DFX Technical Specification status and QA/QC aspects

Y.Leclercq on behalf of the DF development team WP6a
20 June 2019

Detailed design review of the DFX

Document overview

- The description of activities (KE3299 Annex1) are further detailed in a dedicated technical document (draft version)
- Technical requirements based on HL-LHC cryostats requirements
- Reference document for the DFX prototype requirements
  - Requires to fulfil the performance specified in the functional specification
    - Which refers to the interfaces specification
    - Which refers to the WP15 Integration document
  - Defines applicable standards
  - Defines deliverables
  - Defines manufacturing and qualification requirements
  - Defines Items supplied by CERN

KE3299/TE/HL-LHC
ANNEX 1: Activities

KE3299/TE/HL-LHC
Annex1: Activities

WP6: Cold Powering

This WP on the cold powering of HL-LHC by SC-Links aims to deliver novel solutions for the distribution feedboxes to the current leads at high temperature and the Nb3Sn bus-bar at low temperature with integrated optimization and control of helium gas cooling of the SC-Links.

Objectives:

- To cryogenic test and design optimization of SC-Link splices to LTS and HTS in the distribution boxes at low and high temperatures respectively;
- To verify the P1/P5 relevant components and solutions of the HTS/SC-Link interface, such as splicing, flexible HTS linker, Paschen elimination and the hydraulic control for mixing/separating different coolant flow;
- To develop a design concept of P1/P5 DFM(X)J for the electrical/thermal/mechanical interfaces between SC-Links and LTS bus-bar, the flow control for SC-Link cooling and other existing interfaces;
- To transfer the DFM(X)J design concept to full mechanical design and a manufactured pre-series cryomodule;
- To carry out an experimental study of the thermal stability of the SC-Links by helium gas cooling for the optimization of cryogenic stability and quench detection;
- To test a novel SC-Link quench detection method using distributed thermos-mechanical sensing by OFDR (Optical Frequency Domain Reflection) of optical fibres at different temperatures and cooling conditions. To evaluate the feasibility for long-length SC-Links at P1/P5;
- To establish a final design and specifications for the P1/P5 DFM(X)J mini-series.

Description of the work:

WP6 focuses on the design and delivery of SC-Links distribution feedbox prototypes, novel solutions for SC-Link thermal stability with limited cooling by helium gas and quench detection over long lengths. The leader is Yifang Yang (University of Southampton).

1. Task 1: SC-Link interface to HTS current leads: from concept to prototype and test (Yang), University of Southampton
2. Task 2: SC-Link interface to Magnets: Integration studies and pre-series prototype (Yang), University of Southampton

Task 1 will build on the novel concept of DFHM(X) developed during FP7-HiLumi to realize the multi-cable high current (up to 20kA) splices between SC-Link and LTS/CTS current leads/bus-bar. Task 1 has 1.25 PDRA-years of effort and academic time.

Task 2 consists of i) delivering the concept, full mechanical design and manufactured pre-series prototype for P1/P5 DFM(X)J to provide the interfaces between the SC-Links and LTS bus-bar to the magnets and the flow control for the helium gas cooling of the SC-Links, ii) studying the thermal stability of SC-Links by helium gas cooling, the thermal transients due to magnetic coupling among SC-Link cables upon fast discharge, and test quench detection using distributed thermos-mechanical sensing by OFDR (Optical Frequency Domain Reflection) of optical fibres. Task 2 has one PDRA-year of effort and academic time.

Technician and mechanical design support will be provided by the University of Southampton.

EDMS 2169136

EDMS NO.	REV.	VALIDITY
2169136	0.0	DRAFT

REFERENCE : LHC-EQCOD-ES-XXXXX

TECHNICAL SPECIFICATION

DFX CRYOSTAT PROTOTYPE

COLD POWERING WORK PACKAGE – WP6A

Abstract

This technical specification concerns the supply of one DFX device for the High Luminosity Large Hadron Collider project to be tested as a prototype at the CERN magnet facility SM18. It should be noted that the DFX prototype is a spare unit for the HL-LHC machine and shall therefore be designed according to the HL-LHC machine requirements.

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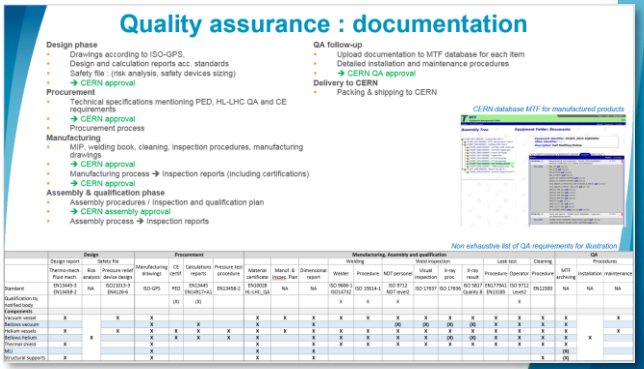
§2 Applicable Documents / General Requirements

- DFX prototype installed in LHC machine (spare unit)
  - ➔ Comply with CERN rules
    - CERN Safety Rules
    - GSI-M-4 - Cryogenic equipment :

GSI-M4: “The manufacture […] by collaborating institutions, of all new cryogenic equipment shall comply with the applicable CERN Safety Rules, European directives and harmonised standards”.

  - ➔ European directives
    - Pressure Equipment Directive 2014-68-EU
  - ➔ HL-LHC QA requirements
    - ALARA principle
    - Material requirements
    - Documentation & MTF

HL-LHC documentation requirements
Details in spare slide



Deliverables & Activities

- Deliverables:
  - One qualified prototype DFX compatible with 5L
  - Documentation

- Activities:
  - Design
  - Manufacturing
  - Cleaning
  - Tracing
  - Qualification testing
  - Reporting & Archiving

1.2 **Deliverables and Activitites included in the Supply**

One DFX cryostat compatible with installation in the point 5 left location in the HL-LHC tunnel shall be provided in the scope of this supply to the requirements detailed in this Technical Specification. The DFX cryostat design shall comply with the performance specified in the DFX Functional Specification, see [3].

The supply to be delivered by SOTON shall include the following deliverables and activites:

- Design of the Supply compatible with the Functional Specifications (see §3.3);
- Design file (see §6.1);
- Manufacturing of the Supply (see §3.4) ;
- Cleaning (see §3.5);
- Assembly (see §3.6);
- Inspection and Tests (see §3.7);
- Tracing and marking of all manufactured parts (see §4);
- Documentation as specified in §6;
- Packing and shipping (see §3.8 and §5).

§3 Technical Requirements

- Materials requirements:
  - Compatible with PED category in operation & HL-LHC QA
  - Traceability ensures from initial certificate to upload to MTF
  - Specific requirements (Cobalt content, CERN spec. N°510-Ed.5, Radiation and Fire resistance)

- Design
  - Compliant with Functional, Interface Specifications and European Standards
  - Verified by calculations (according to PED)
  - Documented in a design report
  - Specific requirements (bellows design, vacuum vessels as PED-Cat.1)


EN Official Journal of the European Union

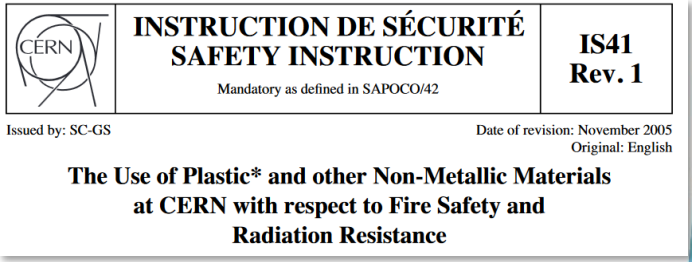
DIRECTIVE 2014/68/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 15 May 2014

on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment

(recast)

(Text with EEA relevance)


CERN

INSTRUCTION DE SÉCURITÉ
SAFETY INSTRUCTION

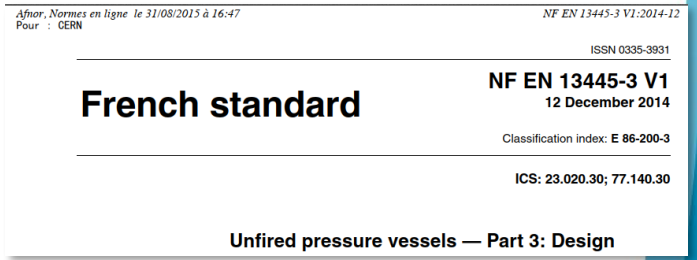
Mandatory as defined in SAPOCO/42

IS41
Rev. 1

Issued by: SC-GS

Date of revision: November 2005
Original: English

The Use of Plastic* and other Non-Metallic Materials at CERN with respect to Fire Safety and Radiation Resistance


Afnor, Normes en ligne le 31/08/2015 à 16:47
Pour : CERN

NF EN 13445-3 V1:2014-12

ISSN 0335-3931

French standard

NF EN 13445-3 V1
12 December 2014

Classification index: E 86-200-3

ICS: 23.020.30; 77.140.30

Unfired pressure vessels — Part 3: Design


European standard

French standard

NF EN 14917+A1
April 2012

Classification index: E 29-824

ICS: 23.040.99

Metal bellows expansion joints for pressure applications

§3 Technical Requirements

- Manufacturing
  - Compatible with PED category in operation
    - Materials, Welding procedures, Welders qualifications and inspections
  - Traceability ensures from start to upload to MTF
  - Specific requirements (bellows welding, 3D forged flanges, vacuum vessels as PED-CAT 1)

- Cleaning to EN12300
- Assembly : Instrumentation supplied (assembled) by CERN

Non exhaustive list of QA requirements for illustration

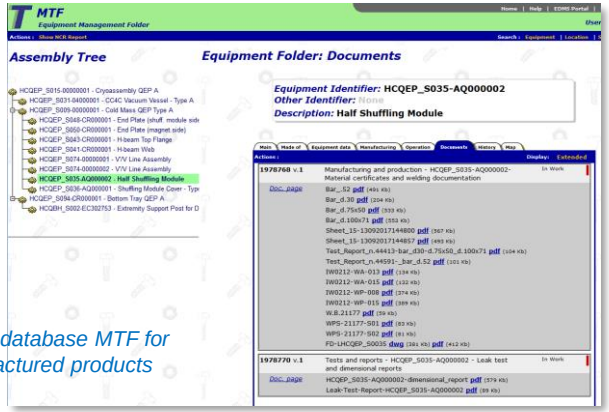
	Design			Procurement				Manufacturing, Assembly and qualification												QA		
	Design report	Safety file									Welding		Weld inspection				Leak test		Cleaning		Procedures	
	Thermo-mech. Fluid mech.	Risk analysis	Pressure relief device design	Manufacturing drawings	CE certif.	Calculations reports	Pressure test procedure	Material certificate	Manuf. & Inspec. Plan	Dimensional report	Welder	Procedure	NDT personel	Visual inspection	X-ray proc.	X-ray result	Procedure	Operator	Procedure	MTF archiving	Installation	maintenance
Standard	EN13445-3 EN13458-2	NA	ISO21013-3 EN4126-6	ISO-GPS	PED	EN13445 EN14917+A1	EN13458-2	EN10028 HL-LHC_QA	NA	NA	ISO 9606-1 ISO14732	ISO 15614-1	ISO 9712 NDT level2	ISO 17637	ISO 17636	ISO 5817 Quality B	EN1779A1 EN13185	ISO 9712 Level2	EN12300	NA	NA	NA
Qualification by notified body					(X)	(X)					X	X	X					X				
Components																						
Vacuum vessel	X		X	X				X	X	X	X	X	X	X	X	X	X	X	X	X		X
Bellows vacuum				X		X		X		X			(X)	(X)	(X)	(X)	X	X	X	X		
Helium vessels	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Bellows helium		X		X	X	X	X	X		X	X	X	X	X	(X)	(X)	X	X	X	X	X	
Thermal shield	X			X				X		X	X	X	X	X	X	X	X	X	X	X		
MLI				X				X		X										(X)		
Structural supports	X			X				X		X									X	(X)		

§3 Production and Acceptance tests

- See dedicated talk
  - Acceptance based on calculations
  - Acceptance based on testing
    - Production test to PED
    - Performance qualification
  - Documentation acceptance (see dedicated slide)

§4 Traceability & shipping

- Traceability & Marking
  - Individual labelling and identification of each part
    - “All manufactured parts […] shall be individually […] marked. […] It shall be possible to identify each material batch used in the manufacturing.[…] The identification system shall ensure that all the material have been subjected to the required level of inspection”
  - QA system to ensure materials, NC, tests follow-up
  - HL-LHC QA : upload all information to EDMS/MTF database
- EC/EU Certification (TBD)
- Shipping



CERN database MTF for manufactured products

4.4 Quality Control and Quality Assurance

The presence of a documented quality assurance program that fulfils all the requirements described in this technical specification is mandatory. In this case the manufacturer shall submit all documents produced in electronic format (PDF format whenever possible).

§6 Documentation

- Documentation compliant with PED Category III (for component part of the helium volume)
  - Design calculation reports
  - Material certificate to standard acc. to application
  - Welds:
    - Welding procedures
    - Welders qualifications
    - Welds inspections reports
    - Weld inspectors qualification
  - Pressure test, procedure and report

- Documentation for performance qualification and QA aspects
  - Design documentation
  - Manufacturing preparation
  - Manufacturing
  - Assembly & qualification

6 DOCUMENTATION

The Supply shall include the documentation specified in §6.1 and §6.2.

6.1 Design documentation

The documentation related to the design of the Supply shall include:

- Detailed design file:
  - Description of operating modes;
  - List of design parameters and operating procedures considered for the design;
  - Design calculation reports, validated by notified body when required by PED:
    - Vacuum vessels design calculation report;
    - Helium vessel design calculation report according to standards (stress distributio
    - Bellows design calculation report according to EN 14917+A1;
    - All others calculations required by standards;
  - Assembly procedure;
- Specification drawings of all manufactured part according to ISO-GPS standards;
- Technical specifications for procurement.

6.2 Manufacturing preparation documentation

The documentation related to the preparation of the manufacturing of the Supply shall include:

- Manufacturing and Inspection Plan (MIP) mentioning schedule and milestones;
- Manufacturing drawings of all manufactured parts according to ISO-GPS standards;
- Welding procedures;
- Production test procedures;
- Cleaning procedure;
- Acceptance test procedure.

6.3 Manufacturing documentation

The documentation related to the manufacturing of the Supply shall include:

- Material certificates;
- Pressure test reports;
- Qualification test certificates of welders and/or welding operators;
- Welding qualification records;
- Non-conformity reports, if applicable.

6.4 Assembly and Qualification documentation

The documentation related to the assembly and qualification of the Supply shall include:

- Dimensional controls report;
- Electric test report of all installed instrumentation;
- Qualification certificates of leak testing personnel;
- Leak test reports using the template provided in Annex 1;
- Leak test operator certification;
- Leak detector calibration certificate;
- Acceptance test report;
- Detailed tunnel assembly sequence including welding, inspection and testing operations;
- Detailed maintenance operation sequence;
- EC/EU declaration of conformity;

6.5 Quality Plan and Progress reports

The Supplier shall submit a Quality Plan in accordance with the schedule defined in § 9. The Quality
Progress reports shall include all the necessary information, in particular, the actual progress in co

§7 Items supplied by CERN

- Insulation vacuum:
  - O-rings for vacuum flanges;
  - Pumps, valves and pressure transducers (for the machine installation, installed at CERN directly);
  - Pressure relief plate;
- Cryogenics:
  - Instrumentation & hardware:
    - Temperature sensors mounted on supports and equipped with wires
    - Level gauges equipped with wires
    - Pressure transducers if required
    - Electrical heaters
    - Electrical feedthroughs
  - Safety relief pressure devices (installed at CERN)
- Survey:
  - External survey targets if needed.
- Cold Instrumentation routing & feedthroughs:
  - IFS tubes equipped with instrumentation wires
  - IFS feedthrough

§9 Performance of the collaboration agreement

- Design Phase
  - (design calculations, operating modes, assembly sequence, specification drawings)
  - ➔ **CERN's approval via DDR**
- Manufacturing preparation
  - (Manufacturing drawings, MIP, manufacturing & testing procedures)
  - ➔ **CERN's approval via PRR**
- Manufacturing phase
  - (Manufacturing, cleaning)
- Assembly and qualification phase
  - (qualification campaign, reporting)
  - ➔ **CERN's approval of documentation**
- Delivery to CERN

9.2	**Acceptance**
	Acceptance of the Supply shall be subject to the successful completion of the tests specified in § 3.7 by the supplier on its premises and the submission to CERN, for written approval, of all compliant tests results or other certificates requested by CERN in § 6.

Summary

- The Technical specification is being finalised
- Qualification according to PED where applicable
- Quality requirements in line with HL-LHC cryostats requirements
- Milestones and Acceptance criteria defined in the document