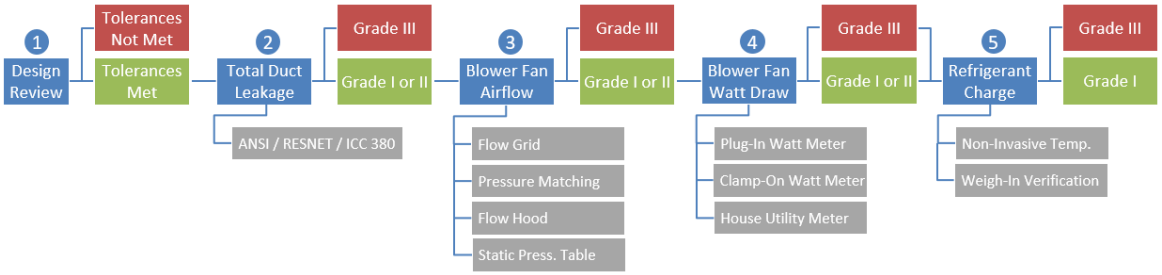
Draft PDS-01
BSR/RESNET/ACCA Standard 310-201x
Standard for Grading the Installation of HVAC Systems

Forward (Informative)

This Standard provides a methodology for evaluating the installation quality of Unitary HVAC systems. It's comprised of five tasks - a design review, a total duct leakage test, a Blower Fan volumetric airflow test, a Blower Fan watt draw test, and a non-invasive evaluation of refrigerant charge. The five tasks are designed to be completed in sequence. With the completion of each task, the results are evaluated for compliance with specified thresholds. For Task 1, these thresholds are design tolerances. For Tasks 2 through 5, the thresholds are installation quality grades. Furthermore, for Tasks 1 through 3, specified thresholds must be satisfied or the subsequent tasks cannot be completed. A visual representation of the workflow and the diagnostic test methods is shown in Figure 1.

Figure 1: Illustration of Workflow and Diagnostic Test Methods



In this standard, the terms Townhouse, Dwelling Unit, and Sleeping Unit are interchangeable with the term Dwelling, except where specifically noted.

This Standard contains both normative requirements and informative supporting material. The normative requirements must be complied with to conform to the Standard. Informative materials only provide supportive content and are marked as such.

1. **Purpose.** This standard establishes the procedures, tolerances, and record keeping required to evaluate elements of an HVAC System's design and installation.

2. **Scope.** This standard is applicable to Unitary HVAC Systems including air conditioners and heat pumps up to 65 kBtuh and furnaces up to 125 kBtuh in detached one- and two-family Dwellings, Townhouses, as well as in Dwelling Units and Sleeping Units that have their own HVAC system separate from other units. It is intended for use by home energy raters, energy auditors, code officials, or HVAC contractors.

3. Definitions.

AHRI Reference Number – The unique identifier assigned by the Air-Conditioning, Heating, & Refrigeration Institute (AHRI) to a specific piece of equipment or combination of equipment that it has certified.

Air Conditioner – A vapor-compression refrigeration device that transfers heat from a location being cooled to another location using the physical properties of an evaporating and condensing fluid known as a refrigerant.

Architectural Option – A modification to a portion of an Architectural Plan that may be optionally used.

Architectural Plan – An architectural drawing defining the room quantity, room type, and dimensions of a Dwelling.

Bedroom – For one- and two-family Dwellings and Townhouses, a room [1] or space 70 square feet of floor area or greater, with egress window or skylight, and doorway to the main body of the Dwelling Unit, that can be used for sleeping. For all other Dwelling Units, a room [2] or space that can be used for sleeping. For all Dwelling or Sleeping Units, the number of Bedrooms shall not be less than one.

Blower Fan – The fan inside the equipment of a Forced-Air HVAC System that forces the heated and/or cooled air to be distributed within a Dwelling.

Boiler – A space-heating appliance with a capacity up to 225 kBtuh in which liquid is heated by burning fuel or converting electrical energy.

Climate Condition – The classification of a climate, as defined by ACCA Manual S, into Condition A or B. Condition B represents climates for which the sensible heat ratio is ≥ 0.95 and the ratio of Heating Degree Days to Cooling Degree Days is ≥ 2.0 [3]. Climates that do not meet Condition B are considered to be Condition A.

Condensing Temperature – The refrigerant Saturation Temperature measured at the service valve at the condenser coil entrance.

Condensing Temperature Over Ambient (CTOA) – A constant value that represents the difference between the Condensing Temperature and the outdoor air used to cool the refrigerant in the condenser coil.

[1] (Informative Note) A "den," "library," "home office" or other similar rooms with a closet, egress window, doorway to the main body of the Dwelling Unit, and 70 square feet of floor area or greater are considered a Bedroom, but living rooms, foyers, and other rooms not intended for sleeping, are not. The number of rooms identified as Bedrooms is used to determine the number of occupants.

[2] (Informative Note) Informative Annex A of Standard ANSI/RESNET/ICC 380 contains a table that summarizes parts of a Dwelling Unit that are included in Conditioned Floor Area.

[3] (Informative Note) ACCA uses a base temperature of 65 °F (18 °C) for heating and 50 °F (10 °C) for cooling.

Conditioned Floor Area (CFA) [4] – The floor area of the Conditioned Space Volume within a building or Dwelling Unit, not including the floor area of attics, crawlspaces, and basements below air sealed and insulated floors. The following specific spaces are addressed to ensure consistent application of this definition:

- The floor area of a wall assembly that is adjacent to Conditioned Space Volume shall be included.
- The floor area of a basement shall be included if the party conducting the evaluation has either:
    - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume, or,
    - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the party conducting evaluations, are capable of maintaining the heating and cooling temperatures specified by the Thermostat section in Table 4.2.2(1) in ANSI/RESNET/ICC 301.
- The floor area of a garage shall be excluded, even when it is conditioned.
- The floor area of a thermally isolated sunroom shall be excluded.
- The floor area of an attic shall be excluded, even when it is Conditioned Space Volume.
- The floor area of a crawlspace shall be excluded, even when it is Conditioned Space Volume.

Conditioned Space Volume [4] **-** The volume within a Dwelling Unit serviced by a space heating or cooling system designed to maintain space conditions at 78 °F (26 °C) for cooling and 68 °F (20 °C) for heating. The following specific spaces are addressed to ensure consistent application of this definition:

- If the volume both above and below a floor assembly meets this definition and is part of the Rated Dwelling Unit, then the volume of the floor assembly shall also be included. Otherwise the volume of the floor assembly shall be excluded.
    - Exception: The wall height shall extend from the finished floor to the bottom side of the floor decking above the Rated Dwelling Unit for non-top floor level Dwelling Units and to the exterior enclosure air barrier for top floor level Dwelling Units.
- If the volume of at least one of the spaces horizontally adjacent to a wall assembly meets this definition, and that volume is part of the Rated Dwelling Unit, then the volume of the wall assembly shall also be included. Otherwise, the volume of the wall assembly shall be excluded.
    - Exception: If the volume of one of the spaces horizontally adjacent to a wall assembly is a Dwelling Unit other than the Rated Dwelling Unit, then the volume of that wall assembly shall be evenly divided between both adjacent Dwelling Units.
- The volume of an attic that is not both air sealed and insulated at the roof deck shall be excluded.

[4] (Informative Note) Informative Annex A of Standard ANSI/RESNET/ICC 380 contains a table that summarizes parts of a Dwelling Unit that are included in Conditioned Floor Area.

- The volume of a vented crawlspace shall be excluded.
- The volume of a garage shall be excluded, even when it is conditioned.
- The volume of a thermally isolated sunroom shall be excluded.
- The volume of an attic that is both air sealed and insulated at the roof deck, the volume of an unvented crawlspace, and the volume of a basement shall only be included if the volume is contiguous with the Rated Dwelling Unit and the party conducting evaluations has either:
    - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume, or,
    - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the party conducting evaluations, are capable of maintaining the heating and cooling temperatures specified by the Thermostat section in Table 4.2.2(1).
- The volume of a mechanical closet, regardless of access location, that is contiguous with the Rated Dwelling Unit shall be included if:
    - it is serviced by a space heating or cooling system designed to maintain space conditions at 78 °F (26 °C) for cooling and 68 °F (20 °C) for heating, and
    - it only includes equipment serving the Rated Dwelling Unit, and
    - the mechanical room is not intentionally air sealed from the Rated Dwelling Unit.

Design Temperature Difference (DTD) – A constant value that represents the difference between the evaporator coil refrigerant's Saturation Temperature and the supply air temperature.

Dwelling – Any building that contains one or two Dwelling Units used, intended, or designed to be built, used, rented, leased, let or hired out to be occupied, or that are occupied for living purposes.

Dwelling Unit - A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

Dwelling-Unit Mechanical Ventilation System – A Ventilation system consisting of powered Ventilation equipment such as motor-driven fans and blowers and related mechanical components such as ducts, inlets, dampers, filters and associated control devices that provides Dwelling-Unit Ventilation at a known or measured airflow rate.

Egress Window – An operable window that provides for a means of escape and access for rescue in the event of an emergency and with the following attributes:

- Has a sill height of not more than 44 inches above the floor; and,
- Has a minimum net clear opening of 5.7 sq. ft.; and,
- Has a minimum net clear opening height of 24 in.; and,
- Has a minimum net clear opening width of 20 in.; and,
- Is operational from the inside of the room without the use of keys, tools or special knowledge.

Forced-Air HVAC System – A type of HVAC System that incorporates a Blower Fan to move conditioned air.

Front Orientation – The direction that the front door of a Dwelling is facing.

Furnace – A space-heating appliance in which air is heated by burning fuel or converting electrical energy.

Heat Pump – A vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow is reversed in order to transfer heat from one location to another using the physical properties of an evaporating and condensing fluid known as a refrigerant.

HVAC System – Cooling-only, heating-only, or combined cooling-heating equipment, including any supply and/or return distribution systems.

Independent Verification Report – A report provided by a party operating under a third-party quality control program.

Mini-Split Air Conditioner (MNAC) – An Air Conditioner that has variable refrigerant flow and distributed refrigerant technology with a single outdoor section serving a single indoor section. The indoor section is typically, but not exclusively, mounted on walls and designed to condition air either directly or through limited duct runs, though duct length is not a determinant for meeting this definition.

Mini-Split Heat Pump (MNHP) – A Heat Pump that has variable refrigerant flow and distributed refrigerant technology with a single outdoor section serving a single indoor section. The indoor section is typically, but not exclusively, mounted on walls and designed to condition air either directly or through limited duct runs, though duct length is not a determinant for meeting this definition.

Multi-Split Air Conditioner (MTAC) – An Air Conditioner that has variable refrigerant flow and distributed refrigerant technology with the capability of serving multiple indoor sections with a single outdoor section. The indoor sections are typically, but not exclusively, mounted on room walls and designed to condition air either directly or through limited duct runs, though duct length is not a determinant meeting this definition.

Multi-Split Heat Pump (MTHP) – A Heat Pump that has variable refrigerant flow and distributed refrigerant technology with the capability of serving multiple indoor sections with a single outdoor section. The indoor sections are typically, but not exclusively, mounted on room walls and designed to condition air either directly or through limited duct runs, though duct length is not a determinant meeting this definition.

OEM Static Pressure Table – Documentation produced by a Forced-Air HVAC System equipment manufacturer that indicates the Blower Fan airflow at specified fan-speed settings, static pressure values, and in some instances voltage.

Other Equipment Type – Any HVAC equipment type that is not an Air Conditioner, Boiler, Furnace, or Heat Pump.

Other Motor Type – Any Blower Fan motor type that is not a Permanent Split Capacitor (PSC) or Electronically Commutated Motor (ECM).

Other Ventilation Standard – Any ventilation standard that is not ASHRAE 62.2-2010, ASHRAE 62.2-20103, or ASHRAE 62.2-2016.

Saturation Temperature – The temperature at which the refrigerant undergoes a phase change in either the condenser or evaporator coils.

Sleeping Unit – A room or space in which people sleep, which can also include permanent provisions for living, eating, and either sanitation or kitchen facilities but not both. Such rooms and spaces that are also part of a Dwelling Unit are not Sleeping Units.

Target Liquid Line Temperature – The calculated target temperature of the liquid line.

Target Subcooling – The manufacturer prescribed subcooling for the equipment being tested.

Target Suction Line Temperature – The calculated target temperature of the suction line.

Target Superheat – The manufacturer prescribed superheat for the equipment being tested.

Townhouse – A single-family Dwelling Unit constructed in a group of three or more attached units in which each unit extends from the foundation to roof and with open space on at least two sides.

Unconditioned Space Volume [5] – The volume within a building or Dwelling Unit that is not Conditioned Space Volume but which contains heat sources or sinks that influence the temperature of the area or room. The following specific spaces are addressed to ensure consistent application of this definition:

- If either one or both of the volumes above and below a floor assembly is Unconditioned Space Volume, then the volume of the floor assembly shall be included.
- If the volume of both of the spaces horizontally adjacent to a wall assembly are Unconditioned Space Volume, then the volume of the wall assembly shall be included.
- The volume of an attic that is not both air sealed and insulated at the roof deck shall be included.
- The volume of a vented crawlspace shall be included.
- The volume of a garage shall be included, even when it is conditioned.
- The volume of a thermally isolated sunroom shall be included.
- The volume of an attic that is both air sealed and insulated at the roof deck, the volume of an unvented crawlspace, and the volume of a basement shall be included unless it meets the definition of Conditioned Space Volume.

Unitary – One or more factory-made assemblies which normally may include an evaporator or cooling coil, a compressor and condenser combination, and may include a heating function. The equipment can be ducted or ductless; it can be a split-system or single package.

[5] (Informative Note) Informative Annex A of Standard ANSI/RESNET/ICC 380 contains a table that summarizes parts of a Dwelling Unit that are included in Unconditioned Space Volume.

Ventilation - The process of providing outdoor air directly to a Dwelling by natural or mechanical means. Such air may or may not be conditioned.

Ventilation Mode – For a Ventilation system that uses the Blower Fan of the Forced-Air HVAC System, the Blower Fan setting used to provide Dwelling-Unit Ventilation rather than the settings to maintain temperature setpoints.

4. Task 1: Evaluation of the Design.

4.1. **Overview**. This procedure shall be completed by first collecting the design information specified in Section 4.2, then verifying that all required information has been provided and falls within the tolerances specified in Section 4.3.

4.2. **Required Design Information**. The following design information shall be collected by the person completing the evaluation for the Dwelling to be rated.

4.2.1. Architectural design documentation, consisting of the following:

4.2.1.1. The Architectural Plan

4.2.1.2. Any Architectural Options for the Plan.

4.2.2. HVAC design overview, consisting of the following:

4.2.2.1. The designer name.

4.2.2.2. The designer company.

4.2.2.3. The date of design.

4.2.2.4. The architectural scope of the HVAC design, consisting of the following:

4.2.2.4.1. If a Dwelling or Townhouse, or a Dwelling Unit or Sleeping Unit within:

4.2.2.4.1.1. The name of the Architectural Plan that the HVAC design is based on or the unique address of the building.

4.2.2.4.1.2. Any Architectural Option(s) used in the HVAC design, and a list of other Architectural Option(s), if any, that the design can be used with.

4.2.2.4.2. If a Dwelling Unit or Sleeping Unit not within a Dwelling or Townhouse:

4.2.2.4.2.1. A unique identifier for the building that the unit is within [6].

4.2.2.4.2.2. The name of the Architectural Plan that the HVAC design is based on, and a list of other Architectural Plan(s), if any, that the design can be used with.

4.2.2.4.2.3. Any Architectural Option(s) used in the HVAC design, and a list of other Architectural Option(s), if any, that the design can be used with.

4.2.2.5. If a software program was used to complete the design, the software program name and version that was used.

[6] (Informative Note) For example, the name of the development or the building's address.

4.2.3. Dwelling-Unit Mechanical Ventilation System design for each system that serves the Dwelling to be rated, consisting of the following:

4.2.3.1. A unique name or identifier for the system [7].

4.2.3.2. The specified system type: supply, exhaust, balanced without recovery, ERV, or HRV.

4.2.3.3. The specified control location for the system [8].

4.2.3.4. For systems serving Dwelling Units or Sleeping Units not within a Dwelling or Townhouse:

4.2.3.4.1. The specified system manufacturer and model number.

4.2.3.4.2. The unit(s) served by the system.

4.2.3.5. The name of the Ventilation zone(s) [9] served by the system.

4.2.3.6. An overview of each Ventilation zone that the system serves, consisting of the following information.

4.2.3.6.1. The design basis for the Ventilation airflow rate and run-time for the Ventilation zone: ASHRAE 62.2-2010, ASHRAE 62.2-2013, or ASHRAE 62.2-2016, or Other Ventilation Standard.

4.2.3.6.2. The number of Bedrooms within the Ventilation zone.

4.2.3.6.3. The floor area of the Ventilation zone.

4.2.3.6.4. The design's Ventilation airflow rate, runtime per cycle, and cycle time for the Ventilation zone.

4.2.3.6.5. The design's time-averaged Ventilation airflow rate for the Ventilation zone, calculated using Equation 1.

$$Time\ \ Averaged\ Vent\ \ Rate = Vent\ \ Rate\ \times \frac{Runtime\ Per\ Cycle}{Cycle\ Time} \qquad (1)$$

Where:

Time_Averaged Vent Rate = The average Ventilation airflow rate.

Vent Rate = The design's Ventilation airflow rate reported in Section 4.2.3.6.4.

Runtime Per Cycle = The runtime per cycle reported in Section 4.2.3.6.4.

Cycle Time = The cycle time reported in Section 4.2.3.6.4.

4.2.4. Heat gain and heat loss loads for each heated or cooled zone in the Dwelling to be rated, consisting of the following:

4.2.4.1. The name of the heated or cooled zone [10].

[7] (Informative Note) For example, "Bath Fan 1", "ERV 1".
[8] (Informative Note) Examples of common locations include bathroom or utility room.
[9] (Informative Note) Examples of Ventilation zones include Whole Dwelling, Upper Level, Lower Level, Basement.
[10] (Informative Note) Examples of heated or cooled zones include Upper Level, Master Suite, Basement.

4.2.4.2. For Dwelling Units and Sleeping Units not within a Dwelling or Townhouse, the unit's location:

4.2.4.2.1. The top floor, mid-level floor, or bottom floor of the building, and,

4.2.4.2.2. Either a corner unit or middle unit that is between two other units.

4.2.4.3. The design basis for the heat gain and heat loss loads: ACCA Manual J v8, 2013; ACCA Manual J v8, 2016; 2017 ASHRAE Fundamentals; or per the Authority Having Jurisdiction.

4.2.4.4. Whether the loads for the zone were calculated room-by-room or as a single block.

4.2.4.5. The indoor heating design temperature and indoor cooling design temperature used.

4.2.4.6. The outdoor heating design temperature and outdoor cooling design temperature used. If located in the United States, then also the county and state, or U.S. territory, that the design was completed for.

4.2.4.7. The number of occupants in the zone.

4.2.4.8. The total occupant internal gains in the zone.

4.2.4.9. The total non-occupant internal gains in the zone.

4.2.4.10. The Conditioned Floor Area of the zone.

4.2.4.11. The window area of the zone.

4.2.4.12. The solar heat gain coefficient value used in the greatest amount of window area in the zone.

4.2.4.13. The nominal R-value of the insulation [11] used in the greatest amount of above-grade wall area in the zone.

4.2.4.14. The nominal R-value of the insulation used in the greatest amount of ceiling area in the zone.

4.2.4.15. The infiltration rate of the zone.

4.2.4.16. The time-averaged mechanical Ventilation airflow rate of the zone.

4.2.4.17. The calculated sensible, latent, and total heat gain at design conditions for one or more orientations for the zone.

4.2.4.18. The difference between the maximum and minimum total heat gain at design conditions across the orientations specified in Section 4.2.4.17.

4.2.4.19. The calculated total heat loss at design conditions of the zone.

4.2.5. Specifications for all HVAC Systems serving the Dwelling to be rated, consisting of the following for each HVAC System:

[11] (Informative Note) If both cavity and continuous insulation are used, the nominal R-value equals the sum of nominal R-value of the cavity and continuous insulation.

4.2.5.1. A unique name or identifier for the HVAC system.

4.2.5.2. The name of the heated or cooled zone(s) [12] that the HVAC system serves.

4.2.5.3. An equipment overview, consisting of the following for each piece of equipment:

4.2.5.3.1. The equipment type: Air Conditioner, Boiler, Furnace, Heat Pump, or Other Equipment Type.

4.2.5.3.2. The equipment manufacturer(s) and model number(s) [13].

4.2.5.3.3. The AHRI Reference Number of the equipment or if an AHRI Reference Number is not available, OEM-provided documentation shall be collected with the rated efficiency of the equipment. If the equipment contains multiple components, the rated efficiency shall reflect the specific combination of indoor and outdoor components, along with confirmation from the OEM that the two components are designed to be used together.

4.2.5.3.4. If the equipment type is an Air Conditioner, Furnace, or Heat Pump, then the Blower Fan motor type: Permanent Split Capacitor (PSC), Electronically Commutated Motor (ECM), or Other Motor Type.

4.2.5.3.5. If the equipment type is an Air Conditioner, Furnace, or Heat Pump, then the Blower Fan speed type: single-speed, two-speed, or variable-speed [14].

4.2.5.3.6. If the equipment type is an Air Conditioner or Heat Pump, then the compressor speed type: single-speed, two-speed, or variable-speed.

4.2.5.3.7. If the equipment type is an Air Conditioner or Heat Pump, then whether it is also a Mini-Split Air Conditioner, Mini-Split Heat Pump, Multi-Split Air Conditioner, or Multi-Split Heat Pump.

4.2.5.3.8. If the equipment type is a Heat Pump, then the ratio of its maximum rated capacity relative to its minimum rated capacity.

4.2.5.3.9. If the equipment type is an Air Conditioner or Heat Pump, then:

4.2.5.3.9.1. The metering device type: piston or capillary tube, Thermal Expansion Value (TXV), or Electronic Expansion Valve (EEV).

4.2.5.3.9.2. If the metering device type in Section 4.2.5.3.9.1 is TXV or EEV, then the OEM-specified subcooling target at the service valve.

[12] (Informative Note) Examples of zones include Whole Dwelling, Upper Level, Lower Level, Basement.

[13] (Informative Note) For equipment types that include both an evaporator/fan-coil and a condenser, include the manufacturer and model number for both components.

[14] (Informative Note) While equipment typically has multiple speed settings to select from during installation, this parameter is related to the number of operational speeds that the system is capable of. Single-speed indicates a system that operates at no more than one speed setting each for heating mode and cooling mode. Two-speed indicates a system that can operate at no more than two speeds each for heating mode and cooling mode. Variable-speed indicates a system that can operate at more than two speeds.

4.2.5.3.10. If the equipment type is an Air Conditioner or Heat Pump, then the equipment's rated cooling efficiency [15].

4.2.5.3.11. If the equipment type is an Air Conditioner or Heat Pump, then the latent, sensible, and total cooling capacity of the equipment at design conditions, from OEM expanded performance data.

4.2.5.3.12. If the equipment type is an Air Conditioner or Heat Pump, then the Cooling Sizing Percentage, calculated using Equation 2:

$$Cooling\ Sizing\ Percentage = \frac{Total\ Cooling\ Capacity}{Total\ Heat\ Gain} \quad (2)$$

Where:

Total Cooling Capacity = The total cooling capacity of the specified equipment at design conditions, as reported in Section 4.2.5.3.11.

Total Heat Gain = The maximum total heat gain among the specified orientations reported in Section 4.2.4.17.

4.2.5.3.13. If the equipment type is a Heat Pump, then the Climate Condition, either A or B.

4.2.5.3.14. If a Condition B Climate is reported in Section 4.2.5.3.13, then the Sensible Heat Ratio shall be calculated and reported using Equation 3:

$$Sensible\ Heat\ Ratio = \frac{Sensible\ Cooling\ Load}{Total\ Cooling\ Load} \quad (3)$$

Where:

Sensible Cooling Load = The sensible cooling load of the maximum total cooling load among the specified orientations reported in Section 4.2.4.17.

Total Cooling Load = The maximum total cooling load among the specified orientations reported in Section 4.2.4.17.

4.2.5.3.15. If a Condition B Climate is reported in Section 4.2.5.3.13 and the Dwelling to be rated is located in the United States, then the HDD_{65}/CDD_{50} Ratio, as determined using Appendix A for the county and state, or U.S. territory, reported in Section 4.2.4.6.

4.2.5.3.16. If the equipment type is a Boiler, Furnace, or Heat Pump, then the equipment's rated heating efficiency.

4.2.5.3.17. If the equipment type is a Boiler or Furnace, then the heating capacity type: single-stage, two-stage, or modulating.

[15] (Informative Note) For example, if the metric for the rated efficiency of the equipment is SEER, then its SEER rating shall be reported; if the metric is EER, then its EER rating shall be reported; if both SEER and EEER, then both rated values shall be reported.

4.2.5.3.18. If the equipment type is a Heat Pump, then the heating capacity at 17 °F (-8 °C) and 47 °F (8 °C).

4.2.5.3.19. If the equipment type is a Boiler or Furnace, then the heating output capacity.

4.2.5.3.20. If the equipment type is a Boiler or Furnace, then the Heating Sizing Percentage, calculated using the Equation 4:

$$Heating\ Sizing\ Percentage = \frac{Heating\ Output\ Capacity}{Total\ Heat\ Loss} \quad (4)$$

Where:

Heating Output Capacity = The heating output capacity of the specified equipment, as reported in Section 4.2.5.3.19 [16].

Total Heat Loss = The total heat loss reported in Section 4.2.4.19.

4.2.5.3.21. If the equipment type is a Boiler or Furnace, then the venting type, either natural draft, mechanically drafted, or direct vented.

4.2.5.4. The specified performance rating and metric [17] of the filter, if one or more will be installed.

4.2.5.5. A duct system design overview, if a duct system will be installed, consisting of the following:

4.2.5.5.1. The design Blower Fan airflow, expressed in cubic feet per minute or cubic meters per second of air with a density of 0.075 pounds per cubic feet (1.201 kg per cubic meter) [18]:

4.2.5.5.1.1. In cooling mode if the equipment type is an Air Conditioner or Heat Pump.

4.2.5.5.1.2. In heating mode if the equipment type is a Furnace or Heat Pump.

4.2.5.5.2. The design Blower Fan speed setting [19]:

4.2.5.5.2.1. In cooling mode if the equipment type is an Air Conditioner or Heat Pump.

4.2.5.5.2.2. In heating mode if the equipment type is a Furnace or Heat Pump.

[16] (Informative Note) For two-stage or modulating equipment, the heating output capacity represents the highest rated output of the equipment.

[17] (Informative Note) For example, MERV or FPR.

[18] (Informative Note) Airflow at this air density is often referred to as Standard CFM (SCFM) or Standard CMS (SCMS) and represents air at 68°F, 50% relative humidity, and at a barometric pressure of 29.92" Hg.

[19] (Informative Note) This is the OEM setting that corresponds with the design Blower Fan airflow. Common examples include low, medium-low, medium, medium-high, and high, but also may be defined in terms of dip-switch settings or other classifications.

4.2.5.5.3. The design external static pressure [20].

4.2.5.5.4. The individual room-by-room names and design airflows and the sum of the design airflows across all rooms.

4.3. **Evaluation of Design Information**. The design documentation collected in Section 4.2 shall be reviewed to verify that all required information has been provided. In addition, the Dwelling to be rated [21] shall be compared to the design documentation to verify that the following criteria have been met.

4.3.1. If a Dwelling or Townhouse, or Dwelling Unit or Sleeping Unit within, is to be rated, then the following criteria shall be met in addition to the criteria in Section 4.3.4:

4.3.1.1. The name of the Architectural Plan or unique address of the Dwelling to be rated matches that used in the HVAC design, as documented in Section 4.2.2.4.1.1.

4.3.1.2. Any Architectural Option(s) used in the Dwelling to be rated match those used in the HVAC design or are in the list of option(s) that the design can be used with, as documented in Section 4.2.2.4.1.2.

4.3.1.3. The Conditioned Floor Area of each zone in the Dwelling to be rated is between 300 square feet smaller and 100 square feet larger than the area in the HVAC design, as documented in Section 4.2.4.10.

4.3.1.4. The window area of each zone in the Dwelling to be rated is between 60 square feet smaller and 15 square feet larger than the area in the HVAC Design, as documented in Section 4.2.4.11, or for zones with > 500 square feet of window area, between 12% smaller and 3% larger.

4.3.1.5. The Front Orientation of the Dwelling to be rated matches one of the orientations included in the orientation-specific heat gains documented in Section 4.2.4.17.

4.3.1.6. The difference between the maximum and minimum total heat gain for each zone, as documented in Section 4.2.4.18, is ≤ 6 kBtuh.

4.3.1.7. The heating and cooling loads have been calculated room-by-room, as documented in Section 4.2.4.4.

4.3.2. If a Dwelling Unit or Sleeping Unit not within a Dwelling or Townhouse is to be rated, and the maximum total heat gain across orientations documented in Section 4.2.4.17 is ≤18 kBTUh, then the following criteria shall be met in addition to the criteria in Section 4.3.4:

4.3.2.1. The name of the unique identifier for the building that the unit is within matches that used in the HVAC design, as documented in Section 4.2.2.4.2.1.

[20] (Informative Note) This is the sum of the supply-side and return-side static pressure, corresponding to the mode with the higher design Blower Fan airflow.

[21] (Normative Note) While an initial review may be completed prior to construction, ultimately the Dwelling as constructed shall be compared to the design documentation to verify that the criteria have been met.

4.3.2.2. The name of the Architectural Plan of the unit to be rated meets one of the following conditions:

4.3.2.2.1. Matches that used in the HVAC design, as documented in Section 4.2.2.4.2.2.

4.3.2.2.2. Is included in the list of Architectural Plans that the HVAC design can be used with, as documented in Section 4.2.2.4.2.2, and the Architectural Plan used in the HVAC design has the largest Conditioned Floor Area among the plans listed.

4.3.2.3. Any Architectural Option(s) used in the unit to be rated meets one of the following conditions:

4.3.2.3.1. Match those used in the HVAC design, as documented in Section 4.2.2.4.2.3.

4.3.2.3.2. Are included in the list of Architectural Options that the HVAC design can be used with, as documented in Section 4.2.2.4.2.3, and the Architectural Options used in the HVAC design have the largest Conditioned Floor Area among the options listed.

4.3.2.4. The window area of each zone in the Dwelling Unit or Sleeping Unit to be rated is less than or equal to the area in the HVAC Design, as documented in Section 4.2.4.11.

4.3.2.5. The location of the unit to be rated meets one of the following conditions:

4.3.2.5.1. Matches that used in the HVAC design, as documented in Section 4.2.4.2 [22].

4.3.2.5.2. The unit location, as documented in Section 4.2.4.2, is the top floor and a corner unit.

4.3.2.6. Orientation-specific total heat gains have been documented for all eight orientations in Section 4.2.4.17.

4.3.3. If a Dwelling Unit or Sleeping Unit not within a Dwelling or Townhouse is to be rated, and the maximum total heat gain across orientations documented in Section 4.2.4.17 is >18 kBTUh, then the following criteria shall be met in addition to the criteria in Section 4.3.4:

4.3.3.1. The name of the unique identifier for the building that the unit is within matches that used in the HVAC design, as documented in Section 4.2.2.4.2.1.

4.3.3.2. The name of the Architectural Plan of the unit to be rated matches that used in the HVAC design, as documented in Section 4.2.2.4.2.2.

4.3.3.3. Any Architectural Option(s) used in the unit to be rated match those used in the HVAC design or are included in the list of Architectural Option(s) that the design can be used with, as documented in Section 4.2.2.4.2.3.

[22] (Normative Note) The top floor, middle floor, or bottom floor and whether the unit is a corner unit or middle unit.

4.3.3.4. The Conditioned Floor Area of each zone in the Dwelling Unit or Sleeping Unit to be rated is between 300 square feet smaller and 100 square feet larger than the area in the HVAC design, as documented in Section 4.2.4.10.

4.3.3.5. The window area of each zone in the Dwelling Unit or Sleeping Unit to be rated is between 60 square feet smaller and 15 square feet larger than the area in the HVAC Design, as documented in Section 4.2.4.11, or for zones with > 500 square feet of window area, between 12% smaller and 3% larger.

4.3.3.6. The Front Orientation of the Dwelling Unit or Sleeping Unit to be rated matches one of the orientations included in the orientation-specific heat gains documented in Section 4.2.4.17.

4.3.3.7. The difference between the maximum and minimum total heat gain for each zone, as documented in Section 4.2.4.18, is ≤ 6 kBtuh.

4.3.4. For all Dwellings, Townhouses, Dwelling Units, and Sleeping Units, the following criteria shall be met:

4.3.5. The indoor design temperatures used in the loads, as documented in Section 4.2.4.5, equals 70 °F (21 °C) for the heating season and 75 °F (24 °C) for the cooling season.

4.3.6. If the Dwelling to be rated is located in the U.S., then the cooling season and heating season outdoor design temperatures used in the loads, as documented in Section 4.2.4.6, shall not exceed the limits defined in Appendix A.

4.3.7. The number of occupants in the Dwelling to be rated, which shall be calculated using Equation 5, are within ± 2 of the sum of the occupants used in the loads across all zones, as documented in Section 4.2.4.7.

$$Occupants = Number\ of\ Bedrooms + 1 \qquad (5)$$

4.3.8. The solar heat gain coefficient value used in the greatest amount of window area for each zone in the Dwelling to be rated is within ± 0.1 of the value used in the loads, as documented in Section 4.2.4.12.

4.3.9. The nominal R-value of the insulation [23] used in the greatest amount of above-grade wall area for each zone in the Dwelling to be rated is within ± R-2 of the value used in the loads, as documented in Section 4.2.4.13.

4.3.10. The nominal R-value of the insulation used in the greatest amount of ceiling area for each zone in the Dwelling to be rated is within ± R-4 of the value used in the loads, as documented in Section 4.2.4.14.

4.3.11. The infiltration rate of the Dwelling to be rated is within ± 2.0 ACH50 of the value used in the loads for each zone, as documented in Section 4.2.4.15.

4.3.12. The sum of the design's time-averaged mechanical Ventilation airflow rates across all Ventilation zones, as documented in Section 4.2.3.6.5, equals the sum

[23] (Informative Note) If both cavity and continuous insulation are used, the nominal R-value equals the sum of nominal R-value of the cavity and continuous insulation.

used in the loads across all heated and cooled zones, as documented in Section 4.2.4.16.

4.3.13. Each HVAC System in the Dwelling to be rated serves the heated or cooled zone(s) documented in Section 4.2.5.2 [24].

4.3.14. Each HVAC System in the Dwelling to be rated matches the equipment type specified in Section 4.2.5.3.1.

4.3.15. For Air Conditioner and Heat Pump equipment, the Cooling Sizing Percentage, calculated using Equation 2, matches the Cooling Sizing Percentage value reported in Section 4.2.5.3.12.

4.3.16. For Boiler and Furnace equipment, the Heating Sizing Percentage, calculated using Equation 4, matches the Heating Sizing Percentage value reported in Section 4.2.5.3.20.

4.3.17. For Heat Pump equipment, if Climate Condition B is reported in Section 4.2.5.3.13, then the Sensible Heat Ratio, calculated using Equation 3, is ≥ 95% and the HDD_{65}/CDD_{50} Ratio, as determined using Appendix A for the county and state, or U.S. territory, reported in Section 4.2.4.6 is ≥ 2.0.

4.3.18. The sum of the design airflows across all rooms reported in Section 4.2.5.5.4 equals the mode with the higher design Blower Fan airflow, as reported in Section 4.2.5.5.1.

5. Task 2: Evaluation of the Total Duct Leakage.

5.1. **Overview**. This procedure shall be completed by first meeting the prerequisites in Section 5.2, then measuring the total duct leakage per Section 5.3, and finally designating the total duct leakage grade per Section 5.4.

As an alternative to measuring the total duct leakage per Section 5.3, if an Independent Verification Report is obtained containing the measured total duct leakage of the Forced-Air HVAC System under test, and the report is approved for use by an entity adopting and requiring the use of this Standard, then the reported value shall be permitted to be used.

If an Independent Verification Report is obtained, the reported value shall be used to designate the total duct leakage grade per Section 5.4.

5.2. **Prerequisites**. The HVAC design of the Dwelling to be rated shall have been evaluated in accordance with Section 4: all the required design documentation defined in Section 4.2 shall have been collected, and shall have been reviewed and verified to be in accordance with Section 4.3. If the design has not been evaluated, then the total duct leakage shall not be evaluated.

5.3. **Procedure to Measure Total Duct Leakage.** The total duct leakage of the Forced-Air HVAC system under test shall be measured in accordance with ANSI/RESNET/ICC 380 and recorded. Exception: If the total amount of supply ductwork or distribution building

[24] (Informative Note) For example, if the design indicates that System A is intended to serve the "Upper Level" zone, then it shall be verified that System A does serve this zone.

cavities does not exceed 10 ft. in length and is entirely in Conditioned Space Volume, then measurement of total duct leakage is not required [25].

5.4. **Designating the Total Duct Leakage Grade**

5.4.1. Grade I shall be designated and recorded for total duct leakage if the Forced-Air HVAC System has a total amount of supply ductwork or distribution building cavities that does not exceed 10 ft. in length and is entirely in Conditioned Space Volume, or if the total leakage does not exceed the limits in Table 1a or Table 1b. As an alternative, if the total duct leakage does not exceed the limits specified within ANSI/ACCA QI 5 Section 5.1.1a, then Grade I shall also be designated.

Table 1a – Duct Leakage Limits for Grade I (IP)

Time of Test	# of Returns	Leakage Limit (CFM at 25 Pa)
Rough-In	≤ 3	The greater of ≤ 4 per 100 ft^2 of CFA or ≤ 40
Rough-In	≥ 3	The greater of ≤ 6 per 100 ft^2 of CFA or ≤ 60
Final	≤ 3	The greater of ≤ 8 per 100 ft^2 of CFA or ≤ 80
Final	≥ 3	The greater of ≤ 12 per 100 ft^2 of CFA or ≤ 120

Table 1b – Duct Leakage Limits for Grade I (SI)

Time of Test	# of Returns	Leakage Limit (CMS at 0.001 IWC)
Rough-In	≤ 3	The greater of ≤ 0.0019 per 9.29 m^2 of CFA or ≤ 0.019
Rough-In	≥ 3	The greater of ≤ 0.0028 per 9.29 m^2 of CFA or ≤ 0.028
Final	≤ 3	The greater of ≤ 0.0038 per 9.29 m^2 of CFA or ≤ 0.038
Final	≥ 3	The greater of ≤ 0.0057 per 9.29 m^2 of CFA or ≤ 0.057

5.4.2. Grade II shall be designated, and recorded, if the total leakage does not exceed the limits in Table 2a or Table 2b.

Table 2a – Duct Leakage Limits for Grade II (IP)

Time of Test	# of Returns	Leakage Limit (CFM at 25 Pa)
Rough-In	≤ 3	The greater of ≤ 6 per 100 ft^2 of CFA or ≤ 60
Rough-In	≥ 3	The greater of ≤ 8 per 100 ft^2 of CFA or ≤ 80
Final	≤ 3	The greater of ≤ 10 per 100 ft^2 of CFA or ≤ 100

[25] (Informative Note) Systems that fall under this exception receive a Grade I designation per Section 5.4.

Final	≥ 3	The greater of ≤ 14 per 100 ft^2 of CFA or ≤ 140

Table 2b – Duct Leakage Limits for Grade II (SI)

Time of Test	# of Returns	Leakage Limit (CMS at 0.001 IWC)
Rough-In	< 3	The greater of ≤ 0.0028 per 9.29 m^2 of CFA or ≤ 0.028
Rough-In	≥ 3	The greater of ≤ 0.0038 per 9.29 m^2 of CFA or ≤ 0.038
Final	< 3	The greater of ≤ 0.0047 per 9.29 m^2 of CFA or ≤ 0.047
Final	≥ 3	The greater of ≤ 0.0066 per 9.29 m^2 of CFA or ≤ 0.066

5.4.3. Unless the exception in Section 5.3 has been met, Grade III shall be designated and recorded if the total duct leakage has not been measured or has been measured and exceeds the limits in Section 5.4.2.

6. Task 3: Evaluation of the Blower Fan Volumetric Airflow.

6.1. Overview. This procedure shall be completed by first meeting the prerequisites in Section 6.2, then preparing the Dwelling and Forced-Air HVAC System for testing, per Section 6.3, then measuring the Blower Fan volumetric airflow using Section 6.4, 6.5, 6.6, or 6.7, consistent with the guidance in Sections 6.2.1.1 through 6.2.1.4, and finally designating the Blower Fan Volumetric Airflow grade per Section 6.8.

As an alternative to completing the procedures defined in Sections 6.4 through 6.7, if the installed equipment contains an on-board diagnostic system that is capable of reporting the Blower Fan volumetric airflow and that is approved for use by an entity adopting and requiring the use of this Standard, then the reported value shall be permitted to be used.

As an alternative to completing the procedures defined in Sections 6.3 through 6.7, if an Independent Verification Report is obtained containing the measured Blower Fan volumetric airflow of the Forced-Air HVAC System under test, and the report is approved for use by an entity adopting and requiring the use of this Standard, then the reported value shall be permitted to be used.

If an on-board diagnostic system is used or Independent Verification Report is obtained, the reported value shall be used to designate the Blower Fan Volumetric Airflow grade per Section 6.8.

As an alternative to completing the procedures defined in Sections 6.4 through 6.7, the following are approved for use:

6.1.1. Section 8.6 from ASTM E1554-13,

6.1.2. Normative Appendix A from ANSI/ASHRAE Standard 152-2004,

6.1.3. Section RA3.3 from the 2016 Reference Appendices for the 2016 Building Energy Efficiency Standards of the California Energy Commission.

6.2. **Prerequisites**. Prior to evaluating the Blower Fan volumetric airflow, all the following requirements shall have been met.

6.2.1. The total duct leakage shall have been evaluated in accordance with Section 5, including all prerequisites in Section 5.2. The test procedure used to evaluate the airflow shall be selected according to Sections 6.2.1.1 through 6.2.1.4.

6.2.1.1. If the Forced-Air HVAC System has a total amount of supply ductwork or distribution building cavities that does not exceed 10 ft. in length and is entirely in Conditioned Space Volume, then measurement of the airflow shall not be required and the volumetric airflow grade shall be designated in accordance with Section 6.8.

6.2.1.2. If the Forced-Air HVAC System does not meet the conditions in Section 6.2.1.1 and the total duct leakage has been designated Grade I, the airflow is permitted to be measured using the Pressure Matching Method (Section 6.4), a Flow Grid (Section 6.5), a Flow Hood (Section 6.6), or the OEM Static Pressure Table Method (Section 6.7) [26].

6.2.1.3. If the total duct leakage has been designated Grade II, the airflow is permitted to be measured using the Pressure Matching Method with Method 1 Installation (Section 6.4), a Flow Grid (Section 6.5), or the OEM Static Pressure Table Method (Section 6.7).

6.2.1.4. If the total duct leakage has been designated Grade III, then Blower Fan volumetric airflow shall not be evaluated.

6.2.2. **Verification of HVAC Components**. If the following components are included in the design of the Forced-Air HVAC System under test, they shall be verified to be present. If these components have not yet been installed, then the test shall not be conducted. The additional requirements defined in Section 6.2.2.1 shall also be met.

6.2.2.1. HVAC equipment. The specified manufacturer(s) and model number(s) of the equipment in the Forced-Air HVAC System under test matches the installed equipment or supplemental documentation has been collected as defined in Section 4.2.5 and verified in accordance with Section 4.3. If the installed equipment does not match the specified equipment in the original or supplemental documentation, then Blower Fan volumetric airflow shall not be evaluated.

6.2.2.2. Dwelling-Unit Mechanical Ventilation Systems integrated with the HVAC System.

6.2.2.3. Distribution systems, including supply registers and return grilles.

6.2.2.4. An air filter with the same performance rating and metric [27] as reported in Section 4.2.5.4. [28]

6.3. Procedure to Prepare the Dwelling and Forced-Air HVAC System

[26] (Informative Note) Grade I total duct leakage is required to ensure that leakage in the return-side of the system is sufficiently small that it does not significantly impact the measured volumetric airflow of the Blower Fan.
[27] (Informative Note) Examples of performance ratings include MERV and FPR.
[28] (Informative Note) Use of a new clean filter is recommended to ensure maximum airflow.

6.3.1. **Position of Dampers**. Dampers within the duct system of the Forced-Air HVAC System under test shall be treated as follows:

6.3.1.1. Non-motorized dampers [29] that connect the Conditioned Space Volume [30] to the exterior or to Unconditioned Space Volume shall be left in their as-found positions.

6.3.1.2. Motorized dampers that connect the Conditioned Space Volume [30] to the exterior or to Unconditioned Space Volume shall be placed in their closed positions and shall not be further sealed.

6.3.1.3. Balancing dampers shall be left in their as-found position.

6.3.2. **Position of Registers**. Supply registers shall be left in their as-found position.

6.3.3. **Ventilation Openings**. Non-dampered Ventilation openings within the duct system of intermittently or continuously operating Dwelling-Unit Mechanical Ventilation Systems, including Ventilation systems that use the Blower Fan of the Forced-Air HVAC System, shall not be sealed.

6.3.4. **Settings for Fans Other than the HVAC System Blower Fan.**

6.3.4.1. Any fans [31] that could change the pressure in either the Conditioned Space Volume or, if present, an Unconditioned Space Volume containing the Forced-Air HVAC System under test, shall be turned off.

6.3.4.2. If a Dwelling-Unit Mechanical Ventilation System contains a fan, other than the Blower Fan of the Forced-Air HVAC System under test [32], that is interconnected with the Forced-Air HVAC System under test, it shall be turned off.

6.3.5. **Settings for HVAC System**. If the Forced-Air HVAC System contains an Air Conditioner, then the test shall be conducted in cooling mode. If the Forced-Air HVAC System contains a Heat Pump, then the test shall either be conducted in the mode with the higher design airflow, as reported in Section 4.2.5.5.1, or in both the heating and cooling mode.

6.3.5.1. Cooling Mode.

6.3.5.1.1. If the outdoor temperature is < 55 °F (13 °C), then power to the compressor shall be cut off [33] for the duration of the test.

6.3.5.1.2. The thermostat shall be set to cooling mode and the setpoint temperature adjusted as low as possible [34].

[29] (Informative Note) For example, pressure-activated operable dampers, fixed dampers.
[30] (Informative Note) This includes space conditioning duct systems.
[31] (Informative Note) For example, bathroom fans, clothes dryers, kitchen vent hood, attic fan, water heater power-venting fans, or other Forced-Air HVAC System.
[32] (Informative Note) For example, an inline fan, an ERV system, or an HRV system.
[33] (Informative Note) For example, by flipping the circuit breaker for the compressor or pulling its disconnect switch.
[34] (Informative Note) If the Blower Fan speed type is not single-speed, as reported in Section 4.2.5.3.5, then the system can operate at two or more speeds each for heating mode and cooling mode. Consult manufacturer instructions to ensure that the Blower Fan is operating at the highest design speed.

6.3.5.1.3. If the Forced-Air HVAC System serves multiple zones, as reported in Section 4.2.5.2, then manufacturer instructions shall be followed to ensure that all zones in the Forced-Air HVAC System are calling for the required mode for testing.

6.3.5.2. Heating Mode.

6.3.5.2.1. The thermostat shall be set to heating mode and the setpoint temperature adjusted as high as possible [34].

6.3.5.2.2. If the Forced-Air HVAC System serves multiple zones, as reported in Section 4.2.5.2, then manufacturer instructions shall be followed to ensure that all zones in the Forced-Air HVAC System are calling for the required mode for testing.

6.4. Pressure Matching Method

6.4.1. Equipment Needed. The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.4.1.1. Manometer. A device that measures pressure difference with an accuracy of ± 1% of the reading or ± 0.25 Pa (0.0010 IWC), whichever is greater.

6.4.1.2. Static Pressure Probe. A pressure measurement device capable of measuring the static pressure within a duct system.

6.4.1.3. Fan Flowmeter. A tool comprised of a variable speed fan and a Manometer that can convert fan pressure differentials into volumetric airflow. The fan shall be capable of moving air into the Forced-Air HVAC System to achieve or approach the pressure of its operating conditions, and measure volumetric airflow with an accuracy equal to or better than ± 3% of the measured flow + 7 CFM (3.3 L/s or 0.0033 CMS).

6.4.1.4. Duct plugs, UL-181 listed tape, or other means of sealing duct holes as approved by the Authority Having Jurisdiction.

6.4.2. Procedure to Conduct Pressure Matching Airflow Test

6.4.2.1. A hole shall be created or located in the supply side of the Forced-Air HVAC System for the placement of the Static Pressure Probe. Moving in the direction of airflow the hole shall be located after any heating and/or cooling equipment but before the first supply duct run. The hole shall not be in flexible ductwork. If the hole cannot be located or created in the supply side, then one of the other airflow test procedures shall be used if airflow is to be measured.

6.4.2.2. The Static Pressure Probe shall be inserted into the hole, positioned according to its manufacturer's instructions, affixed in place so it will not move during the test [35], connected to the Manometer, and then the Manometer shall be turned on.

6.4.2.3. The Forced-Air HVAC System shall run for 10 minutes continuously.

[35] (Informative Note) For example, using a magnetic mount.

6.4.2.4. The average pressure difference between the Static Pressure Probe and the space where the Forced-Air HVAC System is located, Psop, shall be measured over at least a 10-second period. If a negative reading is found, another measurement location shall be created or located, or another procedure shall be selected if airflow is to be measured. If the values are fluctuating by more than 0.05 IWC (12.4 Pa), this turbulent condition shall be noted.

6.4.2.5. One of two methods shall be used to attach the Fan Flowmeter to the Forced-Air HVAC System. Section 6.4.2.5.1 is permitted to be used for all Forced-Air HVAC Systems. Section 6.4.2.5.2 is only permitted to be used for a Forced-Air HVAC System with a duct system that has a single return grille.

6.4.2.5.1. Method 1 Installation: At the Blower Compartment. The Blower Fan shall be turned off, the blower access panel removed, and an air barrier inserted between the return duct system and the Blower Fan inlet [36] to ensure that no air enters the blower compartment from the return duct system. The Fan Flowmeter shall be attached to the blower compartment access, with the connection between the Fan Flowmeter and blower compartment temporarily sealed. If the Fan Flowmeter is to be connected to the blower compartment outside the Conditioned Space Volume, then the door or access panel between the Conditioned Space Volume and the blower compartment location shall be opened. The Blower Fan shall then be turned back on.

6.4.2.5.2. Method 2 Installation: At the Return Grille. The Fan Flowmeter shall be attached to the return grille. The area of the return grille not covered by the connection to the Fan Flowmeter shall be temporarily sealed. Any filter in the return duct shall be removed.

6.4.2.6. The Fan Flowmeter shall be turned on and its airflow adjusted until the static pressure matches Psop, or if Psop cannot be reached, the Fan Flowmeter shall be adjusted to maximum airflow.

6.4.2.7. The average airflow through the Fan Flowmeter, Qtest, and the average coincident pressure difference, Ptest, shall be shall be measured over at least a 10-second period. For a Dwelling located at an elevation >2,500 ft., Qtest shall be corrected to equivalent airflow at sea level using the procedure specified by the Fan Flowmeter manufacturer. Qtest is also permitted to be corrected for elevations ≤2,500 ft and to equivalent airflow at 68 °F (21.1 °C) for a more accurate comparison to the design airflow.

6.4.2.8. The measured airflow, Qtest, and coincident plenum pressure, Ptest, shall be used to determine the Blower Fan airflow at operating conditions, Qop, using Equation 6 and recorded:

$$Q_{op} = Q_{test} \times \left(\frac{P_{sop}}{P_{test}}\right)^{0.5} \quad (6)$$

[36] (Informative Note) For example, blocked at the filter slot

Where:

Qop = The Blower Fan airflow at operating conditions

Qtest = The Fan Flowmeter airflow measured in Section 6.4.2.7

Psop = The pressure in the supply side during operation measured in Section 6.4.2.4

Ptest = The pressure in the supply side during testing measured in Section 6.4.2.7

6.4.2.9. The Fan Flowmeter shall be turned off and removed; the air barrier removed, if inserted; the blower access panel replaced, if removed; and the supply side hole shall be sealed.

6.4.2.10. If the procedure to measure Blower Fan watt draw in Section 7 or to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

6.5. Flow Grid

6.5.1. Equipment Needed.

The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.5.1.1. Manometer. A device that measures pressure difference with an accuracy of ± 1% of the reading or ± 0.25 Pa (0.0010 IWC), whichever is greater.

6.5.1.2. Static Pressure Probe. A pressure measurement device capable of measuring the static pressure within a duct system.

6.5.1.3. Flow Grid. A flow measurement device designed to temporarily replace the filter in the Forced-Air HVAC System and capable of measuring the volumetric airflow through it with an accuracy equal to or better than ± 7% of the measured flow.

6.5.1.4. Duct plugs, UL-181 listed tape, or other means of sealing duct holes as approved by the Authority Having Jurisdiction.

6.5.2. Procedure to Conduct Flow Grid Airflow Test

6.5.2.1. A hole shall be created or located in the supply side of the Forced-Air HVAC System for the placement of the Static Pressure Probe. Moving in the direction of airflow the hole shall be located after any heating and/or cooling equipment but before the first supply duct run. The hole shall not be in flexible ductwork. If the hole cannot be located or created in the supply side, then one of the other airflow test procedures shall be used if airflow is to be measured.

6.5.2.2. The Static Pressure Probe shall be inserted into the hole, positioned according to its manufacturer's instructions, affixed in place so it will not move during the test [37], connected to the Manometer, and then the Manometer shall be turned on.

6.5.2.3. The Forced-Air HVAC System shall run for 10 minutes continuously.

[37] (Informative Note) For example, using a magnetic mount.

6.5.2.4. The average pressure difference between the Static Pressure Probe and the space where the Forced-Air HVAC System is located, Psop, shall be measured over at least a 10-second period. If a negative reading is found, another measurement location shall be created or located, or another procedure shall be selected if airflow is to be measured. If the values are fluctuating by more than 0.05 IWC (12.4 Pa), this turbulent condition shall be noted.

6.5.2.5. The filter shall be replaced with the appropriate flow plate of the Flow Grid. The flow plate shall be in a location where all of the Blower Fan airflow will flow through the Flow Grid. In addition, the flow plate shall be temporarily sealed in place so that air must go through, rather than around, the plate. Flow Grid manufacturer instructions shall be followed to ensure proper setup. If there are multiple filters in the duct system [38], a Flow Grid shall be installed at each filter location so that simultaneous measurements are taken, representing total system airflow.

6.5.2.6. The average static pressure at the hole, Ptest, shall be measured over at least a 10-second period.

6.5.2.7. Using the pressure reading from the flow plate, the average airflow through the Flow Grid, Qtest, shall be measured over at least a 10-second period. If multiple Flow Grids are used, Qtest shall be the sum of the flows through each of the Flow Grids. For a Dwelling located at an elevation >2,500 ft., Qtest shall be corrected to equivalent airflow at sea level using the procedure specified by the Flow Grid manufacturer. Qtest is also permitted to be corrected for elevations ≤2,500 ft and to equivalent airflow at 68 °F (21.1 °C) for a more accurate comparison to the design airflow.

6.5.2.8. The measured airflow, Qtest, and coincident plenum pressure, Ptest, shall be used to determine the Blower Fan airflow at operating conditions, Qop, using Equation 7 and recorded:

$$Q_{op} = Q_{test} \times \left(\frac{P_{sop}}{P_{test}}\right)^{0.5} \quad (7)$$

Where:

Qop = The Blower Fan airflow at operating conditions

Qtest = The Flow Grid airflow measured in Section 6.5.2.7

Psop = The pressure in the supply side during operation measured in Section 6.5.2.4

Ptest = The pressure in the supply side during testing measured in Section 6.5.2.6

6.5.2.9. The Flow Grid shall be removed and the filter replaced; and the supply side hole shall be sealed.

6.5.2.10. If the procedure to measure Blower Fan watt draw in Section 7 or to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor

[38] (Informative Note) For example, a system with multiple return grilles, with a filter at each grille.

shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

6.6. Flow Hood

6.6.1. **Equipment Needed**. The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.6.1.1. Flow Hood. A device consisting of a flow capture element capable of creating an airtight perimeter seal around the return grille, and an airflow meter capable of measuring the volumetric airflow through the flow capture element with an airflow range that that encompasses the design Blower Fan airflow, as reported in Section 4.2.5.5.1, at an accuracy equal to or better than ± 3% of the measured flow + 7 CFM (3.3 L/s or 0.0033 CMS).

6.6.2. Procedure to Conduct Flow Hood Airflow Test

6.6.2.1. The Forced-Air HVAC System shall run for 10 minutes continuously, after which the following procedure shall be completed for each return grille in the Forced-Air HVAC System:

6.6.2.1.1. The flow capture element of the Flow Hood shall be placed over each return grille of the Forced-Air HVAC System, ensuring that a tight perimeter seal has been created and that the flow capture area is at least as large as the return grille in all dimensions. If the flow capture area is smaller than the return grille in any dimension, then a larger flow capture element shall be used or another procedure shall be selected if airflow is to be measured.

6.6.2.1.2. The Flow Hood shall be turned on and the average airflow through the airflow meter, Qtest, shall be measured over at least a 10-second period. Manufacturer instructions to correct for the impacts of back-pressure within the Flow Hood shall be followed [39].

6.6.2.1.3. For a Dwelling located at an elevation >2,500 ft., Qtest shall be corrected to equivalent airflow at sea level using the procedure specified by the airflow measurement device manufacturer. Qtest is also permitted to be corrected for elevations ≤2,500 ft and to equivalent airflow at 68 °F (21.1 °C) for a more accurate comparison to the design airflow.

6.6.2.2. If only one return grille is present in the Forced-Air HVAC System, Qop shall equal Qtest. If multiple return grilles are present in the Forced-Air HVAC System, Qop shall be the sum of Qtest for each of the return grilles. Qop shall be recorded.

6.6.2.3. If the procedure to measure Blower Fan watt draw in Section 7 or to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

[39] (Informative Note) For example, measuring the airflow twice, once with a pressure relief flap closed and then again with the flap open. Other manufacturers may indicate that back-pressure is measured and automatically compensated for within the measurement tool.

6.7. OEM Static Pressure Table Method

6.7.1. **Equipment Needed**. The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.7.1.1. Manometer. A device that measures pressure difference with an accuracy of ± 1% of the reading or ± 0.25 Pa (0.0010 IWC), whichever is greater.

6.7.1.2. Static Pressure Probe. A pressure measurement device capable of measuring the static pressure within a duct system.

6.7.1.3. Duct plugs, UL-181 listed tape, or other means of sealing duct holes as approved by the Authority Having Jurisdiction.

6.7.2. Documentation Needed

6.7.2.1. The OEM Static Pressure Table shall be obtained and verified to match the manufacturer, model number(s), and configuration of the installed equipment [40].

6.7.3. Procedure to Conduct OEM Static Pressure Airflow Test

6.7.3.1. If the Blower Fan motor type, as reported in Section 4.2.5.3.4, is ECM or Other Motor Type, then the elevation of the system shall be verified to be ≤ 2,500 ft. Otherwise, one of the other airflow test procedures shall be used if airflow is to be measured.

6.7.3.2. The fan-speed setting of the Blower Fan shall be observed and recorded for the mode that the test will be conducted in [41]. The setting shall be verified to match one of the settings listed on the OEM Static Pressure Table.

6.7.3.3. A hole shall be located or created in the return-side of the Forced-Air HVAC system for the placement of the Static Pressure Probe. Moving in the direction of airflow, the return-side hole shall be located after the filter but before the Blower Fan. The hole shall not be in flexible ductwork. If the hole cannot be located or created in the return side, then one of the other airflow test procedures shall be used if airflow is to be measured.

6.7.3.4. A hole shall be located or created in the supply-side of the Forced-Air HVAC System for the placement of the Static Pressure Probe. For Furnaces, moving in the direction of airflow the supply-side hole shall be located after the Furnace but before the evaporator coil, if a coil is present. For Heat Pumps, moving in the direction of airflow the hole shall be located after the fan-coil but before the presence of any other components not accounted for in the OEM Static Pressure Table [42]. The hole

[40] (Informative Note) For example, furnace, fan-coil, and/or condenser manufacturer and model number(s); direction of airflow such as upflow or downflow; operating voltage; and the presence of integral electric heating elements, as applicable.

[41] (Informative Note) For example, if the test will be conducted in cooling mode, the fan-speed setting for cooling mode shall be recorded. The fan-speed setting (e.g., low, medium, high) may be indicated in a variety of ways, such as a speed tap on the motor, a wire color, or a dip-switch setting.

[42] (Informative Note) For example, if the OEM Static Pressure Table accounts for the impact of a supplemental electric heater or states that the impact is negligible, then the hole would be located after this element. In contrast, if the table does not account for the impact, then the hole would be located before this element.

shall not be in flexible ductwork. If the hole cannot be located or created in the supply side, then one of the other airflow test procedures shall be used if airflow is to be measured.

6.7.3.5. The Static Pressure Probe shall be inserted into the supply-side hole, positioned according to its manufacturer's instructions, affixed in place so it will not move during the test [43], connected to the Manometer, and then the Manometer shall be turned on.

6.7.3.6. The Forced-Air HVAC System shall run for 10 minutes continuously.

6.7.3.7. The average pressure difference between the Static Pressure Probe in the supply-side of the Forced-Air HVAC System and the space where the system is located, Psop, shall be measured over at least a 10-second period [44]. If a negative reading is found, another measurement location shall be created or located, or another procedure shall be selected if airflow is to be measured. If the values are fluctuating by more than 0.05 IWC (12.4 Pa), this turbulent condition shall be noted.

6.7.3.8. The Static Pressure Probe shall be removed from the supply-side hole and inserted into the return-side hole, positioned according to its manufacturer's instructions, and affixed in place so it will not move during the test [45].

6.7.3.9. The average pressure difference between the Static Pressure Probe in the return-side of the Forced-Air HVAC System and the space where the system is located, Prop, shall be measured over at least a 10-second period [46]. If a positive reading is found, another measurement location shall be created or located, or another procedure shall be selected if airflow is to be measured. If the values are fluctuating by more than 0.05 IWC (12.4 Pa), this turbulent condition shall be noted.

6.7.3.10. If the elevation of the system is > 2,500 ft. (762 m), then an elevation adjustment factor, ρadj, shall be calculated using Equation 8a or 8b. For elevations ≤2,500 ft, ρadj is also permitted to be calculated using Equation 8a or 8b or shall equal 1:

$$\rho adj = \frac{0.07517}{0.07517 * (1 - (0.0035666 * E)/528)\text{^}5.2553} \qquad (8a)$$

Where:

Padj = The density adjustment factor for the elevation of the system

E = Elevation above sea level (ft.)

$$\rho adj = \frac{1.2041}{1.2041 * (1 - (0.0065 * E)/293)\text{^}5.2553} \qquad (8b)$$

Where:

[43] (Informative Note) For example, using a magnetic mount.
[44] (Informative Note) Also known as supply External Static Pressure (e.g., +0.32 IWC)
[45] (Informative Note) For example, using a magnetic mount.
[46] (Informative Note) Also known as return External Static Pressure (e.g., -0.18 IWC)

Padj = The density adjustment factor for the elevation of the system

E = Elevation above sea level (m)

6.7.3.11. The total operational pressure of the system, Ptop, shall be calculated in IWC or Pa using Equation 9 [47]:

$$Ptop = \rho adj * (|Psop| + |Prop|) - Pfilter \quad (9)$$

Where:

Ptop = The total operational pressure of the system

Padj = The density adjustment factor, per Equation 8a or 8b

Psop = The supply-side operational pressure of the system

Prop = The return-side operational pressure of the system

Pfilter = The filter adjustment factor. If the OEM Static Pressure Table indicates that its airflow values were generated using equipment with a filter in place, then Pfilter shall equal 0.1 IWC (24.9 Pa). Alternatively, if the OEM Static Pressure Table indicates the actual pressure drop of the filter that was used to generate its airflow values, then Pfilter shall equal this value. If the OEM Static Pressure Table either indicates that a filter was not in place when generating its values or is ambiguous about the presence of a filter, then Pfilter shall equal 0.

6.7.3.12. The Blower Fan airflow at operating conditions, Qop, shall be determined by looking up the airflow value on the OEM Static Pressure Table that is associated with the observed fan-speed setting and measured Ptop and recorded. If Ptop does not match any of the listed values on the Blower Table, interpolation between two listed values shall be used to determine Qop. Extrapolation beyond listed values on the Blower Table shall not be used.

6.7.3.13. The supply side and return side holes shall be sealed.

6.7.3.14. If the procedure to measure Blower Fan watt draw in Section 7 or to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

6.8. Designating the Blower Fan Volumetric Airflow Grade

6.8.1. If Grade I total duct leakage has been designated and the Forced-Air HVAC System has a total amount of supply ductwork or distribution building cavities that does not exceed 10 ft. in length and is entirely in Conditioned Space Volume, then Qdev shall equal zero. Otherwise, Qdev, the deviation between the design-specified and field-measured Blower Fan volumetric airflow shall be calculated using Equation 10.

$$Q_{dev} = \frac{(Q_{op} - Q_{design})}{Q_{design}} \quad (10)$$

[47] (Informative Note) For properly designed systems, common values of total External Static Pressure range from 0.3-0.5 for fan-coil systems and Furnace systems without cooling and from 0.5-0.8 IWC for Furnaces with coils.

Where:

Qdev = The percent deviation between the design-specified and field-measured Blower Fan volumetric airflow.

Qop = The Blower Fan volumetric airflow at operating conditions, as field-measured per Section 6.4, 6.5, 6.6, or 6.7.

Qdesign = The design-specified Blower Fan volumetric airflow, per Section 4.2.5.5.1, for the test mode, heating or cooling, determined in Section 6.3.5.

6.8.2. The Blower Fan volumetric airflow grade shall be designated according to the ranges in Table 3, and recorded.

Table 3 – Grade Designations for Blower Fan Volumetric Airflow

Grade Designation	Qdev Range		
I	≤ 0 and > -15%	or	≥ 0 and < +15%
II	≤ -15% and > -25%	or	≥ +15% and < +25%
III	≤ -25%	or	≥ +25%

7. Task 4: Evaluation of the Blower Fan Watt Draw.

7.1. **Overview.** This procedure shall be completed by first meeting the prerequisites in Section 7.2, then preparing the Dwelling and Forced-Air HVAC System for testing, per Section 7.3, and then measuring Blower Fan watt draw using Section 7.4, 7.5, 7.6, or 7.7. Finally, the Blower Fan watt draw grade shall be designated per Section 7.8.

As an alternative to completing the procedures defined in Sections 7.4 through 7.7, if the installed equipment contains an on-board diagnostic system that is capable of reporting the Blower Fan watt draw and that is approved for use by an entity adopting and requiring the use of this Standard, then the reported value shall be permitted to be used.

As an alternative to completing the procedures defined in Sections 7.3 through 7.7, if an Independent Verification Report is obtained containing the measured Blower Fan watt draw of the Forced-Air HVAC System under test, and the report is approved for use by an entity adopting and requiring the use of this Standard, then the reported value shall be permitted to be used.

If an on-board diagnostic system is used or Independent Verification Report is obtained, the reported value shall be used to designate the Blower Fan watt draw grade per Section 7.8.

7.2. **Prerequisites.** Prior to evaluating the Blower Fan watt draw, the Blower Fan volumetric airflow shall have been evaluated in accordance with Section 6, including all prerequisites in Section 6.2. In addition, the Blower Fan volumetric airflow shall have been designated Grade I or II, per Section 6.8. If the Blower Fan volumetric airflow has not been evaluated or has been designated Grade III, then Blower Fan watt draw shall not be evaluated.

7.3. Procedure to Prepare the Dwelling and Forced-Air HVAC System [48]

7.3.1. If an Independent Verification Report was used to determine the Blower Fan volumetric airflow, then the procedure to prepare the Dwelling and Forced-Air HVAC System for testing defined in Section 6.3 shall be completed.

7.3.2. **Settings for HVAC System**. If the Forced-Air HVAC System contains an Air Conditioner, then the test shall be conducted in cooling mode. If the Forced-Air HVAC System contains a Heat Pump, then the test shall either be conducted in the mode with the higher design airflow, as reported in Section 4.2.5.5.1, or in both the heating and cooling mode. If the Blower Fan watt draw in Ventilation Mode is being verified, then Section 7.3.2.3 shall be followed. Blower Fan watt draw in Ventilation Mode shall not be used to designate the Blower Fan watt draw grade per Section 7.8.

7.3.2.1. Cooling Mode.

7.3.2.1.1. If the outdoor temperature is < 55 °F (13 °C), then power to the compressor shall be cut off [49] for the duration of the test.

7.3.2.1.2. The thermostat shall be set to cooling mode and the setpoint temperature adjusted as low as possible [50].

7.3.2.1.3. If the Forced-Air HVAC System serves multiple zones, as reported in Section 4.2.5.2, then manufacturer instructions shall be followed to ensure that all zones in the Forced-Air HVAC System are calling for the required mode for testing.

7.3.2.2. Heating Mode.

7.3.2.2.1. The thermostat shall be set to heating mode and the setpoint temperature adjusted as high as possible [50].

7.3.2.2.2. If the Forced-Air HVAC System serves multiple zones, as reported in Section 4.2.5.2, then manufacturer instructions shall be followed to ensure that all zones in the Forced-Air HVAC System are calling for the required mode for testing.

7.3.2.3. Ventilation Mode.

7.3.2.3.1. The thermostat shall be set to Ventilation Mode [51].

7.4. Portable Plug-In Watt Meter

[48] (Informative Note) The procedure for preparing the HVAC settings differs from the one used in the Evaluation of Blower Fan Volumetric Airflow.

[49] (Informative Note) For example, by flipping the circuit breaker for the compressor or pulling its disconnect switch.

[50] (Informative Note) If the Blower Fan speed type is not single-speed, as reported in Section 4.2.5.3.6, then the system can operate at two or more speeds each for heating mode and cooling mode. Consult manufacturer instructions to ensure that the Blower Fan is operating at the highest design speed.

[51] (Informative Note) Ventilation Mode may be indicated on the thermostat as “Fan-On”.

7.4.1. **Equipment Needed**. The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

7.4.1.1. Portable Plug-In Watt Meter. The apparatus for measuring the Blower Fan watt draw shall consist of a wattmeter capable of plugging into a standard electrical receptacle and that itself contains a receptacle for plugging devices into to measure their watt draw. The Meter shall have a true power measurement system (i.e., sensor plus data acquisition system) having an accuracy of ± 2% of reading or ± 10 watts, whichever is greater.

7.4.2. Procedure to Measure Blower Fan Watt Draw

7.4.2.1. The equipment containing the Blower Fan shall be plugged into the Portable Plug-In Watt Meter and the Portable Plug-In Watt Meter turned on.

7.4.2.2. The Forced-Air HVAC System shall run for 10 minutes continuously before completing Section 7.4.2.3 and beyond. The 10-minute period is permitted to include the time the Forced-Air HVAC System was running while conducting the procedure for evaluating the Blower Fan volumetric airflow in Section 6.

7.4.2.3. The average watt draw of the Blower Fan, Wfan, displayed on the Portable Plug-In Watt Meter shall be measured over at least a 10-second period and recorded.

7.4.2.4. The Portable Plug-In Watt Meter shall be removed, and the equipment with the Blower Fan plugged back into the receptacle.

7.4.2.5. If the procedure to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

7.5. Clamp-On Watt Meter

7.5.1. **Equipment Needed**. The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

7.5.1.1. Clamp-On Watt Meter. The apparatus shall consist of a clamp capable of being placed around an electrical wire to measure current combined with leads capable of simultaneously measuring voltage, allowing for the measurement of the Blower Fan watt draw [52]. The Meter shall have a true power measurement system (i.e., sensor plus data acquisition system) having an accuracy of ± 2% of reading or ± 10 watts, whichever is greater.

7.5.2. Procedure to Measure Blower Fan Watt Draw

7.5.2.1. This procedure shall be performed by parties with the proper training and using appropriate safety equipment. The Clamp-On Watt Meter manufacturer's operating instructions and safety instructions shall be followed.

[52] (Informative Note) Some multimeters may be capable of meeting these requirements (i.e., capable of simultaneously measuring voltage and current and calculating Blower Fan watt draw).

7.5.2.2. The Blower Fan watt draw shall be measured at one of the following locations. If neither location is available, then a different procedure shall be selected.

7.5.2.2.1. At the Service Disconnect. If a service disconnect to the equipment with the Blower Fan is available, the service disconnect panel shall be opened.

7.5.2.2.2. At the Forced-Air HVAC System. This location is permitted to be used if an access panel(s) provides access to the electrical supply wiring, and the Blower Fan compartment remains closed. If this location is used, the access panel shall be removed [53].

7.5.2.3. The Forced-Air HVAC System shall run for 10 minutes continuously before completing Section 7.5.2.4 and beyond. The 10-minute period is permitted to include the time the Forced-Air HVAC System was running while conducting the procedure for evaluating the Blower Fan volumetric airflow in Section 6. If the Blower Fan is not capable of operating with the access panels removed, then a different procedure shall be selected if Blower Fan watt draw is to be measured.

7.5.2.4. The nameplate voltage for the equipment with the Blower Fan shall be determined. If the nameplate voltage is between 110 V and 120 V, then Section 7.5.2.4.1 shall be followed. If the nameplate voltage is between 200 V and 240 V, then Section 7.5.2.4.2 shall be followed.

7.5.2.4.1. Equipment with a nameplate voltage between 110 V and 120 V.

7.5.2.4.1.1. The clamp of the Clamp-On Watt Meter shall be placed around the wire [54] supplying power to the equipment with the Blower Fan.

7.5.2.4.1.2. The leads capable of measuring voltage shall be connected to the Clamp-On Watt Meter. The negative lead shall be placed in contact with the grounding wire [55]. The positive lead shall be placed in contact with the connection [56] between the electrical power supply wire and the equipment's power supply wire [54].

7.5.2.4.1.3. The average watt draw of the Blower Fan, Wfan, displayed on the Clamp-On Watt Meter shall be measured over at least a 10-second period and recorded.

7.5.2.4.2. Equipment with a nameplate voltage between 200 V and 240 V.

7.5.2.4.2.1. The clamp of the Clamp-On Watt Meter shall be placed around the first of two wires [57] supplying power to the equipment with the Blower Fan.

7.5.2.4.2.2. The leads capable of measuring voltage shall be connected to the Clamp-On Watt Meter. The negative lead shall be placed in contact with the connection between the first electrical power supply wire and the equipment's

[53] (Informative Note) The party conducting the test shall obtain required licensing, if any, prior to removing the panel. If required licensing has not been obtained, an alternate test method shall be selected.
[54] (Informative Note) Typically black in color.
[55] (Informative Note) Typically green in color.
[56] (Informative Note) Wire nuts are commonly used for this connection, in which case the lead can be inserted into the wire nut.
[57] (Informative Note) Typically either red or black in color.

power supply wire [57]. The positive lead shall be placed in contact with the connection between the second electrical power supply wire and the equipment's power supply wire [57].

7.5.2.4.2.3. The average watt draw of the Blower Fan, WfanA, displayed on the Clamp-On Watt Meter shall be measured over at least a 10-second period.

7.5.2.4.2.4. The clamp of the Clamp-On Watt Meter shall be placed around the second of two wires [57] supplying power to the equipment with the Blower Fan.

7.5.2.4.2.5. The negative lead shall again be placed in contact with the connection between the first electrical power supply wire and the equipment's power supply wire [57]. The positive lead shall again be placed in contact with the connection between the second electrical power supply wire and the equipment's power supply wire [57].

7.5.2.4.2.6. The average watt draw of the Blower Fan, WfanB, displayed on the Clamp-On Watt Meter shall be measured over at least a 10-second period.

7.5.2.4.2.7. Wfan shall be calculated by averaging WfanA and WfanB, and recorded.

7.5.2.5. The Clamp-On Watt Meter shall be removed and the access panel(s) replaced or service disconnect panel closed.

7.5.2.6. If the procedure to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

7.6. Analog Utility Revenue Meter

7.6.1. Equipment Needed.

7.6.1.1. Analog Utility Revenue Meter. An analog utility revenue meter that shall have a documented Kh factor and the ability to view the revolutions of the meter wheel.

7.6.1.2. Stopwatch. A stopwatch that provides measurements in units of seconds.

7.6.2. Procedure to Measure Blower Fan Watt Draw

7.6.2.1. The Forced-Air HVAC System shall run for 10 minutes continuously before completing Section 7.6.2.2 and beyond. The 10-minute period is permitted to include the time the Forced-Air HVAC System was running while conducting the procedure for evaluating the Blower Fan volumetric airflow in Section 6.

7.6.2.2. Every circuit breaker shall be turned off except the one exclusively serving the equipment with the Blower Fan.

7.6.2.3. The Kh factor on the revenue meter shall be recorded.

7.6.2.4. The number of full revolutions of the meter wheel shall be counted over a period exceeding 90 seconds and both the number of revolutions, Nrev, and time period, Trev, recorded.

7.6.2.5. The watt draw of the Blower Fan, Wfan, shall be calculated using Equation 11 and recorded:

$$Wfan = \frac{(Kh \times Nrev \times 3600)}{Trev} \quad (11)$$

Where:

Wfan = The watt draw of the Blower Fan at operating conditions.

Kh = The conversion factor between revolutions and watts, for the meter under test.

Nrev = The number of full revolutions observed in Section 7.6.2.4.

Trev = The duration of the observation in Section 7.6.2.4, in seconds.

7.6.2.6. The circuit breakers shall be returned to their original position.

7.6.2.7. If the procedure to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

7.7. Digital Utility Revenue Meter

7.7.1. Equipment Needed.

7.7.1.1. Digital Utility Revenue Meter. A digital utility revenue meter capable of direct digital display of the Blower Fan watt draw.

7.7.2. Procedure to Measure Blower Fan Watt Draw

7.7.2.1. The Forced-Air HVAC System shall run for 10 minutes continuously before completing Section 7.7.2.2 and beyond. The 10-minute period is permitted to include the time the Forced-Air HVAC System was running while conducting the procedure for evaluating the Blower Fan volumetric airflow in Section 6.

7.7.2.2. Every circuit breaker shall be turned off except the one exclusively serving the equipment with the Blower Fan.

7.7.2.3. Wfan shall be read from the Digital Utility Revenue Meter, and recorded.

7.7.2.4. The circuit breakers shall be returned to their original position.

7.7.2.5. If the procedure to evaluate refrigerant charge in Section 8 will not be conducted, then power to the compressor shall be restored, if cut off for the test, and the thermostat(s) mode(s) and set point(s) shall be returned to their original setting.

7.8. Designating the Blower Fan Watt Draw Grade

7.8.1. Blower Fan Efficiency shall be calculated using Equation 12:

$$Blower\ Fan\ Efficiency = \frac{Wfan}{Q_{op}} \quad (12)$$

Where:

Blower Fan Efficiency = The ratio of field-measured Blower Fan watt draw and field-measured Blower Fan volumetric airflow.

Wfan = The Blower Fan watt draw at operating conditions, as field-measured per Section 7.4, 7.5, 7.6, or 7.7.

Qop = The Blower Fan volumetric airflow at operating conditions, as field-measured per Section 6.4, 6.5, 6.6, or 6.7.

7.8.2. The Blower Fan watt draw grade shall be designated according to the ranges in Table 4, and recorded.

Table 4 – Grade Designations for Blower Fan Watt Draw

Grade Designation	Blower Fan Efficiency (Watts/CFM)
I	≤ 0.45
II	> 0.45 and ≤ 0.58
III	> 0.58

8. Task 5: Evaluation of the Refrigerant Charge.

8.1. **Overview.** This procedure shall be completed by first meeting the prerequisites in Section 8.2. Then the applicable test method shall be determined using Section 8.3 [58] and the refrigerant charge evaluated using the applicable test method, either Section 8.4 or 8.5. Finally, the refrigerant charge grade shall be designated per Section 8.6.

As an alternative to completing the procedures defined in Sections 8.3 through 8.5, if the installed equipment contains an on-board diagnostic system that is capable of reporting either the temperatures defined in this section or the superheat or subcooling of the system, and that is approved for use by an entity adopting and requiring the use of this Standard, then the reported values shall be permitted to be used.

As an alternative to completing the procedures defined in Sections 8.3 through 8.5, if an Independent Verification Report is obtained containing either the temperatures defined in this section or the superheat or subcooling of the system of the Forced-Air HVAC System under test, and the report is approved for use by an entity adopting and requiring the use of this Standard, then the reported value shall be permitted to be used.

If an on-board diagnostic system is used or Independent Verification Report is obtained, the reported value shall be used to designate the refrigerant charge grade per Section 8.6.

8.2. Prerequisites

8.2.1. Prior to evaluating the refrigerant charge, the Blower Fan volumetric airflow shall have been evaluated in accordance with Section 6, including all prerequisites in Section 6.2. In addition, the Blower Fan volumetric airflow shall have been designated Grade I or II, per Section 6.8. If the Blower Fan volumetric airflow has

[58] (Informative Note) The Weigh-In Method requires the collection of documentation about the refrigerant system from the party responsible for charging the system. Charging of the system will likely occur prior to the arrival of the party conducting the test. Therefore, if the party conducting the test believes that the outdoor temperatures might only permit the use of the Weigh-In Method, they may wish to request the required documentation for this method prior to arriving on site.

not been evaluated or has been designated Grade III, then refrigerant charge shall not be evaluated.

8.3. Determination of Applicable Test Method

8.3.1. Equipment Needed. The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

8.3.1.1. Digital Thermometer. A device that can measure dry-bulb air temperature with an accuracy of ± 1.8 °F (1.0 °C).

8.3.2. Procedure to Determine Applicable Test Method.

8.3.2.1. The Weigh-In Method, per Section 8.5, is permitted to be used when the following conditions are met:

8.3.2.1.1. Outdoor air temperatures do not meet the requirements of the Non-Invasive method in Section 8.3.2.2; or,

8.3.2.1.2. The Forced-Air HVAC System is a Mini-Split Air Conditioner, Mini-Split Heat Pump, Multi-Split Air Conditioner, or a Multi-Split Heat Pump.

8.3.2.2. The Non-Invasive Procedure, per Section 8.4, is permitted to be used when the procedures in Section 8.3.2.2.1 and 8.3.2.2.2 are completed and the conditions in Section 8.3.2.2.3 are met:

8.3.2.2.1. The Digital Thermometer shall be shielded from direct sun and the average outdoor air dry-bulb-temperature shall be measured over at least a 10-second period where the outdoor air enters the condensing unit.

8.3.2.2.2. The rated system efficiency, per Section 4.2.5.3.10, of the Forced-Air HVAC System under test shall be determined.

8.3.2.2.3. The outdoor air dry-bulb temperature shall meet the following conditions:

8.3.2.2.3.1. Outdoor air dry-bulb temperature is between 75 °F (24 °C) and 115 °F (46 °C) for equipment with a rated efficiency ≥ 17 SEER, or

8.3.2.2.3.2. Outdoor air dry-bulb temperature is between 70 °F (20 °C) and 115 °F (46 °C) for all other equipment.

8.4. Non-Invasive Method

8.4.1. Procedure to Prepare the Dwelling and Forced-Air HVAC System [59]

8.4.1.1. If an Independent Verification Report was used to determine the Blower Fan volumetric airflow, then the procedure to prepare the Dwelling and Forced-Air HVAC System for testing defined in Section 6.3 shall be completed.

8.4.1.2. **Settings for HVAC System**.

[59] (Informative Note) The procedure for preparing the HVAC settings, damper position, and ventilation openings differs from the one used in the Evaluation of Blower Fan Volumetric Airflow.

8.4.1.2.1. The thermostat shall be set to cooling mode and the setpoint temperature adjusted as low as possible [60].

8.4.1.2.2. If the Forced-Air HVAC System serves multiple zones, as reported in Section 4.2.5.2, then manufacturer instructions shall be followed to ensure that all zones in the Forced-Air HVAC System are calling for the required mode for testing.

8.4.1.3. **Position of Dampers** . Dampers within the duct system of the Forced-Air HVAC System under test shall be treated as follows:

8.4.1.3.1. Non-motorized dampers [61] that connect the Conditioned Space Volume [62] to the exterior or to Unconditioned Space Volume shall be placed in their closed position during the test and shall not be further sealed. If running the Forced-Air HVAC System causes the non-motorized dampers to open after being placed in their closed position, then the Ventilation openings shall be temporarily sealed. If the Ventilation openings are not accessible, or cannot be temporarily sealed, then refrigerant charge shall not be evaluated.

8.4.1.3.2. Motorized dampers that connect the Conditioned Space Volume [62] to the exterior or to Unconditioned Space Volume shall be placed in their closed positions and shall not be further sealed.

8.4.1.3.3. All balancing dampers shall be left in their as-found position.

8.4.1.4. **Ventilation Openings**. Non-dampered Ventilation openings within the duct system of intermittently or continuously operating Dwelling-Unit Mechanical Ventilation Systems, including Ventilation systems that use the Blower Fan of the Forced-Air HVAC System, shall be temporarily sealed. If the non-dampered Ventilation openings are not accessible, or cannot be temporarily sealed, then refrigerant charge shall not be evaluated.

8.4.2. Equipment Needed. The equipment listed in this section shall have its calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

8.4.2.1. Digital Thermometer. A device that can measure dry-bulb air temperature with an accuracy of ± 1.8 °F (1.0 °C).

8.4.2.2. Digital Hygrometer. A device that can measure wet-bulb air temperature with an accuracy of ± 2.0 °F (1.1 °C) or calculate wet-bulb air temperature using measurements of Relative Humidity (RH) with an accuracy of ± (1.8% RH +3.0% of the measured value) at 77 °F (25 °C) and dry-bulb air temperature with an accuracy of ± 2.0 °F (1.1 °C).

[60] (Informative Note) If the Blower Fan speed type is not single-speed, as reported in Section 4.2.5.3.5, then the system can operate at two or more speeds each for heating mode and cooling mode. Consult manufacturer instructions to ensure that the Blower Fan is operating at the highest design speed.

[61] (Informative Note) For example, pressure-activated operable dampers, fixed dampers.

[62] (Informative Note) This includes space conditioning duct systems.

8.4.2.3. Digital Pipe Temperature Probe. A device that can attach to [63] and measure temperatures of pipes and refrigerant lines between -4 °F (-20 °C) and 185 °F (85 °C) with an accuracy of ± 2.3 °F (1.3 °C).

8.4.3. Procedure to Evaluate the Refrigerant Charge.

8.4.3.1. Before proceeding past Section 8.4.3.5, the Forced-Air HVAC System shall run for 15 minutes continuously [64].

8.4.3.2. The location for measuring the return air temperature shall be determined as follows:

8.4.3.2.1. If a hole located in the return side of the Forced-Air HVAC System and is out of line of sight of the evaporator coil [65], then the hole shall qualify for use in this procedure.

8.4.3.2.2. If a hole does not qualify per Section 8.4.3.2.1, then the location shall be where the indoor air stream enters the return grille closest to the Forced-Air HVAC System.

8.4.3.3. Using the Digital Thermometer, the average return air dry bulb temperature ($T_{return\ air,\ db}$), and average return air wet-bulb temperature shall be measured over at least a 10-second period at the location determined in Section 8.4.3.2 and recorded. If the temperatures were measured using a hole, then the hole shall be sealed to prevent leakage after measurements have been completed.

8.4.3.4. The return air temperatures measured in Section 8.4.3.3 shall be evaluated for compliance with the following conditions. The following two conditions shall be met, or the refrigerant charge shall not be evaluated using the non-invasive method [66]:

8.4.3.4.1. Return air dry bulb temperature is between 70 °F (21 °C) and 80 °F (27 °C), and,

8.4.3.4.2. Return air wet-bulb temperature is ≥ 50 °F (10 °C).

8.4.3.5. The following average temperatures shall be measured over at least a 10-second period each and recorded. All three temperatures shall be measured within a five-minute period that begins no more than five minutes after the measurements taken in Section 8.4.3.3 [67].

8.4.3.5.1. Using the Digital Thermometer, the outdoor air dry-bulb temperature ($T_{outdoor\ air}$) shall be measured where the outdoor air stream enters the condensing

[63] (Informative Note) For example, using a clamp, strap, or equivalent device.

[64] (Informative Note) The 15-minute period is permitted to include the time the Forced-Air HVAC System was running while conducting the procedure for evaluating the Blower Fan volumetric airflow in Section 6 and the procedure for evaluating the Blower Fan watt draw in Section 7, as long as power to the compressor was not cut off.

[65] (Informative Note) Return air temperature is measured out of line of sight of the evaporator coil to prevent radiant heat transfer from the coil from impacting the measured temperature.

[66] (Informative Note) If these conditions could be achieved by allowing the system to run longer, that is permitted.

[67] (Informative Note) This time period means that the final measurement taken in Section 8.4.3.5 must be no more than ten minutes after the measurements taken in Section 8.4.3.3.

unit and with the Digital Thermometer shaded from direct sun. If the outdoor dry-bulb temperature does not meet the requirements in Section 8.3.2.2.3, then refrigerant charge shall not be evaluated using the non-invasive method.

8.4.3.5.2. Using the Digital Pipe Temperature Probe with the sensor in contact at the 2:00 or 10:00 o'clock position on the refrigerant line, the suction line [68] temperature ($T_{\text{suction line, measured}}$) shall be measured at the condensing unit within 6 inches of the service valve.

8.4.3.5.3. Using the Digital Pipe Temperature Probe with the sensor in contact with the refrigerant line, the liquid line [69] temperature ($T_{\text{liquid line, measured}}$) shall be measured at the condensing unit within 6 inches of the service valve.

8.4.3.6. The thermostat(s) mode(s) and set point(s) shall be returned to their original setting, the dampers returned to their original as-found positions, and the Ventilation openings unsealed, if temporarily sealed.

8.4.3.7. Determining the Design Temperature Difference (DTD).

8.4.3.7.1. The normalized Blower Fan airflow shall be calculated using Equation 13.

$$Qnorm = \frac{\text{Qdesign}}{\text{Maximum Total Heat Gain}} \; x \; 12{,}000 \qquad (13)$$

Where:

Qnorm = The normalized Blower Fan airflow

Qdesign = The design-specified Blower Fan volumetric airflow, per Section 4.2.5.5.1, for cooling mode.

Maximum Total Heat Gain = The maximum total heat gain among the specified orientations, as reported in Section 4.2.4.17.

8.4.3.7.2. The default value for DTD shall be assigned using Qnorm, per Section 8.4.3.7.1, and the criteria in Table 5.

Table 5 – Default DTD Values

Qnorm	Default DTD Value (DTD_{Def})
≤ 375	40 °F (22 °C)
≥ 375 and ≤ 425	35 °F (19 °C)
> 425	30 °F (17 °C)

[68] (Informative Note) The suction line is the larger of the two refrigerant lines and leads from the evaporator to the condenser in a split system air conditioner or heat pump. This line is insulated since it carries refrigerant at a low temperature, and insulation may need to be removed and replaced to measure the line temperature.

[69] (Informative Note) The liquid line is the smaller of the two refrigerant lines and leads from the condenser to the evaporator in a split system air conditioner or heat pump. The refrigerant in this line is in a liquid state and is at an elevated temperature. This line should not be insulated.

8.4.3.7.3. If the party responsible for conducting the start-up of the Forced-Air HVAC System under test has provided the return air dry bulb temperature and the suction line Saturation Temperature at the time of start-up, then the site-specific DTD shall be calculated using Equation 14.

$$DTD_{Site} = T_{return\ air,db,install} - T_{suction,saturation,install} \quad (14)$$

Where:

DTD_{Site} = The site-specific DTD of the installed equipment.

$T_{returnair,db,install}$ = The return air temperature measured by the contractor at the time of installation

$T_{suction,saturation,install}$ = The suction line Saturation Temperature measured by the contractor at the time of installation

8.4.3.7.4. If DTD_{Site}, per Section 8.4.3.7.3, is within ± 3 °F (2 °C) of DTD_{Def}, per Section 8.4.3.7.2, then DTD shall equal DTD_{Site}. If not, or if DTD_{Site} has not been calculated, then DTD shall equal DTD_{Def}.

8.4.3.8. If the metering device type is piston or capillary tube, per Section 4.2.5.3.9, then this Section shall be completed.

8.4.3.8.1. The Target Superheat shall be determined from the manufacturer-supplied superheat chart for the equipment under test, or Table B1 in Appendix B [70], using the return air wet bulb temperature measured in Section 8.4.3.3 and the outdoor air dry bulb temperature measured in Section 8.4.3.5.1.

8.4.3.8.2. The minimum liquid line temperature shall be calculated using Equation 15.

$$T_{liquid\ line,min} = T_{outdoor\ air} + T_{liquid\ line,min,constant} \quad (15)$$

Where:

$T_{liquidline,min}$ = The minimum allowable liquid line temperature

$T_{outdoor\ air}$ = The outdoor air temperature, measured in Section 8.4.3.5.1

$T_{liquidline,min,constant}$ = 3 °F (2 °C)

8.4.3.8.3. The maximum liquid line temperature shall be calculated using Equation 16.

$$T_{liquid\ line,max} = T_{outdoor\ air} + T_{liquid\ line,max,constant} \quad (16)$$

Where:

$T_{liquidline,max}$ = The maximum allowable liquid line temperature

$T_{outdoor\ air}$ = The outdoor air temperature, measured in Section 8.4.3.5.1

[70] (Informative Note) If a dash mark is read from the table in Table B1, the Target Superheat is less than 5 °F and the test cannot be performed under these conditions. Typically this indicates that the outdoor conditions are too hot and the indoor conditions are too cold, and can be resolved by increasing the indoor temperature or testing at another time.

Tliquidline,max,constant = 12 °F (7 °C)

8.4.3.8.4. If the measured liquid line temperature, per Section 8.4.3.5.3, is < $T_{liquid\ line,\ min}$ or > $T_{liquid\ line,\ max}$, then refrigerant charge shall not be evaluated.

8.4.3.8.5. The Target Suction Line Temperature shall be calculated using Equation 17.

$$T_{suction\ line,target} = T_{return\ air,db} - DTD + Target\ Superheat \quad (17)$$

Where:

Tsuctionline,target = The Target Suction Line Temperature

Treturnair,db = The return air dry bulb temperature, measured in Section 8.4.3.3

DTD = The Design Temperature Difference of the installed equipment, per Section 8.4.3.7.4

Target Superheat = The Target Superheat determined in Section 8.4.3.8.1

8.4.3.8.6. The difference between the measured suction line temperature and the Target Suction Line Temperature shall be calculated using Equation 18 and recorded.

$$Difference_{DTD} = T_{suction\ line,target} - T_{suction\ line,measured} \quad (18)$$

Where:

DifferenceDTD = The difference between the measured suction line temperature and the Target Suction Line Temperature.

Tsuctionline,target = The Target Suction Line Temperature, determined using Equation 17

Tsuctionline,measured = The suction line temperature measured in Section 8.4.3.5.2

8.4.3.9. If the metering device type is TXV or EEV, per Section 4.2.5.3.9, then this Section shall be completed.

8.4.3.9.1. The Target Subcooling shall equal the value specified in Section 4.2.5.3.9.2.

8.4.3.9.2. Determining the Condensing Temperature Over Ambient (CTOA).

8.4.3.9.2.1. The default value for CTOA shall be assigned using the SEER reported in Section 4.2.5.3.10 and the criteria in Table 6.

Table 6 – Default CTOA Values

Reported SEER	Default CTOA Value ($CTOA_{Def}$)
≤ 9	30 °F (16.7 °C)
> 9 and ≤ 12	25 °F (13.9 °C)
> 12 and ≤ 16	20 °F (11.1 °C)

> 16	15 °F (8.3 °C)

8.4.3.9.2.2. If the party responsible for conducting the start-up of the Forced-Air HVAC System under test has provided the outdoor air dry bulb temperature and the liquid line Condensing Temperature at the time of start-up, then the site-specific CTOA shall be calculated using Equation 19.

$$CTOA_{Site} = T_{condensing,install} - T_{outdoor\ air,install} \quad (19)$$

Where:

$CTOA_{Site}$ = The Condensing Temperature Over Ambient of the installed equipment

Tcondensing,install = The liquid line Condensing Temperature measured by the contractor at the time of installation

Toutdoorair,install = The outdoor air temperature measured by the contractor at the time of installation

8.4.3.9.2.3. If $CTOA_{Site}$, per Section 8.4.3.9.2.2, is within ± 3 °F (2 °C) of $CTOA_{Def}$, per Section 8.4.3.9.2.1, then CTOA shall equal $CTOA_{Site}$. If not, or if $CTOA_{Site}$ has not been calculated, then CTOA shall equal $CTOA_{Def}$.

8.4.3.9.3. The minimum suction line temperature shall be calculated using Equation 20.

$$T_{suction\ line,min} = T_{return\ air,db} - DTD + T_{suction\ line,min,constant} \quad (20)$$

Where:

Tsuctionline,min = The minimum allowable suction line temperature

Treturnair,db = The return air dry bulb temperature, measured in Section 8.4.3.3

DTD = The Design Temperature Difference of the installed equipment, per Section 8.4.3.7.4

Tsuctionline,min,constant = 3 °F (2 °C).

8.4.3.9.4. The maximum suction line temperature shall be calculated using Equation 21.

$$T_{suction\ line,max} = T_{return\ air,db} - DTD + T_{suction\ line,max,constant} \quad (21)$$

Where:

Tsuctionline,max = The maximum allowable suction line temperature

Treturnair,db = The return air dry bulb temperature, measured in Section 8.4.3.3

DTD = The Design Temperature Difference of the installed equipment, per Section 8.4.3.7.4

Tsuctionline,max,constant = 26 °F (14 °C).

8.4.3.9.5. If the measured suction line temperature, per Section 8.4.3.5.2, is > 65 °F (18 °C), < $T_{suction\ line,\ min}$, or > $T_{suction\ line,\ max}$, then refrigerant charge shall not be evaluated.

8.4.3.9.6. The Target Liquid Line temperature shall be calculated using Equation 22.

$$T_{liquid\ line,target} = T_{outdoor\ air} + CTOA - Target\ Subcooling \quad (22)$$

Where

$T_{liquidline,target}$ = The Target Liquid Line temperature

$T_{outdoorair}$ = The outdoor air temperature, measured in Section 8.4.3.5.1

CTOA = The Condensing Temperature Over Ambient of the installed equipment, per Section 8.4.3.9.2.3

Target Subcooling = The Target Subcooling determined in Section 8.4.3.9.1

8.4.3.9.7. The difference between the measured liquid line temperature and the Target Liquid Line temperature shall be calculated using Equation 23 and recorded.

$$Difference_{CTOA} = T_{liquid\ line,target} - T_{liquid\ line,measured} \quad (23)$$

$Difference_{CTOA}$ = The difference between the measured liquid line temperature and the Target Liquid Line temperature.

$T_{liquidline,target}$ = The Target Liquid Line temperature, determined using Equation 22

$T_{liquidline,measured}$ = The liquid line temperature measured in Section 8.4.3.5.3

8.5. Weigh-In Method

8.5.1. Equipment Needed.

8.5.1.1. Measuring Tape. A device that can determine length with an accuracy of ± 1/16 inch (1.6 mm).

8.5.2. Documentation Needed

8.5.2.1. The following documentation about the refrigerant system of the Forced-Air HVAC System under test shall be collected from the party responsible for charging the system.

8.5.2.1.1. The total weight of refrigerant added to or removed from the system, an indication of whether the refrigerant was added or was removed, and an indication of whether the factory-supplied refrigerant was first removed [71].

8.5.2.1.2. One or more photographs showing the scale displaying the total weight of refrigerant added or removed from the system indicated per Section 8.5.2.1.1. The

[71] (Informative Note) An indication of whether refrigerant was added or removed may be indicated by the phrase "10 Oz. Added" or "10 Oz. Removed." An indication of whether the factory-supplied refrigerant was first removed may be indicated by the phrase "Factory-supplied charge not removed" or "Factory-supplied charge removed."

photographs shall be timestamped and geotagged to indicate the location of the Forced-Air HVAC System under test.

8.5.2.1.3. The total length of the liquid line [72].

8.5.2.1.4. The outside diameter of the liquid line.

8.5.2.1.5. The length of liquid line accounted for in the factory-supplied charge [73].

8.5.2.1.6. The weight of the factory-supplied refrigerant [74].

8.5.2.1.7. The weight of the refrigerant added to the system for specific components, [75] other than the incremental length of the liquid line.

8.5.3. Procedure to Evaluate the Refrigerant Charge

8.5.3.1. Using the Measuring Tape, the total length [76] of the liquid line shall be measured to the nearest foot (0.3 meters) [72], and recorded. If the refrigerant line has been pre-marked to indicate line lengths, then the markings are permitted to be used in lieu of the Measuring Tape.

8.5.3.2. Using the Measuring Tape, the circumference of the liquid line shall be measured to the nearest 1/16th of an inch (1.6 mm) and divided by 3.14 to calculate the outer diameter, and recorded.

8.5.3.3. The Delta Line Length shall be calculated using Equation 24.

$$L_{delta} = L_{measured} - L_{default} \quad (24)$$

Where:

Ldelta = The difference in line length between the measured liquid line length and the liquid line length accounted for by the factory-supplied charge.

Lmeasured = The liquid line length measured in Section 8.5.3.1.

Ldefault = The liquid line length accounted for by the factory-supplied charge, from Section 8.5.2.1.5.

8.5.3.4. The weight of the refrigerant required for the incremental liquid line length, Wlength_ant, shall be determined from Table C1 in Appendix C using Ldelta, from Equation 24, and the outside diameter of the liquid line, from Section 8.5.3.2.

8.5.3.5. The total anticipated refrigerant weight shall be calculated using Equation 25.

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[72] (Informative Note) The liquid line is the smaller of the two refrigerant lines and leads from the condenser to the evaporator in a split system air conditioner or heat pump. The refrigerant in this line is in a liquid state and is at an elevated temperature. This line should not be insulated.

[73] (Informative Note) Systems typically come charged from the factory to account for a default length of refrigerant line, often 15 feet. Manufacturer instructions will direct installers to add or remove refrigerant if the actual line length is longer or shorter than this default length.

[74] (Informative Note) The factory-supplied charge is typically indicated on the condenser nameplate.

[75] (Informative Note) For correct charge, additional refrigerant may be required if the system was fully evacuated, or there are additional components installed (e.g., filter drier).

[76] (Informative Note) For Multi-splits, the total length of the liquid line includes the refrigerant lines going to all indoor sections.

$$Wtot\ ant = Wlength\ ant + Wcomponent\ rep + Wfactory\ rep \quad (25)$$

Where:

Wtot_ant = The total anticipated weight of refrigerant.

Wlength_ant = The anticipated weight of the refrigerant required for the incremental liquid line length determined in Section 8.5.3.4.

Wcomponent_rep = The reported weight of refrigerant added to the system for specific components, other than the incremental length of the liquid line, from Section 8.5.2.1.7.

Wfactory_rep = The reported weight of factory-supplied refrigerant from Section 8.5.2.1.6.

8.5.3.6. The total reported refrigerant weight, Wtot_rep, shall equal the value reported in Section 8.5.2.1.1 if the factory-supplied refrigerant was first removed, or shall be calculated using Equation 26 if not.

$$Wtot\ rep = Wlength\ rep + Wcomponent\ rep + Wfactory\ rep \quad (26)$$

Where:

Wtot_rep = The total reported weight of refrigerant.

Wlength_rep = The reported weight of the refrigerant added or removed for the incremental liquid line length, as reported in Section 8.5.2.1.1

Wcomponent_rep = The reported weight of refrigerant added to the system for specific components, other than the incremental length of the liquid line from Section 8.5.2.1.7.

Wfactory_rep = The reported weight of factory-supplied refrigerant from Section 8.5.2.1.6.

8.5.3.7. The deviation between the total anticipated and total reported refrigerant weight shall be calculated using Equation 27.

$$Wdev = \frac{Wtot\_rep - Wtot\_ant}{Wtot\_ant} \quad (27)$$

Where:

Wdev = The percent deviation between the total anticipated and total reported refrigerant weight.

Wtot_rep = The total reported weight of refrigerant, from Section 8.5.3.6.

Wtot_ant = The total anticipated weight of refrigerant, from Section 8.5.3.5

8.6. Designating the Refrigerant Charge Grade

8.6.1. If the superheat or subcooling of the Forced-Air HVAC System under test was reported using an on-board diagnostic system or through an Independent Verification Report, then Grade I shall be designated if the superheat or subcooling deviation is within the limits specified within ANSI/ACCA QI 5 Section 4.3.1.

8.6.2. If refrigerant charge was evaluated using the non-invasive method, per Section 8.4, the grade shall be designated based on the following and recorded.

8.6.2.1. If the metering device type is piston or capillary tube, per Section 4.2.5.3.9, then the grade for refrigerant charge shall be designated according to the ranges in Table 7, using DifferenceDTD from Equation 18.

Table 7 – Piston or Capillary Tube Metering Device Grade Designations for Refrigerant Charge

Grade Designation	DifferenceDTD Range
I	> -8 °F (4 °C)
III	≤ -8 °F (4 °C)

8.6.2.2. If the metering device type is TXV or EEV, per Section 4.2.5.3.9, then the grade for refrigerant charge shall be designated according to the ranges in Table 8, using DifferenceCTOA from Equation 23.

Table 8 – TXV or EEV Metering Device Grade Designations for Refrigerant Charge

Grade Designation	DifferenceCTOA Range
I	> -6 °F (3 °C)
III	≤ -6 °F (3 °C)

8.6.3. If refrigerant charge was evaluated using the Weigh-In Method, per Section 8.5, the grade for refrigerant charge shall be designated based on the following and recorded.

8.6.3.1. Grade I shall be designated when both of the following criteria are met.

8.6.3.1.1. The absolute value of the percent deviation between the total anticipated and total reported refrigerant weight, per Equation 27, is ≤ 5%.

8.6.3.1.2. In the judgement of the party conducting the evaluation, the location of the geotagged photo provided in Section 8.5.2.1.2 matches the location of the Forced-Air HVAC System under test.

8.6.3.2. Grade III shall be designated when the criteria in Section 8.6.3.1 are not met.

9. References.

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Appendix A (Normative) –
Design Temperature Limits by State and County, and U.S. Territory

[Due to size, see file, "Appendix A - HVAC Design Temperature Limits v1 2018-02-07"]

Appendix B – Target Superheat

Table B1 – Target Superheat

Outdoor Air Temperature (°F)	Return Air Wet-Bulb Temperature (°F)																												
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17	18.4	19.7	20.9	22.3	23.9	25.4	27	28.5	30	31.5	33	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28	29.5	31	32.5	34	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29	30.5	32	33.5	35	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30	31.5	33.1	34.6	36	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20	21.6	23.2	24.8	26.4	28	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11	12.5	14	15.4	16.8	18.3	20	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26	27.6	29.2	30.8	32.4	34	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12	13.5	15	16.6	18.3	20	21.7	23.3	25	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6	7.9	9.7	11.3	12.9	14.3	16	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24	25.7	27.4	29.1	30.7	32.4	34
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19	20.8	22.6	24.3	26	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5	7	8.9	10.6	12.6	14.4	16.2	18	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10	12	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22	23.8	25.6	27.5	29.3	31.1
91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24	25.9	27.8	29.7

Table B1 – Target Superheat (Continued)

Outdoor Air Temperature (°F)	Return Air Wet-Bulb Temperature (°F)																												
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10	12	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24	26	28
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15	17	19.1	21.1	23.2	25.3	27.3
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27
103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14	16.1	18.2	20.3	22.4	24.5	26.7
104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11	13.1	15.2	17.4	19.5	21.7	23.8	26
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17	19.1	21.3	23.5	25.7
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10	12.2	14.4	16.6	18.7	21	23.2	25.4
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18	20.2	22.5	24.7
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4
111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	8.1	10.4	12.6	14.9	17.2	19.5	21.8	24.1
112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.6	9.9	12.2	14.5	16.8	19.1	21.5	23.8
113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	9.5	11.8	14.1	16.4	18.8	21.1	23.5
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	9	11.4	13.7	16.1	18.4	20.8	23.2
115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.6	10.9	13.3	15.7	18.1	20.5	22.9

Appendix C – Weigh-In Method Refrigerant Charge Verification Weight

Table C1 – Verification Weight (ounces)

Delta Line Length (feet)	Liquid Line Diameter (inches)				Delta Line Length (feet)	Liquid Line Diameter (inches)				Delta Line Length (feet)	Liquid Line Diameter (inches)			
	1/4	5/16	3/8	1/2		1/4	5/16	3/8	1/2		1/4	5/16	3/8	1/2
-50	-15.0	-20.0	-30.0	-60.0	-16	-4.8	-6.4	-9.6	-19.2	18	5.4	7.2	10.8	21.6
-49	-14.7	-19.6	-29.4	-58.8	-15	-4.5	-6.0	-9.0	-18.0	19	5.7	7.6	11.4	22.8
-48	-14.4	-19.2	-28.8	-57.6	-14	-4.2	-5.6	-8.4	-16.8	20	6.0	8.0	12.0	24.0
-47	-14.1	-18.8	-28.2	-56.4	-13	-3.9	-5.2	-7.8	-15.6	21	6.3	8.4	12.6	25.2
-46	-13.8	-18.4	-27.6	-55.2	-12	-3.6	-4.8	-7.2	-14.4	22	6.6	8.8	13.2	26.4
-45	-13.5	-18.0	-27.0	-54.0	-11	-3.3	-4.4	-6.6	-13.2	23	6.9	9.2	13.8	27.6
-44	-13.2	-17.6	-26.4	-52.8	-10	-3.0	-4.0	-6.0	-12.0	24	7.2	9.6	14.4	28.8
-43	-12.9	-17.2	-25.8	-51.6	-9	-2.7	-3.6	-5.4	-10.8	25	7.5	10.0	15.0	30.0
-42	-12.6	-16.8	-25.2	-50.4	-8	-2.4	-3.2	-4.8	-9.6	26	7.8	10.4	15.6	31.2
-41	-12.3	-16.4	-24.6	-49.2	-7	-2.1	-2.8	-4.2	-8.4	27	8.1	10.8	16.2	32.4
-40	-12.0	-16.0	-24.0	-48.0	-6	-1.8	-2.4	-3.6	-7.2	28	8.4	11.2	16.8	33.6
-39	-11.7	-15.6	-23.4	-46.8	-5	-1.5	-2.0	-3.0	-6.0	29	8.7	11.6	17.4	34.8
-38	-11.4	-15.2	-22.8	-45.6	-4	-1.2	-1.6	-2.4	-4.8	30	9.0	12.0	18.0	36.0
-37	-11.1	-14.8	-22.2	-44.4	-3	-0.9	-1.2	-1.8	-3.6	31	9.3	12.4	18.6	37.2
-36	-10.8	-14.4	-21.6	-43.2	-2	-0.6	-0.8	-1.2	-2.4	32	9.6	12.8	19.2	38.4
-35	-10.5	-14.0	-21.0	-42.0	-1	-0.3	-0.4	-0.6	-1.2	33	9.9	13.2	19.8	39.6
-34	-10.2	-13.6	-20.4	-40.8	0	0.0	0.0	0.0	0.0	34	10.2	13.6	20.4	40.8
-33	-9.9	-13.2	-19.8	-39.6	1	0.3	0.4	0.6	1.2	35	10.5	14.0	21.0	42.0
-32	-9.6	-12.8	-19.2	-38.4	2	0.6	0.8	1.2	2.4	36	10.8	14.4	21.6	43.2
-31	-9.3	-12.4	-18.6	-37.2	3	0.9	1.2	1.8	3.6	37	11.1	14.8	22.2	44.4
-30	-9.0	-12.0	-18.0	-36.0	4	1.2	1.6	2.4	4.8	38	11.4	15.2	22.8	45.6
-29	-8.7	-11.6	-17.4	-34.8	5	1.5	2.0	3.0	6.0	39	11.7	15.6	23.4	46.8
-28	-8.4	-11.2	-16.8	-33.6	6	1.8	2.4	3.6	7.2	40	12.0	16.0	24.0	48.0
-27	-8.1	-10.8	-16.2	-32.4	7	2.1	2.8	4.2	8.4	41	12.3	16.4	24.6	49.2
-26	-7.8	-10.4	-15.6	-31.2	8	2.4	3.2	4.8	9.6	42	12.6	16.8	25.2	50.4
-25	-7.5	-10.0	-15.0	-30.0	9	2.7	3.6	5.4	10.8	43	12.9	17.2	25.8	51.6
-24	-7.2	-9.6	-14.4	-28.8	10	3.0	4.0	6.0	12.0	44	13.2	17.6	26.4	52.8
-23	-6.9	-9.2	-13.8	-27.6	11	3.3	4.4	6.6	13.2	45	13.5	18.0	27.0	54.0
-22	-6.6	-8.8	-13.2	-26.4	12	3.6	4.8	7.2	14.4	46	13.8	18.4	27.6	55.2
-21	-6.3	-8.4	-12.6	-25.2	13	3.9	5.2	7.8	15.6	47	14.1	18.8	28.2	56.4
-20	-6.0	-8.0	-12.0	-24.0	14	4.2	5.6	8.4	16.8	48	14.4	19.2	28.8	57.6
-19	-5.7	-7.6	-11.4	-22.8	15	4.5	6.0	9.0	18.0	49	14.7	19.6	29.4	58.8
-18	-5.4	-7.2	-10.8	-21.6	16	4.8	6.4	9.6	19.2	50	15.0	20.0	30.0	60.0
-17	-5.1	-6.8	-10.2	-20.4	17	5.1	6.8	10.2	20.4	-	-	-	-	-