CRYOSAVER SUPERCONDUCTING LEAD INSTALLATION GUIDE

HTS-110 Ltd.
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CryoSaver™ Superconducting Lead Installation Guide

Note: this application guide is written for CryoSaver™ leads manufactured by HTS-110 Ltd, but the general instructions are suitable for any custom current lead manufactured by HTS-110 Ltd unless explicit alternative instructions have been provided for that lead.

Description

The CryoSaver™ family of current leads uses High Temperature Superconducting (HTS) tapes to create a robust, reliable lead.

Second generation CryoSaver™ current leads, rated from 150 A to 2000 A, deliver a lower heat leak than conduction-cooled or vapour-cooled leads. They reduce heat- load, and losses for client systems. Applications include MRI, NMR, beam-line magnets and driven (non-persistent) superconducting magnets. They are particularly applicable to cryogen-free magnets and systems.

The composite conductor consists of HTS filaments in a low thermal conductivity matrix, providing a very high current density and low heat leak through the small cross-section. The anisotropic nature of the CryoSaver™ current leads allows the lead to be positioned in a cryostat such that applied fields are along a favorable axis, an advantage over isotropic bulk materials.

Electrical connection to the caps is easily made, mechanically or by soldering, for low resistance and low Joule heating.

The HTS conductor exhibits tolerance to strain and thermal cycling superior to other types of HTS leads. CryoSaver™ leads have superior ability to tolerate and recover from minor cooling system upsets without damage or burn-out, as the metal matrix in the conductor slows temperature rise after loss of cooling.

Warnings

In order to achieve the best performance from a CryoSaver™ lead a few simple rules should be obeyed during their installation to ensure the lead is thermally stable in operation and to minimise losses from heat leaks and resistive connections.

- Never operate a CryoSaver™ lead at above the specified operating current.
- Never operate a CryoSaver™ lead with its warm end above the specified operating temperature (for standard leads this is normally 64 K).
- If any part of a lead is to be operated in a magnetic field greater than 25 mT, obtain advice from HTS-110 or their agent before using the lead, as external fields can reduce the performance of a lead to below design specification.

Operating Principles

The CryoSaver™ lead is designed to be operated between two heat sinks: a warm-end heat sink – at or below 64 K, and a cold-end heat sink – at the operating temperature of the current load.

Current passes from room temperature to the warm-end of the CryoSaver™ lead via an 'optimised' resistive lead, along the length of the CryoSaver™ lead and out the cold-end of the CryoSaver™ lead to the superconducting load. The major part of the thermal load entering the system (Joule heating and thermal conduction in the optimised resistive lead) is extracted into the warm-end heat sink, leaving only a small residual thermal load (thermal conduction along the CryoSaver™ lead and Joule heating in its cold-end current tab) to be passed into the cold-end heat sink. By following the suggested installation procedures described in this guide the heat leak into the cold-end of the application can be as low as 220 µW/A.

In order for this performance to be achieved it is necessary to appropriately manage both the thermal and electrical connections at both ends of the CryoSaver™ lead.

Thermal Connection

The connection between the warm-end heat sink and the CryoSaver™ lead is critical for operation of the lead. In a well-designed resistive lead between 300 K and 64 K there is an approximate heat load of 45 mW/A at 64 K. If this heat is not extracted efficiently there is a risk that the CryoSaver™ lead will heat up to beyond its safe stable operating temperature. At the cold-end the connection is less critical as the heat-load is small. But good thermal conductivity is still required to ensure the cold- end is at a suitable temperature for the passage of current into the superconducting load.

The interface between the CryoSaver™ lead and heat sinks requires high thermal conductance and high electrical resistance. This is best achieved by the use of sapphire interfaces and HTS-110 recommends that all CryoSaver™ leads are installed with sapphire interfaces.

HTS-110 can provide Sapphire Washer Kits for all standard CryoSaver™ leads in the 150-2000 A range. These kits consist of insulating collars, sapphire washers of appropriate thickness and diameter and retaining rings to maintain the sapphire in position, sufficient for both ends of a pair of CryoSaver™ leads.

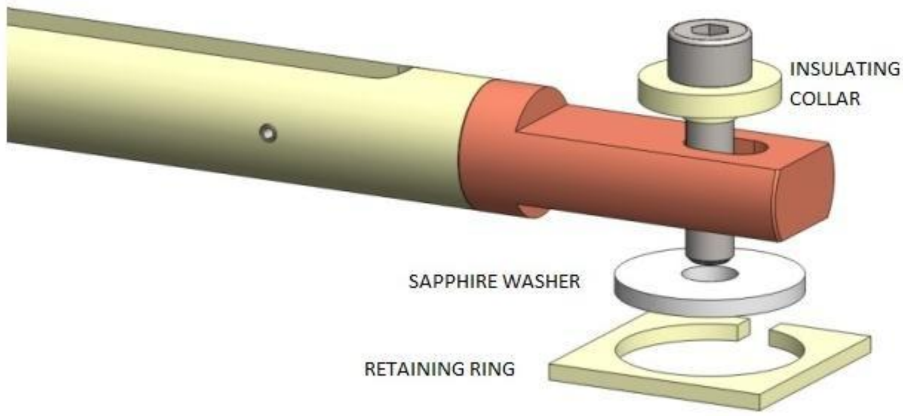

Figure 1. HTS-110 Sapphire Washer Kit

Assembly Instructions for HTS-110 Sapphire Washer Kit

1. The mounting surfaces of the warm-end and cold-end heat sinks should be smooth, flat, and co-planar.
2. Apply a thin film of suitable vacuum grease to both sides of the sapphire washer.
3. Seat the washer in the retaining ring and position the lead end-tab over it. Note that electrical connections to the lead should be on the surface of the end-tab away from the sapphire washer.
4. Bolt the lead in place using the insulating collar to ensure there is no electrical short between the bolt and CryoSaver™ lead. The supplied stainless bolts can be tightened to 2.2 Nm for M4 bolts and 4.3 Nm for M5 bolts.
5. The washer should not crack if the mounting surface of the heat sink is smooth and flat, but if it does it should still meet its purpose so long as the sections of the washer remain held in place by the retaining ring (in this case, replacement washers would be required during disassembly/reassembly of the joint).

Electrical Connection

At the cold-end of the lead a good electrical connection to the superconducting load is vital to minimise Joule heating in the joint. There is a small resistance resulting from current flow through the copper end-tab of the lead (for example, in a 250 A CryoSaver™ lead the cold-end heat load due to this resistance is approximately 2.5 mW at full operating current). A poor electrical connection between the end-tab and the superconducting load would add significantly to the thermal load. The quality of the electrical connection between the warm-end of the CryoSaver™ lead and the resistive lead that extends to room-temperature is less critical but should be of sufficiently low resistance that Joule heating in the joint does not add an excessive heat-load to the warm-end.

Low resistance joints are best achieved by making solder connections onto the CryoSaver™ lead to both the superconducting load and resistive leads. Alternately, an indium shim can be used to achieve an adequate electrical contact but, particularly at the low-temperature interface, this may increase the thermal load.

Assembly Instructions for Soldered Joints

Care should be taken not to overheat the end-tabs of the lead during the soldering operation – the lead ends should not be heated in excess of 120 C. Excessive heating could damage internal joints in the lead and reduce its performance.

1. Standard CryoSaver™ leads are delivered with the faces of the end tabs coated in Silver to minimise tarnishing of the copper.
2. To prepare the surface for soldering lightly polish with an abrasive cloth until a bright finish is achieved. Do not be concerned if this process exposes the underlying copper, as a good solder joint can still be achieved.
3. Tin the lead tab and the mating surface of the resistive lead (warm end) or superconducting component (cold end) with Indium Bismuth (InBi) solder using HF260 flux. A temperature controlled soldering iron set to approximately 180 C is suitable for this process. Then clean off any excess flux with isopropyl alcohol.
4. Bring the two surfaces together and bolt loosely in place. Then heat both surfaces until the (InBi) solder just melts, clamp down on the bolt and remove the soldering iron.

NOTE: If you are using sapphire washers for the thermal connection and need to make the solder connections with the lead in its final installation position, temporarily replace the sapphire washers with a low thermal conductivity material such as G10 or a thin sheet of wood to minimise the heating required to make the solder joint.

Assembly Instructions for Indium Shim Joints

Assembly with an Indium shim is simple, but Indium oxidises rapidly upon exposure to air so care should be taken to minimise this risk.

1. The Tin coating on the CryoSaver™ leads provides an ideal oxygen-free surface for connecting via an indium shim. The resistive lead or superconducting load should be polished or abraded to ensure it is oxide-free.
2. Use an approximately 0.1 mm thick indium shim to make the joint. The shim should cover the entire surface of the HTS lead end-tab. Indium shim can be purchased from suppliers or rolled from wire.
3. If the shim is oxidised use gentle abrasion with a non-ferrous scouring pad to produce a bright oxide-free surface.
4. Sandwich the shim between the CryoSaver™ end-tab and the resistive lead or superconducting load and immediately tighten the mounting bolt.
5. If the lead is de-mounted, the old indium should be removed from both surfaces and a new shim used for re-mounting.

Notes