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DARHT Axis II Cathode 16 (S/N 22) History as Recorded in the Historian and Shot Data Databases

H. Vernon Smith, Juan Barraza, James F. Harrison, Jeffrey B. Johnson, Homa Nassiri, Martin E. Schulze, and Carl A. Ekdahl

Introduction

Long DARHT II injector cathode operating lifetimes are desirable for flash radiography of hydrodynamic tests at the dual-axis radiographic hydrotest facility (DARHT). The specification for cathode operating lifetime given to Spectra-Mat in the purchase orders for the 311X-M cathodes is $\geq$ 1000 hours at full operating temperature (~1120 ^{o}C). Of the five most-recent cathodes operated on DARHT II, only two have met this specification. It is desirable to have cathodes lifetimes considerably longer than the specified 1000 hours.

In this report we present the thermal and vacuum history of cathode 16 (serial no. [S/N] 22), a 311X-M cathode, as recorded in the historian database and the shot data database. The hope is that by examining this history we can identify the parameter (or parameters) that are limiting the DARHT II 311X-M cathode lifetimes.

This is the fifth in a series of 5 DARHT Tech Notes in which recent cathode thermal and vacuum histories are examined. The other tech notes in this series are DARHT Tech Notes Nos. 501 (cathode 12, S/N 15), 502 (cathode 13, S/N 19), 503 (cathode 14, S/N 20), and 504 (cathode 15, S/N 21). In DARHT Tech Note No. 506 we will compare the recorded thermal and vacuum histories of cathodes 12-16 and attempt to understand the cathode lifetime limitations based on the stored cathode data presented in DARHT Tech Notes 501-505 and other relevant information.

Data Analysis and Results

The dispenser cathode is located in the DARHT II injector (Figure 1).

The cathode 16 (S/N 22) parameters investigated in this study are the cathode temperature readback (Pyrometer #1 [FAR Associates model FMP1] and Pyrometer #2 [FAR Associates model FMP2]), injector ion gauge #1 readback, cathode heater power readback, shot number, beam counter, cathode operating hours, number of cathode thermal cycles, and number of vacuum excursions as a function of time. The “tags” for each of the parameters stored in the historian database and in the shot data database are given in Table 1. The locations of the sensors used to record these stored cathode parameters are shown schematically in Figures 2-4.

The shot history and beam counter history over the lifetime of cathode 16 as recorded by the shot data database are shown in Appendix A. The weekly “strip charts” of cathode temperature, injector vacuum pressure, and cathode heater power are shown in the 27 plots in Appendix B. The strip chart data in Appendix B are displayed in 15 minute increments. Table 2 contains the installation, activation, beam shot, and removal history of cathode 16.

The weekly (from 12 AM on Monday morning through midnight on Sunday night) historian database data are imported into Excel spreadsheets. These Excel spreadsheets are used to

generate the "strip chart" plots shown in Appendix B and are used to calculate the cathode operating times given in Table 3. The operating time at ~1120 ^{o}C (column 4 in Table 3) is determined by the time that the cathode heater power readback is > 0.36 kW. The time at ~590 ^{o}C (column 5 in Table 3) is determined by the time that the cathode heater power readback is between 0.30 and 0.36 kW. The time at low temperature (column 6 in Table 3) is determined by the time that the cathode heater readback is < 0.30 kW.

Column 9 of Table 3 contains the cathode operating hours as recorded in the shot data database, 356 h.

The number of cathode operating hours is calculated here by determining the time that

1. the cathode heater power readback is > 0.50 kW
2. and either pyrometer #1 readout is > 950 ^{o}C or pyrometer #2 readout is > 950 ^{o}C, or both readouts are > 950 ^{o}C

The results of this calculation are given in column 10 of Table 3. Note that this result, 345.75 h, is in good agreement with the cathode operating hours recorded in the shot data database, 356 h.

The shot data database calculation of cathode operating hours has a third requirement for recording the cathode operating hours, namely that the cathode heater power set point is > 0.50 kW. This third requirement is not used for the calculation shown in column 10 of Table 3.

The time that the cathode heater power is > 0.50 kW is shown in column 11 of Table 3.

The number of normal cathode thermal cycles for each week is shown in column 2 of Table 3. Taking the cathode from ~590 ^{o}C to ~1120 ^{o}C is counted as ½ normal thermal cycle: from ~1120 ^{o}C to ~590 ^{o}C also is counted as ½ cycle. Taking the cathode from ~590 ^{o}C to ~1120 ^{o}C and returning it from ~1120 ^{o}C to ~590 ^{o}C is counted as 1.0 cycle.

In addition, the number of abnormal cathode thermal cycles is recorded in column 3 of Table 3. Taking the cathode from room temperature to ~1120 ^{o}C without stopping at ~590 ^{o}C is counted as ½ cycle; from ~1120 ^{o}C to room temperature without stopping at ~590 ^{o}C is ½ cycle; from ~590 ^{o}C to anything measurably lower than ~590 ^{o}C (including ambient temperature) is ½ cycle: and from anything measurably lower than ~590 ^{o}C (including ambient temperature) to ~590 ^{o}C is also ½ cycle.

Finally, the number of vacuum excursions > 100 nTorr and < 1000 nTorr, provided the cathode temperature is ~590 ^{o}C, is recorded in column 12 of Table 3. Also, the number of vacuum excursions > 1000 nTorr (1 μTorr), provided the cathode temperature in ~590 ^{o}C, is recorded in column 13 of Table 3..

Discussion and Conclusions

A discussion of the results, and conclusions that are reached, will be presented in DARHT Tech Note No. 506.

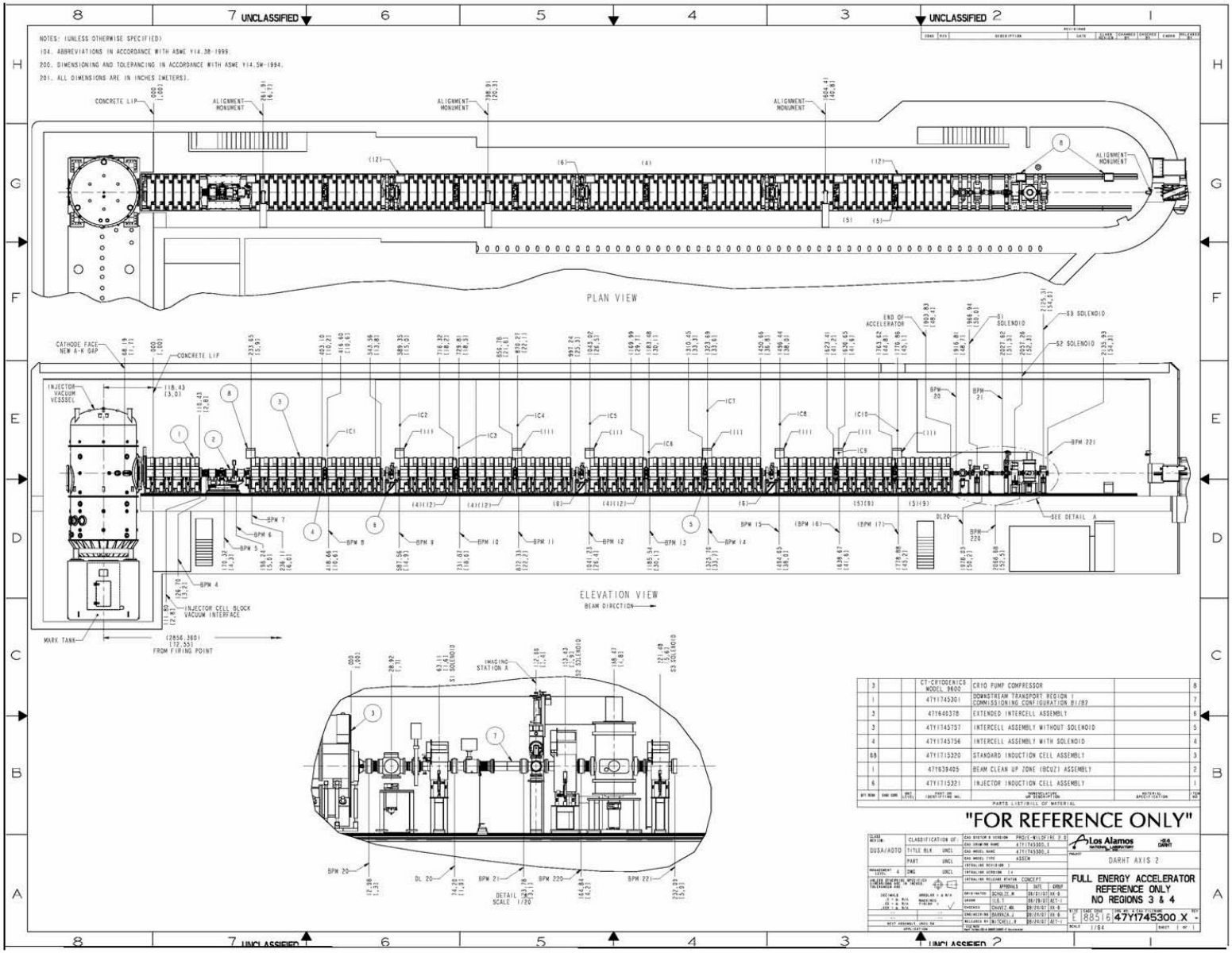


Figure 1. DARHT Axis II full energy accelerator.

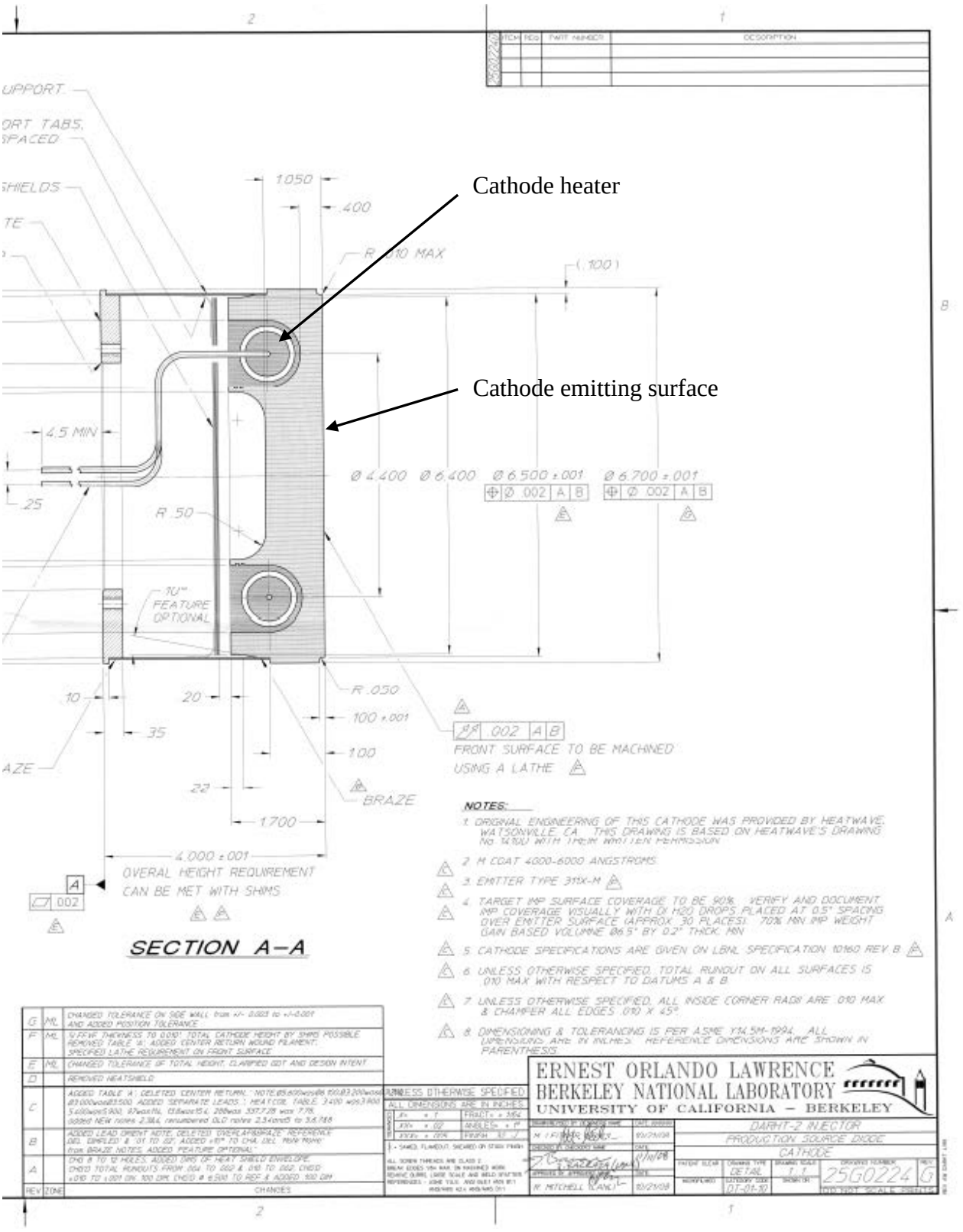


Figure 2. Cathode drawing showing the location of the cathode heater. The cathode power readback is determined from the cathode heater power supply voltage and current readbacks.

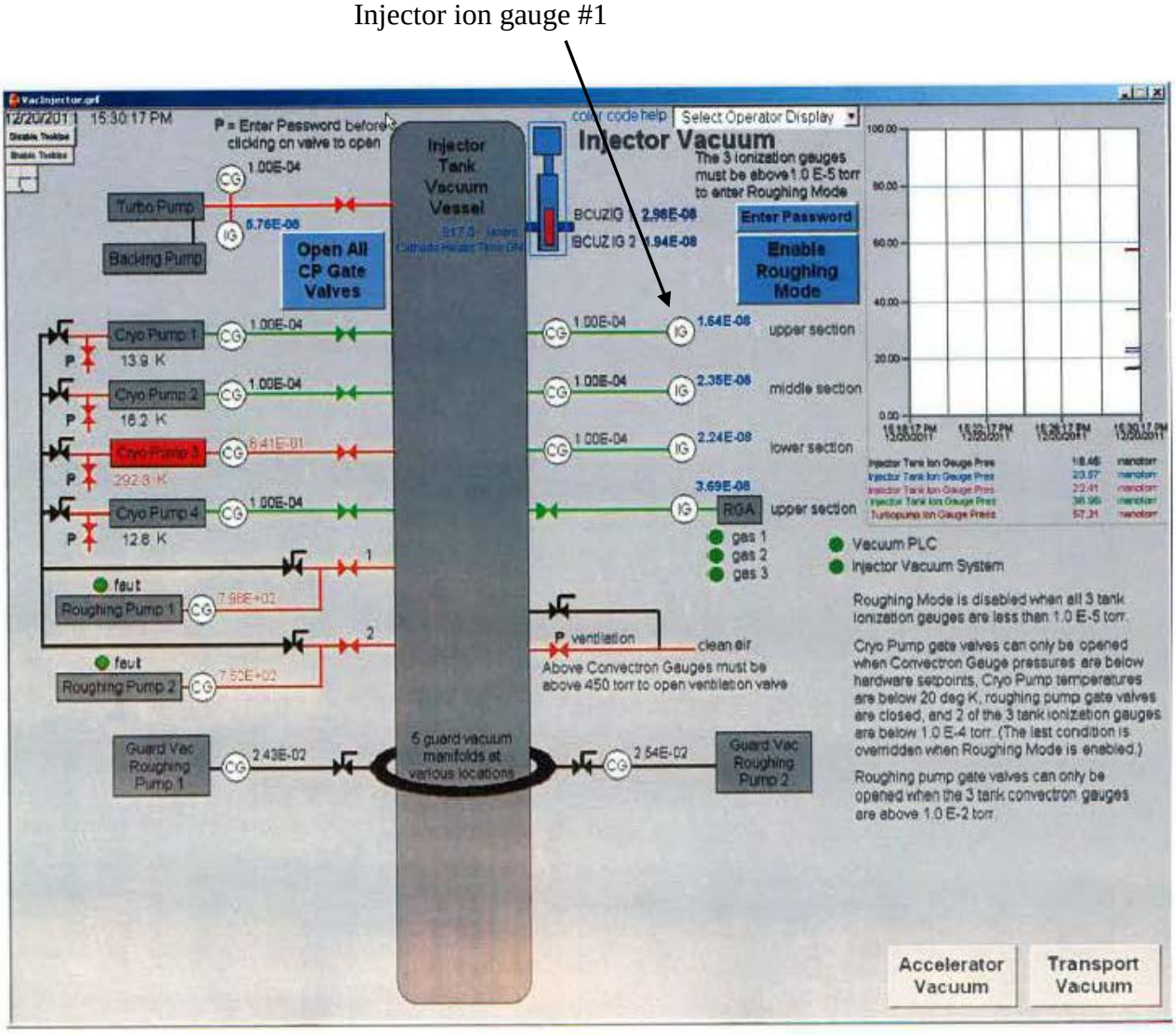


Figure 3. Injector vacuum screen showing schematically the location of injector ion gauge #1.

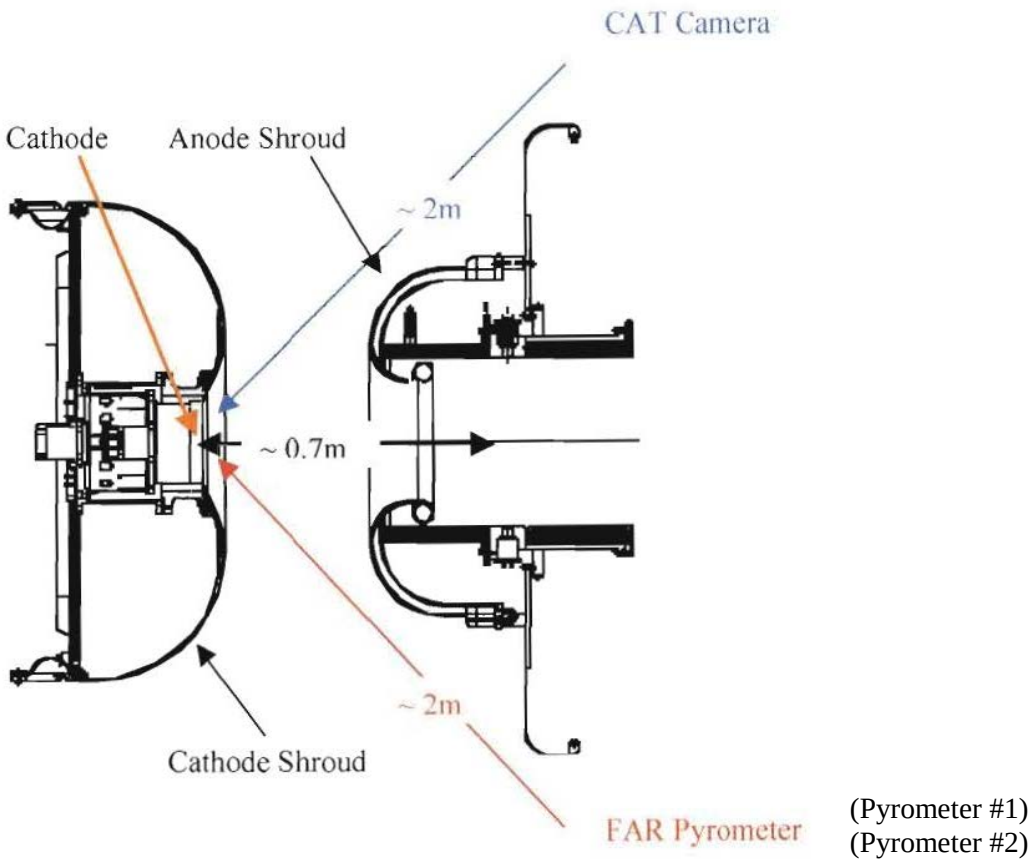


Figure 4. Location of pyrometer #1 and pyrometer #2 that are used to measure the cathode temperature. Both FAR pyrometers view the cathode surface at an angle of about 51^{o} with respect to the normal at a distance of nearly 2 meters due to mechanical restraints.

Table 1. The historian database and shot data database "tags" for the cathode parameters examined in this study.

Parameter	Database	Tag
Cathode Temperature (Pyrometer #1)	Historian	D2SCADA.IKPYRO201TAI.F_CV
Cathode Temperature (Pyrometer #2)	Historian	D2SCADA.IKPYRO202TAI.F_CV
Injector Ion Gauge #1 vacuum pressure	Historian	D2SCADA.VITKIG201PCA.F_CV
Cathode Heater Power	Historian	D2SCADA.IKHPS200PWRAI.F_CV
Shot Number	Shot Data	IMSHOT200CNTRAI
Beam Counter	Shot Data	IMBEAM200CNTRAI
Cathode Heater Timer	Shot Data	IKTIMR200ONAI

Table 2. The installation, activation, beam shot, and removal history of cathode 16.

Date cathode 16 installed	October 3, 2012
Date cathode 16 activation began	October 9, 2012
Date cathode 16 activation ended	October 11, 2012
Date and Beam Shot number of first beam shot	October 16, 2012 Beam shot number 19481
Date and Beam Shot number of last beam shot	March 5, 2013 Beam shot number 21175
Date cathode 16 removed	April 24, 2013

Table 3. A summary of the historian and shot data database cathode 16 stored data for the time period October 8, 2012 through April 7, 2013. See the text for a discussion of the Table entries.

Cathode #16 (S/N 22) Summary

Time Period	Known normal cathode thermal cycles	Known abnormal cathode thermal cycles	Hours at ~1120 °C[1]	Hours at ~590 °C[2]	Hours at low temperature[3]	Shot Number	Beam Counter	Cathode Operating Hours (from Shot Data Database)	Cathode Operating Hours, shot data database calculation	Cathode Operating Hours, pwr >0.50 kW	Number of Known Vacuum Excursions > 100 nTorr	Number of Known Vacuum Excursions > 1000 nTorr
10/08/12 - 10/14/12												
10/15/12 - 10/21/12	2.5	0.5	20.75	54.00	57.25				20.00	20.75	0	1
10/22/12 - 10/28/12	2.5	0.5	21.75	113.25	33.00				17.75	21.50	0	0
10/29/12 - 11/4/12	3.0	0.0	27.00	142.00	0.00				26.00	27.00	0	0
11/5/12 - 11/11/12	3.0	0.0	31.00	137.00	0.00				29.50	30.75	0	0
11/12/12 - 11/18/12	3.0	1.0	19.25	148.50	0.25				17.75	19.00	0	0
11/19/12 - 11/25/12	0.0	0.0	0.00	168.00	0.00				0.00	0.00	0	0
11/26/12 - 12/2/12	4.0	0.0	27.75	140.25	0.00				24.75	27.75	0	0
12/3/12 - 12/9/12	4.0	0.0	35.50	132.50	0.00				31.25	35.25	0	0
12/10/12 - 12/16/12	4.0	0.0	24.50	143.50	0.00				23.00	24.50	0	0
12/17/2012 - 12/23/12	3.0	0.5	24.00	94.00	50.00				23.00	24.00	0	0
12/24/12 - 12/30/12	0.0	0.0	0.00	0.00	168.00				0.00	0.00	0	0
12/31/12 - 1/6/13	1.5	0.5	8.25	101.00	58.75				5.50	8.00	0	0
1/7/13 - 1/13/13	1.0	0.0	8.50	159.50	0.00				8.00	8.50	0	0
1/14/13 - 1/20/13	0.0	1.0	0.00	167.50	0.50				0.00	0.00	0	0
1/21/13 - 1/27/13	3.0	0.0	16.50	151.50	0.00				13.50	16.00	0	0
1/28/13 - 2/3/13	2.0	0.0	10.50	157.50	0.00				9.25	9.75	0	0
2/4/13 - 2/10/13	3.0	0.0	17.75	150.25	0.00				17.25	17.75	0	0
2/11/13 - 2/17/13	3.0	0.0	24.75	143.25	0.00				23.50	24.50	0	0
2/18/13 - 2/24/13	3.0	0.0	20.00	148.00	0.00				18.75	19.50	0	0
2/25/13 - 3/3/13	5.0	0.0	27.75	140.25	0.00				25.00	27.00	0	0
3/4/13 - 3/10/13	1.5	0.0	13.00	23.25	0.00				12.00	13.00	0	0
3/11/13 - 3/17/13												
3/18/13 - 3/24/13												
3/25/13 - 3/31/13												
4/1/13 - 4/7/13												
Total	**52.0**	**4.0**	**378.50**	**2615.00**	**367.75**	**1694**	**602**	**356**	**345.75**	**374.50**	**0**	**1**

Calculated from Excel spreadsheets (data from historian database)

Actual (From shot no. 19481 on 10/16/12 thru shot no. 21175 on 3/5/13) (data from shot data database)

[1] Cathode heater power readback> 0.36 kW

[2] Cathode heater power readback >0.30 kW and <0.36 kW

[3] Cathode heater power readback<0.30 kW

Calculated by requiring that 1) Cath htr pwr readback>500 W and 2) Pyrometer #1 temp >950oC or 3) Pyrometer #2 temp >950oC

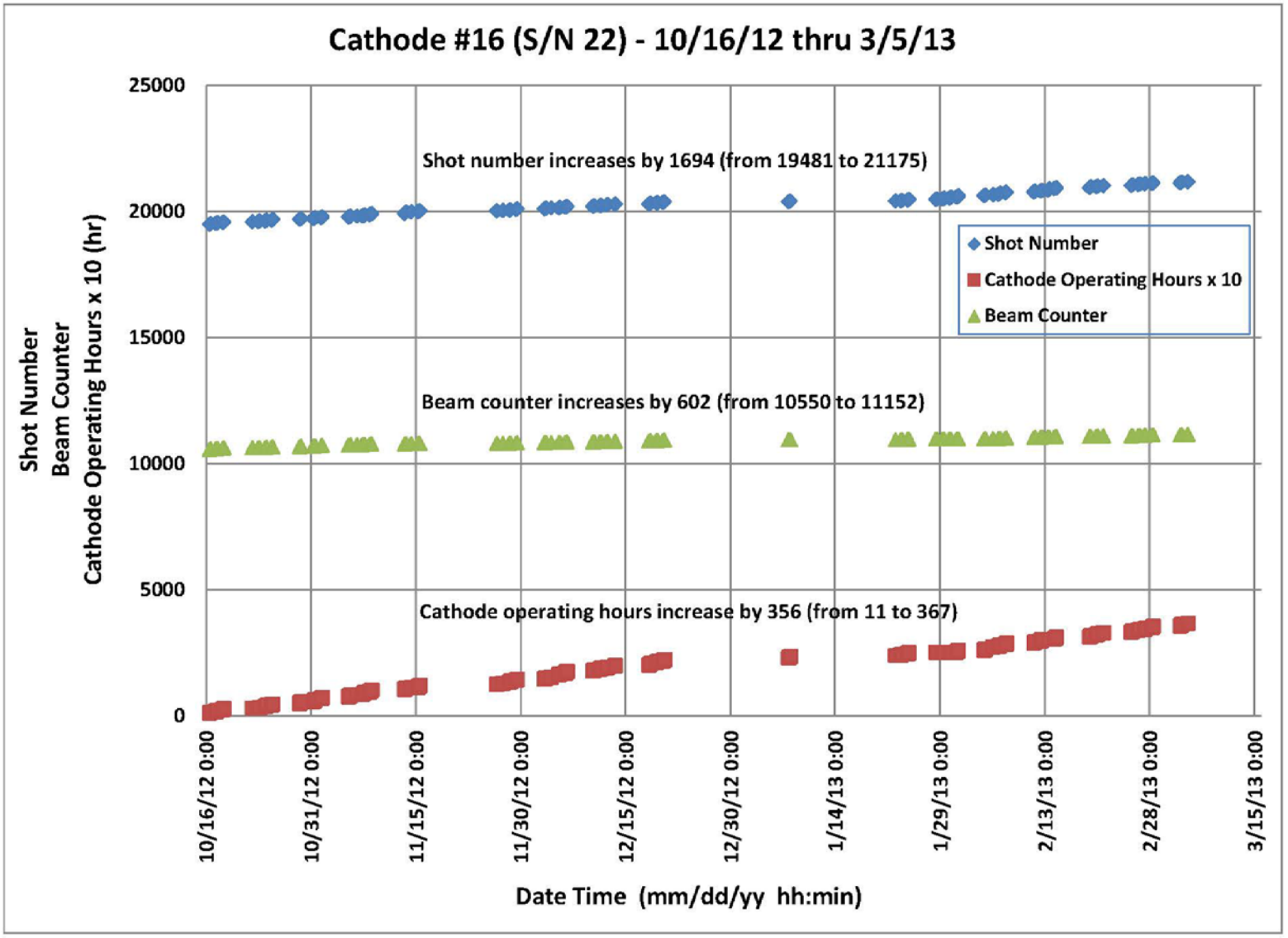
Calculated by requiring 1) Cath htr pwr readback >500 W

Needs to be checked

Pyrometer #1 (or Pyrometer #1 & #2) malfunctioning?

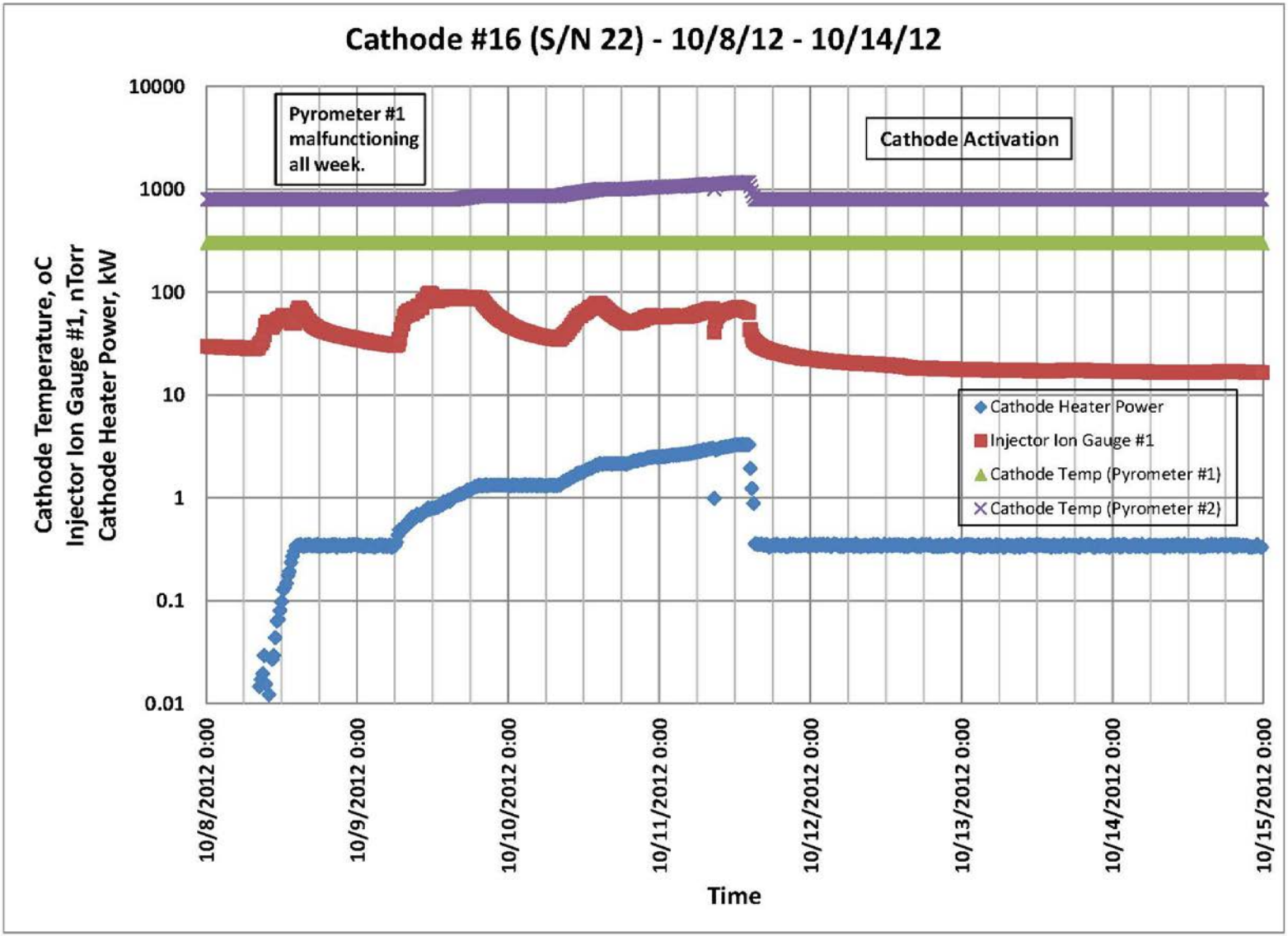
Appendix A

DARHT Axis II Cathode 16 shot number and beam counter as a function of time as recorded by the shot data database.

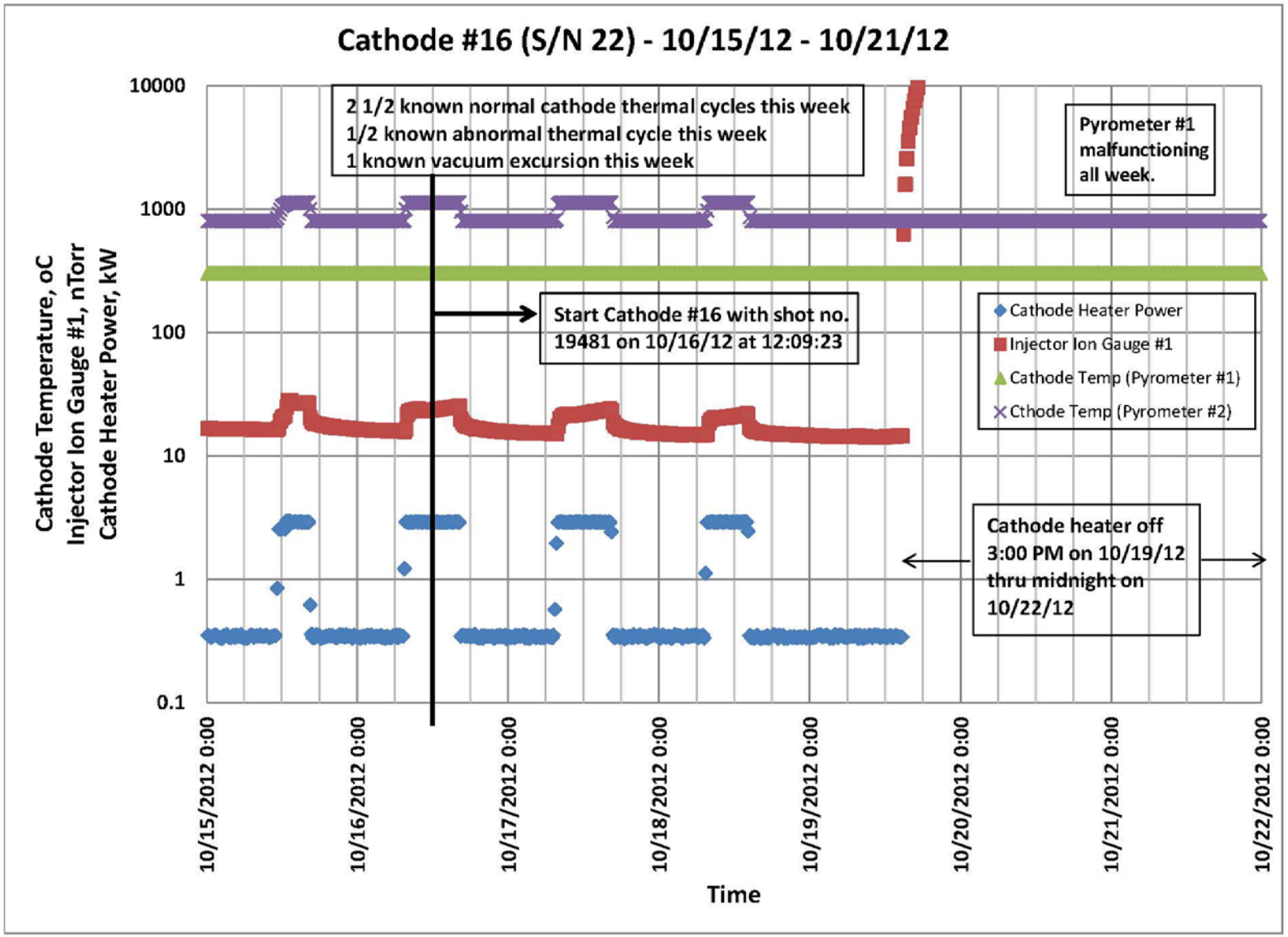


Appendix B

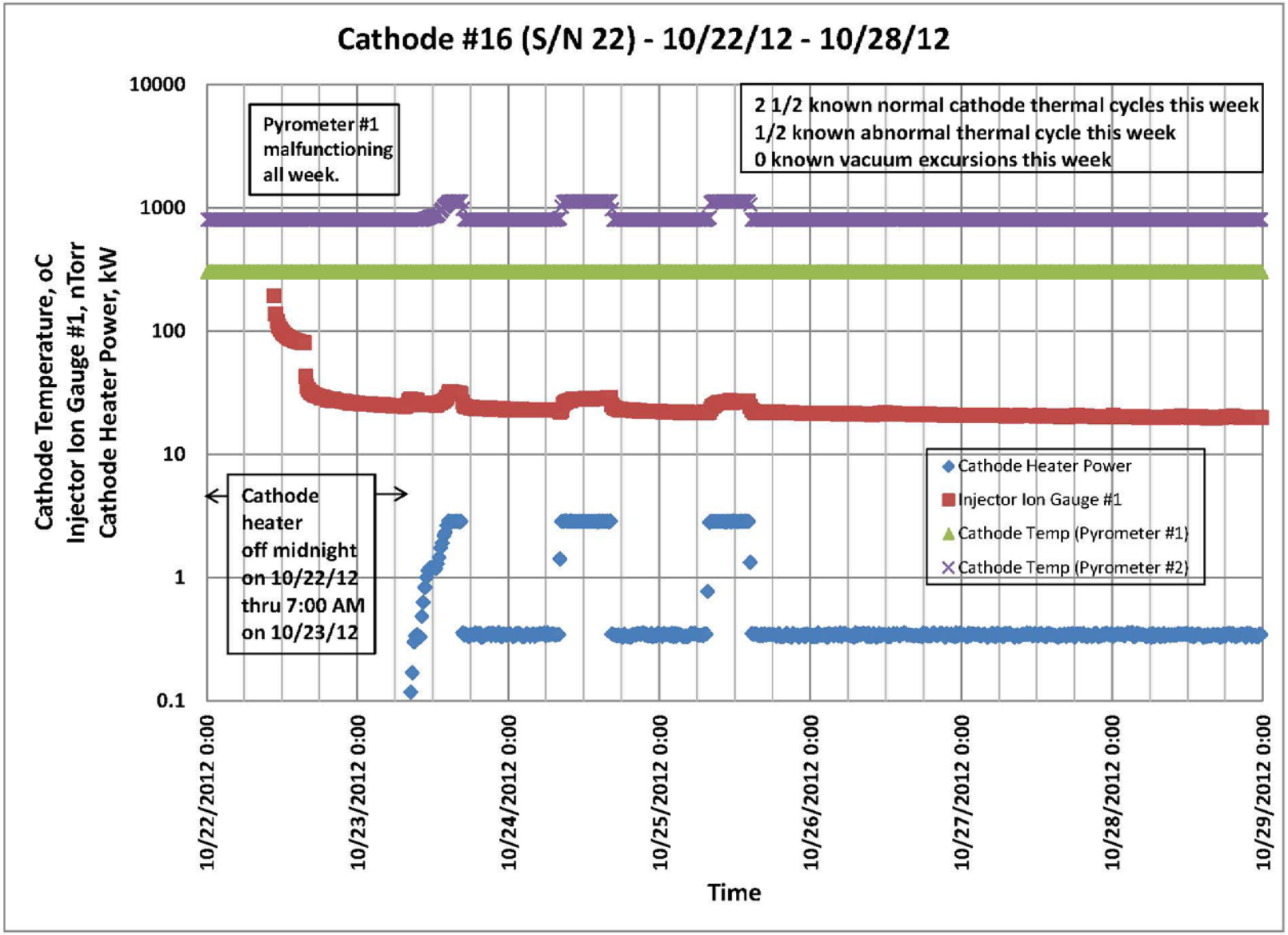
Cathode #16 recorded history for a full week. Cathode temperature readback, injector ion gauge #1 readback, and cathode heater power readback as a function of time in 15 minute intervals.



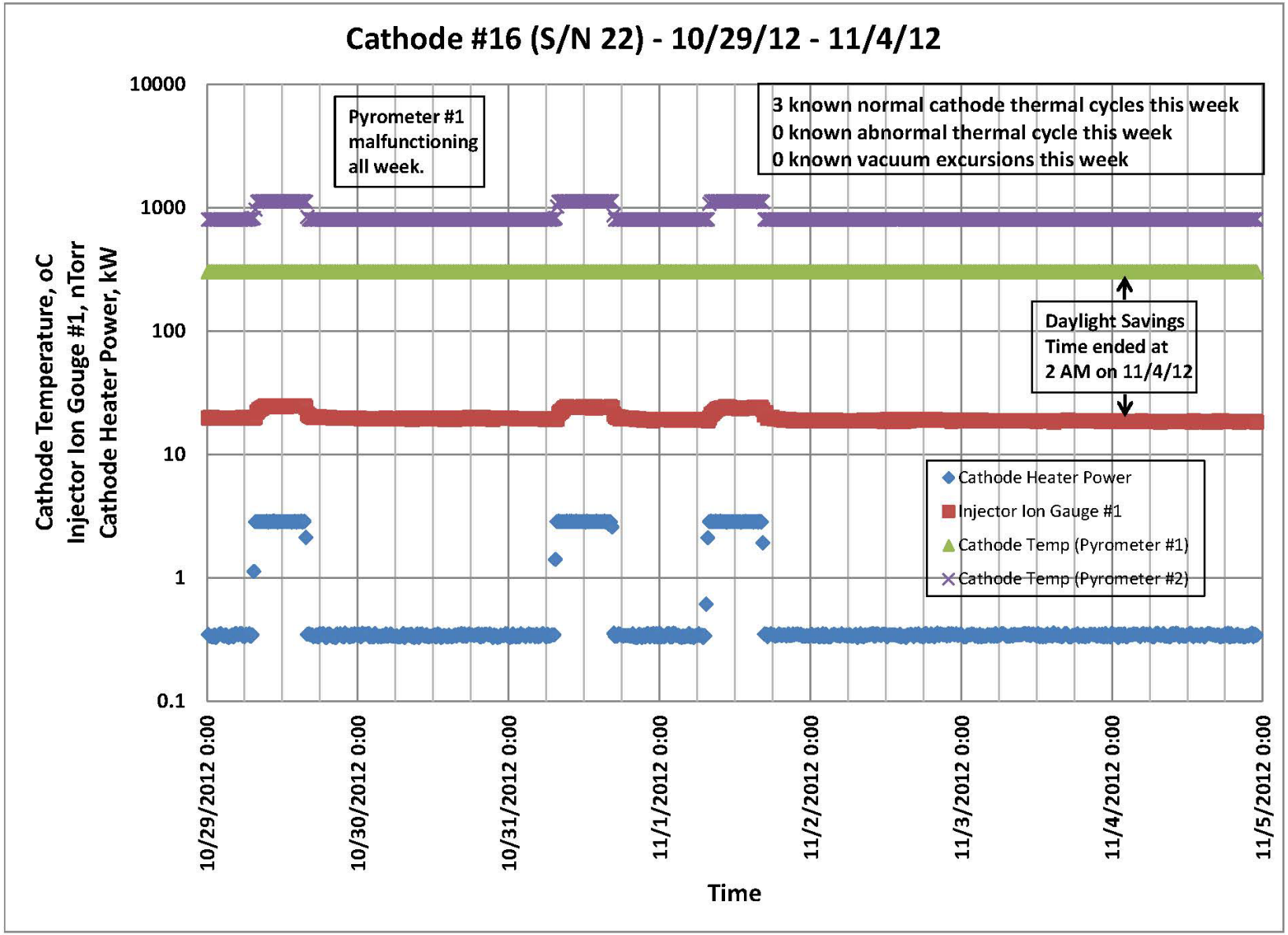
Appendix B. Cathode #16 recorded history for a full week . . . continued



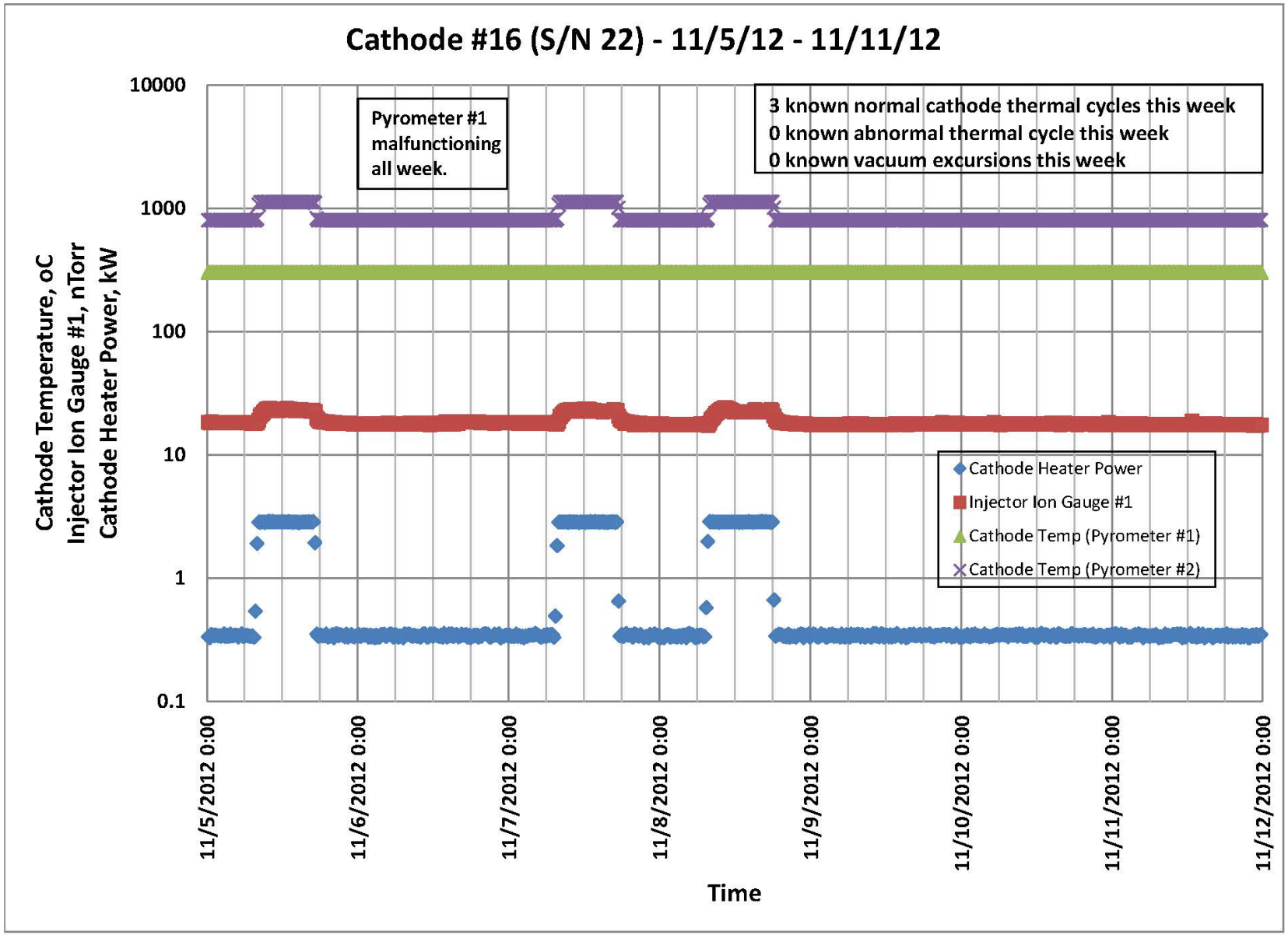
Appendix B. Cathode #16 recorded history for a full week . . . continued



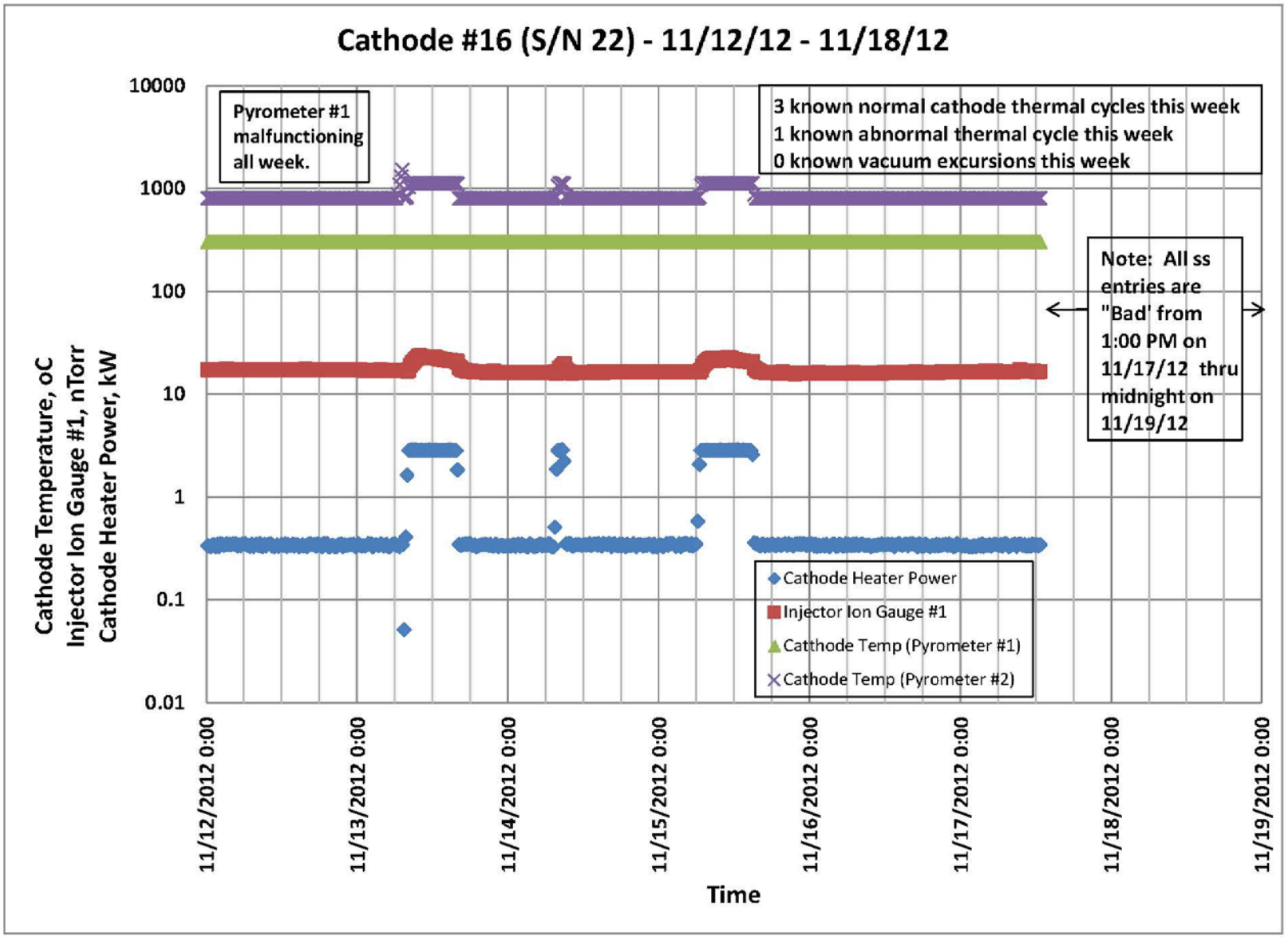
Appendix B. Cathode #16 recorded history for a full week . . . continued



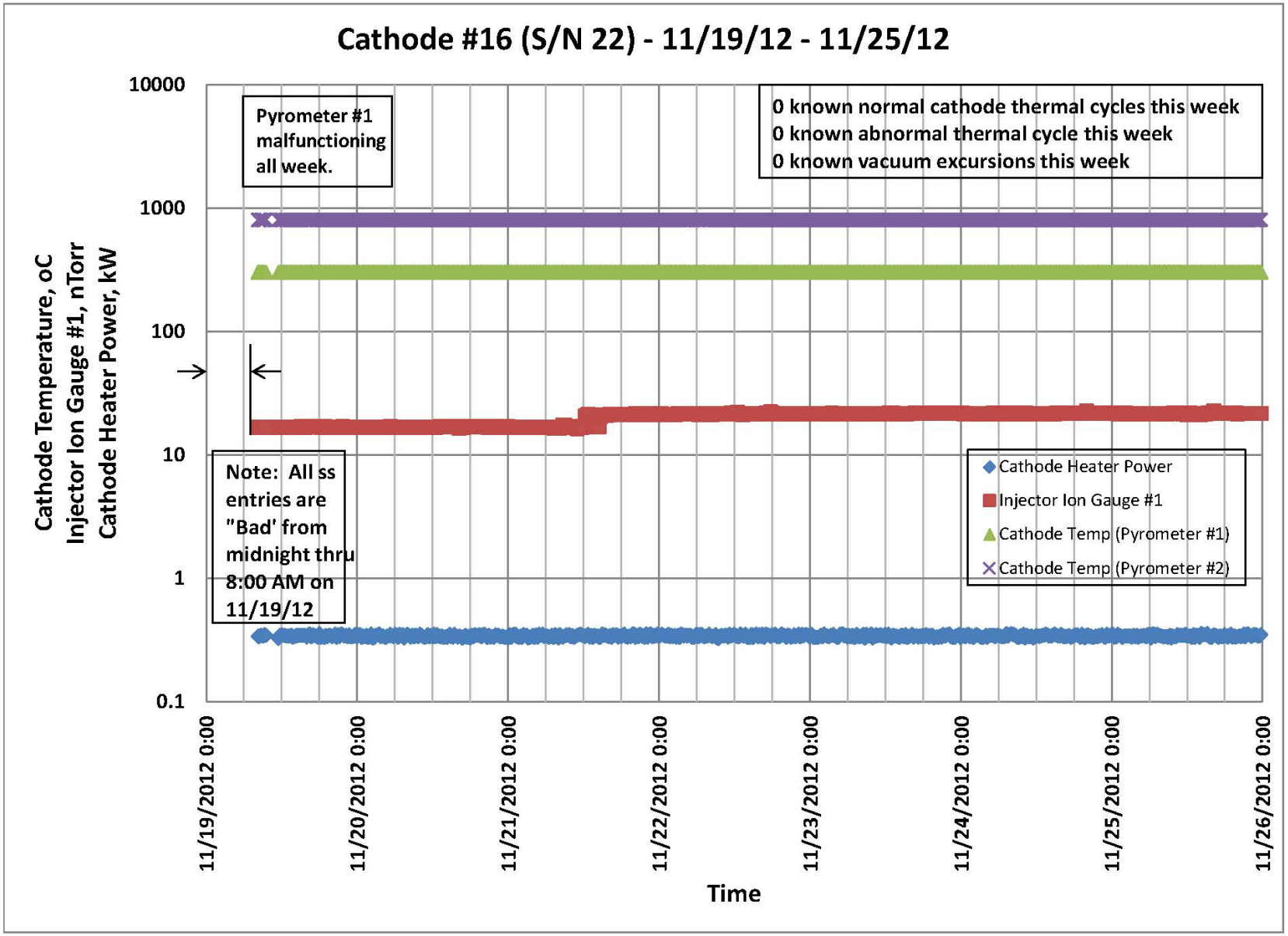
Appendix B. Cathode #16 recorded history for a full week . . . continued



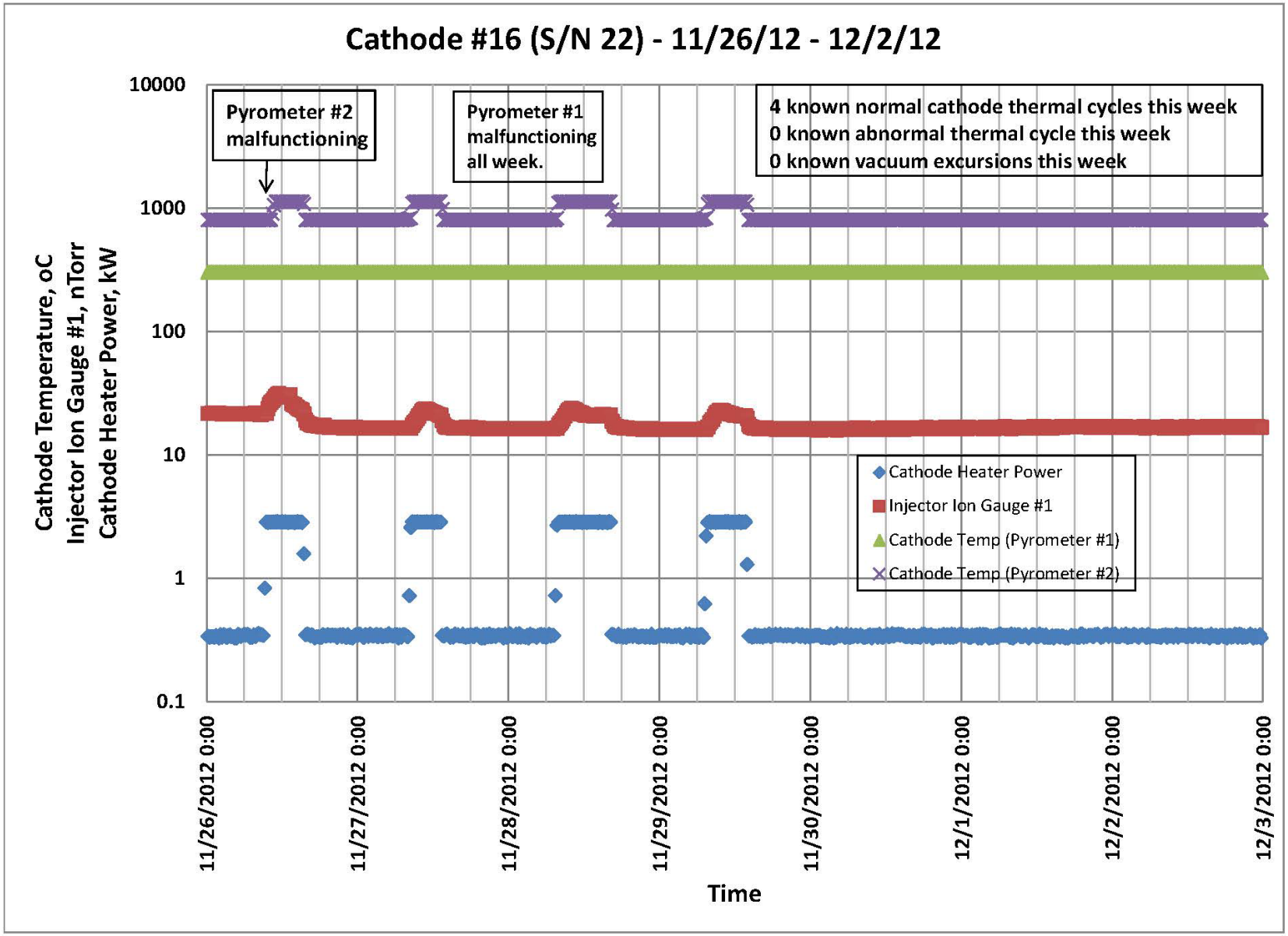
Appendix B. Cathode #16 recorded history for a full week . . . continued



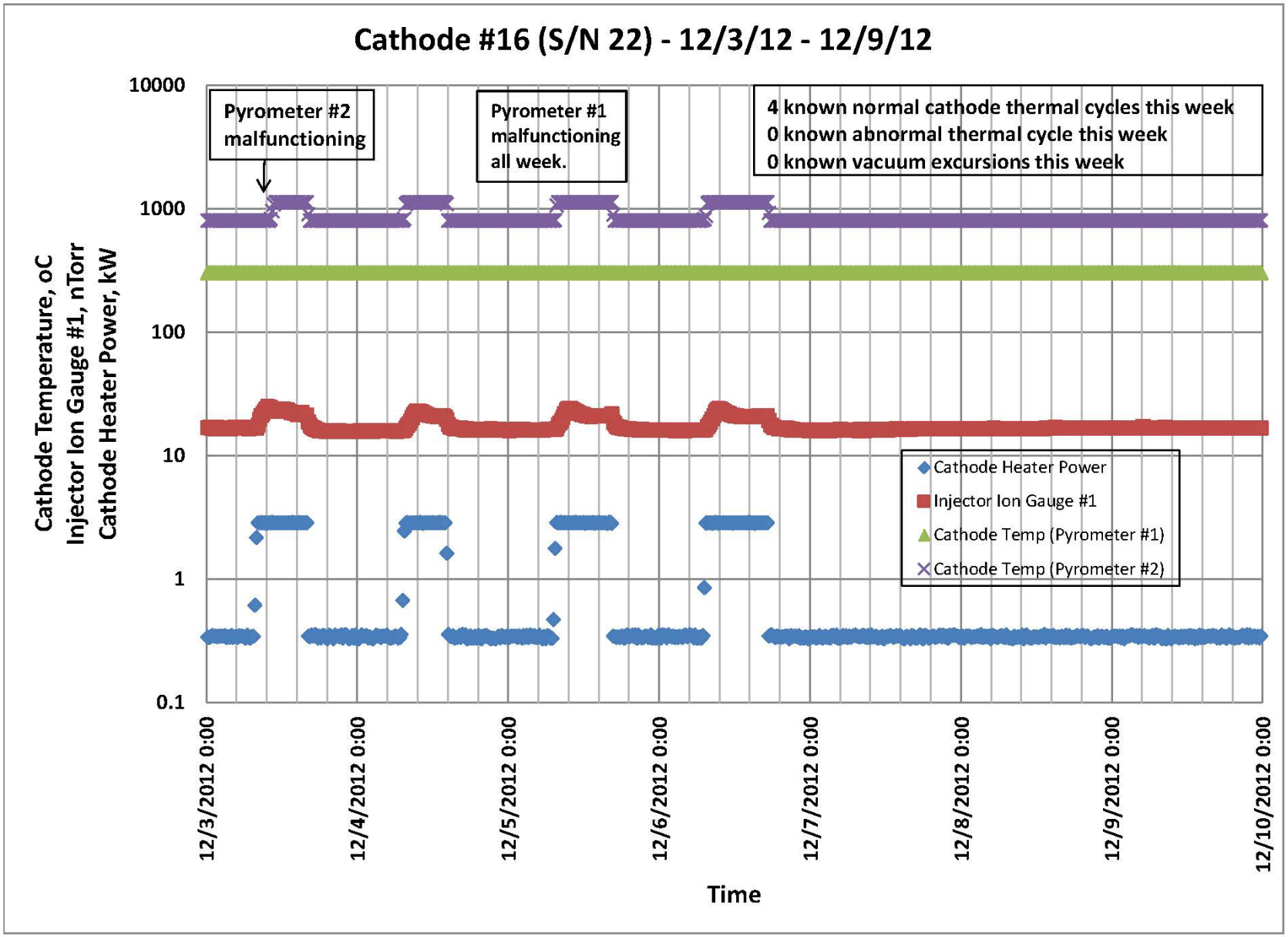
Appendix B. Cathode #16 recorded history for a full week . . . continued



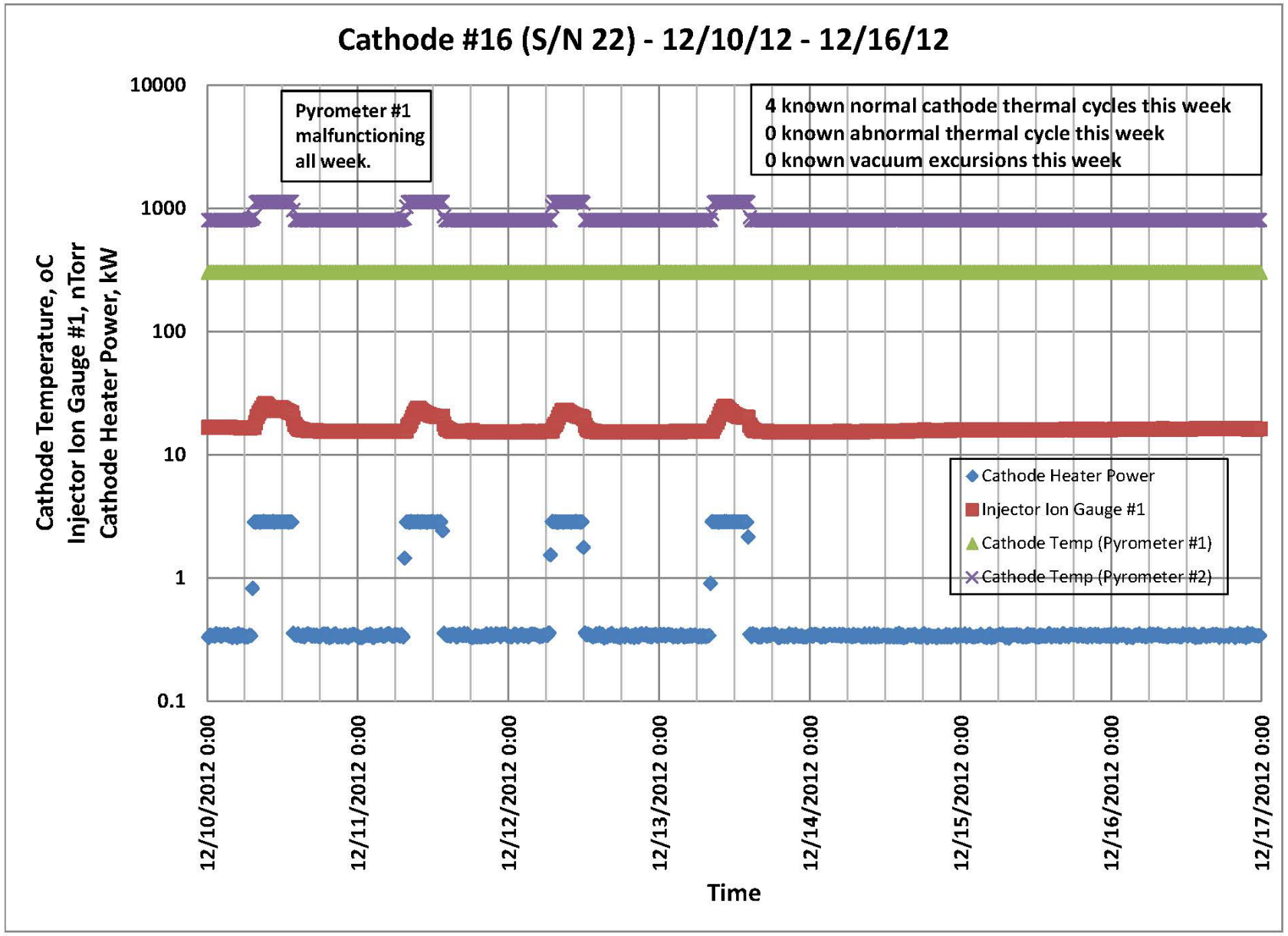
Appendix B. Cathode #16 recorded history for a full week . . . continued



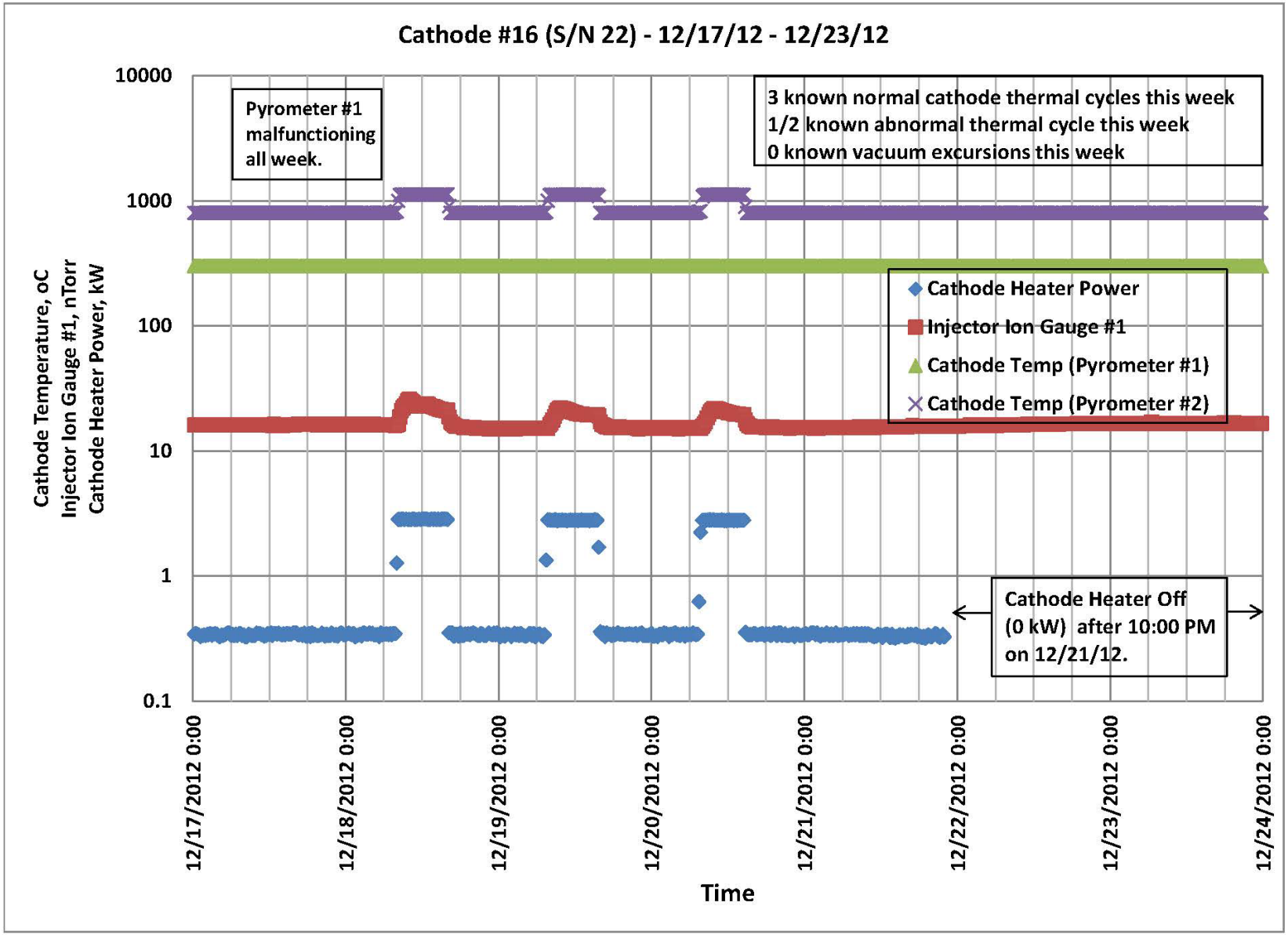
Appendix B. Cathode #16 recorded history for a full week . . . continued



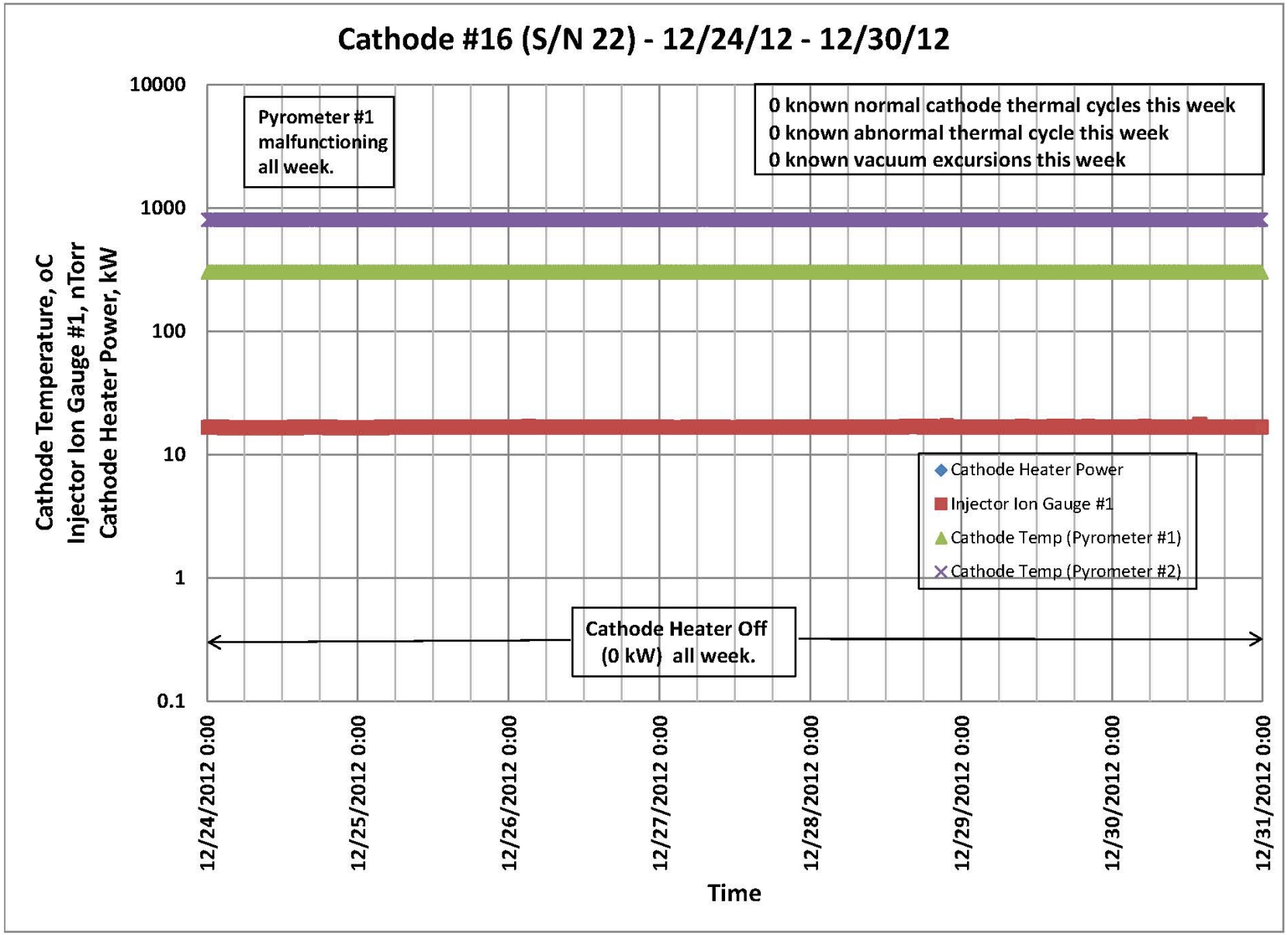
Appendix B. Cathode #16 recorded history for a full week . . . continued



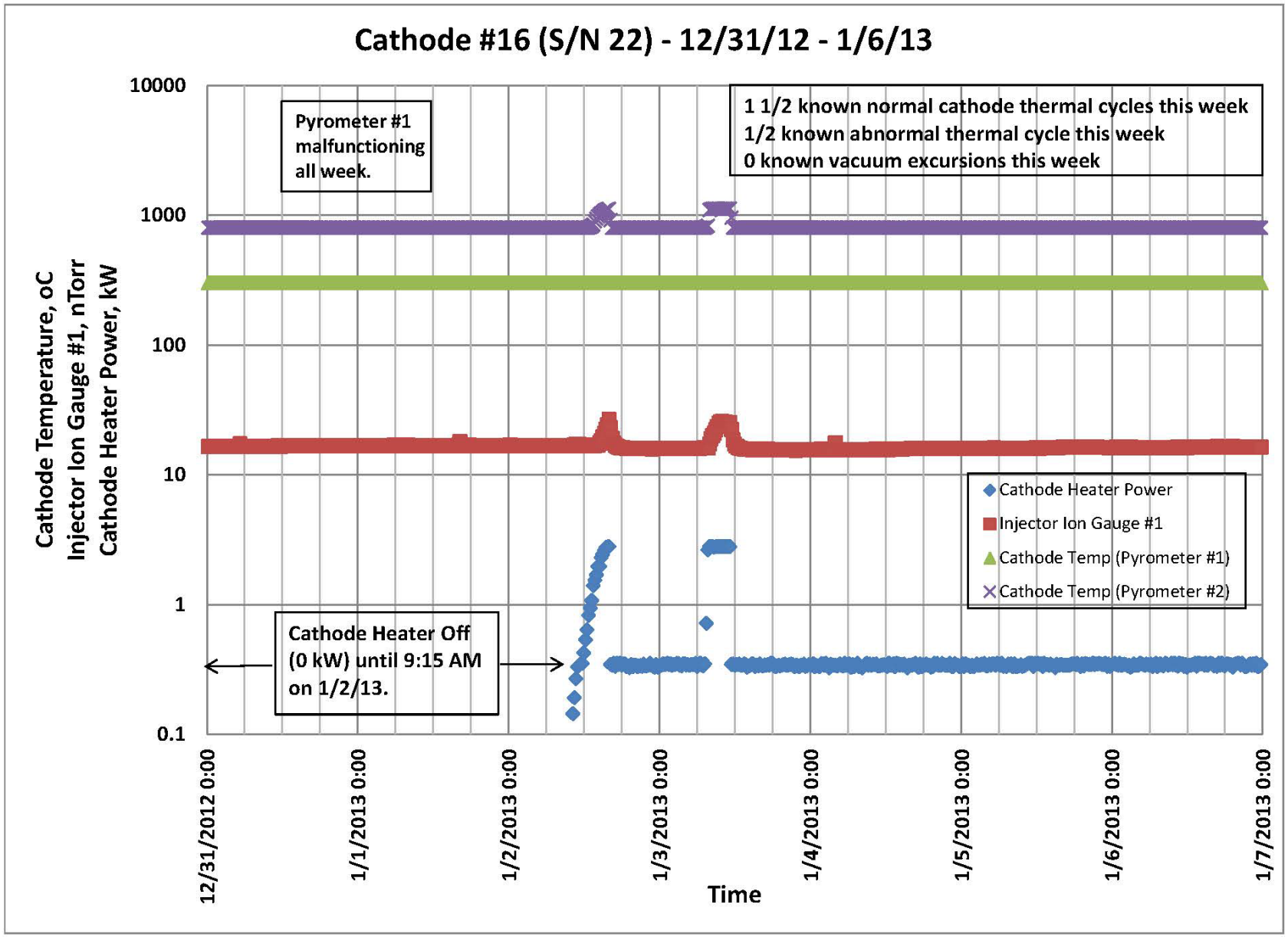
Appendix B. Cathode #16 recorded history for a full week . . . continued



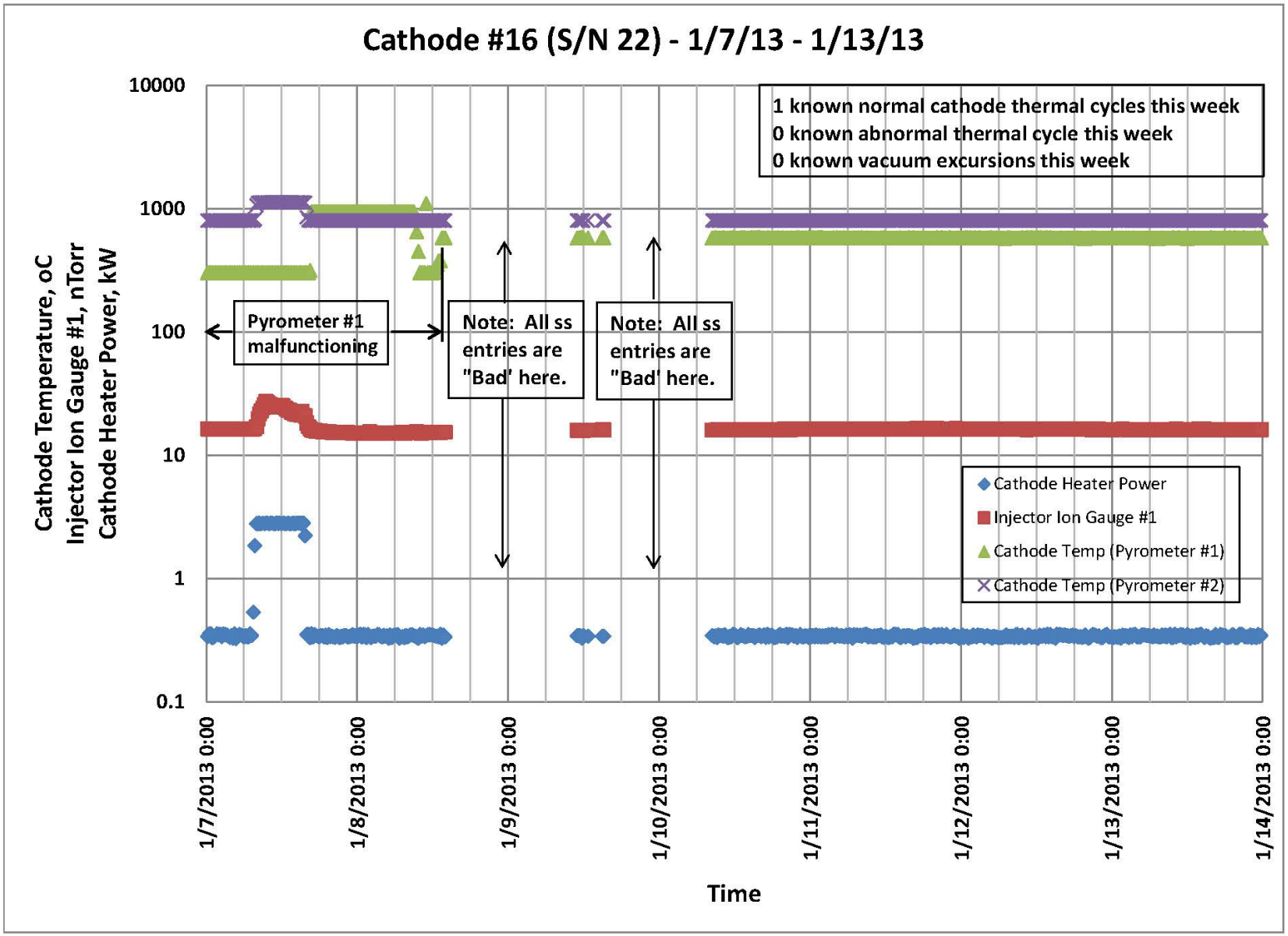
Appendix B. Cathode #16 recorded history for a full week . . . continued



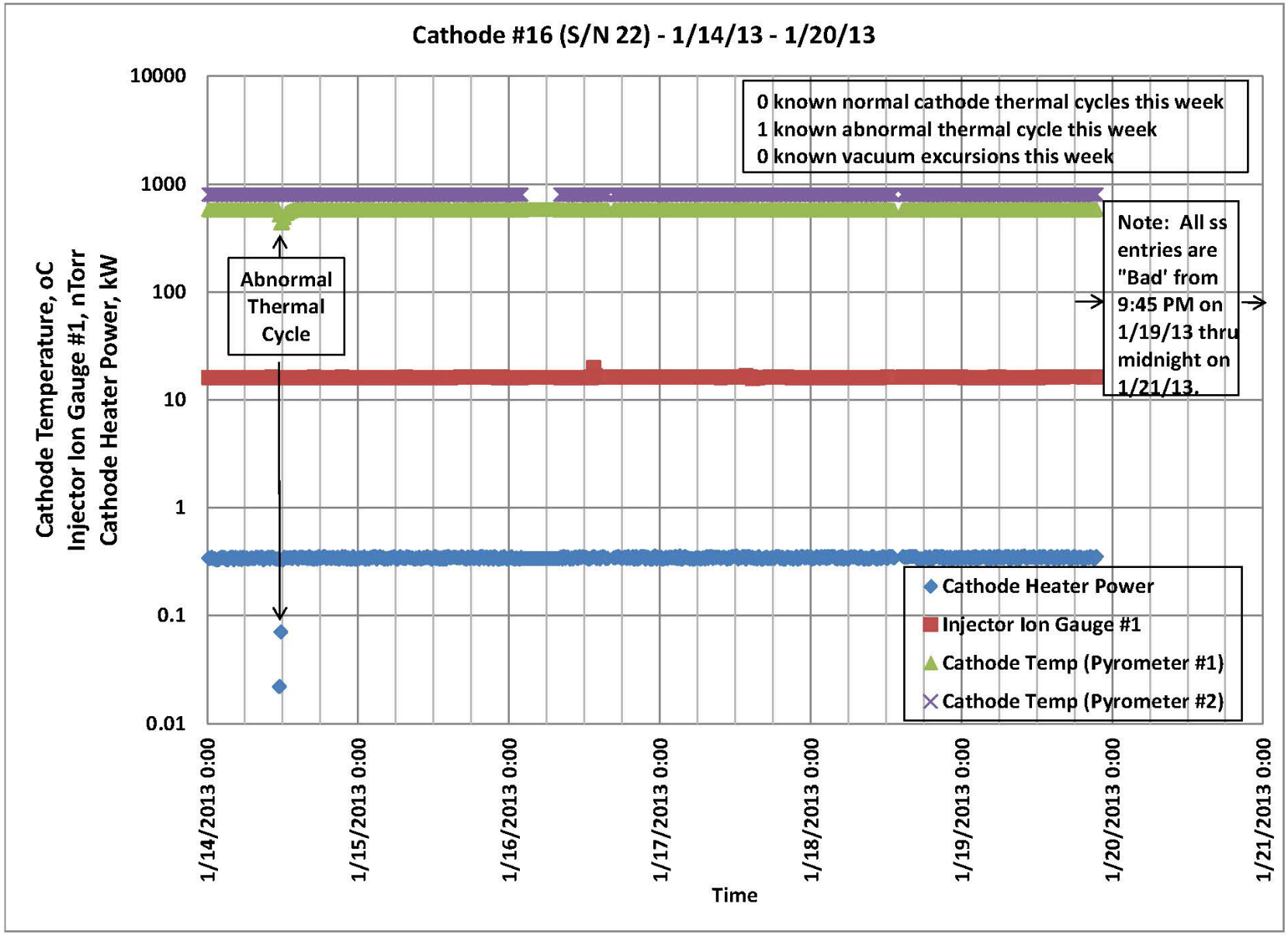
Appendix B. Cathode #16 recorded history for a full week . . . continued



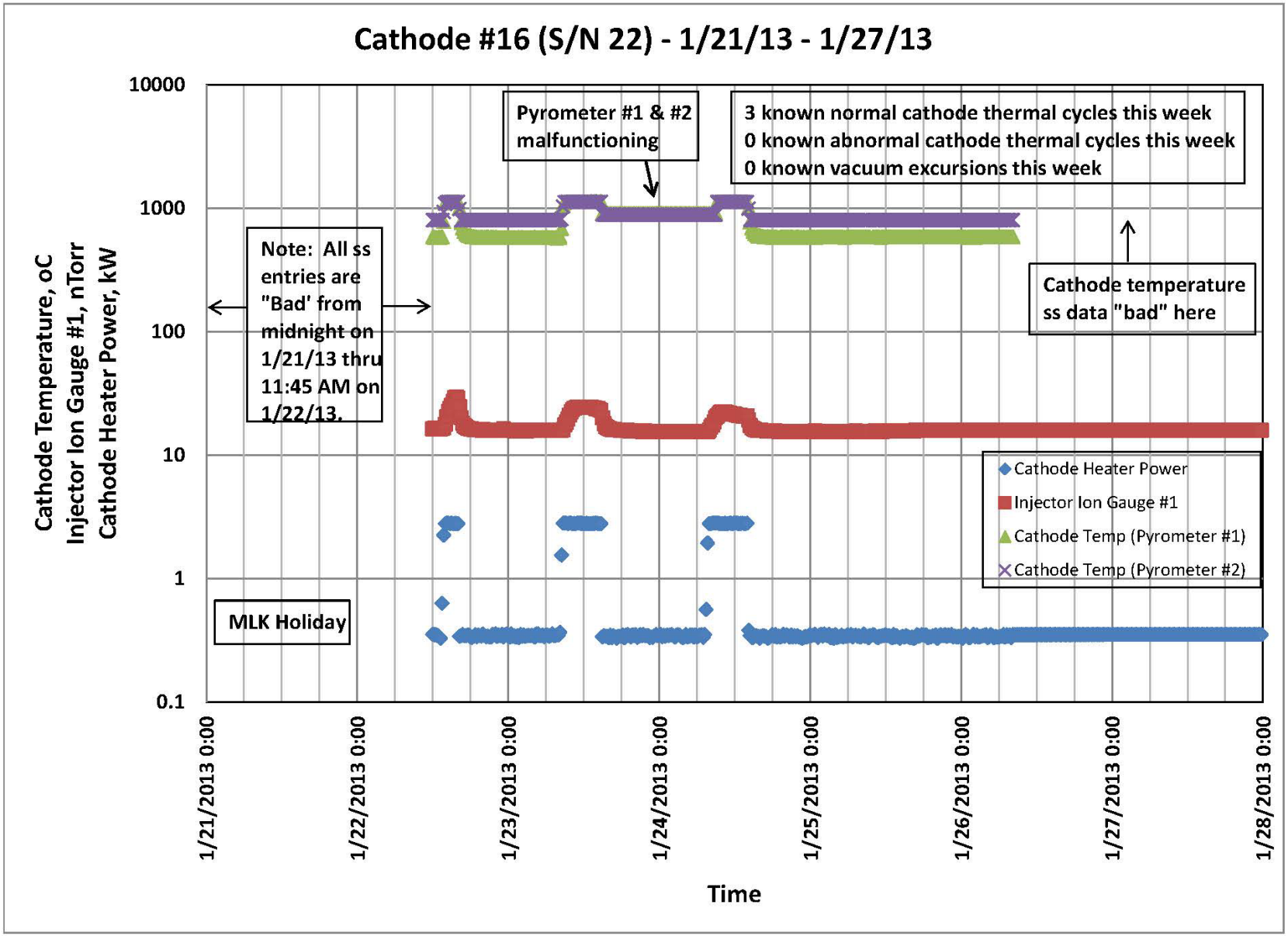
Appendix B. Cathode #16 recorded history for a full week . . . continued



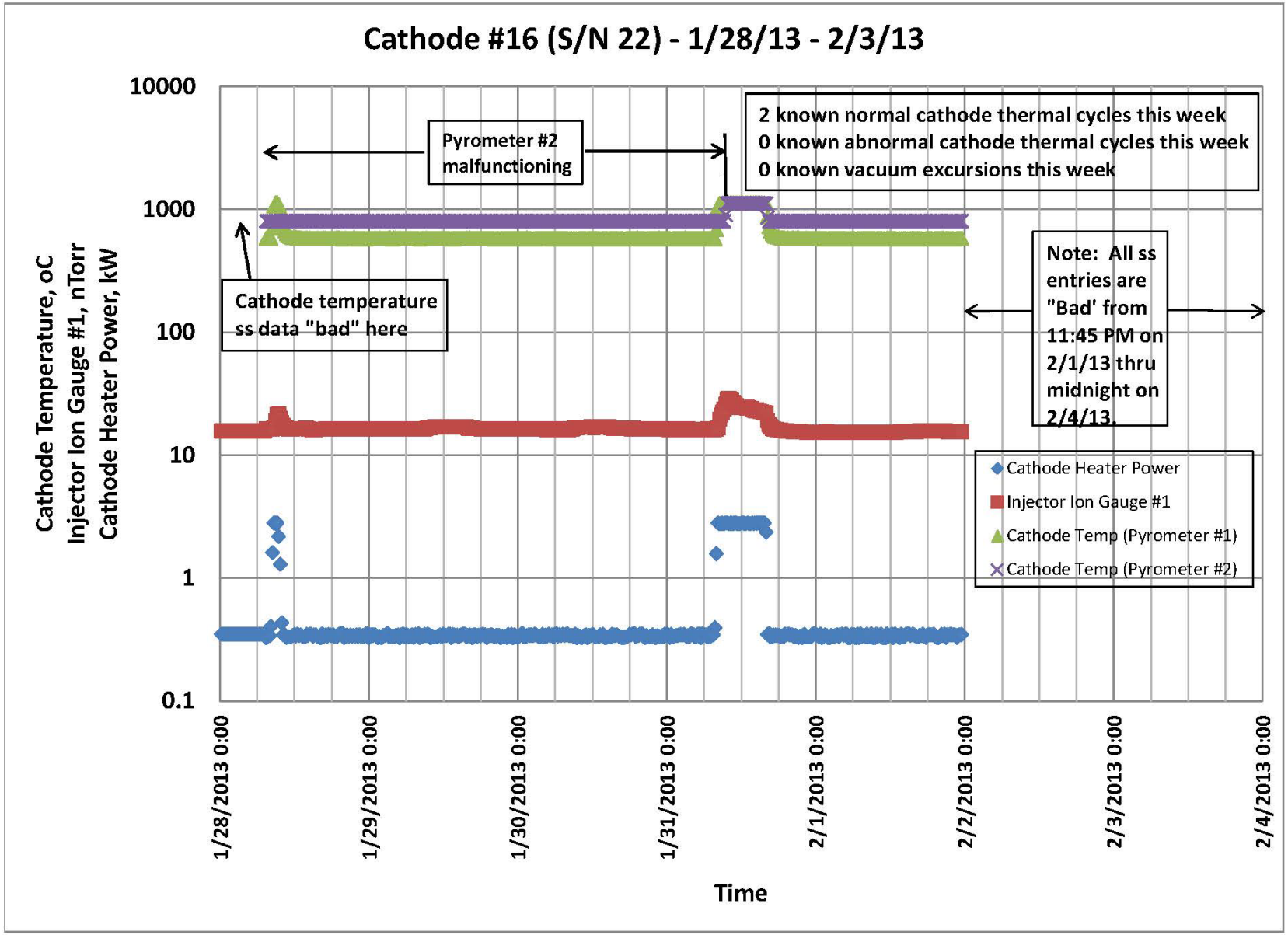
Appendix B. Cathode #16 recorded history for a full week . . . continued



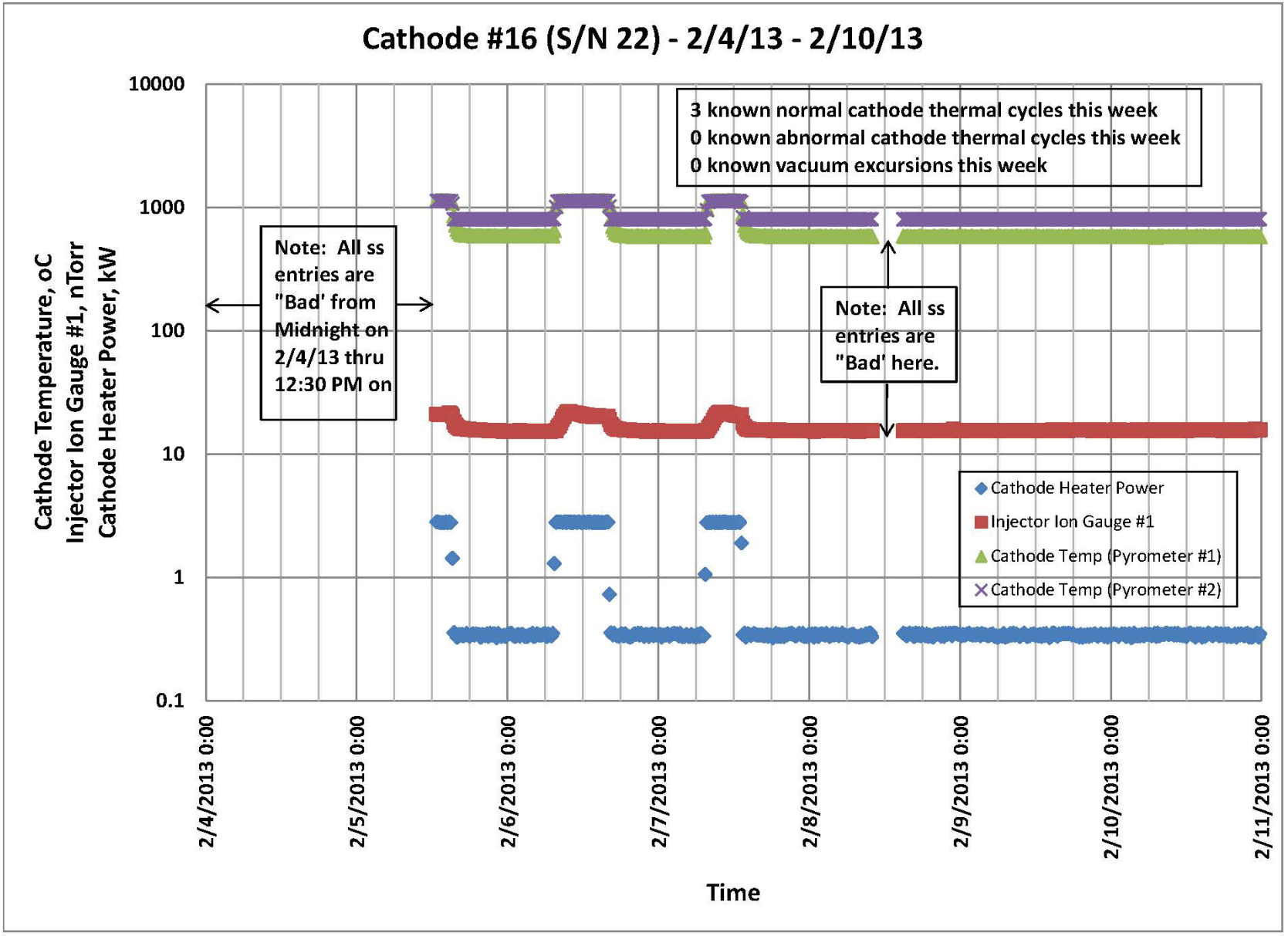
Appendix B. Cathode #16 recorded history for a full week . . . continued



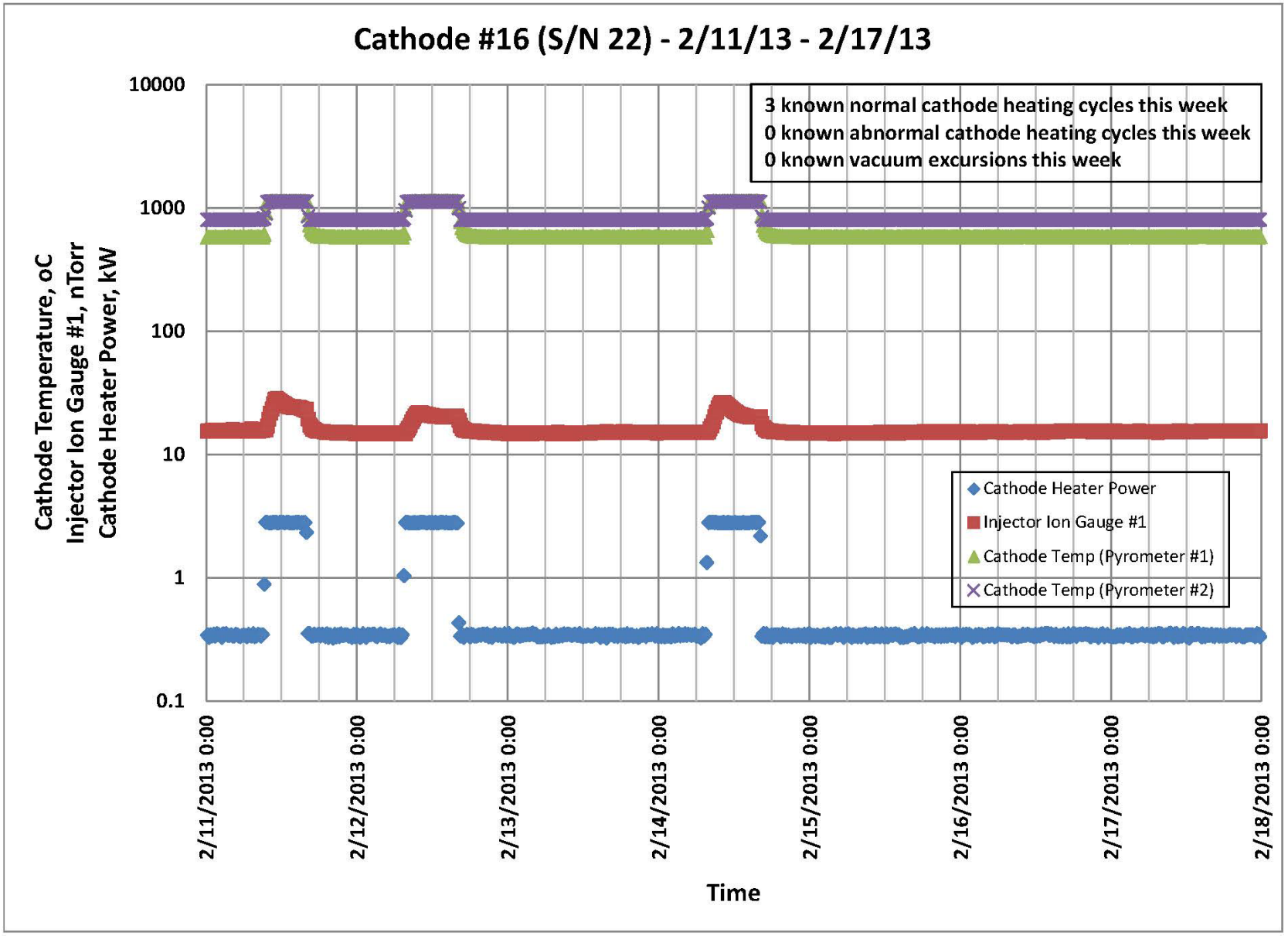
Appendix B. Cathode #16 recorded history for a full week . . . continued



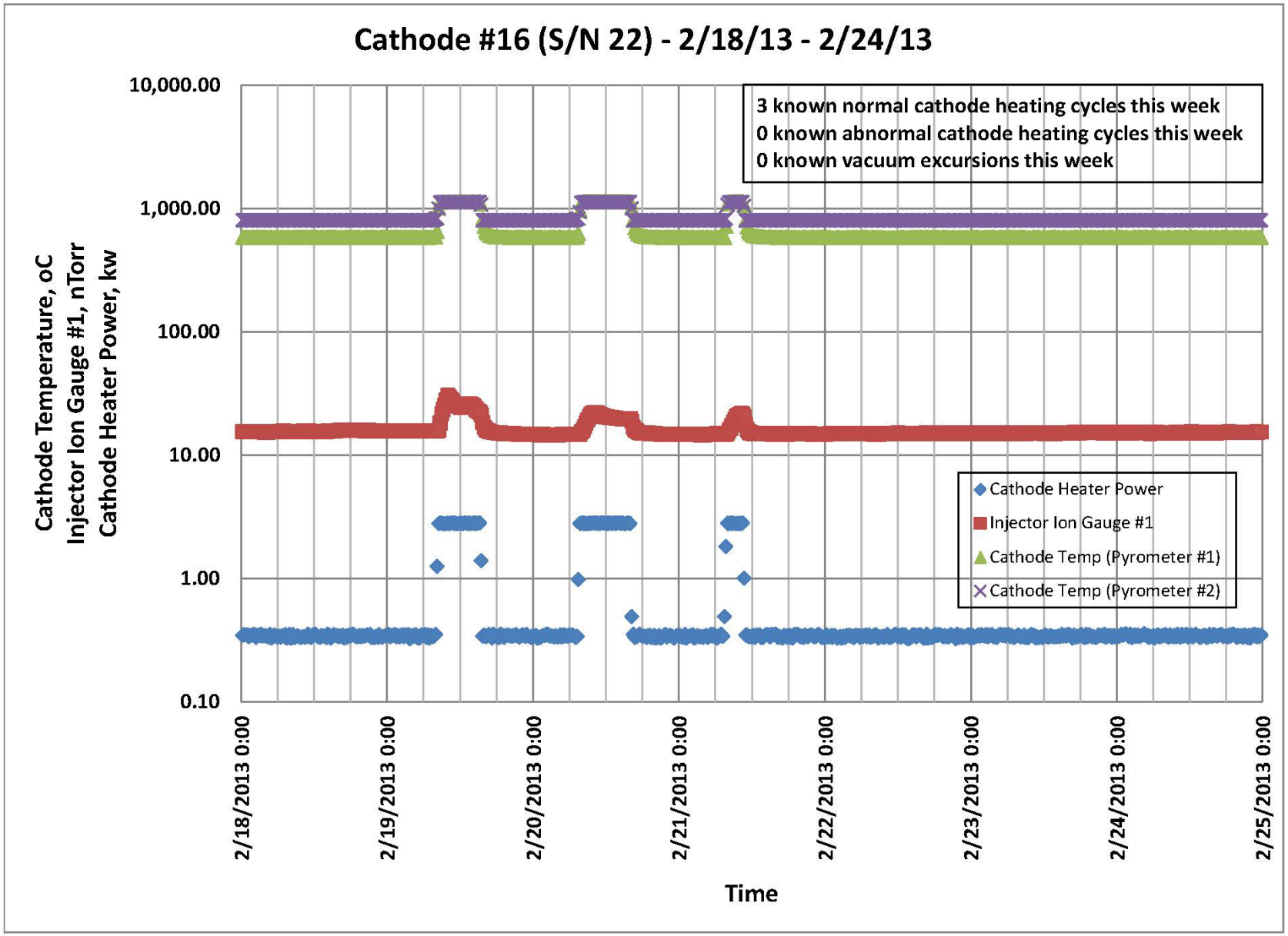
Appendix B. Cathode #16 recorded history for a full week . . . continued



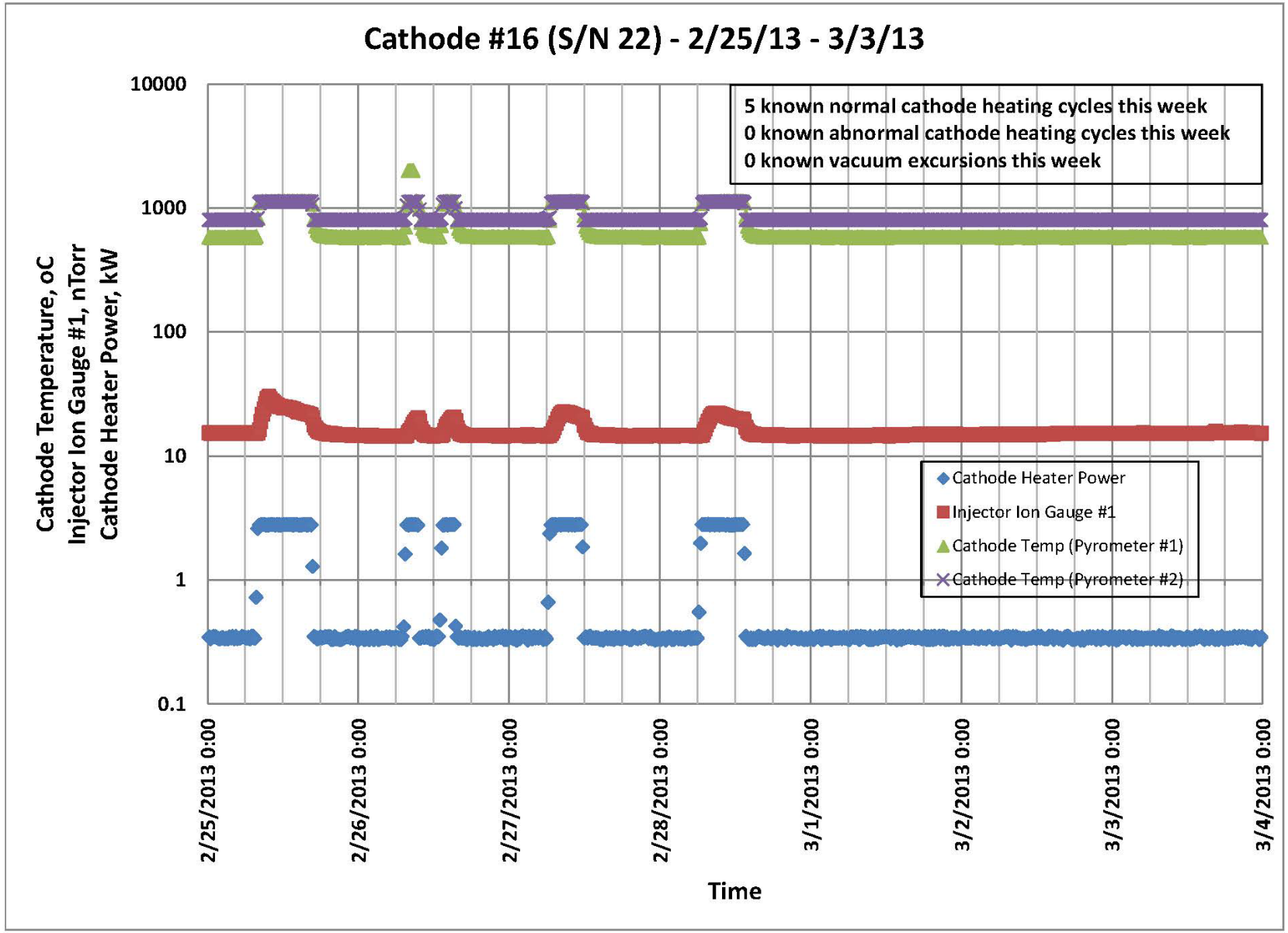
Appendix B. Cathode #16 recorded history for a full week . . . continued



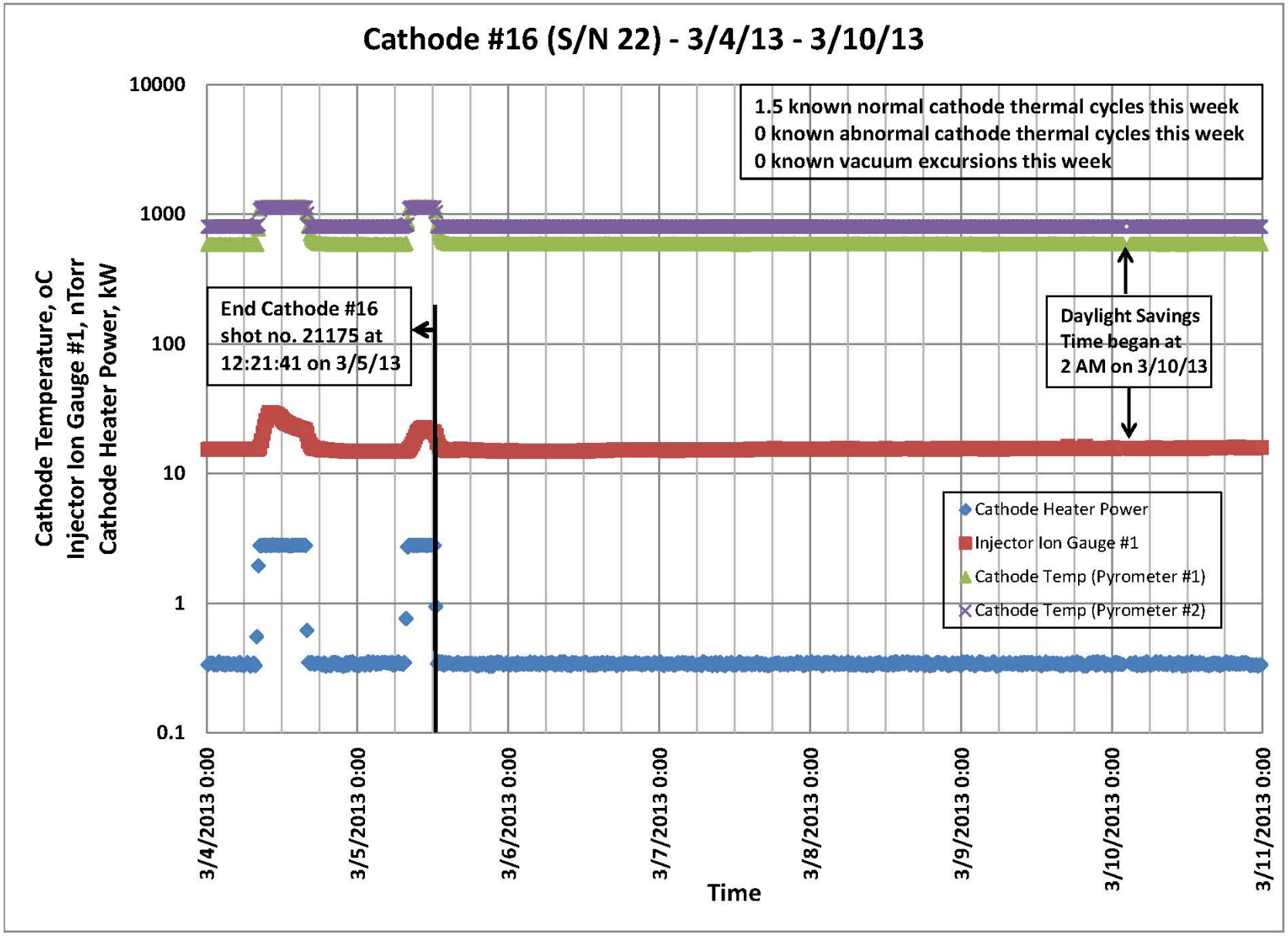
Appendix B. Cathode #16 recorded history for a full week . . . continued



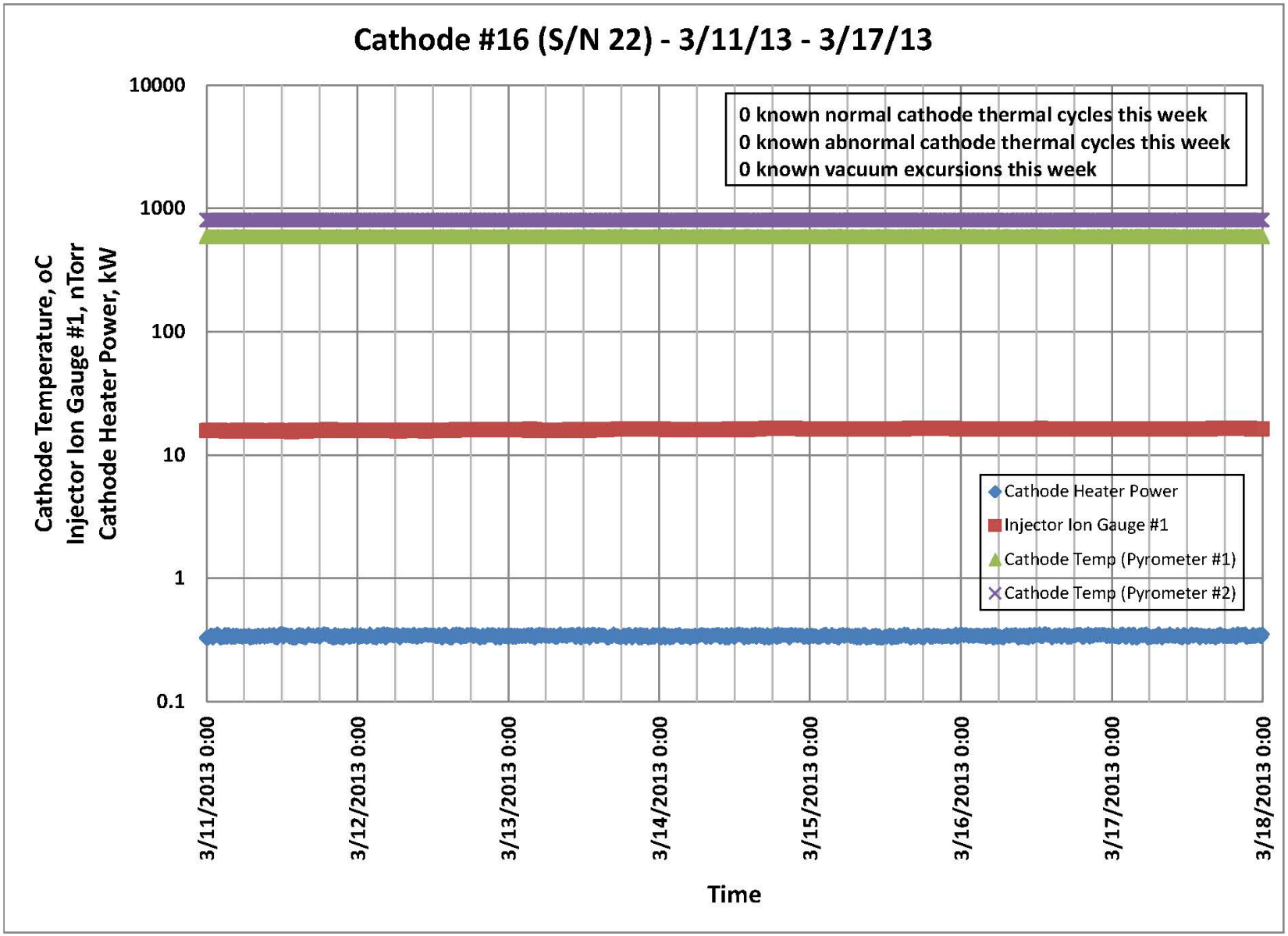
Appendix B. Cathode #16 recorded history for a full week . . . continued



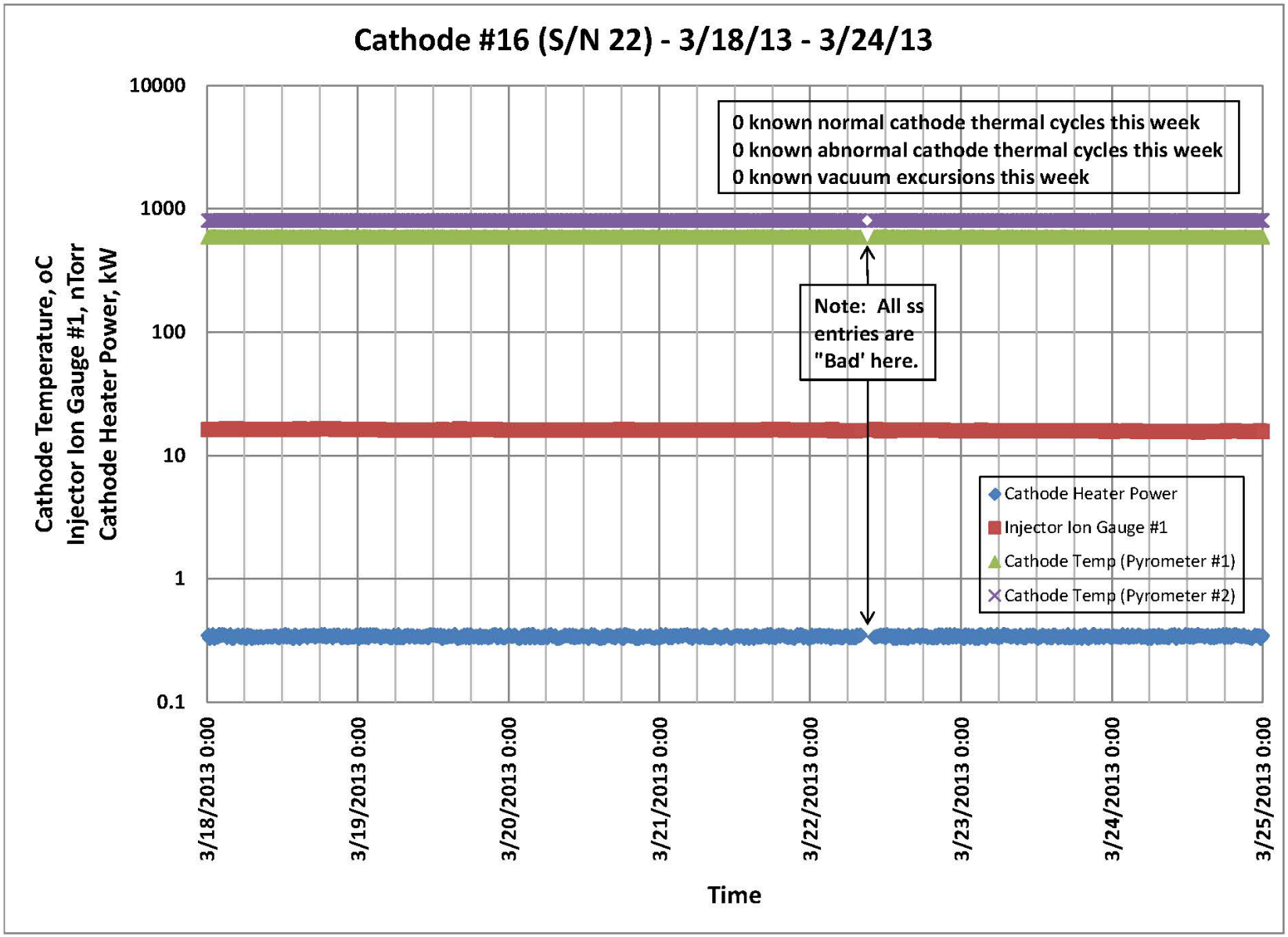
Appendix B. Cathode #16 recorded history for a full week . . . continued



Appendix B. Cathode #16 recorded history for a full week . . . continued



Appendix B. Cathode #16 recorded history for a full week . . . continued



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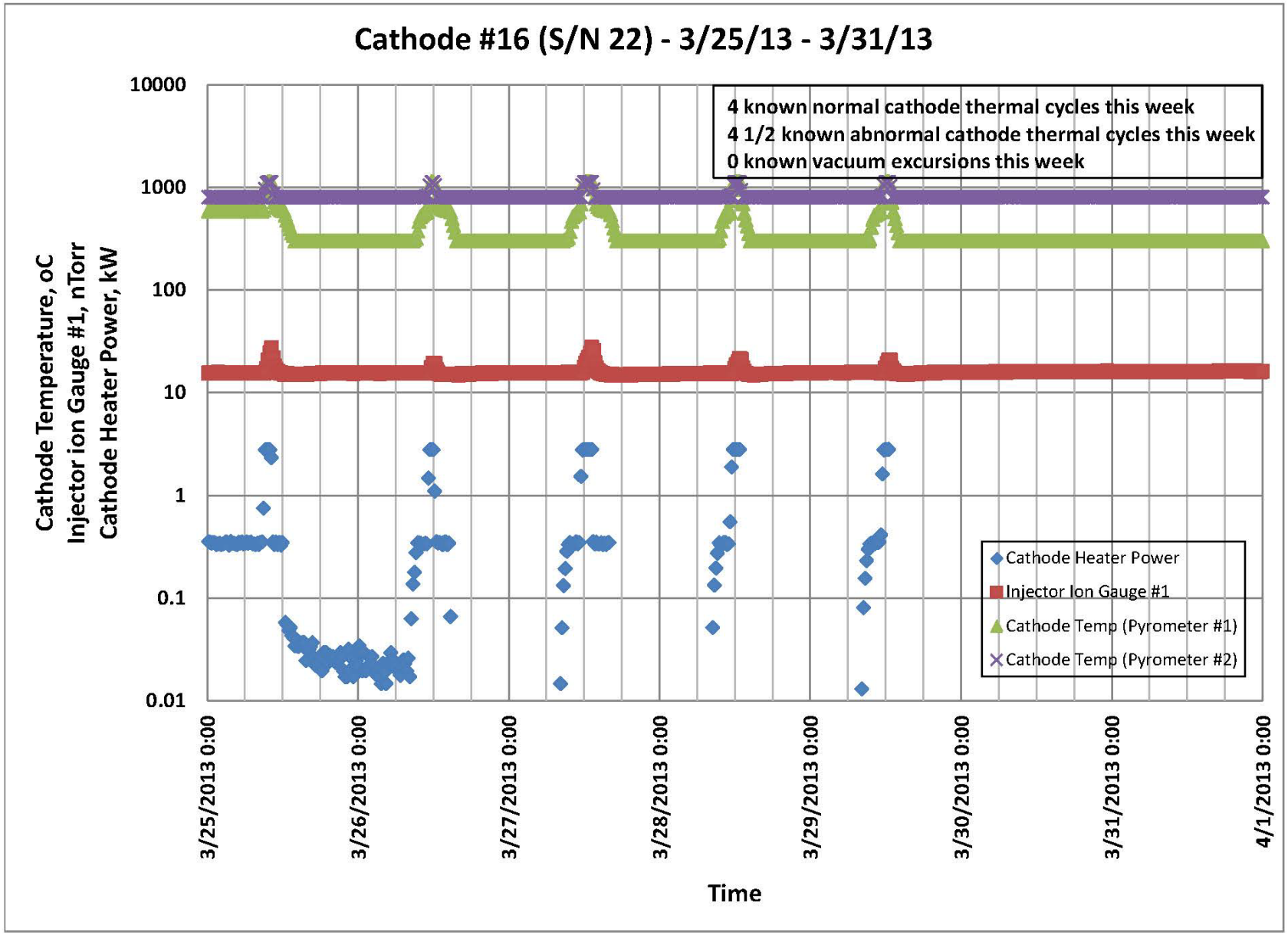
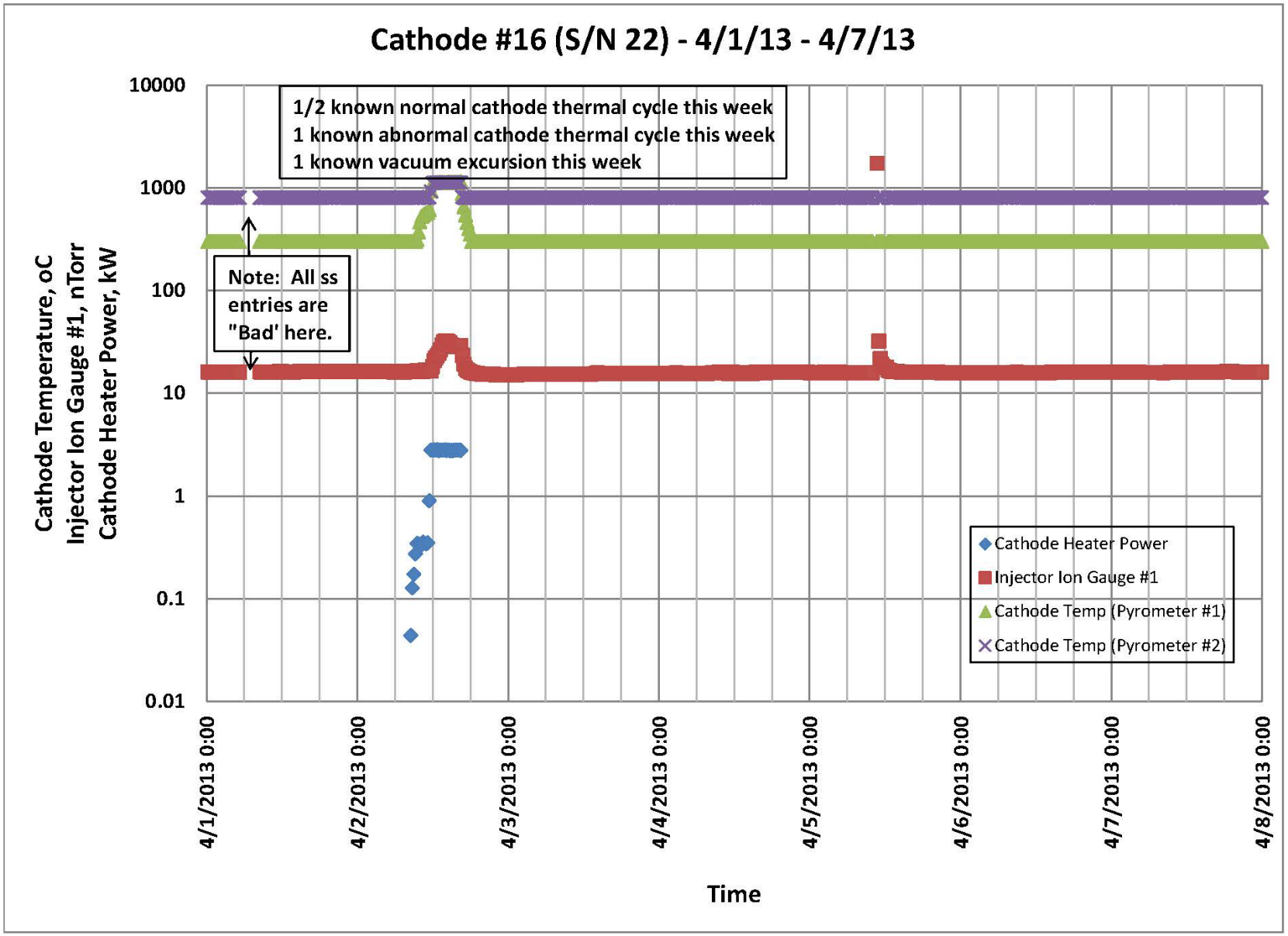


Appendix B. Cathode #16 recorded history for a full week . . . continued



Appendix B. Cathode #16 recorded history for a full week . . . continued