ALTERNATING CURRENT LOSSES IN SUPERCONDUCTING CONDUCTORS FOR LOW-FIELD APPLICATIONS

Westinghouse Research Laboratories
Pittsburgh, Pennsylvania

INTRODUCTION

The loss characteristics of type II superconducting conductors carrying an ac current in the absence of an applied field, either ac or dc, is one of the principal factors which will determine the feasibility of ac power transmission lines constructed with these materials. These self-field conductor losses depend not only upon the intrinsic superconductor characteristics, such as the shape of the critical current density–critical field curve [1], but also upon the conductor geometry, and the amount, type, and distribution of the nonsuperconducting matrix material. In order to obtain a better understanding of these losses and their mechanisms, an experimental investigation of ac losses has been undertaken in a number of types of commercial state-of-the-art superconducting conductors. Conductors investigated include Nb₃Sn tapes, Nb–Ti multifilament and single-core conductors in round and rectangular configurations, and a Nb multifilament conductor.

All measurements were performed at 4.2 K and 60 Hz using a helium boiloff calorimeter capable of measurements between 0.010 and 50 W with sample currents up to 1500 A (rms).

EXPERIMENTAL TECHNIQUE

Proposed operating current densities for transmission lines employing type II materials are typically about two orders of magnitude below the critical current density $J_c$, so that an acceptable loss level and overload capability are obtained [2]. To perform self-field loss measurements on samples in this operating region requires relatively long samples (about 10 to 100 m) and a calorimeter sensitivity of approximately 10 mW. To test these same samples under conditions corresponding to overload conditions requires the calorimeter to be capable of handling power inputs of approximately 10 W or more.

These requirements have necessitated the construction of a helium boiloff calorimeter with a large working volume as shown in Fig. 1. This calorimeter is constructed almost entirely from commercial ultrahigh-vacuum copper-gasketed flange components. Flanges and feedthroughs of this type are highly reliable upon thermal cycling and allow for a modular design which can easily be assembled, disassembled, or modified as necessary. The details of the construction and operation of this probe are reported elsewhere [3]. The essential part is the large (20 cm ID,
Fig. 1. Alternating current loss apparatus for calorimetrically measuring long lengths of conductors in a bifilar coil arrangement.

35 cm long) vessel at the bottom of the probe. The wire sample on a Micarta mandrel is mounted inside this vessel. The vessel and surrounding dewar are filled with liquid helium. Current is fed into and out of the dewar via several vapor-cooled leads in parallel, and into and out of the vessel via massive OFHC copper feed-throughs. In operation, the boiloff from the dewar is throttled to balance the dewar and vessel pressures (and thus their temperatures). This control and the vessel vacuum jacket minimize interbath heat flow. The heat transfer effect of a pressure imbalance was determined to be 5.6 mW/Torr of pressure differential. The balance condition was always within ±0.1 Torr during measurements. The helium vapor evolving from the vessel is ducted up a pipe inside a support tube, the vacuum jacket between them serving to minimize the effects of changing helium level in the dewar when low flow rates are being measured. The evolved gas is first passed through a large heat exchanger and then is metered by variable-area float-type flowmeters calibrated to 2% accuracy for helium gas. The helium flow rate is translated into heat input by correcting for the temperature-dependent heat of vaporization and for the temperature-dependent gas/liquid density ratio (to allow for the gas remaining to fill the space left by the evaporated liquid). The heat input thus calculated was found to agree with the known heat input of a calibrating heater to about 2% (the accuracy obtainable in reading the flowmeters) over the whole range of operation from 50 W down to about 10 mW, at which point the residual heat leak into the vessel, about 25 mW, limits the observable heat input.

The sample mandrels are Micarta cylinders 25.4 cm long by 7.8 cm OD, into which a double helical wire groove is machined. The wire center-to-center distance,