Electrical insulation characterization and endurance tests on MBHSP109

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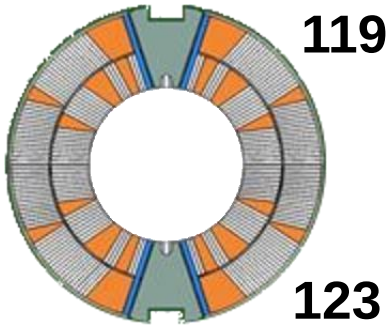
History

- MBHSP109 has been powered during 4 cool downs with many quenches, current cycles and heater firings.
  - ✓ ~1800 current cycles
  - ✓ > 60 quenches
  - ✓ > 300 QH firings
- Quench Heater to Coil insulation strength tested at 1.9 K to nominal qualification voltages
  - **nominal qualification** test values on each QH to coil. 660 V at T_{room} and 3300 V at 1.9 K.
- Hi-pot tests at higher temperature in GHe environment, with stepwise temperature increase from 80 K, 200 K, 300 K resp.at 1.35 Bar and 3.5 Bars (limited by cryostat). The main qualification is at 200 K, 1.35 bar, since this is seen as a worst case condition for the LHC.

Last results Hi Pot in GHe, high temperature.

- Failure case analysis for a 11T cryo-assembly during a quench: **1469 V peak voltage-to-ground** at nominal current with EE, and 2 QH circuits failure.
- Maximum expected coil voltages at quench:
  - **To ground:** 1469 V
  - **To quench heater:** 1350 V (900+450)



	Test name		AW7
	Time constant T		T Mesured [ms]
11T Coil#119	Coil 119 outer layer	YT119OL+	11.56
		YT119OL-	
		YT119OR+	11.96
		YT119OR-	
11T Coil#123	Coil 123 outer layer	YT123OL+	10.76
		YT123OL-	
		YT123OR+	10.88
		YT123OR-	

MBHSP109 test results

Test	Temperature	pressure	HV Test level	Result
0	1.9 K	1.35 bar	3.3 kV	Failed for all heaters between 1.5 and 2.5 kV Spare connectors also failed between 2 and 2.4 kV. Reducing the helium level above lambda plate did not improve the measurements significantly.
1	80 K	1.9 bar	940 V	**Passed**
2	200 K	1.9 bar	940 V	**Passed**
3	200 K	1.35 bar	940 V	**Passed**
4	80 K	1.9 bar	1345 V	**Passed**
5	198 K	2.1 bar	1345 V	123 right **passed** 119 left **passed** 123 left **failed** at 1319 V, but passed in second test **119 right failed at 1291 V, then at 1143 V, then at 941 V and then the leakage current was so high that the test was aborted manually at 612 V**
6	200 K	1.35 bar	1345 V	Breakdown in all 3 remaining QH circuits and dummy cables

Some test improvements ideas

- As voltage breakdown limitations at 2.4 kV on vertical station at level of connectors (no change with He level), idea to epoxy pot to improve voltage withstand level;
- to install one QH wire pair per connector, under check;
- to use some current transformer (High bandwidth) across QH leads, close to top cryostat flange connectors to locate any faults.

Test sequence proposal

1. QH insulation resistance check at RT @ 600V (incl. failing QH119)
2. After cool down, at 1.9 K, discharge test on each QH as reference after long charging (30 mins) at 500V
3. **Real conditions high voltage tests** with provoked quench sequence at nominal current in coil (10) in LHe. Dump resistor adjusted to limit voltage at 900-1000 V. Check of intermediate leakage current evolution.
4. During warming up to 200 K, possible record of leakage current at intermediate Hi-pot points (700 V check)
5. **Endurance Hi-pot test** at one high temperature of 200 K Ghe, 3 bars : 50 x rise to 750 V, record of leakage current to detect first degradation effects (equivalent to number of quench + ELQA campaign over magnet lifetime)
6. **Breakdown test** limits on 3 QH circuits (if intact) in 200K GHe, stepwise rise 600-1500 V

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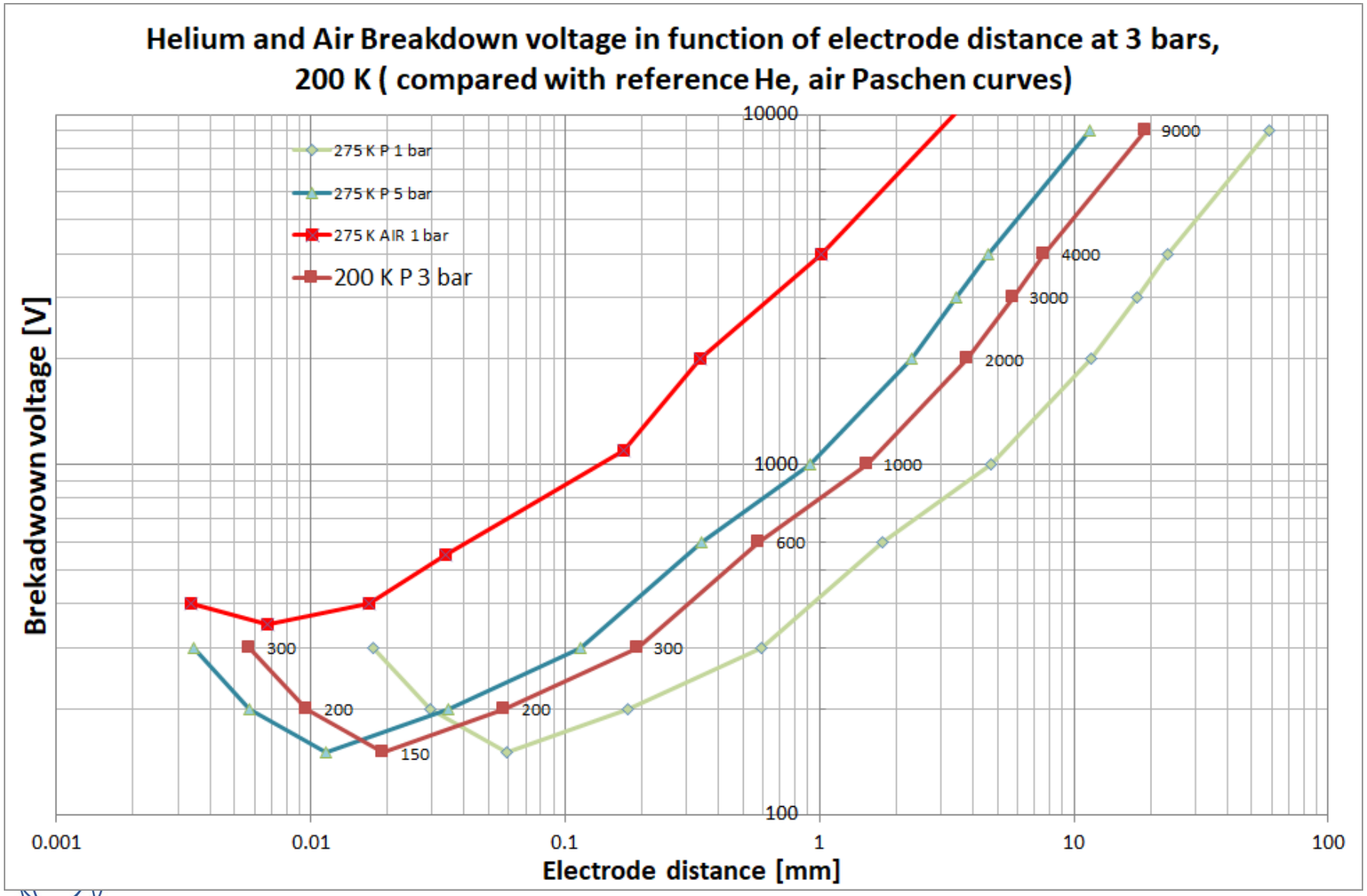
Thank you

Back up slides

Paschen withstand voltage for ideal plate electrode



Test no.	Temperature [K]	Pressure [bar]	Test Level [V]
1	1.9	1.35	3000
2	3.25	1.25	3000
3	80	1.9	940
4	225	1.9	940
5	225	1.35	940
6	89	1.9	1345
7	200	2.1	1345
8	200	1.35	1345
9	200	1.35	1748
10	200	1.35	Up to breakdown

Test level at Nominal Operation Conditions according to Electrical Design Criteria (value lowered from 3.2 kV due to test equipment)

Maximum expected voltage at nominal conditions, with EE, plus 20 % margin

Maximum expected voltage with 1 QH failure, with EE, plus 20 % margin

Maximum expected voltage with 2 QH failure, with EE, plus 20 % margin

EDMS 1995595 v0.1 (2018-05-23)

Table 4. 11T dipole electrical test values

Maximum expected coil voltage at quench (V)	To ground	1400
	To quench heater	1400
Minimum design withstand coil voltage at nominal operating conditions (V)	To ground	3300
	To quench heater	3300
Minimum design withstand coil voltage at warm*(1) (V)	To ground	5000*(2)
	To quench heater	3300*(3)
Test voltage to ground for installed systems at nominal operating conditions (V)		2100*(4)
Test voltage to ground for installed systems at warm (V)		660
Test voltage to heater for installed systems at nominal operating conditions (V)		1680
Test voltage to heater for installed systems at warm (V)		660
Maximum leakage current (μA) – not including leakage of the test station		30
Test voltage duration (s)		120

The maximum leakage current and the test voltage duration needs to be defined after tests.

*(1) T = 20±3 °C and humidity lower than 60%

*(2) Agreed limitation with the designers of the magnets.

*(3) Value agreed due to limitations given by the insulation thickness, considered as enough to cover the failure mode developing across this insulation.

*(4) Value addapted to meet the RB chain requirements

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