ESS Monolith Vacuum Handbook

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Presentation Outline

- Monolith Operational Modes, Operating Pressure and Design Leak Rates
- Description of the Monolith Vacuum System
- Monolith P&ID Vacuum Operation
- Performance of the Monolith Vacuum System
- Modifications to the Accelerator
- Progressive Installation and Test Strategy
- Monolith Vacuum Handbook
- Provision of Vacuum Test Facilities
- Monolith Vacuum System Costs

Monolith Operational Modes

- The monolith vessel will be designed to operate either under a helium atmosphere, nominally 1 bar, or under high vacuum 10^{-5} mbar . The monolith is directly connected to the accelerator beam-line that operates under ultra high vacuum conditions.
- With the monolith under helium the two environments are physically separated by the proton beam window (PBW) and when in the vacuum mode, with the PBW removed, the two vacuum environments will be directly connected.

Monolith Operating Pressure from a Vacuum Prospective

- Standard of-the-shelve vacuum equipment is designed for use ≤1 bar differential pressure and will not meet the Swedish ordinance AFS 2005:2 at higher differential pressures.
- If a higher monolith pressure were selected standard off-the-shelf vacuum equipment would not be available and equipment would need to be qualified as "pressure equipment" i.e. designed and qualified to meet a higher pressure >1 bar differential.

Ex: viewports and feedthroughs for electrical signals as per ESS-0032631 ICD-R MS-PBI

Design Pressure

- “Requirements and Guidelines” specified in the “Target Vacuum Design Handbook” are based on the assumption that the nominal operating pressure of the monolith vessel will be limited to 1 bar differential and the maximum upset pressure will be limited 1.5 bar absolute differential pressure in accordance with the Swedish ordinance.

Monolith Design Leak Rate

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- When operating in a helium atmosphere at 1 bar the design leak rates are as follows:
  - The water removal system is designed to remove 10.8 g/hour of water due to leaks from the water cooling circuits.
  - The helium purification system is designed to remove 0.13 mg/hour of impurities due to air leaks
- The vacuum system will be designed to operate at the **above leak rates** removing water and air leaks, replacing the need for the water removal and helium purification systems during vacuum operation. The design leak rates to be met are:
  - Pumping speed for water at high vacuum -> 3.1 mbar l/s
  - Pumping speed for air leaks at high vacuum -> 4.7e-5 mbar l/s

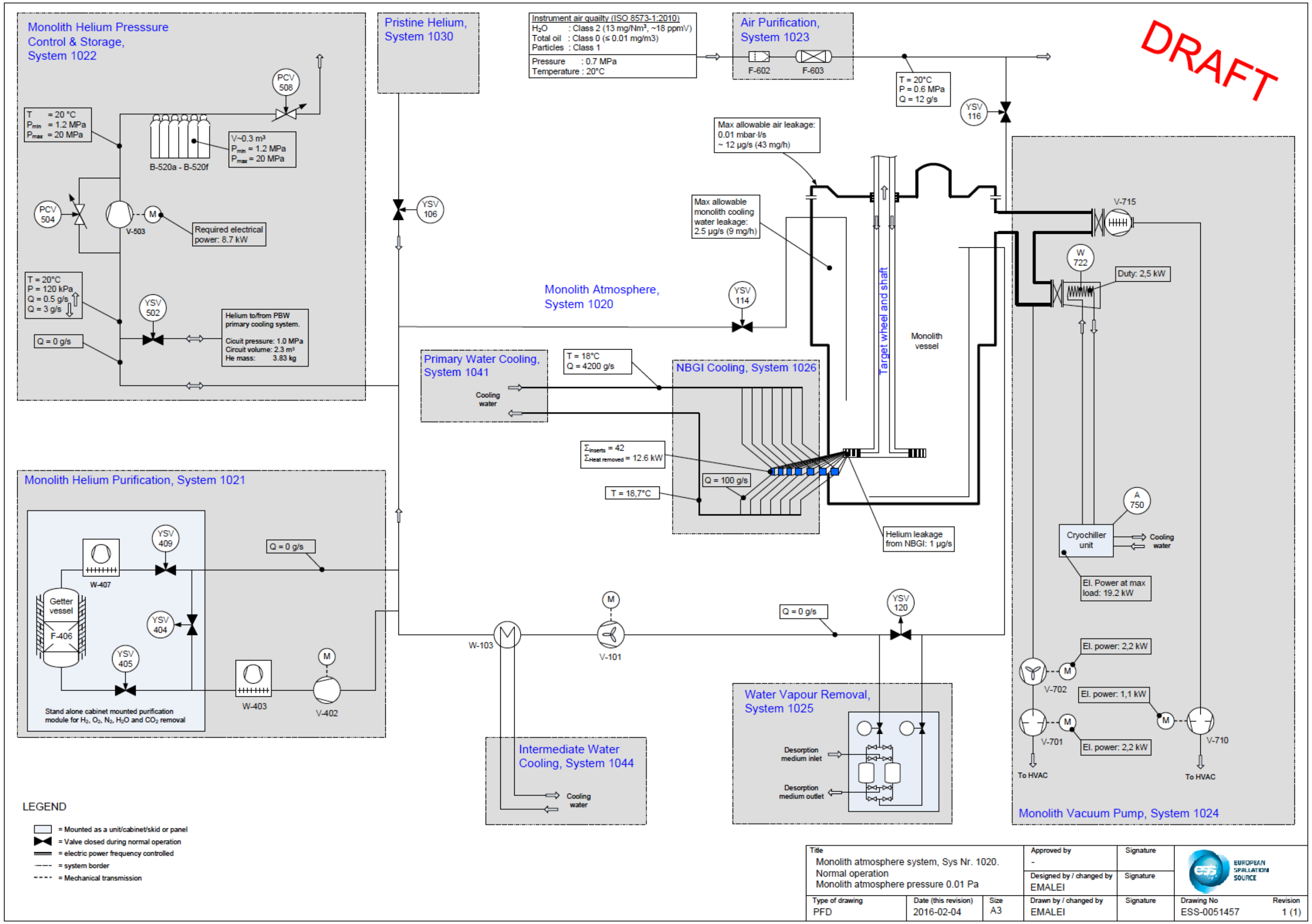
Description of the Monolith Vacuum System

- The monolith vacuum system is designed to:
  - Achieve a pressure at the monolith <–> accelerator interface (PBW location) with the PBW removed so that accelerator operation is not compromised.
  - Provide sufficient pumping speed and capacity to remove leak rates due to:
    - water -> 3.1 mbar l/s
    - air leaks -> 4.7e-5 mbar l/s
  - Locate equipment as remote as possible to minimize exposure to radiation for equipment and personnel during maintenance activities
  - Maximise the time between routine maintenance periods

Description of the Monolith Vacuum System, Continued

- The vacuum system comprises:
  - a roughing system comprising pump/ blower combination with associated valves and gauging
  - cryo-condensing coil for pumping water vapour
  - High vacuum system comprising TMP backed by mechanical pump with associated valves and gauging
- The roughing system roughs the monolith to cross over to the high vacuum system, cryo-condensing system runs continuously to pump water vapour.
- The TMP backed by a leak detector is available for leak detection of the monolith and in-vessel components and subsystems

Monolith P&ID Vacuum Operation



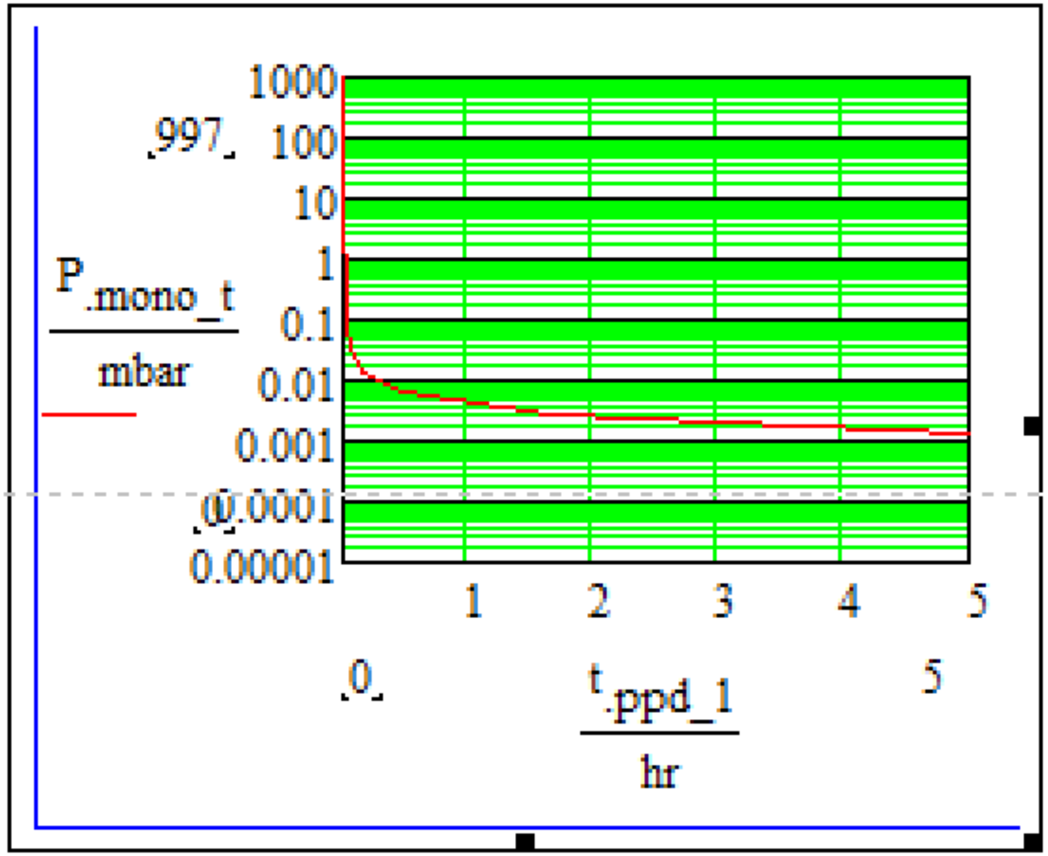
Performance of the Monolith Vacuum System

- The pump-down performance of the monolith based on a preliminary model for the monolith structure and with the design leak rates previously noted and an outgassing rate of 10^{-5} mbar*L/s-cm^2.
- Pumping system comprises:

  i. Mechanical pump with roots blower: 440 m^3/ hr

  ii. TMP: 1000 L/s

  iii. Cryo-coil for water pumping



Modifications to the Accelerator

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- These modifications will be implemented upstream of the neutron shield wall to allow routine maintenance to be conducted.
- An increase in pumping capacity will need be provided due to the higher gas load resulting from the higher operating pressure that will be experienced due to the higher operating pressure in the monolith. Detailed vacuum analysis will need to be conducted once the vacuum design of the monolith has been finalized.
- It is anticipated that increasing the size or number of ion pumps to increase the available gas load capacity will be sufficient, if not, then turbo-molecular pumps, not constrained by capacity limitations, will be used.
- In addition, a fast acting and a safety isolation valves will be installed to provide protection to the accelerator in case of an off normal event occurring in the monolith.

Progressive Installation and Test Strategy

- In order to minimize risk from a vacuum prospective, a progressive installation and test strategy will need to be adopted.
- This will require components to be leak tested at there lowest level progressing through the leak testing of subassemblies etc.
- Specific leak test plans will need to be developed that reflect the installation sequence at ESS site and the completeness of the installation.

ESS Monolith Vacuum Handbook

Major topics addressed:

- Introduction
- Responsibilities
- Vacuum Design
  - Vacuum Design Considerations
  - Boundary conditions
  - Material Selection
  - Analysis to Support the Design
  - Areas Requiring Special Attention During the Design
  - Vacuum Notes on Fabrication Drawings
- Fabrication
  - General
  - Machining
  - Welding and Brazing
  - Cleaning
  - Handling & transport
- Installation
- Vacuum Inspection and Leak Testing
  - Visual inspection
  - Vacuum Leak Tests

ESS Monolith Vacuum System Costs

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Schedule used for cost planning

- The schedule used for costing does not have any influence on the total estimated costs but only their time distribution which is assumed to extend from the start of 2016 through the end of 2018.
- The costing is broken into 5 distinct phases of work:
  - Design
  - Fabrication and fabrication support
  - Installation support
  - Assembly and integration support
  - Final leak tests and vacuum acceptance tests
  - In addition the Pre FY2016 vacuum activities and general support activities including provision of vacuum test facilities.

Provision of Vacuum Test Facilities

Procurement of Vacuum Test Facilities with costs prorated to Target Division:

- Material testing 5% - to support the selection and approval of materials used in a vacuum environment in accordance with the requirements of the ESS Vacuum Design Handbook
- Gauge calibration 5% - to confirm the operation and calibration of all vacuum gauges prior to installation
- Vacuum integration facility 5% - provides the seamless integration of all vacuum systems used on the accelerator, target and neutron instruments with the ICS (ESS Integrated Control System).

Material Test Facility

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– Design to support the selection and approval of materials used in a vacuum environment not listed in ESS Vacuum Design Handbook (VDH) where materials that have characteristics compatible with vacuum are listed.

– The selection of vacuum compatible cabling, to minimize the contamination of vacuum space resulting from outgassing of hydrocarbons from the plasticizers inherent in cable insulation will be made using this facility. The selection process will also include a quality control aspect requiring the batch-to-batch monitoring of materials for potential change as a result of the manufacturing process.

– Surface finishes and coatings are another area that can have an adverse effect on vacuum performance and will need to be qualified for use within the monolith.

Gauge Calibration Facility

- The GCF will be used to confirm the operation and calibration of all vacuum gauges prior to installation with calibration performed against a secondary standard. All vacuum gauges installed on the accelerator, target and neutron instruments will use this facility. Gauge accuracy is important since gauge readings will be used for set point control and the interlocking and sequencing of vacuum system operations.

Vacuum Integration Test Facility

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- This facility will provide the capability for the seamless integration of all vacuum systems used on the accelerator, target and neutron instruments with the ICS (ESS Integrated Control System). This will allow control logic to be developed and interlocks checked before implementation on the actual systems for which they are designed. EPICS control screens will also be developed together with data acquisition functions.
- The VITF comprises a vacuum vessel that with the installation of vacuum pumps, valves, gauging and any other vacuum equipment will be used to replicate any vacuum subsystem or system used in the accelerator, target or for neutron instruments. While the equipment will be physically different (in most cases smaller) it will operate the same manner to allow development of the vacuum to ICS interface.

Breakdown of Costs

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Engineering Hours	Design Hours	Technician Hours	Travel kEuro	Materials kEuro	Total kEuro	%
Pre FY2016 vacuum activities						
200	0	0	0	35.0	48.9	6.5
General tasks						
850*	0	320	0	4.0	79.3	10.6
Design						
1200	80		10	-	95.0	12.7
Fabrication and fabrication support						
520	-	320	22.5	-	71.3	9.6
Installation support						
200	-	1200	-	5.0	69.0	9.2
Assembly and integration support						
240	-	840		1.0	52.6	7.0
Final leak tests and vacuum acceptance tests						
140	-	560	-	2.0	35.0	4.7
Vacuum Hardware						
-	-	-	-	220.5	220.5	29.5
Modification to accelerator						
120	120	160	-	35.0	74.9	10.0
Total Project						
3,470	200	3,400	32.5	322.8	746.49	100

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Back-up Slides

Vacuum System Cost Elements

- **Pre FY2016 Vacuum Activities**
  - This covers the cost of work completed pre FY2016 and that required to establish the practicality of a vacuum monolith design and establish the performance that would not compromise the vacuum performance of the accelerator.
  - Procurement of Vacuum Test Facilities with costs prorated to Target Division:
    - Material testing 5% - to support the selection and approval of materials used in a vacuum environment in accordance with the requirements of the ESS Vacuum Design Handbook
    - Gauge calibration 5% - to confirm the operation and calibration of all vacuum gauges prior to installation
    - Vacuum integration facility 5% - provides the seamless integration of all vacuum systems used on the accelerator, target and neutron instruments with the ICS (ESS Integrated Control System).

- **General tasks**
  - Includes the management and administration of vacuum activities on the project and the use of the Vacuum Test Facilities

Vacuum System Cost Elements, Cont'ed

- **Design**
  - This activity will include the following major elements:
  - Preparation of the "Target Vacuum Design Manual"
    - This replaces the "ESS Vacuum Handbook" specifically addresses issues related to the target monolith, internal components and associated components.
  - Vacuum Design, Analysis and Test
    - This element develops the vacuum design, the analysis to support the design and completes the mechanical design of the vacuum installation.
    - Develops, specific test methods applicable to the monolith design developed.
  - Developing progressive installation and test plan
    - Develop the progressive installation and test plan for the monolith, internal components in conjunction with the Target Division. This is considered to be critical element in developing the assembly and test sequence that needs to be implemented in the overall design of the target monolith, internal components and associated components.
  - Provides a review of the overall design of the monolith, internal components and associated components from a vacuum prospective to ensure compliance with vacuum requirements including:
    - Review of manufacturing drawings,
    - Review of manufacturing procedures, and
    - Review of test procedures.

Vacuum System Cost Elements, Cont’ed

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- **Fabrication and Fabrication Support**
  - Provides support during the pre award and subsequent award phase of the monolith contract:
    - Reviewing vacuum requirements with potential suppliers of the monolith and internal components.
    - Providing support to the selected supplier of the monolith and internal components on vacuum requirements including conducting of vacuum training at the supplier's facility.
  - Conducing visual inspection for "vacuum" parts, especially welding and the witnessing of leak testing at the supplier's facility.
- **Installation Support**
  - Installation support primarily directed towards providing advice and assisting in leak testing of the monolith vessel during its assembly, installation on and final on site welding.

Vacuum System Cost Elements, Cont'ed

- **Assembly and Integration Support**
  - Assembly and integration support will be primarily directed towards leak testing of the monolith vessel and internally mounted components that will be needed during the progressive assembly to ensure an efficient and cost effective installation. From experience it is known that if this activity is not carried out effectively, searching for unlocatable leak will be like looking for a needle in a haystack! and that will potentially impact the overall schedule.
  - In addition, this activity will include the installation of vacuum equipment, electrical hook-up vacuum equipment and vacuum controls check out.
- **Final leak tests and vacuum acceptance tests**
  - This activity will include final leak testing of the monolith installation including vacuum system installation, vacuum equipment start up and performing vacuum systems acceptance tests.