Characterisation of Nb₃Sn Strands by the European Fusion Energy Laboratory in Durham, UK





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Superconductivity Group

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Talk Outline

- Durham University's Involvement with the ITER Project
- Measurement Requirements
- Our Facilities
- Furnaces and Heat-Treatment
- Cryogenic Measurements
- Room Temperature Measurements
- Other Measurements
- Summary and Concluding Remarks







priority

energy

fusion

The ITER Project

It is an experimental attempt at producing the 1st net energy gain from sustained fusion reactions between deuterium and tritium.



A global collaboration has been formed to test the feasibility of fusion g an China Lindia Japan South Russia USA

The **ITER** project is a global collaboration including seven members

The organisation responsible for the European Union's contribution to the project is called Fusion for Energy (F4E). They are officially recognised as a Domestic Agency responsible to the ITER Organisation.

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AST POAstal drag 2012R



The magnet is composed of 4 sub-systems



Main TF Nb₃Sn Strand Specification Parameters

	TF Strand
Strand diameter	0.820±0.005 mm
Strand twist pitch	$15 \pm 2 \text{ mm}$
Cr or Ni-plating thickness	$2 + 0 - 1 \mu m$
Strand piece length	>1000 m
Cu/non-Cu volume ratio	1.0 ± 0.1
Critical current: 12 T for Nb ₃ Sn	
or 6.4 T for NbTi @ 4.22 K,	>190 A
10 μV/m criterion	
n-value at peak field and 4.22 K	>20
RRR after heat treatment	>100
Overall strand hysteresis losses:	
\pm 3 T cycle for Nb ₃ Sn or	$< 500 \text{ mJ/cm}^{3}$
± 1.5 T for NbTi	

[1] C. Sborchia, *et. al.*, "Overview of ITER Magnet System and European Contribution," presented at the 2011 IEEE 24th Symposium on Fusion Engineering (SOFE), 2011, pp. 1–8.

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The Wires

Two makes of Nb₃Sn wire are used

Made with an internal tin process



Made with a **bronze route process**



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Measurement Requirements



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Our Facilities



- Professor Damian Hampshire (laboratory director)
- Mark J. Raine (laboratory manager and senior technical officer)
- A dedicated team of four full time technicians

- A microscopy specialist for sample mounting, polishing and imaging
- A pool of physics research technicians that can be called upon to increase flexibility at short notice

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Furnaces and Heat-Treatment





10 three zone tube furnaces. The temperature of each zone, within the sample space, is independently monitored by calibrated thermocouples during each heat-treatment. Outlying thermocouples are discarded even if they are within specification



The calibration of all thermocouples is checked. Each thermocouple is compared to the others and outlying ones are discarded.







1.4 % increase in diameter during heat-treatment leads to a 2.7 % decrease in sample density



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Furnaces and Heat-Treatment







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Cryogenic Measurement Data

Hysteresis



Magnetic Field



Residual Resistivity Ratio

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Room Temperature Measurement Data

Twist Pitch





Copper non-Copper Ratio

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Variable Strain Measurements

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We have a dedicated team for performing high precision measurements using state-of-the-art equipment.

1

To date we have performed approximately 5000 measurements on 900 samples for the European Union's contribution to the ITER project.

Our facilities are not exclusive to the ITER contract. We are an independent laboratory able to provide a specialist measurement service.

Measurements

17

Cryogenic: Critical Current Hysteresis Losses Residual Resistivity Ratio

Room Temperature Twist Pitch Diameter Chromium Plating Thickness Copper-non-Copper Ratio Tensile Strength

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