



NKT

Silicone rubbers for cable accessories

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Our Business Lines cover the entire path of electricity



Resources

People

NKT's core consists of a diverse, engaged and highly skilled workforce

Innovation

More than 130 years of pioneering the power cable industry with innovative technology for the future

Partners

NKT's business is built on long-standing relations and strong partnerships

Business

Value creation

A greener world

Sustainability is at the heart of NKT with a strong focus on connecting a greener world and have net-zero emissions by 2050

Societal value

NKT has a strong focus on ensuring equal opportunities in the organization, actively engaging in local communities and operating according to high safety standards

Customer value

NKT supports its customers with extensive experience, high quality and solutions and services and strong project execution

Shareholder value

NKT is creating shareholder value through business performance



Business lines

Solutions

Specialized in high-voltage power cable solutions for on- and offshore installation

Applications

Markets building wires, low- and medium-voltage power cable solutions

Service & Accessories

On- and offshore power cables services and a full portfolio of accessories for power cable systems



Key facts



Pushing innovation since

1891




6000



People worldwide

Complete provider of power cables and accessories from



1 kV to 640 kV



SCIENCE BASED TARGETS

We have reduced our total scope **1&2 emissions (68%)** since 2019

2024 revenue

EUR

3.3 bn

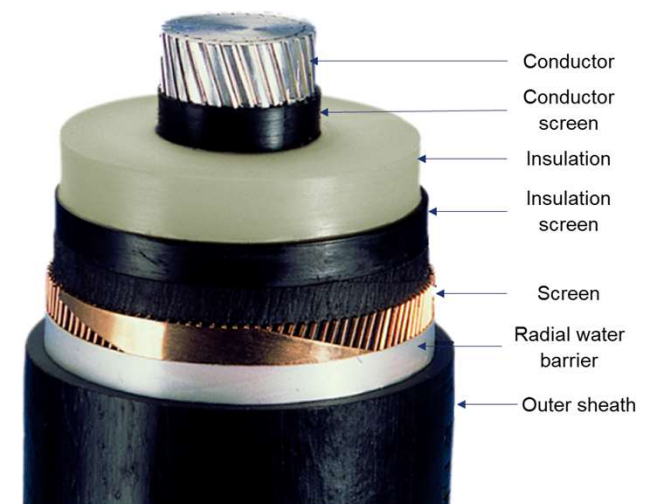


Global organization

Introduction

MV and HV cable accessories at NKT

- Cable accessories is a name for cable joints and terminations. NKT is primarily producing accessories for medium and high voltage cables.
- The function of a cable accessory is to joint cable ends or terminate a cable.
- The cable accessory must retain all vital functions of the cable, where the two main functions are:
 - Connection of the conductor(s) to allow an uninterrupted passage of electrical current (I) – conductor system
 - Electrically insulating the conductor and maintain the conductor at a certain voltage (U) – insulation system
- The relatively high electric field in the cable needs to be controlled during jointing and termination of the cable.
 - The accessory has to be designed in such a way that the electric field strength is maintained below a critical value in the insulation system (different materials and interfaces) at all service conditions (environmental conditions, temperatures, transient and temporary overvoltages, etc)



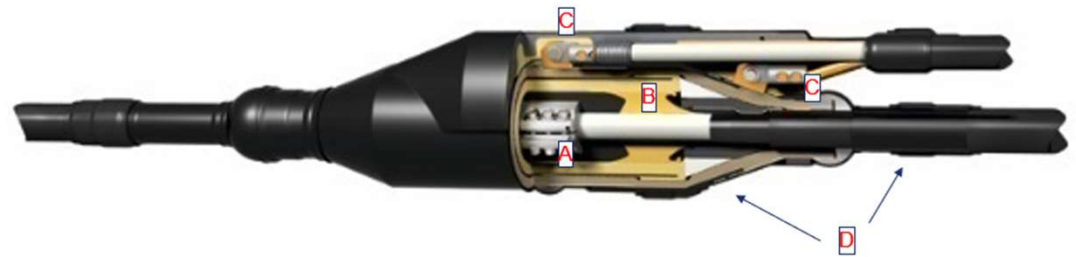
Introduction

MV and HV cable accessories at NKT

- Terminations can often be classified into open type (air insulated), i.e. outdoor/indoor terminations, and screened type, i.e. connectors to GIS, transformers.
- Accessories are mainly prefabricated, and the technologies used include cold-shrink (pre-expanded) and push-on types.



- A. Conductor connection – connector (or welding)
- B. Control of electric field and insulation – main insulation, stress relief cones, insulation rubber bodies etc
- C. Metallic screen connection – connectors
- D. Mechanical protection including water sealing – insulators, housings, O-rings, tapes, outer protection (joints)



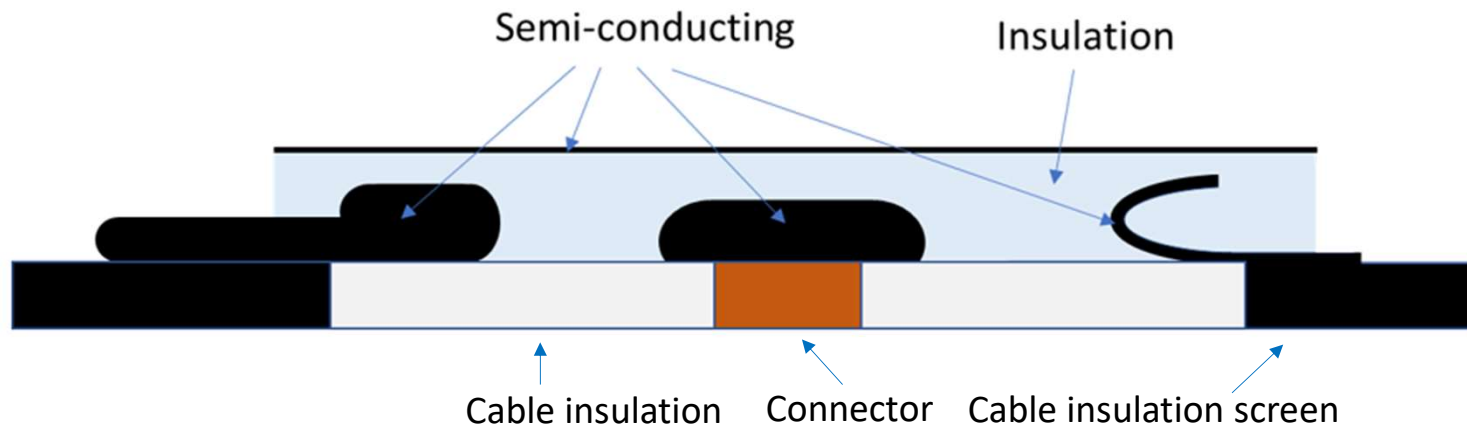
Introduction

MV and HV cable accessories at NKT

There are two main type of materials in the cable accessory; insulation and (semi-)conducting materials.

Electric field control materials, e.g. refractive and resistive materials, are also used. These belong to the insulation type.

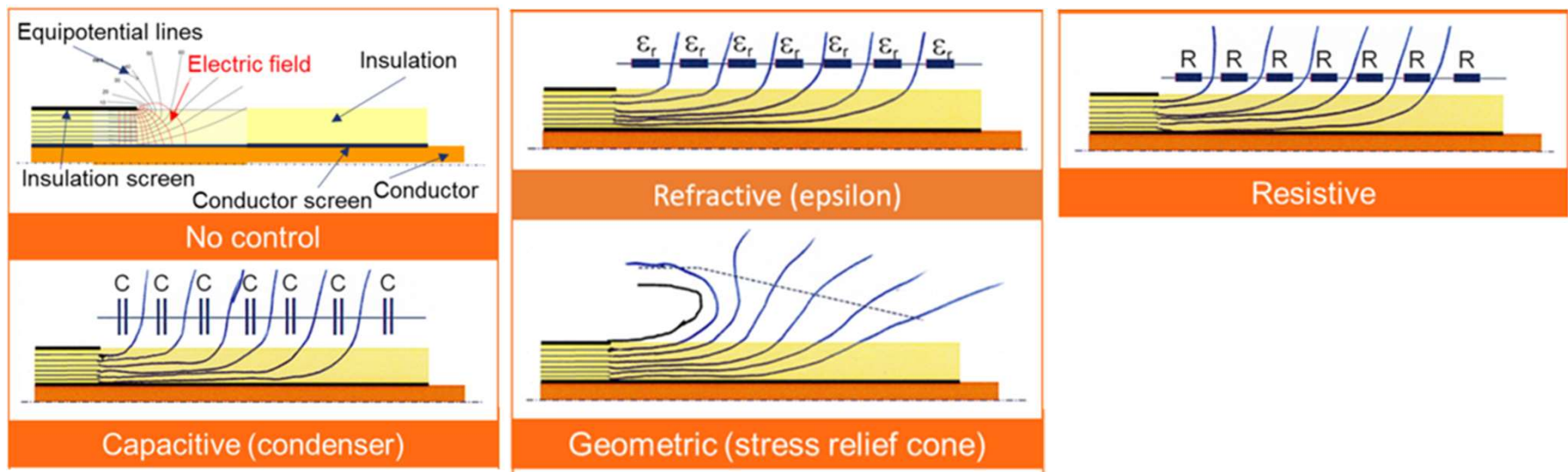
In the prefabricated accessory they are all rubbers, usually based on a insulating polymer matrix e.g. silicone or EPDM rubber.



Introduction

MV and HV cable accessories at NKT

- The main purpose of the rubber part is to control the electrical field, and this can be achieved in several different ways:
 - Geometrical shape of conductive deflector material
 - Controlling the rubber material's electrical properties



Rubbers for accessories

Critical material properties

- The main material types used in any accessories are:
 - Semi-conductive rubber ($< \sim 500 \Omega\text{cm}$)
 - Insulating rubber

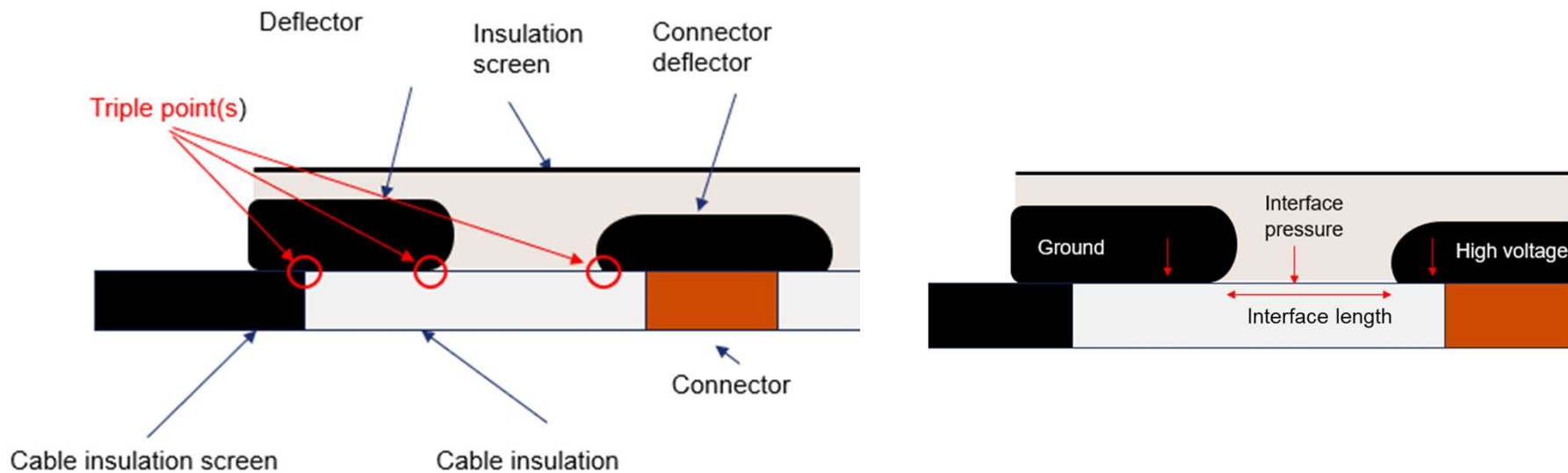
- The materials used in the accessories can be:
 - Tailor-made specifically for each application
 - Standard insulating and conductive grades “off the shelf”

- In the design of materials for high voltage applications, these factors are critical:
 - Stiffness of rubber
 - Conductivity, permittivity and electrical breakdown strength of the material
 - Tension and compression setting of the rubber, especially at elevated temperatures
 - Thermal conductivity
 - Cleanliness of raw materials

Rubbers for accessories

Critical material properties

- There are specific points at the rubber body (joint or stresscone) interface with the cable that are especially sensitive with high electric field enhancement, called triple-points.



Material design of silicones in cable accessories

Mechanical considerations

Installation properties and long-term interface pressure

Material properties	Advantages	Drawbacks
Low modulus / Low Shore A	<ul style="list-style-type: none"> Ease of expanding the accessory onto the cable and handling of the accessory Good adaptation to any cable surface irregularities or transition at cable insulation screen 	<ul style="list-style-type: none"> Risk of stress relaxation / setting over time and temperature cycling Risk of high friction during assembly due to high surface conformity
High Modulus, High Shore A	<ul style="list-style-type: none"> High global pressure between cable and accessory Retention of interface pressure, due to less risk of stress relaxation with time and temperature cycling 	<ul style="list-style-type: none"> Risk of low-pressure areas at irregularities and transition at cable insulation screen due to lower surface adaptation Higher force required for installation

Material design of silicones in cable accessories

Electrical considerations

Electrical field control design

Material design	Material property	Typical products
Refractive field control	Field dependent dielectric constant (epsilon), e.g, ZnO, TiO ₂ , BN, CB	AC accessories to reduce size of accessory. Mainly used for lower voltages due to dielectric losses at higher E-fields
Resistive field control	Field dependent conductivity, SiC, ZnO	DC accessories to reduce space charge accumulation and E-field re-distribution
Capacitive field control	Condenser- based layered system	Bushings etc where layered tape systems can be used



Material design of silicones in cable accessories

Production of accessories

Material design – viscosity and reactivity etc

The most critical factors for an accessory is that the rubber body fulfills the demands below:

- Adhesion between material layers (mainly conductive and insulating silicones)
- Fully free of voids
- Fully free of gel particles or other “contaminants” like color agglomerates

The main parameters of importance for the rubber body production to avoid the risks above:

- Stable reactivity of the polymer vs temperature
- Viscosity vs temperature
- Homogeneity of color and fillers etc.

Summary

Critical parameters in design of a rubber body in a HV accessory

- Mechanical properties, with focus on a constant interface pressure over time
- Design of electrical field control: geometric, refractive, resistive or capacitive
- Design of material properties for production of large rubber bodies with tailoring of reactivity and viscosity etc.

Thank you!