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Design and Analysis of 10” Parallel Plate Relief Device

Kelly Chicas, University of Illinois at Urbana-Champaign – ASPIRE Fellow

Introduction

- The Proton Improvement Plan II (PIP-II) project is an essential upgrade to Fermilab’s accelerator complex to enable the world’s most intense high-energy beam of neutrinos for the international Deep Underground Neutrino Experiment at LBNF.
- The Cryogenic Distribution System (CDS) for the PIP-II is dedicated to distributing cooling power from the Cryoplant (CP) to 23 cryomodules (CM) in total. The system is composed of the following main parts: Distribution Valve Box (DVB), Intermediate Transfer Line (ITL) and the Tunnel Transfer Line (TTL) comprising 25 Bayonet Cans and one Turnaround Can, with two extra Bayonet Cans to support a future upgrade of the Linac with two additional cryomodules.
- All CM and CDS relieving into Helium Low Pressure (LP) return header which is connected to compressor suction so, helium can be preserved during small flow relieving event and recirculated to system. However, during worst case scenario, Helium LP header requires a parallel plate relief device to relieve excess pressure from header. To complete the CDS Warm piping header, a **new design for a 10” parallel plate relief device is necessary** to relieve outside of the tunnel into atmosphere.

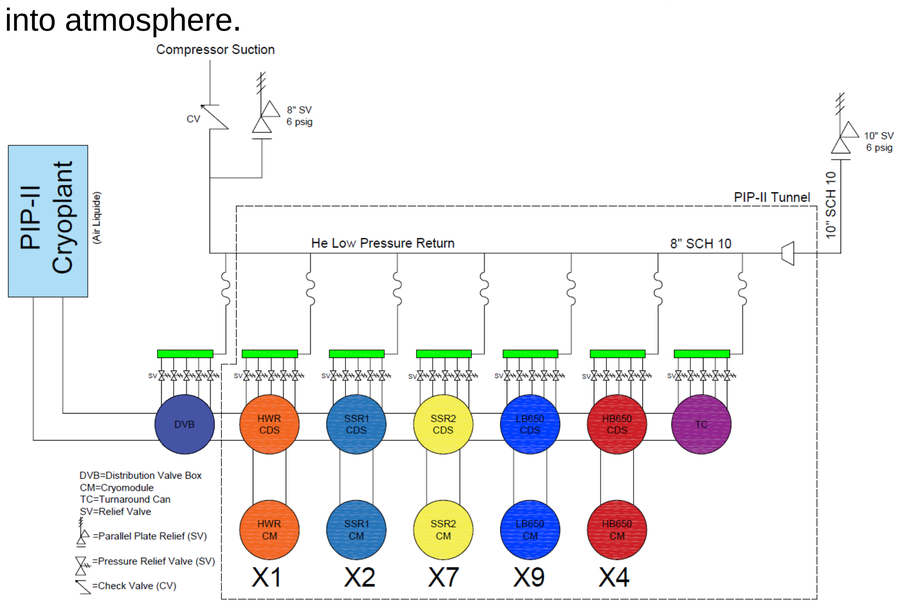

Figure 1: Simplified Cryogenic system for the PIP-II Project

Design and Methods

- If CDS losses vacuum catastrophically, then 10” parallel plate relief device opens to protect the system from over pressurization.
- Requirement of 10” Parallel plate relief device design:
  - Cracking pressure of ~ 6 psi
  - Helium mass flow rate of 47,200 lb_m/hr @ room temp.
- To allow the helium to be released into atmosphere, the lift plate of the 10” relief device will be raised.
- To raise the lift plate:
  - $F_{jet} \geq W_{Lift\ Plate} + F_{Spring}$
- First step is to create a preliminary design of the 10” parallel plate relief device based on an existing design of an 8” parallel plate device.
- The preliminary designed assessed the correct component weights, thrust area, spring type, and the number of springs to acquire an acceptable cracking pressure
- Table 1 shows the final calculated design parameter for the 10” parallel plate relief device
- Figure 4 shows the mass flow rate was calculate using Engineering Equation Solver Software (EES).

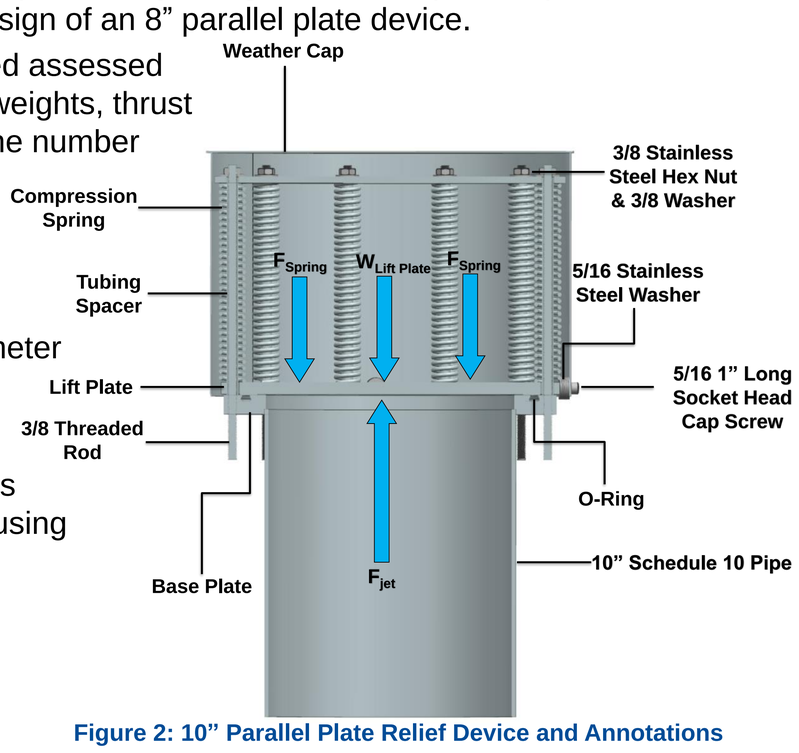

Figure 2: 10” Parallel Plate Relief Device and Annotations

10" Parallel plate Relief Device Final Design Components	Weight Parameter	Total Weight of Lift Plate (lbf)	15.95
	Thrust Parameters	O-ring ID (in)	11.975
		O-ring W (in)	0.275
		O-ring mean diameter (in)	12.25
		Thrust Area (in2)	117.9
	Spring Parameters	Spring Type	North American Spring (PO 09082)
		# of Springs	10
		Spring Constant (lb/in)	45
		Install Force (lbf)	787.5
		Max Lift (in)	2.40
	Flow Area	Nozzle Inner Diameter (in)	10.42
		Flow Area (in2)	85.28
	Vertical Cracking Pressure	Cracking Pressure (psig)	6.82

Table 1: Parallel Plate Relief Device Components

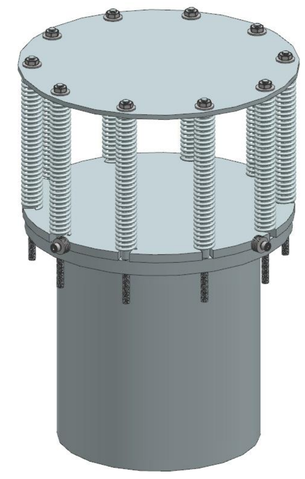

Figure 3: Trimetric View of the 10” Relief Device (Weather Cap Hidden)

Results

- Figure 4 displays the mass flow rate of the helium, nitrogen, and air through the 10” parallel plate relief device
- Capacity of 10” parallel plate relief device
  - Cracking pressure = 6.82 psig ≈ 6 psig
  - Apply overpressure allowance of 3 psi (per ASME BPVC)
  - Mass Flow Rate at 6.82 psig = 48,000 lb_m/hr ≥ 47,200 lb_m/hr

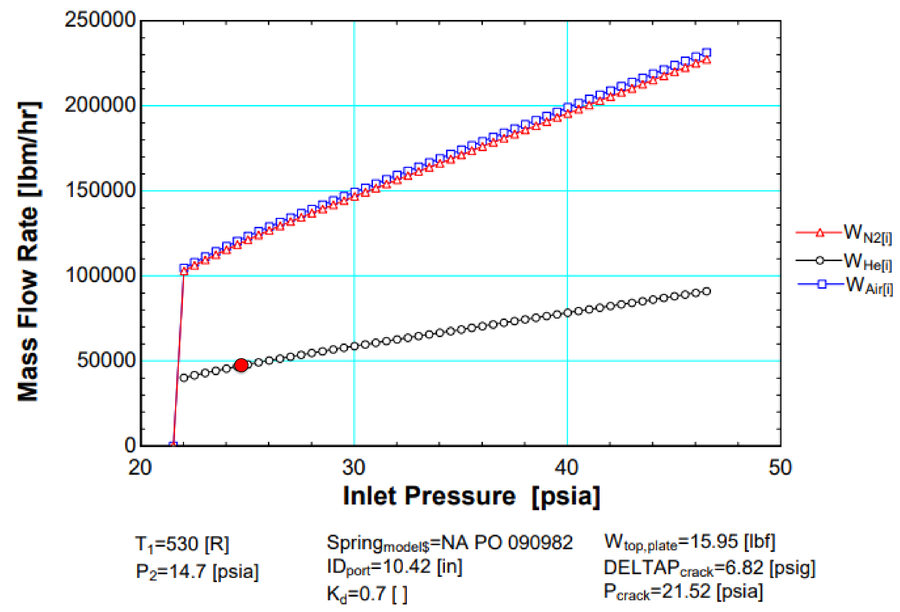

Figure 4: The Inlet Pressure (psia) vs. the Mass Flow Rate (lb_m/hr) from the EES Calculation

Conclusion

- 10” parallel plate relief device will effectively relieve the excess pressure from the LP header at the set pressure of ~ 6 psig.
- The drawing for the 10” parallel plate relief device will be created for the fabrication and installation to the CDS Warm piping header.

Acknowledgements

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