

CEPC vacuum chamber production line development

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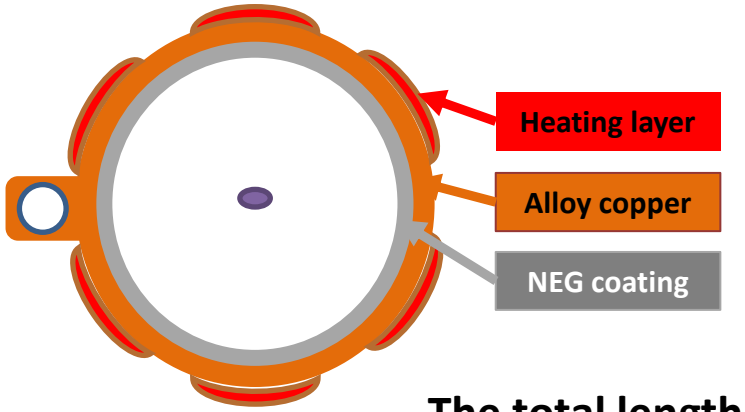
Content

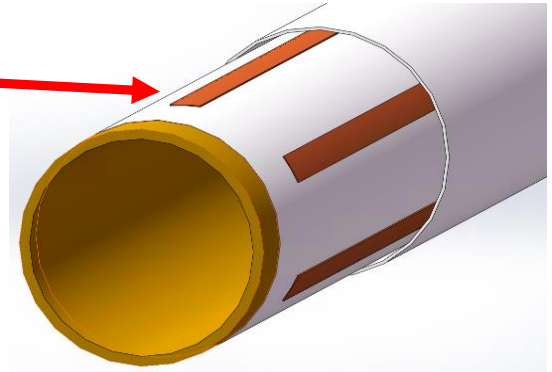
- Structure of vacuum chamber for CEPC collider rings
- Preview of production line
- Procedure of NEG coating & spraying of production line
- Production line development of NEG coating/ Spraying for heating film
- Prototype of Spraying heating-layser and testing results
- Summary

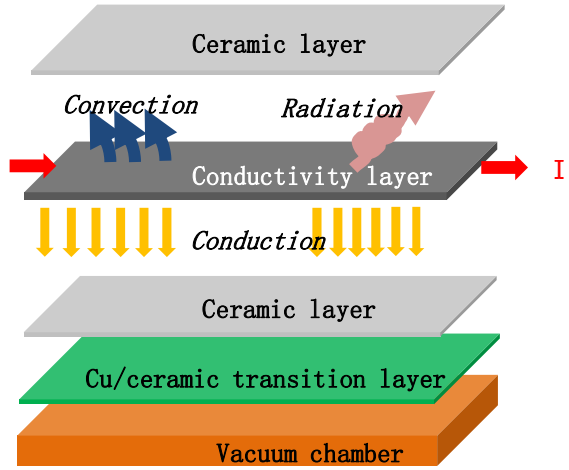
Structure of vacuum chamber for CEPC collider rings

- NEG coating is employed to suppress the e-cloud and provide pumping for residual gases in both e&e+ collider rings. And activated by radiation-resistant heating layer. NEG coating and spraying will be implemented by production line.

One perfect vacuum chamber as follows:







The total length of the VC of CEPC are 190km.

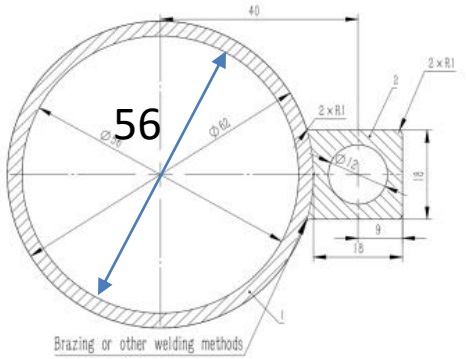
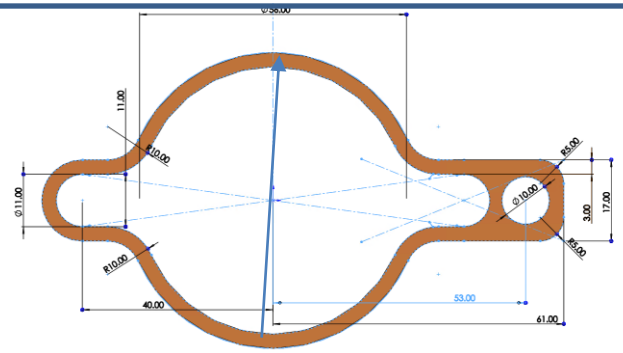
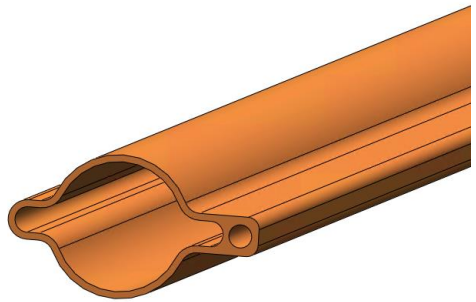


Figure 4.3.6.2: Copper dipole vacuum chamber

SR deposited on VC wall (CEPC EDR plan)





VC with photon absorber (FCC plan)

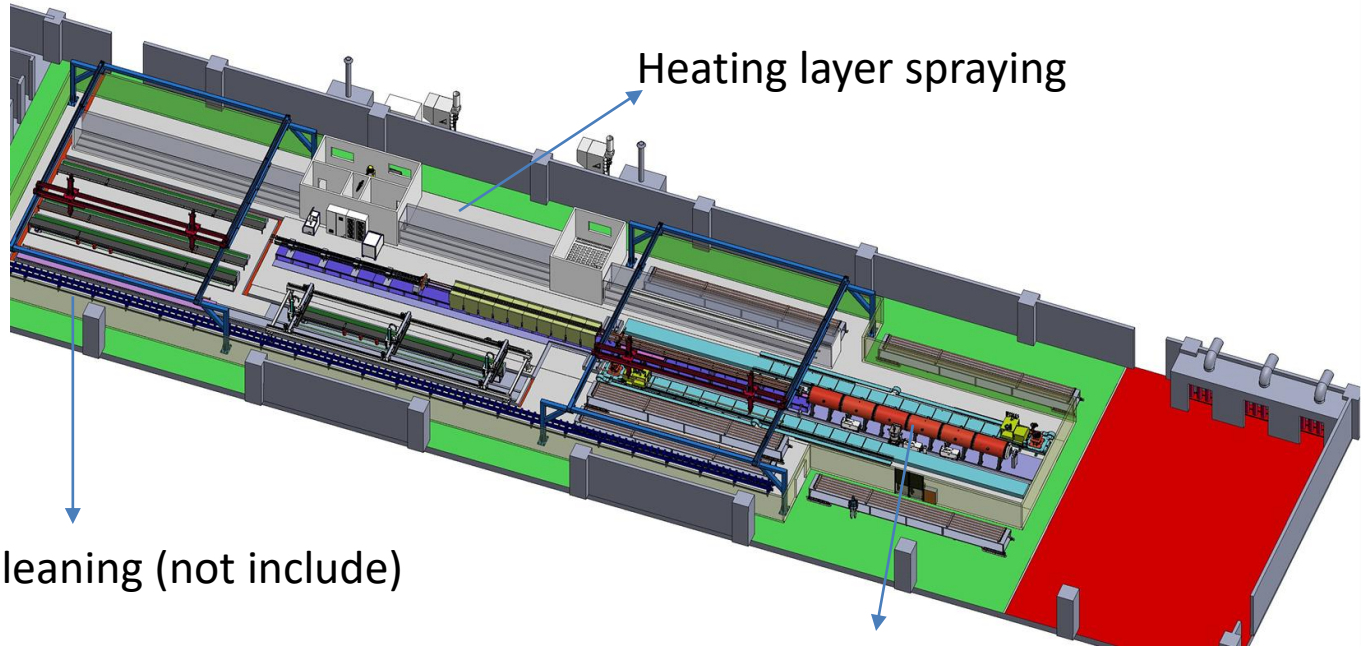
Preview of NEG coating/ Spray for heating film production line

■ Requirement

- Due to the difference in length, two production lines will be used to complete the production of vacuum chambers for the CEPC collider. The quantity of NEG coating and spraying facilities for the two lines varies to match the production speed.
- The full quantity of vacuum chambers for the collider will be manufactured within five years, utilizing two production lines operating at a combined capacity of 4,500 units per year.

■ Advantages

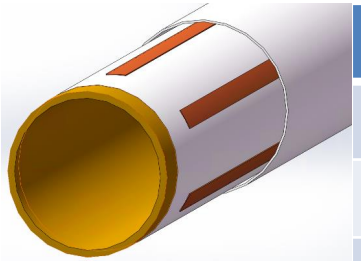
More stable process, less manpower, less NEG coating facility, more adaptive capacity in production, etc.

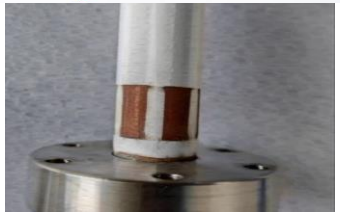


Items	Specifications
Dimension	• L 11400-d56-D62
Weight	• 50~100kg
NEG coating	• Thickness：200nm±30% • SEY<1.1 • S、Q、life-times
Spraying heating	• Thickness<0.5mm • Heating temperature <300℃

Procedure of NEG coating & spraying of production line

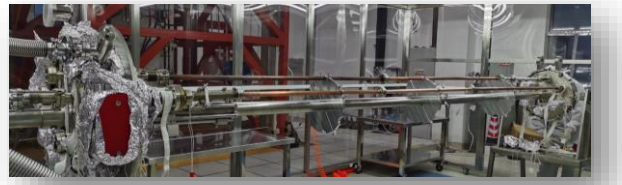
- Spraying (Air plasma spraying)
  - Sandblasting
  - Spraying_Isolation_layer
  - Spraying_Conductivity-layer
  - Spraying_Isolation-layer
  - Spraying_Contactor-layer
- Cleaning
  - Outside
  - Inside
- NEG coating
  - vacuum chambers, cathodes assembling by mechanical arms (flanges sealing).
  - Leakage testing.
  - Deliver the assembles to vacuum oven/ baking/ NEG coating;
  - Disassembly the vacuum chambers







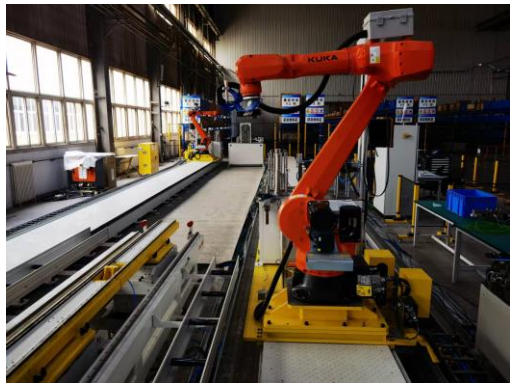
Function	Materials	Thichness/um
Transition-layer	MCrAlY alloy	50~100
Isolation-layer	Al2O3 cermic	~200
Conductivity-layer	NiCr alloy	50~100
Isolation-layer	Al2O3 cermic	~200
Contactor-layer	Copper	~50



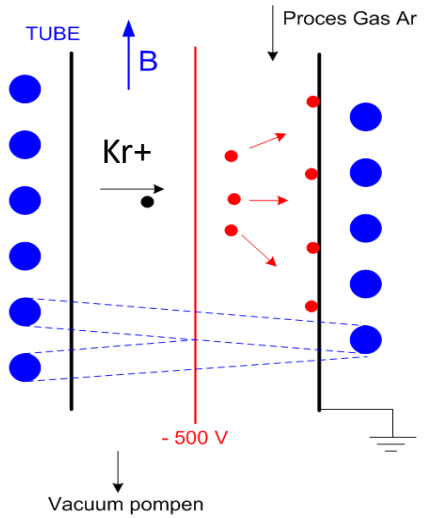


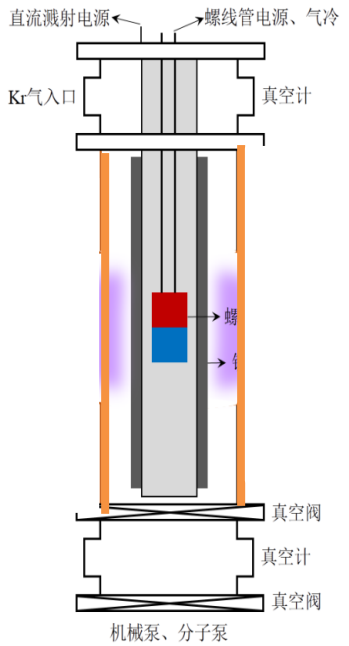
Layout & composition of NEG coating facility

- **NEG coating, VC assembly and disassembly with automatic robot arms.**



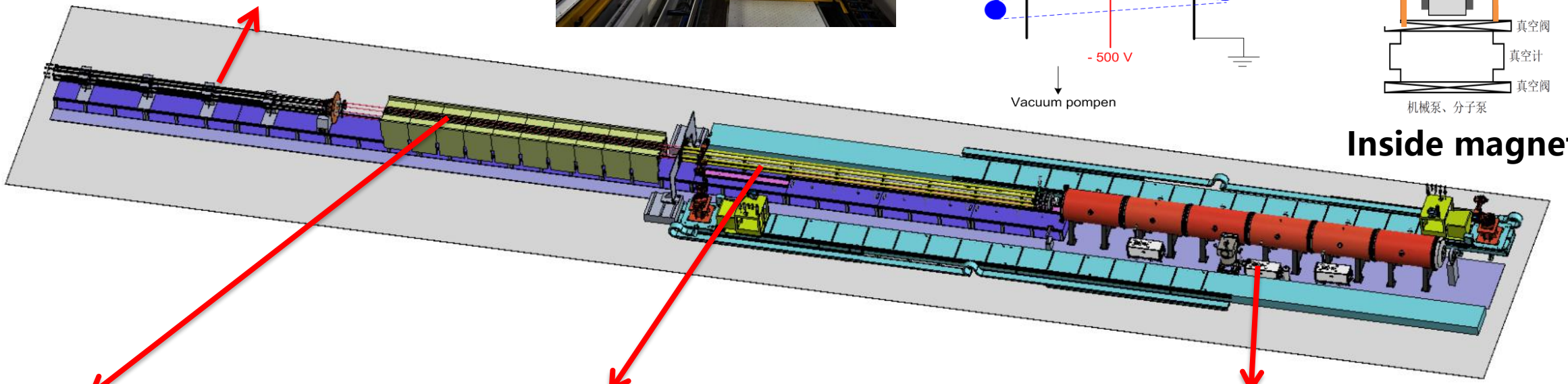
DCMS for NEG coating





Inside magnet

Magnet (coating) driven



Cathodes

VC assembly

Vacuum oven

Process of NEG coating

STAGE	MAIN OPERATIONS	PROCESS TARGET / RELEASE GATE	TIME(h)
01 Assembly & leak testing	Assemble vacuum chambers and perform the first helium leak test. Load into furnace, connect an other chamber and repeat the leak test.	Both helium leak tests pass Leak-rate limit: TBD	8*
02 Pump-down & bakeout	Coolant on. Rough-pump, then start the turbopump. Bake for 48 h after the workpiece reaches T_bake.	Turbo start: ≤ 5 Pa* Bake start: ≤ 5×10^{-4} Pa*	50
03 Base-vacuum qualification	Cool to 100 °C. Enable the ion pump within its limits. Hold at 100 °C for 4 h with continuous pumping.	≤ 5×10^{-7} Pa at 120 °C Valid gauge and stable reading	4.5*
04 Gas & pressure stabilization	Ion pump OFF and isolated. Keep substrate at 100 °C. Set MFC flow and throttle the turbopump inlet.	0.5–2 sccm and ~1 Pa Stable for ≥ 5 min	0.5
05 Magnetron sputtering	Soft-start magnetron power and scan the magnetic ring. Deposit to a validated time / scan-pass recipe.	10–50 A and 0.1–0.2 m/min 100 °C and ~1 Pa	5*
06 Cool, vent & unload	Stop power, gas and heating. Pump while cooling. At room temperature, isolate pumps and backfill with N_2.	Equalize both vacuum spaces to local atmosphere, then unload	4*

*The time needs to be experimentally determined and verified, the total NEG coating time for one stack is about 72 hours.

01 Assembly & leak testing is the most tough work, the robots will save 2 workdays and 2~3 workers

Vacuum furnace for NEG coating

- **The NEG coating vacuum system is divided into two parts:**
- **High vacuum and low vacuum**. The high-vacuum part provides an ultraclean environment with an ultra-low gas-impurity background for NEG coating. The low-vacuum part is created by a vacuum furnace. While the furnace provides baking for the NEG coating, it also keeps the flanges at both ends of the vacuum box—flanges that need to be repeatedly disassembled—in a low-vacuum environment. The interior of the vacuum box remains under high vacuum, thereby reducing the sealing requirements for these flanges and more friendly for robots assembly.



High vacuum in vacuum chambers
5×10^{-7} Pa



Vacuum furnace

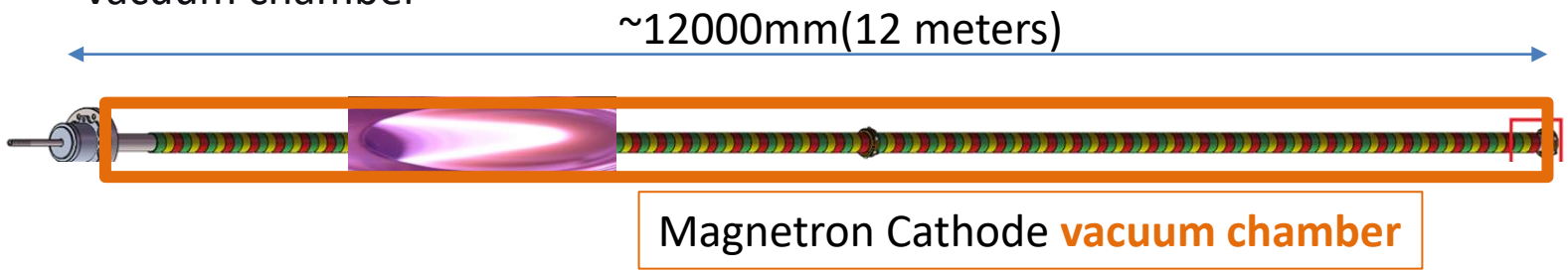


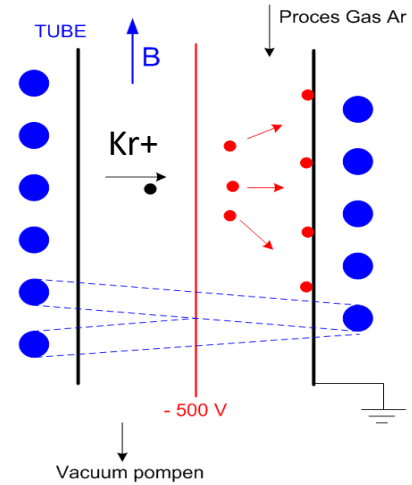
Low vacuum in vacuum furnace
5×10^{-2} Pa

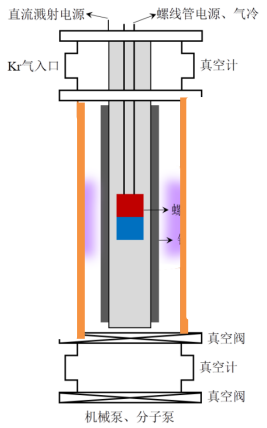
DCMS for massive NEG coating

◆ **DCMS （direct current magnetron sputtering）for NEG coating**

➢ Several magnets will move automatically to control the plasma discharge, thereby controlling the NEG coating area and thickness on the wall of vacuum chamber

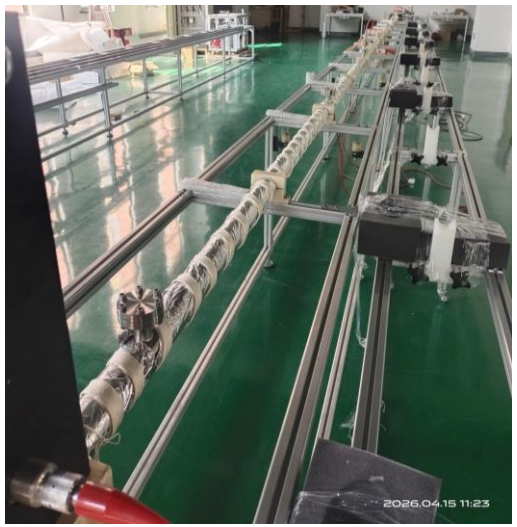






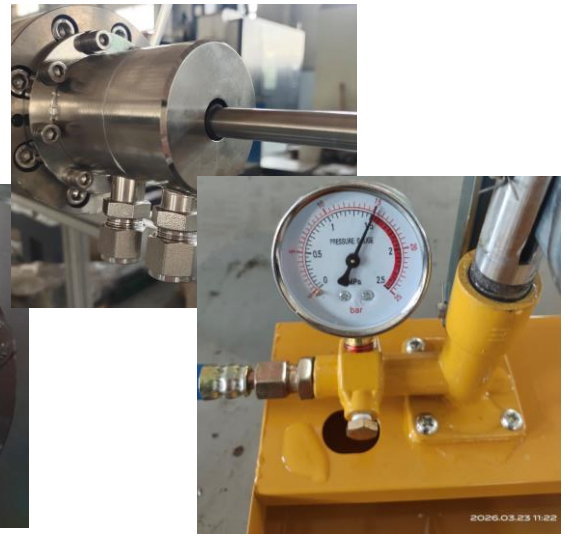
Inside magnet

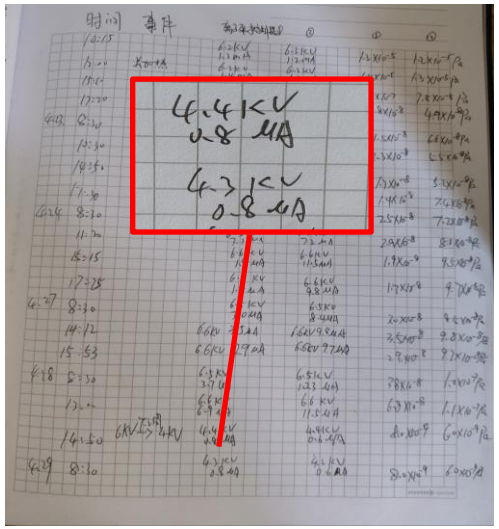
DCMS for NEG coating





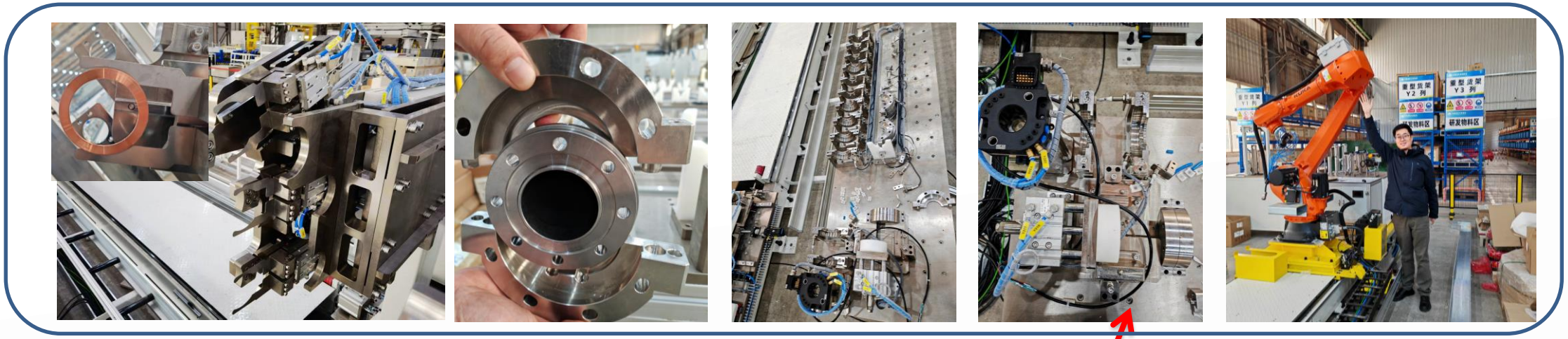






Layout & composition of NEG coating facility

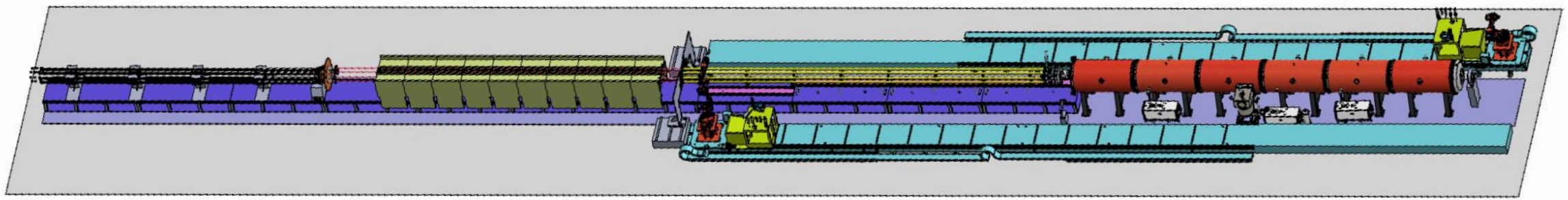
- The assembly of the vacuum chamber to the NEG coating system, as well as its preparation, is tough work that will be taken over by robots.





Layout & composition of NEG coating facility

- The part of NEG coating facility has being installed and conditioning in factory.

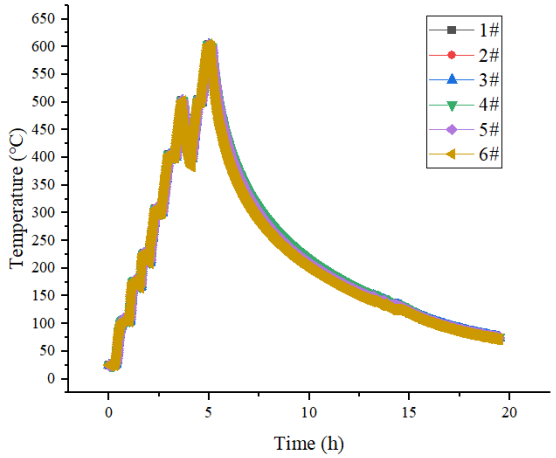




*The picture revised by AI

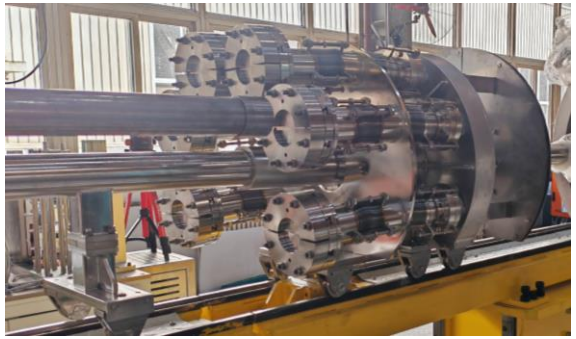
Sub-devices conditioning and testing

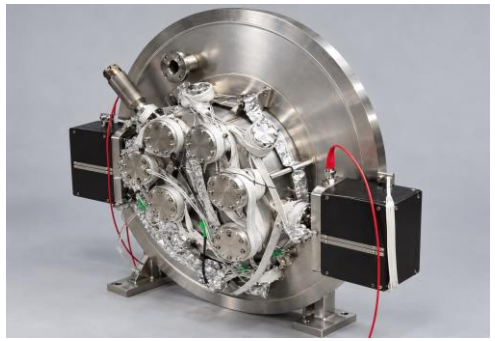
- Vacuum furnace baking temperature reaches to 600℃ and the vacuum of NEG coating chamber reaches to 5×10^{-8}Pa, these conditions can provide a good vacuum background for NEG coating.

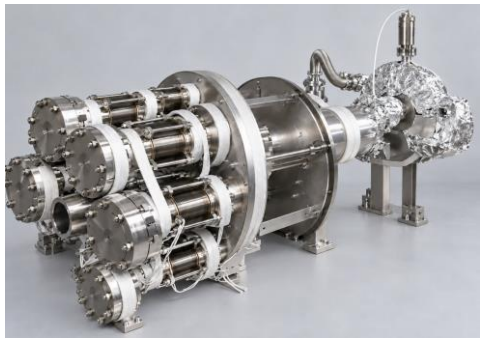




Vacuum furnace





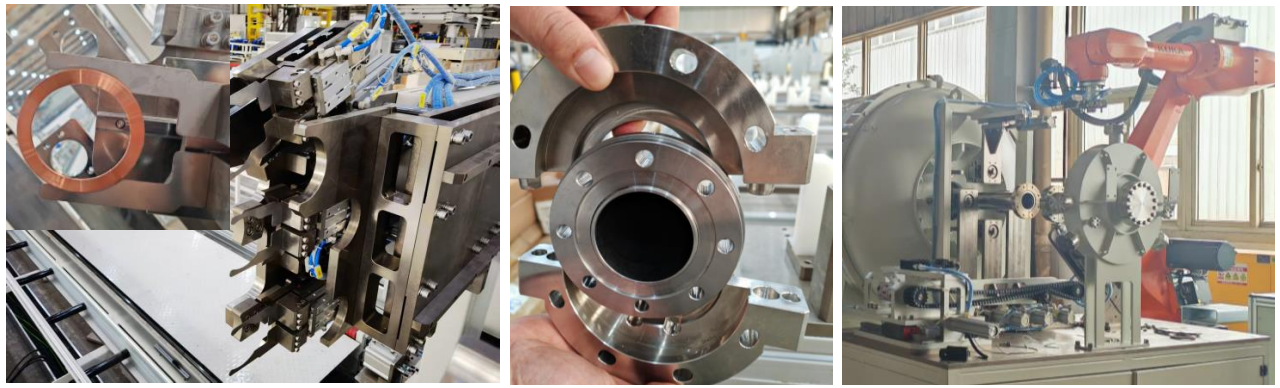




Assembly chamber for NEG coating

Flange assemble & sealing

- The alignment, connection, copper sealing-ring positioning, screw insertion, and tightening between the vacuum chamber tube and the coating chamber flange are major challenges currently being addressed on the production line.

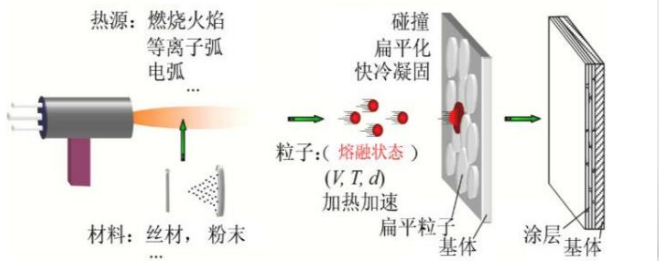


Supporting structure for flange and sealing-ring in automatic assembly

- **The most challengeable issues are:**
  - There is limited space available for robots, since six vacuum chambers must be assembled together.
  - Mechanical deformation of the vacuum chambers and bellows caused by gravity is currently being studied as a key issue affecting robot positioning, and solutions are under development.



Plasma Spraying system

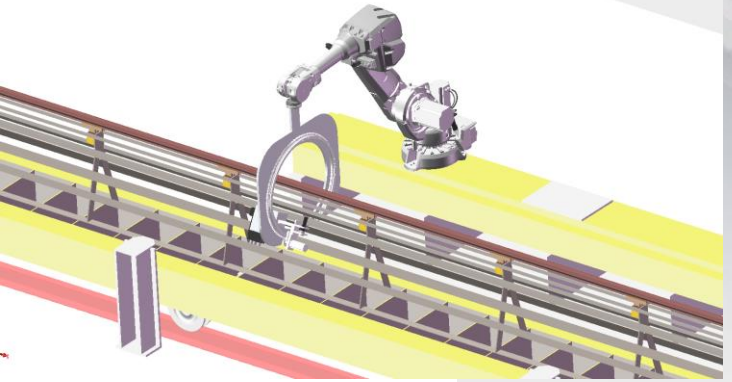




Plasma Spraying
& Laser etching room







Sandblasting room



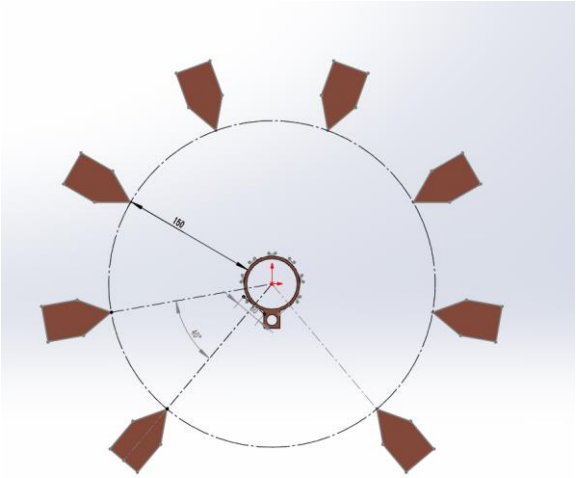


The vacuum chamber will be transferred by motorized conveyance （length21.1m, width 1m ） to the coating station, where a robotic arm will execute multi-layer deposition using an automated spray un.

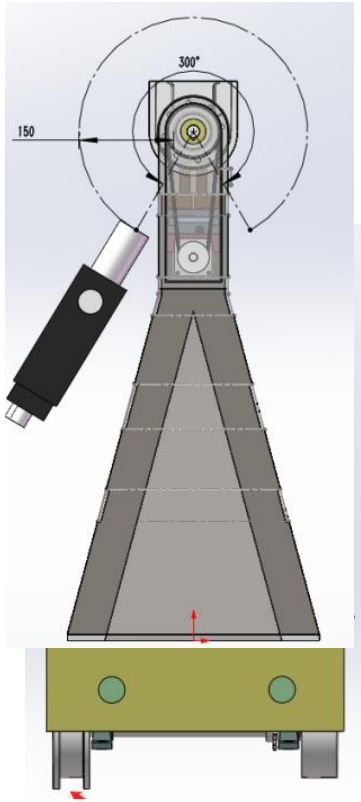
Heating-layer spraying

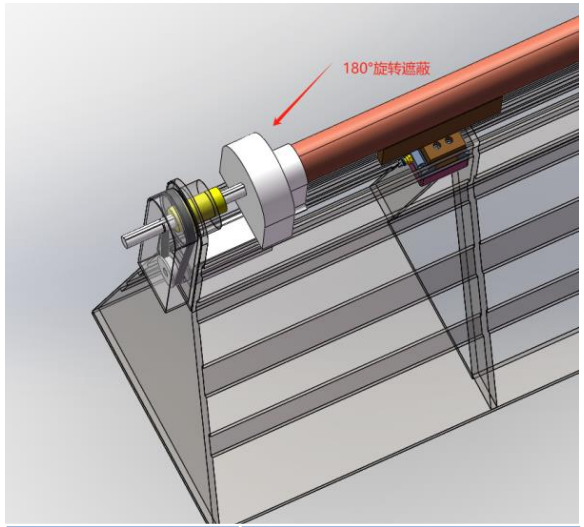
◆ The processing step for the heating-layer spraying

Sandblasting → **Plasma Spraying** → **Etching by laser**



名称	参数
喷砂枪数量	8把
喷砂距离	150~180mm
喷枪喷砂有效区域	≤φ30mm
砂料	白刚玉或棕刚玉
喷枪口径	8mm
喷砂压力	0.25-0.6MPa（可调）
砂流调整范围	1~3KG/min



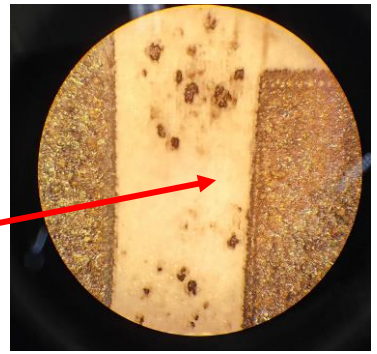


项目	参数
驱动方式	旋转气缸驱动
遮蔽材质	不锈钢
轴向可调节范围	100mm



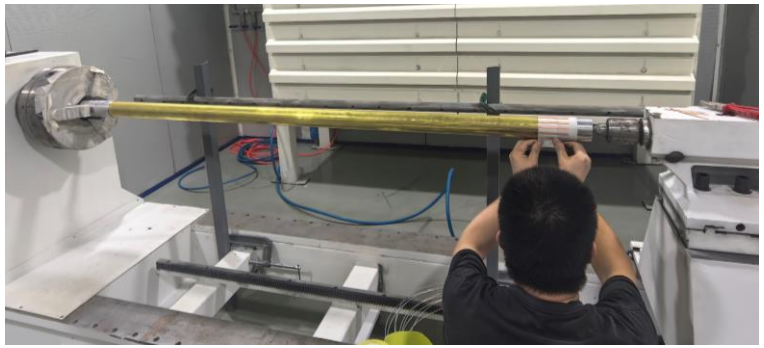




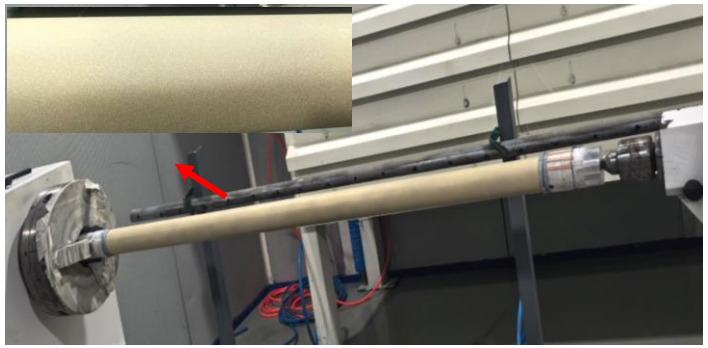


Length of 1.5m prototype_II of Spraying

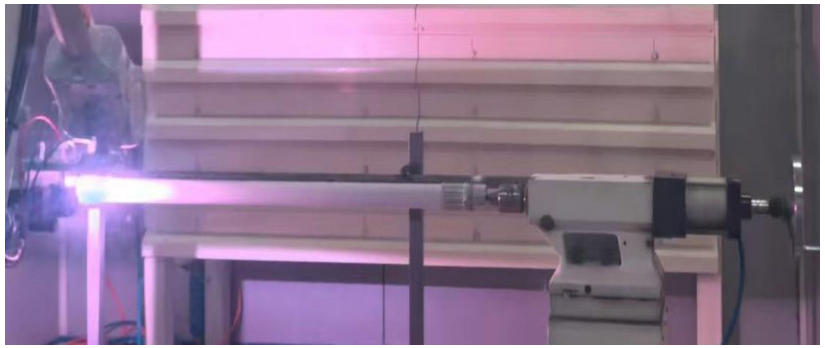
- A 1.5-meter prototype has been developed to validate key process steps that will be implemented in the production line.



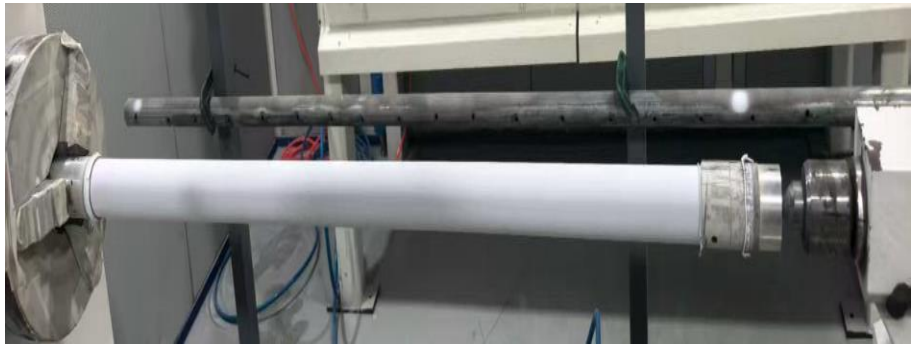
Installation



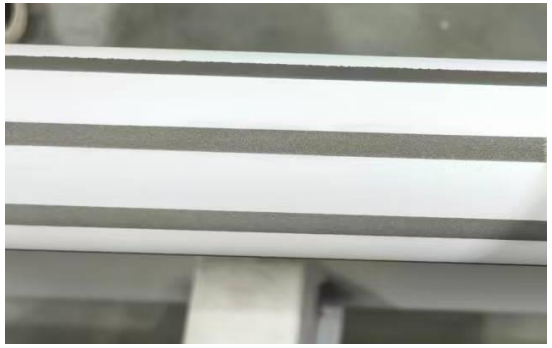
Sandblasting



Spraying



Spraying_Isolation-layer

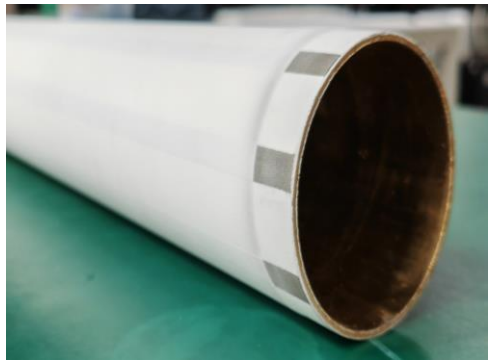


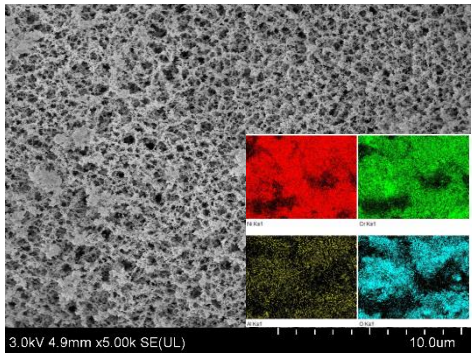
Spraying_Conductivity-layer



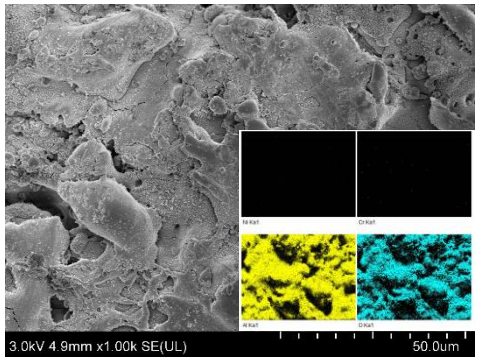
Spraying_Isolation_layer

Elements and thickness of thermal-spray heating layer

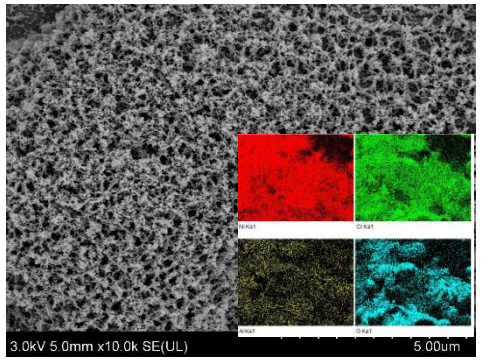




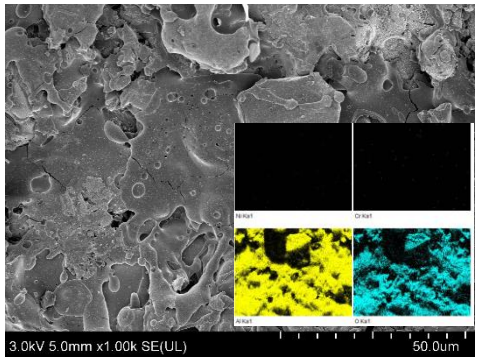
NiCr Conductivity-layer



Al_2O_3 isolation layer

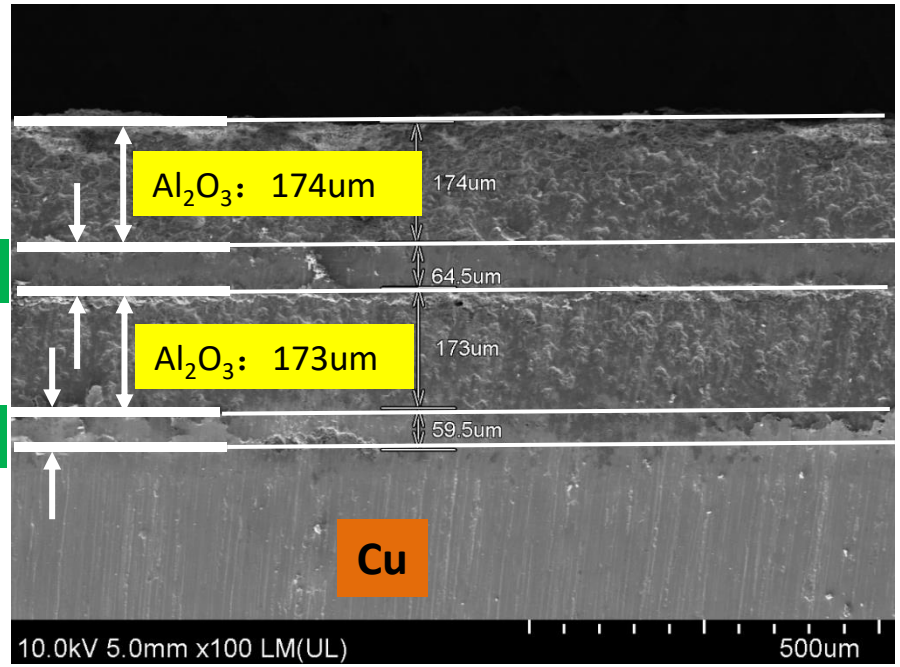


NiCr Transition-layer



Al_2O_3 isolation layer

Thickness

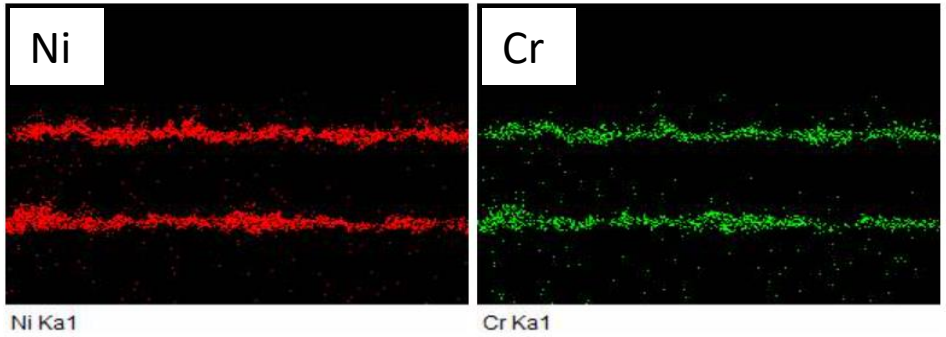


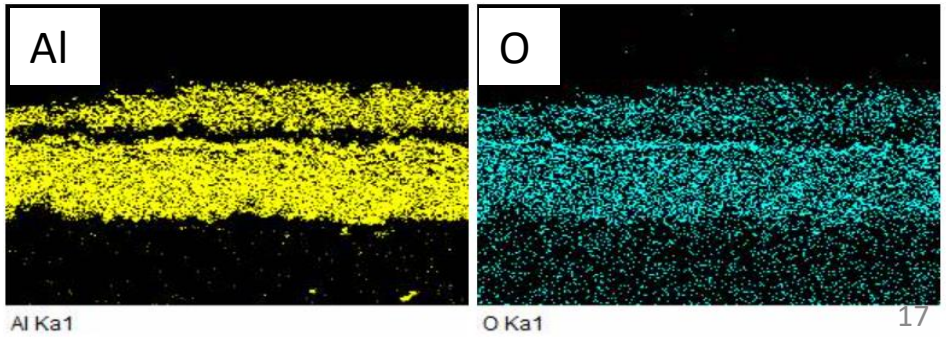
NiCr：64.5um

NiCr：59.5um

=471um

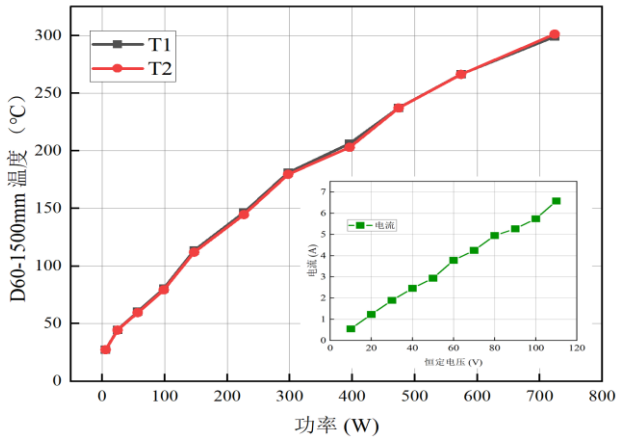
＜0.5mm

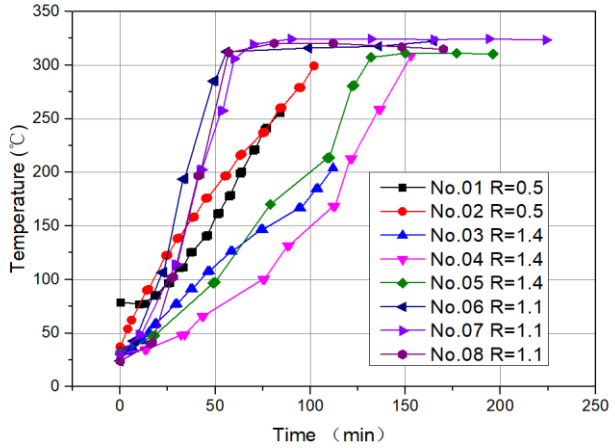


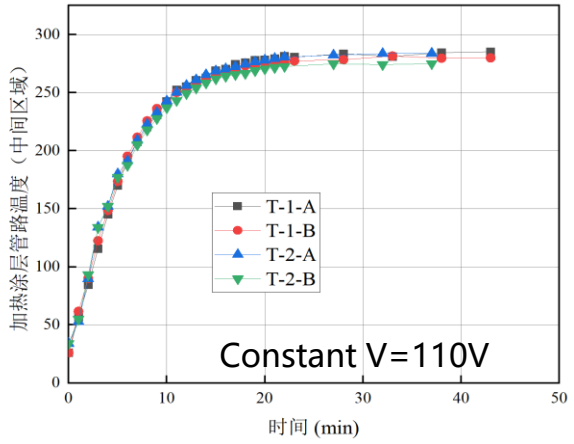


Prototype_II of thermal-spray heating layer and testing

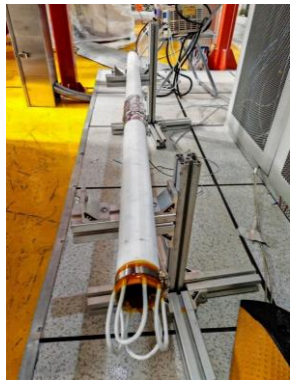
- Process trials have been successfully performed on a 1.5-meter-long coated vacuum-chamber prototype, subject to 65 cyclic heating reliability tests. The prototype consistently delivers a baking-activation temperature of 300 ° C, demonstrating stable performance for both spraying deposition and high-temperature activation.



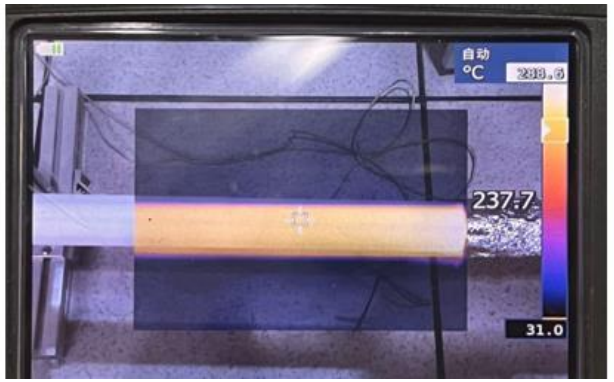





Contact points burn out





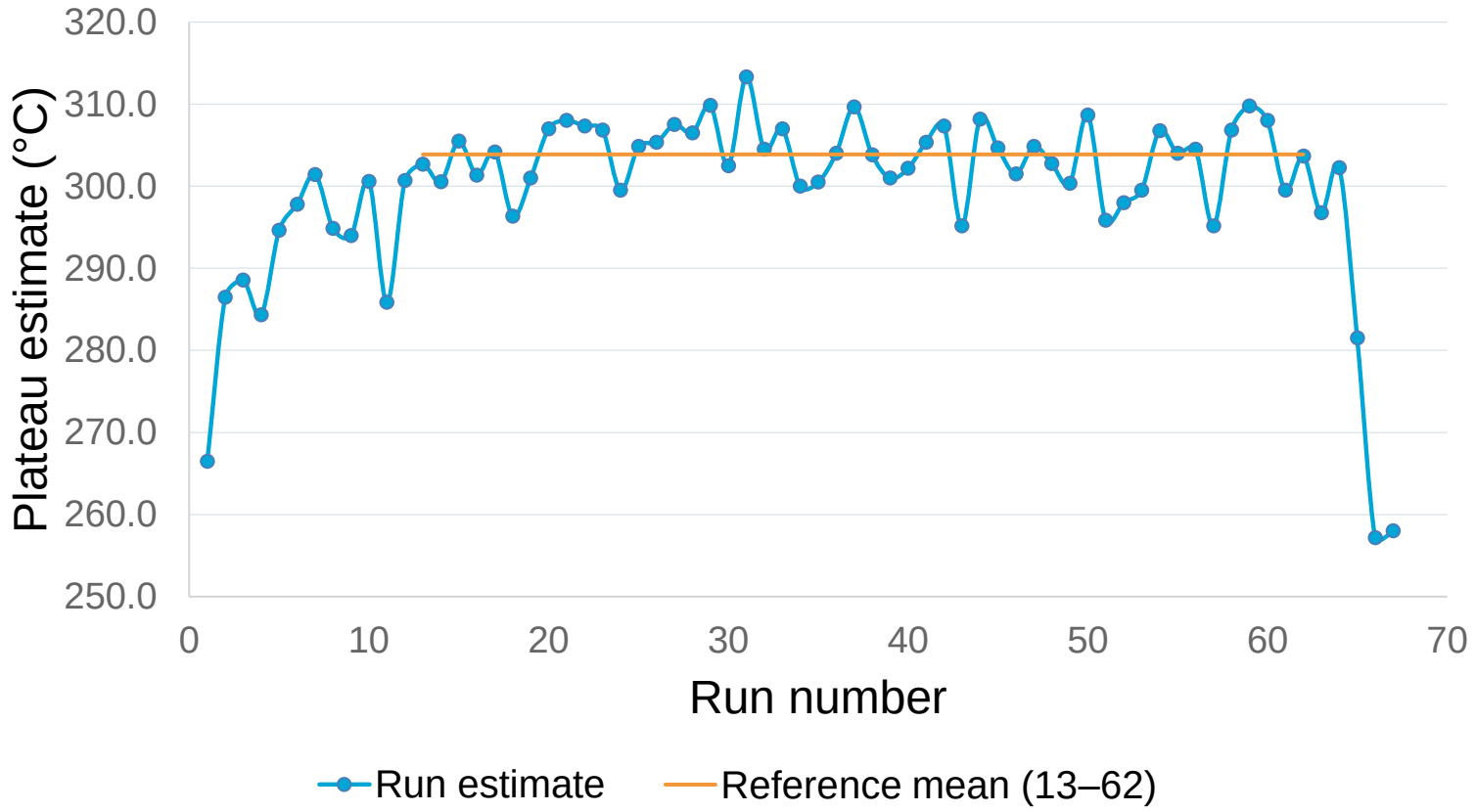




Dimension: L1500*D60 Substrate: copper

65 recycles times reheating tests which shows a good lifetimes and performance, except one of the contact points burn out.

All recorded heating runs since 28 January 2026



67 runs

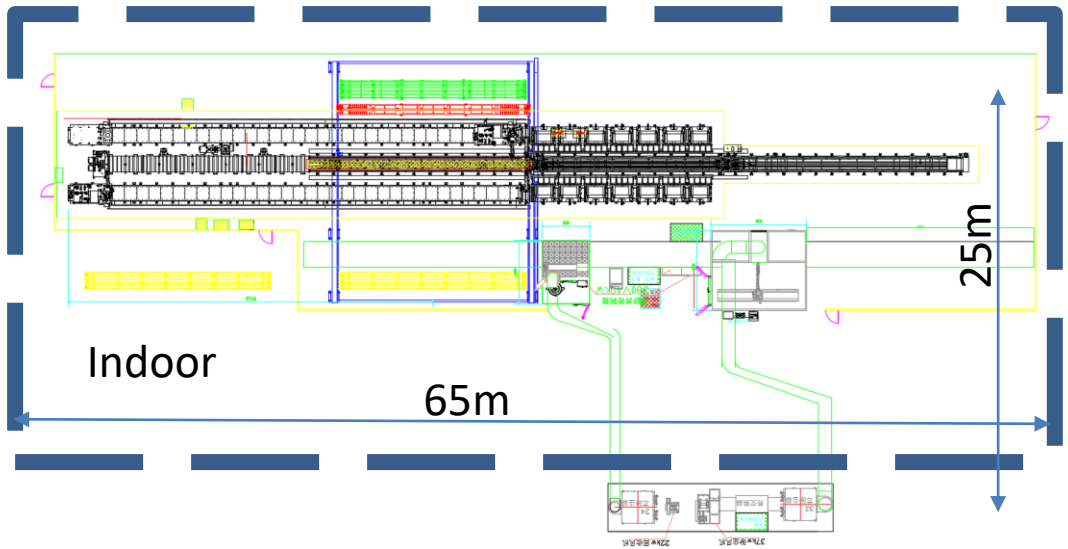
558 h 40 min

Summed recorded intervals (558.7 h)

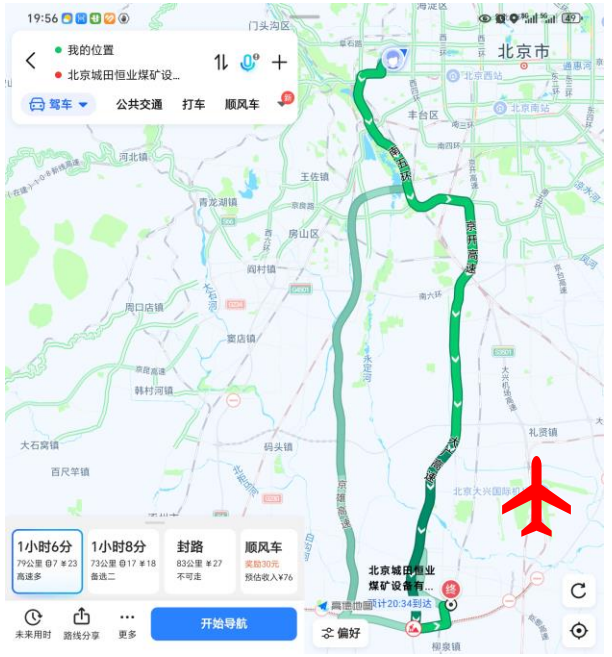
Reference: runs 13–62
303.9 ± 4.1 °C
50 runs / 422.8 h

Site of production line installation

- It will be installed in Guan, Hebei Province, which is 75 km from IHEP, in a few months；
- Equipment moving guide rails, sand boxes and other equipment require site foundation construction that has been completed；
- Vacuum chamber NEG coating, thermal spraying and some testing will be finished in this lab.







Production line conditioning plan and timetable

- NEG coating system
  - Aug ~ Sem. 2026: Foundation construction, rail laying, cable laying （Finished）
  - Otc ~ Nov. 2026: Flange assembly and sealing are performed automatically by robots.
  - Dec. 2026 ~ Jan.2027: The production line will be relocated from the development factory to the Gu'an site.
  - Feb. 2027: Production ability

- Thermal-spray system
  - Aug ~ Sem. 2026: Foundation construction, rail laying, cable laying （Finished）
  - Otc ~ Nov. 2026: Installation & conditioning
  - Dec. 2026: Production ability

Summary

- The production line for vacuum chamber NEG coating and thermally sprayed heating layers is currently under installation and conditioning.
- It is capable of handling vacuum chambers with a minimum dimension of 56 mm and a maximum length of 11.5 meters for NEG coating applications. There are no dimensional restrictions for the thermal-sprayed heating layer process.
- Additionally, a 1.5-meter prototype of the thermally sprayed heating layer has been fabricated, with relevant performance tests successfully completed. **65 recycles times reheating tests which shows a good lifetimes and performance, except one of the contact points burn out.**
- Thermal-spray heating layer: compatible all size of vacuum chambers.

Thanks for your attention!