AHRI Standard 1230 (I-P)

2021 Standard for

Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment

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Foreword

Major changes made from the previous version, AHRI Standard 1230-2014 with Addendum 1 are as follows

1. Definitions have been updated to align with AHRI Standard 210/240-2017 (with Addendum 1) and DOE 10 CFR §429 and Appendix M to 10 CFR §430. Specific examples include Sensible Cooling Capacity, Heat Recovery Unit, Ducted Indoor Units, Manufacturer Instructions, Combined Modules, and Total Power.
2. Added restrictions to maximum sensible heat ratios (SHR) at full load and 75% part-load conditions. Example calculations can be found in Appendix G.
3. Reduced maximum water flow rate for water source products.
4. Modified temperatures of water for part-load conditions.
5. All references to systems less than 65,000 Btu/h have been removed.
6. Updates made to the defrost controls requirements.
7. New requirements added for VRF Air-source Systems and VRF Water-source Heat Pumps that have condenser head pressure controls.
8. Updates made to manufacturer instructions requirements and handling of conflicting information during equipment testing.
9. Requirements added to address different scenarios pertaining to the heating and cooling refrigerant charge.
10. Added clarifying statements under the refrigerant piping length requirements.
11. Modified the requirements for expressing values of system Rated Capacity rating in fixed multiples.
12. Added clarifications in several areas of the standard on whether this standard refers to Nominal Capacity or Rated Capacity.
13. Modified the Tested Combination requirements such that for ducted units, the manufacturer shall first elect to use the Mid-static ducted units in Tested Combinations. In addition, Nominal Capacity buckets in Table 7 have been expanded to < 5,500 Btu/h.
14. Airflow-control Settings have been updated and airflow rate limitations on Ducted Indoor Units and Non-ducted Indoor Units (42 scfm per 1000 Btu/h and 55 scfm per 1000 Btu/h), as well as limitations to no more than 105% of nominal airflow as published in product literature of the individual indoor units, have been added.
15. Static pressure difference measurements for VRF Water-source Heat Pump systems are to be conducted in accordance with ASHRAE 30-2019, Section 6.3.1.6.
16. Modifications made to the test temperature conditions for VRF Water-source Heat Pump systems and for simultaneous heating and cooling tests.
17. New equations added for simultaneous heating and cooling efficiency calculation.
18. Test Operating Tolerances modified for indoor dry bulb and wet bulb temperatures (Table 12).
19. Standard Rating Cooling Capacity uncertainty allowance reduced to ≥ 96%.
20. Calculations have been removed from this standard. ASHRAE Standard 37 and ASHRAE handbook will be referenced for these calculations.
21. Several test procedure clarifications and exceptions to ASHRAE 37-2009 have been newly identified in Appendix E.
22. Unit configuration for standard efficiency determination have been modified. In addition, the requirements are now normative.
23. Examples for IEER calculations based on the new IEER calculation methodology have been added in the informative Appendix G.
24. An informative Appendix D with guiding instructions on developing Supplemental Testing Instructions for set-up and testing of VRF systems has been added.
25. A normative Appendix C has been added on Controls Verification Procedure (CVP) to validate system controls operation parameters for use in steady-state tests
26. A new "budget method" and associated calculation methods have been added to Appendix C6.1 for calculating variation between measured Critical Parameter values and STI-reported Critical Parameter values so that the maximum allowable difference is constrained
27. An informative Appendix H has been added showing example calculations of the budget method for verifying Critical Parameter values listed in the STI are validated by a CVP

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PERFORMANCE RATING OF VARIABLE REFRIGERANT FLOW (VRF) MULTI-SPLIT AIR-CONDITIONING AND HEAT PUMP EQUIPMENT

Section 1. Purpose

1.1 *Purpose.* The purpose of this standard is to establish for Variable Refrigerant Flow (VRF) Multi-split Air Conditioners and Heat Pumps: definitions; classifications; test requirements; rating requirements; determination of Published Ratings; operating requirements; marking and nameplate data; conformance conditions; minimum data requirements for Published Ratings and calculations.

1.1.1 *Intent.* This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.1.1 Specific interests include, but are not limited to, federal regulations, state regulations and efficiency standards developed by ASHRAE, International Energy Conservation Code (IECC), Canadian Standards Association (CSA), and United States Department of Energy (DOE).

1.1.2 *Review and Amendment.* This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 This standard applies to Variable Refrigerant Flow (VRF) Multi-split Air Conditioners and Multi-split Heat Pumps using distributed refrigerant technology, including all capacities of VRF Water-source Heat Pump systems and VRF Air-source systems with cooling capacity ≥ 65,000 Btu/h, as defined in Section 3 and referenced as the "Basic Model".

Note: In the event that this standard is required to demonstrate regulatory compliance, stakeholders must abide by all published requirements applicable to the regulated product. For example, for products that contain one or more design characteristics which either prevent testing according to this standard or cause this standard to evaluate the equipment in a manner unrepresentative of its true energy consumption characteristics, DOE requires the manufacturer to submit a petition for waiver, which would include an alternative method of test.

2.2 This standard applies to Variable Refrigerant Flow (VRF) Systems defined in 3.47.

2.3 *Exclusions.* This standard does not apply to the rating and testing of:

- Individual assemblies, such as separate condensing units or indoor units;
- Air-conditioners and Heat Pumps, with capacities less than 65,000 Btu/h as defined in AHRI Standard 210/240;
- Water-source Heat Pumps (with the exception of Multi-split Systems) as defined in AHRI/ASHRAE ISO Standard 13256-1;
- Unitary Air-conditioners and Unitary Heat Pumps as defined in AHRI Standard 340/360, with capacities ≥65,000 Btu/h;
- Units equipped with desuperheater/water heating devices as defined in AHRI Standard 470;
- Commercial and Industrial Condensing units with a capacity greater than 135,000 Btu/h as defined in AHRI Standard 365 (I-P);

2.4 *Energy Source.* This standard applies only to electrically operated, vapor compression refrigeration systems.

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the *ASHRAE Terminology* website (https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology) unless otherwise defined in this section.

Note: For the purpose of this standard, the terms "equipment" and "systems" are used throughout to mean Multi-split Air-conditioners and/or Multi-split Heat Pumps unless otherwise specified.

3.1 *Acronyms.*

3.1.1 *AHRI.* Air-Conditioning, Heating, and Refrigeration Institute.

3.1.2 *CFR.* Code of Federal Regulations.

3.2 *Air Sampling Device(s)***.** A combination of Air Sampling Tree(s), conduit, fan and Aspirating Psychrometer or Dew-point Hygrometer used to determine dry-bulb temperature and moisture content of an air sample from critical locations.

3.2.1 *Air Sampling Tree.* An assembly consisting of a manifold with several branch tubes with multiple sampling holes that draws an air sample from a critical location from the unit under test (e.g. indoor air inlet, indoor air outlet, outdoor air inlet, etc.).

3.2.2 *Aspirating Psychrometer*. An instrument used to determine the humidity of air by simultaneously measuring both the wet-bulb and dry-bulb temperatures. The difference between these temperatures is referred to as the wet-bulb depression.

3.2.3 *Dew-point Hygrometer*. An instrument used to determine the humidity of air by detecting visible condensation of moisture on a cooled surface.

3.3 *Airflow-control Setting(s)*. Programmed or wired control system configurations that control a fan to achieve discrete, differing ranges of airflow—often designated for performing a specific function (e.g., cooling, heating, or constant circulation)—without manual adjustment other than interaction with a user-operable control (i.e., a thermostat) as specified in Manufacturer's Installation Instructions.

3.4 *Approach Temperature.* The refrigerant temperature at the outdoor liquid service port minus the outdoor ambient temperature.

3.5 *Basic Model.* All units manufactured by one manufacturer within a single equipment class and which have the same or comparably performing compressor(s) that have a common "nominal" cooling capacity and the same heat rejection medium (e.g., air or water).

3.6 *Capacity*.

3.6.1 *Heating Capacity*. The rate of heat that the equipment adds to the conditioned space or heat transfer fluid in a defined interval of time, Btu/h.

3.6.2 *Latent Cooling Capacity*. The rate at which the equipment reduces the moisture content (removes latent heat) of the air passing through it under specified conditions of operation, Btu/h.

3.6.3 *Nominal Cooling Capacity.* Nominal Capacity may be referred to using the following terms:

3.6.4 *Percent Load.* The ratio of the part-load Cooling Capacity over the measured full load Cooling Capacity at Standard Rating Conditions, expressed in units of percent, %.

3.6.5 *Rated Capacity*. The capacity achieved at the Standard Rating Conditions, Btu/h.

3.6.5.1 *Standard Rating Cooling Capacity.* The capacity of the system when all Indoor Units and Outdoor Units are all operated in cooling mode, in the Standard Rating Conditions Cooling, Btu/h.

3.6.5.2 *Standard Rating Heating Capacity.* The capacity of the system when all Indoor Units and Outdoor Units are operated in heating mode, in the Standard Rating Conditions (High Temperature Heating Steady-state Test and Low Temperature Heating Steady-state Test), Btu/h.

3.6.6 *Sensible Cooling Capacity*. The rate at which the equipment lowers the dry-bulb temperature (removes sensible heat) of the air passing through it under specified conditions of operation, Btu/h.

3.6.7 *Total Cooling Capacity*. The sum of Sensible Cooling Capacity and Latent Cooling Capacity, under specified conditions of operation, Btu/h.

3.6.7.1 *Nominal Cooling Capacity* (for Indoor Unit and Outdoor Unit). Nominal Cooling Capacity where referenced, is the approximate cooling capacity tested at Standard Rating Conditions, as published in product literature, Btu/h.

3.7 *Coefficient of Performance (COP_H).* A ratio of the Heating Capacity in watts to the power input in watts at any given set of Rating Conditions, W/W.

3.7.1 *Coefficient of Performance at High Temperature (COP_H).* The Coefficient of Performance obtained at the 47 ºF temperature Rating Condition. For COP_H, supplementary resistance heat shall be excluded.

3.7.2 *Coefficient of Performance at Low Temperature (COP_L).* The Coefficient of Performance obtained at the 17 ºF temperature Rating Condition.

3.8 *Connected Capacity*. The sum of the Nominal Capacity of Indoor Units as a percent of Standard Rated Cooling Capacity, Btu/h.

3.9 *Control Setting(s).* System configurations specified in the Manufacturer's Installation Instructions and Supplemental Testing Instructions.

3.10 *Controls Verification Procedure (CVP)*. The procedure outlined in Normative Appendix C of this standard that is intended to verify the Control Settings for Critical Parameters used during the Steady-state Test.

3.11 *Critical Parameter(s).* Key variables affecting the measured result. Any operating state or position for a component, either set manually or automatically by System Controls, which significantly impacts system performance.

3.12 *Degradation Coefficient (C_D).* A parameter used in calculating the part-load factor, which is a measure of the efficiency loss due to the cycling of the units.

3.13 *Energy Efficiency Ratio (EER).* A ratio of the cooling capacity in Btu/h to the Total Power in watts at any given set of Rating Conditions, (Btu/h)/W.

3.13.1 *Integrated Energy Efficiency Ratio (IEER)*. A weighted calculation of mechanical cooling efficiencies at full load and part-load Standard Rating Conditions, as outlined in Section 11, (Btu/h)/W.

3.14 *Heat Pump(s).* A kind of central air conditioner(s) that utilizes an indoor conditioning coil, compressor, and refrigerant-to-outdoor air heat exchanger to provide air heating, and may also provide air cooling, air dehumidifying, air humidifying, air circulating, and air cleaning.

3.15 *Heat Recovery Control Unit***.** A device that controls refrigerant flow between Indoor Units, allowing for simultaneous cooling and heating operation.

3.16 *Indoor Unit*. A separate assembly of a Split System (a service coil is not an Indoor Unit) that includes the features listed below:

- An arrangement of refrigerant-to-air heat transfer coil(s) for transfer of heat between the refrigerant and the indoor air;
- A condensate drain pan;
- An air temperature sensing device; and
- An integrated indoor blower (i.e. a device to move air including its associated motor).

An Indoor Unit may or may not include the features listed below:

- Sheet metal or plastic parts not part of external cabinetry to direct/route airflow over the coil(s);
- A cooling mode expansion device; and
- External case.

For the purpose of this standard, Indoor Units are categorized into two subparts:

3.16.8 *Ducted Indoor Unit.* An Indoor Unit designed to be permanently installed and deliver all conditioned air through ductwork.

3.16.9 *Non-ducted Indoor Unit.* An Indoor Unit designed to be permanently installed, mounted on room walls, floors and/or ceilings, which directly heats or cools air within the conditioned space. Non-ducted Indoor Units consists of the following types: Wall-mounted, Floor-mounted, Ceiling-suspended, Standard 4-way Ceiling Cassette and Compact 4-way Ceiling Cassette.

3.17 *Indoor Unit Model Family.* A group of indoor unit models consisting exclusively of the same kind of indoor units, as specified in 3.17.1, 3.17.2 and 3.17.3 below.

3.17.1 *Non-ducted Indoor Unit Model Families.*

3.17.1.1 *Ceiling-suspended*. A non-ducted Indoor Unit that is totally encased and is suspended below the ceiling.

3.17.1.2 *Floor-mounted.* A non-ducted Indoor Unit intended for being installed at floor level either enclosed in the wall space in an uncased configuration or extended out from the wall in a cased configuration.

3.17.1.3 *Ceiling Cassette.* Non-ducted Indoor Units intended to be installed flush mounted with the ceiling. These Indoor Units can have configurations of indoor airflow coming from one, two, four, or circular direction(s). Each of the following represents a separate Indoor Unit Model Family.

3.17.1.3.1 *Compact 4-way Ceiling Cassette.* A Ceiling Cassette with air discharge louvers on 4 or more sides (or circular), a central air return grill and main casing dimensions less than 32 in x 32 in (not including flanges).

3.17.1.3.2 *One-way Cassette*. A Ceiling Cassette with air discharge louvers on a single side.

3.17.1.3.3 *Standard 4-way Ceiling Cassette.* A Ceiling Cassette with air discharge louvers on 4 or more sides (or circular), a central air return grill and main casing dimensions greater than, or equal to, 32 in x 32 in (not including flanges).

3.17.1.3.4 *Three-way Cassette*. A Ceiling Cassette with air discharge louvers on three sides.

3.17.1.3.5 *Two-way Cassette*. A Ceiling Cassette with air discharge louvers on two sides.

3.17.1.4 *Wall-mounted.* A non-ducted Indoor Unit that is attached to the wall with a cased configuration, sometimes referred to as a high-wall unit.

3.17.2 *Ducted Indoor Unit Model Families*. Model families when operated at the full-load cooling airflow that produces the following ESP range:

3.17.2.1 *Low-static*. A ducted Indoor Unit that produces ESP between 0.01 and 0.35 in H_2O of external static pressure (ESP).

3.17.2.2 *Mid-static*. A ducted Indoor Unit that produces ESP between 0.20 and 0.65 in H_2O of external static pressure (ESP).

Note: If the Indoor Unit model grouping in manufacturer's publicly available literature is not in accordance with Section 3.17.2, Section 3.17.2 shall take precedence for the determination of Tested Combinations.

If the range of ESP, as published in manufacturer's publicly available literature, for an Indoor Unit falls within the ESP range for more than one type of Ducted System, then the Indoor Unit shall be classified based on where the majority of the ESP capability lies.

If an Indoor Unit can operate between 0.15 in H_2O and 0.65 in H_2O, then this Indoor Unit is considered to be a Mid-static Indoor Unit. Also, if an Indoor Unit can operate between 0.35 in H_2O and 0.75 in H_2O, then this Indoor Unit is considered to be a Mid-static Indoor Unit.

3.17.3 *Small-duct, High-velocity (SDHV) Indoor Unit Model Family*. An Indoor Unit designed to be permanently installed and deliver all conditioned air through ductwork and that produces at least 1.2 in H_2O of ESP when operated at the full-load cooling airflow of at least 220 scfm per ton of Nominal Cooling Capacity. The Small-duct, High-velocity Indoor Unit Model Family is a unique Indoor Unit Model Family Type that is not one of the Ducted Indoor Unit Model Families.

3.18 *Manufacturer's Installation Instructions (MII)*. Manufacturer's documents that come packaged with or appear in the labels applied to the unit(s). Online manuals are acceptable if referenced on the unit label or in the documents that come packaged with the unit. All references to "manufacturer's instructions," "manufacturer's published instructions," "manufacturer's installation instructions," "manufacturer's published recommendations," "manufacturer installation and operation manuals," "installation instructions", "manufacturer-specified", and other similar references means Manufacturer's Installation Instructions.

3.18.1 *Supplemental Testing Instructions (STI).* Additional instructions developed by the manufacturer for the purpose of being able to test a VRF System to this test standard. Refer to Section 5.4.1 for STI requirements.

3.19 *Nominal Point Value.* The value corresponding to a 1% variation in the given critical parameter. Refer to Table C3 for individual parameter values

3.20 *Oil Recovery Mode*. An automatic system operation that returns oil to the compressor crankcase when the control system determines that the oil level in the Outdoor Unit is low.

3.21 *Outdoor 2-position Valves.* Two-position refrigerant valves in the Outdoor Unit.

3.22 *Outdoor Unit*. A separate assembly of a Split System that transfers heat between the refrigerant and the outdoor air or refrigerant and water, and consists of an outdoor heat exchanger, compressor(s), an air moving device, and in addition for Heat Pumps, may include a heating mode expansion device, reversing valve, and/or defrost controls; VRF Water-source Heat Pumps may not have an air movement device. An Outdoor Unit can be either Single Module or Combined Modules.

3.22.1 *Combined Modules.* Two (2) or more Single Modules that are mechanically and electronically joined together to operate as a single Outdoor Unit that is assembled with multiple Indoor Units to form a system. When such equipment is provided in more than one assembly, the separated assemblies shall be designed to be used together, and the requirements of rating outlined in the standard are based upon the use of matched assemblies.

3.22.2 *Single Module.* A single Outdoor Unit that is assembled with multiple Indoor Units and controls to form a system.

3.23 *Outdoor Variable Valves.* Variable position refrigerant valves in the Outdoor Unit.

3.24 *Published Rating.* A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal size and type (identification) produced by the same manufacturer. As used herein, the term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.24.1 *Application Rating.* A rating based on tests performed at application Rating Conditions (other than Standard Rating Conditions).

3.24.2 *Standard Rating.* A rating based on tests performed at Standard Rating Conditions.

3.25 *Rating Conditions.* Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

3.25.1 *Standard Rating Conditions.* Rating Conditions used as the basis of comparison for performance characteristics.

3.26 *Return Air Temperature Unit Sensor(s).* A factory installed component that measures the temperature of the return air or indoor room air entering the unit under test.

3.27 *RSS Point Total*. An instantaneous measure of Critical Parameter variation, the root-sum-square of the points accrued by all overridden critical parameters, as defined by equation C5.

3.28 *Sensible Heat Ratio (SHR).* A ratio of the Sensible Cooling Capacity to the Total Cooling Capacity at a given condition.

3.29 *Set Point Bias.* The difference between 80ºF and the nominal thermostat set point required for the thermostat to control for 80ºF sensed temperature at the sensed location.

3.30 *Set Point Offset*. The difference between the temperature indicated by a thermostat's temperature sensor and the actual temperature at the sensor's location.

3.31 *Service Tool.* A manufacturer's service tool for checking system hardware/software, typically available for download from manufacturer's certified installer website or from an authorized representative.

3.32 *"Shall" or "Should".* "Shall" or "should" shall be interpreted as follows:

3.32.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.32.2 *Should*. "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.33 *Simultaneous Cooling and Heating Efficiency (SCHE).* The ratio of the total capacity of the system (heating and cooling capacity) to the Total Power when operating in the heat recovery mode, (Btu/h)/W.

3.34 *Small-duct, High-velocity System (SDHV).* Split System for which all Indoor Units are SDHV Indoor Units.

3.35 *Stable Conditions*. Balanced operating conditions in the indoor and outdoor section of the test chamber where the test unit is maintaining Steady-state Test conditions and the test chamber is maintaining test room conditions within prescribed tolerances.

3.36 *Standard Air*. Air weighing 0.075 lb/ft^3 which approximates dry air at 70 °F and at a barometric pressure of 29.92 in Hg.

3.37 *Standard Airflow.* The volumetric flowrate of air corrected to standard air conditions, in scfm.

3.38 *Standard Rating Test.* Tests performed at Standard Rating Conditions.

3.39 *Steady-state Test*. A test where the controlled test parameters are regulated to remain within the specified tolerances while the unit operates continuously in the same mode.

3.40 *System Controls*. The following items characterize System Controls:

- An integral network operations and communications system with sensors to monitor and forecast the status of items such as temperature, pressure, oil, refrigerant levels and fan speed.
- A microprocessor, algorithm-based control scheme to: (1) optimally manage Compressor(s), fan speed of Indoor Units, fan speed of the Outdoor Unit, solenoids, various accessories; (2) manage metering devices; and (3) concurrently operate various parts of the system.

- Optimize system efficiency and refrigerant flow through an engineered distributed refrigerant system to conduct zoning operations, matching capacity to the load in each of the zones.

3.41 *Test Condition Tolerance.* The maximum permissible difference between the average value of the measured test parameter and the specified test condition.

3.42 *Test Operating Tolerance.* The maximum permissible range a measurement may vary over the specified test interval. When expressed as a percentage, the maximum allowable variation is the specified percentage of the average value. The difference between the maximum and minimum sampled values shall be less than or equal to the specified Test Operating Tolerance.

3.43 *Tested Combination.* An arrangement of Indoor Units and Outdoor Units that are production units (or for product development purposes are representative of production units) and provides representative performance values. The requirements for Tested Combination are stated in Section 6.2.

3.44 *Thermally Active.* The state of an Indoor Unit in which it is cooling, as indicated by the digital on/off signal from the Service Tool or by an EEV position indicated by the Service Tool greater than the minimum EEV position for that valve.

3.45 *Thermally Inactive.* The state of an Indoor Unit in which it is not Thermally Active.

3.46 *Total Power*. The sum of the average electrical power input consumed by all components of a system, including, W:

- Power input for operation of the compressor(s);
- Power input to electric heating devices used only for defrosting;
- Power input to all control and safety devices of the equipment;
- Power input to factory installed condensate pumps; and
- Power input for operation of all fans and, if applicable, any Water-source condenser pump(s) (including pump power adjustments).

3.47 *Variable Refrigerant Flow (VRF) System.* An engineered direct expansion (DX) air-conditioning or Heat Pump multi-split systems incorporate the characteristics and components of 3.47.1.

Note: VRF Systems less than 65,000 Btu/h are considered as central air conditioners and central air conditioning Heat Pumps in 10 CFR §429, 10 CFR §430 and 10 CFR §431.

3.47.1 VRF Systems characteristics and components are as follows:

- A single refrigerant circuit that has a common piping network to multiple Indoor Units;
- Single Module or Combined Module Outdoor Units;
- Two (2) or more Indoor Units;
- Three or more steps of capacity; and
- A zone temperature control device (i.e. thermostat).

3.47.2 *VRF Air-source System*. A VRF Heat Pump with Single Module or Combined Module Outdoor Units that have air-to-refrigerant heat exchangers.

3.47.3 *VRF Heat Recovery System*. A VRF Air-Source System or VRF Water-source Heat Pump that is capable of providing simultaneous heating and cooling operation via a Heat Recovery Control Unit, where recovered energy from the Indoor Units operating in one mode can be transferred to one or more other Indoor Units operating in the other mode.

Note: This may be achieved by a gas/liquid separator or a third line in the refrigeration circuit.

3.47.4 *VRF Water-source Heat Pump.* The Heat Pump consists of one or more factory-made assemblies which normally include an indoor conditioning coil with air moving means, compressor(s) and refrigerant-to-fluid heat exchanger(s), including means to provide both cooling and heating functions. Any references to VRF Water-source Heat Pumps in this Standard includes all capacities. The four main types of VRF Water-source Heat Pumps are as follows:

3.47.4.1 *Ground-loop Heat Pump.* Brine-to-air Heat Pump using a brine solution circulating through a subsurface piping loop functioning as a heat source/heat sink.

Note: The heat exchange loop may be placed in horizontal trenches, vertical bores, or be submerged in a body of surface water. The temperature of the brine is related to the climatic conditions and may vary from 23ºF to 104ºF.

3.47.4.2 *Ground-water Heat Pump.* Water-source Heat Pump using water pumped from a well, lake, or stream functioning as a heat source/heat sink.

Note: The temperature of the water is related to the climatic conditions and may vary from 41ºF to 77ºF for deep wells.

3.47.4.3 *Water Loop Heat Pump.* Water-source Heat Pump using liquid circulating in a common piping loop as a heat source/heat sink.

Note: The temperature of the liquid loop is usually controlled within a temperature range of 59°F to 104°F.

3.48 *Variable Speed Compressor.* A compressor that has capability of varying its rotational speed in non-discrete stages or steps from low to intermediate to full using an inverter or variable frequency drive.

Section 4. Classifications

4.1 Equipment covered within the scope of this standard shall be classified as shown in Table 1.

Table 1. Classification of VRF Systems

System Identification	VRF Air-conditioner or Heat Pump System	VRF Heat Recovery System
Air-conditioner (Air-source)	MSV-A-CB[1]	Not Applicable
Air-conditioner (Water-source)	Not Applicable	Not Applicable
Heat Pump (Air-source)	HMSV-A-CB[1]	HMSR-A-CB[1]
Heat Pump (Water-source)	HMSV-W-CB[1]	HMSR-W-CB[1]

Notes:
1. "-A" indicates Air-source condenser and "-W" indicates Water-source condenser.

Section 5. Test Requirements

5.1 All testing for Standard Ratings shall be conducted in accordance with the test methods and procedures as described in this standard and its appendices.

5.1.1 VRF Systems shall be tested in accordance with AHRI Standard 1230 Section 6, AHRI Standard 1230 Appendix C, ASHRAE Standard 37 with clarifications in AHRI Standard 1230 Appendix E, AHRI Standard 1230 Appendix G. VRF Water-source Heat Pump systems shall additionally be tested in accordance with ASHRAE 30 Section 6.3.1.6.

5.1.2 To set up equipment for test, manufacturer authorized personnel with knowledge of the control software may support commissioning of the system being tested.

5.1.2.1 The system shall operate per commands from the System Controls except that the Critical Parameter(s) listed below shall be allowed to be manually overridden. Operational settings for Critical Parameters shall be as specified in STI and with RSS Point Total ≤ 70 points as defined in section C6.

- Compressor Speed(s);
- Outdoor Fan Speed(s); and
- Outdoor Variable Valve Position(s).

For a given system, a maximum of three Critical Parameter(s) options listed above shall be permitted to be overridden. Multiple individual parameters of a group may be overridden.

5.1.2.2 All compressors shall initially operate at the speed or setting(s) provided in the STI. Additional adjustments to compressor speed for the purpose of achieving capacity targets or meeting SHR limits are allowed so long as conditions outlined in section 6.3.3 are met. During part-load tests, where more than one compressor is present, the compressors can only be stopped if the manufacturer's operating System Controls would cause that mode of operation in the field.

5.1.2.3 *Control Settings*. Control Settings shall be set by a member of the Laboratory. All Control Settings are to remain unchanged for all load points once system set up has been completed. Component operation shall be controlled by the unit under test once the provisions in Section 6 are met.

5.1.2.3.1 *Airflow-control Setting(s).* These settings shall be in accordance with Section 6.

5.1.2.4 If the Thermally Active state of an indoor unit cannot be determined from the digital on/off signal available from the Service Tool, active status is indicated by an EEV position indicated by the Service Tool greater than the minimum EEV position for that valve. The time history of the temperature difference between the inlet and outlet thermocouple grids of an indoor unit may be examined to confirm either of these indication methods.

5.1.3 *Oil Recovery Mode.* The Oil Recovery Mode shall be enabled during testing. If Oil Recovery Mode prevents a Steady-state Test, use the transient test procedure as described in Section 8.8.3 (except Section 8.8.3.3) of ASHRAE Standard 37, with the revisions in the following section:

5.1.3.1 For tests of VRF Air-source Systems that cannot reach steady-state because of Oil Recovery Mode, Section 8.8.3 (except Section 8.8.3.3) of ASHRAE Standard 37 shall be modified by replacing all mentions of "defrost" with "Oil Recovery Mode", replacing all mentions of "Heat Pump" with "system" and replacing all mentions of "heating" with "conditioning". The test tolerances specified in Table 2 of ASHRAE Standard 37 for "heat portion" under "heat with frost" must be satisfied when conducting the tests. The test tolerance parameters included in Table 2 of ASHRAE Standard 37 must be sampled throughout the preconditioning and data collection period. For the purpose of evaluating compliance with the specified test tolerances, the dry-bulb temperature of the air entering the indoor-side and the outdoor-side, and the water vapor content of the air entering the indoor or outdoor-side must be sampled at least every minute. All other parameters must be sampled at equal intervals that span five minutes or less.

5.1.4 *Defrost Controls*. Defrost controls shall be left at manufacturer's factory settings if the MII provided with the equipment do not specify otherwise. Any Control Settings for defrost specified by the MII which can be achieved through methods outlined in the MII may be used to achieve Steady-state Test operation. If unable to run a Steady-state Test procedure due to Control Settings for defrost, the transient test procedure as defined in ASHRAE Standard 37 shall be used with the following exceptions: 1. The Test Operating Tolerance for the outdoor entering conditions are omitted during the defrost portion. 2. The Test Operating Tolerances and Test Condition Tolerances for the heat portion shall apply when the unit is in heating mode except for the first 30 minutes after terminating a defrost cycle. To facilitate testing of any unit, the manufacturer shall provide information and any necessary hardware to manually initiate a defrost cycle.

5.1.5 *Indoor Unit Temperature Control Set Point.* The temperature set point for each Indoor Unit which is Thermally Active shall be set to 80 °F.

5.1.5.1 Identify and correct for Set Point Offset(s) that may be present in indoor unit thermostats by using the following procedures. Round set point adjustments to the nearest set point increment.

5.1.5.1.1 If the control for the Indoor Unit utilizes an independent return/indoor ambient air temperature unit sensor for each Indoor Unit, for each Indoor Unit adjust the set point by the difference between the measurements of the return air thermocouple grid and the Return Air Temperature Unit Sensor (the latter determined using either the on-board thermostat reading or the Service Tool).

5.1.5.1.2 If the Indoor Unit control utilizes a common Return Air Temperature Unit Sensor for multiple Indoor Units in operation, make a single adjustment by the difference between the average of the thermocouple grid measurements and the Indoor Units group's return/ambient air temperature sensor (determined using either the on-board thermostat reading or from the Service Tool).

5.1.5.2 If the controls of the unit under test include a Set Point Bias, the manufacturer may include the Set Point Bias in the STI. If a Set Point Bias is included in the STI, the temperature set point for each Indoor Unit which is Thermally Active shall be set to 80°F, less the STI-reported Set Point Bias up to 2°F. If the controls have a Set Point Bias and there is also Set Point Offset, the temperature set point for each Indoor Unit which is Thermally Active shall be set to 80°F, less the STI-reported Set Point Bias (up to 2°F), plus the difference between the thermocouple grid measurement (or average) and the Return Air Temperature Unit Sensor.

5.2 *Head Pressure Control for VRF Air-source Systems and VRF Water-source Heat Pump Systems*. For units that have condenser head pressure control to ensure proper flow of refrigerant through the expansion valve during low condenser air or water inlet temperature conditions, the head pressure controls shall be enabled and operate in automatic control mode. The setting should be set at the factory settings or as defined in the MII.

If the head pressure control is engaged by the control logic during part-load cooling tests, then use the following steps. For all part-load cooling tests for VRF Water-source Heat Pump systems, the water flow rate must not exceed the value for the full-load cooling test.

5.2.1 Allow the control logic to control the operation of the unit. If the unit can be run and Stable Conditions are obtained (*e.g.*, test tolerances in Table 15 are met), then a standard part-load cooling test shall be run.

5.2.2 *Head Pressure Control Time Average Test.* If the head pressure control results in unstable conditions (*e.g.*, test tolerances in Table 15 cannot be met), then a series of two 1-hour Steady-state Tests shall be run. Prior to the first 1-hour test the condenser entering temperature (e.g., outdoor air dry-bulb temperature or condenser water temperature) defined by Table 8 or 9 (as applicable) shall be approached from at least a 10ºF higher temperature until the tolerances specified in Table 2 are met. Prior to the second 1-hour test, the condenser entering temperature defined by Table 8 or 9 (as applicable) must be approached from at least a 5ºF lower temperature until the tolerances specified in Table 2 are met. For each test, once all tolerances in Table 2 are met, the 1-hour test shall be started and test data shall be recorded every 5 minutes for 1 hour, resulting in 12 test measurements for each test parameter. During each 1-hour test, the tolerances specified in Table 2 must be met.

If the tolerances in Table 2 are met, the test results for both 1-hour Steady-state Tests shall then be averaged to determine the capacity and efficiency that is then used for the IEER calculation.

Table 2. Tolerances for Head Pressure Control Time Average Test

		Operating Tolerance	Condition Tolerance
Indoor air dry-bulb temperature (°F)	Entering	3.0	1.0
	Leaving	3.0	-
Indoor air wet-bulb temperature (°F)	Entering	1.5	0.5
	Leaving	1.5	-
Outdoor air dry-bulb temperature (°F)	Entering	3.0	1.0
	Leaving	-	-
Outdoor air wet-bulb temperature (°F)	Entering	1.5	-
	Leaving	-	-
Water serving outdoor coil temperature (°F)	Entering	0.75	0.3
	Leaving	0.75	
Voltage		2%	1%

5.2.3 If the tolerances in Table 2 cannot be met for the head pressure control time average test, MII shall be used to determine the settings required to stabilize operation. However, if MII do not provide guidance for stable operation or result in a condensing (liquid outlet) pressure corresponding to a bubble point temperature less than 75°F, proceed to 5.2.4.

5.2.4 If MII cannot be used to achieve stable operation, the fan(s) (for Air-Source units) or valve(s) (for VRF Water-source Heat Pump systems) causing the instability shall be set manually at a speed, operating state (on/off), or position to achieve a condensing (liquid outlet) pressure corresponding to a bubble point temperature as close to 85°F as possible while remaining no lower than 85°F.

5.3 *Instruments.*

5.3.1 Use instruments that meet the applicable requirements specifications in Section 5 of ASHRAE Standard 37 with the amendments in Sections 5.3.2 and 5.3.3.

5.3.2 For measurement of indoor and outdoor air temperatures, the provisions of Appendix E4 applicable to instruments take precedence over Section 5 of ASHRAE Standard 37.

5.3.3 The atmospheric pressure measuring instruments must be accurate to within ±0.5% of the reading.

5.4 *Literature Hierarchy*. For system set-up and Control Settings, use specifications from the STI. For instructions not specified in the STI, hierarchy shall be Outdoor Unit MII, followed by the Outdoor Unit labels, followed by the Indoor Unit MII. For settings not specified in any of the preceding sources, the as-shipped setting shall be used.

5.4.1 STI shall include the following:

5.4.1.1 All instructions that do not deviate from MII but provide additional specifications for test standard requirements allowing more than one option; and

5.4.1.2 Documentation of settings and software required to obtain all deviations from MII necessary to comply with Steady-state Test requirements.

STI shall provide steady operation that matches to the extent possible the average performance that would be obtained without deviating from the MII. STI shall include no instructions that deviate from MII other than those described in 5.4.1.2 above.

5.5 *Test Unit Location.* All Indoor Unit(s) and VRF Water-source Heat Pump Outdoor Unit(s) must be located in an indoor test room(s) (i.e., a test chamber(s) maintained at the air conditions specified for return indoor air) during all tests. VRF Air-source System Outdoor Unit(s) must be located in the outdoor test room(s) (i.e., the test chamber(s) maintained at the air conditions specified for outdoor ambient air) during all tests.

5.6 *Heat Recovery Control Units*. For VRF Heat Recovery Systems, the Heat Recovery Control Unit must be attached during all tests.

5.7 *Atmospheric Pressure*. Tests must be conducted at an atmospheric pressure of at least 13.7 psia.

5.8 *Refrigerant Charging.* All test samples shall be charged at Standard Rating Conditions in accordance with the MII or labels applied to the unit. If the MII give a specified range for superheat, sub-cooling, or refrigerant pressure, the average of the range shall be used to determine the refrigerant charge.

In the event of conflicting information between charging instructions, use the hierarchy of Section 5.4. Conflicting information is defined as multiple conditions given for charge adjustment where all conditions specified cannot be met.

In such instances, follow the hierarchy in Table 3 for priority unless the manufacturer specifies a different priority. Unless the manufacturer specifies a tighter charging tolerance, the tolerances specified in Table 3 shall be used.

Table 3. Test Condition Tolerance for Charging Hierarchy

	Charging Method	Test Condition Tolerance of the Target Value in the MII, ±
1	Charge Weight	1.0 oz
2	Sub-cooling	10%; Not less than 0.5°F, Not more than 2.0°F
3	High Side Pressure or Saturation Temperature	4.0 psi or 1.0°F
4	Low Side Pressure or Saturation Temperature	2.0 psi or 0.8°F
5	Approach Temperature	1.0°F

The resulting refrigerant charge obtained shall then be used to conduct all cooling cycle and heating cycle tests unless an adjustment is required based on the sections below. Once the correct refrigerant charge is determined, all tests shall run until completion without further modification.

Informative Note: After completion of all required tests, it is good laboratory practice to achieve full-load cooling test conditions for 30 continuous minutes and compare results to the previous set of full-load cooling tests. When comparing results, measured charge parameters outside of those listed in Table 3 is an indication refrigerant charge or other parameters may have changed and analysis shall be performed and corrective actions shall be made.

5.8.1 *Heat Pumps.* Refrigerant charge shall be set at the full-load cooling conditions or as specified by the manufacturer. The initial heating test shall be the high-temperature heating test. Charge parameters shall be checked per the MII (if provided). If conditions are within the range specified by MII continue with the remainder of the tests.

5.8.1.1 If heating refrigerant charge parameters are not within the range specified by the MII then the smallest adjustment to refrigerant charge to get within the heating refrigerant charge and cooling refrigerant charge parameters shall be made. If the heating and cooling refrigerant charge requirements cannot be met simultaneously, maintain the charge within the tolerance for the cooling test while keeping the charge as close as possible to the requirement for the heating test. Re-run the cooling tests after any adjustment of system charge.

5.9 *Requirements for Separated Assemblies (Applies to all Systems)*. The Indoor Units and Outdoor Unit are in two separate assemblies.

5.9.1 The Indoor Units and Outdoor Unit shall be installed in the laboratory with a minimum 25 ft. of interconnecting refrigerant piping length (actual, not equivalent) running from the Outdoor Unit to each of the Indoor Units. The distance is measured from the nearest Outdoor Unit to each of the Indoor Units. Note that there will be a common length of piping from the Outdoor Unit to the first branching device. Refer to Table 4 for minimum total refrigerant piping lengths for each capacity range of Outdoor Unit and configuration of either ducted or non-ducted Indoor Units. In some testing situations test room capacity or arrangement may cause the laboratory to run refrigerant piping that is longer than the minimum. To ensure fairness of testing, Table 5 was developed to account for system capacity that will be lost due to the additional refrigerant piping length above the minimum. If the laboratory determines that the minimum refrigerant piping lengths provided in Table 4 need to be exceeded for at least 33% (minimum of 2) of the Indoor Units, then a Cooling Capacity correction factor from Table 5 shall be applied.

Table 4. Piping Requirements from Outdoor Unit to Each Indoor Unit

System Standard Rated Cooling Capacity, Btu/h	Systems with Non-ducted Indoor Units, ft.	Systems with Ducted Indoor Units, ft.
0 to <65,000[1]	25	25
≥65,000 to <105,000	50	25
≥105,000 to <135,000	75	25
≥135,000 to <350,000	100	50
≥350,000	150	75

Notes:
1. For VRF Water-source Heat Pumps

Table 5. Refrigerant Piping Length Correction Factors in Cooling[1, 2, 3,4]

Piping Length [3]	Cooling Capacity Correction Factor
3.3 < X ≤ 20	1.01
20 < X ≤ 40	1.02
40 < X ≤ 60	1.03
60 < X ≤ 80	1.04
80 < X ≤ 100	1.05
100 < X ≤ 120	1.06

Notes:
1. In all cases, the absolute minimum length necessary to physically connect the system shall be used.
2. If the laboratory determines that the minimum refrigerant piping lengths provided in Table 4 must be exceeded for at least 33% (minimum of 2) of the Indoor Units, then a Cooling Capacity correction factor shall be applied.
3. The Cooling Capacity correction factor is determined by the average refrigerant piping length in addition to the minimum defined in Table 4, X.
4. This table applies to Standard Rating Cooling Capacity only.

5.9.2 The complete length of piping shipped with the unit (and not recommended for cutting to length) shall be used in the test procedure, or with 25 ft of refrigerant path, whichever is greater. For VRF Air-source Systems, at least 10 ft of the system interconnection tubing shall be exposed to the outdoor room conditions. The line diameters, insulation, installation details, evacuation and charging shall follow the MII. The manufacturer shall provide a schematic of the Tested Combination installation (See Figure 1). Refer to Appendix E for additional set-up information. For certification and regulatory compliance, refer to Appendix D. To minimize performance degradation, all excess copper tubing shall be coiled in a space in the laboratory where the coils will not be disturbed. The coils shall be horizontal with a minimum diameter of 2 ft. The coils shall be in a place where the manufacturer may check the copper tubing for any potential issues.

5.9.3 For systems with Combined Modules, the modules shall be arranged in a straight line where practical and placed with a spacing of 2 ft (± 3 in) between the modules, unless the MII specifies a greater minimum spacing. If a single outdoor laboratory section will not accommodate the straight alignment of the Combined Modules, then an L-shaped configuration shall be attempted. If an L-shaped configuration is not possible, then a second outdoor laboratory section shall be used.

5.10 *Indoor Unit Operation for Load Point Tests*. For full-load and part-load point tests the Indoor Units that are Thermally Active shall be in accordance with the STI. For the 25% load point test, at least half of the total Indoor Units, as calculated per the total capacity of the connected Indoor Units, shall remain Thermally Inactive. The laboratory shall prevent forced air circulation through any Indoor Unit that is Thermally Inactive (e.g. block the inlet and outlet). For the Indoor Unit(s) that are Thermally Inactive, the indoor unit control settings (e.g., using remote or wireless thermostat) shall be set to “OFF”.

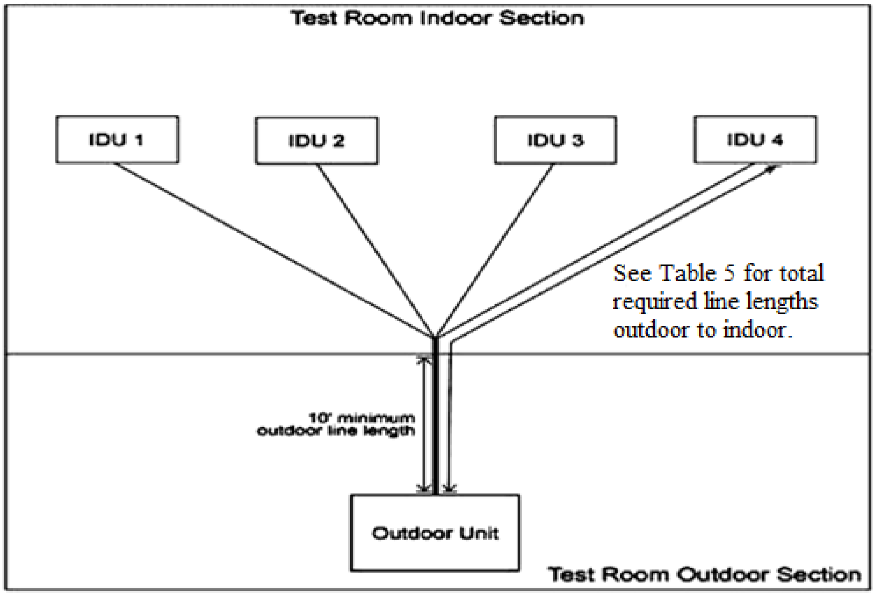

Figure 1. Test Room Layout

Section 6. Rating Requirements

6.1 *Standard Ratings*

6.1.1 *Minimum External Static Pressure Requirements for Ducted Indoor Units.* The minimum ESP for individual ducted Indoor Units are shown in Table 6. Small-duct, High-velocity Systems shall be tested at 1.15 in H_2O.

Table 6. Minimum External Static Pressure (ESP) for Individual Ducted Indoor Units

Capacity [1,2]	ESP [3,4], in H_2O
Up through 28,800	0.10
29,000 to 42,500	0.15
43,000 to 70,000	0.20
71,000 to 105,000	0.25
106,000 to 134,000	0.30
135,000 to 210,000	0.35
211,000 to 280,000	0.40
281,000 to 350,000	0.45
351,000 and above	0.55

Notes:
1. The Indoor Unit capacity as specified in the MII, when operated at the Standard Rating Cooling Conditions.
2. For heating-only Heat Pumps, the value the manufacturer cites in MII for the capacity of the Indoor Unit when operated at the Standard Rating Conditions (High Temperature Steady-state Test) conditions.
3. For ducted units tested without an air filter installed, increase the applicable tabular value by 0.08 in H_2O.
4. If the manufacturer only has Low-static ducted models and if the manufacturer's specified maximum external static pressure is less than 0.10 in H_2O, then the Indoor Unit shall be tested at 0.02 below the maximum external static pressure.

6.1.2 *Electrical Conditions.* Tests shall be performed at the nameplate rated frequency. For equipment which is rated with 208/230 V dual nameplate voltages, tests conducted at Standard Rating Conditions shall be performed at 230 V. For all other dual nameplate voltage equipment covered by this standard, the tests shall be performed at both voltages or at the lower of the two voltages if only a single Standard Rating is to be published.

6.1.2.1 If a Non-ducted Indoor Unit or a Ducted Indoor Unit contains an integral condensate pump, the power to operate the pump shall be included in the system Total Power calculation.

6.2 *Tested Combinations.* A Tested Combination for all VRF Air-source Systems and VRF Water-source Heat Pump systems greater than or equal to 65,000 Btu/h consists of an Outdoor Unit and a minimum of 2 and a maximum of 12 Indoor Units. Only Ducted Indoor Units are used to determine the ratings for ducted VRF systems. Only Non-ducted Indoor Units are used to determine the ratings for non-ducted VRF systems.

6.2.1 The requirements for model families of Indoor Units shall be as follows:

6.2.1.1 All non-ducted Tested Combinations shall use Standard 4-way Ceiling Cassettes with the lowest normalized coil volume, as defined in section 6.2.4. If a manufacturer does not have 4-way Ceiling Cassettes, the Tested Combination shall include Indoor Units (with the lowest normalized coil volume, as defined in section 6.2.4) only from the first Non-ducted Indoor Unit Model Family of the following list from which a valid Tested Combination can be assembled:

- Compact 4-way Ceiling Cassette;
- Three-way Cassette;
- Two-way Cassette;
- Wall-mounted;
- One-way Cassette; and
- Floor-mounted and Ceiling-suspended.

6.2.1.2 All ducted Tested Combinations will use Mid-static Indoor Units with the lowest normalized coil volume, as defined in section 6.2.4. If a manufacturer does not have Mid-static ducted units, the Tested Combination shall include indoor units (with the lowest normalized coil volume, as defined in section 6.2.4) only from the Indoor Unit Model Family with highest static capabilities. See minimum ESP requirements in Table 6.

6.2.1.3 Small-duct, High-velocity Tested Combinations shall use Small-duct High-velocity Indoor Units with the lowest normalized coil volume/motor efficiency, as defined in section 6.2.4.

6.2.2 Indoor Units shall together, have a Nominal Cooling Capacity of 100% ± 5.0% of the system Standard Rated Cooling Capacity.

6.2.3 Indoor Units shall not, individually, have a Nominal Cooling Capacity greater than 50% of the System Standard Rated Cooling Capacity, unless the System Standard Rated Cooling Capacity of the VRF Water-source Heat Pump is 24,000 Btu/h or less.

Note: All capacities of VRF Water-source Heat Pump systems are covered under the scope of this standard.

6.2.4 All Indoor Units must be production units (or units representative of production units). If a manufacturer has multiple Indoor Unit models within an allowable capacity range (defined in Table 7) that meet the Tested Combination requirements, the manufacturer must use the criteria below to select from these models the appropriate Indoor Unit model for testing. The first criterion shall be the coil size described in Section 6.2.4.1, and the second shall be the indoor fan motor efficiency described in 6.2.4.2.

6.2.4.1 The model with the lowest normalized coil volume, calculated using Equation 1, shall be used.

$$NCV = \frac{L_c \times W_c \times D_c}{q_{nom}} \qquad 1$$

6.2.4.2 If more than one of the models has the same lowest normalized coil volume, the one of these models with the lowest efficiency indoor fan motor (highest fan motor input power at rated indoor airflow) shall be used for Standard Ratings.

Table 7. Nominal Indoor Unit Cooling Capacity Buckets	
Allowable Capacity Range	
Btu/h (minimum)	Btu/h (maximum)
2500	4499
4500	6499
6500	8499
8500	10,499
10,500	13,999
14,000	16,999
17,000	19,999
20,000	26,999
27,000	32,999
33,000	38,999
39,000	44,999
45,000	50,999
51,000	56,999
57,000	62,999
63,000	77,999
78,000	89,999
90,000	102,999

6.3 *Conditions for test for VRF Air-source and VRF Water-source Heat Pump Systems.* Tables 8 & 9 indicate the test and test conditions which are required to measure capacity and energy efficiency. VRF Air-source Systems and VRF Water-source Heat Pump Systems with dual-rated frequencies shall be tested at each frequency.

6.3.1 *Indoor Unit Airflow and External Static Pressure.* Airflow-control Setting(s) shall be determined before testing begins. Unless otherwise identified within Section 6.3.1 or its subsections, no changes shall be made to the Airflow-control Setting(s) after initiation of testing. It shall be permissible for the fan operational speeds to be different for each part-load test provided that the Airflow-control setting(s) remain unchanged. The Airflow-control Setting for heating tests may be different than the Airflow-control Setting for cooling tests, however the same Airflow-control Setting shall be used for all heating tests. For the Indoor Unit(s) that are specified Thermally Inactive, the Airflow-control Setting(s) shall be set to “OFF” per section 5.10.

6.3.1.1 *Minimum External Static Pressure for Testing.*

6.3.1.1.1 *Non-ducted Indoor Units.* All tests shall be performed at zero ESP, with a tolerance of –0.00 to +0.02 in H_2O for all test conditions.

6.3.1.1.2 *Ducted Indoor Units.* For the full-load cooling test, test each Indoor Unit using the minimum ESP specified in Table 6. When conducting heating or part-load cooling tests for which the indoor airflow rates are different than the airflow rates used for the full-load cooling test, calculate adjusted minimum ESP requirements using Equation 2. The minimum ESP requirement shall be applied to each individual Indoor Unit. For example, if half of Indoor Units are Thermally Inactive, the full-load ESP requirement is maintained for each Indoor Unit that is Thermally Active if the airflow rate through the Thermally Active Indoor Unit has not changed. If the airflow rate through a Thermally Active Indoor Unit has automatically changed via the Airflow-control Setting for a part-load test, then the ESP for that Indoor Unit shall be modified using Equation 2.

$$ESP_{adj} = ESP_{CFL} \cdot \left(\frac{Q_{dif}}{Q_{CFL}}\right)^2 \quad (2)$$

6.3.1.2 *Airflow Target Values.*

6.3.1.2.1 For the full-load cooling test, use the manufacturer-specified Airflow-control Setting for each Indoor Unit. If the cooling Airflow-control Setting is not specified by the manufacturer, use an Airflow-control Setting resulting in an airflow greater or equal to the manufacturer-specified airflow. If the cooling Airflow-control Setting or airflow are not specified by the manufacturer, use an Airflow-Control Setting resulting in an airflow of no more than 400 scfm per ton (i.e., per 12,000 Btu/h) of Indoor Unit Nominal Cooling Capacity.

6.3.1.2.2 For the heating tests, use the manufacturer-specified Airflow-control Setting for each Indoor Unit. If the delivered airflow differs from the part-load test at the same Airflow-control setting, then adjust the minimum ESP as per the calculation obtained in Equation 2. If the heating Airflow-control Setting is not specified by the manufacturer, use the full-load cooling Airflow-control Setting for the heating tests.

6.3.1.2.3 For the part-load cooling tests, use the full-load Airflow-control Setting as defined in Section 6.3.1.2.1. If the delivered airflow differs from the part-load test at the same Airflow-control setting, then adjust the minimum ESP in accordance with the calculation obtained in Equation 2.

6.3.1.3 *Maximum Airflow for Non-ducted Indoor Units.* For cooling tests, maximum airflow for any indoor unit must not exceed the lower of the two limits: (1) 105% of the nominal airflow as published in product literature for that unit; or (2) 55 scfm per 1,000 Btu/h of nominal Indoor Unit cooling capacity. If the airflow rate exceeds either, or both of these limits, then use an Airflow-control Setting resulting in airflow no more than the lower of the two limits mentioned in this section.

For heating tests, there is no maximum airflow if the Airflow-control Setting used in the heating test is the same as the Airflow-control Setting used in the full-load cooling test. If the Airflow-control Setting used is different, the heating airflow must also not exceed 55 scfm per 1,000 Btu/h of nominal Indoor Unit cooling capacity. If 55 scfm per 1,000 Btu/h is exceeded, use an Airflow-control Setting resulting in airflow no more than 55 scfm per 1,000 Btu/h.

If Nominal Capacity of each Indoor Unit is not available, then use total airflow and system Rated Capacity to determine the maximum allowable airflow rate.

If multiple Indoor Units discharge to a common duct, the airflow limit is the lower of either the sum of nominal cooling capacities at 55 scfm per 1000 Btu/h or 105% of the sum of nominal airflows as published in product literature for all Indoor Units connected to the common duct and applies to the total airflow measured for all Indoor Units connected to the common duct. The grouping of indoor units shall be manufacturer specified. However, if the manufacturer specifications do not consist of this grouping, any grouping of the specified indoor unit models connected to common ducts is acceptable, provided all test standard provisions are met.

6.3.1.4 *Maximum Airflow for Ducted Indoor Units.* The same restrictions in Section 6.3.1.3 for Non-ducted Indoor Units apply to Ducted Indoor Units, except use 42 scfm per 1000 Btu/h instead of 55 scfm per 1000 Btu/h.

6.3.1.5 *Tolerances.* If a common duct is used for the combined discharge airflow of multiple Indoor Units, the measured combined airflow must be compared to the sum of the airflow target value as defined in section 6.3.1.2. In such a case, any airflow tolerance specified in the following sections applies to the measured combined discharge airflow.

6.3.1.5.1 *Condition Tolerances.* All tolerances for airflow and ESP specified in this section for setting airflow and ESP apply throughout each test. Specifically, the average value of a parameter measured over the course of the test must vary from the target value by no more than the condition tolerance as defined in Table 12.

6.3.1.5.2 *Non-Ducted Indoor Units*.

6.3.1.5.2.1 Use the airflow target values defined in section 6.3.1.2 for each respective test.

6.3.1.5.2.2 For all tests, conduct the test at zero ESP with a tolerance of –0.00 to +0.02 in H_2O.

6.3.1.5.2.3 For the full-load cooling test, the airflow tolerance is ±5% of target full-load cooling airflow. For the heating test, if the full-load cooling airflow is used or the target heating airflow is provided, the airflow tolerance is ±5% of the target airflow. Otherwise (if the manufacturer provides instructions to obtain steady-state heating operation per the provisions of Section 6.3.1.2.2), there is no airflow tolerance requirement for the heating test. For part-load cooling tests, if the full-load cooling airflow is used or the target part-load cooling airflow is provided, the airflow tolerance is ±5% of the target airflow. Otherwise if the manufacturer provides instructions to obtain steady-state part-load cooling operation per the provisions of Section 6.3.1.2.3, there is no airflow tolerance requirement for part-load cooling tests.

6.3.1.5.2.4 If both the ESP and airflow cannot be maintained within tolerance for the full-load cooling and heating tests, maintain the ESP within the required tolerance and use an airflow as close to the target value as possible**.**

6.3.1.5.3 *Ducted Indoor Units.*

6.3.1.5.3.1 *Full-Load Cooling Test.*

6.3.1.5.3.1.1 Operate the unit under conditions specified for the full-load cooling test using the airflow target value specified in section 6.3.1.2. Adjust the airflow-measuring apparatus to maintain ESP within -0/+0.05 in H_2O of the requirement specified in Table 6 or to maintain the airflow within ±5% of the full-load cooling airflow target value.

If both the ESP and airflow cannot be maintained within tolerance for the full-load cooling test, maintain the ESP within the required tolerance and use an airflow as close to the manufacturer-specified value as possible.

6.3.1.5.3.2 *Heating Test.*

6.3.1.5.3.2.1 If the manufacturer-specified heating Airflow-control Setting is the same as the manufacturer-specified full-load cooling Airflow-control Setting (or if a heating Airflow-control Setting is not specified and the specified full-load cooling airflow target value is used as the airflow for the test, per the provisions of Section 6.3.1.2.2), use the Airflow-control Settings used for the full-load cooling test. Adjust the airflow-measuring apparatus to maintain the airflow within ±5% of the measured full-load cooling airflow without regard to the resulting ESP.

6.3.1.5.3.2.2 If the manufacturer-specified heating Airflow-control Setting differs from the manufacturer-specified full-load cooling Airflow-control Setting (or if a heating Airflow-control Setting is not specified and the full-load cooling delivered airflow differs from the part-load test at the same Airflow-control Setting, per the provisions of Section 6.3.1.2.2), use the following provisions.

6.3.1.5.3.2.2.1 Operate the unit under conditions specified for the heating test using the airflow target value specified in section 6.3.1.2 for the heating test.

6.3.1.5.3.2.2.2 Adjust the airflow-measuring apparatus to maintain ESP within -0/+0.05 in H_2O of the adjusted ESP requirement calculated by Equation 2 and maintain airflow within ±5% of the manufacturer-specified heating airflow.

6.3.1.5.3.2.2.3 If both the ESP and airflow cannot be maintained within tolerance for the heating tests, maintain the ESP within the required tolerance and use an airflow as close to the manufacturer-specified value as possible.

6.3.1.5.3.3 *Part-load Cooling Tests*.

6.3.1.5.3.3.1 If the manufacturer-specified part-load cooling airflow is the same as the manufacturer-specified full-load cooling airflow (or if a part-load cooling airflow is not specified and the specified full-load cooling airflow target value is used as the airflow for the test, per the provisions of Section 6.3.1.2.3), use the Airflow-control Settings used for the full-load cooling test. Adjust the airflow-measuring apparatus to maintain the airflow within ±5% of the measured full-load cooling airflow without regard to the resulting ESP. No changes are to be made to the Airflow-control Settings for the part-load cooling test. For part-load cooling tests for which an airflow is not specified and the specified full-load cooling airflow target value is not used as the airflow for the test (because the delivered airflow differs from the part-load at the same Airflow-control Setting, per the provisions of Section 6.3.1.2.3), adjust the airflow-measuring apparatus to meet the adjusted ESP requirement determined per Equation 2 with a condition tolerance of -0/+0.05 in H_2O, using the measured part-load cooling airflow in the ESP calculation.

6.3.1.5.3.3.2 If the manufacturer-specified part-load cooling airflow differs from the manufacturer-specified full-load cooling airflow, use the following provisions.

6.3.1.5.3.3.2.1 Operate the system under conditions specified for the part-load cooling test using the manufacturer-specified Airflow-control Settings for the full-load cooling test.

6.3.1.5.3.3.2.2 Adjust the airflow measuring apparatus to maintain ESP within -0/+0.05 in H_2O of the adjusted ESP requirement calculated using Equation 2 and maintain airflow within ±5% of the manufacturer-specified part-load cooling airflow.

6.3.1.5.3.3.2.3 If both the ESP and airflow cannot be maintained within tolerance for the part-load cooling tests, maintain the ESP within the required tolerance and use an airflow as close to the manufacturer-specified value as possible.

Table 8. Operating Conditions for Standard Rating and Performance Operating Tests for VRF Air-Source Systems [1, 4]						
		Indoor Section Air Entering		Outdoor Section Air Entering		
Test Name		Dry-Bulb, ºF	Wet-Bulb, ºF	Dry-Bulb, ºF	Wet-Bulb, ºF
COOLING	Standard Rating Conditions Cooling[2]	80.0	67.0	95.0	NA
COOLING	Low Temperature Operating Cooling[2]	67.0	57.0	67.0	NA
COOLING	Maximum Operating Conditions[2]	80.0	67.0	115	NA
COOLING	Standard Rating Part-Load Conditions (IEER)[2, 3]	80.0	67.0	81.5 (75% Load) 68.0 (50% Load) 65.0 (25% Load)	NA
COOLING	Insulation Effectiveness[2]	80.0	75.0	80.0	NA
COOLING	Condensate Disposal[2]	80.0	75.0	80.0	NA
HEATING	Standard Rating Conditions (High Temperature Steady-state Test for Heating)	70.0	60.0 (maximum)	47.0	43.0
HEATING	Standard Rating Conditions (Low Temperature Steady-state Test for Heating)	70.0	60.0 (maximum)	17.0	15.0
HEATING	Maximum Operating Conditions	80.0	NA	75.0	65.0

Notes:
1. All tests shall be conducted at Stable Conditions.
2. Cooling rating and operating tests are not required for heating only Heat Pumps.
3. For indoor and outdoor airflow requirements, refer to Sections 6.3.1. and 6.3.2, respectively.
4. Refer to Section 6.3.3.2 for SHR limits on 100% and 75% load test points.

6.3.2 *Outdoor-Coil Airflow Rate (Also referred to as outdoor fan speed) (Applies to VRF Air-source Systems Only).* All Standard Ratings shall be determined at the outdoor-coil airflow rate achieved at zero external static pressure. Where the fan drive is non-adjustable, all Standard Ratings shall be determined at the outdoor-coil airflow rate inherent in the equipment when operated with all of the resistance elements associated with inlets, louvers, and any ductwork and attachments shipped with the unit or as specified in MII. For adjustable speed fans, the outdoor fan speed must be set as specified by the STI and within the range defined by Appendix C. If no instructions are provided, follow the hierarchy described in Section 5.1.2.3 for Control Setting(s). Once established, the outdoor-side air circuit of the equipment shall remain unchanged throughout all tests prescribed herein unless automatic adjustment of outdoor airflow rates by system function is made.

6.3.3 *Allowable Critical Parameter Adjustments.* The following sections describe Critical Parameter adjustments performed by lab personnel allowed for meeting part-load capacity targets and SHR limits. For Steady-state Tests conducted in a third-party laboratory, use of proprietary tools by a manufacturer's representative is permitted to set Critical Parameters under the supervision of the third-party laboratory [using the Service Tool to monitor Critical Parameters].

6.3.3.1 *Critical Parameter Adjustments for Meeting Capacity Targets.* When Critical Parameters have been set to their STI-specified values, if the unit cannot operate within 3% of the target load fraction for a given part-load test (75%, 50%, or 25% load) or within 3% of the Rated Capacity for a 100% test, manually-overridden Critical Parameters may be adjusted according to the following provisions:

6.3.3.1.1 *Capacity is Below Lower Tolerance*. If, for any test, the capacity is below the lower tolerance for the required load, the lab shall increase the compressor speed(s) beyond the STI-reported value(s) until the capacity is within 3% of the required load. If multiple compressors are present in the system, the lab shall increase each compressor speed by the same increment so long as 1) The STI indicates the compressor to be active for that test and 2) The compressor has not yet reached maximum speed. The compressor speed(s) may not be less than the STI-reported value(s) at any point during the test.

6.3.3.1.2 *Capacity is Above Upper Tolerance*. If, for any test, the capacity result is above the upper tolerance for the required load, the lab shall adjust any manually-overridden Critical Parameters per the STI so that the deviation results in an RSS Point Total of 70 points or fewer. If the STI does not include instructions for adjusting Critical Parameters to meet capacity targets, then a member of the laboratory shall reduce the compressor speed(s) so that the deviation results in an RSS Point Total of 70 points or fewer. If multiple compressors are present in the system, the lab shall decrease each compressor speed by the same increment so long as 1) The STI indicates the compressor to be active for that test and 2) The compressor has not yet reached minimum speed. For the 75%, 50% and 25% part-load test points, if the RSS Point Total budget is exhausted during Critical Parameter adjustments and the capacity continues to operate more than 3% above the target load fraction, follow Cyclic Degradation procedures in accordance with 11.2.2.1.

6.3.3.2 *Critical Parameter Adjustments for Meeting SHR Limits*. The SHR for 100% load test point and 75% part-load test point shall not be higher than 0.82 and 0.85, respectively (measured to the nearest hundredth). If the SHR exceeds these limits, follow the provisions outlined below to adjust compressor speed(s) until the SHR is within limit. If, after compressor adjustment, the SHR limit is still not met, then the unit will require calculation adjustments as outlined in Section 11.2.2.2.

6.3.3.2.1 If the SHR is above the allowable limit, the lab shall increase the compressor speed(s) until either the SHR is less than or equal to the allowable limit or the capacity reaches 3% greater than the target capacity, whichever happens first. If multiple compressors are present in the system, the lab shall increase each compressor speed by the same increment so long as 1) The STI indicates the compressor to be active for that test and 2) The compressor has not yet reached maximum speed. Should the SHR remain above the maximum limit when the capacity reaches its upper 3% tolerance, no further compressor adjustments shall be made, and the calculation procedures outlined in 11.2.2.2 shall be applied using the adjusted SHR value obtained after increasing the compressor speed(s).

6.4 *Conditions for VRF Water-source Heat Pumps*.

6.4.1 *Power Input of Liquid Pumps.*

6.4.1.1 If no liquid pump is provided with the Heat Pump, a pump power adjustment is to be included in the Total Power consumed by the Heat Pump, using Equation 3.

$$\varphi_{pa} = \frac{q \times \Delta p_{int}}{\eta} \qquad 3$$

6.4.1.2 If a liquid pump is an integral part of the Heat Pump, only the portion of the pump power required to overcome the internal resistance shall be included in the Total Power to the Heat Pump. The fraction which is to be excluded from the Total Power consumed by the pump shall be calculated using the Equation 4.

$$\varphi_{pa} = \frac{q \times \Delta p_{ext}}{\eta} \qquad 4$$

6.4.2 *Liquid Flow Rates*.

6.4.2.1 All Standard Ratings shall be determined at a liquid flow rate described below, expressed as gallons per minute.

6.4.2.2 VRF Water-source Heat Pumps with integral liquid pumps shall be tested at the liquid flow rates specified by the manufacturer or those obtained at zero external static pressure difference, whichever provides the lower liquid flow rate.

6.4.2.3 Systems without integral liquid pumps shall be tested at the flow rates specified by the manufacturer.

6.4.2.4 The manufacturer shall specify a single liquid flow rate for all of the tests required in Section 6.4 with a maximum limit of 4 gallons per minute per ton of Standard Rating Cooling Capacity. Automatic adjustment provided by the equipment to reduce the liquid flow rate from its flow for the full load cooling test shall be allowed. A separate control signal output for each step of liquid flow rate will be considered as an automatic adjustment.

6.4.3 *Test Liquids*.

6.4.3.1 The test liquid for Water Loop Heat Pumps and Ground-water Heat Pumps shall be water.

6.4.3.2 The test liquid for Ground-loop Heat Pumps shall be a 15% solution by mass of ethylene glycol in water.

6.4.3.3 The test liquid shall be sufficiently free of gas to ensure that the measured result is not influenced by the presence of gas.

6.4.4 *Standard Rating and Part-load Rating Test Conditions*.

6.4.4.1 The test conditions for the determination of Standard Rating Conditions and part-load rating cooling conditions are specified in Table 9.

6.4.4.2 The test conditions for determination of Standard Rating Conditions and part-load rating heating conditions are specified in Table 10.

6.4.4.3 Systems intended for a specific application shall be rated at the conditions specified for that application, for example, water-loop, ground-water, or ground-loop, and shall be identified as such (i.e., Water Loop Heat Pump, Ground-water Heat Pump, or Ground-loop Heat Pump). Systems intended for two or three applications shall be rated at the conditions specified for each of these applications and shall be so identified (see Section 7.3 of AHRI/ASHRAE ISO Standard 13256-1)

6.4.4.4 Allowable adjustments to Critical Parameters during the Controls Verification Procedure are specified in Section 6.3.3.

6.4.5 *Part-load Rating Conditions.* Test conditions for part-load ratings shall be in accordance with Table 9 and Table 10. Any water flow required for system function shall be at water flow rates established at (full load) Standard Rating Cooling Capacity Conditions, except as required by Section 6.4.4. If the unit cannot operate within 3% of the target load fraction for a given part-load test point (75%, 50%, or 25%), Section 6.3.3 shall be followed to meet part-load capacity targets with RSS Point Total ≤ 70 points.

Table 9. Operating Conditions for Standard Rating and Performance Operating Tests for the Determination of Cooling Capacity for VRF Water-source Heat Pumps[1]

	Water-Loop Heat Pumps	Ground-water Heat Pumps	Ground-loop Heat Pumps
Air entering indoor side — dry bulb, °F — wet bulb, °F	 80.6 66.2	 80.6 66.2	 80.6 66.2
Air surrounding Outdoor Unit — dry bulb, °F[1]	 80.6	 80.6	 80.6
<u>Standard Rating Test</u> Liquid entering heat exchanger, °F	 86.0	 59.0	 77.0
<u>Part-load Conditions (IEER)</u> Liquid entering heat exchanger, °F[1]	 86 (100% Load) 81.0 (75% Load) 74.0 (50% Load) 67.0 (25% Load)	 59.0	 68.0
Insulation Effectiveness — dry bulb, °F — wet bulb, °F — liquid entering heat exchanger, °F[2]	 80.6 75.2 68.0	 80.6 75.2 50.0	 80.6 75.2 50.0
Condensate Disposal — dry bulb, °F — wet bulb, °F — liquid entering heat exchanger, °F[2]	 80.6 75.2 68.0	 80.6 75.2 50.0	 80.6 75.2 50.0
Voltage, V	Rated	Rated	Rated

Notes:

1. Refer to Section 6.3.3.2 for SHR limits on 100% and 75% load test points.
2. Airflow-control Settings shall be in accordance with Section 6.3.1. Liquid flow rate conditions shall be in accordance with Section 6.4.2.

Table 10. Operating Conditions for Standard Rating and Performance Operating Tests for the Determination of Heating Capacity for Systems that use a VRF Water-source Heat Pump Systems

	Water-Loop Heat Pumps	Ground-water Heat Pumps	Ground-loop Heat Pumps
Air entering indoor side[1] — dry bulb, °F — maximum wet bulb, °F	 68.0 59.0	 68.0 59.0	 68.0 59.0
Air surrounding Outdoor Unit — dry bulb, °F	 68.0	 68.0	 68.0
<u>Standard Rating Test</u> Liquid entering heat exchanger, °F	 68.0	 50.0	 32.0
<u>Part-load Conditions (IEER)</u> Liquid entering heat exchanger, °F	 NA	 NA	 NA
Voltage, V	Rated	Rated	Rated

Notes:

1. Airflow-control Settings shall be in accordance with Section 6.3.1. Liquid flow rate conditions shall be in accordance with Section 6.4.2.

6.5 *Simultaneous Cooling and Heating Efficiency and Capacity Ratings (Applicable to all VRF Heat Recovery Systems.)*

6.5.1 *General Conditions*.

6.5.1.1 All VRF Heat Recovery Systems shall have Simultaneous Cooling and Heating Efficiencies determined in accordance with the provisions of this standard. All tests shall be carried out in accordance with Section 5.

6.5.1.2 All Indoor Units of the selected Tested Combination shall be operating during this test. For the purposes of the simultaneous operation testing, the Nominal Cooling Capacity of the Indoor Units shall be split between the heating and cooling test rooms and as close to 50% as possible. The split ratio of the Nominal Cooling Capacity between units operating in heating and cooling shall be between 45% and 55%.

6.5.1.3 During the SCHE test, the room that has the higher nominal Indoor Unit capacity shall be in cooling mode. The manufacturer shall adjust the compressor speed to operate at 50% of the Standard Rating Cooling Capacity as the minimum used for the cooling capacity for the SCHE test. The heating side capacity should correspondingly be 45% or greater of the Standard Rating Cooling Capacity.

6.5.2 *Temperature Conditions.* The temperature conditions shall be as stated in Table 11.

Table 11. Simultaneous Heating and Cooling Test Conditions

	Three Room Air Enthalpy SCHE3		Two Room Air Enthalpy SCHE2	
	Dry bulb, °F	Wet bulb, °F	Dry bulb, °F	Wet bulb, °F
Outdoor Air				
- Air-source	47.0	43.0	47.0	43.0
- Water-source	68.0	-	68.0	-
Indoor Air (Air-source)				
- Heating	70.0	60.0[1]	75.0	63.6
- Cooling	80.0	67.0	75.0	63.6
Indoor Air (Water-source)				
- Heating	68.0	59.0[1]	74.3	62.7
- Cooling	80.6	66.2	74.3	62.7

Notes:
1. Maximum value.

6.5.3 *Air-flow Conditions*. The test shall be conducted at the same Airflow-control Setting as full-load heating and cooling tests. If the cooling full-load airflow rate is different than the heating full-load airflow rate, the units operating in cooling mode shall be set at the cooling full-load airflow rate and the units operating in heating mode shall be set at the heating full-load airflow rate.

6.5.4 *Test Conditions*.

6.5.4.1 *Preconditions*. The test room reconditioning apparatus and the equipment under test shall be operated until equilibrium conditions are attained, but for not less than one hour, before data is recorded.

6.5.4.2 *Duration of Test*. Data shall be recorded for 30 minutes at least every five minutes at least seven consecutive readings within the tolerance presented in ASHRAE Standard 37, Table 2A have been attained.

6.5.5 *Three-room Air Enthalpy Method*.

6.5.5.1 The Indoor Units in the cooling mode shall be assembled in one room and the Indoor Units in the heating mode in another room. The Outdoor Unit shall be installed in the third room.

6.5.6 *Two-room Air Enthalpy Method*.

6.5.6.1 All Indoor Units, either operating in cooling or heating mode, are assembled in one indoor room. The Outdoor Unit shall be installed in the other room.

6.5.6.2 All Indoor Units operating in the heating mode shall be connected to a common plenum, and all Indoor Units operating in the cooling mode shall be connected to another common plenum, both in accordance with the requirements established in the Indoor air enthalpy test method described in ASHRAE Standard 37.

6.5.7 When testing set up is done using two indoor rooms with total capacity of Indoor Units being 50% in each room, the SCHE shall be calculated using Equation 5. When testing set up is done using three indoor rooms with total combined capacity of Indoor Units being 50% heating in heating indoor room 1 and a total combined capacity of Indoor Units being 50% cooling in cooling indoor room 1 and cooling indoor room 2, the SCHE shall be calculated using Equation 6.

$$SCHE = \frac{\dot{q}_{thir1} + \dot{q}_{tcir1}}{\dot{E}_{tot}} \quad (5)$$

$$SCHE = \frac{\dot{q}_{thir1} + \dot{q}_{tcir1} + \dot{q}_{tcir2}}{\dot{E}_{tot}} \quad (6)$$

6.6 *General Test Methods*.

6.6.1 *Test Tolerances*. Test Operating Tolerances and Test Condition Tolerances for Steady-state Tests shall be as specified in Table 12, superseding values specified in ASHRAE Standard 37 Table 2b.

Table 12. Test Operating Tolerances and Test Condition Tolerances

Measurement		Test Operating Tolerance	Test Condition Tolerance
Outdoor dry-bulb temperature, °F:			
Entering		2.0	0.5
Leaving		2.0 / 3.0[1, 3]	-
Outdoor wet-bulb temperature, °F:			
Entering		1.0	0.3[2]
Leaving		1.0[3]	-
Indoor dry-bulb temperature, °F:			
Entering		2.0	0.5[4]
Leaving		2.0 / 3.0[1, 4]	0.5[4]
Indoor wet-bulb temperature, °F:			
Entering		1.8	0.36
Leaving		1.0	-
Saturated refrigerant temperature corresponding to the measured indoor side pressure[5] ,°F		3.0	0.5
Liquid temperature if not otherwise specified, °F		0.9	0.36
External static pressure	Non-ducted Indoor Units, in H_2O	0.04	0.02
	Ducted Indoor Units (percent of reading)[6]	10	See Table 6
Electrical voltage (percent of reading)[6]		2.0	1.0
Liquid flow rate (percent of reading)[6]		2.0	1.0
Nozzle pressure drop (percent of reading)[6]		5.0	-

Notes:
1. The Test Operating Tolerance is 2.0 °F for cooling tests and 3.0 °F for heating tests.
2. Applies only for heating tests of VRF Air-source Systems.
3. Applies only when using the outdoor air enthalpy method.
4. Applies only when using the indoor air enthalpy method.
5. Tolerance applies only for the compressor calibration and refrigerant enthalpy methods; the saturation temperature, in this case, shall be evaluated based on the pressure transducer located between the indoor coil and the compressor for the given operating mode, heating or cooling.
6. For tolerances expressed as a percentage, the tolerance is the specified percentage of the average value of the measured test parameter.

Section 7. Determination of Published Ratings

7.1 *Standard Ratings Values.* Standard Ratings relating to cooling or heating capacities shall be net values, including the effects of circulating-fan heat, but not including supplementary heat (i.e., disable resistance elements used for heating indoor air at all times). Power input shall be the sum of power inputs to the compressor(s) and fan(s), plus System Controls and other items required as part of the system for normal operation.

7.1.1 *Values of Full System Rated Capacity*. These ratings shall be expressed only in terms of Btu/h, rounded as shown in Table 13.

Table 13. Values of Full System Rated Capacity

Rated Capacity, Btu/h	Multiples, Btu/h
< 20,000	100
≥ 20,000 and < 38,000	200
≥ 38,000 and < 65,000	500
≥ 65,000 and <135,000	1000
≥ 135,000	2000

7.1.2 *Values of Energy Efficiency for VRF Air-source Systems and VRF Water-source Heat Pump Systems*. Energy Efficiency Ratios (EER), and Integrated Energy Efficiency Ratios (IEER) for cooling, whenever published shall be expressed in multiples of the nearest 0.1 (Btu/h)/W. Simultaneous Cooling & Heating Efficiency (SCHE), and Coefficients of Performance (COP) shall be expressed in multiples of the nearest 0.01.

7.2 *Ratings.* Standard Ratings for capacity, $EER_{A, Full}$, IEER, and COP_H shall be established either on test data (as per Section 7.2.1) or computer simulation.

7.2.1 *Ratings Generated by Test Data*. Any capacity, $EER_{A, Full}$, IEER, or COP_H rating of a system generated by test data shall be based on the results of at least two unique production or production representative samples tested in accordance with all applicable portions of this standard. The capacity, $EER_{A, Full}$, $COP_{H,}$ or IEER ratings shall not be higher than the lower of a) the test sample mean ($\bar{x}$), or b) the lower 95% confidence limit (LCL) divided by 0.95 (as defined by the formulas below and Table 14), rounded per Sections 7.1.1 and 7.1.2. The following is an example calculation for LCL:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (7)$$

$$LCL = \bar{x} - t_{.95}\left(\frac{s}{\sqrt{n}}\right) \quad (8)$$

Table 14. Statistics

Number of Systems Tested[1]	$t_{.95}$
2	6.314
3	2.920
4	2.353
5	2.132
6	2.015

Note:
1. From Appendix A of Subpart B of 10 CFR §429.

7.2.2 *Mixed Ratings*. Mixed Ratings shall be determined by the straight average of two individual systems represented (rated) values containing homogenous kinds of Indoor Units (i.e., non-ducted, ducted, or SDHV).

7.2.3 *Documentation*. As required by 10 CFR §429.71, supporting documentation of all Published Ratings subject to federal control shall be appropriately maintained.

7.2.4 *Multiple Standard Ratings*. A single product may have more than one Standard Rating. If multiple Standard Ratings exist, the conditions for each Standard Rating shall be clearly identified for each individual Standard Rating.

7.2.5 *Ducted and Non-ducted Combinations.*

7.2.5.1 For manufacturers that offer either only non-ducted combinations or only ducted combinations, ratings shall be determined by testing at least two complete system samples of the same combination of Indoor Units.

7.2.5.1.1 For any system combinations using only Non-ducted Indoor Units that meet the definition of a Tested Combination, the rating given to any untested VRF System combination having the same Outdoor Unit and all Non-ducted Indoor Units shall be set equal to the rating of the tested system having all Non-ducted Indoor Units.

7.2.5.1.2 For any system combinations using only Ducted Indoor Units that meet the definition of a Tested Combination, the rating given to any untested VRF System combination having the same Outdoor Unit and all Ducted Indoor Units shall be set equal to the rating of the tested system having all Ducted Indoor Units. In order to be considered a Ducted Indoor Unit, the Indoor Unit must be intended to be connected with ductwork and have a rated external static pressure capability greater than zero.

7.2.5.2 For manufacturers that offer both non-ducted combinations and ducted combinations, ratings must be determined by testing two or more combinations of Indoor Units with each Outdoor Unit with one combination consisting of only Non-ducted Indoor Units and the second consisting of only Ducted Indoor Units.

7.2.5.2.1 For any system combinations using only Non-ducted Indoor Units that meet the definition of a Tested Combination, the rating given to any untested VRF System combination having the same Outdoor Unit and all Non-ducted Indoor Units shall be set equal to the rating of the tested system having all Non-ducted Indoor Units.

7.2.5.2.2 For any system combinations using only Ducted Indoor Units that meet the definition of a Tested Combination, the rating given to any untested VRF System combination having the same Outdoor Unit and all Ducted Indoor Units shall be set equal to the rating of the tested system having all ducted Indoor Units. In order to be considered a ducted unit, the Indoor Unit must be intended to be connected with ductwork and have a rated external static pressure capability greater than zero.

7.2.5.2.3 The rating given to any untested VRF System combination having the same Outdoor Unit and a mix of non-ducted and ducted Indoor Units shall be set equal to the average of the ratings for the two required Tested Combinations.

Section 8. Operating Requirements

8.1 *Operating Requirements.* Systems shall comply with the provisions of this section such that any production unit will meet the requirements detailed herein.

8.1.1 *Voltage Tolerance Test.* Systems shall pass the following voltage tolerance test with a cooling coil airflow rate as determined under Section 6.

8.1.1.1 *Temperature Conditions.* Temperature conditions shall be maintained at the standard cooling (and/or standard heating, as required) Steady state conditions as shown in Table 8, as applicable, in accordance with the unit's nameplate. For equipment marked for application for more than one Standard Rating condition the most stringent outdoor ambient conditions shall be used.

8.1.1.2 *Voltages.*

8.1.1.2.1 *Steady state*. Two separate tests shall be performed, one test at the Range B minimum utilization voltage and one test at the Range B maximum utilization voltage from AHRI Standard 110, Table 1, based upon the unit's nameplate rated voltage(s). These voltages shall be supplied at the unit's service connection and at rated frequency. A lower minimum or a higher maximum voltage shall be used, if listed on the nameplate.

8.1.1.2.2 *Power Interrupt*. During the power interrupt portion of each test, the voltage supplied to the equipment (single phase and three phase) shall be adjusted just prior to the shut-down period such that the resulting voltage at the unit's service connection is 86% of nameplate rated voltage when the compressor motor is on locked-rotor. (For 200V or 208V nameplate rated equipment the restart voltage shall be set at 180V when the compressor motor is on locked rotor). Open circuit voltage for three-phase equipment shall not be greater than 90% of nameplate rated voltage.

8.1.1.2.3 *Resume Operation*. During the resume operation portion of the test, the voltage supplied to the equipment shall be the same as the voltage as per Section 8.1.1.2.1.

8.1.1.3 *Procedure.*

8.1.1.3.1 *Steady state*. The equipment shall be operated for one hour at the temperature conditions and each voltage specified in 8.1.1.1 and 8.1.1.2.

8.1.1.3.2 *Power Interrupt*. All power to the equipment shall be shut off for a period sufficient to cause the compressor to stop (not to exceed five seconds) and then immediately restored.

8.1.1.3.3 *Resume Operation.* Within one minute after the equipment has resumed continuous operation, the voltage shall be restored to the values specified in Section 8.1.1.2.1. During the remainder of resume operations phase, voltage and temperature conditions shall be retained as specified in Section 8.1.1.3.1. Refer to Figure 2.

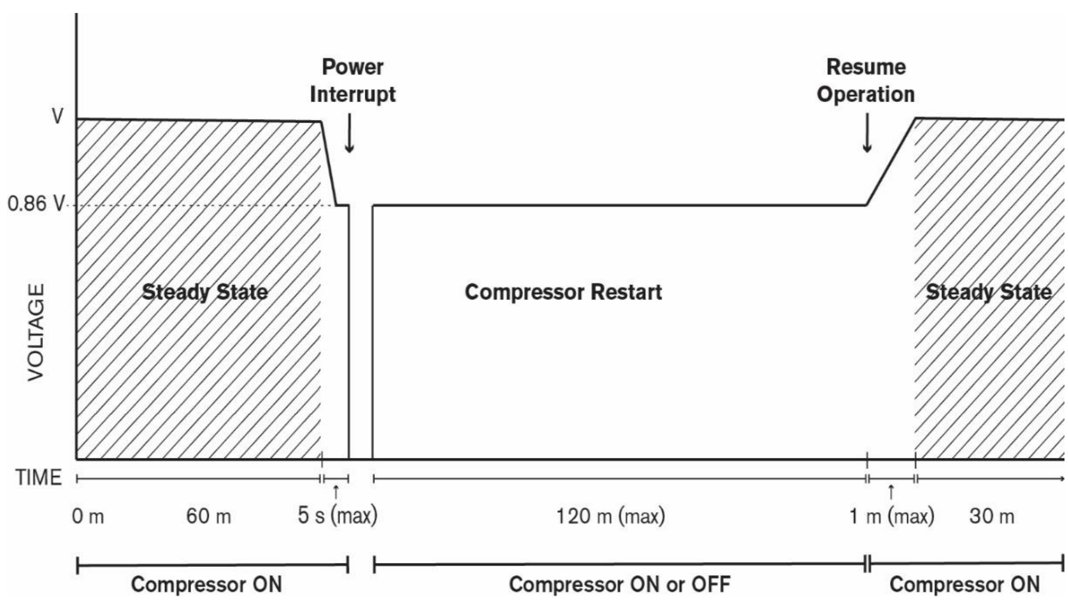

Figure 2. Voltage Tolerance Test Power Interrupt Procedure

8.1.1.4 *Requirements.*

8.1.1.4.1 During the entire test, the equipment shall operate without failure of any of its parts.

8.1.1.4.2 *Steady state*. During the steady state portion of the test, the equipment shall operate continuously without interruption for any reason.

8.1.1.4.3 *Resume Operation*. During the resume operation portion of the test, the unit shall resume continuous operation within two hours of restoration of power and shall then operate continuously for one half hour. Operation and automatic resetting of safety devices prior to re-establishment of continuous operation is permitted.

8.1.2 *Operating Requirements for VRF Air-source Systems.*

8.1.2.1 *Maximum Operating Conditions Test (Cooling and Heating).* VRF Systems shall pass the following maximum cooling and heating operating conditions test with an indoor coil airflow rate as determined under Section 6.

8.1.2.1.1 *Temperature Conditions.* Temperature conditions shall be maintained as shown in Table 8, as applicable, in accordance with the unit's nameplate.

8.1.2.1.2 *Voltages*. Tests shall be run at the minimum and maximum utilization voltages of Voltage Range B as shown in Table 1 of AHRI Standard 110, at the unit's service connection and at rated frequency.

8.1.2.1.3 *Procedure.*

8.1.2.1.3.1 VRF Systems shall be operated continuously for one hour at the temperature conditions and voltage(s) specified.

8.1.2.1.3.2 All power to the system shall be interrupted for a period sufficient to cause the compressor(s) to stop (not to exceed five seconds) and then be restored.

8.1.2.1.4 *Requirements.*

8.1.2.1.4.1 During both tests, the VRF Systems shall operate without failure of any of its parts.

8.1.2.1.4.2 The unit shall resume continuous operation within one hour of restoration of power and shall then operate continuously for one hour. Operation and resetting of safety devices prior to establishment of continuous operation is permitted.

8.1.2.2 *Maximum Operating Conditions Test for Equipment with Optional Outdoor Cooling Coil.* VRF Systems which incorporate an outdoor air cooling coil shall use the conditions, voltages, and procedure (Sections 8.1.2.1.1 through 8.1.2.1.4) and meet the requirements of Section 8.1.1.2 except for the following changes.

- Outdoor air set as in Section 6;
- Indoor return air temperature conditions shall be 80.0ºF dry-bulb, 67.0ºF wet-bulb; and
- Outdoor air entering outdoor air cooling coil shall be 115ºF dry-bulb and 75.0ºF wet-bulb.

8.1.2.3 *Cooling Low Temperature Operation Test*. VRF Systems shall pass the following low-temperature operation test when operating with initial airflow rates as determined in Sections 6, and with System Controls and dampers set to produce the maximum tendency to frost or ice the indoor coil, provided such settings are not contrary to the manufacturer's instructions to the user.

8.1.2.3.1 *Temperature Conditions.* Temperature conditions shall be maintained as shown in Table 8, as applicable, in accordance with the unit's nameplate.

8.1.2.3.2 *Voltage and Frequency*. The test shall be performed at nameplate rated voltage and frequency.

For air-conditioners and Heat Pumps with dual nameplate voltage ratings, tests shall be performed at the lower of the two voltages.

8.1.2.3.3 *Procedure.* The test shall be continuous with the unit in the cooling cycle for not less than four hours after establishment of the specified temperature conditions. The unit will be permitted to start and stop under control of an automatic limit device, if provided.

8.1.2.3.4 *Requirements.*

8.1.2.3.4.1 During the entire test, the VRF Systems shall operate without damage to the equipment.

8.1.2.3.4.2 During the entire test, the indoor airflow rate shall not drop more than 25% from that specified for the Standard Rating Conditions Cooling test.

8.1.2.3.4.3 During all phases of the test and during the defrosting period after the completion of the test, all ice or meltage must be caught and removed by the drain provisions.

8.1.2.4 *Insulation Effectiveness Test (Cooling).* VRF Systems shall pass the following Insulation Effectiveness Test when operating with airflow rates as determined in Section 6, and with System Controls, fans, dampers, and grilles set to produce the maximum tendency to sweat, provided such settings are not contrary to the manufacturer's instructions to the user.

8.1.2.4.1 *Temperature Conditions*. Temperature conditions shall be maintained as shown in Table 8, as applicable, in accordance with the unit's nameplate.

8.1.2.4.2 *Procedure*. After establishment of the specified temperature conditions, the unit shall be operated continuously for a period of four hours.

8.1.2.4.3 *Requirements*. During the test, no condensed water shall drop, run, or blow off from the unit casing.

8.1.2.5 *Condensate Disposal Test (Cooling).* VRF Systems which reject condensate to the condenser air shall pass the following condensate disposal test when operating with airflow rates as determined in Section 6, and with System Controls and dampers set to produce condensate at the maximum rate, provided such settings are not contrary to the manufacturer's instructions to the user (This test may be run concurrently with the insulation effectiveness test (Section 8.1.2.4)).

8.1.2.5.1 *Temperature Conditions.* Temperature conditions shall be maintained as shown in Table 9, as applicable, in accordance with the unit's nameplate.

8.1.2.5.2 *Procedure.* After establishment of the specified temperature conditions, the equipment shall be started with its condensate collection pan filled to the overflowing point and shall be operated continuously for four hours after the condensate level has reached equilibrium.

8.1.2.5.3 *Requirements*. During the test, there shall be no dripping, running-off, or blowing-off of moisture from the unit casing.

8.1.3 *Operating Requirements for VRF Water-source Heat Pumps.*

8.1.3.1 *Capacity Requirements*.

8.1.3.1.1 For VRF Water-source Heat Pumps with capacity control, the performance requirements tests shall be conducted at maximum capacity.

8.1.3.2 *Maximum Operating Conditions Test*.

8.1.3.2.1 *Test conditions.* The maximum operating conditions tests shall be conducted for cooling and heating at the test conditions established for the specific applications specified in Tables 15 and 16.

VRF Water-source Heat Pumps intended for use in two or more applications shall be tested at the most stringent set of conditions specified in Table 15 and Table 16.

Units with VRF Water-source condensers shall be capable of operation under these maximum conditions at a water-pressure drop not to exceed 15.0 psid, measured across the unit.

8.1.3.2.2 *Test Procedures*.

8.1.3.2.2.1 The equipment shall be operated continuously for one hour after the specified temperatures have been established at each specified voltage level.

8.1.3.2.2.2 The 110% voltage test shall be conducted prior to the 90% voltage test.

8.1.3.2.2.3 All power to the equipment shall be interrupted for three minutes at the conclusion of the one hour test at the 90% voltage level and then restored for one hour.

Table 15. Maximum Cooling Test Conditions for Systems that use VRF Water-source Heat Pumps

	Water-Loop Heat Pumps	Ground-water Heat Pumps	Ground-loop Heat Pumps
Air entering indoor side[1] — dry bulb, °F — wet bulb, °F	 89.6 73.4	 89.6 73.4	 89.6 73.4
Air surrounding unit — dry bulb, °F	 89.6	 89.6	 89.6
Liquid entering heat exchanger[1],°F	104	77.0	104
Frequency[2], Hz	Rated	Rated	Rated
Voltage, V	1. 90% and 110% of rated voltage for equipment with a single nameplate rating. 2. 90% of minimum voltage and 110% of maximum voltage for equipment with dual nameplate voltage.	1. 90% and 110% of rated voltage for equipment with a single nameplate rating. 2. 90% of minimum voltage and 110% of maximum voltage for equipment with dual nameplate voltage.	1. 90% and 110% of rated voltage for equipment with a single nameplate rating. 2. 90% of minimum voltage and 110% of maximum voltage for equipment with dual nameplate voltage.

Notes:

1. Air and liquid flow rates shall be as established in Section 6.
2. Equipment with dual-rated frequencies shall be tested at each frequency.

Table 16. Maximum Heating Test Conditions for VRF Water-source Heat Pumps			
	Water Loop Heat Pumps	Ground-water Heat Pumps	Ground-loop Heat Pumps
Air entering indoor side[1] — dry bulb, °F — maximum wet bulb, °F	 68.0 59.0	 68.0 59.0	 68.0 59.0
Air surrounding Outdoor Unit — dry bulb, °F	 68.0	 68.0	 68.0
Liquid entering heat exchanger[1], °F	86.0	77.0	77.0
Frequency[2], Hz	Rated	Rated	Rated
Voltage, V	1) 90% and 110% of rated voltage for equipment with a single nameplate rating. 2) 90% of minimum voltage and 110% of maximum voltage for equipment with dual nameplate voltage.	1) 90% and 110% of rated voltage for equipment with a single nameplate rating. 2) 90% of minimum voltage and 110% of maximum voltage for equipment with dual nameplate voltage.	1) 90% and 110% of rated voltage for equipment with a single nameplate rating. 2) 90% of minimum voltage and 110% of maximum voltage for equipment with dual nameplate voltage.
Notes: 1. Air and liquid flow rates shall be as established in Section 6. 2. Equipment with dual-rated frequencies shall be tested at each frequency.			

8.1.3.2.3 *Test Requirements.* VRF Water-source Heat Pumps shall meet the following requirements when operating at the conditions specified in Tables 15 and 16.

8.1.3.2.3.1 During the entire test, the equipment shall operate without any indication of damage.

8.1.3.2.3.2 During the test period specified in Section 8.1.3.2.2.1, the equipment shall operate continuously without tripping any motor overload or other protective devices.

8.1.3.2.3.3 During the test period specified in Section 8.1.3.2.2.3, the motor overload protective device may trip only during the first five minutes of operation after the shutdown period of three minutes. During the remainder of the test period, no motor overload protective device shall trip. For those models so designed that resumption of operation does not occur within the first five minutes after the initial trip, the equipment may remain out of operation for no longer than 30 minutes. It shall then operate continuously for the remainder of the test period.

8.1.3.3 *Minimum Operating Conditions Test.* VRF Water-source Heat Pumps shall be tested at the minimum operating test conditions for cooling and heating at the test conditions established for the specific applications specified in Tables 17. VRF Water-source Heat Pumps intended for use in two or more applications shall be tested at the most stringent set of conditions specified in Table 17.

8.1.3.3.1 *Test Procedures.* For the minimum operating cooling test, the VRF Water-source Heat Pump shall be operated continuously for a period of no less than 30 minutes after the specified temperature conditions have been established. For the minimum operating heating test, the VRF Water-source Heat Pump shall soak for 10 minutes with liquid at the specified temperature circulating through the coil. The equipment shall then be started and operated continuously for 30 minutes.

8.1.3.3.2 *Test Requirements.* No protective device shall trip during these tests and no damage shall occur to the equipment.

Table 17. Minimum Cooling Test Conditions for VRF Water-source Heat Pumps			
	Water Loop Heat Pumps	Ground-water Heat Pumps	Ground-loop Heat Pumps
Air entering indoor side[1] — dry bulb, °F — maximum wet bulb, °F	69.8 59.0	69.8 59.0	69.8 59.0
Air surrounding unit — dry bulb, °F	69.8	69.8	69.8
Liquid entering heat exchanger[1], °F	68.0	50.0	50.0
Frequency[2], Hz	Rated	Rated	Rated
Voltage, V	Rated	Rated	Rated

Notes:
1. Air and liquid flow rates shall be as established in Section 6.
2. Equipment with dual-rated frequencies shall be tested at each frequency.

8.1.3.4 *Enclosure Sweat and Condensate Disposal Test*.

8.1.3.4.1 *Test Conditions.* The enclosure sweat and condensate disposal test shall be conducted in the cooling mode at the test conditions established for the applications specified in Table 8.

All System Controls, fans, dampers and grilles shall be set to produce the maximum tendency to sweat, provided such settings are not contrary to the manufacturer's instructions to the user. VRF Water-source Heat Pumps intended for two or more applications shall be tested at the most stringent set of conditions.

8.1.3.4.2 *Test Procedures.* After establishment of the specified temperature conditions, the VRF Water-source Heat Pump shall be operated continuously for a period of four hours.

8.1.3.4.3 *Test Requirements.* No condensed water shall drip, run or blow off the equipment's casing during the test.

8.1.4 *Tolerances.* The conditions for the tests outlined in Section 8 are average values subject to tolerances of ±1.0ºF for air wet-bulb and dry-bulb temperatures, ±0.5ºF for water temperatures, and ±1.0% of the readings for specified voltage.

Section 9. Marking and Nameplate Data

9.1 *Marking and Nameplate Data.* As a minimum, the nameplate shall display the manufacturer's name, model designation, and electrical characteristics.

Nameplate voltages for 60 Hz systems shall include one or more of the equipment nameplate voltage ratings shown in Tables 1 and 2 of AHRI Standard 110. Nameplate voltages for 50 Hz systems shall include one or more of the utilization voltages shown in Table 1 of IEC Standard 60038.

9.2 *Nominal Capacity*. The Nominal Capacity for Indoor and Outdoor Units shall be printed on the nameplate and/or listed in the manufacturer's product literature.

Section 10. Conformance Conditions

10.1 *Conformance.* While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's *Purpose* (Section 1) and *Scope* (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

Section 11. Calculations

11.1 *Individual Test Calculations.* For individual test calculations, refer to ASHRAE Standard 37.

11.2 *IEER Calculations.*

11.2.1 *General IEER Equations.* For units covered by this standard, the IEER shall be calculated using test derived data and Equation 9.

$$IEER = \left(0.020 \cdot EER_{A,Full}\right) + (0.617 \cdot EER_B) + (0.238 \cdot EER_C) + (0.125 \cdot EER_D) \qquad 9$$

Note: Definitions of $EER_{A,\ Full}$, EER_B, EER_C, EER_D, can be found in Section 12.1.

11.2.2 *Rating Adjustments.* The IEER shall be determined at the 4 ratings loads and condenser conditions as defined in Tables 8 and 9. Rating adjustments may be required to account for scenarios where the unit is unable to meet load fraction tolerances or when the SHR limit is exceeded. In these scenarios, Section 11.2.3 shall be followed to determine the rating at the required load, using the approaches described in 11.2.2.1 and 11.2.2.2.

11.2.2.1 *Degradation*. If the unit cannot be unloaded to within 3% of the 75%, 50%, or 25% loads and methods for Critical Parameter adjustment described in Section 6.3.3 have been exhausted, then the unit shall be run at the minimum step of unloading and minimum rated indoor airflow at the condenser conditions defined for each of the rating Percent Load IEER points listed in Table 8 and then the part-load EER shall be adjusted for cyclic performance using Equation 10.

$$EER = \frac{LF \cdot q_{PL}}{LF[C_D(P_C + P_{CD})] + P_{IF} \cdot P_{CT}} \qquad 10$$

Where:

$$C_D = (-0.13 \cdot LF) + 1.13 \qquad 11$$

$$LF = \frac{\left({P_L}/{100}\right) \cdot q_{Full}}{q_{PL}} \qquad 12$$

11.2.2.2 *Sensible Heat Ratio Limits.* If the unit cannot meet the SHR limits specified in section 6.3.3.2 and methods for Critical Parameter adjustment described in Section 6.3.3 have been exhausted, then the Sensible Cooling Capacity in the EER calculation for the specific load test point shall be reduced such that the SHR limit is met for the remaining Sensible Cooling Capacity and Latent Cooling Capacity. The Sensible Cooling Capacity shall be adjusted using Equation 13. The Standard Rating Cooling Capacity shall not be adjusted. Then, the EER shall be calculated according to equation 14.

$$q_{Sens,Adj} = q_{Latent} * \frac{SHR_{Req}}{1 - SHR_{Req}} \qquad 13$$

$$EER_{Adj} = \frac{q_{Sens,Adj} + q_{latent}}{\dot{E}_{tot}} \qquad 14$$

11.2.3 *Procedure for Calculating IEER.* The IEER shall be calculated using data, Equation 9, and the following procedures. For test purposes, test units shall be provided with manual means to adjust the unit refrigeration capacity in steps no greater than 5% of the Standard Rated Cooling Capacity by adjusting variable capacity compressor(s) capacity and/or the stages of refrigeration capacity. The EER of individual tests shall not be rounded to fewer than three decimal points (0.001) prior to the calculation of IEER.

11.2.3.1 The following sequential steps shall be followed.

11.2.3.1.1 For part-load rating tests, the unit shall be configured per the manufacturer's instructions, including setting of stages of refrigeration and variable capacity compressor loading percent for each of the part-load rating points. The stages of refrigeration and variable capacity compressor loading percent shall result in capacity closest to the desired part-load rating point of 75%, 50%, or 25%.

11.2.3.1.2 The condenser air or water entering temperature shall be adjusted per the requirements of Tables 8 or 9 and be within tolerance as defined in Section 6.6.1.

11.2.3.1.3 The indoor airflow and ESP shall be adjusted per Section 6.

11.2.3.1.4 Bracketing the Target Load Fraction: If the measured part-load rating capacity ratio is within three percentage points, based on the full load measured test Cooling Capacity, above or below the target part-load capacity point, the EER at each load point shall be used to determine IEER without any adjustment for cyclic degradation. See Table 18.

Table 18. Tolerance on Part-load Percent

Required Part-load Percent	Minimum Allowable Measured Part-load Percent	Maximum Allowable Measured Part-load Percent
75%	72%	78%
50%	47%	53%
25%	22%	28%

11.2.3.1.7 Exceeding the Target Load Fraction at Minimum Capacity: If the unit cannot be unloaded to within 3% of the 75%, 50%, or 25% load points at the minimum stage of unloading after any lab adjustments of overridden Critical Parameters (as described in section 6.3.3) then the rating shall be determined at the minimum stage of unloading and part-load rating condenser air or water inlet temperature defined in Table 8 (or Table 10 for VRF Water-source Heat Pumps) within tolerances defined in Section 6.6.1.

Note: The actual Percent Load will be greater than the required Percent Load and will be adjusted for cyclic performance using Equations 10, 11, and 12 as described in Section 11.2.2.1. Part-load Rated Indoor Airflow, if different than full load airflow, shall be used as required by Section 6.4.

Informative Note: Appendix G contains several example calculations.

Section 12. Symbols, Subscripts and Superscripts

12.1 *Symbols.*

C_D	The Degradation Coefficient to account for cycling of the compressor for capacity less than the minimum step of capacity
D_c	Coil depth (uncased), in
$\dot{E}_{tot}$	Total Power Input
$EER_{A, Full}$	EER at 100% Capacity at AHRI Standard Rating Conditions (see Table 8 or 10)
EER_B	EER at 75% Capacity and reduced condenser air or water inlet temperature (see Table 8 or 10)
EER_C	EER at 50% Capacity and reduced condenser air or water inlet temperature (see Table 8 or 10)
EER_D	EER at 25% Capacity and reduced condenser air or water inlet temperature (see Table 8 or 10)
$IEER$	Integrated Energy Efficiency Ratio
ESP_{adj}	Adjusted ESP requirement at heating airflow or part-load cooling airflow, in H_2O
ESP_{CFL}	ESP requirement at full-load cooling airflow specified in Table 6, in H_2O
f_{pa}	Pump power adjustment

L_c	Coil length (uncased), in
LCL	Lower 90% confidence limit
LF	Fractional ON time for last stage at the desired load point
n	Number of systems tested
NCV	Normalized Coil Volume
P_{adj}	Total power consumption, W
P_C	Compressor power at the lowest machine unloading point operating at the desired part-load rating condition, W
P_{CD}	Condenser Section power, if applicable at the desired part-load rating condition, W. For Air-source Heat Pumps this is the power of the fans and pumps
P_{CT}	Control circuit power and any auxiliary loads, W
P_{IF}	Indoor Fan power, W
P_L	Percent Load
Δp_{int}	Internal static pressure difference, ft H_2O
Δp_{ext}	External static pressure difference, ft H_2O
q	Nominal fluid flow rate, gpm
q_{nom}	Nominal Indoor Unit Cooling Capacity, Btu/h
$\dot{q}_{thir1}$	Total capacity heating indoor room 1, Btu/h
$\dot{q}_{tcir1}$	Total capacity cooling indoor room 1, Btu/h
$\dot{q}_{tcir2}$	Total capacity cooling indoor room 2, Btu/h
q_{Full}	Full load net capacity, Btu/h
q_{PL}	Part-load Net Capacity, Btu/h
q_{Latent}	Latent Net Capacity, Btu/h
q_{sens}	Sensible Net Capacity, Btu/h
$q_{sens,Adj}$	Sensible Net Capacity following adjustments required to meet SHR limit, Btu/h
Q_{dif}	Measured part-load cooling airflow or manufacturer-specified heating airflow, scfm
Q_{CFL}	Measured full-load cooling airflow, scfm
R_2	Rate of indoor dry bulb temperature decrease during R2 period of the CVP, °F/hr
s	Standard deviation
$SCHE$	Simultaneous Heating and Cooling Efficiency
SHR	Sensible Heat Ratio
SHR_{Req}	Sensible Heat Ratio required at 100% load and 75% load test points. See section 6.3.3.
t	Elapsed time since beginning of CVP, indicated by t_{start}
$t_{.95}$	t statistic for a 95% one-tailed confidence interval with sample size n (see also Appendix A of Subpart B of 10 CFR §429)
t_{off}	Time at which the first indoor unit switches to thermally inactive during the CVP
t_{start}	Starting time of the CVP, once all CVP start criteria have been met
t_{82}	Time at which the indoor room dry bulb temperature first reaches 82°F, indicating the start of the R2 period
T_{start}	Starting temperature for the CVP, °F
$T_{Measured,t}$	Indoor room dry bulb temperature at time t during the R2 period of the CVP, measured as the average temperature reading from the room conditioning system resistance temperature detectors, °F
$T_{Target,t}$	Target indoor room dry bulb temperature at time t during the R2 period of the CVP, °F
W_c	Coil width (uncased), in
x_i	Test result value for test sample i
$\bar{x}$	Test sample mean

12.2 *Greek Symbols.*

φ_{pa}	Pump power adjustment, W
η	Conversion Factor ,1.59 gpm•ft H_2O/W by convention

12.3 *Subscripts and Superscripts.*

adj	Adjustment
Full	Operation/compressor speed at full load test

i	Indoor
max	Maximum
min	Minimum
Var	Variance
x	Variable for an individual test, measurement, or compressor set point. For example, *x* can be A_{Full}, B_{Low}, $H0_{Low}$, etc.

Section 13. Minimum Data Requirements for Published Ratings

13.1 *Minimum Data Requirements for Published Ratings.* As a minimum, Published Ratings shall consist of the following information in support of meeting the DOE minimum efficiency standard:

13.1.1 *For VRF Systems (air conditioners):*

- Standard Rating Cooling Capacity, Btu/h ;
- Energy Efficiency Ratio ($EER_{A, Full}$), (Btu/h)/W; and
- Integrated Energy Efficiency Ratio (IEER), (Btu/h)/W.

13.1.2 *For VRF Systems (heat pumps):*

- Standard Rating Cooling Capacity, Btu/h;
- Energy Efficiency Ratio (EERA, Full), (Btu/h)/W;
- Integrated Energy Efficiency Ratio (IEER), (Btu/h)/W;
- High Temperature Standard Rating Heating Capacity, Btu/h;
- High Temperature Coefficient of Performance (COP_H) at 47°F;
- Low Temperature Standard Rating Heating Capacity, Btu/h; and
- Low Temperature Coefficient of Performance (COP_L) at 17°F.

13.1.3 *For VRF Heat Recovery Systems:*

- Ratings appropriate in Sections 13.1.1 and 13.1.2 above; and
- Simultaneous Cooling and Heating Efficiency (SCHE) (50% heating/50% cooling), (Btu/h)/W.

13.1.4 *For VRF Systems (water-source):*

- Standard Rating Cooling Capacity, Btu/h;
- Energy Efficiency Ratio ($EER_{A, Full}$), (Btu/h)/W;
- Integrated Energy Efficiency Ratio (IEER), (Btu/h)/W;
- Standard Rating Heating Capacity, Btu/h ;
- High Temperature Coefficient of Performance (COP_H); and
- Simultaneous Cooling and Heating Efficiency (SCHE) (50% heating/50% cooling)/ (Heat Recovery models only), (Btu/h)/W.

13.2 *Latent Cooling Capacity Designation*. The moisture removal designation shall be published in the manufacturer's specifications and literature. The value shall be expressed consistently in either gross or net in one or more of the following forms:

- Sensible Cooling Capacity/Total Cooling Capacity ratio (sensible heat ratio) and Total Cooling Capacity, Btu/h;
- Latent Cooling Capacity and Total Cooling Capacity, Btu/h; and
- Sensible Cooling Capacity and Total Cooling Capacity, Btu/h

13.3 *Rating Claims*. All claims to Standard Ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 1230". All claims to ratings outside the scope of this standard shall include the statement: "Outside the scope of AHRI Standard 1230". Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

Section 14. Verification Testing Acceptance Criteria

14.1 To comply with this standard, verification tests shall meet the performance metrics shown in Table 19 with an uncertainty allowance not greater than the following:

Table 19. Uncertainty Allowances

Performance Metric	Uncertainty Allowance	Acceptance Criteria[1]
Standard Rating Cooling Capacity	4%	≥ 96%
EER	5%	≥ 95%
IEER[2]	10%	≥ 90%
SCHE[3]	10%	≥ 90%
Standard Rating Heating Capacity	4%	≥ 96%
COP[2]	5%	≥ 95%

Notes:
1. Must be ≥ (1 – uncertainty allowance).
2. Includes the high temperature and low temperature conditions, and the temperature condition for VRF Water-source Heat Pump systems
3. Applies to heat recovery systems only

14.2 *Verification Testing Uncertainty.* When verifying the ratings by testing a sample unit, there are uncertainties that must be considered. Verification tests, including tests conducted for the AHRI certification program shall be conducted in a laboratory that meets the requirements referenced in this standard and ASHRAE Standard 37 and must demonstrate performance with an allowance for uncertainty. The following make up the uncertainty for products covered by this standard.

14.2.1 *Uncertainty of Measurement*. When testing a unit, there are variations that result from instrumentation and measurements of temperatures, pressure, and flow rates.

14.2.2 *Uncertainty of Test Rooms*. A unit tested in multiple rooms will not yield the same performance due to setup variations and product handling.

14.2.3 *Variation due to Manufacturing*. During the manufacturing of units, there are variations due to manufacturing production tolerances that will impact the performance of a unit.

14.2.4 *Uncertainty of Performance Simulation Tools*. Due to the large complexity of options, use of performance prediction tools like an Alternative Efficiency Determination Method (AEDM) has some uncertainties.

14.2.5 *Variability of System under Test*. The requirement to lock the compressor speed to achieve various capacity targets during the test may lead to system instability. This may not yield repeatable results. In addition, as the number of components assembled increases, the variability in the test results also increases.

14.2.6 *Variability due to Environmental Conditions*. Changes to ambient conditions such as inlet temperature conditions and barometric pressure can alter the measured performance of the unit.

APPENDIX A. REFERENCES – NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of this standard.

A1.1 AHRI Standard 110-2016, *Air-Conditioning and Refrigerating Equipment Nameplate Voltages*, 2016, Air-Conditioning Heating and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, U.S.A.

A1.2 AHRI Standard 210/240-2017, *Unitary Air-Conditioning and Air-Source Heat Pump Equipment*, 2017, Air-Conditioning Heating and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, U.S.A.

A1.3 AHRI Standard 340/360-2019, *Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment*, 2015, Air-Conditioning Heating and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, U.S.A.

A1.4 ANSI/AHRI Standard 365 (I-P)-2009, *Commercial and Industrial Unitary, Air Conditioning Condensing Units*, 2009, Air-Conditioning Heating and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, U.S.A.

A1.5 ANSI/AHRI Standard 470-2006, *Performance Rating of Desuperheater/Water Heaters*, 2006, Air-Conditioning Heating and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, U.S.A.

A1.6 ANSI/AMCA Standard 210–2016/ANSI/ASHRAE Standard 51–2016, *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating*, 2016, Air Movement and Control Association International, 30 W. University Drive, Arlington Heights, IL 60004-1893, USA.

A1.7 ANSI/AHRI/ASHRAE ISO Standard 13256-1:1998 (RA 2012), *Water-source Heat pumps - Testing and rating for Performance - Part 1: Water-to-air and Brine-to-air Heat Pumps*, 2012, AHSRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, U.S.A.

A1.8 ANSI/ASHRAE Standard 30-2019, *Methods of Testing Liquid Chillers*, 2019, AHSRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, U.S.A.

A1.9 ANSI/ASHRAE Standard 37-2009, *Methods of Testing for Rating Unitary Air-Conditioning and Heat Pump Equipment*, 2009, AHSRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, U.S.A.

A1.10 ANSI/ASHRAE Standard 41.1-2013, *Standard Method for Temperature Measurement*, 2013, AHSRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, U.S.A.

A1.11 ASHRAE Terminology, https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology, 2018, AHSRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, U.S.A.

A1.12 IEC Standard 60038, *IEC Standard Voltages*, 2002, International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

A1.13 Title 10, *Code of Federal Regulations (CFR)*, §429 and §430, U.S. National Archives and Records Administration, 8601 Adelphi Road, College Park, MD 20740-6001 or www.ecfr.gov.

APPENDIX B. REFERENCES – INFORMATIVE

B1 Listed here are standards, handbooks and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

B1.1 ISO Standard 3966: 2008, *Measurement of Fluid Flow in Closed Conduits — Velocity Area Method Using Pitot Static Tubes*, 2008, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

B1.2 ISO Standard 5151: 2017, *Non-ducted Air Conditioners And Heat Pumps — Testing And Rating For Performance*, 2017, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

B1.3 ISO Standard 5167-Part 1: 2003, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full -- Part 1: General principles and requirements,* 2003, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

B1.4 JIS B 8616:2006, *Package Air Conditioners*, 2006, Japanese Standards Association, 3-13-12 Mita, Tokyo 108-0073 Minato-Ku Japan.

APPENDIX C. CONTROLS VERIFICATION PROCEDURE - NORMATIVE

C1 *Purpose.* The purpose of this procedure is to verify behavior for System Controls and establish system operation boundaries for settings of Critical Parameters that are manually overridden during Steady-state Tests under cooling conditions. This procedure was developed based upon the minimum compressor speed verification procedure specified in JIS B 8616, with significant modifications and steps added.

C2 *Scope.* This procedure shall be applied to system cooling operation and for all VRF Systems covered under the scope of AHRI Standard 1230.

C3 *Test Set-Up Requirements.* All test set-up requirements shall be in accordance with Section 5, except for Control Settings.

C3.1 *Control Settings.* Control settings shall be identical to those used during the Steady-state Tests at cooling conditions, except that the Control Settings for Critical Parameters that are overridden during the Steady-state Test shall not be overridden for the CVP. Refer to the Section 5.1.2 for the Critical Parameters allowed to be overridden during the Steady-state Test. The same settings are to be used and to remain unchanged for the full-load and all part-load test points except for Indoor Unit(s) that are Thermally Inactive, for which the Indoor Unit Control Settings (e.g., using remote or wireless thermostat) shall be set to "OFF".

C3.2 *Thermally Active Indoor Units.* For all load test points, begin the CVP with the Indoor Units specified in the STI as Thermally Active. Refer to section 5.10 for further instruction. The operation of Thermally Active Indoor Units is to be controlled by the system under test for the remainder of the CVP, except for the preliminary set point adjustment procedures in C3.3.

C3.3 *Set Point Adjustment.* Prior to starting the CVP, follow the provisions in Section 5.1.5 to adjust for Set Point Bias and Set Point Offset.

C3.4 *Set Point Bias Validation.* If the manufacturer certifies thermostat set points other than 80 °F in the STI to account for Set Point Bias, the Set Point Bias shall be validated using a CVP at any load point. The Set Point Bias is validated if all Indoor Units that are designated as Thermally Active at the beginning of the CVP become Thermally Inactive by the time the return air decreases to 77 °F.

C3.5 *Oil Recovery During CVP.* All CVP runs shall be conducted with active Oil Recovery Mode.

C4 *Operating Conditions.* The Indoor dry-bulb temperature and ramp-down rates vary during CVP, as specified below. All test operating and condition tolerances shall be in accordance with Section 6, unless otherwise specified below.

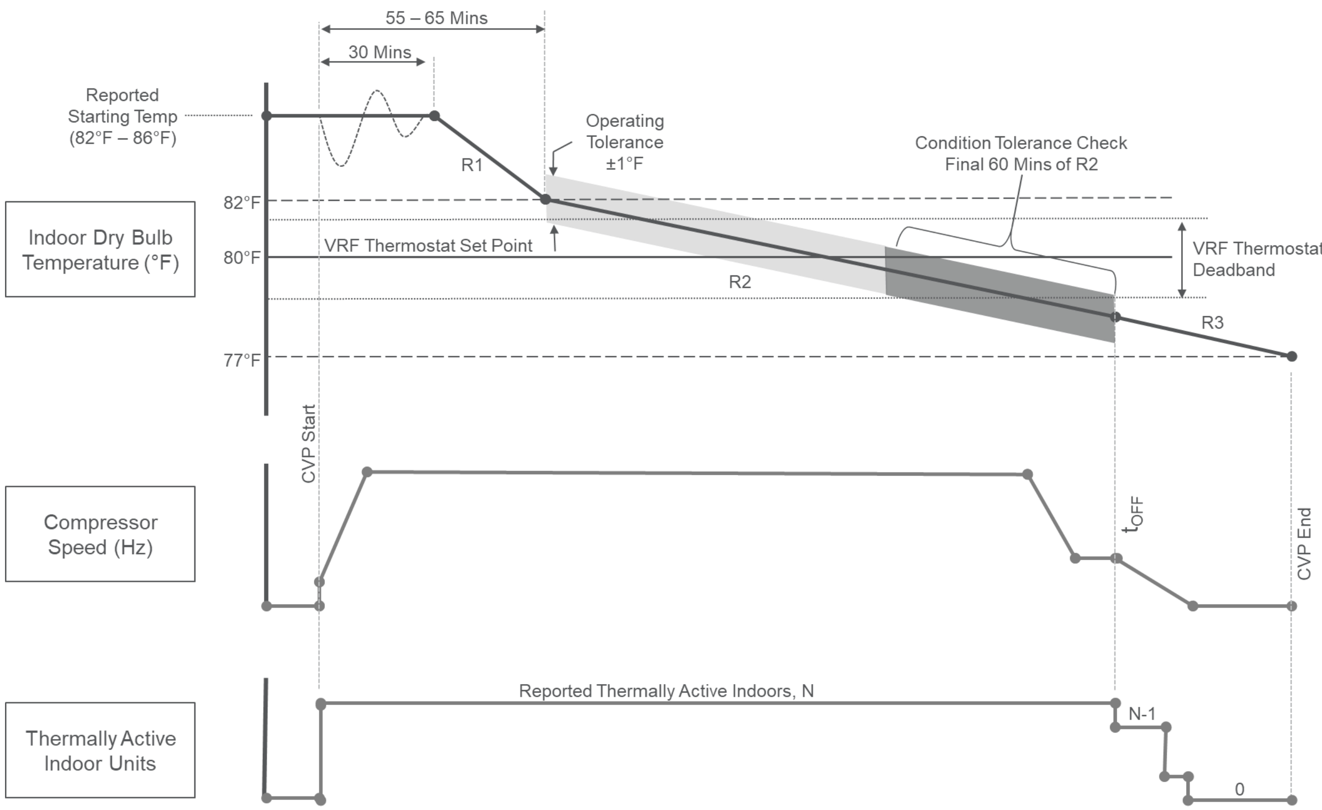

Figure C1. Controls Verification Procedure Schematic

C4.1 *Indoor Dry Bulb Starting Temperature*. Indoor dry bulb temperature is measured as the average temperature reading from the room conditioning system resistance temperature detectors. Instantaneous measurements of indoor dry bulb temperature are denoted as ($T_{Measured,t}$). At each load point, the starting temperature for the CVP (T_{start}) may be specified in the STI and shall be greater than 82°F and at most 86°F. If no starting temperature is specified in the STI, a default starting temperature of 86°F shall be used.

C4.2 *CVP Start Time (t_{start}).* With the VRF System thermally off (i.e. no compressors running), control the room conditioning equipment until test room conditions are in accordance with Section 6, except that indoor dry bulb temperature shall be within +0.5/-0°F of the starting temperature described in C4.1. Once these test room conditions are attained, control the VRF System so that it is thermally on (e.g. by adjusting Indoor Unit thermostat set points until they match the thermostat set points determined in C3.3). The stabilization period discussed in C4.3 is initiated once compressor(s) begin operating.

C4.3 *Stabilization Period.* When the VRF System turns thermally on, fluctuations in indoor room and outdoor room temperatures may occur. Allow test room conditions to stabilize by holding the thermostat set points constant for the VRF System for 30 minutes. Section 6 condition and operating tolerances do not apply during the stabilization period. Maintain indoor room temperature above 82 ºF to avoid nuisance trips of Indoor Units. If Indoor Unit(s) become Thermally Inactive during the stabilization period, restart the stabilization period after bringing the Indoor Unit(s) back to Thermally Active.

C4.4 *Indoor Dry Bulb Temperature Ramp Rate.* The indoor dry bulb temperature ramp rate is defined as the change in indoor dry bulb temperature divided by the change in time. The CVP consists of three periods of indoor dry bulb ramping, R1, R2, and R3.

C4.4.1 *R1 Period.* Immediately following the stabilization period described in section C4.3, begin decreasing the indoor room dry bulb temperature at a constant rate by incrementally reducing the temperature set point for the indoor room conditioning system. The R1 ramp rate shall be selected such that the indoor room reaches 82°F between 55-65 minutes after t_{start}.

C4.4.2 *R2 Period.* From the time that the measured indoor room dry bulb temperature first crosses from above 82°F to below 82°F (t_{82}), begin decreasing the indoor dry bulb temperature at rate R2 (specified within STI between 0.5 and 4.0°F/hr) by incrementally reducing the temperature set point for the indoor room conditioning system. The R2 period ends at the time when any Indoor Unit that was designated Thermally Active at the start of the CVP goes Thermally Inactive (t_{off}).

C4.4.2.1 *Ramp Rate Verification for R2 Period.* Each minute calculate the difference (ΔT_t) between the measured indoor room temperature ($T_{Measured,t}$) and the target indoor room dry bulb temperature ($T_{Target,t}$) using equations C1 & C2. The indoor dry bulb ramp rate shall be verified during the R2 period by applying operating and condition tolerances to ΔT_t as specified in Table C1.

$$T_{Target,t} = 82 - R_2 \times (t - t_{82}) \tag{C1}$$

$$\Delta T_t = T_{Measured,t} - T_{Target,t} \tag{C2}$$

C.4.4.2.2 *Oil Recovery During R2 Period.* If an oil recovery cycle is automatically initiated during the R2 period of the CVP, pause the CVP by holding the indoor room temperature set point constant for 30 minutes. During this 30-minute period, operating tolerances do not apply and the time index "t" shall also pause. Once 30 minutes have elapsed resume the CVP by incrementally reducing the indoor room dry bulb temperature set point to achieve the specified ramp rate R2 and resume the time index "t". If the oil recovery cycle occurs within the final 60 minutes of the CVP where condition tolerances are applied, then the CVP run is invalidated.

Table C1: Indoor Dry Bulb Temperature Tolerances – R2 Period

Tolerance Type	Applies to	Value
Operating	Entire R2 Period[1]	$-1.0°F \le \Delta T_t \le 1.0°F$[2]
		$-1.0°F \le \Delta T_t \le 1.5°F$[3]
		$-1.0°F \le \Delta T_t \le 2.0°F$[4]
Condition	Last 60 minutes of R2 Period	$\frac{\sum_1^N \lvert \Delta T_t \rvert}{N} \le 0.50°F$ N = # of measurements in final 60 minutes of R2 period

Notes:
1. Shall not be applied for 30 minutes following the start of an oil recovery cycle.
2. Applies to System Standard Rated Cooling Capacities less than 120,000 Btu/h.
3. Applies to System Standard Rated Cooling Capacities from 120,000 to 360,000 Btu/h.
4. Applies to System Standard Rated Cooling Capacities greater than 360,000 Btu/h.

C4.4.2.3 *Calculating Critical Parameter Variation During R2 Period.* At each data collection interval during the R2 period, calculate the absolute Parameter Percent Difference ($PPD_{i,t}$) between each measured Critical Parameter value and the STI-reported value for that parameter using Equation C3. At each load point, for any Critical Parameter whose value is not specified in the STI, i.e., not designated as being manually-overridden during the corresponding steady-state test, the Parameter Percent Difference will be calculated as zero for the duration of the CVP.

$$PPD_{i,t} = \left| \frac{CP_{i,t} - CP_{i,STI}}{CP_{Max}} \right| \times 100 \tag{C3}$$

Where:

"i" identifies the Critical Parameter – either Compressors Speed(s), Outdoor Fan Speed(s), or Outdoor Variable Valve Position(s)

$CP_{i,t}$ = The average value across all instances of Critical Parameter "i" as measured at time "t" during the CVP. If multiple instances of a single parameter are present (e.g., multiple compressors), calculate the average value for all instances of that parameter when determining $PPD_{i,t}$.

$CP_{i,STI}$ = The average value across all instances of Critical Parameter "i" as reported in the STI for the corresponding load point

CP_{Max} = The maximum value for Critical Parameter "i", as measured during a CVP conducted at 100% load conditions. If multiple instances of a single parameter are present, first determine the average value across all instances before calculating the maximum [average] value observed during the 100% CVP**.** If the CVP is not conducted at the 100% load, the STI-reported value for the 100% load is used for this calculation.

C4.4.3 *R3 Period.* Once the first Indoor Unit goes Thermally Inactive, the indoor room dry bulb temperature shall continue decreasing at rate R2 until the indoor room reaches 77 °F. Set Point Bias, if present, may be validated using the provisions in C3.4. No operating or condition tolerances on indoor dry bulb temperature apply during the R3 period.

C4.5 *Humidity.* The return air humidity ratio shall be held constant at 0.0112 ±0.0006 lbm_{wv} / lbm_{da} for CVP at 100% and 75% load test points. The same value and tolerance for humidity shall apply for the 50% and 25% load test points, unless the STI indicates that SHR for these load test points is 100%. In this case, the humidity level shall be sufficiently low to prevent latent load.

C5 *Measured Parameters During CVP.* Table C2 outlines the measurement requirements for the CVP parameters that shall be continuously measured as defined by the minimum data collection intervals.

Table C2. Measurement Apparatus and Data Collection Intervals for CVP Parameters

Parameter	Measurement Apparatus	Minimum Data Collection Interval (samples/hour)
Thermostat set points, °F	Indoor Unit thermostat, Service Tool	60
Compressor speed[1], Hz	Accelerometer/Clamp-on frequency meter, Service Tool	60
Number of running compressors and identification of the compressors running[1]	Thermocouple/Clamp-on meter/Accelerometer/Duty cycle, Service Tool	60
Outdoor fan speed and number of outdoor fans running[1], rpm	Lab strobe, Service Tool	60
Identification of active indoor units	Refer to Section 3.44	60
All Outdoor Variable Valve positions[1], pulses	Service Tool	60
All Outdoor 2-position Valve positions	Service Tool	60

Notes:
1. These parameters are both CVP parameters and Critical Parameters. Refer to Section 5.1.2.1.

C5.1 *Service Tool*. Use Service Tool currently available for download from manufacturer's certified installer website (software) or physical tool available publicly to certified installers (hardware). If a Service Tool does not have the capability to automatically record parameters simultaneously at the required time intervals listed in Section C5, then manual recordings shall be taken at the intervals prescribed Section C5.

C6 *Verification Criteria.*

C6.1 *Systems with Observed Critical Parameter Variation*. The verification criteria for systems whose overridden parameters differ from the values reported in the STI involves the implementation of a budget system. Parameters are verified based on points accumulated from Critical Parameter variation and compared to a budget that encompasses the points from all overridden parameters.

C6.1.1 *Calculating RSS Point Total.* At each data collection interval during the R2 period, calculate the RSS Point Total using the calculated $PPD_{i,t}$ described in C4.4.2.3, the Nominal Point Values listed in Table C3, and Equations C4 and C5.

$$Points_{i,t} = PPD_{i,t} \times NPV_i \qquad C4$$

$$RSS\ Points_t = \sqrt{\left(Points_{Compressors,t}\right)^2 + \left(Points_{Fans,t}\right)^2 + \left(Points_{LEVs,t}\right)^2} \qquad C5$$

Where:

The NPV_i is the Nominal Point Value for Critical Parameter "i". Nominal Point Values are listed in Table C3.

C6.1.2 If at least one measurement period of at least three minutes and a minimum of five sample readings exists before t_{OFF} where the average RSS Points Total is less than or equal to 70 points, the reported Critical Parameter values are valid.

C6.1.3 If no measurement period of at least three minutes and a minimum of five sample readings exists before t_{OFF} where the average RSS Points total is less than or equal to 70 points, the reported Critical Parameter values are invalid.

Table C3: Critical Parameter Nominal Point Values

Parameter	Nominal Point Value
Compressor Speed(s)	13
Outdoor Fan Speed(s)	7
Outdoor Variable Valve position(s)	1

APPENDIX D. DEVELOPMENT OF SUPPLEMENTAL TESTING INSTRUCTIONS FOR SET-UP AND TESTING - INFORMATIVE

D1 *Purpose.* The purpose of this appendix is to provide guidance for manufacturers to develop the STI to detail the manufacturer's requirements for installation of a VRF System in a testing laboratory. Manufacturer shall provide Supplemental Testing Instructions, in accordance with Appendix D, 10 CFR §429.12, 10 CFR §429.43 and 10 CFR §429.70, for testing their equipment. This will allow for a uniform approach to determine minimum and other Standard Rating metrics. For official Supplemental Testing Instruction requirements, refer to 10 CFR Parts 429 and 431.

D2 *Background*. Manufacturers are required to certify ratings to the Department of Energy. In 10 CFR §429.43 Commercial heating, ventilating, air conditioning (HVAC) equipment) it is stated:

"(4) Pursuant to § 429.12(b)(13), a certification report must include supplemental information submitted in PDF format. The equipment-specific, supplemental information must include any additional testing and testing set up instructions (*e.g.*, charging instructions) for the basic model; identification of all special features that were included in rating the basic model; and all other information (*e.g.*, operational codes or component settings) necessary to operate the basic model under the required conditions specified by the relevant test procedure. A manufacturer may also include with a certification report other supplementary items in PDF format (*e.g.*, manuals) for DOE consideration in performing testing under subpart C of this part. The equipment-specific, supplemental information must include at least the following:

"(v) Variable refrigerant flow multi-split air conditioners with cooling capacity less than 65,000 Btu/h (3-phase): The nominal cooling capacity in British thermal units per hour (Btu/h); outdoor unit(s) and indoor units identified in the tested combination; components needed for heat recovery, if applicable; rated airflow in standard cubic feet per minute (SCFM) for each indoor unit; water flow rate in gallons per minute (gpm) for Water-source units only; rated static pressure in inches of water; compressor frequency set points; required dip switch/control settings for step or variable components; a statement whether the model will operate at test conditions without manufacturer programming; any additional testing instructions, if applicable; if a variety of motors/drive kits are offered for sale as options in the basic model to account for varying installation requirements, the model number and specifications of the motor (to include efficiency, horsepower, open/closed, and number of poles) and the drive kit, including settings, associated with that specific motor that were used to determine the certified rating; and which, if any, special features were included in rating the basic model. Additionally, upon DOE request, the manufacturer must provide a layout of the system set-up for testing including charging instructions consistent with the installation manual.

"(vi) Variable refrigerant flow multi-split heat pumps with cooling capacity less than 65,000 Btu/h (3-phase): The nominal cooling capacity in British thermal units per hour (Btu/h); rated heating capacity in British thermal units per hour (Btu/h); outdoor unit(s) and indoor units identified in the tested combination; components needed for heat recovery, if applicable; rated airflow in standard cubic feet per minute (SCFM) for each indoor unit; water flow rate in gallons per minute (gpm) for Water-source units only; rated static pressure in inches of water; compressor frequency set points; required dip switch/control settings for step or variable components; a statement whether the model will operate at test conditions without manufacturer programming; any additional testing instructions, if applicable; if a variety of motors/drive kits are offered for sale as options in the basic model to account for varying installation requirements, the model number and specifications of the motor (to include efficiency, horsepower, open/closed, and number of poles) and the drive kit, including settings, associated with that specific motor that were used to determine the certified rating; and which, if any, special features were included in rating the basic model. Additionally, upon DOE request, the manufacturer must provide a layout of the system set-up for testing including charging instructions consistent with the installation manual.

"(vii) Variable refrigerant flow multi-split air conditioners with cooling capacity greater than or equal to 65,000 Btu/h: The nominal cooling capacity in British thermal units per hour (Btu/h); outdoor unit(s) and indoor units identified in the tested combination; components needed for heat recovery, if applicable; rated airflow in standard cubic feet per minute (SCFM) for each indoor unit; water flow rate in gallons per minute (gpm) for Water-source units only; rated static pressure in inches of water; compressor frequency set points; required dip switch/control settings for step or variable components; a statement whether the model will operate at test conditions without manufacturer programming; any additional testing instructions if applicable; if a variety of motors/drive kits are offered for sale as options in the basic model to account for varying installation requirements, the model number and specifications of the motor (to include efficiency, horsepower, open/closed, and number of poles) and the drive kit, including settings, associated with that specific motor that were used to determine the certified rating; and which, if any, special features were included in rating the basic model. Additionally, upon DOE request, the manufacturer must provide a layout of the system set-up for testing including charging instructions consistent with the installation manual.

"(viii) Variable refrigerant flow multi-split heat pumps with cooling capacity greater than or equal to 65,000 Btu/h: The nominal cooling capacity in British thermal units per hour (Btu/h); rated heating capacity in British thermal units per hour (Btu/h); outdoor unit(s) and indoor units identified in the tested combination; components needed for heat recovery, if applicable; rated airflow in standard cubic feet per minute (SCFM) for each indoor unit; water flow rate in gallons per minute (gpm) for Water-source units only; rated static pressure in inches of water; compressor frequency set points; required dip switch/control settings for step or variable components; a statement whether the model will operate at test conditions without manufacturer programming; any additional testing instructions if applicable; if a variety of motors/drive kits are offered for sale as options in the basic model to account for varying installation requirements, the model number and specifications of the motor (to include efficiency, horsepower, open/closed, and number of poles) and the drive kit, including settings, associated with that specific motor that were used to determine the certified rating; and which, if any, special features were included in rating the basic model. Additionally, upon DOE request, the manufacturer must provide a layout of the system set-up for testing including charging instructions consistent with the installation manual.

"(ix) Water-source variable refrigerant flow heat pumps: The nominal cooling capacity in British thermal units per hour (Btu/h); rated heating capacity in British thermal units per hour (Btu/h); rated airflow in standard cubic feet per minute (SCFM) for each indoor unit; water flow rate in gallons per minute (gpm); rated static pressure in inches of water; refrigeration charging instructions (e.g., refrigerant charge, superheat and/or subcooling temperatures); frequency set points for variable speed components (e.g., compressors, VFDs), including the required dip switch/control settings for step or variable components; a statement whether the model will operate at test conditions without manufacturer programming; any additional testing instructions if applicable; if a variety of motors/drive kits are offered for sale as options in the basic model to account for varying installation requirements, the model number and specifications of the motor (to include efficiency, horsepower, open/closed, and number of poles) and the drive kit, including settings, associated with that specific motor that were used to determine the certified rating; and which, if any, special features were included in rating the basic model. Additionally, upon DOE request, the manufacturer must provide a layout of the system set-up for testing including charging instructions consistent with the installation manual."

D3 *Supplemental Testing Instructions.* Manufacturers of VRF Systems are required to develop and submit Supplemental Testing Instructions for each Basic Model to ensure that their VRF Systems can be properly installed in the laboratory and tested by a third party testing organization. The following lists include the requirements identified in 10 CFR §429.43 as a reference only, followed by suggested additional inclusions to the STI for each Basic Model:

D3.1 *10 CFR §429.43 Required STI Inclusion (provided for information in this standard).*

D3.1.1 System Nominal Cooling Capacity, Btu/h
D3.1.2 System Standard Rating Heating Capacity, Btu/h (High-Temperature Steady State Heating for Air-Source)
D3.1.3 Water flow rate per test, gpm
D3.1.4 Rated static pressure, in H_2O, where applicable
D3.1.5 Rated Airflow per test, scfm
D3.1.6 Compressor Frequencies per test
D3.1.7 Required dip switch and Control Setting(s) per test
D3.1.8 Confirmation statement to the requirement of an additional manufacturer software/hardware in order to perform rating tests.
D3.1.9 Additional Test Instructions (general)
D3.1.10 Motor/Drive Kit options for different field applications
D3.1.10.1 For each motor kit option: motor efficiency, horsepower, open/closed windings/number of poles
D3.1.11 Drive kit settings per test
D3.1.12 Special features or accessories required to obtain the listed rating.
D3.1.13 Layout of the system for testing purposes
D3.1.14 Charge instructions or a reference to the installation manual procedure for refrigerant charge
D3.1.15 Items required to permit heat recovery

D3.1.16 Any referenced or included MII (or version identification) used for ratings.

D3.2 *Recommended Items to be Included in Supplemental Testing Instructions.*

D3.2.1 Identify the Tested Combination
D3.2.2 ODU set-up especially for Combined Modules
D3.2.3 Set-up for IDUs in the test room(s)
D3.2.4 Nominal Cooling Capacity of each Indoor Unit
D3.2.5 Identify if the Oil Recovery Mode occurs in less than two hours
D3.2.6 Allocation of IDU's for SCHE testing (For heat recovery systems, identify the split of the IDUs between heating and cooling)
D3.2.7 Refrigerant piping diagram
D3.2.8 Power wiring diagram
D3.2.9 Control wiring diagram
D3.2.10 Identify the System Control device required for testing
D3.2.11 Define which ODUs/compressors will be operating for each test
D3.2.13 Airflow-control Settings per each Indoor Unit
D3.2.14 System break-in requirements
D3.2.15 Steady-State Test Critical Parameter Adjustment Instructions
D3.2.16 Liquid flow rate per module (applicable for VRF Water-source Heat Pump system)
D3.2.17 Standard options used for rating tests

D3.3 *CVP Data Requirements.*

D3.3.1 If applicable, the required thermostat set points to ensure control for 80ºF dry bulb temperature, accounting for Set Point Bias. Adjustments for set point offset are addressed separately in section 5.1.5.2

D3.3.2 The starting indoor dry bulb temperature for the CVP shall be specified in the STI and must be between 82°F and 86°F.

D3.3.3 The indoor dry bulb temperature ramp rate R2

D3.3.4 Model numbers of Tested Combination Indoor Units

D3.3.5 The indoor units to be Thermally Active for testing shall be specified in the STI for all load points. The indoor units to be Thermally Active for the 25% load point must represent no more than a Connected Capacity of 50%.

D3.3.6 The operational settings of all critical parameters to be overridden during steady-state testing shall be reported in the STI for each load point. A unique ID shall be given to each component to identify operation during testing. Use Table D1 as an example template for reporting critical parameter values. The number and composition of overridden critical parameters is unique for each basic model.

Table D1. Example Template Reporting Format for Critical Parameters

Critical Parameters			Test Load Point			
Group	Unique ID	Measurement Units	100%	75%	50%	25%
Compressor	Comp_1	Hz				
Compressor	Comp_2	Hz				
Outdoor Fan	ODF_1	RPS				
Outdoor Fan	ODF_2	RPS				
Modulating Valve	MV_1	Pulses				
Modulating Valve	MV_2	Pulses				
Modulating Valve	MV_3	Pulses				

D4 *Examples of PDF Graphics*. Typical wiring and piping diagrams for VRF Systems can be seen in Figure D1, Figure D2, and Figure D3 below

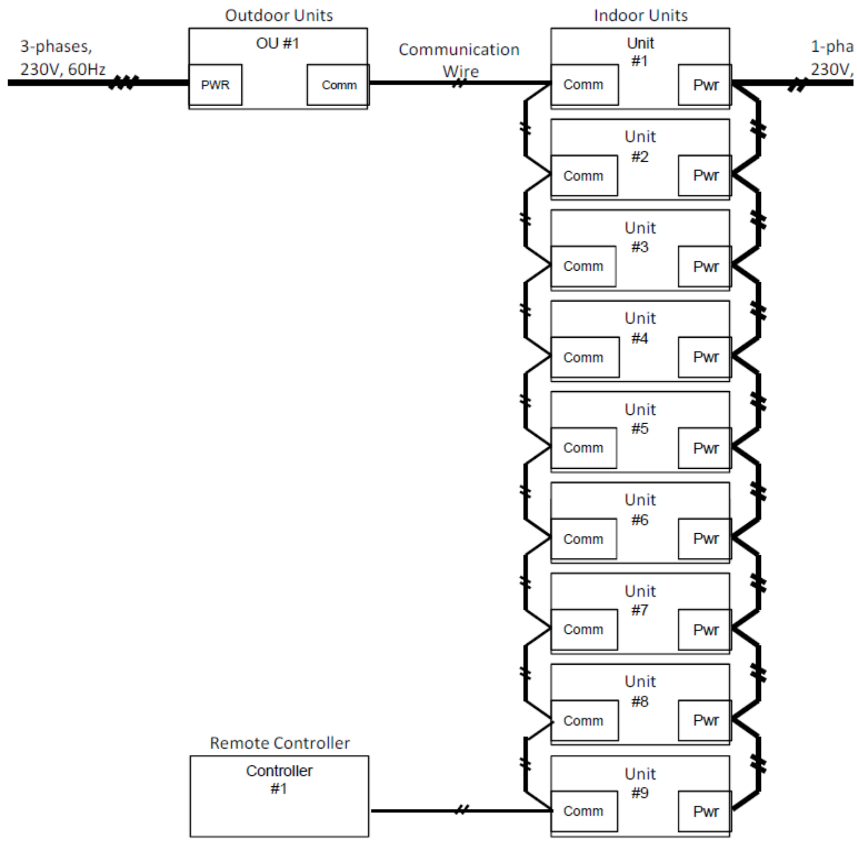

Figure D1. Typical Wiring Diagram for Heat Pump

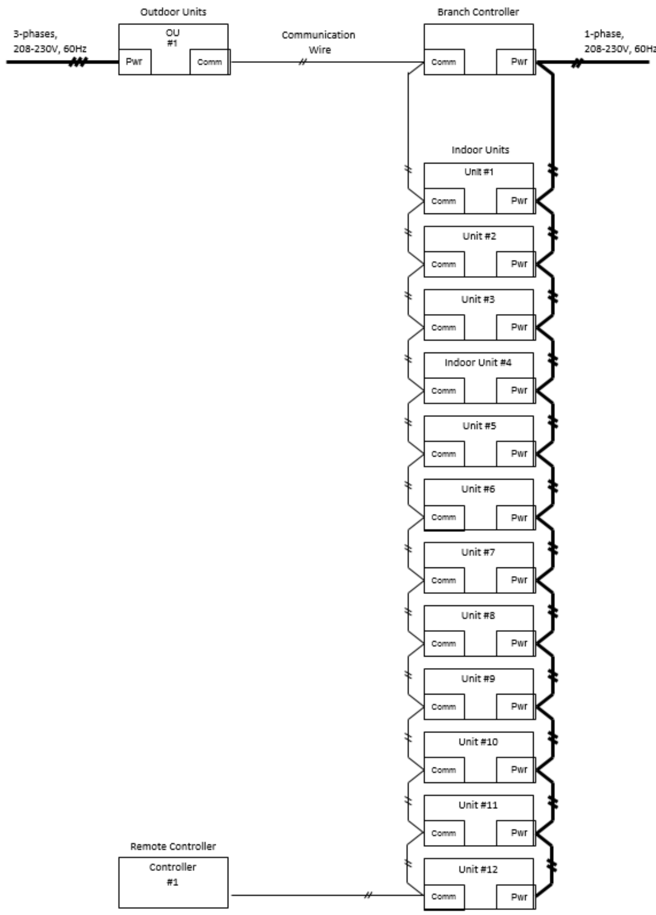

Figure D2. Typical Wiring Diagram for VRF Heat Recovery System

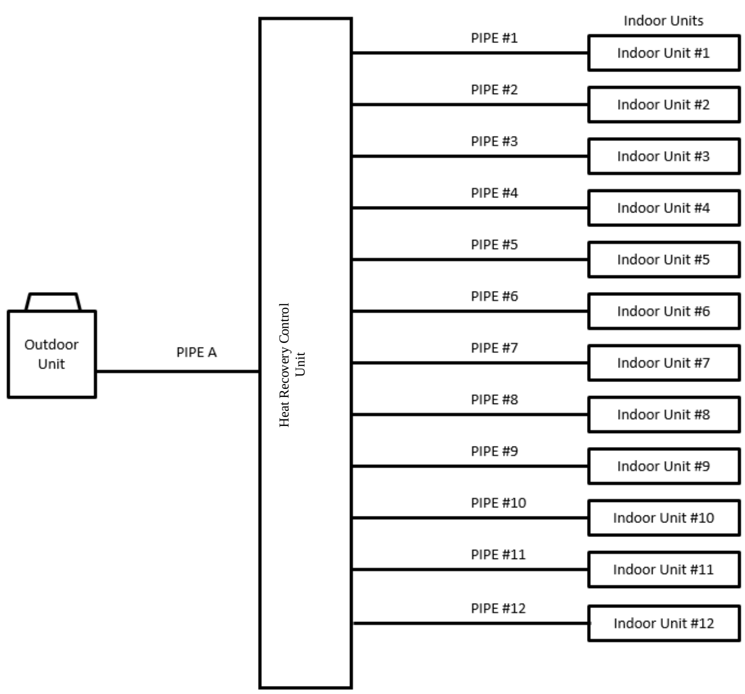

Figure D3. Typical Piping Diagram for VRF Heat Recovery System

D5 *Typical Piping for Heat Recovery Systems.* Table D2 provides typical pipe lengths for Heat Recovery Systems.

Table D2. Typical Piping for VRF Heat Recovery System

System Model Number	Duct/Non-ducted	Indoor Unit		PIPE A (ft)	#1 PIPE #1 (ft)	#2 PIPE #2 (ft)	#3 PIPE #3 (ft)	#4 PIPE #4 (ft)	#5 PIPE #5 (ft)	#6 PIPE #6 (ft)	#7 PIPE #7 (ft)	#8 PIPE #8 (ft)	#9 PIPE #9 (ft)	#10 PIPE #10 (ft)	#11 PIPE #11 (ft)	#12 PIPE #12 (ft)
Outdoor model #1	Ducted	Liquid or high pressure side	Size													
			Length	12	13	13	13	13	13	13	13	13	13	13	13	13
		Vapor or low pressure side	Size													
			Length	12	13	13	13	13	13	13	13	13	13	13	13	13
	Non-ducted	Liquid or high pressure side	Size										–	–	–	–
			Length	37	13	13	13	13	13	13	13	13	–	–	–	–
		Vapor or low pressure side	Size										–	–	–	–
			Length	37	13	13	13	13	13	13	13	13	–	–	–	–
Outdoor model #2	Ducted	Liquid or high pressure side	Size												–	–
			Length	37	13	13	13	13	13	13	13	13	13	13	–	–
		Vapor or low pressure side	Size												–	–
			Length	37	13	13	13	13	13	13	13	13	13	13	–	–
	Non-ducted	Liquid or high pressure side	Size													–
			Length	87	13	13	13	13	13	13	13	13	13	13	13	–
		Vapor or low pressure side	Size													–
			Length	87	13	13	13	13	13	13	13	13	13	13	13	–

APPENDIX E. ANSI/ASHRAE STANDARD 37-2009 CLARIFICATIONS/EXCEPTIONS – NORMATIVE

The following sections are clarifications and exceptions to ASHRAE Standard 37.

Note: All figures in this appendix are example representations of typical test setups and shall be considered as informative.

E1 Section 5.1 of ASHRAE Standard 37 shall have the following clarifications made for temperature measuring instruments:

E1.1 Add the following section: "*Water vapor content measurement".* If measurement of water vapor is required, use one of the following two methods.

E1.1.1 *Aspirating Psychrometer*. To measure both dry-bulb and wet-bulb temperature, construct and set up Aspirating Psychrometers as described in Section E4.1.1.7 of this appendix.

E1.1.2 *Dew-point Hygrometer*. Measure dew point temperature using a Dew-point Hygrometer as specified in Sections 4, 5, 6, 7.1, and 7.4 of ASHRAE Standard 41.6, "Standard Method for Humidity Measurement" with an accuracy of ±0.4°F. Locate the Dew-point Hygrometer downstream of the dry-bulb temperature sensor.

E2 Section 6.1.2 of ASHRAE Standard 37 shall be modified by replacing the last sentence with the following, "Maintain the dry bulb temperature within the test room within ±5.0°F of the required dry bulb temperature test condition for the air entering the indoor unit. Dew point shall be within 2°F of the required inlet conditions."

E3 Section 6.2.7 of ASHRAE Standard 37 shall have the following references added for static pressure tap positioning:

E3.1 Add the following section: "*Airflow Measuring Apparatus.* Refer to Figure 12 of ASHRAE Standard 51–2007/AMCA Standard 210–2007 or Figure 14 of ASHRAE Standard 41.2 for guidance on placing the static pressure taps and positioning the diffusion baffle (settling means) relative to the chamber inlet." Typical indoor unit installation based on different statics is shown in Figure E7a, Figure E7b, and Figure E7c. Schematic of Typical Test Setup for Ducted Indoor Units with Common Duct is shown in Figure E8.

E4 Insert a new Section 8.5.6 "*Air Condition Measurement Requirements."* into Section 8.5 of ASHRAE Standard 37 and add the following new sections as subsections of Section 8.5.6.

E4.1 Per the requirements in Section E4.1.1 and Section E4.1.2 of this appendix, measure the indoor and outdoor air entering dry-bulb temperature and water vapor content conditions that are required be controlled for the test. When using the indoor air enthalpy method to measure equipment capacity, also measure indoor air leaving dry-bulb temperature and water vapor content. When using the outdoor air enthalpy method to measure equipment capacity, also measure outdoor air leaving dry-bulb temperature and water vapor content. For measuring the indoor and outdoor air leaving dry-bulb temperature and water vapor content conditions, follow the requirements in Section E4.1.3 of this appendix. Make these measurements as described in the following sections. Also, maintain test operating and test condition tolerances and uniformity requirements as described in Section E4.1.1.8.1 of this appendix.

E4.1.1 *Outdoor Air Entering Conditions*.

For heating tests of all air-source heat pump systems, measure water vapor content as provided in Section E1.1 of this appendix.

E4.1.1.1 *General Temperature Measurement Requirements.* Temperature measurements shall be made in accordance with ASHRAE Standard 41.1. Where there are differences between this document and ASHRAE Standard 41.1, this document shall prevail.

E4.1.1.2 *Instrument Requirements*.

E4.1.1.2.1 *Temperature Measurements.*

Follow the requirements of Table E1. The specified accuracies shall apply to the full instrument systems including read-out devices. When using a grid of individual thermocouples rather than a thermopile, follow the thermopile temperature requirements of Table E1.

When measuring dry-bulb temperature for sampled air within the sampled air conduit rather than with the Aspirating Psychrometer as discussed in Section E4.1.1.4 of this appendix, use a temperature sensor and instrument system, including read-out devices, with accuracy of ≤ ± 0.2 °F and display resolution of ≤ 0.1 °F.

Table E1. Temperature Measurement Requirements

Measurement	Accuracy, °F	Display Resolution, °F
Dry-bulb and Wet-bulb Temperatures[1]	≤ ± 0.2	≤ 0.1
Thermopile Temperature[2]	≤ ± 1.0	≤ 0.1

Notes:
1. The accuracy specified is for the temperature indicating device and does not reflect the operation of the Aspirating Psychrometer.
2. To meet this requirement, thermocouple wire must have special limits of error and all thermocouple junctions in a thermopile must be made from the same spool of wire; thermopile junctions are wired in parallel.

E4.1.1.3 *Air Sampling Tree Requirements.* Construct and set up at least two Air Sampling Trees. The Air Sampling Tree is intended to draw a sample of the airflow entering the air-source condenser section. A typical configuration for the Air Sampling Tree is shown in Figure E1 for a tree with overall dimensions of 4 ft by 4 ft.

Note: Other sizes and rectangular shapes can be used and should be scaled accordingly as long as the aspect ratio (width to height) of no greater than 2 to 1 is maintained.

It shall be constructed of stainless steel, plastic or other suitable, durable materials. It shall have a main flow trunk tube with a series of branch tubes connected to the trunk tube. The branch tubes shall have appropriately spaced holes, sized to provide equal airflow through all the holes by increasing the hole size as you move further from the trunk tube to account for the static pressure regain effect in the branch and trunk tubes. A minimum hole density of six holes per square foot of area to be sampled is required. The minimum average velocity through the sampling tree holes shall be 2.5 ft/sec as determined by evaluating the sum of the open area of the holes as compared to the volume flow in the Aspirating Psychrometer or conduit connecting the Dew-point Hygrometer. The assembly shall have a standard size circular connection to allow a flexible tube to be connected to the sampling tree.

The sampling tree shall also be equipped with a thermocouple thermopile grid or with individual thermocouples to measure the average temperature of the airflow over the sampling tree, except as noted in E4.1.1.4. The thermocouple arrangement shall have at least 16 measuring points per sampling tree, evenly spaced across the sampling tree. The Air Sampling Trees shall be placed within 6-12 in of the unit to minimize the risk of damage to the unit while ensuring that the air sampling tubes are measuring the air going into the unit rather than the room air around the unit.

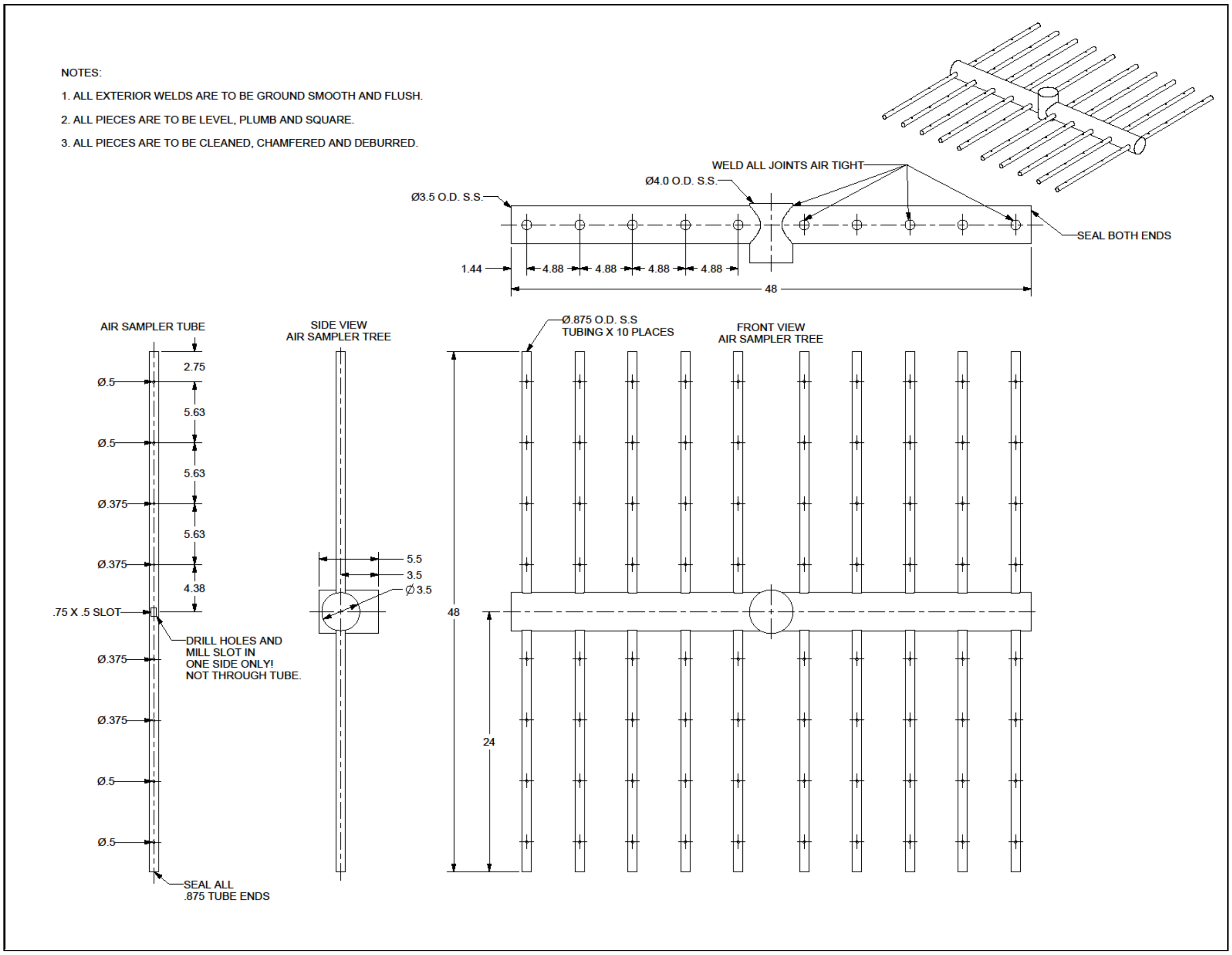

Figure E1. Typical Air Sampling Tree

E4.1.1.4 *Dry-bulb Temperature Measurement.* Measure dry-bulb temperatures using the Aspirating Psychrometer dry-bulb sensors, or, if not using Aspirating Psychrometer, use dry-bulb temperature sensors with accuracy as described in Section E4.1.1.2.1 of this appendix. Measure the dry-bulb temperature, upstream of the water vapor content measurement, within the conduit conducting Air Sampling Tree air to the fan that draws air through the sampling tree. When a fan draws air through more than one Air Sampling Tree, the dry-bulb temperature may be measured separately for each Air Sampling Tree or for the combined set of Air Sampling Tree flows. If dry-bulb temperature is measured at the Air Sampling Tree exit to the conduit, the use of a thermocouple thermopile grid or a grid of individual thermocouples for duplicate measurement of dry-bulb temperature is not required—use the Air Sampling Tree exit measurement when checking temperature uniformity per E4.1.1.8.1.

E4.1.1.5 *Wet Bulb or Dew Point Temperature Measurement to Determine Air Water Vapor Content.* Measure wet-bulb temperatures using two or more Aspirating Psychrometers or measure dew point temperature using two or more Dew-point Hygrometers. If using Dew-point Hygrometers, measure dew point temperature within the conduit conducting Air Sampling Tree air to the air sampling fan at a location downstream of the dry-bulb temperature measurement. When a fan draws air through more than one Air Sampling Tree, the dew point temperature may be measured separately for each Air Sampling Tree or for the combined set of Air Sampling Tree flows.

E4.1.1.6 *Monitoring and Adjustment for Air Sampling Device Conduit Temperature Change and Pressure Drop.* If dry-bulb temperature is measured at a distance from the Air Sampling Tree exits, determine average conduit temperature change as the difference in temperature between the dry-bulb temperature and the average of thermopiles or thermocouple measurements of all Air Sampling Trees collecting air that is measured by the remote dry-bulb temperature sensor. If this difference is greater than 0.5 °F, measure dry-bulb temperature at the exit of each Air Sampling Tree (as described in Section E4.1.1.4 of this appendix), and use these additional sensors to determine average entering air dry-bulb temperature.

Measure gauge pressure at the sensor location of any instrument measuring water vapor content. If the pressure differs from room pressure by more than 2 in H_2O, use this gauge pressure measurement to adjust the atmospheric pressure used to calculate the humidity ratio (in units of pounds of moisture per pound of dry air) at the measurement location.

If either the 0.5 °F temperature difference threshold or the 2 in H_2O pressure difference threshold are exceeded, use a two-step process to calculate adjusted air properties (e.g., wet-bulb temperature or enthalpy) for the one or more affected Air Sampling Devices. First, calculate the moisture level (pounds water vapor per pound dry air) at the humidity measurement location(s) using either the Aspirating Psychrometer dry-bulb and wet-bulb temperature measurements or the Dew-point Hygrometer measurement, using for either approach the adjusted pressure, if it differs from the room atmospheric pressure by 2 in H_2O or more. Then calculate the air properties for the Air Sampling Tree location based on the moisture level, the room atmospheric pressure, and the dry-bulb temperature at the Air Sampling Tree location. If the Air Sampling Device fan serves more than one Air Sampling Tree, and the 0.5 °F threshold was exceeded, the dry-bulb temperature used in this calculation shall be the average of the Air Sampling Tree exit measurements. Also, for multiple Air Sampling Trees, if humidity was measured using multiple Dew-point Hygrometers, the moisture level used in this calculation shall be the average of the calculated moisture levels calculated in the first step.

E4.1.1.7 *Aspirating Psychrometer*. The Aspirating Psychrometer, as shown in Figure E2, consists of a flow section to measure an average value of the sampled air stream. The flow section shall be equipped with two dry-bulb temperature probe connections, one of which shall be used for the facility temperature measurement and one of which shall be available to confirm this measurement using an additional or a third-party's temperature sensor probe. For applications where the humidity is also required, for testing of Heat Pumps in heating mode, the flow section shall be equipped with two wet-bulb temperature probe connection zones of which one shall be used for the facility wet-bulb measurement and one of which shall be available to confirm the wet-bulb measurement using an additional or a third-party's wet-bulb sensor probe.

The Aspirating Psychrometer shall be connected to a fan to draw air through the flow section that either can be adjusted manually or automatically to maintain required velocity across the sensors.

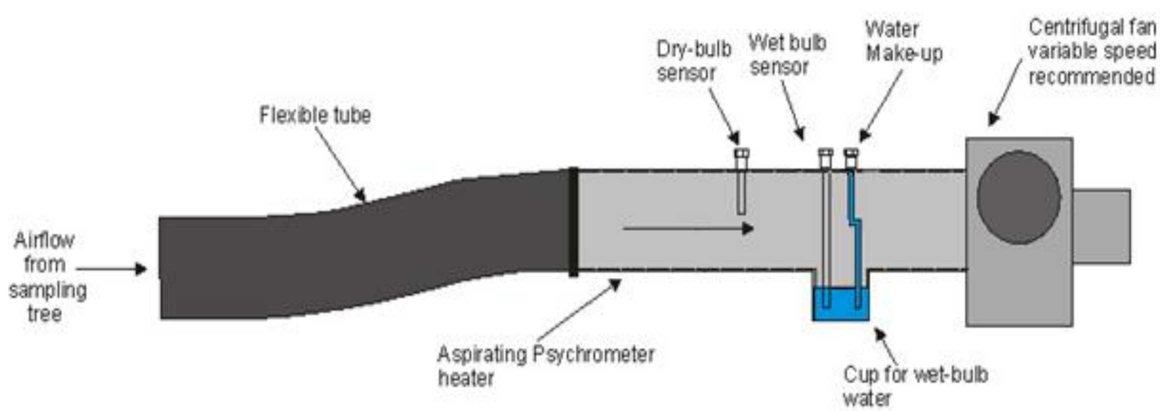

Figure E2. Aspirating Psychrometer

E4.1.1.8 *Test Setup Description.* The nominal face area of the airflow shall be divided into a number of equal area sampling rectangles with aspect ratios no greater than 2 to 1. The nominal face area may extend beyond the coil depending on coil configuration and orientation, and must include all regions through which air enters the unit. Use one of the following two approaches.

1. Each rectangular area shall have one Air Sampling Tree. A minimum of one Aspirating Psychrometer per side of a VRF Multi-split System shall be used. Additional Aspirating Psychrometers shall be used as required to meet the maximum requirement of four Air Sampling Trees per Aspirating Psychrometer. For units that have air entering the sides and the bottom of the unit, additional Air Sampling Trees shall be used.

2. A minimum of two Aspirating Psychrometers or Dew-point Hygrometers shall be used, except as allowed in section E4.1.3.6. The largest rectangular area for each individual unit shall have at least one Air Sampling Tree. Additional Air Sampling Trees shall be used on the next largest rectangular area. For multiple modules that would require more than eight Air Sampling Trees, install a grid of evenly-distributed thermocouples on each rectangular area for which an Air Sampling Tree is not installed. The thermocouples shall be evenly spaced across the rectangular area and be installed to avoid sampling of discharge air or blockage of air recirculation. The grid of thermocouples must provide at least 16 measuring points per rectangular area, evenly spaced across the rectangular area. This grid must be placed within 6 in of the unit.

The Air Sampling Trees shall be located at the geometric center of each rectangle area for which they are sampling; the branches may be oriented either parallel or perpendicular to the longer edges of the air inlet area. The Air Sampling Tree(s) in the outdoor air inlet location shall be sized such that they cover at least 80% of the height and 60% of the width of the air entrance to the unit (for long horizontal coils), or shall cover at least 80% of the width and 60% of the height of the air entrance (for tall vertical coils). The Air Sampling Tree may be larger than the face area of the side being measured, however care shall be taken to prevent discharge air from being sampled. If an Air Sampling Tree dimension extends beyond the inlet area of the unit, holes shall be blocked in the Air Sampling Tree to prevent sampling of discharge air. Holes can be blocked to reduce the region of coverage of the intake holes both in the direction of the trunk axis or perpendicular to the trunk axis. For intake hole region reduction in the direction of the trunk axis, block holes of one or more adjacent pairs of branches (the branches of a pair connect opposite each other at the same trunk location) at either the outlet end or the closed end of the trunk. For intake hole region reduction perpendicular to the trunk axis, block off the same number of holes on each branch on both sides of the trunk. A maximum of four (4) Air Sampling Trees shall be connected to each Aspirating Psychrometer. In order to proportionately divide the flow stream for multiple Air Sampling Trees for a given Aspirating Psychrometer, the tubing or conduit conveying sampled air to the Aspirating Psychrometer shall be of equivalent lengths for each Air Sampling Tree. Examples of Single Module and Combined Module Air Sampling Tree placement are shown in Figure E3 and Figure E4, respectively.

E4.1.1.8.1 *Temperature Uniformity*. To ensure adequate air distribution, thorough mixing, and uniform air temperature, it is important that the room and test setup is properly designed and operated. The room conditioning equipment airflow shall be set such that recirculation of condenser discharged air is avoided except as may naturally occur from the equipment. To check for the recirculation of condenser discharged air back into the condenser coil(s) the following method shall be used: Multiple individual reading thermocouples (at least one per sampling tree location) shall be installed around the unit air discharge perimeter so that they are below the plane of condenser fan exhaust and just above the top of the condenser coil(s). These thermocouples shall not indicate a temperature difference greater than 5.0 °F from the average inlet air. Air distribution at the test facility, at the point of supply to the unit, shall be reviewed to determine if it requires remediation prior to beginning testing.

Mixing fans can be used to ensure adequate air distribution in the test room. If used, mixing fans must be oriented such that they are pointed away from the air intake so that the mixing fan exhaust direction is at an angle of 90°-270° to the air entrance to the condenser air inlet.

When not using Aspirating Psychrometers, the "Aspirating Psychrometer dry-bulb temperature measurement" of Table E2 of this appendix refers to either (a) the dry-bulb temperature measurement in a single common air conduit serving one or more Air Sampling

Trees or (b) the average of the dry-bulb temperature measurements made separately for each of the Air Sampling Trees served by a single Air Sampling Device fan. Similarly, "wet-bulb temperature" refers to calculated wet-bulb temperatures based on dew point measurements.

Adjust measurements if required by Section E4.1.1.6 of this appendix prior to checking uniformity.

The 1.5ºF dry-bulb temperature tolerance in Table E2 between the Air Sampling Tree thermopile (thermocouple) measurements and Aspirating Psychrometer measurements only applies when more than one Air Sampling Tree serves a given Aspirating Psychrometer.

The uniformity requirements apply to test period averages rather than instantaneous measurements.

When water vapor content measurement is required and approach (1) from Section E4.1.1.8 of this appendix is used, also confirm uniformity of wet-bulb temperature variation among all Aspirating Psychrometers .

A valid test shall meet the criteria for adequate air distribution and control of air temperature as shown in Table E2.

Table E2. Criteria for Air Distribution and Control of Air Temperature		
Dry-bulb Temperature	Purpose	Maximum Variation, °F
Deviation from the mean air dry-bulb temperature to the air dry-bulb temperature at any individual temperature measurement station[1]	Uniform temperature distribution	± 2.00
Difference between dry-bulb temperature measured with Air Sampling Tree thermopile and with Aspirating Psychrometer	Uniform temperature distribution	± 1.50
Difference between mean dry-bulb air temperature and the specified target test value[2]	Test condition tolerance, for control of air temperature	± 0.50
Mean dry-bulb air temperature variation over time (from the first to the last of the data sets)	Test operating tolerance, total observed range of variation over data collection time	± 1.50
Wet-bulb Temperature[3]	Purpose	Maximum Variation, °F
Deviation from the mean wet-bulb temperature and the individual temperature measurement stations	Uniform humidity distribution	± 1.00
Difference between mean wet-bulb air wet-bulb temperature and the specified target test value[2]	Test condition tolerance, for control of air temperature	± 1.00
Mean wet-bulb air temperature variation over time	Test operating tolerance, total observed range of variation over data collection time (from the first to the last of the data sets)	± 1.00

Notes:
1. Each measurement station represents an average value as measured by a single Aspirating Psychrometer.
2. The mean dry-bulb temperature is the mean of all measurement stations.
3. The wet-bulb temperature measurement is only required for Heat Pumps operating in the heating mode.

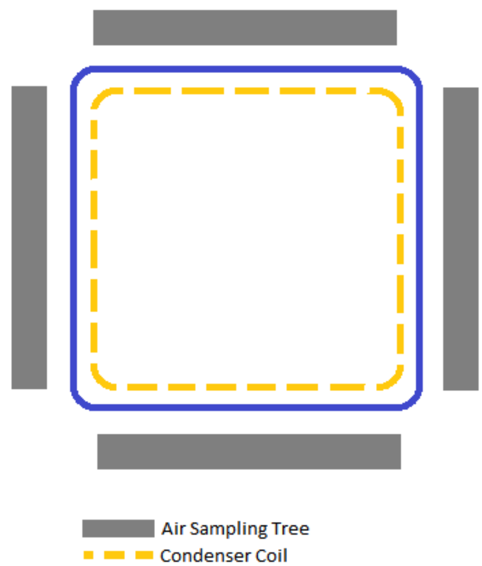

Figure E3. Single Module Air Sampling Tree Placement Example

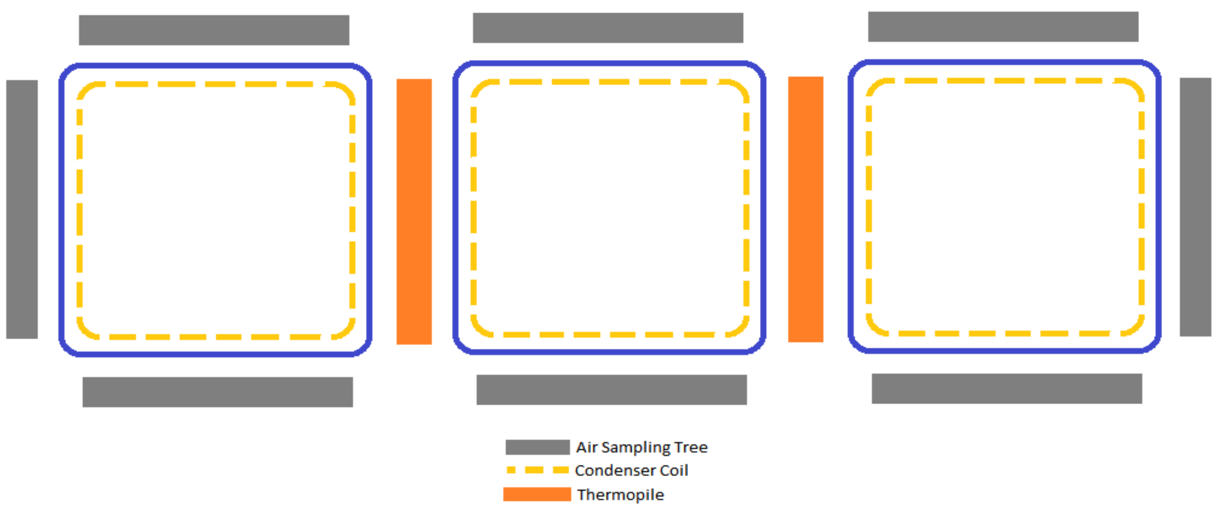

Figure E4. Multiple Module Air Sampling Tree Placement Example

E4.1.2 *Indoor Coil Entering Air Conditions.*

Follow the requirements for outdoor coil entering air conditions as described in Section E4.1.1 of this appendix, except that (a) both dry-bulb temperature and water vapor content measurements are required for all tests, (b) sampled air shall be returned to the room from which the system draws the indoor coil entering air (except if the loop air enthalpy test method specified in Section 6.1.2 of ASHRAE Standard 37 is used, in which case the sampled air must be returned upstream of the Air Sampling Tree in the loop duct between the airflow-measuring apparatus and the room conditioning apparatus), (c) if air is sampled within a duct, the Air Sampling Tree shall be installed with the rectangle defined by the Air Sampling Tree inlet holes oriented parallel with and centered in the duct cross section—this rectangle shall have dimensions that are at least 75% of the duct's respective dimensions.

Additionally, if an inlet plenum is not connected to the air inlet during testing (e.g., for a non-ducted indoor unit other than ceiling cassette), set up Air Sampling Tree(s) as described in Section E4.1.1.8 of this appendix and locate an Air Sampling Tree with dry-bulb temperature measurement approximately 6 in upstream from the inlet of each indoor coil that is being sampled.

E4.1.3 *Indoor Coil Leaving Air and Outdoor Coil Leaving Air Conditions*.

Follow the requirements for measurement of outdoor coil entering air conditions as described in Section E4.1.1 of this appendix, except for the following.

E4.1.3.1 The temperature uniformity requirements discussed in Section E4.1.1.8.1 of this appendix do not apply.

E4.1.3.2 Both dry-bulb temperature and water vapor content measurements are required for indoor coil leaving air for all tests and for outdoor coil leaving air for all tests using the outdoor air enthalpy method.

E4.1.3.3 Air in the duct leaving the coil that is drawn into the Air Sampling Tree for measurement shall be returned to the duct just downstream of the Air Sampling Tree and upstream of the airflow-measuring apparatus. If an independent dry-bulb temperature measurement is conducted at the nozzle location, insulate the conduit transferring the air from the Air Sampling Device fan discharge to the duct.

E4.1.3.4 For a coil that is equipped with a blow-through fan (i.e., where the fan is located upstream of the coil), use a grid of individual thermocouples rather than a thermopile on the Air Sampling Tree, even if Air Sampling Tree exit dry-bulb temperature measurement instruments are installed. If the difference between the maximum time-averaged thermocouple measurement and the minimum time-averaged thermocouple measurement is greater than 1.5 °F, install mixing devices such as those described in Sections 5.3.2 and 5.3.3 of ASHRAE Standard 41.1, "Standard Method for Temperature Measurement" to reduce the maximum temperature spread to less than 1.5 °F.

E4.1.3.5 The Air Sampling Tree (used within the duct transferring air to the airflow measurement apparatus) shall be installed with the rectangle defined by the Air Sampling Tree inlet holes oriented parallel with and centered in the duct cross section—this rectangle shall have dimensions that are at least 75% of the duct's respective dimensions.

E4.1.3.6 If a single common outlet plenum is used, only one Aspirating Psychrometer is required.

E5 Section 6.4.2.2 of ASHRAE Standard 37 shall have the following corrections and clarifications for the inlet duct.

E5.1 Add the following sentences: "For VRF ducted Indoor Units, except Small-duct, High-velocity, an inlet duct equaling the size of the combined inlet opening of all indoors rated at the same static with a length of 6-24 in shall be installed. A static pressure tap shall be located in the center of each face. This inlet duct shall be connected directly to the inlet of the unit."

E6 Section 6.4.3 of ASHRAE Standard 37 shall have the following corrections and clarifications made for Small-duct, High-velocity Systems added.

E6.1 Add the following sentences: "For Small-duct, High-velocity Systems, install an outlet plenum that has a diameter that is equal to or less than the value listed in Table E3 below. The limit depends only on the cooling full-load air volume rate and is effective regardless of the flange dimensions on the outlet of the unit (or an air supply plenum adapter accessory, if installed in accordance with the MII)."

Table E3. Outlet Plenum Maximum Diameter

Cooling Full-Load Air Volume Rate, scfm	Maximum Diameter[1] of Outlet Plenum, in
≤ 500	6
501to 700	7
701 to 900	8
901 to 1100	9
1101 to 1400	10
1401 to 1750	11

Note:
1. If the outlet plenum is rectangular, calculate its equivalent diameter using $(4A)/P$, where A is the area and P is the perimeter of the rectangular plenum, and compare it to the listed maximum diameter.

E7 Section 6.5 of ASHRAE Standard 37 shall have the following information added regarding static pressure measurement.

E7.1 *Indoor coil static pressure difference measurement.* Connect one side of the differential pressure instrument to the manifolded pressure taps installed in the outlet plenum. Connect the other side of the instrument to the manifolded pressure taps located in the inlet plenum. For Non-ducted Systems that are tested with multiple outlet plenums, measure the static pressure within each outlet plenum relative to the surrounding atmosphere.

E7.2 *Test Set-up on The Outlet Side of The Indoor Coil.*

a. Install an interconnecting duct between the indoor coil outlet plenum and the airflow measuring apparatus. If needed, use adaptor plates or transition duct sections to allow the connections. To minimize leakage, tape joints within the interconnecting duct (and the outlet plenum). Construct or insulate the entire flow section with thermal insulation having a nominal overall resistance (R-value) of at least 19 hr·ft ^{2} °F/Btu.

b. Install a grid(s) of dry-bulb temperature sensors inside the interconnecting duct. Also, install an Air Sampling Tree, or the sensor(s) used to measure the water vapor content of the outlet air, inside the interconnecting duct. Locate the dry-bulb temperature grid(s) upstream of the Air Sampling Tree (or the in-duct sensor(s) used to measure the water vapor content of the outlet air). Air that circulates through an Air Sampling Tree and past a remote water-vapor-content sensor(s) shall be returned to the interconnecting duct at a point:

- Downstream of the Air Sampling Tree;
- Upstream of the outlet air damper box, if installed; and
- Upstream of the airflow measuring apparatus.

E7.2.1 *Minimizing Air Leakage.* For Small-duct, High-velocity Systems, install an air damper near the end of the interconnecting duct, just prior to the transition to the airflow measuring apparatus. To minimize air leakage, adjust this damper such that the pressure in the receiving chamber of the airflow measuring apparatus is no more than 0.5 in H_2O higher than the surrounding test room ambient. In lieu of installing a separate damper, use the outlet air damper box if it allows variable positioning. Also apply these steps to any conventional indoor blower unit that creates a static pressure within the receiving chamber of the airflow measuring apparatus that exceeds the test room ambient pressure by more than 0.5 in H_2O.

E8 **S**ection 6.6.1 of ASHRAE Standard 37 shall have the following corrections and clarifications made for duct insulation requirements.

E8.1 Add the following section: "*Indoor coil inlet and outlet duct connections.* Insulate and/or construct the outlet plenum with thermal insulation having a nominal overall resistance (R-value) of at least 19 hr·ft ^{2} °F/Btu."

E8.2 Add the following sentences: "Add a static pressure tap to each face of each outlet plenum, if rectangular, or at four evenly distributed locations along the circumference of an oval or round plenum. Create a manifold that connects the four static pressure taps. Figure E5 shows the options allowed for the manifold configuration."

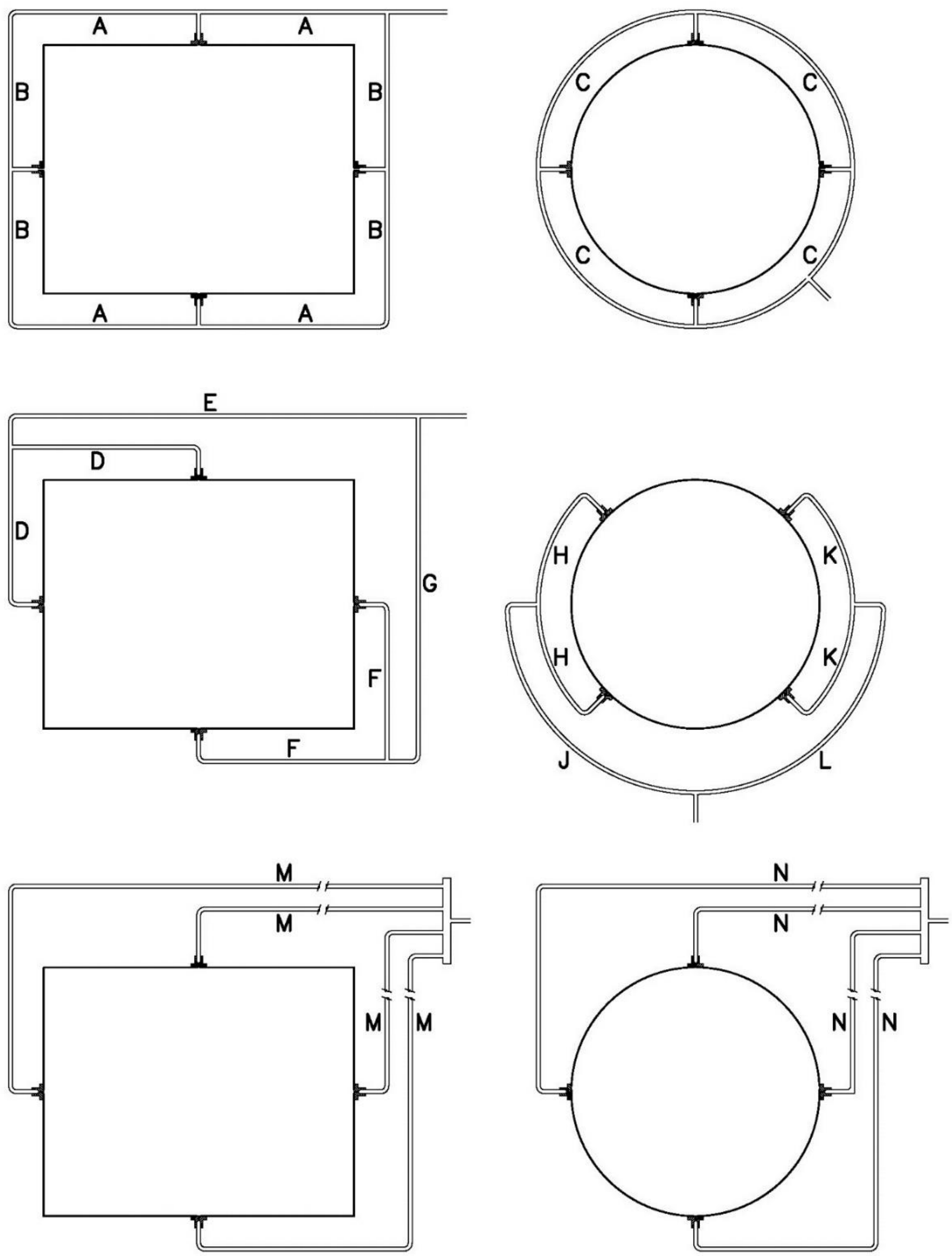

Figure E5. Typical Configurations for Manifolding the Static Pressure Taps

E9 Section 7.2 of ASHRAE Standard 37 shall be modified by inserting a new Section 7.2.4 as follows, "When using the outdoor air enthalpy method as a secondary verification, only the high temperature full load tests for cooling and heating mode require a secondary capacity check. For all other tests in each mode of operation, it is permissible to not use a secondary capacity check.

E10 Section 7.6 of ASHRAE Standard 37 shall be modified by inserting a new Section 7.6.1.3 as follows, "When measurement of more than one module is required, the liquid flow rate, temperature and pressure measurements described below shall apply for each module individually. Temperature measurements shall be made within 6 in of each liquid inlet and within 24 in of each liquid outlet."

E12 Section 8.2.4 of ASHRAE Standard 37 shall have the following requirements and modifications added regarding interconnecting tubing.

E12.1 Modify by appending "At a minimum, insulate all interconnecting vapor line(s) of a split-system with insulation having an inside diameter that matches the refrigerant tubing and an R value between 4 to 6 hr·ft^2 °F/Btu."

E13 Section 8.6 of ASHRAE Standard 37 shall be replaced by the following sections.

E13.1 *General.* When using the outdoor air enthalpy method as the secondary method for capacity measurement, first conduct a test without the outdoor air-side test apparatus connected to the Outdoor Unit ("free outdoor air" test). Then attach the outdoor air-side test apparatus and conduct a test with the apparatus connected to the Outdoor Unit ("ducted outdoor air" test). Use measurements from the free outdoor air test (i.e., indoor air enthalpy method capacity measurements and power input) as the applicable measurements for determination of efficiency metrics, provided the conditions of Appendix E13.2.4 are met.

E13.2 *Free Outdoor Air Test.* For the free outdoor air test, connect the indoor air-side test apparatus to the indoor coil; do not connect the outdoor air-side test apparatus. Allow the test room reconditioning apparatus and the unit being tested to operate for at least one hour.

E13.2.1 After attaining equilibrium conditions, measure the following quantities at equal intervals that span 5 minutes or less:

E13.2.1.1 The evaporator and condenser temperatures or pressures;

E13.2.1.2 Parameters required according to the indoor air enthalpy method (as specified in Section 7.3 of ASHRAE Standard 37).

E13.2.2 Continue these measurements until a 30-minute period (e.g., seven consecutive 5-minute samples) is obtained where the applicable test tolerances are satisfied.

E13.2.3 *Evaporator and Condenser Measurements.* To measure evaporator and condenser temperatures, solder a thermocouple onto a return bend located at or near the midpoints of each coil or at points not affected by vapor superheat or liquid subcooling. Alternatively, if the test unit is not sensitive to the refrigerant charge, install pressure gauges to the access valves or to ports created from tapping into the suction and discharge lines according to Sections 7.4.2 and 8.2.5 of ASHRAE Standard 37. The alternative approach must be used when testing a unit charged with a zeotropic refrigerant having a temperature glide in excess of 1 °F at the specified test conditions.

E13.2.4 For the free outdoor air test to constitute a valid test for determination of efficiency metrics, the following conditions must be met:

E13.2.4.1 For the ducted outdoor test, the capacities determined using the outdoor air enthalpy method and the indoor air enthalpy method must agree within 6%.

E13.2.4.2 The capacities determined using the indoor air enthalpy method from the ducted outdoor air and free outdoor air tests must agree within 2%.

E13.2.4.3 The average of coil midpoint or pressure-equivalent saturation temperatures shall agree within 0.5 °F.

E13.3 *Ducted Outdoor Air Test.*

E13.3.1 After collecting 30 minutes of steady-state data during the free outdoor air test, connect the outdoor air-side test apparatus to the unit for the ducted outdoor air test. Adjust the exhaust fan of the outdoor air-side test apparatus until averages for the evaporator and condenser temperatures, or the saturated temperatures corresponding to the measured pressures, agree within ± 0.5 °F of the averages achieved during the free outdoor air test. Collect 30 minutes of steady-state data for which the applicable test tolerances are satisfied.

E13.3.2 During the ducted outdoor air test, at intervals of 5 minutes or less, measure the parameters required according to the indoor air enthalpy method and the outdoor air enthalpy method for the prescribed 30 minutes.

E13.3.3 For cooling mode ducted outdoor air tests, calculate capacity based on outdoor air enthalpy measurements as specified in Sections 7.3.3.2 and 7.3.3.3 of ASHRAE Standard 37. For heating mode ducted tests, calculate Heating Capacity based on outdoor air-enthalpy measurements as specified in Sections 7.3.4.2 and 7.3.4.3 of ASHRAE Standard 37. Adjust the outdoor-side capacity according to Section 7.3.3.4 of ASHRAE Standard 37 to account for line losses when testing Split Systems. Use the outdoor airflow rate as measured during the ducted outdoor air test to calculate capacity for checking the agreement with the capacity calculated using the indoor air enthalpy method during the ducted outdoor test.

E14 *Test Unit Installation Requirements*. Append the following to Section 8.5.3 of ASHRAE Standard 37. "In the case of non-ducted units having multiple indoor coils, locate a grid approximately 6 in upstream from the inlet of each indoor coil." Typical VRF Multi-split Systems setup is shown in Figure E11.

E15 Section 8.7 of ASHRAE Standard 37 shall have the following changes:

E15.1 Section 8.7 of ASHRAE Standard 37 shall have the following corrections and clarifications made for multiple speed outdoor fan motors. Add the following section: "*Special Requirements for Units having a Multiple Speed Outdoor Fan*. The controls of the unit shall regulate the operation of the outdoor fan during all laboratory tests except dry coil cooling mode tests. For dry coil cooling mode tests, the outdoor fan shall operate at the same speed used during the required wet coil test conducted at the same outdoor test conditions."

E16 Section 8.8 of ASHRAE Standard 37 shall have the following changes:

E16.2 Sections 8.8.2.3 and 8.8.3.4 of ASHRAE Standard 37 shall be modified by replacing "one hour" with "30-minute." This requirement is waived when the heating test is at the frosting condition.

E17 Section 10.1 of ASHRAE Standard 37 shall have the following changes:

E17.1 Insert Section 10.1.2.1 to ASHRAE Standard 37: 10.1.2.1 For this capacity (heat balance) comparison, use the Indoor Air Enthalpy Method capacity that is calculated in Sections 7.3.3 and 7.3.4 of ASHRAE Standard 37.

E18 Add the following as new sections under Section 8 of ASHRAE Standard 37: *Static Pressure Measurements Across Indoor Coil*.

E18.1 *Equipment with Fans and Multiple Outlets or Multiple Indoor Units***.**

E.18.1.1 For systems having multiple indoor coils, or multiple indoor blowers within a single indoor section, attach a plenum to each indoor coil or blower outlet. Connect two or more outlet plenums to a single common duct so that each indoor coil ultimately connects to an airflow measuring apparatus. If using more than one indoor test room, do likewise, creating one or more common ducts within each test room that contains multiple indoor coils. At the plane where each plenum enters a common duct, install an adjustable airflow damper and use it to equalize the static pressure in each plenum. Each outlet air temperature grid and airflow measuring apparatus are located downstream of the inlet(s) to the common duct.

E19 Add the following as new sections under Section 8.3 of ASHRAE Standard 37.

E19.1 *Indoor Leaving Plenum and Duct Requirements for Wall-mount and Ducted Indoor Units*. A plenum (enlarged duct box) shall be installed between the duct and the indoor unit(s). The plenum must have a cross-sectional area at least 2 times the area of the indoor unit(s) combined outlet. For all outlets, the plenum must extend for a distance of at least 3.5 times the square root of the cross-sectional area of the indoor unit(s) combined outlet prior to any duct transitions, elbows, or Air Sampling Trees used for air condition measurement.

E19.1.1 If used, elbows connected to the end of the plenum shall have a centerline radius equal to at least 1.5 times the duct width in the radial direction or have turning vanes. Air velocities calculated as measured volume flow divided by duct or plenum cross-sectional area shall not exceed 250 ft/min inside the plenum and 500 ft/min in the connecting duct at its connection to the plenum.

E19.1.2 Manifolded static pressure taps shall be installed in the plenum in at least four locations spaced uniformly around the plenum per Section 6.5 of ASHRAE Standard 37. The static pressure taps shall be 2.8 times the square root of the cross-sectional area of the combined outlets from the indoor unit(s).

E19.1.3 Air Sampling Trees used for indoor air leaving property measurement shall be placed in the duct between the airflow measurement apparatus and the minimum required plenum length.

E19.1.4 The plenum shall not interfere with the throw angle.

E19.1.5 *Outlet Plenum Requirements.* Typical setup for Wall-mounted Indoor Units is shown in Figure E6. Air velocities calculated as measured volume flow divided by duct or plenum cross-sectional area shall not exceed 250 ft/min inside the plenum.

E19.1.6 Air Sampling Trees used for temperature measurement shall be placed in the duct between the airflow measurement apparatus and the minimum required plenum length.

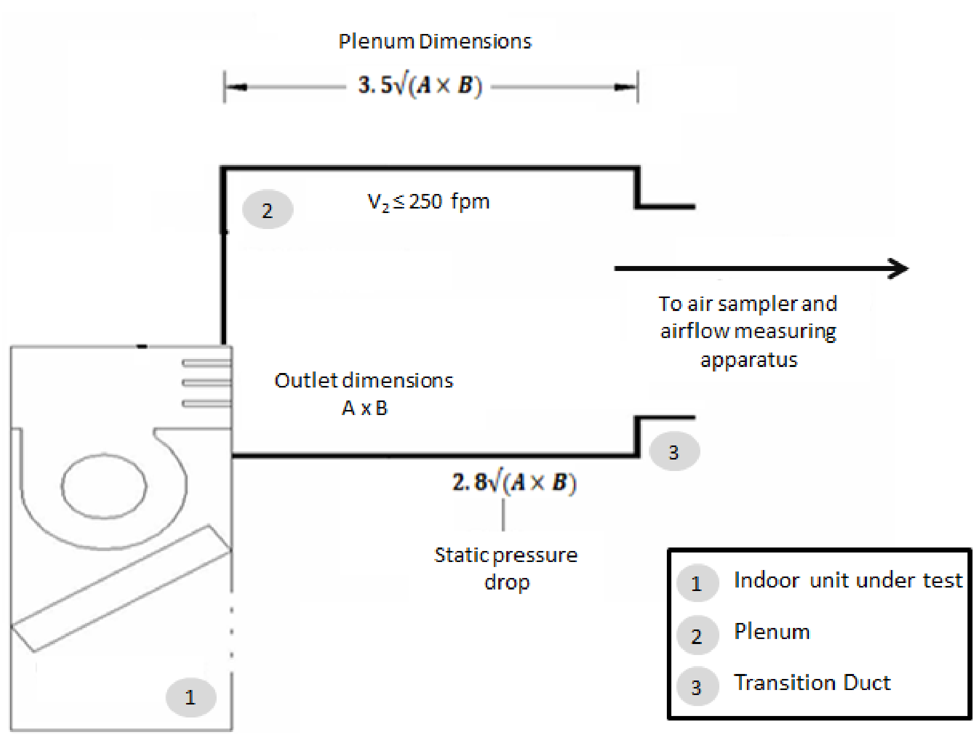

Figure E6. Typical Setup for Wall Mounted Indoor Units

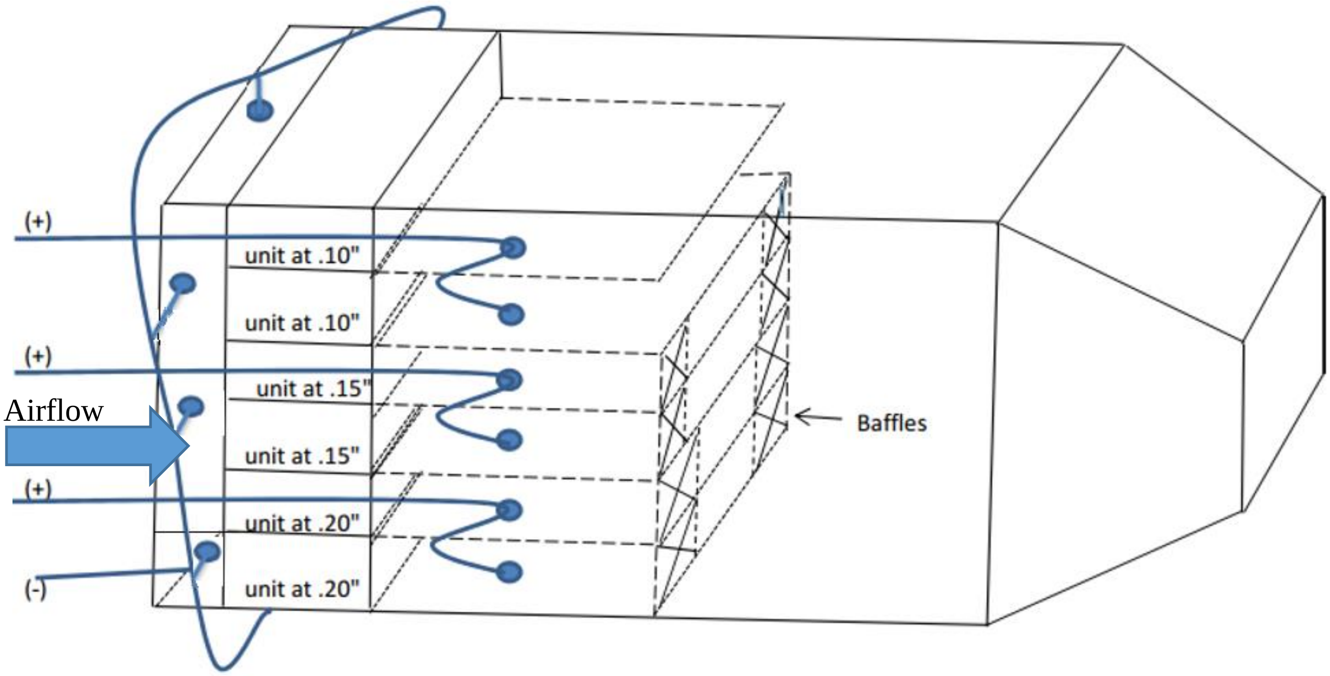

Figure E7a. Typical Indoor Units Installation Based on Different Static Pressures

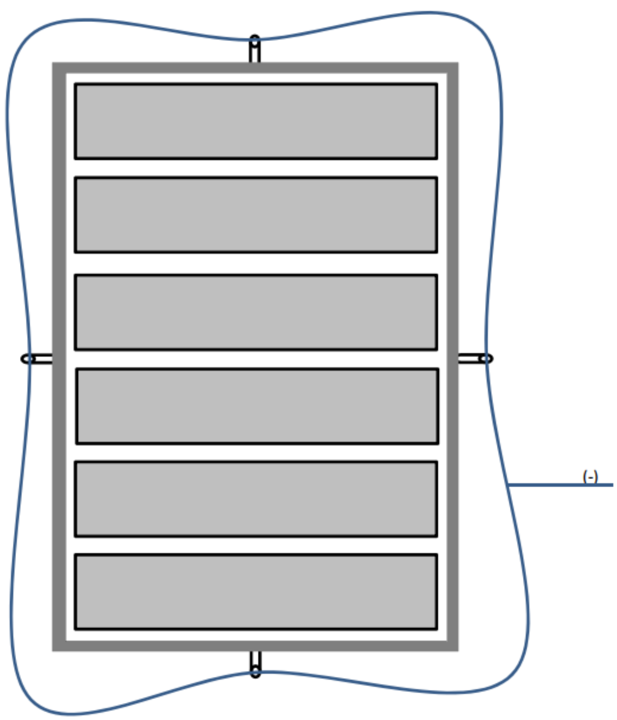

Figure E7b. Typical Indoor Units Installation for IDUs of Same Chassis Size

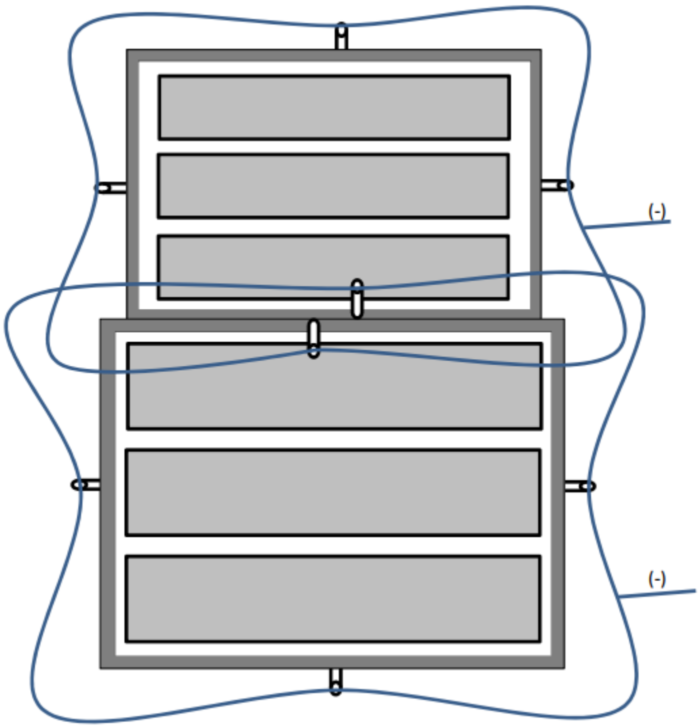

Figure E7c. Typical Indoor Units Installation for IDUs of Different Chassis Size

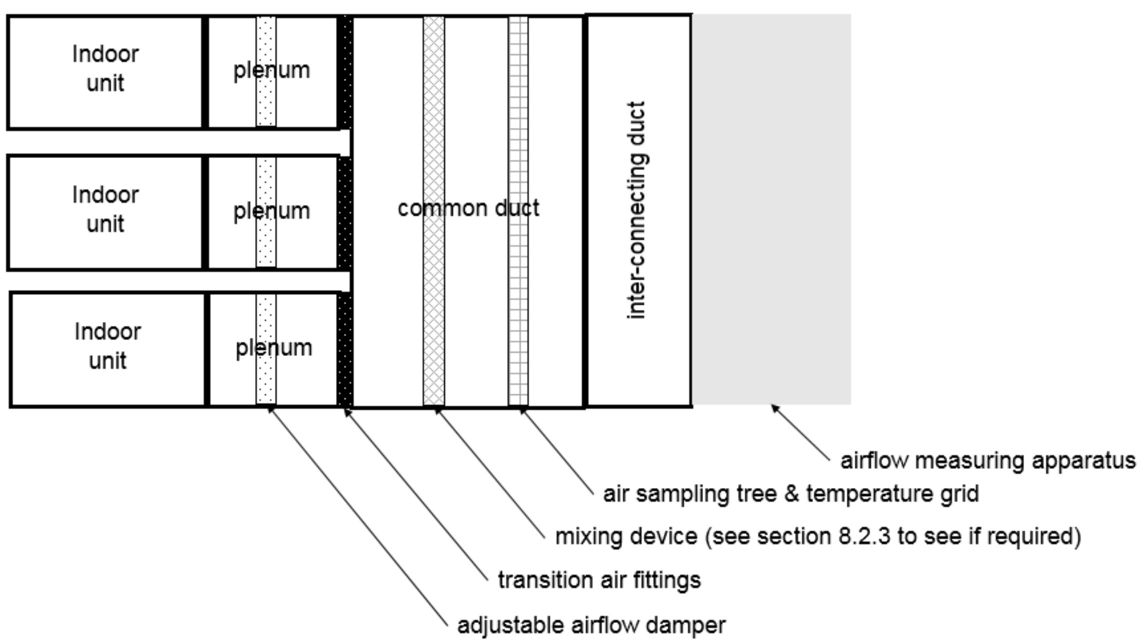

Figure E8. Schematic of Typical Test Setup for Ducted Indoor Units with Common Duct

E19.2 *Indoor Return Plenum Requirements for Wall-mount and Ducted Indoor Units.*

E19.2.1 Except for Ceiling Cassettes, never use an inlet plenum when testing a non-ducted unit. If an inlet plenum is used for Ceiling Cassettes, the inlet plenum shall have a cross-sectional area at least 2 times the area of the Ceiling Cassette(s) combined inlet.

E19.3 *Plenum and Duct Requirements for Ceiling-mount Indoor Units.*

E19.3.1 Typical indoor return air property measurements are shown in Figure E9a, Figure E9b and Figure E10.

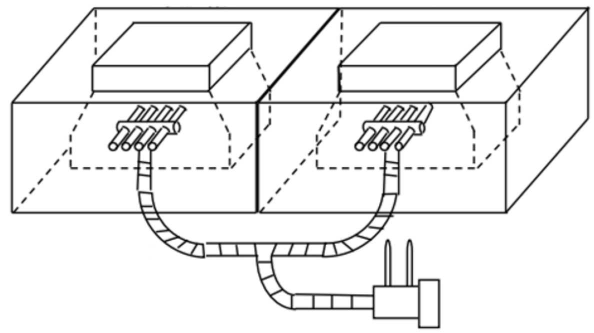

Figure E9a. Typical Return Air Measurement Setup For Non-Ducted Units, Sampling Tree at Unit

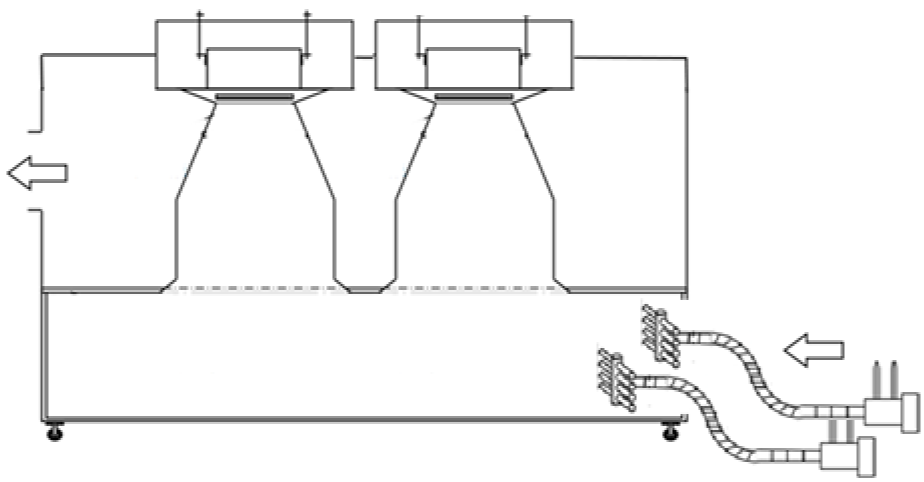

Figure E9b. Typical Return Air Measurement Setup For Non-Ducted Units, Sampling Tree Common

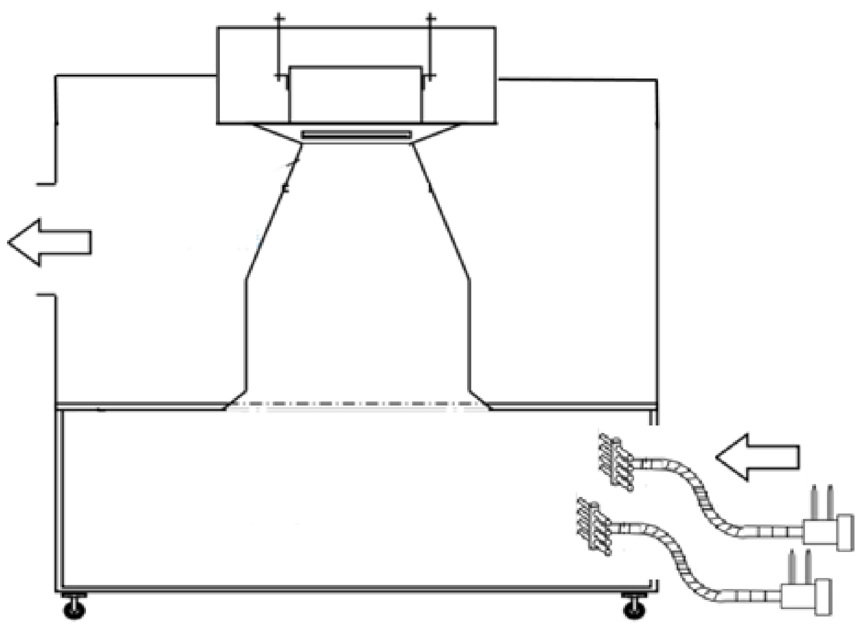

Figure E10. Typical Return Air Measurement Setup For Ceiling Cassette

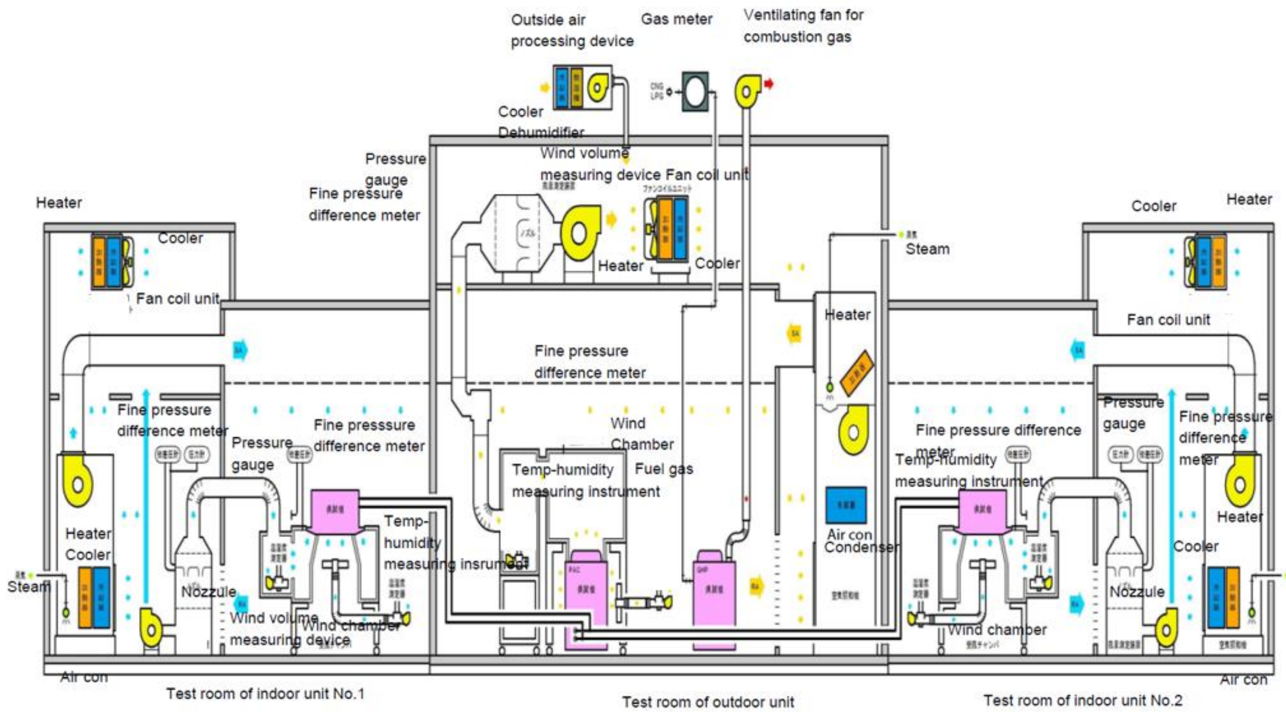

Figure E11. Typical VRF System Setup in Laboratory

APPENDIX F. UNIT CONFIGURATION FOR STANDARD EFFICIENCY DETERMINATION - INFORMATIVE

F1 *Purpose.* The purpose of this appendix is to prescribe the requirements for the configuration of a unit to be used for determining the Standard Rating Cooling and Heating Capacity and efficiency metrics. Certain requirements reduce burden by streamlining the amount of testing manufacturers must do to rate their products.

F2 *Configuration Requirements*. For the purpose of Standard Ratings, units shall be configured for testing as defined in this Appendix.

F2.1 *Individual Model*. An Individual Model means a model distributed in commerce with a unique model number.

F2.2 *Basic Model*. A Basic Model means a grouping of individual models within a single equipment class and which has the same or comparably performing compressor(s), condensing coil(s), evaporator coil(s), and Air Moving System(s) that have a common "nominal" cooling capacity and "essentially identical" energy use characteristics.

F2.3 All components indicated in the following list must be present and installed for all testing for each Indoor Unit and Outdoor Unit, as applicable.

F2.3.1 Indoor air filter(s).

F2.3.1.1 *Ducted Indoor Units*. Test without a filter and increase the applicable tabular value in Table 7 by 0.08 in H_2O.

F2.3.1.2 *Non-ducted Indoor Units.* Test with filter as shipped from the factory.

F2.3.2 Compressor(s)
F2.3.3 Outdoor coil(s) or heat exchanger(s)
F2.3.4 Outdoor fan/motor(s) (Air-source systems only)
F2.3.5 Indoor coil(s)
F2.3.6 Refrigerant expansion device(s)
F2.3.7 Indoor fan/motor(s)
F2.3.8 System Controls

Auxiliary heating and/or heat recovery components must be present and installed for testing individual models distributed in commerce with these components.

F2.4 *Optional System Features*. The following features are optional for installation during testing if an otherwise identical individual model without the feature is sold. If an otherwise identical individual model without the feature is not sold, follow the provisions provided in the subsection below regarding whether and how to remove the feature and test or leave the feature installed and test.

F2.4.1 *Economizers*. An economizer is an automatic system that enables a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather. They provide significant energy efficiency improvements on an annualized basis, but are also a function of regional ambient conditions and are not considered in the IEER metric. If an otherwise identical individual model without an economizer is not sold, test with the economizer installed with outside air dampers fully sealed.

F2.4.2 *Ventilation Energy Recovery System (VERS)*. An assembly that preconditions outdoor air entering the equipment through direct or indirect thermal and/or moisture exchange with the exhaust air, which is defined as the building air being exhausted to the outside from the equipment. Also known as exhaust air energy recovery. Energy recovery devices recover energy from the ventilation or exhaust air and provide significant annualized energy efficiency improvements depending on the regional ambient and building operating load conditions. They are not considered in the IEER metric and are addressed separately by AHRI Guideline V. If an otherwise identical individual model without a VERS is not sold, test with the VERS installed with outside air dampers fully sealed.

F2.4.3 *Desiccant Dehumidification Components*. An assembly that reduces the moisture content of the supply air through moisture transfer with solid or liquid desiccants. If an otherwise identical individual model without desiccant dehumidification components is not sold, test with the desiccant dehumidification components installed and disabled.

F2.4.4 *Power Correction Capacitors*. A capacitor that increases the power factor measured at the line connection to the equipment. These devices are a requirement of the power distribution system supplying the unit. If an otherwise identical individual model without power correction capacitors is not sold, power correction capacitors may be removed for testing.

F2.4.5 *Hail Guards*. A grille or similar structure mounted to the outside of the unit covering the outdoor coil to protect the coil from hail, flying debris and damage from large objects. If an otherwise identical individual model without hail guards is not sold, hail guards may be removed for testing.

F2.4.6 *Fresh Air Dampers*. An assembly with dampers and means to set the damper position in a closed and one open position to allow air to be drawn into the equipment when the indoor fan is operating. If an otherwise identical individual model without fresh air dampers is not sold, test with the fresh air dampers installed and fully sealed.

F2.4.7 *Low Ambient Cooling Dampers*. An assembly with dampers and means to set the dampers in a position to recirculate the warmer condenser discharge air to allow for reliable operation at low outdoor ambient conditions. If an otherwise identical individual model without low ambient cooling dampers is not sold, low ambient cooling dampers may be removed for testing.

APPENDIX G. EXAMPLES OF IEER CALCULATIONS - INFORMATIVE

G1 *IEER Background*. The IEER has been developed to represent a single metric for the annualized performance of the mechanical cooling system**.** It is based on a volume weighted average of 3 building types and 17 climate zones and includes 4 rating points at 100%, 75%, 50% and 25% load at condenser conditions seen during these load points. It includes all mechanical cooling energy, fan energy and other energy required to deliver the mechanical cooling, but excludes energy and cooling capacity for operating hours seen for just ventilation, economizer operation, and does not include System Control options like demand ventilation, Supply Air reset, energy recovery and other system options that might be used in an applied configuration of the unit. It also assumes no oversizing of the unit. The purpose of the metric is to allow for comparison of mechanical cooling systems at a common industry set of conditions.

Building energy consumption varies significantly based on many factors including, but not limited to, local occupancy schedules, ambient conditions, building construction, building location, ventilation requirements and added features like economizers, energy recovery, evaporative cooling, etc. IEER is comparative metric representing the integrated full load and part-load annualized performance of the mechanical cooling of the air- conditioning unit over a range of operating conditions. IEER is not intended to be a predictor of the annual energy consumption of a specific building in a given climate zone. To more accurately estimate energy consumption of a specific building an energy analysis using an hour-by-hour analysis program should be performed for the intended building using the local weather data.

G2 *Example Calculations for Different Compressor and Fan Types*. This appendix contains informative examples that help explain the procedures for calculating the IEER as defined in Section 11 for VRF Systems having a single or multiple compressor(s) with fixed or variable speed indoor fan(s). It is not intended to replace the prescriptive requirements in Section 11 and is intended to help in the application of the IEER to various products covered by this standard.

G2.1 *Example 1 – Air-source Unit with a Single Variable Speed Compressor and a Variable Speed Fan IEER Example Calculations*.

The unit is an Air-source unit with a single Variable Speed Compressor and a variable speed fan that is configured as a unit where the thermostat controls the airflow and the capacity is controlled to a leaving air temperature. The unit has the following rated performance metrics.

Rated Capacity = 118,000 Btu/h
Rated Standard Airflow = 3,400 scfm
Rated EER = 11.2 (Btu/h)/W
Rated IEER = 12.0 (Btu/h)/W

Shown in Table G1a are the test data. During the tests the atmospheric pressure was measured at 14.70 psia and was constant for all tests which is above the minimum allowable atmospheric pressure of 13.700 psia. Note that the pressure could vary between tests and it should be measured for each test.

Table G1a. Example 1:Test Results

Test	Stage	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Test Net Capacity, Btu/h	Test CFM (Std Air), cfm	Compressor (P_C) (Test), W	Condenser (P_{CD}) (Test), W	Indoor (P_{IF}) (Test), W	Control (P_{CT}) (Test), W	EER (Test), (Btu/h)/W
1	100%	95.1	95.0	100.0	117,455	3345	8450	650	1150	125	11.32
2	75%	81.3	81.5	75.4	88,599	2550	5408	650	519	125	13.22
3	50%	68.7	68.0	50.9	59,765	1720	3725	650	166	125	12.81
4	25%	65.3	65.0	29.7	34,863	990	1727	325	33	125	15.77

A total of 4 tests were run to use in the calculation of the EER rating points $EER_{A,\ Full}$, EER_B, EER_C, and EER_D and the calculation of the IEER. Test 1 is the full load rating point. Test 2 was targeted to run at the 75% Load rating point and as you can see the measured test Percent Load is 75.4% so it is with the 3% tolerances and no additional testing is required. For the 50% test 3 was run to get the 50% Load rating and the test measured Percent Load is 50.9% and is also with the allowable tolerance of 3%. Test 4 was run at the 65 °F ambient for the rating point EER_D, but, even after Critical Parameter adjustments as described in Section 6.3.3, the unit could only unload to 29.7% Load so this test will require a degradation calculation to be performed.

As defined in Section 11 the procedure can be performed to calculate the $EER_{A, Full}$, EER_B, EER_C and EER_D point ratings using the test results. Shown in Table G1b are the calculations for the 4 EER rating points used to calculate the IEER.

Table G1b. Example 1: IEER Rating Points and Degradation Calculations

Rating Point	Test	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Net Capacity (Test), Btu/h	Compressor (P_C) (Test), W	Condenser (P_{CD}) (Test), W	Indoor (P_{IF}) (Test), W	Control (P_{CT}) (Test), W	EER (Test), (Btu/h)/W	LF	CD	Rating EER
A	1	95.1	95.0	100.0	117,455	8450	650	1150	125	11.32			
	required load			100.0	use test 1 point directly						-	-	11.32
B	2	81.3	81.5	75.4	88,599	5408	650	650	125	13.22			
	required load			75%	use test 2 point directly						-	-	13.22
C	3	68.7	68.0	50.9	59,765	3725	650	650	125	12.81	-	-	
	required load			50.0	use test 3 point directly								12.81
D	4	65.3	65.0	29.7	34,863	1727	325	33	125	15.77			
	Required Load			25.0	degradation of test 4 required						0.842	1.021	15.27

For rating point A which is the 100% Load rating point the test 1 can be used directly. For the 75% Load rating point EER_B the test load is 75.4% Load so it is with the 3% tolerance so the test point can be used directly for the rating point EER_B and degradation is required. For the 50% Load rating point EER_C test 3 was run to get the 50% Load rating and the test Percent Load is 50.9% so again it is within the 3% tolerance so it can be used directly for the point EER_C EER determination. For the rating point EER_D test 4 was run but due to control limits the unit would only unload to 29.7% Load which is greater than the 25% Load target with a 3% tolerance (25%+3%=28%). Therefore, for degradation calculation is required as shown below.

The degradation factor calculations are performed using the requirements of Section 11.

First the load factor (LF) is calculated using Equation 12.

$$LF = \frac{\left({P_L}/{100}\right) \cdot q_{Full}}{q_{PL}} = \frac{\left({25}/{100}\right) \cdot 117{,}445}{34{,}863} = 0.842$$

What this means is that at a 25% load, the compressor will be on for 84.2% of the time and off for 15.8% of the time.

The Degradation Coefficient is then calculated using Equation 11.

$$C_D = (-0.13 \cdot LF) + 1.13 = (-0.13 \cdot 0.842) + 1.13 = 1.021$$

What this means is the EER will degrade 2.1% due to the cycling of the compressor over a Steady-state on all the time performance.

Once the degradation factor is calculated the rating point EER is calculated using Equation 10 for the rating point EER_D.

$$EER = \frac{LF \cdot Q}{LF \cdot [C_D \cdot (P_C + P_{CD})] + P_{IF} + P_{CT}} = \frac{0.842 \cdot 34{,}863}{0.842 \cdot [1.021 \cdot (1{,}727 + 325)] + 33 + 125} = 15.27\ \text{(Btu/h)/W}$$

The last procedural step 3 is to calculate the IEER using Equation 9.

$$IEER = (0.020 \cdot EER_A) + (0.617 \cdot EER_B) + (0.238 \cdot EER_C) + (0.125 \cdot EER_D)$$

$$= (0.02 \cdot 11.32) + (0.617 \cdot 13.22) + (0.238 \cdot 12.81) + (0.125 \cdot 15.27) = 13.34\ \text{(Btu/h)/W}$$

G2.2 *Example 2. Air-source Unit with Two Compressor with One Being Fixed Speed and the Other Being Variable Speed Compressor and a Variable Speed Indoor Fan IEER Example Calculations.*

The unit is an Air-source unit with 2 compressors in the same refrigeration circuit with 1 being Variable Capacity and the other being a fixed capacity compressor. The indoor fan is a variable speed. The unit has the following rated performance metrics.

Rated Capacity = 118,000 Btu/h
Rated Standard Airflow = 3,400 scfm
Rated EER = 11.2 (Btu/h)/W
Rated IEER = 13.0 (Btu/h)/W

Shown in Table G2a are the test data. During the tests the atmospheric pressure was measured at 14.70 psia and was constant for all tests, which is above the minimum allowable atmospheric pressure of 13.700 psia. Note that the pressure could vary between tests and it should be measured for each test.

Table G2a. Example 2: Test Results

Test	Stage	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Test Net Capacity, Btu/h	Test CFM (Std Air), cfm	Compressor (P_C) (Test), W	Condenser (P_{CD}) (Test), W	Indoor (P_{IF}) (Test), W	Control (P_{CT}) (Test), W	EER (Test), (Btu/h)/W
1	1@100% 2@100%	95.1	95.0	100.0	119,500	3300	8725	650	1,100	125	11.27
2	1@ 48% 2@100%	81.3	81.5	75.1	89,788	2550	5584	650	521	125	13.05
3	1@98% 2@ off	68.7	68.0	50.7	60,563	1720	3846	650	166	150	12.59
4	1@ 46% 2@off	65.3	65.0	24.4	29,197	990	1427	325	33	150	15.09

A total of 4 tests were run to use in the calculation of the EER rating points $EER_{A, Full}$, EER_B, EER_C, and EER_D and the calculation of the IEER. Test 1 is the full load rating point. Test 2 was targeted to run at the 75% Load rating point and as you can see the measured percent load is 75.1% so it is with the 3% tolerances and no additional testing is required. Note that for this test 1 compressor was on and the Variable Speed Compressor was at 48% Load capacity. For the 50% Load rating point, test 3 was run to get the 50% rating and the test measured load is 50.7% and is also with the allowable tolerance of 3%. Note that for this test 1 compressor was turned off and the Variable Speed Compressor was run at 98% Load capacity. Test 4 was run at the 65 °F ambient for the rating point EER_D and the measured Percent Load was 24.4% so it also can be used directly for the EER determination. Because all the tests were be run at the required load, no additional degradation is required.

Using Section 11 procedure calculations are performance to determine the ratings at the $EER_{A, Full}$, EER_B, EER_C and EER_D IEER points. Shown in Table G2b are the calculations for the 4 EER rating points used to calculate the IEER.

Table G2b. Example 2: IEER Rating Points and Degradation Calculations													
Rating Point	Test	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Net Capacity (Test), Btu/h	Compressor (P_C) (Test), W	Condenser (P_{CD}) (Test), W	Indoor (P_{IF}) (Test), W	Control (P_{CT}) (Test), W	EER (Corr), (Btu/h)/W	LF	CD	Rating EER
A	1	95.1	95.0	100.0	119,500	8725	650	1100	125	11.27			
	required load			100.0	use test 1 point directly						-	-	11.27
B	2	81.3	81.5	75.5	89,788	5584	650	521	125	13.05			
	required load			75.0	use test 2 point directly						-	-	13.05
C	4	68.4	68.0	43.0	60,563	3846	650	166	150	12.59			
	required load			50.0	use test 3 point directly						-	-	12.59
D	5	65.3	65.0	24.4	29,197	1427	325	33	150	15.09			
	Required load			25.0	use test 4 point directly						-	-	15.09

Because all 4 tests could be run at the required load within the tolerance no additional calculations are required and the test EER can be used directly for the IEER calculations.

The last procedural step 4 is to calculate the IEER using Equation 9.

$$IEER = \left(0.020 \cdot EER_{A,Full}\right) + \left(0.617 \cdot EER_B\right) + \left(0.238 \cdot EER_C\right) + \left(0.125 \cdot EER_D\right)$$

$$= (0.02 \cdot 11.27) + (0.617 \cdot 13.05) + (0.238 \cdot 12.59) + (0.125 \cdot 15.09) = 13.16\ (\text{Btu/h})/\text{W}$$

G3 *Example Calculations for Systems that do not Meet Capacity Thresholds with STI-specified Critical Parameter adjustments.* This Appendix contains informative example calculations for Critical Parameter adjustments within the tolerance budget and for calculating IEER as defined in section 11 for VRF systems that do not meet the capacity requirement outlined in section 6.3.3.

G3.1 *Example 3. A unit where the capacity exceeds the maximum threshold of 3% of the target load fraction for the 75% and 25% tests.*

A series of CVP tests are performed on a unit with a single compressor, fan, and outdoor LEV. Assume the following rated performance metrics.

Rated Capacity = 100,000 Btu/h
Rated Standard Airflow = 2,200 scfm
Rated EER = 11.2 (Btu/h)/W Rated IEER = 12.0 (Btu/h)/W

The STI-reported critical parameter values are shows in table G3a, below. A 100% CVP test was not conducted for this unit, and therefore the STI-reported values at 100% are used to calculate the Parameter Percent Difference.

Table G3a. STI Reported Critical Parameter Values						
Critical Parameters			Test Load Point			
Group	Unique ID	Measurement Units	100%	75%	50%	25%
Compressor	Comp_1	Hz	100	76	50	28
Outdoor Fan	ODF_1	RPS	1000	780	550	290
Modulating Valve	MV_1	Pulses	100	82	58	28

Shown in Table G3b are the test data. During the tests the atmospheric pressure was measured at 13.90 psia and was constant for all tests, which is above the minimum allowable atmospheric pressure of 13.700 psia. Note that the pressure could vary between tests and it should be measured for each test

A total of 4 tests were run to use in the calculation of the EER rating points $EER_{A,\ Full}$, EER_B, EER_C, and EER_D and the calculation of the IEER; results are shown in Table G3b. Test 1 is the full load rating point and the measured capacity is 2%

greater than the Rated Capacity, which falls within the 3% tolerance. Test 2 was targeted to run at the 75% part-load rating point and the measured percent load is 81% which exceeds the 3% tolerance. For the 50% Load rating point, test 3 was run to get the 50% rating and the test measured load is 49.1% which is within the allowable tolerance of 3%, and no additional testing is required. Test 4 was run at the 65 °F ambient for the rating point EER_D and the measured Percent Load was 40%, which exceeds the 3% threshold.

Table G3b. Example 3: Initial Test Results

Test	Compressor Speed	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Test Power Consumption, W	Test Net Sensible Capacity, Btu/h	Test Net Total Capacity, Btu/h	SHR	SHR Limit	EER (Test), (Btu/h)/W
1	100 Hz	94.7	95.0	102	10,160	99,708	123,096	0.81	0.82	12.11
2	76 Hz	81.7	81.5	81	7230	77,122	95,212	0.83	0.85	13.17
3	50 Hz	67.8	68.0	49.1	4562	59,957	60,563	0.99	-	13.28
4	28 Hz	65.6	65.0	40	1861	28,321	29,197	0.97	-	18.70

The STI specifies that, in situations when the capacity is above 3% of the target load fraction for a given part-load test (75, 50, or 25% load) or the given Rated Capacity for a given 100% test, to decrease the compressor speed. In a second series of tests at the 100% and 25% load points, the lab overrides the compressor speed, gradually decreasing the value. The speed is decreased from 76 to 73 Hz at the 100% load point, and from 28 to 22.7 Hz at the 25% load point. As a result of the compressor speed adjustment, the SHR values increased to within the allowable range. The data is outlined in Table G3c, below.

Table G3c. Example 3: Test Results with Compressor Speed Adjustments

Test	Stage	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Test Power Consumption, W	Test Net Sensible Capacity, Btu/h	Test Net Total Capacity, Btu/h	SHR	SHR Limit	EER (Test), (Btu/h)/W
1	100 Hz	95.1	95.0	102	10,160	99,708	121,595	0.82	0.82	11.97
2	73 Hz	81.3	81.5	78	7592	77,122	90,731	0.85	0.85	11.95
3	50 Hz	68.7	68.0	49.1	4562	59,957	60,563	0.99	-	13.28
4	22.7 Hz	65.3	65.0	34.7	1959	31,355	32,672	0.99	-	16.68

Because the compressor speed was overridden, the adjusted Critical Parameter values must meet the tolerance budget outlined in section C6.2. Using equation C4, the lab calculates the Nominal Point Value for the compressor speed adjustment for the 75% and 25% tests.

$$75\%\text{: } 3\% * 13\ points = 39\ points$$
$$25\%\text{: } 5.3\% * 13\ points = 68.9\ points$$

The RSS Point Totals for the 75% and 25% tests are calculated using equation C5.

$$75\%\text{: } RSS\ Point\ Total = \sqrt{39^2 + 0^2 + 0^2} = 39\ points$$

$$25\%\text{: } RSS\ Point\ Total = \sqrt{68.9^2 + 0^2 + 0^2} = 68.9\ points$$

Because the RSS point total for the 75% test is less than the overall budget is less than 70 points, and the SHR is below the allowable limit, the test is validated. However, the budget was exhausted in the 25% test before the capacity fell within the 3% part-load tolerance. To further adjust the capacity, a degradation calculation must be performed as shown below.

The degradation factor calculations are performed using the requirements of Section 11.

First, the load factor (LF) is calculated using Equation 12.

$$LF = \frac{\left(^{P_L}/_{100}\right) \cdot q_{Full}}{q_{PL}} = \frac{\left(^{25}/_{100}\right) \cdot 121{,}595}{32{,}672} = 0.930$$

What this means is that at a 25% load, the compressor will be on for 93% of the time and off for 7% of the time.

The Degradation Coefficient is then calculated using Equation 11.

$$C_D = (-0.13 \cdot LF) + 1.13 = (-0.13 \cdot 0.930) + 1.13 = 1.009$$

What this means is the EER will degrade 0.9% due to the cycling of the compressor over a Steady-state on all the time performance.

Once the degradation factor is calculated the rating point EER is calculated using Equation 10 for the rating point EER_D. The compressor, condenser, indoor, and control power from the adjusted test are reported in Table G3d, below

Table G3d. Example 3: Power Outputs

Compressor (P_C) (Test), W	Condenser (P_{CD}) (Test), W	Indoor (P_{IF}) (Test), W	Control (P_{CT}) (Test), W
8450	650	1150	125
5408	650	519	125
3725	650	166	125
1727	325	33	125

$$EER = \frac{LF \cdot Q}{LF \cdot [C_D \cdot (P_C + P_{CD})] + P_{IF} + P_{CT}} = \frac{0.930 \cdot 32{,}672}{0.930 \cdot [1.009 \cdot (1{,}727 + 325)] + 33 + 125} = 14.58\ (\text{Btu/h})/\text{W}$$

The last procedural step is to calculate the IEER using Equation 9.

$$IEER = (0.020 \cdot EER_A) + (0.617 \cdot EER_B) + (0.238 \cdot EER_C) + (0.125 \cdot EER_D)$$

$$IEER = (0.020 \cdot 11.97) + (0.617 \cdot 11.95) + (0.238 \cdot 13.28) + (0.125 \cdot 14.58) = 12.59\ (\text{Btu/h})/\text{W}$$

G4 *Example Calculations for Adjusting IEER for Systems that Do Not Meet the Sensible Heat Ratio (SHR) Requirement.* This Appendix contains informative examples for calculating IEER as defined in section 11 for VRF systems that do not meet the SHR requirement outlined in section 6.3.3.

G4.1 *Example 5. A unit where the Sensible Heat Ratio exceeds the allowable limit at 100% load and 75% part-load test points, and the lab has maximized the allowable compressor speed adjustments.*

A series of CVP tests are performed on a unit with a single compressor, fan, and outdoor LEV. Assume the following rated performance metrics.

Rated Capacity = 120,000 Btu/h
Rated Standard Airflow = 2,200 scfm
Rated EER = 11.2 (Btu/h)/W
Rated IEER = 12.0 (Btu/h)/W

The STI-reported critical parameter values are shown in table G4a, below. A 100% CVP test was not conducted for this unit, and therefore the STI-reported values at 100% are used to calculate the Parameter Percent Difference.

Table G4a. STI Reported Critical Parameter Values						
Critical Parameters			Test Load Point			
Group	Unique ID	Measurement Units	100%	75%	50%	25%
Compressor	Comp_1	Hz	100	76	50	28
Outdoor Fan	ODF_1	RPS	1000	780	550	290
Modulating Valve	MV_1	Pulses	100	82	58	28

Shown in Table G4b are the test data. During the tests the atmospheric pressure was measured at 13.90 psia and was constant for all tests, which is above the minimum allowable atmospheric pressure of 13.700 psia. Note that the pressure could vary between tests and it should be measured for each test.

Table G4b. Example 5: Initial Test Results

Test	Stage	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Test Power Consumption, W	Test Net Sensible Capacity, Btu/h	Test Net Total Capacity, Btu/h	SHR	SHR Limit	EER (Test), (Btu/h)/W
1	100 Hz	95.1	95.0	100.0	10,603	101,600	118,139	0.86	0.82	11.14
2	76 Hz	81.3	81.5	75.1	6880	78,115	89,769	0.89	0.85	13.05
3	50 Hz	68.7	68.0	50.7	4732	59,345	60,563	0.98	-	12.59
4	28 Hz	65.3	65.0	24.4	1935	29,197	29,197	1.00	-	15.09

A total of 4 tests were run to use in the calculation of the EER rating points $EER_{A,\ Full}$, EER_B, EER_C, and EER_D and the calculation of the IEER. Test 1 is the full load rating point. Test 2 was targeted to run at the 75% part-load rating point and the measured percent load is 75.1% which is within the 3% tolerance and no additional testing is required. For the 50% Load rating point, test 3 was run to get the 50% rating and the test measured load is 50.7% which is also within the allowable tolerance of 3%. Test 4 was run at the 65 °F ambient for the rating point EER_D and the measured Percent Load was 24.4% and can be used directly for the EER determination. Because tests 2, 3 and 4 were run at the required load no additional degradation is required.

In this example, both Test 1 and Test 2 produced Sensible Heat Ratios above the allowable limits and the lab has increased the compressor speed to the point that the capacity has reached its maximum threshold of 3% above the target load fraction for the 75% test and 3% above the Rated Capacity for the 100% test. The adjusted test results resulting from increasing compressor speed are represented in table G4c.

Table G4c. Example 5: Adjusted Test Results

Test	Stage	Test OAT, °F	Req OAT, °F	Actual Percent Load, %	Test Power Consumption, W	Test Net Sensible Capacity, Btu/h	Test Net Total Capacity, Btu/h	SHR	SHR Limit	EER (Test), (Btu/h)/W
1	103 Hz	95.1	95.0	103.0	10,921	101,600	120,952	0.84	0.82	11.08
2	78.9 Hz	81.3	81.5	78.0	7086	78,115	89,788	0.87	0.85	12.67
3	50 Hz	68.7	68.0	50.7	4732	59,345	60,563	0.98	-	12.59
4	28 Hz	65.3	65.0	24.4	1935	29,197	29,197	1.00	-	15.09

Because the SHR remains above the allowable limits in both the 100% and 75% tests, the methods described in section 11.2.2.3 are used to adjust sensible capacity until the adjusted SHR is equal to the SHR limit. The calculations for the 4 EER rating points are shown in Table G3b. For rating points $EER_{A,\ Full}$ and EER_B, the sensible capacity is adjusted until the SHR target is achieved, using equation 13:

Rating Point A:

$$q_{Sens,Adj} = q_{Latent} * \frac{SHR_{Req}}{1 - SHR_{Req}} = 19{,}352 * \frac{0.82}{1 - 0.82} = 88{,}159$$

Rating Point B:

$$q_{Sens,Adj} = q_{Latent} * \frac{SHR_{Req}}{1 - SHR_{Req}} = 11{,}673 * \frac{0.85}{1 - 0.85} = 66{,}147$$

Then, the rating EER is adjusted based on the new total capacity, using equation 14:

Rating Point A:

$$EER_{Adj} = \frac{q_{Sens,Adj} + q_{latent}}{\dot{E}_{tot}} = \frac{88{,}159 + 19{,}352}{10{,}921} = 9.84$$

Rating Point B:

$$EER_{Adj} = \frac{q_{Sens,Adj} + q_{latent}}{\dot{E}_{tot}} = \frac{66{,}147 + 11{,}673}{7{,}086} = 10.98$$

The last procedural step 4 is to calculate the IEER using Equation 9.

$$IEER = \left(0.020 \cdot EER_{A,Full}\right) + (0.617 \cdot EER_B) + (0.238 \cdot EER_C) + (0.125 \cdot EER_D)$$

$$IEER = (0.020 \cdot 9.84) + (0.617 \cdot 10.98) + (0.238 \cdot 12.59) + (0.125 \cdot 15.09) = 11.85\ \text{(Btu/h)/W}$$

APPENDIX H. EXAMPLE CALCULATIONS FOR CRITICAL PARAMETER BUDGET METHOD - INFORMATIVE

A series of CVP tests are conducted on a unit with 2 compressors, 2 fans, and 2 outdoor variable valves, with a 100% cooling capacity of 100,000 Btu/h. The STI indicates that all three critical parameters: the compressor speed, fan speed, and LEV position, will all be overridden. The STI-reported critical parameter values are reported in Table H1, below.

Table H1. STI Reported Critical Parameter Values

Critical Parameters			Test Load Point			
Group	Unique ID	Measurement Units	100%	75%	50%	25%
Compressor	Comp_1	Hz	100	76	50	28
Compressor	Comp_2	Hz	110	70	64	20
Outdoor Fan	ODF_1	RPS	1000	780	550	290
Outdoor Fan	ODF_2	RPS	1500	750	480	250
Modulating Valve	MV_1	Pulses	122	102	58	28
Modulating Valve	MV_2	Pulses	130	106	66	26

When these values are used to determine variance, the values for each critical parameter group are averaged for each load point. During the CVP, critical parameter values are continuously recorded. For each parameter reading, the two values from each critical parameter group are averaged and used to calculate the variance, using Eq. C3, as displayed below for the compressor speed.

$$\frac{|78-73|}{105} * 100 = 4.8\ \%$$

This calculation process is outlined in Table H2 for the system at 75% capacity.

Table H2. 75% Instantaneous Parameter Variation Calculation

	STI Reported Value #1	STI Reported Value #2	Average STI Value	Measured Value #1	Measured Value #2	Average Measured Value	100% Max Value #1	100% Max Value #2	Average 100% Max Value	Percent Variation (%)
Compressor	76	70	73	82	74	78	100	110	105	4.8
Fan	780	750	765	756	730	743	1000	1500	1250	1.8
LEV	102	106	104	95	85	90	100	104	102	13.7

This variance is used to calculate the points accrued by each parameter (Eq. C4). In order to validate the parameters used in this 75% steady state test, each parameter's points must be combined using equation C5. These calculations are outlined in Table H3.

Table H3. Instantaneous Parameter Point Calculation

	Percent Variation (%)	Nominal Point Value	Points Accrued[1]
Compressor	4.8	13	62.4
Fan	1.8	7	12.6
LEV	13.7	1	13.7
		RSS Point Total	65.12

Note
1. Per equation C5

These calculations will be performed for each measurement throughout the CVP, along with a rolling average of the RSS Point Total. If at least one measurement period of at least three minutes and a minimum of five sample readings occurs where the average RSS point total is ≤ 70 points, the critical parameters in the STI at the 75% load point are validated. This process is displayed in table H4.

Table H4. Measurement Period Point Total Average

Measurement #1	Measurement #2	Measurement #3	Measurement #4	Measurement #5	Average Point Total
74.87	67.87	68.62	70.44	61.23	68.61

Because the average point total is less than 70, the critical parameters for this test are validated, despite the two measurements during the period that exceed the budget.