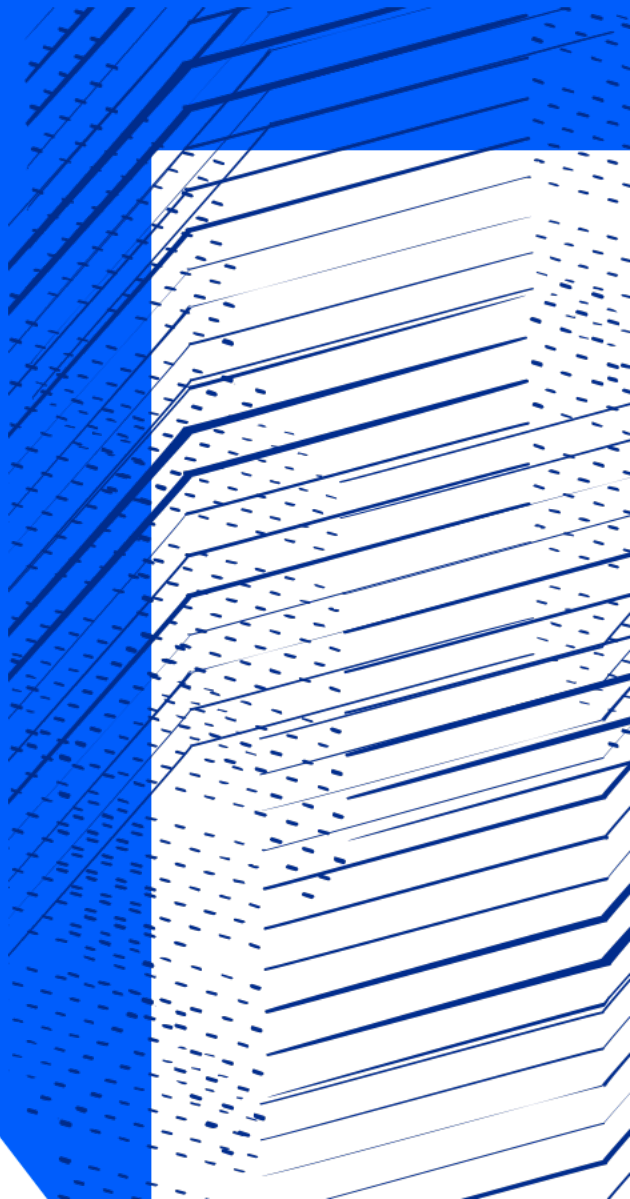
Science and Technology Facilities Council

RFD Prototype Final Test Acceptance Kit Design and Manufacture

Andrew Blackett-May
STFC Daresbury Laboratory
andrew.may@stfc.ac.uk

12th HL-LHC Collaboration Meeting
21-Sept-22



Final acceptance testing

This presentation covers only tests performed on completion of cryostating

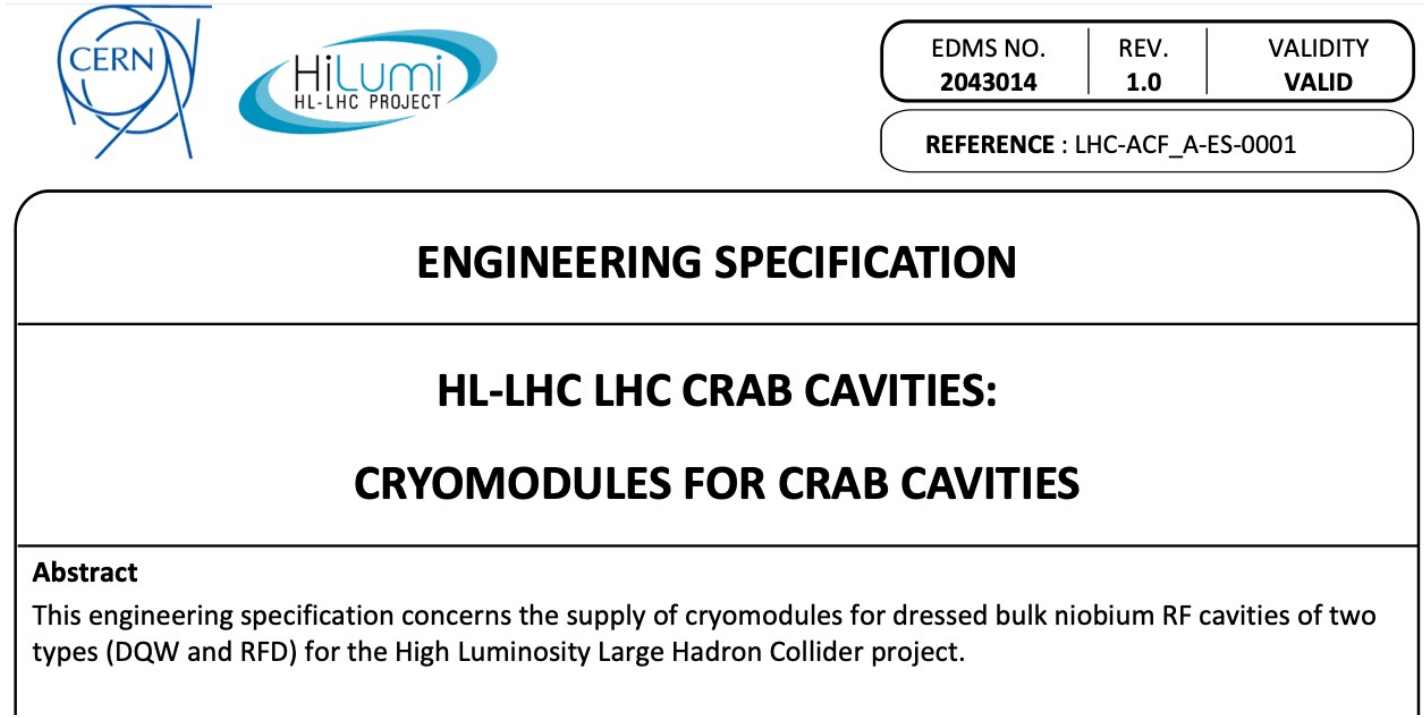
Testing to check integrity of sub-systems are carried out earlier in cryostating and are outside the scope of this talk

FAT split between STFC (i.e., pre-shipment) and CERN (upon arrival at SM18)

Science and Technology Facilities Council

Final acceptance testing

Requirements defined in EDMS2043014



EDMS NO.	REV.	VALIDITY
2043014	1.0	VALID

REFERENCE : LHC-ACF_A-ES-0001

ENGINEERING SPECIFICATION

HL-LHC LHC CRAB CAVITIES:

CRYOMODULES FOR CRAB CAVITIES

Abstract

This engineering specification concerns the supply of cryomodules for dressed bulk niobium RF cavities of two types (DQW and RFD) for the High Luminosity Large Hadron Collider project.

Science and Technology Facilities Council

Testing required at STFC at cryostat completion

§14 Cryostating

§14.5 Functional verification of the cryomodule

§14.5.8 Proof tests: strategy and procedures

Leak and pressure testing of cryogenic lines

- He lines (inc. cavities, HOM couplers, cooling line, biphasic)
- Thermal shield line
- Beam screen cooling line

Science and Technology Facilities Council

Leak and pressure testing

Table 16 – proof tests at the end of cryostating

Line	Test conditions	ΔPS [bara]	ΔPtest [bara]
He lines (including cavities, HOM couplers, cooling lines, biphasic line)[17]	• Vacuum in the insulation volume • Vacuum in the beam vacuum volumes	2.1	2.1x1.25=2.7
thermal shield line	• Vacuum in the insulation volume • Vacuum in the beam vacuum volumes	25	25x1.43=35.8
beam screen cooling line	• Vacuum in the insulation volume • Vacuum in the beam vacuum volumes	20	20x1.43=29

The leak tightness test shall be performed before and after the pressure test.

In case of proof test with the cryomodule connected to fluid supply lines, the 2 following requirements apply to the fluid supply lines:

- **It shall be possible to protect the cavities during possible proof tests or overpressure accidents of the supply lines**
- **It shall be possible to perform independent proof tests on each cooling circuit individually in the cryomodule**

Pressure testing

Pressure test procedure derived from EN 13445-5:20014:

- **Pressure gradually increased to ~50% of P_{test}**
- **Pressure then increased in stages of ~10% of P_{test} up to P_{test}**
- **P_{test} maintained >30 min**
- **At no stage shall the vessel be approached for close examination until the pressure has been positively reduced by >10 % below P_{test}**
- **The pressure shall be maintained at the specified close examination level for a sufficient length of time to permit a visual inspection to be made of all surfaces and joints, whenever possible**

Leak testing

§33 ANNEX: LEAK TESTS references EDMS 2093032 Engineering Specifications: cryolines for Crab cavities §3.4.3

The following requirements shall be respected.

- The helium leak tightness shall be performed according to the tracer gas method EN ISO 20485 (or ASME BPVC Section V) and the maximum allowable leak rate for the entire cryogenic lines shall be, at room temperature, lower than 1x10-9 mbar·l/s (1x10-10 Pa.m3/s) as required in the Engineering Specifications for crab cryomodules EDMS 2043014 [1] .
- Leak rates shall be measured using a calibrated mass spectrometer leak detector with helium as tracer gas. Values are specified at 20°C with 100% helium. Standard test conditions require a pressure differential of 1 bar (unless otherwise stated): vacuum on one side of the enclosure wall and 100% helium on the other side.
- The helium mass spectrometer shall be calibrated according to ISO 3530 or ASME BPVC section V.
- The personnel performing leak tightness tests shall be qualified according to EN ISO 9712 or to Recommended Practice No. SNT-TC-1A (minimum level 2, for both).
- The helium mass spectrometer shall have a sensitivity for helium of at least $1x10^{-11}$ $Pa.m^3/s$. Helium leak rate data charts shall be recorded and annexed to the test reports.
- The helium leak tightness test shall be performed at the manufacturing steps indicated in the Manufacturing and Inspection Plan (MIP).
- Leak test report(s) (including Helium leak rate data charts) shall be in agreement with CERN template EDMS 1318157 [15] .

Leak testing

§33 ANNEX: LEAK TESTS references EDMS 2093032 Engineering Specifications: cryolines for Crab cavities §3.4.3

The following requirements shall be respected.

- The helium leak tightness shall be performed according to the tracer gas method EN ISO 20485 (or ASME BPVC Section V) and the maximum allowable leak rate for the entire cryogenic lines shall be, at room temperature, lower than 1x10-9 mbar·l/s (1x10-10 Pa.m3/s) as required in the Engineering Specifications for crab cryomodules EDMS 2043014 [1] .
- Leak rates shall be measured using a calibrated mass spectrometer leak detector with helium as tracer gas. Values are specified at 20°C with 100% helium. Standard test conditions require a pressure differential of 1 bar (unless otherwise stated): vacuum on one side of the enclosure wall and 100% helium on the other side.
- The helium mass spectrometer shall be calibrated according to ISO 3530 or ASME BPVC section V.
- The personnel performing leak tightness tests shall be qualified according to EN ISO 9712 or to Recommended Practice No. SNT-TC-1A (minimum level 2, for both).
- The helium mass spectrometer shall have a sensitivity for helium of at least $1x10^{-11}$ $Pa.m^3/s$. Helium leak rate data charts shall be recorded and annexed to the test reports.
- The helium leak tightness test shall be performed at the manufacturing steps indicated in the Manufacturing and Inspection Plan (MIP).
- Leak test report(s) (including Helium leak rate data charts) shall be in agreement with CERN template EDMS 1318157 [15] .

Testing required at STFC at cryostat completion

§15 FINAL TESTS ON THE ASSEMBLED CRYOMODULE: PROCEDURES AND ACCEPTANCE CRITERIA

- §15.1 Vacuum cycles and deformation repeatability (insulation vacuum cycles)
- §15.2 Final RF tests at warm on cryomodule
- §15.3 Cool-down tests at 77 K (liquid nitrogen boiling point)
- §15.4 Cool-down tests at 2 K
- §15.5 RF tests at 2 K (nominal operating temperature)
- §15.6 Documentation related to final tests on cryomodule

Thermal cycling

§15 FINAL TESTS ON THE ASSEMBLED CRYOMODULE: PROCEDURES AND ACCEPTANCE CRITERIA

- §15.1 Vacuum cycles and deformation repeatability (insulation vacuum cycles)
- §15.2 Final RF tests at warm on cryomodule
- §15.3 Cool-down tests at 77 K (liquid nitrogen boiling point)
- §15.4 Cool-down tests at 2 K
- §15.5 RF tests at 2 K (nominal operating temperature)
- §15.6 Documentation related to final tests on cryomodule

Thermal cycling

Thermal cycle at DL only to allow repetition of leak and pressure tests post-thermal cycle

RF tests etc. described in §15 to be carried out at SM18

Testing required at STFC at cryostat completion

Science and Technology Facilities Council

Final acceptance test kit

In order to support final acceptance testing of cryomodules at Daresbury, an interface module (FAT-kit) has been developed to sit between the assembled cryomodule and the required utilities for the tests

Science and Technology Facilities Council

Final acceptance test kit

Motivation for this is to replace ad hoc connection of various utilities with a kit that will

- help standardise procedures to support consistency between tests
- minimise risks to operators [safety]
- provide common and systematic DAQ across CM and supply

Science and Technology Facilities Council

Cryomodule P&ID

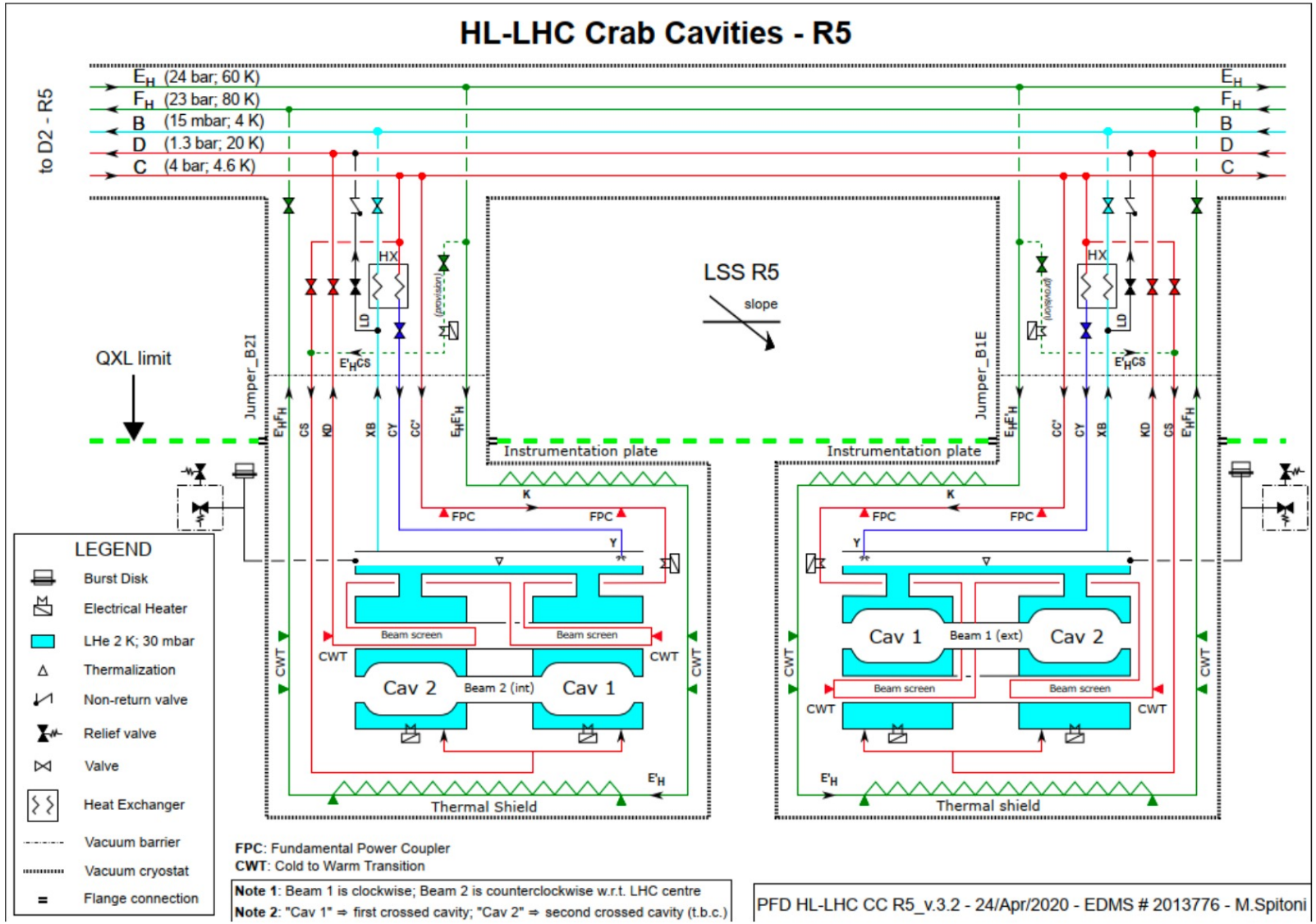
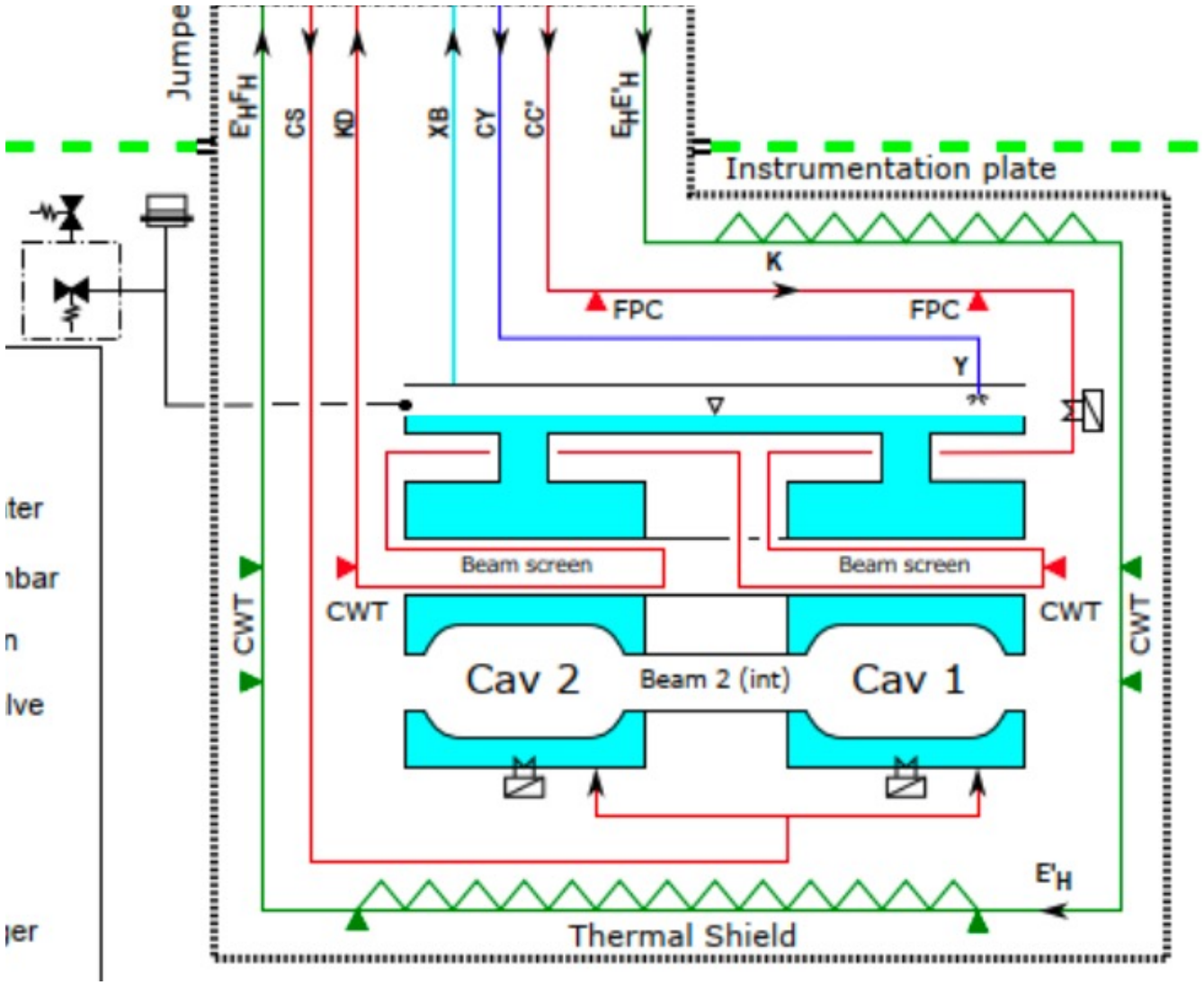


Figure 9 – PFD for the HL-LHC crab cryomodules [28]

Cryomodule P&ID



Science and Technology Facilities Council

Utilities required to interface

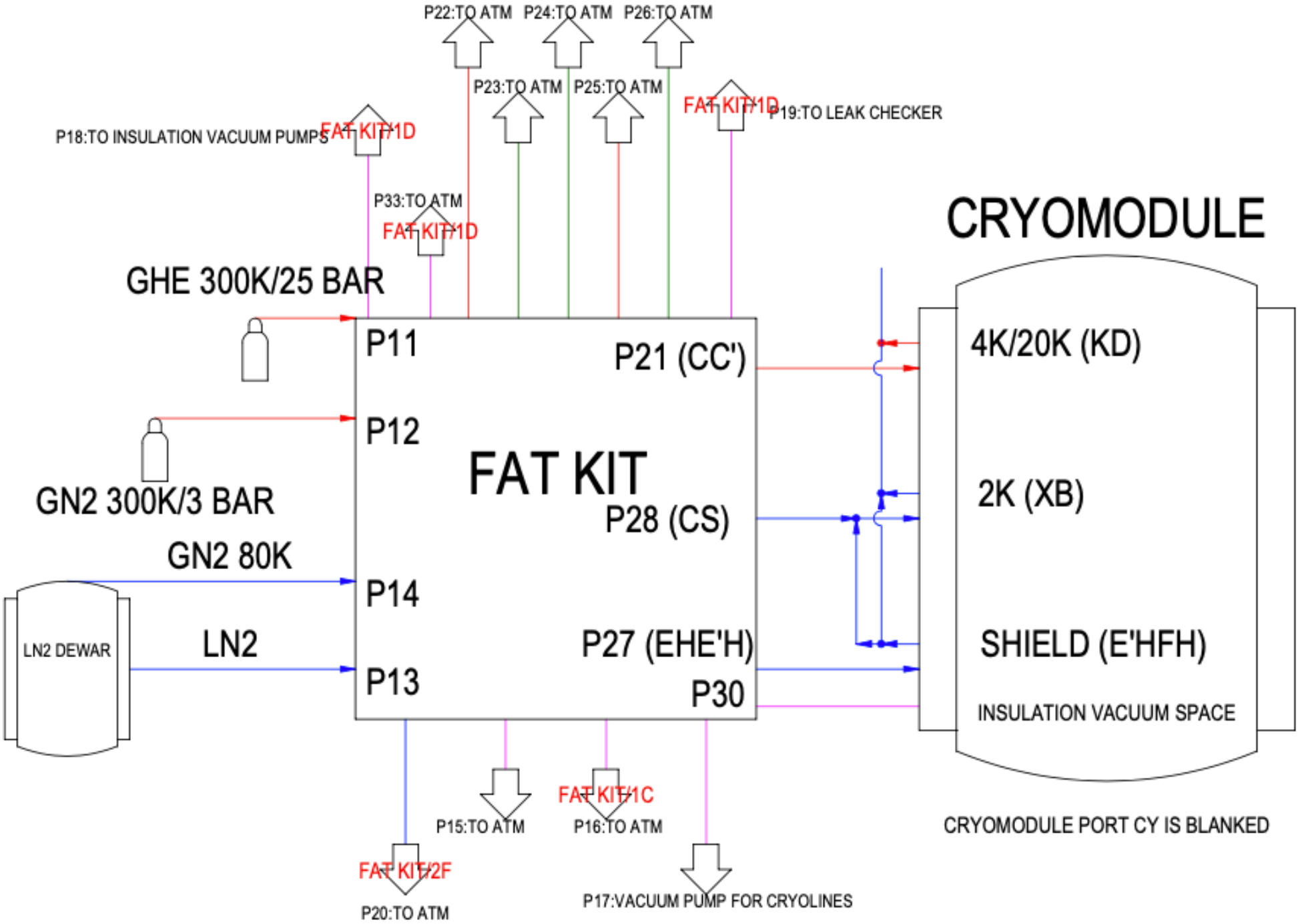
- HP/LP warm He gas
- HP/LP warm N_2 gas
- Cold N_2 gas
- LN_2
- Vacuum pumping station
- Leak detector
- Vent lines
- Pressure limiting valves

Science and Technology Facilities Council

Outline workplan

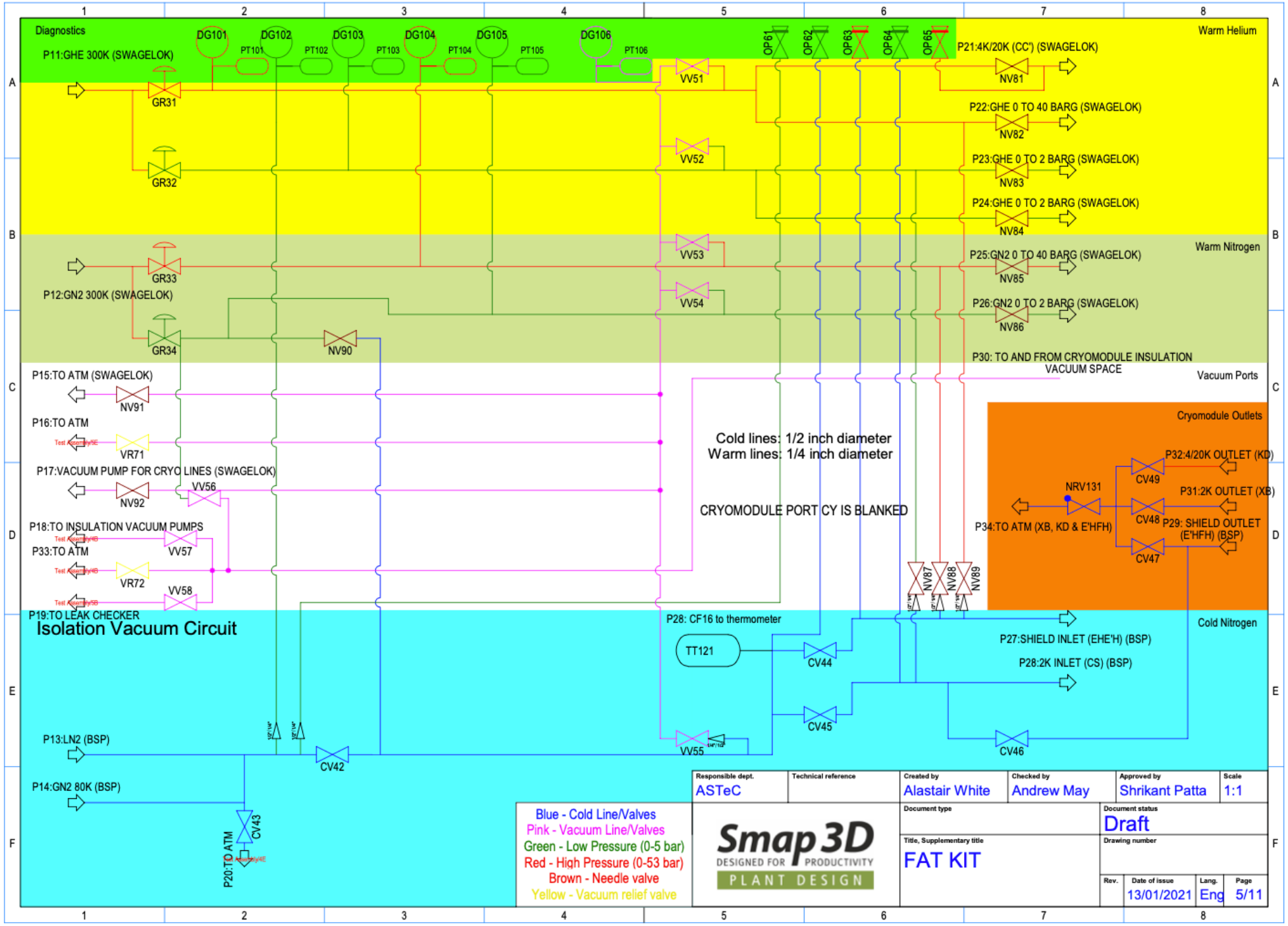
1. Evacuate cryomodule insulating vacuum only
2. Pump and purge 3x cryo circuits w/ GHe
3. Sequentially pressurise (LP GHe) and leak test circuits
4. Sequentially pressurise (HP GHe) and pressure test circuits
5. Vent HP, then sequentially pressurise (LP GHe) and leak test circuits
6. Vent, then pump and purge 3x cryo circuits w/ GN_2
7. Cool circuits with LN_2 to 80 K
8. Warm circuits back to room temperature
9. Pump and purge 3x cryo circuits w/ GHe
10. Sequentially pressurise (LP GHe) and leak test circuits
11. Sequentially pressurise (HP GHe) and pressure test circuits
12. Vent HP, then sequentially pressurise (LP GHe) and leak test circuits

FAT kit P&ID



Science Technol Facilitie

FAT kit P&ID



Science and Technology Facilities Council

FAT kit fabrication

Science and Technology Facilities Council

LN_2 dewar

- Custom 500 L LN_2 dewar from Wessington
- Forklift pockets for transfer around site
- Solenoid valves on both GN_2 and LN_2 supplies
- A10 pressure transmitter
- Level gauge with 4-20 mA output

Science and Technology Facilities Council

LN_2 level probes

- LN_2 level probes required in place of LHe probes in CM for 80 K cycle test
- 2x American Magnetics Inc capacitance-based level probes procured and delivered to DL
- 1x Model 1700 liquid level instrument procured and delivered to DL
- 2x oscillator/transmitter kits procured and delivered to DL to allow greater flexibility in rack location

Instrumentation rack

- Common DAQ for FAT kit and CM
- Spare capacity for future additional instrumentation

Science and Technology Facilities Council

FAT kit status

- Fabrication completed by contractor, delivered to STFC
- Review procedures with CERN
- Commissioning planned for Oct-2022

Science and Technology Facilities Council

Science and
Technology
Facilities Council

Questions?

UKRI Science and Technology Facilities Council

Thank you

Science and Technology Facilities Council @STFC_matters Science and Technology Facilities Council