

# Cryogenic Cooling System for the E951 Pulsed Solenoid Magnet

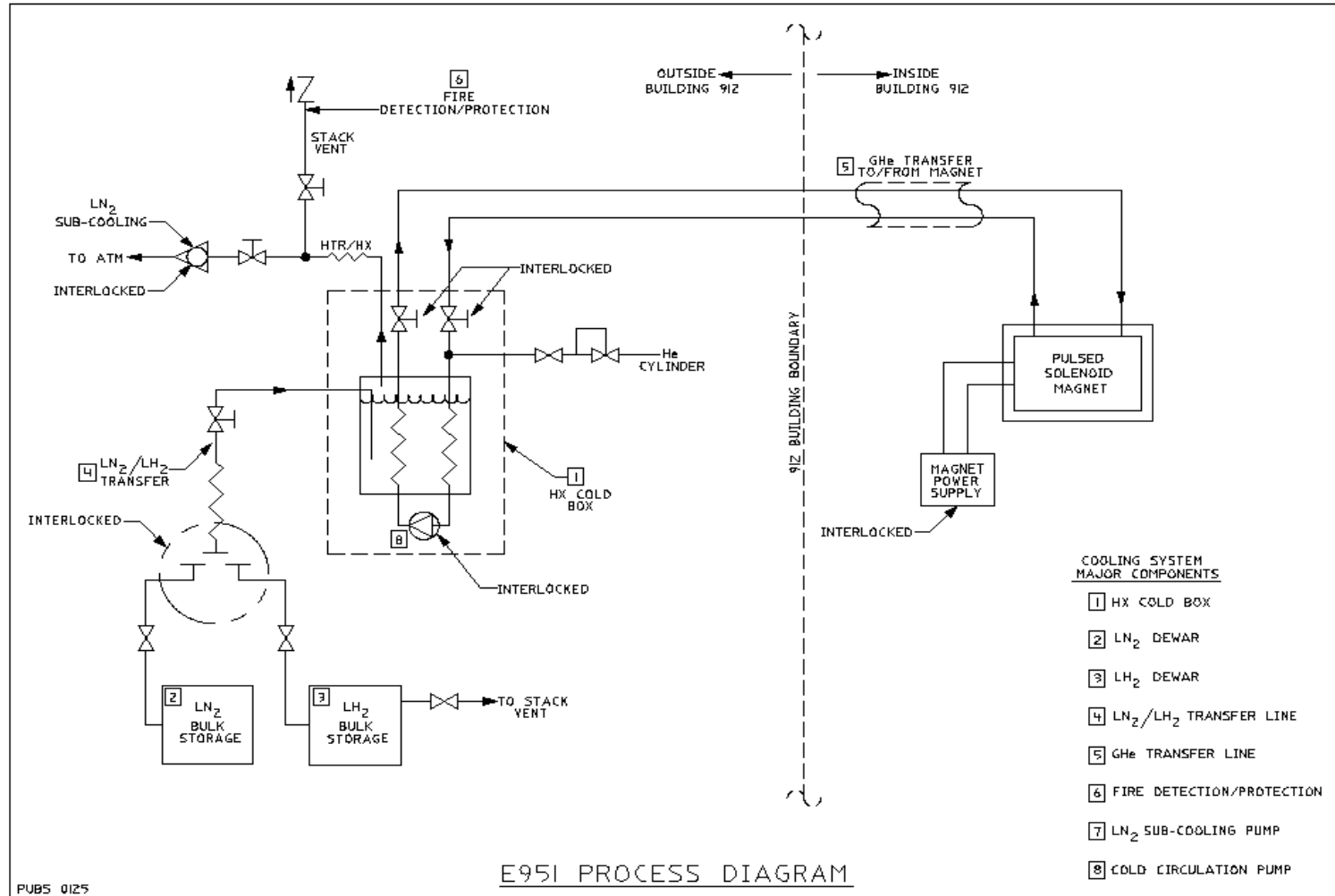
- Basic System Description/ Cooling Scheme
- Cooling Scheme Conceptual P&ID
  - Plan Arrangement, Heat Exchanger Detail & Picture
- System Parameters
  - Circulation Pump Specifications
- Summary of Predicted Heat Exchanger Performances
- Experimental Safety Considerations and Plan
- Cryogen Usage and Case Dependant Operational Costs
- Phased Construction and Installation Costs

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# System Description

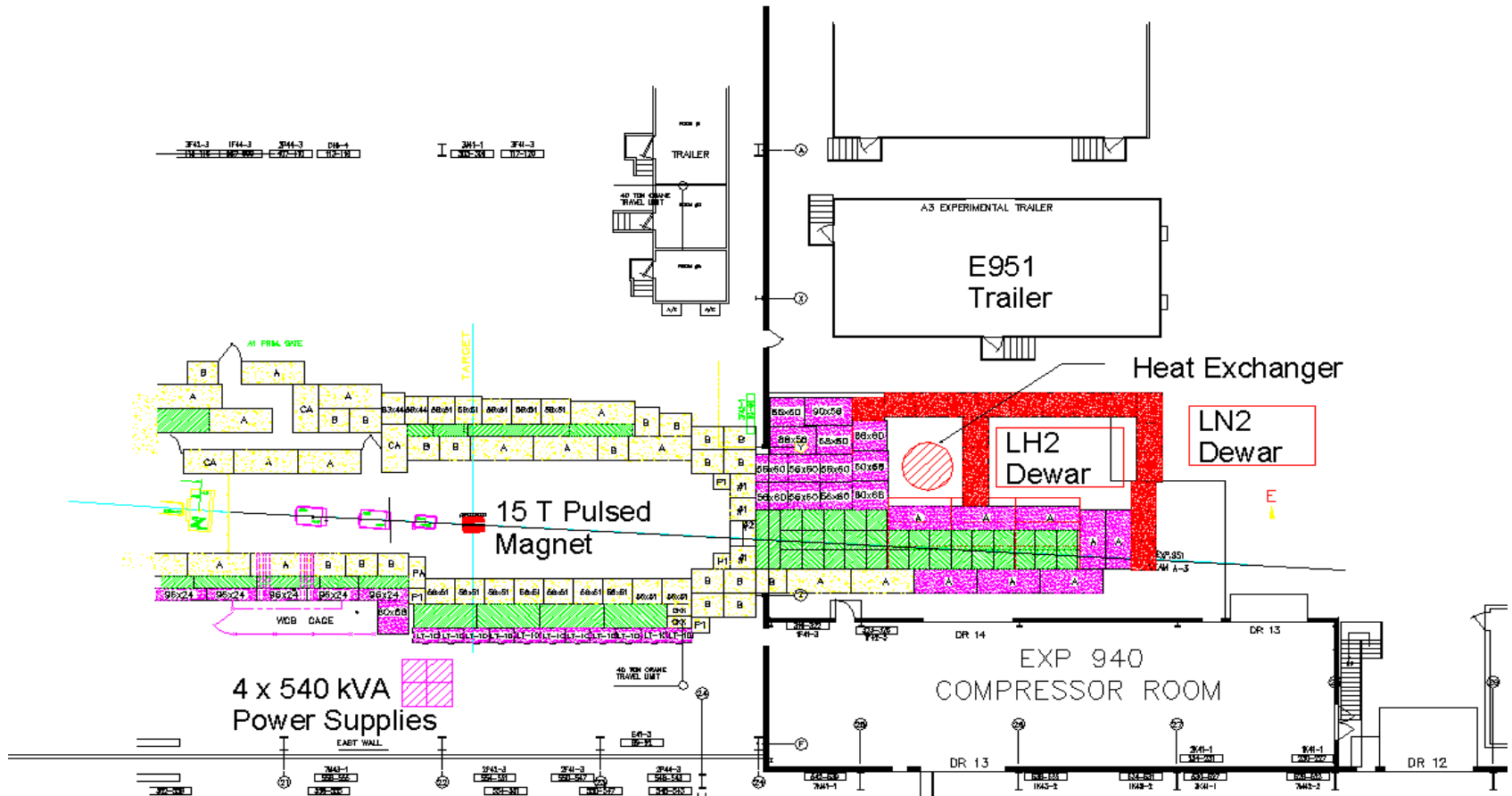
- Magnet energy removal via circulation of gaseous helium at 66 K or 22 K in a closed loop configuration. Phased Temperature Approach.
- Refrigeration via bulk LN2 (sub-cooled to 65K) or bulk LH2 @ ~22 K.
- Existing tube-in-shell heat exchanger and cold box from the SSC Westinghouse Facility in Hammond.
- LN2 and LH2 including the Heat Exchanger located outdoors to mitigate the safety issues associated with the use of LH2.

# Cooling System P&ID

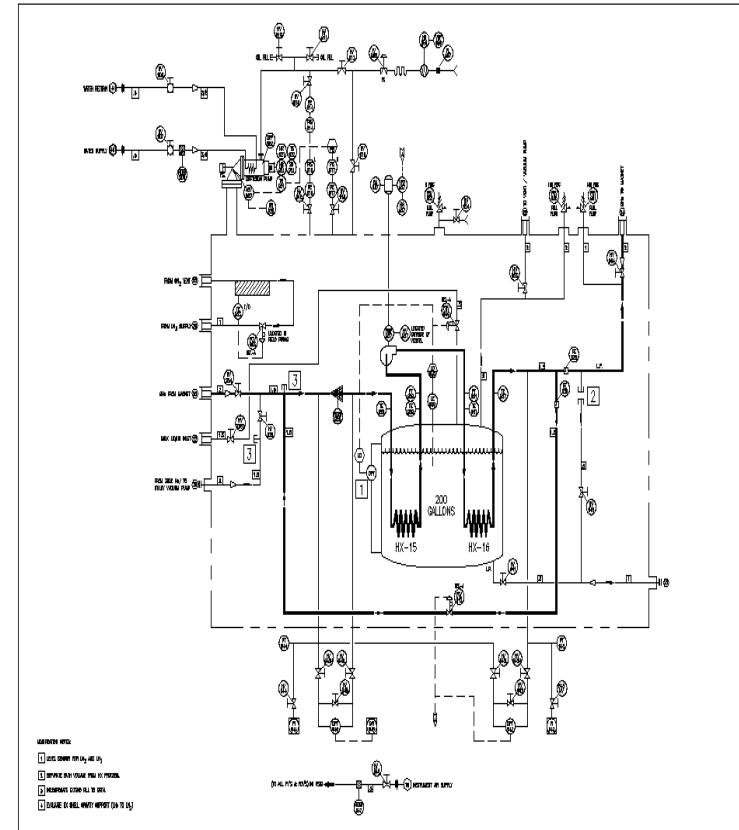
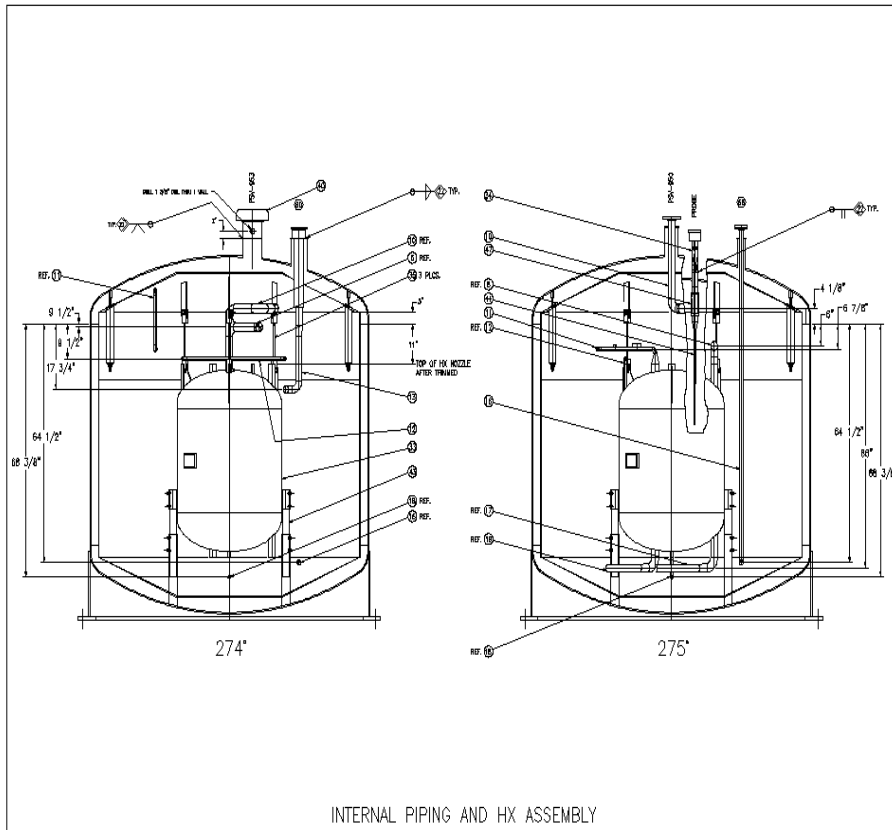


PUBS 0125

# Experimental Plan Layout



# Heat Exchanger Detail



# Heat Exchanger Cold Box



# Cryogenic System Parameters

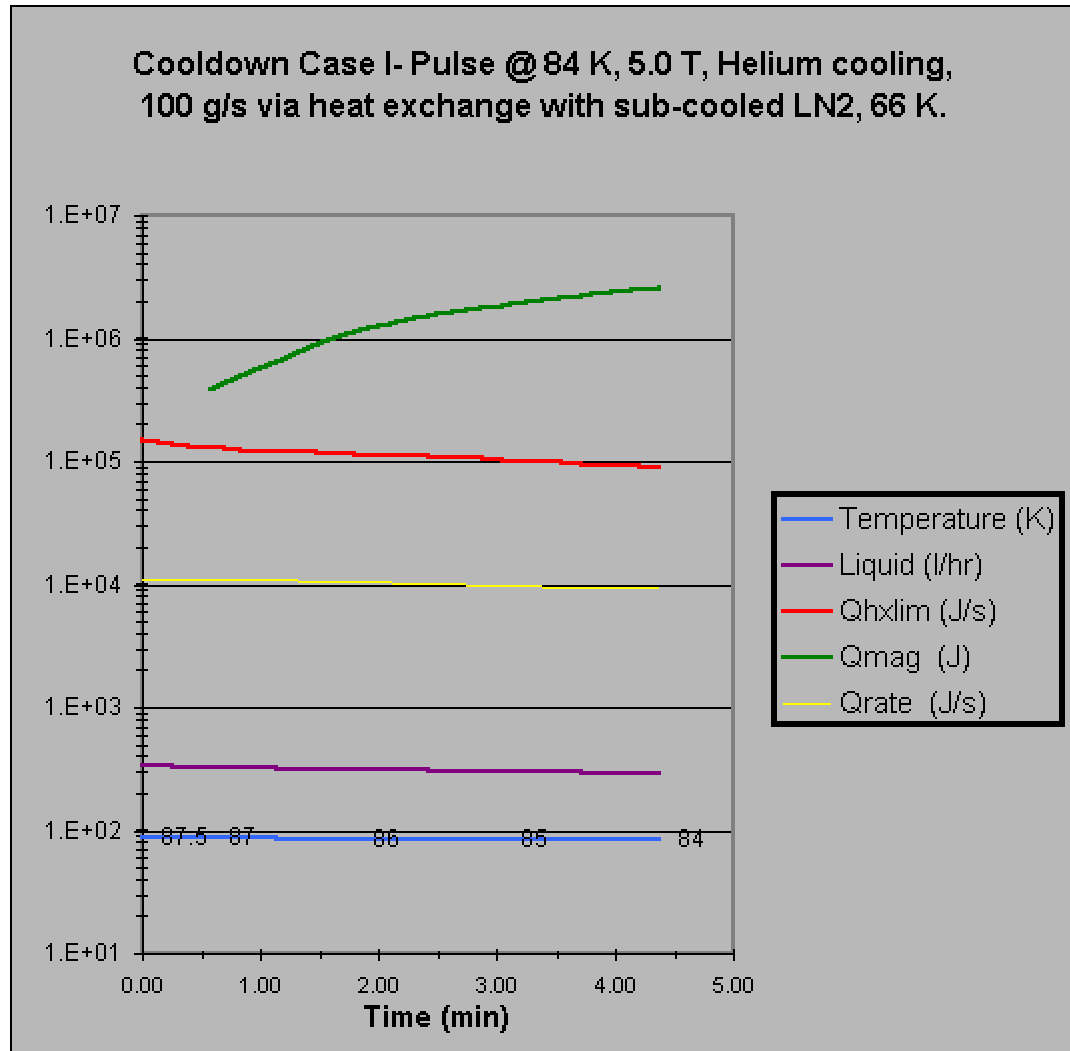
- Magnet Cold Mass- 3,600 kg
- Helium Loop Mass Flow- 100 g/s
- Magnet Energy Removed/Pulse- ~3-15 MJ
- Possible Rep Rate High Temp- >10/hr
- High Temperature Helium Delivery- ~66 K
- Low Temperature Helium Delivery- ~22 K
- Energy Removal Rate (Low Temp)- ~25 kJ/s
- Energy Removal Rate (High Temp)- ~10 kJ/s
- Bulk LH2 Storage Capacity- 5000 gallons ~19,000 L
- Simple Controls- cover all alarm, interlock, and system status with 10 analog and 10 digital signals

# Circulation Pump Specifications

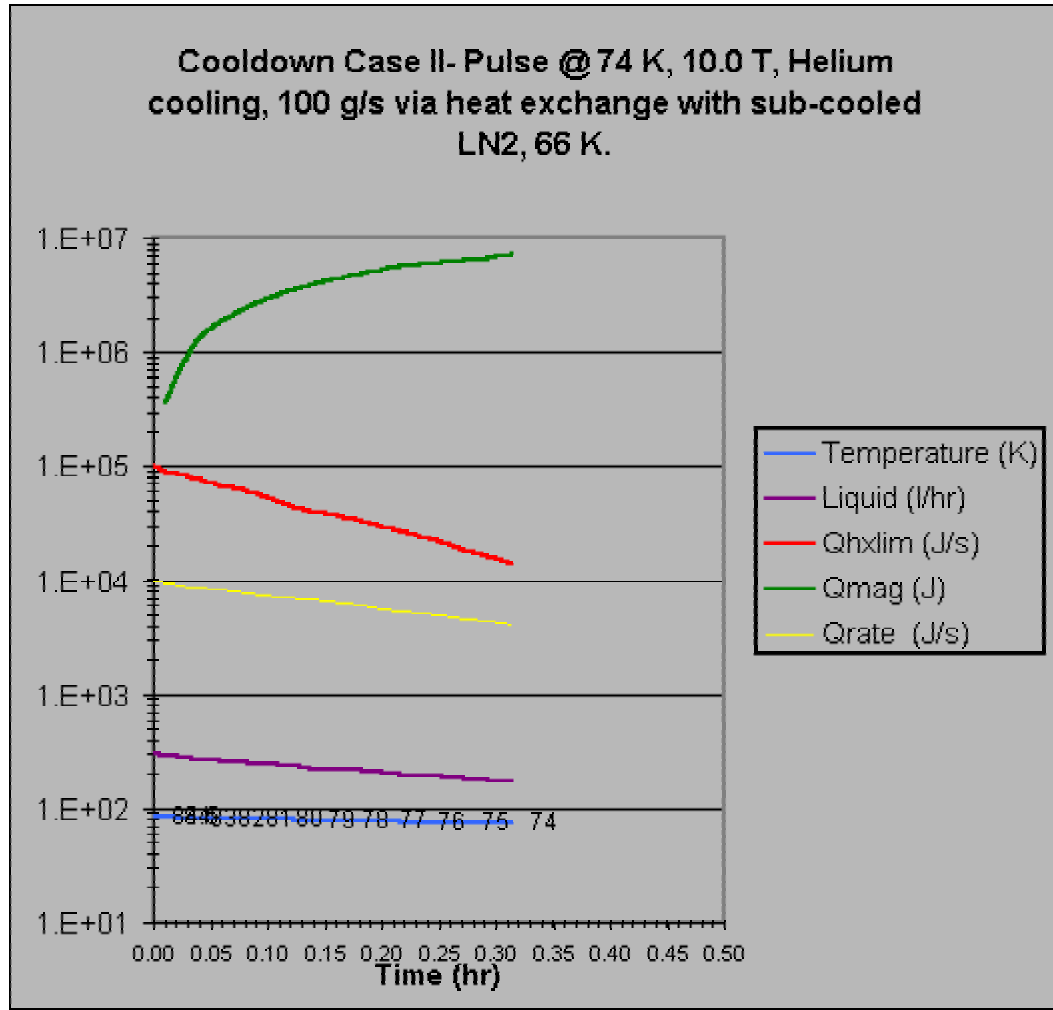
- Semi-hermetic Centrifugal Configuration
- Working Pressure- 15 ATM
- Head Pressure- 1.5 ATM
- Mass Flow Rate- 100 g/s
- Efficiency- ~ 45%
- Pump Work (66 K Mode)- 3.2 kW (~ 25%)
- Pump Work (22 K Mode)- 1.1 kW (~ 5%)
- Turn-down Ratio- ~ 4 (Standby operation)



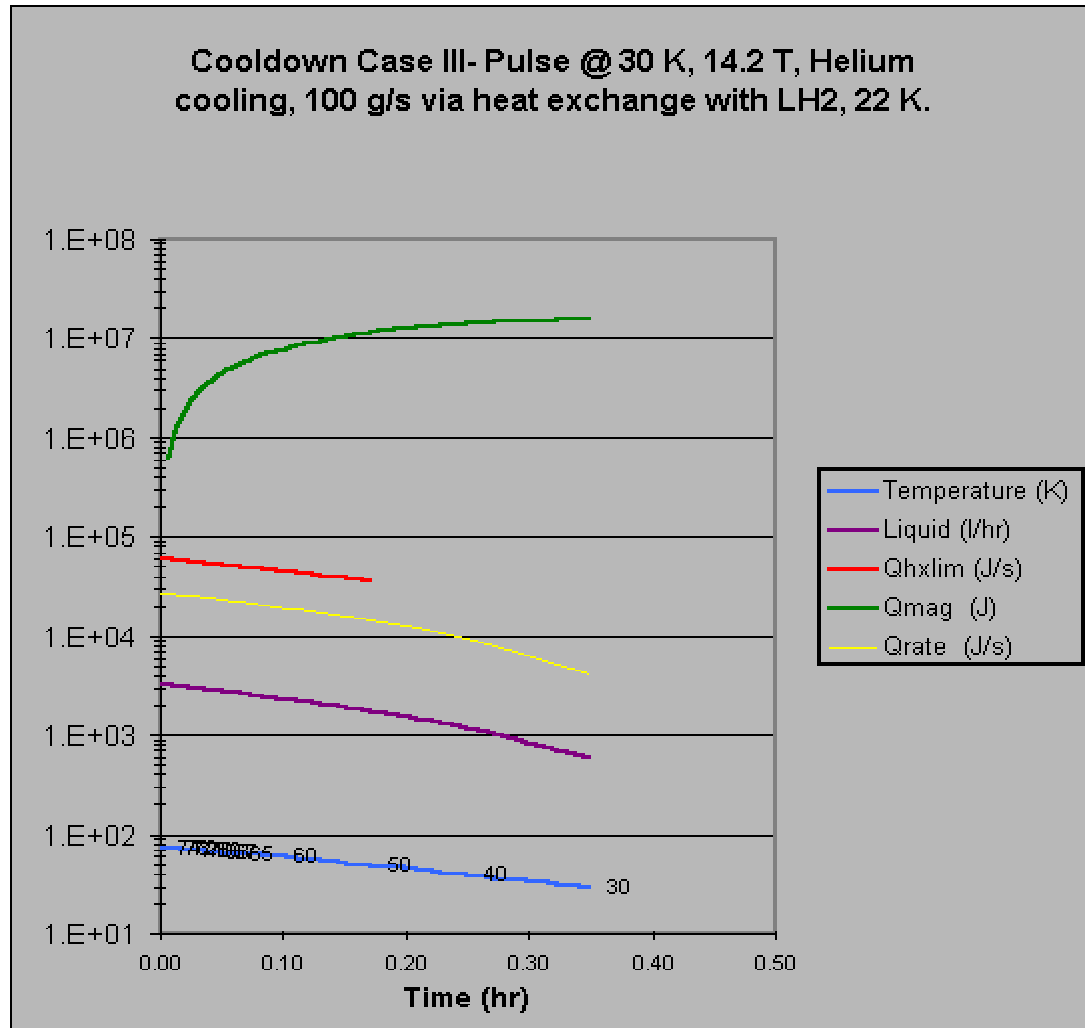
# Expected Heat Exchanger Performance 84 K Pulse



# Expected Heat Exchanger Performance 74 K Pulse



# Expected Heat Exchanger Performance 30 K Pulse



# Experimental Safety Considerations and Plan

- A sub-group of the Experimental Safety Review Committee (ESRC) of the Collider-Accelerator Department was tasked with the Preliminary safety Assessment of E951
- LH2 Storage Installation 5000 gallons
  - Fire Detection and Protection (N2 Stack Purge)
  - Blast Protection for Personnel and Structures- 400'
- Cold Box Volume is 200 gallons so it may be closer to the building, thus reducing transfer line cost
- When the Experimental Arrangement is Settled the ESRC and Cryogenic Safety Committee will need formal presentations of quantified hazards

# Cryogen Usage and Operational Costs

- High Temperature Operation with LN2 Case I
  - Cooling 87.5 to 84 K (5 min) ~ 365 L/hr ~ \$1.60/ pulse
  - Cooling 87.5 to 84 K (Continuous) ~ \$19/hr
  - Standby Operation ~ 70 L/hr ~ \$3.60/hr
- High Temperature Operation with LN2 Case II
  - Cooling 84.5 to 74 K (20 min) ~ 325 L/hr ~ \$5.60/pulse
  - Cooling 84.5 to 74 K (Continuous) ~ \$17/hr
  - Standby Operation ~ 70 L/hr ~ \$3.60/hr
- Low Temperature Operation with LH2 Case III
  - Cooling 74 to 30 K (25 min) ~ 2700 L/hr ~ \$290/pulse
  - Cooling 74 to 30 K (Continuous) ~ \$700/hr
  - Standby Operation ~ 220 L/hr ~ \$60/hr



# Installation Cost Estimate Case 3

Phase II (Case III)- LN2 & LH2 Engineering Cost Estimate for Hardware and Labor- E951, **. note 1											labor cost \$K/ hr.								
Initial Release 02/06/02											weld	tech	eng						
M. Iarocci											0.07	0.047	0.058						
Note 1- Basis \$48/ hr. Technical, \$61/ hr. Engineering, \$79/hr. Scient, \$70/hr. *FY 2001 \$'s																			
Fiscal Year 2002											Fiscal Year 2003			Fiscal Year 2004					
Item #	Task Desc	Materials Cost K\$'s	Labor Cost K\$'s	Burdened Materials Cost K\$'s	Burdened Labor Cost K\$'s	Materials Cost K\$'s	Labor Cost K\$'s	Burdened Materials Cost K\$'s	Burdened Labor Cost K\$'s	Materials Cost K\$'s	Labor Cost K\$'s	Burdened Materials Cost K\$'s	Burdened Labor Cost K\$'s						
I Engineering & Design																			
I-A	Develop Cd	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$10.00	\$0.00	\$18.70	\$0.00	\$0.00	\$0.00	\$0.00						
I-B	Detail P&ID	\$0.00	\$3.00	\$0.00	\$5.61	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
I-C	Verify Hx s	\$0.00	\$3.50	\$0.00	\$6.55	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
I-D	Establish s	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$7.00	\$0.00	\$13.09	\$0.00	\$0.00	\$0.00	\$0.00						
I-E	Detail Cold	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$5.00	\$0.00	\$9.35	\$0.00	\$0.00	\$0.00	\$0.00						
I-F	Develop Es	\$0.00	\$15.00	\$0.00	\$28.05	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
I-G	Detailed P	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$4.00	\$0.00	\$7.48	\$0.00	\$0.00	\$0.00	\$0.00						
I-H	Specificati	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$6.00	\$0.00	\$11.22	\$0.00	\$0.00	\$0.00	\$0.00						
	Engineering	\$0.00	\$21.50	\$0.00	\$40.21	\$0.00	\$32.00	\$0.00	\$59.84	\$0.00	\$0.00	\$0.00	\$0.00						
II LH2/ LN2/ GHe Transfer																			
II-A	Procure G	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$70.00	\$0.00	\$102.90	\$0.00						
II-B	Procure LN	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$0.00	\$4.41	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
II-C	Installation	\$0.00	\$0.00	\$0.00	\$0.00	\$10.00	\$0.00	\$14.70	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
II-D	Installation	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$9.50	\$0.00	\$17.77	\$0.00	\$0.00	\$0.00	\$0.00						
	LH2/ LN2/	\$0.00	\$0.00	\$0.00	\$0.00	\$13.00	\$9.50	\$19.11	\$17.77	\$70.00	\$0.00	\$102.90	\$0.00						
III Warm Piping & Sub-cooling Pump																			
III-A	Install Vac	\$0.00	\$0.00	\$0.00	\$0.00	\$5.00	\$0.00	\$7.35	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
III-B	Piping & P	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$0.00	\$4.41	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
III-C	Welding- v	\$0.00	\$0.00	\$0.00	\$0.00	\$8.00	\$6.00	\$11.76	\$11.22	\$0.00	\$0.00	\$0.00	\$0.00						
III-D	AC Power	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$0.00	\$4.41	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
III-E	Instrument	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$0.00	\$4.41	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
III-F	Relief Valv	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$0.00	\$4.41	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
	Warm Pipi	\$0.00	\$0.00	\$0.00	\$0.00	\$30.00	\$6.00	\$44.10	\$11.22	\$0.00	\$0.00	\$0.00	\$0.00						
Fiscal Year 2002														Fiscal Year 2003			Fiscal Year 2004		
Item #	Task Desc	Materials Cost K\$'s	Labor Cost K\$'s	Burdened Materials Cost K\$'s	Burdened Labor Cost K\$'s	Materials Cost K\$'s	Labor Cost K\$'s	Burdened Materials Cost K\$'s	Burdened Labor Cost K\$'s	Materials Cost K\$'s	Labor Cost K\$'s	Burdened Materials Cost K\$'s	Burdened Labor Cost K\$'s						
IV Misc. Controls & Instrumentation																			
IV-A	Level & Pr	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$20.00	\$1.00	\$51.09	\$1.87						
IV-B	PLC & I/O	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
IV-C	Equipment	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$2.00	\$7.00	\$2.76	\$13.09						
	Misc. Cont	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$22.00	\$8.00	\$53.85	\$14.96						
V Safety System																			
V-A	Stack Fire	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
V-B	Stack Fire	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$5.00	\$4.41	\$9.35	\$0.00	\$0.00	\$0.00	\$0.00						
V-C	Safety Sys	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$10.00	\$0.00	\$25.55	\$0.00						
V-D	Safety Sys	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$7.00	\$0.00	\$13.09	\$0.00	\$0.00	\$0.00	\$0.00						
	Safety Sys	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$12.00	\$4.41	\$22.44	\$10.00	\$0.00	\$25.55	\$0.00						
VI Coldbox Hx Modifications																			
VI-A	Materials f	\$0.00	\$0.00	\$0.00	\$0.00	\$3.00	\$0.00	\$4.41	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
VI-B	Install Lev	\$0.00	\$0.00	\$0.00	\$0.00	\$4.00	\$3.00	\$5.88	\$5.61	\$0.00	\$0.00	\$0.00	\$0.00						
VI-C	Modify Pip	\$0.00	\$0.00	\$0.00	\$0.00	\$4.00	\$4.00	\$5.88	\$7.48	\$0.00	\$0.00	\$0.00	\$0.00						
VI-D	Provide Fil	\$0.00	\$0.00	\$0.00	\$0.00	\$2.00	\$3.00	\$2.94	\$5.61	\$0.00	\$0.00	\$0.00	\$0.00						
VI-E	Procure Ne	\$40.00	\$0.00	\$47.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00						
	Coldbox H	\$40.00	\$0.00	\$47.00	\$0.00	\$13.00	\$10.00	\$19.11	\$18.70	\$0.00	\$0.00	\$0.00	\$0.00						
Fiscal Year 2002														Fiscal Year 2003			Fiscal Year 2004		
Materials	Labor	Burdened Materials	Burdened Labor	Materials	Labor	Burdened Materials	Burdened Labor	Materials	Labor	Burdened Materials	Burdened Labor	Materials	Labor						

# Case 1,2, Case 3 Cost Summary

Cryogenics Phase I (Case 1 &2)															
Fiscal	Year		2002		Fiscal	Year		2003		Fiscal	Year		2004		
			Burdened	Burdened				Burdened	Burdened				Burdened	Burdened	
Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor
Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s
Summary	\$0.00	\$16.50	\$47.00	\$30.86	\$50.00	\$38.00	\$73.50	\$71.06	\$22.00	\$8.00	\$53.85	\$14.96			
Summary TPC:															
Total Unburdened	\$62.50	Burdened Cost with 20% Contingency By FY													
Total Burdened	\$116.88	2002		2003		2004									
Total Unburdened	\$72.00	\$93.43		\$173.47		\$82.57									
Total Burdened	\$174.35														
Burdened	\$291.23														
Burdened	\$349.48														
Cryogenics Phase II (Case 3)															
Fiscal	Year		2002		Fiscal	Year		2003		Fiscal	Year		2004		
			Burdened	Burdened				Burdened	Burdened				Burdened	Burdened	
Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor	Materials	Labor
Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s	Cost K\$'s
Summary	\$40.00	\$21.50	\$47.00	\$40.21	\$59.00	\$69.50	\$86.73	\$129.97	\$102.00	\$8.00	\$182.30	\$14.96			
Summary TPC:															
Total Unburdened	\$99.00	Burdened Cost with 20% Contingency By FY													
Total Burdened	\$185.14	2002		2003		2004									
Total Unburdened	\$201.00	\$104.65		\$260.04		\$236.71									
Total Burdened	\$316.03														
Burdened	\$501.17														
Burdened	\$601.40														