Electrical Test Baseline

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Introduction

- Maximum expected voltages during operation are calculated through simulation of worst conditions during a quench, including failure of protection elements.

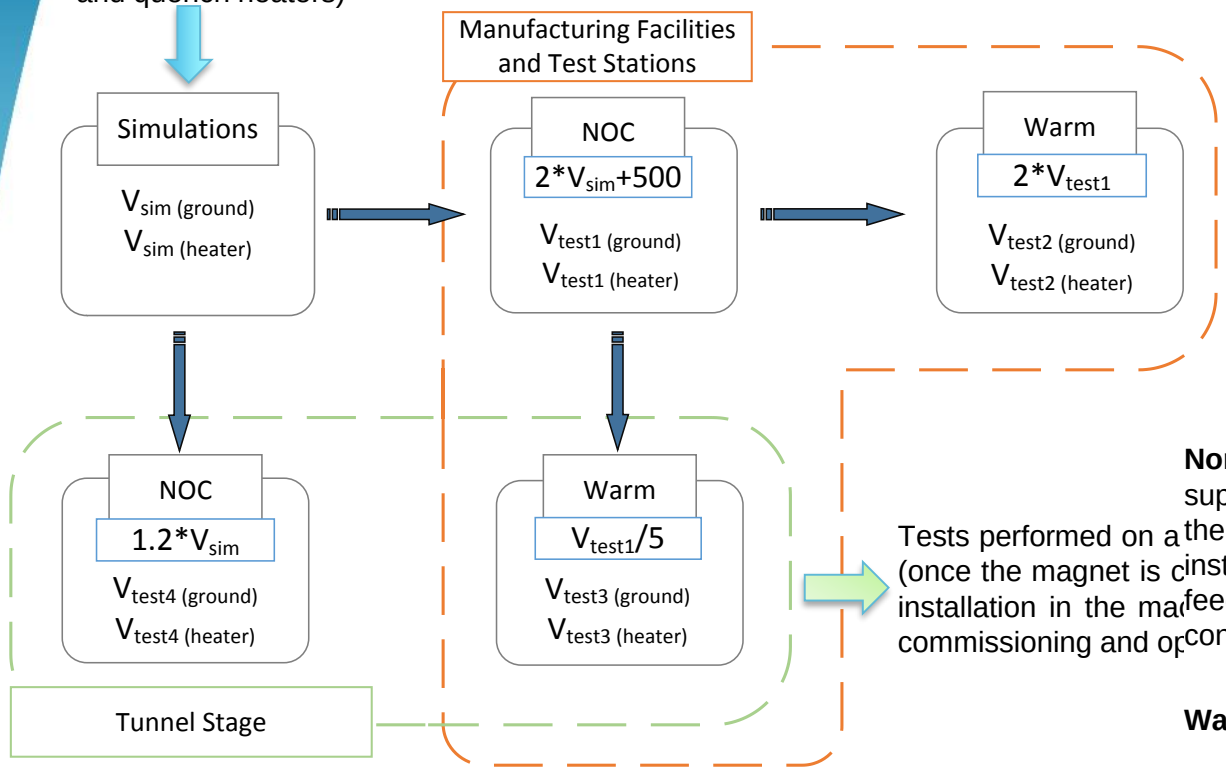
- Calculations are conducted at nominal current. Conditions at ultimate current should be covered by the margin in the components design without applying safety factors. Some exceptional conservative cases must follow the same rule, as they are realistic but with very low likelihood of happening (HL-LHC Project policy).

- Electrical test levels are obtained by applying factors regarding the different environments and temperature-pressure conditions under which the magnet will be tested.

Electrical Test Strategy

Reference document
EDMS 1995595

V_{sim}: maximum expected coil voltage at quench (to ground and quench heaters)



Test voltages diagram

Tests performed on a single magnet from the final test after assembly, through magnet reception at a test facility up to acceptance in test stations at cold.

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Nominal Operating Conditions (NOC): superfluid helium in the cold mass, with all the ancillary components (e.g. instrumentation capillary tube and feedthrough) at the corresponding local conditions;

Warm (RT): room temperature in dry air.

11 T Dipole Worst-case Conditions

- Failure case analysis for a 11 T cryo-assembly during quench [1]:

	Nominal		1 QH circuit failure		**2 QH circuits failure**	
	I_{nom}	I_{ult}	I_{nom}	I_{ult}	I_{nom}	I_{ult}
Current [kA]	11.85	12.80	11.85	12.80	11.85	12.80
Quench integral [MA^2s]	15.8	16.2	16.1	16.4	16.2	16.5
Hot-spot temperature [K]	320	342	327	349	333	356
Peak voltage to ground [V]	245	340	570	680	**950**	1070
Peak turn to turn voltage [V]	75	80	80	90	90	95

- The failure of 2 heater power supplies or circuits at nominal current gives the worst-case voltage to calculate V_{sim} :

Maximum expected coil voltage at quench (V)	To ground	1400 (**950**+**450**)
	To quench heater	1350 (**900**+**450**)

Energy Extraction voltage to ground

Assuming fuse failure in the heater power supply

[1] See Susana I. Bermudez's presentation

11 T Dipole Electrical Test Values

- **Test values at *'Manufacturing Facilities and Test Stations'* stage:**

Test name		Test voltage	Value
Test voltage at NOC at *'Manufacturing Facilities and Test Stations'* stage (V)	To ground	$V_{test1\ (ground)}$	3300
	To quench heater	$V_{test1\ (heater)}$	3200
Test voltage at warm before first helium bath (V)	To ground	$V_{test2\ (ground)}$	**5000**
	To quench heater	$V_{test2\ (heater)}$	**3200**
Test voltage at warm after helium bath (V)	To ground	$V_{test3\ (ground)}$	660
	To quench heater	$V_{test3\ (heater)}$	640
Maximum leakage current (µA) for a cryo-assembly – not including leakage of the test station			**30**
Test voltage duration (s)			120

Limits set by magnet designers

Expecting feedback from tests

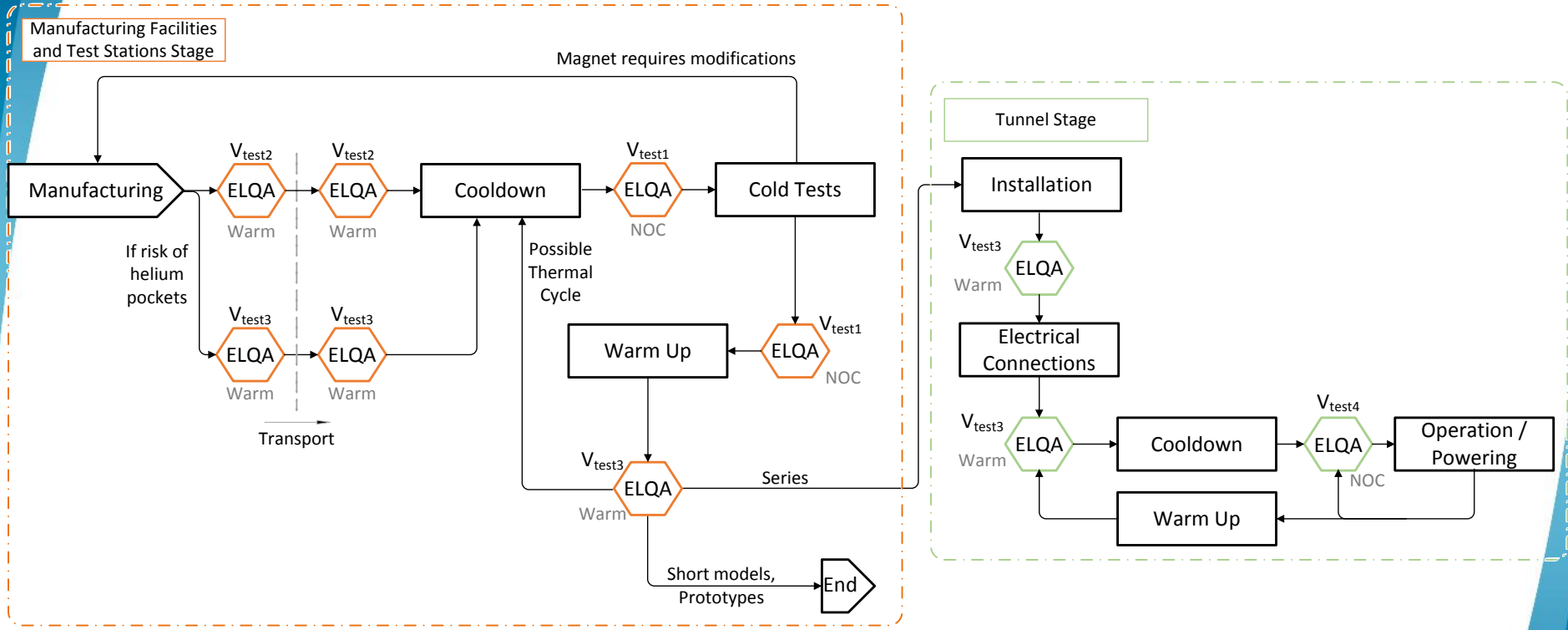
- **Test values at *'Tunnel'* stage:**

Test name		Test voltage	Value
Test voltage at NOC at *'Tunnel'* stage (V)	To ground	$V_{test4\ (ground)}$	**2100**
	To quench heater	$V_{test4\ (heater)}$	1620
Test voltage at warm after helium bath (V)	To ground	$V_{test3\ (ground)}$	660
	To quench heater	$V_{test3\ (heater)}$	640
Maximum leakage current (µA) for a cryo-assembly – not including leakage of the test station			**30**
Test voltage duration (s)			120

ELQA test value in LHC at cold

Expecting feedback from tests

Tests Sequence and Possible Scenarios



Test levels to apply at each ELQA step

Proposed Intermediate Temperature Test

- Tests at an intermediate temperature at 1 bar allow to qualify the magnet in a well-known environment, close to the conditions in which the worst voltages are expected at quench;

Test voltage	Temperature [K]	Maximum detectable defect length [mm]
3200 V, 3300 V (V_{test1})	80	~5
	150	~10
	200	~13

- Reasons for such a test:
  - Verification of the effects of helium pockets after cold tests which might degrade an already weak insulation;
  - Test level at warm for refurbished magnets is still not clear (**to be addressed after proper studies are conducted**);
  - High dielectric strength of liquid helium and air might hide defects due to the less stringent test voltage at warm after helium bath, V_{test3} (660 and 640 V);

- Feasibility of this intermediate temperature test strongly depends on the test station capability in terms of voltage withstand and possible stable cooling conditions (temperature and pressure).

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Thank you for your attention

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Backup Slide – Paschen Curves