Crab Cavity Manufacturing Readiness Meeting

CERN, Switzerland, 1-2 October 2014

CERN Engineering Specification

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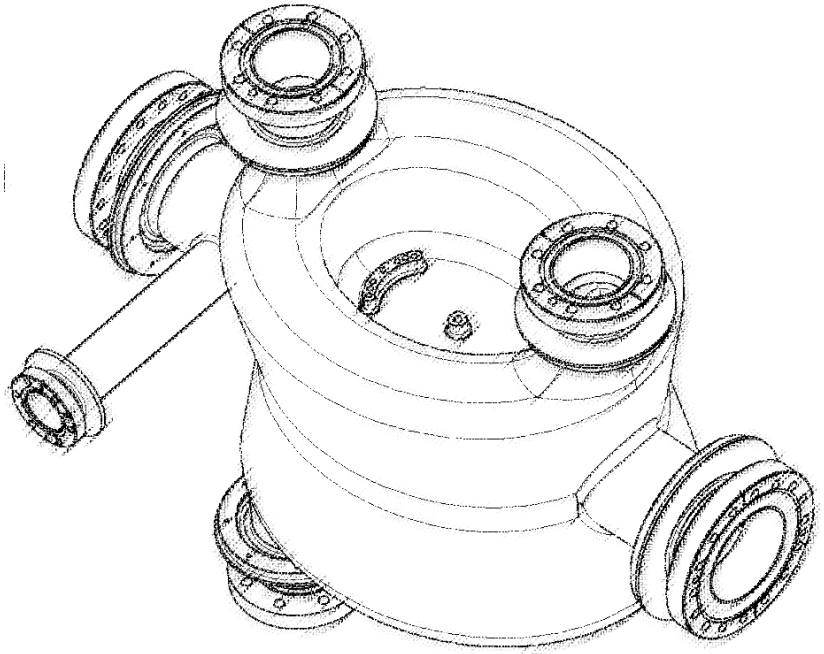
25' Talk + discussion

ENGINEERING DEPARTMENT

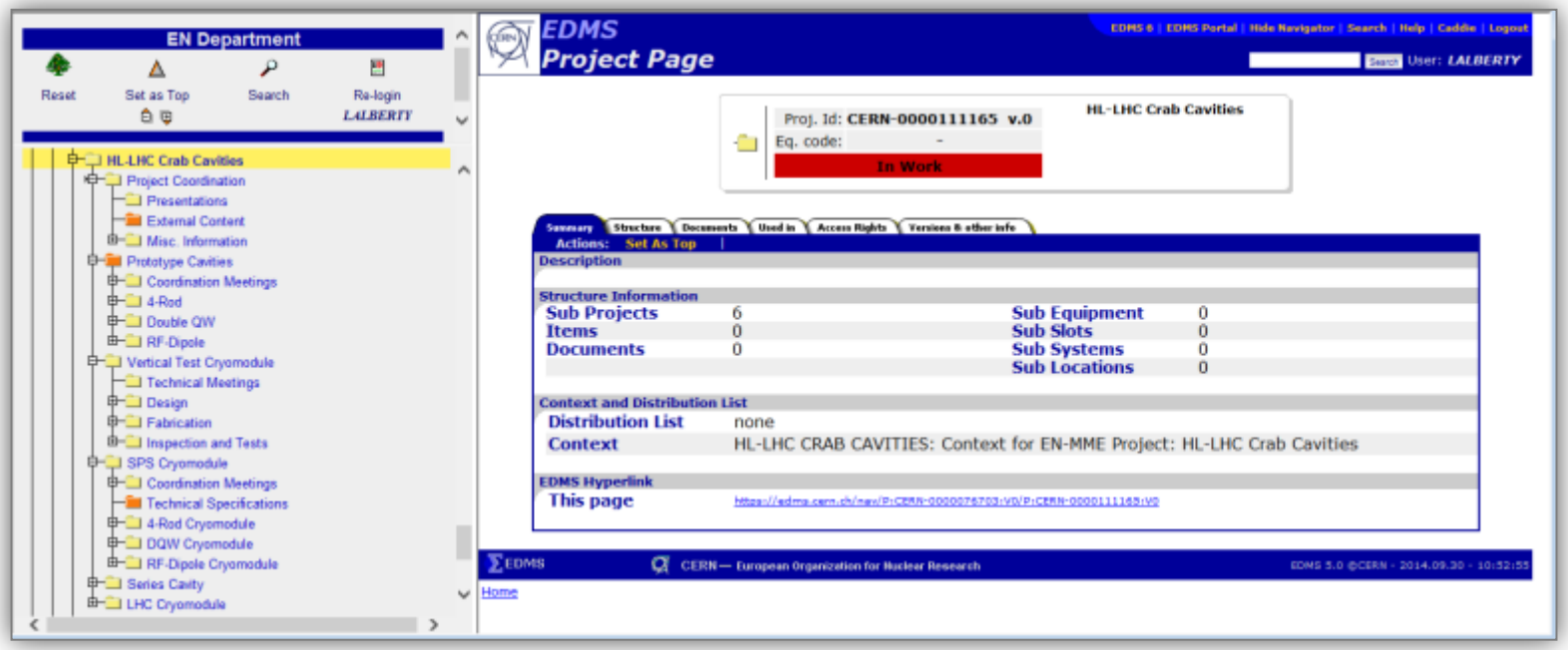
Summary

- Engineering documentation: EDMS guided tour
- CERN's Engineering Specification:
  - Scope
  - Approach
  - Structure & system architecture
  - Processes
  - Steps
  - Content - bare cavities with interfaces:
    - Materials
    - Operational modes and states
    - Interfaces
    - Design
    - Qualifications prior to manufacturing
    - Manufacturing
    - Finalization of manufacturing process
    - Verification
- Conclusions and future work



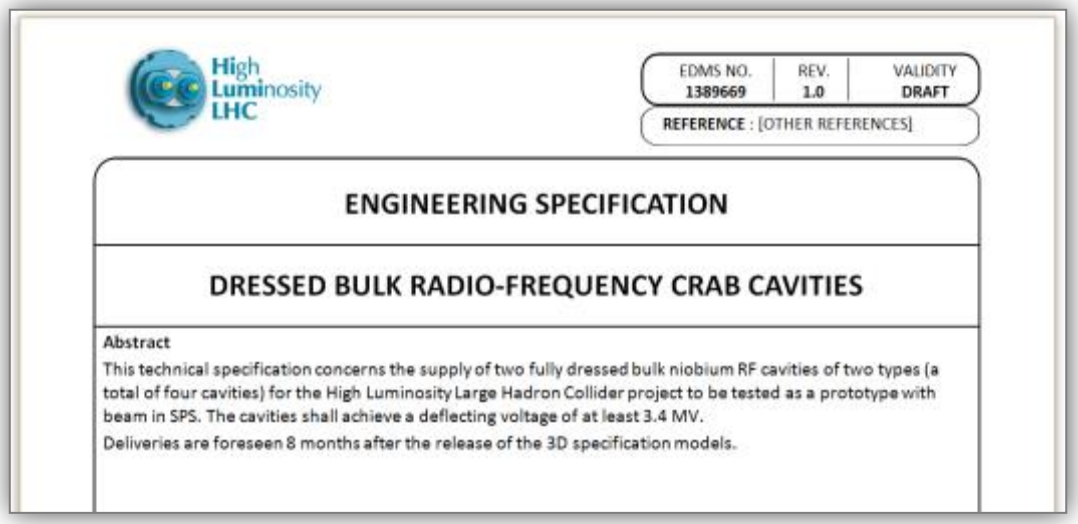
Engineering documentation: EDMS guided tour

EN-MME/CC Engineering Structure in EDMS:



(https://edms.cern.ch/nav/P:CERN-0000076703:V0/P:CERN-0000111165:V0)

CERN Engineering Specification: scope



High Luminosity LHC

EDMS NO.	REV.	VALIDITY
1389669	1.0	DRAFT

REFERENCE : [OTHER REFERENCES]

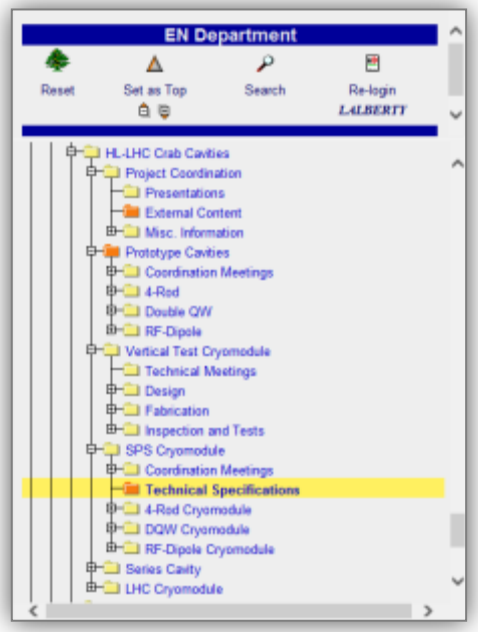
ENGINEERING SPECIFICATION

DRESSED BULK RADIO-FREQUENCY CRAB CAVITIES

Abstract

This technical specification concerns the supply of two fully dressed bulk niobium RF cavities of two types (a total of four cavities) for the High Luminosity Large Hadron Collider project to be tested as a prototype with beam in SPS. The cavities shall achieve a deflecting voltage of at least 3.4 MV.

Deliveries are foreseen 8 months after the release of the 3D specification models.



- Where to find it:

  https://edms.cern.ch/document/1389669/1

- Scope: SPS tests / dressed bulk Radio-Frequency Crab Cavities

  2 x 2 types to be tested as prototypes

CERN Engineering Specification: approach

- The approach to the specification is based on*:

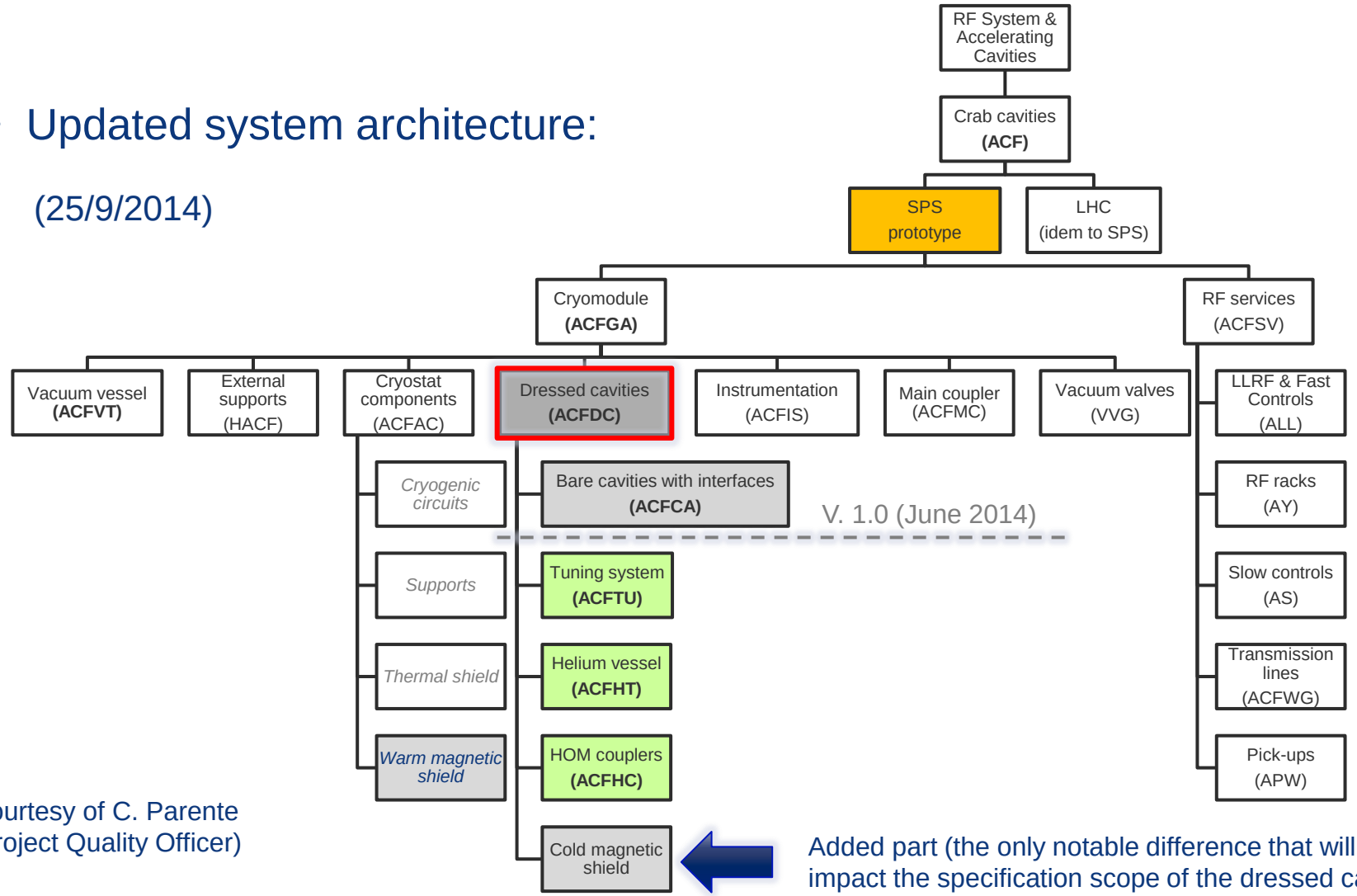
1. Definition of the system architecture, in order to allow clearly identifying the entities to which the specification is addressed;
2. Identification of the processes through which each entity is obtained;
3. Specification of the requirements and verification measures entity by entity, in a bottom-up sense.

**This process was carried out with the support of the Project Quality Office*

CERN Engineering Specification: system

- Updated system architecture:

(25/9/2014)



Courtesy of C. Parente
(Project Quality Officer)

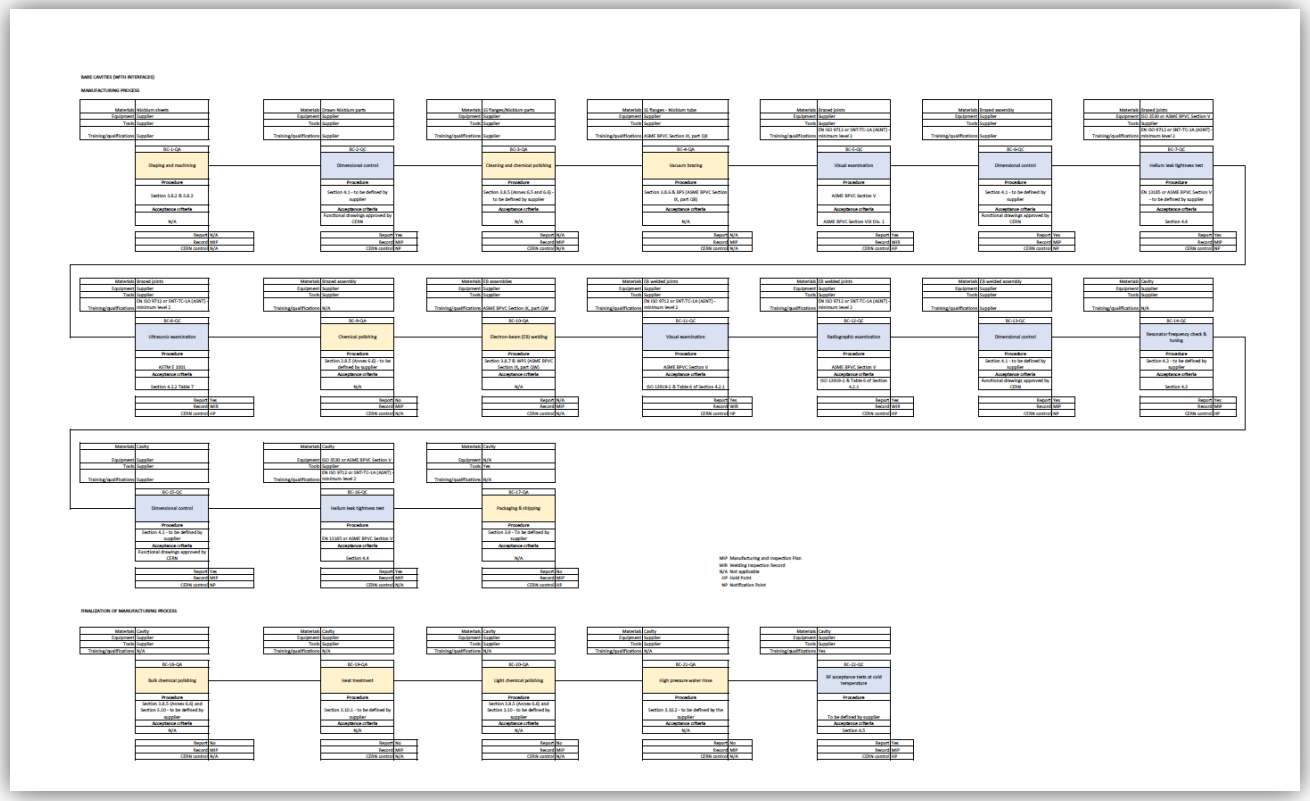
Added part (the only notable difference that will impact the specification scope of the dressed cavities)

CERN Engineering Specification: processes

- The main processes through which each entity is obtained are the following:
  - Design;
  - Qualifications prior to manufacturing (materials, procedures);
  - Manufacturing & assembly;
  - Final Inspection and acceptance tests;
  - Shipping.
- Technical requirements and verification measures were defined for each specific process, for a given entity.

CERN Engineering Specification: steps

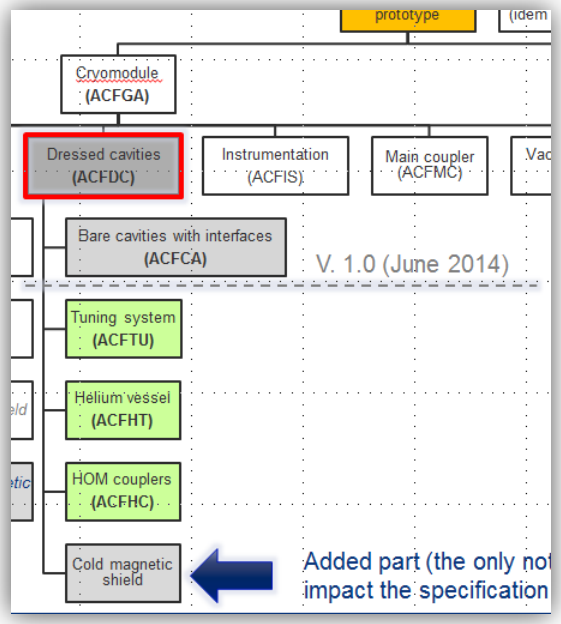
- Key processes known in advance can be specified by steps:



CERN Engineering Specification: content

- The following **entities** and key **processes** are covered by the first version of the Engineering Specification:

  - **Bare cavities** (with interfaces)
    - Technical requirements
      - Materials
      - Operational modes and states
      - Interfaces
      - Design
      - Qualifications prior to manufacturing
      - Manufacturing
      - Finalization of manufacturing process
    - Verification of the bare cavities (with interfaces)
      - Dimensional controls
      - NDT of welded joints
      - Frequency check and tuning
      - Helium leak tightness



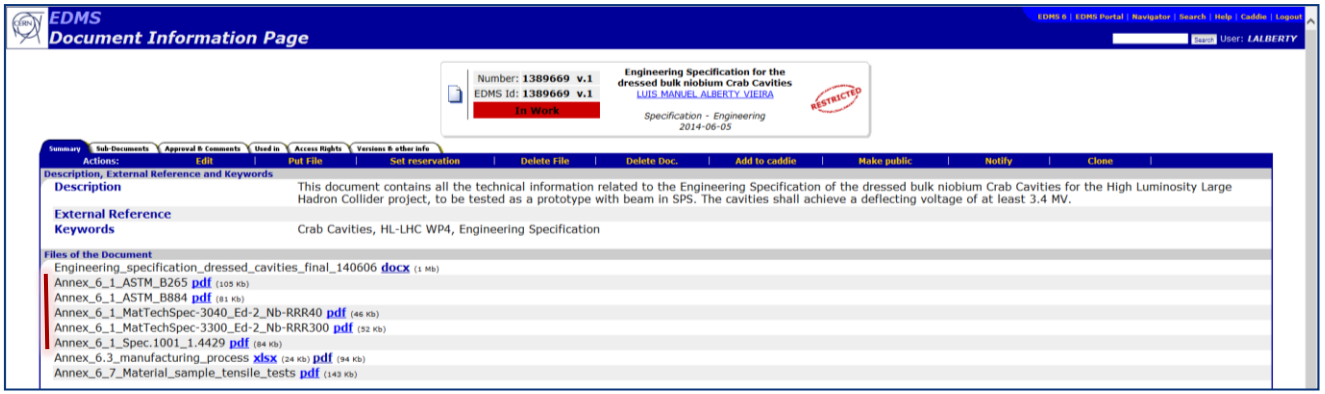
Bare cavities with interfaces: materials

- The following materials are specified (§3.2):

Table 1: Materials specifications

Components	Material	Applicable documents
Flanges	Stainless Steel	Material Technical Specification N°1001
	Niobium-titanium	~~ASTM B884 – 11~~ ***Replaced by MTS nº 4455 (XFEL/008)***
Bare cavity – body	RRR=300 Niobium	Material Technical Specification N° 3300
Bare cavity - reinforcements	RRR=40 Niobium	Material Technical Specification N° 3040
Helium vessel	Grade 2 Titanium	ASTM B265-13a

- Detailed information is given by annex 6.1:



Bare cavities with interfaces: OM & States

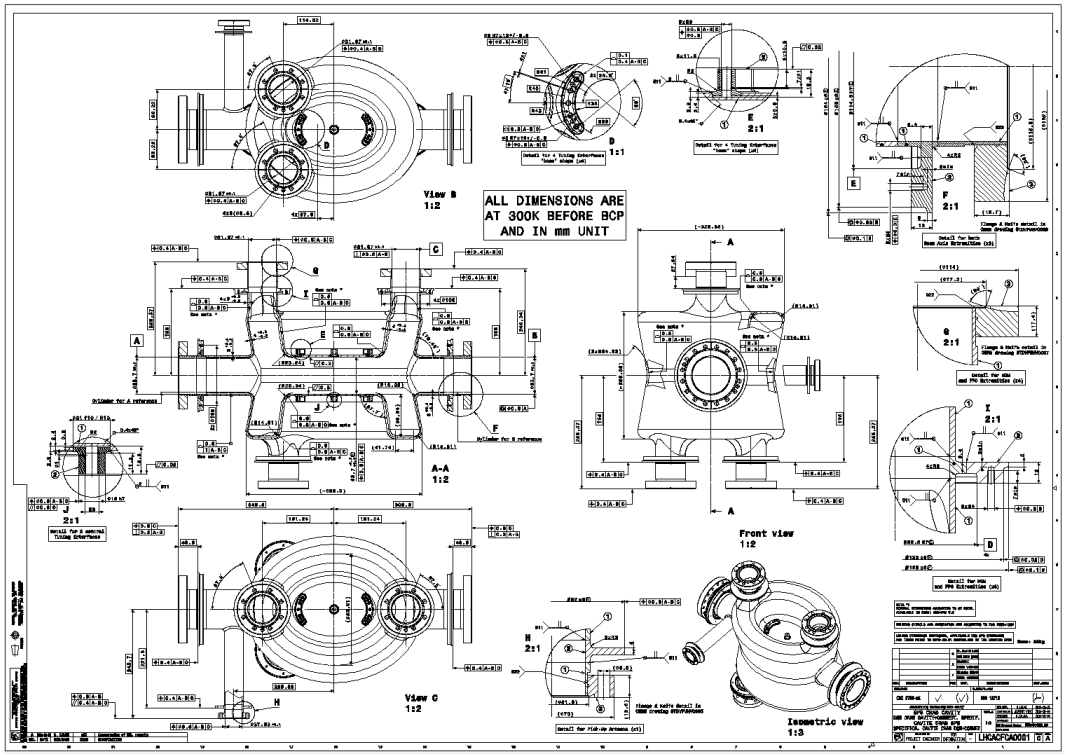
- Three different states of pressure and temperature are foreseen (§3.4):

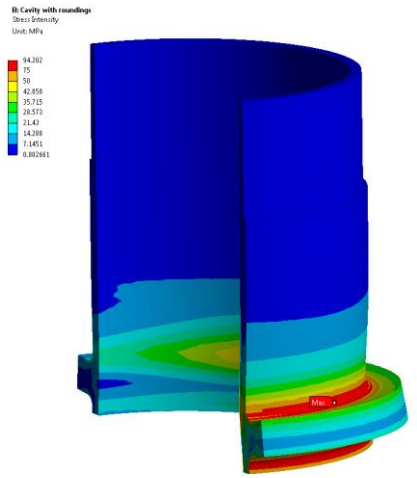
Table 1: Load cases for the design of the bare cavities

Load cases		Internal pressure [MPa-absolute]	External pressure [MPa-absolute]	Temperature [K]	Classification (for selection of safety factors) ASME BPVC
Nominal conditions	Fluid process volumes	20×10^{-4}	Vacuum (0)	2	Sustained (SF= 1.5)
	Vacuum volume	Vacuum (0)	0.1013	293	
	UHV volume (bare-cavities)	Vacuum (0)	20×10^{-4}	2	
Design Conditions	Fluid process volumes	0.18	Vacuum (0)	293	Sustained (SF=1.5)
	Vacuum volume	Vacuum (0)	0.1013	293	
	UHV volume (bare-cavities)	Vacuum (0)	0.18	293	
Test conditions	Fluid process volumes	0.26 (1.43 x 0.18)	Vacuum (0)	293	Occasional (SF=1.05)
	Vacuum volume	Vacuum (0)	0.1013	293	
	UHV volume (bare-cavities)	Vacuum (0)	0.26 (1.43 x 0.18)	293	

Bare cavities with interfaces: interfaces

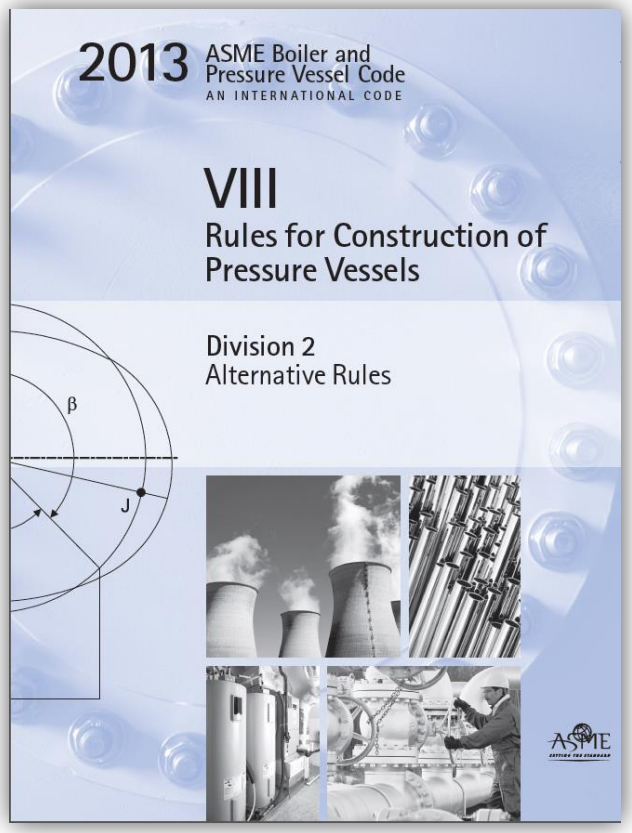
- The requirements for interfaces (mainly dedicated flanges) are presented on issued drawings (§3.5):





Bare cavities with interfaces: design

- § 3.6.1 - Design is to be done according to ASME BPVC Section VIII Div. 2 (alternative rules);
- A mechanical design report shall be submitted to CERN for approval;



Bare cavities with interfaces: qualifications

- Prior to manufacturing (§ 3.7) :
  - Functional and manufacturing drawings (including welds);
  - Manufacturing and inspection plan (MIP);
  - Mechanical assessment of welds (design reports);
  - Detailed welding plan, including amongst other:
    - Welding quality documents (WPQR, BPQR, WPS, BPS, …)
  - Material qualifications (next slide);
  - other…

Bare cavities with interfaces: qualifications

- Material qualifications summary:

Material	Shape	Requirements
Nb RRR=300	Flat	Mechanical tests, UT & RRR measurements for every batch CERN requires 3 test samples of each direction Material shall conform to R04220-Type 5 | ASTM B393-09e1 + AC Additional Criteria include minimum mechanical properties at RT
Nb RRR=40	Flat	Same as for Nb RRR=300, but R04220-Type 1 | ASTM B393-09e1
Nb55Ti	All	CERN requires 3 test samples of each direction Shall conform to MTS nº4455 (similar to XFEL/008) Additional tests will be required (metallographic, EDS)
Stainless steel	All	Supplied by CERN. Certification can be provided upon request

Bare cavities with interfaces: qualifications

- Joining techniques qualification - summary:

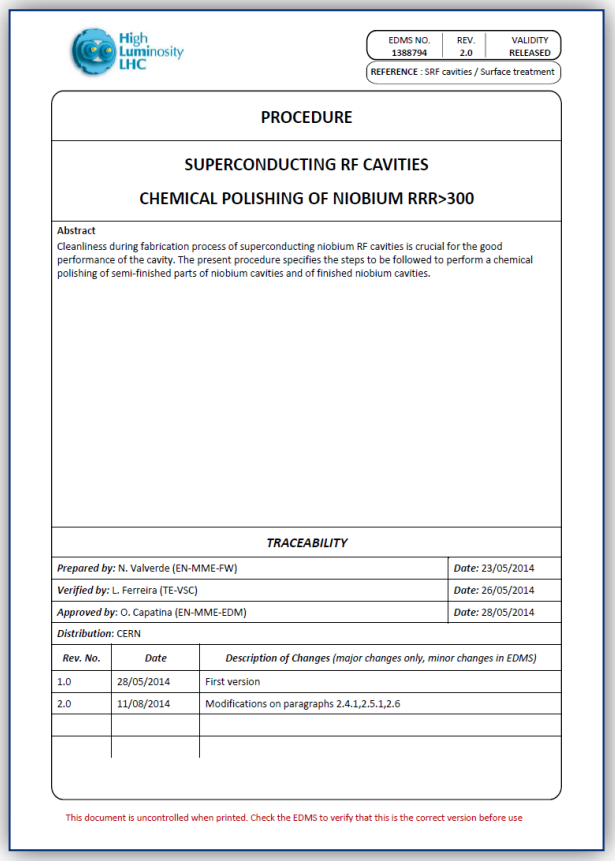
Joining tec.	Joints	Requirements
EBW	Nb/Nb	Full penetration only, groove welds 100% VT, 100% X-rays for longitudinal and T seams, 25% circular Ability to weld without RRR degradation of more than 10% shall be demonstrated RRR test specimens: 3x (2x2x100 mm) from the MZ WPQR: ASME BPVC Section IX Part – QW: All welds to be qualified individually, CERN requires ~~3~~ 1 sample Test extent: 2 tensile + 2 face bend + 2 root bend
	Nb/NbTi	Full penetration only, groove welds. WPQR requirements similar to Nb/Nb 100% VT, 100% X-rays for longitudinal and T seams, 25% circular Remark: T-like joint design shall be avoided
Vacuum brazing	Nb/SS	§ 3.8.6 is clear: filler material shall be high purity copper UNS C10100 only! BPQR: ASME BPVC Section IX: table QB-451.3: 2 tension + 2 peel (sectioning preferred) Additional qualification criterion: thermal shocking in liquid nitrogen CERN requires receiving ~~3~~ 1 sample (production)

Bare cavities with interfaces: manufacturing

- Highlights:
  - Pressure equipment: full traceability (materials, parts) is critical;
  - Silicone, halogens and sulphur are strictly proscribed;
  - ‘Flood’ cooling shall be preferred (helps avoiding Nb degradation);
  - CERN’s procedure for cleaning and chemical polishing of Nb shall be adopted (annex 6.6);
  - A specific brazing procedure is requested for joining SS/Nb - §3.8.6

Bare cavities with interfaces: finalization of the manufacturing process

- Foreseen at the supplier's (US LARP) premises (§3.10):
  - 150 µm BCP according to the procedure of annex 6.6;
  - HT aiming at avoiding hydrogen disease;
  - 15-20 µm light BCP to remove impurities – annex 6.6;
  - High-pressure water rinsing



High Luminosity LHC

EDMS NO.	REV.	VALIDITY
1388794	2.0	RELEASED

REFERENCE : SRF cavities / Surface treatment

PROCEDURE

SUPERCONDUCTING RF CAVITIES

CHEMICAL POLISHING OF NIOBIUM RRR>300

Abstract

Cleanliness during fabrication process of superconducting niobium RF cavities is crucial for the good performance of the cavity. The present procedure specifies the steps to be followed to perform a chemical polishing of semi-finished parts of niobium cavities and of finished niobium cavities.

TRACEABILITY

Prepared by: N. Valverde (EN-MME-FW)	***Date:*** 23/05/2014
Verified by: L. Ferreira (TE-VSC)	***Date:*** 26/05/2014
Approved by: O. Capatina (EN-MME-EDM)	***Date:*** 28/05/2014
Distribution: CERN	

Rev. No.	*Date*	*Description of Changes (major changes only, minor changes in EDMS)*
1.0	28/05/2014	First version
2.0	11/08/2014	Modifications on paragraphs 2.4.1,2.5.1,2.6

This document is uncontrolled when printed. Check the EDMS to verify that this is the correct version before use

Bare cavities with interfaces: verification

- Dimensional checks
  - Also between manufacturing steps (flowchart);
  - Final conformity assessment to the specification drawing;
- NDT of welded joints
  - Nb welds: level B | EN ISO 13919-2 + additional criteria (§4.2.1);
  - Vacuum brazing: channels not accepted, defects area ≤ 5%
- Frequency check and tuning
  - Final frequency tolerance within 200 kHz from ideal 3-D model
- He leak tightness: better than 2×10^{-11} Pa.m^3/s (2×10^{-10} mbar.l/s)

Conclusions & future work

1. CERN Engineering tools are being proficiently used by the collaboration with good results;
2. Sound collaborative work has been developed with the Institutes;
3. The architecture of the system allows identifying five entities related to dressed Crab Cavities for SPS tests;
4. Version 1. (6/2014) of the Engineering Specification defines the technical requirements and verification measures for the processes of the entity ‘bare cavity with interfaces’ – minor updates expected;
5. The next step aims at detailing the entity ‘Helium vessel’, by adopting the same strategies. Magnetic shielding, tuning system and HOM couplers will follow.

Thank you for your attention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60
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EN
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