Hall C SHMS Q2, Q3, and Dipole: Magnet Pressure Safety

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Outline

- **Cryogenic Control Reservoir**
- **Relief Valves**
- **Rupture Discs**
- **Parallel Relief Plates**
- **Independent Sizing Calculation**
- **Pressure Safety of Helium and Nitrogen Circuits**
- **Summary**

Cryogenic Control Reservoir (CCR)

- CCR consists of four components: helium reservoir, nitrogen reservoir, piping, and vacuum can.
- Helium reservoir and nitrogen reservoir were sized per ASME 2007 Section VIII, Division 2.
- Vacuum can, not a pressure vessel, was also sized per code.
- Calculation was reviewed by D. Meekins (Design Authority).

Cryogenic Control Reservoir – Piping

- **Pressure Piping**
  - ASME B31.3-2006 was used to size the piping system.
  - The code does not require formal flexibility analysis because the piping system is essentially a duplication, without significant changes, of the G0 piping system, which has a successful service record.
  - Flanges were sized according to ASME 2007 Section VIII, Division 1, Appendix 2.
  - Both S. Lassiter and D. Meekins (Design Authorities) reviewed the pressure piping safety analysis.

Cryogenic Control Reservoir – Fabrication

- **Fabrication and Test**
  - Vendor: Meyer Tools & Mfg., Inc
  - Fabricated in accordance with the intent of ASME 2007 Section VIII Division 2.
  - JLab witnessed the pressure and vacuum tests.
  - Fabrication documents were reviewed by M. Martin, JLab weld inspector.

Relief Valves

- **Relief Valves**
  - Set pressure: 4 atm (gauge)
  - Helium relief valve
    Anderson Greenwood pilot operated relief valve, Model No. 25905K34/S with a discharge area of 1186 mm^2
  - Nitrogen relief valve
    Flowsafe F84-8 ¾ X 1F SS 0.261 in^2

Relief Valve	Magnet	Failure Mode	Required Capacity (kg/hr)	Design Capacity (kg/hr)
Helium	Q2/3	Quench with active protection	5.175×10^3	16.81×10^3
	Dipole	Quench with active protection	8.646×10^3	16.81×10^3
Nitrogen	Q2/3	Loss of vacuum	0.5591×10^3	1.157×10^3
	Dipole	Loss of vacuum	1.010×10^3	1.157×10^3

Rupture Discs

- Rupture Discs
  - Set pressure: 5 atm (gauge)
  - Rupture disc for helium
    Fike 3'' AXIUS for Q2/3 and Fike 4'' AXIUS for Dipole
  - Rupture discs for nitrogen
    Fike 1'' AXIUS BT

Rupture disc	Magnet	Worst Scenario	Required Capacity (kg/hr)	Design Capacity (kg/hr)
Helium	Q2/3	Loss of vacuum triggers quench with failed dump resistor	30.20×10^3	36.01×10^3
	Dipole	Loss of vacuum triggers quench with failed dump resistor	47.63×10^3	60.50×10^3
Nitrogen	Q2/3	Loss of vacuum	0.5591×10^3	2.616×10^3
	Dipole	Loss of vacuum	1.010×10^3	2.616×10^3

Parallel Relief Plates

- **Parallel Relief Plates (pop-up relief valves) for Vacuum Insulating Space of Magnet**
  - **Relief pressure: 0.5 atm (gauge)**
  - **Two 4'' parallel plates**

Worst Scenario	Required Capacity (kg/hr)	Design Capacity (kg/hr)
A broken helium line	8.071×10^3	17.73×10^3
A broken nitrogen line	1.729×10^3	25.30×10^3

Independent Sizing Calculation

- Charles Monroe, a consultant for Sigmaphi, independently sized the relief valves, and rupture discs for Q2/3 and Dipole.

- He concluded that the chosen relief valves and rupture discs were adequate to relieve helium or nitrogen in the worst-case scenarios.

Pressure Safety of Helium Vessel

- **Helium vessels and piping of Q2/3 and Dipole were sized by APAVE (a French company, specialized in code compliance) per ASME 2010 Section VIII Division 1.**
- **Sigmaphi also conducted supplemental finite element analysis of the vessels.**
- **Helium vessels and piping were fabricated by SDMS and inspected by APAVE per code.**
- **Helium circuits were pressure/leak checked per code.**

Pressure Safety of Nitrogen Shield

- **APAVE conducted sizing calculation of nitrogen shields and piping per ASME Section VIII Division 1.**

- **Ziemann fabricated nitrogen shields and performed burst tests at 60 bar.**

- **According to code, the maximum allowable working pressure of nitrogen shield is 8.46 bar, larger than required 6.08 bar (5 atm [gauge]), for burst tests at 60 bars.**

- **Nitrogen circuit was pressure/leak tested per code.**

Pressure Safety of Vacuum Vessel

- **Vacuum vessels of Q2/3 and Dipole are not pressure vessels because their maximum external pressures are 1.0 atm and maximum internal pressures are 0.5 atm.**

- **Vacuum vessels were sized by Sigmaphi and checked by JLab.**

- **Vacuum vessels were manufactured by SDMS.**

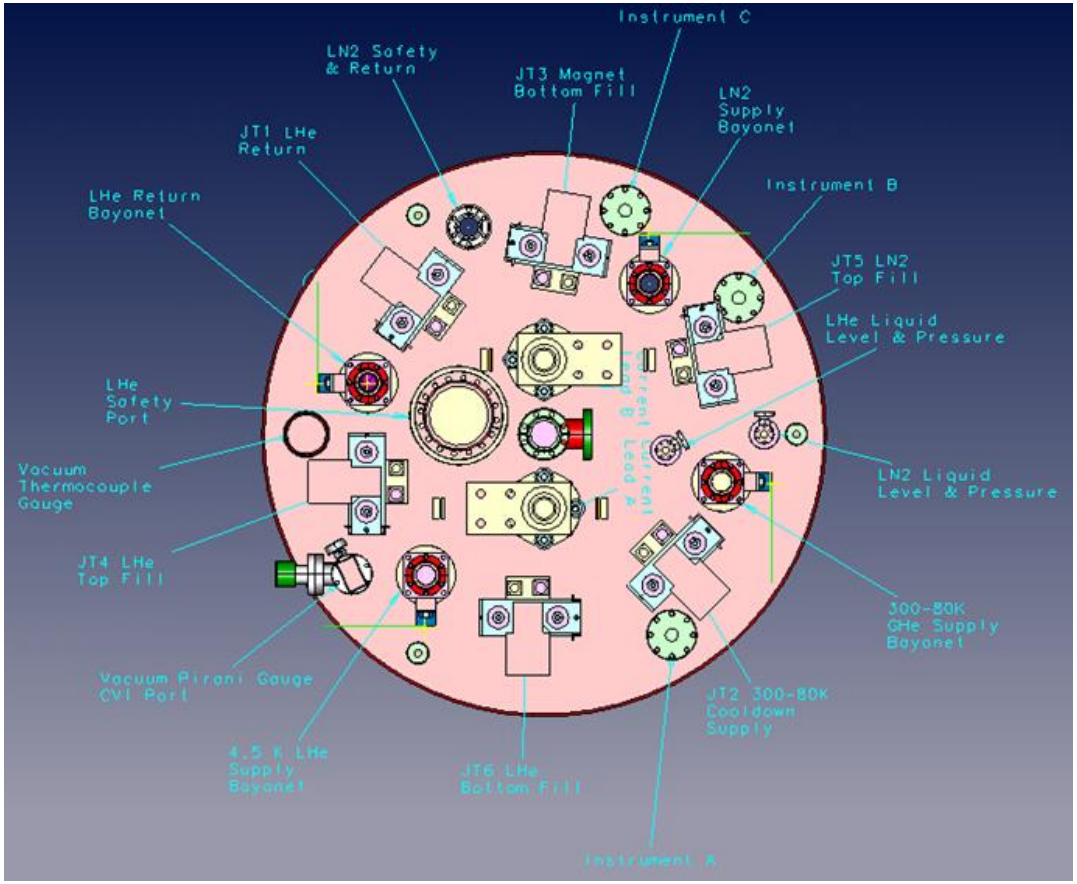
- **Leak tests were performed at Sigmaphi.**

Summary

- Relief valves were sized per specific failure modes.
- Rupture discs and parallel plates were sized to protect the magnets based on the worst-case scenarios.
- Sizing calculation of relief valves and rupture discs was independently verified.
- Helium circuit and nitrogen circuit were designed, fabricated, inspected, and tested in accordance with the intent of ASME pressure vessel code.

Appendix

Cryogenic Control Reservoir - Overview



CCR and sizing calculation were reviewed by D. Meekins, Design Authority

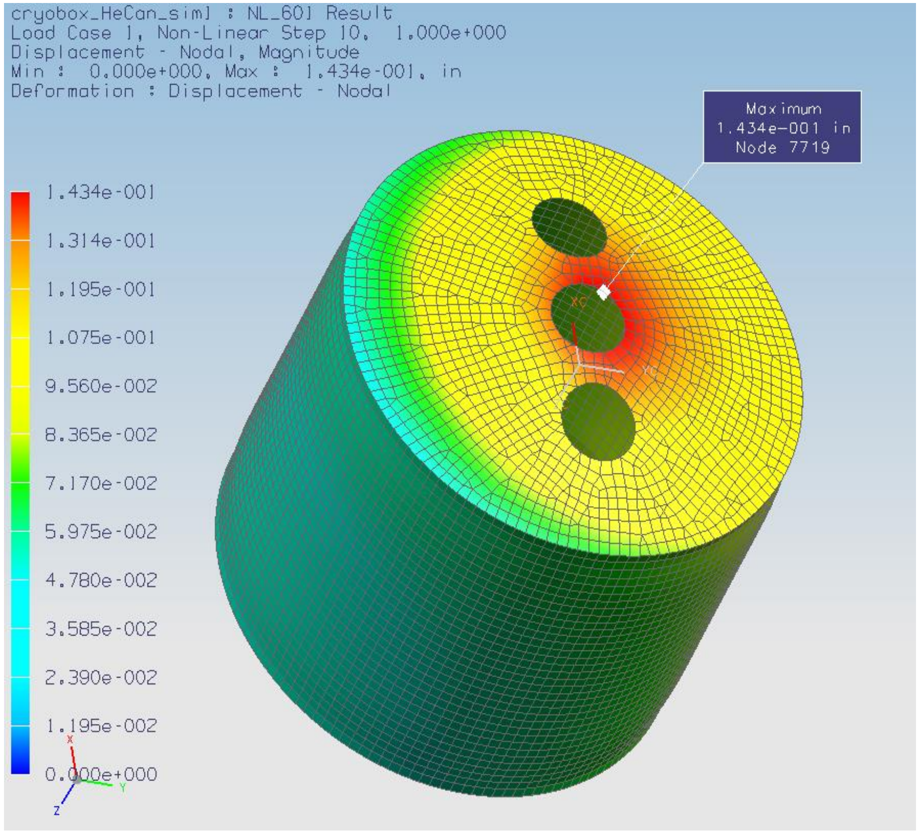
Cryogenic Control Reservoir – Reservoirs

- **Design by code**
  - ASME 2007 Section VIII Division 2
  - Helium reservoir
  - Nitrogen reservoir

		Min required wall thickness by ASME code (inch)	Design wall thickness (inch)
Helium reservoir	Outer wall	0.056	0.1875
	End plates	0.89	1.25
Nitrogen reservoir	Outer wall	0.081	0.1875
	Inner wall	0.081	0.25
	End plates	0.61	1.0

Cryogenic Control Reservoir – Reservoirs

- **Analysis by code**
  - **Elastic-Plastic Stress Analysis**



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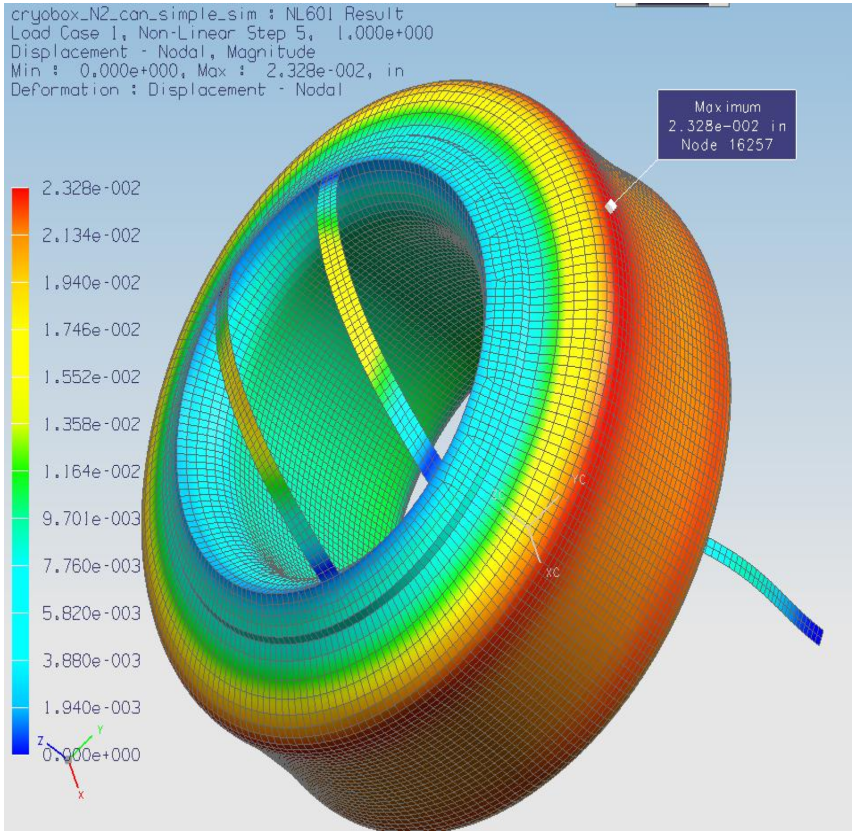
cryobox_HeCan_sim1 : NL_601 Result
Load Case 1, Non-Linear Step 10,  1.000e+000
Displacement - Nodal, Magnitude
Min :  0.000e+000, Max :  1.434e-001, in
Deformation : Displacement - Nodal
```



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cryobox_N2_can_simple_sim : NL601 Result
Load Case 1, Non-Linear Step 5,  1.000e+000
Displacement - Nodal, Magnitude
Min :  0.000e+000, Max :  2.328e-002, in
Deformation : Displacement - Nodal
```

Cryogenic Control Reservoir – Outer Can

- **Outer Can**
  - Wall thickness is 0.25''.
  - Thickness of end plates is 1.0''.
  - Thickness of bottom part is 0.625''.
  - Buckling analysis was done with a buckling load factor of 16.3.
  - Elastic-plastic analysis was performed to check behaviors under external pressure.
  - Elastic analysis was conducted to check stresses under internal pressure.