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. There are flexible metallic envelopes on the market but primarily for the transfer of liquid gases. Transfer lines have to be optimized for use as cryogenic envelopes for HTS cables. The requirements for envelopes for HTS cable are: Extremely good insulation, particularly important for long transfer lines of several 1000 meters. The LN2 flow conditions must be optimized in order to reduce the pressure drop on very long transfer lines.**

I. Introduction

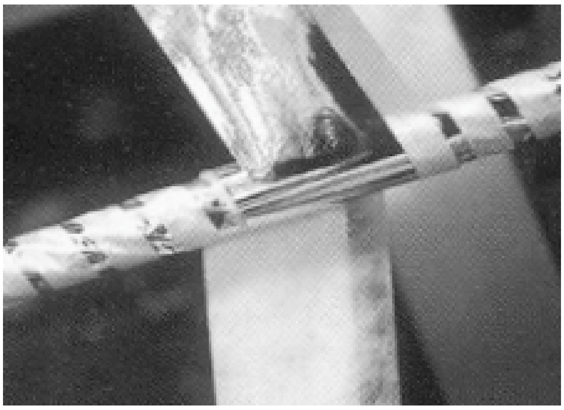
Basic design for long length Cryogenic Envelopes for HTS Cables

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 length. 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. We think we will reduce the heat inleak of these cryogenic envelopes by 50% up to the end of this year.

Heat Inleak Reduction

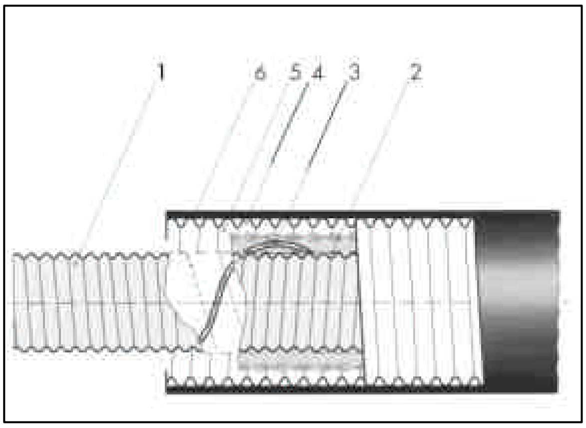
Inner Diameter (mm)	39	60	84
Heat inleak (W/m), today	1.5	2	2.5
Heat inleak (W/m), tomorrow	**0.75**	**1**	**1.25**



II. Different Designs

In principle there are 3 different designs in bendable transferlines

<u>Spacertype 1: Spiral Spacer</u>



1. Corrugated, longitudinal welded stainless steel inner tube

2. 30 layers Superinsulation (Al coated foil with spacer fleece)

3. Spiral Low Loss Spacer

4. Corrugated, longitudinal welded stainless steel outer tube

5. Vacuum Space (vacuum better 1x10E-5 mbar

6. PE Jacket

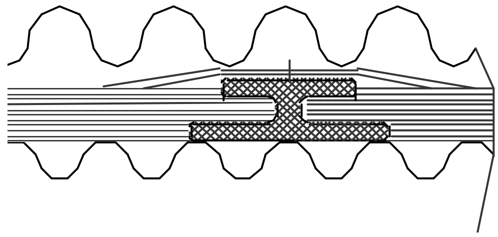
Application: Using LN2 in the industry as a coolant for quick and easy use
Mechnical behaviour: Only for reduced forces to the insulation space, T<100°C
Heat inleak: 1,5 W/m (for 40 mm tube inner dia)

Spacertype 2: Spiral Spacer Several Layers

This design is based on reduced conductance through spacers due to several contact points of the spacer strings along the way from the inner to the outer tube.

Application: HTS Cables long length
Mechnical behaviour: Only for reduced forces to the insulation space, T<100°C
Heat inleak: 1,0 W/m (for 40 mm tube inner dia)

Spacertype 3: Separate Single Spacer Design



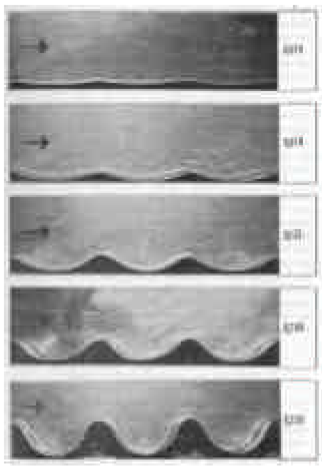
Because of the transferline flexibility there is a need of using more spacing elements than in rigid transferlines.
2 - 4 spacers per meter are necessary with the flexible design. Because of that the spacers have a big contribution to the overall heat inleak.
A positive effect has been reached by a special spacer design with extremly low heat conductance.

Application: HTS Cables long length
Mechnical behaviour: For high forces to the insulation space, T<100°C
Heat inleak: 0,75 W/m (for 40 mm tube inner dia)

III. 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

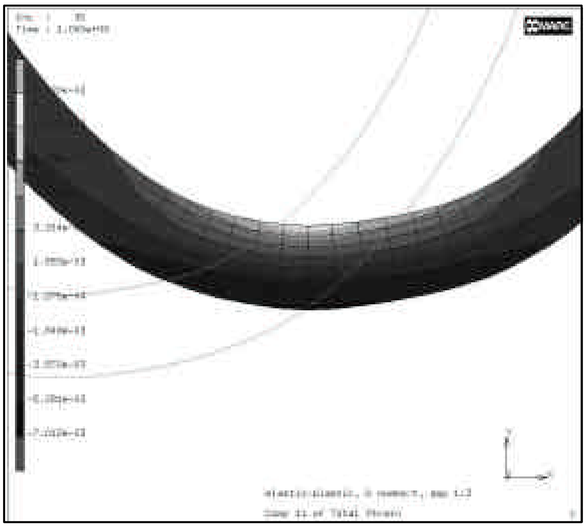
If you look to the different corrugation profiles you can imagine that the pressure drop depends on the height and pitch of the corrugations. If you compare a smooth tube with our standard corrugated tube the friction factor is about 4 times higher. But this is not a real problem. If you look to the 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.

IV. 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 max. stress we have of course in the bending zone.
The light area shows pulling force the dark area compression



V. 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

[1] H. Laeger et al, Long flexible transferlines for gaseous and liquid helium, in: "Cryogenics", Vol.18 (1978), p.659

[2] H. Blessing et al, Four hundred meters of flexible cryogenic helium transfer lines, in: "Proc. Eight Intl. Cryo. Engr. Conf.", L.P.C., Guildford, UK (1980),p. 261.

[3] H. Blessing et al, High-performance flexible cryogenic helium transfer lines, in: "Advances in Cryogenic Engineering", Vol. 27, Plenum Press, New York (1982), p. 761

[4] Yamada et al, First Cycle Operation of SC Current Feeder System for the LHD, in: "ICEC 17, 1998, Bournrmouth, UK, S.5-4

[5] Lucas, Schippl, Special Transfer Lines for the Spallation Neutron Source, Advances in Cryogenic Engineering, Vol. 31, Plenum Publishing Corporation, 1986.