NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

March 18, 2004

MATERIALS LABORATORY FACTUAL REPORT Report No. 04-021

A. ACCIDENT

Place : Miami, Florida
Date : May 25, 2003
Vehicle : Cruise ship S/S Norway
NTSB No. : DCA03MM032
Investigator : Robert Ford

B. LOG BOOKS EXAMINED

Water chemistry log book from January 2000 to May 2001[1]
Stoker's log book[2] from July 1997 through May 2003[3]
Print-outs from boiler 22 and 23 pressure recorders[4]

C. DETAILS OF THE EXAMINATION

The raw data from several boiler log books was examined and transferred into tabulated and graphical form for ease of analysis. The following is a description of the findings.

Water Chemistry: The water chemistry log book included daily readings on parameters such phosphate, hydrazine, conductivity, chloride, pH, and alkalinity levels. The log book also contained the amounts of GC,[5] adjunct-B,[6] Amerzine (hydrazine),[7] and SLLC-A[8] that were added to adjust the chemistry.

Only the levels of hydrazine were tabulated for inclusion in this report. Table 1 shows the levels of hydrazine in all boilers at a randomly selected year (January through December 2000). The green cells at the beginning of the table show where no data was available from January 1 to 26. There were also several individual days (March 13, May 13, July 17, and November 29) and a string of 6 days (December 13 to 18) for which no data was available. The blank regions in days with data show where water chemistry readings were not taken due to specific boilers being idle or being repaired. The required level of hydrazine was between 0.03 and 0.1 parts per million (ppm).[9] The table shows hydrazine levels within the specification limits in black, above the limit in blue, and below the limit in red. The far right column shows the monthly readings of the water chemistry[10] taken by Drew Marine personnel during their on-site examination at the ship. The green cells in the monthly data, again indicate months for which no records could be found. Reviewing the data the following was noted:

1) Almost every time a boiler came out of an idle period (lay-up) the hydrazine level was zero or near zero for one or more days. After reaching the specified range, the

levels typically stabilized and then were generally maintained within operational limits.

2) In some cases continued low levels of hydrazine were observed during operation. For example, in boiler 24 from July 27 to September 28 hydrazine levels were almost always below the specified minimum, at approximately 0.01 ppm.
3) No records were found to show that hydrazine levels were build-up prior to idle periods (for idle conditions 150-200 ppm hydrazine are recommended).[11]
4) It appeared that boiler water chemistry readings were not taken on idle boilers in the wet condition[12] to assess the levels of hydrazine present[13].

According to interviews and documents,[14] typically two boilers were operated on a routine basis with the third boiler operated when there was peak demand. The fourth boiler was typically idle for maintenance. Examination of the data in Table 1 (yellow areas) confirmed that two boilers were operated on a routine basis with a third coming on line as needed.

Boiler Cycling: The number of boiler cycles in a given time period was quantified by collecting data from the stoker's logbook for several time periods: one was chosen randomly and was from July 10, 1997 to July 15, 1998 (1 year), and the other was from January 2002 to the failure date on May 25, 2003 (17 months). One boiler cycle was defined as going from zero load to a full load of 60-62 bar and back down to zero. A summary of the data for these two time periods is shown in Tables 2 and 3, respectively. These tables show the number of cycles experienced by the boilers and the amount of time the boilers were on and off. Tables 4A-C, which contain raw data from the stoker's log book in visual form, contain the following cycle data:

1. All boilers from July 1997 to July 1998 (Table 4A)
2. Boiler 23 from April 2001 to December 2001 (Table 4B)
3. All boilers from January 2002 to May 2003 (Table 4C)

The data from Table 2 showed that, for a 1-year period from 1997 to 1998, the boilers accumulated between 11 and 29 cycles, with the average being 23 cycles that year or approximately one cycle every two weeks. Table 3 shows that from the beginning of the year 2002 through May of 2003, the boilers accumulated between 18 and 26 cycles, with the average being 21.5 in about 17 months, or 15.2 per year. Review of pressure charts (last section in report) and interviews with personnel indicated that when the boilers were shut down they were typically brought down to zero pressure. Therefore, the boiler pressure cycles were from zero pressure to operating pressure of 62 bar (900 psi) and back down to zero. It should be noted that many times the boilers were started and shut down within 1.5 days or less, frequently in less than 0.5 a day.

Boiler Idle Periods: Tables 2 and 3 also show the amount of time the boilers were on and off. The red data in these tables shows periods when the boilers were shut down 20 or more days, and the blue data shows periods when the boilers were shut down for periods of 10 to 20 days. Table 2 (1997-1998) shows that the boilers were shut down for 10 or more days between 2 and 7 times each in this time period. Boiler 21 was not shut down for 20 or more days, boiler 22 had one instance where it was off for more than 20 days, boiler 23 had two instances, and boiler 24 had six instances. Table 3 (2002-2003) shows that in 17 months the boilers were shut off between 3 and 7 times each for periods of 10 days or more.

Boilers 23 had one instance where it was shut down for more than 20 days, boiler 21 had two instances, and boiler 24 had three instances.

Boiler Ramp-up and Cool-Down: A few printouts from of the boiler pressure recorders were examined to determine the rate of pressure build-up and drop-off. The data is summarized in Table 5. The question marks in the table indicate recordings that were interrupted, meaning that a full reading could not be obtained: either the recorders were stopped prior to dropping to zero pressure or the boilers were started back up in the middle of the cycle.

The data indicates that the boilers went from zero pressure to a full pressure of 60-62 bar in 1.5 to 5.5 hours. The average ramp-up rate was 3.4 hours. According to the charts the boilers were fired at 10 minute intervals and shut-down for 10 minutes until the boilers reached pressure. The practice is consistent with the boiler start-up procedure in the operating manual. [15]

The rate of pressure drop from full pressure to zero ranged between 45 minutes (0.75 hrs) and 4 hours, with the average being 2.8 hours. No expected pressure ramp-down time was indicated in the operating manual or other records.

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[1] Norwegian Cruise Line (NCL) log book containing water tests from January 2000 through May 2001 (NTSB D017).
[2] A stoker's log is a record book containing information regarding when boilers are started, shutdown, cleaned, skimmed, blown-down, and the fuel nozzles cleaned. Entries are made at every watch.
[3] NCL stoker's log book 1997-2003 (NTSB D018)
[4] Four print-outs from pressure recorders from boilers 22 and 23 (NTSB D023 through D026).
[5] GC is a concentrated alkaline liquid that neutralizes acid and controls corrosion.
[6] Adjunct B is a phosphate boiler water treatment chemical that works in conjunction with GC to control scale formation due to hardness.
[7] Amerzine (hydrazine) is a liquid catalyzed oxygen scavenger used to minimize oxygen corrosion in the boiler steam and condensate systems. Amerzine also promotes the formation of protective iron and copper oxide films.
[8] SLLC-A is a condensate corrosion inhibitor made from a volatile liquid organic amine designed to minimize corrosion in steam and condensate systems by providing a pH environment, which neutralizes the effects of carbon dioxide.
[9] Drew Marine Control and Dosing chart, BW-CS-4 (5/03), (NTSB D019)
[10] Drew monthly water chemistry service reports (NTSB D020).
[11] NTSB document D014, page 24.
[12] The wet condition indicates that the boiler was shut-down but was still sealed and full of water.
[13] Based on when water chemistry readings were taken in the log book and interviews.
[14] NCL interoffice memo dated March 16, 1998 (D021).
[15] "Liner France, Propulsion Machinery, Operation and Maintenance Guide Volume 3," Norwegian Cruise Line, page 26 (NTSB D022).

2000																															MONTHLY
January	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	22
21																											0	0	0	0.01	0.05	
22																											0.05	0.05	0.07	0.07	0.07	
23																											0.05	0.05				0.05
24																																0
February	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28				19
21	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.1	0.1	0.07	0.07	0.1	0.1	0.07	0.07	0.1	0.1	0.07														
22	0.07	0.07	0.07	0.07						0.07	0.07													0.07	0.05	0.1	0.1	0.07				
23			0														0	0.03	0.07	0.07	0.07	0.07	0.1	0.07	0.05	0.1	0.07	0.07				0.06
24				0	0.01	0	0.03	0.01	0.01	0.01	0.03	0.07	0.07	0.07	0.07	0.1	0.1	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.03							0.07
March	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	25
21		0.01	0.01													0.01	0.01					0	0.03							0		
22	0.3	0.07	0.07	0.07	0.07	0.07	0.1	0.1	0.07																					0.03		
23	0.2	0.07	0.07	0.1	0.07	0.07	0.1	0.1	0.05	0.3	0.2	0.05	?	0.2	0.05	0.03	0.05	0.1	0.05	0.05	0.2	0.03	0.03	0.1	0.1	0.07	0.07	0.1	0.2	0.03	0.1	0.1
24									0	0.03	0.05	0.03	?	0.1	0.07	0.05	0.05	0.1	0.05	0.05		0.03	0.03	0.07	0.1	0.07	0.07	0.1	0.1	0.03	0.1	0.1
April	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		22
21																			0	0	0.03	0.03	0.05	0.05	0.07	0.1	0.05	0.05	0.03	0.03		0.03
22						0.01				0.01			0.03													0.01	0.03	0.05	0.03	0.05		
23	0.1	0.1	0.1	0.3	0.2	0.05	0.07	0.3	0.03	0.03	0.1	0.1	0.03	0.1	0.2	0.07	0.07	0.1	0.07	0.07									0	0.01		
24	0.1	0.1	0.1	0.2	0.2	0.05	0.07	0.2	0.03	0.03	0.1	0.1	0.03	0.1	0.1	0.07	0.07	0.07	0.05	0.02	0.1	0.07	0.07	0.1	0.07	0.1	0.07					0.07
May	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21	0.03	0.07	0.07	0.07	0.1	0.07	0.05	0.05	0.1	0.05	0.03	0.03	?					0.01	0.03	0.07	0.05	0.03	0.07	0.07	0.05	0.03	0.07	0.07	0.07	0.07	0.05	
22	0.05	0.1	0.07	0.05	0.07	0.07	0.07	0.05	0.1	0.07	0.05	0.05	?	0.07	0.07	0.07															0.05	
23	0.01			0.01				0			0.01	0.03	?	0.07	0.07	0.07	0.07	0.05	0.05			0.01			0.03	0.03					
24																	0.01	0.01	0.01	0.01	0.03	0.01	0.05	0.05	0.03	0.03	0.07	0.07	0.07	0.07		
June	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
21	0.05	0.05				0.01		0.03	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.03	0.05	0.05	0.07	0.05	0.05	0.05	0.07	0.05	0.05	0.07	0.05	0.05	0.07		
22	0.05	0.05	0.07	0.05	0.05	0.05	0.03	0.05	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.03	0.05	0.05	0.07	0.05	0.05	0.05	0.01	0.07	0.05	0.08	0.05	0.05	0.01		
23	0.01	0.08	0.07	0.05	0.05	0.03	0.07																									
24								0.01	0.03					0	0.01						0.03	0.03						0.03	0.03			
July	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21	0.07	0.07	0.07	0.07	0.07	0.03	0.07	0.07	0.07	0.07	0.07	0.1	0.05	0.1	0.2	0.05	?	0.05	0.07	0.03	0.05	0.1	0.05	0.07	0.07	0.07	0.05	0.03	0.07	0.05	0.05	
22	0.07	0.07	0.07	0.07	0.07	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.05	0.1	0.1	0.05	?	0.07	0.1	0.05	0.05	0.1	0.01	0.07	0.1	0.07	0.05	0.05				
23						0.01							0.02							0.01	0.03									0.01	0.03	
24																											0	0.01	0.01	0.02	0.01	
August	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21	0.05	0.1	0.05	0.03	0.1	0.05	0.05	0.1	0.05	0.03																				0	0.03	
22						0.03	0.05	0.1	0.05	0.03	0.03					0.01	0.01						0.05	0.07	0.05	0.1	0.05	0.07	0.07	0.1	0.05	
23			0.05	0.03					0.01	0.02	0.05	0.07	0.1	0.1	0.1	0.07	0.05	0.1	0.1	0.1	0.15	0.1	0.2	0.07	0.07	0.1	0.07	0.07	0.07	0.07	0.05	
24	0.01	0.01	0.01	0.01	0.01							0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.02							
September	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
21			0.03	0.05	0.1	0.07	0.07																									
22	0.07	0.2	0.03	0.07	0.1	0.07	0.07	0.1	0.07	0.05	0.07		0.03	0.07	0.07	0.1	0.07	0.05	0.07	0.07	0.03						0.01	0.03	0.1			
23	0.07	0.15	0.05	0.03	0.1	0.07	0.07	0.1	0.07	0.05	0.07	0.1	0.03	0.07	0.07	0.1	0.05	0.05	0.07	0.07	0.03	0.07	0.07	0.07	0.05	0.07	0.07	0.03		0.05		
24										0	0.01	0.01	0.01	0				0.01			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03		
October	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21																																
22					0.01	0.03	0.07	0.07	0.07	0.07	0.07	0.03	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.03												
23	0.05	0.05	0.07	0.07	0.05	0.05	0.07	0.07	0.07	0.07	0.07	0.03	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.03	0.05	0.07	0.05	0.07	0.07	0.07	0.05	0.05	0.05	0.07	0.07	
24	0.03	0.03	0.05	0.07	0.03	0.03						0.01	0.03						0.01	0.01	0.01	0.05	0.05	0.07	0.07	0.05	0.05	0.05	0.05	0.05	0.05	
November	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		18
21	0.01	0.01	0.01						0.01	0.01	0.01	0.03	0.03	0.05	0.05	0.05	0.07	0.07	0.05	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.05	0.05	?	0.03		0.07
22																						0.01	0.01	0.03	0.07	0.05	0.05	0.05	?	0.04		
23	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.07	0.05	0.07					0.01	0.03													?	0.01		
24	0.07	0.05	0.05	0.05	0.05	0.05	0.1	0.07	0.05	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.03	0.05	0.03	0.03	0.03	0.01	0.05								0.03
December	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	16
21	0.06	0.06	0.06	0.05	0.06	0.05	0.05	0.05	0.06	0.06	0.07	0.07	?	?	?	?	?	?			0	0.01		0.01	0.1			0.03	0.03	0.03	0.05	
22	0.07	0.06	0.05	0.05	0.07	0.06	0.06	0.06	0.06	0.06	0.07	0.07	?	?	?	?	?	?	0.05	0.05	0.03	0.05	0.07	0.05	0.05	0.07	0.1	0.05	0.05	0.05	0.05	0.1
23							0.04	0.04					?	?	?	?	?	?	0.03	0.05	0.03	0.05	0.07	0.05	0.05	0.07	0.07	0.05				0.05
24																																

Hydrazine Content
Limits 0.03-0.1 ppm

Table 1: 2000 Hydrazine Content

July 10, 1997 to July 15, 1998

	BOILER OPERATION TIME (DAYS)							
	BOILER 21		BOILER 22		BOILER 23		BOILER 24	
	ON	OFF	ON	OFF	ON	OFF	ON	OFF
cycle 1	0.5	2.5	1.5	12.5	>17	10.5		>37
2	0.5	9.5	16.5	8	21	8.5	8.5	41
3	1.5	1.5	33.5	0	2	3.5	20	4.5
4	12.5	5.5	8	9	8.5	5.5	44.5	26.5
5	1.5	4.5	0.5	1.5	1.5	1.5	15.5	12.5
6	1.5	6.5	1.5	5.5	12.5	6.5	8	7.5
7	16	5	6	22	0.5	11	6.5	27
8	2	0	1.5	1.5	6.5	1.5	39.5	8.5
9	9.5	1.5	2.5	1.5	0.5	7.5	0.5	4
10	0.5	7.5	1.5	2	22.5	12.5	1	23.5
11	19.5	0	2	14.5	8.5	3	3.5	31
12	0.5	1	23.5	13.5	0.5	1.5	>0.5	
13	1.5	1.5	14.5	6.5	12.5	1.5		
14	12.5	19.5	7.5	6	5.5	0.5		
15	15.5	5.5	27	5.5	2.5	3		
16	8.5	3	1	1	0.5	1.5		
17	1	5	1.5	5.5	1.5	10.5		
18	5	3.5	1.5	5.5	0.5	1.5		
19	0.5	1.5	2	3	1.5	2.5		
20	13.5	0	0.5	4.5	1.5	1.5		
21	23	5.5	2	5.5	1.5	5.5		
22	1.5	3.5	39	3	22.5	3.5		
23	0.5	1.5	9	0.5	0.5	20.5		
24	1.5	3.5	22	>0.5	28.5	3.5		
25	0.5	1.5			5.5	22.5		
26	58	5			12	11		
27	23	12.5			3	0		
28	11	3			4	>2		
29	0	4						

Summary Data

AVG DAYS ON	8	9	7	15
AVG DAYS OFF	4	6	6	19
Cycles	29	24	28	11

Table 2: 1997-1998 Boiler Cycling Summary

January 1, 2002 to May 25, 2003

		BOILER OPERATION TIME (DAYS)							
		BOILER 21		BOILER 22		BOILER 23		BOILER 24	
January 2002		ON	OFF	ON	OFF	ON	OFF	ON	OFF
	cycle 1	>12	4	>48	1	1.5	5.5		**>15**
	2	3.5	2	27.5	2.5	16	1.5	0	13
	3	7.5	1	46.5	**16.5**	12	3	0.5	**13.5**
	4	3.5	5.5	58.5	1	29	1	0	6.5
	5	43.5	3.5	33.5	0	46	**16.5**	0	**35.5**
	6	3.5	3.5	14.5	3.5	1.5	2	0	13.5
	7	3.5	**12.5**	12.5	**10**	5	2.5	35.5	0.5
	8	75	3.5	8.5	2.5	32.5	**16.5**	0.5	**44.5**
	9	1	2	18.5	9.5	18.5	5.5	16	4.5
	10	8	**16.5**	11.5	2.5	5.5	5	1.5	0.5
	11	6.5	5.5	4.5	2.5	30	2.5	0.5	0.5
	12	6.5	**15.5**	4.5	2.5	13.5	9.5	2.5	1.5
	13	8.5	4.5	4.5	2.5	1.5	1.5	2	0.5
	14	3	8	12	2	57.5	2	0.5	0.5
	15	19	9.5	33	2	5.5	1	2	1.5
	16	2	**42**			5	**17.5**	2.5	0.5
	17	35	1.5					19.5	0.5
	18							21	1.5
	19							11.5	8.5
	20							5.5	0.5
	21							13.5	4.5
	22							30.5	2.5
	23							8.5	**16.5**
January 2003	1	5.5	0.5	40.5	1.5	3.5	2.5	18.5	**19.5**
	2	12.5	2.5	13	2.5	1.5	1.5	1	5
	3	2.5	**29.5**	25	**12.5**	85.5	**26.5**	29	**23.5**
	4	50.5	0	>37		>9		>51	
	5	7	0						
	6	9.5	>8						
		Failure 5/25/2003							

Summary Data

AVG DAYS ON	14	24	19	11
AVG DAYS OFF	8	4	7	9
2002-2003 cycles	23	18	19	26

Table 3: 2002-2003 Boiler Cycling Summary

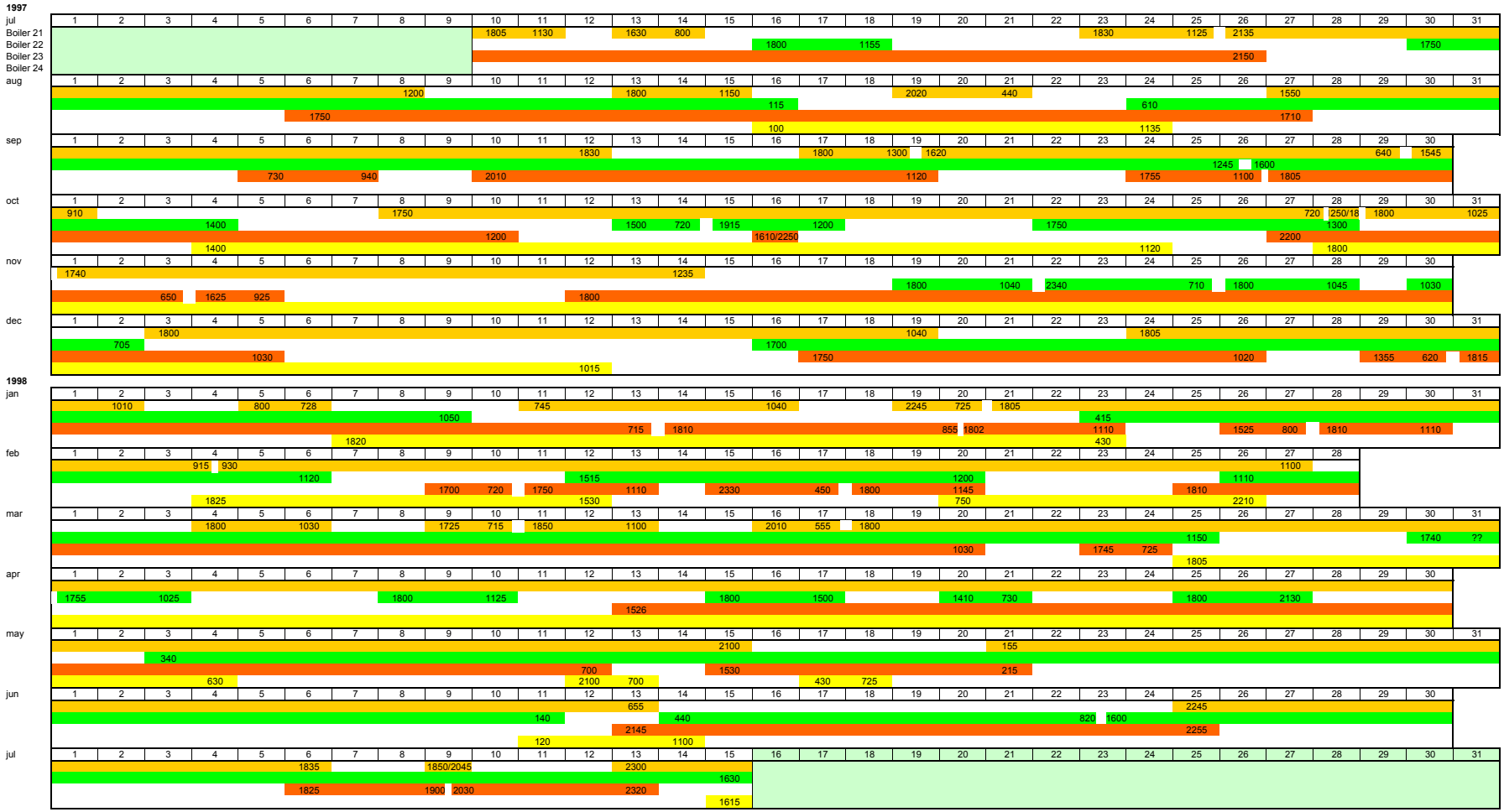

Table 4A: 1997-1998 Boiler Cycling Raw Data

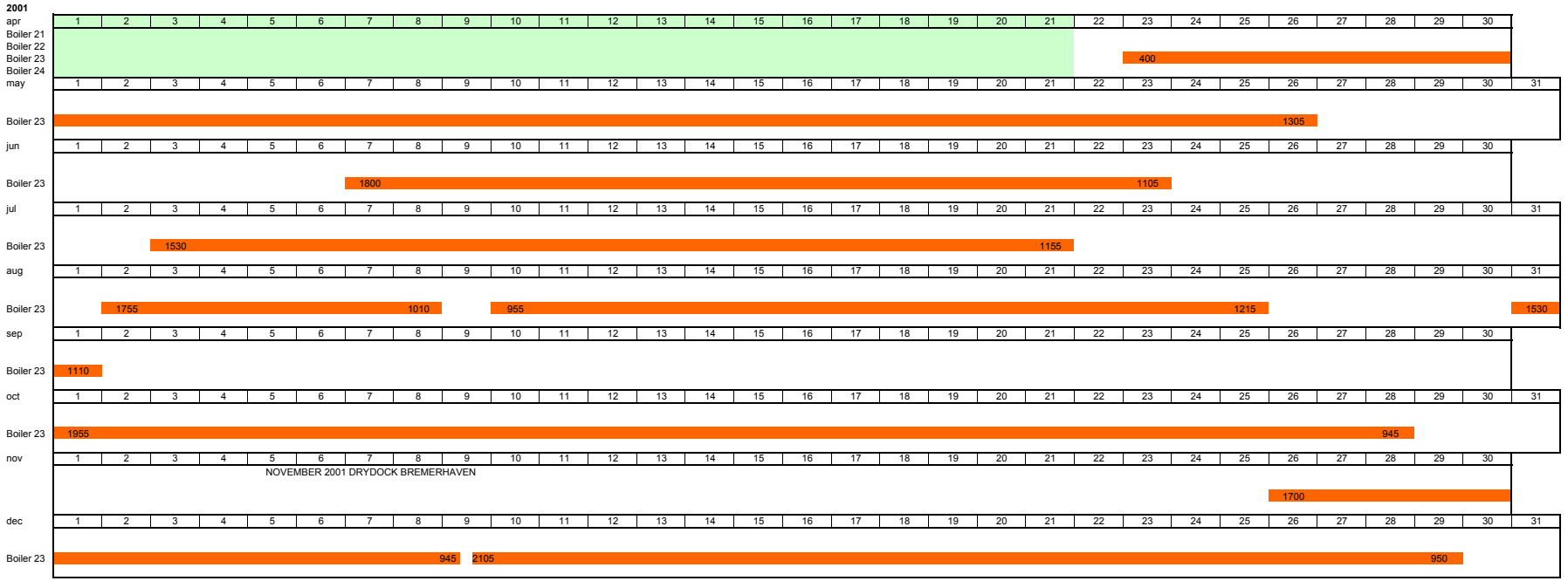

Table 4B: 2001 Boiler 23 Cycling Raw Data

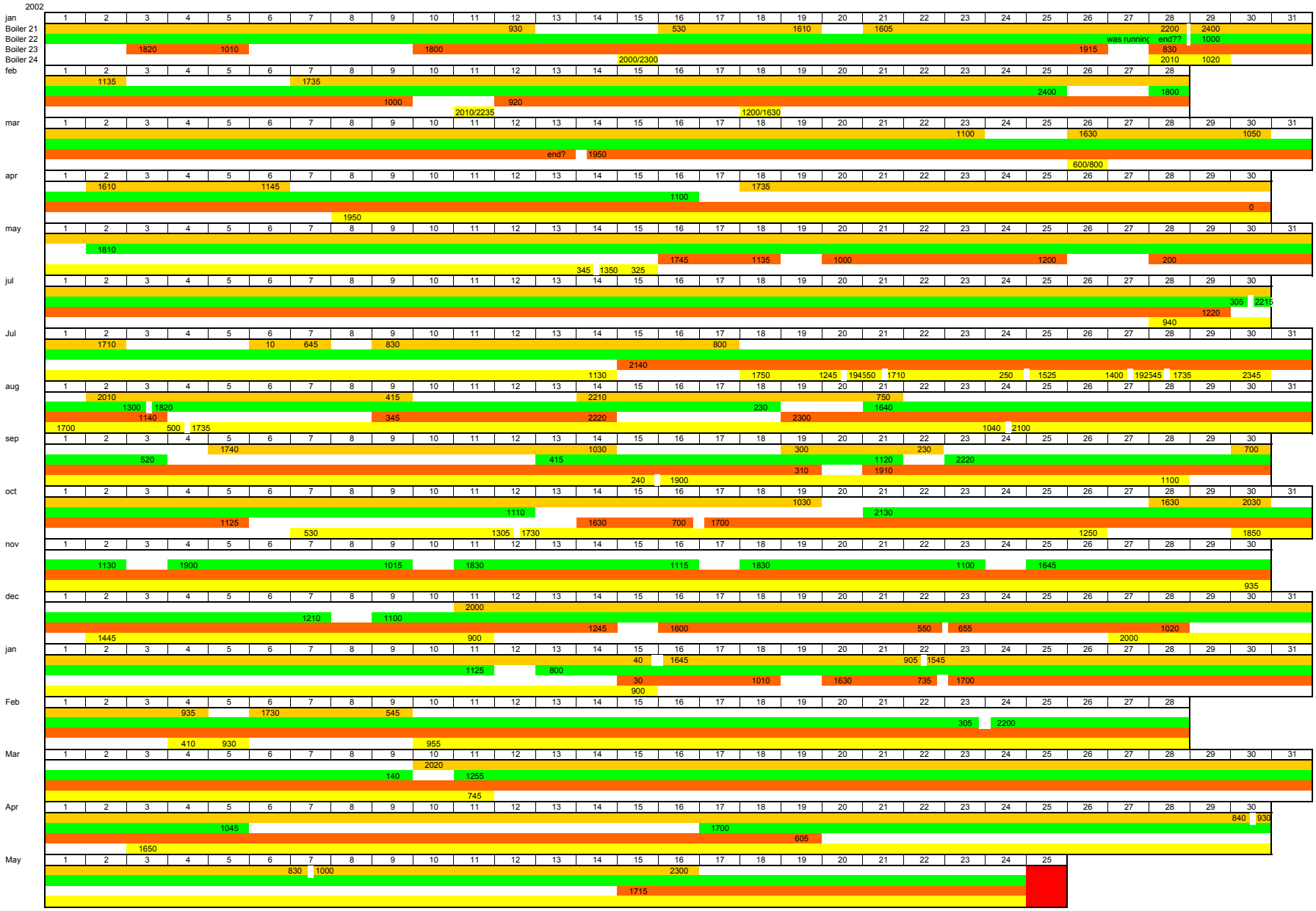

Table 4C: 2002-2003 Boiler Cycling Raw Data

Roll	Boiler	Ramp-Up Time (hrs)	Cool-Down Time (hrs)
NTSB D023	22		0.75
15-Dec-02		?	1
		?	?
		3	?
		3.5	2.5
		3	3
		2.75	?
		3	2.5
		3	
NTSB D024	23	4	?
19-Oct-02		?	2.75
		?	3
		3	?
		3.5	2.75
		?	?
		?	
NTSB D025	23		4
17-Mar-03		4	?
		?	?
		3.5	?
		3	?
		5.5	?
		?	
NTSB D026	22		?
31-Mar-02		?	2.5
		3	?
		1.5	2
		3.5	
	Average	3.4	2.8

Table 5: Boiler Transients