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Steps for Improving a Wall-vented Crawl Space

Step 1: Protect the crawl space from water sources

At a minimum, wall vented crawl spaces need a ground vapor retarder on 100% of the crawl space ground, including steep-sloped earthen walls. There should be no plumbing leaks, no intrusion of ground water, and no intrusion of water from outside. This may require:

- Adding a drainage system to manage rain water,
- fixing leaking irrigation or sprinkler systems,
- blocking off low crawl space vents that allow rainwater to enter,
- reducing flooding potential by altering the exterior grade,
- sealing off below-grade holes,
- adding or repairing a foundation drainage system,
- adding or repairing foundation waterproofing,
- fixing plumbing leaks,
- draining standing water, or
- adding an internal drain system or sump pump

Replace damaged or dirty, incomplete ground vapor retarders with a new vapor retarder that covers all soil and is secured to prevent future movement or damage. All kitchen, bathroom, and clothes dryer vents must terminate outside the crawl space. All air conditioner condensate drain lines and water heater drains must terminate outside the crawl space.

Step 2: Repair structural damage or rot

Eliminating all the sources of water listed in Step 1 will help to prevent rot from occurring in the future. If rot has occurred in the past or is ongoing, you may need to replace or repair structurally damaged framing or flooring in conjunction with completion of Step 1. In either case, Step 1 must be completed to eliminate all the sources of liquid water that caused the rot in the first place.

At this point, cleaning up surface mold in the crawl space is not worthwhile, since the air entering through the crawl space vents in spring and summer will make it possible for mold to grow. If you continue to Step 5 and convert the wall-vented crawl space to a closed design, then cleanup of surface mold growth can be effective.

Step 3: Monitor for water intrusion

Periodically inspect the improved wall-vented crawl space to ensure that all liquid water problems were successfully repaired in Step 1 and to ensure that no new problems have occurred.

Even if all the water problems were properly repaired, you may still encounter small puddles of liquid water on the top of the new vapor retarder. Where ground water is not present, the ground vapor retarder can be punctured to allow small puddles to drain into the soil. This is acceptable because a small hole lets liquid water drain out but only lets a negligible amount of water vapor diffuse into the crawl space.

You might be wondering, "Where these small puddles would come from after all the water intrusion was fixed?" At this point, the foundation vents that remain open will allow outdoor air to enter the crawl space in the spring and summer, and the water vapor in that air will condense on ductwork, water pipes, or other cool surfaces, drip down, and collect in pockets or low areas in the ground vapor retarder. (Refer to the Introduction for an explanation of why this condensation happens.) Note that operating the house at low indoor temperatures in the summer accelerates this problem, especially when the ductwork is in the crawl space, by creating more cold surfaces where condensation can occur. "Low indoor temperatures" means thermostat settings of less than 72° F/22° C in central North Carolina, but could include warmer settings in extremely humid conditions like those found in coastal environments.

Step 4: Isolate the crawl space from the house

To reduce the chance that a damp crawl space will impact the living space above, seal penetrations in the subfloor with fire-blocking materials and seal ductwork in conjunction with an overall assessment of air leakage and combustion safety in the home by a qualified building performance contractor. Sealing ductwork also reduces the leakage of cold air into the crawl space during air-conditioning periods, which reduces the amount of cold surface area that may experience condensation. For reference, see the appendix on duct sealing.

Step 5: Convert the wall-vented crawl space to a closed design

Once steps 1 and 2 are addressed, the crawl space can be closed using the design and implementation guidelines from the course outline, with these additional steps:

- Clean out debris. Remove any materials (e.g. cardboard, paper, etc.) that provide a food source for mold. Ensure that you remove any existing vapor retarder before new material is installed to avoid trapping water and debris that will allow obnoxious molds or other organisms to grow. Remove rubble to provide a smoother surface that is less likely to damage the new vapor retarder material. Ensure that any hazardous contents (e.g. asbestos, gasoline, household chemicals, etc.) are properly handled and removed. Remove any other objects that will interfere with installation of the ground vapor retarder. Abandoned heating equipment and ductwork are common finds, but everything from old tires and other trash to broken lawn equipment and children's toys are found in crawl spaces.

- Replace damaged or contaminated insulation. Porous insulation that has been wetted will likely not recover its rated R-value, even after it dries thoroughly. Support sagging batt insulation in the floor structure with tension wires (sometimes referred to as “tiger teeth”) so that the batts are in continuous contact with the subfloor but is not overly compressed. If there is so much damage that you want to replace all the insulation, use either floor or perimeter wall insulation as desired. If you choose perimeter wall insulation, consult with your pest management contractor to ensure that treatments can continue and that the new insulation will not void your insect pest warranty or bond, if applicable.
- Provide a mechanism to control or detect liquid water problems. It may not be feasible to correct interior grading or install gravity drains in retrofit situations, like when the crawl space or exterior grade is flat or in a low spot. In these situations, sump pumps or liquid water alarm systems are alternatives.
- Provide adequate combustion air for gas- or oil-fired furnaces, water heaters or boilers. Without sufficient combustion air, the appliance can produce carbon monoxide or back draft. A crawl space with atmospheric or “natural” draft equipment should not be closed. Ideally, any fuel-fired furnaces or water heaters in a closed crawl space should be of a “direct vent” (often called “two-pipe”) design, meaning that all air for combustion is piped directly from outside into the appliance and all combustion exhaust gases are piped directly from the appliance to outside. Induced-draft combustion systems may be able to operate safely in a closed crawl space with the installation of a combustion air injection system by a professional mechanical contractor. The system must ensure adequate combustion air for the appliance, and installation should include pressure testing to verify proper draft in the combustion vent pipe and proper pressure in the combustion appliance zone with reference to outside.
- Choose and install a mechanical or passive ventilation system for the crawlspace that is acceptable according to the provisions of the California Building Code and Energy Code. This may be <u>one</u> of the following methods:
    - Passively ventilate the crawlspace to the conditioned interior building space with vent openings equal to the crawlspace floor area divided by 1500.
    - Mechanically ventilate the crawlspace with conditioned air at the rate of 1 CFM of conditioned air per each 50 Square Feet of crawlspace floor area.
    - Passively ventilate the crawlspace to the exterior with automatic closeable vents at the rate of 1 SF of vent opening per each 1500 SF of crawlspace floor area. The dampers shall be closed between in the temperature range of 40 degrees F and 70 degrees F. The vents shall be positioned to provide cross ventilation.
    - Mechanically ventilate the crawlspace to the exterior with a minimum of 1 CFM of outside air per each 50 SF of crawlspace floor area.
- Be aware that objectionable odors may develop when closing an existing wet crawlspace. Advanced Energy has received five reports of strong ammonia-like odors associated with the drying-out of existing crawl spaces in North Carolina, which may be caused by the mold slowly dying or going dormant. The odors persisted for weeks or months without dissipating. Application of a fungicide in conjunction with reducing moisture levels has been reported to eliminate this problem. Some of our Sonoma County building performance contractors have had to temporarily install dehumidifiers in converted crawlspaces to dry out the framing lumber that had excessive moisture content due to the previous wet crawlspace conditions.

- Install a temperature and relative humidity monitor in the repaired or converted crawl space to verify that the improvements are effective or to indicate the need for adjustments to the drying mechanism. Wireless sensors that display the crawl space temperature and relative humidity on a receiving unit inside the house make it very easy for the homeowner or occupant to monitor those conditions. Some of these sensors include a user-adjustable alarm that will indicate when conditions exceed the desired levels.
- Decide whether or not to clean mold contamination. Once the crawl space is properly closed, cleaning up surface mold in the crawl space can be effective since the improved crawl space conditions should prevent mold growth from recurring. In general, it is not necessary to clean up mold, but there are a variety of reasons why you may want to do so.

Basic Maintenance for Crawl Spaces

Most people don't like to go into crawl spaces, but periodic inspection of any crawl space helps to ensure that any problems are caught before they cause damage. Property owners can perform these inspections and basic maintenance checks themselves or hire a private home inspector or other contractor to do it for them. Property owners should:

- Ensure that access doors are closed, especially during warm weather.
- Ensure that there are no solvents, gasoline or other potentially hazardous materials in the crawl space.
- Inspect the crawl space regularly to:
  - Identify vapor retarder damage or water problems. Note that small water leaks in a crawl space may not be caught by relative humidity sensors.
  - Ensure that no damage occurs when any contractors work in the crawl space.
  - Check and replace batteries as needed in sensors or alarms.

• Ensure that any water intrusion, especially flooding, is quickly drained or pumped out of the crawl space.

Extracted From The 2010 California Residential Code:

SECTION R316 FOAM PLASTIC

R316.1 General.

The provisions of this section shall govern the materials, design, application, construction and installation of foam plastic materials.

R316.2 Labeling and identification

Packages and containers of foam plastic insulation and foam plastic insulation components delivered to the job site shall bear the *label* of an *approved agency* showing the manufacturer's name, the product listing, product identification and information sufficient to determine that the end use will comply with the requirements.

R316.3 Surface burning characteristics

Unless otherwise allowed in Section R316.5 or R316.6, all foam plastic or foam plastic cores used as a component in manufactured assemblies used in building construction shall have a flame spread index of not more than 75 and shall have a smoke-developed index of not more than 450 when tested in the maximum thickness intended for use in accordance with ASTM E 84 or UL 723. Loose-fill type foam plastic insulation shall be tested as board stock for the flame spread index and smoke-developed index.

Exception: Foam plastic insulation more than 4 inches (102 mm) thick shall have a maximum flame spread index of 75 and a smoke-developed index of 450 where tested at a minimum thickness of 4 inches (102 mm), provided the end use is *approved* in accordance with Section R316.6 using the thickness and density intended for use.

R316.4 Thermal barrier

Unless otherwise allowed in Section R316.5 or Section R316.6, foam plastic shall be separated from the interior of a building by an *approved* thermal barrier of minimum 1/2 inch (12.7 mm) gypsum wallboard or an *approved* finish material equivalent to a thermal barrier material that will limit the average temperature rise of the unexposed surface to no more than 250°F (139°C) after 15 minutes of fire exposure complying with the ASTME 119 or UL263 standard time temperature curve. The thermal barrier shall be installed in such a manner that it will remain in place for 15 minutes based on NFPA 286 with the acceptance criteria of Section R302.9.4, FM 4880, UL 1040 or UL 1715.

R316.5.4 Crawl spaces

The thermal barrier specified in Section R316.4 is not required where all of the following apply:

1. Crawlspace access is required by Section R408.4
2. Entry is made only for purposes of repairs or maintenance.

3. The foam plastic insulation is protected against ignition using one of the following ignition barrier materials:

   3.1. 11/2-inch-thick (38 mm) mineral fiber insulation;
   3.2. 1/4-inch-thick (6.4 mm) wood structural panels;
   3.3. 3/8-inch (9.5 mm) particleboard;
   3.4. 1/4-inch (6.4 mm) hardboard;
   3.5. 3/8-inch (9.5 mm) gypsum board; or
   3.6. Corrosion-resistant steel having a base metal thickness of 0.016 inch (0.406 mm). The above ignition barrier is not required where the foam plastic insulation has been tested in accordance with Section R316.6.

SECTION R408 UNDER-FLOOR SPACE

R408.1 Ventilation

The under-floor space between the bottom of the floor joists and the earth under any building (except space occupied by a *basement*) shall have ventilation openings through foundation walls or exterior walls. The minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m2) for each 150 square feet (14 m2) of under-floor space area, unless the ground surface is covered by a Class 1vapor retarder material. When a Class 1 vapor retarder material is used, the minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m2) for each 1,500 square feet (140 m2) of under-floor space area. One such ventilating opening shall be within 3 feet (914 mm) of each corner of the building.

R408.2 Openings for under-floor ventilation

The minimum net area of ventilation openings shall not be less than 1 square foot (0.0929m2) for each 150 square feet (14m2) of under-floor area. One ventilation opening shall be within 3 feet (915 mm) of each corner of the building. Ventilation openings shall be covered for their height and width with any of the following materials provided that the least dimension of the covering shall not exceed 1/4 inch (6.4 mm):

1. Perforated sheet metal plates not less than 0.070 inch (1.8 mm) thick.
2. Expanded sheet metal plates not less than 0.047 inch (1.2 mm) thick.
3. Cast-iron grill or grating.
4. Extruded load-bearing brick vents.
5. Hardware cloth of 0.035 inch (0.89 mm) wire or heavier.
6. Corrosion-resistant wire mesh, with the least dimension being 1/8 inch (3.2 mm) thick.

Exception: The total area of ventilation openings shall be permitted to be reduced to 1/1,500 of the under-floor area where the ground surface is covered with an *approved* Class I vapor retarder material and the required openings are placed to provide cross ventilation of the space. The installation of operable louvers shall not be prohibited.

R408.3 Unvented crawl space

Ventilation openings in under-floor spaces specified in Sections R408.1 and R408.2 shall not be required where:

1. Exposed earth is covered with a continuous Class I vapor retarder. Joints of the vapor retarder shall overlap by 6 inches (152 mm) and shall be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches (152 mm) up the stem wall and shall be attached and sealed to the stem wall; and

2. One of the following is provided for the under-floor space:

2.1. Continuously operated mechanical exhaust ventilation at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7m2) of crawlspace floor area, including an air pathway to the common area (such as a duct or transfer grille). *Crawl space* perimeter walls *shall be* insulated in accordance with *the minimum insulation requirements established in the California Energy Code. Crawl space insulation shall be permanently fastened to the wall and extend downward from the floor to the finished grade level and then vertically and/or horizontally for at least an additional 24 inches (610 mm)*.

2.2. *Conditioned air* supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m2) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille). *Crawl space* perimeter walls *shall be* insulated in accordance with *the minimum insulation requirements established in the California Energy Code. Crawl space insulation shall be permanently fastened to the wall and extend downward from the floor to the finished grade level and then vertically and/or horizontally for at least an additional 24 inches (610 mm).*

2.3. Plenum in structures complying with *the California Mechanical Code*, if under-floor space is used as a plenum.

Extracted from 2008 California Residential Energy Compliance Manual:

Page 3-54, Building Envelope Requirements – Insulation

Controlled Ventilation Crawlspace

> *CVC Eligibility Criteria in 2008 Reference Residential Appendix RA4.5.1*

The Energy Commission has approved an exceptional method for buildings with raised floors that use foundation wall insulation and have automatically controlled crawl-space vents. The method is available as an option using the performance method. Refer to Figure 3-22.

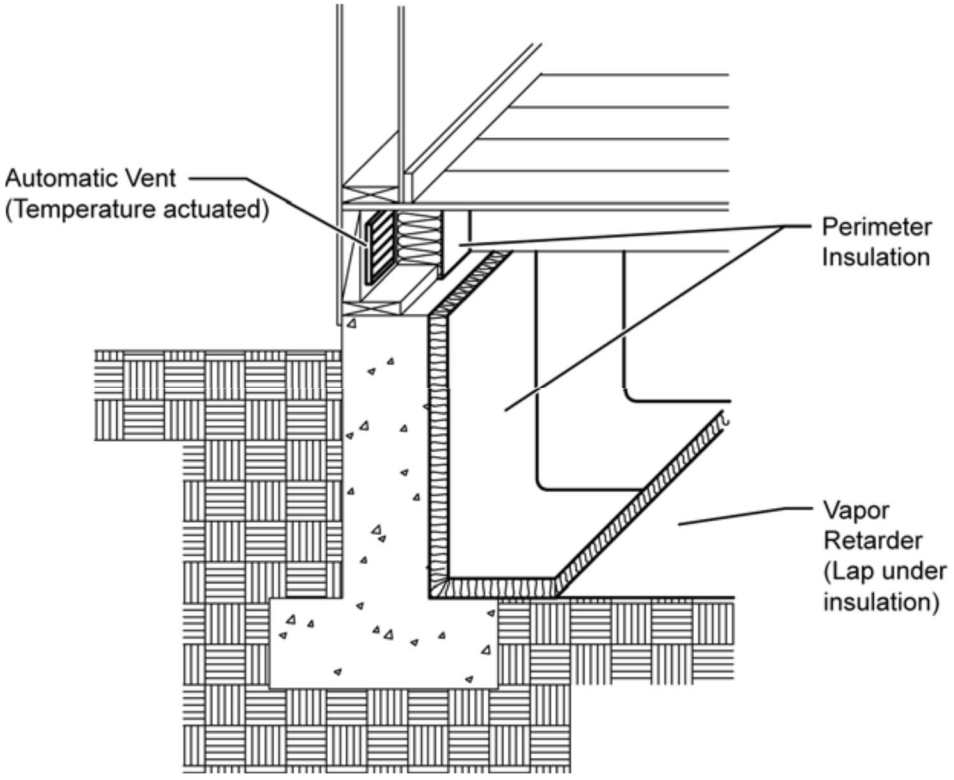

Figure 3-22 – Controlled Ventilation Crawl Space

The following eligibility criteria (from the 2008 Reference Residential Appendix RA4.5.1) are required in order to take credit for a controlled ventilation crawlspace:

1. **Drainage.** Proper enforcement of site engineering and drainage, and emphasis on the importance of proper landscaping techniques in maintaining adequate site drainage, is critical.

2. **Ground Water and Soils.** Local ground water tables at maximum winter recharge elevation should be below the lowest excavated site foundation elevations. Sites that are well drained and that do not have surface water problems are generally good candidates for this stem-wall insulation strategy. However, the eligibility of this alternative insulating technique is entirely at the building officials' discretion. Where disagreements exist, it is incumbent upon the applicant to provide sufficient proof that site drainage strategies (e.g., perimeter drainage techniques) will prevent potential problems.
3. **Ventilation.** All crawl space vents must have automatic vent dampers to receive this credit. Automatic vent dampers must be shown on the building plans and installed. The dampers should be temperature actuated to be fully closed at approximately 40°F and fully open at approximately 70°F. Cross ventilation consisting of the required vent area reasonably distributed between opposing foundation walls is required.
4. **Foam Plastic Insulating Materials.** Foam plastic insulating materials must be shown on the plans and installed when complying with the following requirements:
    - Fire Safety—CBC Section 1712(b)2. Products shall be protected as specified. Certain products have been approved for exposed use in under floor areas by testing and/or listing.
    - Direct Earth Contact—Foam plastic insulation used for crawl-space insulation having direct earth contact shall be a closed cell water resistant material and meet the slab-edge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory measures.
5. **Use of a Vapor Barrier (Ground Cover).** A ground cover of 6 mil (0.006 inch thick) polyethylene, or approved equal, must be laid entirely over the ground area within crawl spaces:
    - The vapor barrier must be overlapped 6 inch minimum at joints and must extend over the top of pier footings.
    - The vapor barrier should be rated as 1.0 perm or less.
    - The edges of the vapor barrier should be turned up a minimum of 4 inches at the stem wall.
    - Penetrations in the vapor barrier should be no larger than necessary to fit piers, beam supports, plumbing and other penetrations.
    - The vapor barrier must be shown on the plans and installed.
    - If the crawl space ground slopes, the vapor barrier should be spiked in place with 5 inch gutter nails.

Extracted from 2008 California Reference Appendices:

Appendix RA4 – Eligibility Criteria for Energy Efficiency Measures

RA4.5 Other Measures

RA4.5.1 Controlled Ventilation Crawlspace (CVC).

Drainage: Proper enforcement of site engineering and drainage, and emphasis on the importance of proper landscaping techniques in maintaining adequate site drainage, is critical.

Ground Water and Soils. Local ground water tables at maximum winter recharge elevation should be below the lowest excavated site foundation elevations. Sites that are well drained and that do not have surface water problems are generally good candidates for this stem-wall insulation strategy. However, the eligibility of this alternative insulating technique is entirely at the enforcement agency officials' discretion. Where disagreements exist, it is incumbent upon the applicant to provide sufficient proof that site drainage strategies (e.g., perimeter drainage techniques) will prevent potential problems.

Ventilation: All crawl space vents must have automatic vent dampers to receive this credit. Automatic vent dampers must be shown on the building plans and installed. The dampers should be temperature actuated to be fully closed at approximately 40°F and fully open at approximately 70°F. Cross ventilation consisting of the required vent area reasonably distributed between opposing foundation walls is required.

Foam Plastic Insulating Materials: Foam plastic insulating materials must be shown on the plans and installed when complying with the following requirements:

Fire Safety—CBC Section 719: Products shall be protected as specified. Certain products have been approved for exposed use in under floor areas by testing and/or listing.

Direct Earth Contact: Foam plastic insulation used for crawl-space insulation having direct earth contact shall be a closed cell water resistant material and meet the slab-edge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory measures.

RA4.5.2 Mineral Fiber Insulating Materials

Fire Safety—CBC Section 719: "All insulation including facings, such as vapor barriers or breather papers installed within ... crawl spaces ... shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with ASTM E 84." In cases where the facing is also a vapor retarder, the facing shall be installed to the side that is warm in winter.

Direct Earth Contact: Mineral fiber batts shall not be installed in direct earth contact unless protected by a vapor retarder/ground cover.

Vapor Barrier (Ground Cover): A ground cover of 6 mil (0.006 inch thick) polyethylene, or approved equal, shall be laid entirely over the ground area within crawl spaces. The vapor barrier shall be overlapped 6 inches minimum at joints and shall extend over the top of pier footings. The vapor barrier should be rated as 1.0 perm or less. The edges of the vapor barrier should be turned up a minimum of four inches at the stem wall. Penetrations in the vapor barrier should be no larger than necessary to fit piers, beam supports, plumbing and other penetrations. The vapor barrier must be shown on the plans and installed.

Studies show that moisture conditions found in crawl spaces that have minimal ventilation do not appear to be a significant problem for most building sites provided that the crawl-space floors are covered by an appropriate vapor barrier and other precautions are taken. The Energy Commission urges enforcement agency officials to carefully evaluate each application of this insulating technique in conjunction with reduced ventilation because of the potential for adverse effects of surface water on crawl-space insulation that could negate the energy savings predicted by the procedure.

Extracted From the 2008 Residential ACM Manual:

5.8 Controlled Ventilation Crawl Spaces (CVC)

5.8.1 Measure Description

A controlled ventilation crawlspace has insulation installed in the side walls of the crawlspace, instead of in the floor that separates conditioned space from the crawlspace. In addition, special dampers are used to provide the required ventilation for the crawlspace which open when it is warm and close when it is cold.

Eligibility criteria for this measure are presented in the Reference Residential Appendix RA4.

5.8.2 Algorithms and Modeling Assumptions

CVC requires that the compliance program have the capability of modeling two thermal zones. The house itself if modeled as a conditioned zone and the crawlspace is modeled as an unconditioned zone.

5.8.3 Test Description

To test this optional capability the compliance program vendor shall model prototype B in climate zones 3, 9, 12, 14, and 16. The CVC to be modeled shall have the following features:

- The CVC unconditioned zone has an exterior perimeter length and floor area (i.e., the ground area) equal to the prototype building B. Crawlspace volume is 3,467 ft3.
- CVC infiltration is modeled using the air changes per hour method and uses 0.22 air changes per hour.
- The floor separating the crawl space from conditioned space is an inter-zone boundary with a U-value of 0.238, representing an un-insulated floor (see Table 4.4.2-A1 from Reference Joint Appendix JA4).
- Insulation that meets the floor insulation requirements used for compliance is placed in the perimeter walls of the crawl space.
- The crawl space vents are modeled with automatic temperature operated louvers.
- When the building is in a heating mode, the vents are assumed to be closed (inlet and outlet are zero). When the building is in a cooling mode, the vents are assumed to be open and the total vent area is 1/150 of the crawlspace floor area or 10.67 ft2. Half of this is inlet and half outlet.
- The ventilation height difference between the inlets and the outlets is zero. Only wind effects apply. Wind speed is reduced to 25 percent of that on the weather tape to account for ground level conditions.
- Heat capacity in the crawlspace is 1.4 Btu/F-ft^2 of crawlspace area.

This system is expected to produce a positive compliance margin. The heating equipment AFUE is then reduced to find the passing solution and the failing solution. The Energy Commission reference method must pass the passing solution and fail the failing solution.

In addition, the vendor shall demonstrate that the compliance program correctly defines the standard design building and calculates the custom budget. The vendor shall create and run the standard design equivalent building for climate zone 12. The proposed design and standard design TDV energy for the be equal. The TDV energy from the standard design equivalent must also equal the standard design TDV energy for this test.