Review of Requirements and Recommendations for Charge Indicator Display (CID)
Subtask 2.1C

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Covering Tasks 3 Subtask 2

2013 RESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

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1. Administration

1.1. Objectives

1.1.1 Subtask: Review the existing JA6 Charge Indicator Display (CID) specification and comment or make recommendations.

1.1.2 Charge Indicator Display (CID): provide an alternate means of compliance with refrigerant charge verification requirements that includes verification of refrigerant charge, metering device and indoor airflow operating performance and indication to the owner/operator.

2. Background Research and Information

2.1. Current Title 24 Requirements (2008)

2.1.1 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (December 2008, CEC-400-2008-001-CMF) Section 151 (f)

7. Space heating and space cooling. All space heating and space cooling equipment shall comply with minimum Appliance Efficiency Regulations as specified in Sections 110 through 112 and meet the requirements of subsections A and B:

> A. When refrigerant charge measurement or charge indicator display is shown as required by TABLE 151-B , TABLE 151-C or TABLE 151-D, ducted split system central air conditioners and ducted split system heat pumps shall:
>
> > i. Have temperature measurement access holes (TMAH**)** saturation temperature measurement sensors (STMS), and proper refrigerant charge confirmed through field verification and diagnostic testing in accordance with procedures set forth in the Reference Residential Appendix RA3.2; **or**
> >
> > ii. Be equipped with a **charge indicator display** (CID) clearly visible to the occupant. The display shall demand attention when the air conditioner fails to meet the requirements contained in Reference Joint Appendix JA6.2. The display shall be constantly visible and within one foot of the thermostat. Systems equipped with a CID shall meet the requirements of Residential Field Verification and Diagnostic Test Procedures of Reference Residential Appendix RA3.4 and the specifications of Reference **Joint Appendix JA6**.

2.1.2 Reference Appendices (December 2008, CEC-400-2008-004-CMF, Revised June 2009) **Joint Appendix JA6** – Charge Indicator Display

2.1.2.1 This document provides the requirements for a Charge Indicator Display (CID) when used to meet the refrigerant charge verification requirement.

2.1.2.2 The first paragraph of the Purpose and Scope (JA6.1) refers to "refrigerant charge or metering device performance"; however, the third paragraph refers to "**refrigerant charge, metering device and airflow operating performance**."

2.1.2.3 "Charge indicator display **technologies other than** that described in JA6.2 are 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 JA6.2, such **alternative charge indicator display technologies** shall be allowed for Charge Indicator Display compliance credit if the manufacturer of the product requests approval from the Executive Director. The Executive Director will grant such approval after reviewing submittals from the applicant. Charge indicator display technologies that are approved by the Executive Director will be published as an addendum to this appendix." [JA6.1]

2.1.2.4 The requirements in JA6.2 are prescriptive and include the superheat or subcooling method for refrigerant charge verification (based on metering device) and the temperature split method for indoor airflow verification.

2.1.2.5 "The charge indicator display may be set to tighter specifications than those in JA6.2.3. The charge indicator display may also be used to signal other system faults as long as these additional diagnostic functions do not detract from the system fault indications specified in JA6.2.3." [JA6.2.4]

2.1.3 Reference Appendices (December 2008, CEC-400-2008-004-CMF, Revised June 2009) **Residential Appendix RA3.4** Procedures for Verifying the Presence of a Charge Indicator Display or High Energy Efficiency Ratio Equipment

RA3.4.2 CID Verification Procedure
The procedure shall consist of visual verification that the CID is installed on the system.

2.1.4 Residential Compliance Manual, (December 2008, CEC-400-2008-016-CMF, Revised July 2010) 4.3.2 Prescriptive Requirements, section titled "Charge Indicator Display" (pages 4-17 to 4-18)

2.1.4.1 This document provides a general discussion of the CID option included in the standard.

2.1.4.2 "Charge indicator display technologies shall be factory installed or field installed according to manufacturer's specifications. Reference Joint Appendix JA6 contains more information about CID technologies."

2.1.4.3 "The presence of a CID on a system must be field verified by a HERS rater. See Reference Residential Appendix RA3.4.2 for the HERS verification procedure, which consists of a visual verification of the presence of the installed CID technology. The rater must inspect to see that the visual indication display component of the installed CID technology is mounted adjacent to the split system's thermostat. The rater must also observe that the system reports no system faults when the system is operated continuously for at least 15 minutes when the indoor air temperature returning to the air conditioner is above 65°F.

2.1.4.4 A CID installation certificate (CF-6R-MECH-24-HERS) is provided in this document (page 513)

2.2. Benchmarking

2.2.1 Wilcox and Proctor presented a section titled "Laboratory Tests of Charge Indicator Display" in the December 2010 CASE Report; however, products were

not specifically identified and insufficient information was presented to make any observations from this work as reported.

2.3. Patent and Patent Application Review

2.3.1 Several potentially relevant patent applications were identified but not investigated in detail.

2.3.1.1 Visual display of temperature differences for refrigerant charge indication description, US Patent Application 20060137368 (2006), assigned to Carrier

2.3.1.2 Single sensor three-step refrigerant charge indicator, US Application 20060137369 (2006), assigned to Carrier

2.3.1.3 Method for Determining Refrigerant Charge, US Patent application 20100088046 (2010), assigned to Carrier

2.3.1.4 Refrigerant Charge Indication, US Patent application 20100089076 (2010), assigned to Carrier

2.3.2 Temple and Hanson, US Patent 6,571,566, Method of Determining Refrigerant Charge Level in a Space Temperature Conditioning System (June 2003), assigned to Lennox Industries, Inc.

2.3.2.1 Abstract: … a method of determining refrigerant charge level in a space temperature conditioning system includes the steps of establishing a relationship between at least one selected system operating parameter and refrigerant charge level, independent of ambient temperature conditions; measuring the selected parameter(s) while the system is in operation; and using the established relationship and the measured parameter(s) to determine the refrigerant charge level. In one embodiment of the invention, both condenser subcooling and evaporator superheat parameters are measured and the predetermined relationship between charge level and each of these parameters is used to determine the actual refrigerant charge level.

2.3.3 Mei, Chen, and Kweller, US Patent 6,868,678, Non-intrusive refrigerant charge indicator (March 2005), assigned to Ut-Battelle, LLC (Oak Ridge, TN)

2.3.3.1 Abstract: A non-intrusive refrigerant charge level indicator includes a structure for measuring at least one temperature at an outside surface of a two-phase refrigerant line section. The measured temperature can be used to determine the refrigerant charge status of an HVAC system, and can be converted to a pressure of the refrigerant in the line section and compared to a recommended pressure range to determine whether the system is under-charged, properly charged or over-charged. …

2.3.3.2 Refer also to report ORNL/CON-489 (February 2003)

2.3.4 Kang, et al., US Patent 7,610,765, Refrigerant charge status indication method and device (November 2009), assigned to Carrier Corporation

2.3.4.1 Abstract: A method and apparatus for determining the sufficiency of the refrigerant charge in an air conditioning system by use of temperature

> measurements. The temperature of the liquid refrigerant leaving the condenser coil and the outdoor temperature are sensed … values that are than compared to predetermined optimal values to determine whether the system is properly charged with refrigerant. …

2.3.5 Braun, et al., US Patent 7,631,508, Apparatus and Method for Determining Refrigerant Charge Level (December 2009), assigned to Purdue Research Foundation

2.4. Standards

2.4.1 NEMA Standard DC 3-2008, Residential Controls – Electrical Wall-Mounted Room Thermostats, and the associated Annex A-2010, Energy-Efficiency Requirements for Programmable Thermostats, were reviewed for applicable user interface requirements; however, no applicable items were identified.

2.4.2 ENERGY STAR® Program Requirements for Programmable Thermostats, Eligibility Criteria (Version 1.2), were reviewed for applicable user interface requirements; however, no applicable items were identified. The draft requirements for Residential Climate Controls (Version 1.0, Draft 2) provide some items that could be applied to specifying the display for CID systems.

3. Review Comments

3.1. Building Energy Efficiency Standards for Residential and Nonresidential Buildings (CEC-400-2008-001-CMF)

3.1.1 The Charge Indicator Display is clearly identified as a compliance option in Section 151 (f) 7.

3.1.2 Joint Appendix JA6 is referenced for requirements.

3.2. Joint Appendix JA6 – Charge Indicator Display

3.2.1 The Purpose and Scope (JA6.1) indicates that the requirement applies to heat pump systems but do not indicate if the requirements apply to cooling and heating performance or cooling mode performance only. The remainder of the appendix applies to cooling mode performance; however, this is not explicitly identified.

3.2.2 The requirements refer to “airflow operating performance” but do not clearly identify that this applies to indoor airflow.

3.2.3 The requirements (JA6.2) do not specify the range of operating conditions over which the CID must meet the required accuracy and provide a valid indication, except for the outdoor air temperature being indicated as 65°F or greater (JA6.2.3). This can potentially be inferred from the target tables, but would not be clear for other technologies.

3.2.4 There are no performance requirements specified for “Charge indicator display technologies other than that described in JA6.2.” Should the CID identify a certain degradation in efficiency or a deviation in refrigerant charge or indoor

airflow? Based on what criteria would a manufacturer proposal, for an alternative CID technology, be deemed acceptable?

3.2.5 The calculation procedure in JA6.2.2 does not specify that "evaporator saturation temperature" is determined from "low side refrigerant pressure" when pressure is measured. A similar comment applies to "condenser saturation temperature" and "high side refrigerant pressure."

3.2.6 The acceptance limit for superheat for a fixed metering device is ±10°F and the acceptance limit for subcooling for a variable metering device is ±6°F. These limits are twice the values for the standard charge verification procedure (without CID). The acceptance limit for temperature split is ±5°F versus ±3°F when the method is used with the standard procedure for refrigerant charge verification.

3.2.7 There are no requirements for display of data (e.g., operating conditions, subcooling and superheat) other than a fault or no-fault condition.

4. Recommendations

4.1. Building Energy Efficiency Standards for Residential and Nonresidential Buildings (CEC-400-2008-001-CMF)

4.1.1 None

4.2. Joint Appendix JA6 – Charge Indicator Display

4.2.1 Identify performance requirements for the CID system that would be applicable to other (alternative) technologies. The requirements could be specified as (i) relative efficiency degradation from nominal or (ii) relative deviation in refrigerant charge and indoor airflow.

4.2.1.1 The acceptance limits (fault / no fault) for the prescriptive method included in JA6 should be verified (and possibly adjusted) based on the performance requirements.

4.2.1.2 Potential performance requirement for efficiency degradation: The system shall indicate a fault when any of the following faults exist and would result in an efficiency (EER) degradation of 7% or more at the standard ARI rating condition of 80/67/95. The manufacturer shall present laboratory test data to verify the system performance at this test condition.

4.2.1.2.1. Low refrigerant charge (relative to nominal)

4.2.1.2.2. High refrigerant charge (relative to nominal)

4.2.1.2.3. Low indoor airflow (relative to design condition)

4.2.1.3 Potential performance requirement for charge or indoor airflow deviation: The system shall indicate a fault when any of the following faults exist. The manufacturer shall present laboratory test data to verify the system performance at the ARI rating condition of 80/67/95. Further investigation would be necessary to establish appropriate fault thresholds.

4.2.1.3.1. Refrigerant charge deviation of 15% or more below the nominal charge level

4.2.1.3.2. High refrigerant charge deviation of 10% or more above the nominal charge level

4.2.1.3.3. Indoor airflow deviation of 20% or more below the design condition

4.2.1.4 Provide criteria for establishing CID system accuracy (based on sensor accuracy) for other (alternative) technologies or indicate specified prescriptive sensor accuracy requirements are applicable to other technologies, e.g., temperature sensor accuracy of ±1.5°F.

4.2.2 Identify the required operating range for cooling mode fault detection:

4.2.2.1 65°F [as currently specified] ≤ (Outdoor air dry-bulb temperature) ≤ 115°F

4.2.2.2 70°F ≤ (Return air dry-bulb temperature) ≤ 84°F

4.2.2.3 50°F ≤ (Return air wet-bulb temperature) ≤ 76°F

4.2.2.4 Allow exception (test not required under specific operating conditions) for fixed metering device system when suction superheat is less than 5°F at test conditions

4.2.3 Provide the following clarifications in the requirements (JA6):

4.2.3.1 Only cooling mode performance verification is required for heat pumps

4.2.3.2 Airflow performance applies to indoor airflow

4.2.3.3 Determination of saturation temperatures from pressure when refrigerant pressures are measured

4.2.4 Reevaluate the prescriptive acceptance limits (for fault indication) based on the performance requirements defined above (4.2.1). Additionally, if test conditions are valid, subcooling less than 2°F (for variable metering device) should result in a fault indication and superheat less than 4°F should result in a fault indication.

4.2.5 Allow manufacturer data for superheat target for fixed metering device

4.2.6 Add requirement for data access that would be available to the installer and HERS rater. The requirements should identify acceptable data access methods (e.g., visual display). The requirement should identify the minimum data including requirements for any data history (or only last values). Appropriate data requirements would also need to be addressed for other technologies. (Proposed by manufacture?) Correspondingly, add a requirement for the installer and HERS rater to record the available data as a part of the verification process. A minimum data requirement (for the prescriptive method) could be the following data points for the last test:

4.2.6.1 Outdoor (condenser entering) air dry-bulb temperature

4.2.6.2 Return air dry-bulb temperature

4.2.6.3 Return air wet-bulb temperature

4.2.6.4 Target subcooling (variable metering device only)

4.2.6.5 Actual subcooling (variable metering device only)

4.2.6.6 Target superheat

4.2.6.7 Actual superheat

4.2.6.8 Target temperature split

4.2.6.9 Actual temperature split

4.2.7 Update JA6 to reflect any changes to the referenced Residential Appendix RA3.2

5. References

5.1. ENERGY STAR®

5.1.1 ENERGY STAR® Program Requirements for Programmable Thermostats, Eligibility Criteria (Version 1.2)

5.1.2 ENERGY STAR® Program Requirements for Residential Climate Controls, Eligibility Criteria (Version 1.0, Draft 2)

5.2. NEMA Standards

5.2.1 NEMA DC 3-2008, Residential Controls – Electrical Wall-Mounted Room Thermostats

5.2.1 NEMA DC 3, Annex A-2010, Energy-Efficiency Requirements for Programmable Thermostats [no applicable items]

5.3. Reports and Papers

5.3.1 V. C. Mei, F. C. Chen, and Z. Gao, Development of Refrigerant Charge Indicator and Dirty Air Filter Sensor, ORNL/CON-489, February 2003.