Technical Specification for

High Pressure Rinse System (HPR)

Introduction

As part of an In-Kind Contribution to the European Spallation Source, STFC-Daresbury Laboratory has agreed to procure, fabricate, test and deliver 84 + 4 (5-cell) High-Beta superconducting (RF)704.41 MHz cavities for the ESS High Beta Project.

Each cavity externally is approximately a cylinder of 1.3m length and 0.45m (**not including He pipe**) diameter **[Figure 6]**, weighing approximately 170kg; The design chosen for ESS are hollow metallic structures (in this case, Niobium), designed to operate in vacuum. In order to achieve their performance specifications, these cavities need to have good vacuum and RF properties. In particular, in order to reduce undesirable electron emission caused by enhancement of the high (~20 MV/m) electric fields, the cavity surfaces must be free of particulate contaminants which can act as field enhancers. This is achieved through utilising a High Pressure ultra-pure water rinsing cycle with specific water jets in an ISO4 cleanroom (similar to a Class 10 cleanroom).

Scope

This requirement is for the design, fabrication, delivery, installation and commissioning of the High Pressure Rinse facility that will be installed within the Cleanroom on the STFC Daresbury Laboratory site. A factory acceptance and acceptance on the STFC site will also be required.

Specific scope includes and is not limited to:

- The mechanical support for translation and rotation of the cavity, capable of the given weight capacity, physical dimensions **[Figures 4, 5 and 6]** and also to ensure accurate alignment and precise motion during the process. This will also include the mechanical interface of the Mechanical lifter to the cavity. Example: Hung or supported with tooling. An example of a HPR system which is supporting the cavity with tooling from the top can be seen in **[Image 1]** *See image on page 17*
- The design for the rinsing wand and Nozzle type to suit and uniformly wash the internal surface of the 704MHz High Beta SRF (Superconducting Radio Frequency) cavity geometry. The Nozzle must be interchangeable from the wand and the interface connection must be a stated metric thread. Also include any special sitec high pressure connectors that may be suitable.
- Nozzles: manufacture and supply if three nozzles made from sapphire. Final design to be agreed with STFC.
- Validation of the alignment of a fixed rinsing wand to the required accuracy.
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- HPR active area has to conform to ISO 4 requirements. Maintenance and service access areas, including any driving units situated outside the HPR active area needs

to be designed in a way that they and the air circulating there do not have impact on the ISO 4 cleanliness of the cleanroom and the HPR active area.

- Full HPR enclosure protection with appropriate safety interlocks and use of correct materials compatible within the cleanroom facility and to withstand High Pressure Jets.
- Full Motorisation and cabling must be cleanroom compatible.
- Design of Software: A minimum of three operator access levels is required. I.e. Pre-set programmes, Supervisor and Expert level, with passcodes or user identity. The type of PLC must be stated as part of this tender. STFC's preferred PLC would be the OMROM CJ2M or the Siemens S 7.
- Flat touchscreen Control panel for operation (located outside the cleanroom) – including graphics for operation and status for the cavity rinsing process. Remote monitoring and connection to wireless network and supporting software.
- Chassis and fixtures: If any external structural support is required for the mechanical cavity lifter, the design and specification must be included as part of the scope. *Note: See **Alignment Page 12** for further information on translation and rotation accuracy.*
- Overflow basin and connection to drains: floor level compatible with the environment (wet and cleanroom). The basin should also enable the cavity lifter legs to be inserted to allow loading of the cavity. Drainage pipe solution should not interfere with loading process and should be protected. **[Figure 3]**
- Surface qualities: All tubes must be Electro-polished.
- Safety - Determine full safety case. E.g. Hazop or similar. The HPR shall have all required interlocks including physical HPR enclosure and <u>cover over the Wand nozzle when not in operation</u>. Emergency stop operation is required within the cleanroom and externally.
- Detailed User manuals: Should include and not be limited to: Operation, maintenance, fault findings, diagnosis of hardware and software.
- Full commissioning of the facility in the presence of STFC staff.
- The wall of the HPR must not be brushed surfaces, suitable materials must be selected to reduce the possibility of surface contamination. All areas must be accessible for maintenance.
- Provide the specification to the interface of the High Pressure Pump. STFC will procure this pump as a separate tender.
- Please state where the air supply and exhaust air from HPR will come from and go to. I.e. Air in from ISO 4 cleanroom - air out to grey or black areas or air supply and exhausting independent from cleanroom.
- Training of STFC staff for full user operation and maintenance.

Cleanroom assembly

Cavity assembly in the cleanroom must conform to well-established standards. The principal operations to be followed relating to the HPR treatment are the following:

- Cleanroom handling
  - Cavities are manipulated using a robot and/or specific tooling allowing handling and positioning of heavy loads.

- Installation/loading of the cavity on the HPR bench
  - The placement of the cavity on the HPR bench will be accomplished using the same handling means, via a robot/mechanical cavity lifter.

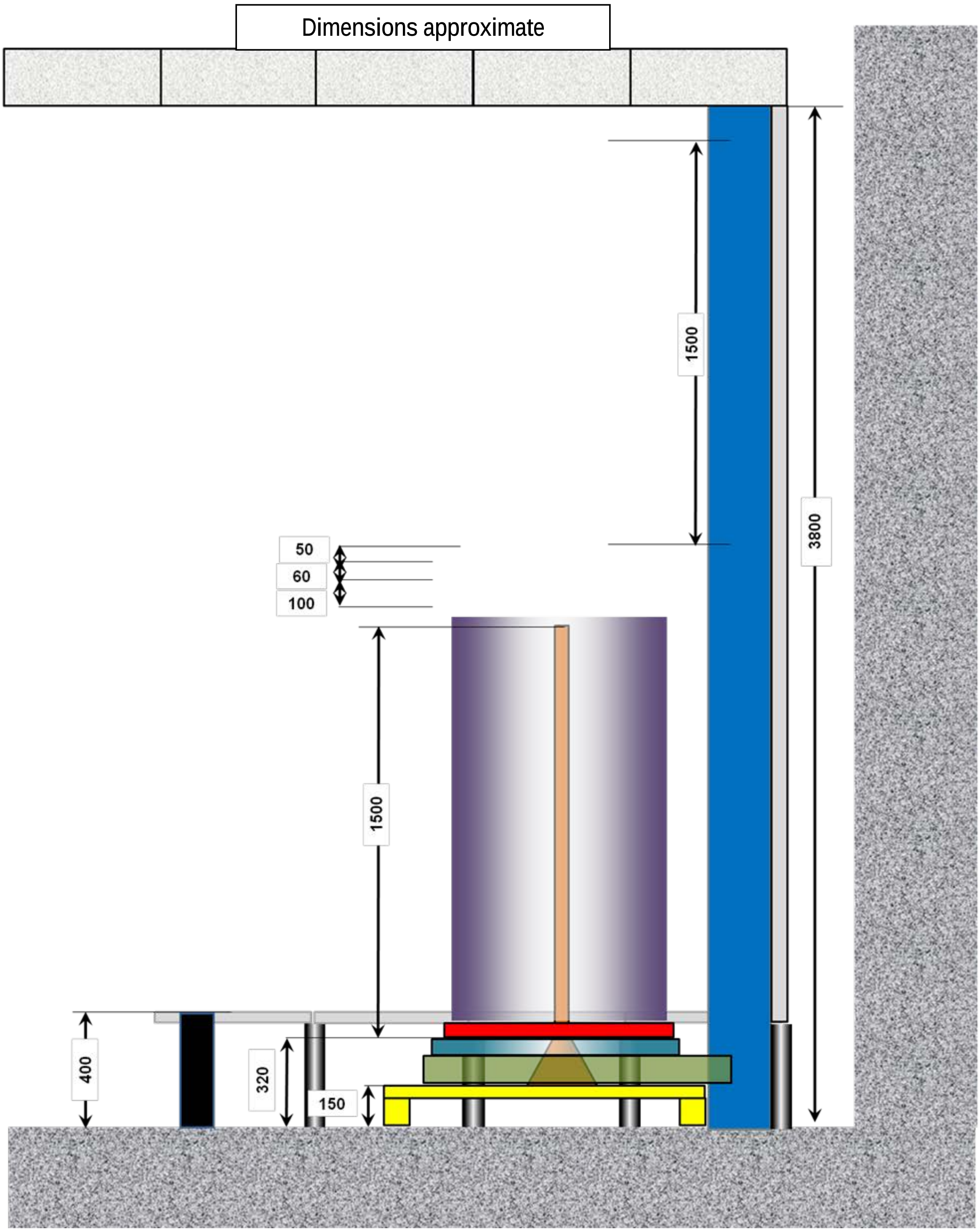
- High pressure rinsing under laminar flow
  - Once the cavity is in place, the handling tools are removed and rinsing can begin, under a laminar flow. Note: Laminar flow conditions must be present at all times, even when the HPR system is on stand-by.

- Removal from HPR bench: Once the rinse is complete, the same handling tools used for installation are used to remove the cavity from the bench. The operator will not intervene near the top half of the cavity to minimise the risk of particulate contamination of the cavity.

General Principles

The schematic of the bench in its raised and lowered position are included in this chapter **[Figure 2]**. Dimensions are also given below as a guide. See detailed cavity drawings for further information. **[Figures 4 & 5]**

As discussed, the HPR bench will be installed inside an ISO 4 cleanroom which will have laminar airflow. During the rinse, the cavity will be positioned vertically. A wand terminated (with the ability to interchange) nozzles is vertical and fixed. A high pressure ultra-pure water jet is emitted horizontally from the nozzles, and the cavity is rotated and lowered until all internal surfaces have been cleaned by the water jets. The cavity is then raised, with the rotation still in place, until the wand is no longer inside. At this point the water compressor and the water flow are stopped, and the rinsing cycle is complete. The protection doors of the HPR can then be opened and the cavity removed using the appropriate tooling.



Cavity in low position

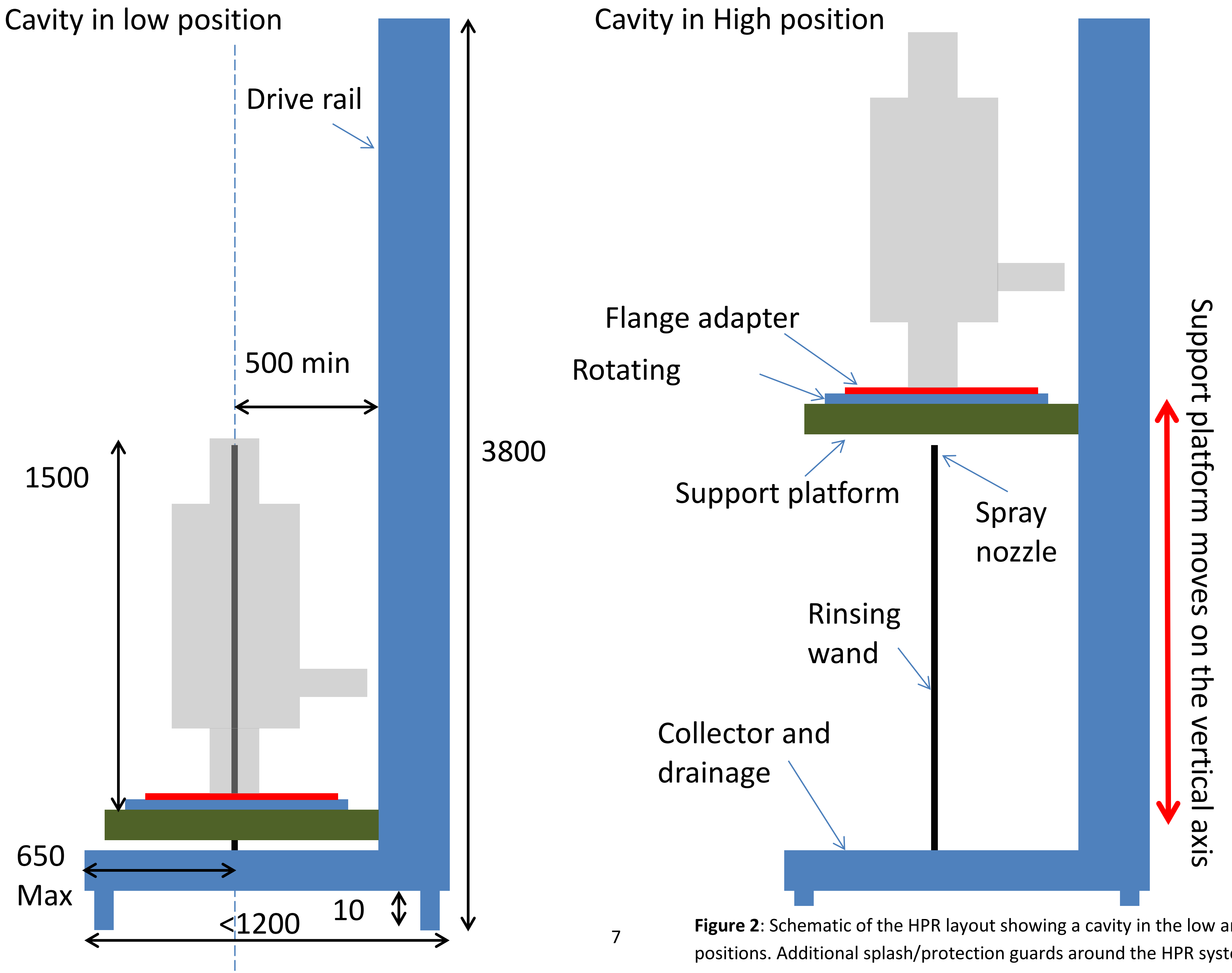


Figure 2: Schematic of the HPR layout showing a cavity in the low and high positions. Additional splash/protection guards around the HPR system are not shown in this diagram. Drawing not to scale.

Example of a rinsing process:

- Doors open.
- Cavity insertion/loading using a cavity lifter/tooling aid.
- Fastening of the cavity on the HPR support – for precise alignment and stability.
- Removal of the tooling.
- Safety enclosure Doors are closed.
- Start (from the external cleanroom control panel) of the water compressor to rinse the wand.
- Start (from the external cleanroom control panel) of the rotation and vertical movement of the cavity.
- Arrival at low position and automatic stop of the water jet.
- Return to high position while rotation and water pressure on.
- Automatic stop of vertical movement when at high point.
- Stop water pressure.
- Stop rotation.
- Opening of the doors.
- Either :
    - Removal of the cavity
    - Drying at high position
- Removal of the cavity fasteners.
- Removal of the cavity using tooling.

The process has to be set up in such a way that the complete inner cavity surface is rinsed within one rinsing cycle. Each standard HPR process has to start with a fast motion in order to wet the inner cavity surface and bring the spraying head from the high position to the low position within a specific time. From the low position the cavity is cleaned intensively from bottom to top in 100 - 120 min. The software must enable levels of intervention to allow user types to change certain parameters for optimisation and updating the required rinse cycle.

Technical Requirements

General principles

- The cavity will be placed on a variable speed rotating support mounted on platform that can rise up and down. Potentially the cavity could be hung from a support and this could be proposed as part of the tender bid.

- Mechanical stability and alignment can be ensured by bracing through the cleanroom walls, connecting to an RSJ type structure. It is recommended that this type of structure will be required to support the HPR system for the required stability during the rinsing process. This shall be specified as part of this tender.

- Full access will be required to the various fixture points for the operators, to allow cleaning and maintenance. The design must be compatible with cleanroom practice.

- The mechanism needs to function in the presence of ultra-pure water without oxidising or generating particulates. Lubrication of moving parts will avoid grease as far as possible. All parts will be covered for safe operation and to prevent particle generation.

- Sensitive elements of the mechanism will be protected from water or placed away/isolated from water. Access to the HPR for maintenance and repairs should be stated and designed in such a way to allow user friendly full access to all of the systems components without negatively impacting the cleanliness.

The platform shall be controlled accurately in terms of vertical movement. The supports and mechanical assembly shall allow the centre of the rotating fixture to remain within +/-1mm on a vertical axis over the length of travel of the platform.

A greaseless guidance system will be required, UPW could be utilised during motion. To avoid particulates unavoidably generated by friction, the sources of friction could be continuously washed by a water flow to remove dust particles or a mechanism should be discussed to confirm that cross contamination will not occur and will meet all cleanroom requirements.

Example: Proposed Cavity lifter (mechanical aid) for loading the cavity onto the HPR Facility.

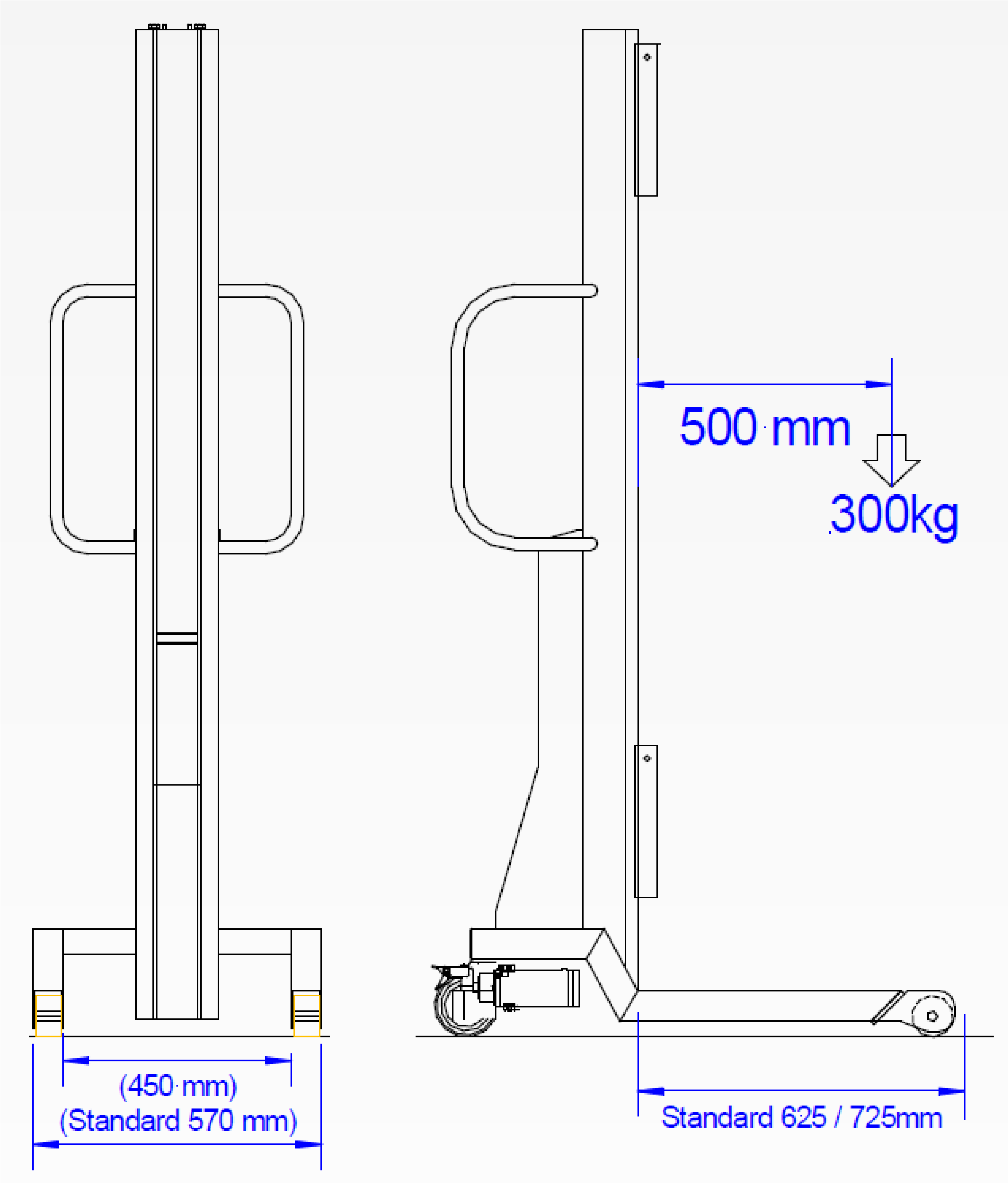


Figure 3: General representation of the lifting aid.

The base tray of the HPR should allow unhindered access for the outrigger legs of the lifting aid. The vertical space required by the legs is 100 mm. Dimensions with be confirmed on place of contract.

Rotating Base/Support

The rotating base will be equipped with adaptor pieces to support/hold cavities during the rinse. These adaptor pieces, supplied for the different intended uses, will match onto the rotating base or holding support. The system shall and must not be limited to:

1. Allow the attachment of the cavity to the support in safe working conditions. This will need to be done in the high position to not interfere with the rinsing wand.
2. Be able to hold the weight of the cavities (170 kg) without movement or flexing, in order to ensure coaxially of the cavity and the rinsing wand.

Alignment

During installation in the cleanroom, the positioning of the system will be adjusted with the use of a laser tracker. This will require a number of fixation points for the tracker targets on the vertical rail as well as the rotation platform. The number and exact location of these survey points will be defined during the mechanical study of the HPR. The intent of this exercise is to ensure and if necessary, correct, the +/- 1mm alignment between the wand and (cavity support) vertical axes.

Motorisation

The vertical movement and the rotational movement will be actuated independently by encoded stepper motors. The motorisation will provide an adjustable, regular rate of motion. Access to the motors can be achieved easily when installed. They will be protected from water projection through the use of waterproof enclosures or by choice of waterproof designs.

The motors will be defined by the contractor for operational characteristics:

Example parameters:

- Rotation of 10 turns/min (adjustable within 5 / 20 turns/min)
- Platform vertical movement :
  - Operational speed : 12 mm/min (minimum setting to 10 mm/min)
  - Maximum speed : 300 mm/min

These parameters should be discussed and concluded during the design phase.

Cleanroom Installation

Installation in the cleanroom will be undertaken by the contractor in conditions compatible with prompt restoration of the cleanroom functionality, although at this stage it is envisaged that the cleanroom will not be in an operational state. Mechanical interfaces and tooling are to be determined during the design process to allow installation in the best possible conditions. Delivery of this tooling will be part of the contract.

Water piping and connections

All water piping provided by the contractor that is located downstream of the water filter must be rigid and made of 316L stainless steel. No flexible connection will be accepted whether before or after the compressor.

General	
Cavity orientation	Vertical
Media	UPW (18MOhm.cm) filtered < 0.04um Inert gas (N_2, Ar)
Water pressure	95 to 150 bar abs
Water flow	10 – 30 L/min
Gas flow	Adjusted to water flow
Water/gas temperature	> 18 deg C (not more than 60 deg C)
HPR Cabinet	
Materials	UPW compatible plastic (i.e. PP, PE and PVDF) and stainless steel
Spraying cane + nozzles	
Material of head, pipes, fittings etc. for high pressure UPW	UPW compatible stainless steel (max internal surface roughness: Ra < 0.25um - Electro polished)
Material for nozzle	Sapphire
Arrangement and number of nozzles	4-8 nozzles for round jet +/- 15 to 45 deg angles wrt horizontal plane Symmetric arrangement wrt vertical axis
Force and sigma of water jet per nozzle	> 3N with i) s<1.7 mm (iris, R=60 mm) ii) s<3.7mm (equator R=190 mm)
Final UPW filter housing	UPW compatible stainless steel or titanium (max internal surface roughness: Ra < 0.25um - Electro polished)
Inert gas outlet	In spraying head
Motion Unit	
Motion	Independent motion for Z and rotation axis
HPR pump	
Materials	Complete UPW compatible design

Ultra-pure water plant

The UPW system will be provided by a separate contract. Provisions will be made to ensure connection of the HPR system to the high-pressure UPW water system. Interfaces between the UPW system and the HPR system must be e clearly defined stating pipe diameters, pressure and flow rates.

Sump and water drains

The frame and water retention system to be furnished by the contractor will fulfil two functions:

- Avoid water projection into the cleanroom
- Collect water for drainage.

The frame will have a manipulable door. It will give the best possible access to personnel and the required tooling to attach the cavities on the support. The frame will be transparent (but not made of glass). **Note:** The cavity lifter access should not be restricted by the proposed enclosure.

The bottom of the frame will be water-tight and lead to a drainage point (to be specified during design phase). The drains and water tray need to be able to handle 30L/min of water flow and have a tap-off point for water sampling.

Should any part of the frame be in a position where it needs to be load-bearing, it must be able to handle a minimum of 500kg.

The frame and basin must also allow for the lifting aid as mentioned above. Drains must not interfere with the lifting aid design.

Base and Wand attachment

The HPR system must have capability to change wand when required for different cavities or maintenance. The rinsing wand will be firmly attached to the base when in operation to maintain alignment.

The system shall be supplied with a wand designed for the ESS high beta design 704MHz elliptical cavities.

The wand shall consist of:

- an inner pipeline for UPW at up to 30Lpm and 100bar.g
- an outer sleeving shall allow flow of high purity dry N2 at up to 2bar.g at the base
- A removable spray head including a hard non-wearing material forming the nozzle (e.g. sapphire), with spray pattern to be agreed with STFC during design phase. The interface (i.e. metric thread) between the wand and nozzle must be clearly stated.

The interface must allow:

- A watertight connection for the high pressure water system.
- The mechanical support of the rinsing wand bearing in mind the tolerances (+/- 1mm transverse and vertical position of the tip of the wand, which can be up to 1500 mm long).
- Dry N2 flow connection
- Connection of a high pressure pump has to fit to the UPW water system .

These functions will be ensured through independent mechanisms. The fixture needs to be sturdy enough to not vibrate or move due to the water pressure.

Dimensional requirements

The mechanical study to be undertaken by the contractor will define the optimum dimensions to allow the rinsing of all cavities defined. *See figure 4, page 18.*

Constraints to consider include:

- The possible requirement of an external bracing strut.
- Footprint of the unit to be reduced as far as possible. See cleanroom drawing, which include cleanroom dimensions – considerations must be taking into account for the cavity and tooling for manoeuvrability and loading requirements.
- Location of the drains and water supply. Please provide requirements to ensure that provisions can be made prior to start of this installation, i.e. Water feed and drainage location.
- The Cavity cannot come closer than **200 mm** from the ceiling/filtration unit at its peak position.
- When the cavity is in its lowered position, the wand must reach to the top flange of the tallest cavity.
- The height of the water basin must be sufficient to prevent overspill, taking the water flow into account.
- The parallelism of the cavity rotation axis and the vertical displacement axis must be guaranteed to better than 1 part in 1000.
- The HPR unit will fit within the dimensions of the cleanroom designated room. *See schematic on page 21.*

Materials

- UPW water circuits : 316L stainless steel and electro-polished.
- Water drains : PVC

As a general note, all materials chosen must be compatible with ISO4 cleanroom operation, and be resistant to ultra-pure water. Materials with a potential for particulate generation or oxidation will be excluded.

Cleanroom specific requirements

The design will avoid dead spaces in the machine, as well as sharp angles. The object is to facilitate cleaning of the apparatus and avoid dust collection spots.

All mechanical services installation shall comply fully with:

- ISO standards including ISO14644 for cleanrooms
- CIBSE Guidelines – Chartered Institution of Building Service Engineers
- GMP Guidelines – Good Manufacturing Practice

Electrical Installation Works

All electrical works for the HPR, Cleanroom (sockets, lighting, Ethernet) and Plant are the responsibility of the tender. STFC will provide main feeds where appropriate and should be indicated on the tender. All electrical installation work must comply to the BS 7671: 2008+A3:2015 the 17th edition.

The installation schedule must be submitted one calendar month before commencement including all technical drawings.

All staff employed to undertake electrical work must be experienced, qualified and trained to a recognised national standard such as ECA, ECS ELECSA or NICEIC.

Before any electrical work commences on the STFC Daresbury Laboratory site all qualification and training certificates must be submitted to the Daresbury Laboratory appointed electrical engineer, as proof of competency.

Full drawings detailing the installation as well as safety documentation including risk assessments and method statements must also be submitted for approval by the appointed electrical engineer before work can commence.
Daresbury Laboratory will provide a local isolator near to the installation area. The system will only be energised after the electrical installation has been inspected and approved by the Daresbury Laboratory appointed electrical engineer.

All electrical systems must be certified to an approved electrical standard such as NICEIC. All certificates must be issued in both hard copy and electronic format.
Note: All equipment for this tender shall be CE marked.

Cavity Tooling: Interface HPR to Cavity

Image 1. Example of an undressed cavity hung and aligned with tooling, allowing the cavity to be rotated from above.

Image 2. Example of a dressed 704 MHz cavity with tooling.

Note: The tooling above is shown as an example. The tooling interface between the HPR and Cavity is to be discussed and concluded at the design phase.

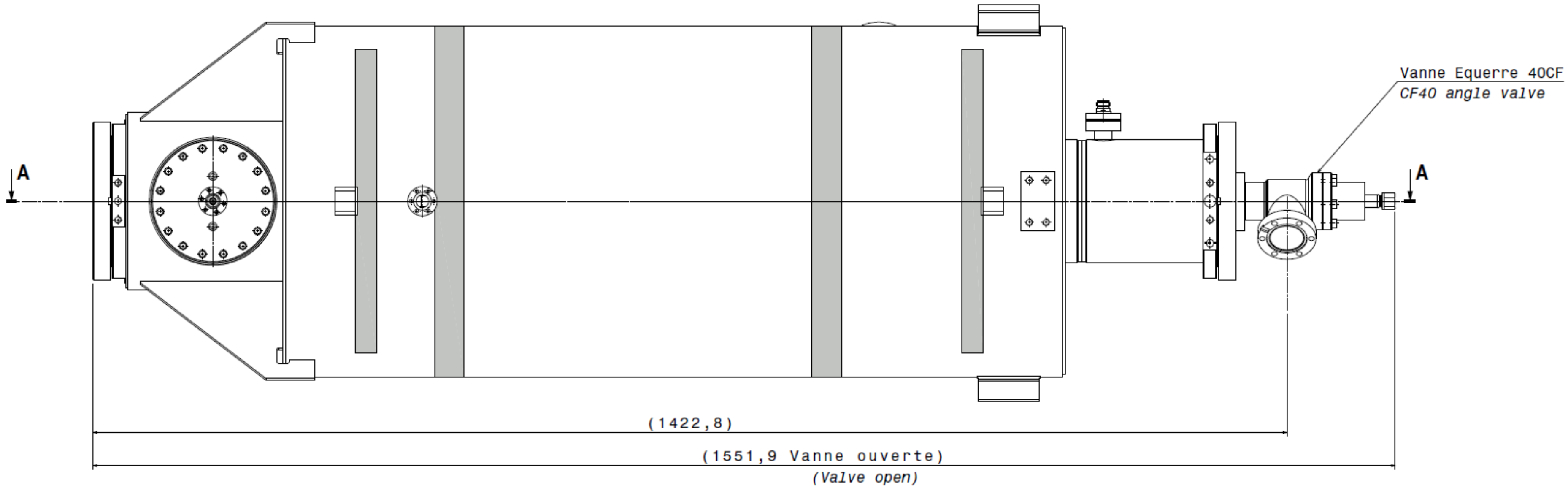


Figure 4 : View of the 'dressed' cavity with flanges and vacuum valve attached.

Note: For the HPR process the end flanges and Vacuum valve will be removed.

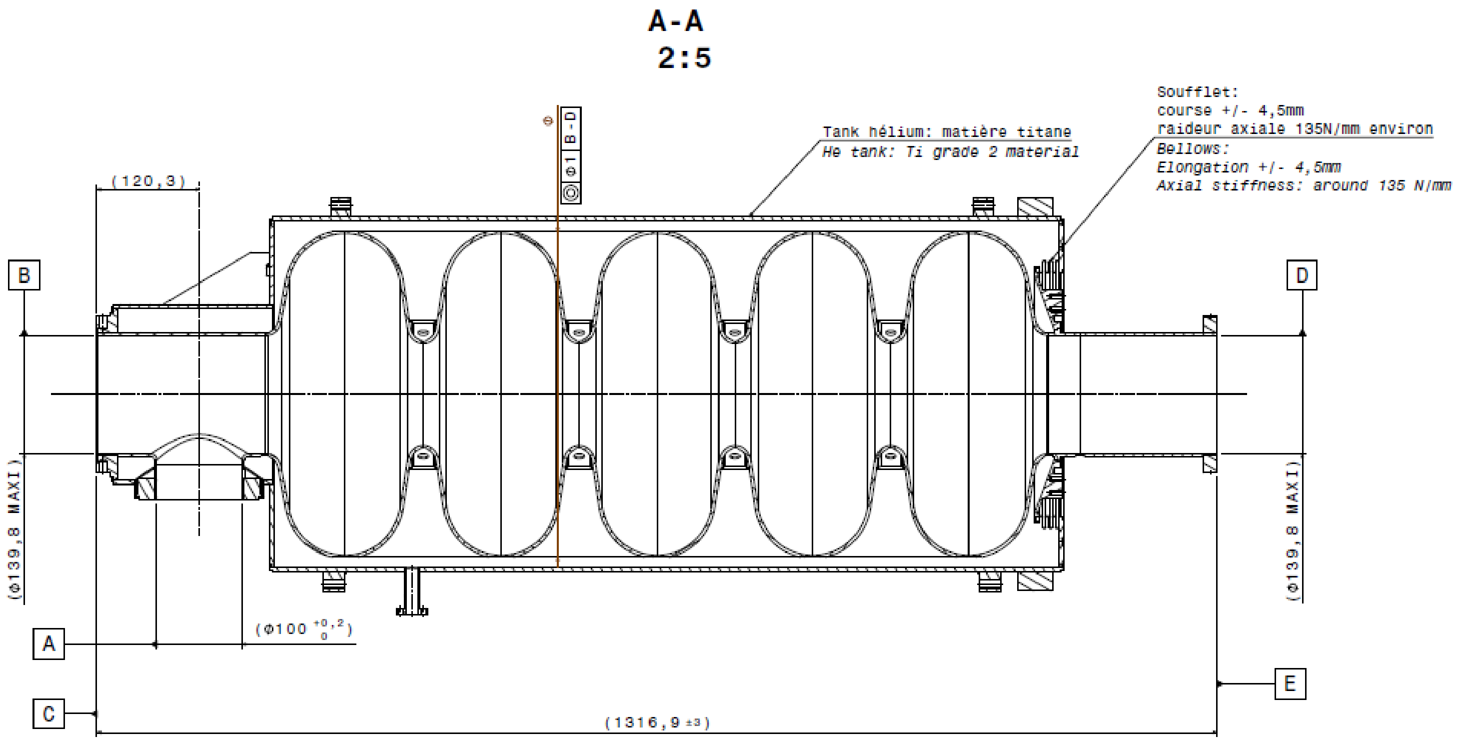


Figure 5: Highlighting the internal section of the cavity – with end flanges removed.

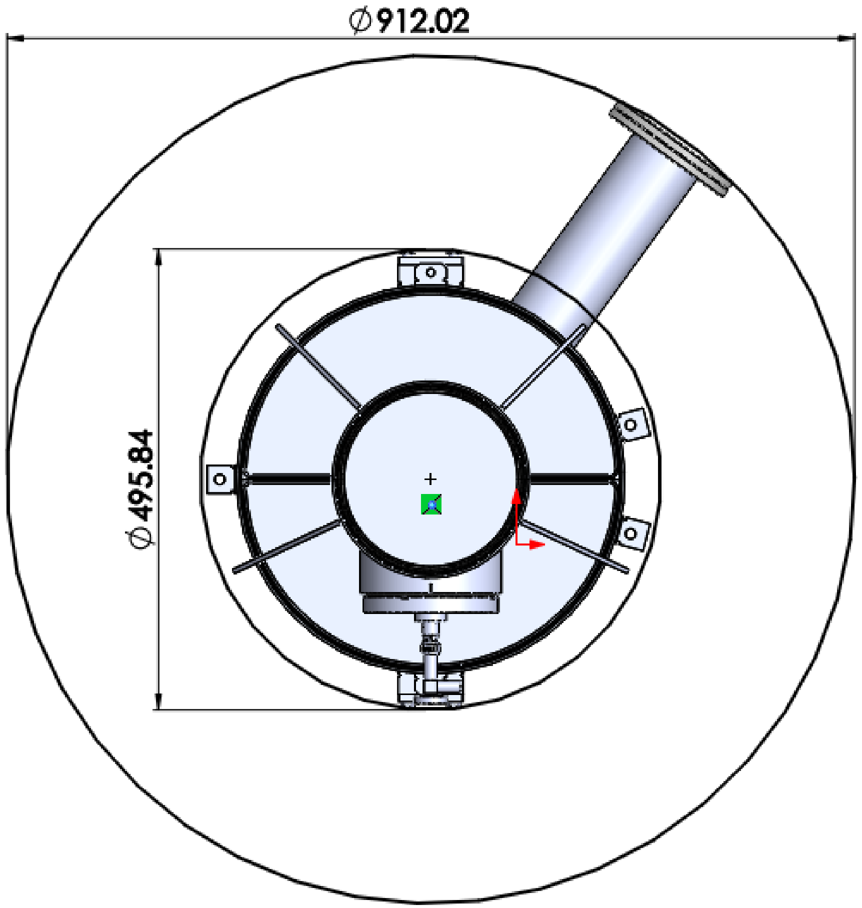


Figure 6: End elevation view of the cavity to highlight the 'rotating' diameter requirements (including the He pipe).

Proposed Cleanroom Layout

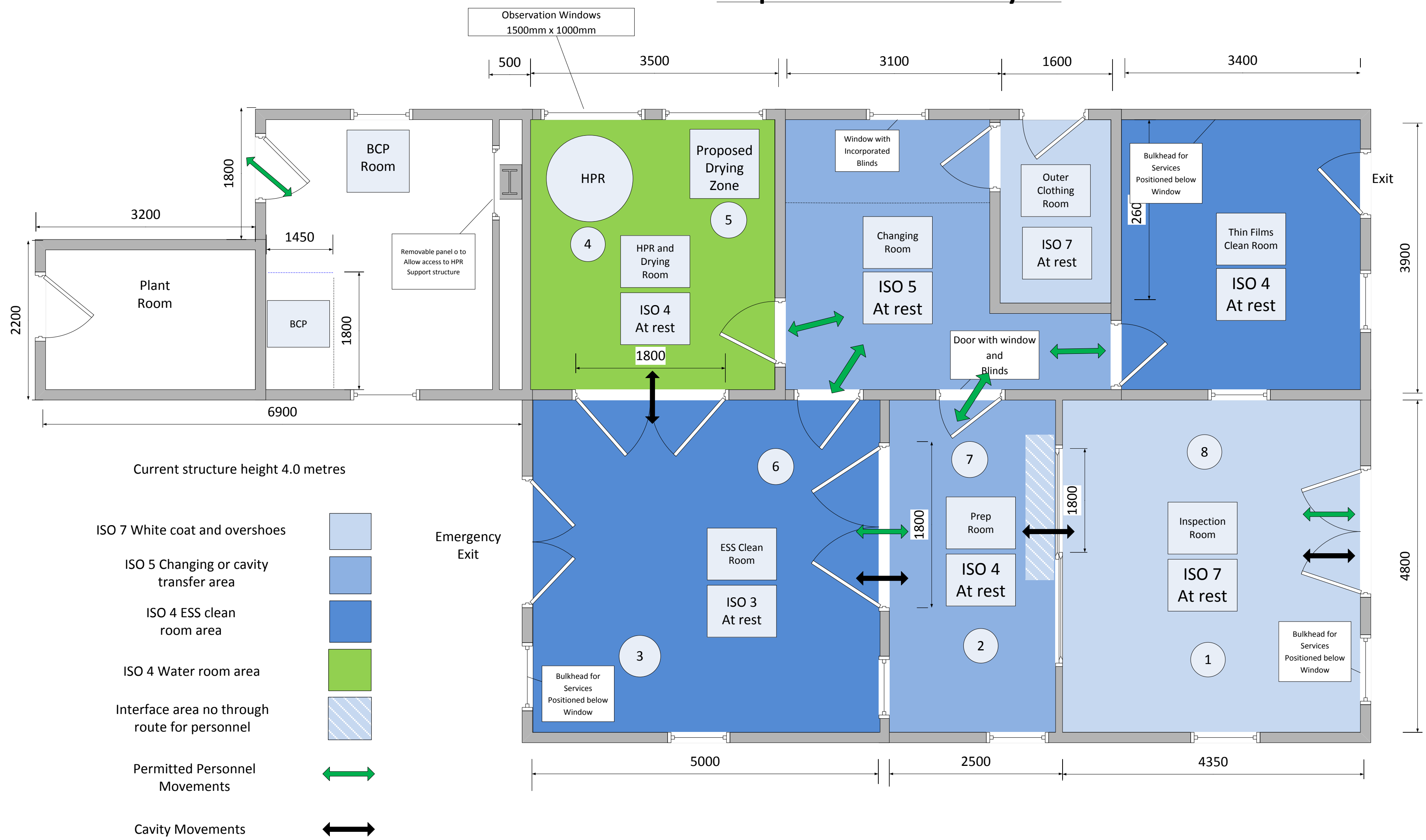


Figure 7. Proposed Cleanroom layout.

Floor plan of the D Block Area.

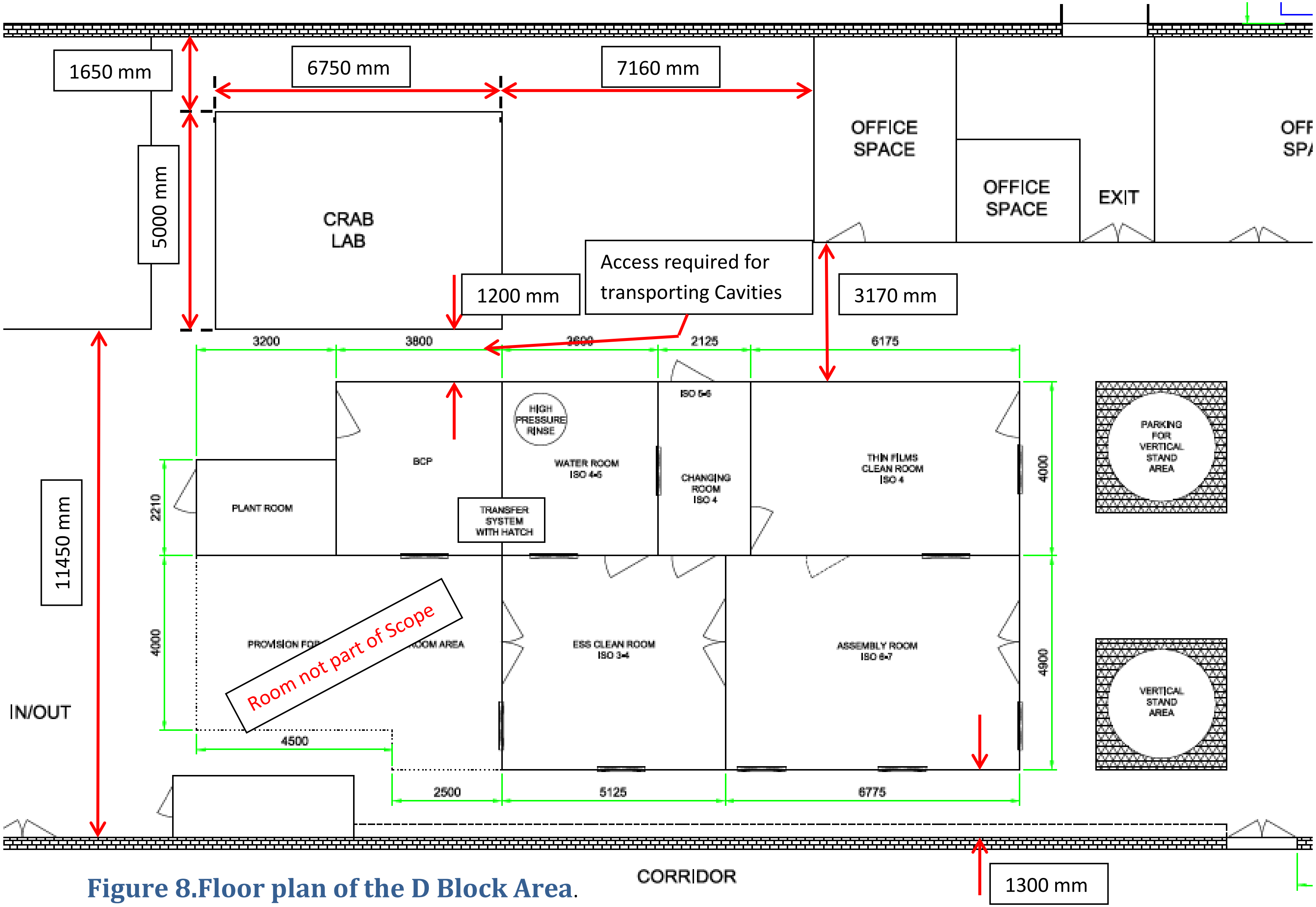


Figure 8.Floor plan of the D Block Area.
(Approximate Dimensions in mm).