Electrical Quality Control (QC): coil to coil parts

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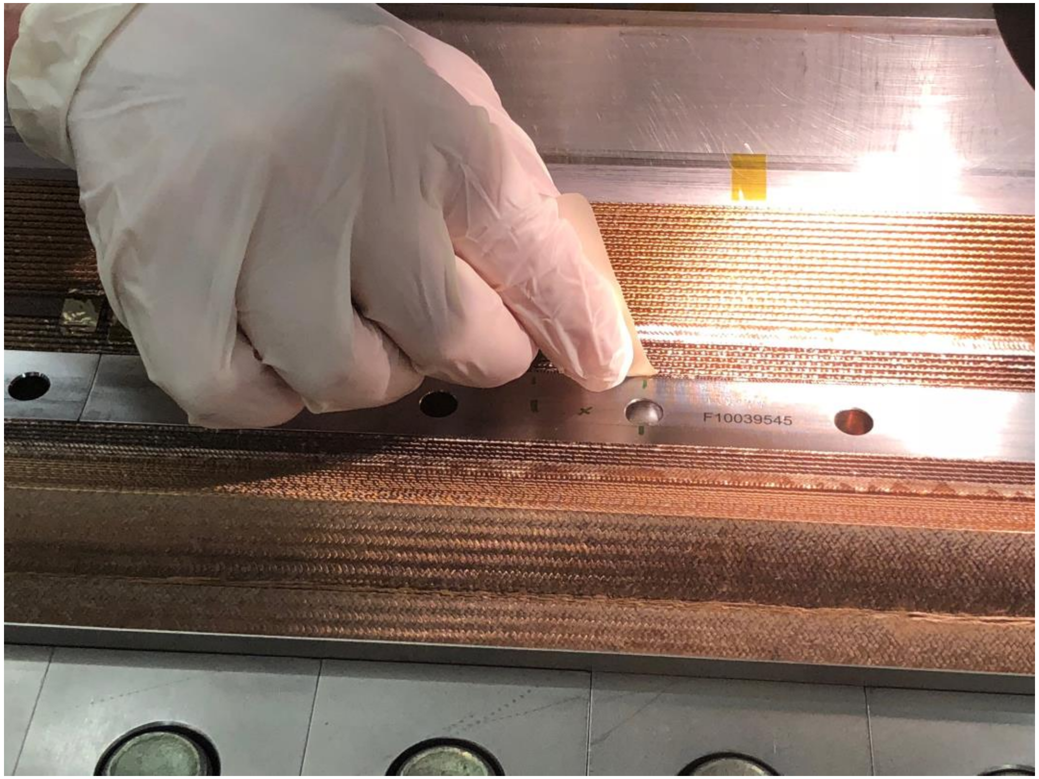
Main electrical issues with coil parts

- Before coil impregnation, resistance between coil and coil parts (pole, end-shoe) is measured
  - Sometimes resistance < 1 GΩ can be observed
- Different causes/mechanisms have been identified
- Really difficult to determine if contact points are more than one
- Sometimes not possible to repair
- Question: which resistance can we consider the safe limit?
  - We want to discuss and re-define our electrical QC criteria for coil parts based on the analysis we are going to present (not available before now)

Example: coil QXFA108

- Showed 170 kΩ resistance to pole before epoxy impregnation
  - Short location identified
  - Tried to repair, with no good results
  - Large contact area → **binder** issue



Present QC tests

QXFA Coil Fabrication Electrical QA
HiLumi doc 521

- HiPot Coil – pole : 500 V
- HiPot Coil – end-shoe: 1000 V
- HiPot end-shoe – end-shoe: 1000 V

- Peak voltages:
  - Pole turn – pole turn: ~ 50 V for MQXFA and MQXFB
  - Midplane turn – midplane turn: ~ 300 V for MQXFA, ~ 500 V for MQXFB

- Options for updated QC criteria:
  - Criterion 1: HiPot at V_max * f + c
    - V_max = maximum voltage during a quench
    - f,c = ? - typical values are f = 2 and c = 500 V
    - Note: c = 500 V looks excessive if V_max = 50
  - Criterion 2: Resistance measurement, after defining minimum acceptable resistance based on power dissipation

Target for criterion 2

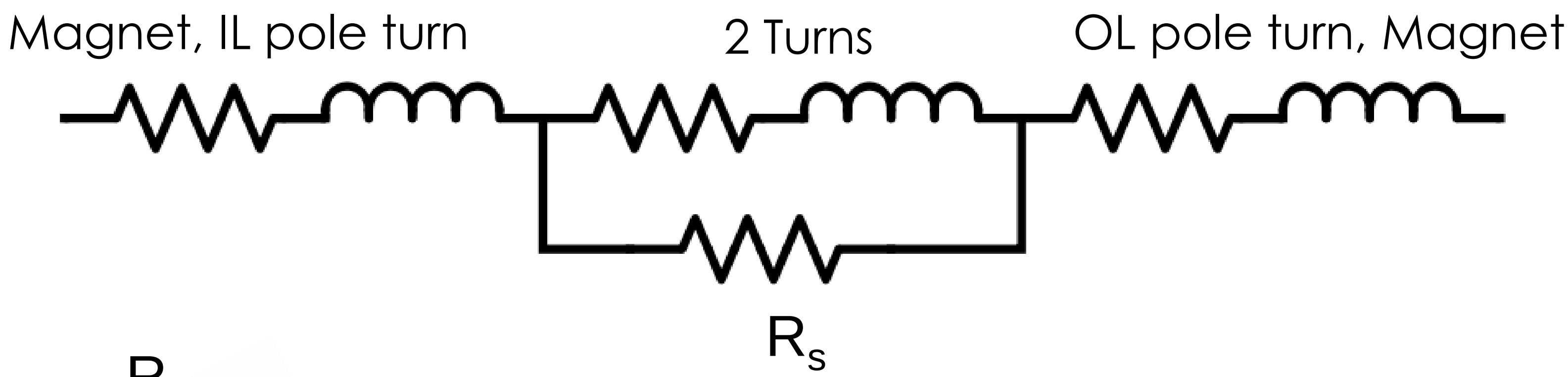
- Identify risks due to short between coils and parts. Evaluate minimum acceptable short resistance
  - Goal: try to avoid high-voltage hipots with coil parts
  - Needed: simulations of coil-parts shorts

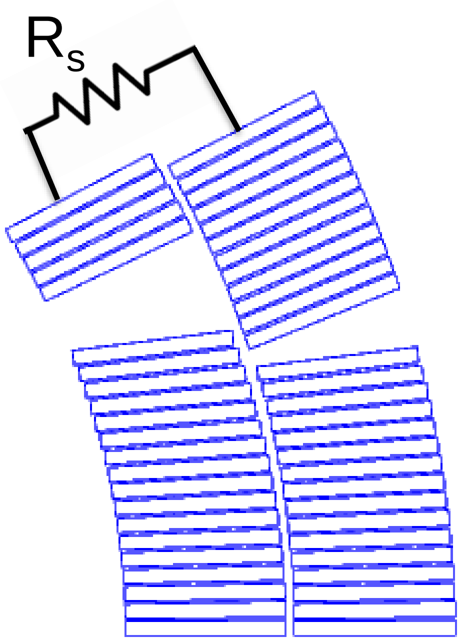
- Cases considered:
  - Short from IL pole-turn to OL pole-turn through the pole
  - Short from IL midplane-turn to OL midplane-turn through the end-shoe
  - Simulations done for MQXFA and MQXFB in nominal protection system (with CLIQ and OL heaters, and no dump)
  - Single shorts could be considered not worrying
    - But, it is difficult to identify them

Assumptions for simulations

- Simulations performed with STEAM
- Current: 17980 A (ultimate)
- No dump resistor
- Quench heaters: Outer Layer (600 V MQXFA, 900 V MQXFB)
- CLIQ:
  - 600 V, 40 mF for MQXFA
  - 1000 V, 40 mF for MQXFB
- Nominal conductor parameters
- Constant short resistance
  - Measured at warm

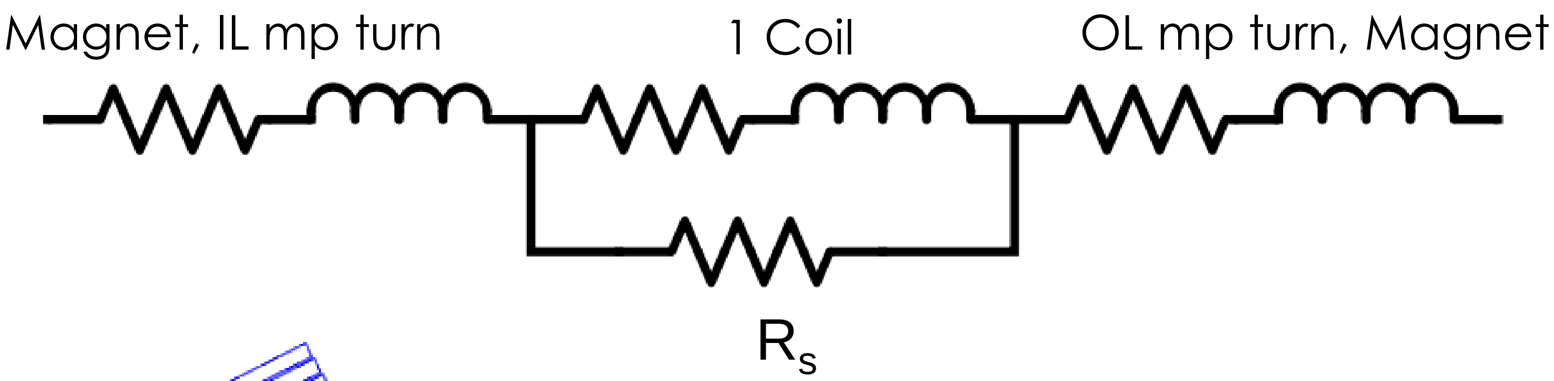
Short from IL pole-turn to OL pole-turn through the pole

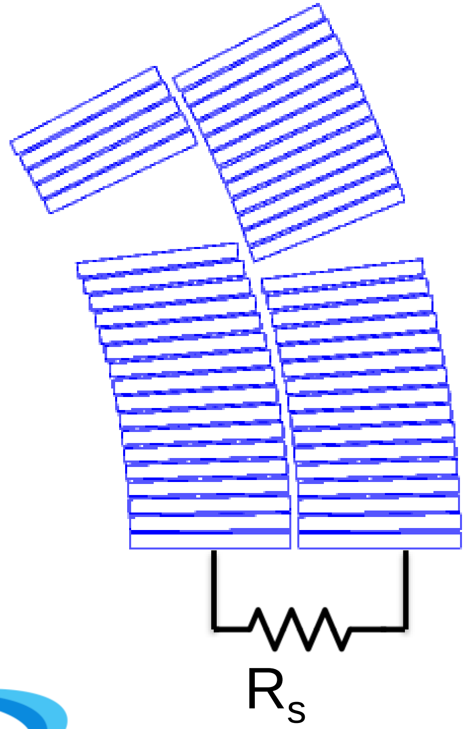




R_s	10 Ω, 1 kΩ, 0.1 MΩ, 10 MΩ, 1 GΩ

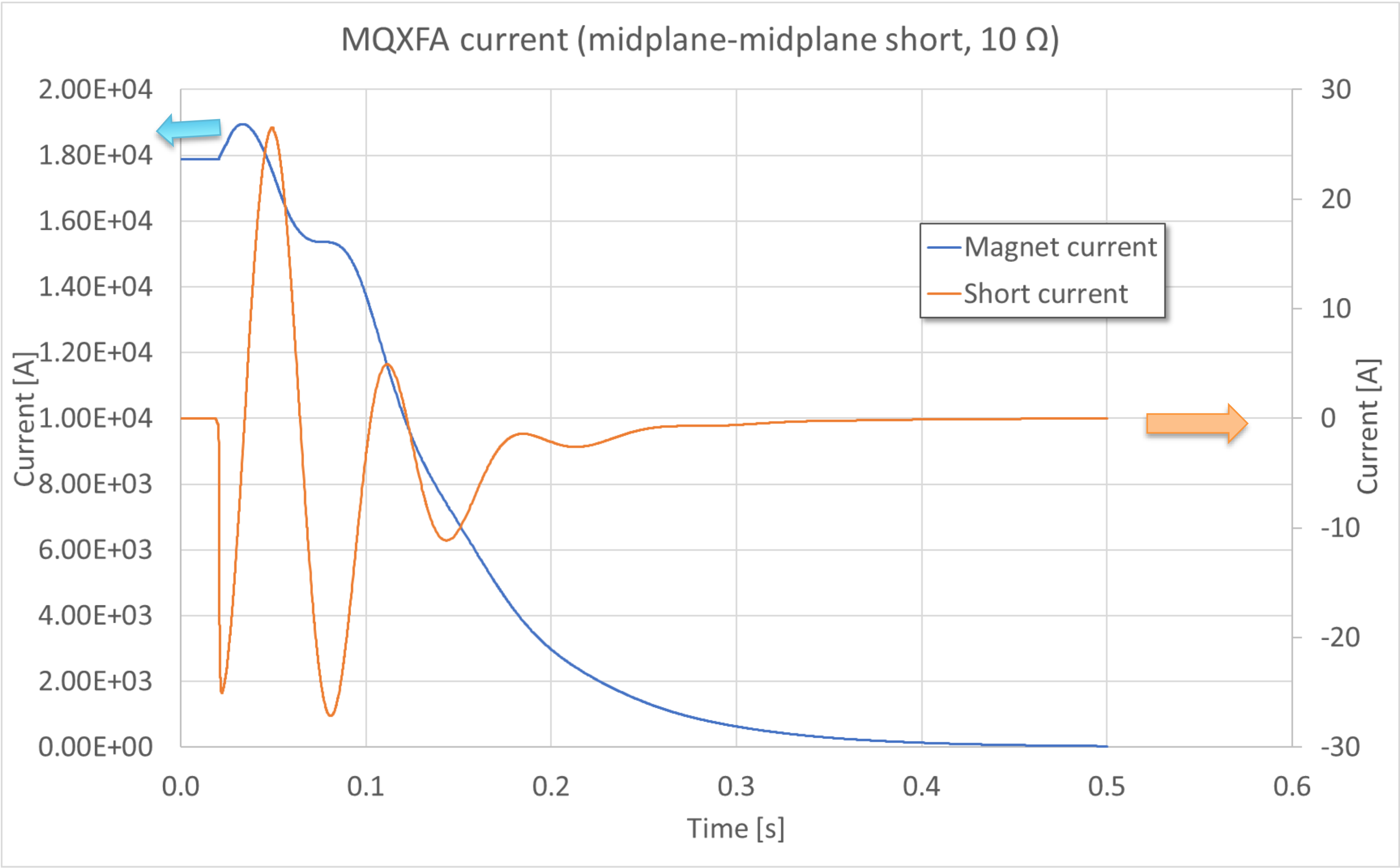
Short from IL midplane-turn to OL midplane-turn through the end-shoe





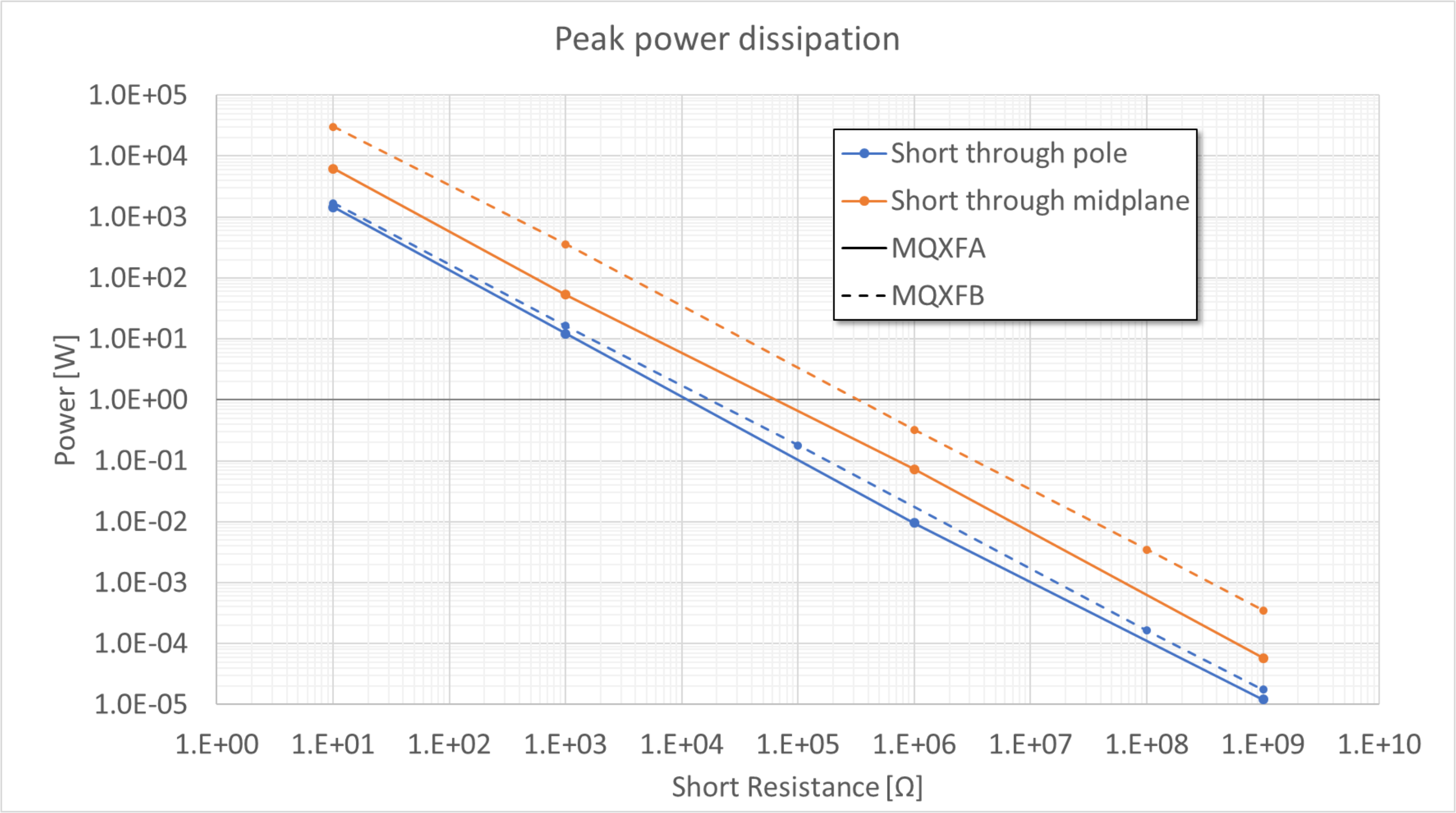
R_s	10 Ω, 1 kΩ, 0.1 MΩ, 10 MΩ, 1 GΩ

Example of Current Discharge



Possible criteria: peak power dissipation

- Define a maximum acceptable peak power dissipation, in order to define minimum acceptable resistance between coil and parts



Examples of power criterion

- Maximum peak power dissipation is set to **10 mW**. Coils are accepted if:
  - Resistance to pole is greater than **1 MΩ** for MQXFA, **2 MΩ** for MQXFB
  - Resistance to end-shoe is greater than **7 MΩ** for MQXFA, **30 MΩ** for MQXFB

- Maximum peak power dissipation is set to **1 mW**. Coils are accepted if:
  - Resistance to pole is greater than **10 MΩ** for MQXFA, **20 MΩ** for MQXFB
  - Resistance to end-shoe is greater than **70 MΩ** for MQXFA, **300 MΩ** for MQXFB

- Possible criterion to choose maximum power:
  - Typical hipot voltage *x* typical leakage current: 1000 V x 10 μA = **10 mW**

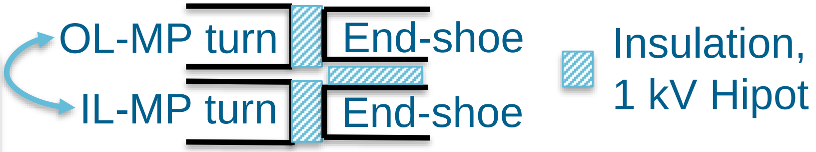
US HL-LHC AUP

Some discussion

- Criterion based on power dissipation through a short can be suitable for coil to pole
  - Likely, contact resistance due to binder, with “large” contact area
  - We had coil-pole shorts in the past magnet tests, with no issues during powering tests

- Criterion based on power dissipation may be unsuitable for coil to end-shoe
  - Possibly, short due to damage of the insulation due to sharpness of end-shoe, with small contact area and difficulty of evaluation of power density and temperature increase
  - Hi-pot may be best solution, even though the present 1 kV level could be revised, considering also that there are three layers of insulation from IL to OL midplane turns through end-shoes, and that each coil shall pass Impulse test at 2.5 kV.

Peak voltage: 300 – 500 V
Impulse test: 2.5 kV



Proposed QC tests and criteria (to be discussed):

- **Coil to pole resistance**
  - **> 1 MΩ** for MQXFA
  - **> 2 MΩ** for MQXFB
  - Power dissipation < 10 mW in case of double short

- **Coil to End-Shoe HiPot,** and
- **IL End-Shoe to OL End-Shoe HiPot** at
  - **300 V** for MQXFA
  - **500 V** for MQXFB
  - Redundancy provided by having three layers of insulation between midplane turns through end-shoes; direct path tested during impulse test at 2.5 kV

- More ideas?

Thank you