CERN experience and strategy for the maintenance of cryogenic plants and distribution systems

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outline

• Introduction
  – CERN and its cryogenic infrastructure
  – The Large Hadron Collider

• Review of operation and maintenance activities
  – Schedule, scenarios and strategy
  – Operation and maintenance methodology

• Maintenance experience
  – Spare parts management
  – Review of the last five years

• Conclusions
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## CERN accelerator complex

<table>
<thead>
<tr>
<th>T level</th>
<th>Installed capacity</th>
<th># of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 K</td>
<td>5 MW</td>
<td>9</td>
</tr>
<tr>
<td>4.5 K</td>
<td>164 kW</td>
<td>23</td>
</tr>
<tr>
<td>20 K</td>
<td>60 W</td>
<td>2</td>
</tr>
<tr>
<td>1.8 K</td>
<td>19.6 kW</td>
<td>9</td>
</tr>
<tr>
<td>300 mK</td>
<td>350 mW</td>
<td>1</td>
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</tbody>
</table>

(CERN Large Hadron Collider and related infrastructure map)
23 km of high-field superconducting magnets operating in superfluid helium at 1.9 K
The LHC cryogenic system and infrastructure

- 8 x 18 kW @ 4.5 K units
- 8 x 2.4 kW @ 1.8 K units
- 5 underground interconnection boxes
- 155 t of helium
- 6 & 1.5 kW @ 4.5 K units for detectors
Now operating at 13 TeV

Francois Englert
Peter W. Higgs

for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN’s Large Hadron Collider”
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Schedule and scenarios

• Continuous operation over the year
  – By CERN’s staff
  – With the support of industrial contractors for
    • Routine operation
    • Maintenance and spare parts management

• Few short technical stops for critical corrective maintenance interventions

• Preventive maintenance performed
  – During one month yearly shutdowns
  – Or every four to five years during major year-long shutdowns
Effective maintenance program

• Progressively implemented for the LHC and retroactively for older installations

• Supported by a Computer Aided Maintenance Management System
  – Infor EAM™
    • Assets inventory and management
    • Maintenance Procedures and documentation management
    • Spare parts analysis and management
    • Work management, control and optimization via KPIs

• Since 1994 partnership with industry to perform the preventive and corrective maintenance of the cryogenic infrastructure
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Continuous review of the required spares to optimize inventory based on criticality

- frequency, number and type of used spares,
- procurement delays and detectability of the fault,
- installed quantities and cost.
Review of the last years activities

**Major overhauls ~ 4% of compressors capital cost per year of operation**
The major long shutdown (LS1) 1/2

Major shutdown (2013 – 2014) after 40’000 h of operation

• More than 5000 Work Orders
• Required: Major overhauls and mechanical preventive maintenance
• Reduced: Instrumentation preventive maintenance (only key systems, e.g. interlocks)

<table>
<thead>
<tr>
<th>type</th>
<th>quantity</th>
<th>unit</th>
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<tbody>
<tr>
<td>Joints O-ring</td>
<td>3769</td>
<td>pc</td>
</tr>
<tr>
<td>Other joints</td>
<td>2919</td>
<td>pc</td>
</tr>
<tr>
<td>Filtration cartridges</td>
<td>613</td>
<td>pc</td>
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<tr>
<td>Oil filters</td>
<td>311</td>
<td>pc</td>
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<tr>
<td>Couplings greasing kits</td>
<td>154</td>
<td>pc</td>
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<tr>
<td>Signal transducers</td>
<td>146</td>
<td>pc</td>
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<tr>
<td>Temperature sensors</td>
<td>35</td>
<td>pc</td>
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<tr>
<td>Maintenance kits pumps</td>
<td>47</td>
<td>pc</td>
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<tr>
<td>Activated charcoal</td>
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<td>kg</td>
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<td>Compressors Breox® oil</td>
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<td>l</td>
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<tr>
<td>Pumps oil</td>
<td>919</td>
<td>l</td>
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<tr>
<td>Cleaning acid</td>
<td>1625</td>
<td>l</td>
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<td>Solvent</td>
<td>139</td>
<td>l</td>
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</table>

<table>
<thead>
<tr>
<th>type</th>
<th>quantity (pc)</th>
</tr>
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<tbody>
<tr>
<td>Major overhauling</td>
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<td>Screw compressors</td>
<td>57</td>
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<tr>
<td>Oil pumps</td>
<td>27</td>
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<tr>
<td>Electrical motors</td>
<td>81</td>
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<tr>
<td>Electrical motors (replaced)</td>
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<tr>
<td>Mechanical</td>
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<tr>
<td>Safety valves revision and test</td>
<td>2000</td>
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<tr>
<td>Coalescers inspected</td>
<td>94</td>
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<tr>
<td>Adsorbers treated</td>
<td>12</td>
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<tr>
<td>Chemical cleaning</td>
<td>28</td>
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<tr>
<td>Instrumentation inspections and revisions</td>
<td></td>
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<tr>
<td>Valves</td>
<td>288</td>
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<tr>
<td>Sensors</td>
<td>2000</td>
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<tr>
<td>Transducers</td>
<td>3500</td>
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<tr>
<td>Vacuum</td>
<td></td>
</tr>
<tr>
<td>Pumps revision</td>
<td>200</td>
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<tr>
<td>Gauges revision</td>
<td>235</td>
</tr>
<tr>
<td>Vacuum valves revision</td>
<td>29</td>
</tr>
</tbody>
</table>
Normal and abnormal wear of rotating machinery, filters
Maintenance of all control valves
Visual inspection of all coalescers cartridges and replacement where needed
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Conclusions 1/2

After two years of consolidation and maintenance work the LHC has started a new physics campaign that will last almost four years.

In parallel CERN is working towards the upgrade of the machine to reach an integrated luminosity of 3000 fb$^{-1}$

**New LHC / HL-LHC Plan**
• CERN has accumulated a significant amount of data for the maintenance and operation of large cryogenic plants and distribution systems based on CAMMS and KPIs.

• To be effective maintenance needs solid bases in terms of analysis, methodology, documentation and procedure.

• The review of the maintenance plans and required spares appears in line with standard practice to guarantee a cost effective and high reliability and availability of the machine.