# Table of Contents

- Definitions .......................................................................................................................... 4
- Introduction and Purpose ..................................................................................................... 8
- General Approach ................................................................................................................ 9
- How to Use This Manual .................................................................................................... 11
- 1.0 Appliances ..................................................................................................................... 14
  - Protocol 1.1 - ENERGY STAR Qualified Appliances ....................................................... 14
- 2.0 Domestic Water Heating ............................................................................................... 16
  - Protocol 2.1 - Central Systems (Serving 5 units or more) .................................................. 16
  - Protocol 2.2 - Distributed (Individual Apartment) Systems ............................................. 19
- 3.0 Envelope ....................................................................................................................... 22
  - Protocol 3.1 - Wall Construction/Insulation, R-value ....................................................... 22
  - Protocol 3.2 - Roof Construction/Insulation, R-value ....................................................... 25
  - Protocol 3.3 - Floor Construction/Insulation, R-value ....................................................... 27
  - Protocol 3.4 - Window Selection, U-value, SHGC, and Visual Transmittance .................. 29
  - Protocol 3.5 - Exterior Door Selection, Entranceway Design, Use of Vestibules, Weather-stripping, and Air Leakage .......................................................... 32
- 4.0 Garages .......................................................................................................................... 34
  - Protocol 4.1 – Heating and Compartmentalization ............................................................ 34
- 5.0 Heating and Cooling ...................................................................................................... 36
  - Protocol 5.1 - Central Heating Systems (Serving 5 units or more) ..................................... 36
  - Protocol 5.2 - Central Cooling Systems (Serving 5 units or more) ..................................... 41
  - Protocol 5.3 - Distributed (Individual Apartment) Heating Systems .............................. 45
  - Protocol 5.4 - Distributed (Individual Apartment) Cooling Systems .............................. 49
- 6.0 Lighting .......................................................................................................................... 53
  - Protocol 6.1 - Common Areas, In-Unit, Garage and Exterior Lighting ............................. 53
  - Protocol 6.2 – Emergency Lighting (Exit Signs) ............................................................... 56
  - Protocol 6.3 – Controls ..................................................................................................... 57
- 7.0 Motors ............................................................................................................................ 59
  - Protocol 7.1 - Motors ........................................................................................................ 59
- 8.0 Ventilation and Infiltration ............................................................................................ 61
Definitions


ASHRAE 90.1-2007: energy standard for all buildings, excluding low-rise residential buildings. Minimum requirements for the energy-efficient design of high-rise multifamily buildings are included within this standard.

ASHRAE 90.1-2007 Appendix G (Appendix G): protocols for generating an energy performance rating for buildings that exceed the requirements of ASHRAE 90.1-2007 is included within this appendix.

As-Built: same as Final Building.

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 Space: any spaces within a building or facility that serves a function in support of the residential part of the building that is not part of a dwelling unit. Common spaces include spaces which may be used by the residents (e.g. corridors and community rooms) or spaces which are used by the staff (i.e. mechanical rooms and offices).
**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, design engineers, and Energy Consultant.

**Developer:** primary party responsible for the design, financing, and construction of a building or facility. Oversees the work of the Design Team, General Contractor and sub-contractors 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 achieving the ENERGY STAR. 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.

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

**General Contractor:** contractor with primary responsibility for the construction of the building. Oversees the work of the sub-contractors.

**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.

**Multifamily High Rise (MFHR):** residential buildings consisting of four (4) or more floors of conditioned space above grade. If the building is located on top of nonresidential commercial space, the residential space must occupy more than 50% of the gross heated square footage of the entire building and must be separately metered from the 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:** percent reduction in predicted annual energy costs across all end-uses when comparing the Proposed Building Design to the Baseline Building. Proposed Building Designs must achieve a Performance Target of 15% or more to be eligible to earn the ENERGY STAR.
Prerequisites: minimum program standards set by EPA and the Program Administrator to restrict the ability of the Energy Consultant and Design Team to make performance trade-offs that would allow individual building components to fall below minimum acceptable standards during the modeling and/or design of an energy efficient building in order to earn the ENERGY STAR.

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.

Program Administrator: a third party organization that works with Energy Consultants to implement the ENERGY STAR Multifamily High Rise Program. In many cases this may be a government entity, public utility, or a non-profit organization dedicated to promoting energy efficiency. The Program Administrator must be legally independent from the developers and owners of the building participating in the Program and are required to sign a partner agreement with EPA.

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)

Statement of Substantial Completion: a Statement of Substantial Completion or approved proxy may be submitted 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 attached to all relevant ENERGY STAR MFHR Testing and Verification Worksheets (T&V Worksheets) completed with all required information, photographs, cut sheets, etc. When submitting a signed Statement of Substantial Completion, the Partner is still responsible for performing the necessary due diligence to ensure that the Statement of Substantial Completion is accurate and complete. A statement of substantial completion can be submitted for the following protocols:

- 1.1 - ENERGY STAR Qualified Appliances
- 3.4 - Window Selection, U-value, 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 will be accepted 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)
- 2.2 - Distributed (Individual Apartment) Systems
- 5.1 - Central Heating Systems (Serving 5 units or more)
- 5.2 - Central Cooling Systems (Serving 5 units or more)
- 5.3 - Distributed (Individual Apartment) Heating Systems
- 5.4 - Distributed (Individual Apartment) Cooling Systems
Introduction and Purpose
This document provides guidance to Energy Consultants and Program Administrators working 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 tandem with the ENERGY STAR MFHR Prerequisites Checklist, Simulation Guidelines, Performance Path, Prescriptive Path, T&V 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 shall be documented and kept on record with the building file by the Energy Consultant and provided to the Program Administrator if requested.

The intent of these protocols is to verify that the Final 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 Final Building and the Proposed Design, the Final Building energy model must represent the actual observed and measured conditions in the Final Building.

- **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, 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 assumed in the Proposed Design.
  b. Allow the component to remain in its current condition but the Final Building energy model must be adjusted to accurately represent this condition. In any case, the Performance Target calculated based on the Final Building 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. A Final Building energy model must be created to accurately represent the Final Building and the Performance Target calculated based on the Final Building 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 for Energy Consultants and project managers:

- As early in the design phase of the project as possible, hold a meeting with the design team and provide them with copies of the Prerequisites Checklist. Emphasize the importance of incorporating the requirements listed in the Prerequisites Checklist into the design documents and review 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 Energy Consultant 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 the Energy Consultant 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 should 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 Energy Consultant 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 and submittals to the Energy Consultant and Program Administrator.

- Schedule inspections 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 sub-contractor to correct improper installations.

- In most cases, the sample set for any given feature to be inspected should not be selected ahead of time to help ensure the inspector 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. It is the Energy Consultant’s responsibility to 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 Energy Consultant or other 3rd party 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 3 buildings submitted to the Program Administrator and/or EPA.

• For wood-framed construction, the ENERGY STAR Qualified Homes Thermal Enclosure System Rater Checklist must be followed 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 sub-contractors.

• 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 sub-contractors what is expected for an acceptable installation. Some possible examples are: insulation installations, air barrier details, duct sealing details, etc.
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.
    iii. If an individual measure has a waiver for a prerequisite, please note this on spec sheet and/or in caption/label of photo.
  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 name-plates 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 Energy Consultant 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 (for example, 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 (for example, heating system)

- **Performance Specification Criteria** – This section lists the actions to be taken by the Energy Consultant 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 ENERGY STAR MFHR Program. All details to be inspected must be incorporated into the construction documents, so it is clear who is responsible for proper installation and construction. In addition, suggested contract language that may be included in the agreement between the Energy Consultant and developer has been provided for each section of the protocols to ensure the developer is aware of his or her responsibility in facilitating the inspection process.
• **Procedures and Documentation** – This section lists the steps to be followed by the Energy Consultant 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 Final Building energy model and final submittal to the Program Administrator 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. It is the Energy Consultant’s responsibility to communicate with the developer or GC to understand the construction schedule and be available for inspections when necessary without slowing down the construction process.

• **Responsible Parties** – This section lists who is responsible for a specific inspection or test and which other parties 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 re-tested.

In general, the Testing & Verification protocols that allow sampling follow a modified RESNET sampling protocol, as opposed to inspecting 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:

  o 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:

  o 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.

  o 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.

  o 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.

  o 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.
o 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.

o 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 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.
- Require ENERGY STAR qualified appliances, or specifications that meet minimum efficiency criteria established by ENERGY STAR performance levels.
- **Contract Language**: “Allow inspection of all appliances. Provide submittal to the Energy Consultant and inform them immediately after installation. Ensure the ENERGY STAR remains attached to appliance.”

Procedures and Documentation:
- Record manufacturer and model number.
- Confirm manufacturer and model number is ENERGY STAR qualified and/or complies with minimum performance criteria established by that program.
- Photograph one representative appliance faceplate of each type of appliance being inspected.
- Photograph ENERGY STAR and/or attach cut sheet proving ENERGY STAR qualification.
- A Statement of Substantial Completion or approved proxy may be submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
- The developer or GC should 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 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.

Responsible Parties:
- 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 laundry room.
2.0 Domestic Water Heating

Protocol 2.1 - Central Systems (Serving 5 units or more)

Type of Testing Protocol:

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

Performance Specification Criteria:

- **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.
- 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.
- Piping carrying fluid with temperatures greater than 105°F must have a minimum of 1” of insulation. Pipes over 1.5” in diameter must have a minimum of 1.5” of insulation.
- **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 and quantity.
- Specify plumbing fixture flow rates to match assumptions made in the Proposed Design model or 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 by the installation contractor or third-party Commissioning Agent (with the system manufacturer’s representative if necessary) and a commissioning report submitted to the Energy Consultant.”
- **Contract Language**: “The installation contractor and/or system manufacturer shall 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 Energy Consultant and inform them immediately after installation.”

Procedures and Documentation:
• The Energy Consultant shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the Prerequisites Checklist. In addition, the Energy Consultant 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 Energy Consultant.

• The Energy Consultant 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.

• Commissioning of the system shall include:
  • Verify boiler room location and venting
    - Boiler room location (i.e. cellar or roof),
    - Combustion air venting configuration (i.e. combustion air piped to boilers or boiler room air used for combustion)
    - Venting Configuration: (if required, inducer fan specified and sequence of operation verified)
  • Verify that domestic hot water system is set to deliver temperatures within the 120-125°F range.
  • Verify domestic hot water supply and return temperatures.
  • 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. Mechanical valves should not be specified. Verify mixing valve temperature set point. Verify piping carrying fluid with temperatures greater than 105°F has a minimum of 1” of insulation and pipes over 1.5” in diameter have a minimum of 1.5” of insulation.
  • Compare the consumption data of the inspected plumbing fixtures to the assumptions made in the Proposed Design model and adjust data inputs for Final Building model as necessary. Reminder: according to requirements listed in the Prerequisites Checklist, in-unit faucets and shower stalls must not exceed 2.0 GPM. If following the requirements listed in the Prescriptive Path, in-unit lavatory faucets must not exceed 1.0 GPM, shower stalls must not exceed 1.75 GPM.
  • Summarize the training performed and personnel involved. Confirm that all applicable operating and specification manuals are delivered to the building staff. Verify that staff members have been trained and are aware of their responsibilities to maintain and operate the systems properly.
  • Provide manufacturer’s cut sheets or invoice detailing system make, model, size, and location.
  • Provide summary of results of commissioning.
  • Photographs:
    - Provide photos of the domestic water heating system and faceplates to verify proper installation and compliance with proposed design.
• Photograph one representative fixture of each type of plumbing fixture being inspected.

• A Statement of Substantial Completion or approved proxy may be submitted 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 and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
• Inspection, testing, and commissioning are 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.
• The developer or GC should 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.
• 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 plumbing fixtures is required.

Responsible Parties:
• 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 following the modified RESNET sampling protocol outlined in the How to Use this Manual section on page 10 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 10 of this document.
2.0 Domestic Water Heating

Protocol 2.2 - Distributed (Individual Apartment) Systems

Type of Testing Protocol:

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

Performance Specification Criteria:

- **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.

- **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.

- Piping carrying fluid with temperatures greater than 105°F must have a minimum of 1” of insulation. Pipes over 1.5” in diameter must have a minimum of 1.5” of insulation.

- **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 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 by the installation contractor or third-party Commissioning Agent (with the system manufacturer’s representative if necessary) and a commissioning report submitted to the Energy Consultant.”

- **Contract Language:** “The installation contractor and/or system manufacturer shall 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 Energy Consultant and inform them immediately after installation.”

Procedures and Documentation:

- The Energy Consultant shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the Prerequisites Checklist. In addition the Energy Consultant 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 Energy Consultant.
• The Energy Consultant 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.
• Commissioning of the system shall include:
• Verify that domestic hot water system is set to deliver temperatures within the 120-125°F range.
• Verify piping carrying fluid with temperatures greater than 105°F has a minimum of 1”
of insulation and pipes over 1.5” in diameter have a minimum of 1.5” of insulation.
• Compare the consumption data of the inspected plumbing fixtures to the assumptions
made in the Proposed Design model and adjust data inputs for Final Building model as
necessary. Reminder: according to requirements listed in the Prerequisites Checklist, in-
unit faucets and shower stalls must not exceed 2.0 GPM. If following the requirements
listed in the Prescriptive Path, in-unit lavatory faucets must not exceed 1.0 GPM, shower
stalls must not exceed 1.75 GPM.
• Summarize the training performed and personnel involved. Confirm that all applicable
operating and specification manuals are delivered to the building staff. Verify that staff
members have been trained and are aware of their responsibilities to maintain and operate
the systems properly.
• Provide manufacturer’s cut sheets or invoice detailing system make, model, size, and
location.
• Provide summary of results of commissioning
• Photographs:
  • Provide photos of the domestic water heating system and faceplates to verify
    proper installation and compliance with proposed design.
  • Photograph one representative fixture of each type of plumbing fixture being
    inspected.
• A Statement of Substantial Completion or approved proxy may be submitted 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 and attached to all relevant T&V Worksheets complete with all required
information, photographs, cut sheets, etc.

Schedule:
• Training shall occur following installation of the system and completion of all quality
  assurance and verification procedures.
• Inspection, testing, and commissioning is conducted upon completion of the installation of
  the system.
• The developer or GC should 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.

- 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 plumbing fixtures is required.

**Responsible Parties:**
- Energy Consultant
- Installing Contractor
- Commissioning Agent
- Building Maintenance Staff

**Sampling Requirements:**
- If the building has both central and distributed DHW systems, 100% of central DHW systems shall be inspected and commissioned.
- 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 10 of this document, including at least one of each unique type.
- All spaces with domestic hot water service (e.g. apartments, public bathrooms, common 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 10 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 10 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:

- Installation specifications must include detail beyond “manufacturer’s specifications” to ensure insulation performance. Specific details must include:
  - 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.
  - 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.
  - 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 Energy Consultant prior to installation of windows building-wide.
  - **Contract Language:** “Allow inspection of wall insulation, including framing, pre-drywall installation and post-drywall construction. Notify Energy Consultant 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. Insulation inspection 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 Final Building energy model. As an alternative to the modeling approach, ensure all the requirements listed in the Prescriptive Path have been met or exceeded. Estimated R-values for insulation that is 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 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 do 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 Homes Thermal Enclosure System Rater Checklist must be followed 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 high-rise 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.

**Responsible Parties:**
- Energy Consultant is primarily responsible and will work with framing and insulation sub-contractors to ensure construction and insulation installation is consistent with the specifications.
- General 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 should 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 10 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 Energy Consultant 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:

• Installation specifications must include detail beyond “manufacturer’s specifications” to ensure insulation performance. 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 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.
• 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 Energy Consultant 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. Effective R-value must 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.
• 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 Homes Thermal Enclosure System Rater Checklist must be followed 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.

Responsible Parties:
- Energy Consultant is primarily responsible and will work with framing and insulation sub-contractors to ensure construction and insulation installation is consistent with the specifications.
- General 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 should be inspected at 1 location per 70 feet of roof perimeter. This should include, at a minimum, two 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 Energy Consultant 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:
- Installation specifications must include detail beyond “manufacturer’s specifications” to ensure insulation performance. 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 ceiling surface (drywall) floor assembly it is intended to insulate. 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.
- 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 Energy Consultant 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 (unheated) insulation, Slab-on-Grade (embedded heated only) insulation, sub-slab 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.
- 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.
Insulation inspection 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.

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 around sample corner and/or trouble area
- Sub Slab insulation – Photo of insulation before pouring of concrete or backfill of foundation
  - If moisture or inspect 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 Homes Thermal Enclosure System Rater Checklist must be followed 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.

Responsible Parties:
- Energy Consultant is primarily responsible and will work with framing and insulation subcontractors to ensure construction and insulation installation is consistent with the specifications.
- General 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 Energy Consultant by the GC are an acceptable alternative.
3.0 Envelope

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

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 factor, low-emissivity, gas fill, SHGC, and labeling by an independent third party (e.g. NFRC).
- 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 must be sealed with minimum 25 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 Energy Consultant prior to installation of windows building-wide.

Procedures and Documentation:
- The installation sub-contractor is responsible for verifying that rough openings are properly constructed\(^1\) 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 Energy Consultant 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.

• On inspection site visits, the Energy Consultant shall check newly installed windows for compliance with the installation specifications and confirm the assumptions in the Proposed Design model. If following the Prescriptive Path confirm assembly U-values and SHGC for the climate zone are met. Window to Wall ratio cannot exceed 30%.

• 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.

• Provide manufacturer’s cut sheet or invoice detailing window construction, U-Value, SHGC, low –e (if applicable) and ENERGY STAR qualified (if applicable)

• Photographs:
  o Photo of each unique window type with third party verification (NFRC label if applicable) of U-Value, SHGC, and ENERGY STAR (if applicable)
  o Photo of installed window that verifies proper fit and effective connections to envelope’s weather and air barriers
  o Photo with low-e sensor device verifying low-e (if applicable)

• A Statement of Substantial Completion or approved proxy may be submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

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 on-going basis during construction at the same time that other building envelope components are inspected to ensure specifications are being met throughout the construction process.

Responsible Parties:
• The installation sub-contractor is responsible for ensuring proper construction of rough openings.

• The Energy Consultant is responsible for verifying manufacturer’s performance data, NFRC label, and installation specifications.

Sampling Requirements:
• For spaces containing windows, follow the modified RESNET sampling protocol outlined in the How to Use this Manual section on page 10 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 low e 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 on-going 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 specification of assumptions made in Proposed Design model. As an alternative to the modeling approach, include the requirements listed in the Prescriptive Path.
- The specified exterior doors shall be ENERGY STAR qualified, where applicable.
- Weather-stripping should be applied on all cellar/mechanical doors, doors between corridors and stairwells, all exterior doors, doors between apartments and corridors, doors separating unconditioned or vented spaces.
- Weather-stripping 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.
- Weather-stripping should be applied 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 with a rigid fastener and replaceable foam gasket has been installed for durability and less maintenance. Option: 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 submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
• After installation.

Responsible Parties:
• Energy Consultant
• General Contractor

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 make and model of all doors using the final 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 10 of this document.
4.0 Garages

Protocol 4.1 – Heating and Compartmentalization

Type of Testing Protocol:

- Visual Inspection
- Data Sheet
- Instrumented Measurement
- Third Party Commissioning

Performance Specification Criteria:

- Provide piping layout or insulation details that do not demonstrate heating of garage space. 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.
- 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 space is not intentionally conditioned.
- Verify that limited heating systems, if present, are used only for safety considerations, such as ice melting, and are properly controlled and locked.
- 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. 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 Homes Thermal Enclosure System Rater Checklist must be followed 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

Responsible Parties:
• Energy Consultant
• General Contractor

**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)

Type of Testing Protocol:

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

Performance Specification Criteria:

- **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. Sizing calculations meeting the standards set forth in the Air-Conditioning Contractors Association (ACCA) Manual J and S, the ASHRAE Handbook of Fundamentals, or equivalent procedure shall be detailed and provided by the design engineer to the Energy Consultant. Installed capacity cannot exceed design by more than 20%. For condensing boilers, plans must specify return water temperature at design conditions.

- The specified heating equipment shall be ENERGY STAR qualified, where applicable.

- Supplemental heating systems should 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 ductwork shall be insulated to a minimum R-4 for supply ducts and R-2 for return ducts. If following the Prescriptive Path, R-6 for supply ducts.

- Piping carrying fluid with temperatures greater than 105°F must have a minimum of 1” of insulation. Pipes over 1.5” in diameter must have a minimum of 1.5” of insulation.

- For hydronic distribution systems, 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.

- Size circulating pumps to meet Chapter 43 of the ASHRAE Handbook.

- 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/cooling distribution system, provide motorized damper control of outside air damper; provide for shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.
• **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 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 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 by the installation contractor or third-party Commissioning Agent (with the system manufacturer’s representative if necessary) and a commissioning report submitted to the Energy Consultant.”
• **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 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 Energy Consultant shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist.* In addition, the Energy Consultant 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 Energy Consultant.
- The Energy Consultant 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.
- Commissioning of the system shall include:
  - Hydronic (water-based) Systems:
    - 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 Boiler room location and venting
  - Boiler room location (i.e. cellar or roof),
  - Combustion air venting configuration (i.e. combustion air piped to boilers or boiler room air used for combustion)
  - Venting Configuration: (if required, inducer fan specified and sequence of operation verified)

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 all terminal heating distribution equipment serving an apartment shall be controlled by a thermostat(s) within the same apartment.

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 fluid with temperatures greater than 105°F has a minimum of 1” of insulation and pipes over 1.5” in diameter have a minimum of 1.5” of insulation.

The installing contractor shall provide verification of proper system airflow and refrigerant charge based on the manufacturer’s specifications. This criteria also applies to heat pump units.

**Forced Air Heating 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 Energy Consultant may be able to perform them. Inspection procedures for furnaces shall include:

1. Visual inspection of duct system for location, zoning, insulation, and conformance with Prerequisites Checklist.
2. Verify heating ductwork has been insulated to a minimum R-4 for supply ducts and R-2 for return ducts (R-6 for supply ducts if following the Prescriptive Path).
3. Call out a preliminary list of duct sealing details to be integrated into the construction documents and inspected must 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.
4. 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.

5. Test for proper airflow over the heat exchanger by measuring the heat rise at steady state to verify compliance with the manufacturer’s specification. This criteria also applies to heat pump units.

6. For systems designed with outdoor-air supplied to the heating/cooling distribution system, verify motorized damper control of outside air damper provides for shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.

   - **Heat Pumps:** All relevant inspection procedures for forced air systems also apply to heat pump units. In addition, the installing contractor shall provide verification of proper system airflow and refrigerant charge based on the manufacturer’s specifications as part of the commissioning report.

   - Provide manufacturer’s cut sheet or invoice detailing system manufacturer, model, size, and location, model, size, and location (including all space heating systems, e.g. vestibule).

   - Provide summary of results of commissioning.

   - Summarize the training performed and personnel involved. Confirm that all applicable operating and specification manuals are delivered to the building staff. Verify that staff has been trained and are aware of their responsibilities to maintain and operate the systems properly.

   - **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 submitted 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 and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

**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 (BPI, NFPA) to determine exact timing of inspections.

- 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.

**Responsible Parties:**

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

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Sampling Requirements:

- 100% of primary equipment (i.e. heating plants) shall be inspected in the quality assurance and verification process.
- Spaces 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 10 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)

Type of Testing Protocol:

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

Performance Specification Criteria:

- **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. Sizing calculations meeting the standards set forth in the Air-Conditioning Contractors Association (ACCA) Manual J and S, the ASHRAE Handbook of Fundamentals or equivalent procedure shall be detailed and provided by the design engineer to the Energy Consultant. Installed capacity cannot exceed design by more than 20%, except when smaller sizes are not available. Outdoor temperatures shall be the 99.0% design temperatures as published by the ASHRAE Handbook of Fundamentals. Indoor temperatures shall be 75°F for cooling.

- **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 modeling approach, verify all window requirements listed in the Prescriptive Path have been met or exceeded.

- **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 ductwork shall be insulated to a minimum R-4 for supply ducts and R-2 for return ducts. If following the Prescriptive Path, R-6 for supply ducts.**
• Piping carrying chilled water and refrigerant with temperatures less than 55°F must have a minimum of 1” of insulation. Pipes over 1.5” in diameter must have a minimum of 1.5” of insulation.

• For systems designed with outdoor-air supplied to the heating/cooling distribution system, provide motorized damper control of outside air damper; provide for shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.

• Size circulating pumps to meet Chapter 43 of the ASHRAE Handbook.

• 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.

• **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 is equipped with VFD controlled by temperature sensor on 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 by the installation contractor or third-party Commissioning Agent (with the system manufacturer’s representative if necessary) and a commissioning report submitted to the Energy Consultant.”

• **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 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 Energy Consultant 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 Energy Consultant 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 Energy Consultant.

- The Energy Consultant 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.

- Commissioning of the cooling system shall include:
  - The installing contractor shall provide verification of proper refrigerant charge based on manufacturer’s specifications.
  - 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 and refrigerants with temperatures less than 55°F have a minimum of 1” of insulation and pipes over 1.5” in diameter have a minimum of 1.5” of insulation.

- **Water Source Heat Pumps and Chilled Water Systems:** 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 from the apartment thermostats.

- Verify all terminal cooling distribution equipment serving an apartment shall be controlled by a thermostat(s) within the same apartment.

- **Ducted Systems:** Verification procedures must confirm that the system meets the specifications and performs according to the *Prerequisites Checklist*. A commissioning agent can be hired to complete this inspection and verification or the Energy Consultant may be able to perform them.
  - Call out a preliminary list of duct sealing details to be integrated into the construction documents and inspected 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.
  - Inspection procedures for ducted air conditioning systems shall include:
    - Visual inspection of duct system for location, zoning, insulation, and conformance with *Prerequisites Checklist*.
    - Verify cooling ductwork has been insulated to a minimum R-4 for supply ducts and R-2 for return ducts (R-6 for supply ducts if following the *Prescriptive Path*).
    - Test for proper airflow over the evaporator coil to verify compliance with the manufacturer’s specification.
    - The installing contractor shall provide verification of proper refrigerant charge based on manufacturer’s specifications as part of the commissioning report.
    - For systems designed with outdoor-air supplied to the heating/cooling distribution system, verify motorized damper control of outside air damper provides for shutoff of
outside air when distribution system is not actively providing space conditioning or ventilation.

- 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 AC units penetrate the building envelope, verify that the opening around the unit has been properly sealed to be air-tight and weather-tight.
- Provide invoice or cut sheet proving ENERGY STAR qualification and efficiency rating.
- Provide summary of results of commissioning report.
- Summarize the training performed and personnel involved. Confirm that all applicable operating and specification manuals are delivered to the building staff. Verify that staff members have been trained and are aware of their responsibilities to maintain and operate the systems properly.
- Provide 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.
- 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 submitted 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 and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

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

Responsible Parties:
- 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 containing terminal devices (fan coils, PTACS, unit heaters, VAV boxes) must be inspected following the modified RESNET sampling protocol outlined in the How to Use this Manual section on page 10 of this document, including at least one of each unique type.
5.0 Heating and Cooling

Protocol 5.3 - Distributed (Individual Apartment) Heating Systems

Type of Testing Protocol:

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

Performance Specification Criteria:

- **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*. Sizing calculations meeting the standards set forth in the *Air-Conditioning Contractors Association (ACCA) Manual J and S* or equivalent procedure and shall be detailed and provided by the design engineer to the Energy Consultant. Installed capacity cannot exceed design by more than 20%. For condensing boilers, plans must specify return water temperature at design conditions.

- Supplemental heating systems should 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, 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 *Air-Conditioning Contractors Association Manuals J and D*, the ASHRAE Handbook of Fundamentals, or an equivalent procedure) and install ducts accordingly.

- Heating ductwork shall be insulated to a minimum R-4 for supply ducts and R-2 for return ducts (R-6 for supply ducts if following the *Prescriptive Path*). Total duct leakage for in-unit systems must not exceed 15% of design airflow.

- Piping carrying fluid with temperatures greater than 105°F must have a minimum of 1” of insulation. Pipes over 1.5” in diameter must have a minimum of 1.5” of insulation.

- For systems designed with outdoor-air supplied to the heating/cooling distribution system, provide motorized damper control of outside air damper; provide for shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.

- **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 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 (if applicable) by the installation contractor or third-party Commissioning Agent (with the system manufacturer’s representative if necessary) and a commissioning report submitted to the Energy Consultant.”

• **Contract Language:** “The installation contractor and/or system manufacturer shall 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 Energy Consultant shall review the sizing calculations from the designer to confirm that the system meets the requirements listed in the *Prerequisites Checklist*. In addition the Energy Consultant 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 Energy Consultant.

• The Energy Consultant 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.

• Commissioning of the system shall include:
  - **Hydronic (water-based) Systems:** Commissioning of the system shall include:
    - Verify piping carrying fluid with temperatures greater than 105°F has a minimum of 1” of insulation and pipes over 1.5” in diameter have a minimum of 1.5” of insulation.

  - **Forced Air Heating 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 Energy Consultant may be able to perform them. Inspection procedures for furnaces shall include:
    1. The quality assurance and verification requirements outlined in Version 3.0 of the *ENERGY STAR Qualified Homes HVAC System Quality Installation Rater and Contractor Checklists*, where applicable to forced air heating systems.
    2. Visual inspection of duct system for location, zoning, insulation, and conformance with the requirements listed in the *Prerequisites Checklist*.
    3. Verify heating ductwork has been insulated to a minimum R-4 for supply ducts and R-2 for return ducts (R-6 for supply ducts if following the *Prescriptive Path*).
    4. Call out a preliminary list of duct sealing details to be integrated into the construction documents and inspected must 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.

5. Following the procedures outlined in *Energy Conservatory’s Minneapolis Duct Blaster Operation Manual (Series B Systems)*, 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 CFM25 duct leakage for in-unit heating and cooling duct systems system must not exceed 10% of the total design CFM. This criteria also applies to heat pump units.
   a. When conducting a duct leakage depressurization test, the flow conditioner and one of the flow rings must always be installed.
   b. Provide a summary of results of any duct leakage or ventilation performance testing; a sample table is provided in the *T&V Worksheets*.

6. 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)\(^3\) standards.

7. Test for proper airflow over the heat exchanger by measuring the heat rise at steady state to verify compliance with the manufacturer’s specification. This criteria also applies to heat pump units.

8. For systems designed with outdoor-air supplied to the heating/cooling distribution system, verify motorized damper control of outside air damper provides for shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.

- **Heat Pumps**: All relevant inspection procedures for forced air systems also apply to heat pump units. In addition, the installing contractor shall provide verification of proper system airflow and refrigerant charge based on manufacturer’s specifications as part of the commissioning report.
- Provide manufacturer’s cut sheet or invoice detailing system manufacturer, model, size, and location (including all space heating systems, e.g. vestibule).
- Provide summary of results of commissioning.
- Summarize the training performed and personnel involved. Confirm that all applicable operating and specification manuals are delivered to the building staff. Verify that staff has been trained and are aware of their responsibilities to maintain and operate the systems properly.
- **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 submitted 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 and attached to all relevant *T&V Worksheets* complete with all required information, photographs, cut sheets, etc.

**Schedule:**

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The quality assurance and verification procedures occur during the pre-construction, construction, and post-construction phases of system installation. Refer to the appropriate standards (BPI, NFPA) to determine exact timing of inspections.

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.

**Responsible Parties:**
- Energy Consultant
- Heating System Designer
- Commissioning Agent
- Building Maintenance Staff

**Sampling Requirements:**
- Individual spaces 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 10 of this document, including at least one of each unique type.
5.0 Heating and Cooling

Protocol 5.4 - Distributed (Individual Apartment) Cooling Systems

Type of Testing Protocol:

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

Performance Specification Criteria:

- **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. Sizing calculations meeting the standards set forth in the Air-Conditioning Contractors Association (ACCA) Manual J and S or equivalent procedure and shall be detailed and provided by the design engineer to the Energy Consultant. Installed capacity cannot exceed design by more than 20%, except when smaller sizes are not available. Outdoor temperatures shall be the 99.0% design temperatures as published by the ASHRAE Handbook of Fundamentals. Indoor temperatures shall be 75°F for cooling.

- **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 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.

- Cooling ductwork shall be insulated to a minimum R-4 for supply ducts and R-2 for return ducts (R-6 for supply ducts if following the Prescriptive Path). Total duct leakage for in-unit systems must not exceed 15% of design airflow.

- Piping carrying chilled water or refrigerants with temperatures less than 55°F must have a minimum of 1” of insulation. Pipes over 1.5” in diameter must have a minimum of 1.5” of insulation.

- For systems designed with outdoor-air supplied to the heating/cooling distribution system, provide motorized damper control of outside air damper; provide for shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.

- **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 is equipped with VFD controlled by temperature sensor on 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 (if applicable) by the installation contractor or third-party Commissioning Agent (with the system manufacturer’s representative if necessary) and a commissioning report submitted to the Energy Consultant.”

• **Contract Language:** “The installation contractor and/or system manufacturer shall 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 Energy Consultant 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 Energy Consultant 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 Energy Consultant.

• The Energy Consultant 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.

• Commissioning of the cooling system shall include:
  1. Documentation of correct refrigerant charge, efficiency, and heat exchange capacity consistent with manufacturer’s specifications.
  2. Documentation of system controls operations consistent with Proposed Design specifications.
  3. Documentation of zoning and operation of terminal units and their controls consistent with Proposed Design specifications.
  4. Verify piping carrying chilled water or refrigerants with temperatures less than 55°F have a minimum of 1” of insulation and pipes over 1.5” in diameter have a minimum of 1.5” of insulation.

• **Packaged Terminal Air-Conditioners (PTAC) and Room Air-Conditioners:** Verify the size, efficiency, location, and controls of the AC units match the assumptions in the Proposed Design model or meet or exceed the requirements listed in the *Prescriptive Path*.

• **Ducted 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 Energy Consultant may be able to perform them.
  - The quality assurance and verification requirements outlined in Version 3.0 of the *ENERGY STAR Qualified Homes HVAC System Quality Installation Rater and Contractor Checklists*, where applicable to forced air cooling systems.
  - Call out a preliminary list of duct sealing details to be integrated into the construction documents and inspected must include the following at a minimum:
1. Roof curb penetration has been sealed
2. 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.
3. All duct transitional junctions have been sealed with mastic or other UL-181 compliant material.
4. Gap between take off duct and gypsum board has been effectively sealed.
   o Following the procedures outlined in *Energy Conservatory's Minneapolis Duct Blaster Operation Manual (Series B Systems)*, 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 CFM25 duct leakage for in-unit heating and cooling duct systems system must not exceed 10% of the total design CFM. This criteria also applies to heat pump units.
   o When conducting a duct leakage depressurization test, the flow conditioner and one of the flow rings must always be installed.
   o Provide a summary of results of any duct leakage or ventilation performance testing; a sample table is provided below. Inspection procedures for ducted air conditioning systems shall include:
     - Visual inspection of duct system for location, zoning, insulation, and conformance with *Prerequisites Checklist*.
     - Verify cooling ductwork has been insulated to a minimum R-4 for supply ducts and R-2 for return ducts (R-6 for supply ducts if following the Prescriptive Path).
     - Duct leakage testing of a sample of units to verify performance meets or exceeds the requirements listed in the *Prerequisites Checklist*. Total duct leakage for in-unit systems must not exceed 15% of design airflow.
     - Test for proper airflow over the evaporator coil to verify compliance with the manufacturer's specification.
     - The installing contractor shall provide verification of proper refrigerant charge based on manufacturer’s specifications as part of the commissioning report.
     - For systems designed with outdoor-air supplied to the heating/cooling distribution system, verify motorized damper control of outside air damper provides for shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.
     - 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*.
     - Provide invoice or cut sheet proving manufacturer, model, size, and location, ENERGY STAR qualification and efficiency rating.
     - Provide summary of results of commissioning report.
     - Summarize the training performed and personnel involved. Confirm that all applicable operating and specification manuals are delivered to the building staff. Verify that staff members have been trained and are aware of their responsibilities to maintain and operate the systems properly.
• Photographs:
  o 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 submitted 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 and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
• The quality assurance and verification procedures occur during the pre-construction, construction, and post-construction phases of system installation.
• Commissioning is conducted upon completion of the installation of the systems.
• Training shall occur following installation of the system and completion of all quality assurance and verification procedures.

Responsible Parties:
• Energy Consultant
• Cooling System Designer
• Commissioning Agent
• Building Maintenance Staff

Sampling Requirements:
• Spaces 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 10 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:

- Include a schedule with make, 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, submittals to conform with modeled power density in Proposed Design.
- If following Prescriptive Path fixtures with screw-base lamps are not permitted and total specified lighting power for the combined non-apartment spaces should not exceed ASHRAE allowances for those combined spaces.
- If following the Prescriptive Path, hard-wired light fixtures must be specified in living rooms and bedrooms and fixtures with screw-base lamps are not permitted inside apartments.
- When ENERGY STAR qualified fixtures are specified, label to remain affixed to fixture.
  Specify that lighting performance (illumination levels) will be expected to meet the requirements specified in the Illumination Engineering Society Lighting Handbook, 9th edition.
- Contract Language: “Provide submittal to the Partner of the manufacturer’s cut-sheet for each type of in-unit fixture installed. Ensure the ENERGY STAR remains attached to the in-unit 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 lighting fixtures are pin-based, where applicable.
- Determine power density of each modeled space by calculating the luminaire wattage as indicated in ASHRAE 90.1-2007, Section 9.1.4 to verify assumptions in the Proposed Design model. As an alternative to the modeling approach, ensure the requirements listed in the Prescriptive Path have been met.
• Fixtures specified with electronic ballasts must be confirmed in the field using an electronic ballast tester.
• Collect make and model data on all non-apartment lighting operating 24/7 and in-unit lighting to confirm combined lamp and ballast efficacies meet or exceed ENERGY STAR efficacy performance levels.
• Photographs
  o Take photo of one sample of each fixture type, with the ENERGY STAR affixed, where applicable.
  o Photograph must show whether lamp is pin-based or screw-based. Collect submittals/invoices for each unique fixture type showing ENERGY STAR qualification (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 submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.
• A Statement of Substantial Completion or approved proxy may be submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
• Begin lighting inspections as early in the construction process as possible. Verify make, model, ENERGY STAR qualification, 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.

Responsible Parties:
• Energy Consultant
• GC
• 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 10 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 10 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 illuminated exit signs shall meet or exceed LED efficiency levels and 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.
- Photographs:
  - 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.

Schedule:

- Project Completion

Responsible Parties:

- 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 10 of this document for similar, or repetitive spaces (stairwells, corridors, trash chute rooms, 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 lobbies, corridors and stairwells.
- Exterior fixtures shall include automatic switching on timers or photocell controls for lighting not intended for 24-hour operation or required for security.
- 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.) Shut-off delay period (5 minutes or owner preference).
- 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 daylighting 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 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)
o Exterior lighting with timers, provide a photo of the controls and provide lighting schedule of when they are supposed to be on.
o 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 submitted 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 and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

• A Statement of Substantial Completion or approved proxy may be submitted 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 and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
• During construction if earlier access (before ceiling closure) is needed to check circuiting layouts (e.g. for daylighting control).
• Anytime following completion of installation.

Responsible Parties:
• 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 10 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 10 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 motors 1 horse-power or larger shall meet or exceed efficiency standards for NEMA Premium™ motors.
- 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.
- 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: “All motors shall be tested and balanced by the installation contractor or third-party Commissioning Agent (with the system manufacturer’s representative if necessary) and a commissioning report submitted to the Energy Consultant.”
- 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 conduct an on-site training with building maintenance staff to review the operating parameters, controls, and maintenance requirements of the motors.”

Procedures and Documentation:

- Record manufacturer and model number of all non-ventilation motors over 1 HP (they 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.
- 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 Final Building model as necessary. As an alternative to the modeling approach, ensure the requirements listed in the Prescriptive Path have been met or exceeded.

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4 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
• Booster pump should be adjusted so pressure at top floor apartments is no more then 35 psi. This pressure can be measured at the faucet using a water pressure gauge and adapters found at a plumbing store. Faucet thread style and size should be found on product specification and data sheets.

• Provide manufacturer’s cut sheet or invoice verifying motor size and efficiency.

• Photographs:
  • Photograph faceplate, and the 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 submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
• The developer or GC should 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.

Responsible Parties:
• Energy Consultant with assistance from General Contractor or Building Maintenance to access motor associated systems for testing and to verify proper operation of controls.

• Installing Contractor

• Test and Balance (TAB) Contractor is primarily responsible for verification of the system performance.

Responsible Parties:
• 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 - Envelope Air Sealing and Total Air Leakage - Common Area, Apartments, and Exterior

Type of Testing Protocol:

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

Performance Specification Criteria:

- 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 should 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.

- 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.

- Bid and contract documents shall demonstrate a continuous, unbroken air barrier separating the conditioned space of the building from the exterior, unconditioned spaces within the building, non-residential spaces, vented mechanical rooms, mechanical chases opening to unconditioned spaces, elevator shafts, and garages or other vehicle/equipment storage facilities.

- Specifications could include, at the discretion of the developer, the inspection of a sample mock-up installation by the Energy Consultant prior to installation of windows building-wide.

- Contract Language: “Allow access to inspect air sealing details during construction and for diagnostic testing of a sample of apartment units.”

Procedures and Documentation:

- 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 Energy Consultant is still responsible to review building plans and field conditions to identify additional leakage sources to be sealed.

- The developer shall set up a sample unit with pre-drywall air sealing details completed for initial inspection. The sample unit inspection will be used to identify problems with the air
• Each common area and in-unit element on the air sealing checklist must be inspected during construction, prior to drywall, to ensure use of proper materials and complete seals exist for each juncture or penetration.

• Inspect framing layout for interior demising (common) walls and interior partitions to ensure:
  o Demising wall gypsum board extends completely to all adjacent walls.
  o Demising wall gypsum board 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:
  o Window openings
  o A/C openings
  o Through wall duct penetrations
  o Transition between wall and roof barrier
  o Plank/Slab Edge (Masonry and Steel Construction) or Rim Joist (Wood Framed Construction)

• Verify that insulated covers for through-wall AC sleeves 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 air tight seal against the drywall. As an alternative to a gasket, sealant may be used but will have to be re-sealed each time it is installed.

• Verify proper thickness of liquid-applied membranes using a wet mil gauge; at a minimum, substrate must not be visible.

• Measure the infiltration of a sample apartment unit using a blower door before building-wide air sealing of apartments is completed. Following the procedures outlined in Energy Conservatory's Minneapolis Blower Door Operation Manual for Model 3 and Model 4 Systems, a one-point test at 50 Pascals using the average CFM50 measured under depressurization or pressurization is acceptable for this measurement.

• When performing this test, the calibrated blower door fan should be located in the entry door of the apartment. Windows in adjacent apartments should be open during the test. If the apartment entry door opens to a corridor or other enclosed space, that space should be well ventilated to the outside during the test.

• It is very important to ensure that the fan flow is in the proper direction for flow measurement (e.g. from the ring-side towards the screen-side if using a Minneapolis Blower Door). “Backwards” fan operation does not provide accurate flow measurements. To switch between pressurization and depressurization tests, physically turn the fan around in the shroud.

• Ensure that the air leakage rate is less than 1.75 ELA per 100 square feet of enclosure (i.e. all surfaces enclosing the apartment, including exterior and party walls, floors, ceiling). Use the results of these tests to develop a punch list of details to be modified as construction continues. Post-construction, follow the same procedure and the sampling requirements below to test infiltration in a sample of apartments.
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.

- Provide a summary and results from blower door tests.
- Provide one representative photographs 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
    - Masonry Wall Preparation
      - 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
    - General Coverage at Adjacent Building Conditions - Liquid Membrane
      - Where unable to install air barrier on the exterior of the building, a low VOC product should be installed on the interior at full height (top of plank to bottom of plank at each floor). This should happen before any interior framing is installed.
    - General Coverage / Transition Membrane – Seams
      - All transition membranes are installed and sealed before insulation is installed on top. Seams are sealed with mastic type liquid membrane or with minimum 25 year compatible sealant.
    - Air Barrier Penetrations
      - Post air barrier penetrations should be sealed with minimum 25 year sealant compatible with all surfaces. Transition membranes should be used to patch as necessary with seams sealed appropriately.
    - Rough Openings (Concrete Masonry Construction) - Windows and Doors
      - Liquid air barrier should 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 with back rod as necessary and minimum 25 year sealant compatible with all surfaces.
    - 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 should be filled with backer rod as necessary and minimum 25 year sealant compatible with all surfaces (Where smooth surfaces are present, mechanical gasket seals can be used)
    - Rough Openings - Cast Stone Sills
      - Cast stone sill should be sealed to sill pan using minimum 25 year compatible sealant where not sealed by grout
    - Rough Openings - Gap at Window Frames
• Gaps between window frame (header, jambs, sill) and rough opening to be sealed on the interior with backer rod as necessary and minimum 25 year sealant that is compatible with all surfaces applied to.

- Rough Openings - Gap at Exterior Door Frames
  • Gaps between window frame (header, jambs, threshold) and rough opening to be sealed on the interior with backer rod as necessary and minimum 25 year sealant that is compatible with all surfaces applied to.
  • Gaps between window frame (header, jambs, threshold) and rough opening to be sealed on the interior with backer rod as necessary and minimum 25 year sealant that is compatible with all surfaces applied to.

- 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 minimum 25 year sealant that is compatible with all surfaces applied to.

- 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 minimum 25 year compatible sealant). Insulated interior cover with compressible gasket must be provided

- Plank Edges (Concrete Masonry Construction) –
  • At plank / CMU joint
    o Option 1 - If gap is greater then 1/4"" Transition Membrane must be used to seal the gap with minimum 3"" over lap
    o Option 2 - If gap is less then 1/4"" Liquid Membrane can be used to seal the gap
    o 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 should be applied up to and continuing on the underside of the shelf angle to achieve continuity.

- Plank Edges - At plank / steel girder joint
  o 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.
  o 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
  o If allowed by local code, EPA suggests gaps should be filled with backer rod as necessary and minimum 25 year sealant that is compatible with all surfaces applied to.
- Wall to Roof Connections
  - Liquid air barrier must be brought up over grout edge part of roof plank and should be sealed over the plank / grout joint

  - Inspected form 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 A/Cs 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 Homes Thermal Enclosure Rater Checklist must be followed in addition to all T&V Protocols.

Schedule:
- This process begins with the construction documentation. A minimum of 3-5 site visits are recommended to properly inspect air sealing details:
  - 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

Responsible Parties:
- The Energy Consultant is responsible for ensuring air sealing details are properly specified and installed. This will require close coordination with the developer and all of the trades.
- General Contractor

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.

- One sample apartment will be inspected and tested to ensure air sealing details are correct before building-wide installations continue.
- 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 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 (0.315 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 A/Cs 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

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 common area and in-unit ventilation systems including:
  - All transverse joint in ducts to be sealed with mastic or other UL-181 compliant material
  - Total exhaust shaft leakage shall not exceed 10 CFM50 per grille at a pressure of 0.2 in WC (5 CFM50 per grille if using the Prescriptive Path).
  - All connections between gypsum board and ductwork must be sealed.
  - Contractor shall adjust roof fan to provide a pressure of 0.2 – 0.3 inches WC at the grille farthest from the fan.
  - In-unit exhaust fans must be ENERGY STAR qualified.

The following notes apply to projects using the Prescriptive Path:
- Central exhaust and in-line exhaust systems serving apartments must have self-balancing dampers at each grille.
- Central exhaust fans up to 300 design CFM must be installed with direct-drive and variable speed control.
- Central exhaust fans between 300 and 2,000 design CFM must be installed with direct-drive, variable speed control, and ECM motors.

The following notes apply buildings with garages:
- If following the Prescriptive Path, when garage exhaust is required by code, CO sensors must be installed that control exhaust fan operation.
- Specify threshold criteria for CO concentration which activates sensors.
- Include a schedule of CO controls with manufacturer, 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.

- EPA suggests that each exhaust and supply grille 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. This is critical to helping ensure the system performs according to project specifications and Proposed Design model and is a requirement 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 regulating dampers have been installed in correct position and are functioning properly.

- Non - Apartment Fan Efficiency
  - Design specifications should include fan energy efficiency criteria (BHP and motor efficiency) for the fans themselves.

- Apartment Fan Efficiency (Roof)
  - Specifications also include fan energy efficiency criteria (BHP and motor efficiency) for the fans themselves.

- Apartment Fan Efficiency (In-Unit)
  - Specifications should also include and energy efficiency criteria (Watts/CFM) for the fans themselves.

- Apartment and Non-Corridor - Capacity, Testing and Balancing
  - Apartment ventilation systems shall be designed and tested to satisfy minimum requirements of ASHRAE 62.2-2007 based upon the anticipated occupancy. Compliance with ASHRAE 62.2-2007 Sections 4.3 and 5.3.1 is recommended but not required.
  - Rooftop fan sizing should include total fan flow CFM capacity and account for duct leakage at 5 CFM per floor per shaft.
  - In-unit fan sizing should include total fan flow CFM capacity and account for duct leakage at 5 CFM per grille.

- 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 Energy Consultant shall provide a balancing report for each shaft with operating pressures at the grille furthest from the fan and with airflow (CFM) measurements at apartment and common area grilles following RESNET sampling protocol.
  - Average supply and exhaust CFM measurement shall be updated in the As-Built model where applicable.
  - If following the Prescriptive Path, common area ventilation systems cannot exceed ASHRAE 62.1-2007 by more than 50%. Apartment ventilation systems cannot exceed ASHRAE 62.2-2007 by more than 50%. Airflow shall be measured with a capture hood that fully encloses the grilles and is able to measure as low as 20 CFM ± 5 CFM. Air intake point should also be inspected.

- Central Supply to Corridor
  - Common area ventilation systems shall be designed and tested to satisfy minimum requirements of ASHRAE 62.1-2007.
  - For systems designed with outdoor-air supplied to the ventilation distribution system, provide motorized damper control of outside air damper; provide for
shutoff of outside air when distribution system is not actively providing space conditioning or ventilation.

- **Heat Recovery**
  - Consider heat recovery for 100% of space heating conditioning 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.
- Call out a preliminary list of duct sealing details to be integrated into the construction documents. At a minimum, must include the following:
  - **For central ventilation systems:**
    - 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.
  - **For in line fan exhaust systems:**
    - 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.
    - 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.

- Following the procedures outlined in *Energy Conservatory's Minneapolis Duct Blaster Operation Manual (Series B Systems)*, a five-point test for total duct leakage in the main duct shaft using a calibrated fan between -50 and -100 Pascals measured under depressurization or 50 and 100 Pascals 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.
- Use the Linear Regression Assistant in the *T&V Worksheets* to find the CFM50 leakage. Per the *Prerequisites Checklist* the CFM50 duct leakage for central exhaust systems must not exceed 10 CFM50 leakage per floor per shaft.
- If credit is being taken for improved energy efficiency of the ventilation duct system, adjust Final 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; a sample table is provided in the *T&V Worksheets*.
- **Contract Language:** “Allow access to inspect duct installations prior to enclosure. Provide Test and Balance (TAB) reports to the Energy Consultant or allow access for diagnostic testing post-installation.”
Procedures and Documentation:

- In-unit exhaust fans must be 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.

- 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 Energy Consultant shall provide a balancing report for each shaft with operating pressures at the grille furthest from the fan and with airflow (CFM) measurements at apartment and common area grilles following RESNET sampling protocol described below. Airflow shall be measured with a capture hood that fully encloses the grilles and is able to measure as low as 20 CFM ± 5 CFM. Air intake point should also be inspected.

- 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 grille) and/or Prescriptive Path (no more than 5 CFM50 leakage per grille) where applicable, 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 Final 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.

- In passive intake systems (i.e. trickle vents), airflow measurements shall be taken using a capture hood and rotating vane or hot-wire anemometer to verify flow rates within design specifications under the range of conditions anticipated for system operation. Rotating vane or hot-wire anemometer shall have an accuracy better than +/- 15% of rated flow. If air flow cannot be directly measured, pressure measurements shall be used to verify that conditions exist to allow the intake apparatus to operate as intended.

- For all make up air systems, ensure pollutants are not being drawn into the building unintentionally from the supply air source.

- 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 tracer gas release (obtain specifications from chemical test suppliers), confirm performance of sensor and activation of fans.

- A Statement of Substantial Completion or approved proxy may be submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

- Photographs:
  - Photo of fan installation, duct work sealing, and duct work insulation
  - Photo of fan faceplates
  - If applicable, photograph location of CO sensors and air intake point.

Schedule:
• The developer or GC should 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 exhaust fans for in-unit ventilation systems.
• 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.
• Flow measurements cannot be verified until the building envelope including interior partitions are completed.
• Inspect and test duct systems for leakage upon installation and prior to enclosure with drywall.
• If construction schedule allows, ducts should be tested after takeoffs, bottom caps, and permanent roof curbs are on and sealed. Take offs are typically put on floor by floor.

**Responsible Parties:**
• Energy Consultant with assistance from General Contractor or Building Maintenance to access duct systems for testing, and verify proper operation of controls.
• Test and Balance (TAB) Contractor is primarily responsible for verification of the system performance.

**Sampling Requirements:**
• 100% of common area ventilation equipment must be inspected and verified for system performance. System performance at each delivery location (register) per floor can be sampled at every other floor.
• Apartment ventilation shafts must be inspected and verified for system performance following the modified RESNET sampling protocol outlined in the *How to Use this Manual* section on page 10 of this document. For each ventilation riser in the sample set, take measurements at every other floor to obtain a representative profile. The sample should include at least one riser for each type/size of fan installed in the building.
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:
- Advanced meter performance criteria for master-metered/sub-metered buildings.
- Specify separate utility meters for any non-residential associated areas of the buildings (i.e. leased commercial spaces).
- Contract Language: “Utility correspondence will need to be submitted to the Energy Consultant.”

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 non-residential associated areas of the building.
- Check meter types against specifications (and/or utility correspondence).
- Confirm metering configuration: master meter, sub-metered, 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 EPA, or their designated official, to assess the building’s energy performance.
- 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 submitted 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 letter head and attached to all relevant T&V Worksheets complete with all required information, photographs, cut sheets, etc.

Schedule:
- After piping and wiring are complete.
- After installation, hook-up, and activation of meters
**Responsible Parties:**
- 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 10 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).


ENERGY STAR Qualified Homes: Version 3.0 of the ENERGY STAR Qualified Homes HVAC System Quality Installation Rater and Contractor Checklists is referenced for forced air system commissioning. Version 3.0 of the ENERGY STAR Qualified Homes Thermal Enclosure System Rater Checklist 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


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.
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 toolkit 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