STANDARD COMMISSIONING PROCEDURE FOR AIR HANDLING UNITS

BUILDING NAME: ____ **APPLICATION #:** ________________
BUILDING ADDRESS: ____
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NAME & FIRM OF PERSON(S) DOING TEST: ____
DATE(S) OF TEST: __________________________________

General Notes:

1. This is a generic test procedure for air handling units (AHUs). For simple packaged units, less than 20 tons in capacity, use the Standard Commissioning Procedure for Packaged Heat Pump (Air-to-Air) & Air Conditioning Units. If the complexity, configuration, or other aspects of a specific project require substitute tests or additional tests, explain on the comments sheets, and attach the additional test procedures and field data. Attach all relevant functional performance verification sheets, and always attach the final signed and dated procedure certification page.
2. In all test sections, circle or otherwise highlight any responses that indicate deficiencies (i.e. responses that don't meet the criteria for acceptance). Acceptance requires correction and retest of all deficiencies, as defined in each test section under "Criteria for Acceptance" or "Acceptance". Attach all retest data sheets. Complete the Deficiency Report Form for all deficiencies.
3. This Commissioning Procedure does not address fire and life safety or basic equipment safety controls.
4. To ensure that this Commissioning Procedure will not damage any equipment or affect any equipment warranties, have the equipment manufacturer's representative review all test procedures prior to execution.

OPERATOR INTERVIEW (Existing Buildings Only):
Determine from a discussion with the building operator whether the air handling units are operating properly to the best of their knowledge. Use the table to note any known problems, and possible solutions. Address each AHU. In the 2nd column, write "none" for any AHUs with no known problems.

AHU SYMBOL & AREA SERVED	PROBLEM DESCRIPTION & EFFECT	PROPOSED SOLUTION

INSTALLED CHARACTERISTICS (From field inspection. Note under response if the feature as installed differs in any way from the design documents. If an item does not apply, write "NA" for not applicable):

Criteria for Acceptance: Installed characteristics must be in accordance with design intent documentation and/or approved submittals.

SYMBOL DESCRIPTION						
1. Is AHU built-up or packaged?						
2. System type (VAV, SZ, MZ, DD, etc.)						
3. Cooling coil type (chilled water or DX)						
4. Heating coil type (hot water, steam, or electric)						
5. Other coils: use & type						
6. Supply fan type (centrif., propeller, vaneaxial, etc.)						
7. Return fan type						
8. Other fan (specify relief, exhaust, etc.)/ type						
9. Supply fan motor control (VFD, inlet vanes, variable pitch blades, etc.) *						
10. Return fan motor control (VFD, inlet vanes, variable pitch blades, etc.) *						
11. Other fan motor control (VFD, inlet vanes, variable pitch blades, etc.) *						
12. Is AHU equipped with economizer?						
13. If AHU has DX coils, does it contain compressors?						
14. Condenser type (air-cooled, evaporative, etc.)						
15. Other sections or accessories						
16.						
17.						

* If the motor is driven by a variable frequency drive (VFD), and if VFDs have been selected for functional performance testing, complete the Standard Commissioning Procedure for VFDs.

COMMENTS ON INSTALLED CHARACTERISTICS ITEMS (item #, unit #, comment). Add more sheets as needed:

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Building Name: ______________________

Nameplate Data: Fill in from equipment nameplates, not from drawings, specs, balance report, etc. If an item does not apply, write "NA" for not applicable. Items that are labeled with a "(P)" refer to packaged AHUs only. Items that are labeled with a "(B)" refer to built-up AHUs only.

SYMBOL DESCRIPTION						
General Items:						
1. (P) Manufacturer						
2. (P) Model #						
3. (P) Serial #						
4. Rated Heating Capacity, MBtu						
5. Rated Cooling Capacity, tons						
6.						
Supply Fan:						
7. (B) Manufacturer						
8. (B) Model #						
9. Fan rated CFM @ design SP						
10. Fan motor, HP						
11. Fan motor, volts/ϕ	/	/	/	/	/	/
12. Fan motor, FLA						
13. Fan motor, full load speed						
14. Fan motor, nominal efficiency						
15. VFD manufacturer						
16. VFD model #						
17. VFD HP rating						
18. VFD voltage rating						
19.						
Return / Relief Fan						
20. (B) Manufacturer						
21. (B) Model #						
22. Fan rated CFM @ design SP						
23. Fan motor, HP						
24. Fan motor, volts/ϕ	/	/	/	/	/	/
25. Fan motor, FLA						
26. Fan motor, full load speed						
27. Fan motor, nominal efficiency						
28. VFD manufacturer						
29. VFD model #						
30. VFD HP rating						
31. VFD voltage rating						
32.						

SYMBOL DESCRIPTION						
Other Fan _________						
33. (B) Manufacturer						
34. (B) Model #						
35. Fan rated CFM @ design SP						
36. Fan motor, HP						
37. Fan motor, volts/φ	/	/	/	/	/	/
38. Fan motor, FLA						
39. Fan motor, full load speed						
40. Fan motor, nominal efficiency						
41. VFD manufacturer						
42. VFD model #						
43. VFD HP rating						
44. VFD voltage rating						
45.						
Compressor Section:						
46. (B) Manufacturer						
47. (B) Model #						
48. Quantity						
49.						
Heating Coil (steam, HW):						
50. (B) Manufacturer						
51. (B) Model #						
52.						
Electric Coil:						
53. Heat section, kW						
54. Heat section, # of stages						
55.						
Cooling Coil:						
56. (B) Manufacturer						
57. (B) Model #						
58.						
Other Coil ________:						
59. (B) Manufacturer						
60. (B) Model #						
61.						
Condenser:						
62. (B) Manufacturer						
63. (B) Model #						
64. Fan motor, quantity/HP	/	/	/	/	/	/
65. Fan motor, volts/φ	/	/	/	/	/	/
66. Fan motor, FLA						
67. Spray pump motor, HP						
68. Spray pump motor, FLA						

SYMBOL DESCRIPTION						
69.						

If any of the equipment nameplate data differ from the design parameters as described in the above equipment description and in the design documents, note data item and unit number, and comment here:

INSTALLATION VERIFICATION:

Instructions: Under each unit write an affirmative response ("OK" or "✓") if the item is in compliance, a "NA" if the item is not applicable, data when requested, or a comment number if the equipment does not satisfy the checklist item. Explain comments in the spaces below the checklists. If a motor is driven by a VFD, fill in the requested data only if the Standard Commissioning Procedure for VFDs is not being completed. If the motor is VFD-driven, make all supply fan electrical measurements upstream of the VFD, unless directed otherwise, and use a true RMS multimeter for all supply fan motor and drive electrical measurements. Items marked "(VFD)" apply only to motors that are equipped with VFDs. For tests that require running VAV system supply fan motors at full speed, verify that the primary dampers on at least one half of the terminal units served by each AHU are fully open, to avoid duct overpressurization.

Current and voltage imbalance is defined as the greatest difference between the measurement for any of the 3 phases and the average of the 3 phases, that quantity divided by the average of the 3 phases. As an example, if the voltage measurements are 451, 461, and 463, then the average is 458.3 volts. The greatest difference between any measurement and the average is 451-458.3, or 7.3 volts. Then, the voltage imbalance is 7.3 volts / 458.3 volts, or 0.016. As a percentage, this is 1.6%, and would be acceptable by the criteria below.

For all compressor tests, record data as "[left hand compressor] / [right hand compressor]", where applicable. If a unit contains more than 2 compressors, attach data for extra compressors to this form.

Criteria for Acceptance: All items must be checked as "OK" (or "NA", where relevant) unless other acceptance criteria are noted.

SYMBOL DESCRIPTION						
General Checklist Items:						
1. Casing condition: dents, cracks, leaks?						
2. Shipping restraints removed?						
3. Adequate maintenance access to all components?						
4. No unusual noise or vibration?						
5. Electrical connections tight?						
6. Air filters clean and tight fitting?						
7. Coils clean?						
8. Return, outdoor, & relief dampers move freely / close tightly?						
9. Return, outdoor, relief dampers properly linked? (Observe stroke.)						
10. Thermometers / wells installed per specifications?						
11. Pressure gages / fittings installed per specifications?						
12. TAB report section for unit reviewed & acceptable (Acceptance: design ±10%)						
13.						

SYMBOL DESCRIPTION						
Supply Fan:						
1. Fan belt tension & condition okay?						
2. Fan rotation correct?						
3. Fan blades clean?						
4. Fan full speed RPM						
5. Motor contactors in good condition?						
6. Motor overload heaters properly sized?						
7. Fan motor volts, rated						
8. Fan motor volts into motor. Acceptance: ±10% of rating, all phases	/ /	/ /	/ /	/ /	/ /	/ /
9. Voltage Imbalance into motor, $(V_{max,min} - V_{avg}) / V_{avg}$						
10. Voltage Imbalance into motor is < 2%?						
11. Fan motor FLA, rated						
12. Fan motor full speed Amps, measured at motor (downstream of VFD)	/ /	/ /	/ /	/ /	/ /	/ /
13. Fan motor measured Amps < Rated FLA?						
14. Current imbalance at motor is < 2%?						
15. (VFD) Fan motor volts into drive. Acceptance: ±10% of rating, all phases	/ /	/ /	/ /	/ /	/ /	/ /
16. (VFD) Voltage Imbalance into drive, $(V_{max,min} - V_{avg}) / V_{avg}$						
17. (VFD) Voltage Imbalance into drive is < 2%?						
18. VFD maximum speed setting. Acceptance: 100% or 60 Hz						
19. VFD minimum speed setting. Acceptance: <50% or 30 Hz. [1]						
20. VFD motor full load speed setting. Acceptance: Equal to motor full load speed rating.	/	/	/	/	/	/
21. VFD motor frequency setting. Acceptance: same as rated motor frequency, usually 60 Hertz.						
22. VFD motor line voltage setting. Acceptance: same as rated motor voltage, usually 460 volts.						
23. No disconnects installed between VFD and motor without shutdown interlock to VFD?						
24. Shutdown interlocks between VFD & motor verified to be operational?						
25. Separate conduit for VFD incoming power and outgoing motor leads?						
26. (VFD) No power correction capacitors connected to motor?						
27. (VFD) Motor rotation correct in bypass mode?						
28. VFD bypass mode verified?						

Building Name: ______________________

SYMBOL DESCRIPTION						
Return /Relief Fan:						
1. Fan belt tension & condition okay?						
2. Fan rotation correct?						
3. Fan blades clean?						
4. Fan full speed RPM						
5. Motor contactors in good condition?						
6. Motor overload heaters properly sized?						
7. Fan motor volts, rated						
8. Fan motor volts into motor. Acceptance: ±10% of rating, all phases	/ /	/ /	/ /	/ /	/ /	/ /
9. Voltage Imbalance into motor, $(V_{max,min} - V_{avg}) / V_{avg}$						
10. Voltage Imbalance into motor is < 2%?						
11. Fan motor FLA, rated						
12. Fan motor full speed Amps, measured at motor (downstream of VFD)	/ /	/ /	/ /	/ /	/ /	/ /
13. Fan motor measured Amps < Rated FLA?						
14. Current imbalance at motor is < 2%?						
15. (VFD) Fan motor volts into drive. Acceptance: ±10% of rating, all phases	/ /	/ /	/ /	/ /	/ /	/ /
16. (VFD) Voltage Imbalance into drive, $(V_{max,min} - V_{avg}) / V_{avg}$						
17. (VFD) Voltage Imbalance into drive is < 2%?						
18. VFD maximum speed setting. Acceptance: 100% or 60 Hz						
19. VFD minimum speed setting. Acceptance: <50% or 30 Hz. [1]						
20. VFD motor full load speed setting. Acceptance: Equal to motor full load speed rating.	/	/	/	/	/	/
21. VFD motor frequency setting. Acceptance: same as rated motor frequency, usually 60 Hertz.						
22. VFD motor line voltage setting. Acceptance: same as rated motor voltage, usually 460 volts.						
23. No disconnects installed between VFD and motor without shutdown interlock to VFD?						
24. Shutdown interlocks between VFD & motor verified to be operational?						
25. Separate conduit for VFD incoming power and outgoing motor leads?						
26. (VFD) No power correction capacitors connected to motor?						
27. (VFD) Motor rotation correct in bypass mode?						

SYMBOL DESCRIPTION						
28. VFD bypass mode verified?						

SYMBOL DESCRIPTION						
Other Fan ______________:						
1. Fan belt tension & condition okay?						
2. Fan rotation correct?						
3. Fan blades clean?						
4. Fan full speed RPM						
5. Motor contactors in good condition?						
6. Motor overload heaters properly sized?						
7. Fan motor volts, rated						
8. Fan motor volts into motor. Acceptance: ±10% of rating, all phases	/ /	/ /	/ /	/ /	/ /	/ /
9. Voltage Imbalance into motor, $(V_{max,min} - V_{avg}) / V_{avg}$						
10. Voltage Imbalance into motor is < 2%?						
11. Fan motor FLA, rated						
12. Fan motor full speed Amps, measured at motor (downstream of VFD)	/ /	/ /	/ /	/ /	/ /	/ /
13. Fan motor measured Amps < Rated FLA?						
14. Current imbalance at motor is < 2%?						
15. (VFD) Fan motor volts into drive. Acceptance: ±10% of rating, all phases	/ /	/ /	/ /	/ /	/ /	/ /
16. (VFD) Voltage Imbalance into drive, $(V_{max,min} - V_{avg}) / V_{avg}$						
17. (VFD) Voltage Imbalance into drive is < 2%?						
18. VFD maximum speed setting. Acceptance: 100% or 60 Hz						
19. VFD minimum speed setting. Acceptance: <50% or 30 Hz. [1]						
20. VFD motor full load speed setting. Acceptance: Equal to motor full load speed rating.	/	/	/	/	/	/
21. VFD motor frequency setting. Acceptance: same as rated motor frequency, usually 60 Hertz.						
22. VFD motor line voltage setting. Acceptance: same as rated motor voltage, usually 460 volts.						
23. No disconnects installed between VFD and motor without shutdown interlock to VFD?						
24. Shutdown interlocks between VFD & motor verified to be operational?						
25. Separate conduit for VFD incoming power and outgoing motor leads?						
26. (VFD) No power correction capacitors						

SYMBOL DESCRIPTION						
connected to motor?						
27. (VFD) Motor rotation correct in bypass mode?						
28. VFD bypass mode verified?						

SYMBOL DESCRIPTION						
Cooling Coil (chilled water):						
1. No damage to heat transfer fins?						
2. No air bypass between coil & casing?						
3. Proper valves installed?						
4. 3-way valves ported properly?						
5. Flow direction correct?						
6. Condensate pan clean & drains properly?						
7.						
Heating Coil (HW & steam):						
8. No damage to heat transfer fins?						
9. No air bypass between coil & casing?						
10. Proper valves installed?						
11. 3-way valves ported properly?						
12. Flow direction correct?						
13. Steam traps don't pass steam when valves open?						
14.						
Refrigeration (DX units only):						
15. Suction lines insulated?						
16. Refrigerant sightglasses clear of bubbles?	/	/	/	/	/	/
17. Sightglasses indicate no moisture?	/	/	/	/	/	/
18. Compressor oil level correct? / Record level.	/	/	/	/	/	/
19. Coil in good condition & clean?						
20. Record head pressure under load, each compressor. Acceptance: per mfctr.	/	/	/	/	/	/
21. TXV external equalizer line properly connected?	/	/	/	/	/	/
22. Record suction pressure under load, each compressor.	/	/	/	/	/	/
23. Record suction temperature at TXV bulb, each compressor.	/	/	/	/	/	/
24. Calculate superheat. Acceptance: 8 to 20 degrees F	/	/	/	/	/	/
25. Refrigerant charge okay based on suction & head pressures, superheat, & sightglasses?						
26.						

SYMBOL DESCRIPTION						
27.	/	/	/	/	/	/

SYMBOL DESCRIPTION						
Condenser. (E) refers to evaporative condensers only:						
28. No unusual noise or vibration?						
29. Fan motor belt tension & condition okay?						
30. All fans are operational?						
31. Fan inlet screens are free of debris?						
32. Fan rotation correct?						
33. (E) Pump & piping are free of leaks?						
34. (E) Make-up water system operating properly? Acceptance: water level is ±1/2" - 3/4" below overflow level.						
35. (E) Pan clean & filled?						
36. (E) Pan suction strainer clean?						
37. (E) Water treatment system or bleed sequence in place?						
38. (E) Calculate rate of evaporation as gpm x °F range x 0.001. Is bleed valve set at the rate of evaporation ± 10%?						
39. (E) Spray distributed evenly across coils? (The pump should be on, and the fans off for this check.)						
40.						
General Run Test:						
41. Run Test: Observe unit under normal operation & load 3 times in a 12 hour period, at least 3 hours apart. Verify that there is no unusual noise, vibration, cycling, overheating, or other problems at the fan section, damper section, coils, compressors, condenser, electrical, etc..						
Observation #1: Time of Day / Acceptable?	/	/	/	/	/	/
Observation #2: Time of Day / Acceptable?	/	/	/	/	/	/
Observation #3: Time of Day / Acceptable?	/	/	/	/	/	/

Notes to the Table:
[1] Operation of the motor at less than about 25 to 30% of the full load speed rating may cause motor overheating due to inadequate motor ventilation. Also, if the motor is driven at less than 50% of the full load speed rating, the thermal over-load protection may not properly protect the motor. A thermally responsive overload protection device that senses actual motor winding temperature may be required. The motor should not be driven below 50% of its full load speed rating without consulting the motor manufacturer's representative.

CHECKLIST COMMENTS:
Number / Comment

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____
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CONTROLS CALIBRATION:

Instructions: All control points listed under each AHU refer to sensors and stats that are dedicated to that AHU system, and for the most part physically located close to or in the AHU, not global (building-level) points. For thermostats and humidistats, slowly adjust the setpoint until the controlled response begins (i.e. contact make or break). Note the setpoint when that occurs and the simultaneous measured value on a calibrated instrument held in close proximity to the sensing bulb. If sensor location is improper, explain in comments. Check calibration of zone temperature for single zone AHUs only. Enter other AHU control points that are critical to the control sequence in the blank spaces for each AHU, as appropriate. It is not necessary to repeat any calibration that was documented in the Standard Commissioning Procedure for EMSs, but refer to that document where relevant.

Criteria for Acceptance: Temperature sensors, EMS or contact make/break values ± 2 F degrees from measured values. Static pressure sensors, less than ± 0.1" from measured values. Relative humidity sensors, less than ± 10% from measured values.

CONTROL TYPE	SENSOR / STAT LOCATION	CONTROL LOCATION OK?	MEASURED VALUE	EMS VALUE or MAKE/BRK VALUE	ACCEPTABLE? / COMMENTS
Outdoor air temp., global (EMS)					
Outdoor air % RH, global (EMS)					
AHU-____:					
OSA temp					
Discharge air temp.					
Mixed air temp.					
Return air temp.					
Static pressure.					
Zone temp. (SZ)					
AHU-____:					
OSA temp					
Discharge air temp.					
Mixed air temp.					
Return air temp.					
Static pressure.					
Zone temp. (SZ)					
AHU-____:					
OSA temp					
Discharge air temp.					
Mixed air temp.					
Return air temp.					
Static pressure.					
Zone temp. (SZ)					

Building Name: ______________________

CONTROL TYPE	SENSOR / STAT LOCATION	CONTROL LOCATION OK?	MEASURED VALUE	EMS VALUE or MAKE/BRK VALUE	ACCEPTABLE? / COMMENTS
AHU-____:					
OSA temp					
Discharge air temp.					
Mixed air temp.					
Return air temp.					
Static pressure.					
Zone temp. (SZ)					
AHU-____:					
OSA temp					
Discharge air temp.					
Mixed air temp.					
Return air temp.					
Static pressure.					
Zone temp. (SZ)					
AHU-____:					
OSA temp					
Discharge air temp.					
Mixed air temp.					
Return air temp.					
Static pressure.					
Zone temp. (SZ)					

CONTROLS CALIBRATION COMMENTS:
AHU # / Control Point / Comment

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FUNCTIONAL PERFORMANCE VERIFICATION:

Instructions: Since there are many possible controls sequences for air handling units and the systems they serve, it is impossible to write generic tests that cover all such sequences. Use the standard test procedures for start/stop control and the various temperature reset controls, if applicable.

If the standard test procedures are not applicable or adequate, document the sequences, tests, and results on the pages that follow the standard procedures. First describe the control sequences for each AHU for each applicable sequence type: start/stop, warm-up mode, fan capacity, temperature control, safeties, and other. Next describe in detail what tests you plan to do to verify each control sequence. Finally, describe your test results and conclusions, including any deficiencies found. **See the attached example for the level of detail required.** Add sheets as necessary. It is not necessary to repeat any tests that were documented in the Standard Commissioning Procedure for EMSs, but refer to that document where relevant.

Attach to this form all relevant field data, monitored data, graphs, trend logs, and so forth. Annotate any data and graphs so that it is clear what the data are proving. EMS trend logs of EMS outputs, program print-outs, or schedule and setpoint print-outs <u>are not acceptable</u> as proof of operation, unless the information is first verified to be accurate and documentation is attached. Trend logs of sensor inputs to the EMS are acceptable.

Scheduled Start/Stop and Unoccupied Setback/Setup Test: Perform the following tests by monitoring and /or observing each piece of controlled equipment under actual operation. It is permissible to adjust the programmed schedules and/or setpoints for easier testing. If this is done, reprogram to the original schedules and setpoints, or as directed by the building operator, at the conclusion of testing. If the original values are not consistent with energy efficient operation, discuss with the building operator. Use of dataloggers or trend logs of EMCS input channels over a one week period (minimum, two days) is recommended. Annotate any logger data and graphs so that it is clear what the data are proving, and attach these to this form. (See attached example of an annotated graph.) EMCS trend logs of EMCS output signals are not acceptable as proof of operation unless you have first verified and documented (attach) that the output signals accurately represent actual operation.

Criteria for Acceptance: The following shall be considered deficiencies: 1) Equipment doesn't start and/or stop within 15 minutes of the scheduled times, 2) Unoccupied space temperatures go more than 3 degrees F below (above) the setback (setup) temperature setpoints, 3) Unoccupied space temperatures are maintained more than 3 degrees F above (below) the setback (setup) setpoints, 4) Equipment that is to be interlocked with the AHU doesn't operate on the same schedule.

AHU #						
1. Programmed start time. *(For the following tests, select 1 typical day from the observed data.)*						
2. Observed (or monitored) start time						
3. Programmed occupied setpoints, heating / cooling (°F)	/	/	/	/	/	/
4. Observed (or monitored) stabilized space temperature range	/	/	/	/	/	/
5. Programmed stop time						
6. Observed (or monitored) stop time						
7. Programmed unoccupied setpoints, heating / cooling (°F)	/	/	/	/	/	/
8. Observed (or monitored) minimum / maximum unoccupied space temperature	/	/	/	/	/	/
9. If observed minimum (maximum) temperature is higher (lower) than the unoccupied heating (cooling) setpoint, does equipment operate to maintain that temperature? If "yes", this is a deficiency.						
10. List all interlocked equipment by symbol. Include pumps, fans, etc. as relevant.						
11. Does all interlocked equipment as listed in #10 start & stop on the same schedule as the AHU?						
12. Are final programmed schedules consistent with energy efficient operation? If "no", comment.						
13. Are final programmed occupied & unoccupied setpoints consistent with energy efficient operation? If "no", comment.						

COMMENTS ON SCHEDULED START/STOP AND SETBACK TEST ITEMS (add more sheets if needed):

ITEM # COMMENT

_____ ____

_____ ____

_____ ____

_____ ____

_____ ____

_____ ____

_____ ____

Building Name: ______________________

Optimum Start/Stop Test: Perform the following tests by monitoring and /or observing each system under actual operation. It is permissible to adjust the programmed schedules and/or setpoints for easier testing. For testing this application, make sure that unoccupied temperature setpoints are at least 10 F degrees below (heating) and above (cooling) the occupied setpoints. If any programmed schedules and/or setpoints are changed for testing, reprogram to the original schedules and setpoints, or as directed by the building operator, at the conclusion of testing. If the original values are not consistent with energy efficient operation, discuss with the building operator. Use of dataloggers or trend logs of EMCS input channels to monitor relevant equipment status and temperatures over a one week period is highly recommended. Annotate any logger data and graphs so that it is clear what the data are proving, and attach these to this form. (See attached example of an annotated graph.) EMCS trend logs of EMCS output signals are not acceptable as proof of operation unless you have first verified and documented (attach) that the output signals accurately represent actual operation.

Test Conditions: Outside air temperature must be between 40°F and 55°F for at least 6 hours during scheduled unoccupancy.

Criteria for Acceptance: The following shall be considered deficiencies: 1) Reference space reaches occupied setpoint more than 30 minutes before scheduled occupancy, 2) Reference space temperature goes above (below, heating) occupied setpoint by more than 4 F degrees more than 30 minutes before the end of scheduled occupancy, 3) Discharge air temperature is reset rather than changing the fan start time in order to reach the occupied setpoint on schedule, 4) Outdoor air damper opens during optimal warm-up mode, unless this is called for as part of a purge or cool-down sequence, 5) Outdoor air damper closes during the optimal stop period, 6) Other spaces served by a single system differ significantly in optimal start and stop response from the reference space, 7) Equipment that is to be interlocked with the AHU doesn't operate on the same schedule..

AHU #						
1. EMCS programmed start of occupancy. *(For the following tests, select 1 typical day from the observed data.)* 2. Observed (or monitored) start time 3. Time at which reference space reaches occupied setpoint						
4. Outdoor air temperature at actual equipment start time (°F) 5. Outdoor air damper status during optimum start						
6. EMCS programmed end of occupancy 7. EMCS programmed occupied setpoint (°F) 8. Observed (or monitored) stop time 9. Temperature which reference space reaches at end of scheduled occupancy						
10. Outdoor air temperature at actual equipment stop time (°F)						
11. Outdoor air damper status during optimum stop 12. Do start & stop times vary on different days? **Acceptance:** Start/stop times must vary.						
13. List all interlocked equipment by symbol. Include pumps, fans, etc. as relevant.						
14. Does all interlocked equipment as listed in #13 start & stop on the same schedule as the AHU?						

COMMENTS ON OPTIMUM START/STOP TEST ITEMS (add more sheets if needed):

ITEM # COMMENT

______ ____

______ ____

______ ____

______ ____

______ ____

______ ____

Discharge Air Temperature Reset Test: Perform the following tests by monitoring and /or observing each system under actual operation. It is permissible to adjust the programmed setpoints for easier testing. If any programmed setpoints are changed for testing, reprogram to the original schedules and setpoints, or as directed by the building operator, at the conclusion of testing. If the original values are not consistent with energy efficient operation, discuss with the building operator. It is also permissible, and often advisable, to place the index temperature sensors in a temperature bath or substitute the index sensor with a temperature simulator. This permits accurate control of the index input to the algorithm.

Use of dataloggers or trend logs of EMCS input channels to monitor index and discharge air temperatures over a one or two day period is recommended if the index temperature is expected to vary widely (at least one half of the upper/lower setpoint range) during this time. Annotate any logger data and graphs so that it is clear what the data are proving, and attach these to this form. (See attached example of an annotated graph.) EMCS trend logs of EMCS output signals are not acceptable as proof of operation unless you have first verified and documented (attach) that the output signals accurately represent actual operation.

Test Conditions: The index temperature must vary over at least 1/2 of its upper/lower setpoint range during the test. If this condition cannot be met, simulate index temperatures or use temperature bath.

Criteria for Acceptance: The following shall be considered a deficiency: The measured discharge air (DA) temperature (lines #10 & 13) is more than ± 3 F degrees from the design DA temperature at the low and high index temperature tests (line #9 & 12).

AHU #						
1. Programmed index type (OSA temperature, space temp, return air temp, etc.)						
2. Programmed discharge air (DA) temperature reset upper limit (°F)						
3. Programmed DA temperature reset lower limit (°F)						
4. Programmed DA upper setpoint versus lower index temp	/	/	/	/	/	/
5. Programmed DA lower setpoint versus upper index temp	/	/	/	/	/	/
6. Does discharge air go above high limit setpoint?						
7. Does discharge air go below low limit setpoint?						
8. Lowest monitored or simulated index temperature						
9. Design DA temp at lowest monitored or simulated index temp (From reset curve or linear relation. Attach graph.)						
10. Discharge air temperature coincident with lowest index temperature						
11. Highest monitored or simulated index temperature						
12. Design DA temp at highest monitored or simulated index temp						
13. Discharge air temperature coincident with highest index temperature						

COMMENTS ON DISCHARGE AIR TEMPERATURE RESET TEST ITEMS (add more sheets if needed):

ITEM # COMMENT

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Fan Volume Full Capacity Test: Perform the following tests and measurements by forcing the system to its maximum capacity (e.g. full flow). Verify that the drive maintains the system at setpoint. Tests 1 & 2 apply to all methods of fan volume control (inlet vanes, VFDs, cone dampers, etc.). All other tests apply to VFDs only.

Test Equipment: Note that use of a true RMS multimeter is highly recommended for all VFD electrical measurements. Multimeters that are not true RMS often give confusing and/or erroneous data when measuring waveforms that are not pure sine wave.

Criteria for Acceptance: As noted under specific test items. Note: Imbalance (current or voltage) is defined as largest phase difference from the average, divided by the average.

AHU #						
1. Controlled variable setpoint & units of measurement (static pressure, °F, etc.). **Acceptance:** Setpoint must be as low as possible, consistent with proper system operation.						
2. Measured controlled variable when fan is at full capacity. **Acceptance:** Must be within -15% to +10% of setpoint.						
3. Maximum Hertz setting. **Acceptance:** <65 Hz						
4. Measured Hertz. **Acceptance:** Within ±10% of maximum setting.						
5. Measured amps into drive. **Acceptance:** Avg must be no more than 5% above rated motor full load amps	/ /	/ /	/ /	/ /	/ /	/ /
6. Measured amps into motor. **Acceptance:** Current imbalance between phases must be <2%; avg must be no more than 5% above rated motor full load amps	/ /	/ /	/ /	/ /	/ /	/ /
7. Measured volts into drive. **Acceptance:** Average must be within ±10% of rating.	/ /	/ /	/ /	/ /	/ /	/ /
8. Measured volts into motor. **Acceptance:** Average must be within ±10% of rating.	/ /	/ /	/ /	/ /	/ /	/ /
9. Voltage imbalance into drive <2%? **Acceptance:** Must be <2%.						
10. Voltage imbalance into motor <2%? **Acceptance:** Must be <2%.						

Flying Start Test (VFDs only): Perform this test only if the drive is equipped with a flying start function. This test verifies that the drive is able to start to a spinning load, without undergoing nuisance trips. With the equipment running, momentarily interrupt power to the drive and restore power before the driven equipment comes to a complete stop. Alternative Test: If it is not possible to interrupt power to the drive, use the drive controls to turn it off momentarily, and then turn it back on before the driven equipment comes to a complete stop. Use this alternative only if it is impossible to interrupt power **to** the drive.

Caution: In some cases, this test has resulted in damage to the VFD because of faulty VFD components. Inform the building operator of this possibility, and get permission to perform the test before starting.

AHU #						
11. Did the drive restart & match the spinning load without tripping any safeties? **Acceptance:** Drive must restart & match load without trips.						
12.						

Fan Volume Control Normal Operation Test, VFDs only: Monitor or measure kW or Amp input to the drive, and trend VFD control signal and controlled variable input signal (static pressure, °F, etc.) for at least 24 hours to document speed modulation under normal operation. If drive is not observed to modulate to less than 50% of full speed, force the flow control devices to minimum positions by changing setpoints, control signal, etc. as needed. Attach annotated graphs of monitored data to this test sheet. If using an energy management system (EMS) to verify drive operation, record the following values, and then attach annotated trend-logs. Test 1 must be at a control signal of between 60 and 75%, and test 2 must be at a control signal of between 30 and 50% of full speed.

Criteria for Acceptance: As noted under specific test items.

AHU #						
13. Test 1: VFD control speed signal, % of maximum signal (60 - 75%)						
14. Divide answer to #13 by 100% and cube the result.						
15. VFD input amps at same time as #13	/ /	/ /	/ /	/ /	/ /	/ /
16. Fractional Current: Divide the avg VFD input amps (#15) by the avg max running amps into the motor (#5).						
17. Calculate the correspondence between the fractional current and the cube of the control signal: (#16 - #14) / #14. **Acceptance:** The calculated correspondence must be within ±20%.						
18. Test 2: VFD control speed signal, % of maximum signal (30 -50%)						
19. Divide answer to #18 by 100% and cube the result.						
20. VFD input amps at same time as #18	/ /	/ /	/ /	/ /	/ /	/ /
21. Fractional Current: Divide the avg VFD input amps (#20) by the avg max running amps into the motor (#5).						
22. Calculate the correspondence between the fractional current and the cube of the control signal: (#21 - #19) / #19. **Acceptance:** The calculated correspondence must be within ±20%.						
23. Was VFD observed to modulate to <60% of full speed under normal (non-forced) operation? If not, comment below on likely reasons. Note if this is to be considered a deficiency. Recommend seasonal retesting if appropriate.						
24.						

Fan Volume Control Normal Operation Test, non-VFD systems: Starting with stable volume control, lower the static pressure setpoint by 30% or adjust other controlled variable setpoints such that fan volume should decrease. It may be necessary to change zone temperature setpoints to achieve stable operation for the duration of this test.

Criteria for Acceptance: As noted under specific test items.

AHU #						
25. Does volume control device modulate fan volume when setpoint is changed?						
26. After changing setpoint, wait 5 minutes. Does volume control device reach point of stability without excessive hunting?						
27.						

COMMENTS ON PERFORMANCE VERIFICATION ITEMS (continued on following page):

ITEM # UNIT # COMMENT

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Criteria for Acceptance for all following custom test procedures: The actual control sequence must be in accordance with the design intent and/or the approved controls submittal. Acceptance is based on thorough documented verification that each control sequence performs exactly as described. Add sheets as required.

Start/Stop Control, AHU# __________ (include interlocks, delays, time-of-day control, outside temperature lockout, etc.)**:**

Describe the control sequence:

Describe the tests that were done to verify the control sequence:

Conclusions:

Warm-Up Mode Control, AHU# __________________ (include damper control, time-of-day control, heating/cooling section control, fan control, etc.)**:**

Describe the control sequence:

Describe the tests that were done to verify the control sequence:

Conclusions:

Fan Capacity Control, AHU# ________ (include all relevant fans, start-up speed, minimum/maximum setpoints, etc. Reference VFD Standard Commissioning Procedure if applicable)**:**

Describe the control sequence:

Describe the tests that were done to verify the control sequence:

Conclusions:

Temperature Control, AHU# _______________ (include heating/cooling section control, mixed air temperature control, discharge air temperature control, economizer and compressor staging, etc.)**:**

Describe the control sequence:

Describe the tests that were done to verify the control sequence:

Conclusions:

System Safeties, AHU# ____________ (include high and low temperature safeties, high pressure safeties, etc.; do not include fire & life safety controls unless otherwise directed)**:**

Describe the control sequence:

Describe the tests that were done to verify the control sequence:

Conclusions:

Other Control, AHU# ______________:

Describe the control sequence:

Describe the tests that were done to verify the control sequence:

Conclusions:

Other Control, AHU# _______________:

Describe the control sequence:

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Describe the tests that were done to verify the control sequence:

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Conclusions:

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Other Control, AHU# _______________:

Describe the control sequence:

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Describe the tests that were done to verify the control sequence:

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Conclusions:

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I certify that the data and test results as recorded herein are accurate.

____ ____________
Signature, Commissioning Agent Date

____ ______________________________
Firm Name (Area Code) Phone Number

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SAMPLE CUSTOM TEST DESCRIPTION

Start/Stop Control, AHU# *AC 2 & 3* (include interlocks, delays, time-of-day control, outside temperature lockout, etc.)**:**

Describe the control sequence:

ACs are started and stopped by the EMS on schedule, and are interlocked with return fan RF-4. RF-4 is to start 1 minute after either of the two supply fans. When AC-2&3 are off, the cooling coil valves and outside air dampers are closed.

Describe the tests that were done to verify the control sequence:

AC-2, 3, and RF-4 status were trended for a 48 hour period. The trend log accuracy was verified by observing each unit twice: once when the status was reported as off at the EMS, and once when the status was reported as on. During visual verification, we also verified that valve and damper status was appropriate for the observed status. We also looked at the reasonableness of the fan schedules, considering the actual building occupancy times.

Conclusions:

Trend logs indicated that AC-2& 3 operation closely follows the programmed schedules. RF-4 started about 70 seconds after the two supply fans, in accordance with the programmed time delay. We observed the three fans for a period starting 5 minutes before the scheduled end of occupancy until 5 minutes after; actual status and reported status (at the EMS) were as programmed in each case. We noted that AC-2 was scheduled to turn on at 5am on weekdays, and to run continuously on weekends. This does not match the actual occupancy schedule of the areas served, and is thus noted as a deficiency. (We pointed this out to the building operator, who adjusted the AC-2 run schedule to 7am to 6pm on weekdays and Saturday, and off on Sunday. This matches the AC-3 schedule.)

Warm-Up Mode Control, AHU# *AC 2 & 3* (include damper control, time-of-day control, heating/cooling section control, fan control, etc.)**:**

Describe the control sequence:

These are cooling-only units, and have no warm-up mode.

Describe the tests that were done to verify the control sequence:

Conclusions:

Fan Capacity Control, AHU# *AC 2 & 3* (include all relevant fans, start-up speed, minimum/maximum setpoints, etc. Reference VFD Standard Commissioning Procedure if applicable)**:**

Describe the control sequence:

AC-2 & 3 blade pitch is adjusted to maintain the respective supply duct static pressures at setpoint. RF-4 blade pitch is adjusted to maintain a positive building static pressure at setpoint. The duct static pressure setpoints for AC-2 & 3 are reset over an adjustable range as a function of duct velocity as measured in the mechanical room. The reset schedule is presently programmed as 1.2" at a duct velocity of 1000 fpm, and 2.5" at a duct velocity of 4000fpm. The blades are pitched at zero flow on start-up and shut-down.

Describe the tests that were done to verify the control sequence:

We first measured the AC-2&3 duct static pressures and duct velocities near the respective EMS sensors, to verify that the EMS input signals are accurate. Then we set up trend logs for the duct static pressure, duct velocity, and the fan pitch output signal. We trended each point at 15 minute intervals over a 48 hour period. Since trending occurred during very warm weather, when the fans were called upon to operate near full capacity throughout occupied hours, we found it necessary to adjust zone cooling setpoints to force terminal units to minimum primary air, thereby driving duct velocities down, and presumably duct static pressure down also. We also visually inspected the fan blade position when the fans were off, to verify that blade pitch was set at no flow.

Conclusions:

Measured duct static pressures and velocities were within 3% and 5% of the EMS sensor read-out for AC-2 and 3, respectively. Trending for the initial 48 hour period indicated very little reset of the duct static pressure setpoint, probably due to the very warm weather. When we globally raised the zone cooling setpoints to 85°F for 30 minutes at the end of occupancy, the terminal unit primary dampers in most zones went to minimum position, and the trend log (reset for 5 minute intervals) showed that the duct static pressures decreased to 1.7" and 1.45" for AC-2 & 3, respectively. The duct velocities that coincided with these pressures were 2000fpm and 1700 fpm, respectively. In each case the trended static pressure was within ±0.1" of the reset setpoint, which we deemed satisfactory. Visual inspection of the fan blade position with fans off revealed that AC-2 operated as intended, but that ***AC-3 fan blades remained at the same pitch that they were last controlled to. (During testing of normal operation, they remained at a pitch consistent with full flow.) On investigation we found that the program code necessary to drive the AC-3 blade pitch to zero flow was missing. This has since been remedied, and we've visually confirmed proper operation.*** *Annotated trend logs are attached.*

Temperature Control, AHU# *AC 2 & 3* (include heating/cooling section control, mixed air temperature control, discharge air temperature control, economizer and compressor staging, etc.)**:**

Describe the control sequence:

These units are equipped with cooling coils only. The coils can see either chilled water or tower water, depending on OSA temperature and building load. The discharge air temperature of each AHU is reset as a function of the average zone differential between zone temperature and cooling setpoint. The return air and outside air dampers are controlled to maintain the mixed air temperature at setpoint, which is reset as a function of OSA temperature. At OSA temperatures above 45°F but below 70°F the MA temperature setpoint is 53°F. At OSA temperatures below 45°F and above 70°F the OSA dampers go to minimum position, and the return air dampers to maximum position.

Describe the tests that were done to verify the control sequence:

We set up trend logs for a 48 hour period (15 minute interval) for discharge air, outside air, and mixed air temperatures, as well as discharge air temperature setpoint. The accuracy of these points was verified during the calibration tests in the EMS Commissioning Procedure. We also trended temperatures in 3 zones for each of the two AHUs. We required test conditions that included an OSA temperature range of 55°F or below to 70°F or above during scheduled occupancy. Fortunately these conditions were met so we didn't have to consider alternate simulation type testing. We analyzed the trend logs to verify that actual discharge air and mixed air temperatures were within 2F degrees of the setpoint at all times during AHU operation. (MA temperature floats up with OSA temperature as the OSA temperature rises above 53°F.)

Conclusions, temperature control verification:

See the attached annotated trend logs. As noted on these trend logs, we observed that the OSA and RA dampers modulated properly to try to maintain the MA temperature at 53°F when the OSA temperature was above 45°F but below 70°F. Since the minimum OSA temperature during the trending period was 52°F, we reset the minimum OSA temperature setpoint to 55°F to observe damper movement during those conditions. We observed the OSA dampers on both AHUs to go to minimum position (about 10% flow) when the OSA temperature was below the minimum setpoint. The trend log of MA temperature reflected this operation. We did observe that the OSA damper modulated to minimum position (and the RA damper went to full open) when the OSA temperature exceeded 70°F (78°F at 3pm, 6/12/96). Though it is difficult to tell from the trend logs exactly how the DA temperature responds to the average zonal differentials, it is obvious that the DA temperature varies smoothly over a range between 53°F and 70°F, with the higher temperatures at low outside temperatures, and early in the day.

System Safeties, AHU# *AC 2 & 3* (include high and low temperature safeties, high pressure safeties, etc.; do not include fire & life safety controls unless otherwise directed)**:**

Describe the control sequence:

If the mixed air temperature in either AHU is below 40°F, an alarm is sent to the EMS, the cooling coil valve and the OSA damper are closed, and the fan is shut off. If the duct static pressure exceeds 3.5", an alarm is sent to the EMS, the fan is shut off, and the OSA damper is closed.

Describe the tests that were done to verify the control sequence:

We arranged for Saturday access to the building so that we could simulate conditions that would result in triggering the safeties. First we reset the mixed air temperature low limit setpoint to 5 F degrees higher than the actual measured MA temperature and observed system response. We then reset the low limit setpoint to 40°F and lowered the duct static pressure high limit setpoint to 0.2" below the actual static pressure and observed system response. Finally we reset the duct static pressure high limit setpoint to 3.5".

Conclusions:

The AC-2 MA temperature was measured at 61°F (AC-3: 59°F) at the beginning of the test. We raised the MA low limit setpoints for both AHUs to 65°F and observed that alarms were sent to the EMS, the fans then shut off, and finally the cooling coil valves and OSA dampers modulated closed. After resetting the low limit setpoint, we measured the duct static pressures at 2.1" and 1.8" for AC-2 & 3, respectively. We lowered the static pressure high limit setpoints to 1.9" and 1.6" respectively and observed that alarms were sent to the EMS, the fans then shut off, and finally the OSA dampers modulated closed.