A new European Standard for the protection of helium cryostats against excessive pressure

Steffen Grohmann, Convenor of CEN/TC 268/WG6
On behalf of the working group

CEC-ICMC 2019, Hartford, CT, 21-25 July 2019
Outline

- Motivation
- Working group CEN/TC 268/WG6
- Scope and structure of the new Standard
- Example content
- Summary and outlook
Motivation

Helium dewars vs. helium cryostats

- Strong influence on potential risk of excessive pressure
- Helium cryostats have active components
  - Sc. magnets
  - Sc. RF cavities
  - Heat exchangers
  - Valves
  - Flexible hoses
  - Pumps

E.g. European
- Machine Directive 2006/24/EC
- Low-voltage Directive 2014/35/EU
- EN 1626
- EN 12434
- EN 24490

No dedicated Standard existing that covers the conditions in helium cryostats and which is harmonized with the European PED.

ISO 21009 (substituting EN 13458)
- Cryogenic vessels – Static vacuum insulated vessels

Source: [https://www.3sioni.enea.it](https://www.3sioni.enea.it)
New working group

CEN/TC 268 - Cryogenic vessels

CEN/TC 268 Scope

Standardization in the field of insulated vessels (vacuum or non-vacuum) for the storage and the transport of refrigerated liquefied gases, as defined in Class 2 of "Recommendations on the Transport of dangerous goods - Model regulation", in particular concerning the design of the vessels and their safety accessories, gas/materials compatibility, insulation performance, the operational requirements of the equipment and accessories. The one-off preparation of standards for hydrogen technologies strictly meeting the European mandate on the draft Directive deployment of alternative fuels infrastructure.

CEN/TC 268 Subcommittees and Working Groups

<table>
<thead>
<tr>
<th>Working group</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEN/TC 268/WG 1</td>
<td>Design</td>
</tr>
<tr>
<td>CEN/TC 268/WG 2</td>
<td>Compatibility, insulation, accessories</td>
</tr>
<tr>
<td>CEN/TC 268/WG 3</td>
<td>Operational requirements</td>
</tr>
</tbody>
</table>

Aim of CEN/TC 268/WG6:

New European Standard on „Helium Cryostats – Protection against excessive pressure“

Officers

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chairperson</td>
<td>Dr Hervé Barthélémy</td>
</tr>
<tr>
<td>Secretary</td>
<td>Ms Laurie Jardel</td>
</tr>
</tbody>
</table>
Experts contributing to CEN/TC 268/WG6

S. Grohmann
KIT

H. Barthélémy
Air Liquide

DIN

CEA

R. Down
STFC

E. Ercolani
Uni Grenoble, CEA

J.-L. Fournel
Air Liquide

A. Henriques
CERN

AFNOR

M. Krichler
Bilfinger Noell

W. Otte
Air Liquide

V. Parma
CERN

R. Pengo
INFN

J.-M. Poncet
Uni Grenoble, CEA

Herose

R. Soika
Linde Kryotechnik

R. Vallcorba-Carbonell, CEA

C. Weber
KIT

DIN

Air Liquide

C. Zoller
PSI
Scope and concept of the new Standard

The **scope** includes:

- a) Superconducting magnet cryostats
- b) Superconducting RF cavities
- c) Ultra-low $T$ refrigerator systems using $^3$He and $^3$He/$^4$He mixtures
- d) Coldboxes of helium refrigerators and liquefiers
- e) Helium distribution systems including valve boxes

**Overall concept**

- Standardization of the **approach** of how to obtain state-of-the-art protection
- Specification of **procedure** and **minimum requirements** in the **main part**
- Alternative/advanced methods, additional information, example solutions, exemplary measures in extensive **Annex**
## Structure of the main part

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>European foreword</td>
<td>3</td>
</tr>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>1 Scope</td>
<td>5</td>
</tr>
<tr>
<td>2 Normative references</td>
<td>5</td>
</tr>
<tr>
<td>3 Terms and definitions</td>
<td>5</td>
</tr>
<tr>
<td>4 Symbols</td>
<td>10</td>
</tr>
<tr>
<td>5 Process flow-chart</td>
<td>14</td>
</tr>
<tr>
<td>6 Risk assessment</td>
<td>16</td>
</tr>
<tr>
<td>7 Protection concepts</td>
<td>21</td>
</tr>
<tr>
<td>8 Dimensioning of pressure relief devices</td>
<td>25</td>
</tr>
<tr>
<td>9 Pressure relief devices</td>
<td>41</td>
</tr>
<tr>
<td>10 Substance release</td>
<td>43</td>
</tr>
<tr>
<td>11 Operation of helium cryostats</td>
<td>44</td>
</tr>
</tbody>
</table>
6 Risk assessment

Definition of 15 risk scenarios as „sources of excessive pressure“

<table>
<thead>
<tr>
<th>Loss of insulating vacuum</th>
<th>Loss of beamline vacuum</th>
<th>Leak of cryogenic fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quench of sc. device</td>
<td>Dielectric breakdown</td>
<td>Thermal acoustic oscillation</td>
</tr>
<tr>
<td>Cryopumping</td>
<td>Entrapment of cryogenic fluid</td>
<td>Power failure</td>
</tr>
<tr>
<td>Pressure surge</td>
<td>Freezing</td>
<td>Backflow</td>
</tr>
<tr>
<td>Other sources</td>
<td>Earthquake</td>
<td>Fire</td>
</tr>
</tbody>
</table>

- Relevant for dimensioning (others t.b. mitigated)

Three phases of risk assessment

1) Risk assessment before ordering (qualitative, HAZOP or equiv. method)
2) Risk assessment in the design phase (quantitative, FMEA or equiv. method)
3) Evaluation of risks by the end-user (National implementations of EU Health and Safety at Work Directive 2009/104/EC)
7 Protection concepts

- Single-stage protection concept as minimum requirement

- Multi-stage protection concepts
  - Primary PRD completely fulfills the pressure protection at the maximum allowable pressure $p_s$ in compliance with the PED and based on the MCI
  - Secondary PRD at either $p_0 < p_s$ or $p_0 > p_s$, either in series or in parallel
  - Particular requirements for five types of helium cryostats
    1) High-pressure superconducting magnet cryostats
    2) Low-pressure helium cryostats, such as superconducting RF cavities
    3) Sub-atmospheric helium cryostats
    4) He-II cryostats
    5) Ultra-low temperature refrigerator systems
Dimensioning of pressure relief devices

The dimensioning of PRD is generally based on:
- Mass-specific energy/momentum conservation + continuity equation for one-dimensional, frictionless, compressible, steady-state and adiabatic fluid flow through short nozzles (with correction factors for non-ideal behavior)

Basic equation:

\[ A_{th} = \frac{\dot{M}}{\rho_{th} \cdot c_{th}} \]

- \( \dot{M} \) relieving mass flow rate \( \rightarrow \) from the heat load in different risk scenarios
- \( \rho_{th} \) density in the throat
- \( c_{th} \) velocity in the throat
- \( \dot{m}_{th} \) mass flux \( \rightarrow \) two types of models
8 Dimensioning of pressure relief devices

Homogeneous equilibrium model (HEM or G-model)

- No case definition in throat needed
- One equation, few operations
- Software for calculation needed (MS Excel sufficient)
- Access to helium EoS needed

Case-specific model

- Simpler, but more individual calculations steps
- Definition of fluid state in the throat needed before dimensioning
- More equations to solve, error-prone

Recommended method in the main part

Presented in the Annex as alternative method
Further aspects

Pressure relief devices

- Emphasis on operating characteristics and tolerances particularly relevant for the combination of PRD in multi-stage protection concepts

Substance release

- Requirements for helium discharge lines and helium recovery systems
- Direct helium release to the environment

Operation of helium cryostats

- User requirements regarding the inspection before commissioning
- Periodic inspections and maintenance of pressure relief devices
Summary and outlook

- Foundation of new working group CEN/TC 268/WG6 in 07/2017
  - „Specific helium technology applications“

- Actual project: New European Standard
  - Title „Helium cryostats – Protection against excessive pressure“
  - Participating experts from 6 European countries, both from industry and research organizations
  - Publication of the draft Standard is planned in late 2019
  - Follow-up project after publication on harmonization with the PED

THANK YOU FOR YOUR ATTENTION!