Center for Night Vision and Electro-Optics

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Reliability Testing of the Hughes Temperature Controlled 1/4 Watt Split Cycle Cryogenic Cooler (HD-1045 (V)/UA)

by
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DECEMBER 1989

FORT BELVOIR, VIRGINIA 22060-5677

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This final report describes and provides data from reliability testing of the Hughes Aircraft Company (HAC) temperature controlled 1/4 Watt Split Cycle Cryogenic Cooler (HD-1045 (V)/UA). The testing was performed at the request of the Driver's Thermal Viewer (DTV) Project Office by the Center for Night Vision and Electro-Optics Far Infrared Engineering Team. The test was operated in accordance with the HD-1045 (V)/UA specification. The coolers successfully met the reliability requirements of the specification.

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PREFACE

This report details the performance and results of reliability testing performed on the Hughes Aircraft Company (HAC) temperature controlled HD-1045 rotary split cryogenic cooler. This test was requested by the Driver's Thermal Viewer (DTV) program to evaluate the probable performance of the cooler during DTV quality, environmental, life, and operational testing.

The test was conducted from 7 June 1988 to 6 March 1989. No major problems were encountered during performance of the test. Three units were tested and jointly accumulated 5,625.62 operating hours before their performance failed to meet the specification. This resulted in a mean-time-to-failure (MTTF) of 1,875.21 hours, meeting the HD-1045 reliability requirement. To further characterize the performance of the coolers, testing was continued past the point where hours accrued counted towards the MTTF. This performance should sufficiently preclude any negative affects on the DTV system due to cooler reliability.

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SECTION I. INTRODUCTION

The US Army CECOM Center for Night Vision and Electro-Optics (C^2NVEO) is responsible for developing cryogenic coolers for all infrared imaging systems for the Army. C^2NVEO also maintains configuration management control of the forward-looking infrared (FLIR) Common Module coolers used in thermal imagers in fielded Army weapon systems such as: M60A3 and M1 Tanks, Bradley Fighting Vehicle (BFV) System, tube-launched, optically tracked, wire-guided (TOW) Missile System, and Army Attack Helicopters. Currently, there are over 30,000 coolers in fielded systems and several thousand more are added each year. C^2NVEO conducts development programs and monitors contractor internal research and development efforts to improve cooler performance such as reliability, audio noise, power consumption, and output vibration.

The HD-1045 1/4-Watt Split Stirling Cooler was originally designed and developed by the C^2NVEO in the early 1970s as a replacement for the gas bottle/cryostat used on the Manportable Common Thermal Night Sights. To date, however, the HD-1045 cooler has been used in the field in the Integrated Sight Unit (ISU) of the BFV System and is currently being used in the Driver Thermal Viewer (DTV) full scale development program.

This document describes and reports the results of reliability testing done on Hughes Temperature Controlled 1/4 Watt Split Cycle Cryogenic Coolers (HD-1045 (V)/UA), referred to herein as the *coolers*. This testing was conducted by personnel of the Far Infrared Engineering (FIRE) Team during the period of June 1988 to March 1989.

SECTION II. BACKGROUND

The Driver's Thermal Viewer (DTV) program was slated to incorporate the 1/4 Watt Linear Cooler during Full Scale Engineering Development (FSED). Because of cost constraints in the DTV program and schedule slips in linear cooler development, this was not possible. Instead, the HD-1045 1/4 Watt Split Cooler was chosen for use in the DTV FSED units. The non-temperature controlled 1/4 Watt Split Cooler was initially developed in the early 1980s and is used in the Bradley Fighting Vehicle (BFV) Integrated Sight Unit (ISU). This cooler has exhibited a very low reliability due to its susceptability to gaseous and particulate contamination from bearing grease, lip seal wear, and gear wear. Because of these shortcomings, no vendor has been able to meet the development specification reliability requirement of a 1,000 hour lower mean-time-before-failure (MTBF). However, over the years, improvements have been made to address these problems and a temperature control feature has been added. No testing had been done on the improved design; therefore, no evaluation of the cooler's reliability was possible.

SECTION III. TEST OBJECTIVE

The objective of this reliability testing was to establish a lower mean-time-to-failure (MTTF) value for the cooler. This value will be used to evaluate the probability of the coolers passing the DTV quality, environmental, life, and operational testing.

SECTION IV. TEST DESCRIPTION

The reliability demonstration test was conducted on three coolers in accordance with the following parameters:

- Test equipment and instrumentation as defined in Figure 1.
- Temperature and cooler power cycling as defined in Figure 2.
- Periodic dismounting of the coolers from the reliability test set for leak rate testing and room temperature baseline testing.
- Hourly monitoring of test conditions and cooler performance.
- Collection of the following data:
  - Cycle data - Date
    - Cycle number
    - [illegible] of cycle
  - Test Conditions - Heat load
    - Chamber temperature
  - Cooler Performance - Coldtip temperature
    - Compressor housing temperature
    - Cooler power

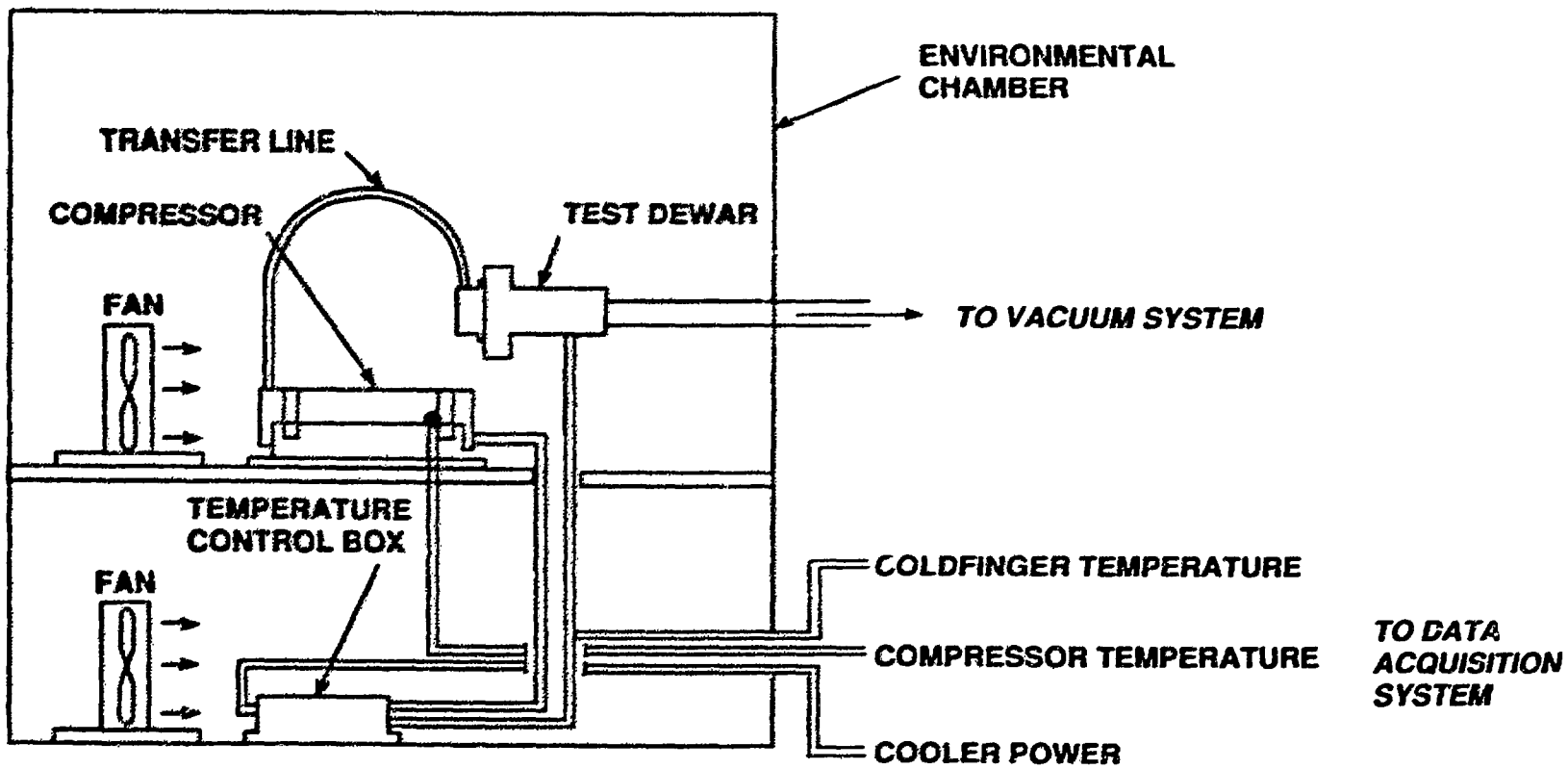

ENVIRONMENTAL CHAMBER
TRANSFER LINE
COMPRESSOR
TEST DEWAR
FAN
TO VACUUM SYSTEM
TEMPERATURE CONTROL BOX
FAN
COLDFINGER TEMPERATURE
COMPRESSOR TEMPERATURE
TO DATA ACQUISITION SYSTEM
COOLER POWER

Figure 1

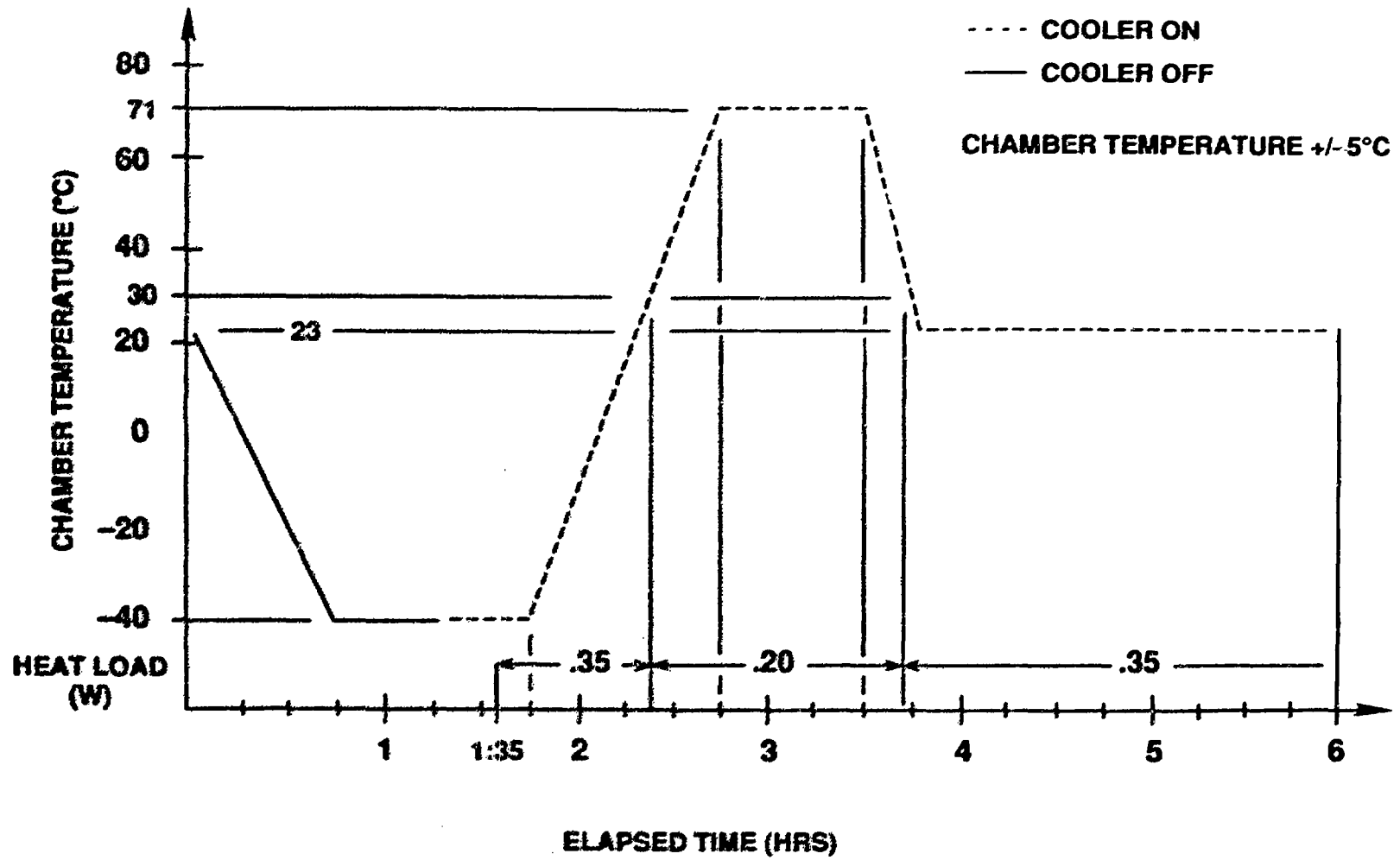

COOLER ON
COOLER OFF
CHAMBER TEMPERATURE +/-5°C
CHAMBER TEMPERATURE (°C)
80
71
60
40
30
23
20
0
-20
-40
HEAT LOAD (W)
.35
.20
.35
1
1:35
2
3
4
5
6
ELAPSED TIME (HRS)

Figure 2

SECTION V. TEST EQUIPMENT

The following equipment (schematically represented in Figure 1) was used by C^2NVEO to conduct the reliability tests:

- A vacuum and test dewar system that provides a vacuum of at least 1 x 10^{-6} Torr at the vacuum manifold during testing.

- A computer test control and data acquisition system that provides the necessary inputs to the cooler during the test and records the data. The parameters that the computer controls are the timing and magnitude of the input voltage to the temperature control boxes and the timing and magnitude of the input voltage to the cooler heat load. The data collected consisted of the temperature of the coldfinger, chamber temperature, compressor housing temperature, and input voltage and current which are used to calculate the cooler input power by the equation—

  Power = Voltage x Current

- An automated environmental chamber that controls the ambient temperature. Fans were positioned inside the chamber to circulate air over the compressor housing bodies, the warm end of the coldfingers, and the temperature control circuit boxes.

- The mounting and instrumenting hardware for the cooler compressor body and the coldfinger. The compressor bodies were mounted in an Aluminum fixture weighing .635 pound. The compressor body temperatures were read by thermistors mounted on the surface of the coolers next to the fixture. The coldfingers were mounted in a vacuum manifold serving as a test dewar. A test mass was secured on the coldfinger of each cooler using thermal grease to form good thermal contact. This thermal mass consisted of: .865 gram of Aluminum; a 2N2222 temperature diode to measure the temperature of the coldfinger; and a 1,000 Ohm +/- 1% resistor to which a bias was applied to generate an applied load. This assembly provided a thermal mass of 120 Joules.

SECTION VI. TEST ITEMS

The items on test were three Hughes Aircraft Temperature Controlled 1/4 Watt Split Stirling Cycle Cryogenic Coolers, serial numbers 5554, 5484, and 5559. They were operated in conjunction with three temperature control circuit boxes.

SECTION VII. TEST REQUIREMENTS

Since no official government specification exists for a temperature controlled rotary drive cooler, this tesing was done only to evaluate confidence in the cooler. The requirements used for the test were:

- Cooldown time: 100K in less than 7.5 minutes
  85K in less than 10 minutes
- Input power: not greater than 35 watts at any time
- Coldtip temperature: not greater than 85K at any time
- Leak rate: must not be greater than 1.0×10^{-6} std cc/sec air equivalent with the ambient temperature +23°C +/- 5°C

Although these requirements were drawn from the HD-1045 (V)/UA specification, this test in no way constituted an official qualification.

SECTION VIII. RESULTS

All of the coolers went out of specification during the test. The mode of failure, common to all three, was an out of specification coldfinger temperature at the high temperature (71°C) section of the reliability cycle. The coolers failed at the following times:

COOLER TEST #	COOLER S/N	FAILURE CYCLE	ACCRUED RUNTIME
1	5554	421	2,029.07
2	5484	379	1,829.10
3	5559	366	1,767.45

These numbers contribute to a total accumulated time of 5,625.62 and an MTTF of 1,875.21.

SECTION IX. OPERATION NOTES

The test was performed during the period of 7 June 1988 to 6 March 1989. The test consisted of reliability testing with periodic stops for cooler leak rate testing, equipment maintenance, and software debugging. Although the coolers were considered failed at the times listed in Section VIII, the test was continued to gain as much information about the cooler's life performance as possible. The coolers were run for a total of 2,560.1 hours each. This total is comprised of the following figures.

• 524 complete cycles @ 4.75 hr/cycle	=	2,489.00 hr
• 15 partial cycles	=	32.35 hr
• Time from a computer malfunction	=	38.75 hr
TOTAL RUNTIME	=	2,560.10 hr

The partial cycles were due to specification violation prompted aborts, test equipment failures, and operator interruptions. The 38.75 hours of runtime from a computer malfunction were accrued when the data logging function hung up and the coolers ran continuously over a weekend. During this period, the temperature chamber, controlled by an independent computer, continued to run through the cycle. The coolers also ran with an applied load of 350 mW over this time period. The Product Assurance Office was consulted and recommended that the hours accumulated be counted as runtime.

APPENDIX
ANALYSIS OF TEST DATA

The data collected during the testing is chronological. During each cycle, the computer collected data and printed it out as it was received. This resulted in the data being produced in the form of a three-page sheet per cycle. Due to the large volume of this information, only the second cycle and the cycle of failure data sheets for all three coolers are included in this report (pages A-2 through A-11). All test data is on file at Night Vision and is available on request.

The pertinent aspects of the data have been summarized into two graphs per cooler. The first shows the input power at 1:45, 3:30, and 6:00 elapsed time into the test (pages A-12 through A-14). The second records the coldtip temperature at these same cycle times (pages A-15 through A-17). These times correlate, respectively, with the ends of the low (–40°C), high (71°C), and room temperature (23°C) sections of the test.

These figures clearly show the degradation of cooler performance at high temperature over the duration of the test. It should be noted that the temperature control voltage was changed for coolers 1 and 3, causing them to run at full speed at cycle 375 in the test. This is evidenced by the drop in coldtip temperature at –40°C and 23°C ambient temperature.

The other important aspect of the data is the variance in coldtip temperature with ambient temperature. The temperature that the coldtip stabilized about appeared to be 74K at –40°C ambient temperature, 77K at 23°C ambient, and 81K at 71°C ambient. With closed loop feedback temperature control, the stabilized temperature should be constant, +/– 1.5K across all ambient temperatures.

CYCLE: 2 STARTED: 8 Jun 1988 06:41:16

TEST DATA WILL BE STORED IN THE FOLLOWING FILES:
/LTDATA/HAC_LIFE2.LTD:CS80,7,0
/LTDATA/HAC_LIFE2.BSL:CS80,7,0
/LTDATA/HAC_LIFE2.SPV:CS80,7,0

ELAPSED TIME	CHAMBER TEMP (C)	#	POWER (W)	FINGER TEMP (K)	COOLER HOUSING TEMP (C)	HEAT LOAD (W)	SPECIFICATION VIOLATIONS
00:00	23.15	1	0.00	***.**	22.78	0.00	
00:00	23.15	2	0.00	***.**	22.66	0.00	
00:00	23.15	3	0.00	***.**	22.79	0.00	
00:15	-5.48	1	0.00	***.**	9.91	0.00	
00:15	-5.48	2	0.00	***.**	4.92	0.00	
00:15	-5.48	3	0.00	***.**	4.33	0.00	
00:30	-22.41	1	0.00	***.**	-13.64	0.00	
00:30	-22.41	2	0.00	***.**	-16.13	0.00	
00:30	-22.41	3	0.00	***.**	-14.60	0.00	
00:45	-36.17	1	0.00	***.**	-28.26	0.00	
00:45	-36.17	2	0.00	***.**	-30.64	0.00	
00:45	-36.17	3	0.00	***.**	-29.04	0.00	
01:00	-40.91	1	0.00	***.**	-35.76	0.00	
01:00	-40.91	2	0.00	***.**	-37.74	0.00	
01:00	-40.91	3	0.00	***.**	-36.64	0.00	
01:15	-41.30	1	0.00	***.**	-37.04	0.00	
01:15	-41.30	2	0.00	***.**	-38.54	0.00	
01:15	-41.30	3	0.00	***.**	-37.69	0.00	

COOLER NUMBER #1 100K COOL DOWN TIME: 3.345

COOLER NUMBER #2 100K COOL DOWN TIME: 3.615

COOLER NUMBER #3 100K COOL DOWN TIME: 3.553

COOLER NUMBER #1 85K COOL DOWN TIME: 3.925

COOLER NUMBER #2 85K COOL DOWN TIME: 3.968

COOLER NUMBER #3 85K COOL DOWN TIME: 3.970

01:30	-40.89	1	6.70	79.82	-34.82	0.00
01:30	-40.89	2	8.68	80.80	-36.62	0.00
01:30	-40.89	3	7.78	81.55	-35.00	0.00
01:45	-40.63	1	12.52	81.81	-33.62	.35
01:45	-40.63	2	12.85	83.18	-34.87	.35
01:45	-40.63	3	13.49	84.09	-32.47	.35
02:00	-1.77	1	13.08	81.67	-8.22	.35
02:00	-1.77	2	14.02	82.26	-6.50	.35
02:00	-1.77	3	14.96	82.86	-4.60	.35
02:15	22.63	1	14.94	80.68	17.20	.35
02:15	22.63	2	15.68	80.60	18.81	.35
02:15	22.63	3	17.41	80.97	20.09	.35
02:30	45.01	1	14.92	78.75	39.87	.20
02:30	45.01	2	15.00	78.17	41.72	.20
02:30	45.01	3	17.03	78.[illegible]	42.00	.20
02:45	63.60	1	13.43	78.66	59.47	.20
02:45	63.60	2	16.96	77.83	61.49	.20
02:45	63.60	3	20.13	77.82	61.36	.20
03:00	71.89	1	16.67	78.72	73.58	.20
03:00	71.89	2	18.09	77.59	74.78	.20
03:00	71.89	3	20.86	77.75	74.87	.20
03:15	72.36	1	17.89	78.60	76.77	.20
03:15	72.36	2	19.32	77.37	77.20	.20
03:15	72.36	3	21.28	77.53	77.46	.20
03:30	71.86	1	17.70	78.63	77.40	.20
03:30	71.86	2	19.10	77.59	77.63	.20
03:30	71.86	3	20.80	77.59	77.95	.20
03:45	32.41	1	15.54	78.28	54.48	.20
03:45	32.41	2	16.20	77.32	50.46	.20
03:45	32.41	3	18.77	77.47	50.95	.20
04:00	24.60	1	18.39	79.74	35.81	.35
04:00	24.60	2	19.41	79.42	33.29	.35
04:00	24.60	3	18.77	79.68	35.25	.35
04:15	23.26	1	17.97	79.94	30.31	.35
04:15	23.26	2	17.44	79.66	29.43	.35
04:15	23.26	3	21.47	79.89	30.78	.35
04:30	23.26	1	16.72	79.90	29.25	.35
04:30	23.26	2	18.15	80.12	28.83	.35
04:30	23.26	3	19.39	79.94	30.16	.35
04:45	22.69	1	17.21	79.88	29.22	.35
04:45	22.69	2	19.13	78.88	28.90	.35
04:45	22.69	3	22.59	79.06	30.16	.35

05:00	23.38	1	17.26	79.91	28.08	.35
05:00	23.38	2	18.68	77.83	28.77	.35
05:00	23.38	3	20.85	77.54	30.41	.35
05:15	23.28	1	16.07	79.90	27.95	.35
05:15	23.28	2	17.60	77.86	28.61	.35
05:15	23.28	3	25.27	77.47	30.26	.35
05:30	23.23	1	16.57	79.89	27.94	.35
05:30	23.23	2	17.94	78.15	28.59	.35
05:30	23.23	3	25.54	77.51	30.25	.35
05:45	23.24	1	17.20	79.91	27.94	.35
05:45	23.24	2	19.14	77.98	28.60	.35
05:45	23.24	3	19.37	77.49	30.25	.35
06:00	22.99	1	17.55	79.87	27.93	.35
06:00	22.99	2	17.61	77.84	28.57	.35
06:00	22.99	3	24.91	77.47	30.18	.35

CYCLE: 366 STARTED: 24 Oct 1988 10:02:30

TEST DATA WILL BE STORED IN THE FOLLOWING FILES:
/LTDATA/HAC_LIFE366.LTD:CS80,7,0
/LTDATA/HAC_LIFE366.BSL:CS80,7,0
/LTDATA/HAC_LIFE366.SPV:CS80,7,0

ELAPSED TIME	CHAMBER TEMP (C)	#	POWER (W)	FINGER TEMP (K)	COOLER HOUSING TEMP (C)	HEAT LOAD (W)	SPECIFICATION VIOLATIONS
00:00	19.37	1	0.00	***.**	22.46	0.00	
00:00	19.37	2	0.00	***.**	21.93	0.00	
00:00	19.37	3	0.00	***.**	23.59	0.00	
00:15	1.87	1	0.00	***.**	8.68	0.00	
00:15	1.87	2	0.00	***.**	8.47	0.00	
00:15	1.87	3	0.00	***.**	7.56	0.00	
00:30	-10.27	1	0.00	***.**	-8.02	0.00	
00:30	-10.27	2	0.00	***.**	-8.12	0.00	
00:30	-10.27	3	0.00	***.**	-5.66	0.00	
00:45	-19.35	1	0.00	***.**	-17.44	0.00	
00:45	-19.35	2	0.00	***.**	-17.48	0.00	
00:45	-19.35	3	0.00	***.**	-15.68	0.00	
01:00	-27.13	1	0.00	***.**	-24.24	0.00	
01:00	-27.13	2	0.00	***.**	-24.83	0.00	
01:00	-27.13	3	0.00	***.**	-23.12	0.00	
01:15	-32.47	1	0.00	***.**	-29.22	0.00	
01:15	-32.47	2	0.00	***.**	-29.99	0.00	
01:15	-32.47	3	0.00	***.**	-28.85	0.00	

COOLER NUMBER #3 120K COOL DOWN TIME: 2.985

COOLER NUMBER #1 120K COOL DOWN TIME: 3.340

COOLER NUMBER #2 120K COOL DOWN TIME: 3.322

COOLER NUMBER #3 100K COOL DOWN TIME: 3.578

COOLER NUMBER #1 100K COOL DOWN TIME: 3.940

COOLER NUMBER #2 100K COOL DOWN TIME: 3.922

COOLER NUMBER #3 85K COOL DOWN TIME: 3.882

COOLER NUMBER #1 85K COOL DOWN TIME: 4.237

COOLER NUMBER #2 85K COOL DOWN TIME: 4.600

01:30	-35.74	1	8.92	75.21	-31.04	0.00	
01:30	-35.74	2	6.89	76.03	-32.07	0.00	
01:30	-35.74	3	12.58	77.02	-29.12	0.00	
01:45	-37.61	1	14.58	78.12	-32.97	.35	
01:45	-37.61	2	13.89	79.92	-34.06	.35	
01:45	-37.61	3	14.83	79.82	-29.92	.35	
02:00	3.83	1	15.59	78.07	1.62	.35	
02:00	3.83	2	16.99	78.82	1.76	.35	
02:00	3.83	3	16.23	79.09	2.03	.35	
02:15	27.58	1	19.09	77.26	25.67	.35	
02:15	27.58	2	18.95	78.24	25.82	.35	
02:15	27.58	3	19.79	77.77	25.23	.35	
02:30	46.65	1	15.19	75.09	45.07	.20	
02:30	46.65	2	16.42	75.82	45.24	.20	
02:30	46.65	3	16.59	75.86	45.96	.20	
02:45	63.68	1	18.35	75.25	62.20	.20	
02:45	63.68	2	15.87	76.13	62.38	.20	
02:45	63.68	3	23.05	76.27	65.01	.20	
03:00	72.17	1	23.80	76.73	73.11	.20	
03:00	72.17	2	21.43	79.01	73.04	.20	
03:00	72.17	3	23.18	81.98	77.71	.20	
03:15	72.05	1	25.72	78.04	74.23	.20	
03:15	72.05	2	22.24	81.95	74.06	.20	
03:15	72.05	3	23.33	91.66	78.59	.20	<- FINGER TEMP OUT OF SPEC
03:30	71.89	1	23.54	78.95	74.26	.20	
03:30	71.89	2	22.72	82.66	74.09	.20	
03:30	71.89	3	18.94	92.61	78.30	.20	<- FINGER TEMP OUT OF SPEC
03:45	40.67	1	19.41	75.15	48.40	.20	
03:45	40.67	2	17.70	75.89	47.13	.20	
03:45	40.67	3	21.59	79.85	55.24	.20	
04:00	24.98	1	15.68	79.64	27.84	.35	
04:00	24.98	2	20.51	77.39	27.98	.35	
04:00	24.98	3	21.36	81.03	35.47	.35	<- LOAD POWER OUT OF SPEC
04:15	23.08	1	17.54	77.32	26.47	.35	
04:15	23.08	2	53	77.42	25.75	.35	
04:15	23.08	3	20.30	77.32	30.27	.35	
04:30	20.36	1	17.12	77.18	23.83	.35	
04:30	20.36	2	19.88	77.35	22.97	.35	
04:30	20.36	3	19.95	77.04	27.24	.35	

04:45	20.27	1	19.02	77.38	23.17	.35
04:45	20.27	2	19.67	77.58	22.35	.35
04:45	20.27	3	20.15	77.18	25.60	.35
05:00	20.25	1	17.37	77.43	23.09	.35
05:00	20.25	2	19.43	77.59	22.27	.35
05:00	20.25	3	19.46	77.10	25.54	.35
05:15	20.21	1	19.71	77.32	23.13	.35
05:15	20.21	2	17.30	77.59	22.26	.35
05:15	20.21	3	20.62	77.12	25.59	.35
05:30	20.15	1	16.83	77.26	23.15	.35
05:30	20.15	2	17.02	77.58	22.28	.35
05:30	20.15	3	20.09	77.40	25.65	.35
05:45	19.98	1	17.39	76.90	23.17	.35
05:45	19.98	2	17.21	77.59	22.28	.35
05:45	19.98	3	20.43	77.34	25.63	.35
06:00	20.45	1	20.39	77.25	23.15	.35
06:00	20.45	2	19.71	77.57	22.31	.35
06:00	20.45	3	20.12	77.13	25.65	.35

CYCLE: 379 STARTED: 1 Nov 1988 17:18:37

TEST DATA WILL BE STORED IN THE FOLLOWING FILES:
/LIDATA/HAC LIFE379.LTD:CS80.7.0
/LIDATA/HAC LIFE379.BSL:CS80.7.0
/LIDATA/HAC LIFE379.SPV:CS80.7.0

ELAPSED TIME	CHAMBER TEMP (C)	#	POWER (W)	FINGER TEMP (K)	COOLER HOUSING TEMP (C)	HEAT LOAD (W)	SPECIFICATION VIOLATIONS
00:00	14.40	1	0.00	***.**	18.55	0.00	
00:00	14.40	2	0.00	***.**	17.20	0.00	
00:00	14.40	3	0.00	***.**	21.46	0.00	
00:15	-4.33	1	0.00	***.**	-1.04	0.00	
00:15	-4.33	2	0.00	***.**	-2.18	0.00	
00:15	-4.33	3	0.00	***.**	1.56	0.00	
00:30	-17.47	1	0.00	***.**	-14.69	0.00	
00:30	-17.47	2	0.00	***.**	-15.52	0.00	
00:30	-17.47	3	0.00	***.**	-12.56	0.00	
00:45	-29.26	1	0.00	***.**	-25.74	0.00	
00:45	-29.26	2	0.00	***.**	-26.84	0.00	
00:45	-29.26	3	0.00	***.**	-23.66	0.00	
01:00	-37.49	1	0.00	***.**	-33.28	0.00	
01:00	-37.49	2	0.00	***.**	-34.63	0.00	
01:00	-37.49	3	0.00	***.**	-32.34	0.00	
01:15	-40.91	1	0.00	***.**	-36.94	0.00	
01:15	-40.91	2	0.00	***.**	-38.37	0.00	
01:15	-40.91	3	0.00	***.**	-37.57	0.00	

COOLER NUMBER #3 120K COOL DOWN TIME: 2.715

COOLER NUMBER #1 120K COOL DOWN TIME: 3.059

COOLER NUMBER #2 120K COOL DOWN TIME: 3.047

COOLER NUMBER #3 100K COOL DOWN TIME: 3.293

COOLER NUMBER #1 100K COOL DOWN TIME: 3.638

COOLER NUMBER #2 100K COOL DOWN TIME: 3.633

COOLER NUMBER #3 85K COOL DOWN TIME: 3.888

COOLER NUMBER #1 85K COOL DOWN TIME: 4.233

COOLER NUMBER #2 85K COOL DOWN TIME: 4.221

01:30	-40.98	1	8.91	76.02	-36.33	0.00
01:30	-40.98	2	6.58	76.71	-38.00	0.00
01:30	-40.98	3	17.78	-89.28	-32.42	0.00
01:45	-41.11	1	13.86	78.82	-35.72	.35
01:45	-41.11	2	14.25	79.55	-37.58	.35
01:45	-41.11	3	20.87	63.18	-31.82	.35
02:00	-.20	1	16.09	78.83	-2.52	.35
02:00	-.20	2	15.13	79.00	-1.93	.35
02:00	-.20	3	20.89	68.77	-.77	.35
02:15	26.45	1	16.55	77.54	24.69	.35
02:15	26.45	2	19.54	78.09	25.11	.35
02:15	26.45	3	21.47	72.46	25.33	.35
02:30	48.52	1	15.36	75.30	46.05	.20
02:30	48.52	2	17.28	76.03	46.87	.20
02:30	48.52	3	23.82	63.29	49.31	.21
02:45	68.80	1	18.08	75.36	65.98	.20
02:45	68.80	2	18.55	76.52	67.14	.20
02:45	68.80	3	23.58	73.39	69.80	.21
03:00	71.97	1	24.41	77.38	73.41	.20
03:00	71.97	2	19.83	84.57	73.30	.20
03:00	71.97	3	24.05	83.57	78.46	.20
03:15	72.20	1	23.76	79.47	74.11	.20
03:15	72.20	2	22.67	86.35	73.98	.20 <- FINGER TEMP OUT OF SPEC
03:15	72.20	3	18.74	89.75	79.08	.21 <- FINGER TEMP OUT OF SPEC
03:30	72.10	1	21.29	80.42	74.18	.20
03:30	72.10	2	22.97	83.93	74.10	.20
03:30	72.10	3	20.13	93.34	78.59	.20 <- FINGER TEMP OUT OF SPEC
03:45	40.95	1	18.01	75.00	49.00	.20
03:45	40.95	2	16.15	75.97	47.28	.20
03:45	40.95	3	24.06	79.47	55.97	.20
04:00	25.47	1	19.63	77.87	28.15	.35
04:00	25.47	2	20.40	77.38	28.20	.35
04:00	25.47	3	21.93	78.77	36.07	.35 <- LOAD POWER OUT OF SPEC
04:15	22.75	1	17.00	76.52	26.30	.35
04:15	22.75	2	18.20	77.30	25.44	.35
04:15	22.75	3	21.74	76.22	30.35	.35

04:30	20.24	1	16.86	77.06	23.61	.35
04:30	20.24	2	17.87	77.57	22.62	.35
04:30	20.24	3	21.62	75.06	27.42	.35
04:45	20.17	1	16.75	77.26	23.28	.35
04:45	20.17	2	19.48	77.62	22.38	.35
04:45	20.17	3	21.62	74.96	26.62	.35
05:00	20.19	1	17.22	76.85	23.28	.35
05:00	20.19	2	18.23	77.61	22.34	.35
05:00	20.19	3	21.58	74.92	26.73	.35
05:15	20.23	1	19.07	76.71	23.28	.35
05:15	20.23	2	18.05	77.60	22.36	.35
05:15	20.23	3	21.61	74.87	26.68	.35
05:30	20.05	1	20.65	76.91	23.29	.35
05:30	20.05	2	19.50	77.59	22.34	.35
05:30	20.05	3	21.65	74.89	26.79	.35
05:45	20.03	1	16.99	76.84	23.32	.35
05:45	20.03	2	19.96	77.58	22.35	.35
05:45	20.03	3	21.69	74.85	26.88	.35
06:00	19.99	1	20.55	76.97	23.32	.35
06:00	19.99	2	17.27	77.58	22.36	.35
06:00	19.99	3	21.68	74.84	26.80	.35

CYCLE: 421 STARTED: 29 Nov 1988 18:36:36

TEST DATA WILL BE STORED IN THE FOLLOWING FILES:
/LTDATA/HAC_LIFE421.LTD:CS80,7,0
/LTDATA/HAC_LIFE421.BSL:CS80,7,0
/LTDATA/HAC_LIFE421.SPV:CS80,7,0

ELAPSED TIME	CHAMBER TEMP (C)	#	POWER (W)	FINGER TEMP (K)	COOLER HOUSING TEMP (C)	HEAT LOAD (W)	SPECIFICATION VIOLATIONS
00:00	12.24	1	0.00	***.**	17.27	0.00	
00:00	12.24	2	0.00	***.**	14.65	0.00	
00:00	12.24	3	0.00	***.**	20.04	0.00	
00:15	-7.49	1	0.00	***.**	-3.67	0.00	
00:15	-7.49	2	0.00	***.**	-5.99	0.00	
00:15	-7.49	3	0.00	***.**	-1.35	0.00	
00:30	-21.66	1	0.00	***.**	-18.45	0.00	
00:30	-21.66	2	0.00	***.**	-20.45	0.00	
00:30	-21.66	3	0.00	***.**	-16.56	0.00	
00:45	-33.40	1	0.00	***.**	-29.87	0.00	
00:45	-33.40	2	0.00	***.**	-31.63	0.00	
00:45	-33.40	3	0.00	***.**	-28.42	0.00	
01:00	-40.88	1	0.00	***.**	-36.91	0.00	
01:00	-40.88	2	0.00	***.**	-38.68	0.00	
01:00	-40.88	3	0.00	***.**	-37.07	0.00	
01:15	-40.77	1	0.00	***.**	-37.43	0.00	
01:15	-40.77	2	0.00	***.**	-38.81	0.00	
01:15	-40.77	3	0.00	***.**	-38.18	0.00	

COOLER NUMBER #3 120K COOL DOWN TIME: 2.683

COOLER NUMBER #1 120K COOL DOWN TIME: 3.035

COOLER NUMBER #2 120K COOL DOWN TIME: 3.014

COOLER NUMBER #1 100K COOL DOWN TIME: 3.325

COOLER NUMBER #3 100K COOL DOWN TIME: 3.256

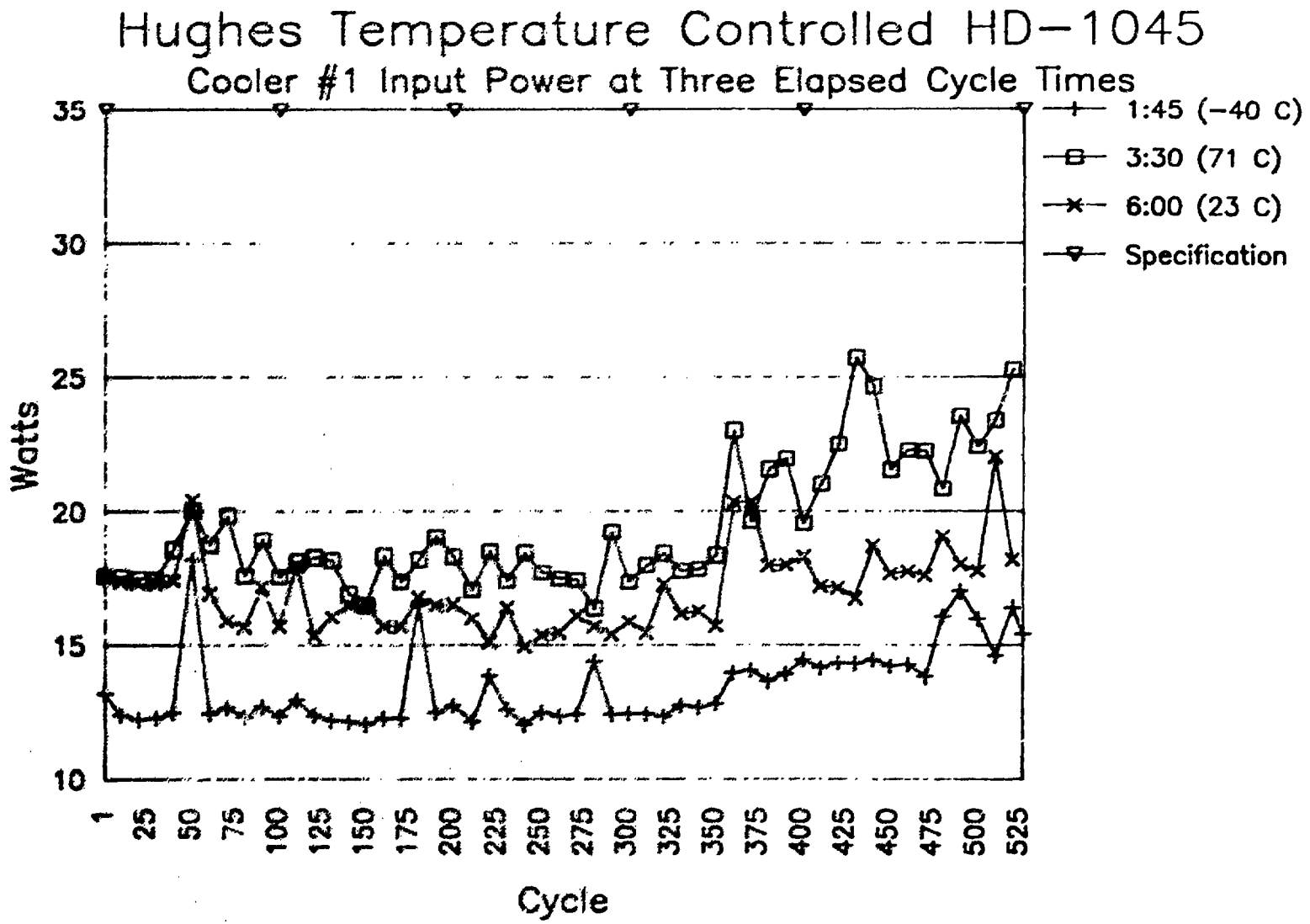
COOLER NUMBER #2 100K COOL DOWN TIME: 3.594

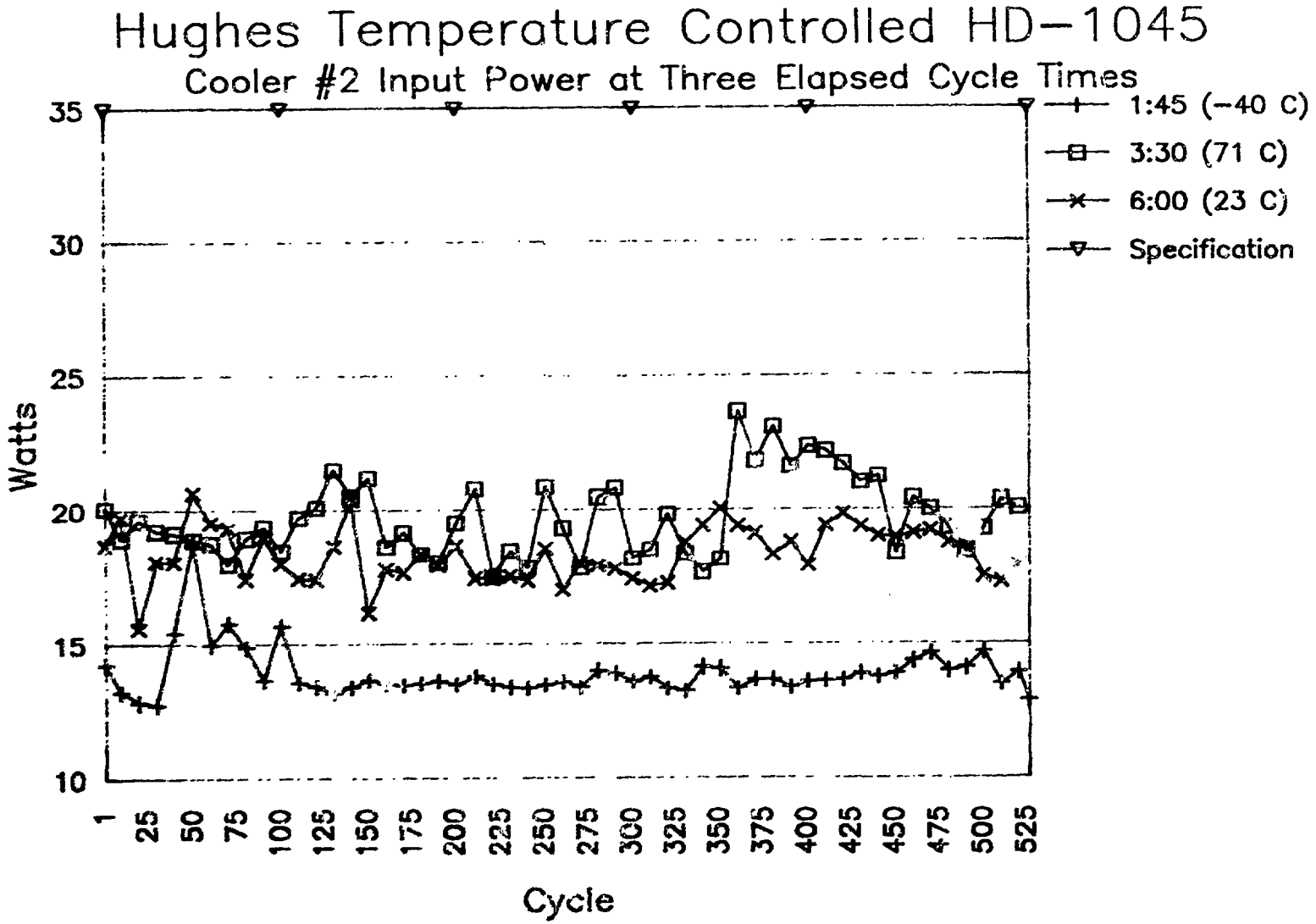
COOLER NUMBER #3 85K COOL DOWN TIME: 3.545

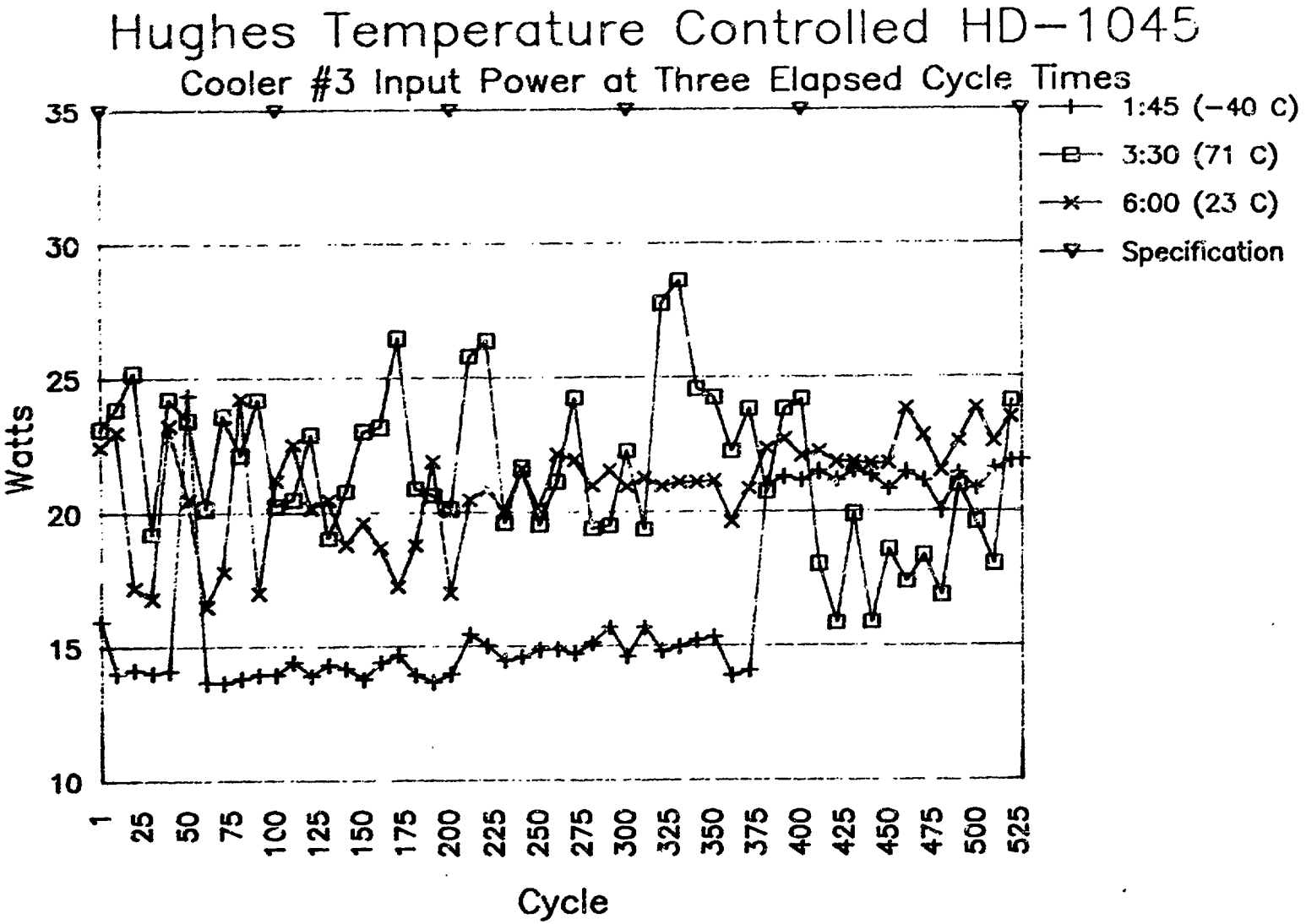
COOLER NUMBER #1 85K COOL DOWN TIME: 3.904

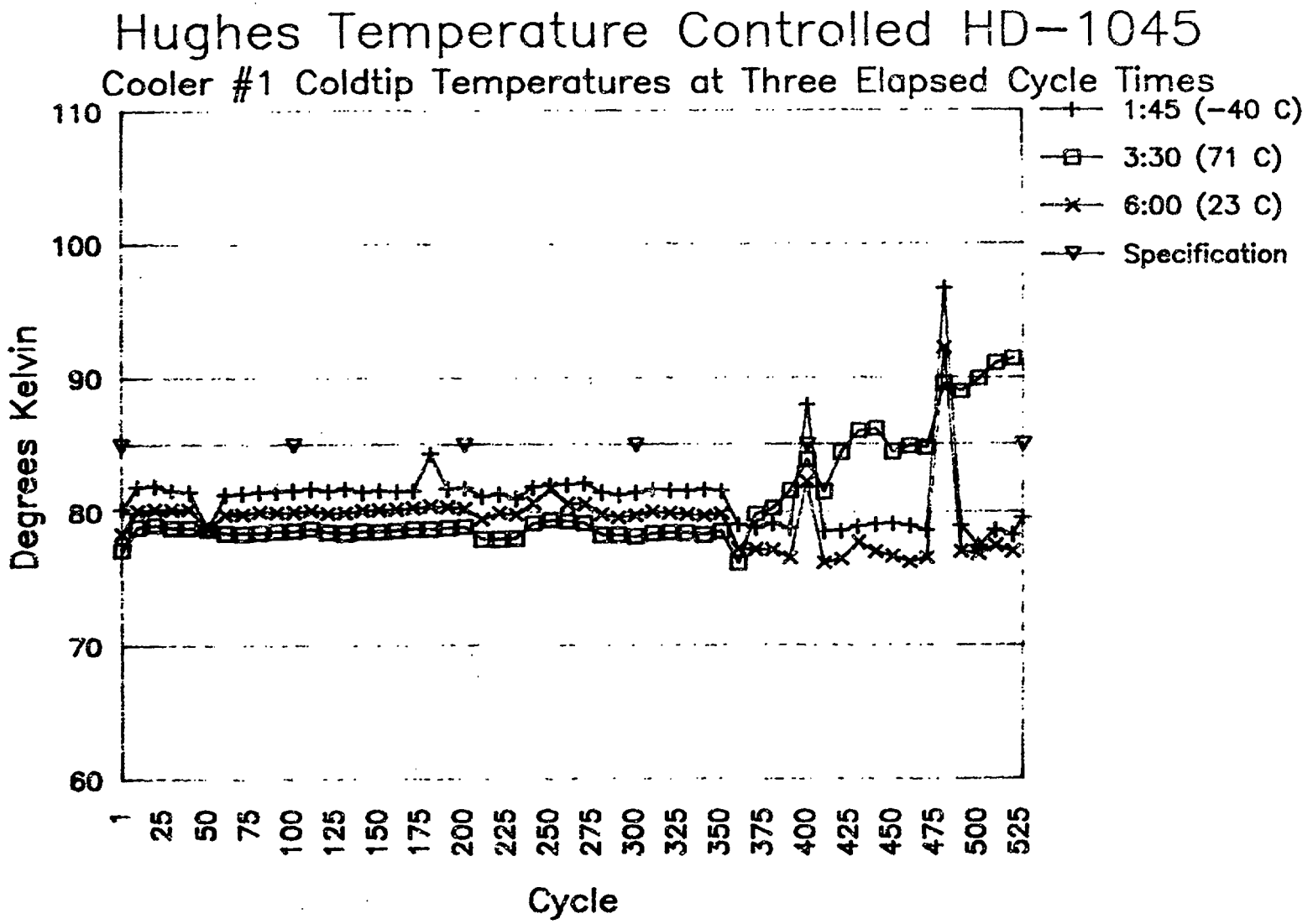
COOLER NUMBER #2 85K COOL DOWN TIME: 4.229

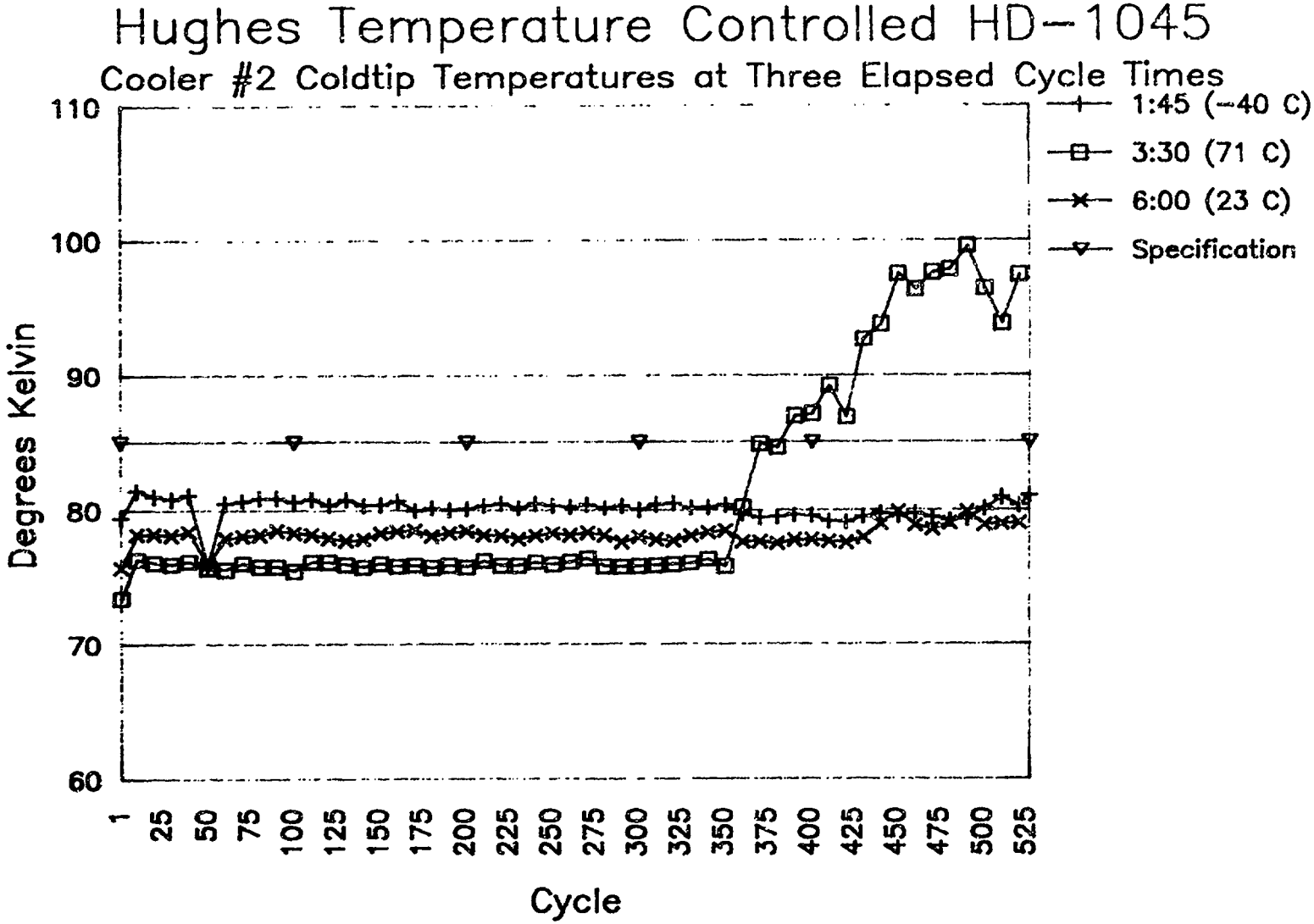
01:30	-40.91	1	9.57	75.99	-36.66	0.00
01:30	-40.91	2	6.51	76.59	-38.52	0.00
01:30	-40.91	3	20.77	-91.64	-33.49	0.00
01:45	-41.06	1	13.90	78.52	-36.08	.35
01:45	-41.06	2	13.69	78.75	-38.07	.35
01:45	-41.06	3	22.05	61.93	-32.01	.35
02:00	.19	1	14.93	78.22	-2.52	.35
02:00	.19	2	14.72	79.14	-.82	.35
02:00	.19	3	21.02	67.44	-.23	.36
02:15	25.93	1	16.92	77.11	23.92	.35
02:15	25.93	2	16.33	78.23	25.50	.35
02:15	25.93	3	21.97	72.23	25.15	.35
02:30	47.29	1	15.90	75.00	45.17	.20
02:30	47.29	2	16.49	76.21	47.08	.20
02:30	47.29	3	23.55	64.57	48.03	.20
02:45	67.39	1	19.69	75.04	64.90	.20
02:45	67.39	2	21.97	77.16	67.58	.20
02:45	67.39	3	24.82	76.97	68.43	.21
03:00	72.03	1	21.45	80.42	73.43	.20
03:00	72.03	2	21.26	87.81	73.88	.20 <- FINGER TEMP OUT OF SPEC
03:00	72.03	3	21.01	89.45	77.65	.20 <- FINGER TEMP OUT OF SPEC
03:15	72.09	1	20.93	83.29	74.23	.20
03:15	72.09	2	21.28	90.34	74.19	.20 <- FINGER TEMP OUT OF SPEC
03:15	72.09	3	19.98	95.37	78.30	.20 <- FINGER TEMP OUT OF SPEC
03:30	72.08	1	23.44	85.23	74.25	.20 <- FINGER TEMP OUT OF SPEC
03:30	72.08	2	21.66	98.94	74.13	.20 <- FINGER TEMP OUT OF SPEC
03:30	72.08	3	18.19	102.43	77.72	.20 <- FINGER TEMP OUT OF SPEC
03:45	38.33	1	17.99	75.12	46.64	.20
03:45	38.33	2	21.62	76.02	42.68	.20
03:45	38.33	3	17.77	81.21	52.32	.20

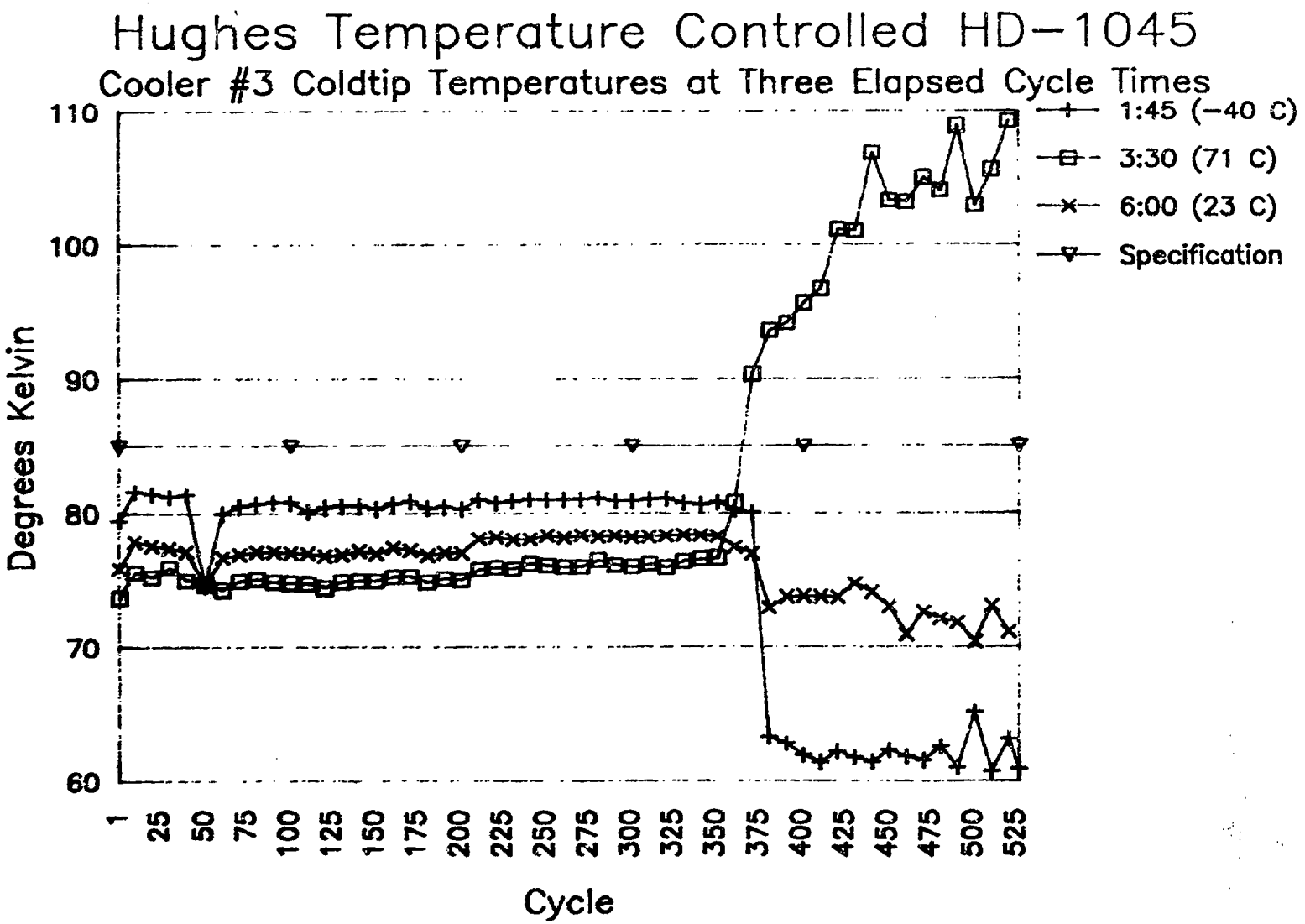

Hughes Temperature Controlled HD-1045
Cooler #1 Input Power at Three Elapsed Cycle Times
1:45 (-40 C)
3:30 (71 C)
6:00 (23 C)
Specification
Watts
35
30
25
20
15
10
1
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
Cycle


Hughes Temperature Controlled HD-1045
Cooler #2 Input Power at Three Elapsed Cycle Times
1:45 (-40 C)
3:30 (71 C)
6:00 (23 C)
Specification
Watts
35
30
25
20
15
10
1
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
Cycle


Hughes Temperature Controlled HD-1045
Cooler #3 Input Power at Three Elapsed Cycle Times
1:45 (-40 C)
3:30 (71 C)
6:00 (23 C)
Specification
Watts
35
30
25
20
15
10
1
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
Cycle


Hughes Temperature Controlled HD-1045
Cooler #1 Coldtip Temperatures at Three Elapsed Cycle Times
1:45 (-40 C)
3:30 (71 C)
6:00 (23 C)
Specification
Degrees Kelvin
110
100
90
80
70
60
1
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
Cycle


Hughes Temperature Controlled HD-1045
Cooler #2 Coldtip Temperatures at Three Elapsed Cycle Times
1:45 (-40 C)
3:30 (71 C)
6:00 (23 C)
Specification
Degrees Kelvin
110
100
90
80
70
60
1
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
Cycle


Hughes Temperature Controlled HD-1045
Cooler #3 Coldtip Temperatures at Three Elapsed Cycle Times
1:45 (-40 C)
3:30 (71 C)
6:00 (23 C)
Specification
Degrees Kelvin
110
100
90
80
70
60
1
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
Cycle

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