Borlink™ compounds for Extra High Voltage cables

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Contents

The leading compound supplier for EHV AC

Crosslinked polyethylene (XLPE) was first introduced for the insulation of power cables in the 1960s. Since then XLPE cables have become the industry standard for voltages up to 525 kV. The excellent electrical properties, easy installation, minimal maintenance, low dielectric losses and low environmental impact of XLPE cables are the primary reasons for the continuing growth in their adoption by electricity transmission system operators and distributors worldwide. In close co-operation with the cable industry globally, Borealis has been at the forefront of XLPE development. Superclean XLPE insulation was first introduced in 1973 for the first XLPE 84 kV submarine cable – 56 km long – connecting the Swedish mainland with the Finnish island of Åland. Further progress came with the introduction of Supersmooth semicon compound LE0500 in 1984, which permitted cable operation at even higher field strengths.

As XLPE cables advanced to Extra High Voltage (> 220 kV) applications, Borealis put in place many research and production technology initiatives to support cable development. Working in partnership with customers and targeting developments that directly respond to their needs, Borealis has established its Borlink technology for the production and supply of compounds that enable the manufacture of high stress XLPE cables. As a result, Borealis has become the leading supplier of compounds to the largest EHV projects in the world. By establishing the Borlink™ technology, Borealis and Borouge have elevated their total network of support to a new level by helping to facilitate the linking of different grids and energy sources together both regionally and globally.

Reference Projects – Proven Borlink EHV Track Record

Project name	Voltage (kV)	Cable length (km)	Entered in service
PUB, Russia	220	168	1995
Powergrid, Singapore	245	58	1997
Copenhagen 1&2, Denmark	400	108	1997 & 1999
Berlin 1&2, Germany	400	63	1998 & 2000
Dublin, Ireland	220	40	2000
Dachaoshan, China	525	7	2001
Taiwan	345	64	2003
Seoul, South Korea	345	66	2003
London Project, UK	400	60	2004
Madrid Airport, Spain	400	90	2004
Rotterdam, The Netherlands	400	12	2005
Zhengzhou City, China	220	8	2005
Bureyskaya, Russia	500	2.5	2005
Vienna, Austria	380	32	2006
Milan, Italy	400	13	2006
Istanbul, Turkey	380	27.9	2008
Porce III Columbia	500	5.4	2010
Tamil Nadu, Chennai India	230	135	2010
Changjiang Tunnel-Bridge China	220	132	2010
Beddington tunnel, UK	400	30	2011
Anholt wind farm submarine, Denmark	245	75	2012
BEC submarine connection, NJ – NY, US	345	34.4	2012
Little Belt, Denmark	420	48	2013
Bejing, China	500	40	2014
Dardanelles I, Turkey	380	24	2015
Chino Hills, US	500	24	2017

230 kV Chennai power distribution – India

The Tamil Nadu Electricity Board ordered the turnkey project of a supply of 230 kV cable 1,200 mm² miliken conductor, accessories and supervision of laying the cable in the busiest centre of the city of Chennai. CCI faced two key challenges. First, the manufacture of 135 km of EHV cable, which is a significant production volume, and second, the installation of the power line in the middle of a busy city.

CCI considered that MDCV technology provided the most reliable production process for EHV cables. And, based on long experience and confidence in Borouge's high purity products for high voltage applications, CCI chose Superclean XLPE for conductor insulation and Supersmooth XLPE for the semiconductive screen.

Summary table

Customer Name	Tamil Nadu Electricity Board, Chennai, India
Contractor and cable producer	Cable Corporation of India
Application	– Cable materials for EHV power supply – Voltage: 230 kV – Cable length: 135 km – Conductor size: (Al) 1,200 mm – Milliken construction – Insulation thickness: 27 mm – Cable weight: 15,000 kg/km – Classification: A2XLy2Y 1x1200 RM/VS
PE materials used	– Superclean LE4244 EHV XLPE insulation compound – Supersmooth LE0592S XLPE semiconductive screen compound – LE7710 semiconductive screen compound
Functional requirements	– Consistent Extra High Voltage performance and long-term reliability – Reliable high performance working life as Superclean compound for extra high voltage excludes contaminants above 100 microns and controls those below 70 microns
Benefits	– Minimised electrical stresses and therefore consistently stable power flow due to the very smooth interface of Supersmooth with the insulation

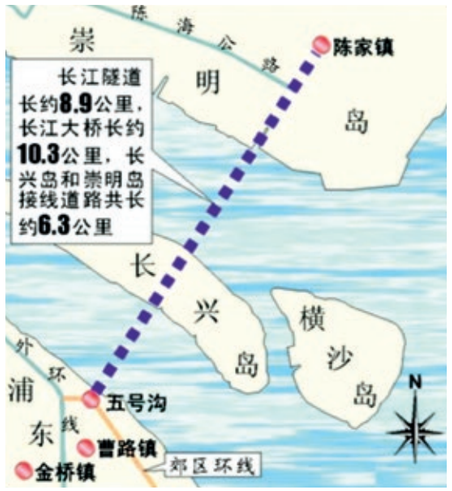
As of 2013, Supercure, Superclean and Supersmooth have become a part of the Borlink™ technology.

220 kV Fujikura Shanghai cable project – China

The "Shanghai-Chongming-Jiangsu" Changjiang Tunnel-Bridge Project is an integral part of the Shanghai-Xi'an connection in China's key highway construction plan. It is a world-class cross-river project at the estuary of the Changjiang River after the Sutong Bridge project.

For the 220 kV Chongming network under this project, two loops of 220 kV cable lines were laid from Zhouhai Station in Pudong via Changxing Island to Chenjiazhen Station in Chongming Island. Breaking points were set up on Changxing Island and the 220 kV Changxing Substation was incorporated into the ring. More than 400 km of 220 kV cables were used for this project (the total length of 110 kV cables used in the Yangshan Project was merely 280 km). These were divided into 62 sections and included 744 phase connections, as well as big and small off-set (retractable cable) devices at 40 locations. The project was completed at the end of year 2009.

Fujikura Shanghai Cable Ltd eventually selected the ultra-clean insulation material, Superclean LE4201S, and ultra-smooth shielding material, Supersmooth LE0500, manufactured by Borealis as the raw materials for this project.



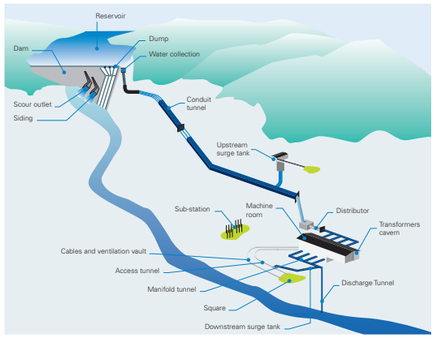
Fujikura Shanghai Cable project

Name of Project	Shanghai-Chongming-Jiangsu Changjiang Tunnel-Bridge 220 kV Cable Project
Length of Cable	>132 km
Conductor Dimensions	– 800/1,000/1,200 mm²
Materials used	– Ultra-clean insulation material Superclean LE4201S – Ultra-smooth shielding material Supersmooth LE0500
Advantages	– The stringent impurity control process ensures a high degree of cleanliness in the materials to ensure long-term reliability of the cables. – The ultra-smooth shielding material ensures a smooth interface between the conductor and insulator to reduce stress concentration and ensure a smooth supply of power

500 kV XLPE Porce III – Columbia

As part of the planned expansion of Columbia's interconnected electrical power system, the Porce III is the latest hydroelectric project and is at an advanced stage of construction. The power plant, with its capacity of 660 MW, came on stream in September 2011 and generates approximately 3600 GWh/year.

Manufactured by Südkabel, the power cable for the Porce III project is based upon Borealis' Superclean LE4224EHV insulation, Supersmooth LE0500 semi-conductive compound and Borealis Borstar® HE6062 sheathing. These XLPE materials are type tested for 500 kV cable, including a one-year pre-qualification test according to the IEC 62067 standard.



Summary table

Customer	Südkabel, Mannheim, Germany
Application	Cable materials for EHV power supply Voltage: 500 kV Cable length: 5.4 km Conductor size: 800 mm² Classification: A2XS(FL)2Y1x800 RM/150 290/500 kV
PE Materials used	Borealis Superclean LE4244EHV XLPE insulation Borealis Supersmooth LE0500 semiconductive shielding Borealis Borstar® HE6062 jacketing
Functional Requirements	Consistent Extra High Voltage performance and long-term reliability
Benefits	– Borealis Superclean compound for extra high voltage excludes contaminants > 100 microns and controls those <70 microns. This gives assured high levels of cleanliness and, therefore, reliable long-term performance. Borealis Supersmooth compound provides a very smooth interface between shielding and insulation to minimise electrical stresses and ensure consistently stable powerflow. – Borstar® HDPE delivers good long-term abrasion and stress crack resistance, together with good barrier properties

As of 2013, Supercure, Superclean and Supersmooth have become a part of the Borlink™ technology.

380 kV EHV power link – Turkey

The restructuring of the Turkish electricity Power Sector in early 2000 saw the establishment of The Turkish Electricity Transmission Corporation (TEIAŞ). At that time TEIAŞ was charged with the task of developing transmission capacity to enable the reliable bulk supply of electricity to suppliers and consumers in a timely, safe and environmentally friendly manner. A key project in its overall planning to upgrade the Turkish national transmission grid, is the strengthening of the electrical transmission network between the urban centres of Istanbul and Izmit.

Known as the TEIAŞ Davutpasa-Yildiztepe project, the network improvement requires the underground installation of three 380 kV XLPE power cables between two newly constructed gas insulated substations (GIS), one each in Istanbul and Izmit, over a distance of 9,304 meters. While most of the cable route follows existing municipal roads, one 300-meter section crosses the Golden Horn estuary which separates the historical from the modern part of Istanbul.

Deminer project

Project name	TEIAŞ Davutpaşa-Yildiztepe 380 kV underground cable
Customer	The Turkish Electricity Transmission Corporation (TEIAŞ)
Application	Demirer Kablo
PE Materials used	– Cable materials for EHV power supply – Insulation thickness: 27 mm – Diameter of cable: 142 mm – Conductor type: copper, milliken – Jacketing: Borstar® HE6062 – Voltage: 380 kV – Total cable length: 27,912 m – Weight of cable: 46,960 kg/km – Conductor size: 2,000 mm²
Functional Requirements	– Superclean LE4201EHV, crosslinkable, low-density polyethylene insulation compound – Supersmooth LE0500, crosslinkable, semiconductive shielding compound – Borstar® HE6062, tough, low shrink jacketing
Benefits	Consistent Extra High Voltage performance and long-term reliability
Benefits	– Borealis Superclean compound for extra high voltage excludes contaminants >100 microns and controls those <70 microns. This assures the high level of cleanliness necessary for reliable long-term performance – Supersmooth compound provides a very smooth interface between shielding and insulation to minimise electrical stresses and ensure consistent, stable power flow

Project layout for Deminer power station


Golden horn

Dachaoshan 525 kV XLPE cable project – China

The Dachaoshan Dam is located on the Lancang River in China's Yunnan Province. Its six Francis turbine-generator units develop 1359 MW and this power is taken to the grid by six 525 kV and 220 kV XLPE cables. The performance of the 525 kV XLPE cables was assured by the successful completion of a stringent test programme.


Cables installed in the power station

Connection, technical data, the "Dachaoshan project"

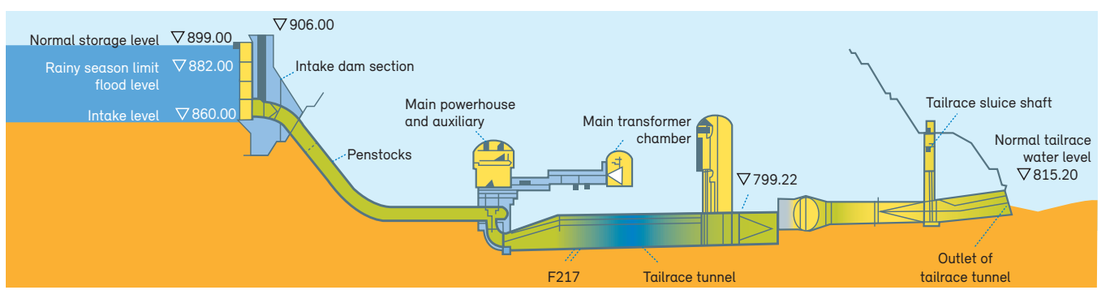
Length	Duration	Voltage	Load cycles	Conductor temperature	Switching impulse	Lightning impulse
100 m	1 year (16.10.1999 – 01.12.2000)	1.7 Uo (500 kV)	>180	90°C	+/- 1,175 kV	+/- 1,550 kV


By courtesy of ABB, Sweden

Cable installation

Technical data, the "Dachaoshan project"

Technical data	
Length of connection	400 m
Total core length	7,200 m
Conductor	800 mm²



Project layout for Dachaoshan power station

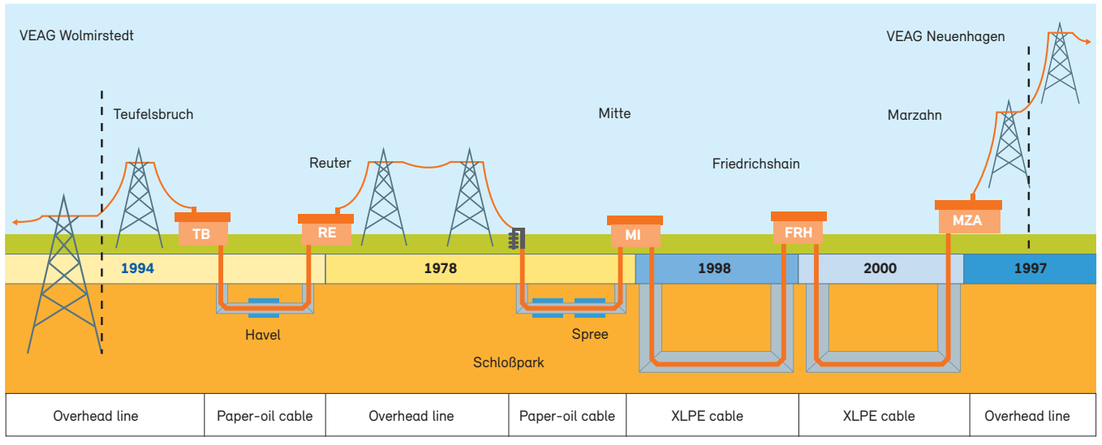
BEWAG 400 kV connection – Berlin

To ensure Berlin's power supply, BEWAG (Berliner Kraft und Licht AG, now Vattenfall Europe) built a 400 kV connection joining the power networks in the west and east of the city.

In late 1993 BEWAG started an extensive qualification programme of 400 kV XLPE insulated cables. The tests followed the recommendation of CIGRE Working Group 21.03. for pre-qualification of XLPE cables with voltages of > 150 (170) and ≤ 400 (420) kV.

Connection, technical data, the "BEWAG Project"

Connection technical data	Part I	Part II
Length of connection	6.5 km	4 km
Total cable core length	39 km	24 km
Conductor	Cu 1,600 mm²	Cu 1,600 mm²



Configuration of the different elements of the BEWAG 400 kV connection in Berlin.

500 kV XLPE power cable project – Russia

The Bureyskaya hydroelectric power station, which is operated by the Russian General Energy System (GES), lies at the 'other end of the world' in the Amur region of Russia's far east. This location provides a highly challenging environment in which the temperatures in summer can reach 40°C and in winter drop to -57°C.

Installed as part of the Bureyskaya power stations third and fourth phases of expansion, the 880 m long 500 kV XLPE High Voltage cable supplied by Südkabel GmbH of Mannheim, Germany, has now been in continuous operation for about two years. This is the first 500 kV XLPE cable connection to be used in Russia. Construction of its supporting steel structure took three weeks and actual cable construction and installation 12 weeks.

"The Südkabel, Germany project"

Summary table

Customer	Südkabel, Mannheim, Germany
Application	Cable materials for HV power supply Voltage: 500 kV Cable length: 2.5 km Conductor size: 800 mm²
PE materials used	Borealis Superclean LE4244EHV, crosslinkable, low-density polyethylene insulation compound Borealis Supersmooth LE0591 crosslinkable, semiconductive shielding compound
Functional requirements	Consistent High Voltage performance and long-term reliability
Benefits	– Borealis Superclean compound for extra high voltage excludes contaminants > 100 microns and controls those < 70 microns. This gives assured high levels of cleanliness and, therefore, reliable long-term performance – Borealis Supersmooth compound provides a very smooth interface between shielding and insulation to minimise electrical stresses and ensure consistently stable power flow

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New 400 kV EHV power grid – Kuwait

The project's key objectives were to provide an underground power grid that would deliver the highest transmission performance with maximum reliability over a long working life.

To satisfy all the specifications set by the Kuwait Ministry of Electricity and Water, Taihan developed an innovative cable solution. This comprised a 2,500 mm^2 cable with enamelled wires, complemented by Superclean LE4201 EHV XLPE insulation compound and Supersmooth LE0500 XLPE semiconductive shielding compound from Borouge and Borealis, and specifically designed for EHV applications.

Taihand Electric Wire Co, Anyang plant

Cable route of 400 kV Kuwait project

Summary table

Customer	Kuwait Ministry of Electricity and Water
Cable producer	Taihan Electric Wire Co Ltd
Application	– Extra high voltage cable – Voltage: 400 kV – Cable length: 85.2 km – Insulation thickness: 27 mm – Cable diameter: 166 mm
PE material used	– Superclean LE4201 EHV XLPE insulation compound – Supersmooth LE0500 semiconductive shielding compound
Functional requirements	– Long-term cable integrity to give the assurance of uninterrupted EHV power supply over an extended, maintenance-free working life

World's longest 345 kV AC submarine cable system – US

Bayonne Energy Center (BEC) is a new high efficiency natural gas power plant located in Bayonne, New Jersey. Built on an old industrial site on the shore of New York Harbour, the plant is strategically located close to the New York City boroughs of Staten Island, Brooklyn and Manhattan.

The power generated by the Bayonne Energy Center is fed into the New York City power transmission network at Con Edison's 345 kV Gowanus substation in Brooklyn via a submarine XLPE cable system, which crosses New York Harbor just south of Ellis Island and the Statue of Liberty. As a leading manufacturer, ABB was selected to provide the three 6.5 mile (10.4 km) single-core submarine XLPE cables, three 900 foot (274 m) underground XLPE cables and three 2,600 foot (792 m) underground XLPE cables that would make the energy transmission possible. The work at the landfall sites included construction of in-water cofferdams and horizontal directional drilling (HDD) in Brooklyn. The construction work at the landing sites and the laying of the cables were performed by a local New Jersey based firm (Caldwell Marine International) under a subcontract with ABB. The submarine cables were buried at a record depth (4.6 m below bottom sediment), and in addition, BEC required that each be extruded in a single continuous length without any factory joints.

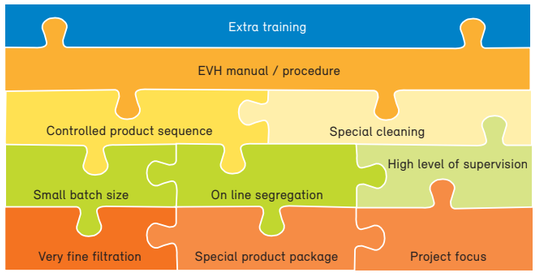
Summary table

Name of Project	Bayonne Energy Centre Project
Customer	BEC
Cable producer	ABB AB
Application	– Extra high voltage cable – Voltage: 345 kV – Cable length: 3 x 10.4 km submarine single-core 3 x 274 m underground cable 3 x 792 m underground cable
PE material used	– Borlink™ LE4201 EHV XLPE insulation compound – Borlink™ LE0500 semiconductive shielding compound – Borstar® HE6062 jacketing compound
Functional requirements	High purity level to be manintained throughout the whole production to the point of delivery

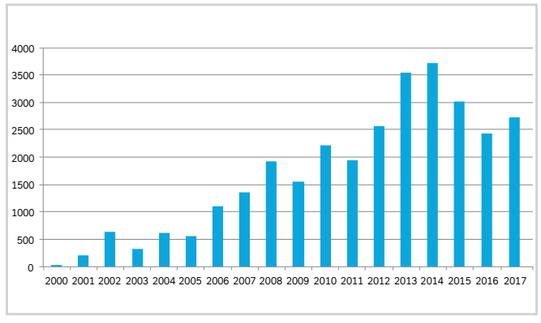
Borlink™ Technology for EHV compounds

The experience gained from many groundbreaking projects has shown that the only way to ensure the provision of XLPE materials of consistently high standard is to employ the Borlink™ technology dedicated EHV production. With all Borlink EHV insulations and semicons produced and packed on dedicated lines specifically designed for their manufacture; the Borlink EHV concept is significantly enhanced above that used to manufacture High Voltage (HV) materials. The improvements include:

- Closed loop production process of XLPE to ensure a minimisation of contaminants
- Tighter control of extrusion and process parameters throughout the whole production chain
- Lower likelihood (> 5 times lower) of contamination occurring in the insulation
- Smaller contaminants and pips being excluded and controlled
- Less chance (> 10 times less) of pips in the semicon
- Higher chemical cleanliness and smoothness of semicons



Additional technology elements integrated into the Borealis Borlink EHV concept.



Estimated EHV AC Cable km installed globally

Together with the correct cable design and manufacturing care, high-quality, clean XLPE compounds make or break cable system reliability.

Contaminants reduce the insulation performance and increase the risk of system failure. That's why Borlink Superclean XLPE compounds are produced in a dedicated clean closed loop production system to ensure a minimisation of contaminants. After production, the cleanliness of the compound is preserved thanks to the Borealis EHV Octabin System. To supplement Borlink Superclean, Borealis and Borouge developed Supersmooth semiconductive compounds. Extruded in conjunction with EHV XLPE insulation, Borlink EHV semicon provides extremely smooth surfaces.

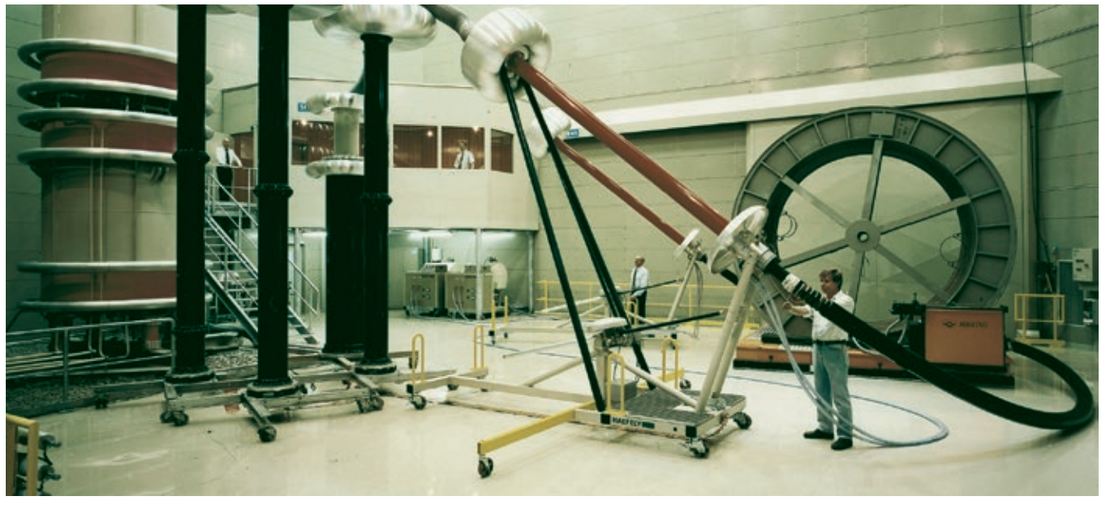
Proven technology for clean product delivery

In ensuring the safe production of EHV cables, the handling of compounds must be made with minimal risk of contamination. Experience with many projects ("EHV AC Cable km installed globally" on this page and "Reference Projects" on page 4) has shown that the Borealis developed "EHV Octabin System" provides a very efficient and flexible solution. The octabin (1 MT approx) is filled under clean room conditions thus preserving 'as produced' quality during transfer to the cable extrusion plant. The correct design of systems within the cable manufacturing facility (gravity unload for example) and effective, regular cleaning procedures to maintain high levels of purity are a necessary complement to this system.

Recommended material systems for EHV cables

Recommended material systems for EHV cables

Production characteristics	Borlink™ semiconductive screen	Borlink™ insulation	Jacket
Normal viscosity	LE0500	LS4201EHV	Borstar® HE6062 / HE6063 Casico™ – Flame retardant FR6082 LE0563 – semiconductive
High viscosity (Low sag)	LE0500	LE4244EHV	



Routine testing confirming the good performance of EHV XLPE

Sources for further information

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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 2018

About Borealis Borealis is a leading provider of innovative solutions in the fields of polyolefins, base chemicals and fertilizers. With its head office in Vienna, Austria, the company currently has around 6,600 employees and operates in over 120 countries. Borealis generated EUR 7.5 billion in sales revenue and a net profit of EUR 1,095 million in 2017. Mubadala, through its holding company, owns 64% of the company, with the remaining 36% belonging to Austria-based OMV, an integrated, international oil and gas company. Borealis provides services and products to customers around the world in collaboration with Borouge, a joint venture with the Abu Dhabi National Oil Company (ADNOC).

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.

For more information visit: www.borealisgroup.com · www.borouge.com · www.waterfortheworld.net

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