LBNL Fault Detection and Diagnostics Data Sets: Single Duct Air Handling Unit

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CONTACT INFORMATION

Website: https://faultdetection.lbl.gov/data/

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This documentation describes the curated single-duct AHU (SDAHU) fault detection and diagnostics data set (LBNL FDD Data Sets_SDAHU). In this documentation, the system information, data points specifications, and input scenarios for faulted and fault-free conditions represented in the data are detailed. The dataset and associated brick model ttl file can be downloaded from https://fdd.hyperarts.com/dataset/simulated-sd-ahu/

1 Building and system information

1.1 System type and diagram

The studied system is a single-duct variable-air-volume (VAV) AHU providing heating and cooling to the middle floor of a three-story DOE large office reference building. The conditioned floor space consists of a single interior zone and four perimeter zones. The AHU distributes conditioned air to each zone via one of five VAV boxes. Hot water utilized by the AHU heating coil and the VAV box reheat coils is supplied by a natural gas-fired boiler. Chilled water used by the AHU cooling coil is provided by a central chiller plant. Figure 1 provides an illustration of the building and floor layout. The figure also illustrates the AHU and VAV box equipment layout.

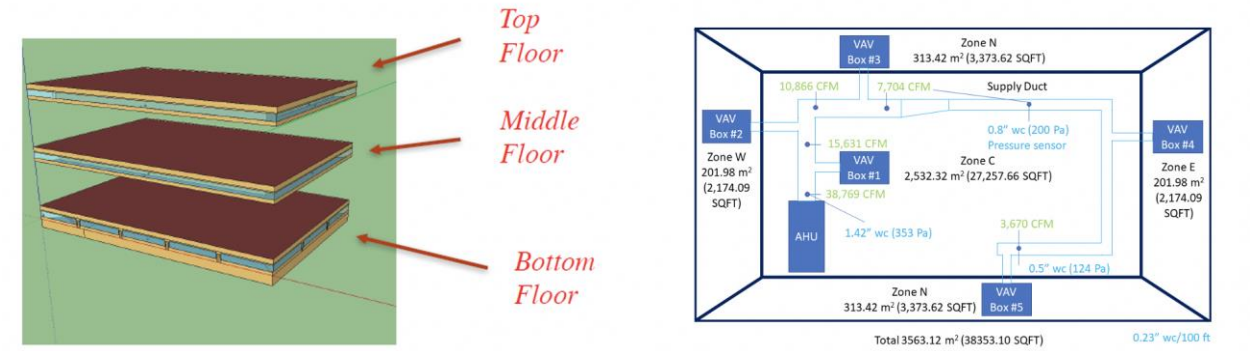

Figure 1. Studied DOE large office reference building and the layout of one floor

A schematic diagram of the simulated AHU used in this study is shown in Figure 2. The main components of the AHU include the supply fan with a variable frequency driver (VFD), return fan with a VFD (not depicted), cooling and heating coils, cooling and heating control valves, and outdoor air (OA) and return air (RA) dampers. The VAV boxes are a typical single-duct pressure-independent VAV box with hydronic reheat. The major components of the VAV boxes are reheating coil, reheating coil valve, and terminal damper.

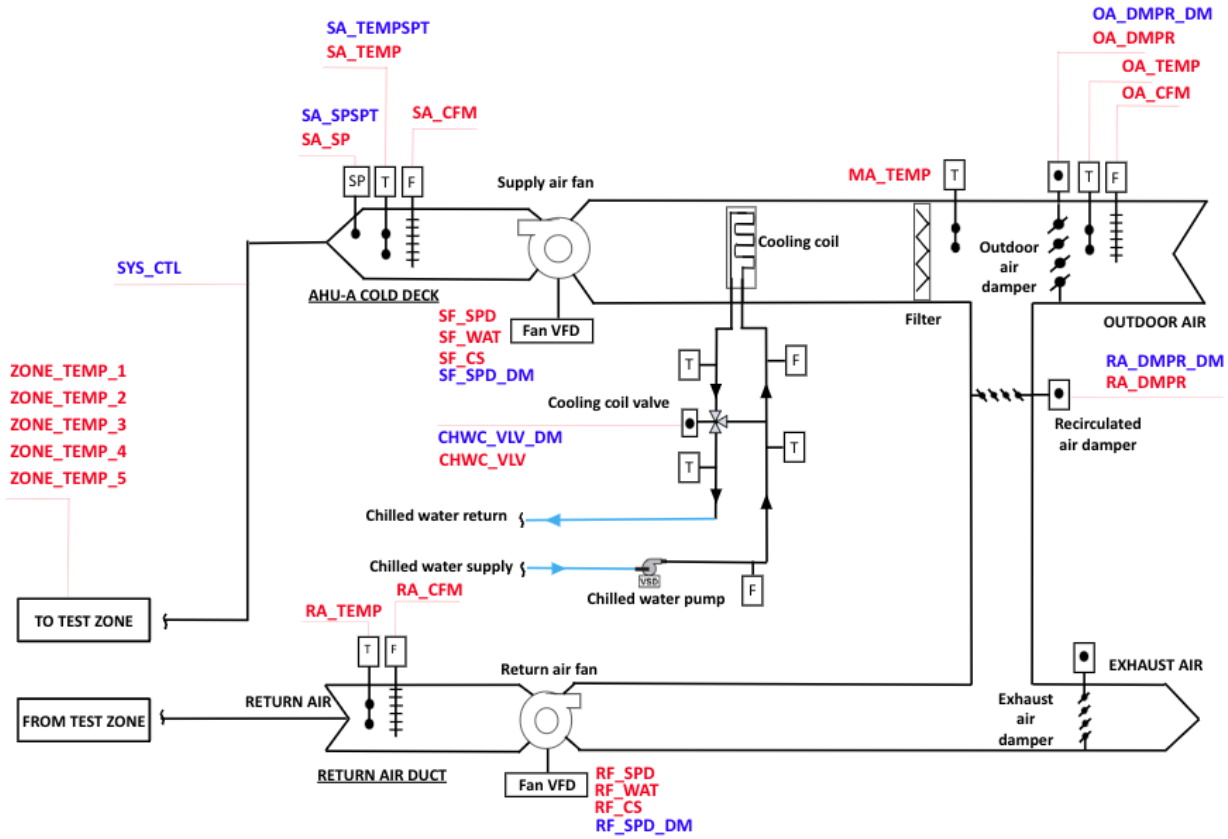

Figure 2. Schematic diagram of single-duct AHU and the connected zones

1.2 Description of control sequence

Control sequences for the single-duct AHU for occupied and unoccupied periods are described below.

Occupied mode (Monday – Friday 6:00am – 10:00pm, Saturday 6:00am – 6:00pm)

- Fan status: The supply fan and return fan run continuously during occupied periods.
- Supply air temperature control: The supply air temperature is controlled via the cooling coil valve to maintain a fixed setpoint of 55°F when OA temperature is higher than 60°F or lower than 33.8°F. For OA temperatures between 33.8°F and 60°F, mechanical cooling is active only when the economizer dampers are 100% open. Otherwise, mechanical cooling is locked out and the cooling coil valve is closed. When mechanical cooling is locked out, the supply air temperature is not directly controlled and may vary from 55°F.
- Supply fan control: The supply fan speed is controlled via a VFD to maintain a constant static pressure setpoint of 1.6 in. w.g.
- Return fan control: The return fan speed is controlled via a VFD to be 90% of the speed of the supply fan.
- Minimum outdoor air control: The OA damper is controlled to a fixed minimum position (10% open) when the unit is not in economizer mode.
- Economizer mode: The AHU operates in economizer mode when outdoor air temperature is between 33.8°F and 60°F. In this mode, the OA damper modulates in sequence with the RA

damper to maintain a 55°F mixed air temperature setpoint. Once the OA damper is greater than 100% open. The cooling coil valve shall be enabled to maintain supply air temperature setpoint.

● Space temperature control: The zone heating and cooling setpoints are 70°F and 75°F, respectively, during the occupied period.

Unoccupied mode

● Fan status: The supply and return fans are off. The cooling coil valve and OA damper are closed. The system cycles ON and OFF to maintain the space temperatures between the unoccupied heating and cooling setpoints.

● Minimum outdoor air control: The OA damper is closed.

● Space temperature control: The zone heating and cooling setpoints are 60°F and 80°F, respectively, during the unoccupied period.

The occupied and unoccupied space temperature setpoints are adopted from Deru et al., 2010. The economizer mode parameters come from ASHRAE Guideline 36-2020 and ASHRAE Standard 90.1-2016. The static pressure setpoint was determined through testing and air balancing analyses of the simulated system under design conditions. All other control setpoints and parameters are based on accepted engineering practice.

2 Data point summary

A total of 30 data points were included in the data sets. The data point descriptions are summarized in Table 2. In the table, the "Basic point" column indicates if the data point is commonly employed in the existing building automation system to monitor the system.

Table 2 Data points summary of the single-duct AHU

NO.	Data point name	Diagram Point Abbreviation	Description	Unit	Basic point?
1	AHU: Supply Air Temperature	SA_TEMP	AHU supply air temperature	°F	Y
2	AHU: Supply Air Temperature Set Point	SA_TEMPSPT	AHU supply air temperature set point	°F	Y
3	AHU: Outdoor Air Temperature	OA_TEMP	AHU outdoor air temperature	°F	Y
4	AHU: Mixed Air Temperature	MA_TEMP	AHU mixed air temperature	°F	Y
5	AHU: Return Air Temperature	RA_TEMP	AHU return air temperature	°F	Y
6	AHU: Supply Air Fan Status	SF_SPD_DM	AHU supply air fan status; 0-off, 1-on	–	Y
7	AHU: Return Air Fan Status	RF_SPD_DM	AHU return air fan status; 0-off, 1-on	–	Y
8	AHU: Outdoor Volumetric Airflow	OA_CFM	AHU outdoor airflow	CFM	N

9	AHU: Return Volumetric Airflow	RA_CFM	AHU return airflow	CFM	N
10	AHU: Supply Volumetric Airflow	SA_CFM	AHU supply airflow	CFM	N
11	AHU: Supply Air Fan Speed Control Signal	SF_CS	Control signal for AHU supply air fan speed; ranges from 0 to 1; 0 - fan speed is 0%, 1 - fan speed is 100%	0-1	Y
12	AHU: Supply Air Fan Speed Position	SF_SPD	AHU supply air fan speed; ranges from 0 to 1; 0 - fan speed is 0%, 1 - fan speed is 100%	0-1	N
13	AHU: Return Air Fan Speed Control Signal	RF_CS	Control signal for AHU return air fan speed; ranges from 0 to 1; 0 - fan speed is 0%, 1 - fan speed is 100%	0-1	Y
14	AHU: Return Air Fan Speed Position	RF_SPD	AHU return air fan speed; ranges from 0 to 1; 0 - fan speed is 0%, 1 - fan speed is 100%	0-1	N
15	AHU: Supply Air Fan Power	SF_WAT	AHU supply air fan power	W	N
16	AHU: Return Air Fan Power	RF_WAT	AHU return air fan power	W	N
17	AHU: Outdoor Air Damper Control Signal	OA_DMPR_DM	Control signal for AHU outdoor air damper; ranges from 0 to 1; 0 – damper should be fully closed, 1 – damper should be fully open	Open(0-1)	Y
18	AHU: Outdoor Air Damper Position	OA_DMPR	AHU outdoor air damper position; ranges from 0 to 1; 0 – damper should be fully closed, 1 – damper should be fully open	Open(0-1)	N
19	AHU: Return Air Damper Control Signal	RA_DMPR_DM	Control signal for AHU return air damper; ranges from 0 to 1; 0 – damper should be fully closed, 1 – damper should be fully open	Open(0-1)	Y
20	AHU: Return Air Damper Position	RA_DMPR	AHU return air damper position; ranges from 0 to 1; 0 – damper should be fully closed, 1 – damper should be fully open	Open(0-1)	N
21	AHU: Cooling Coil Valve Control Signal	CHWC_VLV_DM	Control signal for AHU cooling coil valve; ranges from 0 to 1; 0 – valve should be fully closed, 1 – valve should be fully open	Open(0-1)	Y
22	AHU: Cooling Coil Valve Position	CHWC_VLV	AHU cooling coil valve position; ranges from 0 to 1; 0 – valve should be fully closed, 1 – valve should be fully open	Open(0-1)	N
23	AHU: Supply Air Duct Static Pressure	SA_SP	AHU supply air duct static pressure	Inches H2O	Y

24	AHU: Supply Air Duct Static Pressure Set Point	SA_SPSPT	AHU supply air duct static pressure setpoint	Inches H2O	Y
25	Occupancy Mode Indicator	SYS_CTL	Indicator if the system operates in occupied mode; 1-occupied mode, 0-unoccupied mode	–	N
26	Zone 1: Air Temperature	ZONE_TEMP_1	Zone 1 Air Temperature	°F	Y
27	Zone 2: Air Temperature	ZONE_TEMP_2	Zone 2 Air Temperature	°F	Y
28	Zone 3: Air Temperature	ZONE_TEMP_3	Zone 3 Air Temperature	°F	Y
29	Zone 4: Air Temperature	ZONE_TEMP_4	Zone 4 Air Temperature	°F	Y
30	Zone 5: Air Temperature	ZONE_TEMP_5	Zone 5 Air Temperature	°F	Y

It is noted that, for sensor related faults (i.e., Zone air temperature sensor bias fault), the value of the faulty sensor logged is the faulty value.

A LBNL_FDD_Data_Sets_SDAHU.ttl file was also developed to present the data points and their relationships according to the Brick Schema[1](version 1.2). Figure 2 shows the SDAHU data point relations created under the Brick schema model.

[1] Ref: Brick Schema website https://brickschema.org/ Access: May 01, 2022

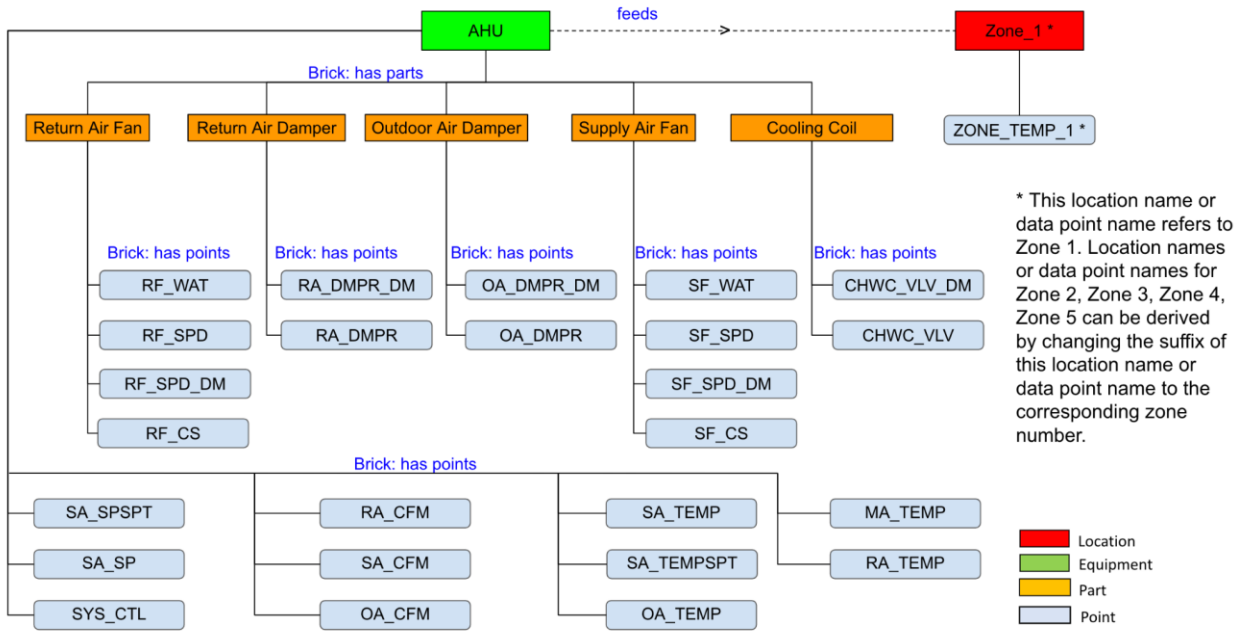

Figure 2 The schematic diagram of SDAHU Brick model

3 Faulty and fault-free scenarios

Faulty and fault-free scenarios included in the data set are shown in Table 3. There are a total of 20 faulted cases and 1 fault-free case. Each faulted case lasts for one year. The TMY weather data for Chicago, IL is used as the weather inputs.

Table 3 Simulated input scenarios included in the dataset for the SDAHU

Input Scenarios		**Method of fault imposition**
Fault type	**Fault intensity**	
Outdoor air temperature sensor bias	Bias = 2°C	Add bias to sensor output.
	Bias = 4°C	
	Bias = -2°C	
	Bias = -4°C	
Supply air temperature sensor bias	Bias = 2°C	Add bias to sensor output.
	Bias = 4°C	
	Bias = -2°C	
	Bias = -4°C	

OA Damper	Stuck	Minimum position (10%)	Automated override of OA damper position to indicate that OA damper is stuck.
		25% open	
		75% Open	
		100% Open*	
Cooling Coil Valve	Leaking	10%	Adjusted the minimum coil valve position value when the control signal is zero.
		25%	
		40%	
		50%	
	Stuck	10%	Automated override of coil valve position to indicate that valve is stuck.
		25%	
		50%	
		75%	
Fault-free			

*Data only available from April 1 to Nov 1

The data set is provided in a set of the csv files. Each .csv file (except OA damper stuck open 100%) represents one-year data of a fault with a specific fault intensity or a fault-free case. The data set uses 1-minute measurement frequency so the data sets can be converted into input samples of any time horizon larger than 1 minute. Table 4 lists the csv file description for each faulty case and fault-free case.

Table 4 File inventory

No.	**Fault file name**	**Fault type**	**Fault intensity**
1	AHU_annual.csv	Fault free	NA
2	sa_bias_-2_annual.csv	Supply air temperature sensor bias	-2°C
3	sa_bias_-4_annual.csv	Supply air temperature sensor bias	-4°C
4	sa_bias_2_annual.csv	Supply air temperature sensor bias	+2°C
5	sa_bias_4_annual.csv	Supply air temperature sensor bias	+4°C
6	coi_leakage_010_annual.csv	Cooling coil valve leaking	10% leakage
7	coi_leakage_025_annual.csv	Cooling coil valve leaking	25% leakage
8	coi_leakage_040_annual.csv	Cooling coil valve leaking	40% leakage
9	coi_leakage_050_annual.csv	Cooling coil valve leaking	50% leakage
10	coi_stuck_010_annual.csv	Cooling coil valve stuck	Stuck at 10%
11	coi_stuck_025_annual.csv	Cooling coil valve stuck	Stuck at 25%
12	coi_stuck_050_annual.csv	Cooling coil valve stuck	Stuck at 50%

13	coi_stuck_075_annual.csv	Cooling coil valve stuck	Stuck at 75%
14	damper_stuck_010_annual.csv	Outdoor air damper stuck	Stuck at 10%
15	damper_stuck_025_annual.csv	Outdoor air damper stuck	Stuck at 25%
16	damper_stuck_075_annual.csv	Outdoor air damper stuck	Stuck at 75%
17	damper_stuck_100_annual_short.csv	Outdoor air damper stuck	Stuck at 100%
18	oa_bias_-2_annual.csv	Outdoor air temperature sensor bias	-2°C
19	oa_bias_-4_annual.csv	Outdoor air temperature sensor bias	-4°C
20	oa_bias_2_annual.csv	Outdoor air temperature sensor bias	+2°C
21	oa_bias_4_annual.csv	Outdoor air temperature sensor bias	+4°C