HEAT SHRINK CABLE ACCESSORIES: A 40 YEARS PROVEN TECHNOLOGY FOR APPLICATIONS IN HARSH ENVIRONMENTS

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Abstract:

Heat shrink Cable Accessories have been successfully in use for more than 40 years in Low and Medium Voltage applications and in the lower range of High Voltage applications. The continuous development of polymers and elastomers has led to steady improvements. While the majority of products are used under normal network conditions in Underground and Overhead networks, some applications were designed for use in harsh environments and have to withstand extreme environmental conditions.

Introduction

More than 40 years ago cross-linked Polyethylene (XLPE) Cables started to replace step by step oil-impregnated paper cables in Low Voltage (LV) and Medium Voltage (MV) Distribution Networks. In parallel to this change in the cable network, Heat shrink Cable Accessories have been introduced to the market and were an ideal solution for both, jointing and terminating for paper and polymeric cable technologies.

While the majority of applications were for normal environments, such as connection of standard cables and terminations, there was a developing need for utility and industrial applications beyond normal environments, such as:

- High UV requirements
- Heavy pollution areas
- Salt Fog environments
- Oil barrier properties
- Flame retardant properties
- Fire resistance and System Integrity
- Gamma radiation resistance
- Functionality under Loss of coolant accident (LOCA) conditions

Heat Shrink Technology

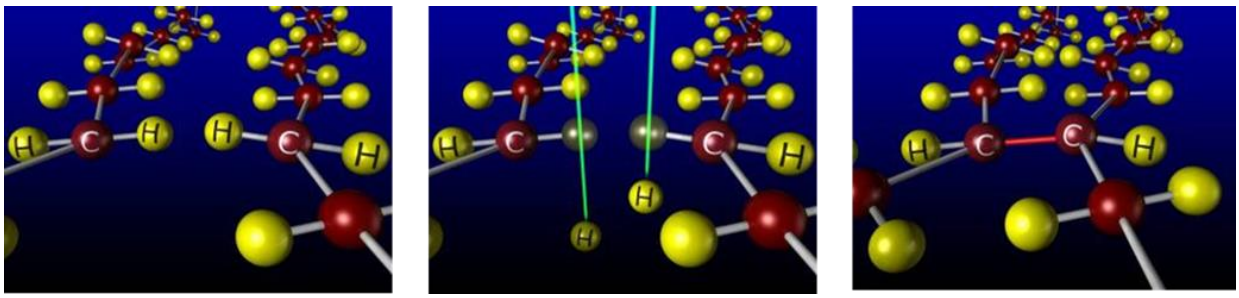

Figure 1. Crosslinking process

The base material for the heat shrink technology are Polyethylene based molecule chains. These are subjected to cross linking processes like e.g chemical or radiation cross linking. In a radiation cross linking process multi MeV electron accelerators are used, where electrons are accelerated to gain such a high energy that they can initiate the crosslinking process (Figure 1). In this case hydrogen atoms are separated from the Polyethylene chains and the carbon elements between adjacent polymer chains can establish a connection between the 2 polymer chains. The higher the number of connections along the chain will be established, the higher the cross linking rate will be. With increased cross linking rate, the material usually gets more rigid.

One key benefit for heat shrink products is due to this crosslinking effect in the material that cause these products to lose their melting properties. Products can now be heated up to temperatures beyond the crystalline melting point without melting. Above this temperature, heat shrink products like extruded tubes or molded parts (breakouts, end caps) can be expanded and formed in shape and will remain in this position while the temperature will decrease below the crystalline melting point again.

If the products will be heated up again beyond the crystalline melting point, which typically happens during the installation by a gas torch or hot air gun, the products will shrink back again to their original shape. This kind of memory effect remains valid for the entire lifetime of the product, and e.g. allows an almost unlimited shelf life for the products under specific storage and warehouse conditions.

Material Modification

By using additives to the formulation, characteristics of the tubes or molded parts can be modified. The chemical formulation is the key element to achieve characteristics, which are required for various industrial applications, but also to ensure, that the material can be processed in a cost efficient manufacturing process.

Figure 2 is showing a general overview of the different ingredients that can be used in the formulation of heat shrink materials to gain the desired properties, depending of the final product.

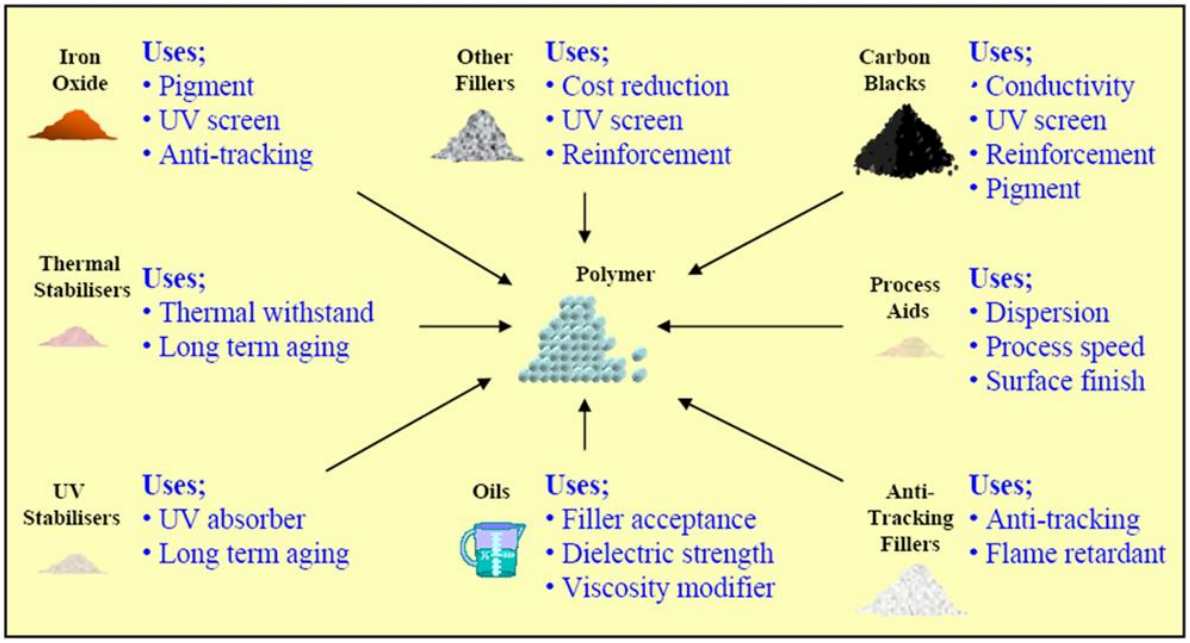

Figure 2. Potential Ingredients to formulate heat shrink materials with the desired properties

As a consequence the formulation of a material can be quite complex, it need to be assured that the combination of all the different materials will combine functions like:

- Mechanical properties
- UV resistance for outdoor applications
- Electrical properties
- Oil blocking characteristics
- Tracking & Erosion
- Radiation resistance
- Flame retardant /fire resistant properties
- Electrical Stress control
- etc.

Without adversely impacting each other.

High UV requirements

Outdoor Heat shrink materials are used in different areas of the world with different UV radiation levels. The most challenging UV requirements might be found in dessert environments where insulation materials are consistently subjected to high UV radiation.

With increased elevation, UV radiation increases in addition. A typical value is that for every 500m of altitude the UV radiation increases by about 3.5%.

Figure 3: Long term UV Materials testing in a dessert area and termination in service in a high UV environment

Test sides in dessert areas, like shown in figure 3, were used to analyze different formulation to proof their long-term UV requirements. For accelerated UV aging tests, UV lamb (Xenon) testing for lab simulation has become standard. EMMAQUA® or Weather-Ometer® testing have been used as an alternative to verify materials properties.

Environments demanding oil blocking characteristics

Environments, where oil blocking characteristics are required, can be seen as another harsh environment. A typical application would be the use of a cable accessory in a joint or termination for oil-impregnated paper cables, either in a Paper-to-Paper cable connection or in a today more common Paper-to-Polymeric cable joint, a so-called Transition Joints.

Without oil blocking characteristic, the oil-impregnated paper cables would face a migration of the oil and would dry out over time. As the oil with its good insulation characteristics plays an important insulation role its loss would lead constantly to the loss of the electrical insulation property of the cable, which finally could end up in a breakdown of the insulation and a failure of the cable accessory. This function usually needs to be maintained for a service life of 40 years under maximum operating temperatures of the cable conductor in the range of ~70°C.

Figure 4.Oil barrier tube used in a 3-core paper cable joint © TE Connectivity

Heat shrink materials with Oil blocking characteristics can also be used in applications in the Oil & Gas or Petrochemical Industry, where oil blocking characteristics are required.

Flame retardant Heat Shrink Cable Accessories

Certain environments like railway, offshore applications, government buildings or power plant applications have requested flame retardant requirements for cables and cable accessories. Typical Standards which need to be met by cables are IEC-60332 and IEEE-1202. As these standards usually refer to cables only, however it has become common practice and industry understanding to qualify cables with cable accessories to proof their suitability.

During the IEEE-1202 test the flame is applied to the cable or cable with accessory for a period of 20 min. After this time the flame will be removed and the product characteristics need to assure that the flame will self-extinguish. Further to this the damaged area or flame propagation caused by this test shall be less than 1.5 m (e.g.in a vertical tray application).

The right material choice which is usually combined with a certain wall thickness in the heat shrink tube will result in a flame retardant heat shrink Tube. Figure 5 shows a typical arrangement where cables with flame retardant heat shrink tubes are subjected to.

Figure 5. Flame retardant heat shrink cable accessories in a vertical tray arrangement © TE Connectivity

Fire resistant Heat Shrink Cable Accessories

Despite flame retardant requirements certain industry requirements are requesting fire resistance properties, where cable and accessories need to maintain system integrity up to 180 min. This request is usually combined with Low Smoke Zero Halogen (LSZH) materials. However, low smoke zero halogen properties on its own will not give the properties needed for heat shrink cable accessories to achieve the system integrity requirements.

As a solution the heat shrink cable accessories are combined with additional protective layers acting as barrier against the fire application and preventing the flame to penetrate to the inner insulation. A typical standard where test procedures for fire resistant cable and cable accessories are defined is IEC-60331.

Figure 6: Fire resistant joint before, during and after a fire resistant test

Heat shrink Cable Accessories for Nuclear Power Plant Environments

One of the most severe environments for cable accessories are applications in the containment area of Nuclear Power Plants, which would include function under accident conditions. One of the most severe accident conditions is a Loss of coolant accident (LOCA).

For more than 40 years Raychem class 1E safety related cable accessories are in use, which in case of an accident can support e.g. the emergency shutdown of the reactor, containment isolation and prevent release of radioactive material.

A full LOCA qualification simulates the severe accident conditions and therefore has to cover the following elements:

- Simulation of ageing (Thermal and Gamma-Radiation)
- Radiation exposure during lifetime
- LOCA – Accident simulation with high radiation, temperature & pressure profile during saturated steam conditions and chemical spray testing

Newest Generation of Nuclear Power Plants like AP1000 or the European Pressurized Water Reactor (EPR) are built for a 60 year service life. Therefore the thermal ageing for the qualification process was already chosen to simulate a 60 year lifetime at a constant temperature of 90°C, which typically represents the maximum conductor temperature in power cables.

While the products installed in the containment area are subjected to nuclear radiation, a 40/60 years gamma radiation need to be simulated. In addition, high gamma radiation can be occur during the accident, which also need to be taken into account and tested during the qualification process. Typical values can exceed 200Mrad of Gamma radiation.

During the accident simulation, the heat shrink cable accessories installed on cables will be taken into a vessel, where the temperature and pressure occurring during an accident will be simulated. A typical profile for a 30 days test on cable accessories is shown below, with maximum temperatures beyond 200°C and a maximum pressure beyond 0.8 Mpa over normal environmental pressure.

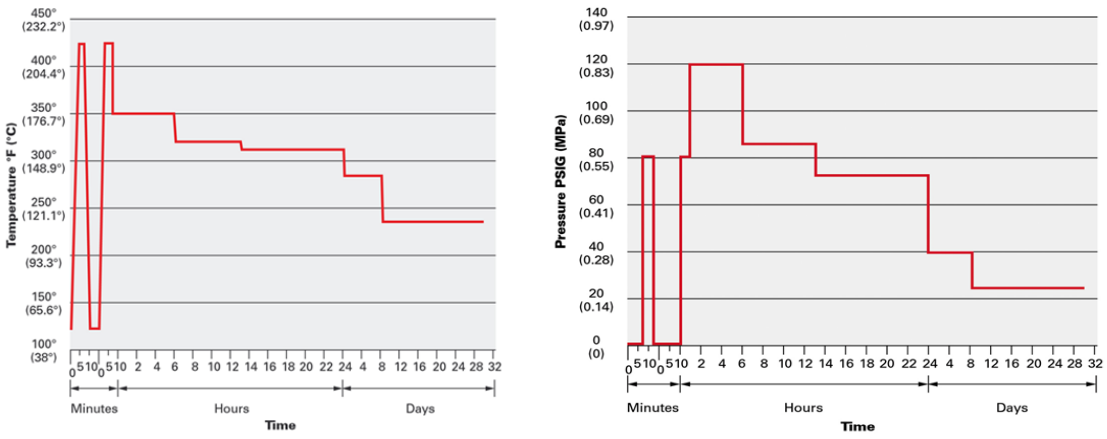

Figure. 7. Temperature and Pressure Profile used to qualify heat shrink Cable Accessories for use in Nuclear Power Plant Environments

Conclusion

Heat shrink cable accessories are successfully used for more than 40 years in Low, Medium and High Voltage networks. One of the challenging areas they are in use are harsh environments with e.g. high UV requirements, heavy pollution, salt fog environments and areas where oil barrier, flame retardant or even fire resistant properties are needed. Nuclear environments are one of the most severe environments where today heat shrink cable accessories are in use and have to fulfil safety related function in case of accident conditions.

The Investigation in heat shrink Material formulation started more than 50 years ago has been the foundation to establish optimum formulations in Heat shrink Cable Accessories to be capable to service properly in these harsh environments. To achieve fire resistant properties zero halogen Heat shrink products can be combined with additional fire protecting materials to achieve a system integrity up to 180 minutes.

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