DFM Safety aspects
(cryogenic safety only)

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- Cryogenic safety
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- Summary

DFM configuration and cryo safety parameters

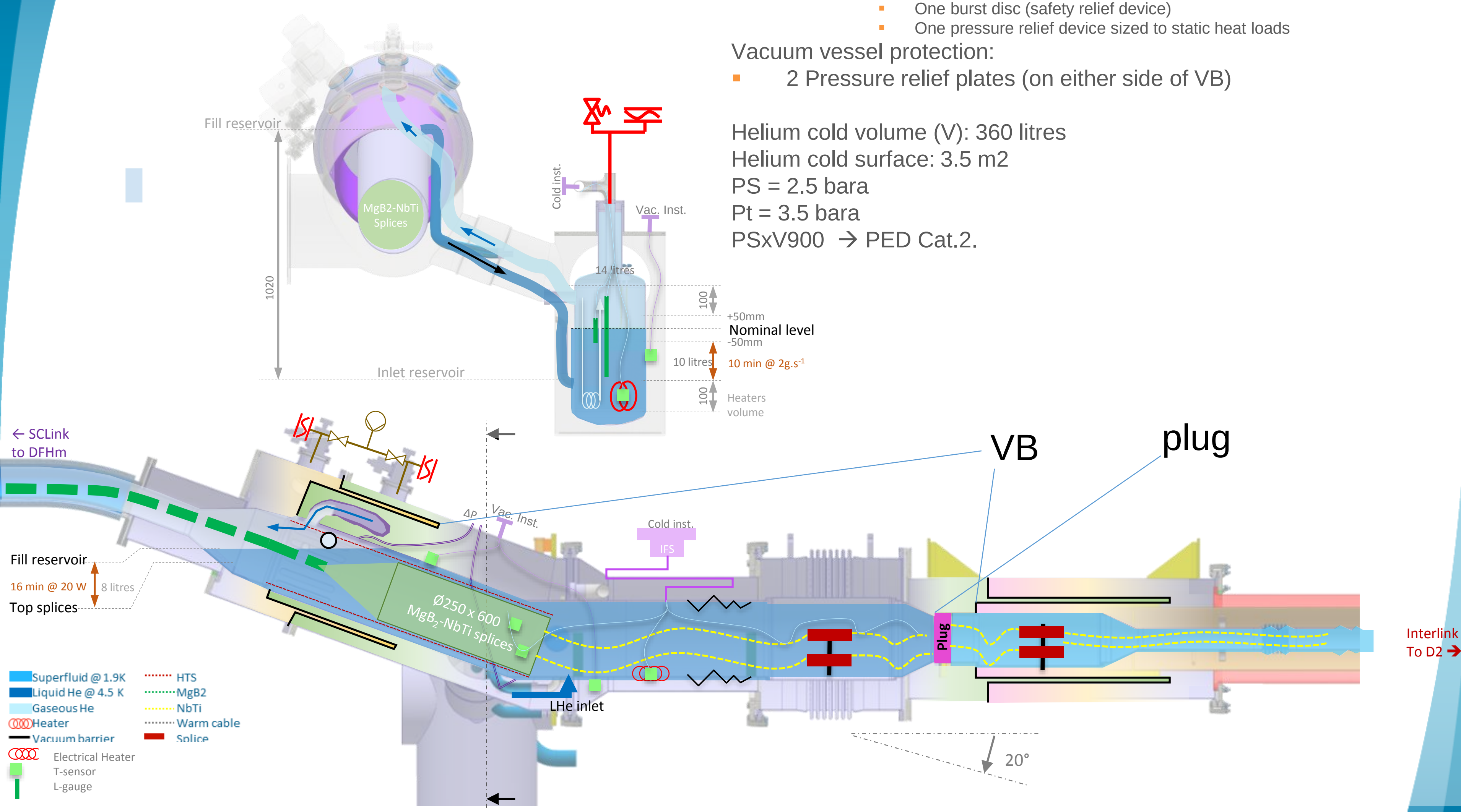
Helium vessel protection:

- Pressure relief devices
  - One burst disc (safety relief device)
  - One pressure relief device sized to static heat loads

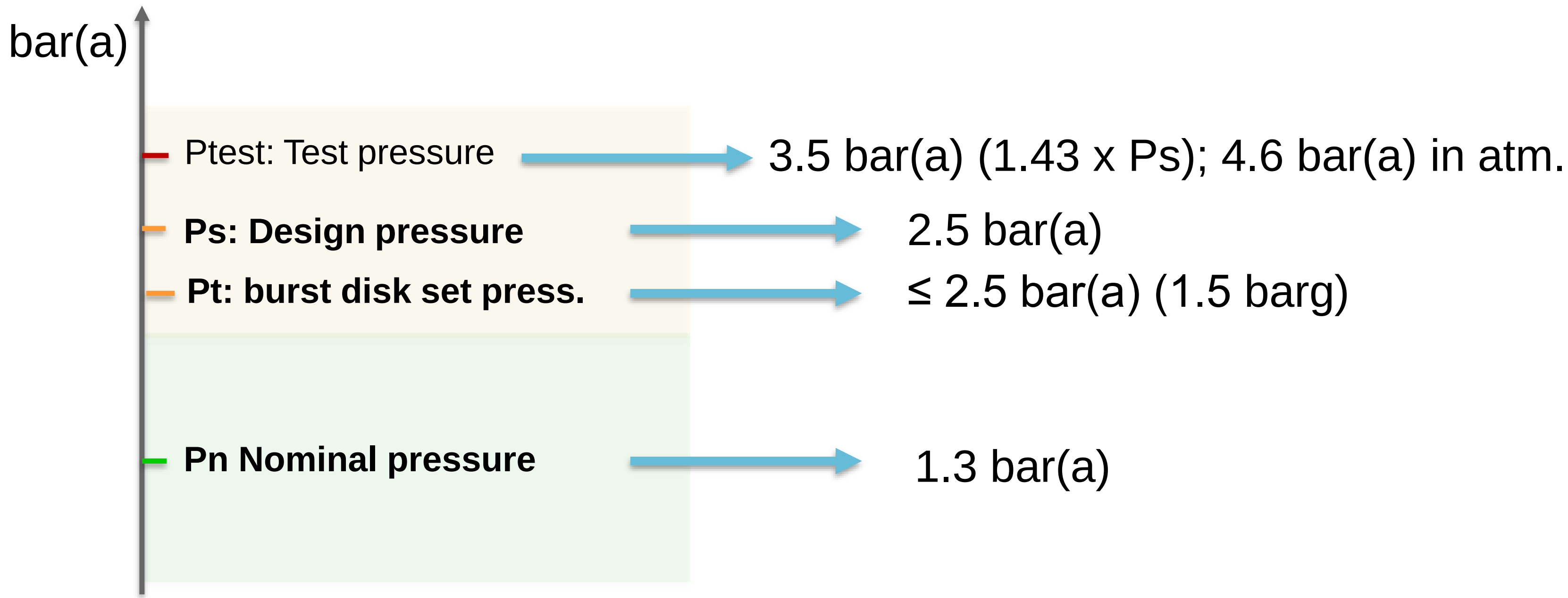
Vacuum vessel protection:

- 2 Pressure relief plates (on either side of VB)

Helium cold volume (V): 360 litres
Helium cold surface: 3.5 m2
PS = 2.5 bara
Pt = 3.5 bara
PSxV900 → PED Cat.2.



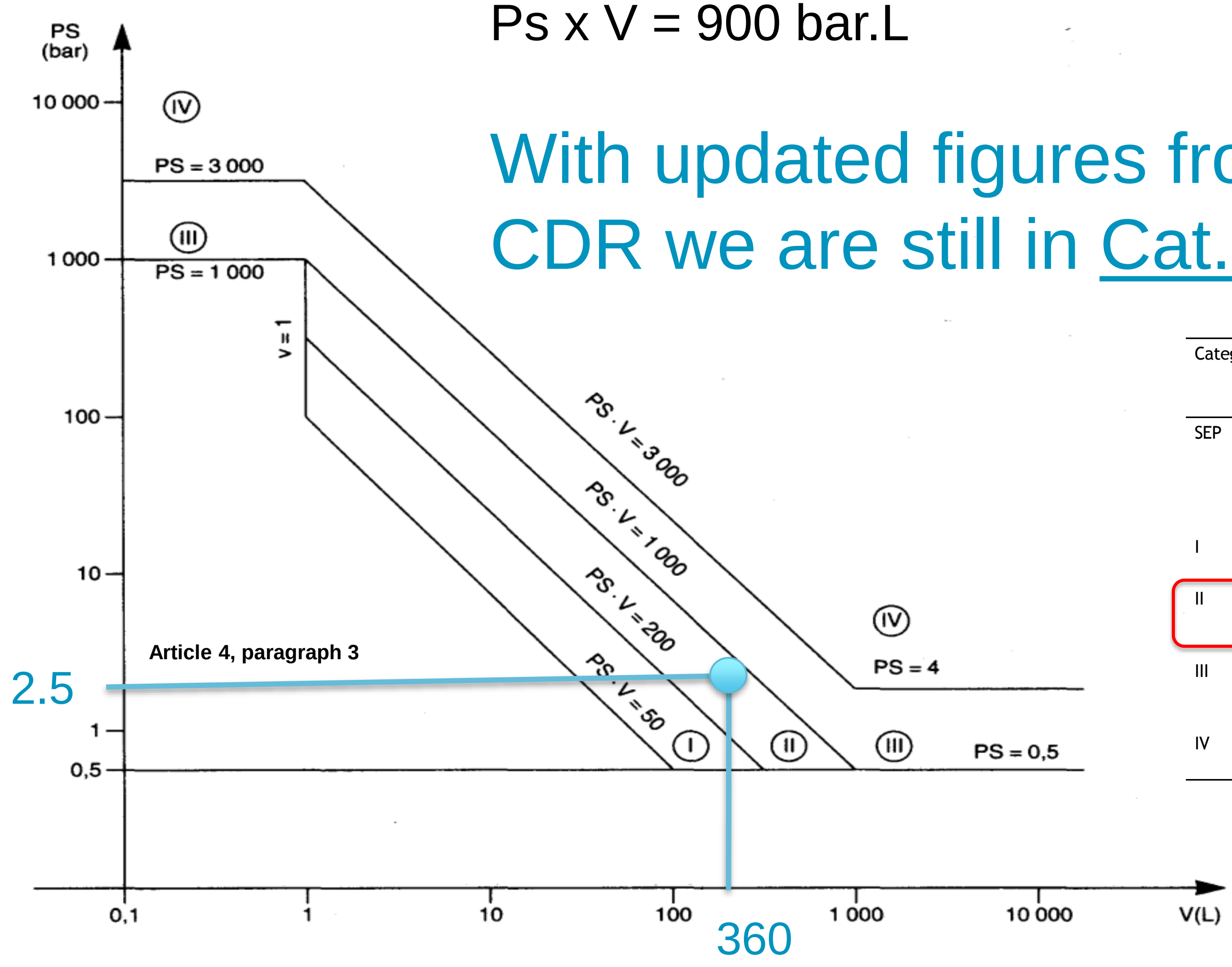
Scale of pressures, helium vessel



PED category

Ps x V = 900 bar.L

With updated figures from CDR we are still in Cat.2



Category	Conf. assessment module	Comment
SEP	None	The equipment must be designed and manufactured in accordance with sound engineering practice. No CE marking and no involvement of notified body.
I	A	CE marking with no notified body involvement, self-certifying.
II	A1	The notified body will perform unexpected visits and monitor final assessment.
III	B1+F	The notified body is required to approve the design, examine and test the vessel.
IV	G	Even further involvement of the notified body.

Risk assessment matrix (as for DFX)

RISK MATRIX, Overpressure hazard for the DFX

	Source of overpressure	Possible cause	Consequence	LIKELIHOOD	IMPACT	Mitigation measures
A	Loss of insulation vacuum to air	External bellows failure, relief plate accidental removal	sudden air inrush and cryocondensation on cold surfaces	Possible	Major	Adequate design, manfacture & QC of bellows; protection of bellows against accidental damage; limited mechanical work in cyogenic operation.
B	Helium spill to insulation vacuum	internal bellows failure	helium spill through orifice (size?) to vacuum vessel.	Possible	Major	Adequate design, manfacture & QC of bellows; consider protection sleeves to limit spill mass flow;
C	Helium spill to insulation vacuum	dielectric failure, development of excessive resistance in splice	arc bursting helium envelope, helium pressurized at burst disk pressure, spill helium inventory to vacuum vessel.	Rare	Catastrophic	Adequate electrical insulation design, installation, and QC; online Vtap measurements acrooss all splices to monitor degradation;
D	Pressure build-up from triplets at quench	Lambda plug failure	sudden mass flow through damaged plug to DFX, providing pressure rise	Possible	Moderate	Adequate design, manfacture and QC testing of plugs;
E	Expansion of cryopumped air leaks	elastomeric ring leaks	Pressure increase at warm-up	Possible	Moderate	Leak checks of all sealed elements;
F	Pressure surge	fluid velocity change caused by e.g. starting/stopping pumps, opening/closing valves	pressure increase with limited mass flow change	Frequent	Moderate	Add rated valve to open at lower pressure than burst disk set pressure
G	Pressure build-up from EH-FH boiler line	failure of a junction (st.steel/Cu)	Pressure increase due to HP helium venting to helium reservoir	Rare	Moderate	Adequate design, manfacture and QC testing of boilers;
H	...					

(red)	**High Risk**
(orange)	**Medium Risk**
(green)	**Low Risk:**

Remarks:

- causes of excessive pressure are considered to be unrelated (single jeopardy theory) unless cause/effect exists

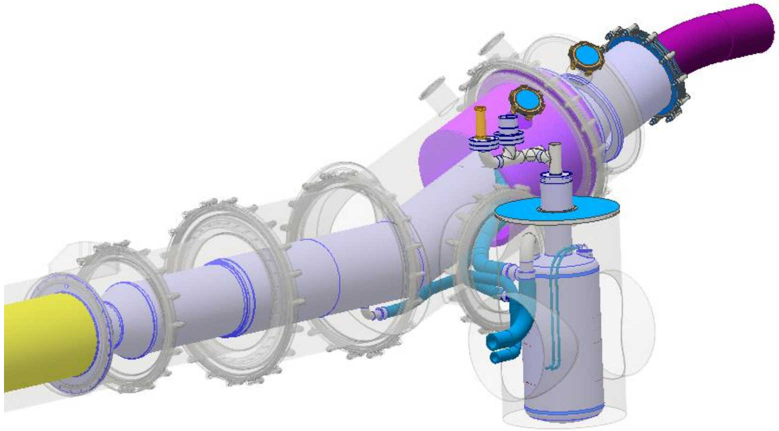
Retained pressure hazards (same as for DFX)

- A) Accidental air venting of insulation vacuum with sudden condensation on cold surfaces, helium boil-off and pressure build-up → sizing of burst disk
- C) Accidental release of cryogenic fluid from helium vessel to insulation vessel due to arc bursting helium envelope, helium pressurized at burst disk pressure, spill of helium inventory to vacuum vessel → sizing of vacuum vessel relief plate

Safety relief devices sizing for DFM

Helium vessel burst disk:

- Data:
  - Cold surfaces exposed to Vacuum : 3.5 m^2 (2.2 m^2 wet surface)
  - 30 layers MLI on helium vessel
  - Design Pressure = 2.5 bara
  - Saturated liquid in nominal configuration
  - Helium volumes in nominal operation : 210 litres liquid + 150 litres gaseous
- Inputs:
  - Vacuum break on 10 MLI layers : 6.2 kW/m^2
  - Power dissipated in liquid : 21 kW
- Relief device sizing according to ISO21013-3
  - ISO21013-3 ➔ Qm = 1.4 kg/s
  - EN4126-6 ➔ D_{relief} > 28 mm



Insulation vacuum relief plates:

- Preliminary sizing:
- Assume orifice: DN50
- Pt= 2.5 bara; Pb=0 bara; T_{rel}= ~5 K
  - → Qm_{vessel} = ~5 kg/s to the vac.vessel
- Relief plate to limit ΔP to 0.5 barg (opens at 1.5 bara)
- Assuming continuity of mass relief (conservative): $Qm_{vessel} = Qm_{relief}$
  - → ~DN100 → 2 DN100 on either side of VB

Summary

- The equipment is Cat.2 of the PED
- Preliminary sizing of burst disks and relief plates done
- The location of the burst disk/rated valve and relief plates needs to be confirmed by the integration study with WP15

Thank you !

Q/A