VLPC SINGLE CASSETTE CRYOSTAT CHRISTMAS TREE TEMPERATURE AS RELATED TO ANNULUS FLOW AND LHE LEVEL

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Data taken from tests of annulus shield flow versus Christmas tree temperature show that the temperature of the tree is controlled by the annulus flow *and* the LHe level in the reservoir. Graphs indicating this are shown in Figures 1 and 2. An equation determined from the data taken on 4/19 to model the flow and LHe level dependence of tree temperature is as follows:

$$T = AL + BF + C \qquad \text{(EQ. 1)}$$

T = tree temperature (K)
A = -0.0055 (K/%)
L = LHe Level (%) 10% (0.6") < L < 65% (3.9")
B = -1.166 (K/scfh air)
F = annulus flow (scfh air) 0.5 < F < 1.0 scfh
C = 7.889 (K)

From the above equation it is evident that shield flow has a significant effect on tree temperature while the percent of LHe in the reservoir is much less significant. The following illustrates the temperature's relative sensitivity to the two variables:

Δflow = 0.5 scfh gives ΔT = 0.58 K
Δlevel = 40% LHe gives ΔT = 0.22 K

A graph of Temperature Calculated vs. Temperature Measured in Figure 3 shows the degree to which the equation conforms to the data taken on 4/19. This test data is included in the appendix. The measured temperature, calculated temperature, and the percent of error between the two is shown among the data.

Figure 3 and the 'Temp.%Error' column in the data indicate the degree of the equation's accuracy. When determining the value of the above equation it is important to consider Figure 4. The graph shows Temperature vs. Annulus Flow data collected on a number of different days. Note that data collected from day to day have similar slopes yet different y-intercepts. This means that the degree to which flow effects temperature remained relatively constant from day to day, yet some unknown variable in temperature control remains. Initially it seems possible that variations in cryostat pressure might be the third variable. But the maximum possible pressure change of 4 psig within the cryostat only accounts for a 0.24 K temperature difference. One other theory is that the GHe used to apply positve pressure to the cassette space is leaking out the cassette top and is causing the change in y-intercepts. A leak in the cassette top would allow warm GHe to enter the cassette volume. Furhter tests will be done to see if this cassette leak is in fact the problem.

The above equation cannot be applied at some instant to determine the annulus flow required at some LHe level to produce a desired tree temperature. Rather its value is that it shows the relative contribution of the two variables to the temperature and the temperature's sensitivity to them. It seems regulation of the tree temperature would best be achieved by providing a feedback loop between temperature and shield flow while maintaining a relatively steady ($\pm$5%) LHe level. As one last note, I found that regulating the LHe level with the inlet valve caused disturbances in the cryostat that resulted in temperature drops as great as 0.2 K. To prevent this, when LHe levels fell too low, I would remove the boil-off hose from the regulator for a few minutes until the LHe level was back to a satisfactory level. From this it seems that the LHe level can be controlled by the boil-off regulator with less upset than by adjusting the LHe inlet valve.

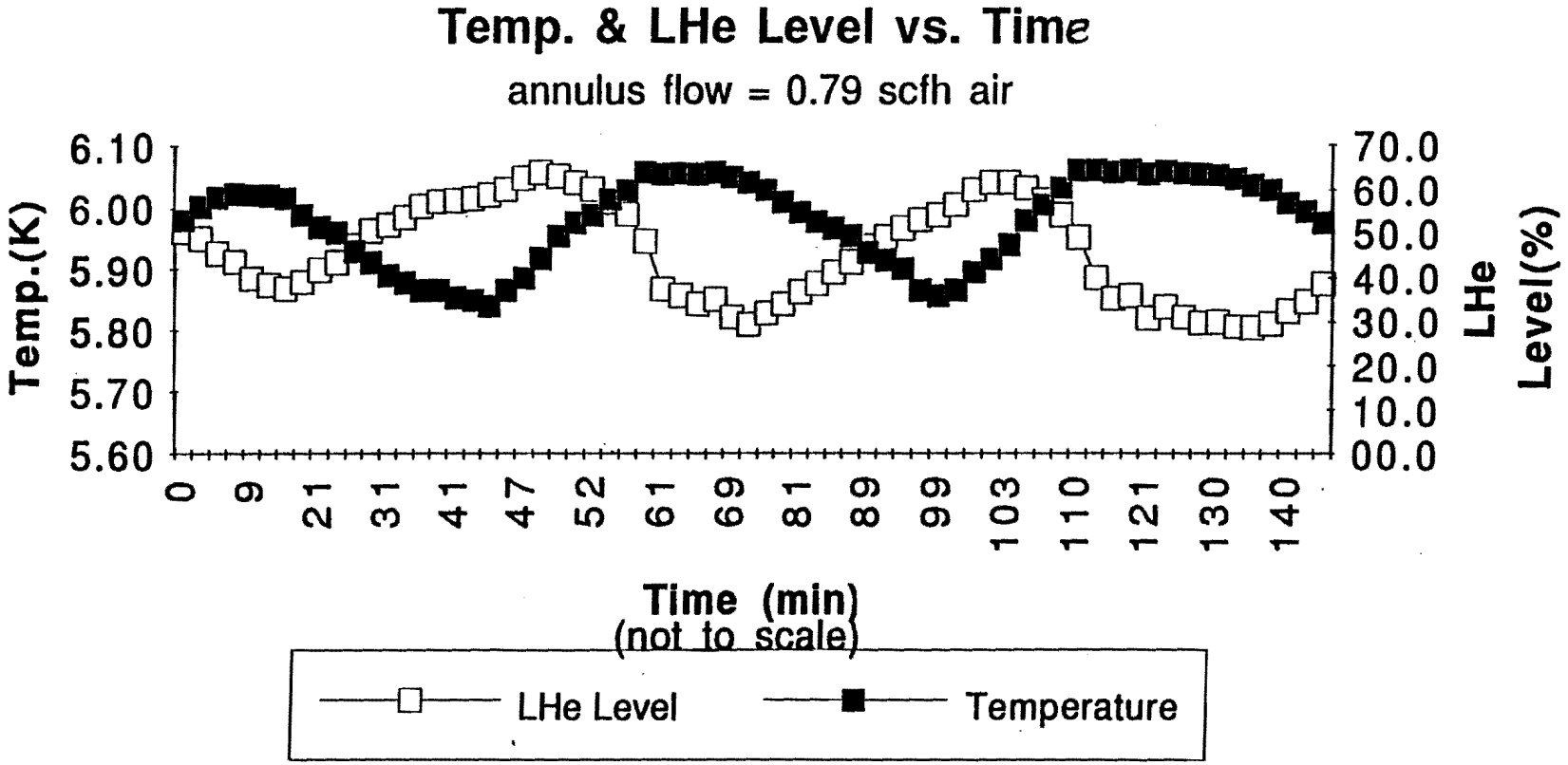


Figure 1.

note: LHe Value is Percent of 0" to 6" LHe Range

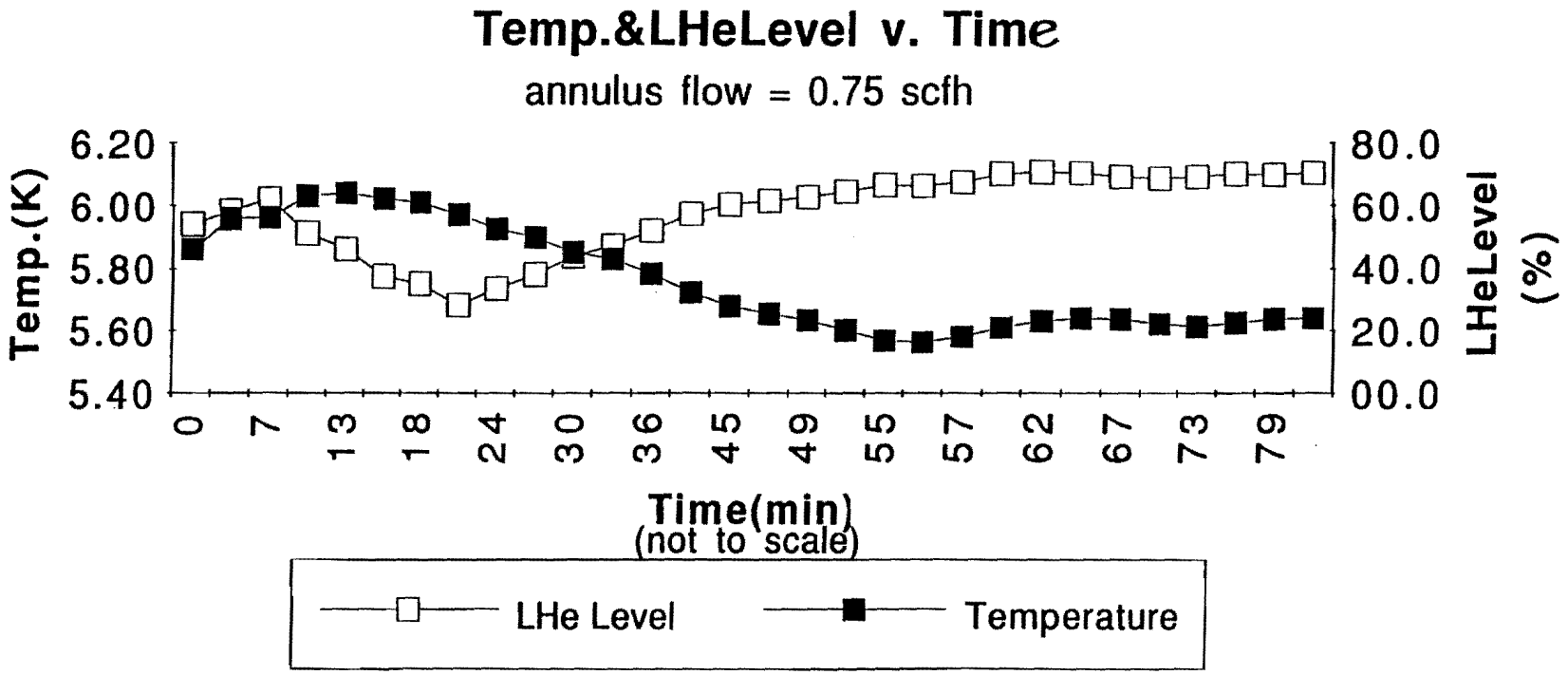
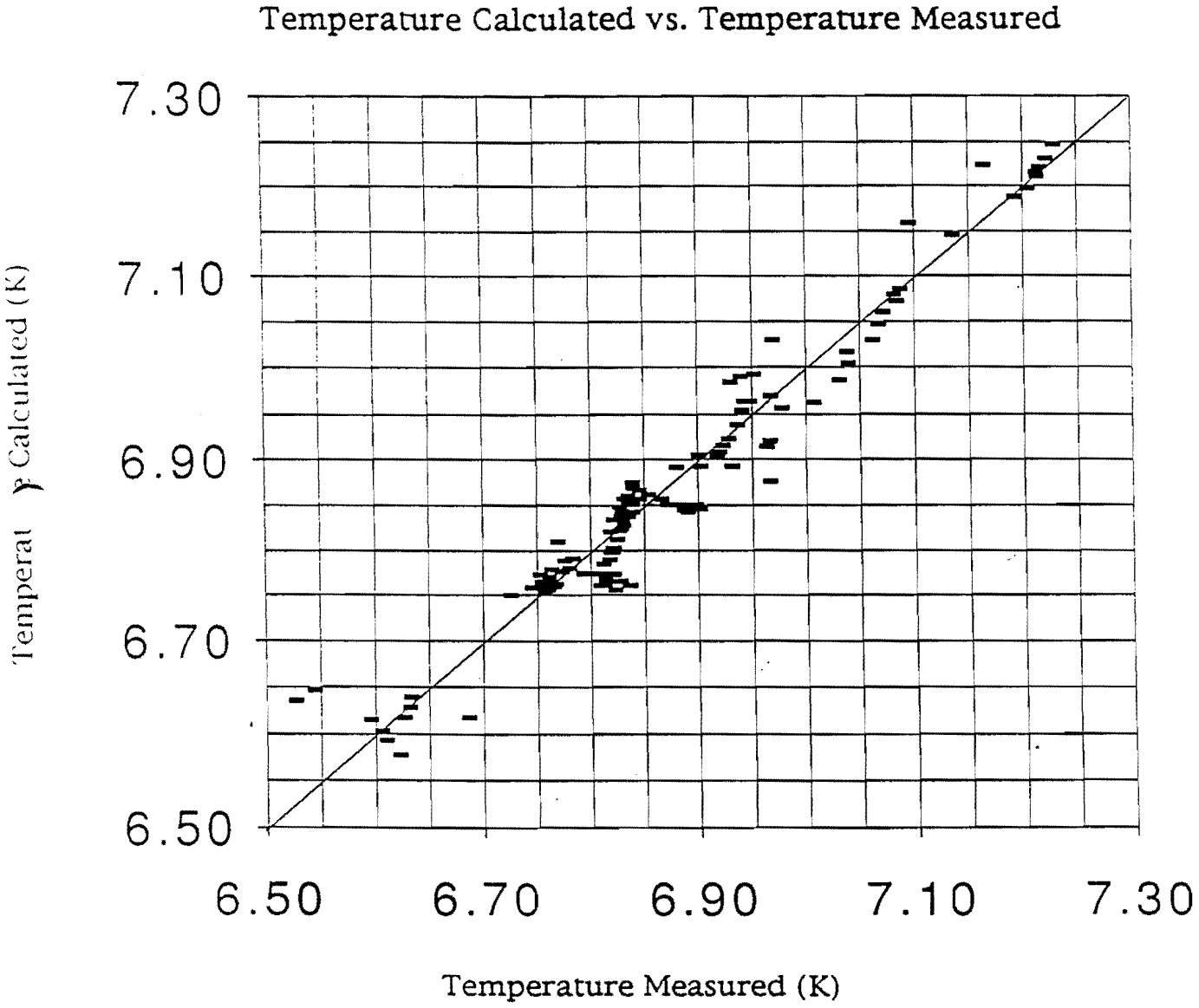

Temp.&LHeLevel v. Time
annulus flow = 0.75 scfh
Temp.(K)
6.20
6.00
5.80
5.60
5.40
80.0
60.0
40.0
20.0
00.0
LHeLevel (%)
0
7
13
18
24
30
36
45
49
55
57
62
67
73
79
Time(min)
(not to scale)
LHe Level
Temperature

Figure 2.



Note: Graph is of data collected on 4/19 and does not include test start-up data points.

Figure 3.

Temperature vs. Annulus Flow

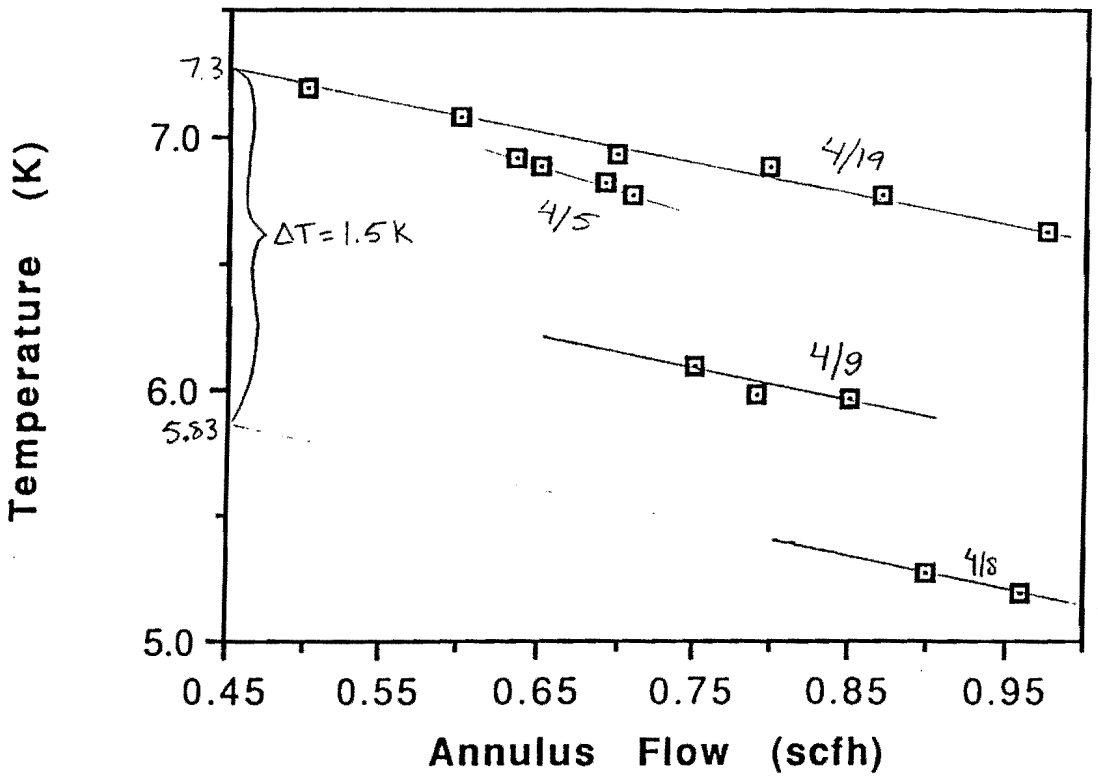


Figure 4.

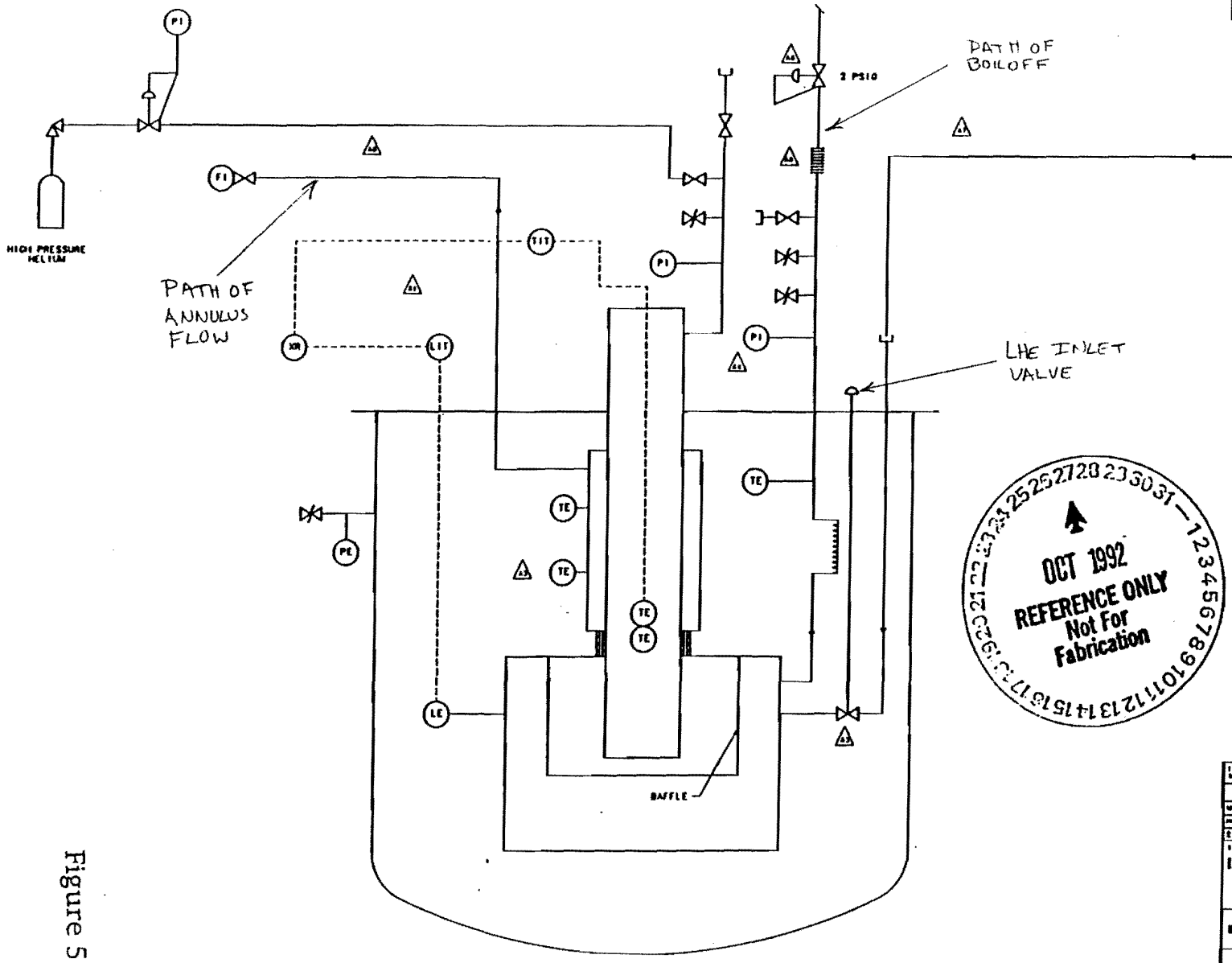


Figure 5.

Schematic of VLPC Single Cassette Cryostat

4/19/93						
flow=.972	annulus		Temp	Temp	Temp	LHe
time	flow	tree res	Measured	Calculated	%Error	Level(%)
10:10	0.974	767.04	5.65	6.53	-15.70	40.1
10:15	0.972	666.02	5.91	6.54	-10.70	38.6
10:21	0.972	608.08	6.09	6.55	-7.53	37.0
10:25	0.972	575.08	6.21	6.57	-5.78	33.8
10:27	0.972	565.00	6.25	6.57	-5.20	33.1
10:30	0.972	550.59	6.31	6.57	-4.17	34.1
10:33	0.972	537.51	6.36	6.57	-3.38	33.1
10:37	0.972	519.56	6.44	6.59	-2.40	30.0
10:41	0.969	511.42	6.47	6.61	-2.11	27.3
10:46	0.969	500.96	6.52	6.64	-1.76	22.5
10:48	0.966	497.32	6.54	6.65	-1.67	21.1
10:51	0.974	486.61	6.59	6.61	-0.37	25.4
10:55	0.974	484.59	6.60	6.60	-0.04	27.5
10:58	0.974	483.79	6.60	6.59	0.14	29.0
11:10	0.974	481.31	6.62	6.58	0.59	32.1
11:34	0.972	480.41	6.62	6.62	0.04	25.1
11:38	0.972	479.33	6.63	6.63	-0.05	23.1
11:41	0.974	479.21	6.63	6.64	-0.19	20.9
11:48	0.974	468.78	6.68	6.62	0.92	24.6
11:50	0.870	461.34	6.72	6.75	-0.46	22.7
11:54	0.870	457.64	6.74	6.76	-0.28	21.3
11:56	0.870	456.25	6.75	6.77	-0.38	18.7
12:00	0.870	454.70	6.75	6.76	-0.14	20.2
12:04	0.870	455.52	6.75	6.75	-0.06	21.9
12:06	0.870	456.10	6.75	6.76	-0.25	20.2
12:08	0.870	455.99	6.75	6.76	-0.22	20.4
12:10	0.870	454.76	6.75	6.76	-0.11	20.6
12:13	0.870	454.92	6.75	6.76	-0.05	21.5
<12:14>	0.870	455.90	6.75	6.76	-0.15	21.2
12:15	0.870	453.90	6.76	6.76	-0.01	21.0
12:17	0.870	453.60	6.76	6.76	-0.03	20.4
<12:19>	0.870	455.40	6.75	6.76	-0.21	20.0
12:22	0.870	454.73	6.75	6.77	-0.23	19.1
<12:23>	0.870	452.60	6.77	6.78	-0.15	18.0
12:25	0.870	454.40	6.76	6.78	-0.35	17.3
12:26	0.870	451.30	6.77	6.78	-0.11	17.2
12:28	0.870	452.05	6.77	6.79	-0.28	15.8
12:30	0.870	450.80	6.78	6.79	-0.23	15.2
	0.870	453.20	6.76	6.81	-0.70	11.8
12:45	0.796	448.79	6.79	6.77	0.18	33.9
12:48	0.796	445.23	6.81	6.77	0.57	35.1
12:51	0.796	448.00	6.79	6.77	0.25	34.0
12:59	0.796	446.06	6.80	6.76	0.61	36.4

13:03	0.796	445.34	6.81	6.76	0.65	36.2
13:04	0.796	445.80	6.80	6.77	0.43	33.9
13:09	0.796	443.97	6.81	6.77	0.58	33.9
13:14	0.796	444.65	6.81	6.79	0.30	31.2
13:17	0.796	443.93	6.81	6.80	0.23	29.6
13:20	0.796	443.85	6.81	6.80	0.19	29.0
13:25	0.796	442.90	6.82	6.82	-0.05	25.1
13:26	0.796	442.25	6.82	6.83	-0.06	24.2
	0.796	443.90	6.81	6.83	-0.31	22.9
	0.796	441.40	6.83	6.84	-0.13	22.5
13:27	0.796	442.79	6.82	6.84	-0.28	22.1
	0.796	440.70	6.83	6.84	-0.13	21.8
	0.796	442.60	6.82	6.84	-0.31	21.5
13:32	0.796	440.77	6.83	6.85	-0.26	20.2
	0.796	442.10	6.82	6.86	-0.48	18.9
13:33	0.796	439.60	6.84	6.86	-0.26	19.0
13:35	0.796	439.65	6.84	6.87	-0.39	17.4
	0.796	440.70	6.83	6.87	-0.62	15.7
13:37	0.796	438.20	6.85	6.86	-0.22	18.1
	0.796	436.00	6.86	6.86	0.04	19.0
13:40	0.796	430.00	6.89	6.85	0.70	20.9
13:41	0.796	430.10	6.89	6.90	-0.15	10.4
13:43	0.796	430.86	6.89	6.85	0.57	20.2
	0.796	431.00	6.89	6.85	0.56	20.2
13:45	0.796	430.50	6.89	6.85	0.59	20.0
13:50	0.796	441.20	6.83	6.76	1.01	36.4
13:55	0.796	443.76	6.81	6.76	0.86	37.2
13:59	0.796	442.76	6.82	6.77	0.81	35.6
14:03	0.796	444.32	6.81	6.82	-0.14	25.4
14:05	0.796	443.85	6.81	6.77	0.62	34.3
14:07	0.796	445.52	6.80	6.78	0.30	32.1
14:10	0.796	444.31	6.81	6.80	0.19	29.5
14:12	0.796	443.94	6.81	6.80	0.18	29.0
14:15	0.796	443.85	6.81	6.80	0.18	28.9
14:17	0.796	443.34	6.82	6.81	0.09	27.2
14:20	0.796	442.52	6.82	6.82	-0.03	24.9
14:23	0.796	442.44	6.82	6.83	-0.18	22.9
14:25	0.796	442.87	6.82	6.85	-0.41	20.5
	0.796	440.90	6.83	6.85	-0.29	20.0
14:27	0.796	441.47	6.83	6.85	-0.35	19.9
14:30	0.796	441.52	6.83	6.86	-0.46	18.5
14:31	0.796	440.79	6.83	6.87	-0.55	16.6
14:33	0.796	435.09	6.86	6.85	0.21	20.2
14:35	0.796	431.89	6.88	6.84	0.60	21.7
14:37	0.796	431.95	6.88	6.84	0.58	21.4
14:38	0.796	432.45	6.88	6.85	0.50	21.0

14:39	0.796	432.72	6.88	6.85	0.43	20.4
14:40	0.796	432.58	6.88	6.85	0.43	20.2
14:42	0.796	432.61	6.88	6.85	0.40	19.9
14:45	0.699	425.02	6.92	6.98	-0.88	16.2
14:48	0.699	423.56	6.93	6.99	-0.83	15.2
14:50	0.699	421.49	6.95	6.99	-0.67	14.9
14:59	0.699	429.74	6.90	6.89	0.04	32.9
15:02	0.699	427.20	6.91	6.90	0.10	30.9
15:04	0.699	426.31	6.92	6.91	0.02	29.0
15:06	0.699	425.37	6.92	6.92	-0.02	27.4
15:09	0.699	424.03	6.93	6.94	-0.11	24.8
15:11	0.699	423.41	6.93	6.95	-0.30	21.7
15:13	0.699	423.09	6.94	6.96	-0.39	20.2
15:15	0.699	422.23	6.94	6.96	-0.32	20.2
15:19	0.600	418.49	6.96	7.03	-0.95	29.0
15:22	0.600	418.92	6.96	6.97	-0.12	40.0
15:25	0.600	419.05	6.96	6.88	1.19	56.8
15:27	0.600	433.75	6.87	6.89	-0.28	54.2
15:30	0.600	424.87	6.92	6.89	0.47	54.0
15:32	0.600	426.79	6.91	6.91	0.08	51.2
15:35	0.600	419.51	6.96	6.91	0.62	50.0
15:37	0.600	419.10	6.96	6.92	0.57	49.0
15:42	0.600	417.28	6.97	6.96	0.21	42.4
15:45	0.600	412.52	7.00	6.96	0.55	41.4
15:49	0.600	408.70	7.02	6.99	0.54	36.9
15:52	0.600	407.45	7.03	7.00	0.40	33.6
15:54	0.600	407.62	7.03	7.02	0.21	31.4
15:56	0.600	403.80	7.06	7.03	0.37	29.0
15:58	0.600	403.02	7.06	7.05	0.20	26.0
16:00	0.600	402.44	7.06	7.06	0.07	23.6
16:02	0.600	400.42	7.08	7.07	0.09	21.5
16:03	0.600	400.81	7.08	7.08	-0.04	20.2
16:05	0.600	399.97	7.08	7.08	-0.06	19.0
16:10	0.499	398.74	7.09	7.16	-0.99	27.0
16:14	0.499	392.73	7.13	7.15	-0.24	29.4
16:17	0.499	388.44	7.16	7.22	-0.92	15.3
16:19	0.499	380.98	7.21	7.22	-0.16	15.8
16:21	0.499	380.07	7.21	7.23	-0.24	13.7
16:22	0.499	379.06	7.22	7.25	-0.33	11.2
16:24	0.499	384.32	7.19	7.19	-0.03	21.8
16:26	0.499	382.53	7.20	7.20	0.02	20.2
16:27	0.499	381.31	7.21	7.21	-0.04	17.8
16:29	0.499	381.40	7.21	7.21	-0.12	16.9
16:30	0.499	381.24	7.21	7.21	-0.09	17.1