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CLEANROOM INSTALLATIONS FOR SRF CAVITIES AT THE HELMHOLTZ INSTITUTE MAINZ

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Abstract

At the Helmholtz-Institut Mainz (HIM) a cleanroom has been equipped with new tools and installations for the planned treatment of different superconducting RF-cavities. Therefore the cleanroom had to be shut down and some walls and part of the ceiling had to be dismantled. In its ISO-class 6 area a large ultrasonic and a conductance rinsing bath has been installed. A high pressure rinsing cabinet has been implemented between the ISO-class 6 and 4 cleanroom so that a cavity can be loaded and unloaded from both sides. For drying the ISO-class 4 cleanroom was equipped with a 160°C vacuum oven. Afterwards the cleanroom was sealed again and put back in operation. New cleanroom lift trolleys allow the handling of heavy objects (max. 200 kg). By a rail system in the cleanroom floor it is possible to move entire cold strings through the different clean room classes separated by a roll-up door. This paper reports on the reclassification of the cleanroom after it went back to operation and first experiences with its cleaning. Particle measurements of equipment in operation will be presented as well.

INTRODUCTION

The new building of the Helmholtz Institute Mainz (HIM) includes a cleanroom (CR), which is foreseen as part of the infrastructure for the SRF projects at GSI in Darmstadt and Johannes-Gutenberg University (JGU) in Mainz [1]. The Helmholtz Linear Accelerator (HELIAC) [2-5] will use 217 MHz superconducting crossbar H-mode (CH) cavities [6-9] and is currently under development by HIM and GSI. Substituting the GSI UNILAC, recently upgraded for FAIR with a short pulse operation with heavy ion [10-13] and proton beams [14,15], HELIAC satisfy the user requirements for SHE program [16,17]. Its first cavity was already tested successfully, accelerating different mass to charge ratio ion beams in 2017 [18]. The Mainz Energy-Recovering Superconducting Accelerator (MESA) uses 1.3 GHz TESLA/XFEL type 9-cell cavities. Its 2 cryomodules each equipped with 2 of those cavities are currently tested for acceptance at HIM [19].

The dimensions of the cleanroom and its installations and tools were chosen to serve both projects. In particular, the CH-cavities have a diameter of approximately 70 cm (with helium vessel and flanges) and thus are considerably larger than the 1.3 GHz cavities. The HIM-ISO-class 4 cleanroom is large enough to allow for assembly of up to 9 m long cold-strings.

CLEANROOM PROPERTIES

The cleanroom without equipment and machines was already put into operation in November 2015. It features a heavy duty aluminium double floor, capable of up to 5 tons per square meter and a rail system through its different zones in order to roll out a complete cold-string. In the basement of the HIM building a water treatment plant with a 5000 l storage tank provides 2500 l/h ultra pure water (18 MΩcm) for the cleanroom. Besides different locks the cleanroom is mainly divided into two parts: a 42 m^2 ISO-class 6 area (CR 1) for cleaning and preparation, and a 43 m^2 ISO-class 4 (CR 2) area, designated for drying and assembly.

In summer 2017 the cleanroom was shut down, several walls and part of its roof were opened to bring in a large vacuum oven, an ultrasonic (US) and conductance rinse (C-rinse) bath together with its lifter system as well as a high pressure rinsing cabinet (HPR). After all electric, water and gas installations were made the cleanroom walls were put back in place or were adjusted to the machines by the cleanroom vendor. For example, the HPR is now part of the barrier between CR 1 and CR 2 and can be loaded and unloaded from both sides acting as an air lock. Figure 1 shows a picture taken with a fisheye perspective from the side of CR 1. Under the aluminium cover (in the middle part), the rail system passes through a roll-up door to CR 2 and to the right leaves the cleanroom (under a broad exit door) into the cryo-module assembly area outside.

In Table 1 all rooms and locks of the cleanroom are listed together with data of their ISO-class, size, overpressure and changes of their air per hour. Figure 2 gives an impression of CR 2. One can see, that the ceiling above the HPR had to be raised from 3 to 4.2 m in order to create enough space for the lever, holding the HPR wand, to move up and down. An additional Filter Fan Unit (FFU), not visible in Fig. 2, has been installed on top of the raised ceiling to ensure ISO 4 quality also on top of the HPR.

Besides those large permanent installations the cleanroom is equipped with smaller tools such as ionized nitrogen spray guns, smaller US baths, a cleanroom dishwasher,

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particle counters, wet and dry CR vacuum cleaners and two lift trolleys, to lift and transport heavy objects. Perforated stainless steel tables, shelfs and trolleys as well as cleanroom chairs have been locked in too.

Figure 1: Fisheye perspective of CR 1. In the middle part the US and C-rinse baths are shown, on the left: Personnel air lock, roll-up door and part of the HPR.

Figure 2: Photo of CR 2: the HPR with its lever for the movable wand (on top) is shown. The door of the vacuum oven and a lift trolley is shown as well.

Table 1: Different Cleanroom Sections with Main Parameters as ISO-class, Size, Overpressure and the Changes of Air Per Pour (φ). Their Purpose and Features are also Listed. The Greyrooms Fullfill ISO 8 Margins in Terms of Particle Concentrations at Rest

Room	ISO	A [m^2]	$(P - P_0)$[Pa]	φ [1/h]	Main purpose / features
Greyroom 1	(8)	18	10	-	Access to car wash, power supplies (USB)
Personnel air lock	6	4.3	30	100	Locker room, CR-clothes, hand-desinfection
Material air lock	6	3.2	30	60	High pressure DI water cleaner (car wash)
Cleanroom 1	6	42	45	60	Cleaning, preparation / large USB and C-rinse
Personnel air lock	4	1.3	45-75	-	Air shower before entering CR 2
Material lock	6	2.1	75	300	Roll-up door + curtain between CR 1 and CR 2
Cleanroom 2	4	43	75	300	cold-string assembly / 160°C CR vacuum oven
HPR cabinet	4	1.9	≥ 75	-	Accessible from CR 1 and CR 2
Greyroom 2	(8)	18	10	-	Infrastructure (Oven and HPR), power supplies

PARTICLE MEASUREMENTS

Bringing in all new machines, the reconstruction of the cleanroom walls, additional feed-throughs and attachments did, of course, generate a lot of contamination. After this and before recommissioning of the cleanroom, the vendor provided for major cleaning of all surfaces. Following this, the cleanroom was re-classified by the same vendor. As before all quality characteristics were met again. Nevertheless, it was found, that the particle concentrations were higher compared to the first commissioning in 2015. With time, particle concentrations went down. It was found that a weekly cleaning of the floors and working surfaces and a monthly cleaning which includes walls, ceilings and other hard reachable places is sufficient (even if this is not industry standard for ISO-class 6 and 4). Once per year also the ground underneath the double floor is cleaned. For cleanroom classifications the particle counters are placed on evenly spread positions. Exemplary, Fig. 3 shows a comparison of particle concentrations in CR 1 (ISO 6). It compares the results at the points of measurements with the highest particle concentration per cubic meter: In 2015, right after the cleanroom was ready to use, 2018 from the re-classification and 2019 after bringing in all the remaining tools and furniture and weekly cleaning. The particle concentration after the modification was significantly increased compared to the first classification in 2015. In fact, the cleanroom was not ISO-class 6 conform to new ISO 14644-1:2015 norm. At its worst measuring point it exceeded the limit for particles/m^3 ≥ 5 µm of 293 as 459 were counted. Additional cleaning solved this problem and during the last classification (2019) in this room not a single particle of equivalent size could be observed in this room (see Fig. 3).

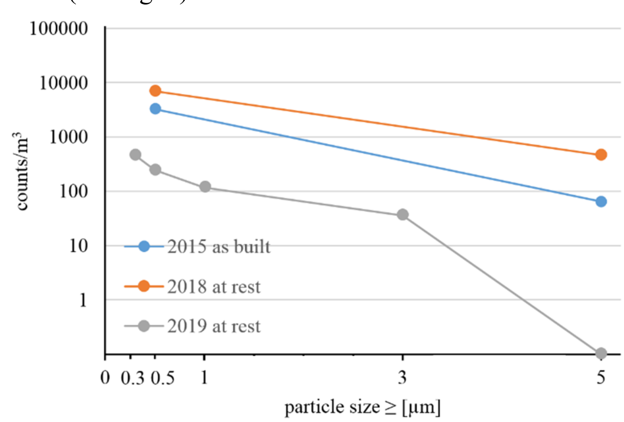

Figure 3: Particle concentrations at the "worst" spot of CR 1 during classification measurements after the CR was built (2015), altered (2018) and today.

High Pressure Rinsing Cabinet

The HPR is accessible from two sides so it acts as an air lock for cavities which are brought in after ultrasonic cleaning and conductance rinse from the ISO-class 6 CR (see Fig. 1). After high pressure rinsing unloading is possible from the ISO-class 4 CR (see Fig. 2). The HPR wand is not fixed. It moves up and down during a rinsing program, moved by a lever on top of the cabinet in the ISO-class 4 room, entering it through a little hole. To avoid par-

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ticles moving through that hole into the cabinet, two additional FFUs on top of the cabinet provide an overpressure on its inside. Measurements with a particle counter* on the HPR table while rotating and its wand moving up and down (without spraying water) so far never counted more than 4 particles ≤ 0.5 µm per m^3. In a different measurement, the cabinet doors to the ISO-class 6 CR were opened, implicating that effectively the air above the HPR is sucked into the cabinet. Due to this only four particles were counted. Leaving the door open for a longer time did not cause additional particles. Therefore the cabinet for itself seems to work excellent with respect to particle contaminations. In the future the particle production of the loading and unloading process of a cavity with a cleanroom lift trolley must be investigated and optimized as well.

Roll-up Door

Due to limited space, the lock for material between cleanroom 1 and 2 is not an air lock. Instead of this a roll-up door serves as a barrier to the ISO 6 and vertical blinds to the ISO 4 CR enclosing an area of just 2.1 square metres as a lock (see Figs. 1 and 2). For this, if the roll-up door is opened, the pressures of both rooms are instantly equalized. Of course, this causes a lot of turbulence, when the air from the ISO 4 is streaming over, also the vertical blinds are flapping. To investigate what this means for particle concentrations the door was opened and closed every two minutes (it stayed open for 15 seconds), while counting particles with the probe was 65 cm above the floor. One measuring point was just in front of the door in the ISO 6 CR and the other was on the inside of the lock (ISO 4). The results are depicted in Fig. 4. Even in operation the inside of the lock meets the ISO-class 4 criteria. In comparison to a measurement at rest the particle concentration on the ISO 6 side (CR 1) is much higher now, but still within the norm margins.

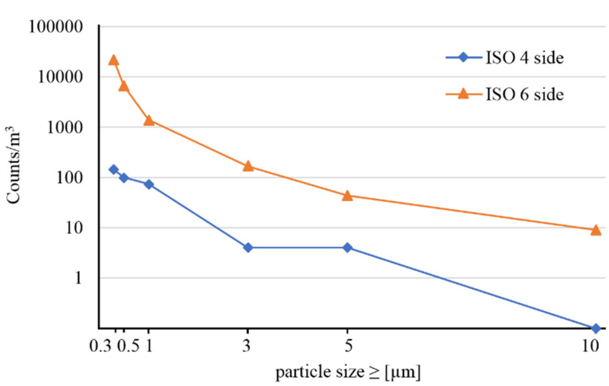

Figure 4: Measured particle concentrations during roll-up door operation inside the lock (ISO 4) and on the ISO 6 side.

Cleanroom Lift Trolleys

Each room is equipped with a dedicated cleanroom lifter to transport cavities and other heavy objects. In Fig. 5 a photo of a lifter can be seen. All surfaces are stainless steel or transparent plastic with rounded edges for an easy wipe. The motor is totally covered at the top, driving the mechanism which rolls up or off a washable polyester belt. This allows to move a rotatable along its pole carrying objects of up to 200 kg. It was designed to hand over cavities to the crane of the ultrasonic bath, the HPR and the vacuum oven vertically and to place them horizontally for cold-string assembly. Most of the particles which are produced by the roll-up mechanism are guided by the covers along the pole down to the floor. As in Fig. 5 and Table 2 shown, the particle measurements were made in three different positions: at pole, on typical cavity height near pole and at typical cavity opening. At cavity opening position significantly less particles were measured. The amount of particles counted were generated due to constantly moving the fork up and down for a minute. This is not the normal time it takes to lift a cavity a few cm.

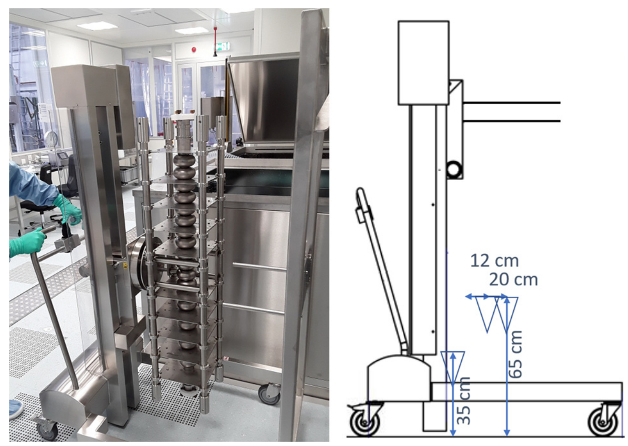

Figure 5: Left: Photo of the lift trolley handing over a cavity in its frame to the lifter system of the ultrasonic bath. Picture was taken during the testing of the cleanroom infrastructure with a 3 GHz cavity from TU Darmstadt [20]. Right: Sketch of the probe positions during particle measurements without cavity.

Table 2: Particle Measurement with CR Lift Trolley During Constant Operation. Probe Positions are Shown in Fig. 5

Position of probe	Particles / ft^2		
	≥ 0.3 µm	≥ 0.5 µm	≥ 0.1 µm
Beneath pole	1041	211	57
12 cm / 65 cm	49	5	1
20 cm / 65 cm	1	0	0

CONCLUSION

After installation of large ultrasonic bath and a conductance rinse bath, a HPR cabinet and a large vacuum oven the SRF cleanroom at HIM has been successfully re-classified. It was shown, that particle concentrations went down due to regularly cleaning. The particle production of different tools in operation were checked. The results are acceptable, but there will be further investigations in order to reduce all sources of particle contamination down to a minimum.

*AeroTrak® Modell 9310

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