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

DKV-Tagung 2019, Ulm, 22.-23. November 2019

Outline

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

Motivation

- Helium **dewars** vs. helium **cryostats**

Helium cryostats have
active components

Strong influence on potential risk
of excessive pressure

Sc. magnets
Sc. RF cavities
Heat exchangers
Valves
Flexible hoses
Pumps

EN 1626 EN 12434 EN 24490

E.g. European

Machine Directive 2006/24/EC

Low-voltage Directive 2014/35/EU

Electromagnetic Compatibility Directive 2004/108/EC

...

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

Liquid helium **dewar**

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.

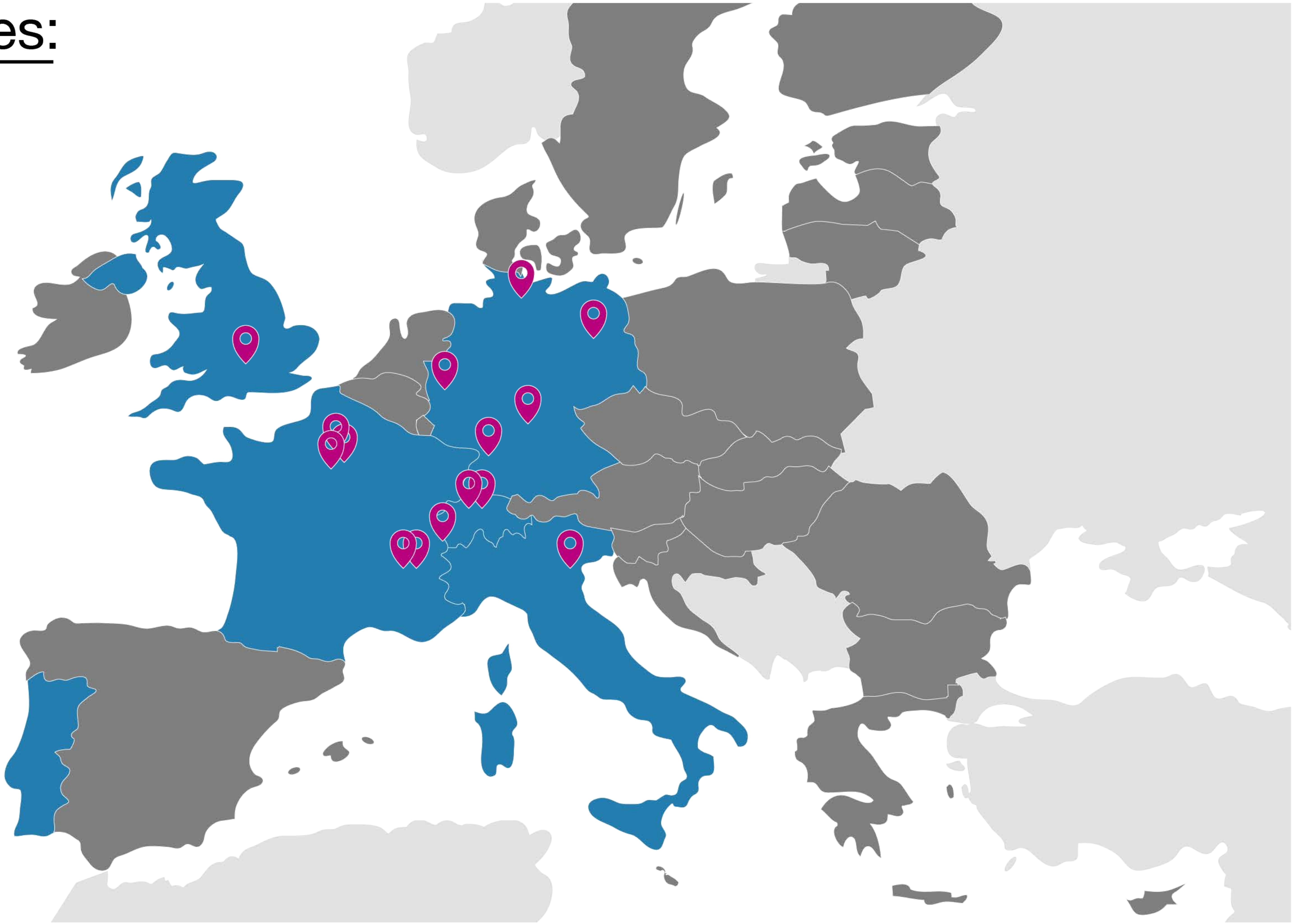
UNI ENTE ITALIANO DI NORMAZIONE — Instituto Português da Qualidade — SNV

- 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



Experts contributing to CEN/TC 268/WG6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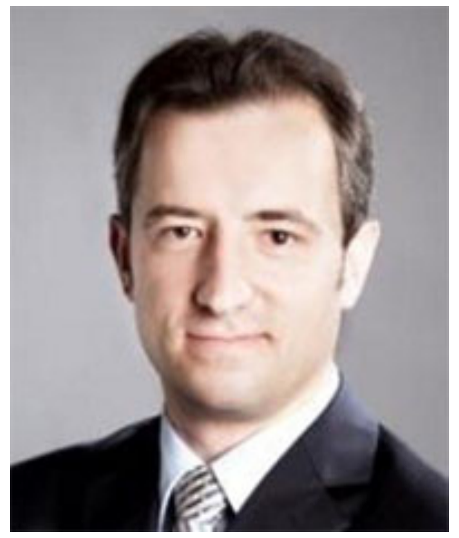
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PSI

Scope and concept of the new Standard

The **scope** includes

a) Superconducting magnet cryostats

b) Superconducting RF cavities

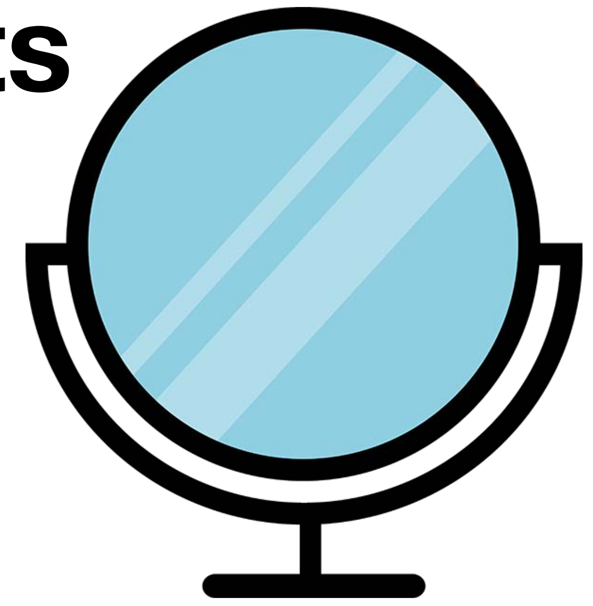
c) Ultra-low *T* refrigerator systems using ^3He and $^3He/^4He$ mixtures

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**

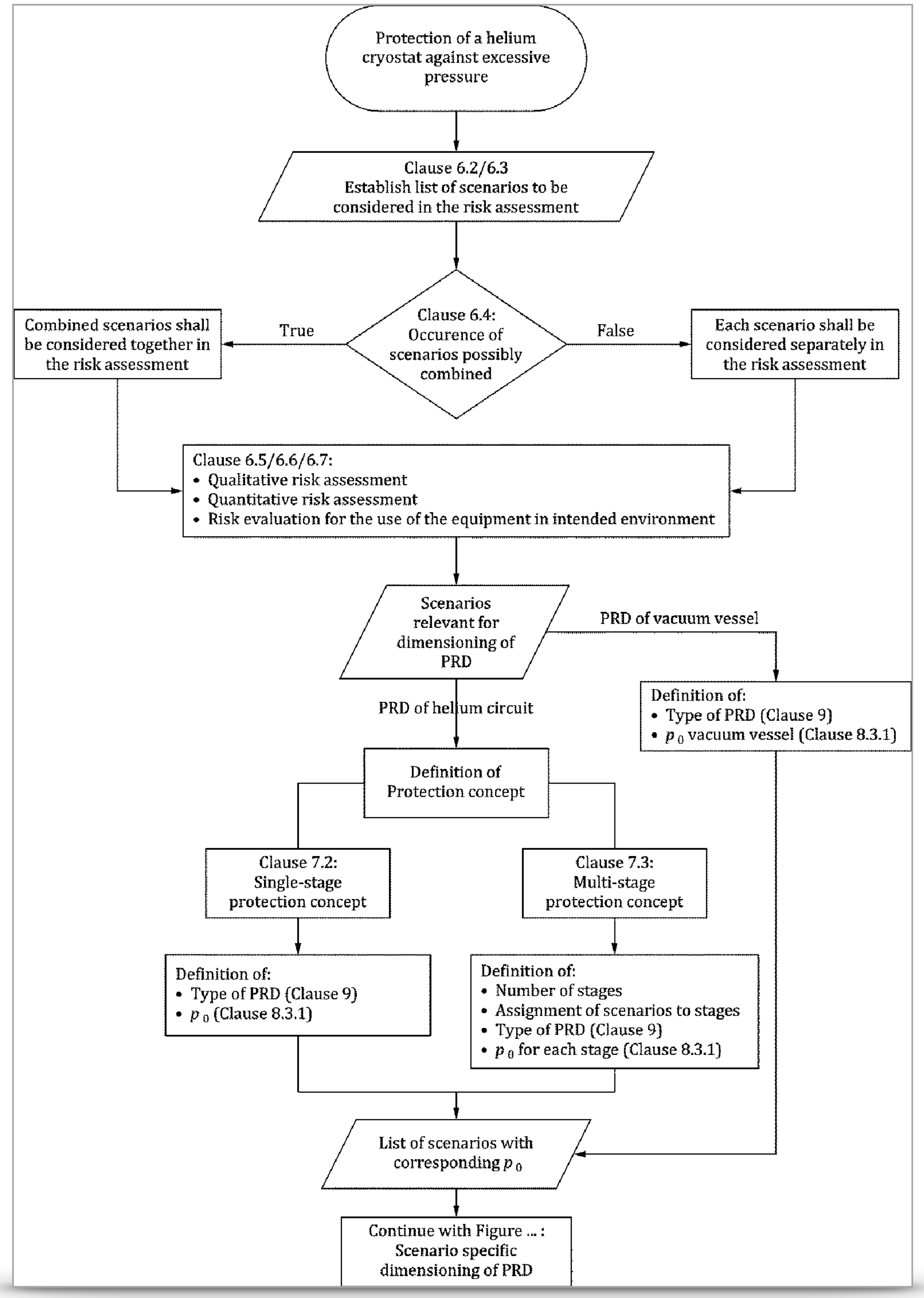


- Alternative/advanced methods, additional information, example solutions, exemplary measures in extensive **Annex**

Structure of the main part

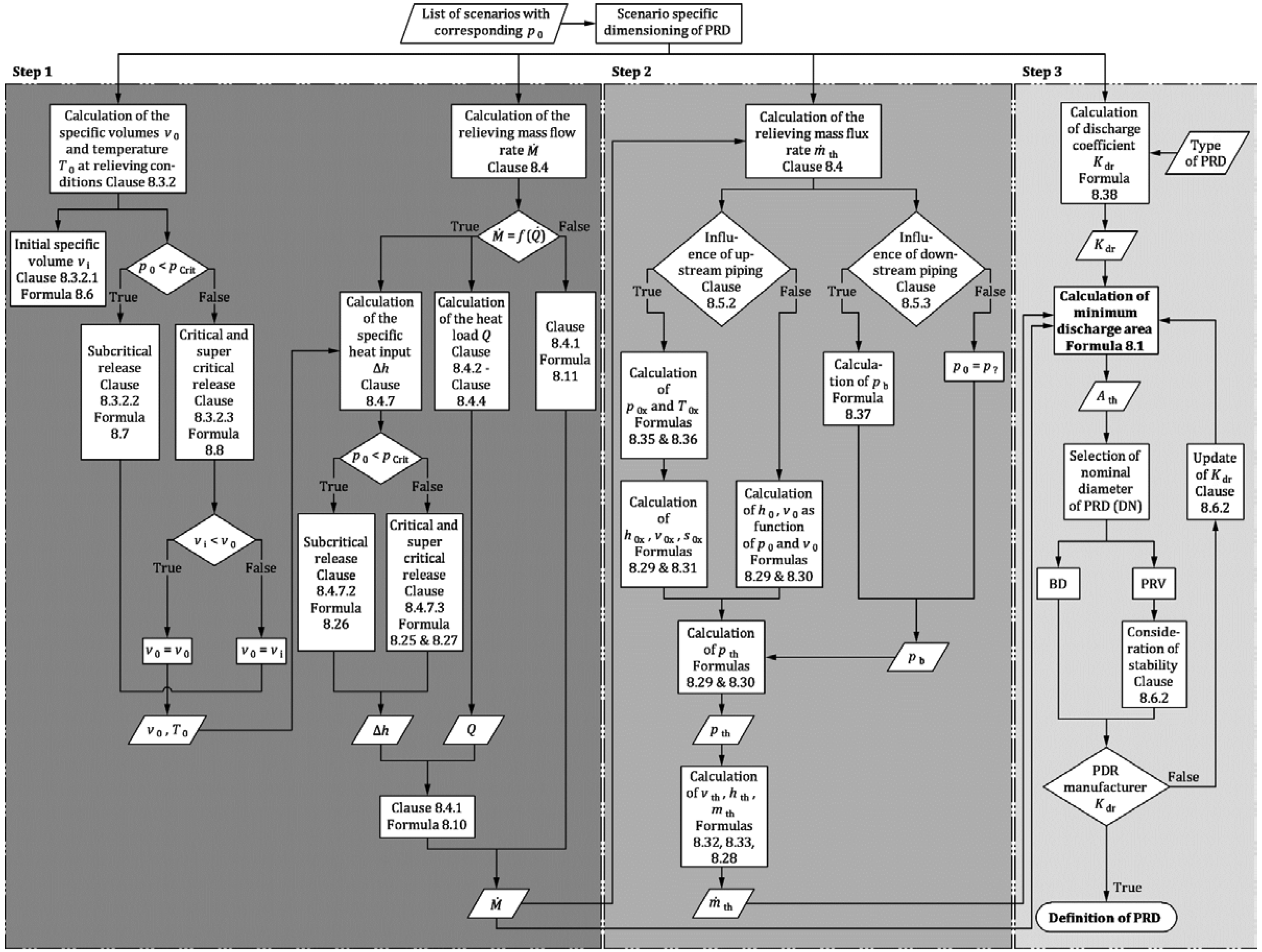
5 Process flow charts

- Risk assessment and protection concepts



5 Process flow charts

- Scenario-specific dimensioning of PRD



6 Risk assessment

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

Loss of insulating vacuum	Loss of beamline vacuum	Quench of sc. device
Leak of cryogenic fluid	Dielectric breakdown	Entrapment of cryogenic fluid
Thermal acoustic oscillation	Cryopumping	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

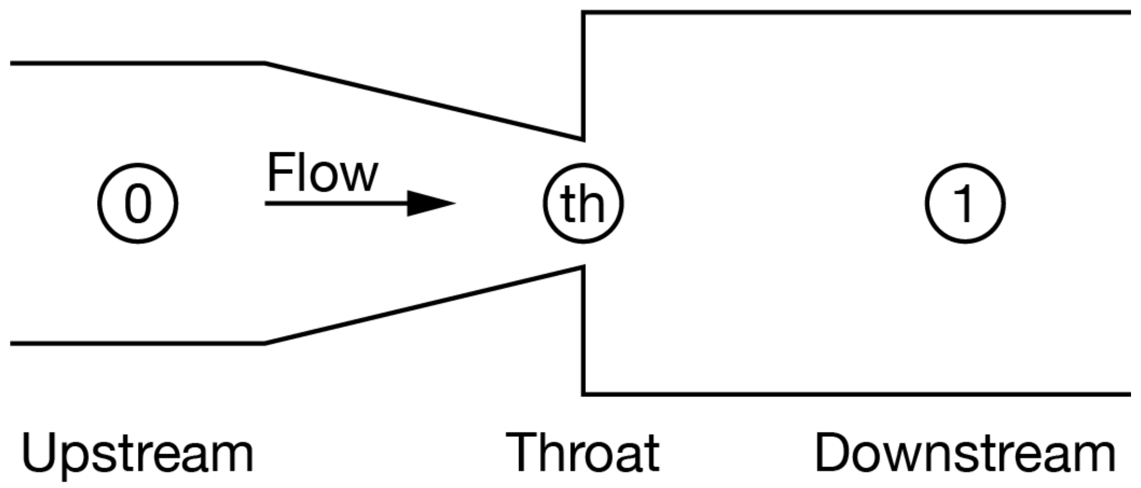
- **Single-stage** protection concept as minimum requirement
- **Multi-stage** protection concepts
  - **Primary PRD** completely fulfills the pressure protection at the maximum allowable pressure p_s in compliance with the PED and based on the MCI
  - **Secondary PRD** at either $p_0 < p_s$ or $p_0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

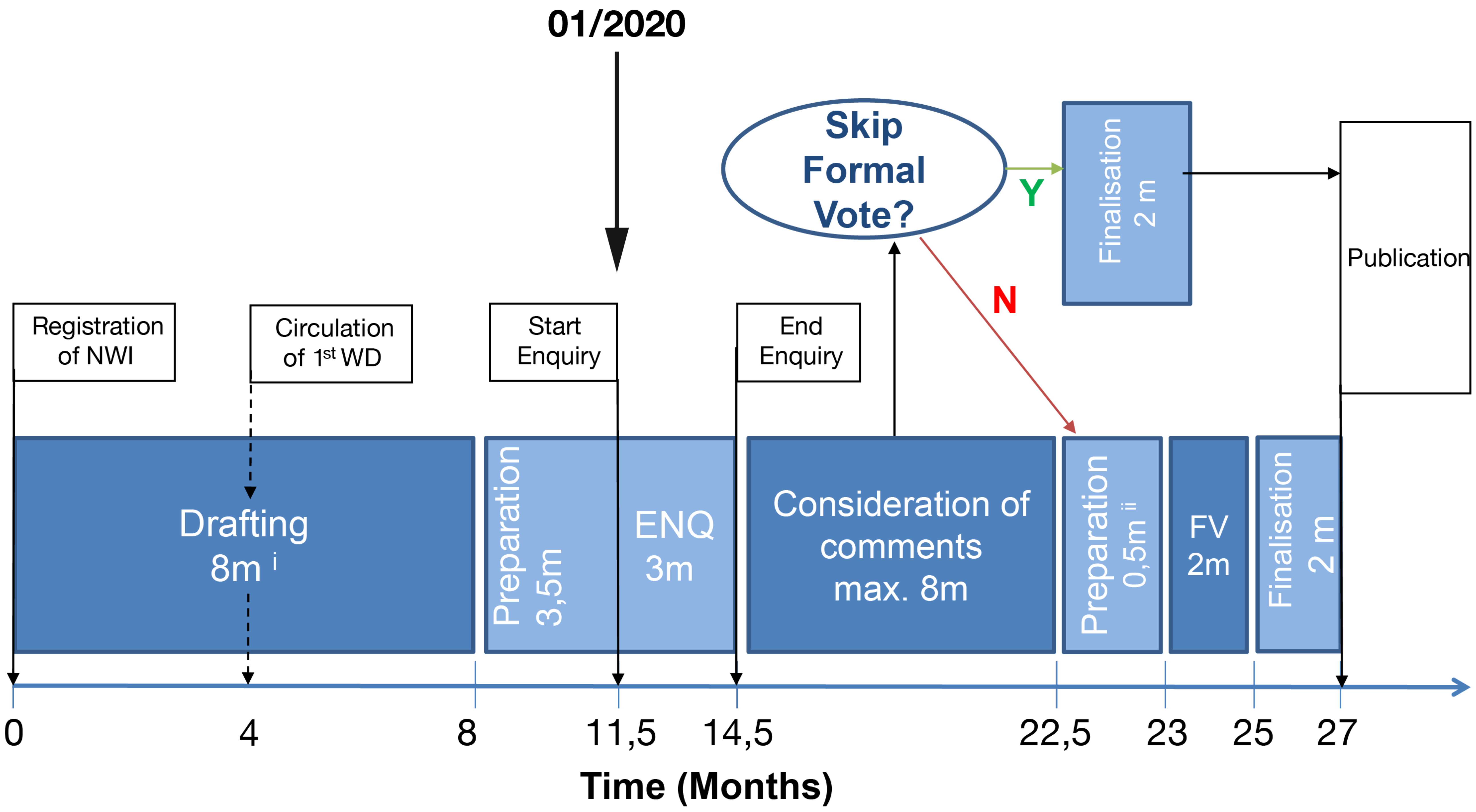
  Presented in the **Annex** as alternative method

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

OUTLOOK

Outlook – Publication procedure



i Possibility to be extended to 12 months

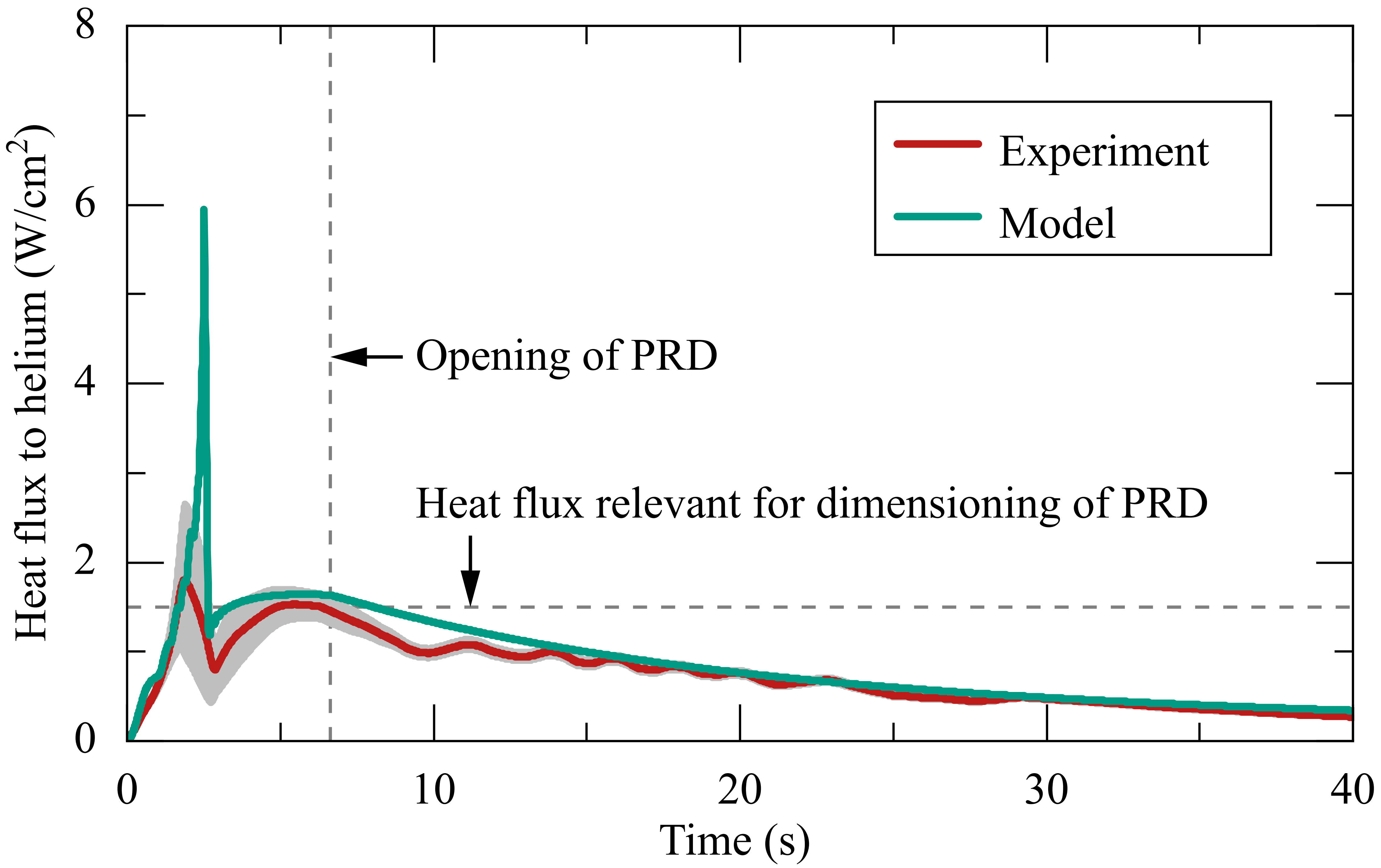
ii Translation previous to Formal vote is optional. If translation is necessary 1,5 months need to be added

Outlook – Harmonization

- PED is applicable legislative reference for $PS \geq 0.5\,\mathrm{bar(g)}$
  - Many Standards available - users are free to choose
  - In parallel to applying Standards, users have to prove their compliance with the essential safety requirements of the PED
  - Additional verification not necessary in case of a **Harmonized Standard**
- Harmonization: Special procedure conducted by external agency (HAS Consultants) upon request by the European Commission
  - Procedure may be initiated after publication by the CEN Technical Board
  - All Clauses cross-checked with PED; certified revision lead by HAS Consultants in cooperation with the technical experts

Outlook – Dynamic model development

- Development of a **baseline dynamic model** is planned by KIT and CERN
  - Heat flux for bare surfaces at $p_0 \geq 1.3\,\mathrm{bar(g)}$ reduced already from $3.8\,\mathrm{W\,cm^{-2}}$ (Lehmann/Zahn) to $2.0\,\mathrm{W\,cm^{-2}}$ in the new Standard
  - Reduction of PRD dimensions by **1 to 2 nominal sizes**!
  - Further reduction by design-specific modeling



  - Planned as public tool complementary to the new Standard

Publication

- Publication on the Standardization project:

  S Grohmann et al. „Status of a European Standard for the protection of helium cryostats against excessive pressure“. In: *IOP Conference Series: Materials Science and Engineering* 502 (Apr. 2019), p. 012171. doi: 10.1088/1757-899x/502/1/012171.

THANK YOU FOR YOUR ATTENTION!