Root Cause Analysis for PBI000000000256

GCC CRB Cooling Failure on 7 June, 2011

Report submitted August 6, 2011

(CD-doc-4366)

Summary of Incident

List of related Incident tickets:

- INC000000086503

Background Concepts

- The following points are useful in understanding the nature and impact of this problem:
  - There are ten Computer Room Air Conditioner (CRAC) units, numbers 13 to 22, in GCC Computer Room B (CRB). Each CRAC contains a pair of pair of compressor stages, and each stage can operate at half or full capacity.
  - Each CRAC exchanges a heat-transfer fluid with a condenser outside the building, on its Northwest side. Each condenser has four fans on its underside, of which 0 to 4 may operate at any time, pulling air upward to remove heat from the circulating fluid and condense it. The condensers for CRB and CRC stand in a row behind GCC.
  - Computer racks in CRB are in six rows of 14 racks. Each row is split into a north and a south half-row by two electrical panels. Each of those panels supplies power to the six nearest racks in one half-row. The seventh, outermost rack in each half-row is powered from the panel in the north wall or the panel in the south wall.

Timeline

This is a partial timeline for the service disruption and restoration.

<u>Monday, June 6, 2011</u>

- CRAC 15 exhibited problems. It was serviced by Emerson and put back in operation by noon on June 7.

<u>Tuesday, June 7</u>

- 2:09 PM CRAC 15 fails. Temperatures at various points in CRB begin to rise 5° F in the following hour. (See CD-Doc 4359.)
- 2:29 PM Two cooling units have problem alerts.

- 2:42 PM Service provider dispatched from FCC to GCC.
- 2:47 PM Other cooling units have problem alerts. CRACs are reset in succession, but shut themselves off again.
- 3:05 PM CRB temperatures begin to rise more sharply: one cold aisle measurement point increased by 18° F in the following five minutes.
- 3:15 PM (apx.) Shut down one half row.
- 3:18 PM (apx) Shut down other specific racks.
- 3:25 PM Lost all cooling; shut down all computing. Temperatures in CRB begin to fall.
- 5:25 PM Partially restored operation to 60% of prior power consumption.

Thursday, June 9

- 6:10 AM All CRB systems are powered on. Normal operation resumes.

A more detailed time line is in the Critical Incident Report, found as Work Info in ticket INC 86503 and as an “Other File” in CD-doc-4366.

Analysis

On seven days in the summer of 2010, individual CRAC units in GCC CRB failed with “HIGH HEAD” alarms. This indicates a high return pressure or temperature in the heat-transfer fluid coming from the condenser. We obtained weather records from the Fermilab ES&H section’s archive and looked for environmental factors that were correlated with cooling failures. We identified the following correlative variables.

- Average temperature > 75° F
- Maximum temperature > 87° F
- Minimum temperature > 65° F
- Average daytime Solar radiation > 276 W/m^2
- Average wind speed < 7 mi/hr

On Tuesday, June 7, 2011 at 13:00, the temperature recorded at Fermilab’s weather station was 93.2° F (day’s average 83.3° F) with insolation of 876 W/m^2 (day’s average 313 W/m^2). The average wind speed for the day was 9.6 mi/hr.

Given our limited data set (seven failures in 2010, at a lower room heat load, and two in 2011) we did not try to develop a sharp predictive model based on weather.

The load shed plan was invoked on July 19. The recorded conditions that day were peak temperature 94.3° F (average 84.7° F), peak insolation 834 W/m^2 (average 288 W/m^2), and average wind speed 4.9 mi/hr.

Investigations of cooling inefficiency in 2010 discovered that quite a bit of the air blown upward through the condensers by the fans was recirculating around the condenser and back up through the fans. Four-foot chimneys were added on the condensers to combat the recirculation. The “smoke test” that had revealed the recirculation was not repeated after installation of the chimneys.

Condensers for CRB and CRC, behind GCC

The photograph above suggests several reasons for the poor performance of the condensers in hot, sunny weather with still air.

- The air intake is low to the ground, possibly restricting flow.
- The condensers are flanked by the building and a berm.
- The condensers are close together.

Not visible in this picture, but evident by visit to the site, are

- The concrete pad under the condensers gets very hot.
- High foliage was present before the June, 2011 incident and cut afterward.
- Air in the space between the condensers and the building gets very hot!

Our provider of air conditioning services, Emerson, has provided performance modeling which shows a fairly linear decrease in CRAC cooling capacity as condenser air intake temperature rises from 95° F to 115° F. Cooling failure occurs at approximately 120° F intake temperature.

Direct Cause

The direct cause of the cooling failure was the failure of the condensers to return sufficiently cool, low-pressure, liquified circulating fluid to the CRACs. The placement of the condensers: close together, low to the ground, and flanked by wind obstructions, is very strongly believed to be responsible for that. When the fluid is not cooled, it returns to the CRAC at high pressure and temperature, leading to the HIGH HEAD alarm and shutdown.

Contributing Factors

During the summer of 2011, more heat is being generated in CRB than during the previous summer: roughly 700 kW, up from roughly 500 kW. With any nine of the ten CRACs operating at full capacity, there should be enough cooling for 900 kW. The closer the CRACs run to their full capacity, the more heat is in the fluid sent to the condensers.

Root Cause

The emplacement of the condensers was such that the air at the intakes would be too hot under a bad combination of weather conditions.

Observations & Comments

The air recirculation problem found in the summer of 2010 should probably have been foreseen and avoided by industry HVAC experts. After corrective action, the smoke test that showed the problem was not repeated. The same thing could still be happening to some extent.

Aesthetic considerations may have been given too much weight in the placement of the condensers. The motion of air around and through the condensers was certainly given too little.

Recommendations

Based on the Problem Investigation and root cause analysis, the following recommendations are made for preventing similar cooling failures.

1. Air flow through the condensers must be improved. This almost certainly will involve moving some or all of the condensers, mounting them higher, and/or altering the nearby topography.
2. Until permanent improvements in the condenser functioning can be made, the mitigations should continue. These include cooling the concrete pad with water, keeping nearby vegetation low, use of portable cooling units,

and proactively reducing heat production in the computer room when weather stresses the cooling.

3. The specification, acquisition and installation of future cooling systems should include careful consideration of the air flow through and around the condensers. This might involve computer modeling.

Root Cause Analysis Committee

The following people served on the RCA committee:

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