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Joint Appendix JA6

Appendix JA6 – HVAC System Fault Detection and Diagnostic Technology

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JA6.1 Fault Indicator Display (FID)

JA6.1.1 Purpose and Scope

Joint Appendix JA6.1 defines required elements for fault indicator display technologies that utilize instrumentation and computer software functionality to monitor and determine the operating performance of vapor compression air conditioning and heat pump systems, to provide visual indication to the system owner/operator if the system's refrigerant charge or metering device performance does not conform to approved target parameters for minimally efficient operation.

JA6.1.6 specifies the required instrumentation, instrumentation accuracy, parameters measured, required calculations, allowable deviations from target values for system operating parameters, and the requirements for system fault indication for a fault indicator display technology that conforms to the methods for verifying refrigerant charge and metering device performance described in Reference Residential Appendix RA3.2.2.

Fault indicator display technologies other than what is described in Section JA6.1are possible, and when vapor compression air conditioner and heat pump system refrigerant charge, metering device and airflow operating performance can be reliably determined by methods and instrumentation other than those specifically defined in section JA6.1 such alternative fault indicator display technologies may be allowed for Fault Indicator Display compliance credit if the manufacturer of the product requests approval from the Energy Commission. The Commission may grant such approval after reviewing submittals from the applicant. Fault indicator display technologies that are approved by the Commission shall be specified in documentation that will be published as an addendum to this appendix.

The applicant shall provide information that specifies the required instrumentation, the instrumentation accuracy, the parameters measured, the required calculations, the allowable deviations from target values for system operating parameters, and the requirements for system fault indication.

JA6.1.2 FID Product Approval

Fault indicator display technology manufacturers shall certify to the Energy Commission that the fault indicator display technology meets the requirements of Reference Joint Appendix JA6.1.

JA6.1.3 FID Installation

Fault indicator display devices shall be factory installed by the space-conditioning system manufacturer, or field installed according to the space-conditioning system manufacturer's requirements and the FID manufacturer's specifications.

JA6.1.4 FID Product Documentation

Manufacturers of FID technologies shall, upon request, provide comprehensive engineering specification documentation, installation and technical field service documentation, and homeowner user instructions documentation to designers, installers, service personnel and homeowners who utilize the technology.

JA6.1.5 Optional Fault Detection Capabilities

The FID may also be used to signal other system operation faults as long as these additional functions do not detract from the proper function of the refrigerant charge, metering device, or airflow operation indications.

JA6.1.6 Requirements for a Fault Indicator Display

This section specifies the required instrumentation, the instrumentation accuracy, the parameters measured, the required calculations, the allowable deviations from target values for system operating parameters, and the requirements for system fault indication for a fault indicator display technology.

JA6.1.6.1 Instrumentation Specifications

Instrumentation for the procedures described in JA6.1.6 shall conform to the following specifications:

JA6.1.6.1.1 Temperature Sensors

The temperature sensors shall have an accuracy of plus or minus1.8°F.

JA6.1.6.1.2 Refrigerant Pressure Sensors

Refrigerant pressure sensors shall have an accuracy of plus or minus 3 percent of full scale.

JA6.1.6.1.3 Parameters Measured

The following parameters shall be measured:

(a) Suction line temperature ($T_{suction,}$).

(b) Liquid line temperature (T_{liquid}).

(c) Evaporator saturation temperature or low side refrigerant pressure ($T_{evaporator, sat}$).

(d) Condenser saturation temperature or high side refrigerant pressure ($T_{condensor, sat}$).

(e) Return air wet bulb temperature or humidity ($T_{return, wb}$).

(f) Return air dry bulb temperature ($T_{return, db}$).

(g) Condenser air entering dry bulb temperature ($T_{condenser, db}$).

(h) Supply air dry bulb temperature ($T_{supply, db}$).

JA6.1.6.2 Refrigerant Charge, Metering Device, and Airflow Calculations

Refrigerant charge, metering device and airflow calculations for determining superheat, subcooling, and temperature split values shall conform to the specifications of this section utilizing the measured parameters data from instrumentation as specified in Section JA6.1.6.1.

JA6.1.6.2.1 Fixed Metering Device Calculations

The fixed metering device calculations are used only for systems equipped with fixed metering devices. These include capillary tubes and piston-type metering devices.

(a) Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature. Actual Superheat = $T_{suction,} - T_{evaporator, sat}$.

(b) Determine the Target Superheat using Reference Residential Appendix RA3 Table RA3.2-2, the return air wet-bulb temperature ($T_{return, wb}$) and the condenser air entering dry-bulb temperature ($T_{condenser, db}$). If a dash mark is read from Reference Residential Appendix RA3 Table RA3.2-2, the target superheat is less than 5°F.

(c) Calculate the difference between Actual Superheat and Target Superheat (Actual Superheat - Target Superheat)

JA6.1.6.2.2 Variable Metering Device Calculations

The variable metering device calculations are used only for systems equipped with variable metering devices. These include Thermostatic Expansion Valves (TXV) and Electronic Expansion Valves (EXV).

(a) Calculate Actual Subcooling as the condenser saturation temperature minus the liquid line temperature. Actual Subcooling = $T_{condenser, sat} - T_{liquid}$.

(b) Determine the Target Subcooling specified by the manufacturer.

(c) Calculate the difference between actual subcooling and target subcooling (Actual Subcooling - Target Subcooling.

(d) Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature. Actual Superheat = $T_{suction} - T_{evaporator, sat}$.

(e) If possible, determine the Superheat Range specified by the manufacturer.

JA6.1.6.2.3 Minimum Airflow Calculations

The minimum airflow calculations are designed to determine whether the rate of airflow across the evaporator coil is above the minimum airflow rate requirement for a valid refrigerant charge test result.

(a) Calculate the Actual Temperature Split as the return air dry-bulb temperature minus the supply air dry-bulb temperature. Actual Temperature Split = $T_{return, db} - T_{supply, db}$

(b) Determine the Target Temperature Split from Table JA6.1-1 using the return air wet-bulb temperature ($T_{return, wb}$) and return air dry-bulb temperature ($T_{return, db}$).

(c) Calculate the difference between target and actual temperature split (Actual Temperature Split - Target Temperature Split).

JA6.1.6.3 System Fault Indication

Data from instrumentation specified in Section JA6.1.6.1 and calculations specified in Section JA6.1.6.2 shall be processed and interpreted continuously or at sufficiently frequent time step intervals, during normal system operation, to insure that system operating conditions that meet the system fault criteria of this section will be detected, and indicated by the fault indicator display. Data from instrumentation specified in Section JA6.1.6.1 and calculations specified in Section JA6.1.6.2 shall be processed and interpreted in a manner that prevents indication of system faults when system fault criteria are triggered by temporary or transitory operating conditions that are not true indicators of problems with refrigerant charge, metering device, or airflow performance.

The fault indicator display shall:

(a) be clearly visible to occupants of the home during normal operation.

(b) be located on or within one foot of (one of) the thermostat(s) controlling the air conditioner.

(c) display an indication of a system fault requiring service or repair when system normal operation fails to meet the required operating performance criteria specified in this section. These system fault indications shall be displayed for a period of at least 7 days after a system fault is detected unless the fault indicator display is reset by the installing or servicing technician.

1. Refrigerant charge verification criterion for fixed metering device systems.

   If the air conditioner has a fixed metering device, runs for 15 minutes, has a Target Superheat value determined by Reference Residential Appendix RA3 Table RA3.2-2 that is greater than or equal to 5°F, the condenser air entering temperature is greater than or equal to 65°F, and the minimum airflow requirement from item d below is satisfied, then the conditions for a valid refrigerant charge test are satisfied.

   If the conditions for a valid refrigerant charge test are satisfied, and the air conditioner has an Actual Superheat value that deviates more than plus or minus 10°F from the Target Superheat value determined by Reference Residential Appendix RA3 Table RA3.2-2, then the system fails the refrigerant charge test, and a system fault shall be reported.

2. Refrigerant charge verification criterion for variable metering device systems.

   If the air conditioner has a TXV or EXV, runs for 15 minutes, the condenser air entering temperature is greater than or equal to 65°F, and the minimum airflow requirement from item d below is satisfied, then the conditions for a valid refrigerant charge test are satisfied.

   If the conditions for a valid refrigerant charge test are satisfied, and the air conditioner has an Actual Subcooling value that deviates more than plus or minus 6°F from the Target Subcooling

value listed by the manufacturer, then the system fails the refrigerant charge test, and a system fault shall be reported.

3. Variable metering device function verification criterion.

   If the air conditioner has a TXV or EXV, runs for 15 minutes, the condenser air entering temperature is greater than or equal to 65°F, and the minimum airflow requirement from item d below is satisfied, then the conditions for a valid metering device test are satisfied.

   If the conditions for a valid metering device test are satisfied, and the air conditioner has an Actual Superheat value outside the range specified by the manufacturer (or outside the range 2°F to 28°F if there is no manufacturer's specification), then the system fails the metering device test, and a system fault shall be reported.

4. Minimum airflow verification criterion.

   If the air conditioner runs for 15 minutes, and the condenser air entering temperature is greater than or equal to 65°F, then the conditions for a valid minimum airflow test are satisfied.

   If the conditions for a valid minimum airflow test are satisfied, and the air conditioner has an Actual Temperature Split value that deviates more than plus 5°F from the Target Temperature Split value determined by Table JA6.1-1, then the system fails the minimum airflow test, and a system fault shall be reported.

JA6.1.6.4 Optional Functionality

The fault indicator display devices may be set to tighter specifications than those specified in Section JA6.1.6.3. The fault indicator display may also be used to signal other system faults as long as these additional diagnostic functions do not detract from the accuracy of the measurement and reporting of system faults as specified in Section JA6.1.6.3.

JA6.1.6.4.1 Self Diagnostic Reporting

When equipped with self diagnostic reporting functionality, the FID shall check for communication with every sensor and provide an indication when there are any sensor failures.

JA6.1.6.4.2 Data Access

In order to provide for verification of sensor data and FID system functionality, data access shall be provided. The FID manufacturer shall specify the data access method(s), and the minimum data reporting capability including requirements for any data history reporting.

Table JA6.1-1 Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry–Bulb (ºF) (T return, db)	Return Air Wet-Bulb (ºF) (T return, wb)																											
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8									
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5								
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1							
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7						
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2					
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7				
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1			
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5		
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

JA6.2 Saturation Pressure Measurement Sensors

JA6.2.1 Purpose and Scope

Appendix JA6.2 specifies the required instrumentation, and the instrumentation accuracy, for a saturation pressure measurement sensor (SPMS) device intended to provide a means for a HERS Rater to observe space conditioning system refrigerant pressure measurement data without attaching refrigerant gages to the refrigerant system service access ports.

The SPMS device manufacturer shall provide certification to the commission that the SPMS device conforms to the requirements of Reference Joint Appendix JA6.2.

JA6.2.2 SPMS Device Approval

SPMS devices, if approved by the Commission, shall be allowed for use for determining compliance with the refrigerant charge verification requirements in the Standards. The Commission may grant such approval after reviewing submittals from the applicant. SPMS devices that are approved by the Commission shall be listed as approved SPMS devices in directories published by Energy Commission.

Manufacturers of approved SPMS devices shall, upon request, provide comprehensive engineering specification documentation, installation and technical field service documentation, and user instructions documentation to installers and service personnel that utilize the procedure.

JA6.2.3 Standard for Saturation Pressure Measurement Sensors

SPMS devices shall measure and report the refrigerant system pressure for both the high pressure side and the low pressure side of the air conditioner or heat pump refrigerant system within the tolerances given in Section JA6.2.3.1.

JA6.2.3.1 Instrumentation Specifications

The pressure measurement instrumentation shall have accuracy equal to or better than the following:

(a) accuracy: ± 7.0 psi liquid line pressure

(b) accuracy: ± 3.5 psi suction pressure

JA6.2.3.2 Installation

SPMS devices shall be installed by the space-conditioning equipment manufacturer, or installed in the field according to any applicable space-conditioning equipment manufacturer requirements, within 12 inches of the refrigerant system service port.

JA6.3 Economizer Fault Detection and Diagnostics Certification Submittal Requirements

Title 24, Part 6, Section 120.2(i) requires that economizer FDD functions be installed on air-cooled unitary air conditioning systems with an air handler mechanical cooling capacity over 54,000 Btu/hr cooling capacity, with the ability to detect the faults specified in Section 120.2(i). Each air conditioning system manufacturer, controls supplier, or FDD supplier wishing to certify that their FDD analytics conform to the FDD requirements of Title 24, Part 6, may do so in a written declaration. This requires that a letter be sent to the California Energy Commission declaring that the FDD conforms to Title 24, Part 6, Section 120.2(i). The declaration at the end of this section shall be used to submit to the California Energy Commission.

JA6.3.1 Information that shall be included with the Declaration

The air conditioning system manufacturer, controls supplier, or FDD supplier provides evidence as shown below:

(a) The following temperature sensors are permanently installed to monitor system operation:
   i. Outside air.
   ii. Supply air.
   iii. Return air, when required for differential economizer operation.

   Evidence: Photograph or schematic of all required sensors indicating their recommended mounting instructions.

(b) Temperature sensors have an accuracy of ±2°F over the range of 40°F to 80°F
   Evidence: Photocopy of sensor specification.

(c) The controller is capable of providing system status by indicating the following:
   i. Free cooling available.
   ii. Economizer enabled.
   iii. Compressor enabled.
   iv. Heating enabled, if applicable.
   v. Mixed air low limit cycle active.
   vi. The current value of each sensor.

   Evidence: Laboratory test: describe how the mode is simulated and the wording used to indicate the status.

(d) The unit controller is capable of manually initiating each operating mode so that the operation of compressors, economizers, fans, and heating system, if applicable, can be independently tested and verified.
   Evidence: Photocopy of controller manual showing instructions for manually initiating each operating mode.

(e) The unit controller is capable of reporting faults one of the following ways:

   A. To an Energy Management Control System regularly monitored by facility personnel, or;

   B. Annunciated locally on one or more zone thermostats, or on a device within five (5) feet of zone thermostat(s), clearly visible, at eye level, and meeting the following requirements:

      i. On the thermostat, device, or an adjacent written sign, display instructions to contact appropriate building personnel or an HVAC technician.

      ii. In buildings with multiple tenants, the annunciation shall either be within property management offices, or in common space accessible by the property or building manager.

   C. To a fault management application which automatically provides notification of the fault to a remote HVAC service provider.

   Evidence: Supplier's description of how they comply, and supporting documentation such as a photocopy of controller manual or photograph of fault management application, zone thermostat, or other device showing indication of a fault.

(f) The unit control is capable of detecting the following faults:
   i. Air temperature sensor failure/fault.
   ii. Not economizing when it should.
   iii. Economizing when it should not.
   iv. Damper not modulating.
   v. Excess outdoor air.

JA6.3.2 Fault Detection Test Specifications

To provide evidence that the required faults are detected by the FDD functionality, the FDD Provider shall perform a No-Fault and Fault test for each of the tests in Table 1. A pre-defined Test Procedure such as the one provided in the example shown in Table 2 could be used to fill out Table 1.

Table 1 – Sample of a completed fault test

Tests	Faults: Air temperature sensor failure/fault	Not Economizing when it should	Economizing when it Should not	Damper not modulating	Excess outdoor air
1. Damper is Stuck Open			X	X	X
2. Damper Stuck at Minimum		X		X	
3. Bad or Unplugged Actuator		X	X	X	
4. Sensor Hard Failure	X	X	X		X
5. Actuator Mechanically Disconnected		X	X	X	X

JA6.3.3 Reporting of Test Results

The results of each test shall be provided in a report using a standard test results reporting format that provides the following information for each test:

a. Organization and individual conducting the test.

b. Time, Date, and Location of test.

c. Make and model of unit/control tested.

d. Range of models represented by test.

e. Test procedure used, including description of the method for imposing fault with repeatability.

f. Test driving Conditions (outdoor air temperature, return air temperature or enthalpy as required by the type of high limit control being used).

g. Results of the test: Alarms generated.

h. Provide a bill of materials for the configuration that is being certified.

i. The FDD supplier shall describe any special field or data verifications that are required for the particular FDD analytics (beyond those included in Acceptance Test requirements).

j. Sample of documentation that would accompany each qualifying set of FDD analytics.

k. Name and contact information of company personnel in charge of certification.

l. A mapping from the manufacturer's alarm description to what is required by Title 24 similar to Table 1.

Table 2 - Sample Test Procedure

Step	**Description**	**Purpose**

1	Close the economizer damper fresh air blades, then secure the blades in a manner that prevents opening.	Test alarm response when “Damper Stuck at Minimum”
2	Simulate conditions such that the damper actuator attempts to open the fresh air blades. Verify the damper blades remains secured and that the fault(s) specified in Table 1 are detected. Record the annunciated fault(s) and fault text.	
3	Release the blades and allow the economizer damper to modulate open. Verify the annunciated fault(s) have cleared.	
4	Open fully the economizer damper fresh air blades, then secure the blades in a manner that prevents closing.	Test alarm response when “Damper is Stuck Open”
5	Simulate conditions such that the damper actuator attempts to modulate the fresh air blade closed. Verify the damper remains secured and that the fault(s) specified in Table 2 are detected. Record the annunciated fault(s) and fault text.	
6	Release the blades and allow the economizer damper to modulate. Verify the annunciated fault(s) have cleared.	
7	Disconnect 1 sensor and verify the fault(s) specified in Table 1 are detected. Record the annunciated fault(s) and fault text.	Test alarm response when “Sensor Hard Failure”
8	Reconnect the sensor and verify that the annunciated fault(s) have cleared.	
9	Repeat steps 7 – 8 for each available sensor.	
10	Electrically disconnect the damper actuator and verify the fault(s) specified in Table 1 are detected. Record annunciated fault(s) and fault text.	Test alarm response when “Bad or Unplugged Actuator”
11	Reconnect the damper actuator. Verify the fault(s) have cleared and normal economizer operation has resumed.	
12	Mechanically disconnect the damper actuator from the damper blade assembly.	Test alarm response when “Actuator Disconnected”
13	Simulate conditions such that the damper actuator would be moving the damper blades. Verify the fault(s) specified in Table 2 are detected. Record annunciated fault(s) and fault text.	
14	Reconnect the damper actuator to the damper blade assembly. Verify the fault(s) have cleared and normal economizer operation has resumed.	
15	Simulate conditions necessary to generate system status of “Free cooling available”. Record text of annunciated status.	Test for System Status Capability
16	Simulate system conditions necessary to generate system status of “Economizer enabled”. Record text of annunciated status.	
17	Simulate system conditions necessary to generate system status of “Compressor enabled”. Record text of annunciated status.	
18	If equipped with a heating system, simulate system conditions necessary to generate system status of “Heating enabled”. Record text of annunciated status.	

19	Simulate system conditions necessary to generate system status of "Mixed air low limit cycle active". Record text of annunciated status.	

JA 6.3.4 Declaration

Consistent with the requirements of Title 24, Part 6, Sections 100.0(h) and 120.2(i), companies wishing to certify to the California Energy Commission shall execute a declaration under penalty of perjury attesting that all information provided is true, complete, accurate, and in compliance with the applicable provisions of Part 6. Companies may fulfill this requirement by providing the information, signing the declaration below and submitting to the California Energy Commission as as specified by the instructions in JA6.3.5.

Manufacturer, Model Name and Number of all devices being certified

Manufacturer	**Model Name**	**Model Number**

When providing the information below, be sure to enter complete mailing addresses, including postal/zip codes.

Certifying Company

Contact Person Name *	Phone 1
Certifying Company Name **	Phone 2
Address	Fax
(Address)	E-mail
(Address)	Company Website (URL)

* If the contact person named above is NOT the person whose signature is on the Declaration, then the full contact information for the person whose signature is on the Declaration must also be provided on a separate page.

** If the company named above is: A) a parent entity filing on behalf of a subsidiary entity; B) a subsidiary entity filing on behalf of a parent entity; or C) an affiliate entity filing on behalf of an affiliate entity, the above contact information must be provided for any additional entities on a separate page.

Manufacturer (if different from Certifying Company)

Contact Person Name	Phone 1
Manufacturing Company Name	Phone 2

Address	Fax
(Address)	E-mail
(Address)	Company Website (URL)

Declaration

I declare under penalty of perjury under the laws of the State of California that:

(1) All the information in this statement is true, complete, accurate, and in compliance with all applicable provisions of Section 120.2(i) of Title 24, Part 6 of the California Code of Regulations.

(2) Each Fault Detection and Diagnostic (FDD) system has been tested in accordance with all applicable requirements of Section 120.2(i)1-120.2(i)7 of Title 24, Part 6 of the California Code of Regulations.

(3) [If the party submitting this statement is a corporation, partnership, or other business entity] I am authorized to make this declaration, and to file this statement, on behalf of the company named below.

Certifying Company Name _____ Date _____

Name/Title (please print) _____ Signature _____

JA6.3.5 Certification

Send declarations and evidence of functionality or test reports to the addresses below. Electronic submittals are preferred.

(1) Electronic submittal:

CertifiedtoCEC@energy.ca.gov

Attn: FDD Certification

(2) Mail:

Attn: FDD Certification

Building Standards Development Office

California Energy Commission

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