SLAC-PUB-1102
(EXPI)
September 1972

A METHOD FOR PRODUCING LONG, CYLINDRICAL, SUPERCONDUCTING FLUX SHIELDS*

A. C. Newton, F. Martin, S. J. St. Lorant,
and W. T. Toner**
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

Abstract

A technique is described for making long, cylindrical, magnetic flux shields from Nb_3Sn superconducting tape.

(Submitted to Rev. Sci. Instr.)

---

* Work supported by the U. S. Atomic Energy Commission.

**Now at Rutherford High Energy Laboratory, Chilton, Didcot, Berkshire, England.

In an earlier paper,[1] we described the development and performance of a magnetic flux-free particle beam channel through the central field of a 1.5-T large-aperture analyzing magnet used in a high-energy physics experiment. The flux-free region is produced by means of a superconducting tube: It is the purpose of this note to describe the method of fabricating this superconducting structure from Nb_3Sn ribbon.

The superconducting flux shield, mounted on a stainless steel support tube, is immersed in a bath of liquid helium contained in a 7-m long coaxial cryostat. The particle beam passes through the evacuated support tube. The geometry of the device, and hence the supercurrent distribution, is such that the tube can be assembled from two identical semi-cylindrical half-shells with the plane of separation oriented perpendicular to the direction of the external field.

The superconducting material is a 50-mm wide Nb_3Sn ribbon, manufactured by KBI[2] in several grades, the principal difference between which is the number of stabilizing copper layers and their thicknesses. Thus, as described by the manufacturer, THC 1 ribbon consists of a double layer of Nb_3Sn, 2 - 3 μm thick, produced by diffusion of tin into a ribbon of pure niobium. This basic module is stabilized with copper, either electrolytically or by cladding with 30 to 120 μm thick copper foil. THC 2 tape consists of two niobium-Nb_3Sn modules sandwiched between similar thicknesses of copper, and thus has four layers of superconductor in each ribbon.

Our final construction used THC 2 material with about 60 μm of copper stabilizer, but we should mention that in our qualifying tests, various materials were tried that had from 15 to 120 μm of copper cladding. The thickness of the copper cladding is ultimately determined only by handling convenience: Our method does not depend on the presence of specific amounts of copper. The superconducting ribbon was pre-coated on both sides with a 25 μm thick strike of 60:40 lead-tin solder by the manufacturer. The tape should have no regions of excess solder on it as it is almost impossible to remove the excess in the forming and bonding operations. Because the copper cladding is soldered to the superconductor, care should be exercised during operations at elevated temperatures so that the tape does not delaminate and that its superconducting properties are not affected. Also the copper on the tape work-hardens easily so that a minimum of handling is recommended.

The dies required for the forming and bonding operation are made of aluminum. For small assemblies, dies can usually be designed for use without additional tooling: For our 4-meter long tube, the die was part of a forming jig, the cross section of which, including the oven, is shown in Fig. 1. The female part of the die consists of a thick strip of aluminum in which a U-shaped channel is milled, the width of the channel being determined by the final outside diameter of the superconducting shells. This forming die is held captive by a massive aluminum base block, which extends beyond both ends of the die. The block is welded to a support beam, whose function it is to ensure alignment and to provide the necessary stiffness. The superconductor is formed by a cylindrical mandrel, machined to the exact outside diameter of the tube on which the final assembly is to be made. The force necessary for forming and compacting the assembly is provided by a compression plate and a series of bolts spaced along the length of the die. The dimensions of the various components are so adjusted that there is adequate clearance between the die and the compression plate in order that during the shaping operation, the excess of superconductor can protrude from the die without interference.

The fabrication sequence for one half-cylinder is as follows: The tinned superconductor tape is cut to length; we constructed a simple guillotine for this operation to eliminate cutting burrs and reverse bending of the tape. The required number of layers of tape are forced into the die, initially by hand and then, as the tape begins to take shape, with the mandrel. It is advisable to coat the die and each layer of tape with a very thin coat of neutral resin flux. Too heavy an application of flux will result in excessive boiling during the heating operation which can lead to improperly bonded regions. Once the tape has taken up the approximate shape of the die, pressure is applied with the compression plate. The assembly is placed in a suitable oven, warmed slowly and evenly to just above the melting point of solder ($\sim 184^{o}$ C), and the compression plate bolts tightened as uniformly as possible. The clamping should be progressive to allow the tapes to settle into the final shape and to permit the solder to flow evenly.

The die and the mandrel are removed from the jig after adequate and slow cooling; great care must be taken at this stage not to remove or otherwise disturb the mandrel as it provides the only means of holding the superconductor in the die for the subsequent machining operation. In order to make a semi-cylinder, the appropriate amount of the protruding superconductor and the excess die material are milled off. A part of the mandrel is also removed at the same time. The superconductor is also cut to length while still in the die. Again, a small amount of the die and mandrel are removed in this operation, but the loss can be minimized by careful design. After the milling and sizing operation, the shaped semi-cylindrical superconductor composite can be removed from the die and handled without a support.

Two half-cylinders are mounted on a copper-plated and tinned stainless steel support tube which has its outside dimensions carefully matched to the inside diameter of the two shells. The two half-cylinders are carefully aligned, placed around the tinned support tube, and clamped by the original corresponding dies in the molding jig. This assembly is reheated and solder added as necessary to make the bond. Again, all parts to be mated should be coated with a thin layer of resin flux. It is most important that the line of separation between the two half-shells be kept as narrow and as uniform as possible because it is the region in which preferential flux penetration will occur. The narrower the slit, the more effective the shield will be.

For reasons of mechanical strength and stability, it is advisable not to rely entirely on the solder bond, but to provide some form of external support for the superconductor. This may take many forms: One approach used successfully is shown in Fig. 2. The stainless steel octagonal spacers with brass inserts provide both the necessary mechanical clamping and a convenient means of aligning and holding the tube in the cryostat correctly oriented with respect to the external magnetic field.

References

1. F. Martin, S. J. St. Lorant, and W. T. Toner, SLAC-PUB-1040, 1972, to be published in Nuclear Instruments and Methods.

2. KBI - Kawecki Berylco Industries, P. O. Box 1462, Reading, Pennsylvania, U. S. distributors of Nb_3Sn tape manufactured by Thomson-CSF, 57 Boulevard de la Republique, 78, Chatou, France.

List of Figure Captions

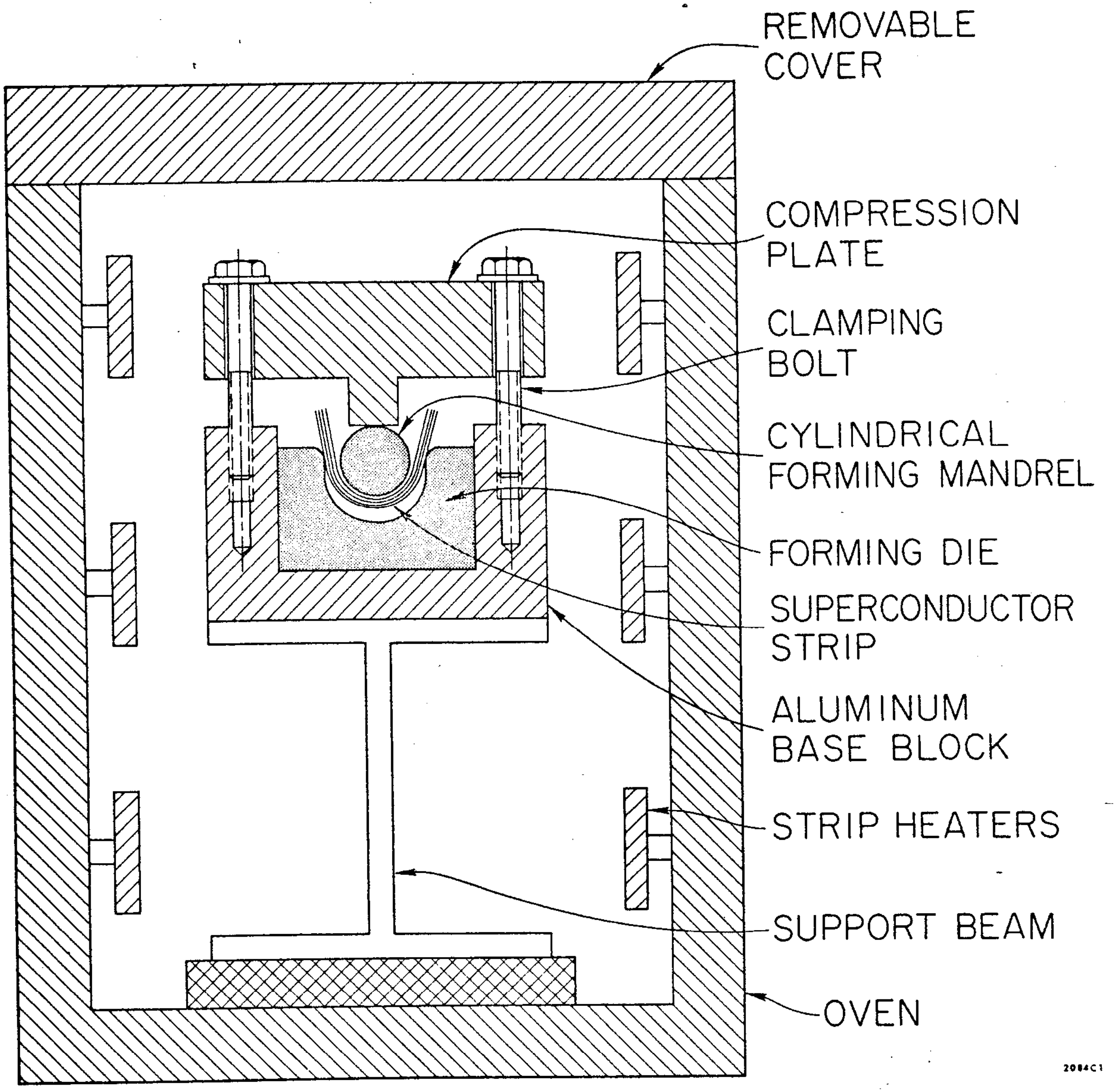
REMOVABLE COVER
COMPRESSION PLATE
CLAMPING BOLT
CYLINDRICAL FORMING MANDREL
FORMING DIE
SUPERCONDUCTOR STRIP
ALUMINUM BASE BLOCK
STRIP HEATERS
SUPPORT BEAM
OVEN
2084C1

Fig. 1

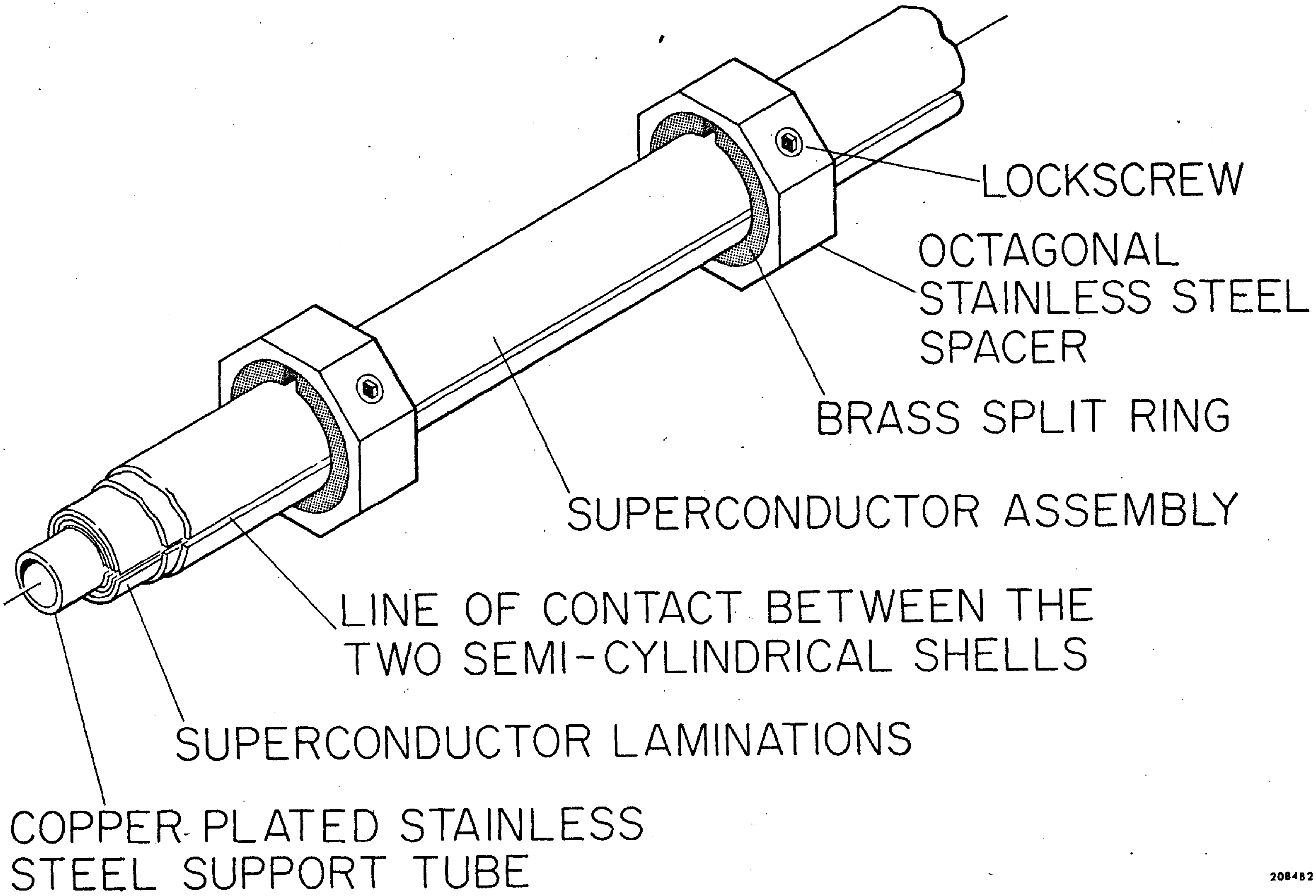
LOCKSCREW
OCTAGONAL STAINLESS STEEL SPACER
BRASS SPLIT RING
SUPERCONDUCTOR ASSEMBLY
LINE OF CONTACT BETWEEN THE TWO SEMI-CYLINDRICAL SHELLS
SUPERCONDUCTOR LAMINATIONS
COPPER PLATED STAINLESS STEEL SUPPORT TUBE
208482

Fig. 2