Very Low Loss Cryogenic Envelope for long HTS-Cables

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Abstract. HTS power cables are a novel technology for the future electric cable industry. Besides the super conducting conductor the required cryogenic envelope represents an essential component for such a cable. The basic design of which is a vacuum insulated transfer line. There are in use today on the market rigid and flexible systems for the transport of liquefied gases. For a cable design a system based on rigid tubes is not an efficient solution.
An electric cable has to be bendable or flexible to allow for easy packing on a shipping reel and for installation around bends. For optimum efficiency such flexible cables must be produced on a manufacturing line allowing continuous production. This is the unique characteristic of such HTS cable envelopes which permit the production of very long lengths economically.
The requirements for envelopes for HTS cable are
? extremely good thermal insulation
? optimized LN2 flow conditions in order to recuce the pressure drop on very long cables
Different designs of HTS-Cables are shown with their advantages and disadvantages. Our focus of the development is the cold dielectric design which is more compact, provides a higher current transmission capacity and is environment-friendly.

1. Basic design for long length cryogenic envelopes for HTS cables

The new type cryogenic envelope for HTS-Cables looks like that:

Bendable tube system with concentrically arranged stainless steel tubes. The insulation with high vacuum at 10E-5 mbar or better, including several layers of superinsulation (spacer material with reflecting foils) is the best possibility in principle.

But there are practical limits, specially for systems with very long lengths. Heat inleak reduction can be reached by a special arrangement of spacer and insulation material. Different designs have been developed and tested. Several tests have been done to find the best way of insulation depending on application.

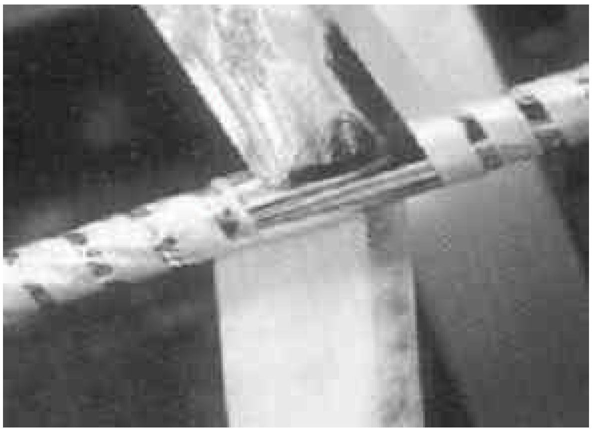

Figure 1.

Heat inleak:

Inner diameter (mm):	39	60	84
Heat inleak:	0.75	1	1.25

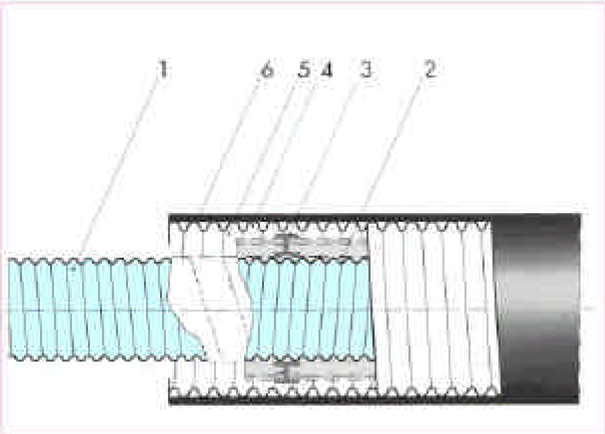

Figure 2.
1 - Corrugated, longitudinal welded stainless steel inner tube
2 - 30 layers superinsulation (Al coated foil with spacer fleece)
3 - Low loss spacer
4 - Corrugated, longitudinal welded stainless steel outer tube
5 - Vacuum space (vacuum better 1x10E-5 mbar)
6 - PE Jacket

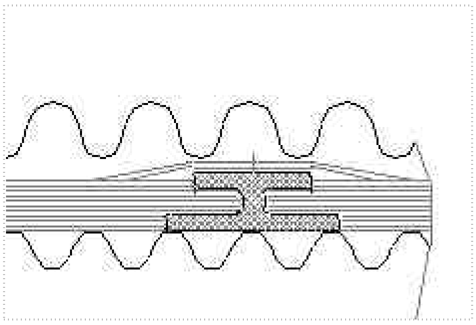

Figure 3. Low loss spacer.

2. Optimization for good flow conditions

Different corrugated tubes with different diameters and corrugations have been examinated. The max. flow of gas for different tube design is established and noted.

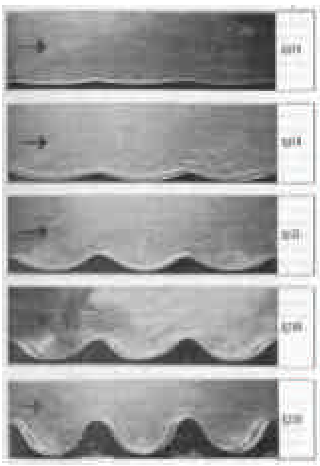

Figure 4.

If you look to the different corrugation profiles you can imagine that the pressure drop depends on the height and pitch of the corrugations. If you compare a smooth tube with our standard corrugated tube the friction factor is about 4 times higher. But this is not a real problem. If you look to the formula of pressure drop, you see the diameter to the power of 5. That means: If we extend the diameter of our corrugated tube by about 25% than we have the same pressure drop than a smooth tube.

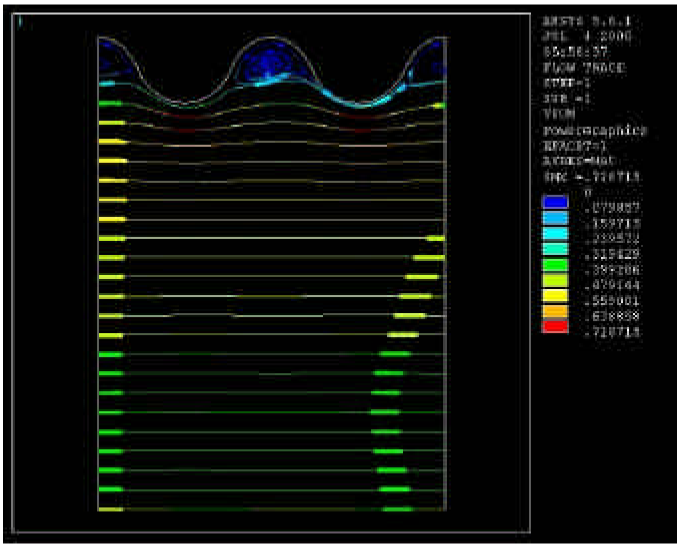

Figure 5.

3. Optimization for max. mechanical stress

We have to connect the thin walled corrugated tube to a termination. There is a lot of mechanical force and all has to be vacuum tight. We use a special design for that with a so called nut which absorbs the forces. The welded area is to provide a vacuum type seal. The light area shows pulling force the dark area compression. The max. stress we have of course in the bending zone.

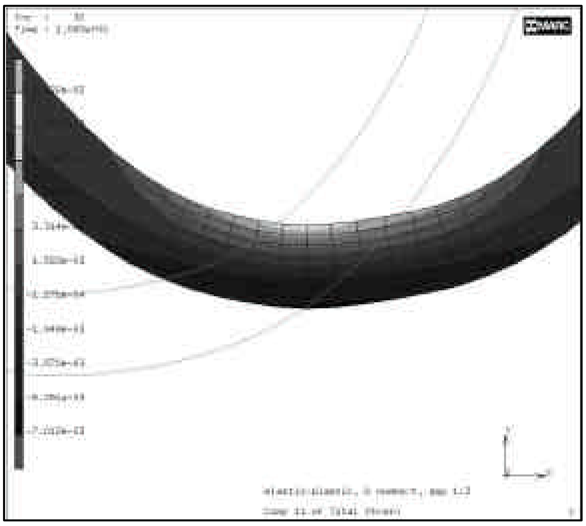

Figure 6.

4. HTS cable design

There are different designs of HTS-Cables with their advantages and disadvantages. Nexans started its new superconducting cable development program in 2002. Our focus of the development is the cold dielectric design which is more compact, provides a higher current transmission capacity and is environment-friendly.

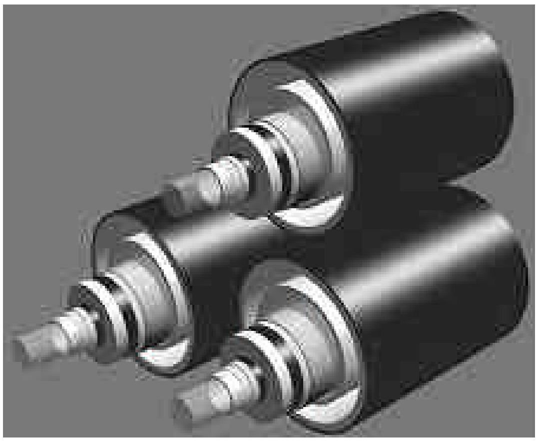

Figure 7.

5. Conclusion

The necessary good insulation for long length cryogenic envelopes will be available end of this year. The heat inleak will be reduced from 10 to 5 W/m².

The technique for the manufacturing of long length cryogenic envelopes up to 2000m length is available now.

References

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