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Reexamining the heat treatment of RRP® Nb3Sn and the potential for further improvements

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The heat treatment of internal tin Nb3Sn wires has historically used multiple low temperature stages designed to mix the Cu and Sn as to minimize liquid contact with the Nb filaments, to inhibit Kirkendall void formation, or to increase the Sn concentration surrounding the Nb filaments prior to the A15 reaction. Our recent studies have shown that the unique geometry of high-Jc RRP® wires, where Nb filaments in a Cu matrix are densely packed around the Sn core, benefits from a very different approach to optimization. In such wires the low Cu:Sn ratio requires the Cu-Sn mixing to occur within the sub element cores. This is facilitated by the early formation of a membrane-like ring of the Sn Nb Cu ternary phase Nausite around the core that allows Cu diffusion from within the filaments into the Sn-rich core, while inhibiting Sn diffusion into the filament pack. Although beneficial as a membrane, the growth of this layer must be controlled as it ultimately decomposes to a disconnected A15 phase. Extensive quantitative image analysis has allowed us to show the relationship between heat treatment temperature and time, the net Cu inward diffusion and the Nausite ring thickness, allowing us to develop optimized low temperature heat treatments that balance the amount of low melting point Cu-Sn with the amount of Sn and Nb lost to Nausite formation. We show that this new heat treatment strategy can significantly increase the Jc of RRP® strands, especially for small diameter sub-elements.

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