ISO and EIGA standards for cryogenic vessels and accessories

CERN, Geneva – September 22nd, 2016  l  Hervé Barthélémy, Ph.D.  l  Air Liquide – Gas Packaging Center
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- Material issues
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- ISO/TC 220 – Cryogenic Vessels
- Future work at ISO/TC 220
Introduction

- Different types of cryogenic vessels:
  - Vacuum insulated / non-vacuum insulated
  - Static / transportable
Introduction

- Used for more than 40 years for the storage and transportation of industrial and medical gases
- In a volume of 1L of liquid, about 800L of gas can be stored
- The gases need to be refrigerated down to very low temperatures to be in liquid form

<table>
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<tr>
<th>Gases</th>
<th>CO₂</th>
<th>Kr</th>
<th>O₂</th>
<th>Ar</th>
<th>Air</th>
<th>N₂</th>
<th>Ne</th>
<th>H₂</th>
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<tr>
<td>Boiling temperatures (°C)</td>
<td>-78.5</td>
<td>-153</td>
<td>-183</td>
<td>-186</td>
<td>-191</td>
<td>-196</td>
<td>-246</td>
<td>-253</td>
<td>-269</td>
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</tbody>
</table>

Boiling temperatures at atmospheric pressure of different gases

Necessary to use high efficiency vacuum insulated vessels
Material issues

- Materials issues (e.g., for liquid hydrogen)

- Hydrogen embrittlement (-150° C) - Warm (vessel almost empty)

- Compatibility of metals and alloys with low temperatures, in particular:
  - Britteness
  - Thermal conduction
  - Expansion and contraction phenomena
  - Condensation of liquid air in the interspace (50/50 O₂-N₂)
Material issues

- Metallic materials commonly used

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<th>Cryogenic vessels and associated equipment</th>
<th>Metallic materials commonly used</th>
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<td>Low alloy steels</td>
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<tr>
<td>Large transportable vessels</td>
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<tr>
<td>Inner vessel</td>
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</tr>
<tr>
<td>Outer jacket</td>
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<tr>
<td>Small transportable vessels</td>
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<tr>
<td>Inner vessel</td>
<td></td>
</tr>
<tr>
<td>Outer jacket</td>
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<td>Static vessels</td>
<td></td>
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<tr>
<td>Inner vessel</td>
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</tr>
<tr>
<td>Outer jacket</td>
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<td>Valves and protective devices</td>
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<td>Vaporizers</td>
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<td>Insulation systems</td>
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</table>

Source: ISO 21010 « Cryogenic vessels » - Gas/materials compatibility
Cold stretching

- Reducing the wall thickness of the vessels -> cold stretching

Stress/strain curve for carbon steel

Stress/strain curve for austenitic stainless steel

Improvement of the yield strength ➞ Reduction of the wall thickness (weight, cost)
## Legislative and normative frameworks

<table>
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<th>Legislative</th>
<th>Regional</th>
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<tr>
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<td>PED, TPED</td>
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<td>Standard</td>
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<td>Industry</td>
<td>EIGA, CGA</td>
<td>IOMA</td>
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</table>
European and a number of non-European companies producing and distributing industrial, medical and food gases.

EIGA/WG-6: Cryogenic Vessels (& accessories)

Design, material compatibility, operational requirements and periodical inspection

- To monitor international standardisation (ISO, CEN) and regulations (UN, TPED, PED) to prepare Codes of Practice or guidelines
- To review accidents and incidents, to determine the causes and to propose ways to avoid re-occurrence
- 12 documents (incl. 4 harmonized with CGA)
## EIGA documents

<table>
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<th>Title</th>
<th>Applies to H₂, He?</th>
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<td>Safety in storage, handling and distribution of liquid hydrogen</td>
<td>H₂</td>
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<td>Doc. 07/14</td>
<td>Metering of Cryogenic Liquids</td>
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<td>Doc. 24/08</td>
<td>Vacuum insulated cryogenic storage tank systems pressure protection devices</td>
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<td>Operation of static cryogenic vessels</td>
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<td>Storage of Cryogenic Air Gases at User’s Premises</td>
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<td>Periodic inspection of static cryogenic vessels</td>
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<td>Doc. 164/10</td>
<td>Safe handling of liquid carbon dioxide containers that have lost pressure</td>
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<td>Doc. 168/11</td>
<td>Calculation Method for analysis and prevention of overpressure during Refilling of Cryogenic Tanks with Rupture Disks</td>
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<tr>
<td>TB 11/14</td>
<td>Recommendations for the Prevention of Brittle failure of the Outer Jacket of Vacuum Insulated Cryogenic Storage Tanks</td>
<td>H₂, He</td>
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</tbody>
</table>

www.eiga.eu
European Industrial Gases Association

Doc. 06/02 - Safety in storage, handling and distribution of liquid hydrogen

Guidance of companies for the installation of liquid hydrogen storage at the user's premises and the distribution of liquid hydrogen by road, rail and sea transport.

A liquid hydrogen storage installation on a user's premises is defined.

It applies to the layout, design and operation of such fixed storages and the transportation of liquid hydrogen in bulk form by tankers or tank containers, by road, sea and rail, to fixed storages at user’s premises.

Portable containers, such as pallet tanks and liquid cylinders, are excluded from the scope of this document.
Doc. 114/09 - Operation of static cryogenic vessels

- Specifies the procedures for putting into service, inspections, requalification according to the PED, taking out of service, maintenance and repair of static cryogenic vessels designed for a maximum allowable pressure of more than 0.5 barg.

Describes the operation of static cryogenic vessels, putting into service, inspections, taking out of service, maintenance and repairs and includes:
- How the user operates the vessel
- How local authorities and competent persons inspect these vessels to get common agreement about the operation that allows free movement within Europe without additional approvals
European Industrial Gases Association

- **Doc. 119/04 - Periodic inspection of static cryogenic vessels**

  - **Periodic inspection** and **testing** of static vacuum insulated cryogenic pressure vessels used in the storage of refrigerated liquefied gases, excluding toxic gases.

  The PED only covers design, manufacturing and placing on the market. The national legislations and practices for periodic inspection and testing varies considerably between European countries (even for similar vessels on similar services).

- **Doc. 151/15 - Prevention of Excessive Pressure during Filling of Cryogenic Vessels**

  - Guidance for the filler/owner of either transportable or static cryogenic tanks, **detailing the systems and procedures** that can be used to **prevent them being over pressurized** during filling.

  To address the issue of receiving vessels greater than 1000 L water capacity. Also used for receiving vessels under 1000 L that are not designed for transport when full.

  Guidance for other products and other transfer systems.
TB. 11/114 – Recommendations for the prevention of Brittle Failure of the Outer Jacket of Vacuum Insulated Cryogenic Storage tanks

Risks to consider:
- **Hidden failure** due to differential thermal expansions within piping
- **Brittle fracture** due to imingment of cryogenic fluids onto the outer jacket

PP 09/09 – The PED – Periodic Inspection and Reassessment of Static Cryogenic Vessels for use in the EU

- The conditions for the periodic inspections are very different from member state to member state of the EU
- No mutual recognition of the periodic inspection performed in another country

The PP gave the future action to be considered at the European level.
ISO/TC 220: Cryogenic Vessels

Standardization in the field of insulated vessels (vacuum or non-vacuum) for the storage and the transport of refrigerated liquefied gases of class 2 of "Recommendations on the Transport of Dangerous Goods - Model regulations - of the United Nations", in particular concerning:

- the design of the vessels
- the operational requirements of the equipment and accessories
- the supporting standards (safety accessories, gas/materials compatibility, insulation performance...)
ISO/TC 220 - Structure

ISO/TC 220
Cryogenic vessels

WG 1
Design and construction
Secretariat: AFNOR
Convenor: HB

WG 2
Operational requirements
Secretariat: DIN

WG 3
Supporting standards
Secretariat: CGA/ANSI

20 published ISO standards under the direct responsibility of ISO/TC 220
ISO/TC 220 - Standards

Large transportable vacuum-insulated vessels
ISO 20421 series

Transportable vacuum-insulated vessels ≤ 1000L
ISO 21029 series

Static vacuum-insulated vessels
ISO 21009 series

Vessels

Valves
ISO 21011

Hoses
ISO 21012

Pressure relief accessories
ISO 21013 series

Pumps
ISO 24490

Accessories

Gas/materials compatibility
ISO 21010

Toughness requirements for materials
ISO 21028 series

Insulation
ISO 21014

Cleanliness for cryogenic service
ISO 23208
ISO/TC 220 – Standards for cryogenic vessels

- **ISO 20421 series – Large transportable vacuum insulated vessels**
  - Part 1: Design, fabrication, inspection and testing
    - Volume > 450L
    - Does not apply to toxic fluids
    - Permanently (fixed tanks) or not permanently (demountable tanks and portable tanks) attached to a means of transport, for one or several
      - Part 2: Operational requirements
        - Putting into service
        - Filling, withdrawal
        - Transport within the location, storage
        - Maintenance, periodic inspection
        - Emergency procedures

- **ISO 21029 series – Transportable vacuum insulated vessels**
  - Part 1: Design, fabrication, inspection and testing
    - Volume ≤ 1000L
    - Does not apply to toxic fluids
    - Permanently (fixed tanks) or not permanently (demountable tanks and portable tanks) attached to a means of transport, for one or several
      - Part 2: Operational requirements
        - Putting into service
        - Filling, withdrawal
        - Transport within the location, storage
        - Maintenance, periodic inspection
        - Emergency procedures
ISO/TC 220 – Standards for cryogenic vessels

- ISO 21009 series – Static vacuum insulated vessels
  - Part 1: Design, fabrication, inspection and testing
  - Part 2: Operational requirements

- Installation
- Putting into service
- Filling, withdrawal
- Transport within the location, storage
- Maintenance, periodic inspection
- Emergency procedures
ISO/TC 220 – Standards for accessories

- **ISO 21011 – Valves**
  - Design
  - Manufacture
  - Testing
  - For a rated temperature of -40° C and below

- **ISO 24490 – Pumps**
  - Design
  - Manufacture
  - Testing

- **ISO 21012 – Hoses**
  - Design
  - Manufacture
  - Testing
  - Marking requirements
  - For a working temperature of -270° C to -65° C
  - Nominal size (DN) from 10 to 100

- **ISO 21013 series – Pressure-relief accessories**
  - Design
  - Manufacture
  - Testing
  - Marking requirements
  - Part 1: Reclosable pressure-relief valves
  - Part 2: Non-reclosable pressure-relief devices (bursting disc, buckling pin)
  - Part 4: Pressure-relief accessories

Part 3: Sizing and capacity determination -> *calculation methods for determining the required mass flow to be relieved depending on specified conditions*
ISO/TC 220 – Standards for accessories

- ISO 21010 – Gas/materials compatibility
  - Compatibility requirements (e.g. chemical resistance)
  - Detailed compatibility requirements for oxygen and oxygen-enriched atmospheres

- ISO 21028 series – Toughness requirements for materials at cryogenic temperature
  - Part 1: Temperatures below -80 degrees C
  - Part 2: Temperatures between -80 degrees C and -20 degrees C

- ISO 21014 – Insulation performance
  - Practical methods for determining the heat-leak performance of cryogenic vessels

- ISO 23208 – Cleanliness for cryogenic service
  - Acceptable level of surface and particle contamination to minimize the risk of malfunction of equipment and ensure safety against ignition when in contact with oxygen or oxidizing fluids
Future work at ISO/TC 220

- Systematic revisions of the published standards (every 5 years)
- New standard for the safety of liquid helium cryostats
End of presentation
Thank you for your attention
Back up slides
The application of the PED on the design codes for cryogenic equipment and future developments foreseen in this field

Paris, 06/09/2016  |  Hervé BARTHELEMY Ph. D., Jean-Luc FOURNEL, Lucien VARASSI  |  AIR LIQUIDE
Summary

- Background
- PED – Advantages for the Industry
- PED – Inconvenients for the Industry
- PED – Main changes compared to national regulations
- PED – Notified Body
- PED – Category and module
- PED – EN and ISO Standards published for pressure vessels
- PED – Requalification of national design vessels when possible
Background

- PED: Pressure Equipment Directive
- First version published in 1997
- First revision in 2014.

- PED covers **Static Pressure Equipment**
- Some cylinders are also covered by PED
- PED only covers **design, manufacturing** and **firstplacing** on the market
- PED is **mandatory** in European union since end of May 2002
PED – Advantages for the Industry

- Same design can be used in all European Union countries
  - Allows manufacturers to optimize design and to reduce manufacturing cost

- Approval from only one notified body is necessary
  - Allows to obtain better conditions from notified Bodies
  - Allows to “open” difficult markets/countries

- Should allow a company to harmonise PE fleet in European Union
  Not always possible because of different practices in the different countries e.g. different service pressures or safety accessories

- Also recognized in Eastern European countries
PED – Inconvenients for the Industry

- Sometimes more stringent than old national codes
  - For materials
  - For safety accessories
  - Vaporisers are considered as pressure vessels

- May lead to cost increase
PED – Main changes compared to national regulations

- All vessels > 0.5 bar are subjected
- Pressure test (coefficient: 1.43)
- Pipes > DN 25 to be PED compliant
- The entire control cabinet (with accessories > DN 25) to be PED compliant
- Risk analysis to be submitted to the Notified Body
- Choice of a Notified Body per product line
PED allows the cryogenic vessel manufacturer to choose a unique Notified Body as per the following criteria:

- Qualification and capability
- Wide recognition, even outside the European borders
- Close collaboration
- Competitiveness
For cryogenic vessel for LIN, LOX and LAR

- Risk category IV
- Module G (unit CE approval)
- Or Modules B + D
  - CE type approval
  - Production quality assurance
# PED – EN and ISO standards published for pressure vessels

## Vessels

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<thead>
<tr>
<th>ISO reference</th>
<th>EN reference</th>
<th>Title</th>
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<tr>
<td>EN ISO 21009-1*</td>
<td>EN 13458-1</td>
<td>Static vacuum insulated vessels Part 1(ISO and EN): Fundamental requirements</td>
</tr>
<tr>
<td>EN ISO 21009-2</td>
<td>EN 13458-3</td>
<td>Static vacuum insulated vessels Part 2(ISO) Part 3(EN): Operational requirements</td>
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<tr>
<td>EN 14197-1</td>
<td>Static non-vacuum insulated vessels Part 1: Fundamental requirements</td>
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<td>EN 14197-2</td>
<td>Static non-vacuum insulated vessels Part 2: Design, fabrication, inspection and tests</td>
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<tr>
<td>EN 14197-3</td>
<td>Static non-vacuum insulated vessels Part 3: Operational requirements</td>
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* Under revision
## PED – EN and ISO standards published for pressure vessels

### Accessories

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<td>EN 1626</td>
<td>Valves for cryogenic services</td>
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<td>EN ISO 21012*</td>
<td>EN 12434</td>
<td>Hoses</td>
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</tbody>
</table>
| ISO 21013-1*  | EN 13648-1   | Pressure relief devices  
|               |              | Part 1: Reclosable pressure-relief devices |
| ISO 21013-2*  | EN 13648-2   | Pressure relief devices  
|               |              | Part 2: Non-reclosable pressure-relief devices |
| ISO 21013-3*  | EN 13648-3   | Pressure relief devices  
|               |              | Part 3: Sizing and capacity determination |
| ISO 21013-4*  |              | Pressure relief devices  
|               |              | Part 4: Pilot operated pressure-relief |
| EN ISO 24490* | EN 13275     | Pumps for cryogenic vessels |

* Under revision
### Materials

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<td>EN 1797</td>
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<td>EN ISO 21028-1*</td>
<td>EN 1252-1</td>
<td>Toughness requirements for materials at cryogenic temperature</td>
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<td>Part 1: Temperature below -80° C</td>
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<td>Part 2: Temperature between -80° C and -20° C</td>
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### Miscellaneous

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<td>ISO 23208*</td>
<td>EN 12300</td>
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</tr>
</tbody>
</table>

* Under revision
To re-qualify cryogenic vessels, original documents of design and manufacturing must be presented to the Notified Body.

Cryogenic vessels are generally built according to different national construction code:
- French code
- German code
- Belgian code
- Dutch code

Documents to be supplied:
- Drawing of approval
- Annex to the drawing of approval (device’s description)
- Calculation of internal bowl
- Certificate of hydraulic test (event)
- Operating modes of soldering
- Qualifications of the welders
- Report of the radiographic examinations
- X-ray