Comments and Recommendations for Mini-Split Air Conditioner and Heat Pump Systems
Subtask 2.2

Work Authorization # 6
Contract #400-09-001
Covering Tasks 3 Subtask 2

2013 RESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

Prepared
August 25, 2011; revised September 27, 2011
Second Draft

By
Keith A. Temple, P.E.

Table of Contents

1. Administration .................................................................................................................. 2
1.1. Objectives ................................................................................................................. 2
2. Background Research and Information ............................................................................ 2
2.1. Manufacturers of Mini-Split Systems (from AHRI directory website) .................... 2
2.2. Characteristics of Mini-Split Systems ...................................................................... 3
2.3. Current Title 24 Requirements (2008) ...................................................................... 3
2.4. Applicable Industry Standards .................................................................................. 4
3. Project Planning ................................................................................................................ 5
3.1. Potential issues associated with refrigerant verification testing of mini-split systems 5
4. Project Results .................................................................................................................. 5
4.1. Manufacturer Performance Data............................................................................... 5
4.2. Comments on the system configuration and performance data ............................. 7
4.3. Recommendations for addressing mini-split systems in the standard ...................... 7
4.4. Recommendations for additional investigation and research ............................... 8
List of Figures

Figure 1. Mitsubishi MUZ-FE09NA Refrigerant Pressure Charts ......................................... 11
Figure 2. Sanyo CH1271 Service Valves (Table 8 of Technical & Service Manual) .......... 11

List of Tables

Table 1. Manufacturer Mini-Split Data .................................................................................. 10

1. Administration

1.1. Objectives

1.1.1 Provide guidance (comments and recommendations) for determining
clarifications to regulations language as pertains to "mini-split" air conditioner
and heat pump systems. Defining language is needed in order to determine which
mini-split systems can be regulated utilizing the existing test protocols for split
system air conditioners and heat pumps, and which mini-split systems cannot
utilize existing test protocols.

2. Background Research and Information

2.1. Manufacturers of Mini-Split Systems (from AHRI directory website)

2.1.1 Carrier
2.1.2 Daikin
2.1.3 Eair
2.1.4 Friedrich
2.1.5 Fujistu
2.1.6 GD Midea
2.1.7 GE Consumer and Industrial
2.1.8 GREE Electric
2.1.9 International Refrigeration Products
2.1.10 Lennox
2.1.11 LG
2.1.12 Mitsubishi
2.1.13 Sanyo
2.1.14 Trane
2.1.15 YMGI

2.2. Characteristics of Mini-Split Systems (as defined for this investigation)

2.2.1 Ductless system – The distinguishing characteristic of these systems is that the indoor unit does not have ductwork (non-ducted). Note: ARI Standard 210/240 does not identify mini-split or multi-split systems as ductless but has a separate term – “non-ducted” – for systems without ducts (refer to 2.4.1).

2.2.2 Thermal expansion valve (TxV) or electronic expansion valve (EEV) for cooling mode operation (no fixed expansion devices for cooling mode operation)

2.2.3 Air conditioner or heat pump system

2.2.4 Most systems have some type of capacity controls associated with the compressor and the indoor fan. Compressor capacity control is most commonly variable speed control with an inverter. Indoor fan capacity control is most commonly a multi-speed fan motor.

2.3. Current Title 24 Requirements (2008)

2.3.1 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (December 2008, CEC-400-2008-001-CMF)

2.3.1.1 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.

2.3.1.2 The refrigerant charge verification requirements apply to “ducted split” systems only and thereby exclude “non-ducted” systems.

2.3.2 Reference Appendices (December 2008, CEC-400-2008-004-CMF, Revised June 2009) Residential Appendix RA3

2.3.2.1 RA3.2 Procedures for Determining Refrigerant Charge for Split System Space Cooling Systems Without a Charge Indicator Display

RA3.2.1 Purpose and Scope
The purpose of this procedure is to determine and verify that residential split system space cooling systems and heat pumps have the required refrigerant charge and that the metering device is working as designed. The procedures only apply to ducted split system central air conditioners and ducted split system central heat pumps. The procedures do not apply to packaged systems.

2.3.2.1.1. The language in RA3.2 is consistent with Section 151 (f) 7.A of the standard.

2.3.2.2 RA3.3 Field Verification and Diagnostic Testing of Forced Air System Fan Flow and Air Handler Fan Watt Draw

RA3.3 contains procedures for verifying airflow in split system and packaged air conditioning systems serving low-rise residential buildings. The procedure is also used to verify reduced fan watts achieved through improved air distribution design, including more efficient motors and air distribution systems with less resistance to airflow.

2.4. Applicable Industry Standards


2.4.1.1 Scope: The standard is applicable to

2.4.1.1.1. Unitary Air-Conditioners, Air-cooled under 65,000 Btu/h [19,000 W]

2.4.1.1.2. Unitary Air-Conditioners, Water-cooled and evaporative-cooled under 65,000 Btu/h [19,000 W]

2.4.1.1.3. Air-Source Unitary Heat Pumps, Air-cooled under 65,000 Btu/h [19,000 W]

2.4.1.2 The standard defines three relevant terms as follows:

2.4.1.3 (1.29) Mini-split air conditioners and heat pumps means systems that have a single outdoor section and one or more indoor sections. The indoor sections cycle on and off in unison in response to a single indoor thermostat.

2.4.1.4 (1.30) Multiple-split air conditioners and heat pumps means systems that have two or more indoor sections. The indoor sections operate independently and can be used to condition multiple zones in response to multiple indoor thermostats.

2.4.1.5 (1.31) Non-ducted system means an air conditioner or heat pump that is designed to be permanently installed equipment and directly heats or cools air within the conditioned space using one or more indoor coils that are mounted on room walls and/or ceilings. The unit may be of a modular design that allows for combining multiple outdoor coils and compressors to create one overall system. Non-ducted systems covered by this test procedure are all split systems.


2.4.2.1 (2.1) Scope: This standard covers matched variable refrigerant flow Multi-Split Air Conditioners and Multi-Split Heat Pumps using distributed refrigerant technology with cooling and heating capacities for
outdoor units from 12,000 Btu/h [3508 W] to 300,000 Btu/h [90,000 W] and indoor units from 5,000 Btu/h [1,000W] to 60,000 Btu/h [20,000 W]. Each indoor unit is designed to condition a single zone.

3. Project Planning

3.1. Potential issues associated with refrigerant verification testing of mini-split systems

3.1.1 Service ports are required at the high and low side of the refrigeration circuit

3.1.2 System needs to be operating at full cooling mode (compressor at high speed and indoor fan and maximum cooling speed)

3.1.3 Multiple indoor units may be operating at different conditions

3.1.4 No indoor ductwork complicates measurement of return and supply air conditions including potential for non-uniform supply air temperature at discharge

3.1.5 No indoor ductwork complicates measurement of indoor airflow

3.1.6 Performance expectations are required. Standard tables (superheat and temperature split) may not be applicable. Manufacturers may not publish the appropriate data.

3.1.7 Liquid line and suction line may not be accessible for temperature measurement. (Some manufacturers have pre-insulated refrigerant lines.)

3.1.8 The onboard diagnostics provided with many systems may not provide adequate refrigerant charge and indoor airflow diagnostics to be deemed equivalent to the Title 24 field test protocol.

3.1.9 A non-ducted system may still have an indoor airflow fault associated with a clogged filter or a dirty indoor coil.

4. Project Results

4.1. Manufacturer Performance Data

4.1.1 Mitsubishi

4.1.1.1 Model Number: MUZ-FE09NA and MSZ-FE09NA

4.1.1.2 Selected data are summarized in Table 1. The manufacturer data included a table with operational data at 80/67/95\(^1\) allowing calculation of the superheat; however the table did not include the liquid temperature (necessary for calculating subcooling). Charts are provided with high and low side pressure data as shown in Figure 1. The manufacturer does not indicate the proper use of these charts; however, they provide normal operating pressures that could be used for system diagnostics. This would provide a first level of system diagnostics with a more detailed level requiring normal (target) refrigerant temperatures to calculate target superheat and subcooling.

\(^1\) indoor dry-bulb/indoor wet-bulb/outdoor dry-bulb (°F)
4.1.1.3 Onboard diagnostics: The system has outdoor unit “failure modes” identified as “Discharge temperature” and “High pressure” with possible causes that include “refrigerant amount”.  
4.1.1.4 Website: http://www.mitsubishiipro.com/en/professional
4.1.1.5 Documents: msz-fe09-12na_installation_manual_jg79a230h03_english_1-28-10.pdf and muz-fe09-18na_service_obh543a_9-10.pdf
4.1.1.6 The manufacturer provides a procedure for adjusting the refrigerant charge based on the refrigerant lineset length [Service manual, p.8]

4.1.2 Carrier
4.1.2.1 Model Number: 40GXM018 and 38GXM018
4.1.2.2 Key model data are summarized in Table 1. The manufacturer’s manuals do not provide any significant performance data.
4.1.2.3 Onboard diagnostics: The system has diagnostic codes identified as “Freeze protection, indoor coil” (E2) and “High compressor discharge temperature” (E4) with possible causes that include “low refrigerant charge”.
4.1.2.4 Website: http://www.commercial.carrier.com/commercial/hvac/carrier/0,3068,CLI1_DIV12_ETI12104_MID4411,00.html
4.1.2.5 Documents: 38-40gxm-1pd.pdf (product data), 38-40gxm-2si.pdf (installation), 38-40gx-3sm.pdf (service)
4.1.2.6 The manufacturer provides a procedure for adjusting the refrigerant charge based on the refrigerant lineset length [Service manual, p.11]

4.1.3 Daikin
4.1.3.1 Model Number: FTXS12DVJU and RXS12DVJU
4.1.3.2 Key model data are summarized in Table 1. The manufacturer’s manuals do not provide any significant performance data.
4.1.3.3 This system has a “Powerful” Operation mode that operates the indoor fan and compressor at full capacity and could be beneficial for testing.
4.1.3.4 Onboard diagnostics: The system has an “insufficient gas” error code with the following methods of detection:
4.1.3.4.1 Gas shortage detection I: A gas shortage is detected by checking the compressor running frequency.
4.1.3.4.2 Gas shortage detection II: A gas shortage is detected by checking the difference between indoor unit heat exchanger temperature and room temperature as well as the difference between outdoor unit heat exchanger temperature and room temperature.
4.1.3.4.3 Gas shortage detection III: A gas shortage is detected by checking the difference between inhale and exhale temperature.
4.1.3.5 Website: http://www.daikinac.com/commercial/home.asp?sec=homerun.asp
4.1.3.7 The manufacturer provides data for adjusting the refrigerant charge based on a refrigerant lineset length other than nominal [Service manual, pp.6-9]

4.1.4 Sanyo

4.1.4.1 Model Number: KHS1271 and CH1271

4.1.4.2 Key model data are summarized in Table 1. The manufacturer’s manuals include suction pressure and discharge air temperature but did not provide sufficient information to determine subcooling or superheat.

4.1.4.3 This system only has a service port in the suction line as illustrated in Figure 2 which is taken from the product Technical & Service Manual.

4.1.4.4 Onboard diagnostics: The system has an error code (E09) “No-refrigerant protection”.

4.1.4.5 Website: http://us.sanyo.com/HVAC

4.1.4.6 Documents: Install_KHS_09-12_71_Series-35461117 and Service KHS 9-12 71 Series Rev D-26430045

4.1.4.7 The manufacturer provides data for adjusting the refrigerant charge based on a refrigerant lineset length other than nominal [Installation manual, p.4]

4.2. Comments on the system configuration and performance data

4.2.1 The system data are summarized in Table 1

4.2.2 For the manufacturer models investigated a field charge verification test procedure was not provided in the service literature

4.2.3 Only one of the four models investigated was confirmed to have both a high side and low side refrigerant service port

4.2.4 For the manufacturer models investigated a target subcooling value could not be determined based on the data in the product literature (including the installation and service manuals). The systems investigated all had an electronic expansion valve for cooling mode operation.

4.2.5 Only one system had sufficient data to determine superheat which was 1°F at the 80/67/95 operating condition.

4.2.6 The available temperature split values at 80/67/95 varied from 20 to 21°F compared to 18.3°F from the table in the standard

4.2.7 All of the systems investigated had some type of onboard diagnostics; however, the effectiveness of these diagnostics is unknown.

4.2.8 It is not clear how these systems respond to low refrigerant charge and the corresponding impact on the system efficiency when operating in cooling mode.

4.2.9 It seems likely that a mini-split outdoor unit could be matched with a ducted indoor unit and, therefore, the system would require refrigerant charge verification testing to comply with Title 24. This would not be possible if the outdoor unit was one of the models which does not include a high side service port.

4.3. Recommendations for addressing mini-split (non-ducted) systems in the standard
4.3.1 In general, field verification of mini-split systems (based on testing) is currently not practical for several reasons as follows:

4.3.1.1 The systems do not generally have a high side service port
4.3.1.2 Subcooling data are not provided by the manufacturer
4.3.1.3 The system controls would likely need a test mode to ensure that the compressor and indoor fan are operating at the maximum speed for the duration of the field test
4.3.1.4 The indoor airflow measurement procedures are not generally applicable to non-ducted systems and temperature split data are not available for all models (manufacturer data). The standard temperature split table does appear to be applicable to these systems (refer to 4.2.6).

4.3.2 Evaluation of temperature split at high compressor speed and indoor fan speed could potentially serve as a minimum field test in the absence of adequate provisions for the refrigerant charge test. Manufacturer data would need to be available to determine the target temperature split value based on the return air conditions.

4.3.3 The most feasible approach to refrigerant charge verification for mini-split systems would likely be with on-board diagnostics. Adequate requirements need to be developed (for the standard) that provide a method for manufacturers to demonstrate the adequacy of their diagnostic capabilities.

4.3.4 Testing of systems with multiple indoor units would require a procedure for verification of indoor airflow at multiple (non-ducted) units unless airflow verification was deemed to be not necessary.

4.3.5 As an alternate to testing, refrigerant charge verification could be addressed by applying the Alternate Charge Measurement Procedure of RA3.2.3 as a mandatory measure for mini-split systems. This should include a requirement for new installations and for retrofit of existing systems which require removing the refrigerant charge. [Verification by HERS rater will not be possible.]

4.3.5.1 The requirement should apply to the following systems (based on ARI Standard 210/240 definitions):

4.3.5.1.1. All non-ducted split systems
4.3.5.1.2. Ducted mini-split systems that do not have both a high and low side refrigerant service port
4.3.5.1.3. All multi-split systems

4.3.5.2 Option 1 (Charge Adjustment): Applicable to a new system or existing system when a new outdoor unit is installed (with factory charge in outdoor unit). The method can be used by an installer (or technician). Installer shall weigh in lineset charge adjustment after evacuation of lineset and indoor coil. The documentation shall include the calculated charge adjustment for the lineset.

4.3.5.3 Option 2 (Total Charge): Applicable to all systems. The method can be used by an installer (or technician). The installer shall weigh in the total system charge after evacuation of the entire system. The total system
charge includes the nameplate charge for the outdoor unit and any adjustment for the lineset length in accordance with the manufacturer’s instructions. The documentation shall include the nameplate charge and the calculated lineset adjustment.

4.4. Recommendations for additional investigation and research

4.4.1 Assemble performance data for mini-split systems based on available manufacturer data and any laboratory research including system performance at low refrigerant charge and impact of indoor airflow on system performance.

4.4.2 Discuss provisions for refrigerant charge verification with manufacturers including field testing and onboard diagnostics.

4.4.3 Investigate the spatial variation of the indoor air discharge (supply) temperature for a given system. Investigate the variation of supply temperature with return (inlet) conditions and outdoor air temperature for multiple systems. Investigate the feasibility of developing a standard temperature split table for these systems.

4.4.4 Solicit input from AHRI and manufacturers on how to address refrigerant charge verification for mini-split systems
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
<th>Refrigerant</th>
<th>Expansion Device (cooling)</th>
<th>Service Ports</th>
<th>SH</th>
<th>SC</th>
<th>TS 80/67/95</th>
<th>Procedure*</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitsubishi</td>
<td>MUZ-FE09NA</td>
<td>R410a</td>
<td>EEV</td>
<td>Suction, Discharge</td>
<td>1°F</td>
<td>NA</td>
<td>21°F</td>
<td>NA</td>
<td>Note 1</td>
</tr>
<tr>
<td></td>
<td>and MSZ-FE09NA</td>
<td>R410a</td>
<td>EEV</td>
<td>Suction, Liquid?</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Note 2</td>
</tr>
<tr>
<td>Carrier</td>
<td>40GXM 018 and 38GXM 018</td>
<td>R410a</td>
<td>EEV</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Note 3</td>
<td></td>
</tr>
<tr>
<td>Daikin</td>
<td>FTXS12 DVJU and RXS12 DVJU</td>
<td>R410a</td>
<td>EEV</td>
<td>Suction</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Note 4</td>
</tr>
<tr>
<td>Sanyo</td>
<td>KHS12 71 and CH1271</td>
<td>R410a</td>
<td>EEV</td>
<td>Suction</td>
<td>NA</td>
<td>NA</td>
<td>20°F</td>
<td>NA</td>
<td>Note 4</td>
</tr>
</tbody>
</table>

* Manufacturer’s charge verification procedure
EEV = Electronic Expansion Valve
NA = Not available
SC = Subcooling
TS = Temperature Split

Note 1 (Mitsubishi): Diagrams are provided with high and low side refrigerant pressures over a range of indoor (70 to 86°F dry-bulb) and outdoor (68 to 105°F) operating conditions. A table is provided with sensible heat capacity over a range of indoor (63 to 71°F wet-bulb with 80°F dry-bulb) and outdoor (75 to 115°F) operating conditions.

Note 2 (Carrier): The manufacturer manuals do not provide any significant performance data.

Note 3 (Daikin): The manufacturer manuals do not provide any significant performance data.

Note 4: Diagrams are provided with low side (suction) refrigerant pressure and discharge air temperature over a range of indoor (75 to 86°F dry-bulb, 46% relative humidity) and outdoor (5 to 104°F) operating conditions. A table is provided with sensible heat capacity over a range of indoor (72 to 88°F dry-bulb, 59 to 75°F wet-bulb) and outdoor (65 to 115°F) operating conditions.
Figure 1. Mitsubishi MUZ-FE09NA Refrigerant Pressure Charts

<table>
<thead>
<tr>
<th>Action</th>
<th>Narrow Tube Service Valve (2-Way)</th>
<th>Wide Tube Service Valve (3-Way)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>CLOSED</td>
<td></td>
</tr>
<tr>
<td>Operating and test running the air conditioner</td>
<td>Fully OPEN</td>
<td></td>
</tr>
<tr>
<td>Measuring pressure and gas charging</td>
<td>Fully OPEN</td>
<td></td>
</tr>
<tr>
<td>Air purging with a vacuum pump</td>
<td>CLOSED</td>
<td></td>
</tr>
</tbody>
</table>

* The service port on the wide tube service valve uses a Schrader core valve to access the refrigerant system. Therefore, be sure to use a hose connector which has a push-pin inside. (Fig. 00x)

Figure 2. Sanyo CH1271 Service Valves (Table 8 of Technical & Service Manual)