosslink Visico within a realistic timeframe, even under ambient conditions. Take up of the cables on the reel while wet and warm dramatically increases crosslinking speed and reduces lead time. A practical way to add water to cable cores is to wet the surface by spraying it as a thin mist over the reel during take-up. To prevent drying of the wet cable surface, stretch film can be wrapped around the reel before crosslinking storage.

With good control of the manufacturing process, the jacketing step can be undertaken without storage of the cores for crosslinking, provided they have been exposed to a minute amount of water in advance. In this case the crosslinking of the cores will take place under the jacket.

Relative humidity (%)	Temperature (°C)	Tin catalyst Time to reach 100% hot set (days)	Ambicat catalyst Time to reach 100% hot set (days)
35	23	22	3.5
50	23	10	2.5
100	23	8.5	2.5

Table 2: Effect of humidity on crosslinking speed (1 mm² conductor, 0.9 mm insulation thickness)

Relative humidity (%)	Temperature (°C)	Ambicat catalyst Time to reach 100% hot set (days)
100	23	3.0
100	60	0.12 (3 hours)
100	85	0.06 (1.5 hours)

Table 3: Effect of temperature on crosslinking speed (1.5 mm² conductor, 0.9 mm insulation)

Relative humidity (%)	Temperature (°C)	Insulation thickness (mm)	Ambicat catalyst Time to reach 100% hot set (days)
50	23	0.7	1
50	23	0.9	2
50	23	1.8	7

Table 4: Effect of insulation thickness on crosslinking speed (1.5 mm² conductor)

Precaution for quality control – ageing

Cable standards typically specify a maximum change of mechanical properties (tensile strength and elongation) after the ageing of specimens in an oven at elevated temperature.

As Visico/Ambicat insulated cores require time to crosslink, it must be ensured that the correct degree of crosslinking has been achieved before the ageing test is started. If not, the results after ageing will reflect both change in crosslinking level and thermal ageing combined and will therefore be incorrect.

To ensure correct sample preparation, it is recommended that specimens are preconditioned at 70°C/24 hours according to IEC60811-501. A hot set value below 70% or elongation below 350% before starting oven ageing will, in general, give results that meet standard specifications i.e. a 25% maximum change in mechanical properties after ageing.



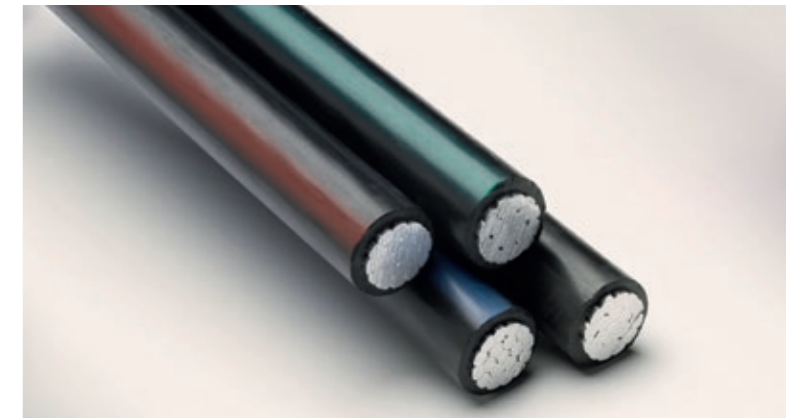
Tensile testing

Visico™/Ambicat™ summarised

Visico/Ambicat is a cost effective solution that delivers:

- Easy processing
- No die drool
- Scorch resistance
- Ambient curing
- Consistent quality
- Tin-free system

to provide higher throughput at a lower cost in Low Voltage cable insulation production.



Low voltage energy cable with solid sector shaped aluminum conductors

Borealis and Borouge – Dedicated to Wire & Cable Solutions

Borealis and Borouge are the world's leading providers of innovative, value creating plastics solutions for the wire and cable industry. Our solutions are customer-driven and designed to satisfy the industry's continuously evolving demands for higher technical performance. Consequently, they can be found in the most challenging EHV and HV cable applications, as well as MV and LV energy transmission and distribution cables, building wires, and communications cables.

In answer to the need for production, installation and cable-system lifetime enhancements, we create the innovation links that secure world-class, step-change solutions and benefit the whole wire and cable value chain. Through the introduction of unique polymer technologies, which include Borlink™, Visico™/Ambicat™, Borstar®, and Casico™, we continue to pioneer the development of advanced insulation and jacketing systems for both energy and communication cables.

Built on more than 50 years experience, Borealis and Borouge have a well-established track record in serving customers' needs with the consistently high quality products expected of global leaders. We are committed to extending that leadership position and our role as reliable partners for the long-term – a commitment not only supported by our forward thinking in innovative solutions, but also confirmed by ongoing investments for our customers' continued success.

Through ongoing research and development, investment in the future and a dedicated team with solid industry knowledge, we aim to remain fully responsive to our customers' needs throughout the world.

Bringing energy all around | Date of issue: March 2019

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Borealis and Borouge aim to proactively benefit society by taking on real societal challenges and offering real solutions. Both companies are committed to the principles of Responsible Care®, an initiative to improve safety performance within the chemical industry, and work to solve the world's water and sanitation challenges through product innovation and their Water for the World programme.

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