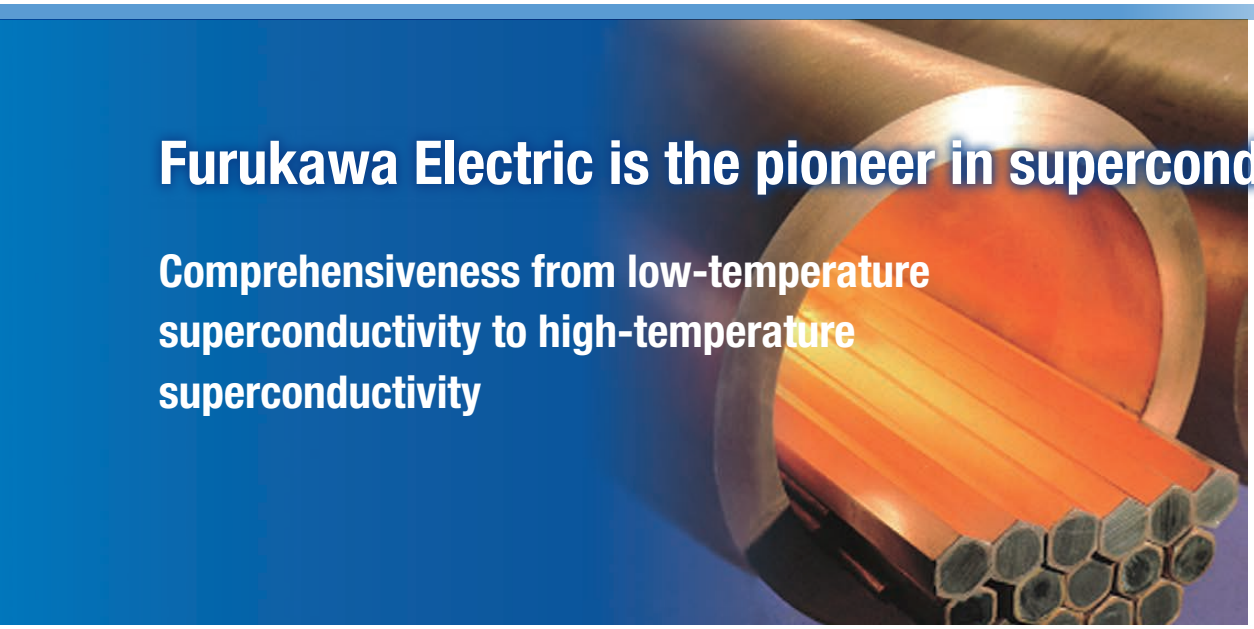
FURUKAWA ELECTRIC GROUP

Low Temperature Superconductors

Contribution to Advanced Science & Technology



Furukawa Electric is the pioneer in superconductivity

Comprehensiveness from low-temperature superconductivity to high-temperature superconductivity

Discovering the Higgs boson!

Furukawa Electric's superconductive technology aids the experiment

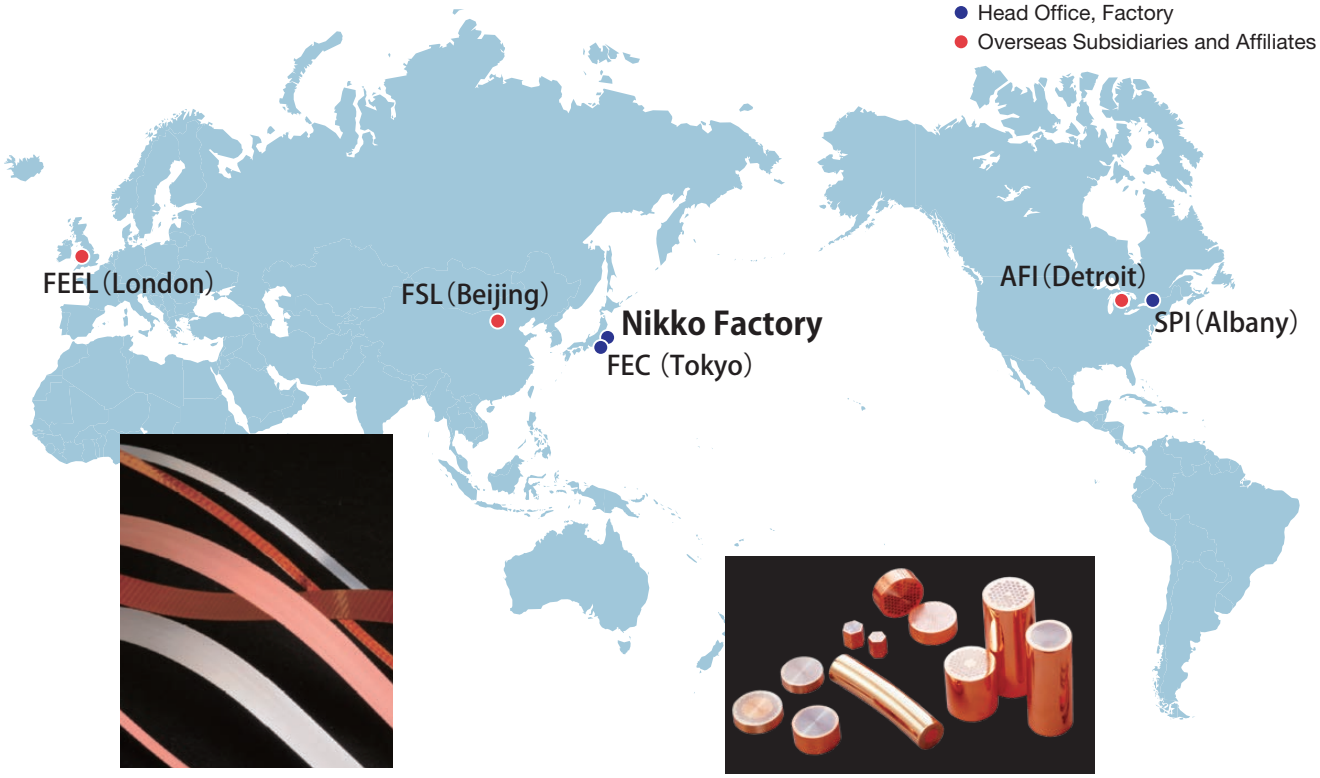
©CERN

FURUKAWA ELECTRIC

1 Factory

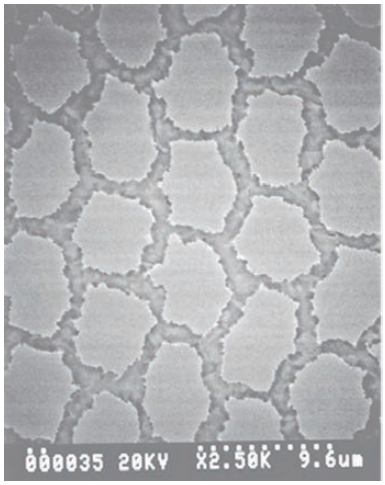
In 1963, Furukawa Electric Co, Ltd. (FEC) became the world's first company to commence research and development work on superconductivity.
Based on our manufacturing technologies for electrical wires and non-ferrous metals, commercial production of NbTi multi-filamentary wire began in late 1960s in Nikko works. We have been providing unique products for more than 50 years and our products are being applied to a broad range of areas, such as MRI, NMR, experimental nuclear fusion reactor and accelerators for high energy physics.

2 Global Network



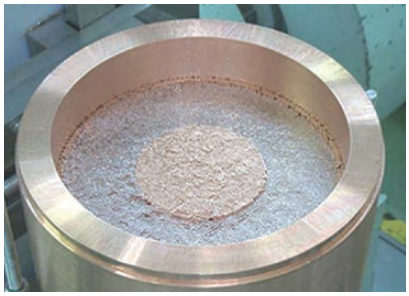
3 Manufacturing Technology

3.1 Fine Filament & Long Length

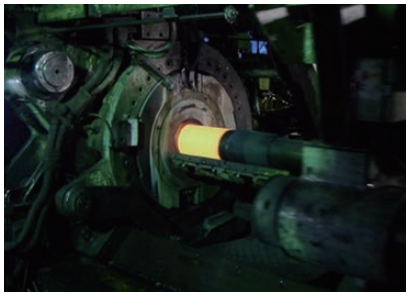


NbTi Filaments

Our excellent manufacturing processes enable FEC to produce long NbTi and Nb_3Sn superconducting wires with thousands of several μm diameter filaments. Key processes are billet assembling without inclusions, high power hot extrusion for large size billets and 75m long drawing bench for long length.
Clean factory, optimized drawing conditions and adequate shaving thickness of surface Cu prevents filament breakage, filament sausaging and wire breakage.



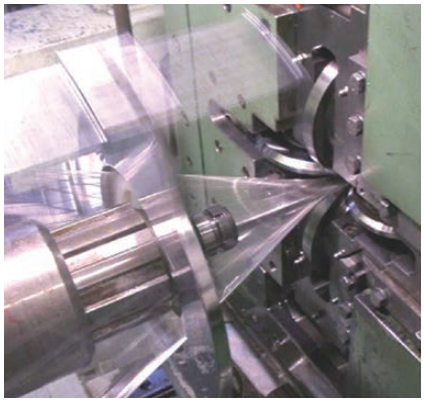
Billet Assembling



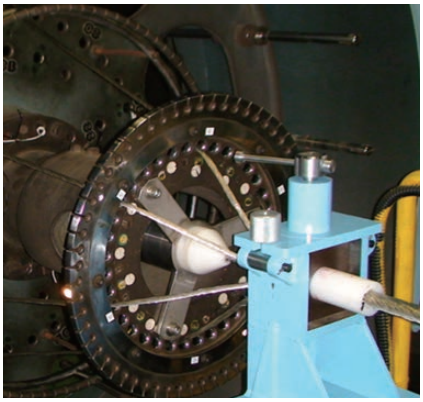
Hot Extrusion

75m Long Drawing Bench

3.2 Cabling



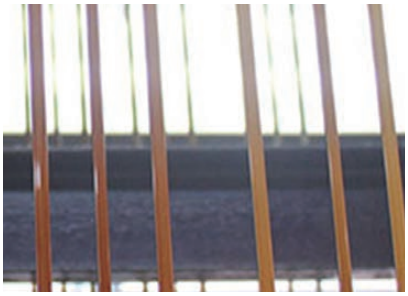
Rutherford Cable



Multiplex Cable

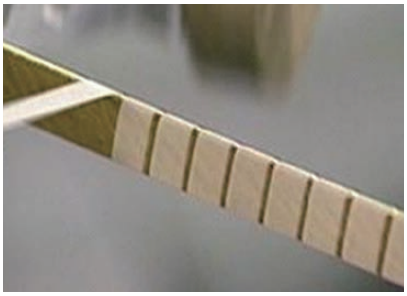
FEC manufactures precisely dimension controlled Rutherford type cable without sharp edges and multiplex cables with round shape, and stainless steel tape wrapping for CIC conductor.

3.3 Insulation



Polyvinyl Formal

Glass Braiding



Taping

FEC can supply several types of insulations: Polyvinyl Formal for round and rectangular NbTi wires, glass braiding for round and rectangular Nb_3Sn wires and polyimide tape or glass tape for NbTi cables.

3.4 Quality Assurance

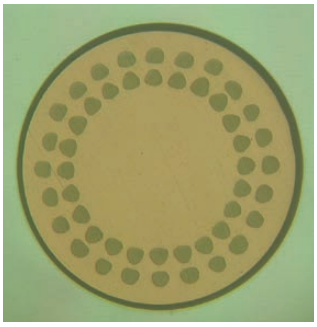
FEC has excellent quality products: Specific properties of the wires and cables are checked using its own testing equipment, which is properly checked for accurate measurement - Ic measurement up to 17T, AC loss measurement, dimension measurement with laser micrometers and eddy current test for whole length quality assurance.

Automotive Products & Electronics Laboratories in Nikko works supports the development of new conductors and solving manufacturing problems, such as wire breakages, with its high investing and analysis ability.

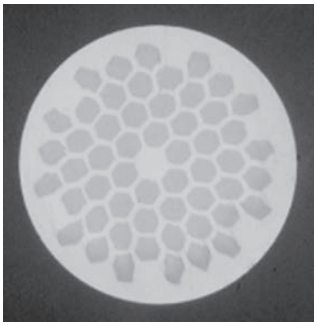
FEC continues to support the success of our customers by supplying high-quality products.

4 Products & Properties

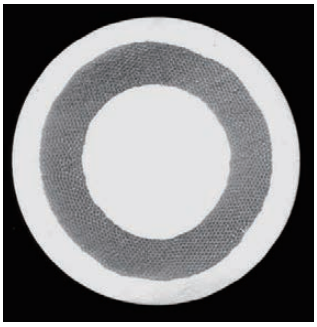
4.1 Multi-Filamentary Superconductors



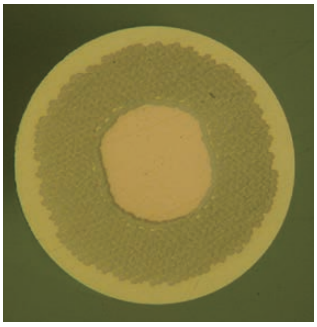
MRI



PCS

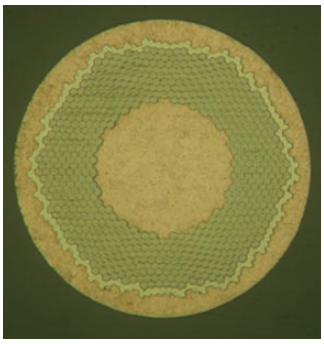


Crystal Growth

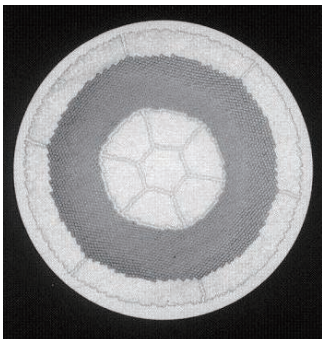


NMR

4.2 Low AC Loss NbTi Superconductors



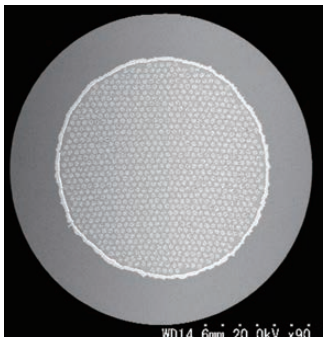
JT-60SA/TF



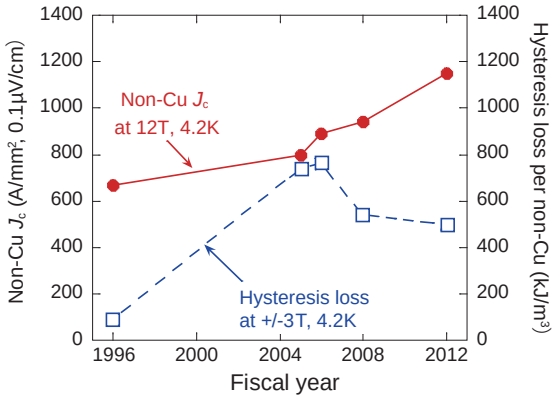
SMES

FEC has extensive experience in developing low AC loss NbTi wires: Applications include generator, nuclear fusion reactor and SMES.
SMES for load fluctuation compensation and frequency control was developed using FEC's conductor and successfully demonstrated a verification test for glid linkage at FEC's power plant in Nikko.

4.3 High Jc & Low AC Loss Nb_3Sn Superconductor



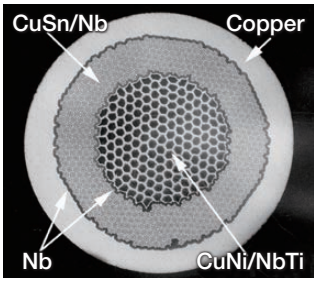
ITER



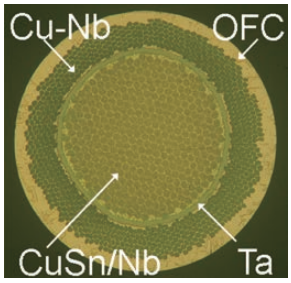
Improvement of Non-Cu Jc

Non-Cu Jc of Nb_3Sn wire (bronze processed) increased remarkably from 650A/mm² to 1,200A/mm² at 12T, 4.2K through R&D for ITER.
High Sn content bronze, round shape fine filament and adequate heat treatment for Nb_3Sn formation are important factors for this improvement.
Hysteresis losses were decreased due to filament diameter reduction and adopting Ta instead of Nb for the barrier between outer Cu and bronze preventing Sn diffusion.

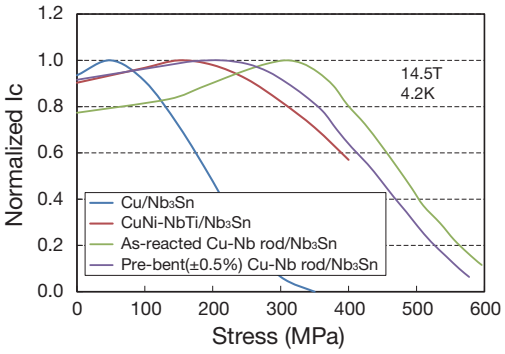
4.4 High Strength Nb_3Sn Superconductors



CuNi-NbTi Reinforced



Cu-Nb Rod Reinforced



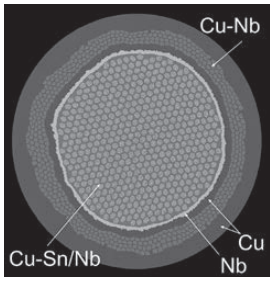
Normalized Ic vs. Stress

Two types of high strength Nb_3Sn wires (bronze processed) have been developed:

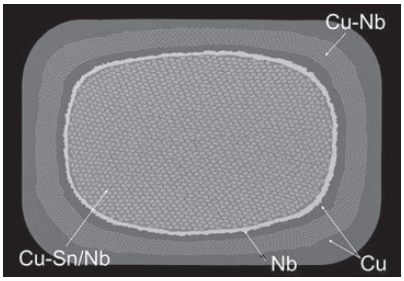
- CuNi-NbTi reinforced wire excels in price and quality and is being applied to high field magnets.
- Cu-Nb rod reinforced wire can be used for react & wind method due to its relatively high tolerance for mechanical strain.

FEC supplies cables composed of both these wires.

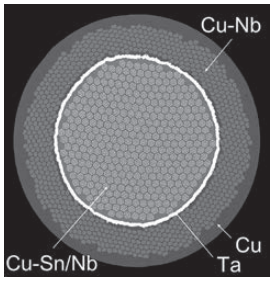
4.5 React and Wind Nb_3Sn superconductors



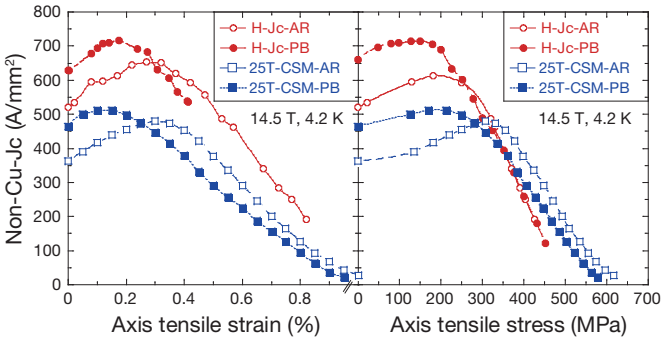
High-Jc



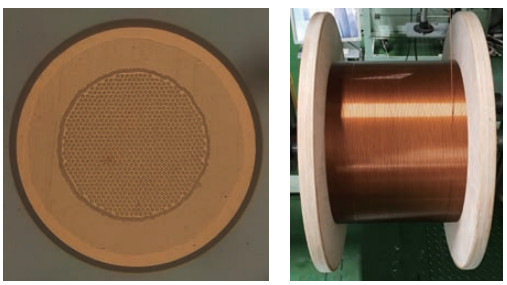
Rectangle



25T-CSM

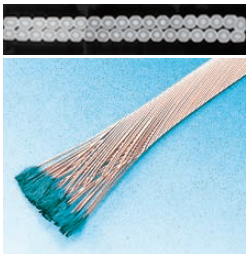


FEC has developed react & wind Nb_3Sn superconducting wire.
FEC can supply various shapes of this wire such as rectangle and Rutherford cable.
This wire has already been used for 25T-CSM in Tohoku university and some magnets in Japan manufacturer.
This wire can be insulated by Polyvinyl Formal.

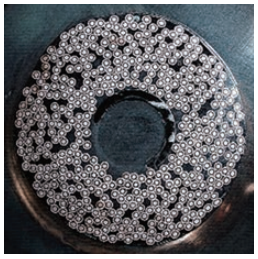


Polyvinyl Formal insulation

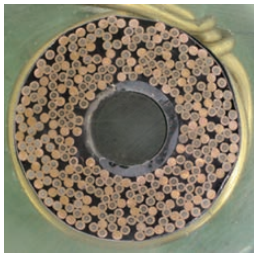
4.6 High Current Superconductors



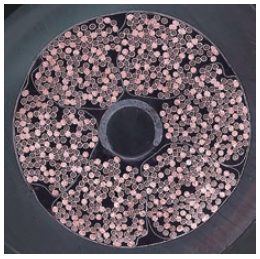
LHC



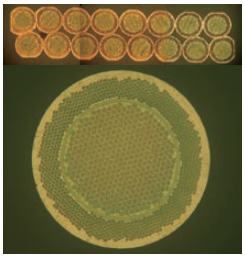
JT-60SA/EF



JT-60SA/CS



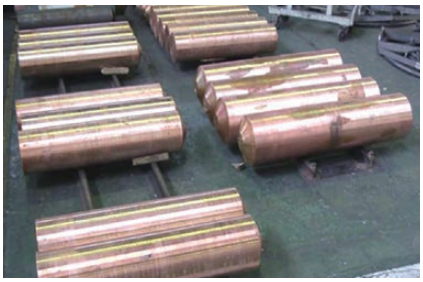
ITER/CS

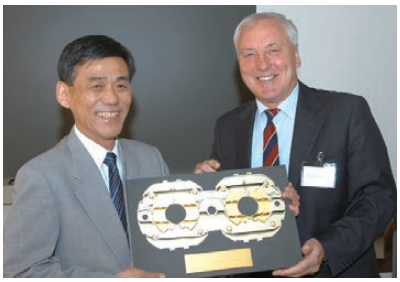


High Field Magnet

5 Large Scale Production

5.1 LHC (CERN)





FEC manufactures 180 tons of strands and 360 tons of Rutherford type cables for LHC dipole and has received the Golden Hadron Award from CERN for the uniformly high quality of its products and the earliest delivery in the world.

5.2 JT-60SA (JAEA & F4E)

JT-60 of Japan Atomic Energy Agency (JAEA) is being upgraded to JT-60SA through Broader Approach Program: Multiplex cabling technology for long length without strand breakage was successfully established. FEC supplied on schedule 52 tons of NbTi conductors for EF coil, 21 tons of Nb_3Sn conductors for CS coil and 43 tons of NbTi strands for TF coil.

5.3 ITER (JAEA & IO)

FEC develops high-performance CS conductor with the world's highest current shearing temperature (Tcs) by the world's highest critical current density of bronze method Nb_3Sn strand and special short-pitch cable, and is manufacturing 60 tons of ITER-CS cables for two modules.

FURUKAWA ELECTRIC CO., LTD. https://www.furukawa.co.jp/en/

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