ENERGY STAR®

MULTIFAMILY HIGH RISE PROGRAM

Testing and Verification Protocols

Version 1.0, Revision ~~01~~02

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Definitions

ASHRAE 62.1-2007: Ventilation for Acceptable Indoor Air Quality: Provides guidance for ventilation system design and other related building features to ensure acceptable indoor air quality. Scope includes all buildings, except low-rise residential.

ASHRAE 62.2-2007: Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings: Provides guidance for ventilation system design and other related building features to ensure acceptable indoor air quality.

ASHRAE 90.1-2007 and 90.1-2010: Energy standard for buildings, except low-rise residential buildings. Minimum requirements for the energy-efficient design of ~~high rise~~ multifamily buildings over three stories above grade are included within this standard.

As-Built: Conditions observed and measured in the completed building. The As-Built ~~Building~~ energy model must represent the actual observed and measured conditions in the ~~As-Built Building~~constructed building, excluding envelope leakage and duct leakage of in-unit forced air systems.

Baseline Building Design: A computer representation of a hypothetical design based on the proposed building project. This representation is used as the basis for calculating the *baseline building performance* for rating above-standard design.

Baseline Building Performance: The annual energy cost for a building design intended for use as a baseline for rating above-standard design.

Commissioning: A formal process, sometimes required by code, through which a building system is tested and verified to be operating within the design specifications.

Commissioning Agent: A qualified professional with expertise in a specific building system or set of building systems that is authorized to complete Commissioning procedures and sign off on the final Commissioning Report.

Commissioning Report: A report produced by the Commissioning Agent documenting Commissioning inspections, test data and verifying compliance with design specifications, manufacturer's specifications, and/or local codes and regulations.

Common Areas: Any ~~nonresidential~~ spaces within a building ~~or facility~~ that ~~serves~~serve a function in support of the residential part of the building that is not part of a dwelling unit. This includes spaces used by residents, such as corridors, stairs, lobbies, laundry rooms, exercise rooms, residential recreation rooms, parking used exclusively by residents, building staff, and their guests. This also includes offices used by building management, administration or maintenance and all special use areas located in the building to serve and support the residents such as day-care facilities, gyms, dining halls, etc.

Design Team: Group of professionals responsible for the final design of a building including, but not limited to: the developer, the general contractor, the architect and design engineers.

Developer: Primary party responsible for the design, financing, and construction of a building or facility and oversees the work of the Design Team, General Contractor and subcontractors working on the project. On some projects, the Developer and the General Contractor may be the same person or entity.

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.

Energy Consultant: Individual or corporate entity engaged in services supporting developers in improving building performance. These services may include, but are not limited to: design review and consultation, design assistance, energy modeling, field inspections, sub-contractor training, project management, etc.

~~**Facility:** An entire building or set of buildings and associated grounds that function as a single unique site.~~

General Contractor: Contractor with primary responsibility for the construction of the building who also oversees the work of the subcontractors.

In-Unit: Term used to describe features in the building that are located within the dwelling units. For example, “in-unit lighting” is used to reference lighting located within the apartments.

Licensed Professional: Must be a Professional Engineer or Registered Architect and possess a current license and be in good standing. The Licensed Professional should also have:

- A license in a discipline related to residential and/or commercial building systems (e.g. mechanical engineering or commercial/residential architecture)
- Working knowledge of building systems, ASHRAE Standard 90.1-2007, ASHRAE Standard 62.1-2007, and ASHRAE Standard 62.2-2007.

Nonresidential: spaces in mixed-use buildings other than residential or common space, such as commercial space.

Performance Path: Where software is used to model the building's energy use to verify that it attains the Performance Target of 15% energy cost savings above the ASHRAE 90.1-2007 baseline using the Appendix G protocols and the *ENERGY STAR MFHR Simulation Guidelines*. Exceptions: In California, the Performance Target is 15% above Title 24 using Title 24 modeling guidance and the *Simulation Guidelines*.

Performance Target: Minimum performance rating required to earn the ENERGY STAR. Proposed Building Design and As-Built must achieve a Performance Target of 15% or more to be eligible to earn the ENERGY STAR.

Prerequisites: Minimum program standards set by EPA to restrict the ability of the -Design Team to make performance trade-offs that would allow individual building components to fall below minimum acceptable standards. A Prerequisites Checklist is provided in the *Testing and Verification Worksheets*.

Prescriptive Path: Where a builder constructs the building using a prescribed set of construction specifications that meet program requirements outlined in the *ENERGY STAR MFHR Prescriptive Path* for their particular climate zone.

Proposed Building Performance: The annual energy cost calculated for a proposed design.

Proposed Design: A computer representation of the actual proposed building design, or portion thereof, used as the basis for calculating the design energy consumption and costs.

RESNET: Residential Energy Services Network (http://www.resnet.us)

Residential: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations.

Residential-associated: see *common areas*.

Ventilation: the process of supplying outdoor air to or removing air from a space by mechanical means.

whole-unit ventilation: A mechanical exhaust system, supply system, or combination that provides each dwelling unit with outdoor air each hour at no less than the rate specified in Table 4.1a of ASHRAE 62.2-2007 or, equivalently, Equation 4.1a of ASHRAE 62.2-2007, based on the floor area of the dwelling unit and number of bedrooms.

local mechanical exhaust: An intermittent or continuously operating exhaust fan that removes air from the dwelling unit's bathrooms and kitchen and discharges to the outside. A bathroom is any room containing a bathtub, a shower, a spa, or similar source of moisture. A kitchen is any space containing cooking appliance

Statement of Substantial Completion: A Statement of Substantial Completion or approved proxy may be used to establish completion of the work. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead and must provide all information, photographs, cut sheets, etc., as required in the applicable *Testing and Verification Protocol* and corresponding *T&V Worksheet.* When reviewing a signed Statement of Substantial Completion, the responsible party ~~should~~shall perform the necessary due diligence to ensure that the Statement of Substantial Completion is accurate and complete and all relevant information has been included within the *T&V Worksheets*, prior to submission to EPA. A statement of substantial completion can be used for the following protocols:

- 1.1 - ENERGY STAR ~~Qualified~~Certified Appliances
- 3.4 - Window Selection, U-value, and SHGC~~, and Visual Transmittance~~
- 3.5 - Exterior Door Selection, Entrance-way Design, Use of Vestibules, Weather stripping, and Air Leakage
- 6.1 - Common Areas, In-Unit, Garage and Exterior Lighting
- 6.2 - Emergency Lighting (Exit Signs)
- 6.3 - Lighting Controls
- 7.1 - Motors
- 9.1 - Metering Configuration

For the following HVAC protocols a Statement of Substantial Completion can be used per the procedure explained above, however it must be completed by a third-party qualified representative:

- 2.1 - Central Systems (Serving 5+ units~~ or more~~/spaces)
- 2.2 - Distributed (Individual Apartment or Common Space) Systems
- 5.1 - Central Heating Systems (Serving 5+ units~~ or more~~/spaces)
- 5.2 - Central Cooling Systems (Serving 5+ units~~ or more~~/spaces)
- 5.3 - Distributed (Individual Apartment or Common Space) Heating Systems
- 5.4 - Distributed (Individual Apartment or Common Space) Cooling Systems
- 8.2- Common Area and In-Unit Ventilation (CFM), ~~Intake Source, and Intake/Exhaust~~ Fan Efficiency, and Central Exhaust Duct Leakage

Introduction and Purpose

This document provides guidance to those providing testing and verification services in the ENERGY STAR Multifamily High Rise Program. The specifications contained within this document are mandatory requirements for the inspection, testing, and verification of components related to the building's energy performance. This is not a stand-alone document. It is designed to work in conjunction with the *ENERGY STAR MFHR Simulation Guidelines, Performance Path, Prescriptive Path, Testing & Verification Worksheets* and *Photo Template*. All inspections and diagnostic tests described within these protocols are required for each of the energy-related components and systems that exist in the participating building. Results of inspections must be documented and provided to the EPA, at the completion of construction.

The intent of these protocols is to verify that the As-Built Building has successfully achieved the performance levels predicted by the Proposed Design energy model or as specified in the *Prescriptive Path* and is in compliance with the *Prerequisites Checklist*. If differences exist between the As-Built and the Proposed Design, the As-Built energy model must represent the actual observed and measured conditions in the completed building.

Note: Within this document, any time the Proposed Design model is mentioned, the statement applies only to projects following the Performance Path. Any time the *Prescriptive Path Requirements* is mentioned, the statement applies only to projects following the Prescriptive Path. Any time the *Prerequisites Checklist* is mentioned, the statement applies to all projects, regardless of Path followed.

- **Failure to comply with *Prerequisites Checklist:*** All building components must comply with the specifications contained within the *Prerequisites Checklist*. During an inspection, if a building component is determined to be in non-compliance with the *Prerequisites Checklist*, corrective action must be taken to bring the building into compliance with the *Prerequisites Checklist*. Otherwise, the building may become ineligible to earn the ENERGY STAR.
- **Performance less than predicted in the Proposed Design model:** If an individual building component is found to be performing at a less energy efficient level than that which was included in the Proposed Design energy model, then one of the following actions shall be taken. Otherwise, the building may become ineligible to earn the ENERGY STAR.
    a. Take corrective action to remedy the problem and bring the building component to the efficiency levels assumed in the Proposed Design.
    b. Allow the component to remain in its current condition but the As-Built energy model must be adjusted to accurately represent this condition. In any case, the Performance Target calculated based on the As-Built energy model must represent at least a 15% improvement above the Baseline Building Design.
- **Performance less than level required in *Prescriptive Path*:** If an individual building component is found to be performing at a less energy efficient level than that which was required in the *Prescriptive Path*, one of the following actions shall be taken:

a. Take corrective action to remedy the problem and bring the building component to the efficiency levels required in the *Prescriptive Path*.
b. Allow the component to remain in its current condition, but can no longer use the *Prescriptive Path*. An As-Built energy model must be created to accurately represent the completed building and the Performance Target calculated based on the As-Built energy model must represent at least a 15% improvement above the Baseline Building Design.

General Approach

To improve the chances of a MFHR building project successfully earning the ENERGY STAR, the following guidelines are offered:

- As early in the design phase of the project as possible, the Licensed Professional responsible for submissions to EPA should meet with the design team and provide them with copies of the *Prerequisites Checklist*. Emphasis should be placed on the importance of incorporating the requirements listed in the *Prerequisites Checklist* into the design documents and reviewing any unique features of the building that will require special attention in design or construction to ensure the building meets all the requirements of the Prescriptive Path or meets the Performance Target once the energy simulations are complete.
- Near the end of the design phase, the Licensed Professional, or the parties responsible for verification of the various protocols, should work with the developer to ensure that all energy-related details are included in the bid documents so that subcontractors are fully informed of the scope of work they are bidding on. It is also recommended that they attend any pre-bid meetings to help answer questions and clarify the subcontractors' roles in the successful construction of a high performance building.
- The developer shall specify details to be inspected and conformance criteria in the construction documents so it is clear who is responsible for corrective actions to remedy inspection failures.
- The Licensed Professional, or the parties responsible for verification of the various protocols, should attend a pre-construction meeting with the developer, general contractor (GC), and all trades contractors to cover all of the details to be inspected. Close attention should be paid to those details that are most commonly overlooked in standard construction (air sealing details, duct sealing details, insulation installation specifications, etc). All parties should be informed at this time of their specific responsibilities for documentation.
- Inspections should be scheduled to occur as soon as possible after construction reaches the point where an inspection of a specific feature is possible. This will improve the likelihood that corrective action can be taken in a cost-effective and timely manner. Inspecting a sample of a specific feature (e.g., wall insulation in an apartment) near the beginning of the installation of that feature will allow for corrections to be made on installations going forward, rather than causing the subcontractor to correct improper installations.
- In most cases, the sample set for any given feature to be inspected shall not be selected ahead of time to help ensure the verifier is seeing a truly representative sample of the work as it progresses. An exception to this would be measures such as air sealing details where it may be more effective to have a sample unit prepared for inspection at the beginning of construction, so corrections to details can be specified for all units going forward.
- Timing is critical on many of the inspections described in this document. The construction process may not always progress in a manner that allows for multiple building elements to be inspected in a single visit. The responsible party should maintain close contact with the developer and stay up-to-date on anticipated construction schedules so inspection staff can be available at the time they are needed on the site.

- Use the *T&V Worksheets* to track the overall progress of the project and keep track of inspections completed to date, results of inspections, photo documentation, corrective actions, and final compliance.
- The *T&V Worksheets* and *Photo Template* are to be used by the Licensed Professional or other verification provider to document that each prerequisite and each energy conservation measure included in the As-Built Building meets all requirements and follows the *T&V Protocols*. Submission of the *Photo Template* is ~~only required for the first~~waived once a Developer Partner or Licensed Professional successfully certifies 3 buildings ~~submitted to EPA~~.
- For wood-framed construction, the *ENERGY STAR ~~Qualified~~Certified Homes Thermal Enclosure System Rater Checklist Sections 3 and 5* ~~must be followed~~is recommended in addition to all applicable *T&V Protocols*. Visit www.energystar.gov for the most current checklist.
- For some elements and specifications, it may be desirable to have a sample installation completed for inspection prior to building-wide installation. Some possible examples are: air sealing details of apartments, some lighting/lighting control strategies, insulation installations, and other special or unique details that are new to the GC and/or subcontractors.
- For some elements and specifications, it may be desirable to create a mock-up of the detail or conduct a field demonstration to show the GC and/or subcontractors what is expected for an acceptable installation. Some possible examples are: insulation installations, air barrier details, or duct sealing details.
- For measures that contribute to the project's energy savings that are not specifically addressed in this manual, the responsible party is expected to perform similar testing and verification, as appropriate, and is expected to report those findings in the *T&V Worksheets*.

How to Use This Manual

For each building component addressed in this manual, a set of protocols have been defined using a standardized system and nomenclature. The standard elements of the protocol for each building component are as follows:

- **Type of Testing Protocol** -- The type of inspection or test required is listed in this section based on a standardized set of options as follows:
    a. *Visual Inspection* – Indicates that the conditions can be inspected via direct visual inspection of the existing condition and documented with detailed photographs.
        i. Photos of faceplates, fixture type, insulation type, etc., must be clear enough to read what is being checked. For example, reviewers must be able to read model # from faceplate, GPM from faucets, and fixture type from lamps.
        ii. Caption/Label each photo giving location.
    b. *Data Sheet* – Used for elements such as mechanical equipment and appliances where an itemized schedule with proof of delivery/installation is verified through visual inspection and relevant performance data is recorded from nameplates and manufacturer's specifications. Please refer to the *T&V Worksheets* to be used as templates for data collection.
    c. *Test Procedure* – Indicates elements that can be verified for proper performance by running a piece of equipment through a standard operation cycle, verifying correct operation of specialized controls, etc., and the test can be performed by the responsible party without the need for a Third-Party Commissioning Agent.
    d. *Instrumented Measurement* – Indicates the use of specialized diagnostic equipment to verify the performance of specific building elements (e.g., a blower door kit, flow hood, or infrared camera).
    e. *Third-Party Commissioning* – used for building systems that require special expertise and/or are subject to regulatory requirements such as licensure of the inspector or permits for operation of those systems (e.g., heating system).
- **Performance Specification Criteria** – This section lists the actions to be taken by the responsible party during the design, bidding, and construction phases of the project to ensure that appropriate language is included in bid and contract documents and that subcontractors are properly informed of their responsibilities, namely that the building meets the requirements listed in the *Performance Path* or *Prescriptive Path*. All details to be inspected must be incorporated into the construction documents, so it is clear who is responsible for proper installation and construction. For particular protocols, suggestions for contract language have been provided in this section.
- **Procedures and Documentation** – This section lists the steps to be followed by the responsible party to ensure that each building element is inspected at the appropriate time and that the necessary data is collected and documented for use in the As-Built energy model and final submittal to EPA or to prove that requirements of the *Prescriptive Path* have been met.

- **Schedule –** Although exact timing of inspections may vary significantly from one building to another, this section identifies the point in construction when a particular inspection or test should take place. The responsible party should communicate with the developer or GC to understand the construction schedule and be available for inspections when necessary without slowing down the construction process.
- **Examples of Responsible Parties** – Although not limited to this list, this section identifies examples of parties that could be responsible for a specific inspection or test and which other parties may need to be available or coordinated with to effectively carry out the inspection.
- **Sampling Requirements** – For building elements that are duplicated many times throughout the building (e.g., windows, light fixtures) or cover large areas or sections of the building (e.g., wall insulation), the specific protocol identifies the minimum required area or sample to be inspected. If the minimum sample is inspected with a 100% compliance rate, then the inspection process is complete. If a failure is detected within the sample set, corrective actions must be implemented and the sample retested.

  In general, the *Testing and Verification Protocols* that allow sampling follow a modified RESNET sampling protocol, as opposed to requiring inspection of 100% of the installed components. Please refer to *RESNET's 2006 Mortgage Industry National Home Energy Rating Systems Standards, Chapter 6* for the full description of RESNET's sampling protocols; however, the intent is captured in the following sections:

  - 603.7.1 - A complete set of Sampling Controls shall be performed at a minimum ratio of one (1) test or inspection out of seven (7) *spaces/apartments* within a given sample set, per the sampling rate requirements below:

  - 603.7.2 - Sampling Providers may complete the sampling controls collectively on a single *space/apartment* or distribute the tests and inspections across several *spaces/apartments* within a given sample set, provided the total number of individual tests and inspections meets or exceeds the minimum ratio set forth in 603.7.1.

  - 603.7.3 **-** To qualify for sampling in a metropolitan area, a builder shall first complete, without any incidence of failure, a complete set of sampling controls on at least seven (7) consecutive apartments in that metropolitan area. For this initial phase of testing and inspections, the complete set of sampling controls shall be performed on each of the seven (7) *apartments*.

- 603.7.6 - When an “initial failure” occurs, the failed item(s) shall be tested or inspected in two (2) additional *spaces/apartments* selected from the same sample set. Testing and/or inspections for any item(s) that may become inaccessible during the construction process, (e.g., wall insulation) must be timed so additional testing and/or inspections can occur on other *spaces/apartments* in the sample set before they become inaccessible for inspection or testing.

- 603.7.7 - When an “additional failure” occurs, in one or more of the two (2) additional *spaces/apartments*, the failed item(s) shall be tested or inspected in the remaining four (4) *spaces/apartments* selected for the same sample set.

- 603.7.8 - Until the failure is corrected in all identified (failed) *spaces/apartments* in the sample set, none of the *spaces/apartments* shall be deemed to meet the threshold or labeling criteria.

- 603.8 - Action is required if three (3) “additional failures” occur within a ninety (90) calendar day period. The required action depends on whether those “additional failures” apply to the same failed item or various failed items.

1.0 Appliances

Protocol 1.1 - ENERGY STAR ~~Qualified~~Certified Appliances

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✗	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- Include a schedule with location and quantity.
- When provided in common areas and/or apartments, refrigerators, dishwashers, clothes washers, ceiling fans and vending machines must be ENERGY STAR ~~qualified~~certified. Note: Kitchen range hoods are not required to be ENERGY STAR ~~qualified~~certified.
- Contract Language: "Allow inspection of all appliances. Provide submittal to the responsible party and inform them immediately after installation. Ensure the ENERGY STAR label remains attached to products and appliances."

Procedures and Documentation:

- ~~Record~~Prior to purchase, enter the manufacturer and model number~~.~~
- ~~Confirm manufacturer and model number is~~ of the appliance in the ENERGY STAR ~~qualified~~Product Finder online to confirm ENERGY STAR certification. This documentation should be retained with the building file as ENERGY STAR criteria are subject to change.
- ~~Photograph~~Once installed, photograph one (1) representative appliance faceplate of each type of appliance being inspected~~.~~
- ~~Photograph~~, including ENERGY STAR label and~~/or attach cut sheet proving ENERGY STAR qualification~~ model number. Record/confirm manufacturer and model numbers in the T&V Worksheets.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet*.

Schedule:

- The developer or GC shall ensure that deliveries are inspected prior to accepting them to verify that product substitutions by the distributor or manufacturer have not resulted in non-ENERGY STAR ~~qualified~~certified appliances.
- Minimum of one on-site inspection required, preferably immediately after installation so that corrective action can be taken, if necessary. Delivery tickets may be used to verify complete shipments, but on-site inspections of a sample of installed appliances is required.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- Installing Contractor

Sampling Requirement:

- For spaces containing appliances, follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section of this document. For buildings with common laundry rooms, RESNET sampling protocols are modified to require inspection of all the clothes washers in at least one (1) laundry room.

2.0 Domestic Water Heating

Protocol 2.1 - Central Systems (Serving 5+ units ~~or more~~/spaces)

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✓	Instrumented Measurement
✓	Third-Party Commissioning

Performance Specification Criteria:

- All DHW systems serving the building must follow either Protocol 2.1 or Protocol 2.2. The Licensed Professional may use their discretion to determine which Protocol is most appropriate for a particular system.
- *DHW Plant:* Heating system size, type, design, and rated efficiency shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Sizing calculations shall be detailed and provided by the design engineer.
- DHW equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the Prescriptive Path and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website. If WaterSense certification is required, model numbers must be verified through the WaterSense website.
- Ensure storage tanks for central DHW systems are insulated per code.
- *Distribution System:* Specifications for distribution system (supply and return) piping configuration, mixing valves, zoning, and insulation requirements shall match assumptions made in Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- ~~For automatic recirculating systems, piping~~ Piping carrying liquid ~~or steam~~ with temperatures greater than 105°F must have a minimum of 1" of insulation. Pipes ~~over~~ 1.5" in diameter and greater must have a minimum of 1.5" of insulation. Construction documents must account for piping total thickness including required insulation when passing through planks or any other penetrations. Construction documents shall specify that the piping must be inspected before access is covered up. Extent and location to be determined by ASHRAE 90.1-2007 Section ~~6~~7.4.~~4.1.~~3 or local code.
- *Controls:* System controls and settings shall match operating assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.

- Include a schedule of plumbing fixtures with GPM, location, WaterSense certification, and quantity.
- Specify plumbing fixture flow rates to match assumptions made in the Proposed Design model or to meet or exceed the requirements listed in the *Prescriptive Path*.
- Contract Language: "The domestic hot water plant(s), controls, and distribution system shall be made available to allow for thorough inspection and performance verification."
- Contract Language: "The domestic hot water system shall be tested, including all applicable Functional Performance Test checklists, by the installation contractor to demonstrate the system is installed and functioning according to the specifications in the contract documents."
- Contract Language: "The responsible party or a third-party commissioning authority/agent will verify the domestic hot water system as tested will perform and function according to the specifications in the contract documents and submit a summary of the commissioning results."
- Contract Language: "The installation contractor and/or system manufacturer ~~shall~~should conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the domestic hot water system(s)."
- Contract Language: "Allow inspection of all plumbing fixtures. Provide submittal to the responsible party and inform them immediately after installation."

Procedures and Documentation:

- The responsible party shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist*. In addition, the responsible party must verify the system will perform according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*.
- The developer shall hire a commissioning agent who will perform the quality assurance and verification requirements that cannot be completed by the responsible party.
- The responsible party shall review the results of the commissioning report to confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*. Any significant problems discovered during commissioning must be satisfactorily addressed.
- Whether performed by a third-party Commissioning Agent or by the responsible party (if appropriate), the following commissioning of the system must be performed:
    - Verify location of domestic hot water system (e.g., cellar or roof), combustion air venting configuration (e.g., combustion air piped to boilers, boiler room air used for combustion), and venting configuration (e.g., inducer fan specified and sequence of operation verified, if required).
    - ~~The temperature setting of in-unit storage water heaters must not exceed 140°F. For both in-unit and central DHW systems,~~ Verify temperatures measured at faucets and showerheads ~~must~~do not exceed 125°F.

- Verify domestic hot water supply and delivery temperatures. Verify ~~return~~entering water temperature meets design for condensing ~~boiler~~ systems.
- Verify storage tanks for central DHW systems are insulated per code.
- Verify a self-contained or electronic mixing valve is used to control hot water temperature for central domestic water heating systems~~.~~ serving apartments. Mechanical valves shall not be specified. Verify mixing valve temperature set point.
- Verify ~~automatic circulating systems with~~ piping carrying liquid ~~or steam~~ with temperatures greater than 105°F ~~have~~has a minimum of 1" of insulation and pipes ~~over~~ 1.5" in diameter and greater have a minimum of 1.5" of insulation. Verify that minimum thickness is met at all locations where required, including piping passing through planks, other penetrations, and domestic hot water branch piping. Extent and location to be determined by ASHRAE 90.1-2007 Section ~~6~~7.4.~~4.1.~~3 or local code.
- Compare the rated flow rate ~~data~~ of the inspected plumbing fixtures to the assumptions made in the Proposed Design model and adjust data inputs for As-Built Building model as necessary; or compare the ~~consumption data~~rated flow rate to the requirements listed in the *Prescriptive Path*. Confirm WaterSense certification using the online product search.
- ~~Summarize the training performed and personnel involved. Confirm~~EPA recommends confirming that all applicable operating and specification manuals are delivered to the building staff. ~~Verify~~EPA also recommends verifying that staff members have been trained and are aware of their responsibilities to maintain and operate the systems properly. Summarize any training performed and personnel involved.

- Review manufacturer's cut sheets or invoice detailing system manufacturer, model, size, and location, and keep with the building file. ~~These should also be used to prove ENERGY STAR qualification and efficiency rating~~DHW equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, it must be verified through the ENERGY STAR website.
- Provide summary of commissioning results to the EPA through the use of the *T&V Worksheets* and the *Photo Template*.
- Photographs:
  - Provide photos of the domestic water heating system and faceplates to verify proper installation and compliance with proposed design.
  - Photograph one (1) representative fixture of each type of plumbing fixture being inspected.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion must be completed by a third-party qualified representative on company letter head, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*

Schedule:

- Commissioning of the system occurs during pre-construction and construction phases of installation. Inspection, testing, and final commissioning are conducted during the turn over/acceptance phase of the installation of the system.
- Training shall occur following installation of the system and completion of all quality assurance and verification procedures.
- The developer or GC shall ensure that deliveries are inspected prior to accepting them to verify that product substitutions by the distributor or manufacturer have not resulted in plumbing fixtures with higher flow rates than those in the Proposed Design or required by the *Prescriptive Path* and that fixtures are WaterSense certified, where required.
- Minimum of one (1) on-site inspection required, preferably immediately after installation so that corrective action can be taken if necessary. Delivery tickets may be used to verify complete shipments, but on-site inspections of a sample of installed plumbing fixtures is required.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- DHW System Designer
- Commissioning Agent
- Building Maintenance Staff
- Installing Contractor

Sampling Requirements:

- 100% of central DHW systems shall be inspected and commissioned.
- All spaces with Domestic Hot Water service (i.e., apartments, public bathrooms, common kitchens, etc.) shall be tested for hot water delivery temperature ~~and pressure~~ following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document, with the additional requirement that, for each central DHW system, the spaces sampled must include the first space supplied by the system and the last space supplied by the longest run of the system.
- Inspect all spaces containing plumbing fixtures following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document.

2.0 Domestic Water Heating

Protocol 2.2 - Distributed (Individual Apartment or Common Space) Systems

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✓	Instrumented Measurement
✓	Third-Party Commissioning

Performance Specification Criteria:

- All DHW systems serving the building must follow either Protocol 2.1 or Protocol 2.2. The Licensed Professional may use their discretion to determine which Protocol is most appropriate for a particular system.
- *DHW Plant:* Heating system size, type, design, and rated efficiency shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Sizing calculations shall be detailed and provided by the design engineer.
- DHW equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website. If WaterSense certification is required, model numbers must be verified through the WaterSense website.
- *Distribution System:* Specifications for distribution system (supply and return) piping configuration and insulation requirements shall match assumptions made in Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- ~~For automatic circulating systems, piping~~ Piping carrying liquid ~~or steam~~ with temperatures greater than 105°F must have a minimum of 1" of insulation. Pipes ~~over~~ 1.5" in diameter and greater must have a minimum of 1.5" of insulation. Construction documents must account for piping total thickness including required insulation when passing through planks or any other penetrations. Construction documents shall specify that the piping must be inspected before access is covered up. Extent and location to be determined by ASHRAE 90.1-2007 Section ~~6~~7.4.~~4.1.~~3 or local code.
- *Controls:* System controls and settings shall match operating assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- Include a schedule of plumbing fixtures with GPM, location, WaterSense certification, and quantity.

- Specify plumbing fixture flow rates to match assumptions made in the Proposed Design model or to meet or exceed the requirements listed in the *Prescriptive Path*.
- Contract Language: "The domestic hot water plant(s), controls, and distribution system shall be made available to allow for thorough inspection and performance verification."
- Contract Language: "The domestic hot water system shall be tested, including all applicable Functional Performance Test checklists, by the installation contractor to demonstrate the system is installed and functioning according to the specifications in the contract documents."
- Contract Language: "The responsible party or a third-party commissioning authority/agent will verify the domestic hot water system as tested will perform and function according to the specifications in the contract documents and submit a summary of the commissioning results."
- Contract Language: "The installation contractor and/or system manufacturer ~~shall~~should conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the domestic hot water systems."
- Contract Language: "Allow inspection of all plumbing fixtures. Provide submittal to the responsible party and inform them immediately after installation."

Procedures and Documentation:

- The responsible party shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist*. In addition, the responsible party must verify the system will perform according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*.
- The developer shall hire a commissioning agent who will perform the quality assurance and verification requirements that cannot be completed by the responsible party.
- The responsible party shall review the results of the commissioning to confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*. Any significant problems discovered during commissioning must be satisfactorily addressed.
- Whether performed by a third-party Commissioning Agent or by the responsible party (if appropriate), the following commissioning of the system must be performed:
    - Verify combustion air venting configuration (e.g., combustion air piped to system), and venting configuration (e.g., inducer fan specified and sequence of operation verified, if required).
    - Verify ~~that domestic hot~~temperature setting of in-unit storage water ~~system is set to deliver~~heaters does not exceed 140F°.
    - Verify temperatures ~~within the 120~~ measured at faucets and showerheads do not exceed 125°F ~~range~~.
    - ~~Verify automatic circulating systems with~~ piping carrying liquid ~~or steam~~ with temperatures greater than 105°F has a minimum of 1" of insulation and pipes ~~over~~ 1.5" in diameter and greater have a minimum of 1.5" of insulation. Verify that

minimum thickness is met at all locations where required, including piping passing through planks, other penetrations, and domestic hot water branch piping. Extent and location to be determined by ASHRAE 90.1-2007 Section 67.4.4.1.3 or local code.

- ~~Verify return water temperature meets design for condensing boiler systems.~~
- Compare the rated flow rate ~~data~~ of the inspected plumbing fixtures to the assumptions made in the Proposed Design model and adjust data inputs for As-Built Building model, as necessary; or compare the consumption data to the requirements listed in the *Prescriptive Path.* Confirm WaterSense certification using the online product search.
- ~~Summarize the training performed and personnel involved. Confirm~~EPA recommends confirming that all applicable operating and specification manuals are delivered to the building staff. ~~Verify~~EPA also recommends verifying that staff members have been trained and are aware of their responsibilities to maintain and operate the systems properly. Summarize any training performed and personnel involved.
- Review manufacturer's cut sheets or invoice detailing system manufacturer, model, size, and location, and keep with the building file. ~~These should also be used to prove ENERGY STAR qualification and efficiency rating~~DHW equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, it must be verified through the ENERGY STAR website.

- Provide summary of commissioning results to the EPA through the use of the *T&V Worksheets* and the *Photo Template*.
- Photographs:
  - Provide photos of the domestic water heating system and faceplates to verify proper installation and compliance with proposed design.
  - Photograph one (1) representative fixture of each type of plumbing fixture being inspected.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion must be completed by a third-party qualified representative on company letter head, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*

Schedule:

- Commissioning of the system occurs during pre-construction and construction phases of installation. Inspection, testing, and final commissioning are conducted during the turn over/acceptance phase of the installation of the system.
- Training shall occur following installation of the system and completion of all quality assurance and verification procedures.

- Inspection, testing, and commissioning are conducted upon completion of the installation of the system.
- The developer or GC shall ensure that deliveries are inspected prior to accepting them to verify that product substitutions by the distributor or manufacturer have not resulted in plumbing fixtures with higher flow rates than those in the Proposed Design or required by the *Prescriptive Path* and that fixtures are WaterSense certified, where required.
- Minimum of one (1) on-site inspection required, preferably immediately after installation so that corrective action can be taken if necessary. Delivery tickets may be used to verify complete shipments, but on-site inspections of a sample of installed plumbing fixtures is required.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- Installing Contractor
- Commissioning Agent
- Building Maintenance Staff

Sampling Requirements:

- Distributed DHW systems shall be inspected and tested following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document, including at least one of each unique type.
- All spaces with domestic hot water service (e.g., bathrooms, kitchens, etc.) shall be tested for hot water delivery temperature following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document.
- Inspect all spaces containing plumbing fixtures following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document.

3.0 Envelope

Protocol 3.1 - Wall Construction/Insulation, R-value

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✗	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- General Exterior Enclosure:
    - The construction drawings and specifications must clearly identify systems that manage the flow of rainwater (e.g. cladding, air gap and weather resistant barrier), heat (insulation) and air (air barriers) through the exterior enclosure. Continuity of these three systems must be shown in section, plan and details. Typical sections must show continuity from the center of the roof assembly, down the walls and fenestration, to the center of the foundation floor. Submittal of shop drawings detailing continuity of these systems and installer qualifications must be required in the specifications.
    - Exterior enclosure assemblies must be designed and constructed to prevent condensation within the assemblies during heating mode, cooling mode or both as the climate dictates. Assemblies may be drawn from published guidance documents that include hygro-thermal performance analysis. Alternatively assemblies should pass year – long, hourly hygro-thermal simulations conducted in accordance with ASHRAE 160P.
- Installation specifications must include detail beyond “manufacturer’s specifications” to ensure insulation performance. Specific details must include the following:
    - Interior and cavity insulation must be protected from air intrusion, moisture intrusion and free of voids, gaps, and compression.
    - Cavity insulation must be in contact with the interior wall surface (i.e., drywall) and completely fill the interior wall cavity.
    - Batt insulation must be installed properly using splices to surround wires, electrical outlet/switch/junction boxes, pipes, and other obstructions within the insulated cavity.
    - For steel-framed and metal ~~buildings~~building walls, continuous exterior insulation (≥R-3) is required. For mass or masonry ~~buildings~~walls with metal framing, continuous interior insulation (≥R-3) is required.

    - Insulation that is intended to be continuous (interior or exterior) must be installed without breaks and at full thickness at all locations.
    - Air barrier must be continuous around the entire building. Air barrier must be detailed at all penetrations and transitions including structural components, connections between dissimilar materials, and window rough openings. Flashing materials and sealants must be used at window openings, through-wall duct penetrations, the transition between the wall and roof barrier, and the transition between the wall and foundation barrier.
    - All wall insulation must be installed such that they achieve RESNET-defined Grade I installation or, alternatively, Grade II for walls with continuous insulation.
- Vapor impermeable air barriers for general coverage should only be specified on the warm side of insulation (i.e., interior side of insulation in predominately heating dominated climates). Vapor permeable air barriers should be specified in other cases.
- Specifications could include, at the discretion of the developer, the inspection of a sample mock up installation by the responsible party prior to installation of windows building-wide
- Contract Language: "Allow inspection of wall insulation, including framing, pre-drywall installation and post-drywall construction. Notify responsible party prior to enclosing wall insulation in areas designated for inspections."

Procedures and Documentation:

- Initial framing inspection will verify that the wall assembly is compliant with the Proposed Design model (from exterior finish to interior finish) and that excessive use of framing materials that may compromise the final effective R-value of the wall assembly is properly accounted for in the building energy model. Verify that framing factor assumptions in the model are consistent with the actual building construction. As an alternative to the *Performance Path*, projects must ensure that all of the requirements listed in the *Prescriptive Path* have been met or exceeded.
- Insulation inspection (pre-drywall) will verify insulation type, thickness, location, coverage, and installation. Location and continuity of air and vapor barriers (if specified) and protection from air and moisture intrusion of interior and cavity insulation will also be verified. The effective R-value of the installed insulation shall be used in the As-Built Building energy model. As an alternative to the *Performance Path*, projects must ensure that all of the requirements listed in the *Prescriptive Path* have been met or exceeded. Estimated R-values for insulation that are improperly installed must be derated using the standards and procedures described in the *Mortgage Industry's National Home Energy Rating Systems,* Section 303.4.1.4.2 and *Appendix A, "On-Site Inspection Procedures for Minimum Rated Features."*
- Verify that insulation is properly secured in place (e.g., fiberglass batts are secured in steel stud cavities in a manner that avoids compression and slippage).
- Verify that insulation achieves RESNET-defined Grade I installation or, alternatively, Grade II for walls with continuous insulation. (For details on RESNET-defined grading system, see Appendix A of the 2006 Mortgage Industry National Home Energy Rating Systems Standards).

- Verify proper installation of the air and weather barrier. Inspect for proper location, adhesion (if applicable), continuity, and thickness.
- Final inspection will verify proper enclosure of insulated cavities through visual inspection.
- Photographs:
  - All Insulation
    - Photo clearly identifying type of insulation to be installed and thickness using ruler (can measure each individual piece of insulation or entire assembly)
    - Photo showing continuous insulation around sample corner and other challenging details
  - Below-Grade Wall/Foundation
    - Photo of pre-insulation showing application of water/vapor/air barrier
    - Photo of post-installation
  - Above Grade walls
    - Photo of pre-installation to verify framing construction
    - Photo of post-insulation indicating proper installation
    - Photo of completion showing proper drywall installation
  - Plank/Slab Edge and Rim Joist Insulation
    - Photo of insulation between ceiling/floor levels before cladding is installed
- For wood-framed construction, Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes Thermal Enclosure System Rater Checklist Sections 3 and 5* ~~must be followed~~is recommended in addition to all *T&V Protocols*.

Schedule:

- A minimum of three (3), and as many as five (5), separate site visits are required for most multifamily buildings.
  - Load-bearing wall inspection: air/vapor/weather barrier and slab-edge insulation prior to enclosure
  - Continuous interior insulation (which may occur before, during, or after the framing inspection depending on location of continuous insulation)
  - Interior framing inspection
  - Interior/cavity insulation inspection
  - Post-completion inspection
- Inspections of interior and cavity insulation must take place during construction: at framing pre-insulation, post-insulation and pre-drywall, and post-completion.
- Inspections of exterior insulation, air, vapor, and weather barrier systems must be completed prior to enclosure.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor (GC)
- Installing Contractor

Sampling Requirements:

- Each unique wall assembly shall be inspected. (For example: If the basement walls are constructed differently from the upper floors, both areas must be inspected independently. Also, if insulation specifications are different for living areas vs. common areas or other special use areas, each different specification shall be inspected independently.)
- Sampling may be used to inspect wall assemblies that are consistent throughout large sections of the building. Inspections done from the exterior shall sample at least 15% of each wall area. For inspections done from interior spaces, follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document, for each unique wall type. In addition, the sample set must include, at a minimum, all unique assemblies. If problems are found in the sample set, additional inspections must be conducted to determine the full extent of the problems and to ensure that repairs are completed in all areas of the building where they are needed.
- Documentation of post-repair conditions is required for correction of problems that represent large surface areas (greater than 50 square feet) and/or systemic problems (e.g., all corner units are insulated improperly). On-site inspection to verify corrections is preferable, but if this is not possible/practical due to construction schedules, photographic documentation of repairs submitted to the responsible party by the GC are an acceptable alternative.

3.0 Envelope

Protocol 3.2 - Roof Construction/Insulation, R-value

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✗	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- General Exterior Enclosure:
    - The construction drawings and specifications must clearly identify systems that manage the flow of rainwater (e.g. cladding, air gap and weather resistant barrier), heat (insulation) and air (air barriers) through the exterior enclosure. Continuity of these three systems must be shown in section, plan and details. Typical sections must show continuity from the center of the roof assembly, down the walls and fenestration, to the center of the foundation floor. Submittal of shop drawings detailing continuity of these systems and installer qualifications must be required in the specifications.
    - Exterior enclosure assemblies must be designed and constructed to prevent condensation within the assemblies during heating mode, cooling mode or both as the climate dictates. Assemblies may be drawn from published guidance documents that include hygro-thermal performance analysis. Alternatively assemblies should pass year – long, hourly hygro-thermal simulations conducted in accordance with ASHRAE 160P.
- Installation specifications must include detail beyond “manufacturer’s specifications” to ensure insulation performance. Specific details must include the following:
    - Insulation must be protected from air and moisture intrusion and free of voids, gaps, and compression.
    - Cavity insulation must be in contact with the interior ceiling surface (i.e., drywall).
    - Batt insulation must be installed properly using splices to surround wires, electrical junction boxes, pipes, and other obstructions within the insulated cavity.
    - Insulation that is intended to be continuous must be installed without breaks and at full thickness at all locations.
    - All roof insulation must be installed such that they achieve RESNET-defined Grade I installation or, alternatively, Grade II for roofs with continuous insulation.

- Sprinkler systems to be designed to not interfere with the performance of thermal and air barriers.
- For built-up insulation on flat roofs, minimum and average R-value for roof surfaces must be specified. Specifications must require contractor to submit roof insulation software calculator results (e.g., "Taper Plus" or equivalent) to demonstrate R-value.
- Contract Language: "Allow inspection of roof insulation. Notify the responsible party prior to sealing roof insulation in areas designated for inspections."

Procedures and Documentation:

- Initial framing inspection will verify that the roof assembly is compliant with the proposed design model (from exterior finish to interior finish) and that excessive use of framing materials, installation of roof ventilation, or other details that may compromise the final effective R-value of the roof assembly is properly accounted for in the building energy model. Verify that framing factor assumptions in model are consistent with the actual building construction. As an alternative to the *Performance Path*, projects must ensure that all of the requirements listed in the *Prescriptive Path* have been met or exceeded.
- Effective R-value must be verified with roof insulation software calculator results (e.g., "Taper Plus" or equivalent). This should be provided by most roofing material manufacturers without additional cost.
- Insulation inspection will verify insulation type, thickness, location, coverage, and installation with reference to roof insulation layout used in R-value calculator. Protection from air and moisture intrusion will also be verified.
- Verify that insulation achieves RESNET-defined Grade I installation or, alternatively, Grade II for roofs with continuous insulation. (For details on RESNET-defined grading system, see Appendix A of the 2006 Mortgage Industry National Home Energy Rating Systems Standards).
- Inspect installation of air and vapor barrier (if specified) for location and continuity.
- Final inspection will verify proper enclosure of insulated cavities through visual inspection.
- Photographs:
    - Photo clearly identifying type of insulation to be installed and thickness using ruler (can do each individual piece of insulation or entire assembly)
    - Photo showing continuous insulation at sample corner and other challenging details
    - Post insulation photo (pre-drywall for cavity insulation, prior to roof finish for exterior rigid insulation) showing complete and even distribution of insulation
    - Photo of proper enclosure of insulated cavities (if applicable)
- For wood-framed construction, Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes Thermal Enclosure System Rater Checklist Sections 3 and 5* ~~must be followed~~is recommended in addition to all *T&V Protocols.*

Schedule:

- A minimum of three (3) site visits are recommended.
- Inspections must take place during construction: pre-insulation, post-insulation and pre-drywall or prior to roof finish, and post-completion.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor (GC)
- Installing Contractor

Sampling Requirements:

- Each unique roof assembly shall be inspected. (For example: If unique sections of the building are constructed differently, all distinct areas must be inspected independently. Also, if insulation specifications are different for living areas vs. common areas or other special use areas, each different specification shall be inspected independently.)
- Sampling may be used to inspect roof assemblies that are consistent throughout large sections of the building. At each stage of the inspection process, a minimum of 15% of total roof area must be inspected for each unique roof type. If problems are found in the sample set, additional inspections must be conducted to determine the full extent of the problems and to ensure that repairs are completed in all areas of the building where they are needed.
- To verify the predicted overall R-value, 100% of locations where roof insulation achieves the minimum thickness are to be inspected. Insulation thickness at roof perimeters shall be inspected at one (1) location per 70 feet of roof perimeter. This shall include, at a minimum, two (2) instances where the roof insulation achieves its maximum thickness. Each location inspected cannot be within 70 feet of each other along the roof perimeter.
- Documentation of post-repair conditions is required for correction of problems that represent large surface areas (greater than 50 square feet) and/or systemic problems (e.g., all corner units are insulated improperly). On-site inspection to verify corrections is preferable, but if this is not possible/practical due to construction schedules, photographic documentation of repairs submitted to the responsible party by the GC are an acceptable alternative.

3.0 Envelope

Protocol 3.3 - Floor Construction/Insulation, R-value

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✗	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- General Exterior Enclosure:
    - The construction drawings and specifications must clearly identify systems that manage the flow of rainwater (e.g. cladding, air gap and weather resistant barrier), heat (insulation) and air (air barriers) through the exterior enclosure. Continuity of these three systems must be shown in section, plan and details. Typical sections must show continuity from the center of the roof assembly, down the walls and fenestration, to the center of the foundation floor. Submittal of shop drawings detailing continuity of these systems and installer qualifications must be required in the specifications.
    - Exterior enclosure assemblies must be designed and constructed to prevent condensation within the assemblies during heating mode, cooling mode or both as the climate dictates. Assemblies may be drawn from published guidance documents that include hygro-thermal performance analysis. Alternatively assemblies should pass year – long, hourly hygro-thermal simulations conducted in accordance with ASHRAE 160P.
- Installation specifications must include detail beyond “manufacturer’s specifications” to ensure insulation performance. Specific details must include the following:
    - Insulation must be protected from air and moisture intrusion, and free of voids, gaps, and compression.
    - Cavity insulation must be in contact with the interior floor surface and completely fill the floor cavity.
    - Batt insulation must be installed properly using splices to surround wires, electrical junction boxes, pipes, and other obstructions within the insulated cavity.
    - Insulation that is intended to be continuous (interior or exterior) must be installed without breaks and at full thickness at all locations.
    - All floor insulation must be installed such that they achieve RESNET-defined Grade I installation or, alternatively, Grade II for floors with continuous insulation.

- If specified, rim joists between ceiling/floor levels must be insulated around the entire perimeter, and necessity of shelf angles should be evaluated by structural engineer.
- Contract Language: "Allow inspection of floor insulation. Notify the responsible party prior to sealing floor insulation in areas designated for inspections."

Procedures and Documentation:

- For floor insulation above unconditioned space, below grade slab floor insulation, slab-on-grade insulation, and foundation wall insulation, inspection must take place prior to pouring of concrete or backfill of foundation walls respectively. This may require two separate inspections to verify floor and wall insulation. Sub-slab and exterior foundation wall insulation must be verified for type, thickness, and coverage consistent with assumptions used in the Proposed Design model, or to meet or exceed the requirements listed in the *Prescriptive Path*. If moisture or insect protection is required in the specifications, this must be verified before backfill is installed.
- If following the *Prescriptive Path* slab-on-grade floor insulation shall be placed on the outside of the foundation or on the inside of a foundation wall. The insulation shall extend downward from the top of the slab for a minimum distance as shown in *Prescriptive Path* Table 3 or to the top of the footing, whichever is less, or downward to at least the bottom of the slab and then horizontally to the interior or exterior for the total distance shown in the table.
- For framed floors: The initial framing inspection will verify that the floor assembly is compliant with the Proposed Design model (from exterior finish to interior finish) and that excessive use of framing materials, installation of crawlspace ventilation, or other details that may compromise the final effective R-value of the floor assembly is properly accounted for in the building energy model. Verify that framing factor assumptions in model are consistent with the actual building construction. As an alternative to the *Performance Path*, projects must ensure that all of the requirements listed in the *Prescriptive Path* have been met or exceeded.
- Insulation inspection (pre-drywall) will verify insulation type, thickness, location, coverage, and installation. Location and continuity of air and vapor barriers and protection from air and moisture intrusion will also be verified.
- Verify that insulation achieves RESNET-defined Grade I installation or, alternatively, Grade II for floors with continuous insulation. (For details on RESNET-defined grading system, see Appendix A of the 2006 Mortgage Industry National Home Energy Rating Systems Standards.)
- Final inspection will verify proper enclosure of insulated cavities through visual inspection.
- Photographs:
    - Photo clearly identifying type of insulation installed and thickness using ruler (can do each individual piece of insulation or entire assembly)
    - Photo showing continuous insulation around sample corner and/or trouble area
    - Sub-Slab insulation – Photo of insulation before pouring of concrete or backfill of foundation

        - If moisture or insect protection is required, photo of proper installation is required
    - Framed floors – Photo of post-insulation to show proper installation showing no signs of compromised R-Value
- For wood-framed construction, Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes Thermal Enclosure System Rater Checklist Sections 3 and 5* ~~must be followed~~is recommended in addition to all *T&V Protocols*.

Schedule:

- Inspections must take place during construction: before pouring slab, before back-filling foundation walls, at framing (pre-insulation), post-insulation and pre-drywall, and post-completion.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor (GC)
- Installing Contractor

Sampling Requirements:

- Each unique floor assembly shall be inspected. (For example: If unique sections of the building are constructed differently, all distinct areas must be inspected independently. Also, if insulation specifications are different for living areas vs. common areas or other special use areas, each different specification shall be inspected independently.)
- Sampling may be used to inspect floor assemblies that are consistent throughout large sections of the building. At each stage of the inspection process, a minimum of 15% of total floor area must be inspected for each unique floor type. If problems are found in the sample set, additional inspections must be conducted to determine the full extent of the problems and to ensure that repairs are completed in all areas of the building where they are needed.
- Documentation of post-repair conditions is required for correction of problems that represent large surface areas (greater than 50 square feet) and/or systemic problems (e.g., all corner units are insulated improperly). On-site inspection to verify corrections is preferable, but if this is not possible/practical due to construction schedules, photographic documentation of repairs submitted to the responsible party by the GC are an acceptable alternative.

3.0 Envelope

Protocol 3.4 - Window Selection, U-value, and SHGC

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✓	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- Include selection of window type (by operation, e.g., double-hung, single-hung, casement, fixed, etc.), dimensions, frame, U-value, low-emissivity, gas fill, SHGC, and labeling by an independent third-party (e.g., NFRC). If an NFRC label is not available, manufacturer must provide assembly U-values, not center-of-glass. Alternatively, LBNL's WINDOW 6.3 software or NFRC's CMAST may be used.
- Specified windows must be double or triple pane, with low-emissivity glass or coatings.
- Windows shall be installed properly to ensure weather tightness and air tightness performance within manufacturer's specifications in addition to proper operation.
- All joints between window frame and rough opening should be sealed with minimum 20-year sealant compatible with all surfaces.
- Specifications could include, at the discretion of the developer, the inspection of a sample mock-up installation by the responsible party prior to installation of windows building-wide.

Procedures and Documentation:

- The installation subcontractor is responsible for verifying that rough openings are properly constructed including: structural soundness of sill, header, and jambs; opening should be square, level, and plumb; and building materials should be protected from moisture damage prior to window installation. Construction deficiencies should be reported to the developer or GC and corrected prior to installation of windows.
- If approved by the developer, the responsible party shall inspect a sample installation of the window prior to the installation of windows building-wide. The manufacturer's data shall be inspected to verify energy performance specifications (window type, frame, U-value factor, gas fill, SHGC). In addition, the installed window must be inspected for proper fit and operation and effective connections to the building envelope weather barrier and air barrier. Low-e glass must be verified using a low-e meter.
- The responsible party shall check newly installed windows for compliance with the installation specifications and confirm the assumptions in the Proposed Design model. As an alternative to the *Performance Path*, projects must ensure that all of the requirements listed in the *Prescriptive Path* have been met or exceeded.

- Visually confirm all joints between window frame and rough opening have been sealed. Optional: To verify air tightness of the weather stripping and window installation, use a smoke pencil around the window, casing, and frame with the building ventilation system running or with the space under pressurization/depressurization using a blower door.
- Review manufacturer's cut sheet or invoice detailing window construction, U-Value, SHGC, low–e and whether ENERGY STAR ~~qualified~~certified (if applicable).
- Photographs:
    - Photo of each unique window type with third-party verification (NFRC label if applicable) of U-Value, SHGC, and ENERGY STAR (if applicable)
    - Photo of installed window that verifies proper fit and effective connections to envelope's weather and air barriers
    - Photo with low-e sensor device verifying low-e
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*

Schedule:

- If the developer has elected, the initial sample installation shall be inspected upon completion. If problems are identified with the sample installation, a return site visit may be necessary to verify that the problems were properly addressed and corrected before proceeding with the installation of windows building-wide.
- All other window inspections will take place on an ongoing basis during construction at the same time that other building envelope components are inspected to ensure specifications are being met throughout the construction process.

Examples of Responsible Parties:

- The installation subcontractor is responsible for ensuring proper construction of rough openings.
- Licensed Professional
- Energy Consultant

Sampling Requirements:

- For spaces containing windows, follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document, which shall include, at a minimum, one of each different type of window installation based on different window types (fixed, double hung, etc.) and different energy performance specifications (e.g., if triple-pane glass is specified on part of the building but not all of it). In addition, the sample set shall include, at a minimum, the inspection of all windows in a representative apartment from each apartment style or type. If problems are identified, additional windows must be inspected to determine if problems are systemic. Problems found will be reported to the GC for correction and re-inspection on an ongoing basis throughout construction.

3.0 Envelope

Protocol 3.5 - Exterior Door Selection, Entranceway Design, Use of Vestibules, Weather stripping, and Air Leakage

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✓	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- Design and specifications for exterior doors shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- Weather-stripping ~~shall be applied on all cellar/mechanical doors,~~is mandatory at doors between conditioned spaces and the exterior; unconditioned spaces; and spaces vented to the outside.
- Weather-stripping is recommended, but not required, at doors between corridors and stairwells~~, all exterior doors, doors~~; between apartments and corridors~~,~~; and doors ~~separating unconditioned or vented spaces~~leading to mechanical rooms.
- Weather-stripping at mandatory locations shall be installed with a rigid fastener and replaceable foam gasket specified for durability and less maintenance.
- Weather-stripping shall be installed to not interfere with door closing properly.

Procedures and Documentation:

- Inspect vestibule and entryway areas to verify construction is consistent with design specifications.
- Inspect exterior doors for proper operation, fit, and weather stripping.
- When required by local building code, verify entranceways contain vestibules with weather-stripping hard-fastened to the door or frame.
- Verify weather-stripping on all cellar/mechanical doors, doors between corridors and stairwells, all exterior doors, doors between apartments and corridors, doors separating unconditioned or vented spaces.
- Verify weather-stripping is installed with a rigid fastener and replaceable foam gasket has been installed for durability and less maintenance. Optional: Use a smoke pencil with the building under pressurization (or depressurization) from the ventilation system to verify air tightness of components.
- Photographs:

  - Photo of installed door that verifies proper fit and effective connections to envelope's weather and air barriers
  - Photo of each unique door type with third-party verification, NFRC and/or ENERGY STAR (if applicable)
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*

Schedule:

- After installation.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor (GC)

Sampling Requirements:

- 100% of entryways and designed vestibule areas shall be inspected.
- Visually verify proper installation of at least 50% of all common area exterior doors and check the manufacturer and model of all doors using the As-Built Building door schedule provided by the developer. For garden-style apartments with doors to the exterior, follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document.

4.0 Garages

Protocol 4.1 – Heating and Compartmentalization

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✓	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- Garages, including plenums and dropped ceilings within the garage, shall not be heated for comfort or to prevent pipes from freezing. Piping design and layout shall locate piping within conditioned spaces or grouped and properly insulated to prevent freezing. If following the *Performance Path*, heat tracing may be used for freeze protection, but it must be activated based on pipe wall temperature, rather than air temperature, and the energy consumption must be modeled in the As-Built (but excluded in the Baseline). The heat tracing thermostat set point must be no higher than 40°F.
- Radiant heating, either wall or ceiling-mounted or within the garage floor (or sidewalks) may be used to prevent ice formation on the ground as a safety feature only and temperature-based controls must comply with ASHRAE 90.1-2007 Section 6.4.3.8. If following the *Performance Path*, energy consumption associated with these systems must be modeled in the As-Built (but excluded in the Baseline).
- Include a list of elements to be sealed in the garage based on the plan review and the requirements listed in the *Prerequisites Checklist* that would minimize air flow between the garage and the rest of the building, including entrance door(s) leading into building from garage.
- Contract Language: "Allow inspection of all air sealing details."

Procedures and Documentation:

- Confirm that garage is not intentionally conditioned for comfort or to prevent pipes from freezing.
- If pipes are located in garages or unconditioned spaces, heat tape is permitted, but only in the *Performance Path*, where the energy penalty associated with the electricity consumption can be modeled. If selecting this alternative, heat tape that is activated based on pipe wall temperature rather than air temperature is required must comply with ASHRAE 90.1-2007 Section 6.4.3.8. Verify heat tape thermostat set point is no higher than 40°F.
- Verify that any garage space heating systems, if present, are radiant type heating used only for safety considerations, such as ice melting, and are properly controlled and locked. Verify

these systems include automatic controls capable of shutting off the systems when outdoor air temperatures are above 40°F or when the conditions of the protected fluid will prevent freezing. Verify snow- and ice-melting systems include automatic controls capable of shutting off the systems when the pavement temperature is above 50°F and no precipitation is falling and an automatic or manual control that will allow shutoff when the outdoor temperature is above 40°F so that the potential for snow or ice accumulation is negligible.

- Visually confirm that garage is properly air sealed and fully compartmentalized from rest of building.
- Verify all pipe and conduit penetrations have been sealed with material compatible with the surface and resilient to temperature fluctuations.
- Inspect the door(s) leading into the building from the garage for proper operation, fit, and weather stripping. Optional: Use a smoke pencil around the door, casing, and frame with the garage ventilation system running.
- For wood-framed construction, Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes Thermal Enclosure System Rater Checklist Sections 3 and 5* ~~must be followed~~is recommended in addition to all *T&V Protocols*.

Schedule:

- Inspect air sealing details at framing before insulation is installed.
- Inspect insulation after installation and prior to enclosure with finish materials.
- Final inspection may occur anytime following completion of installations.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor (GC)

Sampling Requirements:

- Inspect 100% of the connections between the garage and the conditioned space of the building for air sealing.
- Inspect 100% of heating elements and controls.

5.0 Heating and Cooling

Protocol 5.1 - Central Heating Systems (Serving 5+ units ~~or more~~/spaces)

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✓	Instrumented Measurement
✓	Third-Party Commissioning

Performance Specification Criteria:

- All heating systems serving the building must follow either Protocol 5.1 or Protocol 5.3. The Licensed Professional may use their discretion to determine which Protocol is most appropriate for a particular system.
- *Heating Plant:* Heating system size, type, design, and rated efficiency shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Heating loads shall be calculated, equipment capacity shall be selected, and duct systems shall be sized according to the latest editions of *Air-Conditioning Contractors Association (ACCA) Manual J, S, & D* respectively, ASHRAE 2009 Handbook of Fundamentals, or a substantively equivalent procedure, and provided by the design engineer to the responsible party. Indoor temperatures shall be 70°F for heating, outdoor temperatures shall be the 1.0% design temperatures as published by the ASHRAE Handbook of Fundamentals. Installed capacity cannot exceed design by more than 20%, except when smaller sizes are not available. For condensing boilers, plans must specify return water temperature at design conditions.
- ~~Supplemental~~Heating equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.
- EPA recommends that supplemental heating systems ~~should~~are not ~~be~~ specified for pipe freeze protection in unconditioned spaces. If specified, their energy consumption must be modeled.
- *Distribution System:* Specifications for distribution system (supply and return) piping and/or ductwork configuration, mixing valves, and zoning requirements shall match assumptions made in Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.

- ~~•~~ Heating supply and return ductwork shall be insulated to a minimum R-6 in unconditioned spaces. If following the *Prescriptive Path,* R-8 is required in unconditioned spaces.
- ~~•~~ Piping carrying ~~liquid~~fluid or steam with temperatures greater than 105°F must have a minimum of 1" of insulation. Pipes ~~over~~ 1.5" in diameter and greater must have a minimum of 1.5" of insulation. Construction documents must account for piping total thickness including required insulation when passing through planks or any other penetrations. For PTACs or any other heating systems that require branch pipe insulation, the insulation thickness must be considered when designing room dimensions and access chases. Construction documents shall specify that the piping must be inspected before access is covered up. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.
- For hydronic distribution systems without automatic balancing valves, all supply/return headers must be designed in a "reverse return" configuration (i.e., first riser supplied is the last returned, etc.) and/or sized based on a water velocity of less than 4 ft/s. Total pressure drop of terminal unit branch piping and fittings between a supply and return riser must be significantly greater than the total pressure drop from the top to the bottom of these risers.
- Calculations and assumptions for sizing circulating pumps must meet Chapter 43 of the ASHRAE Handbook, HVAC Systems and Equipment or equivalent industry accepted standard and kept with the building file.
- Although not required, EPA recommends adding a Note requiring heating circulator pressure controls to be adjusted to ensure that: (1) at terminal units furthest from the pump, sufficient GPM is achieved and (2) at terminal units closest to the pump, differential pressure across terminal unit zone valves when closed does not exceed valve manufacturer guidelines.
- For systems designed with outdoor-air supplied to the heating system, provide motorized dampers that will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- For all forced air systems, call out a preliminary list of duct sealing details to be integrated into the construction documents and must include the following at a minimum:
    - Roof curb penetration has been sealed.
    - Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
    - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
    - Gap between take-off duct and gypsum board has been effectively sealed.
- *Terminal Units:* Specification for the terminal unit type, size, design, location, and controls shall match the assumption made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Sizing calculations shall be detailed and provided by the design engineer.
- For hydronic systems, all terminal heating distribution equipment must be separated from the riser or distribution loop by a control valve or terminal distribution pump so that heated

fluid is not delivered to the apartment distribution equipment when there is no call from the apartment thermostats.

- All terminal heating distribution equipment serving an apartment shall be controlled by a thermostat(s) within the same apartment.
- *Controls:* System controls and settings shall match operating assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. At a minimum, controls ~~shall~~should have the capability for outdoor reset of supply water temperature, warm weather shut down and night setback.
- Contract Language: "The heating plant(s), controls, and distribution system shall be made available to allow for thorough inspection and performance verification."
- Contract Language: "The heating system shall be tested and balanced, including all applicable Functional Performance Test checklists, by the installation contractor to demonstrate the system is installed and functioning according to the specifications in the contract documents."
- Contract Language: "A summary of the commissioning results verifying that the heating system performs and functions according to specifications in the contract documents must be provided."
- Contract Language: "Allow access to the terminal heating units to verify the installation and operation as required by the ENERGY STAR MFHR program."
- Contract Language: "The installation contractor and/or system manufacturer ~~shall~~should conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the heating systems."

Procedures and Documentation:

- The responsible party shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist*. In addition, the responsible party must verify the system will perform according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*.
- The developer shall hire a commissioning agent who will perform the quality assurance and verification requirements that cannot be completed by the responsible party.
- The responsible party shall review the results of the commissioning to confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*. Any significant problems discovered during commissioning must be satisfactorily addressed.
- Whether performed by a third-party Commissioning Agent or by the responsible party (if appropriate), the following commissioning of the system must be performed:
  - Verify all terminal heating distribution equipment serving an apartment shall be controlled by a thermostat within the same apartment.
  - Hydronic (water-based) Systems: Verification procedures must confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model of the project or meets or exceeds the requirements listed in the

Prescriptive Path. A commissioning agent can be hired to complete this inspection and verification or the responsible party may be able to perform them. Inspection procedures for hydronic systems shall include:

- Verify installation of temperature gauges and temperature readings during inspection.
- Verify outdoor temperature sensor is functioning properly.
- Verify supply temperature is set correctly and sensor is functioning properly.
- Verify return water temperature meets design.
- Verify location of hydronic heating system (e.g., cellar or roof), combustion air venting configuration (e.g., combustion air piped to boilers, boiler room air used for combustion), and venting configuration (e.g., inducer fan specified and sequence of operation verified, if required).
- Verify all terminal heating distribution equipment has been separated from the riser or distribution loop by a control valve or terminal distribution pump, so that heated fluid is not delivered to the apartment distribution equipment when there is no call from the apartment thermostats.
- ~~Verify~~Verify automatic balancing valves; if none, verify all supply/return headers have been installed in a "reverse return" configuration (i.e., first riser supplied is the last returned, etc.) and/or sized based on a water velocity of less than 4 ft/s. Verify total pressure drop of terminal unit branch piping and fittings between the supply and return risers is significantly greater than the total pressure drop from the top to the bottom of these risers.
- Verify piping carrying liquid or steam with temperatures greater than 105°F has a minimum of 1" of insulation and pipes ~~over~~ 1.5" in diameter and greater have a minimum of 1.5" of insulation. Verify that minimum thickness is met at all locations where required, including piping passing through planks, any other penetrations, and heating branch piping. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.

o Forced Air Heating Systems (Including Heat Pumps): Verification procedures must confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model of the project or meets or exceeds the requirements listed in the *Prescriptive Path*. A commissioning agent can be hired to complete this inspection and verification or the responsible party may be able to perform them. Inspection procedures for these forced air systems shall include the following, where applicable:

- Visual inspection of duct system for location, zoning, insulation, and conformance with *Prerequisites Checklist*.
- Verify heating supply and return ductwork has been insulated to a minimum R-6 for unconditioned spaces (R-8 is required in unconditioned spaces, if following the *Prescriptive Path*).
- Verify that all heating ductwork that has been specified as flex duct meets the Sheet Metal Air Conditioning Contractors National Association (SMACNA) installation standards (*see Appendix C*).

- Visual inspection of duct sealing details shall include the following at a minimum:
  a. Roof curb penetration has been sealed.
  b. Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
  c. All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
  d. Gap between take-off duct and gypsum board has been effectively sealed.
- Visual inspection of combustion venting system to verify conformance with Proposed Design model, the requirements listed in the *Prescriptive Path*, and appropriate National Fire Protection Association (NFPA)[1] standards.
- Obtain and keep documentation on file showing correct field measured refrigerant charge, field measured airflow over condenser coil, field measured airflow over heat exchanger, nameplate efficiency, and nameplate heat exchange capacity consistent with manufacturer's specifications.

- For systems designed with outdoor-air supplied to the heating system, verify that motorized dampers will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- Review manufacturer's cut sheets or ~~invoices~~invoice detailing system manufacturer, model, size, and location ~~(including all space heating systems, e.g., vestibule).~~, and keep with the building file. Heating equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.
- Provide summary of commissioning results to the EPA through the use of the *T&V Worksheets* and the *Photo Template*.
- ~~Summarize the training performed and personnel involved. Confirm~~EPA recommends confirming that all applicable operating and specification manuals are delivered to the building staff. ~~Verify~~EPA also recommends verifying that staff ~~has~~members have been trained and are aware of their responsibilities to maintain and operate the systems properly. Summarize any training performed and personnel involved.
- Photographs:
  - Photos of equipment and faceplates corresponding to each heating unit/system to verify proper installation and compliance with proposed design.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. For HVAC protocols, a Statement of Substantial Completion must be completed by a third-party qualified representative on company letter head, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*

[1] For gas systems reference NFPA 54 (National Fuel Gas Code). For oil systems reference NFPA 31.

Schedule:

- The quality assurance and verification procedures occur during the pre-construction, construction, and post-construction phases of system installation. Refer to the appropriate standards (e.g. NFPA) to determine exact timing of inspections.
- Commissioning of the system occurs during pre-construction and construction phases of installation. Inspection, testing, and final commissioning are conducted during the turn over/acceptance phase of the installation of the system.
- Training shall occur following installation of the system and completion of all quality assurance and verification procedures.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- Heating System Designer
- Commissioning Agent
- Building Maintenance Staff

Sampling Requirements:

- 100% of primary equipment (i.e., heating plants) shall be inspected in the quality assurance and verification process.
- ~~Spaces~~Common spaces and apartments containing terminal devices (fan coils, PTHPS, unit heaters, VAV boxes) must be inspected following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document, including at least one of each unique type.

5.0 Heating and Cooling

Protocol 5.2 - Central Cooling Systems (Serving 5+ units ~~or more~~/spaces)

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✓	Instrumented Measurement
✓	Third-Party Commissioning

Performance Specification Criteria:

- All cooling systems serving the building must follow either Protocol 5.2 or Protocol 5.4. The Licensed Professional may use their discretion to determine which Protocol is most appropriate for a particular system.
- *Cooling Plant:* Cooling system size, type, design, and rated efficiency shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Cooling loads shall be calculated, equipment capacity shall be selected, and duct systems shall be sized according to the latest editions of *Air-Conditioning Contractors Association (ACCA) Manual J, S, & D* respectively, ASHRAE 2009 Handbook of Fundamentals, or a substantively equivalent procedure, and provided by the design engineer to the responsible party. Indoor temperatures shall be 75°F for cooling, outdoor temperatures shall be the 99.0% design temperatures as published by the ASHRAE Handbook of Fundamentals. Installed capacity cannot exceed design by more than 20%, except when smaller sizes are not available.
- Cooling equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.
- *Heat Rejection:* Specifications for the heat rejection system type, size, location and efficiency shall match the assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- *Distribution System:* Specifications for distribution system (supply and return) piping configuration, mixing valves, and zoning shall match assumptions made in Proposed Design model. As an alternative to the *Performance Path*, projects must ensure that all of the requirements listed in the *Prescriptive Path* have been met or exceeded.

- ~~All~~For hydronic distribution systems without automatic balancing valves, all supply/return headers must be designed in a "reverse return" configuration (i.e. first riser supplied is the last returned, etc.) and/or sized based on a water velocity of less than 4 ft/s. Total pressure drop of terminal unit branch piping and fittings between a supply and return riser must be significantly greater than the total pressure drop from the top to the bottom of these risers.
- Specifications for distribution system (supply and return) chilled water piping and/or ductwork configuration, zoning, and insulation requirements shall match assumptions made in Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- Cooling supply and return ductwork shall be insulated to a minimum R-6 for unconditioned spaces. If following the *Prescriptive Path,* R-8 is required in unconditioned spaces.
- Piping carrying ~~chilled water or refrigerant~~fluid with temperatures less than 60°F must have a minimum of ~~1~~0.5" of insulation. Pipes ~~over~~ 1.5" in diameter and greater must have a minimum of 1.~~5~~0" of insulation. Construction documents must account for piping total thickness including required insulation when passing through planks or any other penetrations. For cooling systems that require branch pipe insulation, the insulation thickness must be considered when designing room dimensions and access chases. Construction documents shall specify that the piping must be inspected before access is covered up. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.
- For systems designed with outdoor-air supplied to the cooling system, provide motorized dampers that will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- Calculations and assumptions for sizing circulating pumps must meet Chapter 43 of the ASHRAE Handbook, HVAC Systems and Equipment or equivalent industry accepted standard and kept with the building file.
- Although not required, EPA recommends adding a Note requiring cooling circulator pressure controls to be adjusted to ensure that: (1) at terminal units furthest from the pump, sufficient GPM is achieved and (2) at terminal units closest to the pump, differential pressure across terminal unit zone valves when closed does not exceed valve manufacturer guidelines.
- For all forced air systems, call out a preliminary list of duct sealing details to be integrated into the construction documents and must include the following at a minimum:
    - Roof curb penetration has been sealed.
    - Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
    - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
    - Gap between take-off duct and gypsum board has been effectively sealed.
- *Terminal Units:* Specification for the terminal unit type, size, design, location, and controls shall match the assumption made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Sizing calculations shall be detailed and provided by the design engineer.

- All terminal cooling distribution equipment must be separated from the riser or distribution loop by a control valve or terminal distribution pump, so that cooled fluid is not delivered to the apartment distribution equipment when there is no call from the apartment thermostats.
- All terminal cooling distribution equipment serving an apartment shall be controlled by a thermostat(s) within the same apartment.
- *Controls:* System controls and settings shall match operating assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- If following the *Prescriptive Path*, cooling tower fan motor must be equipped with VFD controlled by a temperature sensor on the condenser water supply pipe.
- Contract Language: "The cooling plant(s), controls, and distribution system shall be made available to allow for thorough inspection and performance verification."

- Contract Language: "The cooling system shall be tested and balanced, including all applicable Functional Performance Test checklists, by the installation contractor to demonstrate the system is installed and functioning according to the specifications in the contract documents."
- Contract Language: "A summary of the commissioning results verifying that the cooling system performs and functions according to specifications in the contract documents must be provided."
- Contract Language: "Allow access to the terminal cooling units to verify the installation and operation as required by the ENERGY STAR MFHR program."
- Contract Language: "The installation contractor and/or system manufacturer ~~shall~~should conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the cooling systems."

Procedures and Documentation:

- The responsible party shall review the cooling systems' sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist*. In addition, the responsible party must verify the system will perform according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*.
- The developer shall hire a commissioning agent who will perform the quality assurance and verification requirements that cannot be completed by the responsible party.
- The responsible party shall review the results of the commissioning to confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*. Any significant problems discovered during commissioning must be satisfactorily addressed.
- Whether performed by a third-party Commissioning Agent or by the responsible party (if appropriate), the following commissioning of the system must be performed:
  - Documentation of system controls operations consistent with Proposed Design specifications.
  - Documentation of zoning and operation of terminal units and their controls consistent with Proposed Design specifications.
  - Verify piping carrying ~~chilled water or refrigerants~~fluid with temperatures less than 60°F ~~have~~has a minimum of ~~1~~0.5" of insulation and pipes ~~over~~ 1.5" in diameter and greater have a minimum of 1.~~5~~0" of insulation. Verify that minimum thickness is met at all locations where required, including piping passing through planks, any other penetrations, and cooling branch piping. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.
  - Verify all terminal cooling distribution equipment serving an apartment is controlled by a thermostat(s) within the same apartment~~.~~

- Chilled Water and Condenser Water Systems: Verification procedures must confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model of the project or meets or exceeds the requirements listed in the *Prescriptive Path*. A commissioning agent can be hired to complete this inspection and verification or the responsible party may be able to perform them. Inspection procedures for these chilled water and condenser systems shall include the following, where applicable:

  - Verify all terminal cooling distribution equipment has been separated from the riser or distribution loop by a control valve or terminal distribution pump, so that cooled fluid is not delivered to the apartment distribution equipment when there is no call for cooling from the apartment thermostats.
  - ~~Verify~~Verify automatic balancing valves; if none, verify all supply/return headers have been installed in a "reverse return" configuration (i.e., first riser supplied is the last returned, etc.) and/or sized based on a water velocity of less than 4 ft/s. Verify total pressure drop of terminal unit branch piping and fittings between the supply and return risers is significantly greater than the total pressure drop from the top to the bottom of these risers.
  - Obtain and keep documentation on file showing correct field measured airflow over evaporator coil, nameplate efficiency, and nameplate heat exchange capacity consistent with manufacturer's specifications.
- Forced Air Cooling Systems (Including Heat Pumps, Split System Air Conditioners, ~~Packaged Terminal Air Conditioners (PTAC) and Room Air Conditioners:~~rooftop make-up air units): Verification procedures must confirm that the system meets the specifications and performs according to the *Prerequisites Checklist* as well as the assumptions in the Proposed Design model of the project or meets or exceeds the requirements listed in the *Prescriptive Path*. A commissioning agent can be hired to complete this inspection and verification or the responsible party may be able to perform them. Inspection procedures for these forced air systems shall include the following, where applicable:
  - Visual inspection of duct sealing details shall include the following at a minimum:
    a. Roof curb penetration has been sealed.
    b. Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
    c. All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
    d. Gap between take-off duct and gypsum board has been effectively sealed.
  - Inspection procedures for ducted air conditioning systems shall include:
    a. Visual inspection of duct system for location, zoning, insulation, and conformance with *Prerequisites Checklist*.
    b. Verify cooling supply and return ductwork has been insulated to a minimum R-6 for unconditioned spaces (R-8 is required in unconditioned spaces, if following the *Prescriptive Path.*

c. Verify that all cooling ductwork that has been specified as flex duct meets the Sheet Metal Air Conditioning Contractors National Association (SMACNA) installation standards (*see Appendix C*).
d. Obtain and keep documentation on file showing correct field measured refrigerant charge, field measured airflow over evaporator coil, nameplate efficiency, and nameplate heat exchange capacity consistent with manufacturer's specifications.

- For systems designed with outdoor-air supplied to the cooling system, verify that motorized dampers will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- Insulation and vapor barrier for chilled water lines and ducted distribution systems shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- Where terminal distribution equipment penetrates the building envelope, verify that the opening around the unit has been properly sealed to be air-tight and weather-tight.

- Provide summary of commissioning results to the EPA through the use of the *T&V Worksheets* and the *Photo Template*.
- ~~Summarize the training performed and personnel involved. Confirm~~EPA recommends confirming that all applicable operating and specification manuals are delivered to the building staff. ~~Verify~~EPA also recommends verifying that staff members have been trained and are aware of their responsibilities to maintain and operate the systems properly. Summarize any training performed and personnel involved.
- Review manufacturer's cut sheets or invoice detailing system manufacturer, model, size, and location (including all space cooling systems, e.g. lobby). ~~These should also be used to prove ENERGY STAR qualification and efficiency rating~~ Cooling equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.
- Photographs:
  - Photos of cooling system equipment and faceplates to verify proper installation and compliance with Proposed Design.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. For HVAC protocols, a Statement of Substantial Completion must be completed by a third-party qualified representative on company letter head, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*

Schedule:

- The quality assurance and verification procedures occur during the pre-construction, construction, and post-construction phases of system installation.

- Commissioning of the system occurs during pre-construction and construction phases of installation. Inspection, testing, and final commissioning are conducted during the turn over/acceptance phase of the installation of the system.
- Training shall occur following installation of the system and completion of all quality assurance and verification procedures.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- Cooling System Designer
- Commissioning Agent
- Building Maintenance Staff

Sampling Requirements:

- 100% of primary equipment (i.e., cooling plants) shall be inspected in the quality assurance and verification process.
- ~~Spaces~~Common spaces and apartments containing terminal devices (fan coils, PTACS, VAV boxes) must be inspected following the modified RESNET sampling protocol outlined in the How to Use this Manual section on page 11 of this document, including at least one of each unique type.

5.0 Heating and Cooling

Protocol 5.3 - Distributed (Individual Apartment or Common Space) Heating Systems

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✓	Instrumented Measurement
✓	Third-Party Commissioning

Performance Specification Criteria:

- All heating systems serving the building must follow either Protocol 5.1 or Protocol 5.3. The Licensed Professional may use their discretion to determine which Protocol is most appropriate for a particular system.
- *Heating ~~Plant~~System:* Heating system size, type, design, and rated efficiency shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Heating loads shall be calculated, equipment capacity shall be selected, and duct systems shall be sized according to the latest editions of *Air-Conditioning Contractors Association (ACCA) Manual J, S, & D* respectively, ASHRAE 2009 Handbook of Fundamentals, or a substantively equivalent procedure, and provided by the design engineer to the responsible party. Indoor temperatures shall be 70°F for heating, outdoor temperatures shall be the 1.0% design temperatures as published by the ASHRAE Handbook of Fundamentals. Installed capacity cannot exceed design by more than 20%, except when smaller sizes are not available. For condensing boilers, plans must specify return water temperature at design conditions.
- Heating equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.
- *Distribution System:* Specifications for distribution system (supply and return) piping and/or ductwork configuration, zoning, terminal devices (e.g., registers, convectors, etc.) and insulation requirements shall match assumptions made in Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. For in-unit forced air distribution systems, perform design calculations using the *Air Conditioning Contractors Association (ACCA) Manuals J and D, the ASHRAE Handbook of Fundamentals,* or equivalent design procedures and install ducts accordingly. Additionally, bedrooms must be pressure-balanced.

- In-unit duct systems shall be designed to effectively meet the heating loads for the spaces served using the *Air Conditioning Contractors Association (ACCA) Manuals J, D, and T* ASHRAE 2009 Handbook of Fundamentals, or a substantively equivalent procedure, and provided by the design engineer to the responsible party.
- Heating supply and return ductwork shall be insulated to a minimum R-6 for unconditioned spaces (R-8 is required in unconditioned spaces, if following the *Prescriptive Path Requirements*).

- For all forced air systems, call out a preliminary list of duct sealing details to be integrated into the construction documents and must include the following at a minimum:
    - Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
    - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
    - Gap between take-off duct and gypsum board has been effectively sealed.
- ~~Total duct leakage for~~For in-unit systems, total duct leakage post-construction shall be ≤8 CFM25 per 100 ft^2 of conditioned floor area, or as an alternative, total duct leakage measured at rough-in, shall be ≤4 CFM25 per 100 ft^2, with air handler and all ductwork installed.
- For systems designed with outdoor-air supplied to the heating system, provide motorized dampers that will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- Piping carrying ~~liquid~~fluid or steam with temperatures greater than 105°F must have a minimum of 1" of insulation. Pipes ~~over~~ 1.5" in diameter and greater must have a minimum of 1.5" of insulation. Construction documents must account for piping total thickness including required insulation when passing through planks or any other penetrations. For PTACs or any other heating systems that requires branch pipe insulation, the insulation thickness must be considered when designing room dimensions and access chases. Construction documents shall specify that the piping must be inspected before access is covered up. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.
- *Controls:* System controls and settings shall match operating assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. At a minimum, hydronic system controls ~~shall~~should have the capability for night setback, which may be provided via a programmable thermostat.
- Contract Language: "The heating plant(s), controls, and distribution system shall be made available to allow for thorough inspection and performance verification."
- Contract Language: "The heating system shall be tested and balanced, including all applicable Functional Performance Test checklists, by the installation contractor to demonstrate the system is installed and functioning according to the specifications in the contract documents."
- Contract Language: "A summary of the commissioning results verifying that the heating system performs and functions according to specifications in the contract documents must be provided."
- Contract Language: "The installation contractor and/or system manufacturer ~~shall~~should conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the heating systems."

Procedures and Documentation:

- The responsible party shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist*. In addition the responsible party must verify the system will perform according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*.
- The developer shall hire a commissioning agent who will perform the quality assurance and verification requirements that cannot be completed by the responsible party.

- The responsible party shall review the results of the commissioning to confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*. Any significant problems discovered during commissioning must be satisfactorily addressed.
- Whether performed by a third-party Commissioning Agent or by the responsible party (if appropriate), the following commissioning of the system must be performed:
  - Hydronic (water-based) Systems: Verification procedures must confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model of the project or meets or exceeds the requirements listed in the *Prescriptive Path*. A commissioning agent can be hired to complete this inspection and verification or the responsible party may be able to perform them. Inspection procedures for hydronic systems shall include:
    - Verify installation of temperature gauges and temperature readings during inspection.
    - Verify outdoor temperature sensor is functioning properly.
    - Verify supply temperature is set correctly and sensor is functioning properly.
    - Verify combustion air venting configuration (e.g., combustion air piped to system), and venting configuration (e.g., inducer fan specified and sequence of operation verified, if required).
    - Verify piping carrying liquid or steam with temperatures greater than 105°F has a minimum of 1" of insulation and pipes ~~over~~ 1.5" in diameter and greater have a minimum of 1.5" of insulation. Verify that minimum thickness is met at all locations where required, including piping passing through planks, any other penetrations, and heating branch piping. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.
  - Forced Air Heating Systems (Including Heat Pumps): Verification procedures must confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model of the project or meets or exceeds the requirements listed in the *Prescriptive Path*. A commissioning agent can be hired to complete this inspection and verification or the responsible party may be able to perform them. Inspection procedures for these forced air systems shall include the following, where applicable:
    - For improved performance, EPA recommends, but does not require compliance with the quality assurance and verification requirements outlined in Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes HVAC System Quality Installation Rater and Contractor Checklists*, where applicable to forced air heating systems.
    - Visual inspection of duct system for location, zoning, insulation, and conformance with the requirements listed in the *Prerequisites Checklist.*
    - Verify that bedrooms have been provided with any combination of transfer grills, jump ducts, dedicated return ducts, and/or undercut doors to provide pressure-balancing.

- Verify heating supply and return ductwork has been insulated to a minimum R-6 for unconditioned spaces (R-8 is required in unconditioned spaces, if following the *Prescriptive Path).*
- Verify that all heating ductwork that has been specified as flex duct meets the Sheet Metal Air Conditioning Contractors National Association (SMACNA) installation standards (*see Appendix C*).
- Visual inspection of duct sealing details shall include the following at a minimum:
  - Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
  - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
  - Gap between take-off duct and gypsum board has been effectively sealed.
- ~~Following~~For in-unit systems, following the procedures outlined in your duct leakage tester operation manual, a one-point test for total duct leakage in the main duct shaft using a calibrated fan measured under depressurization or pressurization is acceptable for this measurement. Per the *Prerequisites Checklist*, the total duct leakage post-construction for in-unit systems shall be ≤8 CFM25 per 100 ft^2 of conditioned floor area or, as an alternative, total duct leakage measured at rough-in, shall be ≤4 CFM25 per 100 ft^2, with air handler and all ductwork installed.
  - When conducting a duct leakage depressurization test, the flow conditioner and one of the flow rings must always be installed.
  - Provide a summary of results of any duct leakage ~~or ventilation~~ performance testing; a sample table is provided in the *T&V Worksheets*.
- Visual inspection of combustion venting system to verify conformance with Proposed Design model, the requirements listed in the *Prescriptive Path* and appropriate National Fire Protection Association (NFPA)[2] standards.
- Obtain and keep documentation on file showing correct field measured refrigerant charge, field measured airflow over condenser coil, field measured airflow over heat exchanger, nameplate efficiency, and nameplate heat exchange capacity consistent with manufacturer's specifications.

- For systems designed with outdoor-air supplied to the heating system, verify that motorized dampers will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- Review manufacturer's cut sheet or invoice detailing system manufacturer, model, size, and location (including all space heating systems, e.g., vestibule). Heating equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.

[2] For gas systems reference NFPA 54 (National Fuel Gas Code). For oil systems reference NFPA 31.

- Provide summary of commissioning results to the EPA through the use of the *T&V Worksheets* and the *Photo Template*.
- ~~Summarize the training performed and personnel involved. Confirm~~EPA recommends confirming that all applicable operating and specification manuals are delivered to the building staff. ~~Verify~~EPA also recommends verifying that staff ~~has~~members have been trained and are aware of their responsibilities to maintain and operate the systems properly. Summarize any training performed and personnel involved.

- Photographs:
  - Photos of equipment and faceplates corresponding to each heating unit/system to verify proper installation and compliance with proposed design.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. For HVAC protocols, a Statement of Substantial Completion must be completed by a third-party qualified representative on company letter head, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*

Schedule:

- The quality assurance and verification procedures occur during the pre-construction, construction, and post-construction phases of system installation. Refer to the appropriate standards (e.g. NFPA) to determine exact timing of inspections.
- Commissioning of the system occurs during pre-construction and construction phases of installation. Inspection, testing, and final commissioning are conducted during the turn over/acceptance phase of the installation of the system.
- Training shall occur following installation of the system and completion of all quality assurance and verification procedures.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- Heating System Designer
- Commissioning Agent
- Building Maintenance Staff

Sampling Requirements:

- Individual common spaces or apartments containing electric and fossil-fuel heating systems shall be inspected and tested following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document, including at least one of each unique type.

5.0 Heating and Cooling

Protocol 5.4 - Distributed (Individual Apartment or Common Space) Cooling Systems

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✓	Instrumented Measurement
✓	Third-Party Commissioning

Performance Specification Criteria:

- All cooling systems serving the building must follow either Protocol 5.2 or Protocol 5.4. The Licensed Professional may use their discretion to determine which Protocol is most appropriate for a particular system.
- *Cooling ~~Plant~~System:* Cooling system size, type, design, and rated efficiency shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. Cooling loads shall be calculated, equipment capacity shall be selected, and duct systems shall be sized according to the latest editions of *Air-Conditioning Contractors Association (ACCA) Manual J, S, & D* respectively, ASHRAE 2009 Handbook of Fundamentals, or a substantively equivalent procedure, and provided by the design engineer to the responsible party. Indoor temperatures shall be 75°F for cooling, outdoor temperatures shall be the 99.0% design temperatures as published by the ASHRAE Handbook of Fundamentals. Installed capacity cannot exceed design by more than 20%, except when smaller sizes are not available.
- Cooling equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.
- *Distribution System:* For ducted systems, specifications for the distribution system (supply and return) ductwork configuration, zoning, terminal devices (e.g., registers, convectors, etc.) and insulation requirements shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*. For in-unit forced air distribution systems, perform design calculations (using *Air-Conditioning Contractors Association Manuals J and D*, the ASHRAE Handbook of Fundamentals, or an equivalent procedure) and install ducts accordingly. Additionally, bedrooms must be pressure-balanced.
- In-unit duct systems shall be designed to effectively meet the cooling loads for the spaces served using the *Air Conditioning Contractors Association (ACCA) Manuals J, D, and T*

ASHRAE 2009 Handbook of Fundamentals, or a substantively equivalent procedure, and provided by the design engineer to the responsible party.

- Cooling supply and return ductwork shall be insulated to a minimum R-6 for unconditioned spaces (R-8 is required in unconditioned spaces, if following the *Prescriptive Path*).

- For all forced air systems, call out a preliminary list of duct sealing details to be integrated into the construction documents and must include the following at a minimum:
    - Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
    - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
    - Gap between take-off duct and gypsum board has been effectively sealed.
- ~~Total duct leakage for~~ For in-unit systems, total duct leakage post-construction shall be ≤8 CFM25 per 100 ft^2 of conditioned floor area, or as an alternative, total duct leakage measured at rough-in, shall be ≤4 CFM25 per 100 ft^2, with air handler and all ductwork installed.
- Piping carrying ~~chilled water or refrigerants~~fluid with temperatures less than 60°F must have a minimum of ~~1~~0.5" of insulation. Pipes ~~over~~ 1.5" in diameter and greater must have a minimum of 1.~~5~~0" of insulation. Construction documents must account for piping total thickness including required insulation when passing through planks or any other penetrations. For cooling systems that requires branch pipe insulation, the insulation thickness must be considered when designing room dimensions and access chases. Construction documents shall specify that the piping must be inspected before access is covered up. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.
- For systems designed with outdoor-air supplied to the cooling system, provide motorized dampers that will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- *Controls:* System controls and settings shall match operating assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- Contract Language: "The cooling plant(s), controls, and distribution system shall be made available to allow for thorough inspection and performance verification."
- Contract Language: "The cooling system shall be tested and balanced, including all applicable Functional Performance Test checklists, by the installation contractor to demonstrate the system is installed and functioning according to the specifications in the contract documents."
- Contract Language: "A summary of the commissioning results verifying that the cooling system performs and functions according to specifications in the contract documents must be provided."
- Contract Language: "The installation contractor and/or system manufacturer ~~shall~~should conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the cooling systems."

Procedures and Documentation:

- The responsible party shall review the cooling systems (including through-wall air conditioners) sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist*. In addition, the responsible party must

verify the system will perform according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*.

- The developer shall hire a commissioning agent who will perform the quality assurance and verification requirements that cannot be completed by the responsible party.

- The responsible party shall review the results of the commissioning to confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model or meets or exceeds the requirements listed in the *Prescriptive Path*. Any significant problems discovered during commissioning must be satisfactorily addressed.
- Whether performed by a third-party Commissioning Agent or by the responsible party (if appropriate), the following commissioning of the system must be performed:
  - Documentation of system controls operations consistent with Proposed Design specifications.
  - Documentation of zoning and operation of terminal units and their controls consistent with Proposed Design specifications.
  - Verify piping carrying ~~chilled water or refrigerants~~liquid with temperatures less than 60°F ~~have~~has a minimum of ~~1~~0.5" of insulation and pipes ~~over~~ 1.5" in diameter and greater have a minimum of 1.~~5~~0" of insulation. Verify that minimum thickness is met at all locations where required, including piping passing through planks, any other penetrations, and heating/cooling branch piping. Extent and location to be determined by ASHRAE 90.1-2007 Section 6.4.4.1.3 or local code.
  - Forced Air Cooling Systems (Including Heat Pumps, Split System Air Conditioners, Packaged Terminal Air Conditioners (PTAC) and Room Air Conditioners): Verification procedures must confirm that the system meets the specifications and performs according to the assumptions in the Proposed Design model of the project or meets or exceeds the requirements listed in the *Prescriptive Path*. A commissioning agent can be hired to complete this inspection and verification or the responsible party may be able to perform them. Inspection procedures for these forced air systems shall include the following, where applicable:
    - For improved performance, EPA recommends, but does not require compliance with the quality assurance and verification requirements outlined in Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes HVAC System Quality Installation Rater and Contractor Checklists*, where applicable to forced air cooling systems. Visual inspection of duct sealing details shall include the following at a minimum:
      - Mastic or other UL-181 compliant material has been applied within temperature range and according to all other manufacturer's requirements at ALL transverse joints and take offs.
      - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
      - Gap between take-off duct and gypsum board has been effectively sealed.

- ~~Following~~For in-unit systems, following the procedures outlined in your duct leakage tester operation manual, a one-point test for total duct leakage in the main duct shaft using a calibrated fan measured under depressurization or pressurization is acceptable for this measurement. Per the *Prerequisites Checklist*, the total duct leakage post-construction for in-unit systems shall be ≤8 CFM25 per 100 ft^2 of conditioned floor area or, as an alternative, total duct leakage measured at rough-in, shall be ≤4 CFM25 per 100 ft^2, with air handler and all ductwork installed.
  - When conducting a duct leakage depressurization test, the flow conditioner and one of the flow rings must always be installed.
  - Provide a summary of results of any duct leakage or ventilation performance testing: a sample table is provided in the *T&V Worksheets*.
- Inspection procedures for ducted air conditioning systems shall include:
  - Visual inspection of duct system for location, zoning, insulation, and conformance with *Prerequisites Checklist*.
  - Verify that bedrooms have been provided with any combination of transfer grills, jump ducts, dedicated return ducts, and/or undercut doors to provide pressure-balancing.
  - Verify cooling supply and return ductwork has been insulated to a minimum R-6 for unconditioned spaces (R-8 is required in unconditioned spaces, if following the *Prescriptive Path*).
  - Verify that all cooling ductwork that has been specified as flex duct meets the Sheet Metal Air Conditioning Contractors National Association (SMACNA) installation standards (*see Appendix C*).
  - Obtain and keep documentation on file showing correct field measured refrigerant charge, field measured airflow over evaporator coil, nameplate efficiency, and nameplate heat exchange capacity consistent with manufacturer's specifications.

- For systems designed with outdoor-air supplied to the cooling system, verify that motorized dampers will automatically shut when the systems or spaces served are not in use. If the same system is providing continuous ventilation, it would not be required to have a motorized damper, as the system is always in use.
- Where AC units penetrate the building envelope, verify that the opening around the unit has been properly sealed to be air-tight and weather-tight and that an insulated cover has been provided as required in the *Prerequisites Checklist*.
- ~~Review invoice or cut sheet proving ENERGY STAR qualification and/or efficiency rating.~~
- Review manufacturer's cut sheets or invoice detailing system manufacturer, model, size, and location. Cooling equipment efficiency must be verified through AHRI ratings. If not available, OEM-provided performance data must be used, in compliance with ASHRAE 90.1-2007, Section 6.4.1.4. If following the *Prescriptive Path* and ENERGY STAR certification is required, model numbers must be verified through the ENERGY STAR website.
- Provide summary of commissioning results to EPA through the use of the *T&V Worksheets* and the *Photo Template*.

- ~~Summarize the training performed and personnel involved. Confirm~~EPA recommends confirming that all applicable operating and specification manuals are delivered to the building staff. ~~Verify~~EPA also recommends verifying that staff members have been trained and are aware of their responsibilities to maintain and operate the systems properly. Summarize any training performed and personnel involved.
- Photographs:
  - Photo of cooling system equipment and faceplates to verify proper installation and compliance with proposed design.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. For HVAC protocols, a Statement of Substantial Completion must be completed by a third-party qualified representative on company letter head, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding T&V Worksheet.

Schedule:

- The quality assurance and verification procedures occur during the pre-construction, construction, and post-construction phases of system installation.
- Commissioning of the system occurs during pre-construction and construction phases of installation. Inspection, testing, and final commissioning are conducted during the turn over/acceptance phase of the installation of the system.
- Training shall occur following installation of the system and completion of all quality assurance and verification procedures.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- Cooling System Designer
- Commissioning Agent
- Building Maintenance Staff

Sampling Requirements:

- ~~Spaces~~Individual common spaces or apartments containing cooling systems shall be inspected and tested following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document, including at least one of each unique type.

6.0 Lighting

Protocol 6.1 - Common Areas, In-Unit, Garage and Exterior Lighting

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✓	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- Construction documents must include performance criteria for lighting including:
  - Total specified lighting power for the combined non-apartment spaces must not exceed ASHRAE 90.1-2007 allowances for those combined spaces by more than 20%.
  - Include a schedule with manufacturer, model, total wattage, bulb type, control, location, and quantity of each type of lighting fixture.
  - Include location of fixtures on plans.
  - Type and wattage of fixtures and lamps on lighting schedule, specifications, and submittals shall match modeled power density in Proposed Design.
  - 80% of installed light fixtures must be ENERGY STAR ~~qualified~~certified or have ENERGY STAR ~~qualified~~certified lamps installed. Alternatively, 100% of installed light fixtures must have "high-efficacy" lamps installed, as defined in Appendix B of *Performance or Prescriptive Path*.
  - When ENERGY STAR ~~qualified~~certified fixtures are specified, label shall remain affixed to fixture.
  - Lighting must comply with ASHRAE 90.1-2007, Section 9.4.
  - At a minimum, interior lighting must be designed to meet light levels (footcandles) by space type as recommended by the *Illumination Engineering Society (IESNA) Lighting Handbook, 9th edition*. Values for commonly used spaces are listed in the *Performance Path*. For senior housing, minimum illumination requirements may follow recommendations in IESNA's 2007 Lighting and the Visual Environment for Senior Living, and an increase in lighting power densities and allowances corresponding to the increase in footcandles, is permitted. See Appendix B of the *Performance Path* to determine lamp lumens.
- Construction documents must also include the following criteria for projects using the *Prescriptive Path:*
  - Total specified lighting power for the combined non-apartment spaces must not exceed ASHRAE 90.1-2010 allowances for those combined spaces.

- Lighting power densities and allowances must be determined using ASHRAE 90.1-2010, Table 9.5.1 or Table 9.6.1. For senior living, an increase in lighting power densities and allowances corresponding to the increase in footcandles, is permitted.
- Overall in-unit lighting power density may not exceed 0.75 W/ft2. When calculating overall lighting power density, use 1.1 W/ft2 for spaces where lighting is not installed.
- For spaces where installed light fixtures do not meet illumination requirements and occupants are expected to provide supplemental lighting (ie. bedrooms, living rooms), assume the installed light fixture can illuminate at most ~~2~~3 ft^2 per Watt installed.
- The total specified exterior lighting power cannot exceed ASHRAE 90.1-2010 allowances.

- Contract Language: "Provide submittal to the responsible party of the manufacturer's cut-sheet for each type of light fixture installed. Where applicable, ensure the ENERGY STAR label remains attached to the fixture."

Procedures and Documentation:

- Assemble documentation from plans, specs and submittals.
- Check quantity, locations, unit specifications for conformance/deviation including types of fixtures, wattages of lamps, etc.
- Verify that at least 80% of installed light fixtures are ENERGY STAR ~~qualified~~certified or have ENERGY STAR ~~qualified~~certified lamps installed. Alternatively, verify that 100% of installed light fixtures have high-efficacy lamps installed, as defined in Appendix B of *Performance or Prescriptive Path*.
- Verify that interior lighting is designed to meet light levels by space type as recommended by the IESNA, Lighting Handbook, 9th edition. See Appendix B of *Performance or Prescriptive Path* to determine lamp lumens.
- Determine power density of each space by calculating the luminaire wattage as indicated in ASHRAE 90.1-2007, Section 9.1.4. Verify assumptions in the Proposed Design model or ensure that all of the requirements listed in the *Prescriptive Path* have been met. ASHRAE 90.1-2007, Section 9.1.4a, requires that fixture wattage be calculated using the maximum labeled wattage of the fixture. EPA will allow light fixtures to be calculated based on the installed wattage of the lamps. Ex: A fixture with a 13 W screw-in CFL can be calculated as 13 W, plus any associated ballast power. See Appendix B of *Performance or Prescriptive Path* to determine input power.
- If following the *Performance Path*, verify that total installed lighting power for the combined non-apartment spaces does not exceed ASHRAE 90.1-2007 allowances for those combined spaces by more than 20%. If following the *Prescriptive Path*, verify that total installed lighting power for the combined non-apartment spaces does not exceed ASHRAE 90.1-2010 allowances for those combined spaces. Also, verify that the total specified exterior lighting power does not exceed ASHRAE 90.1-2010 allowances.
- Fixtures specified with electronic ballasts must be confirmed in the field using an electronic ballast tester.
- Photographs
  - Take photo of one sample of each fixture type, with the ENERGY STAR affixed, where applicable.

  - Photograph must show whether lamp is pin-based or screw-based. Collect submittals/invoices for each unique fixture type showing ENERGY STAR ~~qualification~~certification (where applicable) and wattage.
- Obtain a Statement of Substantial Completion for all spaces with non-24/7 lighting prior to inspection.
- A Statement of Substantial Completion or approved proxy must be used to establish completion of the work associated in all spaces with lighting not operating 24/7 associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet.*
- A Statement of Substantial Completion or approved proxy may be used to establish completion of all other work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet*.

Schedule:

- Begin lighting inspections as early in the construction process as possible. Verify make, manufacturer, ENERGY STAR ~~qualification~~certification, and rated wattage upon delivery or when lighting installations commence. This will allow time to make corrections before all of the fixtures have been installed.
- If possible, ask to have a sample installation completed for verification and testing before the electrician proceeds with all installations.

Examples of Responsible Parties:

- General Contractor (GC)
- Licensed Professional
- Energy Consultant
- Electrician

Sampling Requirements:

- Inspect 100% of unique common areas (basements, lobbies) with 24/7 lighting and follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document for similar, or repetitive spaces (stairwells, corridors, trash chute rooms, etc.).
- For all other spaces with non-24/7 lighting (apartments, storage rooms, mechanical rooms, etc.) follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document. This shall include, at a minimum, one representative apartment from each floor.

6.0 Lighting

Protocol 6.2 – Emergency Lighting (Exit Signs)

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✗	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- All exit signs shall be specified as LED (not to exceed 5W per face) or photo-luminescent and shall conform to local building code.
- Fixtures located above stairwell doors and other forms of egress shall contain a battery back-up feature.

Procedures and Documentation:

- Inspect in field for conformance.

Schedule:

- Project Completion

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor or Building Maintenance for opening of fixtures.

Sampling Requirements:

- Inspect 100% of unique common areas (basements, lobbies) and follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document for similar, or repetitive spaces (stairwells, corridors, etc).

6.0 Lighting

Protocol 6.3 – Controls

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✗	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- All non-apartment spaces, except those intended for 24-hour operation or where automatic shutoff would endanger the safety of occupants, must have occupancy sensors or automatic bi-level lighting controls. If following the *Prescriptive Path,* automatic controls must be specified for spaces intended for 24-hour operation such as corridors and stairwells.
- Fixtures must include automatic switching on timers or photocell controls except fixtures intended for 24-hour operation, required for security, or located on apartment balconies.
- Specify operational sensitivity settings (adjust so lights turn on when occupant enters controlled area, but remain off while unoccupied, i.e., unaffected by HVAC and VAV systems, etc.) and shut-off delay period (5 minutes or owner preference).
- Specify power settings (as low as possible while still meeting any code requirements).
- Include type and quantity of controls and associated fixtures in lighting schedule.
- Note all locations of sensors on plans, and indicate which fixtures each sensor controls.

Procedures and Documentation:

- Assemble documentation from plans, specs and submittals to determine type and location of controls.
- Check location of control types for conformance/deviation and take quantity of total number of controls in that space.
- Confirm that each control type is operable for stairwells, corridors, and exterior fixtures.
  - For occupancy sensors, step in and out of the zone, check for blind spots.
  - For timers, set timer to current time and confirm control of fixture.
  - For photocells, cover or black-out photocell and confirm control of fixture.
  - For day lighting controls, dim or black-out location to observe change in fixture light level.
  - For occupancy dimmers, check lower power limit and on-time settings.
- Take a photo of each type of lighting control specified for each unique space (motion sensors, timers, and daylight sensors).
  - If there are sensors in the stairwell and corridor, provide representative photo of each space and clearly label their location.

  - Provide photo showing bi-level lighting is installed (half the lamps on in a fixture, or all fixtures dimmed).
  - Exterior lighting with timers, provide a photo of the controls and provide lighting schedule of when they are supposed to be on.
  - To document daylight sensor performance, take one photo showing the light fixture is off during the day and another photo showing the fixture is on when the daylight sensor is covered.
- A Statement of Substantial Completion or approved proxy must be used to establish completion of the work associated in all spaces with lighting not operating 24/7 associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet*.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of all other work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet*.

Schedule:

- During construction if earlier access (before ceiling closure) is needed to check circuiting layouts (e.g., for day lighting control).
- Anytime following completion of installation.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor or Building Maintenance for opening of fixtures
- Optional: Commissioning Agent report (if available) that includes test, calibration, and setting of lighting controls.

Sampling Requirements:

- Inspect 100% of unique common areas (basements, lobbies) with 24/7 lighting and follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document for similar, or repetitive spaces (stairwells, corridors, trash chute rooms, etc.).
- For all other spaces with non-24/7 lighting (apartments, storage rooms, mechanical rooms, etc.) follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document. This shall include, at a minimum, one representative apartment from each floor.

7.0 Motors

Protocol 7.1 - Motors

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✓	Test Procedure
✓	Instrumented Measurement
✓	Third-Party Commissioning

Performance Specification Criteria:

- All three-phase pump motors 1 horse-power or larger shall meet or exceed efficiency standards for **NEMA Premium™** [3] motors. Note: Motors that are packaged as an integral component of mechanical equipment, fire pump motors and booster pump motors are exempt from this requirement.
- For projects following the *Prescriptive* Path, motors 5 horse-power or larger for circulating pumps serving hydronic heating or cooling systems must be specified with variable frequency drives.
- If following the *Prescriptive Path*, cooling tower fan motor must be equipped with VFD controlled by a temperature sensor on the condenser water supply pipe.
- Motor size, type, design, and rated efficiency shall match assumptions made in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- Contract Language: "All motors shall be tested and ~~balanced~~calibrated by the installation contractor or third-party Commissioning Agent (with the system manufacturer's representative if necessary) and a commissioning report submitted to the responsible party."
- Contract Language: "Allow access to the motors to verify the installation and operation as required by the ENERGY STAR MFHR program."
- Contract Language: "The installation contractor and/or system manufacturer ~~shall~~should conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the motors."

Procedures and Documentation:

[3] Many motors are NEMA labeled and this label alone does not ensure that a motor is energy efficient. This requirement refers specifically to the **NEMA Premium** energy efficient motors program. ~~Product specifications for NEMA Premium Motors may be found at http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf~~ Participating companies may be found at http://www.nema.org/Policy/Energy/Efficiency/Documents/NEMA_Premium_Partners.pdf

- Record manufacturer and model number of all non-ventilation motors over 1 HP (ventilation motors are covered in the ventilation section, *Protocol 8.2 - Common Area and In-Unit Ventilation (CFM), Intake Source, and Intake/Exhaust Fan Efficiency).*
- Confirm manufacturer and model number is **NEMA Premium** labeled and/or complies with minimum performance criteria established by that program.
- For projects following the *Prescriptive* Path, confirm motors 5 horse-power or larger for circulating pumps serving hydronic heating or cooling systems have been installed with variable frequency drives.
- For projects following the *Prescriptive Path*, confirm cooling tower fan motors have been equipped with a VFD controlled by a temperature sensor on the condenser water supply pipe.
- Compare the performance data of the inspected motors ~~(http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf)~~ to the assumptions made in the Proposed Design model and adjust data inputs for As-Built Building model as necessary. As an alternative to the *Performance Path*, projects must ensure that all of the requirements listed in the *Prescriptive Path* have been met or exceeded.
- Provide manufacturer's cut sheet or invoice verifying motor size and efficiency.
- Photographs:
  - Photograph faceplate and NEMA Premium label (if applicable) of one representative motor of each size. Given the number of motors and pumps in any given building make sure to clearly identify location and use of each motor represented.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet*.

Schedule:

- The developer or GC shall ensure that deliveries are inspected prior to accepting them to verify that product substitutions by the distributor or manufacturer have not resulted in appliances with lower efficiencies than those in the Proposed Design.
- Minimum of one on-site inspection required, preferably immediately after installation so that corrective action can be taken if necessary. Delivery tickets may be used to verify complete shipments but on-site inspections of a sample of installed motors is required.
- Commissioning is conducted upon completion of the installation of the system.
- Training shall occur following installation of the system and completion of all quality assurance and verification procedures.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- Heating System Designer

- Commissioning Agent
- Building Maintenance Staff

Sampling Requirements:

- 100% of motors over 1 HP and all those servicing primary ~~HVAC~~ equipment (e.g., heating/cooling plants, domestic water heating systems, etc.) shall be inspected in the quality assurance and verification process.

8.0 Ventilation and Infiltration

Protocol 8.1 ~~–~~ – Building Envelope Air Sealing and ~~Total Air Leakage - Common Area, Apartments, and Exterior~~Compartmentalization Testing

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✓	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- General Exterior Enclosure:
  - The construction drawings and specifications must clearly identify systems that manage the flow of rainwater (e.g. cladding, air gap and weather resistant barrier), heat (insulation) and air (air barriers) through the exterior enclosure. Continuity of these three systems must be shown in section, plan and details. Typical sections must show continuity from the center of the roof assembly, down the walls and fenestration, to the center of the foundation floor. Submittal of shop drawings detailing continuity of these systems and installer qualifications must be required in the specifications.
  - Exterior enclosure assemblies must be designed and constructed to prevent condensation within the assemblies during heating mode, cooling mode or both as the climate dictates. Assemblies may be drawn from published guidance documents that include hygro-thermal performance analysis. Alternatively assemblies should pass year – long, hourly hygro-thermal simulations conducted in accordance with ASHRAE 160P.
- Exterior Enclosure Air barriers:
  - Bid and contract documents must demonstrate a continuous, unbroken air barrier separating the conditioned space of the building from the exterior, unconditioned spaces within the building, mechanical rooms vented with unconditioned air, mechanical chases opening to unconditioned spaces, elevator shafts and garages or other vehicle/equipment storage facilities. All air barrier materials must be compatible with other air barrier elements to which they connect.
  - Bid and contract documents must include detailed information that shows the air barrier continuity through the various conditions of the exterior enclosure (e.g.,

transitions between dissimilar materials and penetrations) and that serves as an index to relevant details.
  - Include list of elements to be sealed in construction documents. List must include all elements identified in ASHRAE 90.1-2007, Section 5.4.3.1, or applicable state code, all elements listed in the *Prerequisites Checklist*, and any additional site-specific elements identified during plan review that shall be addressed to ensure air leakage in the exterior building envelope is effectively controlled. Bid and contract documents must include locations to be sealed as well as acceptable methods and materials.
  - When feasible all air barriers membranes and accessories (transition membranes, flashing membranes, mastics, sealants, primers and tapes) will be from the same manufacturer. When products from a variety of manufacturers are used, a letter must be obtained from at least one manufacturer of the products in contact stating the materials proposed for use are permanently chemically compatible and adhesively compatible with adjacent materials proposed for use. Gaps and joints must be primed and sealed with transition membrane, tape or sealant that is rated to withstand the thermal and structural deflection calculated for the joint in question. For joints that are anticipated to have more than ½" deflection, special details are needed to allow flexibility.
  - Specifications could include, at the discretion of the developer, the inspection of a sample mock-up installation by the responsible party prior to installation of windows building-wide.
- Apartment Compartmentalization:
  - Walls, ceilings and floors that separate each apartment from neighboring apartments, corridors, common space, trash chutes, utility chases and trenches, upper floor, lower floors, stairwells and elevator shafts must be air sealed to form a continuous air barrier surrounding the apartment and connecting to the exterior enclosure air barrier system.
  - As with the exterior air barrier, the compartmentalization air barrier bid and contract documents shall demonstrate a continuous, unbroken air barrier separating each apartment from surrounding spaces. Air barrier materials and accessories shall be clearly identified in section, plan and details.
  - Enclosed apartments must be fan pressure tested as an independent unit in accordance with either ASTM E779 2010 or ASTM E1827. The ~~target~~ maximum air leakage rate is 0.3 CFM per square foot of the enclosure bounding the apartment at an induced pressure difference of 50 pascals. ~~At~~EPA recommends at least two sample apartments ~~shall be~~are fan pressure tested as soon as they can be scheduled. A subset of the remaining apartments shall be fan pressure tested for quality assurance purposes. See the section on "Fan Pressure Testing" for details.
- Contract Language: "Provide access to inspect air sealing details during construction and for diagnostic testing of a sample of apartment units."

Procedures and Documentation:

Air Sealing Inspections~~:~~

- Use the *T&V Worksheets* to identify areas to be inspected based on building geometry, construction, location of mechanicals and building utilities, etc. The list is not exhaustive and the responsible party must still review building plans and field conditions to identify additional leakage sources to be sealed.
- The developer shall set up at least two sample units with both exterior enclosure and apartment compartmentalization air sealing details completed for initial inspection. The units shall include a corner unit and a middle unit. All air sealing details must be open ~~to~~for inspection – visible from the interior or exterior of the building. The sample unit inspection will be used to identify problems with the exterior enclosure air sealing approach and apartment compartmentalization before building-wide construction and air sealing of apartments is completed. The inspection may be spread over more than a single visit to accommodate schedules but all air sealing details ~~must~~should be inspected. The sample units ~~shall~~should also be used for Preliminary Fan Pressure Testing if applicable.
- Inspect framing layout for interior demising (common) walls and interior partitions to ensure:
  - Demising wall air barrier (e.g. ~~-~~sealed gypsum board or coated CMU) extends completely to all adjacent walls and is connected in an air tight way to the exterior enclosure air barriers.
  - Demising wall air barrier (e.g.~~-~~ sealed gypsum board or coated CMU) extends completely to ceiling plank (or other solid ceiling material) where drop ceilings are present.
- Air/Vapor/Weather barrier shall be continuous around the entire building. Inspect transitions between dissimilar materials and penetrations. Flashing materials and/or sealants must be used at:
  - Window openings
  - AC openings
  - Through-wall duct penetrations
  - Transition between foundations and walls
  - Transition between one wall type and another
  - Transition at inside and outside corners
  - Transition between wall and roof barrier
    - Parapet wall details
    - Sloped roof-soffit details
    - Intersection of lower roof with higher wall (e.g. through-wall air barrier details)
  - Plank/Slab Edge (Masonry and Steel Construction) or Rim Joist (Wood Framed Construction)
  - Transition between exterior enclosure and interior walls, floors and ceilings that bound non-conditioned spaces (e.g. garages, some mechanical rooms, vented attics, vented crawlspaces). At these transitions the rain water control elements remain as part of the exterior enclosure while the insulation, air barrier and condensation control functions connect to the interior walls, floors and ceilings.

- Verify that insulated covers for through-wall AC units have been provided by the building for use during heating season and when AC units are not installed. Ensure the cover is equipped with a gasket so when installed it will have an airtight seal against the drywall. As an alternative to a gasket, sealant may be used but will have to be resealed each time it is installed.
- Verify installation of air barrier systems in accordance with manufacturer's instructions. Air barrier materials to be inspected include, but are not limited to:
  - Fluid applied air barrier membrane
  - Self-adhering air barrier membrane
  - Mechanically attached air barrier membrane
  - Board stock air barrier
  - Spray applied polyurethane insulation
  - Gypsum board, CMU or foam board substrate
  - Accessories:
  - Sealants
  - Primer
  - Mastic
  - Transition membrane
  - Tapes

- Provide one representative photograph of continuous air barrier at all types of typical joints, junctions, and general coverage areas to include the following applicable details at a minimum:
  - Inspected from the exterior
    - Wall Preparation
      - Masonry
        - Gaps are filled, Joints struck, CMU is dry, all snags are gone.
        - General Coverage - Liquid Membrane
        - Verify proper thickness of liquid-applied membranes using a wet mil gauge; at a minimum, substrate must not be visible
      - Gypsum board sheathing
        - Gaps and joints primed and sealed with appropriate transition membrane or tape that is rated to withstand the thermal and structural deflection calculated for the joint in question
        - Edges of transition membrane or tape (termination seams) sealed with compatible sealant where not sealed by liquid membrane
        - Air barrier applied in accordance with manufacturer's instructions
    - General Coverage at Adjacent Building Conditions - Liquid Membrane
      - Where unable to install air barrier on the exterior of the building, a low VOC product shall be installed on the interior at full height (top of plank to bottom of plank at each floor). This shall happen before any interior framing is installed.
    - General Coverage / Transition Membrane – Seams

- All transition membranes should be installed and sealed before insulation is installed on top. Seams shall be sealed per manufacturer's instructions.

- Air Barrier Penetrations
  - Post air barrier penetrations shall be sealed per air barrier manufacturer's requirement. Transition membranes shall be used to patch as necessary with seams sealed appropriately.
- Rough Openings (Concrete Masonry Construction) - Windows and Doors
  - Liquid air barrier shall wrap in at masonry rough openings to be flush with inside edge of window or door frame.
  - Sheet membrane or metal panel enclosure can be used as alternative as long as it is clear the air barrier is continuous and any gaps are sealed per manufacturer's instructions with backer rod as necessary.
- Rough Openings (Steel Stud Construction) - Windows and Doors
  - Rough opening must be wrapped with sheet membrane all the way inside to be flush with inside edge.
- Rough Openings - Pipes, Conduits, Ducts, Etc.
  - Gaps shall be filled with backer rod as necessary and sealant compatible with all surfaces (Where smooth surfaces are present, mechanical gasket seals can be used). EPA recommends using a minimum 20 year sealant.
- Rough Openings - Cast Stone Sills
  - Cast stone sill shall be sealed to sill pan. EPA recommends using minimum 20 year compatible sealant where not sealed by grout.
- Rough Openings - Gap at Window Frames
  - Gaps between window frame (header, jambs, sill) and rough opening shall be sealed on the interior with backer rod as necessary and sealant that is compatible with all surfaces applied to. EPA recommends using a minimum 20 year sealant.
- Rough Openings - Gap at Exterior Door Frames
  - Gaps between door frame (header, jambs, threshold) and rough opening shall be sealed on the interior with backer rod as necessary and sealant that is compatible with all surfaces applied to. EPA recommends using a minimum 20 year sealant.
- Rough Openings - A/C Sleeves
  - Gaps between A/C sleeves and rough openings to be sealed on the interior with backer rod as necessary and sealant that is compatible with all surfaces applied to. EPA recommends using a minimum 20 year sealant. Insulated interior cover with air tight compressible gasket must be provided.
- Doors – Weather-stripping
  - When required by local building code, verify entranceways contain vestibules with weather-stripping hard-fastened to the door or frame.
  - Weather-stripping is mandatory at doors between conditioned spaces and the exterior; unconditioned spaces; and spaces vented to the outside.

- Weather-stripping is recommended, but not required, at doors between corridors and stairwells; between apartments and corridors; and doors leading to mechanical rooms.
- Weather-stripping at mandatory locations shall be installed with a rigid fastener and replaceable foam gasket specified for durability and less maintenance.

- Plank Edges (Steel Stud Construction) - At plank / exterior sheathing join
  - Transition Membrane must be installed over top spanning the sheathing / plank edge joint creating a bellows with backer rod
  - All termination seams must be sealed with compatible sealant. EPA recommends using a minimum 20 year sealant.
- Plank Edges (Concrete Masonry Construction)
  - At plank / CMU joint
    - Option 1 - If gap is greater than 1/4", Transition Membrane must be used to seal the gap with minimum 3" overlap
    - Option 2 - If gap is less than 1/4", Liquid Membrane can be used to seal the gap
    - Option 3 - When shelf angles are to be installed, through wall flashing must be draped from above to completely cover the joints at top and bottom edges of the plank and sealed to the shelf angle. The Liquid Membrane shall be applied up to and continuing on the underside of the shelf angle to achieve continuity
  - Plank Edges - At plank / steel girder joint
    - Through wall flashing must be draped from above to completely cover this joint and the entire face of the girder and sealed to the shelf angle.
    - This can be sealed with a transition membrane from the interior underside of the plank if the girder is solid and is allowed by local code.
  - Steel Columns - Steel / CMU joints
    - If allowed by local code, EPA suggests gaps shall be filled with backer rod as necessary and minimum 20 year sealant that is compatible with all surfaces applied to. Alternatively a transition membrane can be installed over top spanning the entire steel column, extending 3" beyond each edge of the column and adhered to the substrate per manufacturer's recommendations.
- Wall to Roof Connections
  - Liquid air barrier must be brought up over grout edge part of roof plank and shall be sealed over the plank / grout joint

- Inspected from the interior:
  - Rough openings to windows and doors
  - Window to interior gypsum board
  - Rough opening for A/C sleeve
  - Air conditioner sleeve sealed to drywall (cover is installed if ACs provided by building)
  - Outlet/Electrical Box - Exterior and Demising Walls
  - Heating pipe penetrations through exterior walls

  - Heating pipe penetrations through interior partitions
  - Plumbing / Sprinkler Pipe Penetrations
  - Range Gas Line Penetration
  - Gypsum board to concrete ceiling plank connection - Exterior walls and all interior partition walls
  - Gap between take-off duct and gypsum board
  - Electrical Panel
  - HVAC Access Doors
  - Thermostats
  - Intercoms
  - Lighting Fixtures
  - Door Latch Hole
  - Medicine Cabinet
- For wood-framed construction, Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes Thermal Enclosure Rater Checklist Sections 3 and 5* ~~must be followed~~is recommended in addition to all *T&V Protocols*.

Fan Pressure Testing~~:~~

- Fan pressure testing shall be conducted for two purposes: Preliminary testing ~~shall~~should be conducted on an initial set of apartments to verify the performance of the air barrier detailing and installation and Final verification testing shall be conducted on a subset of the remaining apartments for program compliance and quality assurance.
  - Preliminary Testing~~:~~ (Recommended):
    - The initial set of tested apartments ~~shall~~should include at least one corner unit and one middle unit.
    - The preliminary testing ~~shall~~should be conducted at the earliest time in the construction process possible before building-wide air sealing of apartments is completed.
    - Before an apartment can be tested, the air barrier systems for both the exterior enclosure and the interior compartmentalization ~~must~~should be installed and inspected.
    - The apartments selected for preliminary testing shall be tested using the methods described below. If the units meet or beat the air leakage ~~target~~maximum of 0.30 CFM per square foot of enclosure at 50 pascals, the inspections described above continue to ensure air barrier integrity of the exterior enclosure and apartment compartmentalization continues at the same quality.
    - If an apartment fails to meet or beat the ~~target~~maximum air leakage rate, then deficiencies in the air barriers ~~will~~should be identified and corrected until all apartments in the preliminary test set have passed. Use the results of these tests to develop a punch list of details to be modified as construction continues. The inspection checklist ~~shall~~should be modified to incorporate the lessons learned from the preliminary tests and the modified inspections ~~shall~~should proceed to ensure air barrier integrity of the exterior enclosure and for apartment compartmentalization continues at the newly identified quality.
    - Send a summary of the preliminary tests, results and any recommendations to the project team to reduce apartment infiltration moving forward.
  - Final Verification Testing~~:~~ (Required):
    - When seven apartments are ready for final testing, all 7 apartments must be tested and demonstrate compliance with program requirements before sampling may begin. Once sampling is permitted, one apartment shall be selected at random from ~~the~~a set of seven apartments. More than one group of seven may be available for testing at the same time, but they must be divided into identified groups of seven or less. The logic for responding to units that pass or fail then follows the RESNET 2006 Mortgage Industry National Home Energy Rating Systems Standard sampling protocol.
      - If the randomly selected test apartment passes, then all apartments in that set are deemed to pass.
      - If the randomly selected test unit fails, then an additional 2 units in that group of seven must be tested. If either of those two units fail, then the remaining 4 units must be tested. Any unit that fails must have the air barrier deficiencies

corrected until it meets or beats the air leakage ~~target~~maximum of 0.30 CFM at 50 pascals induced pressure difference. See the Sampling Requirements section of this protocol for more details.

- Continue this process until all apartments have been included in a group of seven.

- Fan Pressure Testing Method:
  - Measure the air leakage rate of a test apartment using fan pressurization techniques following either ASTM E779 2010 or ASTM E1827. If using ASTM E1827, a one-point test at 50 Pascal using the average CFM50 measured under depressurization is acceptable for this measurement.
  - When performing this test, the calibrated blower door fan shall be located in the entry door of the apartment. Windows in adjacent apartments shall be open during the test. Alternatively, the pressure difference between the test unit and the neighboring units can be measured when the test unit is depressurized 50 pascals relative to outdoor air. Windows do not need to be opened in a neighboring unit if the pressure difference between it and the test unit is greater than or equal to 45 pascals. If the apartment entry door opens to a corridor or other enclosed space, that space shall be well open to the outside during the test (e.g., opening the windows and corridor doors in neighboring units achieves both ends).
  - Conduct any QA procedures on test equipment and set-up recommended by the blower door manufacturer (e.g., ensure that the fan flow is in the proper direction for flow measurement to be accurate). Check the tubing connections to the flow sensing element and that the flow sensing element is properly positioned.
  - Conduct test to see whether or not the apartment air leakage rate is less than or equal to 0.30 CFM50 per square foot of enclosure (e.g., all surfaces enclosing the apartment, including exterior and party walls, floors, ceiling). Use the guidance in the Preliminary or Final Verification Testing sections above to determine the next action (e.g., test more apartments, make repairs or write report).
  - *Note: This test does not distinguish between leakage from the apartment to outside and leakage from the apartment to other interior and/or interstitial spaces. The allowable limit for measured leakage is for the total enclosure of the apartment unit.*

Schedule:

- This process begins with the construction documentation. A minimum of 3-5 site visits are recommended to properly inspect air sealing details. Each exterior, common area and in-unit element on the air sealing checklists must be inspected at each of the following stages to ensure use of proper materials and complete seals exist for each juncture or penetration:
  - Interior framing layout
  - Pre-drywall visual inspection of penetrations
  - Sample apartment inspection and blower door test
  - Post-correction testing of sample apartment
  - Final inspection and testing of apartments post-completion

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor (GC)

Sampling Requirements:

- For elements that provide central services to the building (i.e., entry doors, central duct chases, utility service penetrations, etc.) a minimum 50% sample shall be inspected. For elements that are repeated throughout the building or occur in every living unit (i.e., windows, wall/floor connections, air conditioner sleeves, etc.) follow RESNET sampling protocol. If problems are identified, additional units must be inspected to determine if the problems are systemic so an appropriate repair order can be issued.
- During construction, apartment units must be visually inspected prior to drywall and upon final completion following RESNET sampling protocol. The sample set shall be representative of the variety of apartment types in the building, including: end/corner units and inside units; top-floor, middle-floor, bottom-floor units; and at least one unit of each size/type (i.e., studios, 1-bed, 2-bed, etc.).
- Post-construction, single-point blower door testing of apartment units must be conducted following RESNET sampling protocol. The sample set shall require testing of at least ~~5~~7 units and be representative of the variety of apartment types in the building, including: end/corner units and inside units; top-floor, middle-floor, bottom-floor units; and at least one unit of each size/type (i.e., studios, 1-bed, 2-bed, etc.). Any apartment that exceeds the allowed leakage rate (0.30 CFM50/square feet of enclosure), must confirm that all items below have been properly sealed prior to retesting. Per RESNET Section 603.7.8, until the failure is corrected in all identified (failed) apartments in the sample set, none of the apartments shall be deemed to meet the threshold ~~or labeling~~ criteria.
  - Window to interior gypsum board
  - Air conditioner sleeve sealed to drywall (cover is installed if ACs provided by building)
  - Outlet/Electrical Box - Exterior and Demising Walls
  - Heating pipe penetrations through exterior walls
  - Heating pipe penetrations through interior partitions
  - Plumbing / Sprinkler Pipe Penetrations
  - Range Gas Line Penetration
  - Gypsum board to concrete ceiling plank connection - Exterior walls and all interior partition walls
  - Gap between take-off duct and gypsum board
  - Electrical Panel
  - HVAC Access Doors
  - Thermostats
  - Intercoms
  - Lighting Fixtures
  - Door Latch Hole
  - Medicine Cabinet

8.0 Ventilation and Infiltration

Protocol 8.2 - Common Area and In-Unit Ventilation (CFM), ~~Intake Source, and Intake/Exhaust~~ Fan Efficiency, and Central Exhaust Duct Leakage

Type of Testing Protocol:

✓	Visual Inspection
✓	Data Sheet
✗	Test Procedure
✓	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- Construction documents must include performance criteria for duct leakage, airflow and fan efficiency for central, common space and in-unit ventilation systems including:
  - For all central ~~exhaust~~or common space ventilation systems:
    - Roof curb or wall penetration has been sealed
    - Mastic or other UL-181 compliant material shall be applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
    - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
    - All connections between gypsum board and ductwork must be sealed.
    - ~~Total exhaust shaft leakage shall not exceed 10 CFM50 per floor per shaft at a pressure of 0.2 in WC.~~
    - Contractor shall adjust roof exhaust fan to provide a pressure of 0.2 – 0.3 inches WC at the ~~grille~~register farthest from the fan.
  - For central exhaust systems serving at least one apartment: ductwork must be tested for leakage, prior to sheetrock, where the maximum leakage allowance is calculated as 5 CFM per register per shaft plus 5 CFM per floor per shaft, or if following the Prescriptive Path, 2.5 CFM per register per shaft plus 2.5 CFM per floor per shaft. A "floor" is given an allowance regardless of whether or not it serves any apartments on that floor. A shaft must be tested for leakage whether it is passively or actively ventilated.
  - For in-line fan exhaust systems:
    - Mastic or other UL-181 compliant material shall be applied within temperature range and according to all other manufacturer's requirements at **ALL** transverse joints and take offs.
    - All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.

- All connections between gypsum board and ductwork must be sealed.
- If plank core is to be used as duct, ceiling plank penetration has been sealed.
- If plank core is to be used as duct, plank core has been effectively connected to exterior of the building.
- The appropriate plank core was selected that aligns with exterior louver.
- In-unit exhaust fans must be ENERGY STAR ~~qualified~~certified.

- Construction documents must also include the following criteria apply to projects using the *Prescriptive Path:*
  - For central exhaust systems~~, total exhaust shaft~~ serving at least one apartment, the maximum duct leakage ~~shall not exceed~~ allowance is calculated as 2.5 ~~CFM50~~CFM per register per shaft plus 2.5 CFM per floor per shaft ~~at a pressure of 0.2 in WC~~.
  - Central exhaust and in-line exhaust systems serving apartments must have self-balancing dampers at each ~~grille~~register.
  - Central exhaust fans 1/16 HP and less must be direct-drive and have variable speed controllers.
  - Central exhaust fans greater than 1/16 HP and less than 1 HP must be direct-drive with ECM motors and variable speed controllers.
  - Central exhaust fans 1 HP and larger must have NEMA Premium efficient motors.
  - Powered common laundry ventilation must be installed with automatic demand control to turn off exhaust fans when no dryers are operating.
- Construction documents must include performance criteria for buildings with garages including:
  - If following the *Prescriptive Path*, when garage exhaust is required by code, CO and NO_2 sensors must be installed that control exhaust fan operation.
  - Include threshold criteria for CO and NO_2 concentration which activates sensors.
  - Include a schedule of CO and NO_2 controls with make, model, location and count.
  - Include locations, powering of sensors, and connecting wiring on plans.
  - Include fan size (CFM capacity) in ventilation schedule and air intake points on plans to properly ventilate throughout garage area.
- Common Area Fan Efficiency
  - Design specifications shall include fan energy efficiency criteria (BHP and motor efficiency) for the fans themselves.
- Apartment Fan Efficiency (Roof/Central)
  - Specifications shall include fan energy efficiency criteria (BHP and motor efficiency) for the fans themselves.
- Apartment Fan Efficiency (In-Unit)
  - Specifications shall include fan energy efficiency criteria (Watts/CFM) for the fans themselves.
- Apartment and Non-Corridor - Capacity, Testing and Balancing
  - Apartment whole-unit ventilation systems shall be designed and tested to satisfy minimum requirements of ASHRAE 62.2-2007 Section 4.1 based upon the anticipated occupancy, without reliance on natural ventilation. Compliance with ASHRAE 62.2-2007 Sections 4.3 and 5.3.1 is recommended but not required.

- Providing outdoor air to each apartment directly from the outdoors is recommended, but not required.
- Apartment local mechanical exhaust systems must be vented directly to the outdoors or to ventilation risers. They shall be designed and tested to satisfy minimum requirements of ASHRAE 62.2-2007 Section 5.1. For kitchen exhaust fans, prescriptive duct sizing requirements described at www.energystar.gov/newhomesresources may be used in lieu of measuring the actual air flow rate.
- Common space ventilation systems shall be designed and tested to satisfy minimum requirements of ASHRAE 62.1-2007. Mechanical ventilation is recommended, but not required, for naturally ventilated spaces that meet criteria of Section 5.1.1. Spaces that exceed the 25' distance may use a combination of natural and mechanical ventilation to meet the requirement.
- EPA recommends that each exhaust and supply ~~grille~~register assembly ~~should~~ be equipped with a self-balancing damper that responds to changes in duct pressure to allow a constant airflow (+/- 20%) over a range of operating pressures from 0.2 in WC to the greater of: 0.5 in WC or the maximum system operating pressure at the particular exhaust register/~~grille~~register. This is critical to helping ensure the system performs according to project specifications and Proposed Design model and is a requirement for centrally exhausted apartments listed in the *Prescriptive Path:*
  - Adjustable register assemblies that allow for the free area to be manually adjusted in the field should not be used to meet this requirement. Self-balancing dampers shall be designed and installed in any situation where more than one exhaust point is connected to a fan so that they may be easily removed for cleaning or replacement. For inspection: Self balancing dampers have been installed in correct position and are functioning properly.
- The developer may choose to hire a Test and Balance (TAB) contractor to commission the system or any part thereof. Either the TAB contractor or the responsible party shall provide a balancing report for each shaft with operating pressures at the ~~grille~~register furthest from the fan and with airflow (CFM) measurements at apartment and common area ~~grills~~registers following RESNET sampling protocol.
- If following the *Prescriptive Path*, common ~~area~~space ventilation systems cannot exceed ASHRAE 62.1-2007 by more than 50%. Apartment whole-unit and local exhaust ventilation systems cannot exceed ASHRAE 62.2-2007 by more than 50%.

- Central Supply to Corridor
  - Corridor ventilation systems shall be designed and tested to satisfy minimum requirements of ASHRAE 62.1-2007. Mechanical ventilation is recommended, but not required, for naturally ventilated corridors that meet criteria of Section

5.1.1. If following the *Prescriptive Path*, corridor ventilation systems cannot exceed ASHRAE 62.1-2007 by more than 50%.

- For systems designed with outdoor-air supplied to the ventilation system, provide motorized dampers that will automatically shut when the systems or spaces served are not in use. Continuously running ventilation would not be subject to a motorized damper, as they are always in use.
- Heat or Energy Recovery
    - Consider heat or energy recovery for 100% of corridor supply air. Capacity of heat recovery unit should match the design corridor ventilation rates.
- For both active and passive intake systems, design specifications must indicate operation sequence as it relates to controls, sensors, fans, dampers, etc.
- ~~System performance may be highly dependent on the level of duct leakage in the ventilation system. Duct leakage must be tested for central exhaust systems to verify the requirements listed in the *Prerequisites Checklist* (no more than 10 CFM50 leakage per floor per shaft)~~If applicable and~~/or *Prescriptive Path* (no more than 5 CFM50 leakage per floor per shaft) have been met.~~
- ~~Test for duct leakage in the main duct shaft using a calibrated fan. If credit is being taken for improved energy efficiency of the ventilation duct system, adjust As-Built Building energy model based on actual duct leakage rates as described in the *Simulation Guidelines*. Provide a summary of results of any duct leakage or ventilation performance testing.~~
- ~~If~~ allowed by local code, ~~EPA recommends stairwell bulkhead~~stair and elevator ~~hoist way smoke vents be normally~~shaft vents shall be equipped with motorized dampers that are capable of being automatically closed during normal building operation and are interlocked ~~with motorized damper~~ to open as required by fire and smoke ~~detector/fire alarm system~~detection systems.
- Contract Language: "Allow access to inspect duct installations prior to enclosure. Provide Test and Balance (TAB) reports to the responsible party ~~or~~and allow access for diagnostic testing post-installation."

Procedures and Documentation:

- ~~Verify that all in-unit exhaust fans are ENERGY STAR qualified and all ventilation equipment is consistent with the project specifications and Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.~~

~~Either the TAB contractor or the responsible party shall provide a balancing report for each shaft with operating pressures~~***Ventilation Duct Sealing***

- Inspect all ventilation ductwork sealing upon installation including all take offs and branches and prior to enclosure with drywall.

Central Exhaust Duct Leakage Testing

- For central exhaust systems serving at ~~the grille furthest from the fan and with airflow (CFM) measurements at~~least one apartment ~~and common area grills following RESNET sampling protocol described below. Airflow shall~~, ventilation ductwork must be ~~measured with a capture hood that fully encloses the grills and is able to measure as low as 20 CFM ± 5 CFM.~~ tested for leakage prior to enclosure with drywall.

- Following the procedures outlined in your duct leakage tester operation manual, a single point or five-point test for total duct leakage in the main duct shaft using a calibrated fan between -50 and -100 Pascal measured under depressurization or 50 and 100 Pascal under pressurization is acceptable for this measurement.
- When conducting a duct leakage depressurization test, the flow conditioner and one of the flow rings must always be installed.
- EPA does not require the duct tester to be connected to a specific location in the shaft, however ~~typically~~, typical central exhaust duct tightness tests are conducted from the roof with the duct tester connected to the roof curb. Often a transition plate is needed to effectively seal the duct tester to the roof curb opening. Cardboard is usually a readily accessible material on construction sites and can be easily adapted into such a transition plate (precut plastic, acrylic glass and or rubber sheets could also be used).
- The pressure probe should be installed approximately 5' downstream of the connection between the duct and the duct tester, with the probe configured so it's openings face perpendicular to the direction of flow and only static pressure is measured, not velocity pressure. When connecting the duct tester to the roof curb, ~~poke~~create a hole in the transition sheet and run the tubing and pressure probe inside of the shaft before connecting the transition sheet. Often static pressure probes come with a magnet to help configure the probe in the right direction, but if the inside surface of the duct is not magnetic, a weighted pressure hose could be used with holes cut out of the sides to prevent velocity pressure from being measured.
- ~~Use~~If conducting a five-point test, use the Linear Regression Assistant provided in the *T&V Worksheets* to ~~find~~calculate the CFM50 leakage. ~~Per the *Prerequisites Checklist*, the CFM50 duct leakage for central exhaust systems must~~If performing a single-point test, Linear Regression Assistant does not ~~exceed 10 CFM50 leakage per floor per shaft (5 CFM50 per floor per shaft if using the *Prescriptive Path*).~~need to be used.
- If credit is being taken for improved energy efficiency of the central ventilation duct system, adjust As-Built energy model based on actual duct leakage rates as described in the *Simulation Guidelines*. Provide a summary of results of ~~any~~ duct leakage ~~or ventilation performance testing; a sample~~in the table ~~is~~ provided in the *T&V Worksheets*.
- Once drywall has been installed, verify through visual inspection that joints and gaps between all exhaust and supply ducts and sheetrock at the ~~grills~~registers have been sealed.

Ventilation Fan Efficiency

- Verify that all in-unit exhaust fans are ENERGY STAR certified.
- Verify all ventilation equipment is consistent with the project specifications and Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.
- Provide manufacturer's cut sheets or invoice detailing system manufacturer, model, HP/Watts and CFM.

Ventilation Performance (ASHRAE 62 compliance)

- The developer may choose to hire a Test and Balance (TAB) contractor to commission the system or any part thereof. Either the TAB contractor or the responsible party shall provide

a balancing report for each ventilation system with supply and/or exhaust airflow (CFM) measurements at apartment and common space registers following RESNET sampling protocol described below. Airflow measurements may be taken at the inlet or outlet. Airflow shall be measured with equipment that fully enclose registers and is able to measure as low as 20 CFM ± 5 CFM. Airflow (CFM) measurements must provide the minimum rates per ASHRAE 62.1-2007 or 62.2-2007. If following the *Prescriptive Path*, airflow (CFM) measurements cannot exceed ASHRAE 62.1-2007 or 62.2-2007 by more than 50%. For kitchen exhaust fans, prescriptive duct sizing requirements described at www.energystar.gov/newhomesresources may be used in lieu of measuring the actual air flow rate.

- Provide a summary of the ventilation performance testing in the table provided in the *T&V Worksheets.* Average supply and exhaust CFM measurement shall be updated in the As-Built model where applicable.
- Air intake point shall also be inspected.

Final Inspections

- In passive intake systems (i.e., trickle vents), EPA recommends, but does not require, that airflow measurements ~~shall~~ be taken ~~using a capture hood and rotating vane anemometer~~ to verify flow rates are within design specifications under the range of conditions anticipated for system operation. ~~Rotating vane anemometer shall have accuracy better than +/- 15% of rated flow.~~ If airflow cannot be directly measured, pressure measurements ~~shall be used to verify that conditions exist to allow the intake apparatus to operate as intended.~~can be used to estimate airflow based on manufacturer's data for different pressure levels.
- For all make-up air systems, a visual inspection of the supply air source shall be conducted to ensure pollutants are not being drawn into the building unintentionally.
- Verify control systems including timing devices, demand control sensors, or other devices match the Proposed Design and are functioning properly.
- ~~Provide manufacturer's cut sheets or invoice detailing system manufacturer, model, HP and CFM.~~
- Using quantified CO/NO_2 tracer gas release (obtain specifications from chemical test suppliers), confirm performance of sensor and activation of garage exhaust fans.
- If ~~applicable~~allowed by local code, verify stairwell bulkhead and elevator hoist way smoke vents are normally closed and interlocked with motorized damper and smoke detector/fire alarm system per ASHRAE 90.1-2007, Section 6.4.3.4.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet*.
- Photographs:
    - Photo of fan installation, duct work sealing, and duct work insulation
    - Photo of fan faceplates

- If applicable, photograph location of CO/NO_2 sensors and air intake point

Schedule:

- Minimum of one on-site inspection required to document duct sealing, preferably immediately after installation so that corrective action can be taken if necessary. Inspect all ventilation ductwork sealing upon installation including all take offs and branches and prior to enclosure with drywall. Test central exhaust duct systems for leakage upon installation including all take offs and branches and prior to enclosure with drywall. The intent is to test the duct system before drywall and registers are installed so corrections can be made if duct leakage is excessive, however all take offs, branch duct work, bottom caps and permanent roof curbs must be installed prior to testing. Takeoffs are typically installed floor by floor.
- The developer or GC shall ensure that deliveries are inspected prior to accepting them to verify that product substitutions by the distributor or manufacturer have not resulted in non-ENERGY STAR ~~qualified~~certified exhaust fans for in-unit ventilation systems.~~—~~
- Minimum of one on-site inspection required to document fan efficiency, preferably immediately after installation so that corrective action can be taken if necessary. Delivery tickets may be used to verify complete shipments but on-site inspections of a sample of installed ~~appliances~~ventilation systems is required.
- ~~Inspect and test duct systems for leakage upon installation including all take offs and branches and prior~~Minimum of one on-site inspection required to ~~enclosure with drywall. The intent is to test the duct system before drywall and grills are installed so corrections can be made if duct leakage is excessive, however all take offs and other horizontal duct work must be installed prior to testing.~~document ventilation performance. ~~Ducts should be tested after bottom caps and permanent roof curbs are on and sealed.~~
- Flow measurements cannot be verified until interior drywall and ~~grills~~registers are installed.

Examples of Responsible Parties:

- Licensed Professional
- General Contractor
- Building Maintenance
- Energy Consultant
- Test and Balance (TAB) Contractor

Sampling Requirements:

- ~~100% of common area ventilation equipment~~Central exhaust ductwork serving at least one apartment must be inspected and ~~verified~~tested for ~~system performance. System performance at the delivery location (register) can be sampled at every other floor.~~
- ~~Apartment ventilation risers must be inspected and verified for system performance~~duct leakage following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document. ~~For each ventilation riser in the sample set, take measurements at every other floor to obtain a representative profile. The~~The overall

sample shall include at least one riser for each type/size of fan installed in the building~~.~~ serving apartments.

- 100% of ventilation equipment serving common spaces must be inspected and verified for system performance (ie. fan efficiency, controls). Ventilation performance (CFM) at the delivery location (register) can be sampled at every other floor. The overall sample shall include at least one riser for each type/size of fan installed in the building serving common space.
- 100% of central ventilation equipment serving apartments must be inspected and verified for system performance (ie. fan efficiency, controls). Ventilation performance (CFM) at the delivery location (register) can be sampled following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document. The overall sample shall include at least one riser for each type/size of fan installed in the building serving apartments. For each ventilation riser tested, take measurements at every other floor to obtain a representative profile.
- Verification of in-unit ventilation equipment performance (ie. fan efficiency, controls) and in-unit ventilation performance (CFM) at the delivery location (register) can be sampled following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document.

9.0 Metering

Protocol 9.1 - Metering Configuration

Type of Testing Protocol:

✓	Visual Inspection
✗	Data Sheet
✗	Test Procedure
✗	Instrumented Measurement
✗	Third-Party Commissioning

Performance Specification Criteria:

- Specify separate utility meters (electricity, gas, fuel oil, water, steam, and hot water) for any nonresidential associated areas of the buildings (i.e., leased commercial spaces).
- Contract Language: "Utility correspondence will need to be submitted to the responsible party."

Procedures and Documentation:

- Review specifications, electrical drawings, and correspondence with utilities (service applications, meter requests).
- Confirm location and existence of electric, gas, and water meters and observe configurations (areas served) in relation to plans and specifications.
- Confirm location and existence of separate meters that serve the nonresidential associated areas of the building.
- Check meter types against specifications (and/or utility correspondence).
- Confirm metering configuration: master meter, submetered, direct metered.
- For buildings that are direct metered for utilities to the apartments, verify the building owner has secured signed releases from individual apartment occupants to allow for benchmarking.
- Provide photographs of all types of meters (electrical, gas, water) for building:
  - Be sure to properly label location and type of meter represented.
- A Statement of Substantial Completion or approved proxy may be used to establish completion of the work associated with this protocol. A Statement of Substantial Completion is to be completed by the installation contractor or other qualified representative on company letterhead, complete with all information, photographs, cut sheets, etc., required in this protocol and in the corresponding *T&V Worksheet*.

Schedule:

- After piping and wiring are complete.
- After installation, hook-up, and activation of meters.

Examples of Responsible Parties:

- Licensed Professional
- Energy Consultant
- General Contractor or Building Maintenance to assist with identification of meters

Sampling Requirements:

- Where metering is in basement central location, check all meter banks. Where metering is distributed in common areas, such as hallway utility closets or is inside individual apartments, follow the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 11 of this document to include, at a minimum, one apartment from each line.

Appendix A: Referenced Standards and Data Sources

Air Conditioning Contractors Association (ACCA) Manuals J, S, and D: These manuals provide standardized procedures for completing sizing calculations for heating and cooling systems (Manuals J and S) and duct system sizing and design (Manual D)

Air-Conditioning, Heating, and Refrigeration Institute (AHRI): Reference AHRI ratings to determine seasonal efficiencies of heating and cooling systems, www.ahridirectory.org.

American Society of Refrigeration and Air-conditioning Engineers (ASHRAE) Standard 62.1-2007: Ventilation for Acceptable Indoor Air Quality: Provides guidance for ventilation system design and other related building features to ensure acceptable indoor air quality. Scope includes all buildings except low-rise residential.

(ASHRAE) Standard 62.2-2007: Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings: Provides guidance for ventilation system design and other related building features to ensure acceptable indoor air quality.

(ASHRAE) Standard 90.1-2007 and 90.1-2010: Energy Standard for Buildings Except Low-Rise Residential Buildings: Primary source document for Baseline Building design features and guidance for creating a performance-based evaluation of a proposed building's energy features.

(ASHRAE) Standard 189.1-2009: Standard for the Design of High Performance Green Buildings Except Low-Rise Residential Buildings: Primary source document for Building Envelope Requirements and Minimum Equipment Efficiencies for the Prescriptive Path.

(ASHRAE) Standard 160P: Criteria for Moisture Control Design Analysis in Buildings: The standard sets criteria for moisture design loads, moisture analysis methods, and building performance and applies to the above-grade portions of all types of buildings.

ASTM E779 - 10 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization: This test method measures air-leakage rates through a building envelope under controlled pressurization and de-pressurization.

ASTM E1827 – 96 (2007): Standard Test Methods for Determining Air tightness of Buildings Using an Orifice Blower Door: These test methods describe two techniques for measuring air leakage rates through a building envelope in buildings that may be configured to a single zone.

ENERGY STAR ~~Qualified~~Certified Homes: Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes HVAC System Quality Installation* ***Rater and Contractor Checklists*** is referenced for forced air system commissioning. Version 3.0 of the *ENERGY STAR ~~Qualified~~Certified Homes Thermal Enclosure System Rater Checklist Sections 3 and 5* is referenced to verify envelope installations for buildings with wood framed construction. Both documents can be found at the following website:
http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/InspectionChecklists.pdf

Illuminating Engineering Society Lighting Handbook: Handbook of lighting design published by the Illuminating Engineering Society of North America (IESNA), www.iesna.org.

National Fire Protection Association (NFPA) Standards 54 and 31: These standards provide guidance for the proper installation of natural gas (54) and oil-fired (31) heating systems.

National Fuel Gas Code: Same as NFPA 54

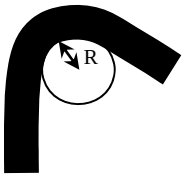
Residential Energy Services Network (RESNET) Mortgage Industry's National Home Energy Rating Systems: This standard includes the sampling procedure described in the "How to Use this Manual" section, as well as in the Wall Construction/Insulation protocol.
http://resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf

Appendix B: Recommended Equipment List

The specific equipment required will depend on the systems that are present in any given building. In addition to a standard tool kit containing measuring tape(s), flashlight, assorted hand tools, and personal safety gear, the following performance testing equipment may be required to complete the procedures described in this manual.

- Balometer (flow hood)
- Blower door fan, frame & shroud
- Flowplate
- Duct leakage tester
- Electronic Ballast Tester
- Low-e Detector
- Digital manometer and hoses
- Pressure pan
- Smoke pencil
- Static pressure probes
- Thermometer (hand-held) for measuring hot water temperatures
- Thermometer (dual-channel, digital) with appropriate thermocouples for measuring air temperatures inside ductwork, pipe temperatures, etc.
- Infrared Camera
- Digital Camera
- Water Pressure Gauge
- Light Meter

Appendix C: Specifications for Flexible Duct Installation

Component/Location	Standard
Duct length	Limit duct length to no more than 25' per run for flex duct, not to exceed the manufacturer's recommended limit
Excess ductwork	Runs shall be as direct as possible. Excess ductwork shall be no more than 5% for any given section of flexible duct.
Supports	Suspended horizontal ducts shall be supported at least every 5'.
Hangers	Hanger material shall be at least 1-1/2" in width and hangers shall not crimp the ductwork, causing the interior dimension of the duct to be less than specified
Sag	Suspended ductwork shall be allowed to sag no more than ½" for every 1' of run
Trunk and boot connections	Flexible duct shall be allowed to run straight out of any connection at least 12" before taking a turn
Bends	The radius at the centerline of a bend must be a minimum of one duct diameter as shown in the diagram (R = 1 duct diameter): 
Connections	Connections to boots, collars, and trunks must be mechanically fastened and substantially airtight
Sealants	Sealants and tapes used to make ductwork airtight must be compliant with UL=181 standards and installed according to the manufacturer's specifications

Reference: Sheet Metal and Air Conditioning Contractor's National Association