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

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On behalf of the working group

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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 – EN 1626
- Flexible hoses – EN 12434
- Pumps – EN 24490

E.g. European

- Machine Directive 2006/24/EC
- Low-voltage Directive 2014/35/EU
- Electromagnetic Compatibility Directive 2004/108/EC
- ...

Liquid helium **dewar**


Source: http://www.fusione.enea.it

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

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

New working group

CEN/TC 268 - Cryogenic vessels

General | Structure | Work programme | Published Standards

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.

Officers

Chairperson	Dr Hervé Barthélémy
Secretary	Ms Laurie Jardel

General | Structure | Work programme | Published Standards

CEN/TC 268 Subcommittees and Working Groups

Working group	Title
CEN/TC 268/WG 1	Design
CEN/TC 268/WG 2	Compatibility, insulation, accessories
CEN/TC 268/WG 3	Operational requirements

Aim of CEN/TC 268/WG6:

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

Organizations contributing to CEN/TC 268/WG6

- National Standardisation Bodies:

DIN afnor GROUPE bsi.

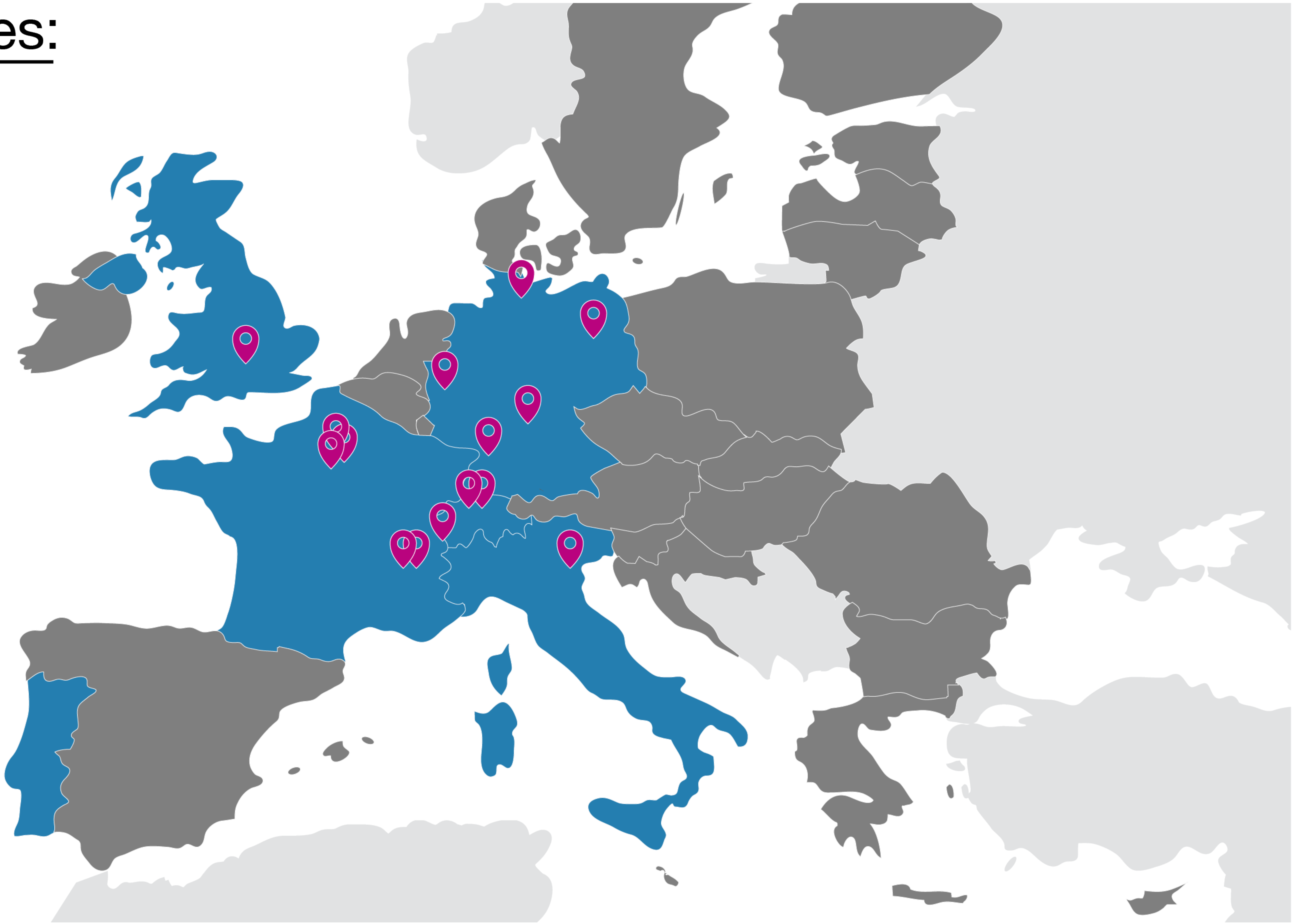
UNI ENTE ITALIANO DI NORMAZIONE · Q Instituto Português da Qualidade · SNV

- Organizations:

Air Liquide creative oxygen · BILFINGER · cea · CERN

HEROSE · INFN · KIT Karlsruhe Institute of Technology · THE LINDE GROUP Linde

PAUL SCHERRER INSTITUT PSI · Science & Technology Facilities Council



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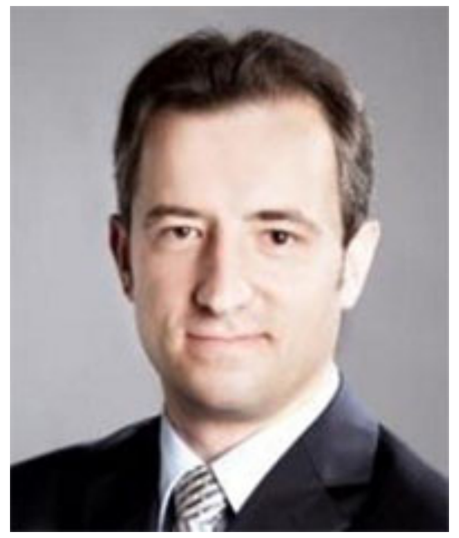
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Scope and concept of the new Standard

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

6 Risk assessment

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

Loss of insulating vacuum	Loss of beamline vacuum	Leak of cryogenic fluid
Quench of sc. device	Dielectric breakdown	Thermal acoustic oscillation
Cryopumping	Entrapment of cryogenic fluid	Power failure
Pressure surge	Freezing	Backflow
Other sources	Earthquake	Fire

☐ 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

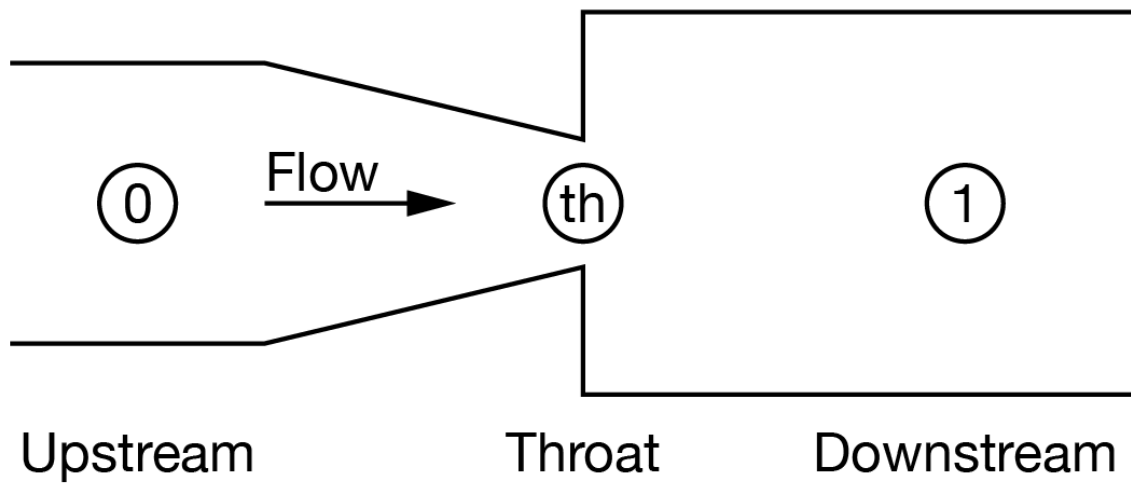
- **Single-stage** protection concept as minimum requirement
- **Multi-stage** protection concepts
  - **Primary PRD** completely fulfills the pressure protection at the maximum allowable pressure p_s in compliance with the PED and based on the MCI
  - **Secondary PRD** at either $p_0 < p_s$ or $p_0 > p_s$, 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

PRD: Pressure relief device
PED: Pressure equipment directive
MCI: Maximum credible incident

8 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 $$A_{\mathrm{th}} = \frac{\dot{M}}{\rho_{\mathrm{th}} \cdot c_{\mathrm{th}}}$$



  - $\dot{M}$ relieving mass flow rate → from the heat load in different risk scenarios
  - ρ_{th} density in the throat
  - c_{th} velocity in the throat

  (ρ_{th}, c_{th}): $\dot{m}_{\mathrm{th}}$ mass flux → 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

> Recommended method in the **main part**

Case-specific model

- Consistent with ISO 4126-7:2013 and ISO 21013-3:2016

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

> 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!