

# Introduction to Energy Management and Information Systems (EMIS) and Fault Detection and Diagnostics (FDD)

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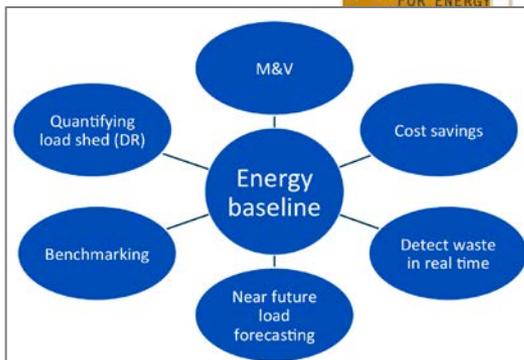


# Outline

- Context, recap of last year's EMIS session
- EMIS and FDD technologies
- FDD Overview
  - Current state of FDD
  - How FDD is conducted
- FDD exercise
- Discussion

# Context

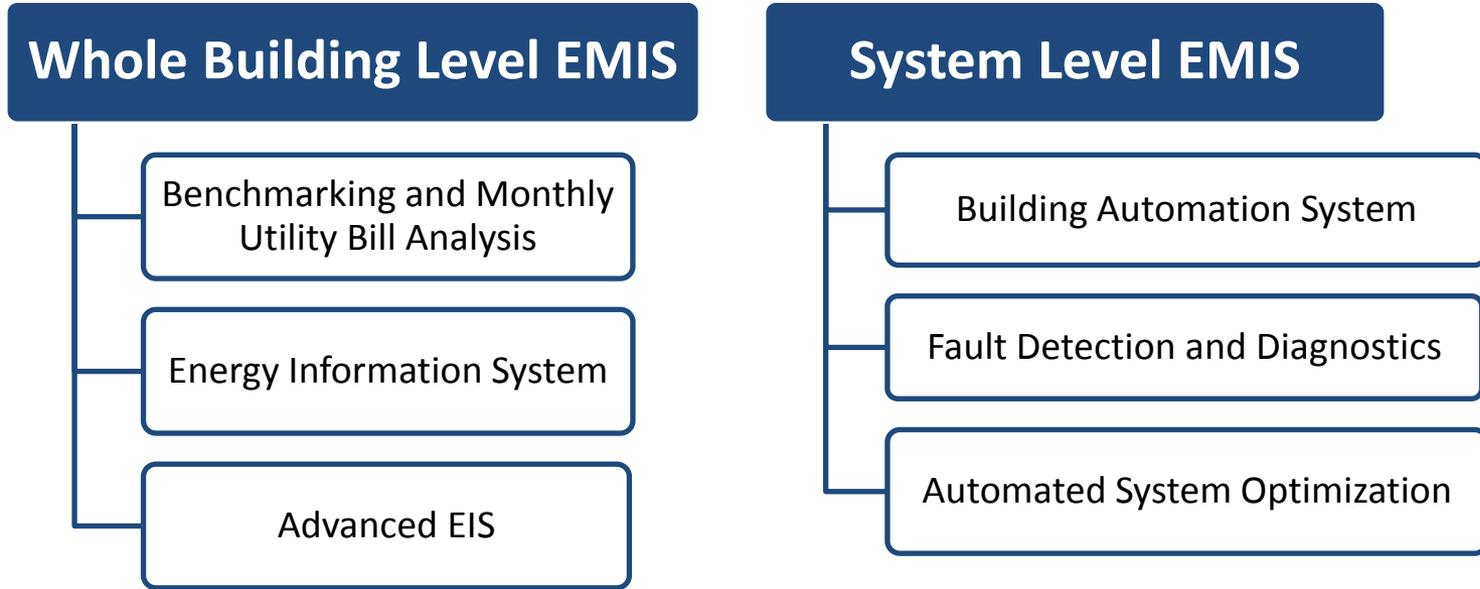
- In the 2015 workshop we covered
  - EMIS technology definitions, motivation
  - Common questions about EMIS use and associated LBNL resources
  - Discussion of best practice, how LBNL resources can be integrated into curricula



# Context

- This year we will continue the dialogue
  - building upon last year's EMIS session and recent Siemens BAS Workshop
  - focus on Fault Detection and Diagnostics (FDD)

# Recap: EMIS Comprise a Family of Technologies

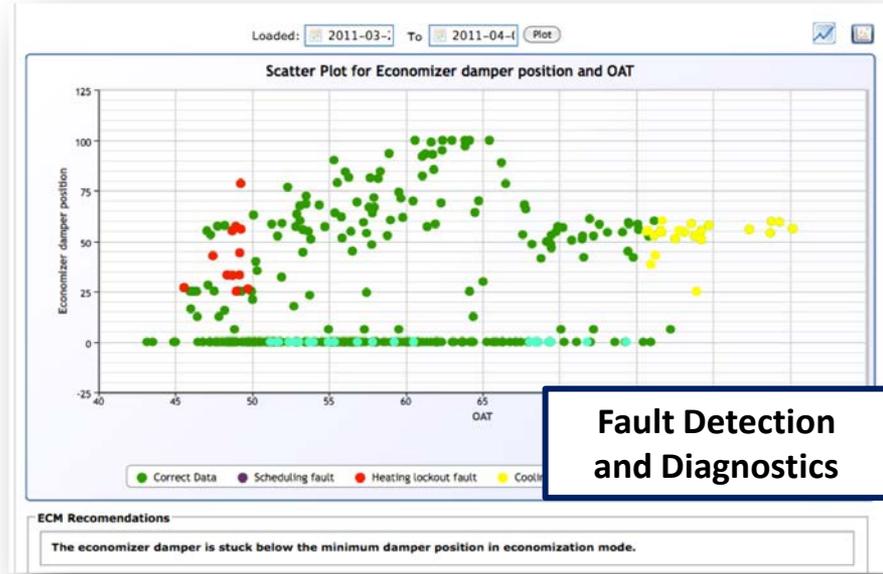


**\* The boundaries can be fuzzy; some tools cross categories, e.g., energy information systems with FDD and benchmarking capabilities**

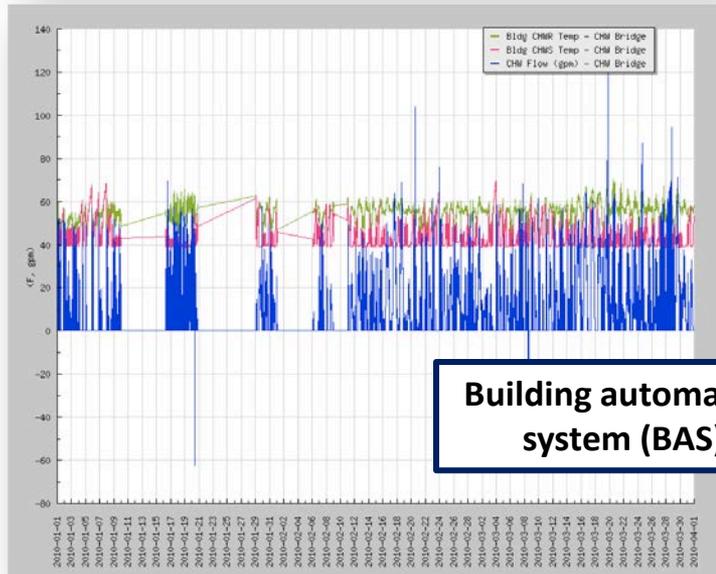
# EMIS Examples



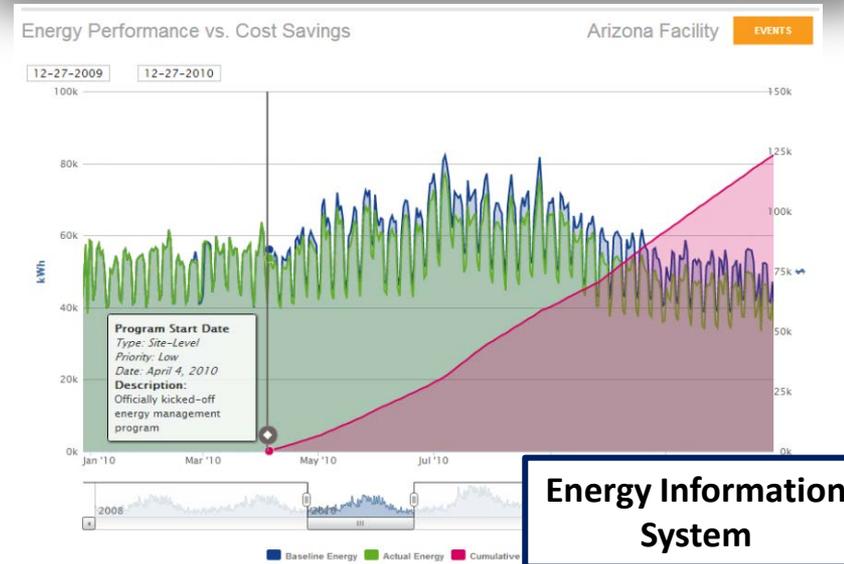
**Benchmarking and Monthly Utility Bill Analysis**



**Fault Detection and Diagnostics**



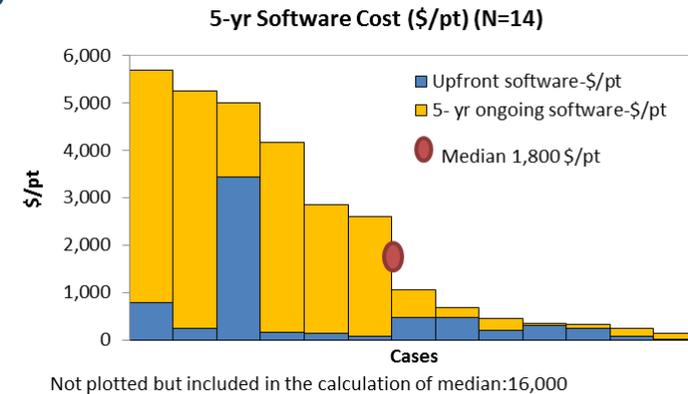
**Building automation system (BAS)**



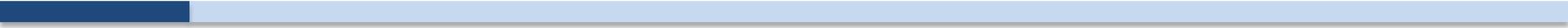
**Energy Information System**

# Recap: EMIS Resources for Curriculum Development

- How do I distinguish all these commercial tools?
  - EMIS technology characterization framework
- What do I do with the data?
  - Energy Information Handbook
- What other useful information is out there?
  - ‘Cliff’s Notes’ synthesis of ~40 resources
- How do I make it all work in my company?
  - EMIS Crash Course, Procurement Spec, and Organizational Primer
- What do analytics tools cost, and how much do they save?
  - Costs and Benefits study of two dozen+ cases



\*Available from [eis.lbl.gov](http://eis.lbl.gov)



# FDD Overview

# Current State of FDD

- FDD is the identification of problems or malfunctions, and determine of location and root causes
- FDD common in high value - expensive, critical, dangerous – systems
  - Aerospace, nuclear, chemical and industrial
- FDD is less commonly integrated into building operations
  - Usually focused on specific HVAC equipment
  - Chiller, or VAV, or AHU packages
  - Whole building energy faults or anomalies, ‘exception reporting’ also come up in tools and discussion



# Why Should FDD be used in Buildings?

- Save energy

**15-30 %**

Of energy used in commercial buildings is wasted by poorly maintained, degraded, and improperly controlled equipment

- Maintain equipment lifespan

- Increase occupant comfort

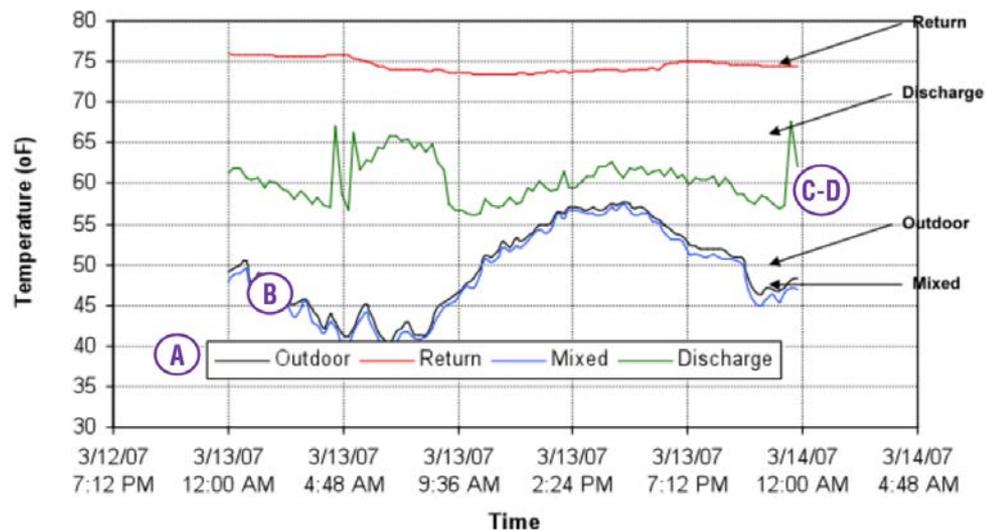
- Improve building operations

**\$ 3.3 Bil**

Worth of energy wasted by 13 of the most common faults

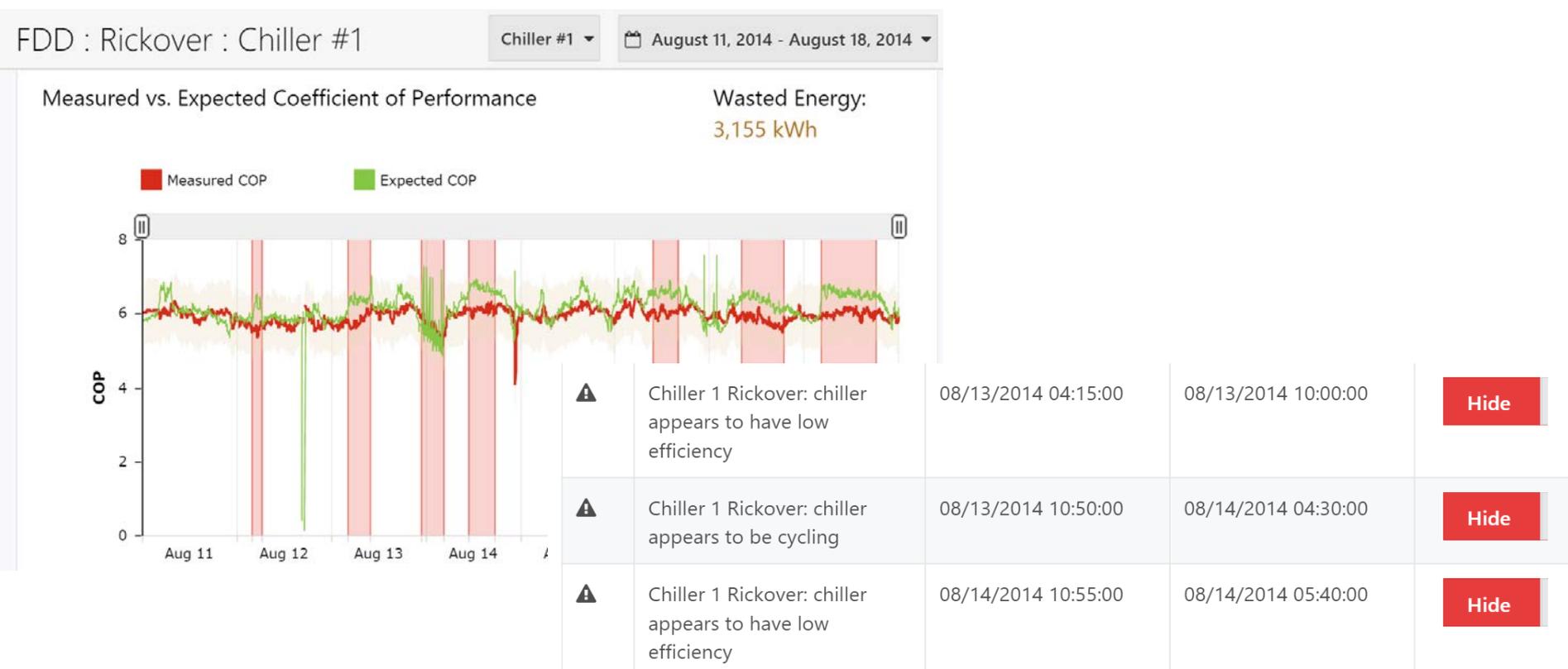
# How is FDD Conducted in Buildings?

- FDD is more than BAS alarming!
- Detection (problem exists) easier than diagnosis (cause of problem)
- FDD can be done manually, w BAS trend logs and data from temporary loggers,
  - Requires sufficient system knowledge, decent data quality



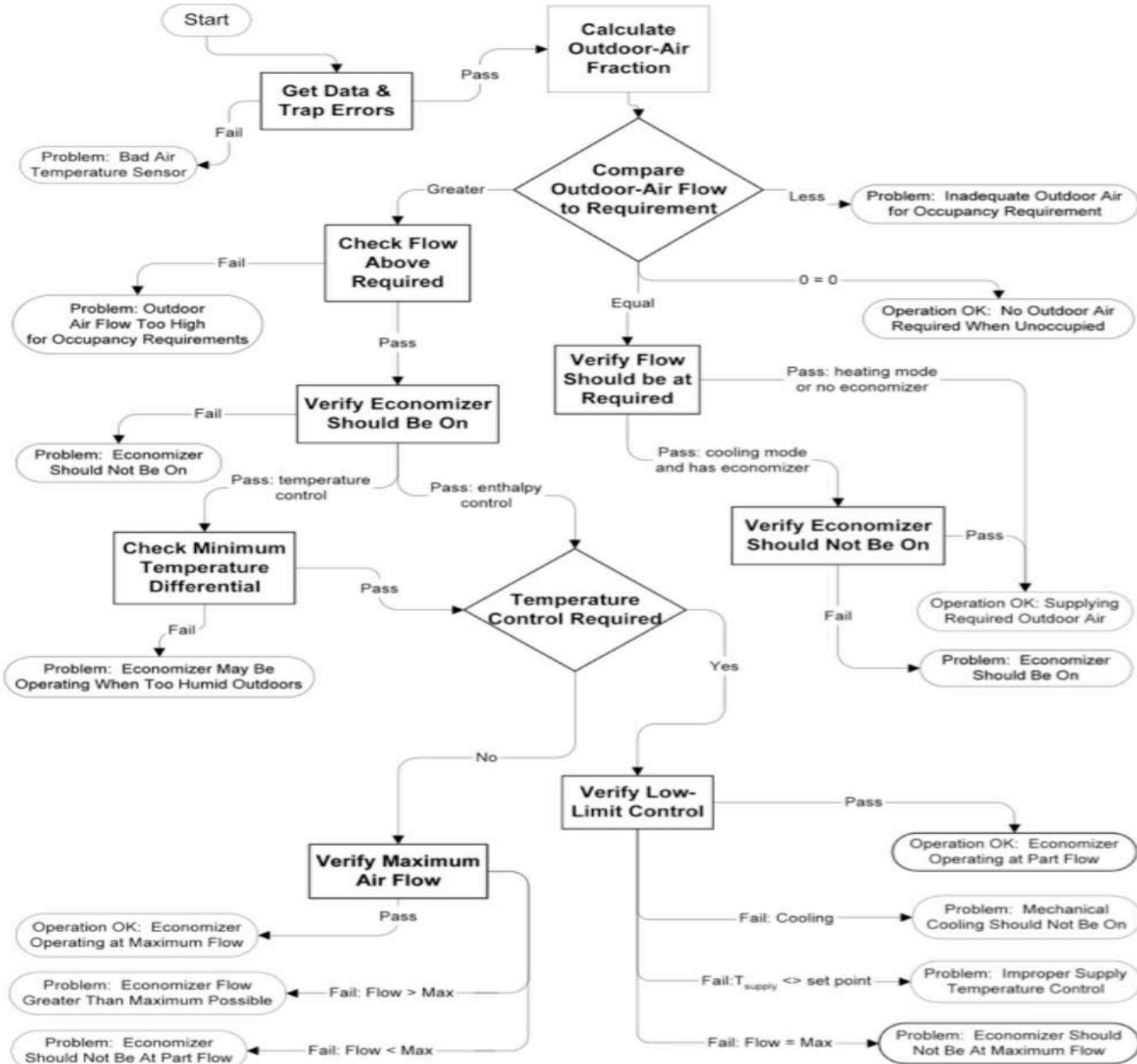
# How is FDD Conducted in Buildings?

- FDD can be done with automated tools that use algorithms to process the data, display results to the user
  - Requires technology investment, maintenance



# How is FDD Conducted in Automated Tools

- Like equipment benchmarking
  - Which fan, pump, etc, has different run-hours, energy use, on/off times
- Rule-based approaches using engineering knowledge
- Equipment-level anomaly detection using performance models, usually regression
- Research is exploring integration of physics-based models with data-driven models for FDD



# Examples of Functionalities in Automated Tools

- Summarize faults
- Sort by location, avoidable costs, and number of faults

Last Month's Top Portfolio Diagnostic Summaries			
Total Faults = 114			
Total Avoidable Costs (USD) = \$30,465			
Total Avoidable Costs (AUD) = \$10,314			
Total Avoidable Costs (EUR) = 7 759 €			
Total Avoidable Costs (GBP) = £6,565			
Building	Faults	Avoidable Costs	
Demo Headquarters	23	\$20,952	<a href="#">view</a>
Australia Office	22	\$10,314	<a href="#">view</a>
Western Regional Office	19	\$9,513	<a href="#">view</a>
Paris Office	25	7 759 €	<a href="#">view</a>
London Office	25	€6,565	<a href="#">view</a>

Yesterday's Top Portfolio Diagnostic Summaries			
Total Faults = 102			
Total Avoidable Costs (USD) = \$411			
Total Avoidable Costs (AUD) = \$107			
Total Avoidable Costs (EUR) = 112 €			
Total Avoidable Costs (GBP) = £85			
Building	Faults	Avoidable Costs	
Western Regional Office	19	\$247	<a href="#">view</a>
Demo Headquarters	17	\$164	<a href="#">view</a>
Paris Office	22	112 €	<a href="#">view</a>
Australia Office	22	\$107	<a href="#">view</a>
London Office	22	€85	<a href="#">view</a>

# Examples of Functionalities in Automated Tools

Descriptions of faults by buildings, equipment, dates, and costs to energy, comfort, and maintenance

169 data records found for 5/27/2014 to 5/27/2014 in daily intervals.

 [Download Full Diagnostics Results](#)

<u>Building</u>	<u>Equipment</u>	<u>Analysis</u>	<u>Start Date</u>	Notes Summary	<u>Cost</u>	<u>E</u>	<u>C</u>	<u>M</u>	Actions
Western Regional Office	AHU-W4 (Air Handler)	AHU Coils	5/27/2014	Simultaneous heating and cooling. Sensor error.	\$186				
Demo Headquarters	AHU-1 (Air Handler)	AHU Coils	5/27/2014	Simultaneous heating and cooling. Leaking cooling valve. Supply air temperature short cycling.	\$111				
Australia Office	AHU-4 (Air Handler)	AHU Coils	5/27/2014	Simultaneous heating and cooling. Leaking cooling valve. Supply air temperature short cycling.	\$61				
Paris Office	AHU-5_VentSys (Ventilation System)	VAV System Reheats	5/27/2014	Excessive reheating.	60 €				
Paris Office	AHU-4 (Air Handler)	AHU Coils	5/27/2014	Simultaneous heating and cooling. Leaking cooling valve. Supply air temperature short cycling.	43 €				

# Examples of Functionalities in Automated Tools

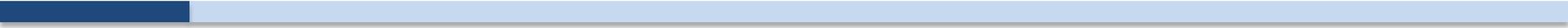
Plot avoidable costs and cost breakdowns for visual comparison



# Examples of Functionalities in Automated Tools

Create custom mathematical expressions from data points

The screenshot displays a software interface for creating a custom mathematical expression. The window is titled "Create Expression" and features a "Name" field containing "MyExpression1" and an "Expression" field containing "b-c". Below these fields is a "Points" section with three entries: "AHU-1 - CoolingCoilValve (Fraction)" (black square), "AHU-1 - PreheatingCoilDischargeAirTemp (F)" (red square), and "AHU-1 - SupplyAirTemp (F)" (blue square). To the right of these entries are three input boxes labeled "a", "b", and "c". A "Operators" section is also visible, listing "Basic" (+, -, \*, /, %), "Logic" (&, |), "Conditional" (=, <, >), and "Grouping" (()). At the bottom left are "Save" and "Cancel" buttons. In the background, a chart shows time-series data for the selected points, with the x-axis labeled with dates and times (5/26, 12:00pm, 4:00pm, 8:00pm, 5/26).



# FDD Exercises

# Question 1: Where can we get data for fault detection?

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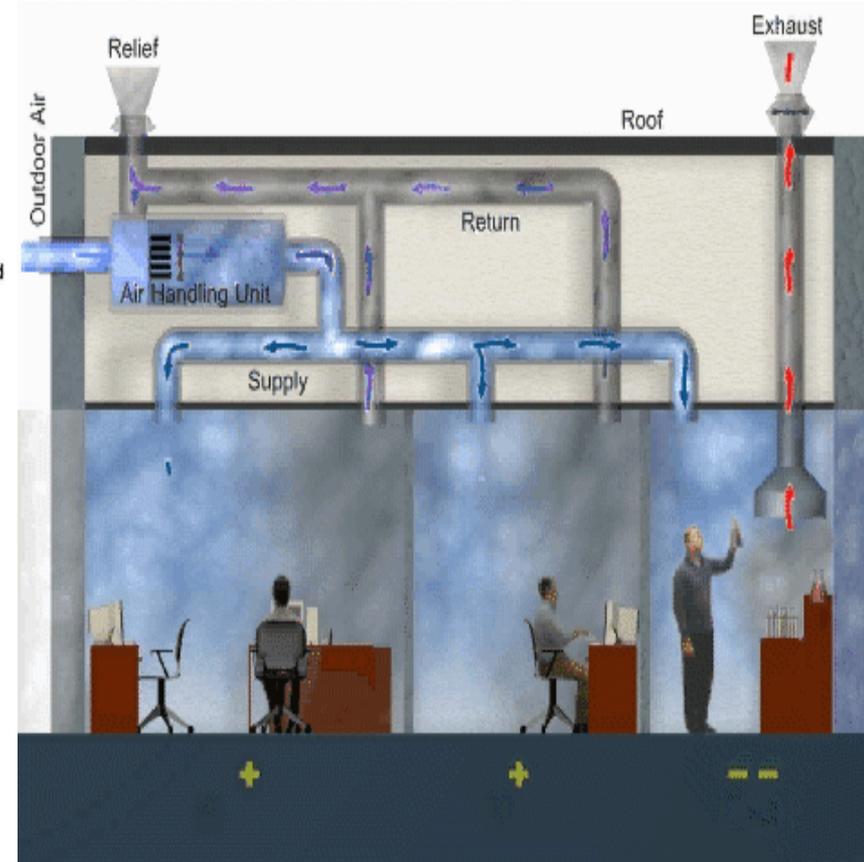
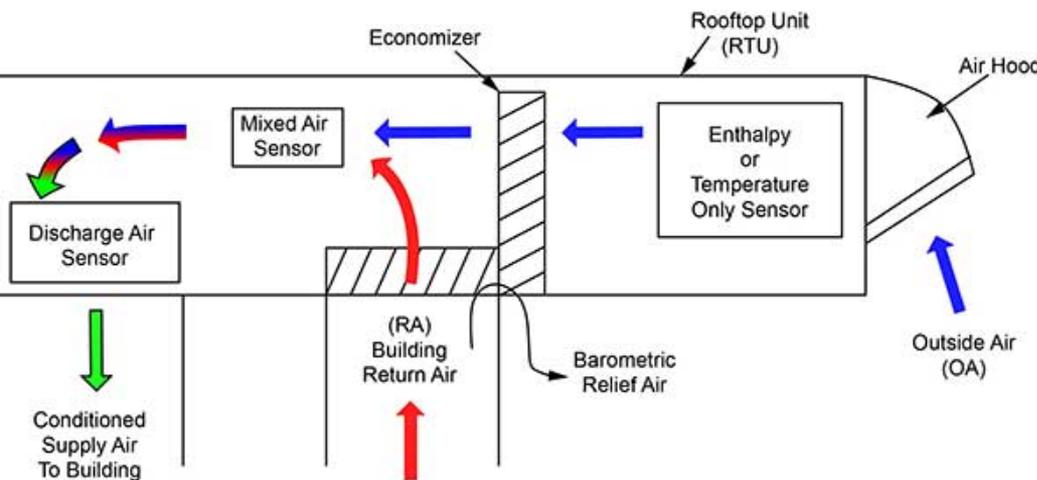
# Question 1: Where can we get data for fault detection?

Sources include:

- Historical data: from the EMS/BACS/other building systems, maintenance records, financial records
- Install sensors to collect data
- Physics based simulations

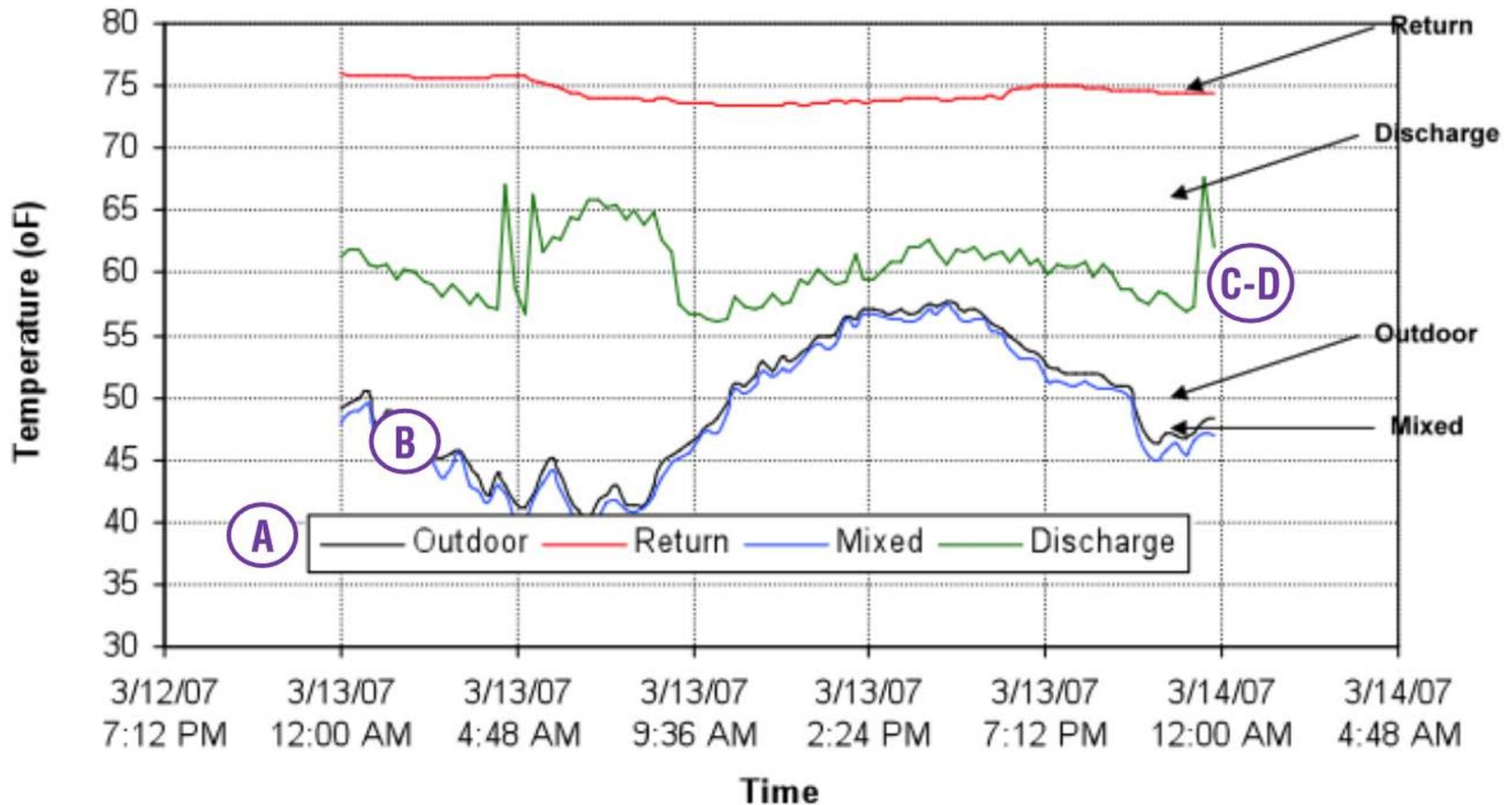
# Manual Fault Detection Using Trendlogs

Case study **Air-Side Economizer** can obtain free cooling by using cool outdoor air in place of (or to supplement) mechanical cooling when outdoor conditions are suitable for doing so



# Question 2a: What is Happening?

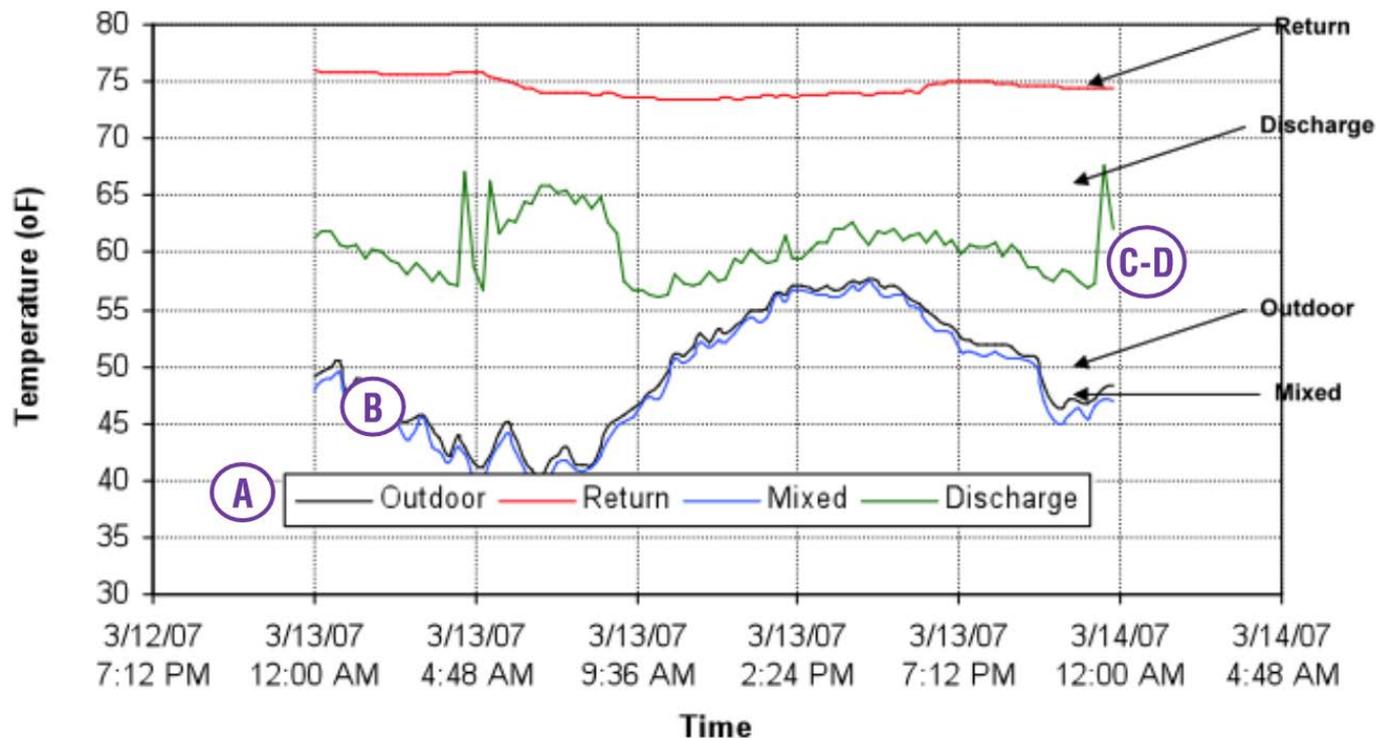
- A** One day of temperature data is plotted: OAT, return air, mixed air, and discharge air.



# Question 2a: Fault - Damper Stuck Fully Open

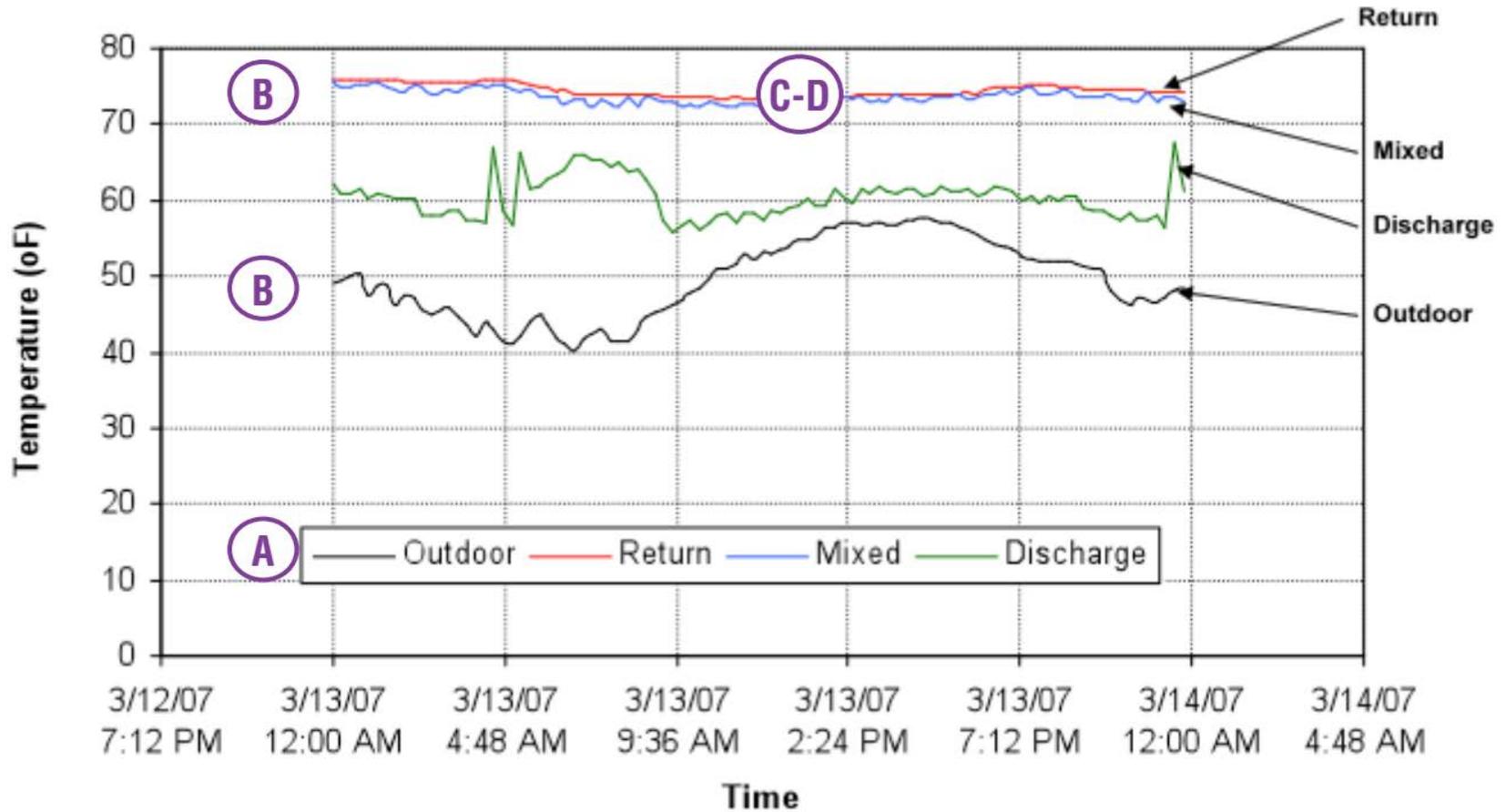
- B** MAT tracks OAT, indicating that the outdoor air damper is fully open.
- C** Since the discharge air setpoint is higher than OAT, the damper should not be fully open.
- D** The outdoor air damper is not closing, although it should be.

Potential causes are a stuck damper or failed or disconnected actuators or linkages.



# Question 2b: What is Happening?

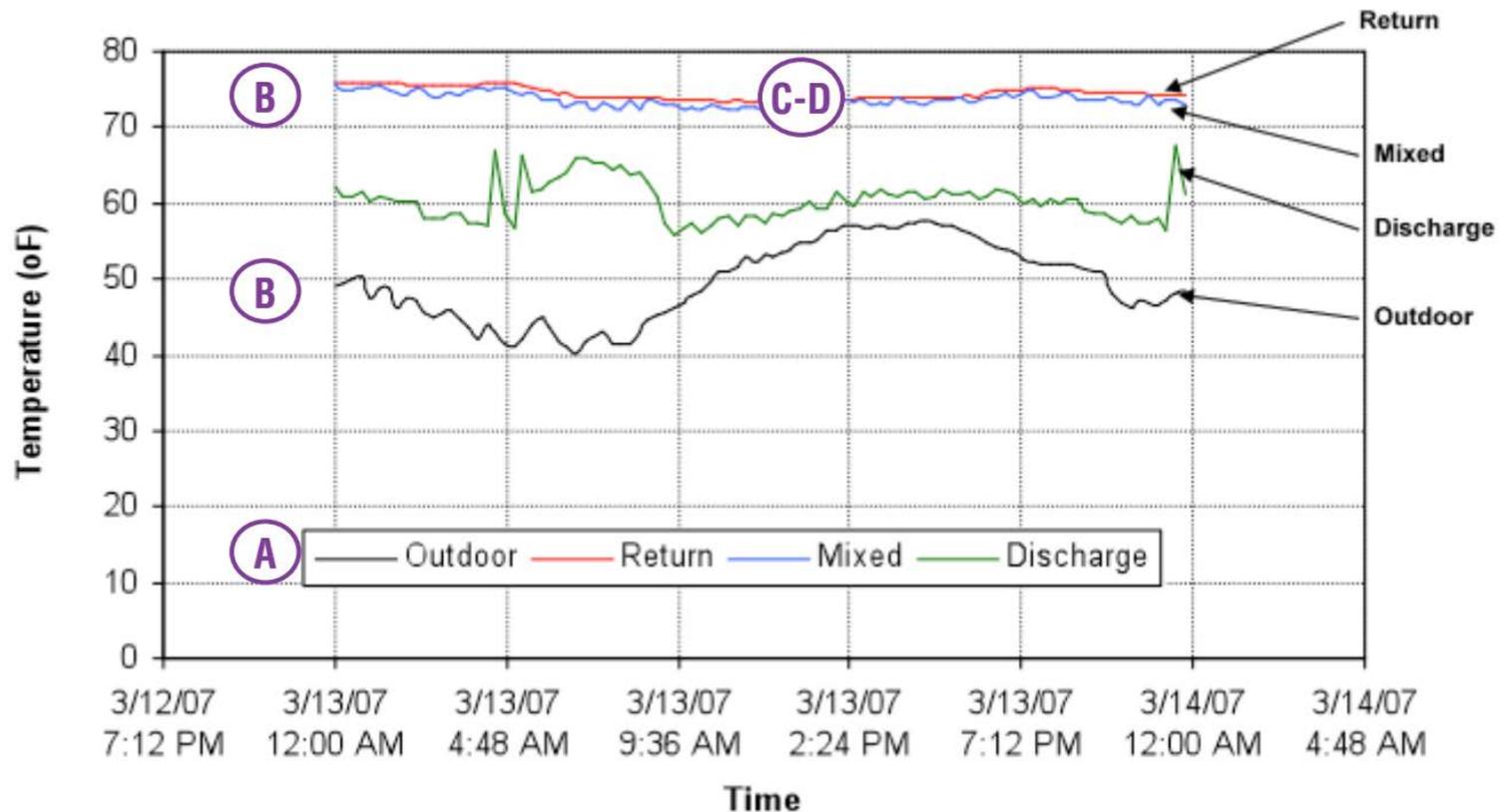
(A) One day of temperature data is plotted: OAT, return air, mixed air, and discharge air.



# Question 2b: Fault - Damper Stuck Fully Closed

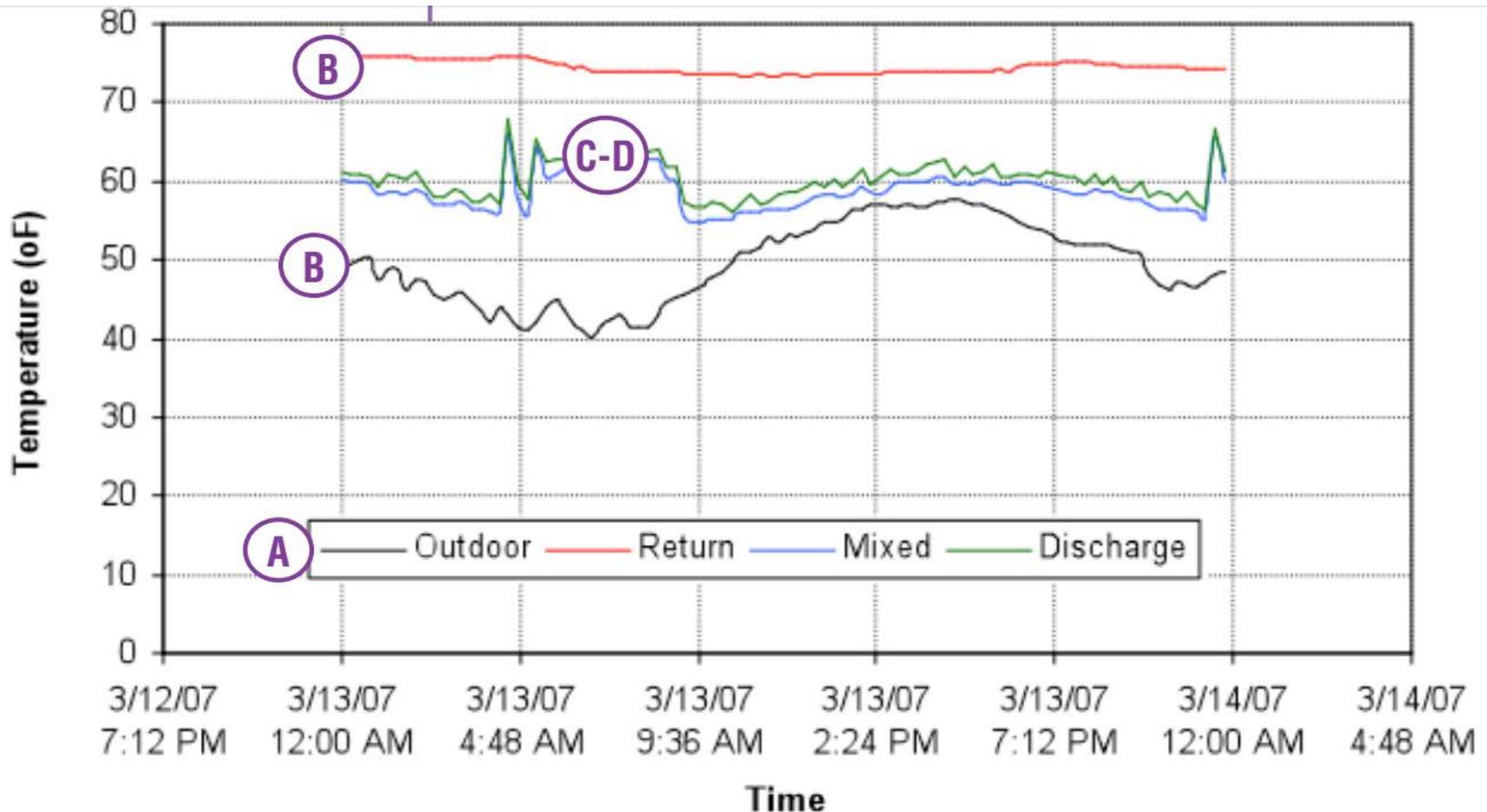
- B** OAT is lower than the RAT, and is therefore acceptable for economizing.
- C** MAT tracks RAT, indicating that outdoor air is not entering the mixing box.
- D** The outdoor air damper is not opening, as it should be.

Potential causes are a stuck damper or failed or disconnected actuators or linkages.



# Question 2c: What is Happening?

- (A) One day of temperature data is plotted: OAT, return air, mixed air, and discharge air.

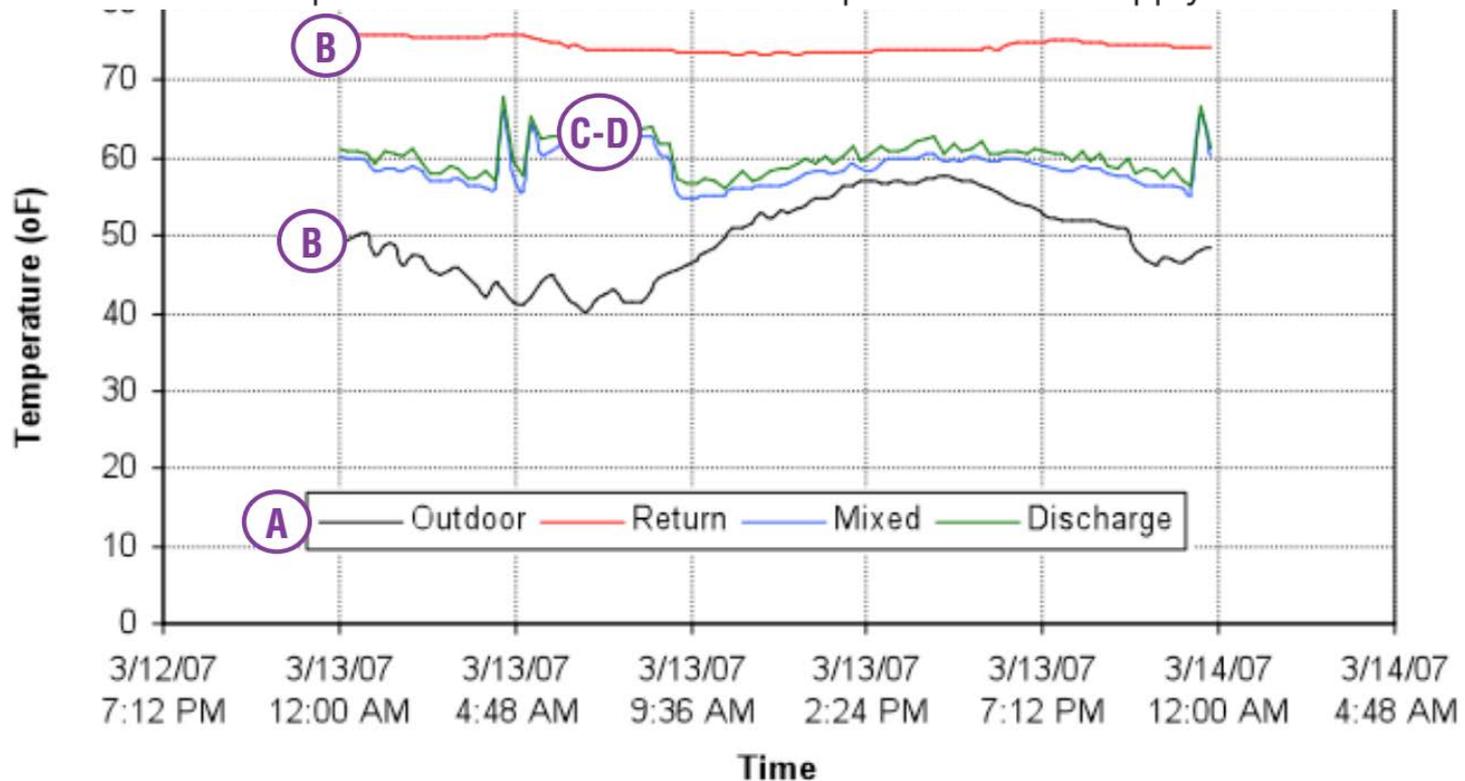


# Question 2c: No Fault

The return-air temperature varies between 72°F and 75°F.

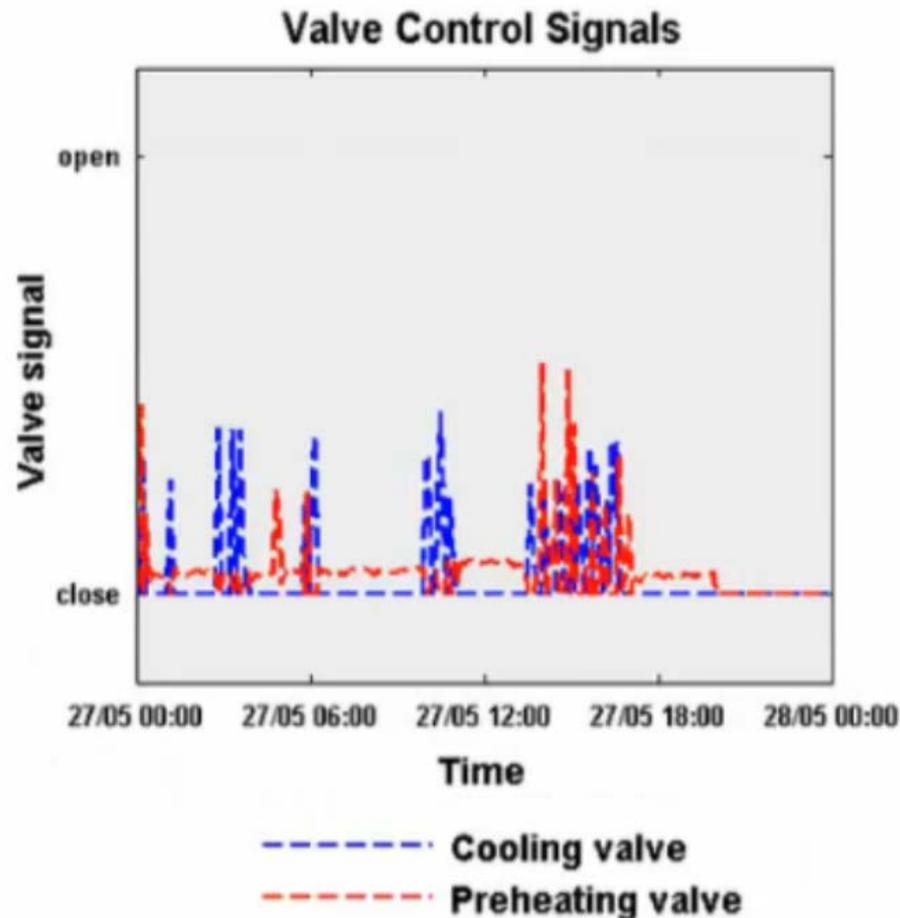
- B** OAT is lower than the RAT, and is therefore acceptable for economizing.
- C** DAT closely tracks MAT, indicating no use of mechanical cooling.
- D** Discharge and mixed air trends also indicate proper modulation of outside airflow.

In this example the MAT sensor is located upstream of the supply fan.

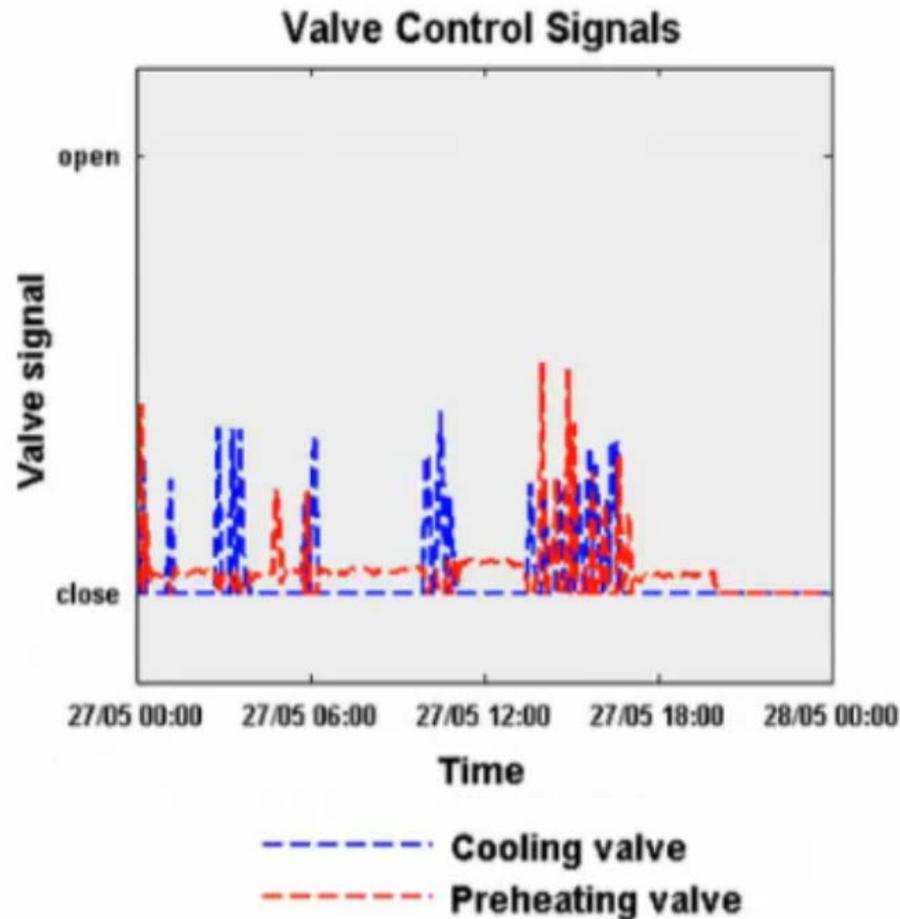


# Question 3: What is Happening?

Valve control signals for an air handler with economizer is plotted for one day

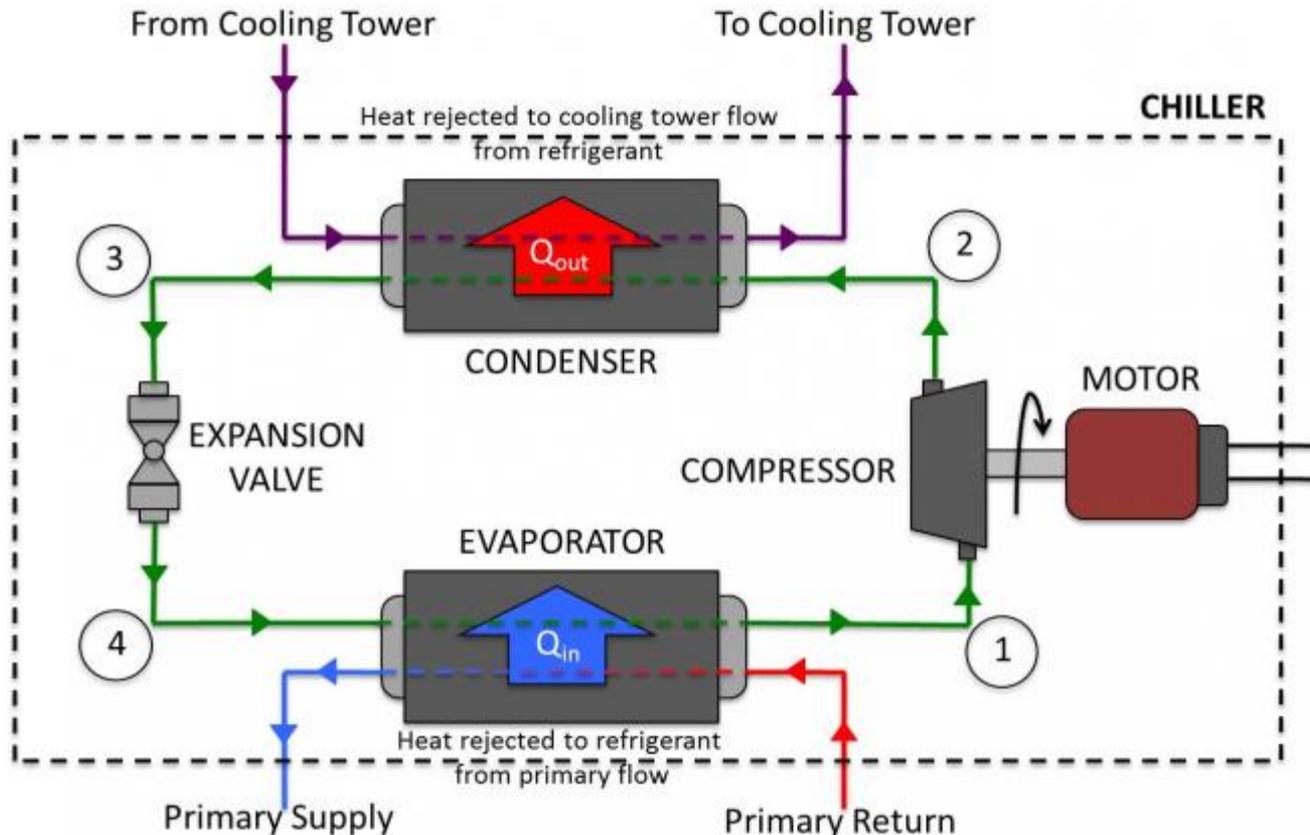


# Question 3: Fault - Valve Control Signal Excessive Cycling



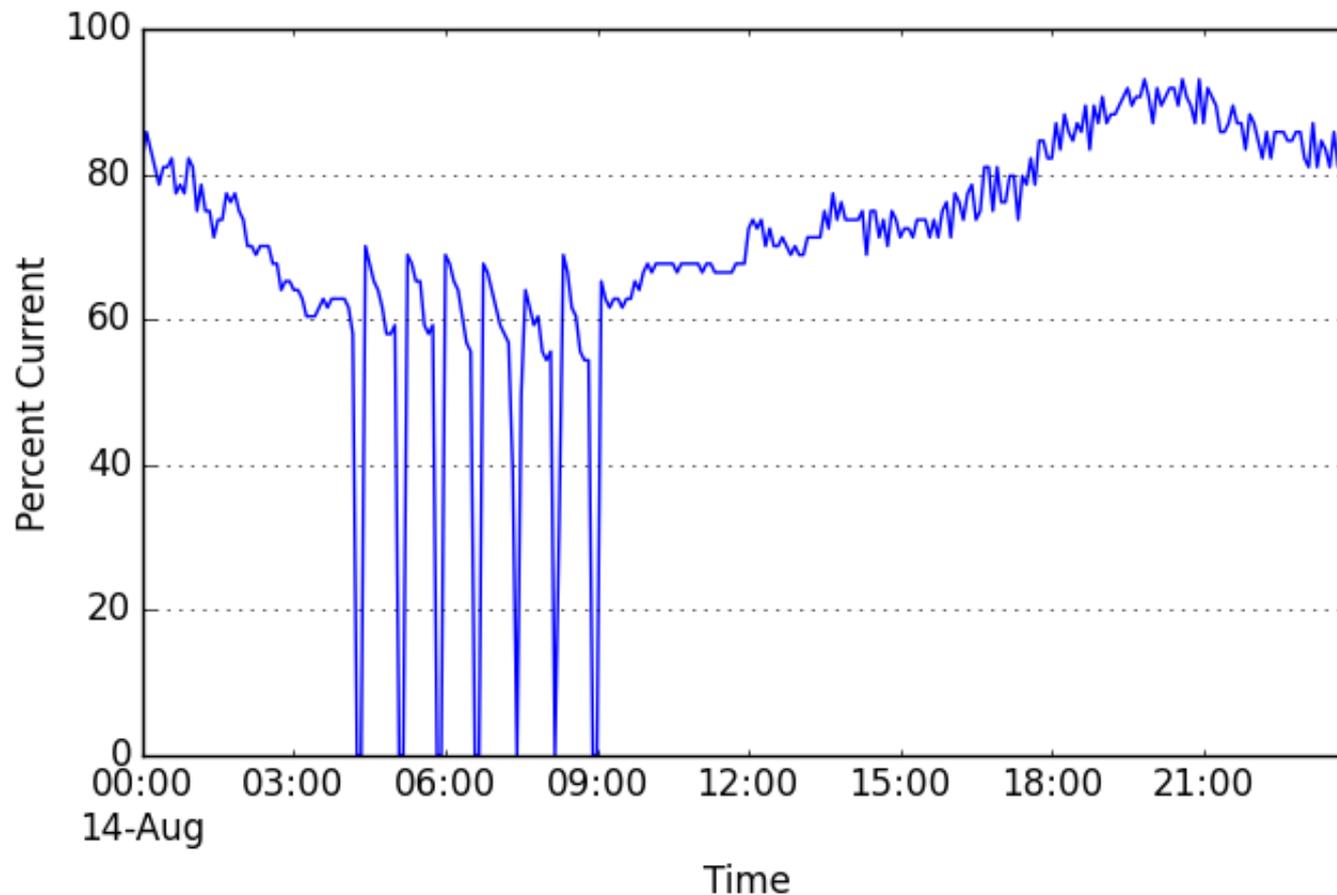
# Case study Chillers

**Chiller** a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle.



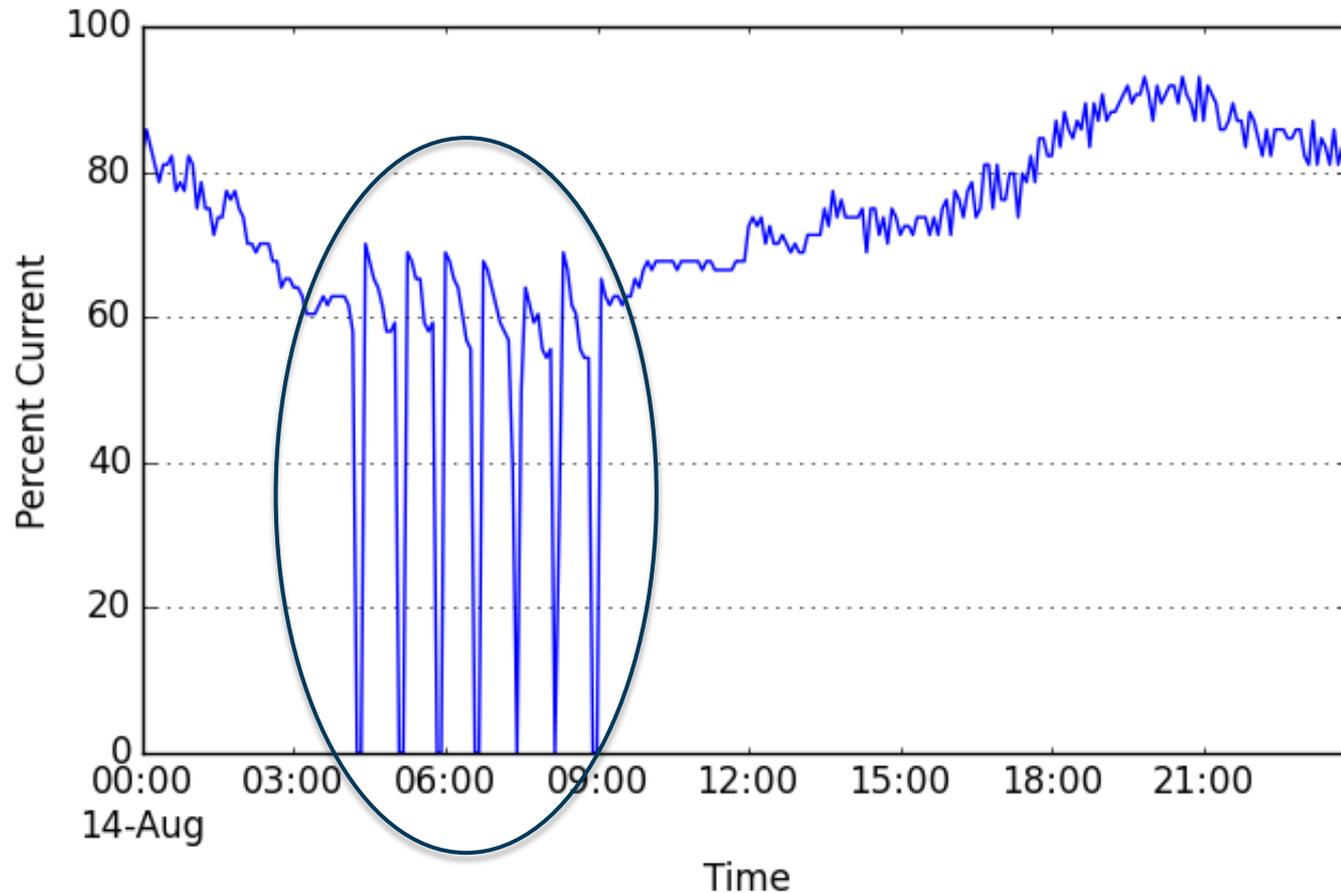
# Question 4: What is Happening?

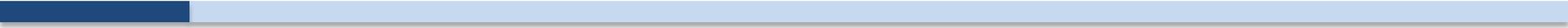
Chiller compressor percent motor current is plotted for one day



# Question 4: Fault: Excessive Chiller Cycling

Chiller is turning on/off too quickly





Questions?

# Please Contact Us

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