Refurbishment and Reactivation of a Niobium Retort Furnace at DESY

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ABSTRACT

For research in the field of heat treatments of superconducting cavities, a niobium ultra-high vacuum furnace built in 1992 – originally used for the titanization of 1.3 GHz nine-cell cavities – and later shut down was recently refurbished and reactivated. A significant upgrade is the ability to run the furnace in partial pressure mode with nitrogen. The furnace is connected directly to the ISO4 area of the clean room for cavity handling. At room temperature vacuum values of around 3×10^{-8} mbar are achieved. The revision included the replacement of the complete control system and a partial renewal of the pump technology. The internal mounting structures are optimized for single-cell operation including tandem operation (two single-cell cavities at once) and corresponding accessories such as witness-samples and caps for the cavities. The installation of additional thermocouples for a detailed monitoring of the temperature curves is also possible at the mounting structure. Due to the furnace design, its location and the strict routines in handling, very high purity levels are achieved in comparison to similar set-ups and hence provide a mighty tool for SRF cavity R&D at DESY.

Technical Specifications

Capacity:	2 single-cell cavities or 1 nine-cell cavity
Temperature:	T ≤ 1400°C
Gas flow:	1.69×10^{-6} – 824 mbar l/s
Support vacuum	
• Volume:	1000 l
• Target pressure:	p < 1x10-6 mbar
• Turbo pump:	Leybold Turbovac 1000C
• Scroll pump:	Edwards nXDS10i
Recipient vacuum	
• Volume:	330 l
• Target pressure:	depends on recipe
• Cryo pumps:	2x Leybold COOLVAC 2000
• Compressor:	Leybold COOLPAK 6000H
• Turbo pump:	Edwards NEXT85D
• Roots pump:	Edwards EH250EU
• Scroll pump:	Edwards XDS35i
Intermediate suction (lid)	
• Target pressure:	p < 2 mbar
• Membrane pump:	Welch Ilmvac MP201T
Jacket cooling	
• Net cooling capacity:	90 kW
• Work pressure:	4 – 6 bar
• Flow rate:	125 l/min
Cryo chiller	
• Net cooling capacity:	0,97 kW
• Work pressure:	1,5-2,5 bar
• Flow rate:	20-30 l/min

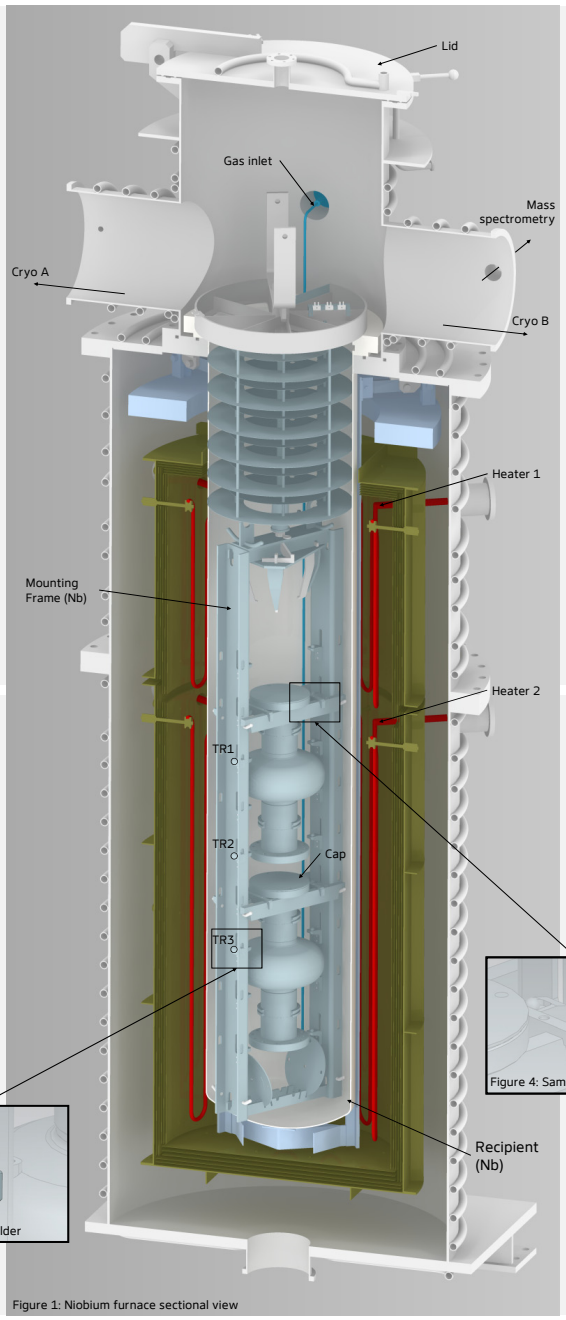

Figure 1: Niobium furnace sectional view

Mounting Structure

The niobium furnace frame, based on the nine-cell design, has been optimized for single-cell use. Every mechanical connection is designed to be form-fitting. The passage of the gas inlet required a continuous notch of the frame holder and associated shielding.

Tandem Loading
For single-cell cavity runs, the loading capacity has been doubled by installing an additional slot. The cavities are held by corresponding niobium profiles on the upper flange which are also the holder for witness-samples.

Temperature Monitoring
Three thermocouples (TR1-TR3) are used to monitor the temperature inside the recipient. These sensors inserted in adjustable niobium holders which are attached permanently to the frame to simulate the warm-up behavior inside the cavity material and to increase the service life of the equipment. Two of the sensors are mounted near to the equators of the cavities. The third sensor is mounted in the middle between the two loading slots. The temperature is controlled using the temperature sensors in the support vacuum.
During the test runs a constant temperature gradient occured between top and the bottom sensor of approx. 10 K (800 °C-run). This phenomenon was reduced by changing the control of the heaters. The offsets between the heating circuit and the actual temperature at the cavity depends on the target temperature.

Caps
In order to avoid potential particle contamination of the interior of the cavity, the cavity is fitted with niobium caps on the top of the cavity flange (only laid on) and optionally also at the bottom flange.

Controls & Recipes

As part of the revamp of the furnace, the entire control system, including the electrical wiring and control cabinets, was renewed. The new system includes a new operating concept with the possibility of modular recipe creation and a redesigned user interface.
Different operating states were defined, which represent the building blocks for recipe creation.

Nr.	Recipes	Runs
1	20h@250°C, UHV	2
2	20h@300°C, UHV	1
3	3h@250°C, UHV	2
4	3h@300°C, UHV	4
5	3h@800°C, UHV	2
6	48h@120°C, 3.3×10^{-2} mbar (N_2)	3
7	5h@1150°C, UHV	4

Table 1: Tested recipes

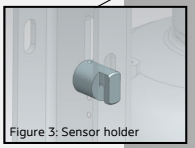

Figure 3: Sensor holder

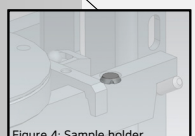

Figure 4: Sample holder

Partial Pressure Mode

The furnace now can be run in partial pressure mode. For this purpose, a niobium tube was routed to the bottom of the recipient. The volume flow is controlled by a mks mass flow controller, which is secured with an additional diaphragm valve. The nitrogen (purity 5.0) is taken from an existing ring line that is fed from a liquid tank.
The target pressure is regulated via a butterfly valve which adjusts the power of the pumps under a given mass flow of nitrogen.

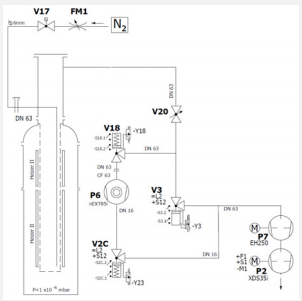

Figure 2: Control loop

Conclusion

The refurbishment was carried out successfully and thus equips the DESY SRF team with a flexible and high-purity furnace as a solid basis for research in the field of heat treatments of cavities. Due to the sluggish temperature control behavior, especially at low temperatures, there is still potential for improving the temperature curves. Furthermore, preparations for the nine-cell cavity treatment are currently taking place. In order to increase the flexibility in the infusion treatments, a gas bypass is to be installed in order to be able to connect conventional gas bottles. In addition, new sample holders are being planned and in order to establish an alternative temperature measurement a pyrometer will be included.

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