RESNET Guidelines for Multifamily Energy Ratings

These Guidelines were developed by the
Residential Energy Services Network (RESNET)
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Introduction

The RESNET Guidelines for Multifamily Ratings was developed by the RESNET Multifamily Working Group. Members of the working group were:

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The purpose of these guidelines is to augment RESNET's Mortgage Industry National Standards (Standard) technical guidelines for HERS and other rating services provided in the multifamily sector and to define "multifamily" as needed to apply this guidance.

Although the Standard currently only applies to "existing or proposed, site-constructed or manufactured, single- and multi-family residential buildings three stories or less in height excepting hotels and motels", Raters, Energy Efficiency Program Sponsors and national green building programs that support energy efficiency in mid and high rise multifamily buildings will benefit from guidelines that consistently cover the entire multifamily sector.

The scope of the working group was therefore to cover all multifamily residential buildings regardless of the number of stories or heating, cooling, ventilation and domestic hot water configurations (i.e. individual and central). The guidelines developed include the units and many aspects of the residential-associated common spaces, but exclude commercial space. After much debate, the guidelines limit "Ratings" to the *dwelling unit* (not the building) and selected elements of the residential-associated common spaces. The guidelines focus primarily on newly constructed or significantly rehabilitated (gut rehab) multifamily buildings, but can be applied to existing buildings.

Guidance specific to multifamily ratings was developed based on the Standard (as adopted in January 1, 2013) and addresses definitions, energy modeling, performance testing, inspections, and sampling. Given the time constraints, some issues were raised which require further development, and therefore are not included in this guidance.

Each section of guidance begins with a “justification” and is then followed by the proposed “guidelines”. The intent is to provide the Standards Development Committee with the rationale and need for the guidelines that were created, and to also provide the actual text that could be separately developed into an actual multifamily guidelines document for HERS Raters to use. If accepted, supporting examples and graphics can be developed. Where future research is needed or input from RESNET is needed, that is also identified.

Table of Contents

Forward
This document is not a standard developed through RESNET standards development process. It is rather voluntary guidance for conducting home energy ratings on multifamily buildings. It has not undergone the RESNET standard public review and comment process but rather is a set of interim guidelines developed by a working group composed of individuals with experience in conducting multifamily ratings.

Justification
There are many definitions of "multifamily" being used in the industry today. Rather than trying to create a new definition, the goal for this section was to simply define exactly which types of "multifamily" residential buildings the new guidelines can apply to and to consolidate definitions from other sections, similar to Appendix B ("Glossary of Terms") in the current Standard.

Future Work/Questions for RESNET SDC
When defining "dwelling unit", the Working Group also discussed "sleeping units" (i.e. hotel rooms, assisted living, single room occupancies (SRO), dormitories), which typically do not have both a full kitchen and bathroom within the unit. The proposed guidelines are based upon dwelling units, and would need further development, specifically to modeling, to also include sleeping units. The current scope of the Standard explicitly excludes "hotels and motels" in section 301.2.1. If these other examples of sleeping units are equally excluded, they should also be explicitly stated in the Standard.

A definition within the "Glossary of Terms" should be included that defines "residential buildings" or the term "residential" should be removed from section 301.2.1. With multifamily buildings, there are often mixed-use buildings that could be interpreted as "commercial" buildings based on code definitions, although the dwelling units are certainly "residential".

Proposed Guidelines

Scope
The RESNET Multifamily Guidelines can be applied to all *multifamily residential buildings* regardless of the number of stories or heating, cooling, ventilation and domestic hot water configurations (i.e. distributed and central). *Multifamily residential buildings*, as defined below, include all residential buildings and mixed-use buildings with residential spaces except for *detached single family buildings*. This definition does not supersede the definitions established by local code, building certification programs, utility sponsors, or mortgage lenders. It simply establishes the basis for application of these guidelines. These guidelines are intended to supplement the current Standard and are not to be used as a standalone document.

If a *dwelling unit* is in a *multifamily residential building* that is eligible for a HERS Rating (see Section 301.2.1 of the Standard), these guidelines shall be followed if rating the unit. Where guidelines developed do not directly relate to the minimum rated features required to produce a HERS Rating, they are identified. Those guidelines are recommended, but not required.

If a *dwelling unit* is in a *multifamily residential building* that is not eligible for a HERS Rating, these guidelines may still be followed.

Glossary of Terms
Where used within these guidelines, the following definitions must be used. Defined terms are italicized when used in the guidelines.

Above-grade floor: An above-grade floor is one for which more than half of the gross surface area of the exterior walls is above-grade.

Attached Single Family Building – A building with a group of two or more attached single-family *dwelling units*. The building must have a roof, foundation, and a separate external entrance for each unit. Includes townhomes, attached homes, twins and duplexes.

Central mechanical system: A mechanical system (heating, cooling, ventilation, hot water) serving two or more *dwelling units* and/or *residential-associated common spaces.* This may include a combination of "central" and "individual" systems, such as a "central" boiler where *dwelling units* have "individual" fan coils for distribution.

Compartmentalization: air-sealing of a space relative to all adjacent spaces, outdoors and adiabatic.

Detached Single Family Building – A stand alone structure containing a single-family *dwelling unit*. Each unit must have a roof, foundation, exposure on all four sides, and a separate external entrance for each unit.

Ducted mechanical systems: Systems that supply air to an occupiable space through supply ductwork exceeding 10 ft. in length and through a thermal conditioning component, except for evaporative coolers. Does not include balanced ventilation systems not connected to the space heating or cooling systems. When measuring supply duct length, 10 ft. is measured from the source to the supply register(s), including all supply trunks and branches. The 10 ft. is a total system allowance, and not the allowance for each supply run.

Dwelling unit: Per the ICC, section 106.5, "a single unit providing complete, independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking and sanitation." ICC 2003 Commentary: "a dwelling unit contains independent facilities for living, sleeping, eating, cooking and sanitation (i.e., living room, bedroom, a full kitchen and a bathroom). This group covers all types of units individuals or families think of as their house and a minimal number of transient lodging facilities. Examples are: apartments, condominiums, townhouses, single-family homes and residential type hotel guestrooms. A *sleeping unit* is something that is not a full dwelling unit." Per ASHRAE 62.2, a kitchen is "any room containing cooking appliances" and a bathroom is "any room containing a bathtub, a shower, a spa, or similar source of moisture".

Dwelling unit Leakage to Outside: Air leakage across a surface separating conditioned and unconditioned space.

Dwelling unit Enclosure Area: The sum of all the boundary surfaces that define the *dwelling unit*, including top, bottom, and all sides. This does not include interior partition walls within the *dwelling unit.* Wall height should be measured from the finished floor of the *dwelling unit* to the underside of the floor above (rather than stopping at the finished ceiling).

Heat Pump: A vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed in order to transfer heat from one location to another using the physical properties of an evaporating and condensing fluid known as a refrigerant. Most commonly, heat pumps draw heat from the air or from the ground moving the heat from a low temperature heat source to a higher temperature heat sink.

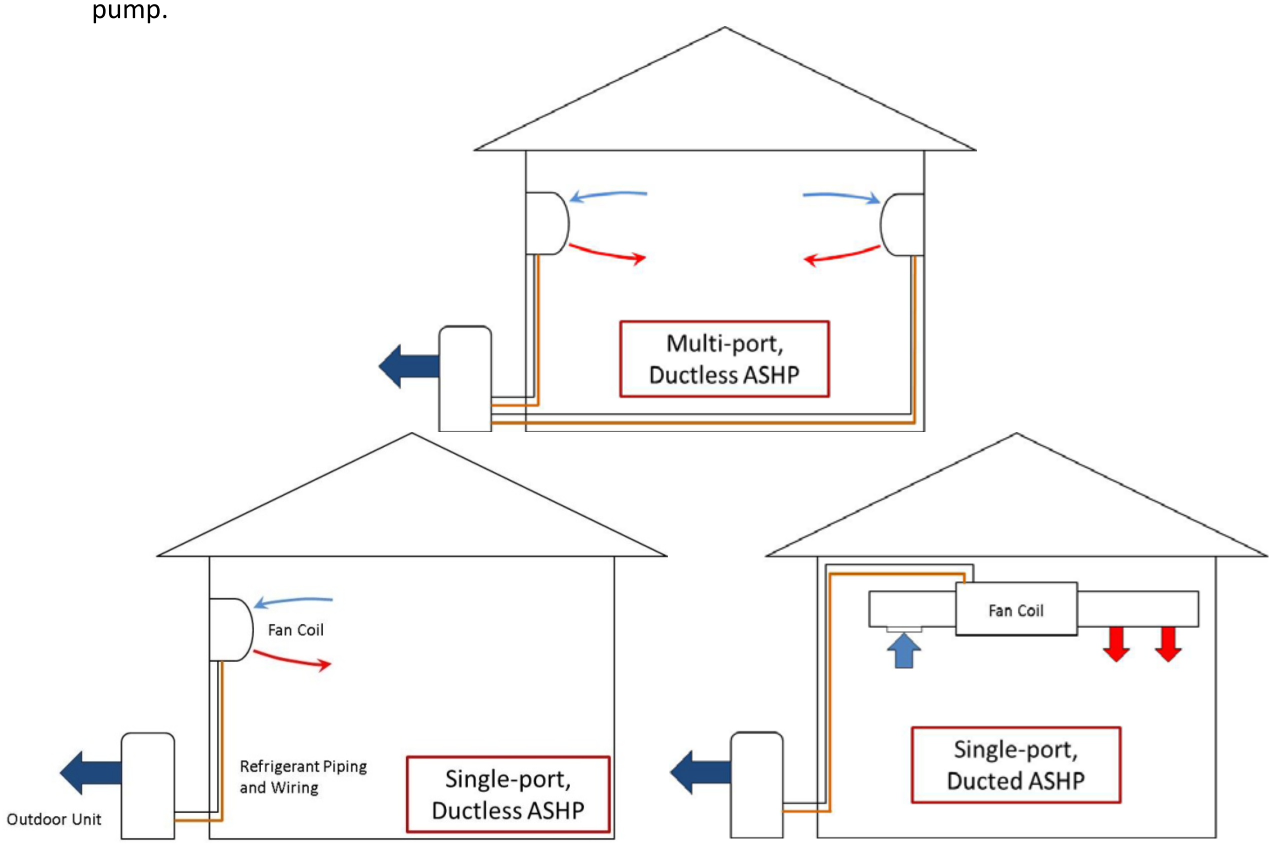
Geothermal Heat Pumps (water-to-air or water-to-water):

Water Loop Heat Pump (WLHP): Although classified as "geothermal", the WLHP is a closed-loop system where heat is drawn from circulating heated or cooled water, provided by a central boiler and chiller/cooling tower.

Ground Water Heat Pump (GWHP): The GWHP is an open-loop system where heat is drawn from circulating water that comes directly from a well, lake, stream, or body of water.

Ground Loop Heat Pump (GLHP): The GLHP is a closed-loop system where heat is either drawn from the ground, through horizontal trenches or vertical columns/wells, or drawn from a body of water, through loops/coils inside the body of water.

Variable-speed Mini-Split and Multi-Split Heat Pumps: These systems are listed under "residential" in the AHRI Directory and are used in *detached single family buildings* and *multifamily residential buildings.* They can have multiple configurations, as shown below, depending on whether the system is "single-port" or "multi-port" and whether it's ducted, non-ducted or a mix. They are generally considered *individual mechanical systems,* if they serve only one *dwelling unit*. The term "mini-split" generally refers to a non-ducted, "single-port" heat pump.



Example schematics of several residential air-source heat pump configurations.

Variable Refrigerant Flow (VRF) Multi-Split Heat Pumps: These air-source heat pump systems are listed under "commercial" in the AHRI Directory and are used in commercial buildings and some *multifamily residential buildings*. They are considered *central mechanical systems,* as they serve more than one *dwelling unit*. The large outdoor units (5 tons or greater) are generally located on the roof of the buildings. The distribution within the *dwelling unit* is generally a ducted or non-ducted fan coil.

Individual mechanical system: A mechanical system (heating, cooling, ventilation, hot water) serving only one *dwelling unit.* This system may or not be located within the *dwelling unit*.

Interstitial Space: The cavity that exists between the finished surfaces of a *dwelling unit* and the finished (or unfinished) surface of adjacent occupiable spaces.
Multifamily Residential Buildings – Includes all residential buildings and mixed-use buildings with residential spaces except for *detached single family buildings.*
Nonresidential Spaces – Any areas within the building not considered *dwelling unit or residential-associated common spaces*, including commercial, office, and retail spaces.
Occupiable Space: A *dwelling unit*, *residential-associated common spaces*, and commercial space. A parking garage is not considered an *occupiable space*.
Residential-Associated Common Spaces: Any spaces within the building that serve a function in support of the residential part of the building that is not part of a *dwelling unit.* This includes spaces used by residents such as corridors, stairs, lobbies, laundry rooms, exercise rooms, garages and residential recreation room. This also includes offices used by building management, administration or maintenance and all special use areas located in the building to serve and support the residents such as day-care facilities, gyms, dining halls, etc.
Sleeping Unit: Per ICC, section 106.5, "a room or space in which people sleep that may also include permanent provisions for living, eating, and either sanitation or kitchen facilities but not both. Such rooms and spaces that are also part of a *dwelling unit* are not sleeping units." ICC 2003 Commentary: "The definition for "sleeping unit" is needed to clarify the differences between sleeping units and dwelling units. Some examples would be a hotel guestroom, a dormitory, a boarding house, congregate residences, assisted living facilities, nursing homes, etc."
Story(ies): Any *above grade floor* with living or commercial space. A floor that is 80% or more garage or other non *occupiable space* is not considered a story.
Target Dwelling unit: An individual *dwelling unit* serving as a single zone with its air barrier and test boundary defined by the fire rated assembly.
Total Dwelling unit Leakage: Air leakage across any adjacent surface.

Energy Modeling

Justification

A primary goal of this guidance, was to determine whether the HERS index was technically appropriate for whole *multifamily residential buildings, or* just individual *dwelling units,* or perhaps a limited configuration of *multifamily residential buildings*. Other goals for this section were to provide improved guidance for modeling *central mechanical systems* and other components common to *multifamily residential buildings*, such as common laundry, parking garages, etc., to ensure consistent results among HERS Raters; guidance for modeling infiltration results for *dwelling units*; and guidance for modeling duct leakage results for *dwelling units.*

A. Justification for applying the HERS Index only to *dwelling units*

After much debate, it was decided by the Working Group to explicitly prohibit modeling of a *multifamily residential building* in order to determine the HERS Index for that building or to apply that building-level HERS Index to the *dwelling units* in that building. The primary technical justification for limiting HERS Ratings to *dwelling units*, is that the Sherman-Grimsrud infiltration model, which is a prominent component of calculating the heating and cooling end-uses in the HERS calculation, assumes a "building" behaves as a single zone. This is not the case for *multifamily residential buildings* and is not an appropriate assumption to make. Also, modeling a *multifamily residential building* and assigning it a building-level HERS Index without accounting for the energy performance of the *residential-associated common spaces* is not appropriate and can be misleading in the industry.

The arguments in support of building-level HERS Ratings are typically that they reduce costs and time. Also, there are examples where interior *dwelling units* do not score as well as the building and infiltration and duct leakage are not modeled accurately at the *dwelling unit* level. Rather than allowing building-level HERS Ratings, the approach we are recommending is to improve the modeling to better represent the *dwelling unit,* and to improve modeling and sampling to reduce the modeling costs, time and negative impact of interior units (which may score poorly, but in general have lower energy use intensities).

The benefits to requiring that all HERS Ratings must be conducted on *dwelling units* include consistency in the market, a push toward improvements to compartmentalization and therefore reduced stack effect, improved energy efficiency and indoor air quality, and potential future applicability to rating units in *multifamily residential buildings* above 3 stories.

B. Justification for developing specific guidance for modeling infiltration results for *dwelling units* in *multifamily residential buildings*

Following Chapter 8 of the Standard, a blower door test for a *dwelling unit* is typically conducted the same way as a *detached single family building,* and all enclosure leakage is entered into the HERS Rating software. This approach to testing evaluates compartmentalization, but does not isolate infiltration from the exterior, and thus over-estimates the energy penalty associated with the measured enclosure leakage. Guidance was therefore developed to allow a multifamily infiltration coefficient to be applied that will reduce the energy penalty associated with modeling the results from enclosure leakage testing. It also explicitly permits results from <u>limited</u> types of “guarded” tests (as described in the Performance Testing section) that do isolate enclosure leakage to the outdoors, since they provide an accurate input for the standard infiltration calculation.

C. Justification for developing specific guidance for modeling duct leakage results for *dwelling units* in *multifamily residential buildings*

Similar to enclosure leakage testing, following Chapter 8 of the Standard and modeling the duct leakage results as-is can lead to over-estimating the energy penalty associated with the measured duct leakage to the outside. This is because the “outside” may be an adjacent conditioned space which is simply outside the pressure boundary of the tested *dwelling unit*. Guidance was therefore developed to allow certain ducted systems to be exempt from testing duct leakage to the outside if they were entirely within conditioned space, within the *dwelling unit*’s pressure boundary, AND the *dwelling unit* demonstrated high levels of *compartmentalization*, in which case measured duct leakage is likely an insignificant energy penalty.

Future Work/Questions for RESNET SDC

One item for future work is particularly urgent.
The existing HERS Index calculation creates the impression that interior *dwelling units* in *multifamily residential buildings* perform poorly compared to end units, even when they have matching construction specifications and performance measurements. However, on the basis of energy usage, those interior units are clearly more efficient than the end units. The HERS calculation emphasis on exterior envelope savings is not appropriate for multifamily *dwelling units*, where units with less exterior envelope are inherently more efficient, not less. This issue urgently needs attention in order to make multifamily *dwelling unit* ratings fully credible. We recommend including the following ideas in this high-priority effort:

- The formula for determining the Reference Home window area may need adjustment for MF. This is one way in which the envelope may be getting over-emphasized in the HERS calculation for MF dwellings. This emphasis may in turn be amplifying the HERS differences between middle and end dwelling units.
- Interior versus end units may merit an adjustable Shelter Class to help correct the HERS inequity. (It may also be reasonable to adjust for level above grade in taller buildings.)
- Wall area adjustments may be another way to address the inequity.

Because the modeling guidance proposed for *dwelling units* in *multifamily residential buildings* requires some changes to the existing HERS calculation procedure, and because the ANSI Standard requires significant time to change, it may be appropriate to identify a “Multifamily” HERS Index as distinct from the HERS Index until such time as it can be incorporated in a future revision of the ANSI Standard. Software could implement any changes proposed at any point based on a non-ANSI RESNET Standard and only apply them to *dwelling units* in *multifamily residential buildings* that are either not seeking, or not eligible, for a HERS Rating. However, if the proposed guidance is accepted by RESNET, to the extent that the proposed guidance conflicts with Standard 301 for low-rise buildings, some interim solution would need to be developed.
Future research could be conducted:

- establishing a supplemental Index which evaluates the energy efficiency of *residential-associated common spaces*.
- creating specific "multifamily" inputs that modify the Reference Home (ex. modifying how internal gains are assigned from equipment that may not be located within the *dwelling unit;* modifying the Reference Home to better represent conditions that apply to multifamily *dwelling units*; modifying the Reference Home to capture energy loss due to increased stack effect resulting from poor compartmentalization and; modifying to allow for a multifamily "Lighting, Appliances, and MELs" value, etc.)
- developing, if eligible for a HERS Rating, proper inputs and reference home configuration for "sleeping units"

Although progress was made on providing guidance on modeling some *central mechanical systems* and other components common to *multifamily residential buildings* using the current rating software, due to time constraints, not all systems were addressed. Future modeling guidance could address or improve handling of:

- Control systems for *central mechanical systems*
- Central hot water circulation loops (for heat loss & pumping power)
- Low-flow plumbing fixtures
- Central Variable Refrigerant Flow space conditioning systems (moving heat between units as well as between building & outdoors)
- Multi-split Heat Pump systems
- Central Ground Water and Central Ground Loop Heat Pump systems
- Auxiliary pumping & fan energy
- Garage and Exterior lighting inputs
- Multifamily infiltration coefficient (introduced, but could be updated based on new research)

Some of the current proposed guidance (and suggestions for future guidance), imply that beneficial changes could be made to HERS Rating software in order to automate some of the procedures and calculations.

Proposed Guidelines

To determine the energy rating for a *dwelling unit* in a *multifamily residential building*, follow Chapter 3 of the Standard, replacing "home" or "house" with "*dwelling unit*" and conforming to the additional guidelines below. Modeling a *multifamily residential building* in order to determine the HERS Index for that building or applying that building-level HERS Index to the *dwelling units* in that building is not permitted.

Guidance for modeling *central mechanical systems* in *multifamily residential buildings*

Ventilation systems

Per Appendix B of the RESNET Standards, a mechanical ventilation system is defined as "a fan designed to exchange the air in the house with outside air, sized to provide whole-house service per ASHRAE 62.2, and controlled automatically (i.e. not requiring human intervention to turn on and off)." Fans exclusively providing local exhaust per ASHRAE 62.2 are not modeled.

a. **Individual ventilation systems (serving only one *dwelling unit*)**. When the ventilation system serves only one *dwelling unit*, it shall be modeled similar to a *detached single family building*, including the measured flow rate, ventilation type, and the rated electrical consumption of the fan(s). Examples include:

    i. Individual *dwelling units* with balanced ventilation, with or without heat or energy recovery, where outdoor supply air is delivered directly to and exhaust air is taken directly from each *dwelling unit* by a ventilation system dedicated to that one *dwelling unit*. "Balanced" may not always be "equal".

    ii. Supply-only ventilation systems serving only one *dwelling unit* that supply outdoor air directly to the *dwelling units*, including HVAC return-integrated systems.

    iii. Exhaust-only systems serving only one *dwelling unit* where exhaust air is taken from the *dwelling units*, passive air inlets are present within the *dwelling units*, and supply ventilation serving *residential-associated common spaces* is sized only for the outdoor air needs of those spaces, and is not oversized to include outdoor air for the *dwelling units*. [To evaluate system sizing, if outdoor air exceeds the ASHRAE 62.1-2007 rates for those *residential-associated common spaces* by more than 100%, ventilation for the *dwelling unit* shall follow the guidelines below for a 'central ventilation system'.]

        1. If no passive air inlets are present within the *dwelling units*, no mechanical ventilation system is modeled. Unlike *detached single family buildings,* exhaust-only systems that rely on normal leakage paths through the envelope to provide outdoor air are not modeled for *dwelling units* in *multifamily residential buildings*.

        2. If the exhaust fan serves only one *dwelling unit*, but exhausts air into a central riser, this is considered "individual", unless the central riser also includes a central exhaust fan.

b. **Central ventilation systems**. Central ventilation systems are those designed to serve the ventilation needs of more than one *dwelling unit.* Examples include:

   i. Balanced central ventilation: with or without heat or energy recovery, where outdoor supply air is delivered directly to the *dwelling units* and exhaust air is taken from the *dwelling units*, using a central ventilation system. The system may also be serving *residential-associated common spaces.* “Balanced” may not always be “equal”.

   ii. Central supply-only ventilation systems serving multiple *dwelling units* that supply outdoor air directly to the *dwelling units.* This can include HVAC return-integrated systems.

   iii. Mechanical exhaust from *dwelling units* (using central and/or individual fans) and a ventilation system that supplies outdoor air to common spaces, such as corridors, with the intent of indirectly serving as the primary outdoor air supply for the individual *dwelling units*.

   iv. Mechanical exhaust from *dwelling units* (using central fans), where passive air inlets are present within the *dwelling units*, and supply ventilation serving *residential-associated common spaces* is sized only for the outdoor air needs of those spaces, and is not oversized to include outdoor air for the *dwelling units*.

      1. If no passive outdoor air inlets are present within such *dwelling units*, no mechanical ventilation system is modeled.

   The following method shall be used to allocate central ventilation system air flows, electrical consumption of fan(s), and heating/cooling equipment of differing efficiencies to the rated *dwelling units*:

   v. To allocate the ventilation air flow in CFM to each *dwelling unit*:

      1. Sum the continuous ventilation exhaust air flows (whether exhaust fan is central or individual) from each of the *dwelling units* served by the central system. Use design flows for a projected rating, and measured flows for a confirmed/sampled rating.

      2. When outdoor air is supplied directly to the *dwelling units,* sum the ventilation supply air flows delivered to each of the *dwelling units* (on a per-system basis). When outdoor air is supplied to common spaces (such as corridors) and is intended indirectly as the ventilation supply air to the *dwelling units*, sum the ventilation supply air flows delivered to that common space (also on a per-system basis). Do not include ventilation supply air flows of other common spaces if they are served by a separate ventilation system. Also, do not count the recirculated portion of the airflow as ventilation air.

a. For ventilation supply systems that are not 100% outdoor air, use testing and balancing reports or design outdoor air CFM to determine the outdoor air supplied.

3. When the exhaust air flow totals and supply/outdoor air flow totals for all the *dwelling units* do not match, take the average of the total exhaust rate and the total supply rate determined in steps 1 and 2 above. This average is the "all dwelling unit" ventilation rate. (Note this averaging procedure assumes that the HERS software does not explicitly model multiple, separate supply and exhaust ventilation systems. If it does, simply include the supply air equipment at the appropriate air flow Q_n as determined below, using the design flow rate as the "all dwelling unit" rate for the supply system; the exhaust flows from each *dwelling unit* must then be modeled separately at their own specific CFM.)

4. Apportion the "all dwelling unit" rate to the individual *dwelling units* according to equation (1), using "design" flows for a projected rating, and measured flows for a confirmed/sampled rating:

$$Q_n = \frac{Q_{design,n}}{\sum Q_{design}} \times All\ Dwelling\ Unit\ Rate \qquad (1)$$

Where:
Q_n is the ventilation flow rate to use for *dwelling unit n*
$Q_{design,n}$ is the design (or measured) exhaust ventilation flow rate for *dwelling unit n*
$\sum Q_{design}$ is the sum of the design (or measured/sampled, as appropriate) exhaust ventilation flow rates for all *dwelling units* in the building or group of *dwelling units* served by the central ventilation system.

vi. For each *dwelling unit*, model the system "type" as a *balanced* (supply and exhaust) ventilation system, using the average rate Q_n as apportioned to that *dwelling unit* in the previous step.

1. If there is heat or energy recovery, include the recovery efficiency in accordance with the equipment specifications. If there is no heat recovery, model as a balanced system with no heat recovery.

2. Model the run time as appropriate; use 24 hours per day unless otherwise specified.

3. The ventilation fan power (in Watts) must include both supply and exhaust fans, whether they are located in the *dwelling unit* or centrally. When exhaust fans serve multiple *dwelling units*, the total associated wattage or "total power" shall be apportioned according to equation (2) for that group. When supply fans serve multiple *dwelling units* directly via ducted systems or indirectly through central corridors, the total power shall be apportioned according to equation (2) and added to the associated exhaust wattage for

the *dwelling unit*, along with any other fan power (e.g. for a booster fan) that is dedicated to the *dwelling unit*'s continuous ventilation air flow. (Fan power dedicated to intermittent ventilation air flow for local exhaust is not included.)

$$P_n = \frac{Q_{design,n}}{\sum Q_{design}} \times Total\ Power \quad (2)$$

Where:
P is the power in Watts to use for *dwelling unit n*

4. Fan motors rated in horsepower shall be converted to Watts as follows:

$$\text{Watts} = \text{hp} * 746 / \text{Eff}_{\text{fan}} \quad (3)$$

where hp = rated horsepower
Eff_{fan} = fan motor rated efficiency, as a decimal (e.g, use 0.80 rather than 80).
If fan efficiency is unknown, use 0.65 for single-phase and 0.75 for 3-phase motors.

vii. When ventilation air is conditioned before delivery to the *dwelling unit*, the *central mechanical system* that actively conditions (heats and/or cools) the ventilation supply air (e.g, a rooftop unit) shall be apportioned to the *dwelling units*. The ventilation conditioning load is the only space conditioning load that will be assigned to that equipment. (The following procedure assumes that the HERS software does not explicitly model these dedicated HVAC systems that supply conditioned outdoor air. If it does, simply include the supply air units at the appropriate air flow Q_n as determined above, at the heating and cooling efficiency of the equipment).

1. Determine the load (Btu) created by the "Ventilation" as a percentage of the *dwelling unit*'s total heating load for the heating season, and similarly for the cooling season. This "Vent Load Share" is satisfied by the *central mechanical system* that actively conditions (heats and/or cools) the ventilation supply air. It is typically necessary to first model the *dwelling unit* with the appropriate ventilation CFM and other mechanical systems in order to determine the share of the total heating and cooling load represented by the ventilation.

$$Vent\ Load\ Share = \frac{Ventilation\ Btu}{Ventilation\ Btu + Shell\ Btu} \quad (4)$$

2. The *dwelling unit*'s energy model shall include the mechanical systems that directly heat and/or cool the dwelling, AND additional HVAC equipment to represent the *central mechanical system* that actively conditions (heats and/or cools) the ventilation supply air.

3. Use the "Vent Load Share" percentage to attribute the heating and cooling load served by the *central mechanical system* to that system; attribute the remainder to the *dwelling unit*'s heating and/or cooling systems (even if those are also *central mechanical systems*), as appropriate. For example, if

the “Vent Load Share” is determined to be 25%, 25% of the heating and cooling load should be assigned to the *central mechanical system* that actively conditions (heats and/or cools) the ventilation supply air, and the remaining 75% is assigned to the *dwelling unit*’s heating and/or cooling systems.

Individual mechanical systems.

When the individual *dwelling unit* HVAC or DHW system is contained within the unit or serves an individual *dwelling unit* but is located in a common space, it will typically have residential efficiency ratings (such as AFUE, SEER, EF, etc). Such equipment shall be modeled in the HERS Rating in accordance with the RESNET Standards for the relevant equipment type.

Central mechanical systems - heating plants and distribution.

Central heating plants in *multifamily residential buildings* are typically boilers with heated water distribution. Distribution inside the *dwelling unit* may be hydronic/radiant, fan coils, or terminal *water loop heat pumps* (WLHP).

a. Model the *dwelling unit* heating system efficiency using the rated efficiency of the central boiler (AFUE, or rated steady state efficiency if there is no AFUE rating). For the *dwelling unit* heating system capacity, use the nominal capacity of the terminal distribution equipment connected to the boiler loop within the *dwelling unit* (fan coil, terminal heat pump, radiator/convectors, etc).

b. For hydronic/radiant distribution, use the RESNET default values for auxiliary electric to represent pump power; heating system type modeled as the equivalent of "fuel-fired hydronic distribution".

c. For fan coil distribution, use the RESNET default values for auxiliary electric to represent pump power and fan power. If the fan coil is not a *ducted mechanical system* (has ≤10 ft. of supply ductwork), it shall be modeled as a ductless system; heating system type modeled as the equivalent of "fuel-fired air distribution". If the fan coil is a *ducted mechanical system* (has >10ft. of supply ductwork), it shall be modeled with a duct system; heating system type modeled as the equivalent of "fuel-fired air distribution".

d. For terminal heat pump distribution, the boiler shall be modeled as supplying half of the *dwelling unit*'s heating load (which may have been reduced by the "Vent Load Share", depending on its ventilation system). The other half of the *dwelling unit*'s heating load shall be modeled as being supplied by a *water loop heat pump*, using the AHRI rated efficiency of the *water loop heat pump*.

Central mechanical systems - cooling plants and distribution.

Central cooling plants in *multifamily residential buildings* are typically chillers and cooling towers with cold water distribution. Distribution inside the *dwelling unit* may be hydronic/radiant, fan coils, or terminal *water loop heat pumps* (WLHP).

a. Model the *dwelling unit* cooling system efficiency (SEER) using the rated efficiency of the chiller (typically rated in kW/ton), with allowance for circulation pumps and fans according to the following formula:

$$SEER_{eq} = \frac{Capacity - \left(\frac{aux}{3.41}\right)}{Input + aux} \qquad (5)$$

Where:
$Capacity$ is the chiller system output in Btu/hour
aux is the total of the pumping and fan power* in Watts
$Input$ is the chiller system power in Watts

*The total pumping power shall include all pumps that are necessary for normal service operation, including central distribution pumps (for both primary and secondary loops) and cooling tower circulation pumps. Pump motor Watts must be determined using this equation, Watts = hp*746/Eff_m. If pump motor efficiency is unknown, use 0.30. The total fan power shall include all fans that are necessary for normal service operation, including cooling tower fan(s). If the system uses terminal heat pumps located within the *dwelling unit*, do not count that heat pump's electrical energy as part of *aux*; instead, see section (f) below. Note: do not include backup (redundant) distribution or cooling tower loop pumps that exist as a backup for failure of primary pump, if they are not expected to operate during normal service.

b. If detailed chiller and/or pump performance under part-load conditions is available, it is acceptable to develop a seasonal average $SEER_{eq}$ by using equation (5) for a range of outdoor temperature conditions (bins), weighted by the number of cooling hours in each bin for typical year climate data appropriate to the building site.

c. For the *dwelling unit* cooling system capacity, use the nominal capacity of the terminal distribution equipment (fan coil, terminal heat pump, etc).

d. For hydronic/radiant distribution, use the RESNET default values for auxiliary electric; cooling system type modeled as "air conditioner".

e. For fan coil distribution, if the fan coil is not a *ducted mechanical system* (has ≤10 ft. of supply ductwork), it shall be modeled as a ductless system; cooling system type modeled as "air conditioner". If the fan coil is a *ducted mechanical system* (has >10ft. of supply ductwork), it shall be modeled with a duct system; cooling system type modeled as "air conditioner".

f. For terminal heat pump distribution, the chiller shall be modeled as supplying half of the *dwelling unit*'s cooling load (which may have been reduced by the "Vent Load Share", depending on its ventilation system). The other half of the *dwelling unit*'s cooling load shall be modeled as being supplied by a *water loop heat pump*, using the AHRI rated efficiency of the *water loop heat pump*.

Central mechanical systems - service (domestic) water heating.

Central water heating systems in *multifamily residential buildings* are typically commercial in nature and efficiency ratings for thermal efficiency and standby loss are generally available in the Commercial section of the AHRI Directory under “boilers” or “water heaters”.

From the DOE’s EERE website: “Commercial water heating equipment includes gas-fired, electric, and oil-fired commercial storage water heaters, gas-fired and oil-fired instantaneous water heaters and hot water supply boilers, and unfired hot water storage tanks. Commercial water heating equipment is used to provide hot water on demand and is industrial equipment. Storage water heaters heat and store water in a thermostatically controlled tank. Instantaneous water heaters heat water on demand. Hot water supply boilers heat potable water for uses other than space heating. Unfired hot water storage tanks are tanks that store water that is heated externally.”

“Indirect water heaters” are designed for installation with a space heating boiler as the heat source, and typically contain a heat exchanger.

a. Central storage water heaters (tank-type) shall be modeled as the *dwelling unit*’s water heating system using the rated EF or equivalent EF (based on www.resnet.us/uploads/documents/standards/Commercial_Hot_Water_EF_Calculator_12-10.xls).

b. Boiler-driven water heating systems, whether dedicated or integrated with space heating, shall be modeled as the *dwelling unit*’s water heating system using the same spreadsheet, using the boiler efficiency as the thermal efficiency and the standby loss (% per hour, BTU per hour, or degree per hour) of the unfired storage tank or of the indirect water heater.

c. Central heat pump water heaters shall be modeled the same as for a *detached single family building*.

d. The storage tank volume of the *dwelling unit*’s water heating system shall be input as 40 gallons, regardless of the actual storage tank volume, so that the Reference Home water heater EF will be correctly determined.

e. Model the location of the water heating equipment outside the *dwelling unit*, so that the internal gains do not affect the *dwelling unit*.

Guidance for modeling other components common to *multifamily residential buildings*

Guidance for Addressing Clothes Washers & Dryers in shared Laundry Rooms

a. In the event that a *dwelling unit* does not have a clothes washer or clothes dryer within the unit, and instead the *multifamily residential building* includes a laundry room(s) within the *residential-associated common space*, the following procedure should be followed to account for the hot water usage and electricity or gas usage of the laundry equipment:

   i. When the *dwelling unit* hot water is generated by the same shared central equipment that supplies the laundry room(s), model the central water heating equipment as described previously. No extra steps are required.

   ii. When the *dwelling unit* hot water is generated by a separate water heater from the water heater supplying the laundry room(s):

      1. In addition to the *dwelling unit* water heater, the water heating equipment that is providing hot water to the common space clothes washer shall be modeled explicitly, and in an appropriate location outside the *dwelling unit,* so that the internal gains do not affect the *dwelling unit.*

      2. The hot water load of this water heating equipment shall be set according to the following equation (which is based upon ENERGY STAR MFHR Simulation Guidelines that estimate a conventional residential clothes washer to use approximately 6.7 gallons of hot water/day):

      $$Dwelling\ unit\ Laundry, \frac{gal}{day} = [\ 3 + 1.23 \times \#BR] \qquad (6)$$

      Where:

      #BR is the number of bedrooms in the *dwelling unit* (use 0 for studios)

      3. The hot water use within the *dwelling unit* is then calculated per the RESNET Standard, minus the gal/day for "*Dwelling unit* Laundry". Calculation is as follows:

      $$Dwelling\ unit\ use, \frac{gal}{day} = [30 + 10 \times \#BR - (3 + 1.23 \times \#BR)] \qquad (7)$$

      4. Until HERS Rating software can be revised to automate this adjustment, Raters shall assign the water heater load percentages as follows:

      $$Laundry\ DHW\ \% = 100 \times \frac{(3+1.23\times\#\mathrm{BR})}{(30+10\times\#\mathrm{BR})}$$

      $$Dwelling\ unit\ DHW\ \% = 100 - Laundry\ DHW\ \%$$

      5. The electricity and/or gas usage of the actual laundry equipment (clothes washer and clothes dryer) shall be modeled in accordance with the RESNET Standards, which will allow Ratings to show credit for installing ENERGY STAR certified clothes washers when located within the *dwelling unit* or in a common laundry room.

Guidance for modeling Elevated Slab floors

In *multifamily residential buildings*, elevated concrete slab floors can be observed as the floor assembly between stories, or as the floor assembly between a parking garage and the dwelling units above. These elevated concrete floors shall be modeled differently from slab-on-grade, because they are not in contact with the ground. There are two facets to an elevated concrete floor: the perimeter, and the conditions below the concrete floor.

<u>Perimeter</u>: Elevated concrete slab floors frequently are exposed (or at least uninsulated) along the perimeter. When this is true, model that perimeter slab cross-section as a short above-grade concrete "wall" to capture the thermal losses it represents. Set the thickness of this "wall" to match the exterior wall that is resting on the concrete floor, and use the thickness of the concrete floor (8"-12" is typical) as the height of this "wall". If this perimeter area is insulated, include that insulation in this "wall" component. Note: the modeled volume of the dwelling unit shall remain the real volume. This guidance changes only the modeled wall area.

For elevated concrete slab floors that extend beyond the exterior walls (such as cantilevered balconies) without a thermal break of at least R-5, model the total outdoor exposed surface area of the slab up to a maximum horizontal projection from the exterior wall of 1 foot (top and/or bottom). This area shall be added to the perimeter concrete wall entry described above. This will account for the increased heat loss through the slab floor perimeter.

<u>Conditions below the elevated concrete slab floor</u>: If an elevated concrete slab assembly has conditioned space above and unconditioned or semi-conditioned space below, the heat flow through that slab shall be included in the energy model for that *dwelling unit*. Often the unconditioned space below is a garage or ambient conditions; that temperature difference shall be part of the energy model. If the space below is semi-conditioned (e.g., maintained above freezing), and the modeling software has no explicit option for semi-conditioned space, use the following guidance:

- Model the concrete floor as being above an unconditioned basement. Depending on the software used, this may require modeling imaginary basement walls in line with the perimeter of the *dwelling unit*; if so, model those imaginary walls as below-grade walls with height equal to the height of the semi-conditioned space. Model the imaginary walls with R-values matching the actual walls of the semi-conditioned space. Define the location of the imaginary unconditioned basement walls as facing conditions that match the actual walls of the semi-conditioned space.

The elevated slab assembly shall capture the thermal characteristics of the concrete thickness, flooring above, and any insulation directly contacting the concrete floor assembly. Insulation not directly contacting the concrete floor assembly shall not be included.

Guidance for modeling Parking Garages under dwelling units in a multifamily residential building

Modeling *dwelling units* over a parking garage involves a wide range of possibilities, ranging from open garages (very little wall area, similar to ambient conditions) to underground garages (very sheltered, often ventilated) to garages (above or underground) with an insulated plenum above the garage ceiling containing plumbing and heaters to keep the plenum at a temperature so pipes will not freeze and/or to improve occupant comfort in the *dwelling units* above. The following guidance is general in nature, intended to support the Rater in considering all the relevant aspects that should be captured in the energy model. Refer to the previous section on elevated concrete floors and the specific HERS Rating software for additional guidance.

a. Floors over “conditioned” garages shall be modeled like floors above conditioned spaces (See Appendix A to determine whether the garage is “conditioned” or not).

Floors that do not meet those criteria must follow the guidelines below:

b. Floors over open garages shall be modeled like floors over ambient conditions.
c. Floors over underground or very sheltered garages shall be modeled like floors above a typical single-family garage.
d. Floors over a heated garage or garage with a heated plenum ceiling shall be modeled like floors above an unconditioned basement (for guidance on how, see previous section on elevated concrete floors). They shall not be modeled as floors above conditioned space unless they meet the criteria for a “conditioned” garage. See Appendix A to determine whether the garage is “conditioned” or not.

   Note that although the plenum heaters do contribute to the space heating of the *dwelling units* above the plenum, they shall not be included in the *dwelling unit* energy model. The space conditioning energy that maintains any spaces adjacent to the rated *dwelling unit* is considered external to the *dwelling unit*, just as with space conditioning for adjacent *dwelling units* or other *residential-associated common spaces*.

Onsite Power Generation (OPG)

Onsite power generation used for *dwelling units* shall be allocated based on the amount of electricity produced onsite and the number of *dwelling units*. Typically, a *multifamily residential building* with onsite power generation (such as solar PV) will use a “master” electric meter that serves the entire *multifamily residential building.*

Unit OPG = Total kWh Production of system / Number of *dwelling units* served by the system

The Unit OPG can also be allocated by prorating the total production by square footage of the *dwelling units*, such that a studio is allocated less OPG than a 3-bedroom unit.

In other cases, the *dwelling units* may have individual electric meters and individual OPG systems, exclusively serving that *dwelling unit*. This is treated the same way as a *detached single-family building*.

In some situations, the *dwelling units* have their own electric meters, and the *residential-associated common spaces* of the *multifamily residential building* are served by a separate electric meter. Onsite power generation associated exclusively with *nonresidential* or *residential-associated common spaces* within the building, or directly supplying the electric grid rather than the *multifamily residential building*, shall not be modeled in the HERS Rating of the *dwelling units*. This shall not be interpreted to exclude net-metered systems serving *dwelling units*.

Guidance for modeling infiltration results for *dwelling units* in *multifamily residential buildings*

a. HERS Ratings must use individual or *target dwelling unit* blower door test results; (see testing options 1, 3, or 4 in the Performance Testing section). It is not acceptable to use a blower door test result from a whole-building test (option 2 in the Performance Testing section) in HERS Ratings of *dwelling units*, nor is it acceptable to extrapolate the whole-building test results for application at the *dwelling unit* level.

b. If guarded blower door test results are obtained for a *dwelling unit* and comply with the Performance Testing procedures within these guidelines for tests 3 and 4, those guarded results must be used in the Rating, but without applying multifamily infiltration coefficients as introduced below. Other "guarded" test results shall not be used in the Rating.

c. For modeling purposes only, unguarded blower door test results (*compartmentalization* test results) shall be multiplied by a multifamily infiltration coefficient of XXX or YYY, as follows.

    i. If results of a *dwelling unit* unguarded blower door test are to be used for the purpose of calculating the expected energy savings from a retrofit, conducting an energy audit, or assessing the relative enclosure leakage of a group of buildings, then the test results shall be multiplied by a multifamily infiltration coefficient of XXX.

        1. For *dwelling units* built on a slab, or with no conditioned space below (i.e. they serve as the lowest conditioned leak points in the building),

           XXX=0.98

        2. For all other *dwelling units*, follow the guidance below, where "exposed" refers to assemblies facing unconditioned space (e.g. outdoors, vented attic, vented crawlspace, etc.).

           If <50% of the *dwelling unit enclosure area* is exposed,

           XXX= 0.65

           If >50% the *dwelling unit enclosure area* is exposed (e.g. top corner unit),

           XXX=0.70

    ii. If the results of a *dwelling unit* unguarded blower door test are to be used for conducting a home energy rating, then the test results shall be multiplied by a multifamily infiltration coefficient of YYY.

        1. For *dwelling units* that indirectly use corridor air as the ventilation supply air, or that are built on a slab, or that have no conditioned space below (i.e. they serve as the lowest conditioned leak points in the building),

           YYY=1.0

        2. For all other *dwelling units*,

           YYY=0.85

    iii. If the results of a *dwelling unit* unguarded blower door test are to be used for assessing compliance with a *dwelling unit* enclosure leakage limit (e.g., defined by code or by an energy efficiency program), application of a multifamily infiltration coefficient may not be appropriate unless approved by the local code official or program administrator.

Guidance for modeling duct leakage results for *dwelling units* in *multifamily residential buildings*

All *ducted mechanical systems* in *dwelling units* must be tested for duct leakage to outside the unit, or use the RESNET Default leakage.

Exception:

Testing of duct leakage to outside the *dwelling unit* may be skipped, and zero duct leakage to the outside modeled, if all three of the following conditions are true.

1. The *dwelling unit* unguarded blower door test (*compartmentalization* test) demonstrates leakage no greater than 0.30 CFM50/ft^2 of *enclosure area*.
2. If a passive outdoor air ventilation duct is connected to the return side of the space conditioning duct system, an automatically-controlled mechanical damper must close off the outdoor air when there is no call for ventilation. This damper must be installed even for continuous ventilation strategies, such that if the power goes off, the damper closes.
3. The entire duct system, including the manufacturer's air handler enclosure, is within the *dwelling unit*'s tested pressure boundary during the *dwelling unit* blower door test.

Example: a duct system in a vented attic does not qualify, but one located entirely in the interstitial space between conditioned units may qualify. Similarly, systems may qualify when the air handler is in a mechanical closet located on a balcony or accessed via the corridor, if that mechanical closet is within the tested pressure boundary during the *dwelling unit* blower door test (ie. pressure in the closet must be within 10% of the living space during the test).

Note: If the duct leakage results are to be used for assessing compliance with a *dwelling unit* duct leakage limit (e.g., defined by code or by an energy efficiency program), application of this exception may not be appropriate unless approved by the local code official or program administrator.

Performance Testing

Justification

The goal of these guidelines was to modify Chapter 8 of the RESNET Standards, where needed, to apply specifically to *dwelling units* in *multifamily residential buildings.* The decision to limit HERS Ratings to *dwelling units* only made it possible to focus on tests that would produce results that could be used in the HERS Rating software. Discussions resulted in a need for tests that would not assume that all measured leakage was from the "outside" when modeled.

In addition, where guidance was needed to explicitly address systems in *residential-associated common spaces*, those were developed, as well as guidance for tests not currently addressed by the Standard*,* such as low-flow plumbing fixtures and non-ducted returns.

Future Work/Questions for RESNET SDC

Future work should address measuring outdoor air to central ventilation systems and complicated supply systems that are integrated with HVAC or ERVS; multifamily-specific guidance on combustion appliance, gas leakage and CO testing; and consistent procedures regarding sealing or not sealing ventilation openings during infiltration testing and duct leakage testing. There were discussions on this topic, although consensus could not be reached on whether these openings should be sealed or not, or under what conditions. The following were proposed, which conflict with the current protocols in Chapter 8 of the Standards.

Current:

802.2.8 Fans: Any fan or appliance capable of inducing air flow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, outdoor air ventilation fans, air handlers, and crawl space and attic ventilation fans. Continuously operating ventilation systems shall be turned off and the air openings sealed, preferably at the exterior terminations.

Proposed:

802.2.8 Fans: Any fan or appliance capable of inducing air flow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, outdoor air ventilation fans, air handlers, and crawl space and attic ventilation fans. Continuously operating ventilation systems <u>(whether central or individual)</u> shall be turned off and the air openings <u>left unsealed.</u>

Current:

802.2.11 Un-dampered or fixed-damper intentional openings between conditioned space and the exterior or unconditioned spaces: Shall be left open or fixed position, however, temporary blocking shall be removed. For example: fixed-damper ducts supplying outdoor air for intermittent ventilation systems (including central-fan-integrated distribution systems) shall be left in their fixed-damper position. *Exception*: Un-dampered supply-air or exhaust-air openings of *continuously operating* mechanical ventilation systems shall be sealed (preferably seal at the exterior of enclosure) and ventilation fans shall be turned off as specified above.

Proposed:

802.2.11 Un-dampered or fixed-damper intentional openings between conditioned space and the exterior or unconditioned spaces: Shall be left open or fixed position, however, temporary blocking shall be removed. For example: fixed-damper ducts supplying outdoor air for intermittent ventilation systems (including central-fan-integrated distribution systems) shall be left in their fixed-damper position. ~~*Exception*: Un-dampered supply-air or exhaust-air openings of *continuously operating*~~

~~mechanical ventilation systems shall be sealed (preferably seal at the exterior of enclosure) and ventilation fans shall be turned off as specified above.~~

Current:

802.2.14 Operable window trickle-vents and through-the-wall vents: Shall be closed.

Proposed:

802.2.14 Operable window trickle-vents and through-the-wall vents: Shall be <u>opened fully</u>.

The justifications for leaving these opened or unsealed are as follows:

If central ventilation is ducted directly to the individual dwelling units (continuous or intermittent), the system is turned off, but the ventilation openings are not sealed. The reasons for this are:

1. There is no consistent way to distinguish between holes that deliver ventilation air versus those that are intended as ventilation openings but actually leak, uncontrollably in both directions.
2. Not all ventilation openings will be accessible for sealing.

A simple and consistent approach to treating intentional ventilation openings in the envelope and ductwork is needed. Their impact on the *compartmentalization* test results will likely be reduced through the MF infiltration coefficients proposed for HERS Ratings.

Mechanically controlled dampers will still be permitted to move to their closed position, but not additionally sealed. This holds even when the ventilation system is described as "continuous" and the opening is intended as part of the ventilation strategy.

If the *dwelling unit* has a corridor supply ventilation strategy, the leakage around the door frame becomes the intentional ventilation opening, and procedures are already in place to either select a different opening for the blower door system or to increase the leakage area accordingly (see modifications to 802.4 in the Proposed Guidelines below).

Proposed Guidelines

Procedures for Multifamily *Dwelling unit*/Building Air Tightness Testing

This section provides protocols for conducting an air barrier performance test in order to obtain heating/cooling season infiltration inputs for the HERS Rating software measured in cubic feet per minute at a 50 Pa pressure difference (CFM50).

The heating/cooling season infiltration input for the HERS rating software would ideally be the leakage to ambient conditions for the modeled *dwelling unit*. However, determining this value at the *dwelling unit* level can be difficult. There are three options for conducting the performance test required to determine the infiltration input. The decision of which pathway is dependent on the project/building type and/or program requirements. There is one option for evaluating building leakage, however, results using that option shall not be used in the HERS Rating.

1. **An unguarded *dwelling unit*-level blower door test – "*Compartmentalization*" test**
   a. Output – target *dwelling unit* <u>total</u> leakage, including leakage to ambient conditions as well as adjacent, conditioned spaces.
   b. General Comments: This method typically yields the highest, or most conservative target *dwelling unit* infiltration rate. A multifamily infiltration coefficient is applied to

this result under the modeling guidelines in order to account for the air leakage detected by this test that is coming from adjacent, conditioned spaces.

This method is required if seeking an exemption to duct leakage testing to the outside.

c. Compartmentalization metric (CFM50/ft^2 of *enclosure area*) – For the purposes of defining the test boundary, the surface area of the *dwelling unit* enclosure, inclusive of all bounding walls, floor, and ceiling, shall be calculated as follows:

    i. The wall height shall extend from the finished floor to the bottom side of the floor decking above the target *dwelling unit* for non-top floor level *dwelling units* and to the exterior enclosure air barrier for the top floor.

    ii. The floor and ceiling area shall extend to the centerline of the adjacent walls.

    The unit enclosure surface areas shall be calculated prior to testing.

d. Measure and record results, following the referenced Sections from Chapter 8 of the RESNET Standard:

    i. 802.5 Procedure for Conducting a One-Point Airtightness Test; OR

    ii. 802.6 Procedure for Conducting a Multi-Point Airtightness test; OR

    iii. 802.7 Procedure for Conducting a Repeated Single Point Test

e. Procedure –

    i. Follow the procedures for Building Enclosure Airtightness Testing, as described in Section 802 of the RESNET Standards, by replacing “building” and “house” with “target *dwelling unit*” and as clarified below.

    ii. The reference tube for the *dwelling unit* pressure shall pass through the blower door shroud. If the exhaust is into an enclosed space (e.g. a corridor), the end of the reference tube must be located where it is not impacted by the pressure or turbulence created by the fan.

    iii. Adjacent spaces shall be connected to the outside. The objective is to connect the adjacent spaces to the outside, either through opening windows in the adjacent spaces or connecting the corridor to outside and then connecting the adjacent spaces to the corridor.

        1. For the purposes of this test, adjacent spaces shall include the spaces immediately abutting the target *dwelling unit* in the horizontal plane, but does not need to include spaces abutting the target *dwelling unit* in the vertical plane.

2. Instead of opening spaces to the outside, the induced pressure difference between the target *dwelling unit* and the adjacent spaces can be measured during the test to verify that adjacent spaces are close to outside pressure. Doors and/or windows do not need to be opened in adjacent spaces if the induced pressure difference between the target *dwelling unit* and the adjacent space is equal to or greater than 90% of the induced pressure difference between the target *dwelling unit* and outside. For example, 45 Pascal between the target *dwelling unit* and the adjacent space at a target unit induced pressure of 50 Pascal with respect to outside.

iv. Any access panels to interstitial spaces in the target *dwelling unit* shall be opened during the test. For top floor *dwelling units*, access panels can be closed where the access panel is part of the exterior enclosure air barrier assembly.

v. Follow Section 802.2 of the RESNET Standards (Protocol for Preparing the Building Enclosure for Testing); where that guidance is modified or supplemented, it is copied below and the additional guidance is underlined:

1. 802.2.8 **Fans**: Any fan or appliance capable of inducing air flow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, outdoor air ventilation fans, air handlers, and crawl space and attic ventilation fans. Continuously operating individual ventilation systems shall be turned off and the air openings sealed, preferably at the exterior terminations. Continuously operating central ventilation systems shall instead be sealed at the *dwelling unit* registers. The central system does not need to be turned off as long as taping select registers will not compromise the system and the sealed registers remain sealed during the test.

2. 802.2.11 – **Un-dampered or fixed-damper intentional openings between conditioned space and the exterior or unconditioned spaces**: Shall be left open or fixed position, however, temporary blocking shall be removed. For example: fixed-damper ducts supplying outdoor air for intermittent ventilation systems (including central-fan-integrated distribution systems) shall be left in their fixed-damper position. Exception: Un-dampered supply-air or exhaust-air openings of continuously operating individual mechanical ventilation systems shall be sealed (preferably seal at the exterior of enclosure) and ventilation fans shall be turned off as specified above. Un-dampered supply-air or exhaust-air openings of continuously operating central mechanical ventilation systems shall instead be sealed at the *dwelling unit* registers.

The central system does not need to be shut down as long as taping select registers will not compromise the system and the sealed registers remain sealed during the test.

3. 802.2.14 - **Operable window trickle-vents and through-the-wall vents (e.g. passive air intakes)**: Shall be closed, but not sealed.

vi. Follow Section 802.4 of the RESNET Standards (Installation of the Blower Door Airtightness Testing System); where that guidance is modified or supplemented, it is copied below and the additional guidance is underlined:

1. 802.4.1.2 – Entry doors to *dwelling units* in *multifamily residential buildings* shall not be used for the blower door installation in *compartmentalization* tests unless the threshold is designed and adjusted to block airflow, comparable to an exterior door threshold.

   a. Exception 1: The entry door opening may be used if the normal open area between the closed entry door and threshold is measured, recorded, and duplicated by opening a window to create an air leak of equivalent area. *Compartmentalization test* shall be conducted with the added leak, which serves as proxy for the entry door threshold leak.

      i. Vertical gaps shall be estimated visually using a tape measure or ruler and rounding down to the nearest 1/8"

   b. Exception 2: Alternatively, the entry door opening may be used if the blower door results are transformed to ELA (Effective Leakage Area), and the threshold leak area (documented as above) is added to the ELA. The resulting sum shall be treated as the raw *compartmentalization* test result.

vii. Results from this test may be used in a HERS Rating, with the appropriate multifamily infiltration coefficient from the modeling guidelines.

2. A full building single zone blower door test

a. Output – whole building leakage to outside.

b. The results of this test option are not applicable for HERS Ratings for multifamily *dwelling units*. The whole-building leakage results shall not be used or extrapolated to represent leakage in the individual *dwelling unit* HERS Ratings. Reminder: HERS Ratings for *multifamily residential buildings* are not permitted. The HERS Rating must be performed on the *dwelling unit*.

c. General Comments: Unlike airtightness Test Option #1, this test treats the whole building as a single zone and measures only the leakage from the building to ambient conditions. This method does not address leakage between adjacent, conditioned spaces. Again, this method cannot be used for HERS Ratings.

d. Measure and record results, following the referenced Sections from Chapter 8 of the RESNET Standard:

   i. 802.6 Procedure for Conducting a Multi-Point Airtightness test; OR

   ii. 802.7 Procedure for Conducting a Repeated Single Point Test

e. Procedure -

   i. Follow the procedures for <u>Building Enclosure Airtightness Testing</u>, as described in Section 802 of the RESNET Standards, by replacing "house" with "building".

   ii. The induced pressure difference between all interior spaces within the test zone shall be less than 10% of the induced pressure difference with respect to outside. If this pressure uniformity is not achieved, corrections shall be made to achieve it.

   Pressure uniformity measurements are not required if there is one person door sized opening for each test fan employed. For example, there may be a restriction if there is a double or triple fan setup in a corridor that leads through one doorway.

   iii. Follow section "vi" under part "d" of Test Option #1.

   iv. Results from this test shall not be used in a HERS Rating.

3. A full building multi zone blower door test

a. Output – multi-zone total leakage to outside and target *dwelling unit* leakage to outside

b. The individual target *dwelling unit* results of this test option must be entered as the infiltration rate in the HERS rating software because these results are the leakage to outside. Unlike the results from airtightness Test Option #1, a multifamily infiltration coefficient of 1.0 shall be applied to the results from this test option under the modeling guidelines.

c. General Comments: Similar to the airtightness Test Option #2, this test measures leakage to outside and does not address leakage between adjacent, conditioned spaces. This strategy is most applicable to attached townhouses or to multifamily buildings with corridors open to the outside, where air tightness Test Option #4 is not feasible. This method can only be used when the pressure is induced in <u>each</u> unique zone in the building simultaneously (one blower door per zone). This test option does <u>not</u> allow for setups that only negate pressure differences across the adjacent boundaries of the target *dwelling unit* and not the rest of the zones in the building. In order to perform such a test, airtightness Test Option #4 shall be employed.

d. Measure and record results, following the referenced Sections from Chapter 8 of the RESNET Standard:

   i. 802.6 Procedure for Conducting a Multi-Point Airtightness test; OR

   ii. 802.7 Procedure for Conducting a Repeated Single Point Test

e. Procedure –

   i. Follow the procedures for Building Enclosure Airtightness Testing, as described in Section 802 of the RESNET Standards, by replacing "building" and "house" with "*dwelling unit*" and as clarified below.

   ii. A test fan shall be installed in an exterior opening (e.g. *dwelling unit* entry door, window, patio door) in each separate zone, typically a *dwelling unit*.

   iii. The reference tube for the *dwelling unit* pressure shall pass through the blower door shroud.

   iv. Follow section "vi" under part "d" of Test Option #1.

   v. Results from this test may be used in a HERS Rating, with a multifamily infiltration coefficient of 1.0.

4. A full building blower door test simultaneously with a target *dwelling unit* test

a. Output – target *dwelling unit* leakage to outside

b. General Comments: This strategy is most applicable to multifamily buildings with a shared entrance and interior corridors. Similar to Test Option #3, this method produces a "guarded" result that can be entered into a *dwelling unit* HERS Rating. Similar to Test Options #2 and #3, it does not address leakage to adjacent, conditioned spaces. Unlike Test Option #2, this method isolates leakage to ambient conditions from a target *dwelling unit*, rather than the whole-building, providing a more accurate input to the HERS Rating software than Test Option #1. A multifamily infiltration coefficient of 1.0 shall be applied to the results from this test option under the modeling guidelines.

c. Measure and record results, following the referenced Sections from Chapter 8 of the RESNET Standard:

   i. 802.6 Procedure for Conducting a Multi-Point Airtightness test; OR

ii. 802.7 Procedure for Conducting a Repeated Single Point Test

d. Procedure -

i. Follow the procedures for Building Enclosure Airtightness Testing, as described in Section 802 of the RESNET Standards, by replacing “house” with “building”.

ii. Follow section “ii” under part “e” of Test Option #2.

iii. Follow section “vi” under part “d” of Test Option #1.

iv. A test fan shall also be installed in an opening between the target *dwelling unit* with reference to the main part of the building. Using fan controlling software, the target *dwelling unit* test fan shall be operated in a manner so as to maintain the same pressure difference between the target *dwelling unit* and the main part of the building as was measured during the baseline. For example, if the pressure difference between these two zones was 0.5 Pa during the baseline, a pressure difference of 0.5 Pa shall be maintained while pressure is induced in the main part of the building.

1. If the target *dwelling unit* fan is set up so that it is fully contained within the test zone (e.q. in the entry door from an enclosed corridor) then the outdoor reference for the target *dwelling unit* shall not exit through the target *dwelling unit (e.g. through an exterior opening in an adjacent space and not through a target dwelling unit window)*. The flow through this fan is not included when calculating the flow for the total building.

2. If the target *dwelling unit* fan is set up in an exterior opening (e.g. window, deck door) the outdoor reference may pass through the blower door shroud. The entry door from the corridor shall be closed. The flow through this fan is part of the total flow for the building and shall be included when calculating the flow for the total building.

v. Results from this test may be used in a HERS Rating, with a multifamily infiltration coefficient of 1.0.

Procedures for Multifamily *Dwelling unit*/Building Heating and Cooling Testing

Supply/Return air flow (inside dwelling units or residential-associated common spaces)

When measuring supply and return air flow of ducted space conditioning systems at the register or grille, follow the procedures as described in Section 804 of the RESNET Standards for measuring "Air Flows into Grilles" (ie. return) and "Air Flows out of Grilles" (ie. supply). Although not currently a minimum rated feature for inclusion in the HERS Rating, this procedure may be applied to registers/grilles located inside *dwelling units*, as well as registers/grilles located in *residential-associated common spaces*. Alternatively, supply and return air flow can be measured using ANSI/ACCA 5 QI-2007 protocol.

Supply/Return duct static pressure (individual ducted mechanical systems)

Although not currently a minimum rated feature for inclusion in the HERS Rating, measuring supply and return duct pressure can be useful for evaluating performance of forced air systems.

How to Measure External Static Pressure:

External static pressure measurement is one method to determine that the appropriate level of air flow can be supplied by the system. The measured external static pressure will be compared to the capability of the system as shipped by the manufacturer.

To measure external static pressure, utilize a digital manometer with two static pressure probes. As shown in Figure 1, holes should be carefully drilled just prior to the inlet (between filter and unit) and just after the outlet of the system. The static pressure probe should be inserted in the direction of the air flow. The static pressure differential between the two measurement points provides the external static pressure. Static pressure measurements with respect to a reference area surrounding the system can be made. In this case, the return side should have a negative static pressure and the supply should have a positive static pressure. Subtract the return side static pressure from the supply side static pressure to get the total external static pressure. Alternatively, the static pressure differential (supply side on the input tap and return side on the reference tap) between the two measurement points provides the external static pressure.

For measurement of cooling units, whether the coil is dry or wet during testing should be noted when comparing to manufacturer's published data.

Though a simple measurement, getting suitable locations to insert the static pressure probes can be difficult with typical installations. Some examples of common issues that arise during measurement:

- Obtaining a suitable measurement point at the inlet of the system if there is no transition piece between the filter slot and the system.
- Obtaining a suitable measurement point at the outlet of a furnace if there is an external case coil for air conditioning.
- Obtaining a suitable measurement point at the outlet of the system if there is electric heat elements added. Even though these are within the system, they are not included in the published external static pressure data of the manufacturer. If a suitable location prior to the electric elements cannot be obtained, the manufacturers typically publish the rated pressure drop of these units in their systems, so the test results can be adjusted based on the size of the electric elements.

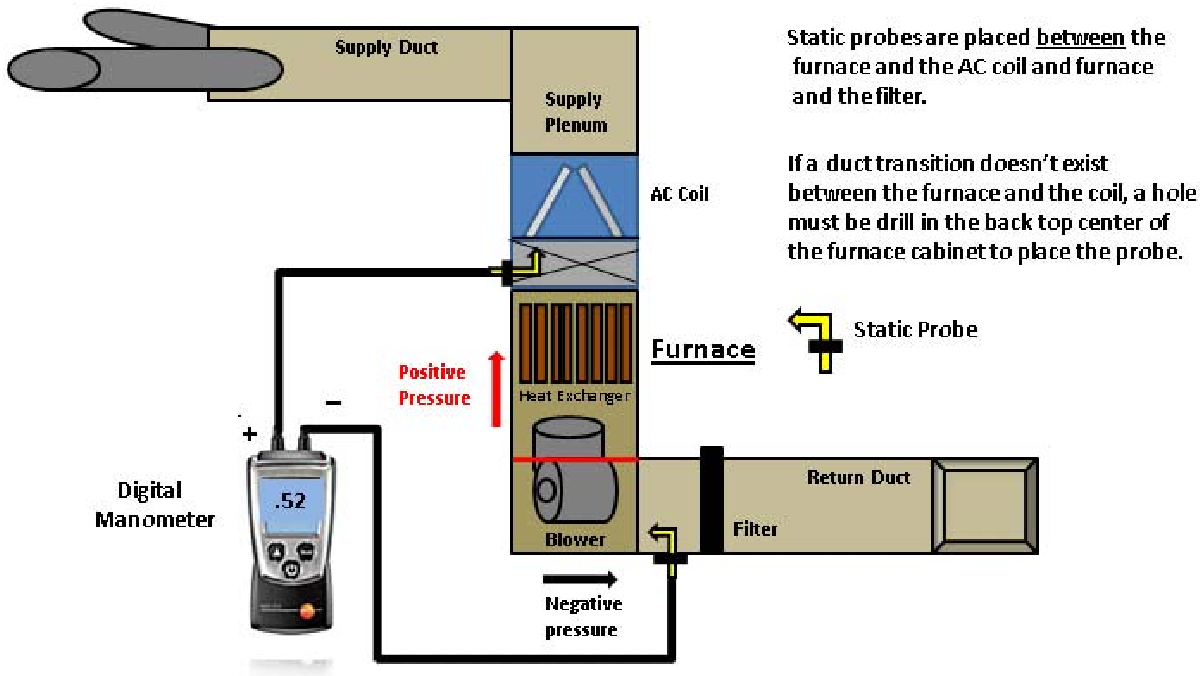


Figure 1: Location of ideal test hole locations (Courtesy of Jim Bergman, Tru Tech Tools)

Procedures for Multifamily *Dwelling unit*/Building DHW Testing

Although not currently a minimum rated feature for inclusion in the HERS Rating, measuring components of the DHW system can be useful for evaluating their performance or may be required by other multifamily building performance programs.

Measuring the stored pipe volume between an individual water heating source and fixture

- Conduct testing of the hot water delivery system prior to testing any indoor water draws to obtain the most accurate response time on the delivery of hot water. Testing must be conducted at the fixture that is located the farthest distance from the hot water source.
- Verify that the water heater is operational.
- For demand-initiated hot water recirculation systems, turn on the applicable switch or hit the control button for the hot water in the room where you are conducting the inspection and wait about 40 seconds.
- Place a bucket/container or a flow measuring bag (pre-marked at an increment relative to the specific requirement) underneath the hot water fixture.
- Turn the hot water completely on and place a digital thermometer in the stream of water. Record the starting temperature.
- Once the water meets the pre-marked line, turn off the water and record the ending temperature.
- The temperature must increase by 10°F or 5.5°C to demonstrate compliance.

Fixture flow rate

- Obtain the make and model number of the specific water fixture and/or accessory installed in the house. Retain a copy of the documentation as part of the inspection records.
- Check the maximum flow rate from the fixture to ensure that the fixture is meeting the stated flow rate:
    - Use a small bucket/container underneath or attach a calibrated flow-measuring bag to the fixture.
    - Turn on the water completely while starting a stopwatch. If the fixture has two handles, turn both handles on completely.
    - After 10 seconds on the stop watch, turn off the water.
    - Multiply the volume of water collected by 6 to obtain the approximate flow rate in gallons per minute

Verifying delivery temperature at a fixture for individual DHW or centralized systems

- Ensure that the DHW system is operational and note the temperature set point

- Turn the hot water at a fixture completely on and place a digital thermometer in the stream of water. Observe the thermometer and record the temperature when no additional rise in temperature occurs after 10 seconds.

- Record water temperature at fixture. Record into the inspection record the DHW setpoint, design temperature and program requirement (where applicable). If the water temperature at the fixture differs by more than 5 degrees from the design temperature, notify the building owner.

Procedures for Multifamily *Dwelling unit*/Building Ventilation Testing

Procedures for Ventilation air flow Testing

The purpose of these test procedures is to measure the air flow through ventilation systems, whether central or individual, whether serving *dwelling units* or *residential-associated common space*, or whether providing whole-"unit" ventilation or local exhaust. The test procedures treat air moving toward the test equipment (typically supply air when measuring from within the building) separately from air moving away (typically exhaust or extraction air when measuring from within the building) from the test equipment. Alternate flow testing methods not described here may be employed if they are substantially equivalent, if they follow procedures established by the manufacturer of the equipment, and such methods are widely recognized as being accurate when performed correctly. For example, use of a manometer with manufacturer-installed calibrated ports (common on ERV/HRV equipment) is an acceptable method if the manufacturer's instructions are followed.

Air Flows into Grilles, Away from Test Equipment (typically, exhaust)

A. Powered Flow Hood

A powered flow hood consists of:

- A flow capture device that is to be placed over the grille to be measured. The flow capture element needs to be large enough to cover the whole grille and be airtight.
- A pressure measuring system inside the flow capture element that is designed and installed to measure the static pressure inside the flow capture element.
- A manometer to measure the pressure difference between the inside of the flow capture element and the room.
- An air flow meter to measure the air flow through the air flow capture element. The air flow meter shall measure air flow with an accuracy of +/-5%.
- A variable-speed fan to move air through the flow capture element and the flow meter.

Basic Steps

1. Place the flow capture element over the grille to be measured.
2. Turn on the air flow assisting fan and adjust the air flow until zero pressure difference is measured between the flow capture element and the room.
3. Record the air flow through the air flow meter.

Equipment Accuracy Requirements and Specification

The manometer shall measure pressure differences with a resolution of 0.1 Pa and have an accuracy of +/-1% of the reading or 0.5 Pa, whichever is greater.

B. Air Flow Resistance

The Air Flow Resistance method measures the pressure difference across a flow capture element with a known air flow resistance.

Basic Steps

1. Place the flow capture element over the grille to be measured. Ensure there is air tight seal around the grille and the flow device so that all of the air entering the grille goes through the device.

2. Measure the pressure difference (ΔP) between the flow capture element and the room at a corner of the inlet side of the box. The hole in the flow capture device should be sized so that the pressure difference is between 1 and 5 Pa.
3. Calculate the air flow using the manufacturer's calibration of the air flow resistance device.
4. For user fabricated devices that do not have a manufacturer's calibration, the following equations shall be used to calculate the air flow.

$$\text{Air Flow (cfm)} = \text{Open Area}\cdot 1.07\cdot (\Delta P)^{0.5}\text{; for Area in in}^2\text{, } \Delta P \text{ in Pa}$$

$$\text{Air Flow (L/s)} = \text{Open Area}\cdot 0.078\cdot (\Delta P)^{0.5}\text{; for Area in cm}^2\text{, } \Delta P \text{ in Pa}$$

Equipment Accuracy Requirements and Specification

The manometer shall measure pressure differences with a resolution of 0.1 Pa and have an accuracy of +/-1% of the reading or 0.5 Pa, whichever is greater.

The capture element shall have a hole no larger than half the size of the box in each direction, and the distance from the hole to the grille shall be at least as large as the larger dimension of the hole. User fabricated devices shall be approved by a Provider prior to use.

Air Flows Out of Registers, Toward Test Equipment (typically, supply)

A. Powered Flow Hood

The measurement procedure and equipment accuracy requirements are the same as for air flow <u>into</u> grilles but with the fan and flow meter arranged to have flow <u>out</u> of the register.

B. Bag Inflation

The Bag Inflation method requires the use of a bag of a known volume, a method to hold the bag open (typically a lightweight frame of wood, plastic or metal wire), a shutter to start the air flow and a stopwatch.

Basic Steps

1. Completely empty the bag of air and place a shutter over its opening.
2. Rapidly withdraw the shutter and start the stopwatch.
3. When the bag is completely full stop the stopwatch.
4. Calculate the air flow by dividing the bag volume by the elapsed time. Calculate the air flow in cfm as 8 X bag volume in gallons/number of seconds.
5. Repeat measurement one or more times and average the results.

Equipment Accuracy Requirements and Specification

How to Choose a Bag

Plastic thickness. Bags made from thinner material often do not fill uniformly because the air flow from the register blows them about too much. If the bag sides flap a lot and measuring the same register twice gives results that differ by more than 20%, then try a bag with thicker material.

Use the right sized bags. Bags that fill in less than two seconds will have increased errors because of resolution issues in timing how fast the bag is filled. Conversely, bags that are too large for a given register flow will have increased leakage around the edges of the bag before it fills completely and may not generate enough pressure to push a bag into its final shape. Aim for a fill time of 2 to 20 seconds.

Calibrate the bag. Actual volume of plastic bags can vary significantly from the nominal volume. Assemble the bag and frame. Using a known air flow measure the time to fill the bag three times; average the results. Multiply the time, in seconds, by the known air flow, in CFM, divide by 60. This is the actual volume of the bag, as assembled, in CFM.

Dwelling Unit Whole-"unit" Ventilation

For use in an Energy Rating, and for determining program or code compliance

Ventilation functions as whole-unit ventilation if it is automatically controlled by a timer, or if it operates continuously. Demand ventilation that responds to occupant control or to a sensor (such as a carbon dioxide sensor) shall not be considered whole-unit ventilation. Systems typically are exhaust-only, supply-only, balanced or air-cyclers, and the fans can be individual (ie. inline, ceiling, air handlers with outdoor air dampers) or central (rooftop fans or make-up air units).

System specific Steps

1. Use the flow measuring devices per the section above.
2. If the system requires balancing or if the fan speed is intended to be adjusted based on delivered air flow, measurements of the whole-unit ventilation system must occur after testing and balancing of the system.
3. Refer to the ventilation specification or the ventilation design to determine the design speed of the system and operate the ventilation system at the design speed during testing.
4. In the case that a single ventilation system operates both as whole-unit ventilation and as local exhaust, operate the system at the speed designated for whole-unit ventilation.

Dwelling Unit Local Exhaust Ventilation

Not currently reflected in an Energy Rating: for program or code compliance only

Local exhaust is point-source ventilation that runs continuously or is activated on demand, typically serving kitchens and bathrooms, although the actual fans may be located elsewhere. Local exhaust fans that also provide whole-unit ventilation may operate continuously at a speed less than 100%, or cycle on and off based on an automated schedule, to meet the whole-unit ventilation rate needed. Fans that only provide intermittent local exhaust are typically in the off position as the default operation.

System specific Steps

1. Use the flow measuring devices per the section above.
2. If measuring a branched system operated by a boost switch, ensure that the fan remains at the intended speed throughout the test.
3. Operate the fan at the highest speed permitted by the local exhaust controls: an on/off switch, a speed boost switch, a delay-off timer, etc. Do not adjust the speed except with the permission of the building owner, and only in the case in which the adjusted speed is intended to persist for regular operation while the building is occupied.

Residential-Associated Common Space Supply Ventilation and Exhaust

Ventilation serving *residential-associated common spaces* generally includes the supply of outdoor air using dedicated outdoor air systems or ERVs, or through a forced heating or cooling system. Exhaust, where required, like in laundry rooms, trash rooms and public restrooms, is generally provided by inline or ceiling exhaust fans or larger commercial rooftop fans and central risers. Supply ventilation and exhaust air flow exclusively serving these spaces are not currently included in the HERS Rating, but steps are provided for measuring their air flow. Modeling guidelines have established a procedure for including supply ventilation air flow to these spaces in the HERS Rating if intended as providing outdoor supply air for the *dwelling units*.

System specific Steps

1. Use results from testing and balancing reports or the flow measuring devices per the section above.
2. Operate the ventilation system at the design speed.
3. Measure ventilation air flow in *residential-associated common spaces* (ie. corridors, laundry rooms, lobbies) at the registers/grilles or the outdoor air intake, after the system has been balanced. Follow mechanical plans to ensure that registers/grilles being measured are associated with the correct system. For air flow measurements that exceed the flow rating of equipment or where air flow cannot be measured due to location or register/grille shape/size, until test procedures are developed, "measured" CFM can be derived from "design" CFM values provided by the design engineer or from testing and balancing reports.

Duct leakage of central ventilation systems

Although not currently a minimum rated feature for inclusion in the HERS Rating, measuring duct leakage of central ventilations systems can be useful for evaluating their performance.
To evaluate duct leakage of central ventilation systems, follow the procedures outlined in your duct leakage tester operation manual, for a single point or five-point test for total duct leakage in the main duct shaft using a calibrated fan between -50 and -100 Pascal measured under depressurization or 50 and 100 Pascal under pressurization. Unlike duct leakage testing of typical *ducted mechanical systems*, this test is not conducted at 25 Pascals. Follow the procedures in Section 803.3 of the Standard for preparing the building and the duct system for a duct leakage test.
When conducting a ventilation duct leakage depressurization test, the flow conditioner and one of the flow rings must always be installed. The duct tester is not required to be connected to a specific location in the shaft, however, typical central ventilation duct tightness tests are conducted from the roof with the duct tester connected to the roof curb. Often a transition plate, such as cardboard, precut plastic, acrylic glass or rubber sheets, is needed to effectively seal the duct tester to the roof curb opening.
If testing under pressurization, the pressure probe should be installed approximately 5' downstream of the connection between the duct and the duct tester, with the probe configured so its openings face perpendicular to the direction of flow and only static pressure is measured, not velocity pressure. When connecting the duct tester to the roof curb, create a hole in the transition sheet and run the tubing and pressure probe inside of the shaft before connecting the transition sheet. Often static pressure probes come with a magnet to help configure the probe in the right direction, but if the inside surface of the duct is not magnetic, a weighted pressure hose could be used with holes cut out of the sides to prevent velocity pressure from being measured.
If conducting a five-point test, use a linear regression model to calculate the CFM50 leakage. If performing a single-point test, a linear regression model does not need to be used.

Procedures for Multifamily *Dwelling unit*/Building Duct Testing

Duct testing, total leakage and Duct testing, leakage to outside

When performing a duct leakage test (both Total Duct Leakage and Leakage To Outside) follow the procedures as described in Section 803 of the RESNET Standards and replacing "building" with "*dwelling unit*."

When following Section 803.3 of the RESNET Standards (Protocol for Preparing the Building and the Duct System for a Duct Leakage Test); original guidance is below and additional guidance is underlined and provided below:

803.3.4 Any intentional openings into the duct system such as combustion air or ventilation ducts shall be left in their normal non-ventilation operating position. Motorized dampers should be closed. If openings are part of a continuous ventilation system, openings shall not be sealed.

Duct leakage testing protocol for non-ducted returns

In multifamily buildings with individual *ducted mechanical systems* in each *dwelling unit*, a common strategy for delivering return air to the air handler is via a non-ducted return system. Usually this is accomplished by raising the air handler off the floor on a platform or stand, and leaving the return side of the fan compartment open to the air handler closet. An opening in the closet is then created so that air from the conditioned space can be drawn into the air handler. This can be accomplished in a number of ways including:

- Installing a grille in the mechanical closet wall that meets the manufacturer's specifications for minimum return grille size ;
- Installing a louvered door on the mechanical closet;
- Leaving the ceiling of the closet open and using a dropped ceiling plenum and ceiling grilles as the return pathway back to the air handler.

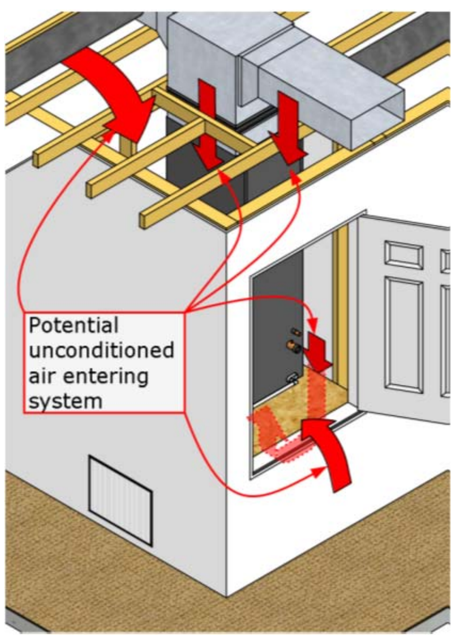


Image from DOE Measure Guideline: Air Sealing Mechanical Closets in Slab-On-Grade Homes

An additional scenario where return plenums are commonly seen are in instances of a heating and cooling system utilizing ceiling furr-downs to conceal slim air handlers. If the return is not hard ducted in this fur-down, duct leakage testing should be performed by connecting to the plenum transfer grille, ensuring that all leakage within the furr-down is accounted for.

If there are combustion appliances in these open plenums, there are concerns for combustion safety. Make sure to follow Section 802.2.17 (combustion appliances shall remain off) during testing preparation and throughout the test. After testing is complete, return the *dwelling unit* to its as-found conditions prior to the test. For example, make sure that any combustion appliance pilots that were on prior to testing remain lit after testing. If the mechanical system configuration could lead to potential combustion safety concerns during normal operation, it is strongly encouraged to notify the building owner and *dwelling unit* tenant of these concerns.

Installation of the Duct Leakage Testing System

The mechanical closet and any peripheral cavities being used as return paths back to the air handler must be included in the duct leakage testing requirement unless the system qualifies under the exception listed below:

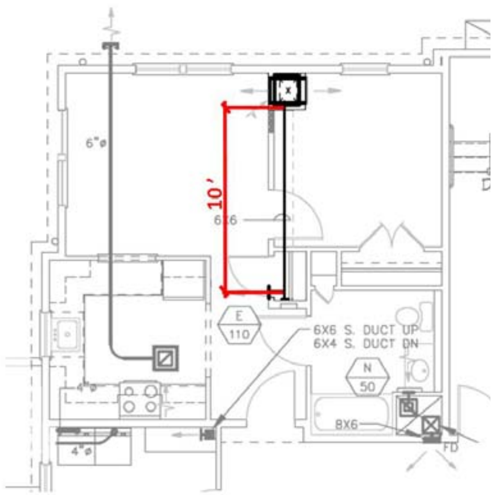
a. If a larger opening than manufacturer's minimum return grille free area sizing is installed AND
b. the pressure difference between the mechanical area and the conditioned space <= 3 Pa with the air handler running at high speed AND
c. there shall be an induced pressure difference between the mechanical area and the conditioned space of less than 10% of the induced pressure difference with respect to outside

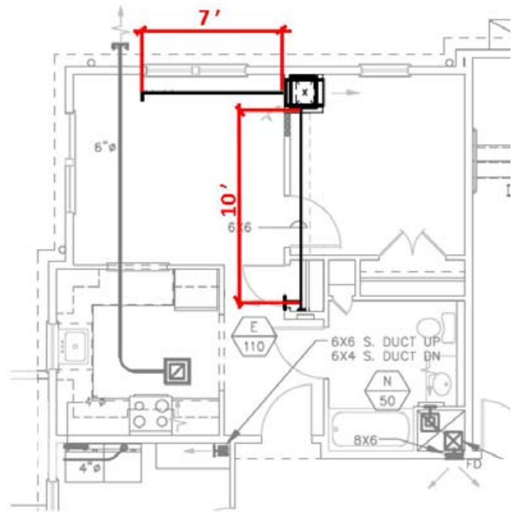
If all three criteria are met, the duct blaster fan may be hooked directly to the return side of the air handler during the duct leakage test excluding the rest of the mechanical area from the duct leakage results.

Otherwise, the duct blaster <u>must</u> be attached to the grille leading <u>into</u> the mechanical closet or furr-down plenum, essentially <u>including</u> any leakage in the closet or furr-down in the duct leakage results. Any building cavity plenums – ceiling, wall, floor – being used to direct air from the conditioned space to these mechanical areas must be left open to the mechanical area. Transfer grilles in the conditioned space leading to these ancillary plenums shall be sealed off. The duct blaster fan must be connected to a transfer grille in the ceiling plenum. This would result in the mechanical closet and ceiling plenum being <u>included</u> as part of the duct testing requirements.

Duct Leakage Testing to Outside and Duct Leakage Total Exception

Ducted mechanical systems are those that supply air to an occupiable space through supply ductwork exceeding 10 ft. in length and through a thermal conditioning component, except for evaporative coolers. Systems that do not meet this definition (ie. balanced ventilation systems not connected to the space heating or cooling systems, or ducted mini-splits with 10 ft. or less of supply duct length) are <u>**not**</u> required to be tested for any duct leakage (to the outside or total), unless any portion of the system (ductwork or air handler) is located in unconditioned space. They can be modeled as "ductless" systems in the HERS Rating software. When measuring supply duct length, 10 ft. is measured from the source to the register(s), including all supply trunks and branches. The 10 ft. is a <u>total</u> system allowance, and not the allowance for each supply run. The image on the left qualifies for the exception. The image on the right does not qualify for the exception.





Note: If the duct leakage results are to be used for assessing compliance with a *dwelling unit* duct leakage limit (e.g., defined by code or by an energy efficiency program), application of this exception may not be appropriate unless approved by the local code official or program administrator.

Duct Leakage Testing to Outside Exception

All *ducted mechanical systems* in *dwelling units* must be tested for duct leakage to outside the unit, or use the RESNET Default leakage.

Exception:

Testing of duct leakage to outside the *dwelling unit* may be skipped, and zero duct leakage to the outside modeled, if all three of the following conditions are true.

1. The *dwelling unit* unguarded blower door test (*compartmentalization* test) demonstrates leakage no greater than 0.30 CFM50/ft^2 of *enclosure area*.
2. If a passive outdoor air ventilation duct is connected to the return side of the space conditioning duct system, an automatically-controlled mechanical damper must close off the outdoor air when there is no call for ventilation. This damper must be installed even for continuous ventilation strategies, such that if the power goes off, the damper closes.
3. The entire duct system, including the manufacturer's air handler enclosure, is within the *dwelling unit*'s tested pressure boundary during the *dwelling unit* blower door test.

Example: a duct system in a vented attic does not qualify, but one located entirely in the interstitial space between conditioned units may qualify. Similarly, systems may qualify when the air handler is in a mechanical closet located on a balcony or accessed via the corridor, if that mechanical closet is within the tested pressure boundary during the *dwelling unit* blower door test (ie. pressure in the closet must be within 10% of the living space during the test).

Note: If the duct leakage results are to be used for assessing compliance with a *dwelling unit* duct leakage limit (e.g., defined by code or by an energy efficiency program), application of this exception may not be appropriate unless approved by the local code official or program administrator.

Procedures for Multifamily *Dwelling unit*/Building Combustion Appliance Testing

When performing combustion appliance, gas leakage, worst case depressurization testing, or carbon monoxide testing in multifamily buildings, follow the procedures as described in Section 805-808 of the RESNET Standards by replacing "home" with "*dwelling unit*" or "building". In some multifamily buildings, the combustion appliance zone (CAZ) will be located outside of the *dwelling unit*, but still within the building, and therefore must still be tested.

On-Site Inspection Procedures for Minimum Rated Features

Justification

Similar to Appendix A in the Standard, the goal of this guidance is to provide on-site inspection procedures for minimum rated features that include *residential-associated common spaces* in *multifamily residential buildings* and explicitly address *central mechanical systems* not located within a *dwelling unit*. It is not intended to replace the current Inspection Procedures in the Standard that apply to the *dwelling units*, but rather as a supplement to those procedures. Where the inspection applies to a building component that is not currently used within the Rating and is not being proposed as an addition to the current minimum rated features, they are grouped within a table for "non-rated" features.

Future Work/Questions for RESNET SDC

In the future, the "non-rated" features could be incorporated into the HERS Rating methodology to capture the energy performance of the *residential-associated common spaces*.
Additional work is needed to address inspection procedures related to controls related to central mechanical systems.

Proposed Guidelines

When performing inspections for *dwelling units* in *multifamily residential buildings*, follow Appendix A of the Standard, replacing "home" or "house" with "*dwelling unit*". Follow Appendix A for the "On-Site Inspection Procedures for Minimum Rated Features" of these multifamily guidelines for additional guidance related to *dwelling units* in *multifamily residential buildings* and *residential-associated common spaces*. Inspection procedures are provided for certain "non-rated" features, although they are not required and are not included in the HERS Rating. They are recommended inspections as they can be useful for evaluating performance of the *multifamily residential building*.

Sampling

Justification

The goal of these guidelines was to revise sampling, as presented in Chapter Six of the RESNET Standards, to explicitly address HERS Ratings of *dwelling units* in *multifamily residential buildings*. Currently, there are inconsistent interpretations among Raters and Providers of how to apply the current sampling protocols to *dwelling units* in *multifamily residential buildings.*

The current sampling procedures were modified as needed, but where possible, the intent of Chapter 6 was maintained. The guidelines clarify the projected rating modeling process, explain how to assign the HERS index to the appropriate *dwelling units* in the *multifamily residential building,* and explain when a Confirmed Rating for a specific *dwelling unit* within a building following sampling procedures is permitted. To improve upon the current sampling protocols, the guidelines require units selected for testing/inspection to be appropriately "representative" based on unit type and establish alternate requirements for sampling by stage of construction (i.e. pre-drywall and final), by unit type, and/or by time of completion.

Future Work/Questions for RESNET SDC

If the guidelines proposed are acceptable, future work includes the creation of a subset of Sampling Providers who are designated as Multifamily Sampling Providers and who will be asked to review Sampling Plans submitted by their HERS Rater prior to the first inspection of the building.

Ultimately, the working group could not reach consensus on if/how to recommend the use of actual test data to update Projected Ratings to determine the final HERS Index of the Sampled Ratings. Many proposals were offered which could be considered in the future. Overall, the intent was to strike a reasonable balance between using conservative pre-construction projected thresholds for testing and allowing the final HERS Index of the Sampled ratings to use actual test results from the units with the worst results. Using the initial projected thresholds is conservative, but reasonable, since performance of the non-tested units is unknown. Using actual test results may be more indicative of actual performance, but non-tested units may not perform as well.

One proposal in favor of revising Projected Rating based on actual test results is as follows:

After performance testing is completed for the sampled units, the estimated values in the Projected Ratings can be updated to reflect the worst tested values for that specific unit type to determine the final HERS Index for that unit type. For example, in a building where 10 unit type A's were tested for envelope leakage and pass the initial projected threshold of 7 ACH50, yet the worst tested value for envelope leakage is 5 ACH50, the Projected Rating can be updated with 5 ACH50 to determine the final HERS Index for unit type A.

Q: How would "initial" and "additional" failures be addressed?

A: In the event of an "additional failure" or "failure" that cannot be brought into compliance, the value used to determine the final HERS Index for that unit type <u>must</u> remain as the original threshold and cannot be revised based on the worst tested values for that unit type from the other sample sets in the Sampling Cohort. For example, a building has 10 unit type A's that were tested for envelope leakage and 9 passed the initial projected threshold of 7 ACH50, but there was 1 "initial failure", which was corrected and "passed". If there was an "additional failure" within that sample set, then the Sampled Ratings for unit type A <u>remain</u> with the initial projected threshold of 7 ACH50, regardless of the actual performance of the 10 passing units. If there were no "additional failures" in that sample set, the unit type A may use the worst tested value of the 10 unit type A's that were tested.

Q: How would a failed home be addressed if it is not corrected?

A: If the failure is not corrected, the unit type A still uses the initial projected threshold of 7 ACH50 in the Sampled Rating, and that particular unit constitutes a “failure” and the units in the sample set containing the “failure” do not meet the labeling criteria, identical to the current standard. Although the other six units in the Sample Set will not be labeled, their test data must be included when evaluating worst tested values within the building for their respective unit types.

Various proposed modifications to this proposal:

1. Use the worst normalized test result of all tested units, rather than by unit types.
2. Establish a minimum number of dwelling units in the building before sampling can commence (ex. buildings with less than 20 units cannot use sampling).
3. To qualify for sampling, increase from 7 to 10 consecutive units, and those 10 must include one of each unique unit type.
4. In addition to the “minimum ratio of one (1) test or inspection per seven (7) homes within a given sample set”, require a minimum ratio of the units tested within the building (ex. 50% of the units in a building must be tested).
5. Prohibit sampling at pre-drywall inspections if test data will be used to adjust initial projected thresholds.
6. Establish the initial projected thresholds that must be used if pursuing this approach.
7. Any failure (“initial”, “additional”, corrected or not) should prevent the use of actual test results.

Proposed Guidelines

Sampling is intended to provide a reliable, efficient and cost effective mechanism for certification that the *dwelling units* within a *multifamily residential building*, or in some cases the units contained within a group of multifamily buildings, meet a particular threshold for assignment of a HERS Index or meet other requirements such as those established for ENERGY STAR certification, energy code compliance, or qualification for an energy efficiency lending program. It is based on pre-analysis of building plans meeting the intended qualification (e.g. a HERS Index threshold), and subsequent random testing and inspections of a representative sample set of the units as built (and in some programs the *residential-associated common spaces* within the building envelope). Certifying a group of units in a building (or buildings) using sampling according to this standard entitles the customer to documentation certifying that the *dwelling units* meet the desired threshold for labeling with the corresponding HERS Index or program qualification; it does not constitute a confirmed HERS Rating on any one unit, but rather a "sampled" rating.

These guidelines set out the procedures for accreditation of Multifamily Sampling Providers and the technical requirements for implementation of sampling in multifamily buildings. Accredited Multifamily Sampling Providers shall assume all warranties and liabilities associated with the sampling of multifamily buildings. RESNET does not provide any warranty, either explicit or implied, that any specific sampled *dwelling unit* will meet or exceed the threshold specifications for the sample set. There may be instances in which state laws or regulations differ from these guidelines. In such instances, state law or regulation shall take precedence over these guidelines.

Compliance Requirements

The testing and inspection of *dwelling units* in *multifamily residential buildings* for minimum rated features shall be conducted in compliance with the procedures for conducting home energy ratings contained within the RESNET Standards. Where applicable or required, the testing and inspection of *residential-associated common spaces* in *multifamily residential buildings* for minimum rated features shall be conducted in compliance with the procedures for conducting home energy ratings, although not all minimum rated features in those *residential-associated common spaces* are currently included in the HERS Rating.

Multifamily Units Eligible to be Sampled

Multifamily *dwelling units* being sampled shall be of the same construction type, use the same envelope systems, and have the same minimum rated features across all units within the "Sampling Cohort".

> *Dwelling units* may be grouped in a "Sampling Cohort" within which *dwelling units* in separate multifamily buildings are considered interchangeable and equivalent for the purposes of applying sampling controls. Multifamily buildings within the Sampling Cohort must be located in the same climate zone and use the same key contractors (insulation, electrical, framing, HVAC) across the Sampling Cohort.

Analysis of Multifamily Units

When performing unit-level ratings, at a minimum, a Projected Rating shall be performed on each unique unit type. Floorplans with the same number of bedrooms, same number of bathrooms, same conditioned floor area (±10%), and same enclosure area (±10%) can be considered the same unit type. For each unique unit type, an evaluation must be performed using the various exposures, orientations and levels within the building, to determine the configuration that results in the highest HERS Index for that unit type. Mid-level, interior configurations, which typically have a higher HERS index, may be excluded from this evaluation. The Projected Rating with the highest HERS Index for that unit type must then be used to represent all sampled units of that same unit type, regardless of actual exposure, orientation or level in the building. Alternatively, a given unit type can have multiple Projected Ratings based on the various exposures, orientations, and/or levels within the building, but that Projected Rating can then only be used to represent sampled units of that same unit type with the same exposure, orientation and/or level. For example, a Projected Rating for a mid-level unit type A could be created, along with a Projected Rating for a top-level unit type A, such that the HERS index for the mid-level unit type A will only be applied to other mid-level unit type A's.

a. During the initial analysis, values for performance testing (envelope leakage, duct leakage, and ventilation flow) should be estimates based on the Rater's experience, code or Program requirements. These normalized values (i.e. ACH50, CFM25 per 100 ft2) can differ by unit type or by building type, if certain characteristics of the unit warrant a different performance testing threshold. These are the values that establish the points of "failure" for each unit type tested, as referenced in the "Sampling Controls" section.
b. The estimated values in the Projected Ratings can be updated to reflect the worst performance criteria visually verified in the field for certain minimum rated features. For example, if the Projected Rating indicated air conditioning equipment as SEER 13, but the worst air conditioning equipment confirmed in the field was SEER 14.5, the Sampled Rating could be updated using SEER 14.5. Where possible, the Rater should use invoices or other documentation to confirm that the upgraded rated feature does apply to all units in the Sampling Cohort.

Labeling of Multifamily Units

Every multifamily unit within a given Sampling Cohort is represented by one of the Projected Ratings performed and shall be assigned the same HERS Index as determined by the HERS Rating for its respective unit type.

Every multifamily *dwelling unit* subjected to these sampling guidelines shall be provided with a label in accordance with Section 303.3 of the RESNET standards, which contains the following statement: "This multifamily *dwelling unit* has been certified using a sampling protocol in accordance with Chapter 6 of the RESNET Standards (see http://resnet.us.standards/ ." This label shall be located on the electrical panel and the font shall be a minimum of 10 points

Exception: If a *dwelling unit* within a Sampling Cohort meets all the requirements for a Confirmed Rating (all minimum rated features were inspected and tested), the *dwelling unit* may be rated and labeled as a Confirmed Rating, using the actual performance testing data for that unit in its Confirmed Rating.

Sample Set of Multifamily *Dwelling units*

The sample set, a subset of the Sampling Cohort, shall be selected such that sampling controls on one or more of the *dwelling units* may be represented in the analysis for all the *dwelling units* within the sample set. The sample set may not exceed 7 *dwelling units*.

Sample Set of Residential-Associated Common Spaces

Although testing and inspections of most *residential-associated common spaces* are not currently required to be represented in the analysis of the *dwelling units*, where testing or inspections are required in those spaces by programs or building codes, the sample set shall be selected such that sampling controls on one or more of the *residential-associated common spaces* may be used to represent other spaces within the sample set. The sample set may not exceed 7 spaces, but spaces can serve different functions if they have the same minimum rated features applicable to the sampling control being applied. For example, if inspecting exterior wall insulation, a stairwell, corridor, lobby, office, bathroom, community room and closet can be in the same sample set, if they have the same envelope systems. If verifying HVAC equipment efficiencies, it is likely that spaces with the same function, such as stairwells, will have the same HVAC system and can be in a sample set together, but could not be in the same sample set as a community room, if it has a different HVAC system.

Selecting the Sample Set

Dwelling units grouped within a sample set must meet one of the criteria below. A sample set is constituted for a single sampling activity only. Any individual *dwelling unit* may be reconstituted in a different sample set for subsequent inspections or tests.

1. Sample Set by Completion Date

   Dwelling units within the sample set can be of different types, as defined in "Analysis of Multifamily Units", but must be at the same state of completion (ready for pre-drywall or final inspection) within a 30-day period.

2. Sample Set by Unit Type

   Dwelling units within the sample set must be of the same type, as defined in "Analysis of Multifamily Units", but do not need to be at the same state of completion within a 30-day period, if they use the same key contractors (insulation, electrical, framing, HVAC).

Each *dwelling unit* subject to sampling is required to be part of an identified set of sampling controls for each test or inspection that is sampled.

Application of Sampling

The application of the sampling controls in this standard is only required for those tests and inspections that are not conducted on every *dwelling unit*. Sampling controls shall be conducted for any tests and inspections not conducted on every *dwelling unit*, according to the field testing and inspection requirements of the RESNET Standard.

Although not all minimum rated features in *residential-associated common spaces* are currently included in the HERS Rating, sampling is <u>not</u> permitted for <u>inspections</u> of minimum rated features for HVAC or water heating <u>equipment</u> serving *residential-associated common spaces*.

Sampling is <u>not</u> permitted for <u>inspections</u> of minimum rated features for *central mechanical systems* serving more than seven *dwelling units*.

Sampling <u>is</u> permitted for <u>testing</u> ventilation air flows of registers/grilles located within *dwelling units*, regardless of the equipment type (central or individual).

If a building utilizes a ventilation system that supplies outdoor air to common spaces, such as corridors, with the intent of indirectly serving as the primary outdoor air supply for the individual *dwelling units,* sampling is permitted for testing ventilation air flows out of those supply registers. Use the design CFM per register (±15% or ±10 CFM, whichever is greater) as the threshold for "failures" and replace "dwelling unit" with "supply register" in the Sampling Controls section below. Supply registers that are not tested may be assumed to supply their design CFM, if all tested registers are within the above tolerance. If any tested register is not within the tolerance and is not corrected within the tolerance, all supply registers must be measured to determine system air flow.

Sampling Controls

1. To qualify for sampling of a specific inspection or test within a Sampling Cohort, a builder shall first complete, without any incidence of failure, that specific sampling control on at least seven (7) consecutive *dwelling units* within the Sampling Cohort. For example, to qualify for sampling of pre-drywall inspections, pre-drywall inspections must be conducted without any incidence of failure on at least seven (7) consecutive *dwelling units* within the Sampling Cohort. To qualify for sampling of final testing and inspections, final testing and inspections must be conducted

without any incidence of failure on at least seven (7) consecutive *dwelling units* within the Sampling Cohort. To qualify for sampling of *residential-associated common spaces*, a builder shall first complete, without any incidence of failure, that specific sampling control on at least seven (7) consecutive *residential-associated common spaces* within the Sampling Cohort.

2. A complete set of Sampling Controls shall be performed at a minimum ratio of one (1) test or inspection per seven (7) *dwelling units* within a given sample set. At a minimum, a certified Rater or Rating Field Inspector shall oversee this process.

    Note: For multifamily buildings with *central mechanical systems*, <u>testing</u> of most of those systems is not currently part of the HERS Rating. If testing is required for program compliance and sampling is permitted, sampling controls related to the <u>testing</u> of those systems shall be performed at a minimum ratio of one (1) test per seven (7) "systems". For example, for a multifamily building with 13 rooftop fans providing exhaust ventilation to the *dwelling units*, all 13 fans must be <u>inspected</u> for minimum rated features. If ventilation duct leakage <u>testing</u> is required, after 7 risers have been successfully tested for duct leakage, only 1 of the remaining 6 risers needs to be tested.

3. Within a given sample set, the sampling controls may be completed collectively on a single *dwelling unit*, or the tests and inspections may be distributed across several *dwelling units*, provided the total number of individual tests and inspections meets or exceeds the minimum ratio of 1 in 7. In addition, tests and inspections must be distributed across floors within a building and across buildings within the Sampling Cohort. A complete set of sampling controls must be completed in any building with 7 or more *dwelling units*.
4. Within a Sampling Cohort, the *dwelling units* selected for testing or inspection must be appropriately "representative" of the *dwelling units* in the building and demonstrate a similar distribution of unit types, level, exposure, and orientation. At a minimum, for each Projected Rating, a *dwelling unit* that matches that Projected Rating's unit type and worst-case configuration, must be tested for infiltration, duct leakage and ventilation.
5. Having successfully met the requirements of item 1 of the "Sampling Controls" section, sample sets for the remainder of the *dwelling units* within the Sampling Cohort until a "failure" occurs or they no longer meet the completion date or contractor consistency requirement.
6. A complete set of sampling controls, whether performed on a single *dwelling unit*, or spread across several *dwelling units*, must be completed whether or not one or more failure(s) are found.
7. When an "initial failure" occurs, the failed item(s) shall be tested or inspected in two (2) additional *dwelling units* 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 *dwelling units* in the sample set before they become inaccessible for inspection or testing.
8. When an "additional failure" occurs, in one or more of the two (2) additional *dwelling units*, the failed item(s) shall be tested or inspected in the remaining four (4) *dwelling units* selected for the same sample set.

9. Until the failure is corrected in all identified (failed) *dwelling units*, none of the *dwelling units* in the sample set shall be deemed to meet the threshold or labeling criteria, with the exception of units that meet the requirements of a "Confirmed Rating".

Multiple "Additional Failures"

Action is required if three (3) "additional failures" occur in any sample set within the Sampling Cohort. The required action depends on whether those "additional failures" apply to the same failed item or various failed items.

1. If the multiple "additional failures" all apply to the same failed item, the builder shall submit to 100% inspection of that failed item, for a minimum of seven (7) *dwelling units*, before resuming sampling of that item. Unrelated tests or inspections within the sampling controls may be conducted on a sampled basis throughout this process.
2. If the multiple "additional failures" apply to various failed items, or additional failed items are found during testing and inspection of additional *dwelling units*, sampling must be qualified anew with a minimum of 10 consecutive *dwelling units* meeting all requirements, before continuing with sampling.
3. Exception: If a builder conducts a "root cause analysis" on an item or items covered under item 1 or item 2 above, and submits it in writing to the Multifamily Sampling Provider, sampling may resume as soon as the Provider deems that the solution has been implemented. The "root cause analysis" report shall contain at a minimum:
   i. A written description of the problem(s) covered by the analysis;
   ii. A written explanation of the underlying reason(s) that the problem(s) occurred (e.g. inadequate training of subcontractor(s) or site supervisors, insufficient information or inadequate detail in the plans or specifications, etc);
   iii. A written description of a clearly defined process to correct the underlying cause(s);
   iv. A written description of when and how that process has been carried out;
   v. A copy of the root cause analysis report shall be kept by the Multifamily Sampling Provider as part of the QA file, for a period of time of three (3) years, consistent with the requirements of Chapter 1 of the RESNET Standards.

Quality Assurance by Multifamily Sampling Providers

The Multifamily Sampling Provider's QA Designee shall be responsible for monitoring compliance with the sampling process and maintaining records in accordance with the requirements of Chapter 9 of the RESNET Standards.

In addition to the Quality Assurance requirements specified in Chapter 9 for Home Energy Rating Quality Assurance Providers, a Multifamily Sampling Provider's quality assurance process shall include, at a minimum, the following:

All *dwelling units* that are certified or qualified by the use of sampling shall be considered to be "ratings". QA file review and field monitoring shall be conducted on a percentage of all the *dwelling units* certified or qualified under sampling, rather than the percentage of tested and inspected *dwelling units*.

The field QA required in Chapter 9 of the RESNET Standards may be conducted on any of the certified or qualified *dwelling units* within the sample sets, and shall not be limited to the tested and inspected *dwelling units*.

Appendix A: On-Site Inspection Procedures for Minimum Rated Features

Rated Feature	Task	On-Site Inspection Protocol
Equipment Type	Data Collection for Centralized Heating and Cooling Equipment	*Central Boilers* - Record the model number of the boiler off of the nameplate. These are typically located in a central boiler room. Record the nameplate data shown on all supporting distribution pumps (for both primary and secondary loops). *Central Chiller* - Record the model number of the chiller off of the nameplate. These are typically located on the roof or grounds of a building. Record the nameplate data shown on all supporting distribution pumps (for both primary and secondary loops) and cooling tower circulation pumps if applicable. Record the nameplate data shown on all supporting fans that are necessary for normal service operation, including cooling tower fan(s) if applicable.
	Determining terminal heating/cooling type in each *dwelling unit*	Determine the terminal heating/cooling type that is present in each *dwelling unit*. Typical terminal unit types are defined below: *Fan coil* - hot/cold water from a centralized source is circulated through a coil. A fan blows air over the coil to provide heating/cooling. This would be classified as a forced air system, but may or may not have ductwork. *Hydronic/radiant* - fluid from a boiler/chiller is pumped through a series of radiator elements to supply heating or cooling. The radiator elements may be conventional radiators, baseboard "fin tube" radiators, cast iron baseboards or radiant panels located at the baseboards or on walls or ceilings. *Water Loop Heat Pumps* - hot/cold water from a centralized source is circulated through a heat pump in each *dwelling unit*. Typically the source is a boiler/cooling tower or chiller arrangement.
	Data Collection for Centralized Domestic Hot Water Heating Systems	*Domestic Hot Water Supply Boiler with Unfired Storage Tanks* - Record the model number of the boiler(s) and the storage tanks used in this configuration. Visually determine if the storage tank is wrapped with exterior insulation. If so, measure thickness of the wrap and determine R-value. *Space Heating Boiler with Indirect Water Heater - Record the model number of the boiler(s) and the indirect water heater used in this configuration. Visually determine if the indirect water heater is wrapped with exterior insulation. If so, measure thickness of the wrap and determine R-value.* *Commercial Storage Water Heater* - Record the model number off of the nameplate of the equipment.
	Data Collection for Centralized	*Centralized exhaust fans* - Record the model number of each fan serving the *dwelling units*. These are typically located on the roof of a building. The model number can be used to determine the rated CFM and fan horsepower of the exhaust fan, unless the rated CFM and fan horsepower is noted on the nameplate of the equipment.

Rated Feature	Task	On-Site Inspection Protocol
	Ventilation Systems	*Centralized supply fans* - Record the model number of each supply fan that is intended to provide ventilation air to the *dwelling units* including air handlers that serve *residential-associated common spaces*, with the intent of serving directly or indirectly as the primary outdoor air supply for the *dwelling units*. The model numbers can be used to determine the rated CFM and fan horsepower of the supply fans.
Roof Insulation	Inspecting insulation installed on top of the roof deck	When it is possible, inspect insulation as installed. Note that all insulation installation techniques require proper care to ensure they are completed correctly; if they are not, thermal performance can suffer dramatically. Verify the insulation type, thickness, location, coverage, and installation with reference to roof insulation layout as shown on plans. Verify the thickness of the insulation by checking the depth marker which should be in place roughly every 30' or utilizing a ruler. Verify that all seams are properly sealed per manufacturer's specifications.
Infiltration	Inspecting for proper *compartmentalization* of *dwelling units*	Verify that all walls, ceilings and floors that separate each *dwelling unit* from adjacent spaces (conditioned or unconditioned, such as neighboring units, corridors, trash chutes, utility chases and trenches, upper floor, lower floors, stairwells and elevator shafts) must be air sealed to form a continuous air barrier surrounding the *dwelling unit* and connecting to the exterior enclosure air barrier of the building. Demising Wall Air Barrier - Verify that an air barrier extends completely to all adjacent walls and is connected in an air tight way to the exterior enclosure air barriers and that it extends completely to the ceiling plank (or other solid ceiling material) where drop ceilings are present. Note: Sound attenuation strategies can negatively impact *compartmentalization* - Resilient channel systems are often utilized in multifamily wall assemblies to reduce sound transmission between units. These resilient channel systems provide a 1/2" gap between the gypsum wallboard and the wall stud. In these cases, it is important that either framing strategies are utilized to negate the 1/2" gap on the perimeter of each demising wall or air tight gypsum board is installed including proper sealing of all penetrations through the gypsum board. Verify that weather-stripping is installed on all doors between dwelling units and corridors.
Conditioning of space	Determine whether a garage ceiling plenum is unconditioned or conditioned space	A garage, regardless of any space heating systems present, must be treated as unconditioned space in the Rating unless it meets all of the following criteria: *Conditioned* - The garage ceiling consists of an insulated plenum space (dropped ceiling), where the ceiling separating the plenum space from the garage consists of an air barrier, is insulated, and the vertical walls of the plenum space are insulated and in contact with an air barrier on all six sides. Under these conditions only, that plenum space is considered to be inside the thermal and pressure boundary of the building and thus the floor separating the *dwelling units* from this space can be considered adiabatic. Note: Suspended or lay-in ceiling tiles are not considered an air barrier.

Rated Feature	Task	On-Site Inspection Protocol
	Determine whether *residential-associated common spaces* in a multifamily building are unconditioned or conditioned spaces	*Unconditioned* - The exterior *residential-associated common space* walls are uninsulated and there is no mechanical equipment directly conditioning the space. Under these conditions that space is considered to be outside the thermal and pressure boundary of the building and thus the surface separating the *dwelling units* from this space must be considered as adjacent to the exterior, ambient or unconditioned space. *Conditioned* - The exterior *residential-associated common space* walls are insulated or the *residential-associated common spaces* are directly conditioned by means of a mechanical heating or cooling system. Under these conditions that space is considered to be inside the thermal and pressure boundary of the building and thus the surfaces separating the *dwelling units* from this space can be considered adiabatic.

Non Rated Feature	Task	On-Site Inspection Protocol
Lighting in the *Residential-Associated Common Spaces* of a Multifamily Building	Verifying that the common space lighting installed in a multifamily building meets the design	While lighting systems exclusively serving *residential-associated common space* are not currently included in the HERS Rating, Raters working in *multifamily residential buildings* can apply the following inspection protocols to ensure overall building performance. 1. Assemble documentation from plans, specs, and submittals 2. Check quantity, locations, unit specifications for conformance/deviation including types of fixtures, wattages of lamps, occupancy sensor locations, etc. 3. Using a light-meter, verify that interior lighting is designed to meet light levels by space types as recommended by the IESNA, Lighting Handbook, 9th edition 4. Fixtures specified with electronic ballasts should be confirmed in the field using an electronic ballast tester. Spaces specified with occupancy sensors should be verified in the field.
Air Sealing in the *Residential-Associated Common Spaces*	Inspecting a common space vestibule for proper air sealing	1. Ensure that vestibule doors have weather-stripping installed
HVAC Systems serving *Residential-Associated Common Spaces*	Inspecting common space HVAC systems and associated ductwork	While HVAC systems exclusively serving *residential-associated common space* are not currently included in the HERS Rating, Raters working in *multifamily residential buildings* should apply the same inspection protocols used for *dwelling unit* HVAC systems and associated ductwork towards the *residential-associated common space* systems to ensure overall building performance.