

Conf-950722--7

LA-UR- 94-2461

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Title:

ASSEMBLY AND TESTING OF A COMPOSITE HEAT PIPE THERMAL INTERCEPT FOR HTS CURRENT LEADS

Author(s):

M. A. Daugherty, D. E. Dancy, F. C. Prenger, D. D. Hill, P. M. Williams, H. J. Boenig

Submitted to:

Cryogenic Engineering Conf.
Columbus, OH
July 17-21, 1995

MASTER

RECEIVED
AUG 29 1995
OSTI

Los Alamos
NATIONAL LABORATORY



Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Form No. 836 R5
ST 2629 10/91

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ASSEMBLY AND TESTING OF A COMPOSITE HEAT PIPE THERMAL INTERCEPT FOR HTS CURRENT LEADS

M.A. Daugherty, D.E. Daney, F.C. Prenger, D.D. Hill,
P.M. Williams, and H.J. Boenig

Los Alamos National Laboratory
Los Alamos, New Mexico, 87545, USA

ABSTRACT

We are building high temperature superconducting (HTS) current leads for a demonstration HTS high gradient magnetic separation (HGMS) system cooled by a cryocooler. The current leads are entirely conductively cooled. A composite nitrogen heat pipe provides efficient thermal communication, and simultaneously electrical isolation, between the lead and an intermediate temperature heat sink. Data on the thermal and electrical performance of the heat pipe thermal intercept are presented. The electrical isolation of the heat pipe was measured as a function of applied voltage with and without a thermal load across the heat pipe. The results show the electrical isolation with evaporation, condensation and internal circulation taking place in the heat pipe.

INTRODUCTION

In this paper we report on the assembly and testing of a heat pipe thermal intercept for HTS current leads. The thermal intercept is a key component of high performance (low heat leak) HTS current leads because it enables significant reductions in overall refrigeration requirements.^{1,2} High performance current leads are an important component of the demonstration high gradient magnetic separation system we are building at Los Alamos.³ The system is cooled by a cryocooler, so no liquid cryogen is used. The current leads for this project are therefore completely conductively cooled and must operate in a vacuum. The leads must be high performance to minimize the size of the refrigeration system and must also be rugged to withstand the shock and vibration experienced during transportation of the system.

The principal challenge in designing and building thermal intercepts for current leads is determining how to combine good electrical insulation with high thermal conductivity. Recent work at Argonne National Laboratory and Fermi National Accelerator Laboratory on low thermal resistance, high electrical isolation heat intercept connections has addressed this problem.⁴ Niemann, Gonczy, and Nicol have developed a heat intercept design which involves clamping, by thermal interference fit, of an electrically insulating cylinder between an outer metallic ring and an inner metallic disc. The connections use the high clamping pressures made possible by the thermal interference fit to reduce the thermal resistance of joints between conducting and insulating materials.

HEAT PIPE DESIGN AND ASSEMBLY

The most critical aspect of the design of the heat pipe is to ensure the mechanical and electrical integrity of the interface between the conducting and non-conducting portions of the assembly. This joint must be able to contain the 138 bar (2,000 psi) nitrogen gas with which the heat pipe is filled at room temperature. In addition, it must also remain leak tight during the cool down from room temperature to the 75-80 K operating temperature.

Initial designs used a disc of machinable ceramic material as the non-conducting portion of the heat pipe end caps. These discs were soldered into each end of the heat pipe body to insulate it from the center rod. In spite of careful attention to surface preparation and soldering techniques the solder joint could not withstand the 138 bar (2,000 psi) nitrogen fill pressure. These joints also failed to remain leak tight when cooled from room temperature to the 75 K operating temperature.

A revised design was developed using epoxy joints as shown in figure 2. The high pressure nitrogen charge is effectively contained by the solid heat pipe body and the solder cap. These two ETP copper components are assembled with a silver solder joint. The thickness of the epoxy joint between the heat pipe body and the center rod is minimized to reduce the forces exerted on it by the high pressure nitrogen gas. Further limitations on the joint are that it must be thick enough to maintain electrical isolation yet thin enough to insure that the joint does not fail due to differential thermal contraction on cool down.

The joint is made using epoxy which has been degassed in a vacuum chamber to remove any bubbles which could compromise electrical isolation. Any soldering done on the heat pipe after the epoxy joints are made must be with a low melting point solder to ensure that the nylon washers and epoxy are not damaged. The flexible upper copper lead is soldered into the heat pipe center rod using a soft silver solder before the epoxy joint is made. The flexible links are soldered to the bottom of the heat pipe center rod using a low melting point (58 C) solder after both epoxy joints are made. No soldering can be done after the heat pipe is filled with nitrogen due to the danger of exceeding design stresses by heating the nitrogen gas.

Filling the heat pipe with 138 bar (2,000 psi) nitrogen gas at room temperature is the final step in the assembly of the current leads. The shape of the cavity between the center rod and the heat pipe body was determined by thermal design requirements. When the heat pipe is cooled to its operating temperature the nitrogen will exist in the cavity as a two-phase fluid. The liquid nitrogen will just fill the well in the bottom of the cavity. This well was designed to balance the area required for boiling heat transfer on the center rod with the upper area required for condensation on the heat pipe body. By making the heat pipe body in two pieces the center cavity with the required geometry, as discussed above, can be easily machined. The rounded corners of the nitrogen cavity are intended to reduce electrical arcing which can occur at sharp projections.

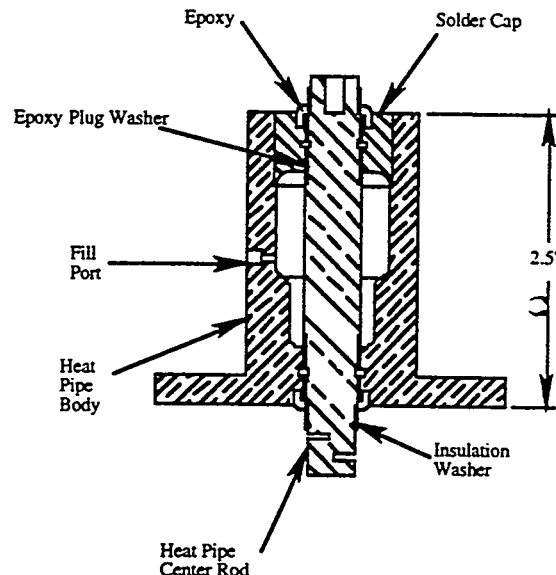


Figure 2. Heat pipe thermal intercept.

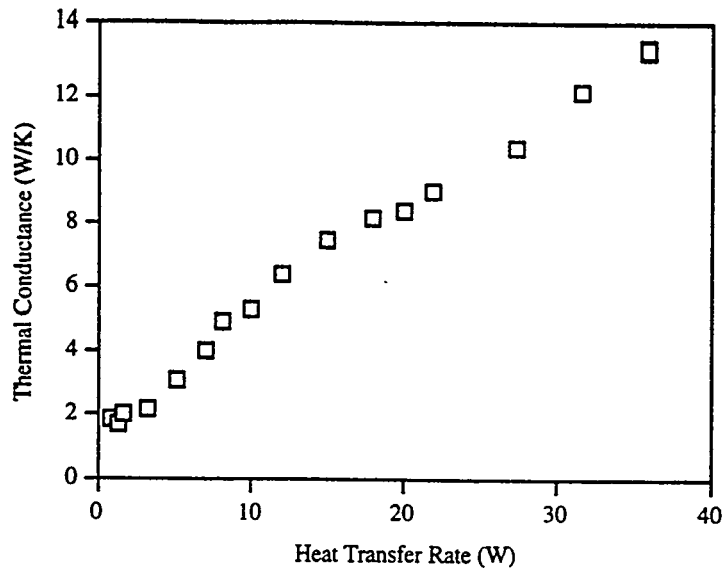


Figure 4. Thermal conductance of the heat pipe.

Electrical Testing

Electrical performance measurements were obtained by measuring the leakage current across the heat pipe as a function of the applied voltage. A positive voltage was applied to the heat pipe center rod with the heat pipe body connected to electrical ground. A large resistance (10 M Ω) was placed in the circuit to limit current flow in the event of electrical breakdown. The leakage current across the heat pipe was then measured.

Initial measurements were made with no heat flowing across the intercept, first at room temperature and then at 87 K. Once the integrity of the heat pipe electrical isolation was verified, measurements were made with heat loads on the heat pipe ranging from 5 to 15 W and with the temperature at 87 K. As figure 5 shows, there is essentially no difference between the room temperature and 87 K measurements with no heat load. Furthermore, a comparison of the data with an applied thermal load with the data with no thermal load indicate that the evaporation and condensation occurring in the heat pipe do not affect the electrical performance. No electrical breakdown was observed at voltages up to 8,000 volts. This performance is in excess of that required for current leads in large electric utility applications.⁷

The heat pipe greatly exceeded its electrical performance target of withstanding 1,000 volts with a 5 W thermal load. Initial concerns that the bubbles produced by boiling at the heat pipe center rod would significantly degrade electrical performance were demonstrated to be unfounded.

CONCLUSIONS

We have demonstrated the ability of a composite heat pipe, made of conducting and non-conducting materials, to function as an HTS current lead thermal intercept. The heat pipe transferred 35 W with a 2.7 K temperature difference, which gives a thermal conductance significantly higher than designs which rely on thermal conduction through solids. The heat pipe thermal intercept successfully withstood 8,000 volts without breakdown while carrying a thermal load of 15 watts. The heat pipe greatly exceeded its performance targets of 1,000 volts electrical isolation with a 5 watt thermal load.

4. R.C. Niemann, J.D. Gonczy and T.H. Nicol, Low-Thermal -Resistance, High-Electrical-Isolation Heat Intercept Connect, *Advances in Cryogenic Engineering*, Volume 39, p. 1665, 1994.
5. M.A. Daugherty, F.C. Prenger, D.D. Hill, D.E. Daney and K.A. Woloshun, HTS Current Lead Using a Composite Heat Pipe, Paper LNC-3, presented at the 1994 Applied Superconductivity Conference, Boston, MA, October 16-21, 1994. Submitted to *IEEE Transactions on Applied Superconductivity*.
6. R.C. Niemann, Y.S. Cha and J.R. Hull, W.E. Buckles, B.R. Weber and S.T. Yang, Performance Evaluation of High-Temperature Superconducting Current Leads for Micro-SMES Systems, Paper LNC-8, presented at the 1994 Applied Superconductivity Conference, Boston, MA, October 16-21, 1994. Submitted to *IEEE Transactions on Applied Superconductivity*.
7. R.C. Niemann, Y.S. Cha and J.R. Hull, C.M. Rey and K.D. Dixon, Design of High-Temperature Superconductor Current Lead for Electric Utility SMES, Paper LNC-7, presented at the 1994 Applied Superconductivity Conference, Boston, MA, October 16-21, 1994. Submitted to *IEEE Transactions on Applied Superconductivity*.