THERMAL STABILITY OF THE NEW ESRF EXTREMELY BRILLIANT SOURCE

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Instabilities
**Instabilities**

1. Permanent static errors from the origin
2. Permanent variable errors (quick effects)
3. Errors triggered by beam operation
4. Long period errors
INTRODUCTION

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 mechanical source effects
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- Longitudinal tunnel air-cooling temperature rise of ~2°C along a tunnel quarter

- Mechanical source effects
- Thermal source effects
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Errors observed, compensated, operated for 20 years.

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electromagnets, cables, RF, absorbers

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**Cooling systems**
- air ventilation, water cooling

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### Exterior perturbations
- Exp. hall and groundwater temperatures

### Cooling systems
- Air ventilation, water cooling

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EBS ELECTROMAGNETS

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very first CFD model (very simplified)

3D ¼ tunnel ventilation → velocity field → 3D more local
post processing

second CFD and thermal model (finer)

Heat transfer analysis: forced convection

compared with natural convection
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3D ¼ tunnel ventilation → Post processing → Velocity field → Inserted in → 3D more local

Second CFD and thermal model (finer)

Heat transfer analysis: forced convection compared with natural convection

Inner volume of electromagnets: natural convection is predominant
• Each coil dissipates 500W of heat (2000W total)
• Coils are water cooled in parallel
  0.45L/min
  Tinlet = 24°C
  Toutlet = 40°C
• Air: only natural convection is considered
  Tambient considered constant at 24°C
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convective coefficient computed with Nusselt correlation (natural convection)

Tcoil = 40°C
gravity forces

local convective coefficients computed all along inside surfaces of the quadrupole
• Local convective coefficients from 2D model: into a 3D model
• A part of the girder is modeled
• Same boundary conditions than 2D model, but without CFD and assuming ground temperature at 24°C
• Initially, quadrupole at 24°C
EBS QUADRUPOLE – TEMPERATURE

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Temperature field [°C]

Average temperature: 25.4°C (+1.4°C from initial value)
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Average temperature (yoke & poles) [°C] against time [d]

Steady state reached after: $5\tau \sim 1.5$ days
Time constant $\tau \sim 0.3$ day

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time constant of ~0.3 day

temperature increase by ~1°C
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observed experimentally 😊
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- Temperature increase by \(~1°C\) observed experimentally 😊
- Temperature increase by \(~1°C\) not observed experimentally 😞 (actually it is +3°C)
EBS QUADRUPOLE – HEAT BALANCE

Diagram showing heat balance of a quadrupole: 2.8W (holders), 6.7W (air), 3.9W, 2.1W, 0.3W to Concrete ground. 8.3W (spacers), 3.9W, 1.8W to Air exterior. 16.3W.
EBS QUADRUPOLE – HEAT BALANCE

- Coils → Quadrupole:
  - 17.7W in
    - 46.9% from spacers
    - 53.1% from air
  - 9.5W out
    - 29.5% from holders
    - 70.5% from air
- 24.2W in air (1.2% of the total heat in coils)
- 0.3W in ground

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**EXP. magnet more than twice as deep as the FEA one**
more heat added to quadrupole
more investigations to do
EBS QUADRUPOLE – THERMOMECHANICAL DISPLACEMENTS

Continuity
EBS QUADRUPOLE – THERMOMECHANICAL DISPLACEMENTS

Continuity

Contacts

Displacement = 0
Full scale mock-up girder prototype with power cables inside
GIRDER MOCK-UP

Full scale mock-up girder prototype with power cables inside
Why cables inside the girder?
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- might be dangerous (girder deformation due to the heat)
- difficult to implement
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Why cables inside the girder?

mainly for space savings reasons

But: • might be dangerous (girder deformation due to the heat)
  • difficult to implement

Mock-up:
• probed with several PT100
• girder is isolated by walls and ceiling to reproduce a cell of the storage ring
• fan is integrated
GIRDER MOCK-UP – TEMPERATURE PROBES

Power and ventilation Transient phase at Chartreuse test model

- Concrete floor left side
- Concrete floor right side
- Lower side girder
- Top side girder
- Girder probes
- Floor probes

Ventilation cut and power on cables still cut

Time scale [days] in July - August 2016
EBS girder thermal behaviour at Chartreuse test model

- No Ventilation on tunnel this period
- Experiment hall general ventilation restart
- Ventilation cooling start at 25% of nominal flow
- Start 100% nominal flow

Temperature measurement [°C]

Lower girder downstream
Upper girder downstream

Timescale [days during August 2016]
• Cables inside the girder: abandoned
CONCLUSION

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  → preventing heat source to affect relevant parts of the system (ex: coils)
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  → listening all heat sources (RF, cables and absorbers already under investigations)
  → influence of concrete on storage ring thermal stability?
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THANK YOU FOR YOUR ATTENTION