Measuring and Managing a Data Center Cooling Shutdown

Columbia University Information Technology - August 24, 2012

Table of Contents

- Overview
- Timeline
- Cricket Graphs
  - What's being graphed
    - Mechanical
    - Electrical
    - Ambient Temperature
  - 24 hours as of 9am 8/17/12
  - 24 hours as of 8:46pm 8/18/12
  - 36 hours as of 10:00 8/19/12
  - Final tenant system - EE cluster - restored 8/20/12

Overview

A full mechanical shutdown of the cooling plant for the University Data Center was performed Saturday August 18, 2012. This work was required by construction for the Core Research Computing Facility (NIH grant 1G20RR030893-01) which is upgrading the Data Center's electrical service. The work consisted of demolition of unused cooling pipe and electrical work needed to prepare for further construction activities. The chilled water cooling system and electrical power to the computer room air conditioners (CRAC) were shut down. The shutdown was also used as an opportunity to perform extensive preventative maintenance on the cooling and electrical systems in this 50-year old facility.

As the Data Center is a critical facility that can't afford to be shut down for a full day, a 50-ton temporary cooling system was employed, providing enough capacity to operate at a reduced load by shutting down non-critical services for the day. The normal operating load is about 120 tons, so approximately ⅔ of the approximately 700 servers in the data center were planned to be shut down.

Thanks to support from the New York State Energy Research and Development Authority (NYSERDA contract ST11145-1) extensive instrumentation of the cooling and electrical distribution systems had been recently installed. This monitoring capability helped us plan for and manage the shutdown. Following are representative graphs of the installed monitoring capability that helped us successfully plan for and manage this work.

Timeline

Planned and actual times for the work were developed and tracked for this event. Following is a summary of major milestones and incidents of note:

Milestone/Incident	Planned Time	Actual Time
First 3 hour temporary cooling test completed.	Thursday 8/16/2012 17:00	Thursday 8/16/2012 18:45
Second 3 hour temporary cooling test completed. 40 ton reduction in central cooling load measured.	Friday 8/17/2012 17:00	Friday 8/17/2012 16:45
Commence server shutdowns (confirm overnight batch complete)	Saturday 8/18/2012 06:00	Saturday 8/18/2012 06:00
Electrical monitoring data collector failed for 30 minutes (7:30-8)		Saturday 8/18/2012 07:30
Commence electrical and mechanical work	Saturday 8/18/2012 08:00	Saturday 8/18/2012 08:18
Cricket data collected failed for 1 hour (11-12)		Saturday 8/18/2012 11:00
Mechanical and electrical construction work complete. CRAC PMs ongoing. Some CRACs and air handlers (AC1&2) operating.	Saturday 8/18/2012 19:00	Saturday 8/18/2012 11:36
Chilled water operating through backup dry coolers (12-2:30)		Saturday 8/18/2012 12:00
Chilled water switched over to normal campus CHW operation		Saturday 8/18/2012 14:30
Recovery of IT systems commences	Saturday 8/18/2012 20:00	Saturday 8/18/2012 15:00
Majority of central IT systems recovered -- some tenants elected to wait until later to restart their systems.	Saturday 8/18/2012 23:59	Saturday 8/18/2012 21:26
Last major tenant IT system -- 800-core HPC cluster -- restored starting 2pm. Full load reached at 5:30pm.		Monday 8/20/2012 17:30

Cricket Graphs

What's being graphed

The following mechanical and electrical infrastructure elements are instrumented using the SNMP monitoring protocol (with translation from ModBus).

Mechanical

Mechanical systems monitoring consists of Flexim temperature and flow rate metering installed on three subsystems which measures temperature, flow in gallons per minute, and calculates heat transferred in tons.

ac1-2 chilled water loop serving the overhead air handlers (ac1 and ac2).
liebert1-6 chilled water through a plate-frame heat exchanger that serves the computer room air conditioners (CRAC)
drycoolers water loop is the backup system, switched to via butterfly valve to reroute the "liebert1-6" water through rooftoop dry coolers. Notably, the dry coolers operate at ambient temperature and typically see water temperatures of over 90 degrees as the CRAC compress transfer heat to the water loop. This is to be contrasted with the normal operation chilled water loop with temperatures in the 42-50 degree range.

Electrical

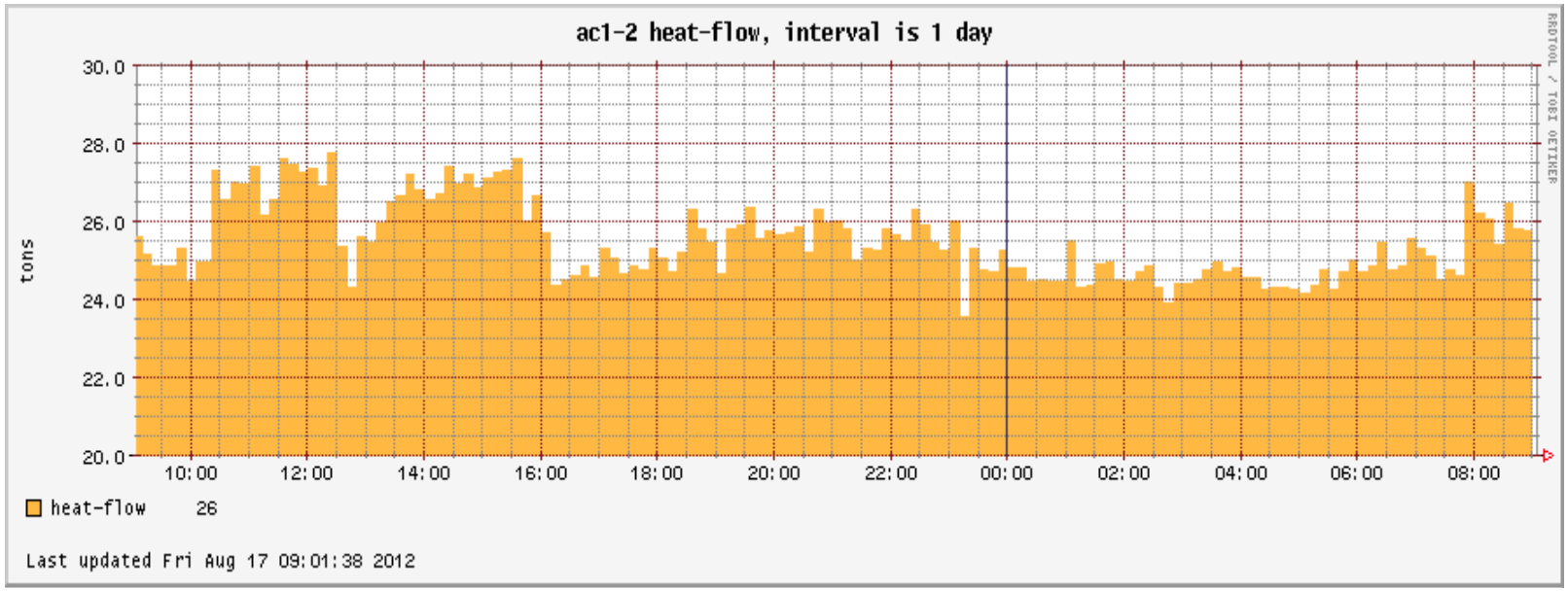
Electrical systems monitoring is installed at several levels throughout the facility: Wattnode meters monitor the main 3-phase distribution panels (and several subpanels) for mechanical and IT loads; Raritan instrumented power distribution units are mounted in key server racks. Further monitoring is available via several of the rack-mounted UPSes as well as several of the servers.

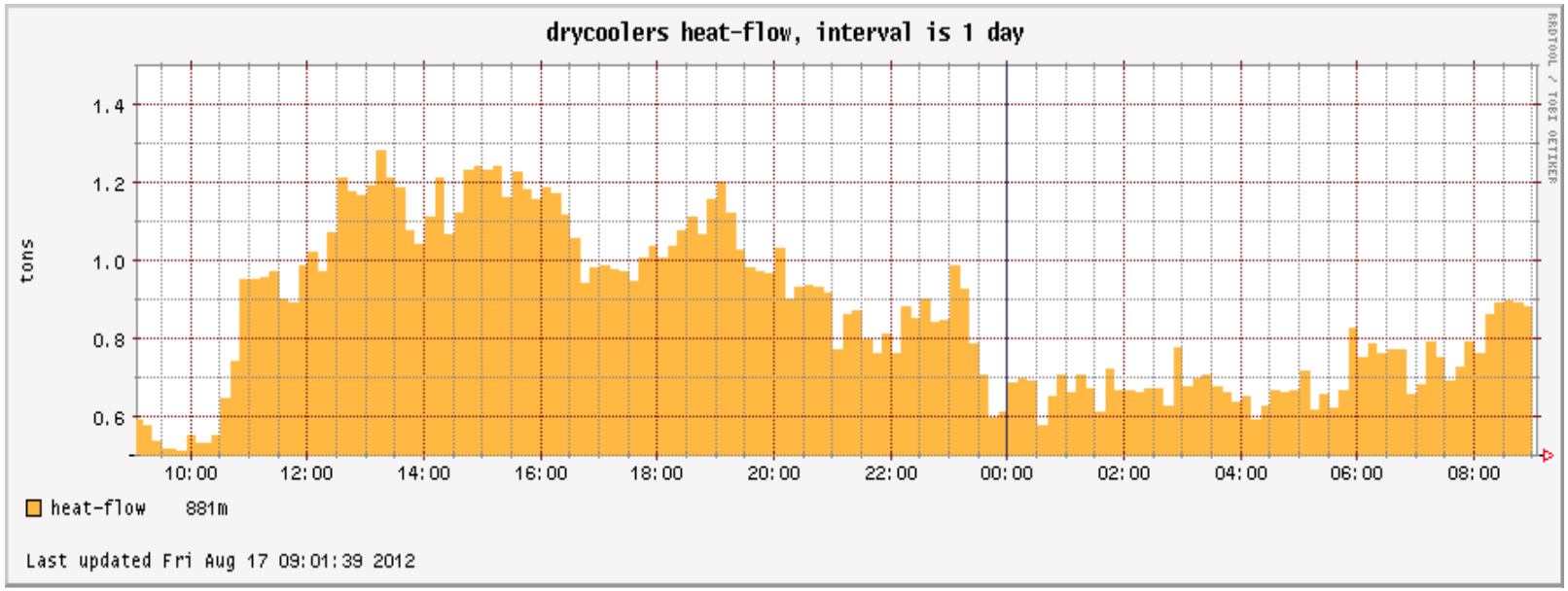
ats2 & 3 are the automatic transfer switches feeding MCC1 and MCC2, respectively. These MCCs supply power to the CRACs, AC1&2 air handlers, chilled water pumps, and various lighting and office electrical loads throughout the Computer Center building.
ats4 is the automatic transfer switch feeding the majority of the IT load in the data center.
pp26 & 27 are two power panels that carry IT load but are not fed from the main IT panel, ats4. These were installed within the past 5 years and are connected to a totally different source from the rest of the Computer Center building.
unixrack*N*-**pdu***N* from Raritan are mounted in several equipment racks as mentioned above.

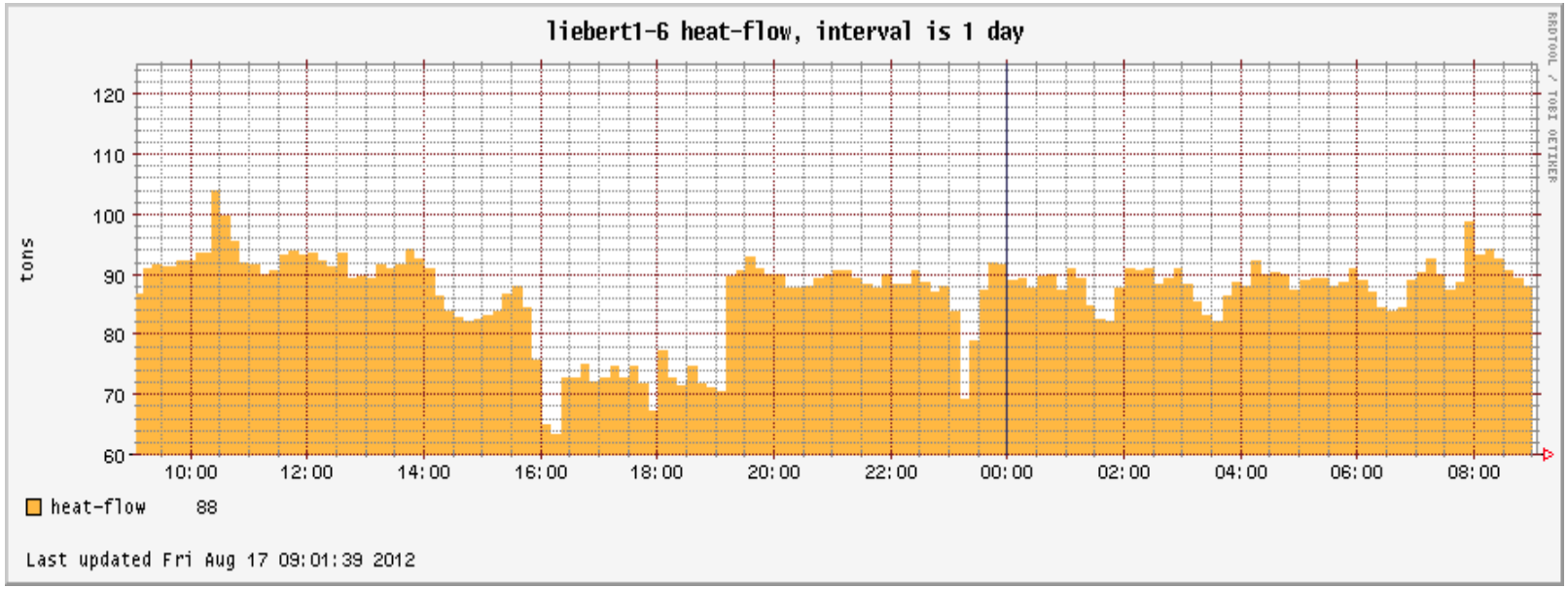
Ambient Temperature

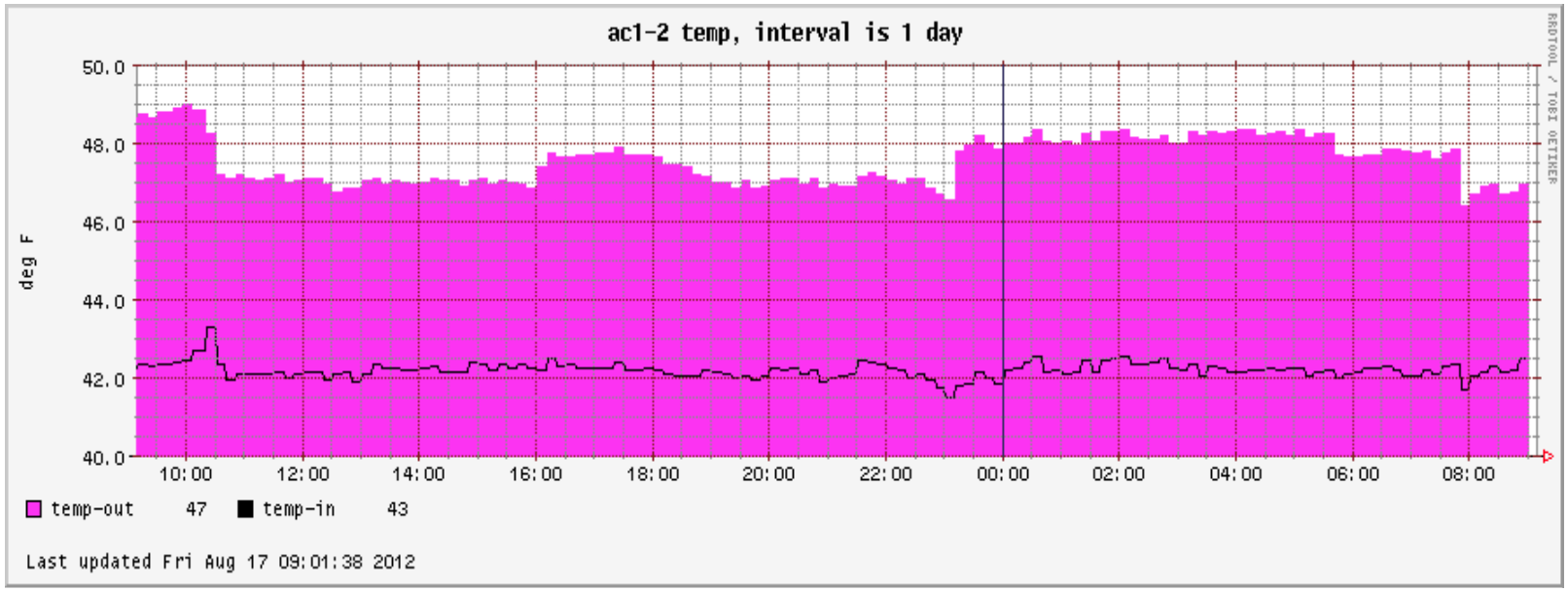
Ambient temperature monitoring is available from several systems:
all sensors graph shows ambient temperature data from several zones throughout the room using Neteye monitors which provide video as well as environmental conditions monitoring.
unixrack*N*-**pdu***N* from Raritan are also set up with ambient input air temperature probes that are mounted on the front grilles of the equipment racks.
XIV enterprise storage system has input temperature monitoring for each of 15 storage shelf modules.

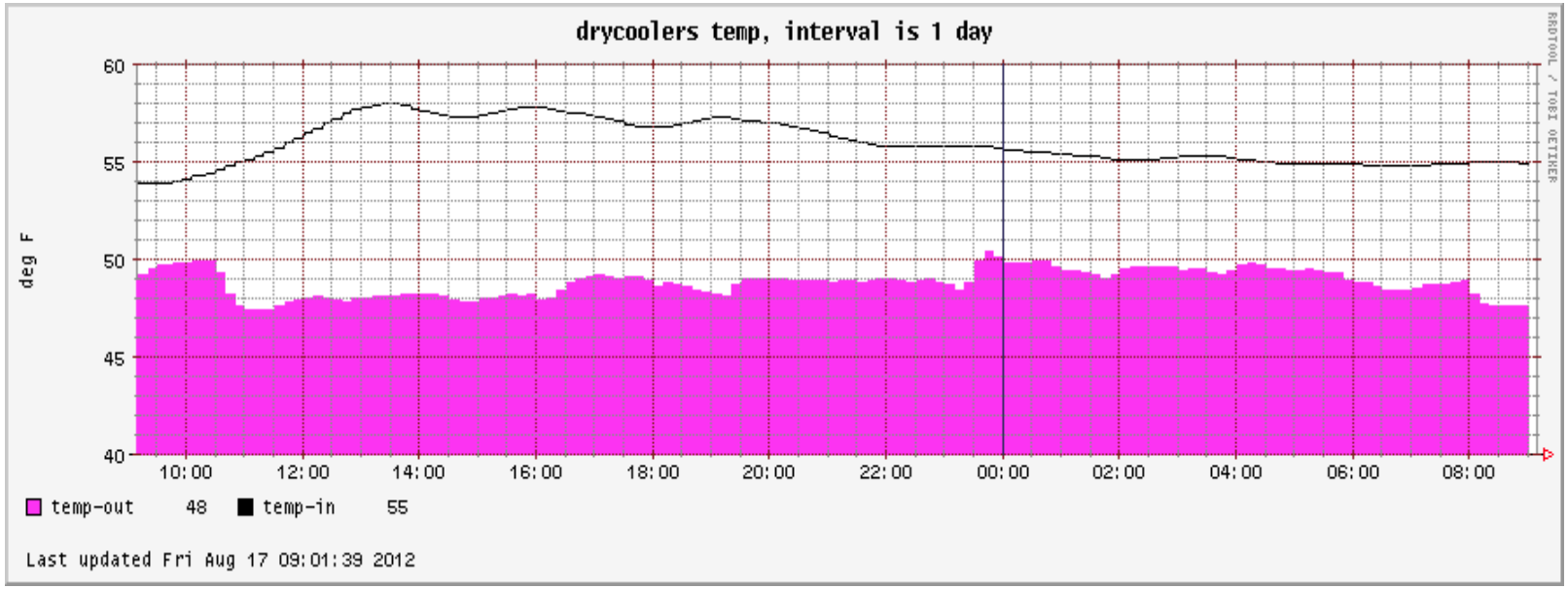
24 hours as of 9am 8/17/12

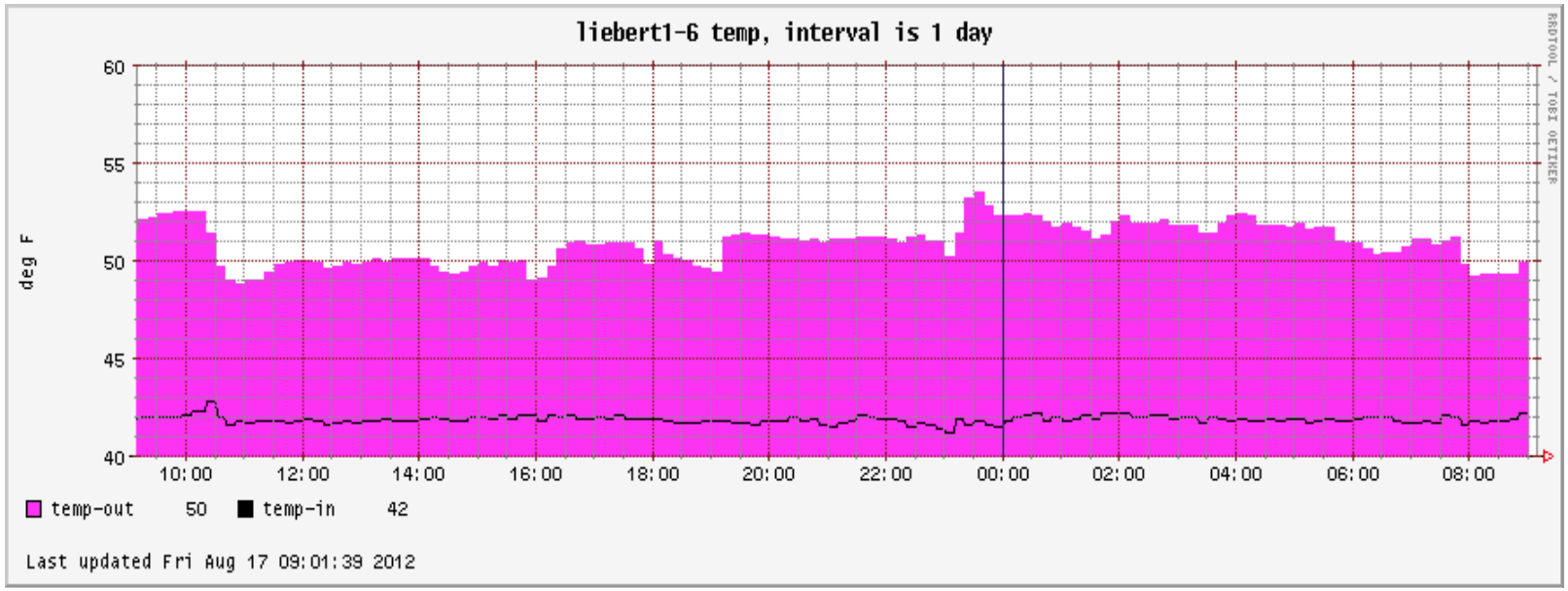


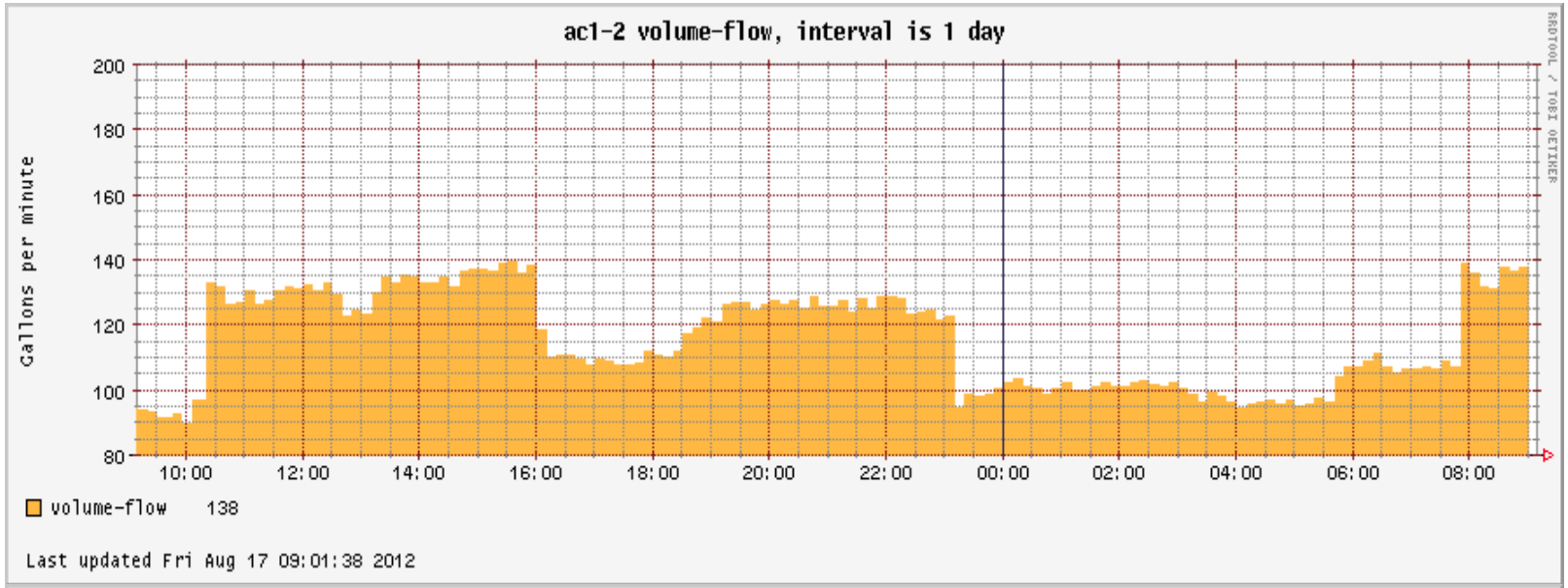


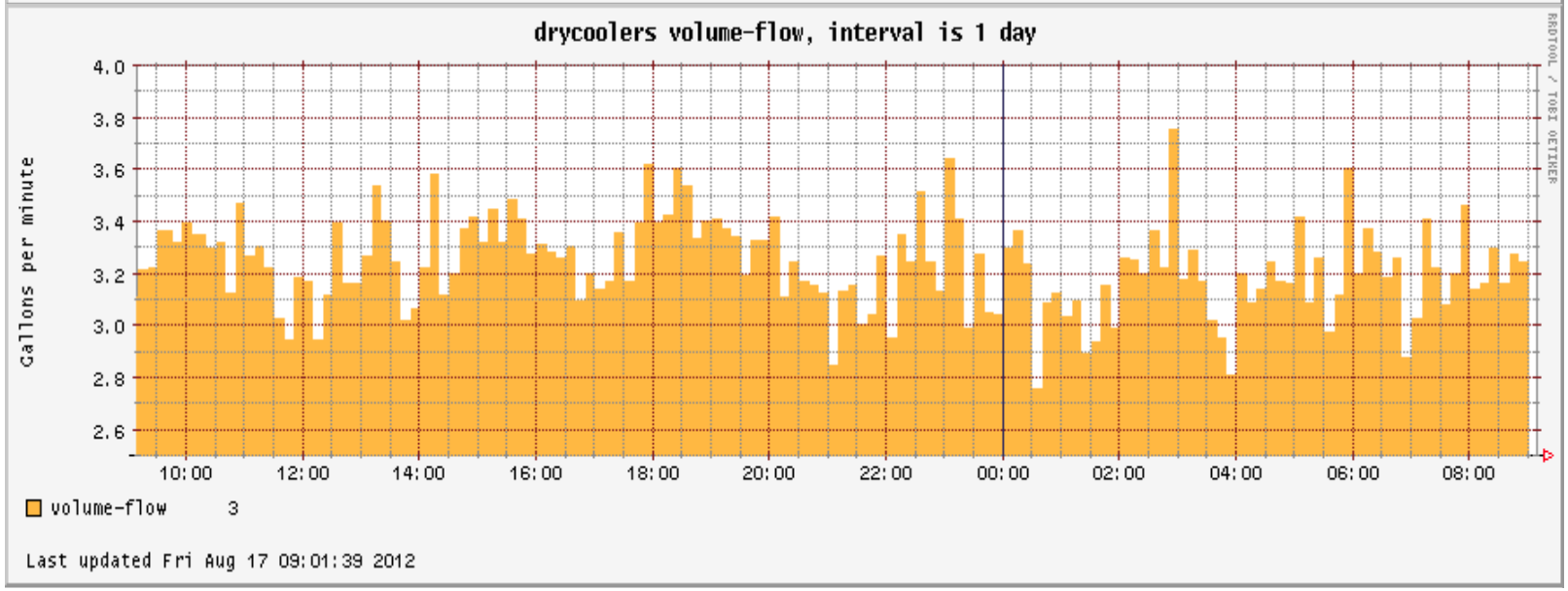

liebert1-6 heat-flow, interval is 1 day
tons
120
110
100
90
80
70
60
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
heat-flow 88
Last updated Fri Aug 17 09:01:39 2012
RRDTOOL / TOBI OETIKER

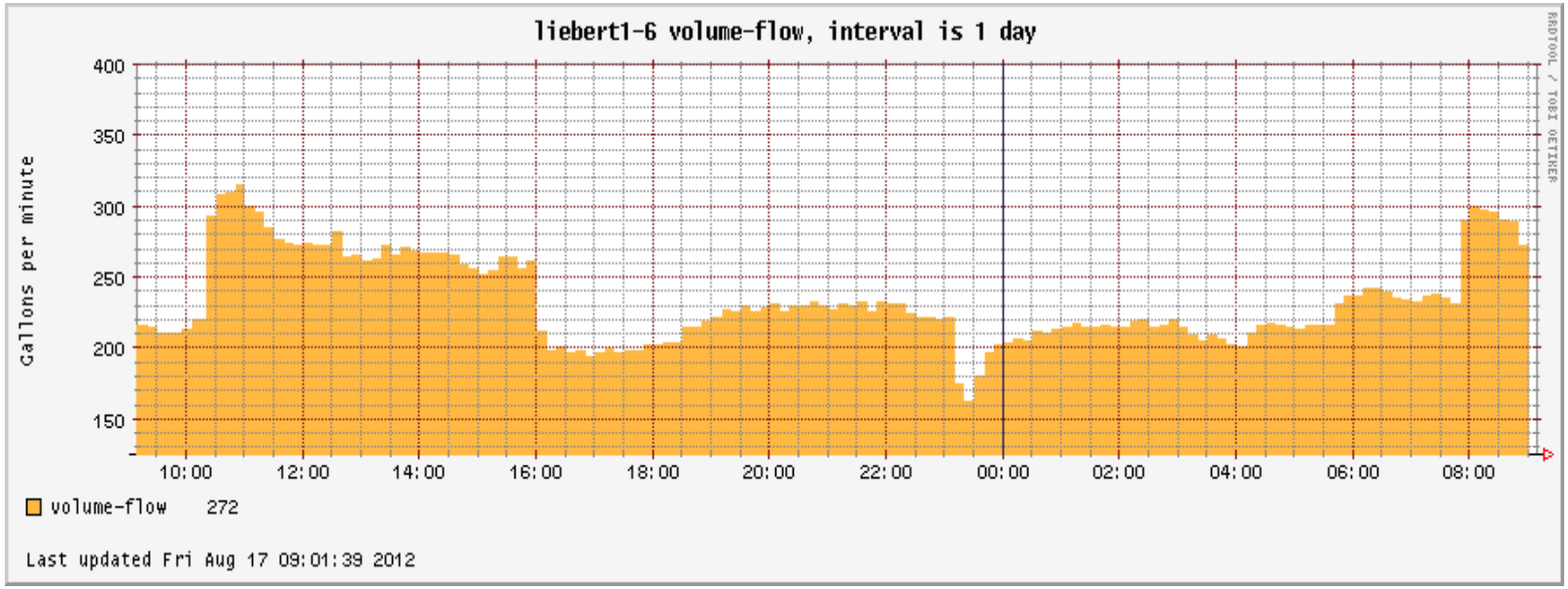

ac1-2 temp, interval is 1 day
deg F
50.0
48.0
46.0
44.0
42.0
40.0
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
temp-out 47
temp-in 43
Last updated Fri Aug 17 09:01:38 2012
RRDTOOL / TOBI OETIKER

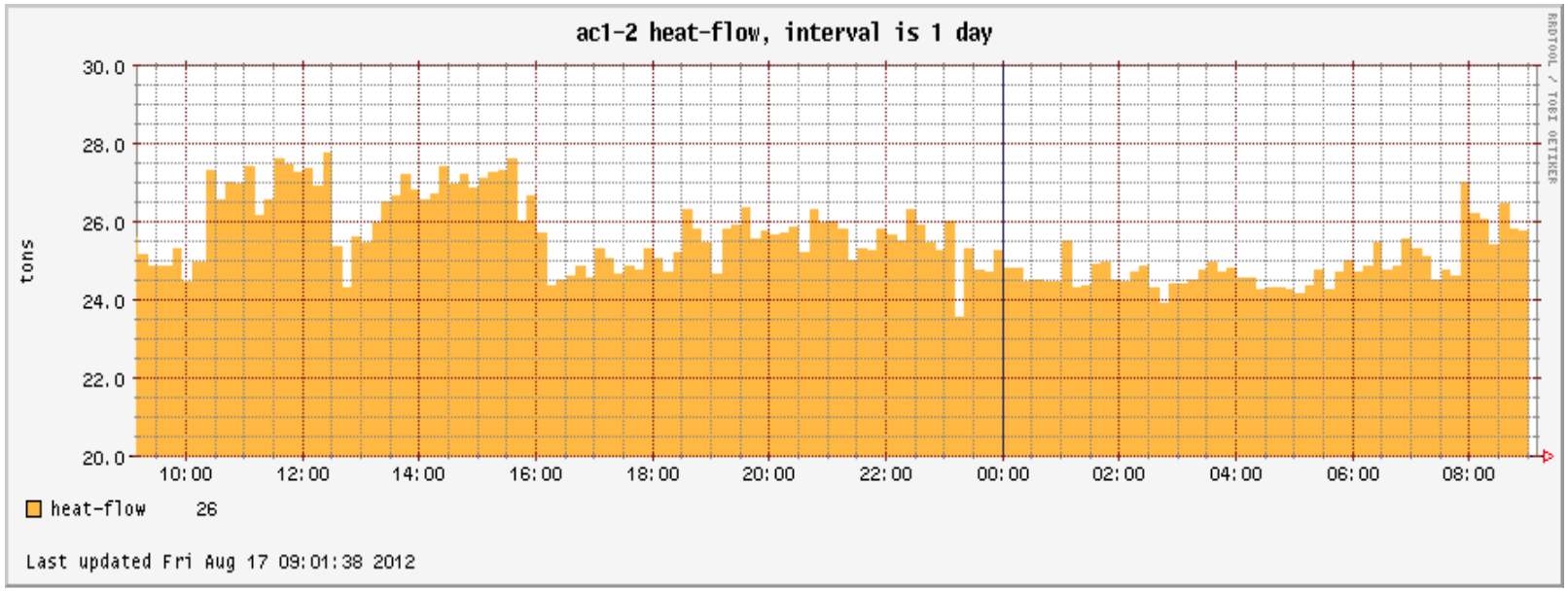

drycoolers temp, interval is 1 day
deg F
60
55
50
45
40
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
temp-out 48
temp-in 55
Last updated Fri Aug 17 09:01:39 2012
RRDTOOL / TOBI OETIKER

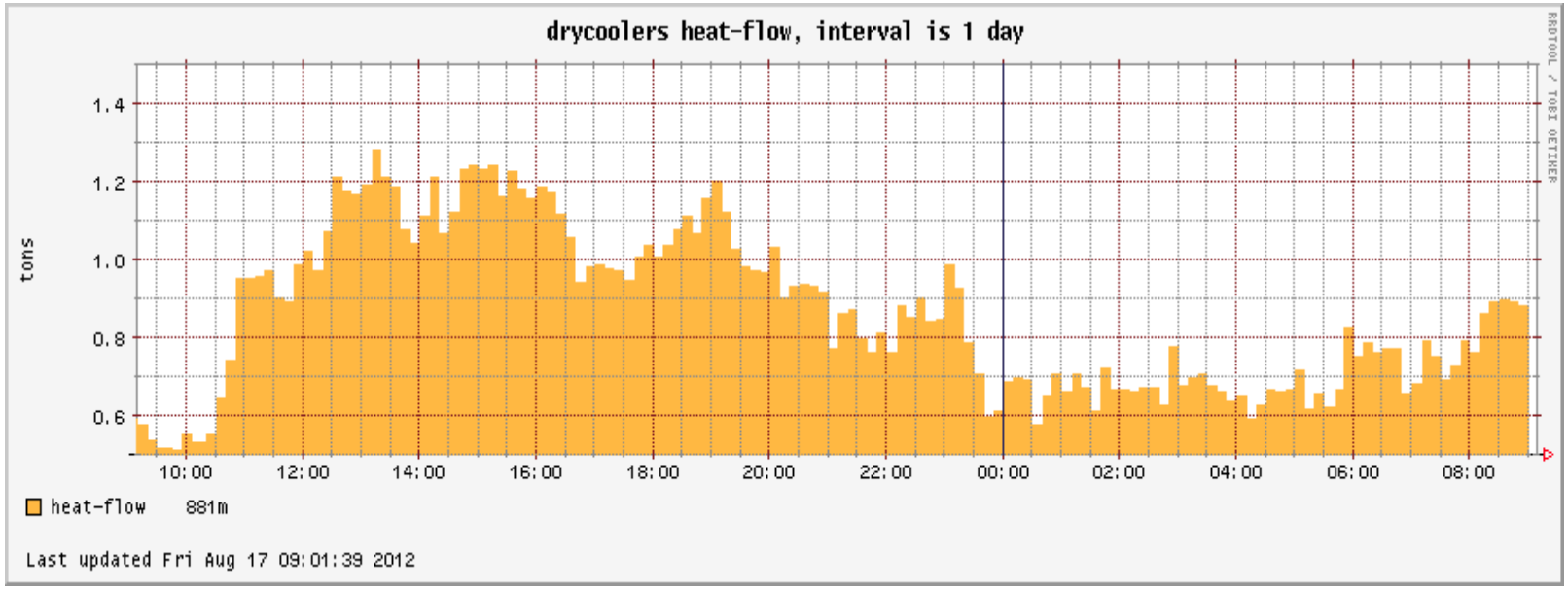

liebert1-6 temp, interval is 1 day
deg F
60
55
50
45
40
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
temp-out 50
temp-in 42
Last updated Fri Aug 17 09:01:39 2012
RRDTOOL / TOBI OETIKER

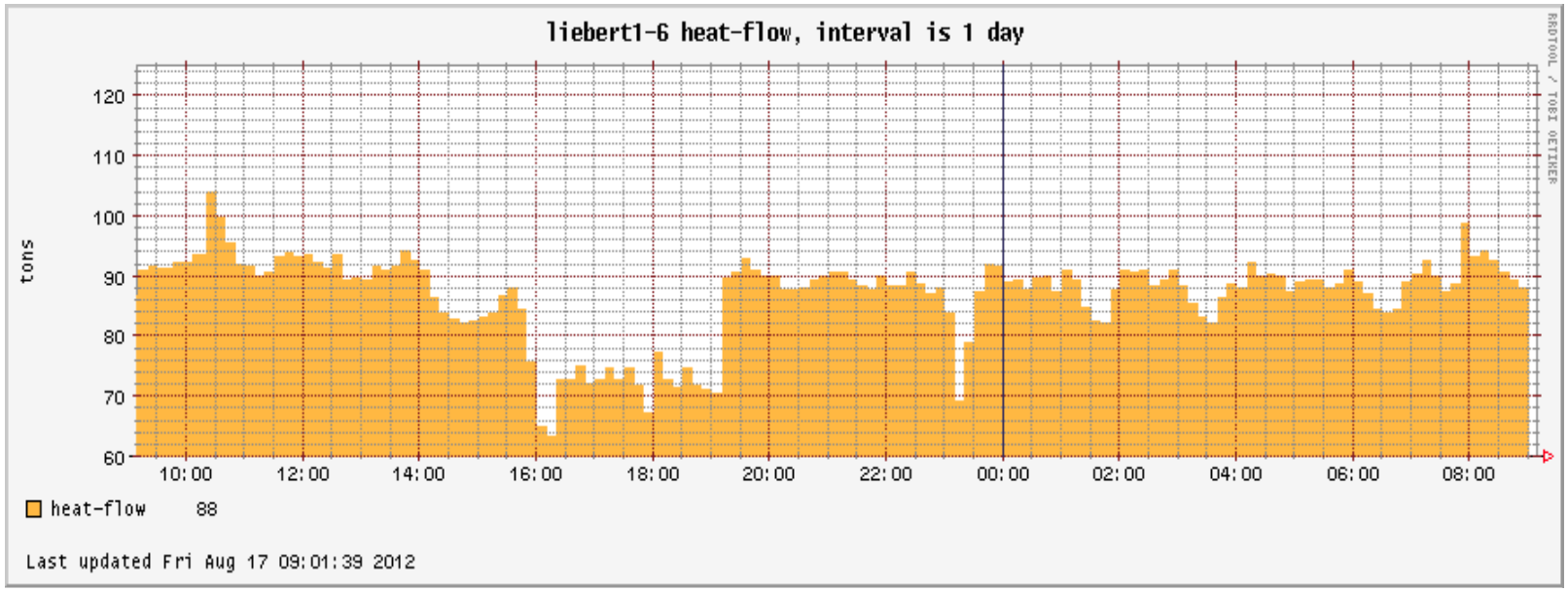

ac1-2 volume-flow, interval is 1 day
Gallons per minute
200
180
160
140
120
100
80
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
volume-flow 138
Last updated Fri Aug 17 09:01:38 2012
RRDTOOL / TOBI OETIKER


drycoolers volume-flow, interval is 1 day
Gallons per minute
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
volume-flow 3
Last updated Fri Aug 17 09:01:39 2012
RRDTOOL / TOBI OETIKER

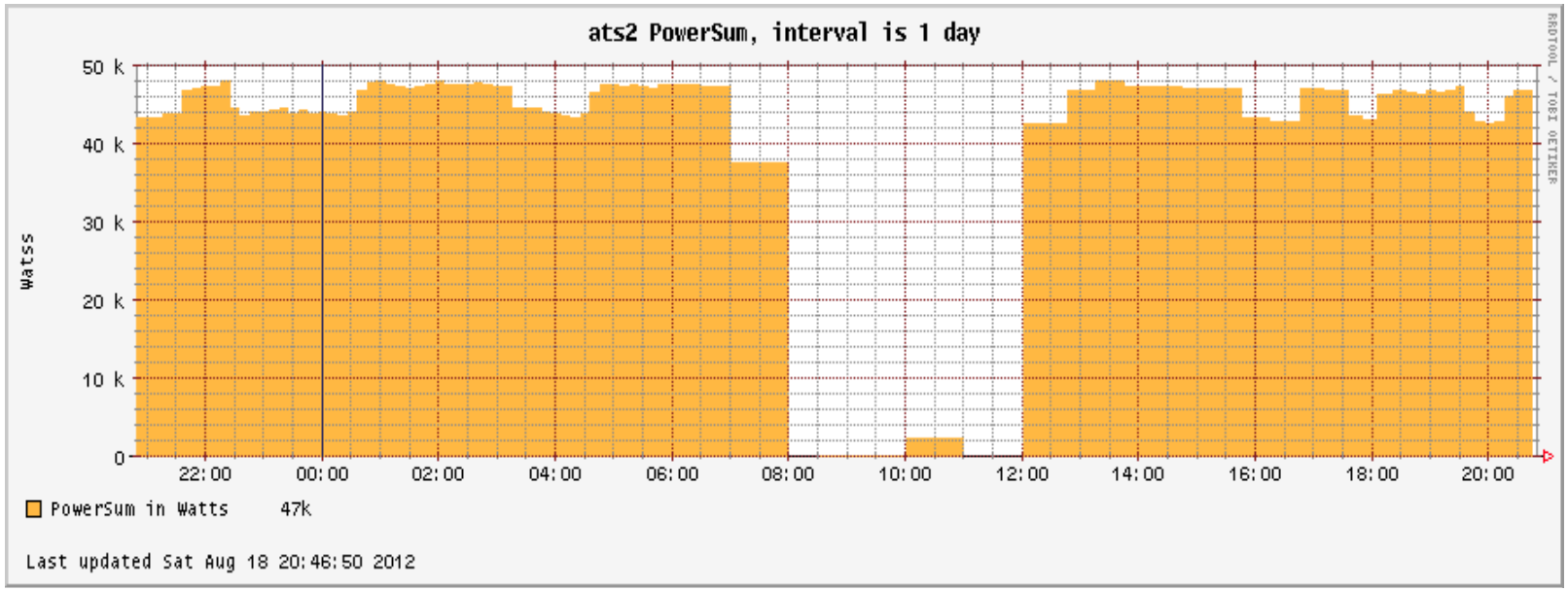

liebert1-6 volume-flow, interval is 1 day
Gallons per minute
400
350
300
250
200
150
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
volume-flow 272
Last updated Fri Aug 17 09:01:39 2012
RRDTOOL / TOBI OETIKER

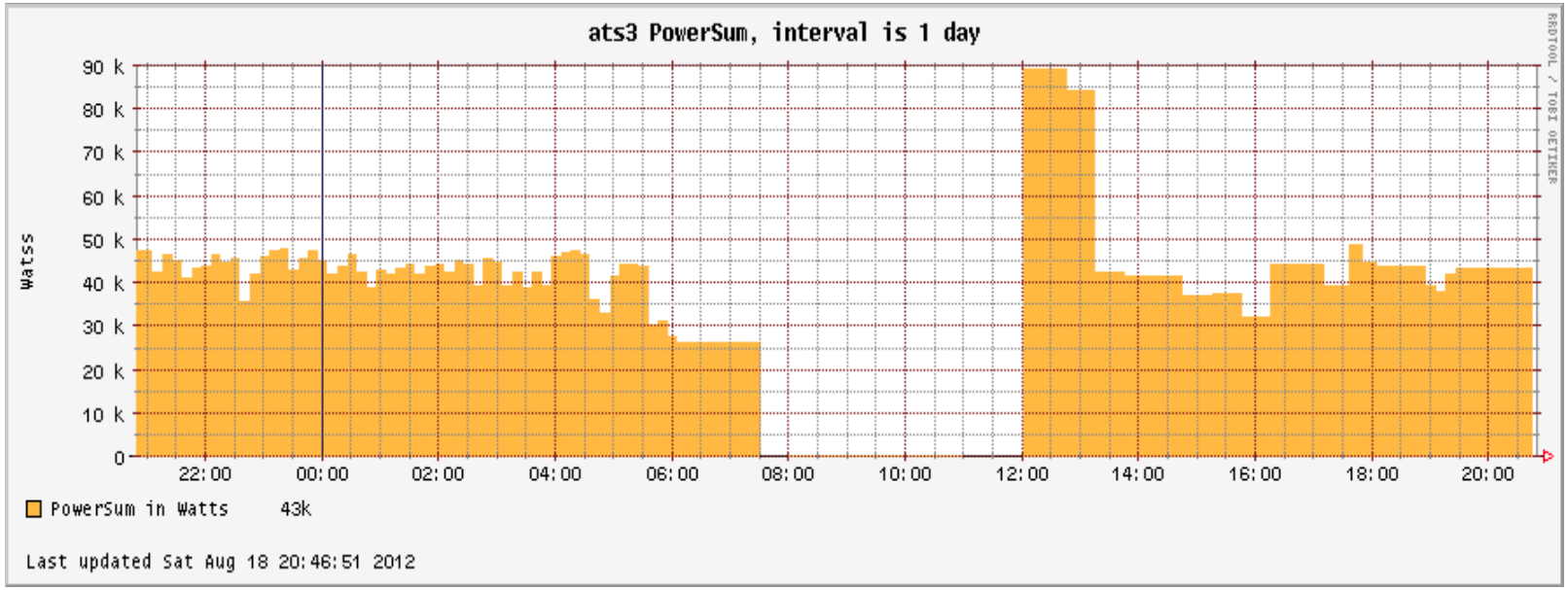

ac1-2 heat-flow, interval is 1 day
tons
30.0
28.0
26.0
24.0
22.0
20.0
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
heat-flow 26
Last updated Fri Aug 17 09:01:38 2012
RRDTOOL / TOBI OETIKER

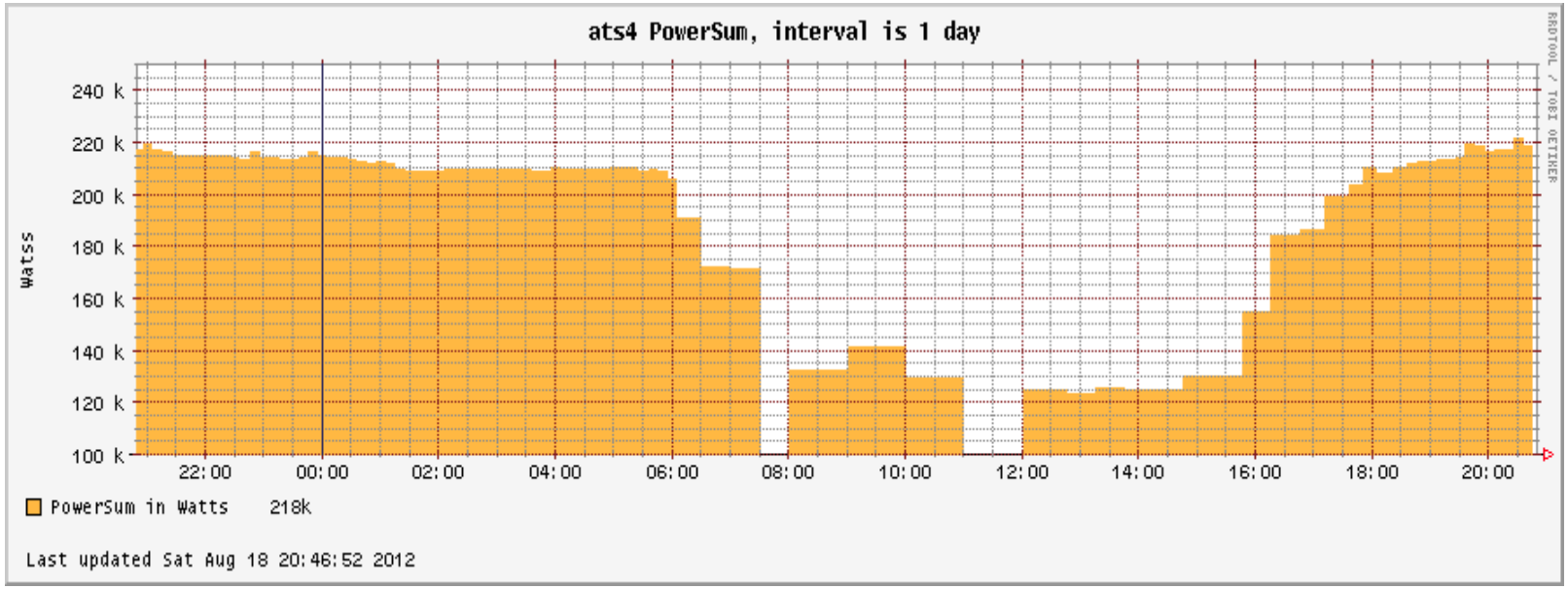

drycoolers heat-flow, interval is 1 day
tons
1.4
1.2
1.0
0.8
0.6
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
heat-flow 881m
Last updated Fri Aug 17 09:01:39 2012
RRDTOOL / TOBI OETIKER

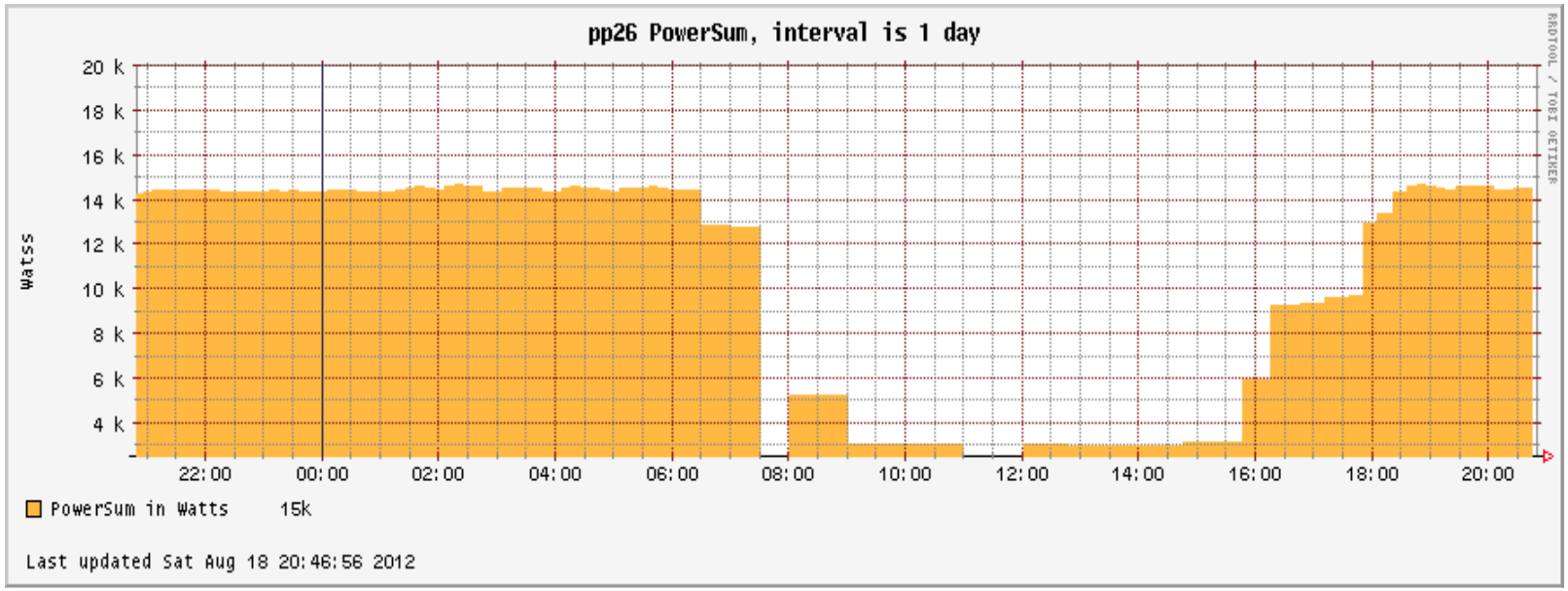

liebert1-6 heat-flow, interval is 1 day
tons
120
110
100
90
80
70
60
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
heat-flow 88
Last updated Fri Aug 17 09:01:39 2012
RRDTOOL / TOBI OETIKER

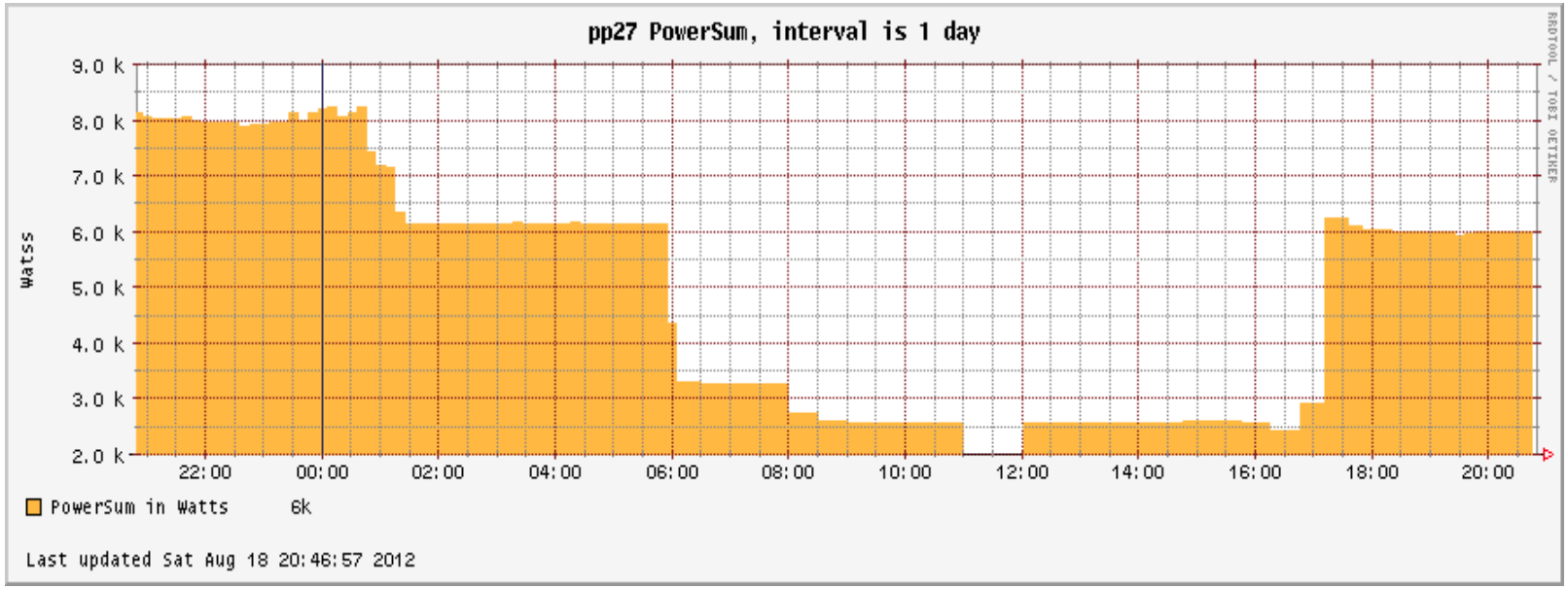
24 hours as of 8:46pm 8/18/12



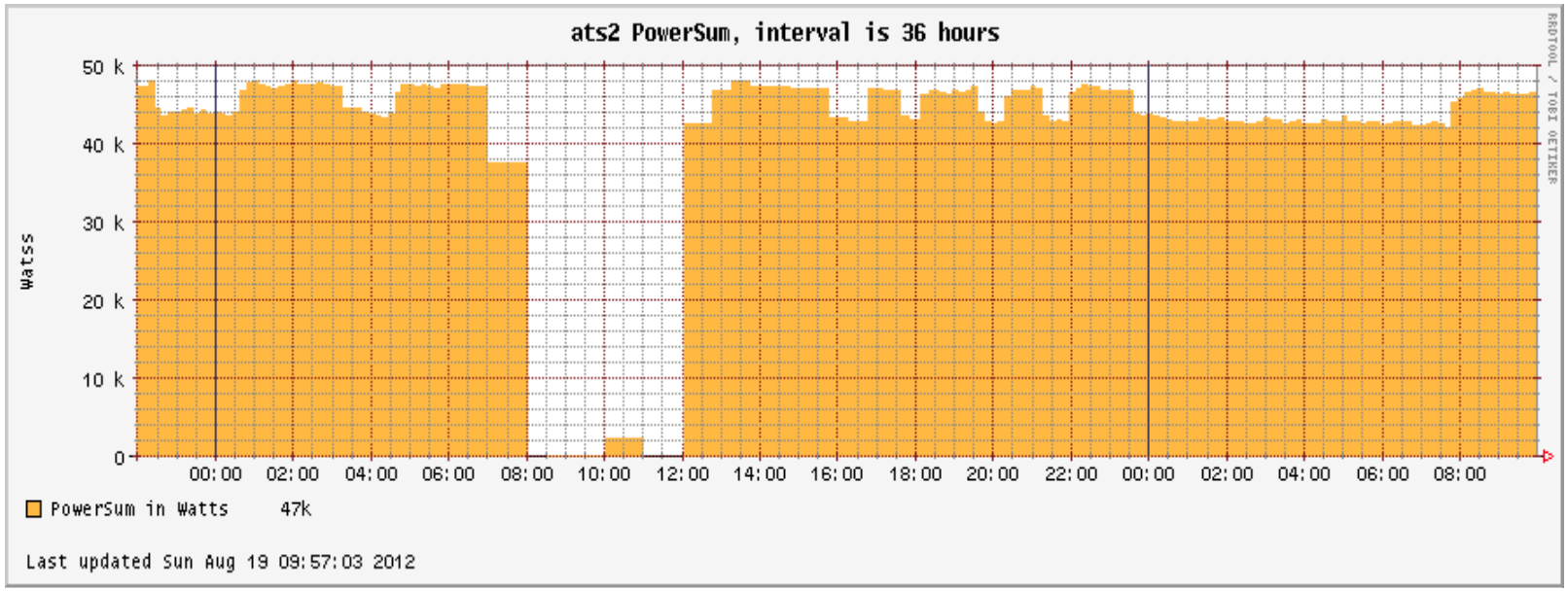


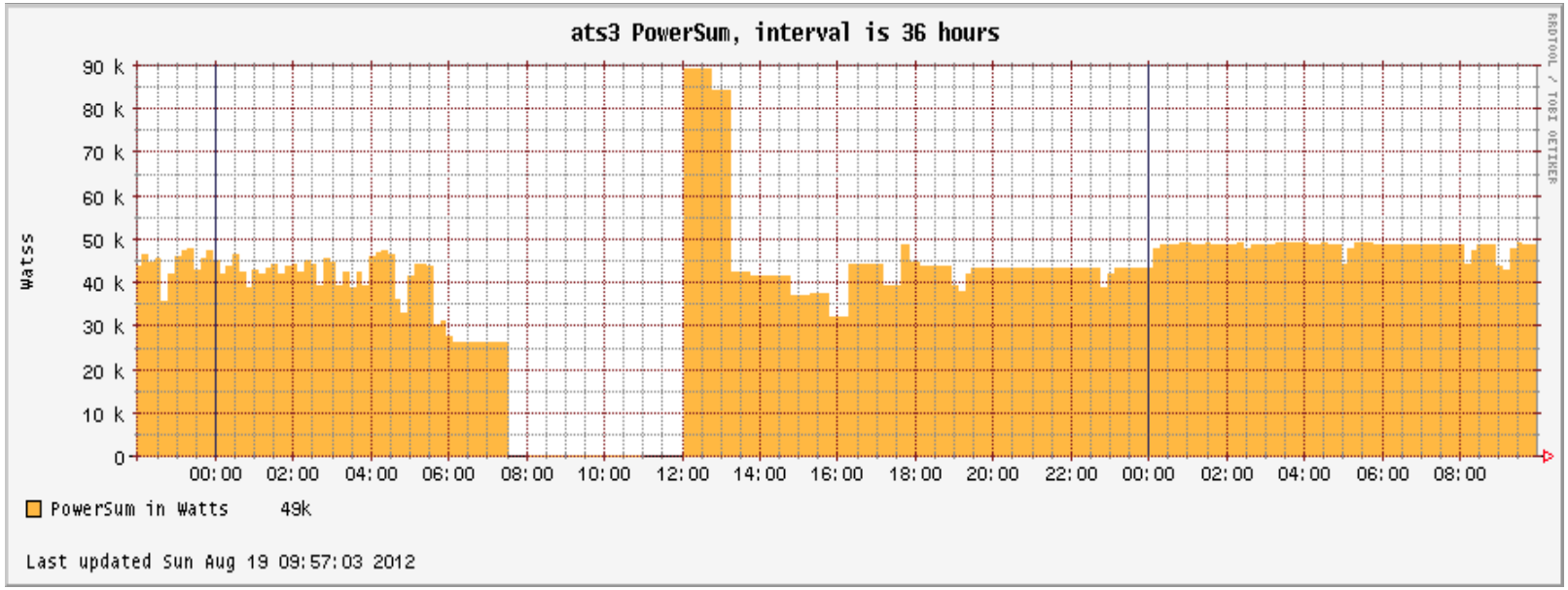

ats4 PowerSum, interval is 1 day
Watss
240 k
220 k
200 k
180 k
160 k
140 k
120 k
100 k
22:00
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
PowerSum in Watts 218k
Last updated Sat Aug 18 20:46:52 2012
RRDTOOL / TOBI OETIKER

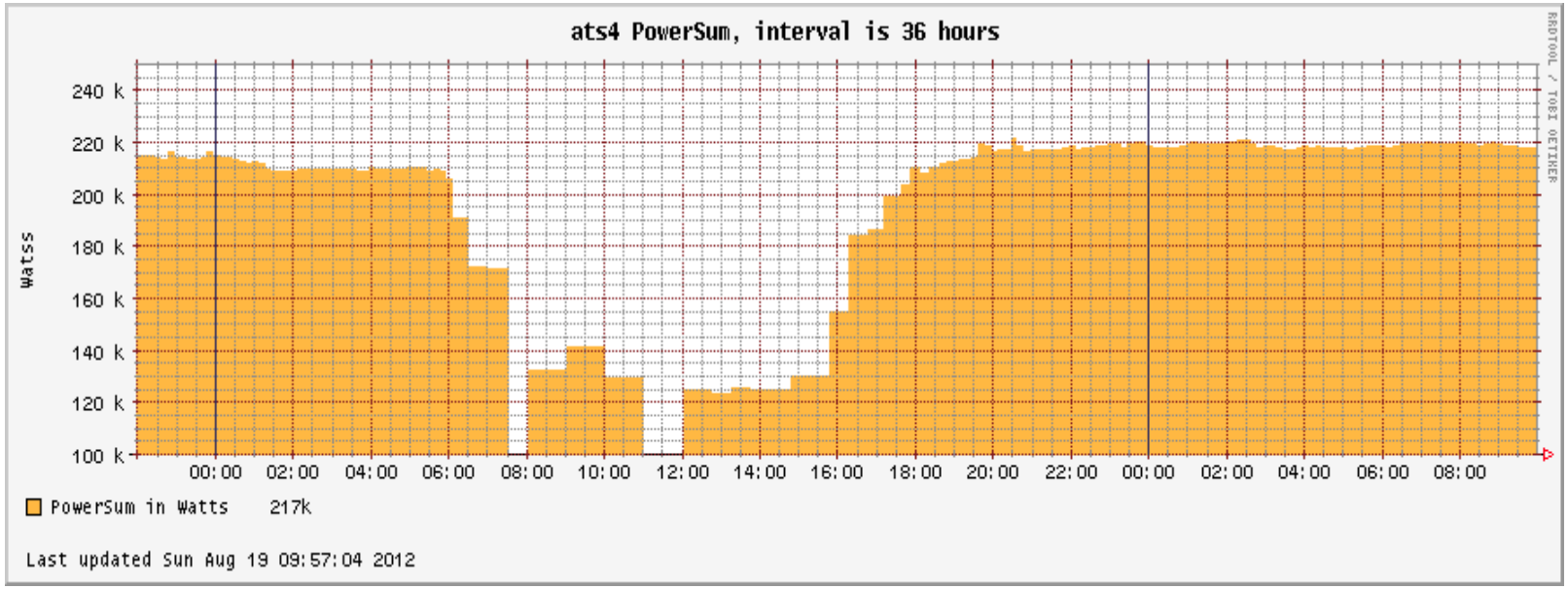

pp26 PowerSum, interval is 1 day
Watss
20 k
18 k
16 k
14 k
12 k
10 k
8 k
6 k
4 k
22:00
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
PowerSum in Watts 15k
Last updated Sat Aug 18 20:46:56 2012
RRDTOOL / TOBI OETIKER

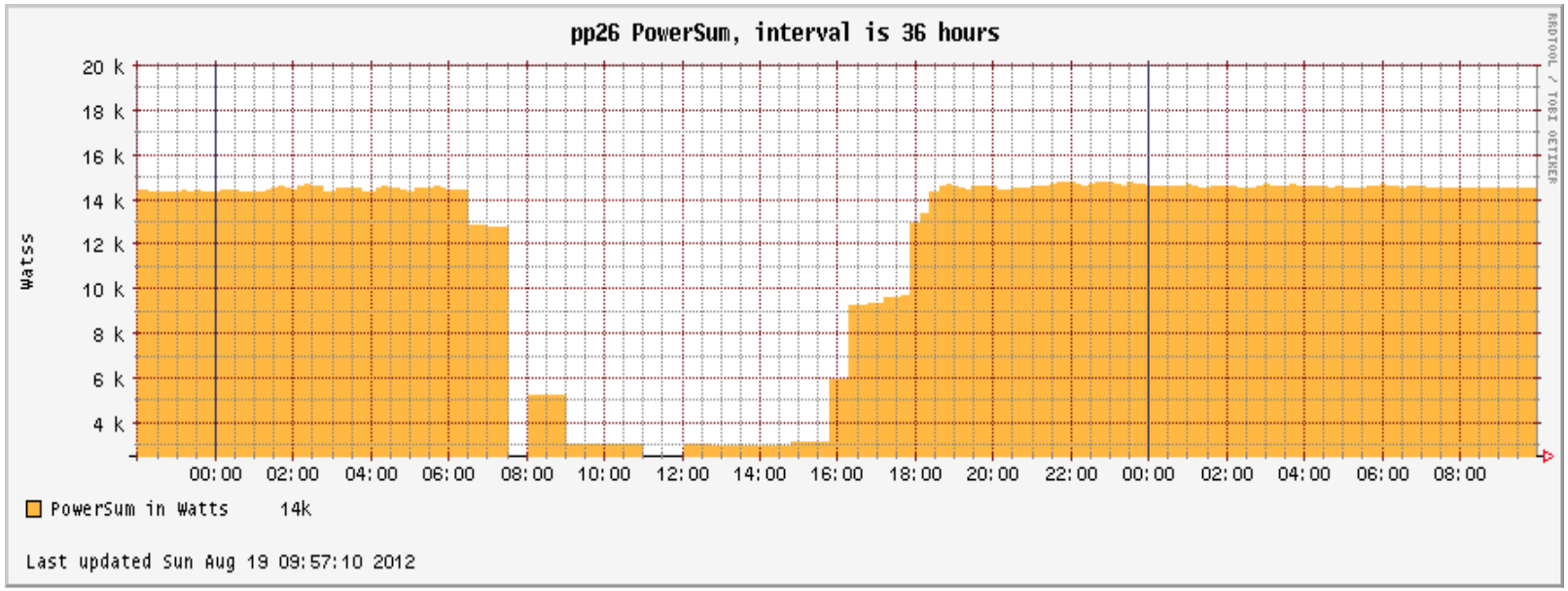

pp27 PowerSum, interval is 1 day
Watss
9.0 k
8.0 k
7.0 k
6.0 k
5.0 k
4.0 k
3.0 k
2.0 k
22:00
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
PowerSum in Watts
6k
Last updated Sat Aug 18 20:46:57 2012
RRDTOOL / TOBI OETIKER

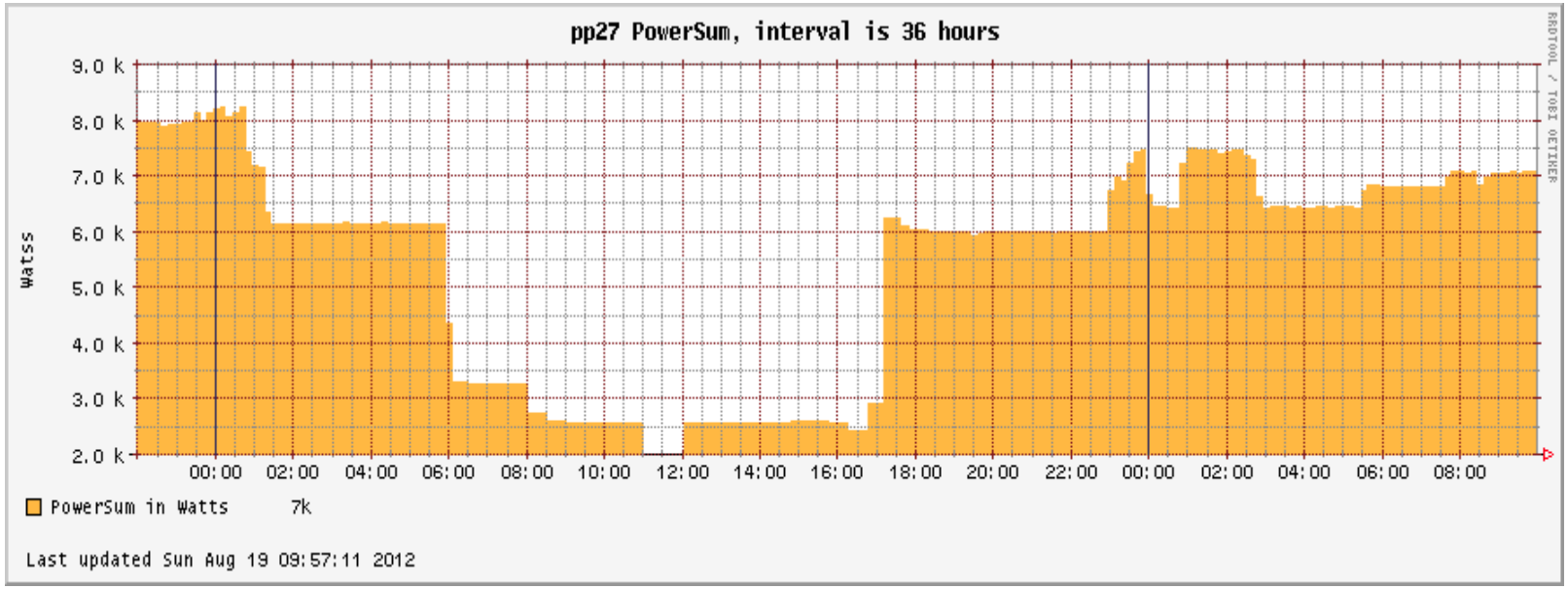
36 hours as of 10:00 8/19/12

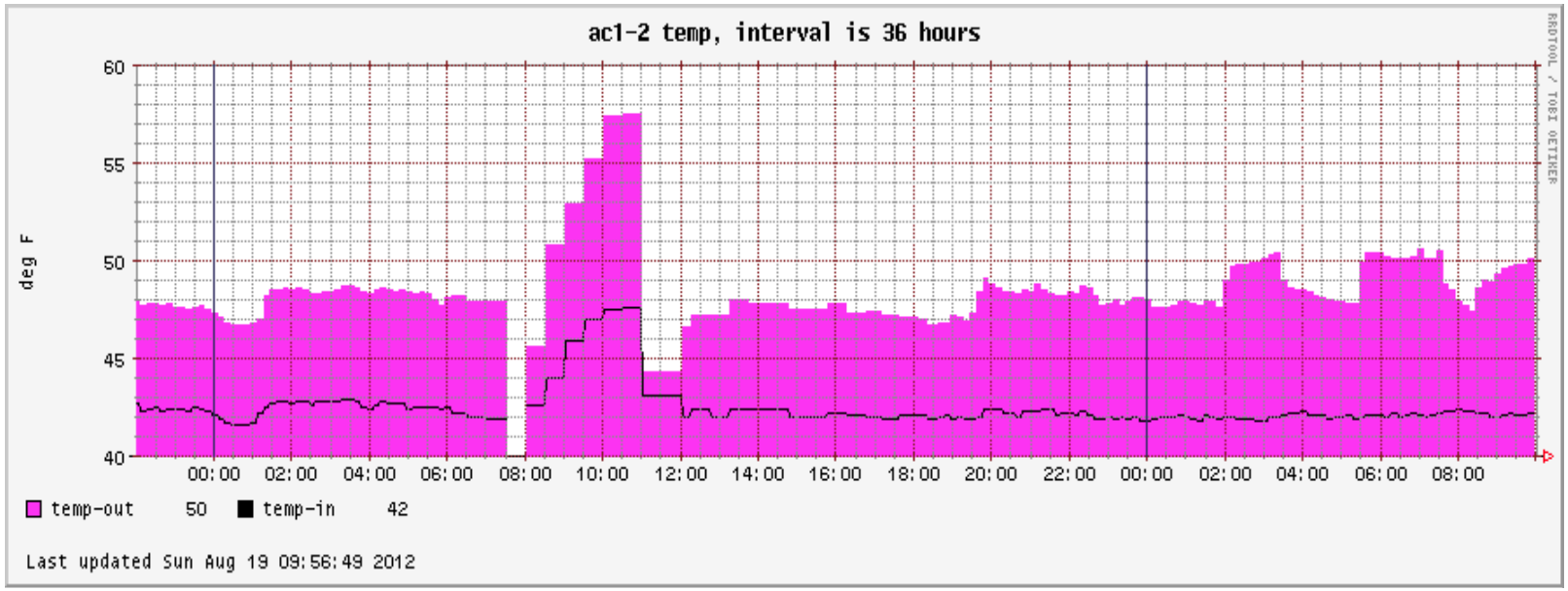


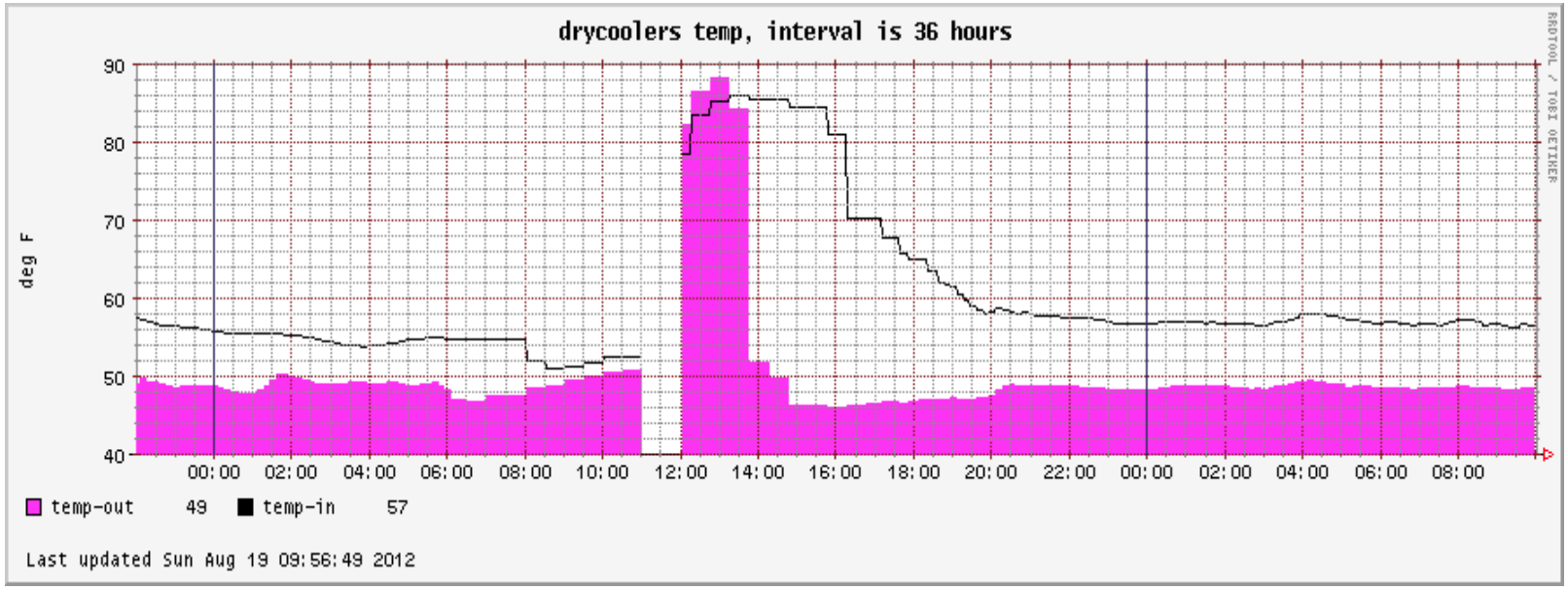


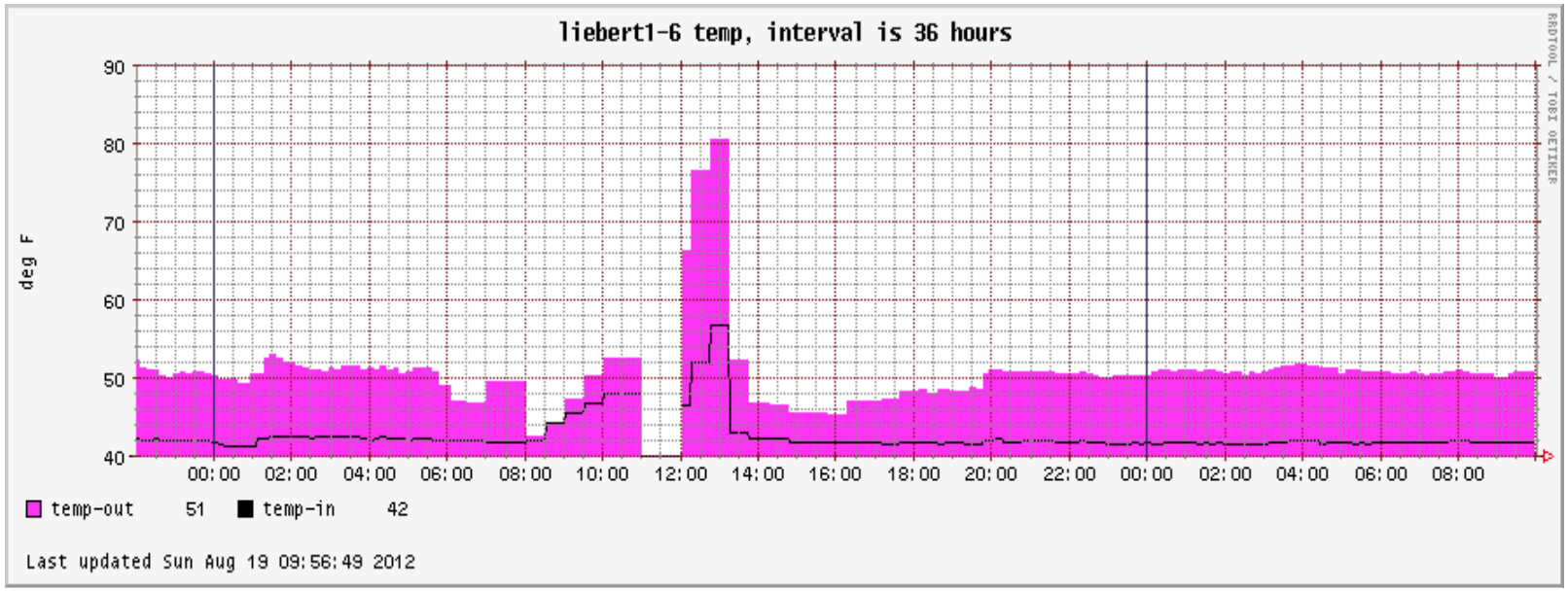

ats4 PowerSum, interval is 36 hours
Watss
240 k
220 k
200 k
180 k
160 k
140 k
120 k
100 k
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
PowerSum in Watts 217k
Last updated Sun Aug 19 09:57:04 2012
RRDTOOL / TOBI OETIKER

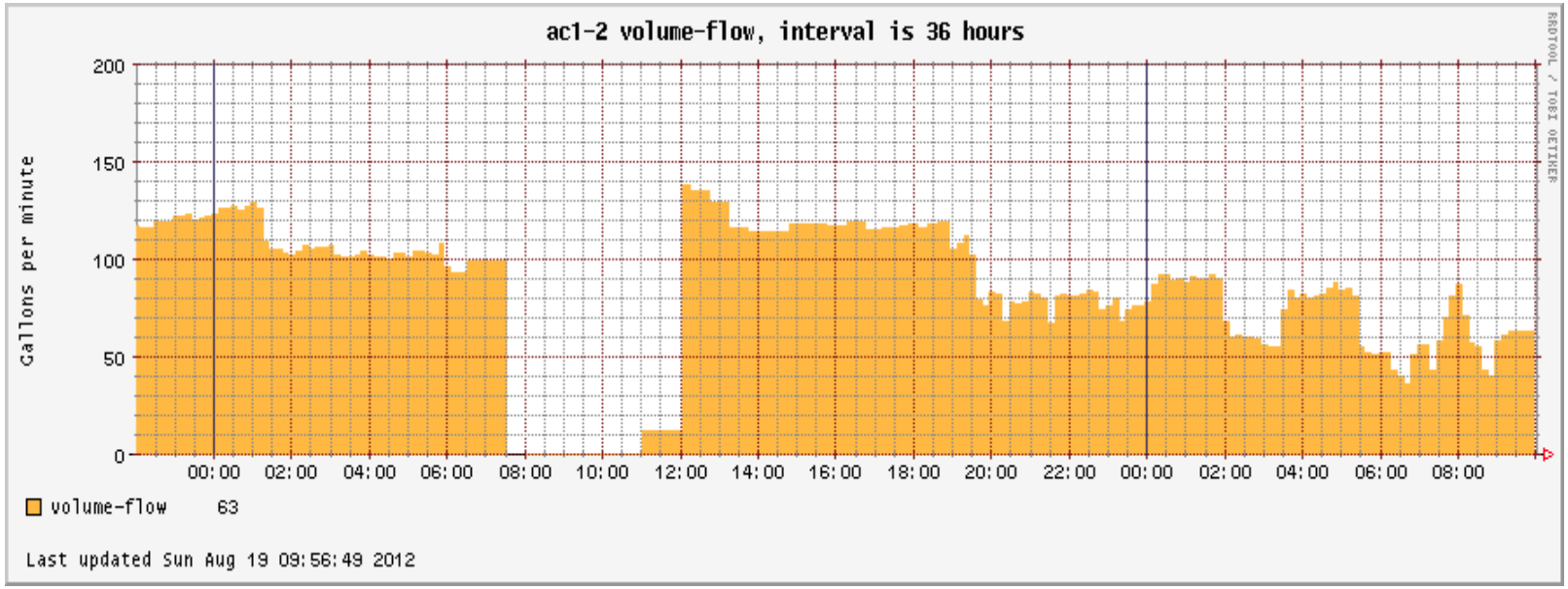

pp26 PowerSum, interval is 36 hours
Watss
20 k
18 k
16 k
14 k
12 k
10 k
8 k
6 k
4 k
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
PowerSum in Watts 14k
Last updated Sun Aug 19 09:57:10 2012
RRDTOOL / TOBI OETIKER

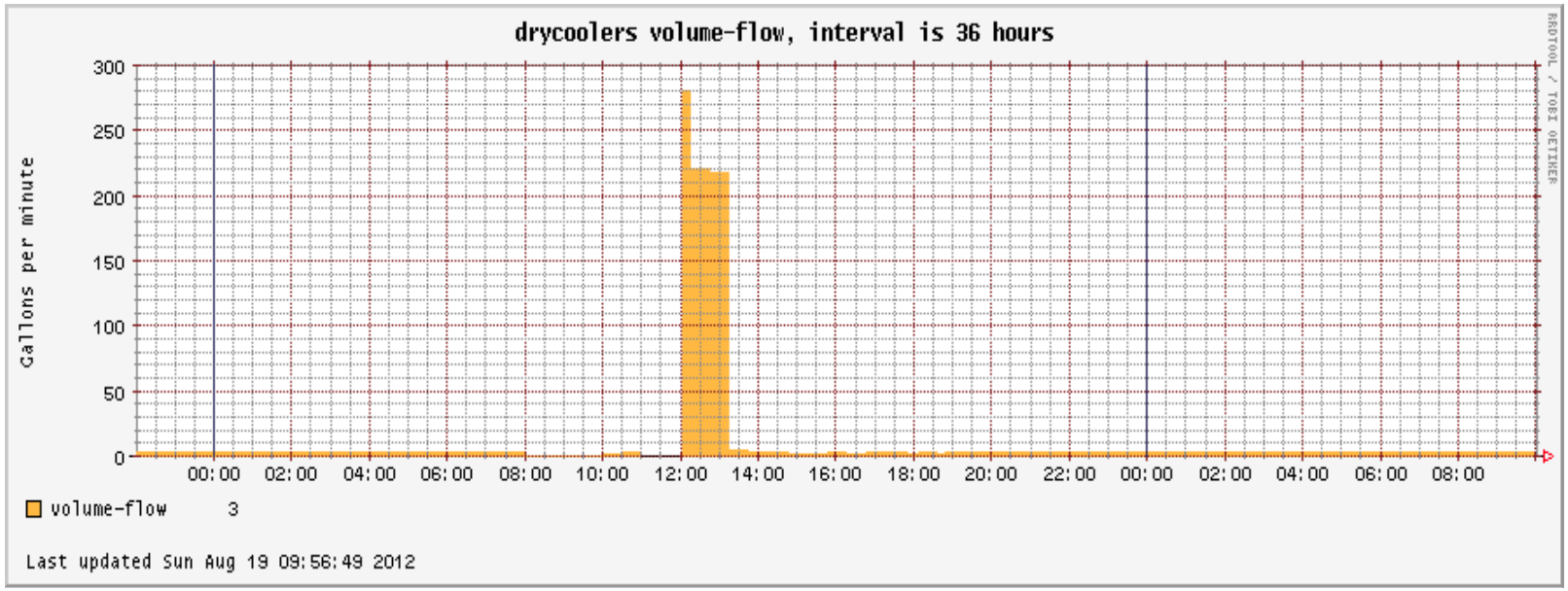

pp27 PowerSum, interval is 36 hours
Watss
9.0 k
8.0 k
7.0 k
6.0 k
5.0 k
4.0 k
3.0 k
2.0 k
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
PowerSum in Watts 7k
Last updated Sun Aug 19 09:57:11 2012
RRDTOOL / TOBI OETIKER

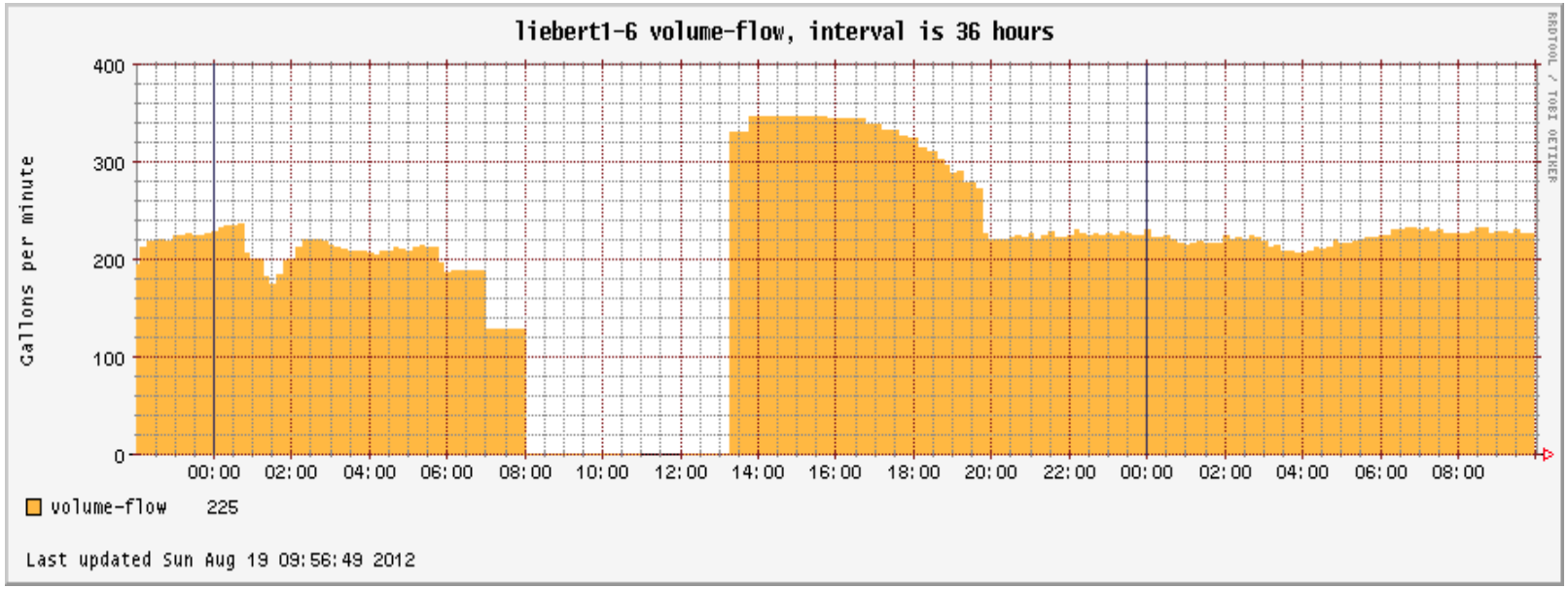

ac1-2 temp, interval is 36 hours
deg F
60
55
50
45
40
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
temp-out 50 temp-in 42
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

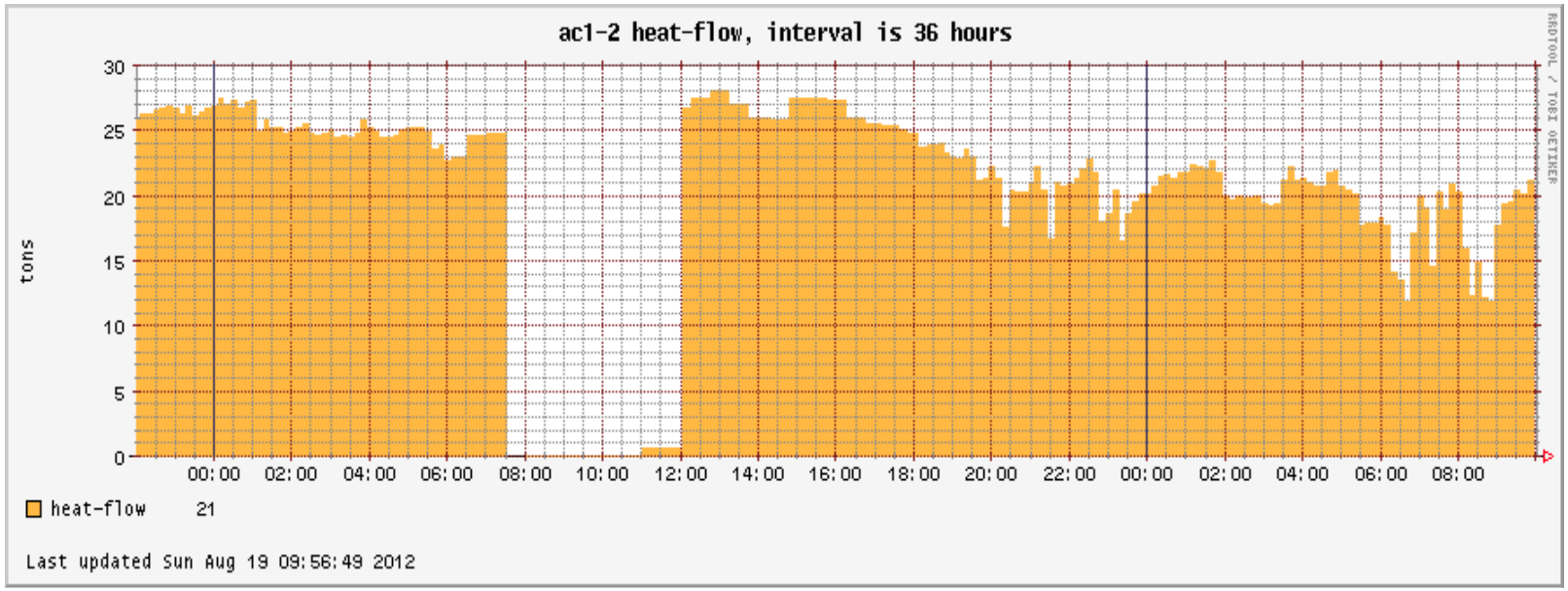

drycoolers temp, interval is 36 hours
deg F
90
80
70
60
50
40
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
temp-out 49
temp-in 57
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

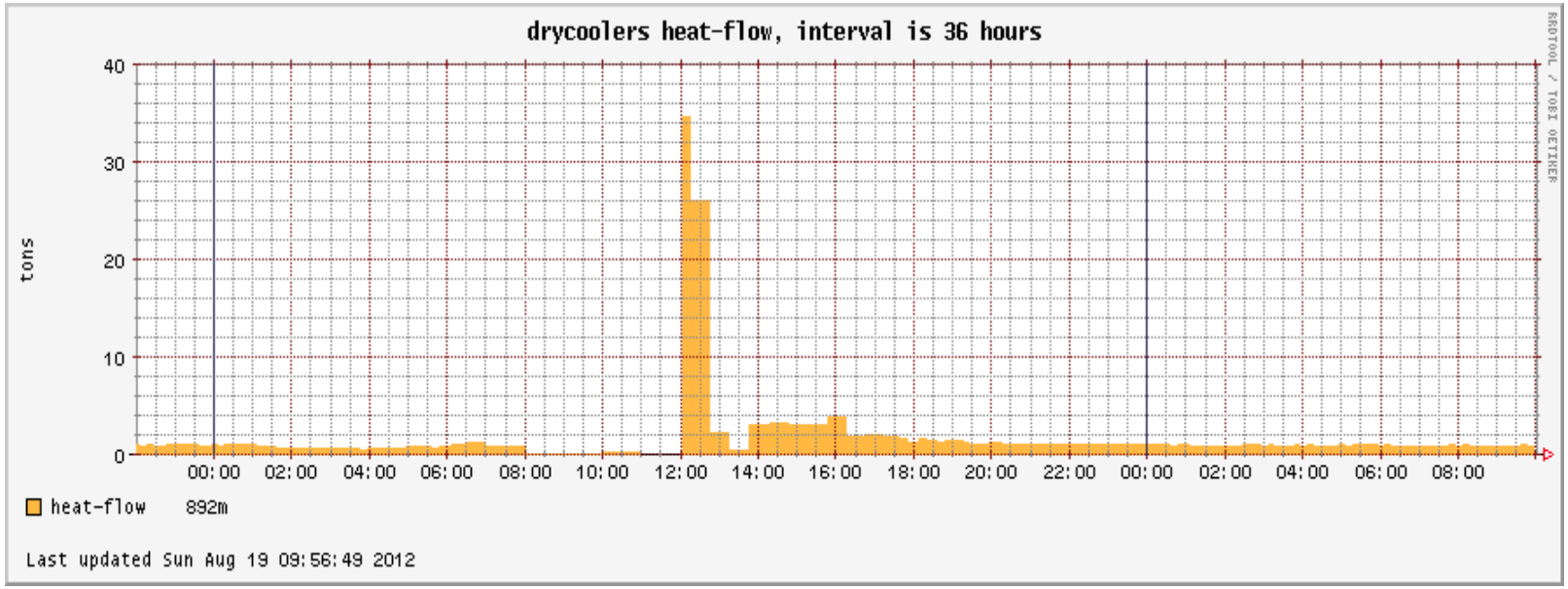

liebert1-6 temp, interval is 36 hours
deg F
90
80
70
60
50
40
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
temp-out 51
temp-in 42
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

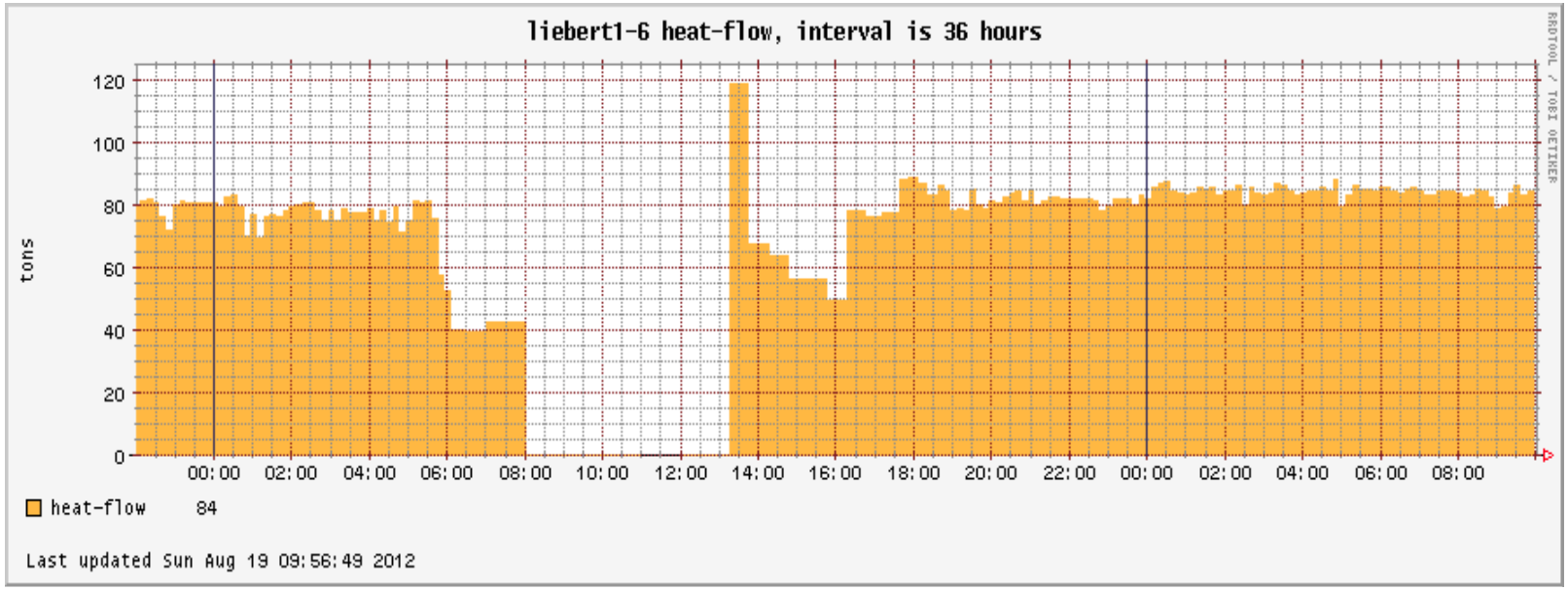

ac1-2 volume-flow, interval is 36 hours
Gallons per minute
200
150
100
50
0
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
volume-flow 63
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

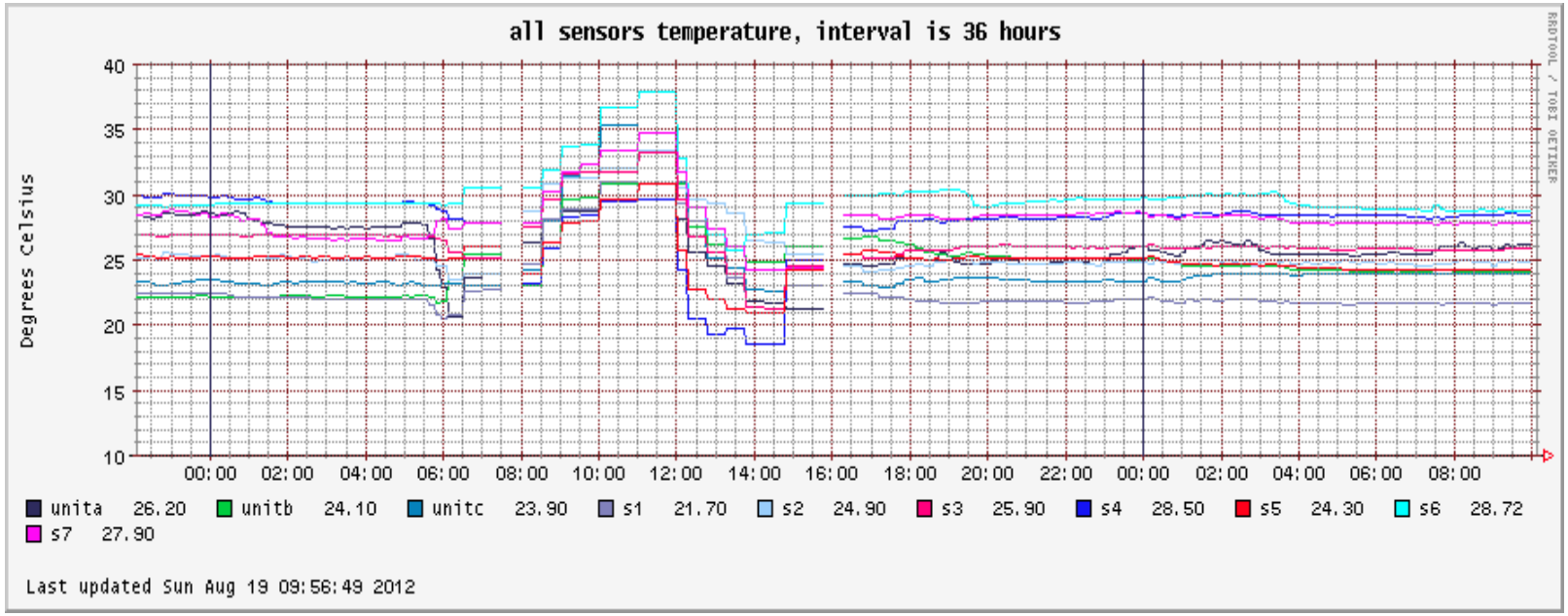

drycoolers volume-flow, interval is 36 hours
Gallons per minute
300
250
200
150
100
50
0
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
volume-flow 3
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

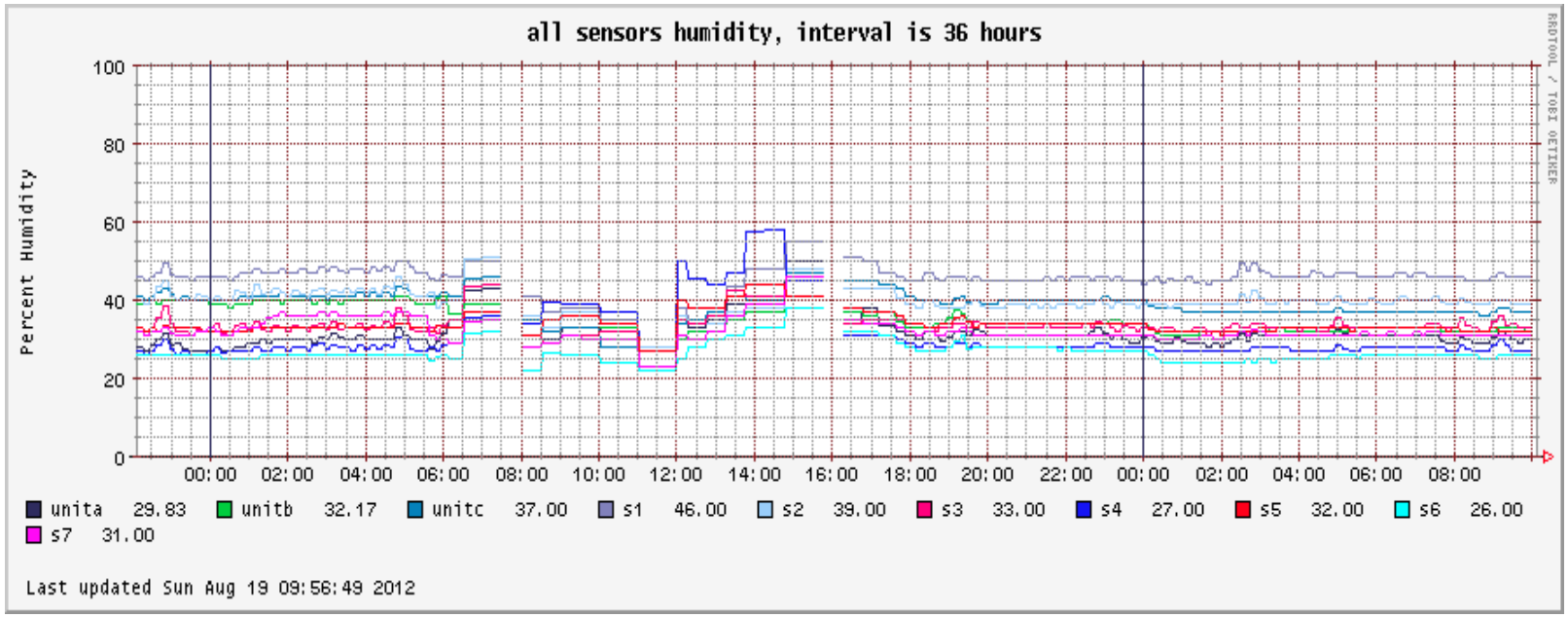

liebert1-6 volume-flow, interval is 36 hours
Gallons per minute
400
300
200
100
0
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
volume-flow 225
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

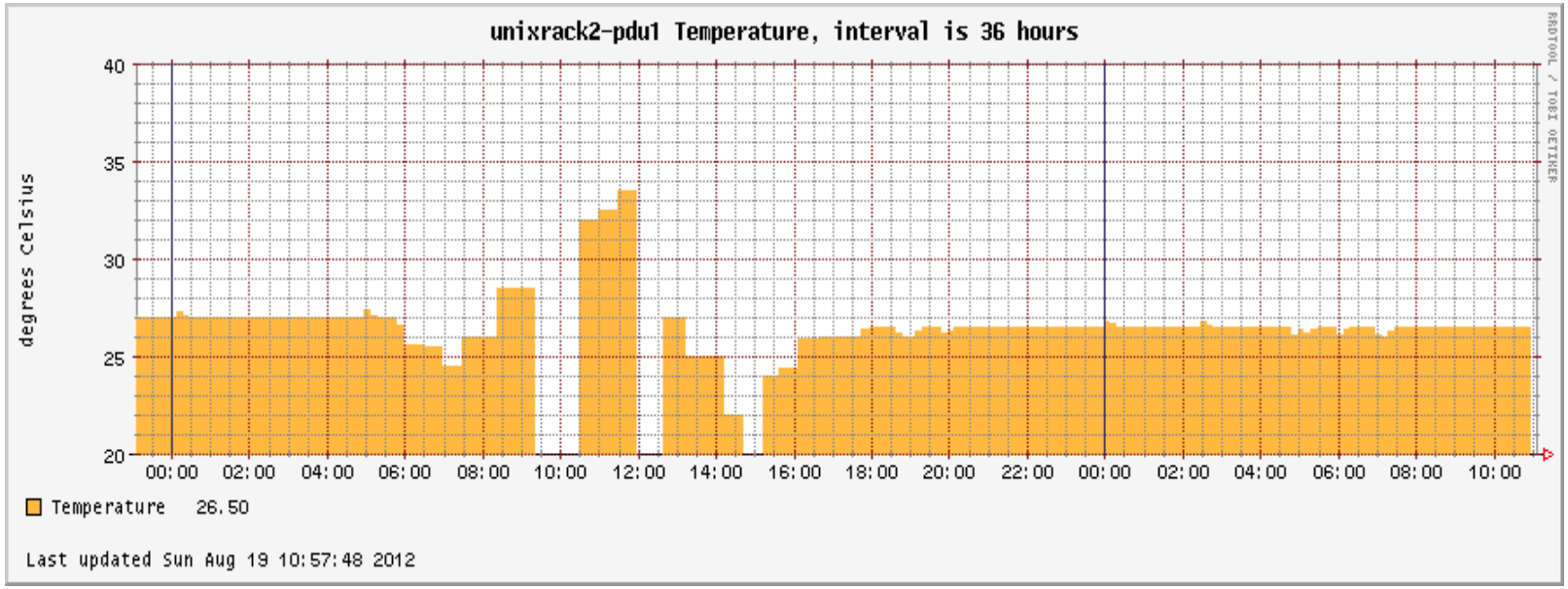

ac1-2 heat-flow, interval is 36 hours
tons
30
25
20
15
10
5
0
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
heat-flow 21
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

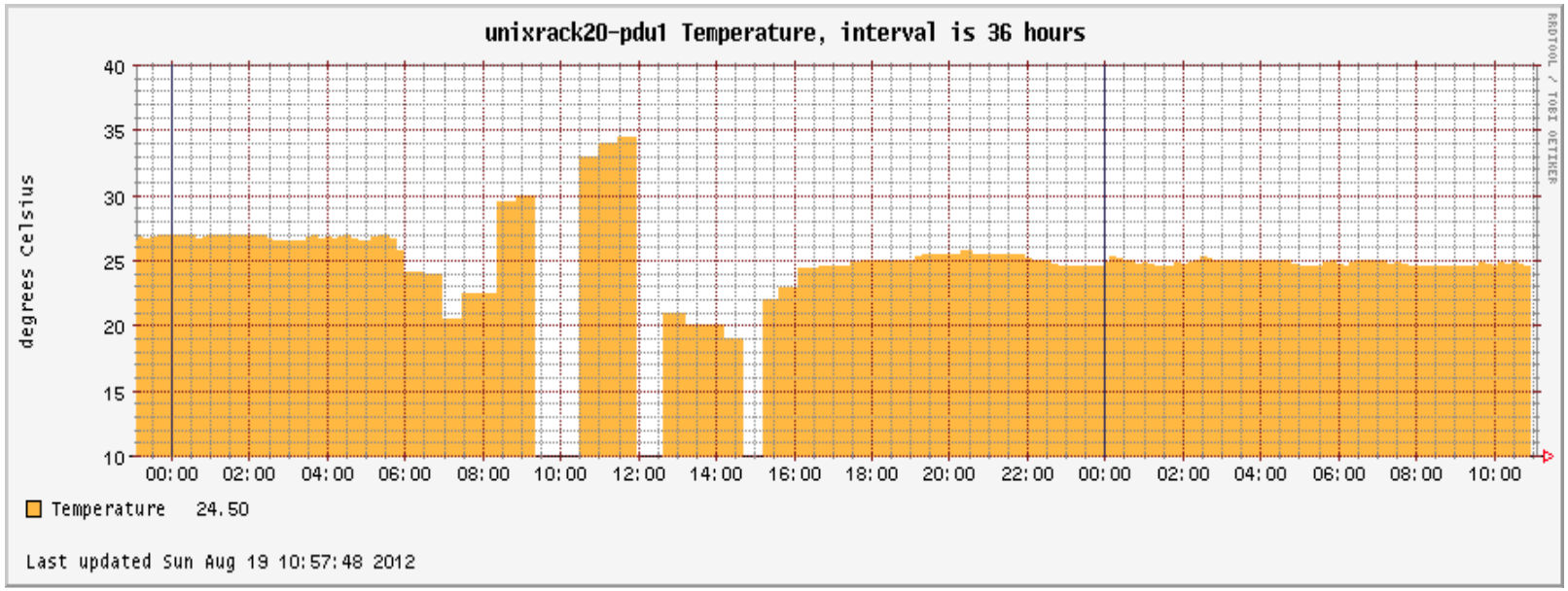

drycoolers heat-flow, interval is 36 hours
tons
40
30
20
10
0
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
heat-flow 892m
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

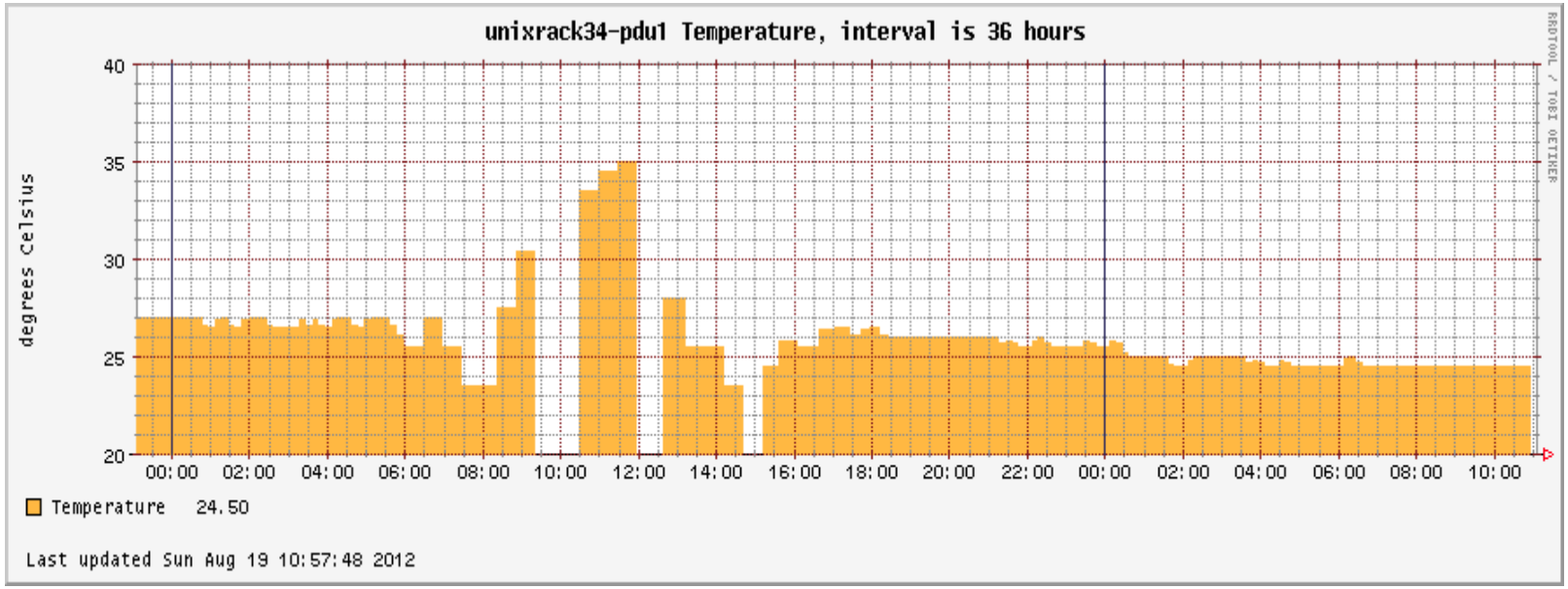

liebert1-6 heat-flow, interval is 36 hours
tons
120
100
80
60
40
20
0
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
heat-flow 84
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

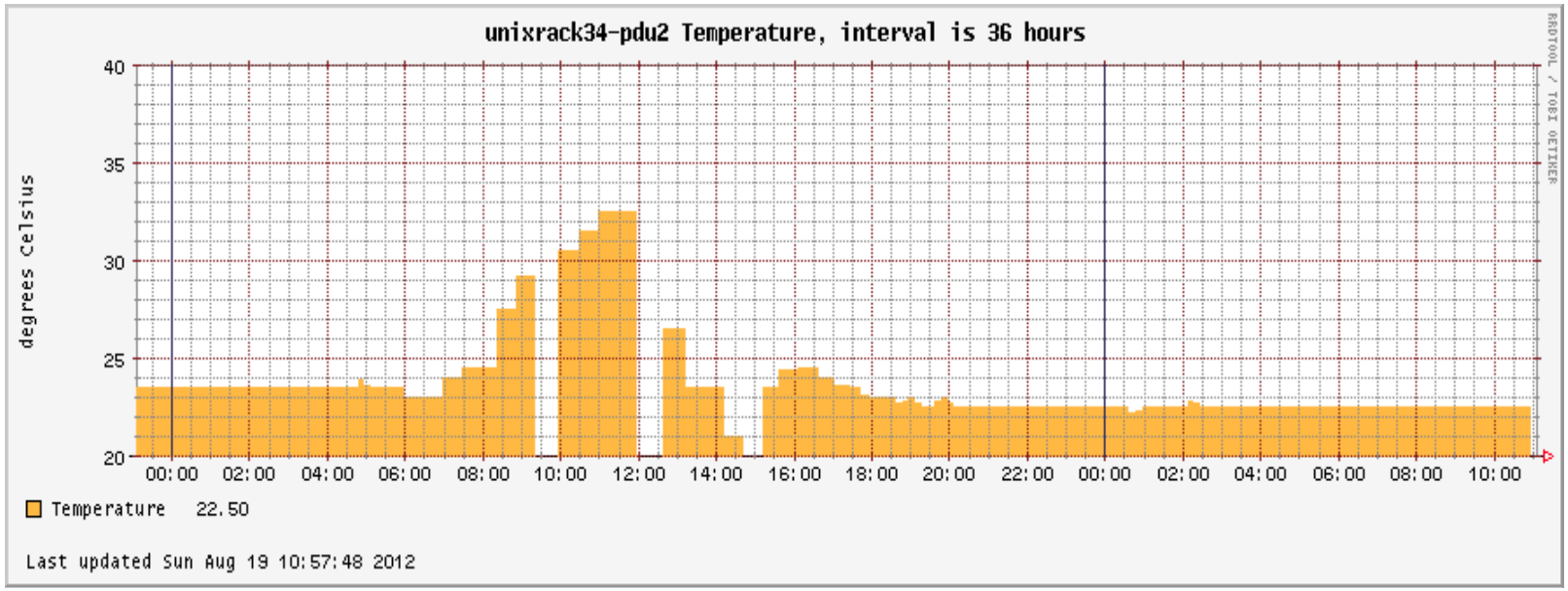

all sensors temperature, interval is 36 hours
Degrees Celsius
40
35
30
25
20
15
10
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
unita 26.20 unitb 24.10 unitc 23.90 s1 21.70 s2 24.90 s3 25.90 s4 28.50 s5 24.30 s6 28.72
s7 27.90
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER

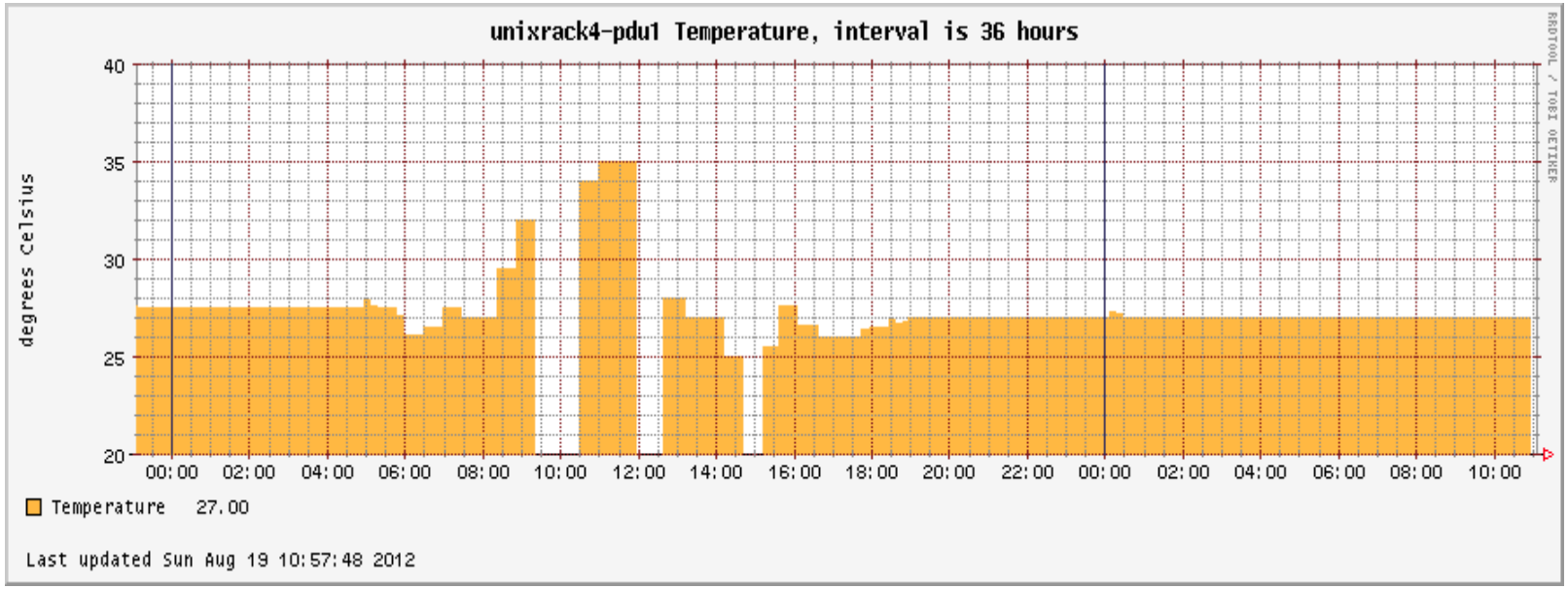

all sensors humidity, interval is 36 hours
Percent Humidity
100
80
60
40
20
0
00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00
unita 29.83 unitb 32.17 unitc 37.00 s1 46.00 s2 39.00 s3 33.00 s4 27.00 s5 32.00 s6 26.00
s7 31.00
Last updated Sun Aug 19 09:56:49 2012
RRDTOOL / TOBI OETIKER


unixrack2-pdu1 Temperature, interval is 36 hours
degrees Celsius
40
35
30
25
20
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
10:00
Temperature 26.50
Last updated Sun Aug 19 10:57:48 2012
RRDTOOL / TOBI OETIKER

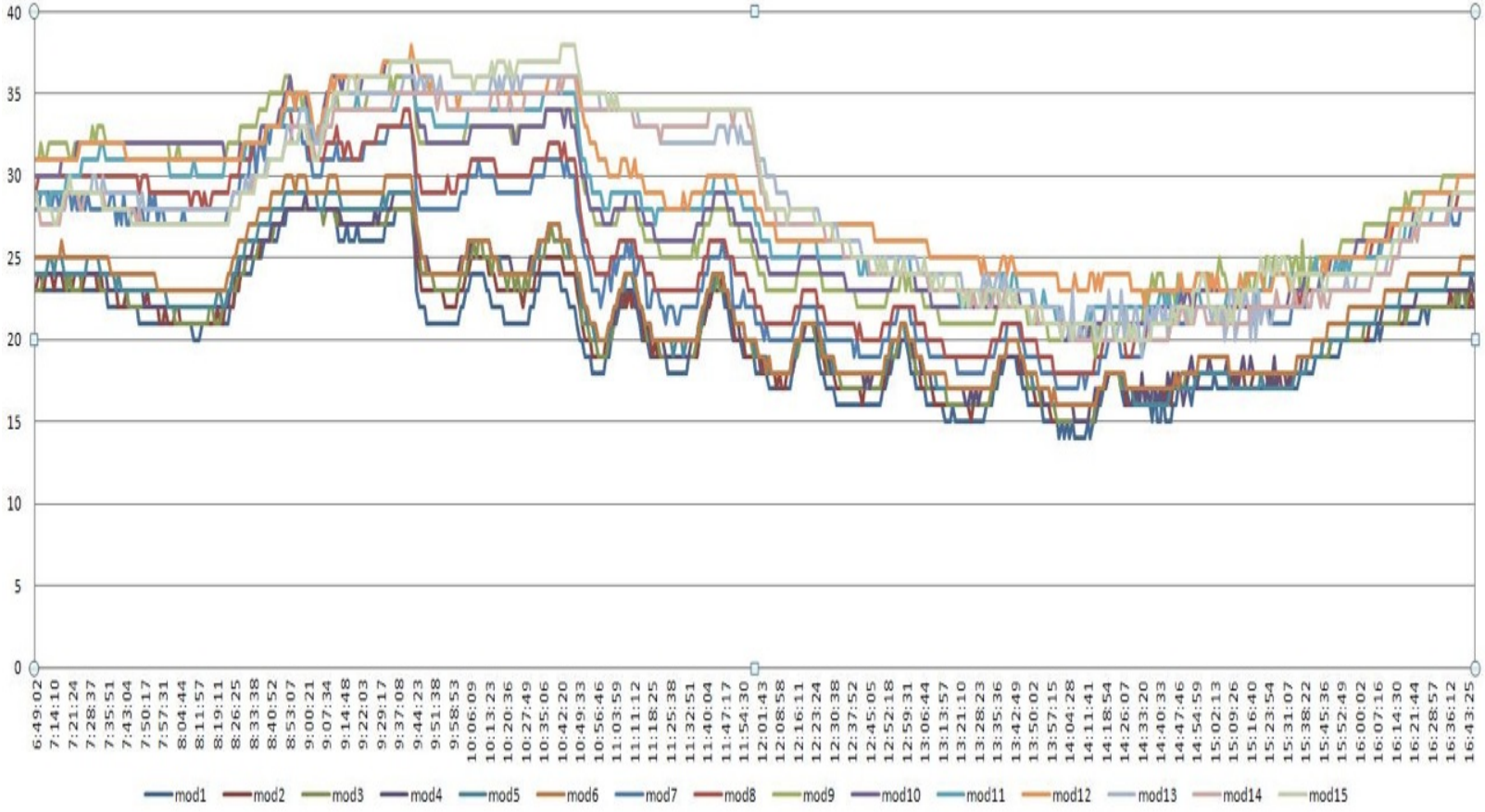
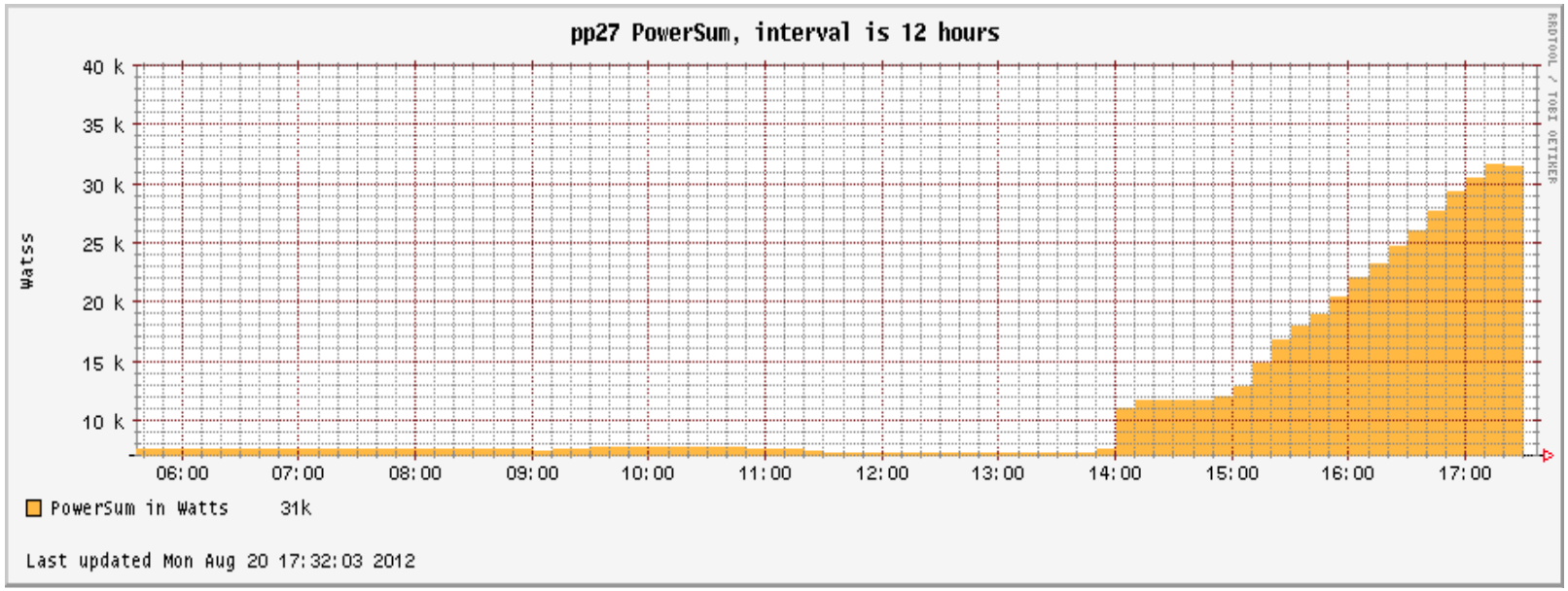

unixrack20-pdu1 Temperature, interval is 36 hours
degrees Celsius
40
35
30
25
20
15
10
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
10:00
Temperature 24.50
Last updated Sun Aug 19 10:57:48 2012
RRDTOOL / TOBI OETIKER


unixrack34-pdu1 Temperature, interval is 36 hours
degrees Celsius
40
35
30
25
20
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
10:00
Temperature 24.50
Last updated Sun Aug 19 10:57:48 2012
RRDTOOL / TOBI OETIKER


unixrack34-pdu2 Temperature, interval is 36 hours
degrees Celsius
40
35
30
25
20
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
10:00
Temperature 22.50
Last updated Sun Aug 19 10:57:48 2012
RRDTOOL / TOBI OETIKER


unixrack4-pdu1 Temperature, interval is 36 hours
degrees Celsius
40
35
30
25
20
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
10:00
Temperature 27.00
Last updated Sun Aug 19 10:57:48 2012

XIV Module Temperature
August 18, 2012



Final tenant system - EE cluster - restored 8/20/12