Ucr-15156

CENTRAL RESEARCH LABORATORIES

AIRCO, INC.

MURRAY HILL, N.J. 07974

MASTER

FINAL REPORT COVERING WORK DONE

UNDER LLL P.O. # 4155009

PREPARED BY: CARY SPENCER

SEPTEMBER 21, 1979

SU-79-107

FINAL REPORT COVERING WORK DONE

UNDER LLL P.O. # 4165009

Prepared by: Cary Spencer

September 21, 1979

DISCLAIMER

This book was prepared as an unclassified 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. References 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.

LIST OF FIGURES

- FIG. 1 Embossed OFHC copper strip which is soldered bonded to Nb_3Sn superconducting core.
- FIG. 2 Cross-section of Nb_3Sn superconductor solder bonded to embossed OFHC stabilizer strip.
- FIG. 3 Tape is applied to prevent electroplating of Sn on unembossed side of strip. Solution in tank prepares embossed surface for solder electroplating process.
- FIG. 4 Tank in which embossed surface of the strip is electroplated with 50 Pb-50 Sn solder.
- FIG. 5 Hot inert gas is used to heat the solder plated strips and the Nb_3Sn conductor to the soldering temperature needed for a strong bond.
- FIG. 6 Compressor registers and compresses strips and conductor together while water sprays on the composite to quench the solder. The pads on the side chains have been widened to improve registry of the strips and conductor.
- FIG. 7 Rolling mill and strip payoff which are used to emboss HFTF stabilizer strip.
- FIG. 8 Design of rolls to emboss OFHC stabilizer strip.
- FIG. 9 Photograph of aligned rolls used to emboss HFTF stabilizer strip.
- FIG. 10 Stands and spools which payoff the embossed OFHC strip are shown. The Nb_3Sn conductor can be seen entering the cladding line between the two embossed strips.
- FIG. 11 The 5 m long furnace and inert gas pressurized retort in which intermediate anneals are made on Nb_3Sn superconductor while in rod form.
- FIG. 12 Gas-fired bell furnace in which intermediate anneals and reactions can be made on Nb_3Sn conductors in coil form.
- FIG. 13 New 15.5 m draw bench for drawing metals in rod form.

INTRODUCTION

The High Field Test Facility (HFTF) to be built at Lawrence Livermore Laboratories (LLL) consists of a magnet which will be wound with Nb_3Sn superconductor. Embossed and electroplated copper strip will be soldered to the two broad sides of a rectangular Nb_3Sn superconductor 5.4 mm x 11.0 mm x approximately 100 m long. It is the purpose of this project to upgrade existing facilities to emboss the copper stabilizer strip, electroplate the strip with 50 Pb-50 Sn solder, and to solder two such strips to the superconductor. This program has been approached in seven separate tasks which are described in this report.

Task 1 - Fabricate Clad Samples of HFTF #1 and HFTF #2

Two 50 ft long samples of clad superconductor were delivered to LLL for evaluation. One sample was HFTF #1 embossed strip, shown in Figure 1, which was electroplated and soldered to a "flat" superconducting core. The soldered composite is pictured in Figure 2. The other sample was the HFTF #2 embossed strip in which each embossed pad contains a rectangular projection in the center which was soldered into a slot drawn into the superconducting core.

Task 2 - Change Electroplating Line to 50 Pb-50 Sn Solder

An existing line at Airco was modified to plate 50 Pb-50 Sn solder. Figures 3 and 4 show two views of the solder line. Converting the line from 90 Pb-10 Sn meant that new solder cathode plates were obtained and installed and that appropriate

Figure 1. Embossed OFHC copper strip which is solder bonded to Nb₃Sn superconducting core.

Figure 2. Cross-section of Nb₃Sn superconductor solder bonded to embossed OFHC stabilizer strip.

Figure 3. Tape is applied to prevent electroplating of Sn on unembossed side of strip. Solution in tank prepares embossed surface for solder electroplating process.

Figure 4. Tank in which embossed surface of the strip is electroplated with 50 Pb-50 Sn solder.

alterations to the chemistry of the plating solutions were made. Payoff and takeup spools had to be made to handle the HFTF strip and the payoff and takeup had to be modified for the narrow HFTF strip. An apparatus shown in Figure 3 was set in line to dispense tape onto the flat side of the embossed strip to prevent plating on the flat side. Additional circulating jets were placed into the plating bath to promote uniform plating texture and surface. A better temperature control has been installed to maintain a constant temperature in the plating bath. Three 100 ft long trial lengths of copper strip have been run to establish plating parameters and a 3 ft piece of each trial strip has been supplied to LLL for evaluation.

Task 3 - Improve Registry Between HFTF #1 and Core.

An existing cladding line has been realigned to register the sides of the embossed strip with the superconducting core. After exiting the furnace (Figure 5), the two embossed copper strips and superconductor enter a compressor (Figure 6) which registers the sides under light pressure and which compresses the strips and superconductor until the solder is quenched and solidified to form a strong bond (Figure 2).

Rolling mill rolls have been modified slightly to correct any rounding of the embossed pads. A very slight degree of rounding is unavoidable because of the manner in which the strip must separate from the rolls upon exiting the rolling mill.

The rolling mill and payoff which emboss the OFHC stabilizer strip are shown in Figure 7. Rolls were designed which are 720 mm in diameter with 120 slots around the circumference. The slots which form the embossed pads are spaced every 3° around the circumference. A sketch of the rolls is shown in Figure 8 and a photograph of the HFTF #1 rolls are shown in Figure 9.

Figure 5. Hot inert gas is used to heat the solder plated strips and the Nb_3Sn conductor to the soldering temperature needed for a strong bond.

Figure 6. Compressor registers and compresses strips and conductor together while water sprays on the composite to quench the solder. The pads on the side chains have been widened to improve registry of the strips and conductor.

Figure 7. Rolling mill and strip payoff which are used to emboss HFTF stabilizer strip.

Figure 8. Design of rolls to emboss OFHC stabilizer strip.

Figure 9. Photograph of aligned rolls used to emboss HFTF stabilizer strip.

Task 4 - Modify Tooling To Roll HFTF #2 Strip

A set of rolling mill rolls similar to those in Figure 9 were machined for use in the rolling mill to produce HFTF #2 copper strip. Using these rolls lengths of HFTF #2 stabilizer strip have been fabricated.

A special die was purchased to draw the slot into the HFTF core. This die forms a slot in the center of broad sides of the core with which the projection of pads in the HFTF #2 cladding mates, causing the strip and core to register properly. A 3 ft long sample of core material with HFTF clad #2 was furnished to LLL for evaluation.

Task 5 - Prepare 50 ft samples of HFTF #1 and HFTF #2

Because of the failure to produce superconducting core with uniform filament diameters, no useable core has been produced under LLL P.O. #3237409. Problems encountered with monolith core fabrication are described in reports issued describing work done under P.O. #3237409. No 50 ft samples have been produced because no superconducting core is available.

Task 6 - Scale Up Rolling, Plating, and Cladding Lines

A rolling mill with appropriate payoff and takeup is available to emboss the HFTF stabilizer strip (Figure 7). On this mill we have produced over 2000 ft of high quality stabilizer on which the pads have well defined edges. Rolling speeds of over 200 ft/hr are easily obtained, allowing us to roll required lengths of strip in a very reasonable time span. Reels are available which handle approximately 450 ft of strip in continuous lengths.

Scaleup of the solder electroplating line occurred simultaneously with the conversion to 50 Pb-50 Sn solder and the line is shown in Figures 3 and 4. We have successfully plated 350 ft lengths of strip with solder on 4 different runs.

Task #3 was part of the modification of the cladding line to handle long lengths of HFTF conductor. A traversing payoff has been built for the reacted superconductor core dispensation. Two 273 kg (600 lbs) capacity, automatic centering, braked reels (Figure 10) have been purchased to pay off the embossed and plated strip. Guide rolls have been placed in line with the furnace to align the strips and conductor as they enter the furnace and an improved flux tank has been added to flux the solder surfaces. A graphite jig maintains registry of the strips and conductor in the furnace and a weighted strip in the furnace compresses them after they have been heated to soldering temperature. Compressor modifications were described in TASK 3. An ultrasonic test cell has been installed in-line to continuously test the soldered interfaces between the strip and the conductor. Constant speed is maintained using a Bartell tractor to pull the strip and conductor through the line. A traversing takeup has been built to spool the clad conductor onto wooden spools. Three 350 ft runs were made and a 3 ft sample has been supplied from each run to LLL.

Task 7 - Fabrication of 350 ft Continuous Lengths

Airco facilities are capable of producing 350 ft continuous lengths of conductor. A tube furnace, shown in Figure 11, is available for the annealing required by bronze in the straight configuration and a gas-fired bell furnace, shown in Figure 12, is available for annealing coils and reacting the finished superconductor on spools. A new 57 ft draw bench (Figure 13) has been set up to

Figure 10. Stands and spools which payoff the embossed OFHC strip are shown. The Nb_3Sn conductor can be seen entering the cladding line between the two embossed strips.

Figure 11. The 5 m long furnace and inert gas pressurized retort in which intermediate anneals are made on Nb_3Sn superconductor while in rod form.

Figure 12. Gas-fired bell furnace in which intermediate anneals and reactions can be made on Nb_3Sn conductors in coil form.

Figure 13. New 15.5 m draw bench for drawing metals in rod form.

allow us to draw long lengths in-house, avoiding the traditional delays associated with commercial drawing facilities in our area. Acid and reagent cleaning facilities are available for cleaning the core and strip in the various stages of production.

CONCLUSION

A considerable amount of effort has been placed into the modification of existing rolling, plating, and cladding lines in order that we at Airco can reliably fabricate the approximately 120 mm (400 ft) continuous lengths of clad conductor which will be required for the HFTF facility. We have supplied the required samples of the plating and cladding to LLL for evaluation and have completed all of the tasks defined in this contract with the exception of TASK 5 which was precluded by a lack of suitable superconductor.