European standardization activities on safety of liquid helium cryostats

Steffen Grohmann
Cryogenic Safety Seminar, CERN, September 21-23, 2016
Outline

- Safety of pressure equipment – What is special in LHe cryostats?
- Brief review of a national standardization project (2010 – 2015)
- European standardization project
- Cross-link among projects
Safety of pressure equipment

WHAT IS SPECIAL IN LHe CRYOSTATS?
Safety of cryogenic pressure equipment

- Cryogenic installations usually contain **pressure vessels** subject to the European PED 2014/68/EU \( \{P > 0.5 \text{ bar(g)}\} \)
  - **Storage containers** [static, transportable, (non-)vacuum insulated]: Dedicated standards such as EN 13458, EN 13648, … (→ H. Barthélémy)
  - **LHe cryostats**: No dedicated safety design standard/rule

- **LHe cryostat** conditions **not covered** by other standards:
  - Necessity of staging multiple safety levels, e.g. for quench recovery
  - Large stored energies, loss of insulating vacuum
  - 3 % rule (inlet piping pressure drop) and 0.6 m rule (heat loads)
  - Thermal acoustic oscillations
  - Two-phase flow
  - Electric arcs
  - Helium discharge in confined spaces
  - …
What is special in LHe cryostats?

- Process dynamics
  - Large heat fluxes of several W/cm² during failures
  - Very low latent heat of helium $\frac{\Delta h_v}{L \text{ liquid}}_{1\text{bar}}$ (He : N₂ : H₂O) = 1 : 62 : 835
- Nearly instantaneous evaporation
- Pressure gradients in the range of (bar/s)

Quench test of a sc. solenoid (KATRIN)
### What is special in LHe cryostats?

<table>
<thead>
<tr>
<th>Common pressure equipment</th>
<th>Liquid helium cryostats</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cryogenic storage containers</td>
<td>• Sc. magnet cryostats, RF cavities</td>
</tr>
</tbody>
</table>
| • Protection against **disruptive failure**  
  ➢ **Extreme** and **rare** failure scenarios | • Protection against **disruptive failure**  
  ➢ **Extreme** and **rare** failure scenarios |
|  | + Protection against **operation failure**  
  ➢ **Expected** and **frequent** failure scenarios (**quenches**)  
  ➢ Need of **staging** safety levels! |
| • Standardized task (limited complexity) | • Large number **papers**, individual **reports** and **experience**  
• **BUT** no systematic guideline |
|  | • Individual and **complex** design task |
## Examples of typical safety units

<table>
<thead>
<tr>
<th>LN2 storage tank ($\approx 50,000$ L)</th>
<th>Liquid helium cryostat ($\approx 500$ L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Set pressure $p_0 = 17$ bar(g)</td>
<td>• Safety valve DN25 at $p_0 = 2$ bar(g)</td>
</tr>
<tr>
<td>• Two safety valves 1/2” ($d_0 = 7$ mm)</td>
<td>• Two rupture disks DN65 at $p_0 = 3$ bar(g)</td>
</tr>
<tr>
<td>• Shuttle valve</td>
<td>• Quench gas line DN100</td>
</tr>
</tbody>
</table>

Source: Air Liquide

Source: KATRIN
Safety of liquid helium cryostats

NATIONAL STANDARDIZATION PROJECT
(2010 – 2015)
## Contributions

### Industry

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blum, Lars</td>
<td>Linde Kryotechnik AG</td>
</tr>
<tr>
<td>Otte, Wolfgang</td>
<td>Air Liquide Deutschland GmbH</td>
</tr>
<tr>
<td>Reinhardt, Matthias</td>
<td>Herose GmbH</td>
</tr>
<tr>
<td>Schulenberg, Olaf</td>
<td>Goetze KG Armaturen</td>
</tr>
</tbody>
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### Universities and Research Centers

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grohmann, Steffen</td>
<td>Karlsruhe Institute of Technology</td>
</tr>
<tr>
<td>Haberstroh, Christoph</td>
<td>Technical University Dresden</td>
</tr>
<tr>
<td>Heidt, Carolin</td>
<td>Karlsruhe Institute of Technology</td>
</tr>
<tr>
<td>Raccanelli, Andrea</td>
<td>Research Center Jülich GmbH</td>
</tr>
<tr>
<td>Schröder, Claus</td>
<td>GSI Gesellschaft für Schwerionenforschung mbH</td>
</tr>
<tr>
<td>Süßer, Manfred</td>
<td>Karlsruhe Institute of Technology</td>
</tr>
</tbody>
</table>

### Organization

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lau, Markus</td>
<td>German Institute for Standardization (DIN)</td>
</tr>
</tbody>
</table>
Workout of a DIN SPEC

- Technical **guideline** rather than a standard
- Can be the basis for a consensus-based standardization process

- Publication of the DIN SPEC 4683 in 04/2015
Safety of liquid helium cryostats

EUROPEAN STANDARDIZATION PROJECT
European standardization project

- Satellite meeting at European Cryogenics Days 2015 (Grenoble)
  - Agreement to advance a European standardization process
  - Translation of DIN SPEC 4683 and CEA documents

- Inconsistent nomenclature in different standards

prEN 4683:2015
Working document (07/2016)
Present contents of prEN 4683:2015

(1)…(4) Scope, references, terms…
(5) Hazard analyses, risk assessment and safety concept
(6) Scenarios of pressure increase
(7) Dimensioning of safety relief devices
(8) Design and operation of safety relief devices and safety units
(9) Release of the working fluid
(10) Commissioning, maintenance
(11) Materials for safety relief devices
+ 10 Annexes = 84 Pages

Presentations in this seminar

→ Thomas Otto, Duy Phan, Gunnar Lindell, Hans Guenter Mueller, Vladislav Benda, Ruggero Pengo, Luca Dassa, Carlos Arregui Rementeria, Stefan Rath

→ Carolin Heidt, Eric Ercolani, Jaroslaw Polinski, Maciej Dziewiecki,

→ Andre Henriques, Sebastian Protz, Jean-Marc Poncet, Eric Ercolani, Christina Weber, Jürgen Schmidt, Quang Dang Le, Ziemowit Malecha

→ Vittorio Parma, Fridolin Holdener

→ Ziemowit Malecha, Thorsten Koettig

→ Simon Marsh

Organizational/strategic talks:
Carlos Arregui Rementeria, Zoe Lawson, Simon Marsh, Hervé Barthélémy
Aim of the European standard

- Collect, structure and harmonize state-of-the-art rules, procedures and know-how from labs, institutes and companies in Europe.

- Provide a comprehensive overview on all major aspects of safe design and operation of liquid helium cryostats.

- Solve conflicts with other standards by the indication of alternative options.

- Provide the first international standard on safety of LHe cryostats.

- European standards are produced by all interested parties through a transparent, open and consensus based process.
Project organization

- Establishment of a **new working group** at CEN/TC 268 – *Cryogenic vessels and specific hydrogen technologies applications*
  - Chairperson: Dr. Hervé Barthélémy, Air Liquide
  - Link: [CEN/TC 268](#)

<table>
<thead>
<tr>
<th>WG 1</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>WG 2</td>
<td>Compatibility, insulation, accessories</td>
</tr>
<tr>
<td>WG 3</td>
<td>Operational requirements</td>
</tr>
<tr>
<td>WG 4</td>
<td>Fundamental requirements</td>
</tr>
<tr>
<td>WG 5</td>
<td>Specific hydrogen technologies applications</td>
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<td>+</td>
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<tr>
<td>WG 6</td>
<td>Liquid helium cryostats</td>
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</table>
Formal procedure to start the project

- DIN sends **new work item proposal** to CEN/TC 268
- **Secretariat** verifies proposal and sends inquiry within CEN/TC 268
  - Typical deadline for response 4-6 weeks

- **National Standardization Bodies** contact their experts concerning relevance and participation
  - Some countries have **mirror committees** of CEN/TC 268, some countries don’t…
  - Make sure you get registered at your National Standardization Body as a participating expert
  - Your National Standardization Body will delegate you later to the new WG

- The National Standardization Bodies vote at the end of the deadline
  - For the project approval, at least 5 participating countries must indicate active members with their names
Expert registration

Example for individual registration at the National Standardization Body

Dear Mr. André Henriques

Your registered data have been modified in the Global Directory.

You are informed of the following modifications which have been made to the Global Directory data. If you have any questions regarding the reason for such modifications, please contact the CEN Helpdesk.

<table>
<thead>
<tr>
<th>Report</th>
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<tbody>
<tr>
<td>Person</td>
</tr>
<tr>
<td>Henriques, André Mr</td>
</tr>
</tbody>
</table>

This email was sent by the CEN Business Events Notifications application. If you no longer want to receive this email notification, please click here.

If you want to participate, please register and send me a confirmation

- Contact: steffen.grohmann@kit.edu
- DIN files the new work item proposal once experts from 5 countries have registered
Project planning

- Project management by WG secretariat at DIN (Berlin)

- Kick-off meeting in early 2017
  - Doodle poll among participating experts

- Two project meetings/year

- Finalization of the working draft in ≤ 3 years

- Submission to TC chairperson and TC secretary for CEN Enquiry
Safety of liquid helium cryostats

CROSS-LINK AMONG PROJECTS
Horizon 2020 project

- **Approval** of EU project:
  - *Accelerator and Magnet Infrastructure for Cooperation and Innovation (AMICI)*
  - **Aim:** Knowledge transfer
  - **Coordination:** CEA Saclay
  - **10 participating organizations**

<table>
<thead>
<tr>
<th>1</th>
<th>CEA</th>
<th>FRANCE</th>
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<tbody>
<tr>
<td>2</td>
<td>CERN</td>
<td>SWITZERLAND</td>
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<td>3</td>
<td>DESY</td>
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<td>SWITZERLAND</td>
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<tr>
<td>10</td>
<td>KIT</td>
<td>GERMANY</td>
</tr>
</tbody>
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- **WP5.3:** Harmonization – Cryogenic safety procedures
  - KIT, CEA, CERN
  - Cross-link to the new working group at CEN/TC 268
Thank you for your attention!