HELIUM AND LN2 STORAGE
REQUIREMENTS FOR D-ZERO UPGRADE

D-ZERO ENGINEERING NOTE # 3823.115- EN- 421

April 4, 1995

Russ Rucinski
RD/DØ Mech.

Approved :

Summary

Calculations were done to determine a recommended size for the liquid helium storage dewar, gas helium storage tanks, and liquid nitrogen dewar requirements.

I recommend a **Liquid helium storage dewar** with a nominal size of at least 2500 liters (660 gallons), preferably 3000 liters (792 gallons).

I recommend obtaining **gas helium storage tanks** with a maximum allowable working pressure (MAWP) of 250 psig or greater. Combined volume to be at least 5880 cubic feet (44,000 gallons).

I recommend obtaining a second **liquid nitrogen dewar** at D-Zero, dedicated to the refrigerator, solenoid and VLPC systems. The ideal dewar would have a volume of around 16,000 gallons. It's MAWP needs to be greater than 55 psig.

Liquid helium storage dewar

The steady state liquid consumption rate for the solenoid (83 L/hr) and VLPC (329 L/hr) give a total consumption rate of 412 liquid liters per hour. It takes about 4 hours to change out a wet or dry engine. It is desirable to keep the solenoid and VLPC cold (but not operational) for this period of time. You can't completely fill the dewar nor can you use every drop stored. A nominal size of 2500 liters would give you say 70% usable liquid inventory or 4.2 hours of steady state operation. It is always better to have more storage so I would prefer a 3000 liter nominal size.

The dewar needs to have a MAWP of at least 90 psig with full vacuum to allow for pressures encountered during quenches and cool downs. No unused existing LHe dewars meeting this specification are known to reside at the Fermi. It is possible but unlikely that one could be obtained through government surplus channels. I recommend pursuit of a brand new commercial dewar.

Gas helium storage tanks

It is desired to run the D-Zero helium refrigerator independent of the accelerator ring system. To do this we need to have storage to hold helium inventory. During normal operation with the system cold, the storage tank would operate somewhere around 30 psig. When the system is warmed up the storage would run at close to it's MAWP. To get the most storage in as

little space, I recommend that the storage tanks have a MAWP of at least 250 psig. Normal warm storage pressure would be around 230 psig. The nominal tank volume needed is 5880 cubic feet or 44,000 gallons.

To get this volume, more than one tank may be needed. A common size for a large tank at Fermi is 30,000 gallons with a MAWP of 250 psig. An attempt will be made to utilize existing tanks available at Fermilab to obtain the required storage volume. Another option that can be explored is a search of government excess stock listings. A third option is to purchase the desired vessel from a commercial vendor.

Liquid nitrogen dewar

The existing D-Zero LN2 dewar supplies the liquid argon storage dewar and calorimeters. It can be filled to a maximum of 12,000 gallons. The steady state usage rate is around 44 gal/hr. It is sized large enough so that on average we have a 'buffer time' of 7.5 days if a disruption of LN2 delivery occurs.

I estimate that the planned upgrade will require a total of 64 gallons/hr of liquid nitrogen. The solenoid, refrigerator, VLPC, and purifier were estimated roughly at 2, 10, 18, and 35 gallons/hr respectively. With this added usage, the time buffer on the existing dewar becomes an unacceptably short at 3 days. In addition, the existing dewar is not set up to support another service tap.

In order to maintain a comparable buffer time, I recommend installing a second dewar with a volume of 16,000 gallons and a MAWP of at least 55 psig. There are several existing LN2 storage dewars available on site at Fermilab that should be pursued for use at D-Zero. The known existing vessels have less than 16,000 gallons but considering their price, I think they would be adequate.

SUBJECT

He STORAGE REQUIREMENTS

NAME

RUSS RUCINSKI

DATE

3-3-95

REVISION DATE

CHECKED: Todd Hecht 4/4/95

• SIZE OF LHe STORAGE DEWAR

THE STORAGE DEWAR PROVIDES A BUFFER OF LHe TO ALLOW CONTINUED OPERATION OF THE VLPC & SOLENOID SYSTEMS DURING A REFRIGERATOR UPSET. IT SHOULD BE SIZED TO HANDLE STEADY STATE FLOW REQUIREMENTS.

STEADY STATE FLOW REQUIREMENTS:

SOLENOID SYSTEM:Total Heat Loads for the Magnet System

item	300 to 80 K (W)		80 to 4 K (W)	
	Fermilab.	Toshiba	Fermilab.	Toshiba
Coil	165.3W	29.5W	12.5W+20W*	2.7W+6W*
Control Dewar	8.2W	18.3W	3.9W + 28.8L/h	7.0W + 28.8L/h
Service Chimney	107.6W	55.7W	1.4W	1.4W
Total	281.1W	103.5W	17.8W + 20W	11.1W + 6W
			28.8L/h	28.8L/h

* CHARGING LOAD

USE LARGER
VALUES TO BE
CONSERVATIVE

CONVERTING TO FLOW UNITS:

$$\text{ROUGHLY } 17.8 \text{ W} \times \frac{1 \text{ L/hr} \cdot 0.13 \text{ MPa}}{0.6513 \text{ WATTS}} + 28.8 \text{ L/hr} = 56.1 \text{ L/hr LHe}$$

TRANSFER LINE FROM DEWAR, TO COLLISION HALL = 17.4 WATTS
 { 2 UTUBES @ 10 W, 270 FT LINE = 3 WATTS, VALVES etc 4.7 W? } $\Rightarrow 26.7 \text{ L/hr}$

SOLENOID LHe USAGE $\approx 83 \text{ L/hr.} \approx 2.9 \text{ g/s STEADY STATE}$

VLPC SYSTEM:

PER LATEST 3-23-95 VLPC ^{CRYO} MEETING; TED GASTEYER'S HEAT LOAD ESTIMATE FOR THE 2 CRYOSTATS IS 194 WATTS TO LHe.

TRANSFER LINE FROM DEWAR: 2 UTUBES = 10 W, 600 FT LINE = 6 W, 2 VALVES = 2 W
 FLOW METERS etc = 2 W TOTAL LINE = 20 WATTS

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VLPC (CONT.) TOTAL = $[194W + 20W] \times \frac{1 \text{ L/HR } 10.13 \text{ MPa}}{0.6513 W} = 329 \text{ L/HR LHe}$ CHECKED: Todd Ziehl 4/4/95
 $\approx 11.4 \text{ g/s}$

CONSUMPTION TOTAL = $83 \text{ L/HR SOLENOID} + 329 \text{ L/HR VLPC} = 412 \text{ L/HR}$

IT WOULD BE NICE TO LIMP ALONG KEEPING THINGS COLD BUT NOT POWERED DURING AN ENGINE SWAP. CDF CLAIMS ≈ 4 HRS FOR A SWAP. WE WON'T HAVE THE DEWAR COMPLETELY FULL SAY 80% AND WE CAN'T DRAIN IT COMPLETELY DRY $< 10\%$.

M.I.N. SIZE = $412 \text{ L/HR} \times 4 \text{ HRS} \times \frac{100\% \text{ SIZE}}{70\% \text{ USEABLE}} = 2354 \text{ LITERS}$
 $\approx 648 \text{ gallons}$

I RECOMMEND A LHe STORAGE DEWAR SIZE OF 2500 LITERS TO 3000 LITERS.
 [660 GALLONS TO 792 GALLONS]

TYPICAL SIZE OF SUCH A DEWAR IS SMALLER THAN

153 1/2 INCHES X 68" X 72"

REF: CUI MODEL
LHe 1000G
CONTAINER

FOR 3785 LITERS
1000 gallons

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• SIZE OF GHe STORAGE

IT WOULD BE NICE FOR GHe STORAGE TO HOLD ENOUGH INVENTORY AT CLOSE TO IT'S MAXIMUM PRESSURE WITH A WARM REFRIGERATOR.

THE AVAILABLE TANKS @ LAB A HAVE A MAWP = 150 psig AND A VOLUME = 790 CU. FT EACH. QTY. = 3. (5,910 gallons) TWO MORE @ MP9 LOOK LIKE SAME SIZE & MAWP.

SAY MAXIMUM STORAGE PRESSURE = 145 PSIG = 10.9 ATM.

• COLD SYSTEM INVENTORY:

LHe STORAGE DEWAR = 3000 L LIQUID @ 1.8 ATM

HIGH PRESSURE PIPING; 3" ϕ x 400 ft @ 20 ATM

SUCTION PIPE: 8" ϕ x 400 ft @ 1 ATM ← DON'T NEED TO STORE WHEN WARM.

• INVENTORY TO STORE:

$$V_{He} = 3000 L \times 26.63 \frac{\text{SCF}}{\text{L}} + \frac{\pi (1.25 \text{ ft})^2}{4} \times 400 \text{ ft} \cdot 20 \text{ ATM}$$

$$= 80,300 \text{ SCF.}$$

• STORAGE VOLUME: NORMAL OPERATING PRESSURE $\approx$ 3 ATM

10.9 ATM - 3 ATM = 7.9 ATM PRESSURE TO INCREASE.

$$Q = \frac{80,300 \text{ SCF}}{7.9 \text{ ATM}} = 10,160 \text{ SCF @ 1 ATM} \quad \left(\begin{array}{c} 76,000 \\ \text{GALLONS} \end{array} \right)$$

WE OBVIOUSLY DON'T HAVE THE ROOM FOR THIS MUCH STORAGE. IT'S NOT PRACTICAL UNLESS WE CAN PUMP UP TO A MUCH HIGHER PRESSURE.

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THE MOST STORAGE PRACTICAL WOULD BE FOR THE 5 IDENTICAL TANKS W/ MAWP = 150 PSIG. COULD MAKE A STACK 2 ON 3.

$$Q = 5(790 \text{ cu. ft.}) \times 7.9 \text{ ATM} = 31,205 \text{ scf}$$

$$V_{\text{LIQUID}} = \frac{31,205 \text{ scf}}{26.63 \text{ scf/L}} = 1,172 \text{ LITERS RECOVERY}$$

I DON'T KNOW IF THIS MUCH REAL ESTATE IS AVAILABLE TO DØ. THE DECISION ON HOW MUCH STORAGE WILL PROBABLY BE BASED ON AESTHETIC'S AND SPACE. FROM A CRYO STANDPOINT WE WOULD LIKE A LOT.

< SEE PAGE 5 FOR FINAL CONCLUSION: >

• TUBE TRAILERS REQ'D FOR START UP.

$$V_{\text{REQ'D}} = 80,300 \times \frac{10.9}{7.9} = 110,794 \text{ scf}$$

EACH TUBE TRAILER HOLDS $\approx 40,000 \text{ scf}$

NEED ABOUT 3 TUBE TRAILERS FOR START UP

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4-3-95

REVISION DATE

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HOW MUCH VOLUME IS REQ'D IF WE COULD STORE AT 275 psig?

$$P_{\text{FINAL}} = (275 + 14.7) / 14.7 = 19.7 \text{ ATM}$$

$$P_i = 3 \text{ ATM}$$

$$Q_{\text{REQ'D}} = \frac{80,300 \text{ scf}}{(19.7 - 3 \text{ ATM})} = \underline{4,808 \text{ scf @ 1 ATM.}}$$

LOOKS LIKE THERE MAY BE SOME 250 psig MAWP VESSELS.
WHAT VOLUME IF $P_{\text{MAX}} = 230 \text{ psig}$?

$$P_{\text{FINAL}} = 16.6 \text{ ATM}$$

$$Q_{\text{REQ'D}} = 5880 \text{ scf @ 1 ATM} \\ = 44,000 \text{ gallons.}$$

A "STANDARD" SIZE I'VE FOUND ON-SITE IS A 30,000 gallon
VOLUME. 4010 scf

I RECOMMEND TRYING TO OBTAIN ONE OR TWO
EXISTING TANKS FOR GHE STORAGE @ DØ
WE WANT A VESSEL WITH A MAWP $\geq 250 \text{ psig}$
AND COMBINED VOLUME $> 44,000 \text{ GALLONS}$
5880 CUBIC FEET.

ANOTHER SOURCE TO TRY IS THE GOVERNMENT SURPLUS
INVENTORY LISTING SERVICE.

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LN₂ STORAGE REQUIREMENTS

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3-31-95

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CHECKED: Todd Leicht 4/4/95

CURRENTLY @ DD WE HAVE A 20,000 GAL LN₂ STORAGE DEWAR THAT FULL CAN HOLD 12,000 GAL. DUE TO SAFETY ISSUES.

EXISTING USAGE: 44 GAL/HR FOR AR DEWAR, 3 CALORIMETER (STEADY STATE) + BOLL OFF

$$\text{TIME BUFFER IS } \approx \frac{8000 \text{ gal}}{44 \text{ gal/HR}} \times \frac{1 \text{ DAY}}{24 \text{ HRS}} \approx 7.6 \text{ DAYS}$$

SOLENOID USE: PER FERMI DESIGN REPORT; 281.1 WATTS

REFRIGERATOR*: COLD & RUNNING 38 LITERS/HR = 10 gal/HR
COOLDOWN 300K TO 90K 23.3 g/s, 105 LITERS/HR
STEADY STATE 65 lb/HR = 9.63 gal/HR

* FROM SATELLITE REFRIGERATOR DESIGN MANUAL.

$$\begin{aligned} \dot{m}_{\text{SOLENOID}} &= \frac{281.1 \text{ WATTS}}{200 \text{ J/g}} = 1.4 \text{ g/s} \quad \left\{ \text{BID SPEC MAX ALLOW} = 8 \text{ g/s} \right\} \\ &= 1.4 \text{ g/s} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{0.3262 \text{ gal LIQUID}}{1 \text{ kg}} \times \frac{3600 \text{ s}}{1 \text{ HR}} = 1.65 \text{ gal/HR} \\ &\quad \text{FOR SOLENOID} \end{aligned}$$

VLPC USE:

ESTIMATE HEAT LOAD TO LN₂ IS IN SAME RATIO THAT IT IS FOR THE SOLENOID, A FACTOR OF 10.

$$Q_{\text{LN}_2} \approx 10 \times 200 \text{ WATTS} = 2000 \text{ WATTS}$$

$$\dot{m} = \underline{11.74 \text{ gal/HR.}}$$

BETTER ESTIMATE PER TED GASTEYER. PHONE CONVERSATION

$$Q_{\text{LN}_2} = 3000 \text{ WATTS} \quad \text{or} \quad \dot{m}_{\text{VLPC LN}_2} = 17.6 \text{ gal/HR}$$

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4-3-95

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CHECKED: Todd Leicht 4/4/95

- PURIFIER FOR HE STREAM:

PER RICH SCHMITT, HEAT EXCHANGER IS PRETTY GOOD.
TO FIGURE CONSIDER 100 K GHE IN 80 K GHE
OUT, $\dot{m} = 57 \text{ g/s}$

PRESSURE = 20 ATM = 2 MPa

$$Q = \dot{m} (h_{in} - h_{out}) = 57 \text{ g/s} [540.3 \frac{\text{J}}{\text{g}} - 435.7 \frac{\text{J}}{\text{g}}] \\ = 5962 \text{ WATTS}$$

$$Q_{1 \text{ gal/hr}} = 1 \frac{\text{gal}}{\text{hr}} \times \frac{1 \text{ hr}}{3600 \text{ s}} \times \frac{6.745 \text{ lbs}}{1 \text{ gal}} \times \frac{200 \text{ Joules}}{1 \text{ gram}} \times \frac{1000 \text{ grams}}{2.2 \text{ lbs}} \\ = 170.33 \text{ WATTS FROM } 1 \text{ gal/hr OF LN}_2$$

FOR PURIFIER. = 35 gal/hr

- TOTAL ADDED LN₂ USE:

$$\dot{m}_{\text{total}} = \underset{\text{SOLENOID}}{1.7 \frac{\text{gal}}{\text{hr}}} + \underset{\text{REFRIGERATOR}}{10 \frac{\text{gal}}{\text{hr}}} + \underset{\text{VLPC}}{17.6 \frac{\text{gal}}{\text{hr}}} + \underset{\text{PURIFIER}}{35 \frac{\text{gal}}{\text{hr}}} = 64.3 \frac{\text{gal}}{\text{hr}}$$

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IF WE USED OUR EXISTING DEWAR OUR TIME BUFFER
WOULD BECOME:

$$t_{\text{WEEK}} \approx \frac{8000 \text{ gal}}{44 \frac{\text{gal}}{\text{hr}} + 64.3 \frac{\text{gal}}{\text{hr}}} \times \frac{1 \text{ DAY}}{24 \text{ HRS}} = \underline{3 \text{ DAYS}}$$

THIS IS TOO SHORT OF A TIME. WE NEED A 2nd
LN₂ DEWAR AT DØ.

WE SHOULD AT LEAST HAVE AS MUCH OF A TIME
BUFFER AS FOR THE CALORIMETERS.

$$t_{\text{BUFFER}} = \frac{(.70)(V_{\text{STORAGE TOTAL}})}{\text{USAGE}} \Rightarrow V_{\text{STORAGE TOTAL}} = \frac{7.6 \text{ DAYS} (64.3 \frac{\text{gal}}{\text{hr}}) 24}{.70} \times \frac{1 \text{ DAY}}{10 \text{ HRS}}$$

$$V_{\text{STORAGE TOTAL}} = 16,755 \text{ GALLONS}$$

NOTE THE ASSUMPTION IS THAT THE DEWAR IS 70%
FULL WHEN YOU REALIZE THERE IS A LN₂ CONCERN.

CONCLUSION: WE NEED A 2nd LN₂ DEWAR
@ DØ FOR THE UPGRADE. IT WOULD
BE NICE TO HAVE ONE AROUND
16,000 gallon SIZE.

FERMILAB NITROGEN DELIVERY REPORT
MONTH OF SEPTEMBER, 1994

report date: 10/4/94
deliveries through: 9/30/94

B4-

TANK	T	P	TANK	MEASURED	PER CENT	APPROX.
#	LOCATION NAME	E	VOLUME	VOLUME	SHARE OF	COST
		(")	(GAL.)	DELIVERED	VOL. DELIV.	BASED ON
			B/C	(SCF)		VOLUME
			ORG/MS			

P.O. D24780 (AIRCO/BOC @ \$0.00168/SCF)

01	A0	V	1,500	FNI	AD/340	1,201,212	1.74%	\$2,018.04
02	MAG. STOR. SITE 50	V	1,000	MPA	TS/316	181,658	0.26%	\$305.18
03	B0, inner ring (moves)	T	4,000	FNI	AD/347	755,588	1.10%	\$1,269.39
04	M.T.F.	TX	4,000	FNI	TS/316	0	0.00%	\$0.00
06	F3, inner ring (moves)	T	4,000	FNI	AD/347	2,150,934	3.12%	\$3,613.57
07	M.T.F.	TX	4,000	FNI	TS/316	0	0.00%	\$0.00
08	A2, inner ring (moves)	T	4,000	FNI	AD/347	195,438	0.28%	\$328.34
09	A0	V	1,500	FNI	AD/340	560,895	0.81%	\$942.30
10	LAB 2, VILLAGE	T	4,000	FNI	TS/346	312,756	0.45%	\$525.43
14	PS1	H	1,800	BLO	RD/310	0	0.00%	\$0.00
16	T.P.L. (PE6)	H	1,800	EHH	RD/310	305,308	0.44%	\$512.92
18	CDF EAST	H	12,000	CBO	RD/310	4,116,114	5.97%	\$6,915.07
19	LAB A	VX	5,000	EOC	RD/310	0	0.00%	\$0.00
22	LAB A	TX	4,000	BLO	RD/310	563,502	0.82%	\$946.68
23	NWA	T	4,000	DOD	RD/310	0	0.00%	\$0.00
24	Out of Service	VX	1,000	MPA	TS/316	0	0.00%	\$0.00
25	IND. BLDG. 2	SK	800	CLQ	TS/314	34,358	0.05%	\$57.72
26	HE LIQUIFIER	HX	14,000	FNI	AD/313	0	0.00%	\$0.00
30	In Storage at Lab A	TX	4,000	BLO	RD/310	0	0.00%	\$0.00
31	PS4	H	3,500	BLO	RD/310	0	0.00%	\$0.00
32	CDF EAST	V	3,000	CBO	RD/310	324,395	0.47%	\$544.98
33	MESON CRYO CENT	H	10,000	BLO	RD/310	0	0.00%	\$0.00
38	LAB A	TX	4,000	---	RD/310	0	0.00%	\$0.00
39	MW9 EAST	V	10,000	EGS	RD/310	0	0.00%	\$0.00
40	LAB E	H	500	POG	PHY/309	0	0.00%	\$0.00
41	28 NEQUA	V	600	ESL	RD/329	89,758	0.13%	\$150.79
42	D0 ASSEMBLY SW	H	20,000	DOD	RD/357	3,620,675	5.25%	\$6,082.73
43	IND. BLDG. 2	HX	250	CLQ	TS/314	0	0.00%	\$0.00
44	NMS (MUON LAB)	HX	11,300	AKL	RD/310	0	0.00%	\$0.00
* 45	MP9	VX	5,800	BLO	RD/310	0	0.00%	\$0.00
46	In Storage at Railhead	VX	5,500	-	RD/219	0	0.00%	\$0.00
47	MTF	V	10,000	FNI	TS/316	0	0.00%	\$0.00
35	CHL Emergency Fill	H	20,000	FNI	AD/313	0	0.00%	\$0.00
-	(@ \$.0035/SCF)	-	-	-	-	0		
-	-	-	-	-	-	0		

SUBTOTALS: 14,412,590 20.92% \$24,213.14

P.O. NUMBER D24770 (PRAXAIR, \$0.00231/SCF)

35	N2 RELIQUIFIER	H	20,000	FNI	AD/313	54,412,208	78.97%	\$125,692.20
35A	N2 RELIQUIFIER	H	20,000	FNI	AD/313	75,900	0.11%	\$175.33

SUBTOTALS: 54,488,108 79.08% \$125,867.53

LABORATORY TOTALS: 68,900,698 100.00% \$150,080.67