中色东方 CNMNC

东方钽业 OTIC
中国有色集团成员企业

Breakthroughs in the Processing and Fabrication of Superconducting Cavities and Their Industrial Applications

Ningxia Oriental Superconducting Technology Co., Ltd.

2025-11-6

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Introduction to OTIC and Its Quality Management

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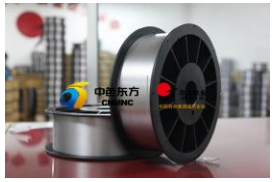
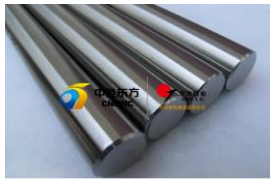
Ningxia Orient Tantalum Industry Co., Ltd. （OTIC）is a holding subsidiary under China Nonferrous (Ningxia) Orient Group Co., Ltd. and a member unit of China Nonferrous Metals Mining (Group) Co., Ltd. It was incorporated in 1999. In 1999, it publicly issued 65 million A shares, and in 2000, it was listed on the Shenzhen Stock Exchange. In 2023, it was included in the list of demonstration enterprises featuring specialization, refinement, uniqueness and innovation released by the State-owned Assets Supervision and Administration Commission. It is one of the major global producers of tantalum raw materials.

The company has a history of nearly 30 years in the production of various tantalum and niobium materials. Among them, sodium-reduced tantalum powder has been recognized as a national manufacturing single champion product. The products such as high-purity niobium oxide, tantalum oxide, and tantalum-niobium metals and their alloy plates, rods, wires, strips and metal products are of first-class quality in China.




Introduction to OTIC and Its Quality Management

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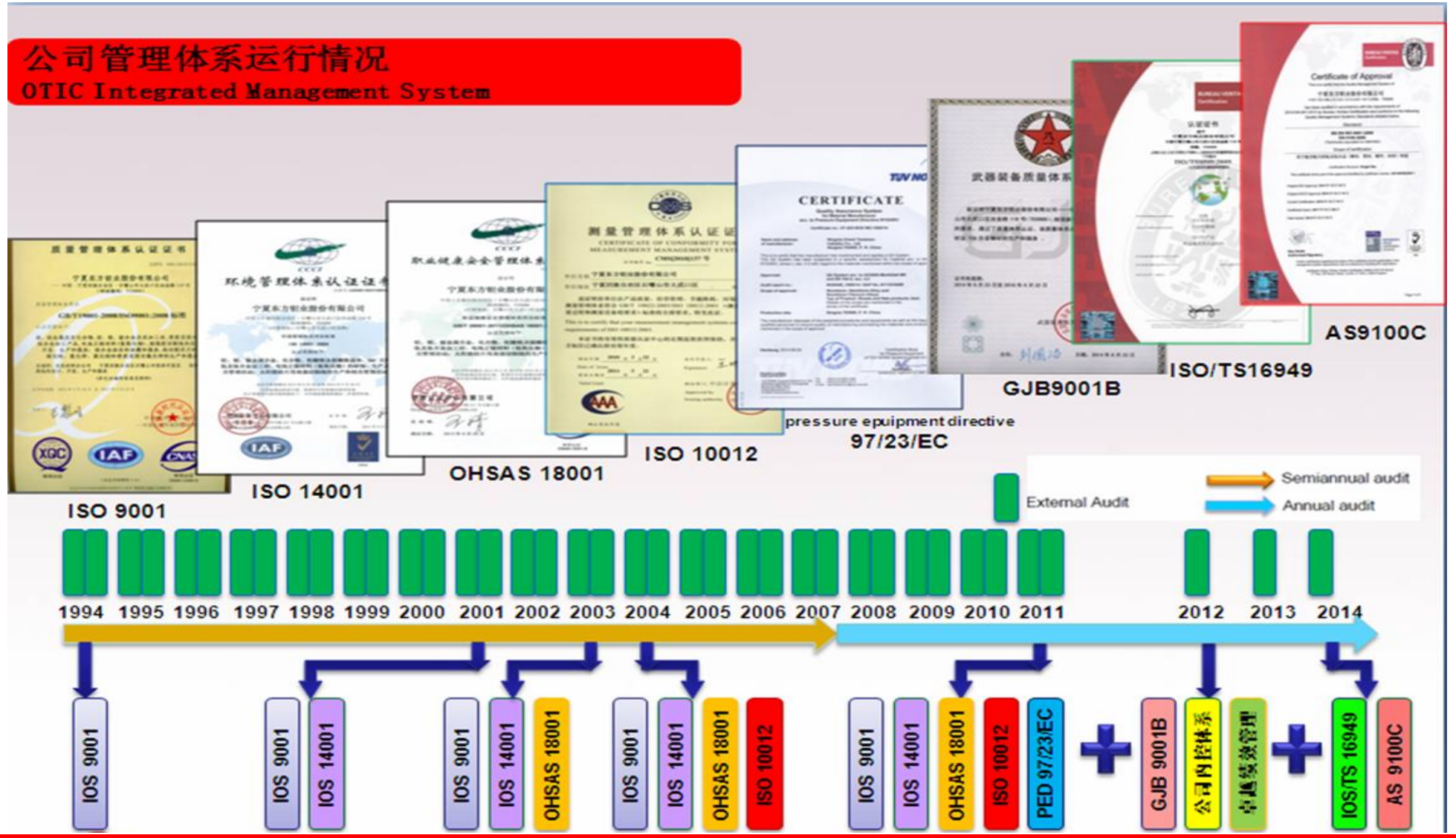

Superconducting Niobium Material Manufacturing Capability and Industrialization

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Superconducting niobium material production line

Industrial chain: Take the lead in undertaking the future industry superconducting material source base of the State-owned Assets Supervision and Administration Commission of the State Council, and build a research and development as well as manufacturing base with a complete industrial chain of superconducting niobium materials and superconducting cavities.

Superconducting Niobium Material Manufacturing Capability and Industrialization

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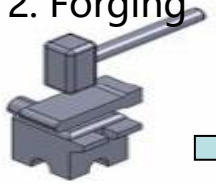
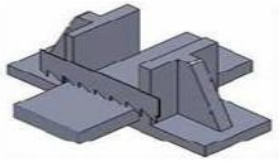
1.Ingot

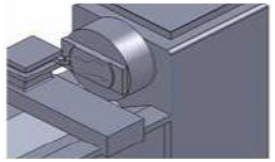
2. Forging



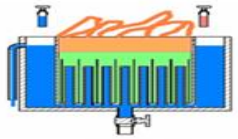
3.Sawing



4. Machine peeling



5. Acid Etching

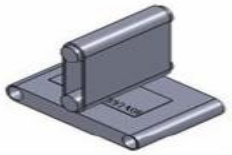


6. Annealing

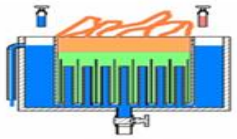
7.Rolling

8. levelling

9. Polishing



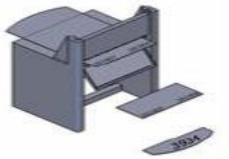
10. Acid Etching



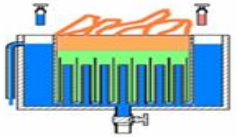
11. Rolling

12. levelling

13.Cutting



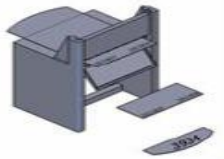
14. Acid Etching



15. Annealing

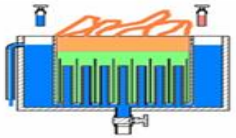
16. levelling

17. Cutting



18. Polishing

19. Acid Etching



20. Packaging

Superconducting Niobium Material Manufacturing Capability and Industrialization

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Products	Annual capacity	Spec.
RRR Nb sheet	20 Tons	RRR40, RRR250, RRR300
RRR Nb tube	5 Tons	RRR40, RRR250, RRR300
RRR Nb rod	5 Tons	RRR40, RRR250, RRR300
Nb-55Ti rod	20 Tons	ASTM B381

Superconducting Niobium Material Manufacturing Capability and Industrialization

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2011 DESY - XFEL
RRR300 Nb: 8 tons, 30% of the project

2012 Michigan State University - FRIB
RRR250 Nb: 8.5 tons, 70% of the project

2014 Fermilab - LCLS II
RRR300 Nb: 5 tons, 50% of the project

2017 INFN and STFC - ESS
RRR300 Nb: 12.5 tons, 100% of the project

2019 IBS - RISP, CERN - HL-LHC, Fermilab - PIP-II, Shanghai - SHINE
RRR300 niobium material procurement in progress

We had built the business relationship with many great customers such as DESY, MSU, Fermilab, JLAB, INFN, STFC, CERN, TRIUMF, RI, ZANON, IHEP, IBS, RRCAT etc.

The R&D History of OSTEC

OSTEC is a joint venture established by OTIC, Ltd. and Peking University. It has a full-process production line covering high-purity niobium plate preparation, superconducting cavity stamping, electron beam welding, radio frequency tuning and post-processing, etc. It has also set up a testing center with the capability to test the mechanical properties, chemical composition and RRR value of tantalum-niobium materials. The accelerating performance of the superconducting cavities developed by the company has reached the international advanced level and been recognized by the international industry.

2010年

The company was founded

2011-2017年

Product Pre-research

R&D of Manufacturing ProcessesVerification and IterationSample VerificationAnnual Production of 20 Superconducting Cavities

The R&D History of OSTEC

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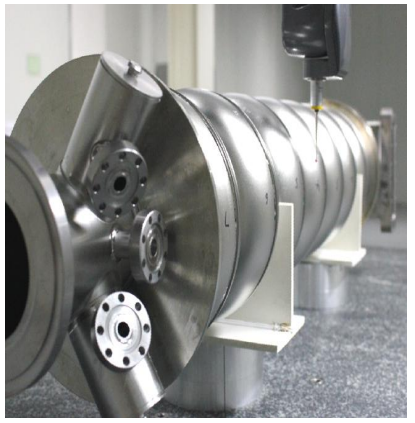
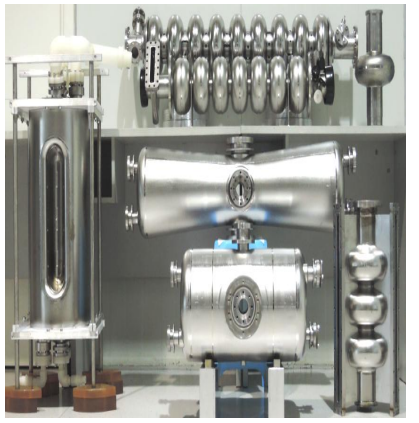
2017-2023年	2024年-至今
Small-batch development	Mass production
Technological BreakthroughsContinuous OptimizationRealization of Small-Batch Trial ProductionAnnual Production of 35 Superconducting Cavities	Curing Process Technology Promotion and Application Market Expansion Annual Production of 100 Superconducting Cavities





The R&D History of OSTEC

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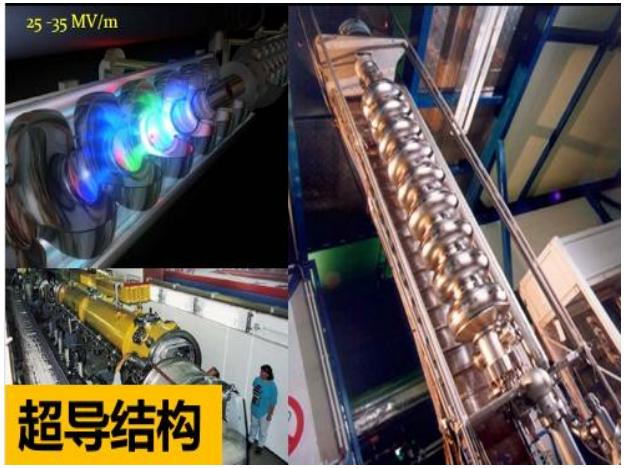
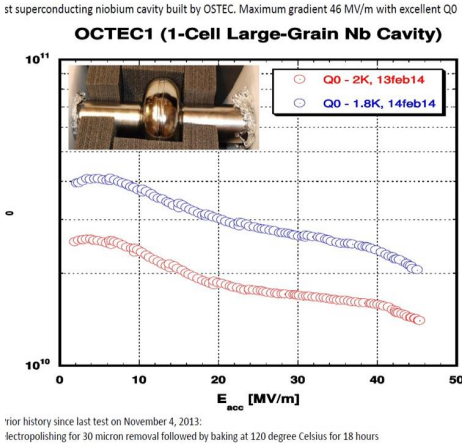
■Superconducting cavity production line

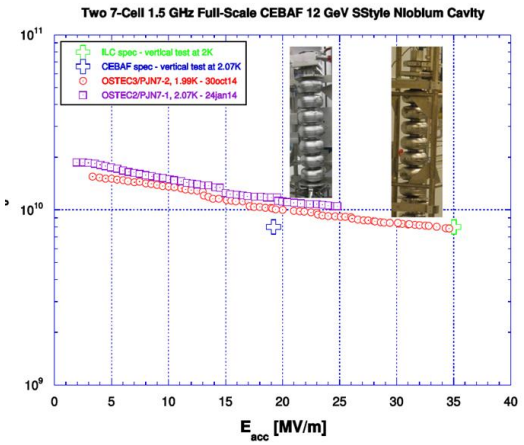
The Superconducting Company has completed the construction of the technological transformation project. The project has newly introduced 7 sets of key equipment, including electron beam welders, laser welding machines, and boring and milling machining centers. This has significantly enhanced the processing and manufacturing capabilities of the Superconducting Company. At present, the Superconducting Company is capable of producing 100 radio-frequency superconducting cavities per year.



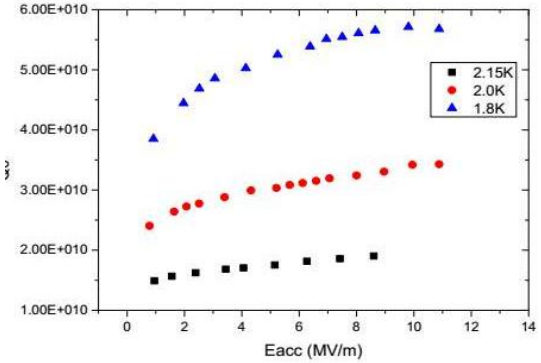
The R&D History of OSTEC



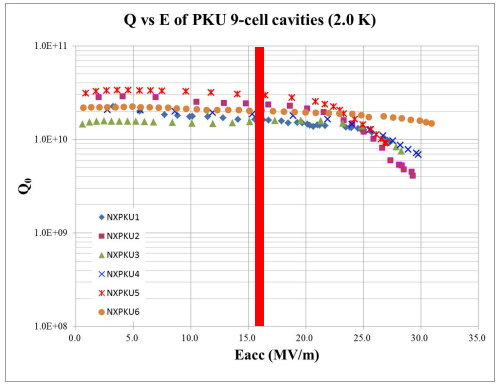
1.5GHz large grain single cell superconducting Nb cavity, its maximum acceleration gradient reached 46MV/m. It was the first Nb cavity which was manufactured in OSTEC in 2013.



In 2013, OSTEC cooperated with Jlab for the first time to develop a 1.5GHz 7-cell superconducting cavity for CEBAF upgrade. Superconducting cavity was tested at 2K low temperature and the acceleration gradient reached 36MV/m. It was the first time for OSTEC to have the manufacturing capability of superconducting cavity.



In cooperation with IHEP and Peking University, OSTEC established BCP and HPR post- processing facilities, improved nitrogen doping process and EP facilities, and possessed the capability of post-processing of superconducting cavity in the first half of 2019.

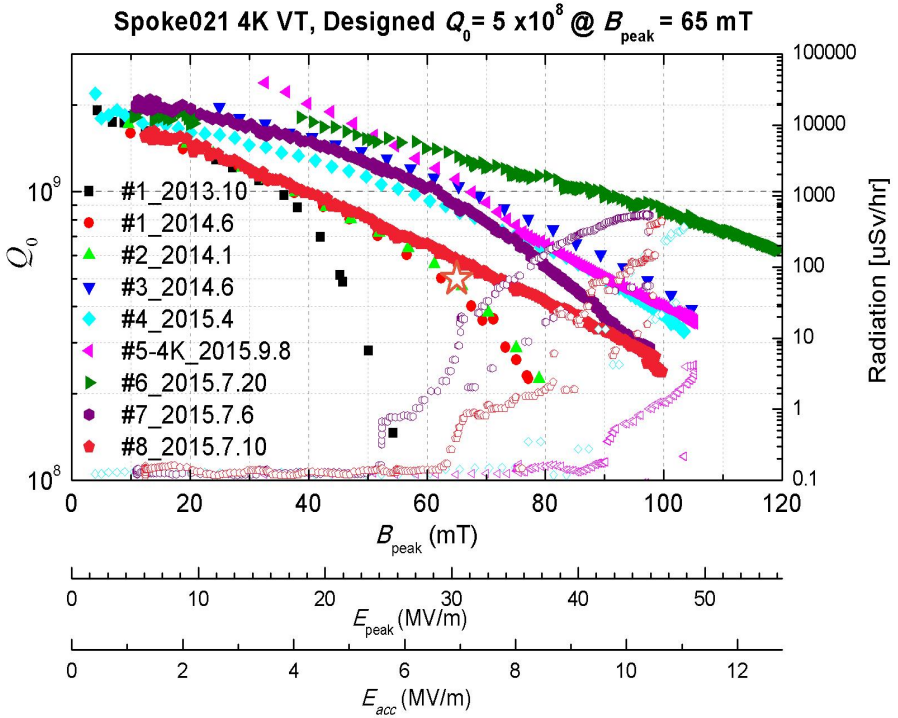


1. E_{acc} of all 6 cavities larger than 25 MV/m
2. Q_0~1.6-2.4E10 @ 16 MV/m

   #3, 2nd test (Sept. 2017), with additional BCP &HPR

OSTEC's Cooperative Projects and Honors

Complete the project name	Superconducting Cavity Model	quantity	technical level
International cooperation projects	HWR029	7	Meet the project requirements
	HWR QWR	2 2	
	1.5GHz 7cell	2	
China's CiADS and HIAF projects	Spoke012 Spoke021 TaperHWR015 325MHz HWR Taper HWR009 HWR010	5 5 60 2 2 12	Meet the project requirements
Shanghai Hard X-ray Project	Large-Grain 1.3GHz 9-CellFine-Grain 1.3GHz 9-Cell 3.9GHz Single-Cell 3.9GHz -9cell 1.3GHz Single-cell	6+6 40 8 20 12	the first domestic manufacturer Meet the project requirements
Pre-research of the CEPC Project	CellFine-Grain 650MHz Single-cell Large-Grain 650MHz Single-cell 650MHz-2-cells	6 4 2	the first domestic manufacturer
Dongguan Spallation Neutron Source	648MHzSpoke	1	the first domestic manufacturer
BISOL Project of CNNC	QWR	1	the first domestic manufacturer



The company undertakes a number of important scientific and technological projects, including the International Cooperation Program of the Ministry of Science and Technology of the People's Republic of China, the National Science and Technology Support Program, the Technology Innovation Fund Project for Small and Medium-sized Scientific and Technological Enterprises, and the Key R&D Projects of the Autonomous Region.

OSTEC's Cooperative Projects and Honors

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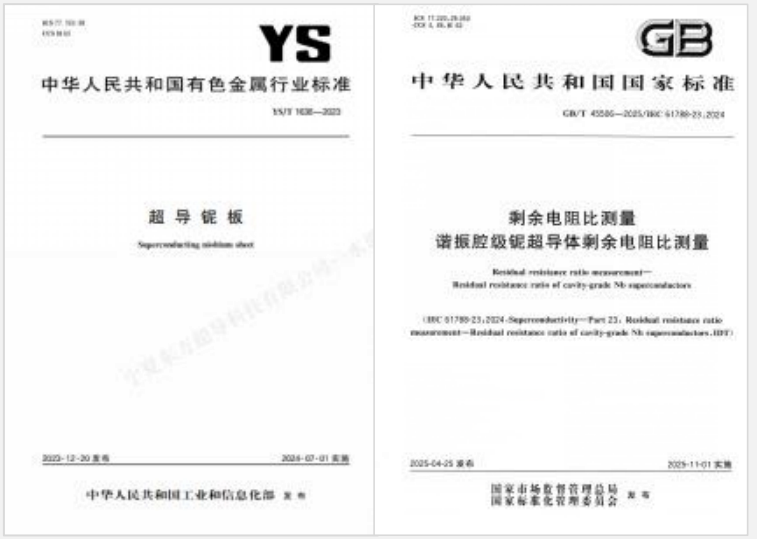
12 Patents *2 Standards* *9 Papers*

- 6 Invention Patents
- 6 Utility Model Patents
- 1 National Standard
- 1 Industry Standard



OSTEC's Cooperative Projects and Honors

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Since OSTEC was first conferred the title of National High - tech Enterprise in 2014, it has been successively recognized. In 2020, it was approved as a small and medium - sized technology - based enterprise in Ningxia. In 2022, it was approved as a "specialized, refined, distinctive and innovative" small and medium - sized enterprise in Ningxia.

OSTEC's Equipment Manufacturing Capabilities —machining

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hydraulic press

CNC lathe

CNC milling machine

OSTEC's Equipment Manufacturing Capabilities —welding

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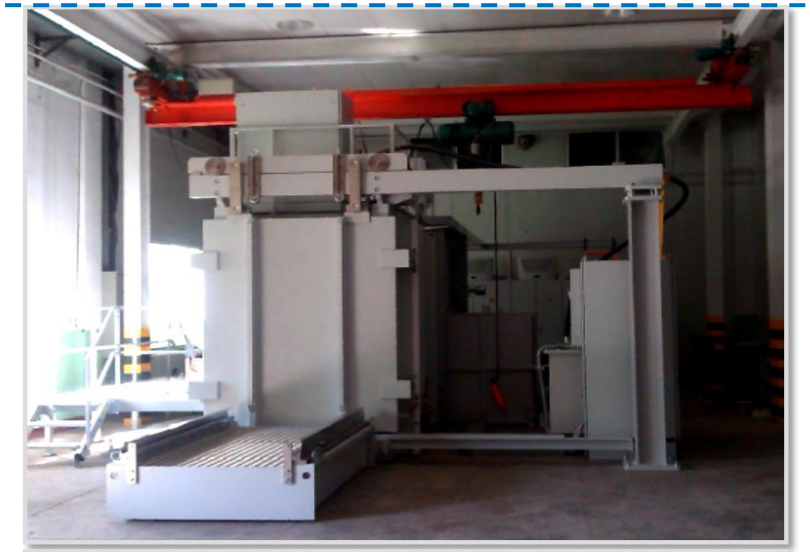
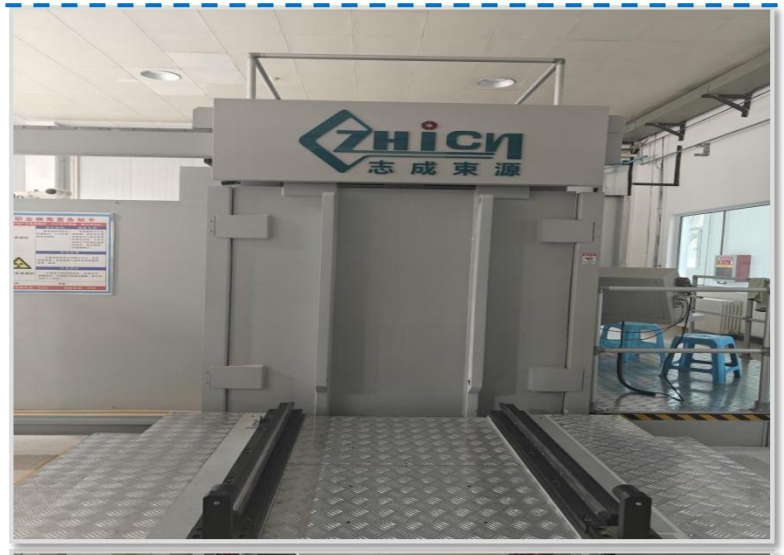


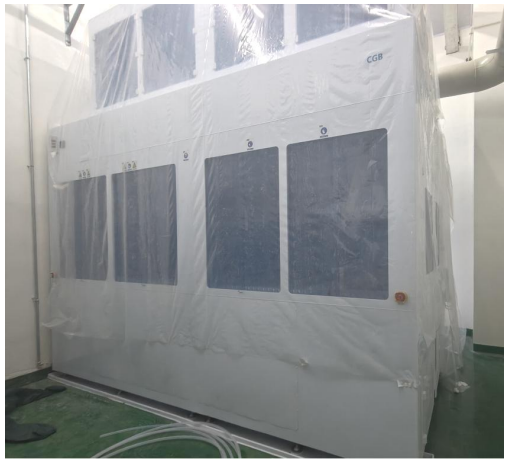
EBW machine



TIG machine

LBW machine

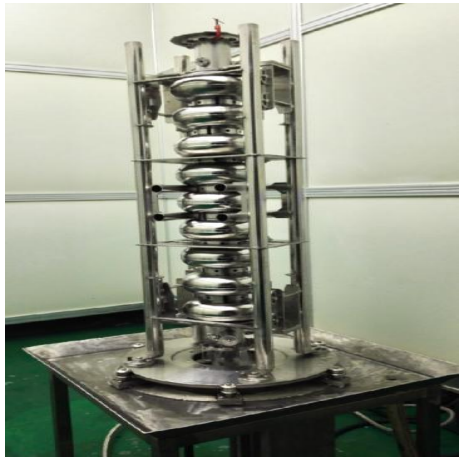
OSTEC's Equipment Manufacturing Capabilities —post-processing

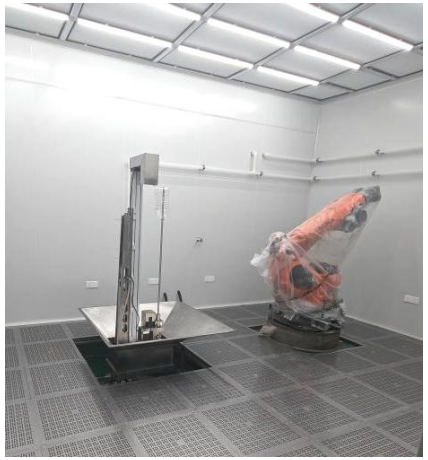


BCP equipment

Ultrapure Water System

EP equipment





HPR equipment

OSTEC's Equipment Manufacturing Capabilities —post-processing

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Clean Room

Vacuum furnace

OSTEC's Equipment Manufacturing Capabilities —inspection

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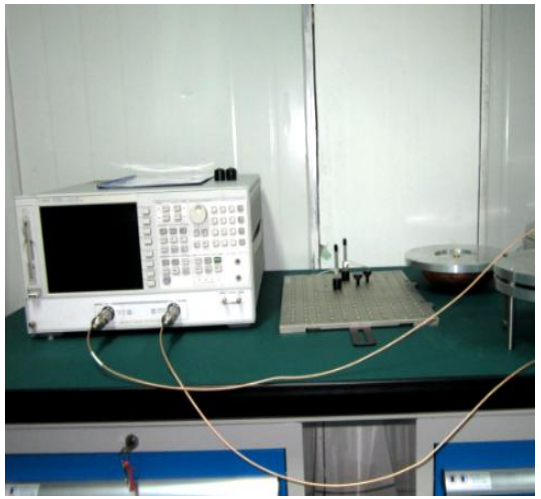
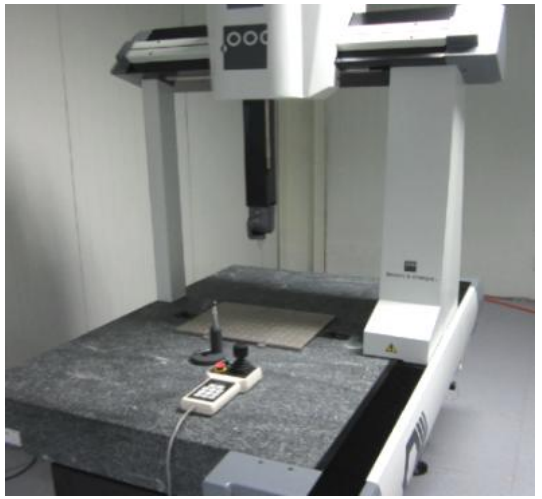
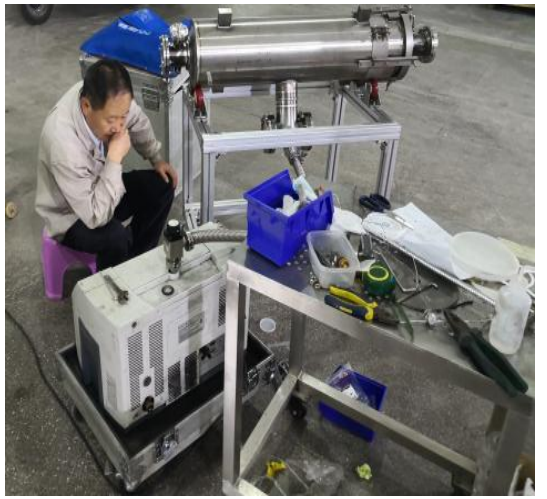


RF meas.

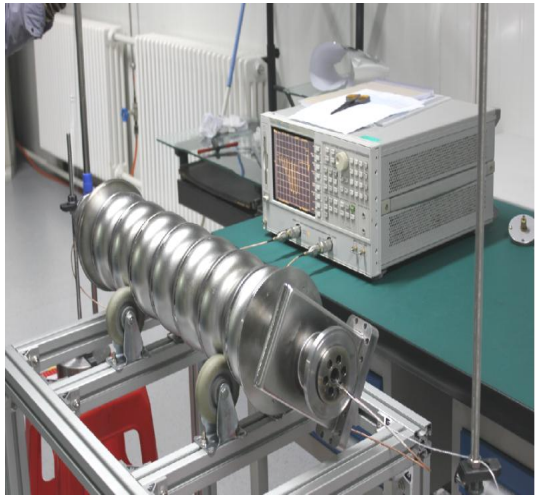


3D CMM

Articular arm measuring



He leak.



OSTEC's Equipment Manufacturing Capabilities

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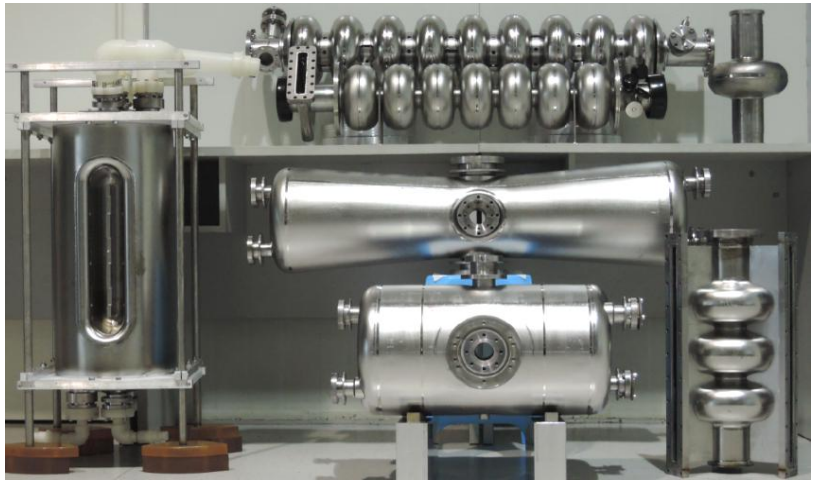
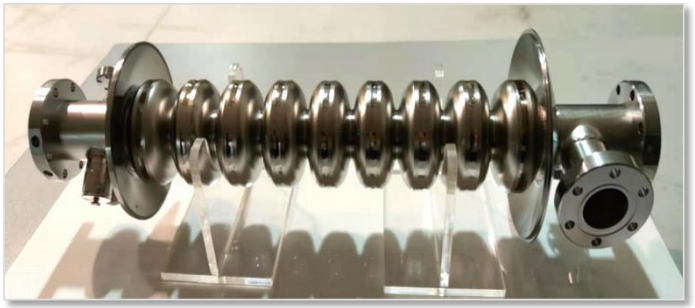
Radio-Frequency Superconducting Cavity Components

OSTEC's Equipment Manufacturing Capabilities



HWR010

spoke



3.9GHz 9-cell

1.3GHz 1.5-cell

The superconducting company has completed the manufacturing and delivery of over 210 radio-frequency superconducting cavity products in more than 30 types, which have been well recognized by customers.

OSTEC's Equipment Manufacturing Capabilities

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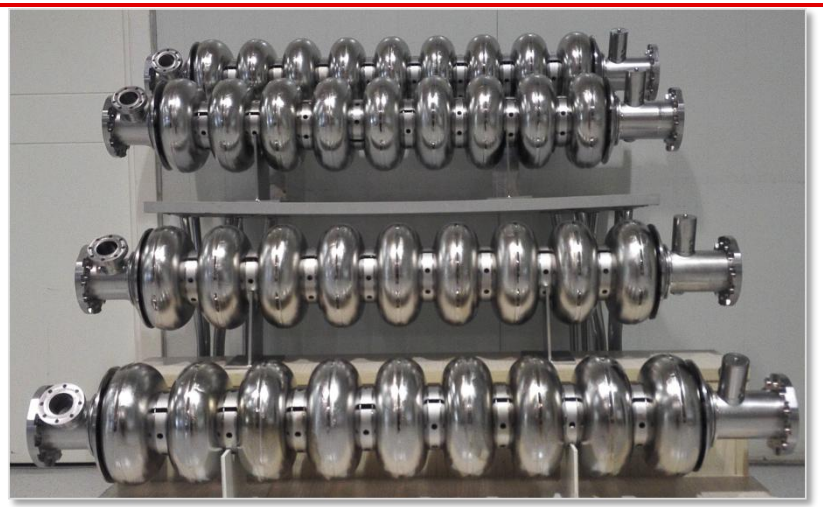
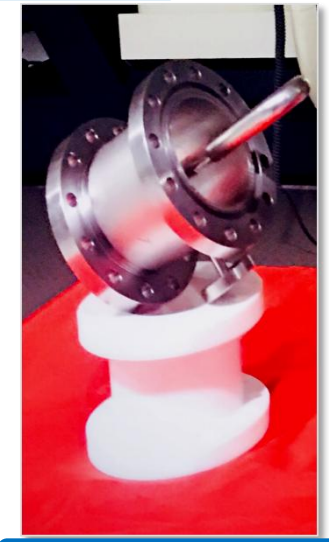
3.9GHz Single-Cell



1.3GHz 9-cell

HWR021

1.3GHz Single-Cell



650MHzCouple

HWR015

QWR

650MHz Single-Cell

OSTEC's Equipment Manufacturing Capabilities

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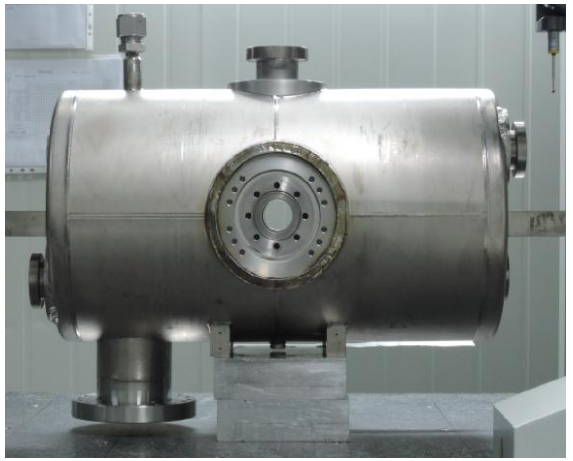
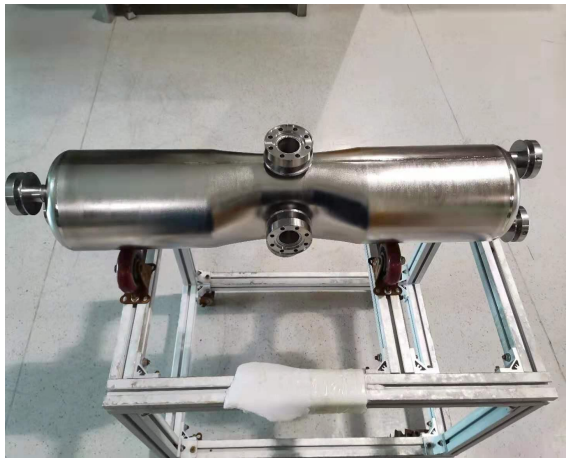
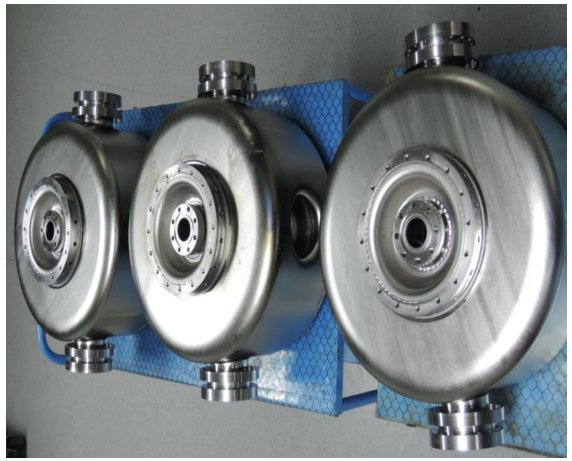
HWR015



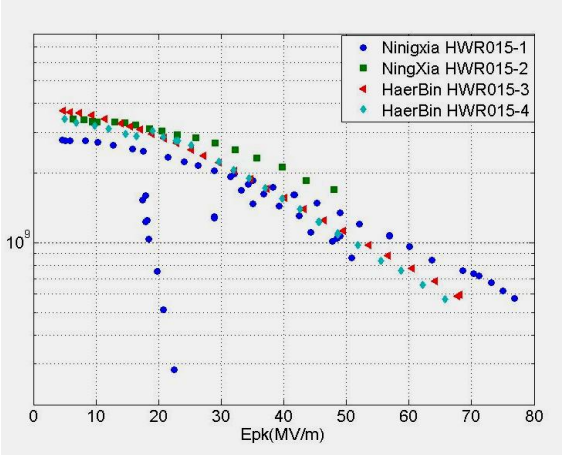
HWR 029

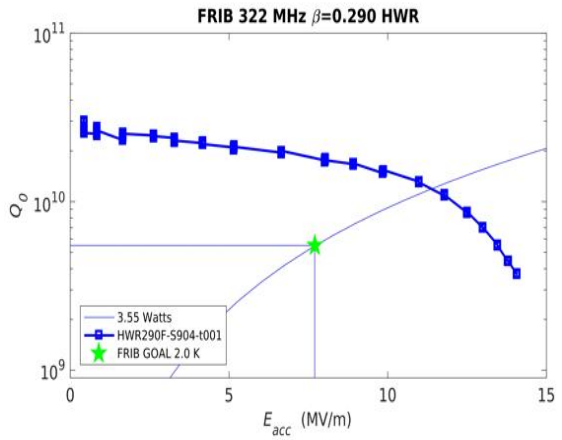


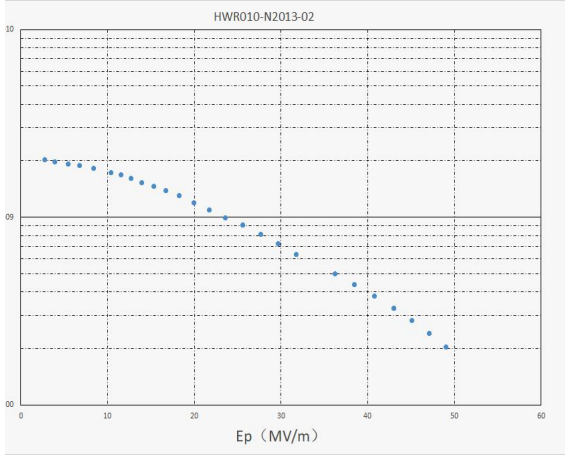
HWR010

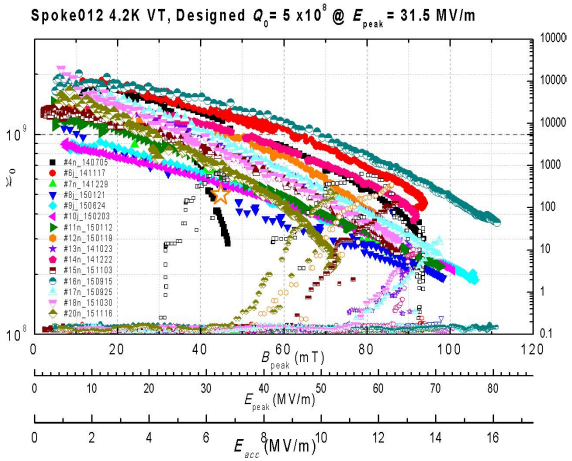


spoke 012









Enhancement of Superconducting Cavity Manufacturing Technology

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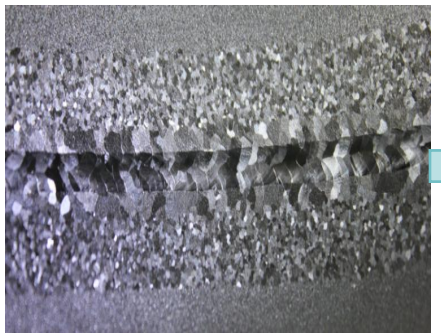
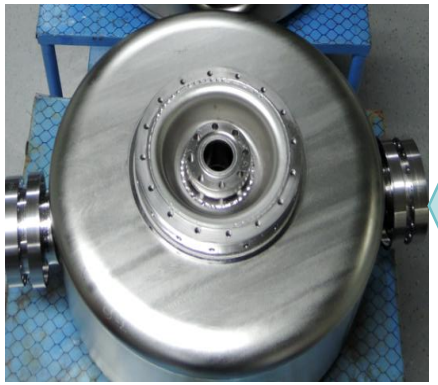
中国有色集团成员企业

Technology 1: Forming, Machining and Welding Technologies for Radio-Frequency Superconducting Cavity Components


Inner Surface of the Equatorial Weld

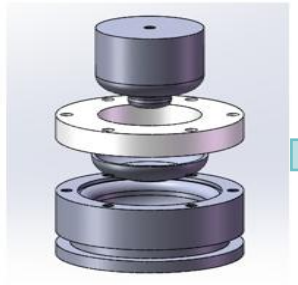

Welding Components


Welded End Cavity Assembly

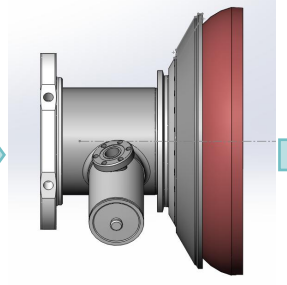

Complete Cavity


4D Welded Assembly


HOM Tube Welded Assembly


Half-Bowl Stamping Process


Half-Bowl Contour Measurement


End Cavity Assembly Machining


HOM Tube Assembly

Based on the physical design model of the radio-frequency superconducting cavity, comprehensively considering the manufacturing processes, and through process tests, parameter optimization, verification and iteration, the precision machining and welding of superconducting cavity components are realized, thus forming a standardized manufacturing process.

Enhancement of Superconducting Cavity Manufacturing Technology

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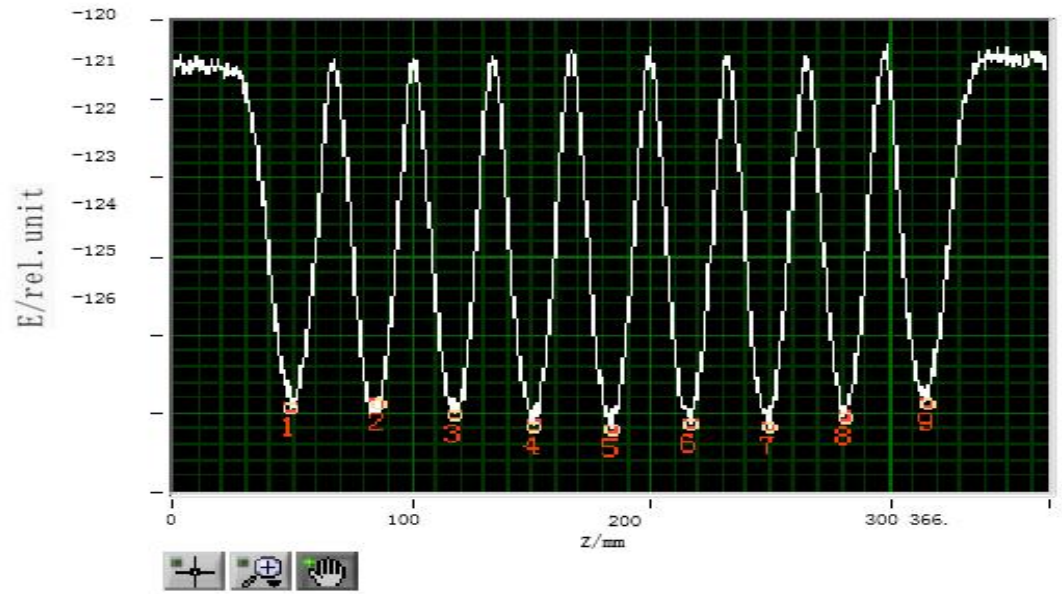
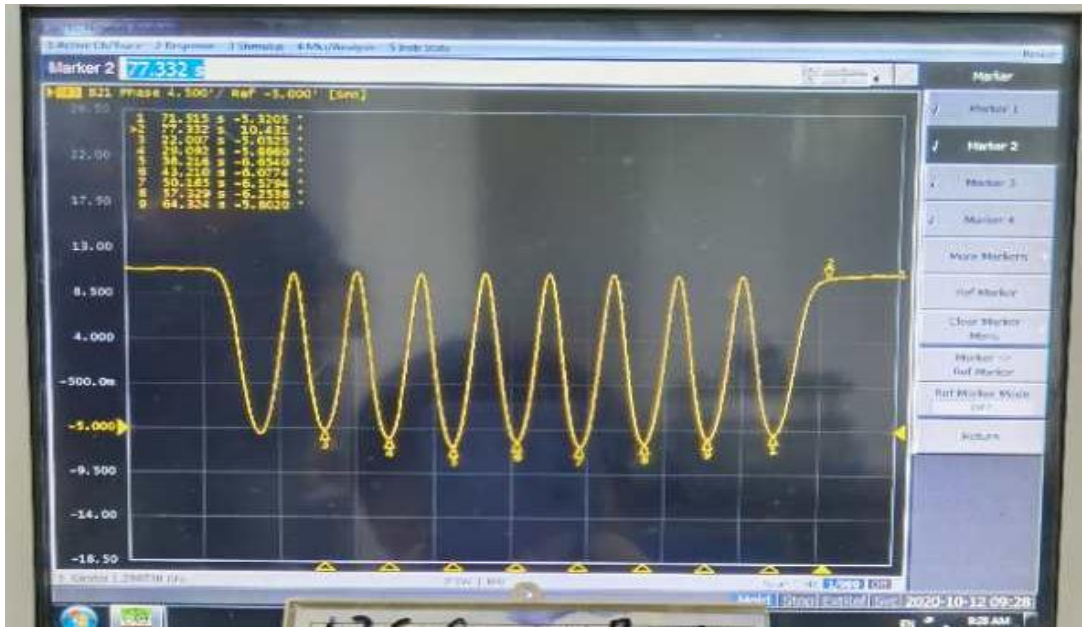
Technology 2: Radio-Frequency Superconducting Cavity Frequency Control Technology



Frequency Measurement



The field flatness of PKU1.3G9cell-1# reaches 97.1%.

Based on the physical design of the radio-frequency superconducting cavity, precise control is exerted over the frequency of each accelerating unit of the radio-frequency superconducting cavity to improve the uniformity of the overall accelerating capability of the radio-frequency superconducting cavity, thereby achieving a field flatness of over 95% for the 1.3GHz-9Cell radio-frequency superconducting cavity.

Enhancement of Superconducting Cavity Manufacturing Technology

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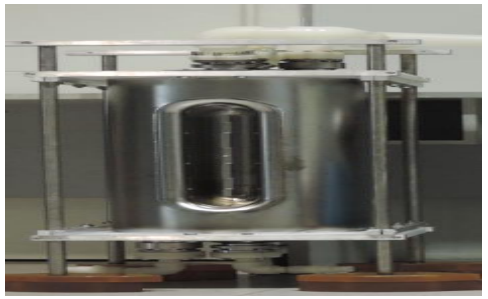
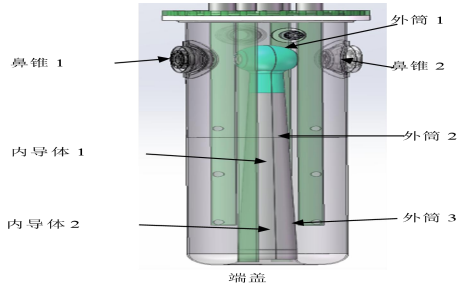
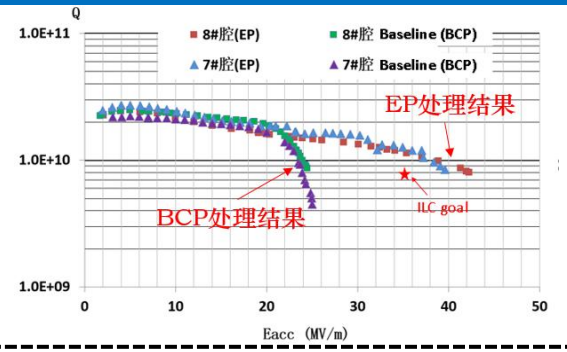
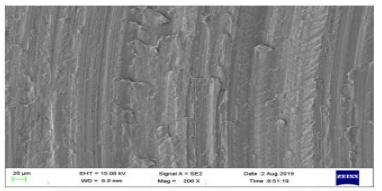
Technology 3: Radio-Frequency Superconducting Cavity Surface Treatment Technology

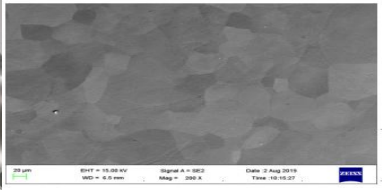




Buffered Chemical Etching and Polishing Model







Study the relationship between the technical parameters (voltage, current, acid temperature) of chemical etching polishing (BCP) and electrochemical etching polishing (EP) for radio-frequency superconducting cavities and the surface removal amount as well as surface quality, so as to achieve precise control over the surface removal amount of radio-frequency superconducting cavities and meet the requirements for surface finish and cleanliness.

Enhancement of Superconducting Cavity Manufacturing Technology

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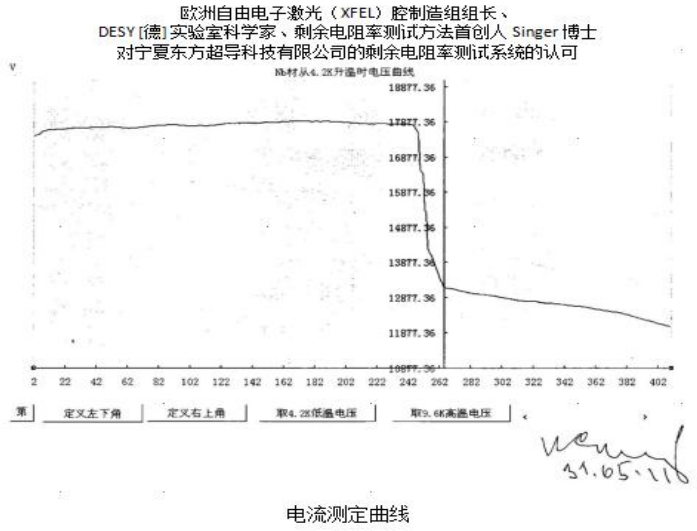
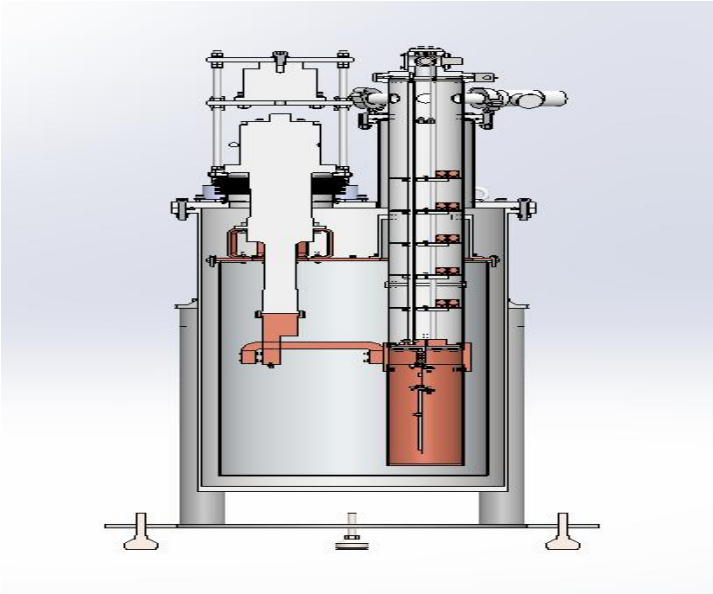
Technology 4: RRR Value Testing Technology for High-Purity Niobium Materials

A method for measuring the RRR value of high-purity niobium materials under different low-temperature environments has been realized. A newly developed cold chain conduction system with a cryopump is used to replace the traditional liquid helium environment to create low-temperature conditions, enabling more accurate RRR value measurement.



电流测定曲线



Technical Recognition

- Residual Resistivity Testing System

Testing System

- Intelligent Testing
- Cold Chain Conduction

Enhancement of Superconducting Cavity Manufacturing Technology

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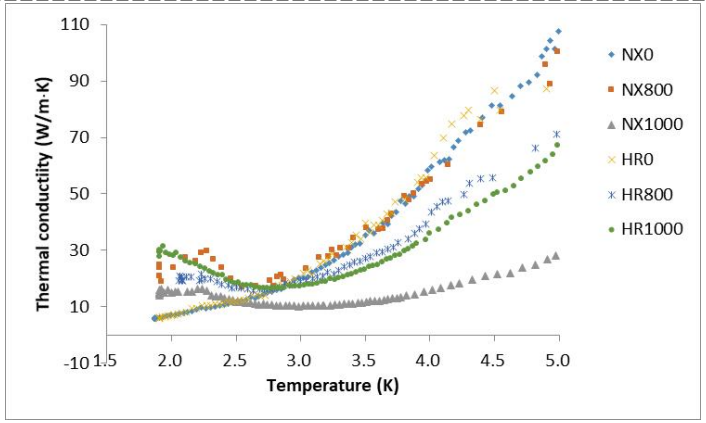
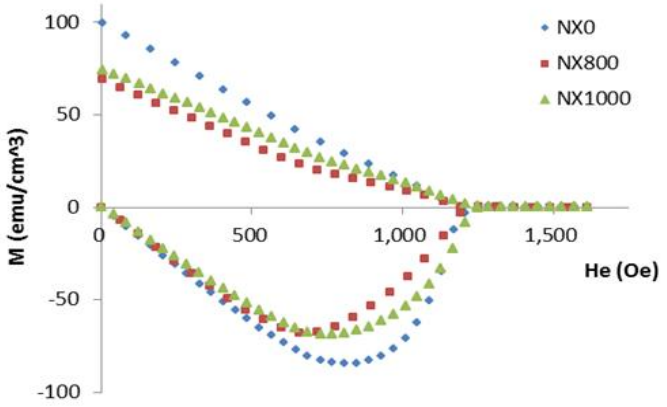
Technology 5: Technology for Manufacturing Radio-Frequency Superconducting Cavities Using Large-Grain Niobium Materials

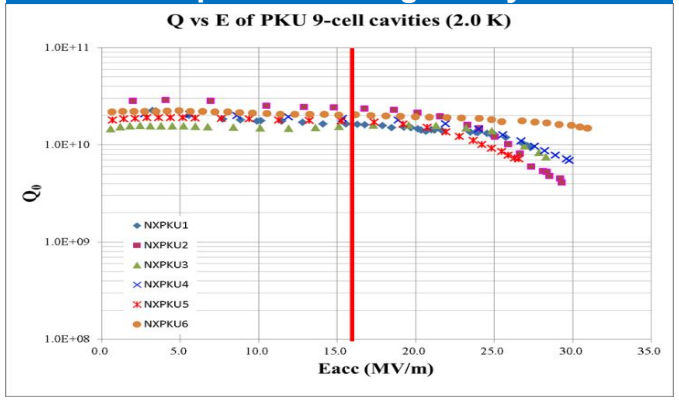


Thermal Conductivity of Large-Grain Niobium Materials with Different Heat Treatment Temperatures from Various Companies



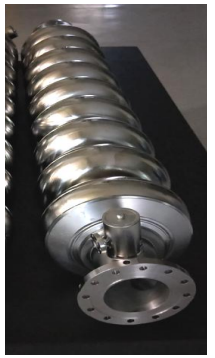
Magnetization Curves of Different Large-Grain Niobium Samples

TESLA-Type Large-Grain 9-Cell Superconducting Cavity



Vertical Test Results of 9-Cell Superconducting Cavity at 2.0 K

After heat treatment, the area of the magnetization curve of the large-grain samples has decreased to some extent, indicating a reduction in the number of pinning sites.



Enhancement of Superconducting Cavity Manufacturing Technology

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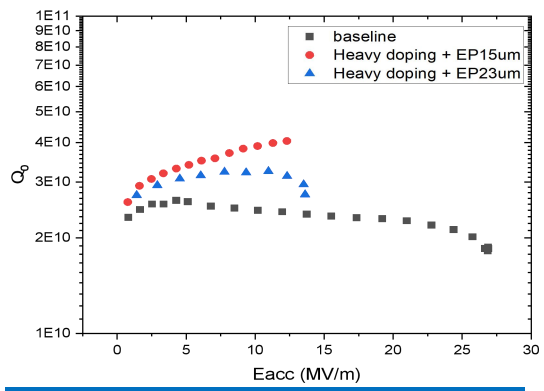
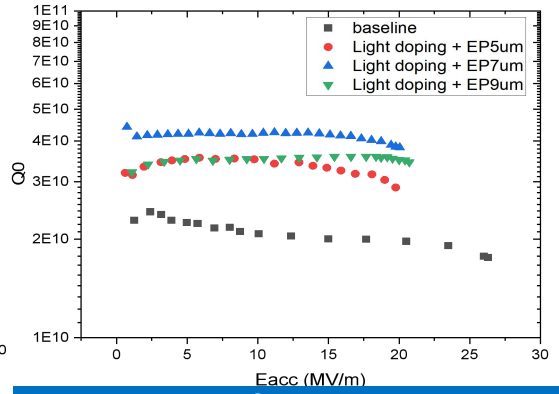
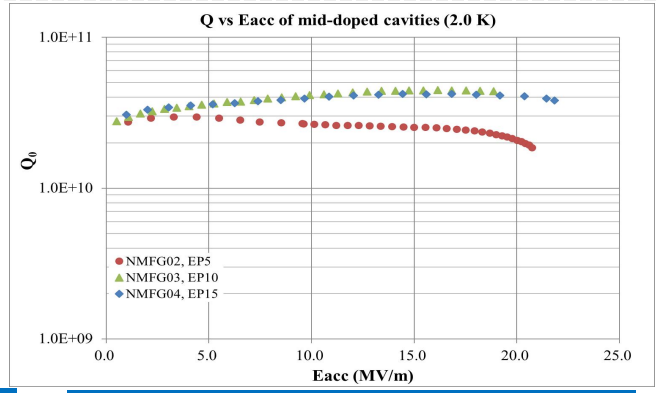
Technology 6:Radio-Frequency Superconducting Cavity Doping Technology



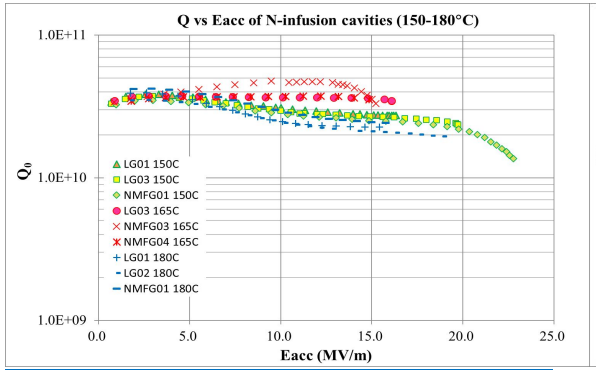
Test Results of Heavily Doped Superconducting Cavities



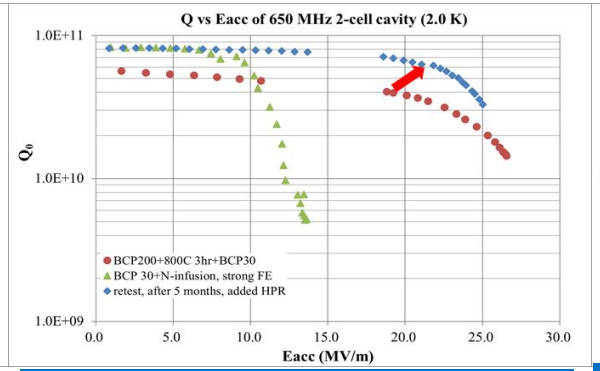
Test Results of Moderately Doped Superconducting Cavities



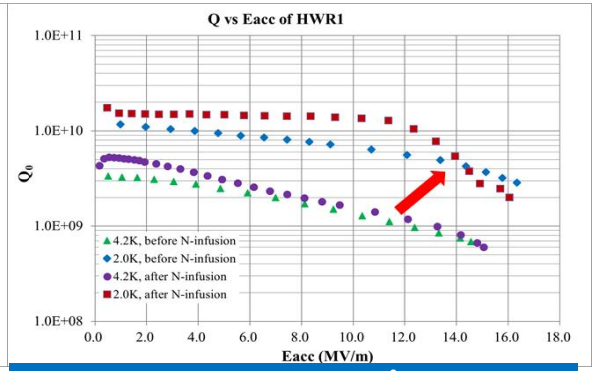
Test Results of Lightly Doped Superconducting Cavities



Low-Temperature Nitrogen-Doped 1.3 GHz Single-Cell Superconducting Cavity



Low-Temperature Nitrogen-Doped 650MHz 2-Cell Superconducting Cavity



Low-Temperature Nitrogen-Doped 162.5MHz HWR Superconducting Cavity

Research Results

Through the research on nitrogen doping processes and performance testing of superconducting cavities and niobium samples, optimized nitrogen doping treatment parameters were obtained. The Q_0 value of the superconducting cavity reached over 3.5×10^{10} (at 2.0 K, 16 MV/m), achieving a higher Q_0 value.

Enhancement of Superconducting Cavity Manufacturing Technology

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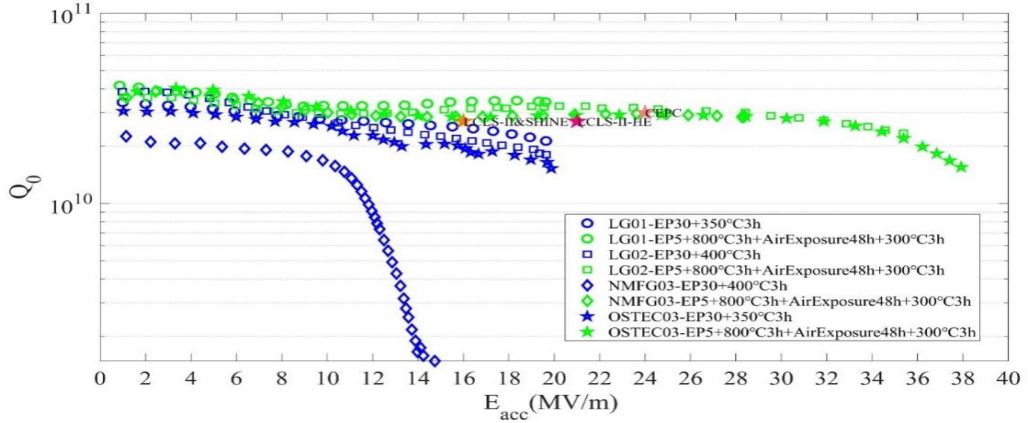
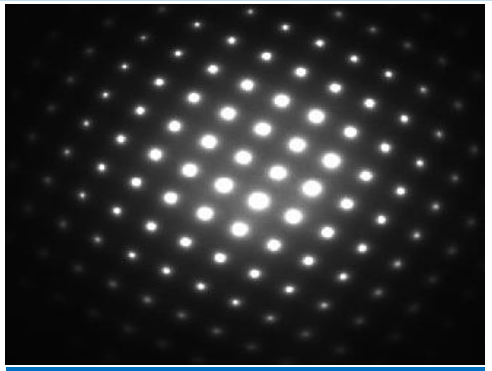
中国有色集团成员企业

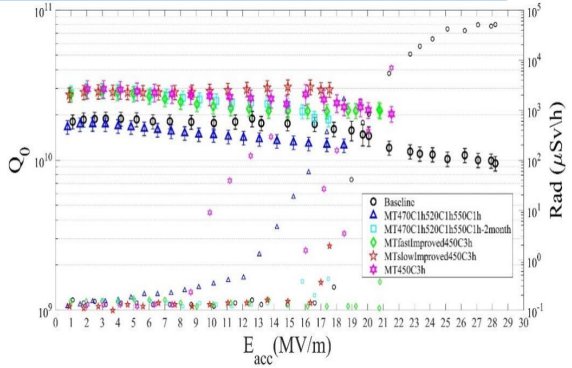
Technology 7:Medium-Temperature Baking of Superconducting Cavities and Its Mechanism



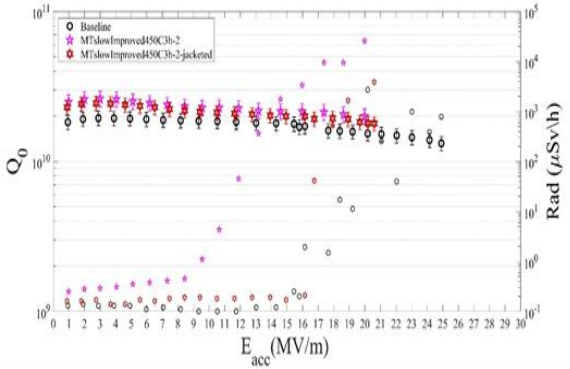
Test Results of Medium-Temperature Baked 1.3 GHz Single-Cell Superconducting Cavity



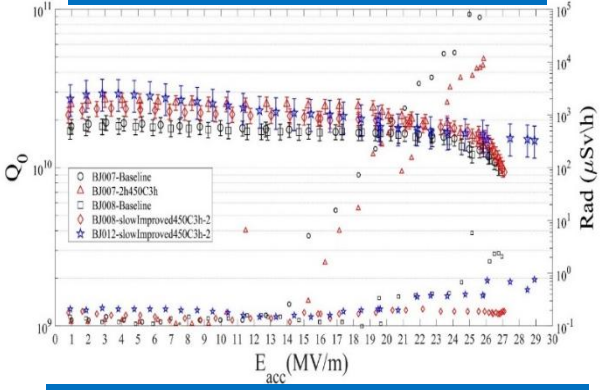
Electron Diffraction Image



BJ004



Medium-Temperature Baked 9-Cell Superconducting Cavity with BCP Background



Medium-Temperature Baked 9-Cell Superconducting Cavity with EP Background

Baking effect:

From the analysis of the resistance component at low magnetic field and 2K temperature, the medium-temperature baking scheme significantly reduces the mean free path of electrons by using the appropriate increase of oxygen and carbon-related impurities as scattering sources, thereby significantly reducing the BCS resistance of niobium cavities, resulting in a decrease in surface resistance and an increase in Q0 value.

OSTEC's Manufacturing Upgrade

■Overview of the Newly Added Intelligent Production Line for Niobium Superconducting Cavities with an Annual Output of 400 Units

After the completion of the project, the combined annual production capacity of niobium superconducting cavities will reach 500 units, integrating the existing capacity of 100 units, making it the world's largest manufacturer of niobium superconducting cavities. It will break through a batch of core and key technologies in low-temperature superconducting niobium materials, support the sustainable and high-quality development of China's future low-temperature superconducting material industry, and gain the initiative in the development of future industries.

OSTEC's Manufacturing Upgrade —Intelligent production line

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■Construction of Intelligent Production Line for Superconducting Cavities

The flexible production system consists of stamping forming, flexible turning, milling automated processing units, etc.	The intelligent system in the superconducting cavity manufacturing workshop comprehensively schedules multiple systems for collaborative operations.	The information system consists of a control center, an MES system, a UPS, and other components.
Realize the automatic stamping, processing, measurement and polishing of superconducting cavity components	Realize the automatic transfer of materials between various processes	Construct a digital management platform for the entire lifecycle of superconducting cavities
automation	intelligentization	informatization

After the construction of the intelligent production line is completed, the level of intelligent manufacturing of superconducting cavities at Oriental Superconductivity will be significantly improved.

OSTEC's Manufacturing Upgrade —automated processing

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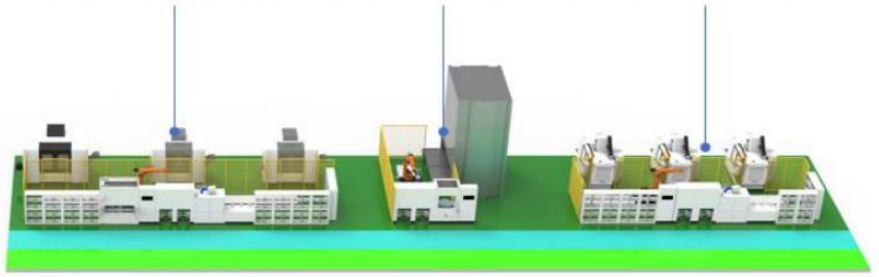
Existing equipm-ent

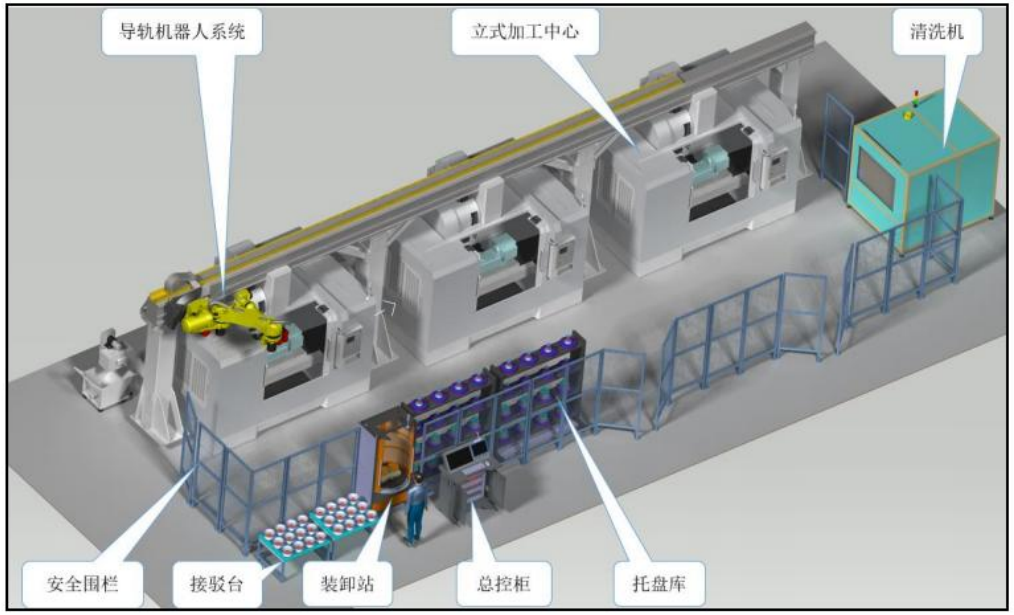

CNC lathes and milling machines

upgrade

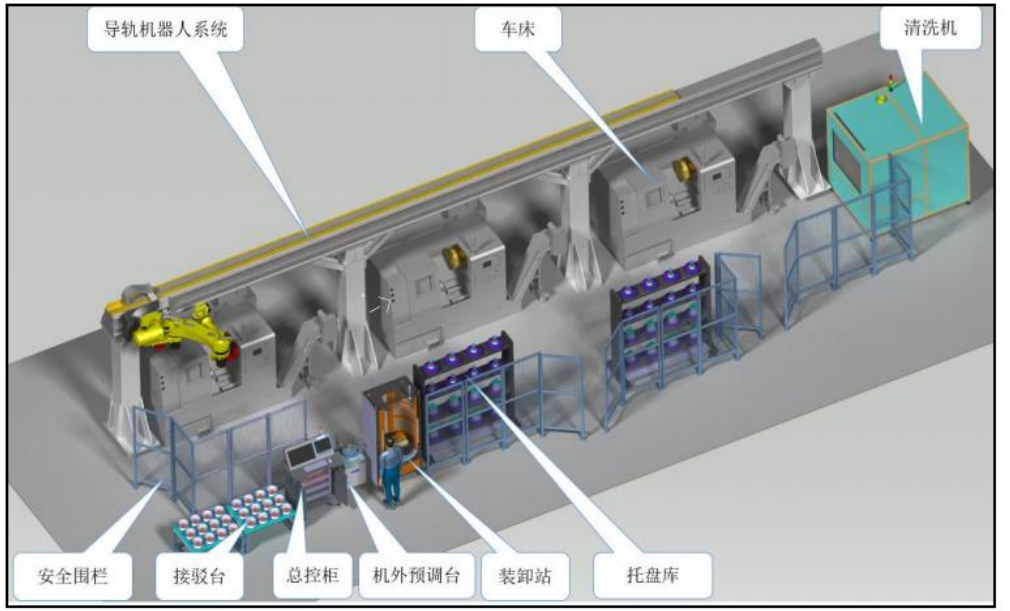


3D Layout Drawing of Flexible Production Line

Specific plan



3D Layout of Flexible Flexible Flexible Milling Automation Unit



3D Layout of Flexible Turning Automation Unit

OSTEC's Manufacturing Upgrade —Automated stamping and grinding

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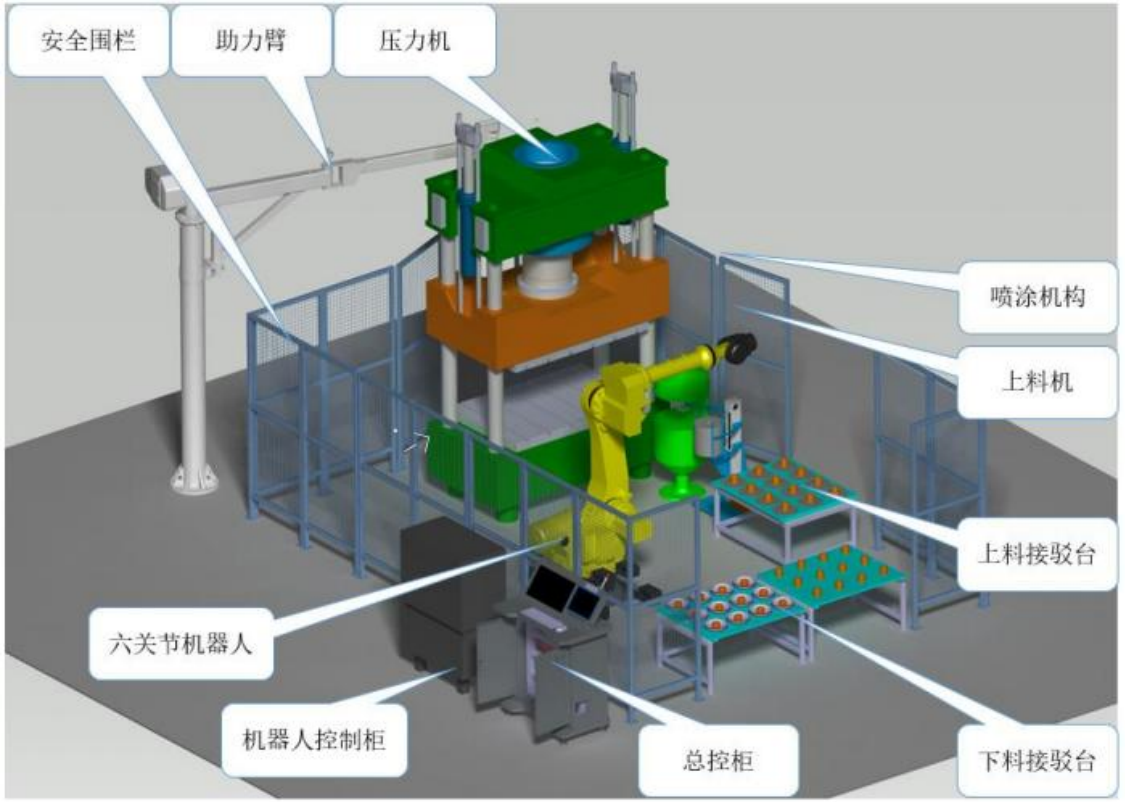
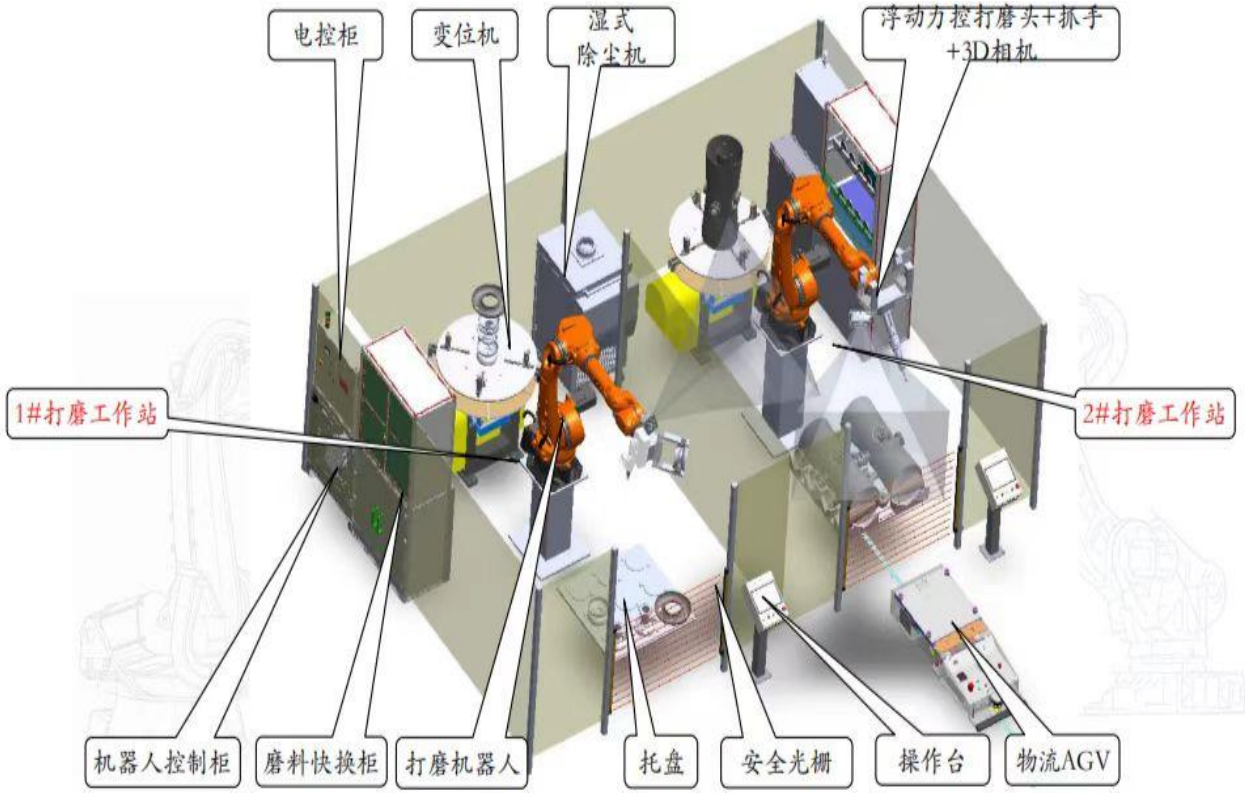


3D Layout of Stamping and Forming Automation Unit



Overall Layout of Flexible Polishing Production Line

OSTEC's Manufacturing Upgrade —intelligentization

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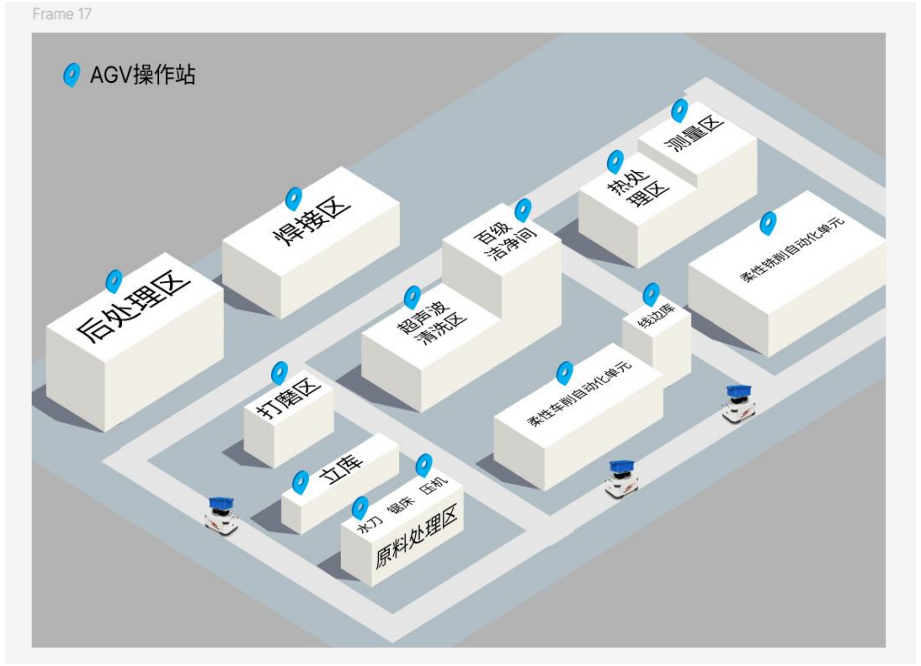


Schematic Diagram of AGV Route Planning for the 400-Unit Production Line

WMS Warehouse Management System

WCS Warehouse Control System

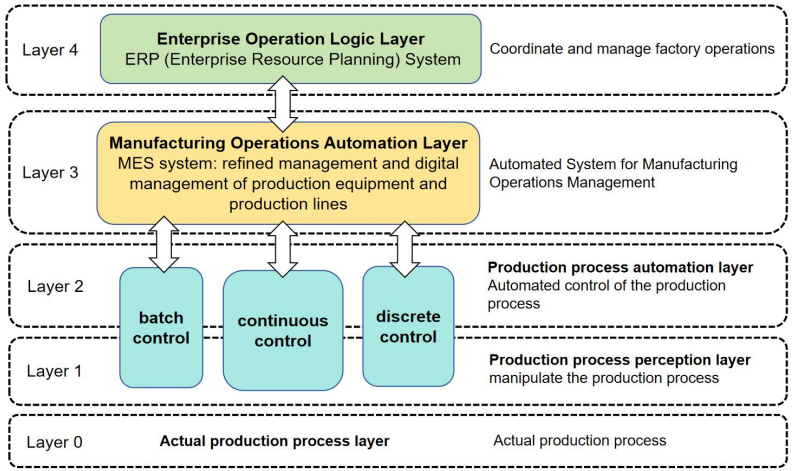
MES Intelligent Manufacturing System

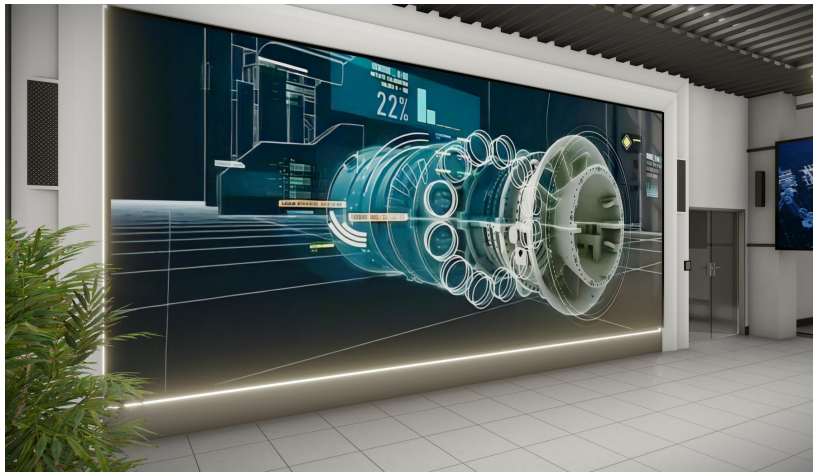
ERP Resource Management System

Intelligent Warehousing System

AGV system

OSTEC's Manufacturing Upgrade —informatization





Construction of Informatization System

中色东方 CNMNC

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中国有色集团成员企业

THANKS!

祝好！

BY OTIC 06/11/2025