1st Accelerators Technology Sector Workshop

Engineering Design Tools and Processes
Project Management Methodologies and Tools

Chair: Mike Lamont

Interconnecting knowledge, experience, methods, people & data to foster learning & collaboration

CERN

ATS
Accelerators and Technology Sector

Engineering design tools and processes for cryogenics

Andrew Lees (TE-CRG-ME)

CERN | ATS Accelerators and Technology Sector

Cryogenics

- The branch of physics dealing with the production and effects of very low temperatures
  (https://en.oxforddictionaries.com/definition/cryogenics; Oxford Dictionaries)

- All scientific and technological disciplines dealing with temperatures below 120 K
  (http://dictionary.iifiir.org/search.php; International Dictionary of Refrigeration)

Gas	Boiling point (K) @ P_{atm}	Inventory at CERN (t)	Consumed per year (t)
Krypton	119.8	24	-
Methane	111.6	-	-
Oxygen	90.2	-	-
Argon	87.3	1800	-
Nitrogen	77.4	-	7100
Neon	27.1	-	-
Hydrogen	20.3	< 1	-
Helium	4.2	160	35

Key enabling technology for accelerators and physics experiments

Cryogenics at CERN: Overview

LHC
- 8 cryoplants
- 8 Cryogenic sectors
- 56 DFBs , 5 SC links

LHC Detecto

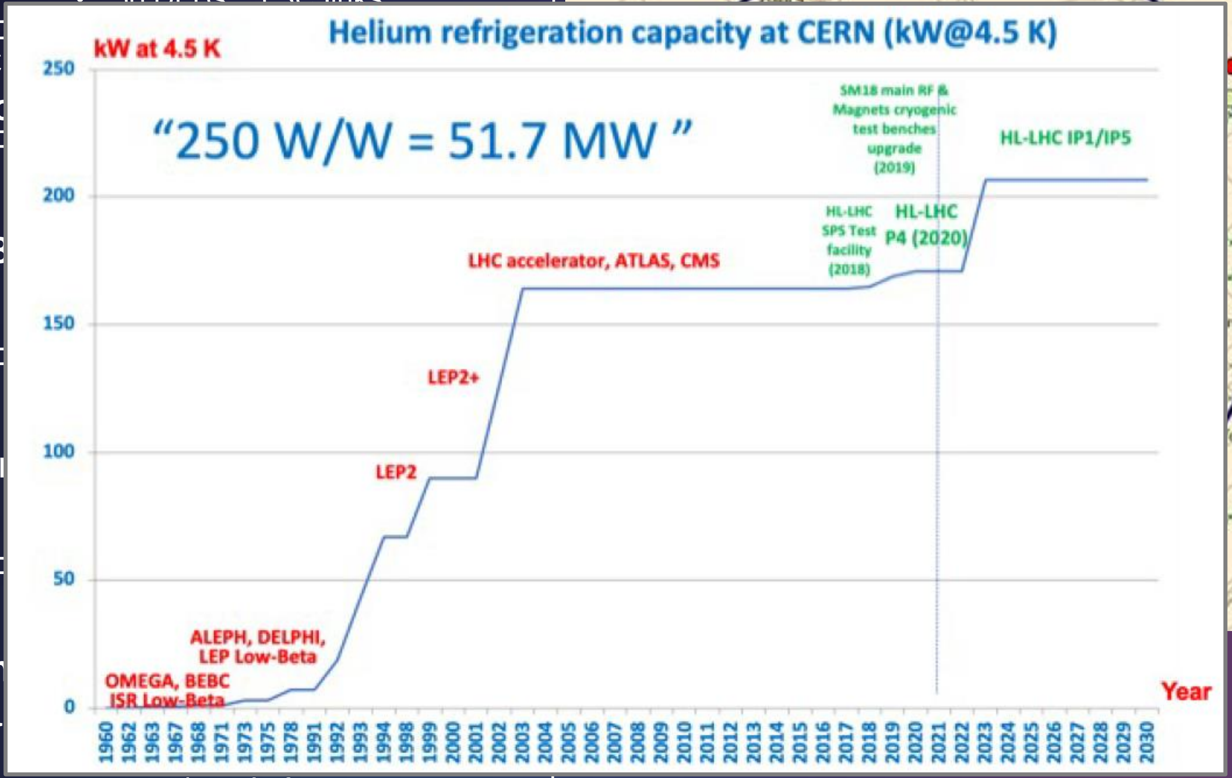
SM18

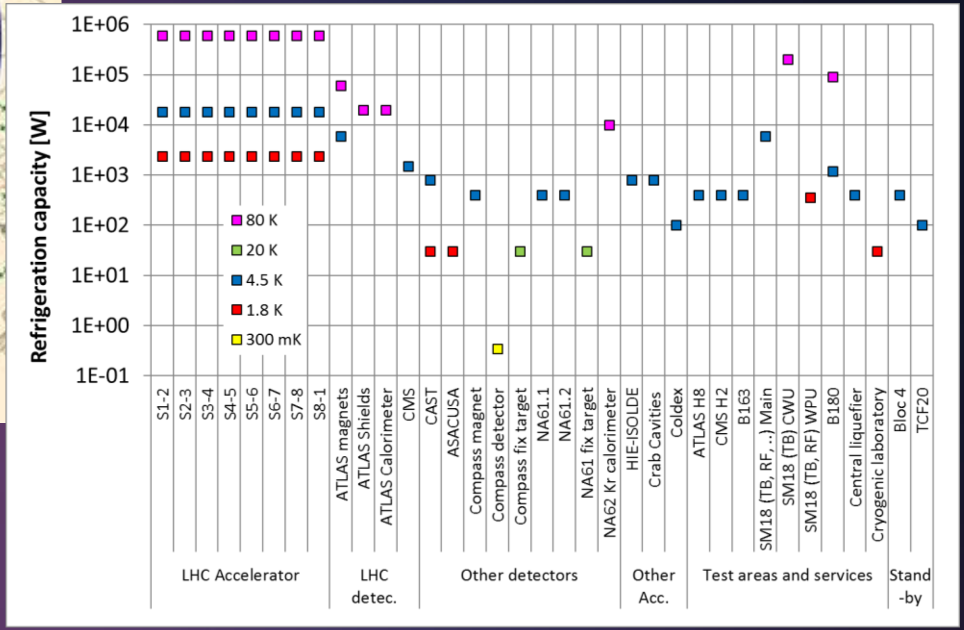
Meyri

North Area
- Neutrino Platform

SPS
- BA6 (CC)
- BA4 (Coldex)

- LHC Accelerator
- LHC Detectors
- Other Detectors
- Other Accelerators
- Test Areas
- Central Services



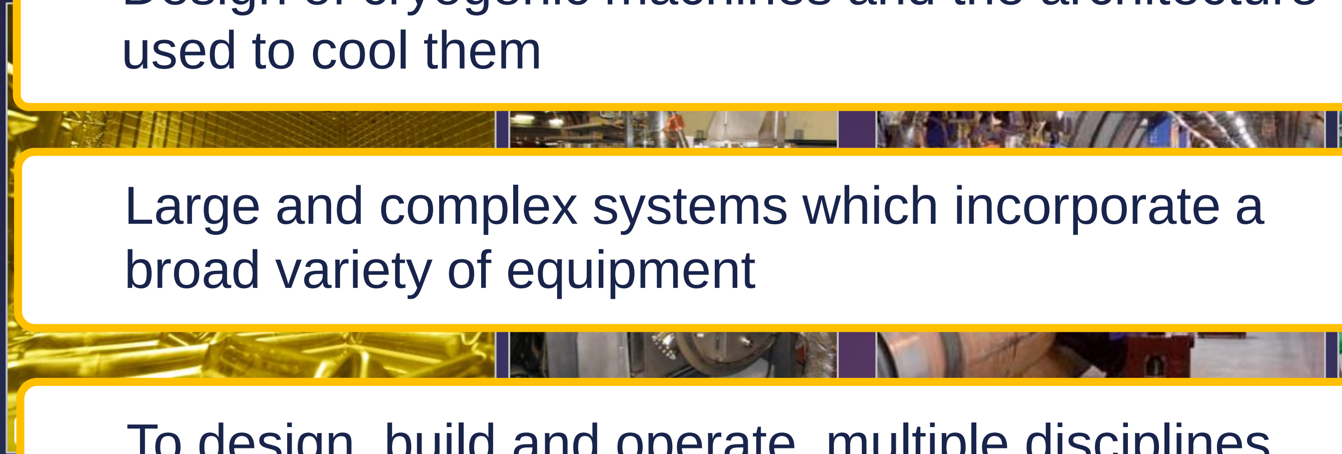


Cryogenic capacity of TE-CRG cryogenic facilities

Cryogenics at CERN: Equipment

Refrigeration


SM18 36 g/s LHe Refrigerator



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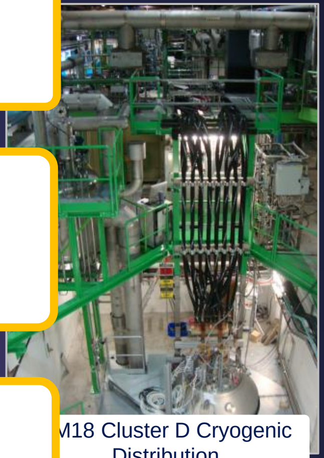
M18 Cluster D Cryogenic Distribution

Cold Storage


B163 20m³ LHe Dewar

Design of cryogenic machines and the architecture used to cool them

Large and complex systems which incorporate a broad variety of equipment

To design, build and operate, multiple disciplines must be mastered:

- ⇨ Thermo-hydraulic and process
- ⇨ Mechanics, design and layout
- ⇨ Instrumentation, electronics & control
- ⇨ Project management
- ⇨ Maintenance, operation and logistics

Compress


LHC LHe Compressor system Pt 4


SM18 GHe Storage


B165 Warm GHe Management Panel

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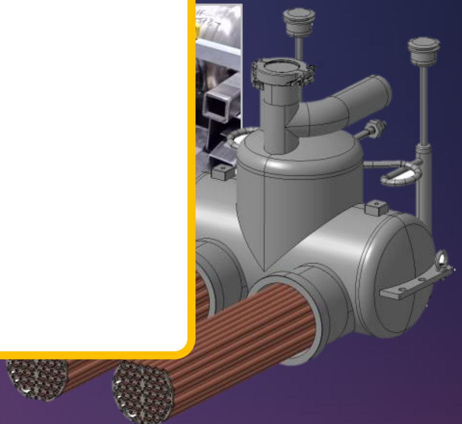

The Cryogenics Group (TE-CRG) at CERN

TE-CRG
Cryogenics

GL. D. Delikaris
DGL. J. Bremer

- **TE-CRG-CL**
  Cryolab
  J. Bremer
- **TE-CRG-IC**
  Instrumentation & Control
  M. Pezzetti
- **TE-CRG-ME**
  Mechanical & Engineering Support
  A. Perin
- **TE-CRG-ML**
  Methods & Logistics
  F. Ferrand
- **TE-CRG-OP**
  Cryogenics Operation
  B. Bradu
- **TE-CRG-GLO**
  Group leaders Office
  D. Delikaris

- Design, construction, commissioning, operation and maintenance of the cryogenic systems for CERN accelerators, detectors and cryogenic test facilities
- Low-temperature developments and tests at the Central Cryogenic Laboratory
- Supply of cryogenic fluids on the CERN site
- Consultancy and support in cryogenic design and cryogenic instrumentation.

Projects in the Cryogenics Group

CRG project

Function & Concept
- Functional requirement
- R & D (CRG-CL)
- Process flow diagram & Piping and Instrumentation Diagram (CRG-ME, CRG-CL)
- Process definition & Functional analysis (CRG-OP, CRG-IC & CRG-ME, (CRG-CL)

Design
- Mechanical design and integration (CRG-ME)
- Thermo-mechanical (CRG-ME)
- Dynamic process simulation (CRG-OP & CRG-ME)
- Electricity, control and instrumentation (CRG-IC)

Procurement
- Technical specification (CRG-ME, CRG-CL & CRG-IC)
- Costing (CRG-ME, CRG-CL & CRG-IC)
- Contract placement (IPT)

Manufacture & Contract
- Mechanical (CRG-ME & EN-MME)
- Electrical & Instrumentation (CRG-IC)
- Contract follow-up (CRG-ME, CRG-IC, CRG-CL & IPT)
- Quality assurance (CRG-ME, CRG-IC, CRG-CL & EN-MME)

Installation
- Site management (CRG-OP, CRG-ML, CRG-ME & CRG-IC)
- Inspection (CRG-ME, CRG-IC, HSE, EN-MME & BE-GM)

Commissioning
- Pressure test (CRG-ME, HSE)
- Leak test (CRG-ME & TE-VSC)
- Functional tests (CRG-OP, CRG-ML, CRG-ME, CRG-CL & CRG-IC)

Operation & Maintenance
- Operation (CRG-OP & CRG-ML)
- Support (CRG-ME & CRG-IC)
- Logistics (CRG-ML)

Cryogenics at CERN: TE-CRG-ME

TE-CRG-ME specialties:

- ⇨ Cryogenic process
- ⇨ Thermo-mechanical engineering
- ⇨ Design and integration
- ⇨ Project management and supplier follow-up
- ⇨ Mechanical field-work and construction

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CERN
acilities

and tests

TE-CR
Cryogeni

GL. D. Delikaris
DGL. J. Bre

TE-CRG-ML

- Supply of cryogenic fluids on the CERN site

gn and

Challenges:

- ⇨ Design and manufacture of complex cryogenic equipment in line with relevant regulation
- ⇨ Large variety of equipment and technology
- ⇨ Complex environment → Location and access constraints

D. Delikaris

Cryogenic Engineering Tools & Methods

Standardised methods available to the section/group:

- ⇨ Based on rules, standards and past practice at CERN

Streamlined engineering approach:

- ⇨ Improved efficiency, confidence in results and accessibility
- ⇨ Best practice guidelines for CRG-ME projects but not rigid set of rules

Each section in Cryogenics Group has developed and uses a set of tools to perform their work, this presentation focuses on the tools used by TE-CRG-ME.

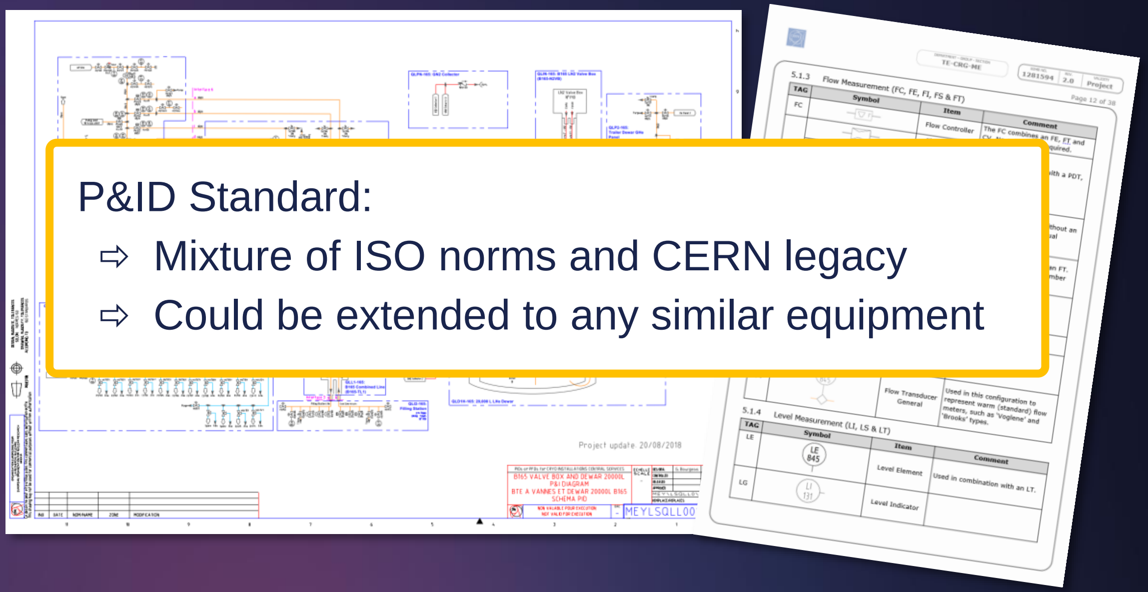
Subject		Guideline	Checklist	Tool	Report Templates	Library
Cryogenic Process	P&ID Symbols for CRG	X			X	
	Control valve sizing	X	X	X	X	
	Pressure drop	X	X			X
	Ecosim. dynamic simulation			X		X
Thermo-mechanical engineering and design	Design and Layout			X		
	Mechanical Analysis			X		
	Protection against overpressure	X		X	X	
	Application of pressure codes	X	X			
Mechanical Intervention	Standard CRG components					X
	Standard CRG methodology	X				

Cryogenic process

Cryogenic process

Piping & Instrumentation Diagram (P&ID):

- ➪ The basis of all cryogenic projects!
- ➪ Produced using AutoCAD → now BricsCAD with PLM
- ➪ Guideline → Standardise the symbols used on P&ID across CRG
  (EDMS 1281594)

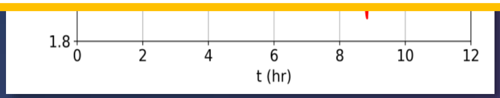


P&ID Standard:

- ➪ Mixture of ISO norms and CERN legacy
- ➪ Could be extended to any similar equipment

Used throughout Project:

- ➪ During the design phase to study and define thermo-hydraulic behaviour
- ➪ During the commissioning phase to validate control strategies
- ➪ During the operation phase to train new operators and verify control improvements



Cryogenic Dynamic thermo-hydraulic simulation with EcosimPro:

- ➪ Commercial software used in combination with “CRYOLIB” cryogenic library
- ➪ “CRYOLIB” was initially developed at CERN in 2006 and commercialised today (KT agreement)

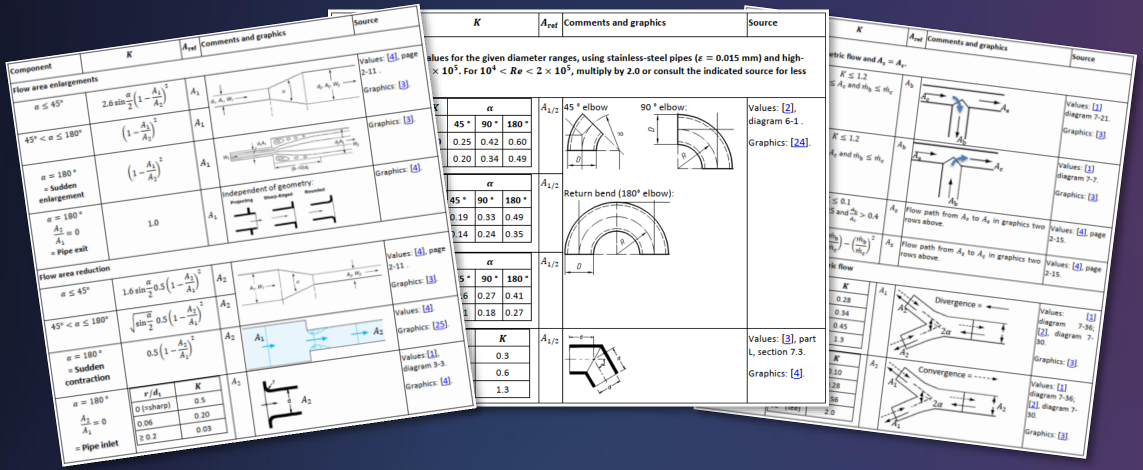
Credits: B. Bradu (TE-CRG-OP)

Cryogenic Process

Pressure drop calculations & control valve sizing:

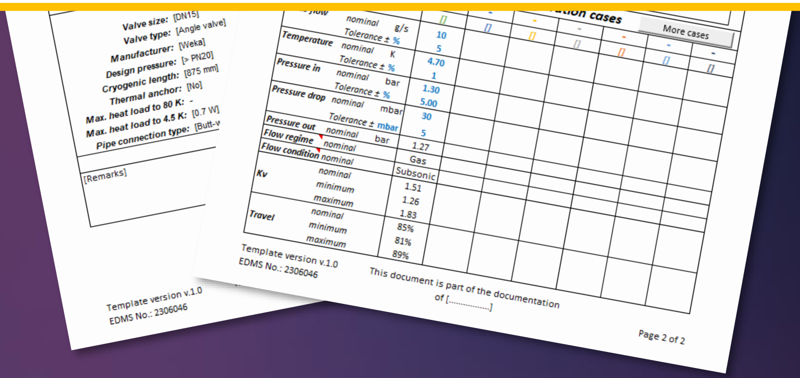
Fundamental part of process design

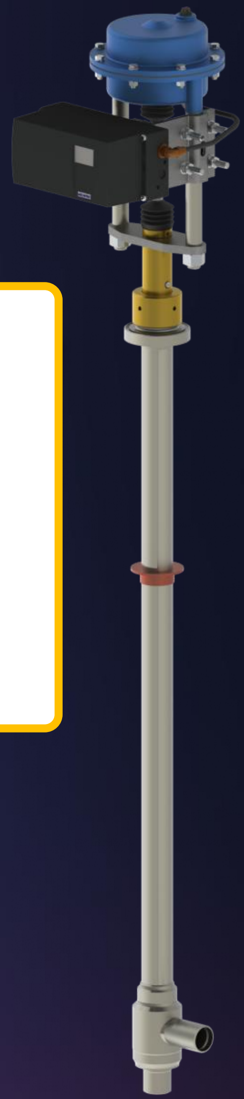
- ⇨ Guideline → Standardises TE-CRG-ME methodology
  (EDMS 2376016)
- ⇨ Checklists → To ensure methodology is correctly applied
  (EDMS 2306030)
- ⇨ Sizing tool → To aid calculation
  (EDMS 2306046)



TE-CRG-ME tool kits are based around:

- ⇨ Guidelines → bringing together procedures from norms and standards, CERN best practice and manufacturer guidelines.
- ⇨ Checklist → helping to guide engineer through the design process
- ⇨ Tools → to simplify calculation





Credits: A. Wanninger & A. Perin

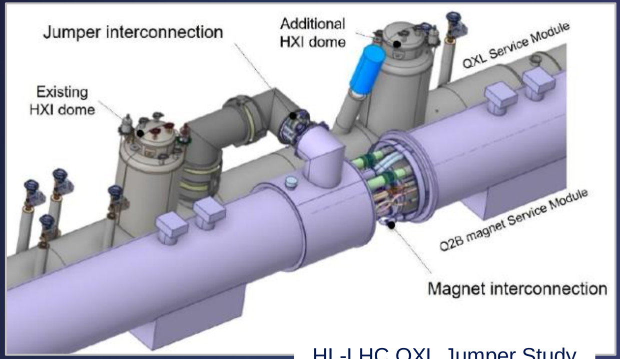
Thermo-mechanical Engineering and Design

Thermo-mechanical Design & Analysis

Integration, studies and component design:

- ⇨ 3D Design tools → Catia V5 with SmarTeam
- ⇨ Transition to PLM in collaboration with CAD Services

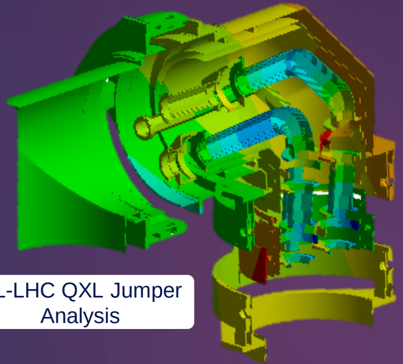
HL-LHC SD Refrigerator Integration



HL-LHC QXL Jumper Study

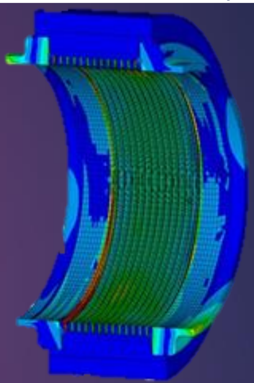
Thermo-mechanical Analysis

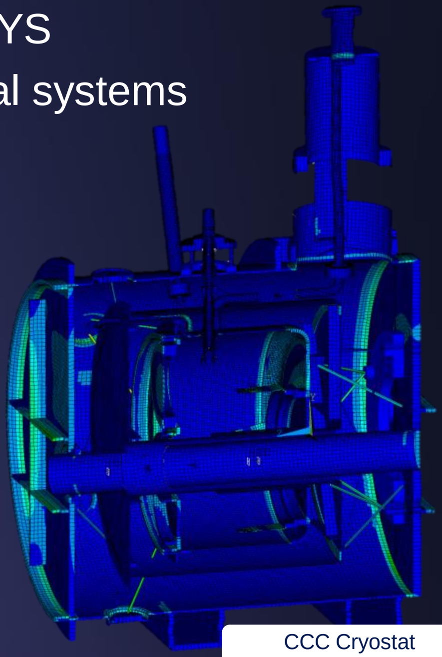
- ⇨ Finite Element Analysis tool → ANSYS
- ⇨ Development of complex mechanical systems
  e.g., CCC Cryostat / HL-LHC QXL Jumper
- ⇨ Component benchmarking studies
  e.g., flexible hose stiffness study



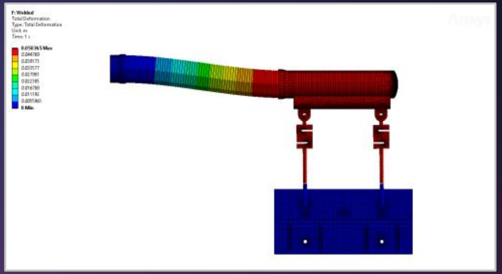
HL-LHC QXL Jumper Analysis

DFBA Gimble Bellows Analysis





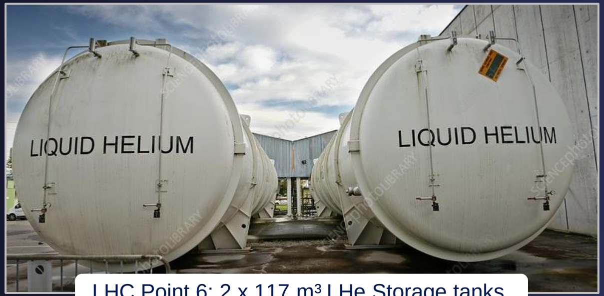
CCC Cryostat
Antiproton Decelerator



Flexible hose stiffness study

Cryogenic Pressure Equipment

Safety sensitive equipment → Highly regulated for design, production and maintenance



LHC Point 6: 2 x 117 m³ LHe Storage tanks

LHC Point 18: 12 x 250 m³ GHe Storage tanks

LHC Pt 18 GHe storage:

- ⇨ Volume / pt = 250m³ x 12 = 3000 m³
- ⇨ Design Pressure = 24 bar
- ⇨ PED Category = IV
- ⇨ Stored energy at design pressure = 7.760 GJ (Equivalent to 1.67 t of TNT)

CERN HSE

Risk assessment → SG OHS-0-0-1

Pressure equipment → GSI-M-2

European Pressure Equipment Directive (PED)

		Harmonised standard	Other standards
Safety systems and devices	General	EN 764-7, ISO 4126-7	ASME code, API, AD 2000
	Cryogenic	ISO 21013-, EN 13648	CGA, EIGA
Mechanical Design	General	EN 764, EN 13445, EN 13480	ASME code, AD 2000
	Cryogenic	EN 13458	CGA, EIGA

Cryogenic Pressure Equipment

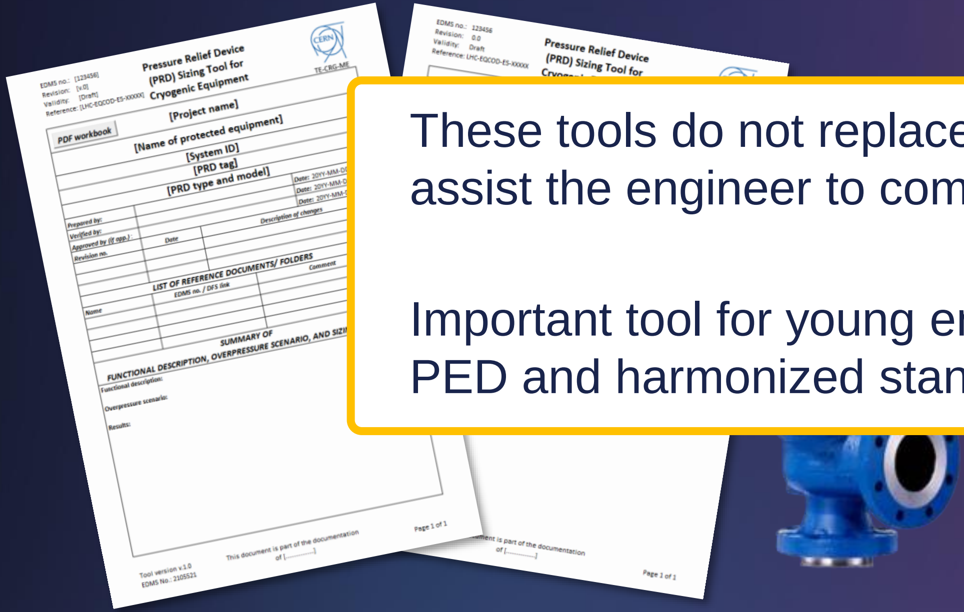
Protection against overpressure:

- Guideline → Standardises TE-CRG-ME methodology
  (EDMS 2105567)
- Checklist → To ensure methodology is correctly applied
  (EDMS 2105522)
- Sizing tool → To aid calculation
  (EDMS 2105521)

Mechanical design:

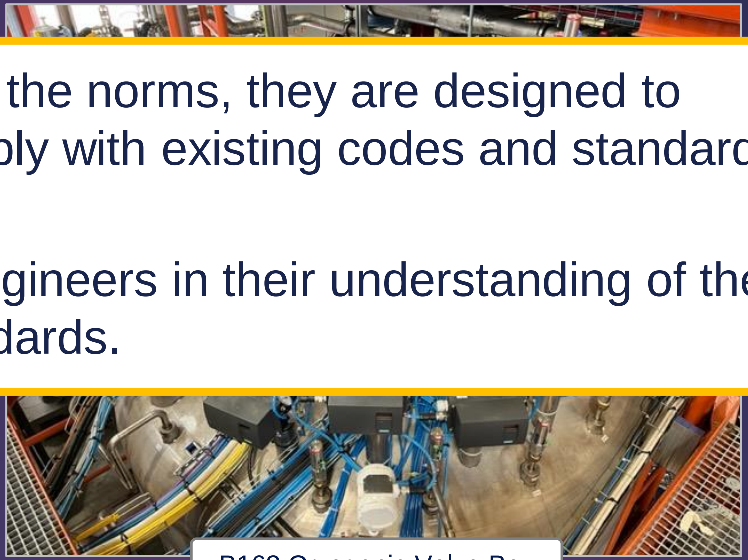
- Guideline → Standardises TE-CRG-ME methodology
  (EDMS 2402943)
- Checklist → To ensure methodology is correctly applied
  (EDMS 2402959)

Designed to accompany and engineer through the design, manufacture and testing of pressure equipment, to avoid missing crucial aspects.

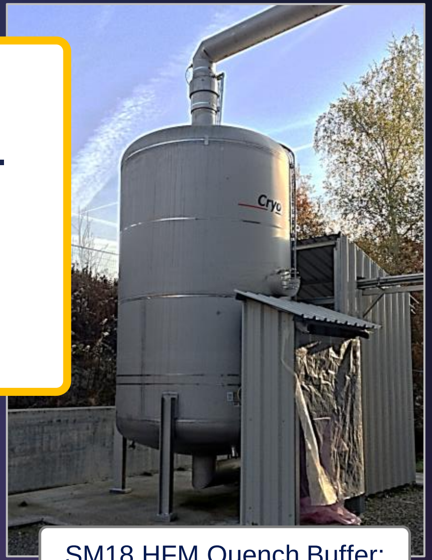


These tools do not replace the norms, they are designed to assist the engineer to comply with existing codes and standards.

Important tool for young engineers in their understanding of the PED and harmonized standards.



B163 Cryogenic Valve Box



SM18 HFM Quench Buffer:
15 m³ @ 5 bar @ 5 K

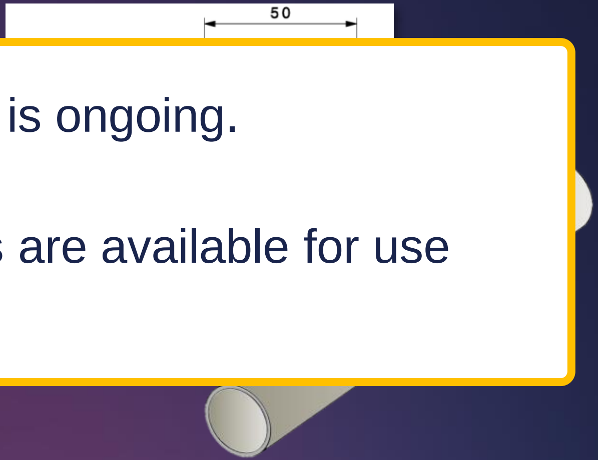
Credits: A. Wanninger & A. Perin

Cryogenic Construction Methods and Components

Cryogenic Construction Methods and Components

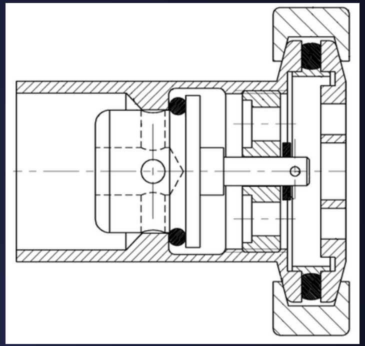
Standard CRG Co

- Thermalised pipe
- Pumping ports for
- Spinning rotor vac
- He Guard system
- Mechanical integration cryogenic instrumentation



The development of our cryogenic library is ongoing.

These standard components and designs are available for use outside CRG.



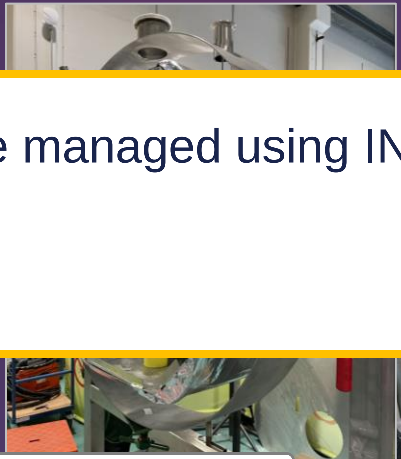
Transfer Line Pumping Port

Mechanical interventions on Cryogenic Systems:

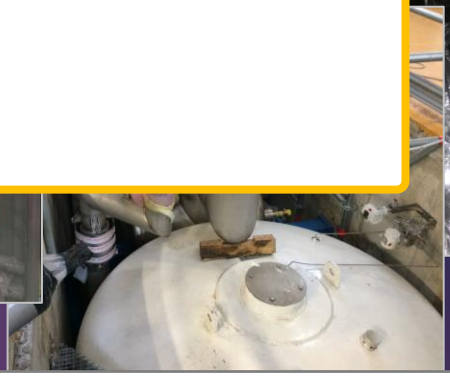
- Management of confined spaces.
- Significant exper
- In-house manufa
- Mechanical support for CRG systems

Mechanical support activities are managed using INFOR EAM:

- Spare part management
- Work requests and follow-up



IT String Flow Meter Box



B163 cryogenic system and LHe Dewar

Constrained work in SM18 6 KW Coldbox

Conclusion

To fulfil our role in the cryogenics group at CERN, TE-CRG-ME has developed tools, guidelines and standards in the areas of:

- ⇨ Cryogenic process
- ⇨ Thermo-mechanical engineering and design
- ⇨ Cryogenic construction methods and components

Our aim is to continue to develop a wide-ranging tool kit to provide tools and reference designs for most aspects of cryogenic engineering

Current areas of development:

- ⇨ Tool kits are by nature in continuous evolution
- ⇨ We aim to include future developments and trends in cryogenic applications
  - – Different temperatures
  - – Different cryogens and cooling mechanics

Thanks for Listening

Credit: CERN

Pressure Equipment

HSE regulations relevant to Cryogenic pressure equipment

Safety Regulations (SR)	SR-M	en	fr	Mechanical hazards	Mechanical equipment
General Safety Instructions (GSI)	GSI-M-2	en	fr	Mechanical hazards	Standard pressure equipment
	GSI-M-4	en	fr	Mechanical hazards	Cryogenic equipment
Specific Safety Instructions (SSI)	SSI-M-2-1	en	fr	Mechanical hazards	Pressure vessels
	SSI-M-2-2	en	fr	Mechanical hazards	Simple pressure vessels
	SSI-M-2-3	en	fr	Mechanical hazards	Safety accessories for standard pressure equipment
	SSI-M-2-4	en	fr	Mechanical hazards	Metallic pressurised piping
	SSI-M-2-6	en	fr	Mechanical hazards	Transportable pressure equipment
Safety Instructions (IS)	IS 42	en	fr	Mechanical hazards	Compressed gas bottles (1995)
Safety Guidelines	SG-M-4-0-1	en		Mechanical hazards	Cryogenic equipment
	SG-OHS-0-0-1	en		Safety and Health risks	Risk assessment