CONTROL DEWAR

VALVE CALCULATIONS

D-ZERO ENGINEERING NOTE # 3823.111- EN- 437

October 20, 1995

Russ Rucinski
RD/DØ Mech.

Approved : ______________________________

Summary

This engineering note documents the calculations that were done to support the valve size selection for the magnet flow control valve, EVMF in the solenoid control dewar. The size selected was a control valve with a $C_V = 0.32$.

Explanation of Calculations Done

(SEE APPENDIX FOR RAW CALCS.)

A. ISOLATION VALVES

There are three valves in the control dewar. Two are simply isolation type valves which direct the solenoid helium return either to the control dewar helium reservoir (PV-3209-H) or to the suction header during quench recovery or cooldown (PV-3201-H). These valves are Cryolab model CV1997B valves with an on/off bullet of $C_V = 6.0$. At the design flowrate, a negligible pressure drop is expected at these valves. Having these valves on hand, I measured the stroke to 9/16". The maximum flow cross section in these valves is about 3/4" dia. If 300 psig acted on this area, a force of 132 lbs. is required to counteract this. We are planning on using 1/2" size Badger actuators with 11.3 in^2 of diaphragm area. An I/P control pressure 11.7 psi on the diaphragm will supply 132 lbs. of force. The actual maximum pressure either of these two valves should see is 60 psig, the set point of the quench relief valve immediately upstream.

B. MAGNET CONTROL VALVE

1. Steady state requirements:

A design flow rate of 2.5 g/s was determined from Toshiba's latest design report (Oct. 1995). The fluid thermodynamic state (Pressure and Temperature) on either side of this valve was taken from D-Zero EN-351, "Control Dewar Subcooler Heat Exchanger Calculations". Plugging the flowrate, density and 3.675 psi pressure drop into the standard C_V equation for a non-vaporizing liquid, a design $C_V = 0.06$ was obtained. A design philosophy of being able to operate at 20 g/s has been taken through out the refrigerator design. Based on this, a $C_V = 0.32$ bullet size was chosen. A pressure drop of 8.3 psi is expected at this flow and C_V. This is at the borderline of an acceptable pressure drop. If required, the trim set is interchangeable and can be modified in situ.

2. Cooldown requirements:

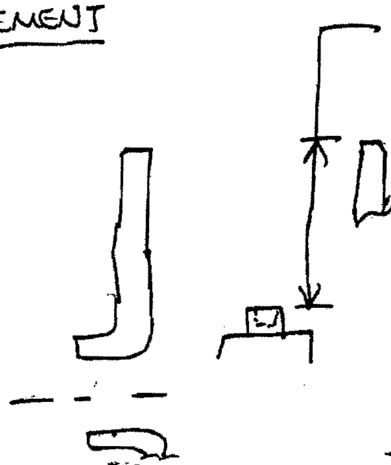
The seat orifice is only 5/32". As referenced from D-Zero EN-416 " Pipe Sizing for Solenoid/VLPC Cryogenic Systems" this orifice will choke flow to 2 g/s at the very start of cooldown with 300K, 1 atm Helium. Also from calculations in EN-416, the most demanding flow rate required for a 5 K/hr cooldown is 7 g/s with a helium supply temperature of 200 K and a supply pressure of say 43 psig or so. A pressure drop of 18 psi is expected at this flow and C_V. This is an acceptable pressure drop.

3. Physical valve:

The valve is a modified Cryolab model CV1997B valve given a special Cryolab project part #CV2288. It incorporates a badger bullet and seat that can be removed and changed. The original order (PO#B80660) called out a Valtek actuator. Due to the space limitations, a 1/2" size badger actuator has been used. Both the isolation valves and control valve were ordered with a liquid nitrogen intercept and a design heat load of less than 0.4 watts per valve.

BLOCK VALVE CV1997B

STROKE MEASUREMENT



$1\frac{1}{32}$" FULL OPEN

$\frac{13}{32}$" FULL CLOSED.

$\frac{18}{32}$" = $\frac{9}{16}$" STROKE.

3/4" φ × 300 psi

132 lbs. FORCE

BADGER ACTUATOR

1/4" SIZE 7.3 in^2 → 18 psi

1/2" SIZE 11.3 in^2 → 11.7 psi

OK. EITHER SIZE

SUPPLY 1/2" BADGER SIZE

SIZE EVNF VALVE

STATE (1)

SUBCOOLED LIQUID

$T_1 = 4.64\,K$

$h_1 =$ ~~17.33 J/g~~ 12.606 J/g

$P_1 = 1.7\,ATM = 0.172\,MPa$

$$\dot{m}_{DESIGN} = \frac{Q_{SS+CHARGING}}{h_{fg}} = \frac{19\ \text{WATTS}}{13.03\ J/g}$$

$$= 1.46\ g/s + 1\ g/s = 2.5\ g/s$$

(1 g/s → LEADS FLOW)

STATE (2)

$P \approx 1.45\,ATM = .147\,MPa$

$X = 0.0$

$h_f =$ ~~17.33~~ J/g   12.60 J/g

$h_g =$ ~~[illegible]~~ J/g

$T_2 =$

$\Delta P = 1.7 - 1.45 = 0.25\,ATM = 3.675\,psi$

FLOWRATE

$$Q\,(gpm) = 2.5\,\frac{g}{s} \times \left[\frac{1}{119\,\frac{kg}{m^3}}\right] \times \left[\frac{1\,kg}{1000\,g}\right] \times \left[\frac{1000\,LITER}{1\,m^3}\right] \times \left[\frac{1\,gallon}{3.785329\,Liters}\right]$$

$Q = 0.333\,gpm$

INTERPOLATING DENSITY ρ_1

$P_1 = .16$ MPa

$h = 11.59$ J/g $\quad \rho = 121.5$ kg/m³
$h = 10.02 \quad \rho = 128.8$
$h = 13.38 \quad \rho = 112.1$ kg/m³

} $h = 12.606 \quad \rho \approx 120.45$

$P = .18$ MPa

$h = 11.59 \quad \rho = 122.9$
$13.69 \quad 112.2$

} $h = 12.606 \quad \rho = 117.7$

$P = .172$, $\rho \approx 119.1$ kg/m³ $= 7.4414$ lbm/ft³

$$C_v = Q \sqrt{\frac{\rho}{62.4\,\Delta P}}$$

{NON VAPORIZING FLUID $F_p = 1.0$}

$$C_{v\,\text{DESIGN}} = .333 \sqrt{\frac{7.4414}{62.4\,(3.675)}} = 0.06$$

TRY $C_V = 0.32$ OR 0.20 → FLOW FORWARD TRAVEL $\approx .20''$

↓

.06 @ 0.37" LIFT

EVJT IN VERTICAL HX = 0.20 LINEAR

GO WITH $C_V = 0.20$

SEAT DIA. = .1563"

TRIM SIZE G FROM BADGER.

WILL THIS RESTRICT FLOW?

$Q_{MAX\,5.5} = 20$ g/s $= \frac{20}{2.5} = 8$ TIMES HIGHER

WHAT ΔP FOR $C_v = 0.20$ & FLOW = 20 g/s ?

$$\left[\frac{Q}{C_v}\right]^2 = \frac{62.4\,\Delta P}{\rho}$$

$$\Delta P = \frac{\rho}{62.4}\left[\frac{Q}{C_v}\right]^2 = \frac{7.4414}{62.4}\left[\frac{2.664}{0.2}\right]^2 = 21.16 \text{ psi}$$

DRIVING PRESSURE NOT AVAILABLE.

→ **GO WITH $C_v = .32$** , SEAT DIA. = 5/32"

$\Delta P_{C_v .32,\ \dot m = 20 g/s} = 8.26$ psi

- WHAT ABOUT CHOKING FLOW DURING COOLDOWN?

$$\dot m_{CHOKE} = 83.99 \frac{g}{s\text{-}IN^2} d^2$$ FOR T = 300 K, P = 1 ATM, He

$\dot m_{CHOKE} = 2.05$ g/s   Ref. pg. A1 EN-416

AT START OF COOLDOWN.

NEED 7 g/s @ T_{IN} = 200K, P = 43 psig. (~.40 MPa)

(FOR 5 K/HR COOLDOWN)

$$\dot m_{CHOKED} = \rho V_s \left(\frac{\pi}{4}\right) d^2$$

$$\dot m_{CHOKED} = \left(0.9601 \frac{kg}{m^3}\right)\left(834.3 \frac{m}{s}\right)\left(\frac{\pi}{4}\right)\left(\frac{5}{32}\text{IN.}\right)^2\left(\frac{.0254\,m}{1\,IN.}\right)^2\left(\frac{10}{1}\right)$$

$\dot m_{CHOKED} = 9.9$ g/s   SIZE IS O.K.

- ΔP FOR THIS FLOW RATE? 25 psi? OR SO.

• WHAT ΔP FOR $C_v = 0.32$, $T = 200K = -99.7°F$
$P = 0.40 MPa$
$\dot{m} = 7 g/s$

FROM BADGER

$$C_v = \frac{SCFH \sqrt{460 + °F} \; S.G.}{1360 \sqrt{P_1 \times \Delta P}}$$

$$\Delta P = \left[\frac{SCFH \; (S.G.)}{1360 \quad C_v}\right]^2 \cdot \left[\frac{460 + °F}{P_1}\right]$$

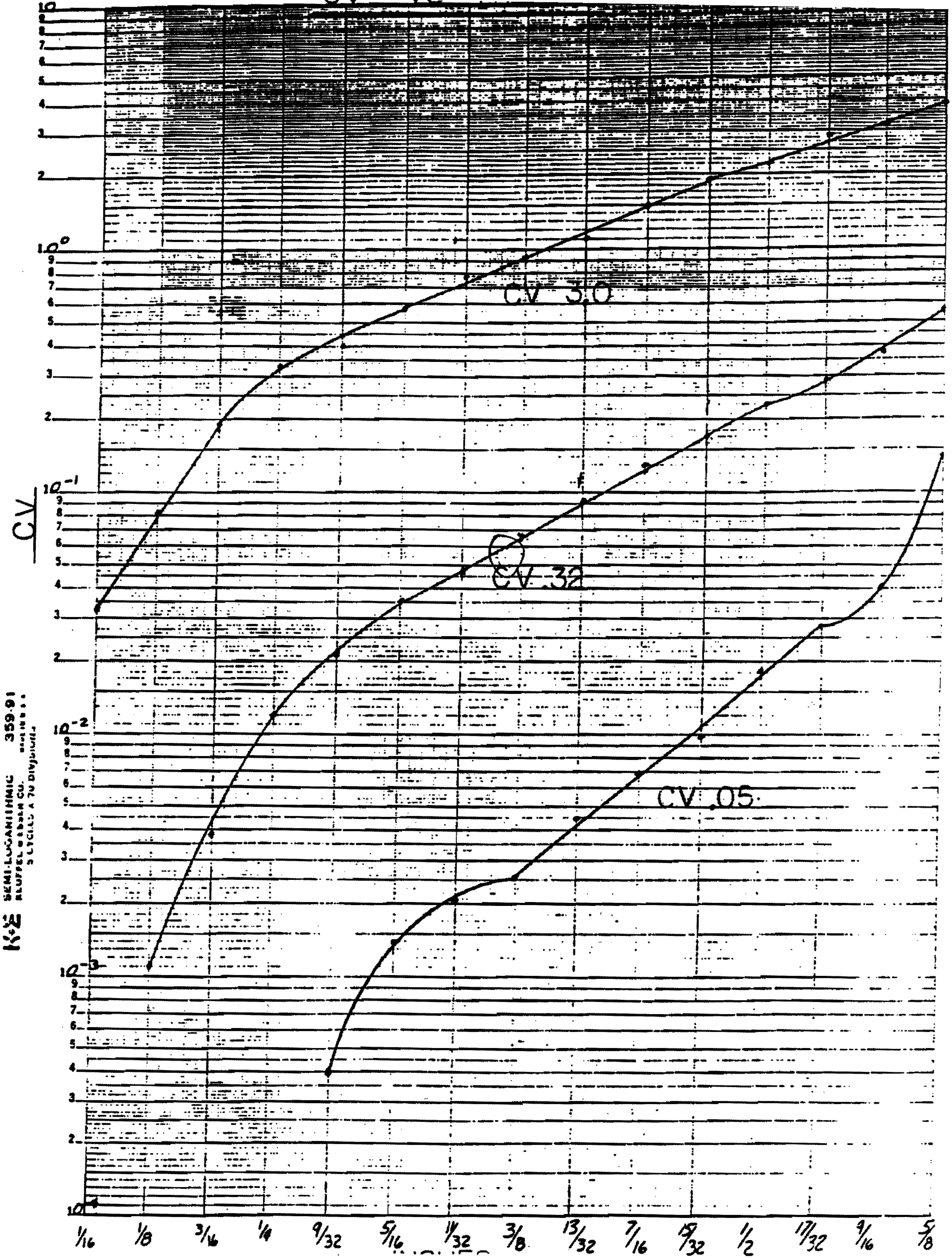
$$SCFH = 7 \, g/s \times \frac{3600 s}{1 \, HR} \times \frac{213.2 \, scf}{1000 \, g} = 5372.6 \; scfh$$

$$\Delta P = \left[\frac{(5372.6)(.138)}{1360 \, (.32)}\right]^2 \left[\frac{460 - 99.7}{58 \; psia}\right] = \underline{\underline{18.0 \; psi}}$$

↑ LOOKS O.K.

CONCLUSION:

USE $C_v = 0.32$ 100 TO 1 EQUAL % BULLETS.


CV
CV 3.0
CV .32
CV .05
1/16
1/8
3/16
1/4
9/32
5/16
11/32
3/8
13/32
7/16
15/32
1/2
17/32
9/16
5/8
SEMI-LOGARITHMIC 359-91
KEUFFEL & ESSER CO.
5 CYCLES X 70 DIVISIONS

Cryolab™ Bellows-Sealed Cold Box Valve

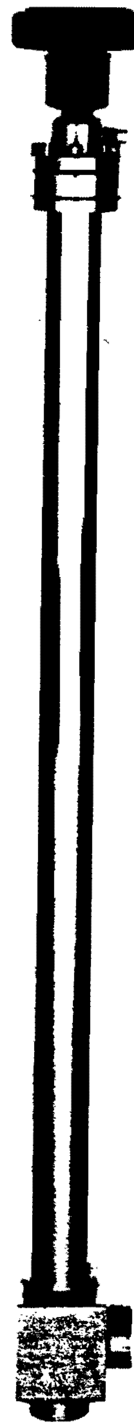
B1

Cryo!ab CV1997B

The CV1997B valve series has been designed for a long service life and to meet or exceed the specifications of the Superconducting Super Collider magnet test lab facilities. In liquid helium service, the CV1997B features a formed 321 stainless steel bellows, mass-spec helium tight seals to 1 x 10^{-9} scc/sec, low heat leak, 300 psig (20.7 bar g) allowable working pressure, 304 stainless steel bar stock and tube construction, and a thermal-acoustic oscillation (T.A.O.) barrier.

The Design

The design is simple and reliable. Internal components are identical so that conversion to manual or pneumatic operation is achievable without valve disassembly. The bellows and seals are designed and tested for service in excess of 20,000 cycles. A sample port is provided to monitor internal bellows pressure. The extremely low heat leak of this series can be further reduced by 70% with the addition of a liquid nitrogen thermal intercept. All valves are supplied with 20 layers of superinsulation to assure minimum radiant losses.



Features

- liquid helium service
- bellows-sealed stem
- superinsulation
- 300 psi MAWP
- T.A.O. barrier
- 304 stainless bar stock construction
- redundant upper seals of Viton® and Fluorogold™
- bellows pressure port
- butt-weld ends

Benefits

- simple and reliable
- mass-spec seal to 1 x 10^{-9} scc/sec He (g)
- minimum 20,000 cycle life
- thermally efficient
- excellent flow coefficient

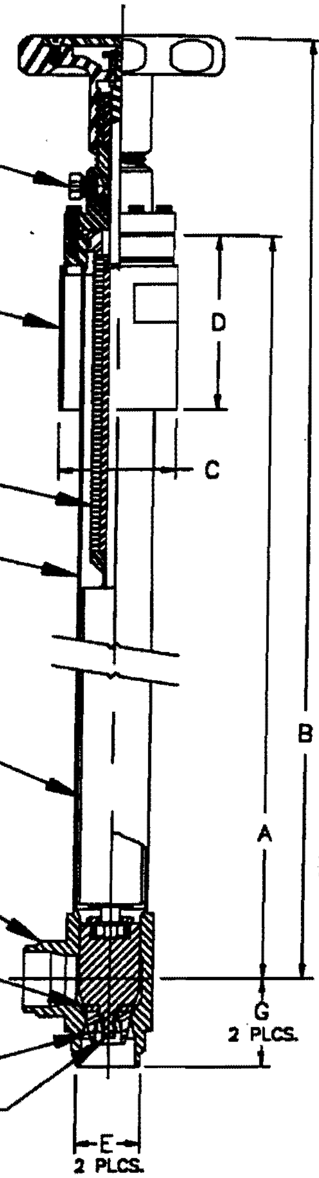
Options

- manual or pneumatic operation
- special flow control plugs
- simple actuator adaptor
- liquid nitrogen intercept
- cold-box cuff or fully jacketed
- socket-weld ends

Cryolab
CIRCLE SEAL CONTROLS, INC.
2301 Wardlow Circle • PO Box 3300 • Corona, California 91718 • (909) 270-6200 FAX: (909) 270-6201

Bellows-Sealed Cold Box Valve CV1997B Technical Data

Item	Vacuum-insulated cryogenic valve
Service	Liquid helium or hydrogen
Ranges	Operating temperatures of -456°F to +200°F Maximum allowable working pressure, 300 psig Proof pressure, 450 psig
Tests	Each valve is mass-spec tested to 1 x 10^{-9} scc/sec He (g) Proof tested and seat leakage tested with helium at 300 psig
Heat leak	See table
Flow coefficient	See table



Dimensions and Performance Characteristics

Dimensions (inches) IPS size	Dash #	A	B	C	D	E	F*	G	Flow coefficient C_v	Weight (kg) lbs.	Heat leak (watts)
.5	-084	24.0	29.0	2.38	3.5	.85	.15	1.50	8	(3.4) 7.5	1.07
.75	-086	24.0	29.0	2.38	3.5	1.06	.25	1.38	17	(3.6) 8.0	1.43
1.0	-088	24.0	29.0	2.38	3.5	1.32	.25	1.75	17	(3.6) 8.0	1.43
1.5	-812	24.0	31.0	4.0	3.5	1.92	.25	2.50	41	(6.8) 15.0	2.25
2.0	-816	24.0	31.0	4.0	3.5	2.39	.25	3.0	60	(6.8) 15.0	2.69
3.0	-824	27.7	45.0	5.56	3.5	3.52	.50	4.0	145	(34.0) 75.0	7.27

*Socket-weld only

Cryolab™
CIRCLE SEAL CONTROLS, INC.
2301 Wardlow Circle • PO Box 3300 • Corona, California 91718 • (909) 270-6200 FAX: (909) 270-6201

Fermilab

PURCHASE REQUISITION

(SEE INSTRUCTIONS ON REVERSE SIDE) DO NOT WRITE IN SHADED AREAS)

REQUESTED BY	EMPLOYEE NO.	EXT.	ORGANIZATION UNIT	MAIL STATION	REQUESTER'S IDENTIFIER	REQ. DATE
RUSS RUCINSKI	8351	2888	RD/D0 MECH.	357		3-27-95

SUGGESTED VENDOR: FLUID PROCESS CONTROL, 15W700 79th ST., BURR RIDGE, IL 60521

PHONE NO.: JOEL WARREN 708-986-1600

PROJECT DESCRIPTION: D-ZERO UPGRADE SOL. TRANSFER LINE & VLPC VALVE BOXES & TEST STAND

DELIVER TO (INCLUDE NAME & BLDG. NO.): RUSS RUCINSKI, D-ZERO ASSEMBLY BUILDING.

APPROVALS | EMPLOYEE NO

BUS. OFFICE

DIR. OFFICE

SHORT DESCRIPTION (30 CHARACTERS OR LESS): LHe CONTROL VALVES

PREVIOUS P.O.:

REC. AREA CODE	QUANTITY	ITEM DESCRIPTION	ESTIMATED UNIT PRICE	DO NOT USE: UNIT PRICE	DISCOUNT	DEL. DATE
	4	CRYOLAB BELLOWS SEALED COLD BOX CONTROL VALVE. THIS IS A	$3615—			
		MODIFIED CRYOLAB VALVE # CV1997B AS FOLLOWS:				
		INCLUDES A VALTEK MODEL 25 ACTUATOR WITH BETA PNEUMATIC				
		POSITIONER. INCLUDES BADGER METER TRIM SET WITH				
		$C_V = 2.0$ EQUAL PERCENTAGE FLOW CHARACTERISTICS. TRIM				
		SET IS REMOVEABLE AND CHANGEABLE IN THE VALVE BODY.				
		THIS VALVE IS FOR LIQUID HELIUM SERVICE AND INCLUDES A LIQUID				
		NITROGEN INTERCEPT HEAT STATION. CRYOLAB SPECIAL PROJECT PART# CV2288.				
		VALVE BODY IS 1/2" PIPE RIGHT ANGLE CONFIGURATION. DBS WBS#1.1.2.5, DBI WBS# 1.1.2.4, EEE WBS# 3.1.1.3.6.1				

CHECK BOX IF CONFERENCE REQ. | CHECK BOX TO RECEIVE P.O. COPY VIA E-MAIL | TOTAL AMOUNT OF THIS REQUISITION $ 14,460—

BUDGET CODE	PERCENTAGE	NEPA APPROVAL	DIVISION OFFICE APPROVAL	BUDGET OFFICE APPROVAL	PURCHASING/CONTRACTS DEPT. STAMP
DBS	50				
DBI	25				
~~EEE~~ EEG	25				

B3 W

P.O. NUMBER	VENDOR CODE	BUYER	AT RIGHT, INDICATE SPECIAL ORDER TYPE (SPARES/ISS/GSA/CAFE/FAB/T&M)	GSA/FSS CONTRACT NO.

SEND P.O. TO ATTENTION OF	SHIP VIA	F.O.B. & POINT OF SHIPMENT FOR FB/FC/FD	TERMS	REPORTING CODE	COST ELEMENT	CONFIRMED TO & DATE

CHECK IF P.O. FOR INTERNAL USE ONLY	CHECK IF REQUESTER TO APPROVE PAYMENT	BEGINNING STD. TEXT CODES	ENDING STD. TEXT CODES	REQUISITION NUMBER

FL-28 REV 6/9