Gas-Fired Boilers

Last Updated: 06/09/2017

Scope

Choose the highest performing boiler that project funding will allow to meet the design heating load of the project. The highest performance boilers are sealed-combustion, direct-vent boilers, which can have Annual Fuel Utilization Efficiencies (AFUE) exceeding 94%. These are also the safest boilers to install within a home because they draw combustion air from and release combustion byproducts directly to the outdoors.

Calculate the heating load for the home and properly size the boiler and distribution system to meet this load. Look at the boiler’s output rating and if the design load is equal to or lower than the equipment’s lowest output rating, consider alternative heating equipment options that better match the design load of the home.

Select a boiler with a modulating burner for increased efficiency.


Set equipment control settings to optimize system efficiency. See the Building America report Condensing Boilers – Control Strategies for Optimizing Performance for guidance.

For condensing boilers, install an outdoor reset control to match system output to actual load and recommend that homeowners do not use a night-time temperature setback strategy. Select settings for the boiler reset curve and flow rates to optimize the performance in the system and to ensure that the return temperatures are low enough to promote condensing (Arena 2012).

Design an efficient zoned distribution system with a compact piping layout, insulated pipes, and correctly sized equipment for the radiators, baseboards, convectors, or radiant floor loop system. For hydro coil forced-air heating systems, design a compact duct layout following the Air Conditioning Contractors of America (ACCA)’s Manual S duct sizing guidelines and install ducts properly in accordance with ACCA Manual D for maximum airflow and efficiency.

If you are participating in an energy-efficiency program, select a boiler whose efficiency complies with the requirements for your climate zone, as described in the Compliance tab.

To determine your climate zone, see the International Energy Conservation Code (IECC) climate zone map on the Climate tab.

See the Compliance Tab for related codes and standards requirements, and criteria to meet national programs such as DOE’s Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.
According to the U.S. Energy Information Administration (EIA), up to 11% of existing households use some form of hot water or steam heat (EIA 2009). Boilers produce hot water that can be used to heat homes through several different distribution methods. The hot water can be sent through plastic pipe loops in the floor for radiant floor heat or through metal radiators mounted along the wall or baseboard radiators mounted near the floor. Hot water can also be directed from a combustion tank water heater to a coil in an air handler equipped with a fan to blow air across the coil and through supply air ducts to the home. Most combustion boilers are fueled by natural gas. Fuel oil, propane, and wood are other fuel sources used in locations where natural gas is not readily available. The hot water for a boiler may also be heated or preheated by a solar thermal water heating system, a ground-source (geothermal) heat pump, or an air-source heat pump. The boiler may heat water in a tank or it may be a tankless (instantaneous) wall-hung model. Some boilers provide heat for a potable hot water tank in addition to providing hot water to room heaters; this is referred to as indirect water heating. Some newer, very efficient models combine space heating, water heating, and heat recovery ventilation.

For best performance, the heating system should be properly sized to match the heating design load of the home, as described below. If the home is constructed with high levels of insulation and air sealing, a smaller heating system can often be installed. When equipment is oversized, it can “short cycle,” or turn on and off repeatedly before the demand is met, which can have negative impacts on energy use, comfort, and equipment durability.

Combustion boilers, furnaces, and water heaters are classified by the International Mechanical Code (IMC) and in the National Fuel Gas Code. Understanding the descriptions of these appliance types based on both codes is important with respect to safety and efficiency.

The International Mechanical Code classifies boilers based on vent type: direct, mechanical, or atmospheric. Per the 2009 and 2012 International Mechanical Code, Chapter 2 Definitions:

- a direct-vent appliance is one that is constructed and installed so that all air for combustion is derived from the outdoor atmosphere and all flue gases are discharged to the outside atmosphere;
- a mechanical draft system is a venting system designed to remove flue or vent gases by mechanical means consisting of
  - an induced draft portion under non-positive static pressure; or, a forced draft portion under positive static pressure;
- a natural draft system is a venting system designed to remove flue or vent gases under non-positive static vent pressure entirely by natural draft.

The 2015 National Fuel Gas Code (NFPA 54) puts furnaces in four categories based on flue vent pressures, flue gas temperatures (relates to condensing or non-condensing), and vent pipe materials, as shown in Table 1.

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<thead>
<tr>
<th>Flue Negative Pressure</th>
<th>Flue Positive Pressure</th>
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<tr>
<td><strong>Non-Condensing</strong></td>
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<tr>
<td>Category I Vented Appliance</td>
<td>An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.</td>
</tr>
<tr>
<td>Category II Vented Appliance</td>
<td>An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that can cause excessive condensate production in the vent.</td>
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<tr>
<td><strong>Condensing</strong></td>
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<tr>
<td>Category III Vented Appliance</td>
<td>An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.</td>
</tr>
<tr>
<td>Category IV Vented Appliance</td>
<td>An appliance that operates with a positive vent static pressure and with a vent gas temperature that can cause excessive condensate production in the vent.</td>
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</tbody>
</table>

Table 1. The National Fuel Gas Code (NFPA 54) identifies four categories for combustion furnaces and water heaters based on combustion type (sealed or unsealed), vent pipe pressure, and vent pipe temperature.

The lowest efficiency boilers are atmospherically vented, Category I boilers. A Category I boiler operates with the flue at negative pressure with respect to the combustion appliance zone (CAZ), i.e., the room in which the boiler is located, and the stack temperature is above 140°F, which is hot enough to avoid condensation in the vent. The burner draws its combustion air from the CAZ. The combustion chamber is also open to the CAZ; i.e., if you are standing next to the boiler, you can peer in and see the burner and the flames.
Older Category I boilers use an open draft hood that allows dilution air to enter the vent pipe and mix with the exhaust gases (Figure 1). A draft diverter at the base of the flue protects the flame from downdrafts coming down the chimney or flue. These older boilers are not mechanically drafted but are called natural draft (or atmospheric draft) because they rely entirely on high flue temperatures (relative to outside temperatures) to draw exhaust gases up and out of the flue. Because so much of the heat goes up the chimney, natural draft boilers have very low Annual Fuel Utilization Efficiency (AFUE) ratings, usually 70% or less.

A newer type of Category I boiler replaced the draft hood with a small fan, referred to as an induced draft fan, which pulls air through the combustion chamber, although the boiler still relies on flue temperatures to lift the combustion gases up the flue stack. The induced draft fan helps to prevent back drafting on startup and assists in getting the draft started. Once the vent pipe gets up to temperature (140°F+), a draft is established and the pressure inside the vent pipe (on the positive side of the fan) becomes negative with respect to the CAZ. The induced draft fan did away with the draft hood and dilution air, which wasted energy. Category I boilers that incorporate an induced draft fan typically have cleaner or more complete combustion than their older counter parts and therefore expel less pollutants in the air. The improved Category I boilers and furnaces also have an electronic ignition rather than a standing pilot light. Induced draft Category I boilers can have efficiencies of 78% to 83%.

ENERGY STAR permits naturally drafted boilers in IECC climates zones 1 through 3 and the DOE Zero Energy Ready Home program permits them in climates zones 1 and 2, if they have an AFUE of ≥ 80%. However, draft-hood-equipped boilers are very unlikely to exceed 70% efficiency, so essentially all ≥ 80% boilers and furnaces are induced draft or power vented or direct vent. When naturally drafted boilers and furnaces are installed, a combustion safety test must be performed.

An induced draft fan-equipped boiler or furnace is considered mechanically drafted. However, because it is still open combustion (i.e., it draws its combustion air from the CAZ) and because it relies on negative flue pressure to carry away combustion byproducts, it can, like the naturally vented boiler or furnace, have the potential to backdraft. Backdrafting, when combustion gases spill down into the CAZ rather than going out the flue, can occur if the CAZ becomes depressurized with respect to the flue. Several things could cause this to occur – running multiple exhaust fans and the dryer and the fireplace all at the same time, for example.

Figures 1 and 2 below are Category I boilers. The boiler in Figure 1 uses the older technology of a draft hood, which pulls dilution air into the vent pipe. The newer boiler in Figure 2 replaces the draft hood with a small induced-draft fan that pulls the products of combustion through the combustion chamber and flue by pushing the byproducts of combustion out through the vent pipe.

![Figure 1](image_url) In a Category I gas-fired, natural-draft boiler, the natural draft of the heated flue pulls combustion air through the draft hood into the combustion chamber. (Image courtesy of Calcs Plus)
Figure 2. A Category I induced draft boiler uses an induced draft fan to pull air through the combustion chamber and to the flue. (Image courtesy of Calcs Plus)

Category II applies to some commercial furnaces but no residential appliances.

A Category III combustion appliance has a vent pipe that is under positive pressure and the appliance is non-condensing, meaning its flue gases only go through one heat exchanger then exit through the vent at temperatures above 140°F. Category III appliances may include instantaneous gas water heaters and gas- or oil-fired boilers. For further discussion of oil-fired boilers, see the guide Oil-Fired Boilers.

Category IV boilers are combustion appliances that have a vent pipe under positive pressure and flue gases under 140°F. The vent exhaust is low temperature because Category IV appliances are equipped with two heat exchangers (or sometimes one extra-large heat exchanger). In the second heat exchanger any remaining heat in the combustion air is extracted and water vapor (a byproduct of combustion) cools and condenses to liquid water. This liquid is drained to the sewer or outside through a condensate drain. The condensate is highly acidic (pH ? 3) so local code may require that it be pretreated before disposing to the sewer. (See Condensing Boilers.)

Category III and Category IV boilers are both forced draft (also referred to as power vented) appliances meaning that they are equipped with a combustion fan that is located before the burner to push air through the combustion chamber and out of the vent (Figure 5). The fan is continually operating when the burner is firing so the vent stack pressure is always positive. The byproducts of complete combustion are CO₂, H₂O, and N.

Category IV boilers, like Category III boilers, vent their combustion exhaust gases directly outside through a sealed pipe so they cannot be back drafted. Category III and IV appliances should be installed as sealed-combustion/direct vent appliances, which means their combustion chamber is sealed off from the CAZ and they draw their combustion air from outside via a second vent pipe or concentric pipes that bring combustion air directly to the combustion chamber from outside the home. However, although manufacturers do not recommend it, they are sometimes installed as non-direct-vent appliances (where the exhaust pipe is installed but the pipe for incoming air is not installed so the boiler draws its combustion air from the CAZ).

Category IV boilers can be either gas fired or oil fired. For more information on oil boilers refer to the guide Oil-Fired Boilers. For more on Category IV boilers see Condensing Boilers.

Since 1992, the U.S. Department of Energy (DOE), under the National Appliance Energy Conservation Act, has required that small gas boilers have an AFUE of at least 80%. In November 2007, the DOE established a revised minimum efficiency standard of 82% for residential boilers, which will take effect in November 2015. To be ENERGY STAR labeled, a boiler must have an efficiency of 85% or higher.

ENERGY STAR for Homes (Version 3, Rev 08) allows gas and oil furnaces and boilers to be 80% AFUE in Climate Zones 1, 2, and 3. In Climate Zones 4-8, ENERGY STAR requires that boilers be 85% and ENERGY STAR labeled.

The DOE Zero Energy Ready Home program allows 80% AFUE boilers in Climate Zones 1 and 2 only. In Climate Zones 3 and 4 (except marine climate zone 4), boilers must have an AFUE of 90% and in Climate Zones 5 through 8 (plus marine climate zone 4), boilers must have an AFUE of 94%.

Boiler Controls

While older boilers are either on or off, newer boilers with multi-stage or modulating burners have adjustable output to better match heating loads. This reduces the number of on-off cycles (and cycling losses) and allows the boiler to operate for longer hours at lower firing rates, which improves efficiency. Non-modulating boilers have efficiencies of 85% to 90%. Boilers that operate in modulation mode rather than just on-off can improve average boiler efficiency by up to 8%. Higher-efficiency models are also equipped with electronic controllers that can increase equipment life, improve boiler efficiency, and enhance comfort, by
adjusting boiler water temperature, creating time-delay relays, performing automatic post-purge, preventing warm-weather boiler operation, controlling the position of mixing valves, and controlling pump speeds. These controls can increase the efficiency of noncondensing boilers by 10% or more and reduce idle losses to 0.3%. Condensing gas boilers that are fully modulating and have advanced controls can achieve efficiencies ranging from 92% to 96%.

There are many settings that can be adjusted on a modern boiler to improve the efficiency and comfort performance of the equipment; these adjustments may provide better performance than the default factory settings.

An outdoor reset control, which matches the system output to the actual outdoor temperature conditions, will improve comfort for owners of both condensing and non-condensing equipment by preventing extreme spikes in indoor temperature when the outdoor temperatures are warmer than design conditions. If you install an outdoor reset, recommend that homeowners do not use a night-time temperature setback strategy unless special controls have been installed that can override the reset control. Locate the outdoor sensor where it will not be exposed to a heat source such as direct sunlight or a dryer exhaust vent.

When installing an outdoor reset control with a noncondensing boiler, choose settings so that the return temperature to the boiler is no lower than 140°F to prevent condensing. However, when selecting the outdoor reset curve set points for a condensing boiler, choose settings so that the temperature of the water returning to the boiler is below 130°F. This ensures that the return temperatures are low enough to promote condensing, which will greatly increase the energy efficiency of the system (see Arena 2012 for more details). To ensure the return temperature is below 130°F, the supply temperature will likely have to be reduced to below the factory setting. Make sure the heat emitters used (baseboards, radiators, etc.) are properly sized based on the average temperature in the distribution loop. If undersized, they won’t release enough heat to the space and the water will return to the boiler at too high a temperature, preventing condensing. Radiant floor systems are typically set up to run at lower temperatures when installed, so they do not require additional adjustment to the boiler’s supply temperature.

If you are specifying toe kick heaters in homes that have condensing boilers with outdoor reset controls, make sure the toe kick model specified is capable of operating at low temperatures. Many of the toe kick heaters currently available will not operate below a supply temperature of 140°F. A properly designed and configured condensing hydronic system will have return temperatures below 130°F most of the year, leaving the occupants without heat in rooms with toe kick heaters.

In highly insulated, energy-efficient homes with correctly sized equipment, nighttime setback can cause comfort issues and customer complaints. A boiler that is correctly sized to meet the home’s design heating load will not have enough capacity to recover from the setback in a reasonable amount of time, especially if the system is designed with an outdoor reset control. Outdoor reset controls match the boiler’s supply temperature to the heating load based on the current outdoor conditions, severely hindering the system’s ability to raise the temperature in the space. If the boiler was set up with an outdoor reset control and no capability to override it, advise homeowners not to set their thermostat temperature back during nighttime hours. This is also recommended if the home is highly energy efficient and the boiler was sized to meet the design heating load.

If you know that the homeowner will employ a setback strategy or if you would like to provide that capability, you can install controls to speed up temperature recovery such as 1) a boost control that automatically raises the boiler output target temperature if heating demand is not satisfied within a set number of minutes, 2) an indoor sensor that works with the outdoor reset control to compensate for lags in response based on interior temperature, or 3) a simple manual override switch. Oversizing the heat emitters and possibly the boiler may be necessary to meet the additional load induced during periods of setback recovery.

If the boiler is oversized compared to the design load, oversizing the heat emitters will help reduce short cycling of the boiler. This may be the only option in situations where the smallest boilers are too large for the design load or there are several zones, each of which has very small loads compared to the boiler’s capacity. In these cases, oversizing the emitters will reduce cycling, improve response time, and increase efficiency. Note that many manufacturers set a maximum temperature difference between the boiler’s supply and return to protect the heat exchanger. Oversizing the heat emitter will result in an increase in the delta T, so make sure that you do not oversize to the point that the manufacturer’s limit is exceeded. If installing a non-condensing boiler, make sure that increasing the emitter does not result in return water temperatures below 140°F.

For both condensing and noncondensing boilers, a warm weather shutoff turns off the boiler when the temperature setting is exceeded by the outdoor temperature. Boilers commonly come from the factory with the shutoff set between 68°F and 72°F. In locations with large day-night temperature swings or in spring and fall in homes that use a setback, if the shutoff is set too low, warm midmorning outside temperatures could prevent the heat from coming on even if it is still cold inside. Make sure the warm weather shutoff setting is no lower than the desired indoor winter temperature. For example, if 70°F is the normal setting, the warm weather shutoff should be no lower than 70°F.

Make sure your system includes an automatic post-purge control, which keeps the system pump on for several minutes after the boiler stops firing to disperse the heat still residing in the mass of the boiler.

Some boiler manufacturers have started offering controls that can limit the boiler’s maximum input. This can be especially useful if the boiler is used for both space heating and domestic hot water and one load is significantly less than the other. This limit reduces cycling in situations where the boiler’s maximum firing rate is significantly higher than the demand, for example if when the water heater is calling for heat but the space heater is not.

Heat dumping is a strategy that diverts excess boiler heat to the domestic hot water (DHW) tank after the space heating demand is satisfied. Studies have shown this technique can greatly improve overall system efficiency (Butcher 2011).

See the Building America measure guideline report: Condensing Boilers—Optimizing Efficiency and Response Time During Setback Operation for additional guidance on setting boiler controls.
Distribution

One of the big advantages of hot water heating is the ease with which it can be zoned. Radiant heating systems in older homes were often set up in a series with a single pipe going from the boiler to first one radiator than the next (with subsequent loss of temperature in each successive emitter). But newer distribution systems feature parallel or primary-secondary piping arrangements with separate zones that can be controlled by separate thermostats to easily accommodate different temperature set points and schedules.

**Typical Parallel Loop Piping**

![Typical Parallel Loop Piping Diagram](image1)

**Figure 3.** Boilers can provide zoned heating with parallel piping loops. (Image courtesy of Calcs Plus)

**Primary and Secondary Loops**

![Primary and Secondary Loops Diagram](image2)

**Figure 4.** A boiler system can be set up with primary and secondary loops to supply hot water for multiple uses. (Image courtesy of Calcs Plus)
How to Select and Install a Boiler

1. Choose the highest performing boiler that project funding will allow to meet the design heating load of the project. If you are participating in an energy-efficiency program, select a boiler that complies with the requirements for your climate zone, as described in the Compliance tab.


3. Design an efficient distribution system that allows for zoning.

4. Properly size the boiler by first calculating the heating load of the home. Calculate heat load as described in the ASHRAE Fundamentals Handbook. Many software products are also available that can guide you through the calculations, and several boiler manufacturers include sizing guidelines or software on their web sites. If the design load is equal to or lower than the selected boiler’s lowest output rating, consider alternative low-load heating equipment options that better match the design load of the home.

5. Install the boiler as a direct-vent installation where combustion air is piped directly to the boiler combustion chamber from outside. If the boiler must use the CAZ for combustion air, verify that required combustion air is provided in the CAZ and perform a combustion safety test after installation. room. See methods for calculating and providing combustion air in the guide Combustion Furnaces.
6. Select appropriate vent piping in accordance with the National Fuel Gas Code (see the Compliance tab).

7. Set the equipment control settings to optimize system efficiency as described above and in Arena 2012.

8. If your boiler heats a hydro coil for forced air heating, see Compact Air Distribution and Proper Sizing of HVAC Ducts.

9. After the boiler is installed and before the initial filling, fill the system with water plus a cleaning solution. Allow this to circulate for several hours to remove grease, oil, and chemicals from solder and flux. Drain then fill with clean water. If the city water is corrosive, include an initial treatment. If properly installed, the boiler should operate indefinitely without needing additional water or cleaning.

10. For condensing boilers, ensure that condensate drains properly to the sewer or directly outdoors. Because the condensate is highly acidic, follow local code requirements regarding pretreatment of condensate before disposing to the sewer. Protect the condensate line from freezing. Provide a secondary (emergency) drain pan constructed of durable material.

11. Verify correct boiler operation by testing the outdoor reset control, and evaluating the boost control if one is installed.
Ensuring Success

Choose a Category IV high-efficiency, sealed-combustion, direct-vent system whenever possible.

Verify that the boiler is not oversized for the home’s heating load.

If you choose a Category I or non-direct vented boiler (not recommended), before installation, calculate the required adequate combustion air for the selected boiler model and verify that that amount is provided in the CAZ. If the boiler is a Category I boiler, a BPI- or RESNET-certified rater should perform a combustion safety test after installation.

For Category IV boilers, ensure that the horizontal portion of the exhaust vent pipe slopes slightly toward the boiler. Follow local code requirements regarding whether the condensate should be drained to the sewer and treated before draining to reduce its acidity. Ensure that the condensate line is in a location where it will not freeze. Also ensure that a drain pan is installed under the boiler as a backup measure.

After installation, inspect to verify the following in accord with ACCA Standard 5: HVAC Quality Installation Specification and the ACCA’s Technician’s Guide for Quality Installations and ACCA Standard 9: HVAC Quality Installation Verification Protocols. These standards address quality installation and commissioning requirements for vapor compression cooling systems, heat pumps, and combustion and hydronic heating systems.

- Verify that any baseboard emitters installed are large enough to deliver the capacity needed.
- Ensure a minimum of a 20°F temperature differential between the supply and return temperatures under design conditions.
- Verify that the warm weather shutoff is high enough to prevent no-heat situations during the swing seasons.
- Verify that the outdoor reset sensor has been placed away from any exhaust vents including kitchen, bath, dryer, and mechanical system vents and that it will not be in direct sunlight during any portion of the day.
Rater Field Checklist

HVAC System.
10.1 Furnaces, boilers, and water heaters located within the home’s pressure boundary are mechanically drafted or direct-vented. Alternatives in Footnote 57, 55, 56, 57

Footnote 57) Naturally drafted equipment is allowed within the home’s pressure boundary in Climate Zones 1-3 if the Rater has followed Section 802 of RESNET’s Standards, encompassing ANSI / ACCA 12 QH-2014, Appendix A, Sections A3 (Carbon Monoxide Test) and A4 (Depressurization Test for the Combustion Appliance Zone), and verified that the equipment meets the limits defined within.

Please see the Compliance Tab for more ENERGY STAR Certified Homes and DOE Zero Energy Ready Home program requirements.

To determine your climate zone, see the International Energy Conservation Code (IECC) climate zone map.
Training

Right and Wrong Images

Display Image: 2015_Amaris7_mechanical.jpg
None Available
Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

ENERGY STAR Certified Homes, Version 3/3.1 (Rev. 09)

The ENERGY STAR Reference Design Home is the set of efficiency features modeled to determine the ENERGY STAR ERI [energy rating index] Target for each home pursuing certification. Therefore, while the features below are not mandatory, if they are not used then other measures will be needed to achieve the ENERGY STAR ERI Target. In addition, note that the Mandatory Requirements for All Certified Homes, Exhibit 2 [see list below], contain additional requirements such as total duct leakage limits, minimum allowed insulation levels, and minimum allowed fenestration performance. Therefore, EPA recommends that partners review the documents in Exhibit 2 prior to selecting measures.

Please note that the Reference Design Home HVAC efficiencies for Version 3.1 differ from those for Version 3.0. Please see the ENERGY STAR Certified Homes Implementation Timeline for the program version and revision currently applicable in your state.

### Exhibit 2: Mandatory Requirements for All Certified Homes Version 3/3.1 (Rev. 09)

<table>
<thead>
<tr>
<th>Party Responsible</th>
<th>Mandatory Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rater</td>
<td>• Completion of National Rater Design Review Checklist</td>
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<tr>
<td></td>
<td>• Completion of National Rater Field Checklist</td>
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<td>HVAC Installing Contractor</td>
<td>• Completion of National HVAC Commissioning Checklist</td>
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<tr>
<td>Builder</td>
<td>• Completion of National Water Management System Builder Requirements</td>
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Version 3.0 - Exhibit 1: ENERGY STAR Reference Design Home (Source: ENERGY STAR Certified Homes, Version (Rev. 09))

Version 3.1 - Exhibit 1: ENERGY STAR Reference Design Home (Source: ENERGY STAR Certified Homes, Version (Rev. 09))

Exhibit 2 of the National Program Requirements for ENERGY STAR Certified Homes Version 3/3.1 (Rev. 09) requires that homes complete the following checklists:
Rater Field Checklist

HVAC System.

10.1 Furnaces, boilers, and water heaters located within the home’s pressure boundary are mechanically drafted or direct-vented. Alternatives in Footnote 57.

Footnote 57) Naturally drafted equipment is allowed within the home’s pressure boundary in Climate Zones 1-3 if the Rater has followed Section 802 of RESNET’s Standards, encompassing ANSI / ACCA 12 QH-2014, Appendix A, Sections A3 (Carbon Monoxide Test) and A4 (Depressurization Test for the Combustion Appliance Zone), and verified that the equipment meets the limits defined within.

DOE Zero Energy Ready Home (Revision 07)

Exhibit 1 Mandatory Requirements.
Exhibit 1, Item 1) Certified under the ENERGY STAR Qualified Homes Program or the ENERGY STAR Multifamily New Construction Program.

Exhibit 2 DOE Zero Energy Ready Home Target Home.
The U.S. Department of Energy’s Zero Energy Ready Home program allows builders to choose a prescriptive or performance path. The DOE Zero Energy Ready Home prescriptive path requires builders to meet or exceed the minimum HVAC efficiencies listed in Exhibit 2 of the National Program Requirements (Rev 07), as shown below. The DOE Zero Energy Ready Home performance path allows builders to select a custom combination of measures for each home that is equivalent in performance to the minimum HERS index of a modeled target home that meets the requirements of Exhibit 2 as well as the mandatory requirements of Zero Energy Ready Home Exhibit 1.

### Exhibit 2: DOE Zero Energy Ready Home Target Home

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DOE ZERH Target Home HVAC Equipment Requirements (Source: DOE Zero Energy Ready Home (Revision 07))

ACCA Standards

**ACCA Manual S, Residential Equipment Selection**, ANSI/ACCA 3-Manual S-2004, provides information on how to select and size heating and cooling equipment to meet Manual J loads based on local climate and ambient conditions at the building site. Manual S covers sizing strategies for all types of cooling and heating equipment, as well as comprehensive manufacturers’ performance data on sensible, latent, or heating capacity for various operating conditions.

**ACCA Manual D: Residential Duct Systems**, ANSI/ACCA 1-Manual D-2011, provides ANSI-recognized duct sizing principles and calculations that apply to all duct materials; the system operating point (supply cfm and external static pressure) and airway sizing for single-speed and multi-speed (ECM) blowers; a method for determining the impact of duct friction and fitting pressure drop on blower performance and air delivery; and equivalent length data.


**ACCA Standard 5: HVAC Quality Installation Specification**, ANSI/ACCA 5 QI-2010, details nationally recognized criteria for the proper installation of residential and commercial HVAC systems, including forced air furnaces, boilers, air conditioners, and heat pumps. The Standard covers aspects of design, installation, and distribution systems, as well as necessary documentation. The Technician’s Guide for Quality Installation, produced by ACCA, explains the HVAC Quality Installation (QI) Specification and provides detailed procedures for the steps technicians must complete and document to show compliance with the HVAC QI Specification.

**ACCA Standard 9: HVAC Quality Installation Verification Protocols**, ANSI/ACCA 9 QIVP-2009, specifies the protocols to verify the installation of HVAC systems in accordance with ACCA Standard 5. The protocols provide guidance to contractors, verifiers, and administrators who participate in verification efforts using independent objective and qualified third parties to ensure that an HVAC installation meets the requirements in Standard 5.
The products of combustion from a gas-fired furnace (non-condensing) are vented out of the building using specific types of vent pipes made up of different materials depending on the flue gas temperatures, as specified in ANSI Z223.1, the National Fuel Gas Code (NFPA-54 2015), "Table 12.5.1 Type of Venting System to Be Used." Table 2 shows appropriate venting materials for residential vented combustion appliances, excerpted from the NFPA Table 12.5.1.

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<thead>
<tr>
<th>Appliance</th>
<th>Type of Venting System</th>
<th>NFPA Section Location</th>
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<td>Chimney</td>
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<td>Single-wall metal pipe</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>Listed chimney lining system for gas venting</td>
<td>12.6.1.3</td>
</tr>
<tr>
<td></td>
<td>Special gas vent listed for these appliances</td>
<td>12.5.4</td>
</tr>
<tr>
<td>Category III appliances</td>
<td>As specified or furnished by manufacturers of listed appliances</td>
<td>12.5.2, 12.5.4</td>
</tr>
<tr>
<td>Category IV appliances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listed combination gas- and oil-burning appliances</td>
<td>Type I vent Chimney</td>
<td>12.7, 12.6</td>
</tr>
<tr>
<td>Direct vent appliances</td>
<td></td>
<td>12.3.5</td>
</tr>
</tbody>
</table>

Table 2. Acceptable Venting Types for Different Combustion Appliance Types, excerpted from NFPA 54 2012, the National Fuel Gas Code, Table 12.5.1.

See the National Fuel Gas Code for additional relevant requirements.

RESNET Mortgage Industry National Home Energy Rating Systems Standards

Procedures and technical standards by which home energy ratings are conducted including home energy audits.

2009 IECC

403.1 Each heating and cooling system should have its own thermostat.

403.2 Ducts - Insulate supply ducts in attics to at least R-8 and all other ducts to at least R-6. Duct tightness shall be verified as described in 403.2.2 Sealing.

403.3 Mechanical system piping capable of carrying fluids >105°F or < 55°F must be insulated to at least R-3.

403.6 Heating equipment sizing shall be in accordance with Section M1401.2 of the International Residential Code.

2012 IECC

R403.1 Each heating and cooling system should have its own programmable thermostat.

R403.2 Ducts - Insulate supply ducts in attics to at least R-8 and all other ducts to at least R-6. Duct tightness shall be verified as described in 403.2.2 Sealing. The air handler shall have a manufacturer's designation showing air leakage is no more than 2% of the design air flow rate when tested in accordance with ASHRAE 193.

R403.3 Mechanical system piping capable of carrying fluids >105°F or < 55°F must be insulated to at least R-3. Piping insulation exposed to weather must be protected from damage cause by sunlight, moisture, equipment, and wind. The protection cannot be provided by adhesive tape.

R403.6 Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methods.

2015 and 2018 IECC

R403.1 Each heating and cooling system should have its own thermostat. If the primary heating system is a forced-air furnace at
least one thermostat must be programmable.

R403.2 Hot water boilers that supply heat to the building through one- or two-pipe heating systems shall have an outdoor setback control that lowers the boiler water temperature based on the outdoor temperature.

Section 403.3 Insulation (Prescriptive). Supply and return ducts in attics insulated to at least R-8 if 3 inches in diameter or more or R-6 if less than 3 inches. All other ducts insulated to at least R-6 if 3 inches in diameter or more and R-4.2 if less than 3 inches. Duct tightness verified as described in R403.3.2 Sealing. The air handler shall have a manufacturer’s designation showing air leakage is no more than 2% of the design air flow rate when tested in accordance with ASHRAE 193.

R403.4 Mechanical system piping capable of carrying fluids >105°F or < 55°F must be insulated to at least R-3. Piping insulation exposed to weather must be protected from damage caused by sunlight, moisture, equipment, and wind. The protection cannot be provided by adhesive tape.

403.7 Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methods.


Section R101.4.3 (Section R501.1.1 in 2015 and 2018 IECC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)


Comply with all relevant sections of the applicable International Residential Code, including pertinent sections of Chapter 13: General Mechanical System Requirements, Chapter 14: Heating and Cooling Equipment, Chapter 20 Boilers and Water Heaters, Chapter 21 Hydronic Piping, and Chapter 24 Fuel Gas.


Section N1101.3 (Section N1107.1.1 in 2015 and 2018 IRC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)

Appendix J regulates the repair, renovation, alteration, and reconstruction of existing buildings and is intended to encourage their continued safe use.


Comply with all relevant sections. Note, Chapter 2 - Definitions defines categories of combustion appliances based on venting type.

Gas-Fired Boilers - Code Compliance Brief

Overview:

The intent of this brief is to provide code-related information about gas-fired boilers to help ensure that the measure will be accepted as being in compliance with the code. Providing notes for code officials on how to plan reviews and conduct field inspections can help builders or remodelers design installations and prepare construction documents, and provide jurisdictional officials with information for reviews, inspection and acceptance. Providing the same information to all interested parties (e.g., code officials, builders, designers, etc.) is expected to result in increased compliance and fewer innovations being questioned at the time of plan review and/or field inspection.

A boiler typically uses a fuel such as natural gas, propane, or fuel oil in a vented combustion chamber, much like a furnace. Whereas a furnace directly transfers heat from combustion to supply air in the air distribution unit, a boiler heats a secondary transfer fluid (typically water, but sometimes steam) that is, in turn, pumped through a radiation/convection system located throughout a building or home. The hot water can also be used to heat air via a coil and blower. Boilers are more commonly used in commercial construction than residential construction, but they may be more prevalent in residential construction in some areas of the country and in older homes. Boilers are typically between 75% and 96% efficient in the primary process of heating the water, but any un-insulated heating water piping will lower the overall efficiency of space heating.

In addition to the boiler unit, a gas-fired boiler requires a feed water supply, a boiler loop/heat delivery system (e.g., hydronic radiators or fan coil units), fuel supply piping and equipment, and a temperature control system. The chapters of the International Residential Code (IRC) that are likely relevant to the installation of a gas-fired boiler include Chapter 13, General Mechanical System Requirements; Chapter 14, Heating and Cooling Equipment; Chapter 20, Boilers and Water Heaters; Chapter 21, Hydronic Piping, and Chapter 24, Fuel Gas.

The relevant energy-efficiency sections of the 2015 International Energy Conservation Code (IECC) and IRC (Chapter 11, Energy Efficiency) that relate to gas-fired boilers include Section R403, Systems (IECC) and N1103, Systems (IRC). For existing buildings, new heating and cooling systems that are part of a remodel or alteration or an addition must comply with Section R502/N1108 with the exception of where ducts from an existing heating and cooling system are extended to an addition, duct systems with less than 40 linear feet in unconditioned spaces are not required to be tested per R502.1.1.2/N1108.1.1.2.
The Energy Efficiency provisions related to hot water boilers for the 2009, 2012, and 2015 code versions have mostly remained the same except for inclusion of an outdoor setback control requirement to control the water temperature based on the outdoor temperature. This specific requirement, which was added in the 2015 version, is detailed below under the Plan Review and Field Inspection sections.

The focus of this brief is on boiler efficiency, sizing requirements, controls, combustion air, and duct and pipe insulation for the 2015 version of the IECC/IRC.

**Plan Review:**

Per the 2015 IECC/IRC, Section R103.3/R106.3, Examination of Documents. The code official/building official must examine, or cause to be examined, construction documents for code compliance.

This section lists the applicable code requirements followed by details helpful for plan review regarding the provisions to meet the requirements for “gas-fired boilers.”

**Construction Documentation.** Review the construction documents to identify the equipment, system controls, design, and ventilation choices to the equipment.

- **2015 IECC/IRC, Section R103.2/N1101.5, Information on Construction Documents.** Construction documents should include:
  - Insulation materials and their R-values
  - Mechanical system design criteria
  - Mechanical system equipment types, sizes, and efficiencies
  - Equipment and system controls
  - Duct sealing, duct and pipe insulation and location
  - Air sealing details
  - Flashing and moisture control.

- **2015 IRC** requirements for gas-fired boiler installations are found throughout Chapter 13, General Mechanical System Requirements; Chapter 14, Heating and Cooling Equipment; Chapter 20, Boilers and Water Heaters; Chapter 21, Hydronic Piping; and Chapter 24, Fuel Gas. This section lists the applicable IRC and IECC code sections.

— 2015 IRC, Sections M2001, General, and G2404, General. Boilers should be designed and constructed in accordance with the requirements of ASME CSD-1, and gas-fired boilers should conform to the requirements listed in Chapter 24 of the IRC. Gas-fired boilers should be listed and labeled in accordance with IRC M1302.1, and should be installed:

1. In accordance with the manufacturer's instructions G2408.
2. On level platforms in accordance with Section G2408.4
3. With proper clearances as specified in Sections G2408.4 and G2408.5
4. With shutoff valves in the supply and return piping per Sections M2001.3 and G2420
5. With operating and safety controls in accordance with Sections M2002 and G2421
6. So openings in exterior walls are flashed in accordance with Section R703.4
7. To protect the potable water supply in accordance with Section P2902
8. So air intake openings are located are in accordance with Section R303.5.1
9. With circuit breakers that are sized in accordance with equipment data plate per manufacturer's installation instructions and electrical connections that conform to requirements of Part VIII (Electrical) of the IRC.
10. With expansion tanks that have been specified to meet minimum capacity requirements per Section M2003.1 and, M2003.2. Minimum requirements (as listed in Table M2003.2) are specified below:

Expansion Tank Minimum Capacitya for Forced Hot-Water Systems

<table>
<thead>
<tr>
<th>System Volumeb</th>
<th>Pressurized Diaphragm Type</th>
<th>Nonpressurized Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>20</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>30</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>40</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>50</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>60</td>
<td>6.0</td>
<td>7.0</td>
</tr>
<tr>
<td>70</td>
<td>7.5</td>
<td>8.0</td>
</tr>
<tr>
<td>80</td>
<td>8.5</td>
<td>9.0</td>
</tr>
<tr>
<td>90</td>
<td>9.0</td>
<td>10.0</td>
</tr>
<tr>
<td>100</td>
<td>10.5</td>
<td>11.5</td>
</tr>
<tr>
<td>110</td>
<td>11.0</td>
<td>12.0</td>
</tr>
<tr>
<td>120</td>
<td>12.0</td>
<td>13.0</td>
</tr>
<tr>
<td>130</td>
<td>13.0</td>
<td>14.0</td>
</tr>
<tr>
<td>140</td>
<td>14.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

— 2015 IRC, Section G2408.4, Clearance from grade. Equipment and applications supported from the ground should be level and firmly supported on a level concrete slab or other approved material extending not less than 3 inches (76 millimeters) above adjoining grade or should be suspended not less than 6 inches (152 millimeters) above adjoining grade. Such support should be in accordance with the manufacturer's installation instructions.

— 2015 IRC, Section G2408.2, Elevation of Ignition Source. Installations within a garage should have ignition source raised 18 inches from the floor, and the boiler should be protected from impact.

— 2015 IRC, Sections G2406 and G2407.2, Appliance Location. Appliances shall not be located in sleeping rooms, bathrooms, toilet rooms, storage closets, or surgical rooms, or in a space that opens only into such rooms or spaces. Appliances should be located so as not to interfere with proper circulation of combustion, ventilation and dilution air.

Equipment Controls. Review the construction documents and confirm that controls have been installed in accordance with manufacturer instructions. The furnace pressure switch and control shall be a control with persistence of 30 psig. System volume includes volume of water in boiler, convectors, and piping, not including the expansion tank.

— 2015 IECC/IRC, Section R403.1/N1103.1, Controls. Each heating and cooling system should have its own thermostat. Each thermostat controlling the primary heating and cooling system should be a programmable thermostat.

Hot water boilers that supply heat to the building through one- or two-pipe heating systems should have an outdoor reset control that lowers the boiler water temperature based on the outdoor temperature per R403.2/N1103.2.

Equipment Sizing. Verify that the boiler is sized based on building loads calculated in accordance with ACCA Manual J or other approved methods (IECC R403.7/IRC M1401.3 and N1103.7).

— 2015 IECC/IRC, Section R403.7/N1103.7, M1401.3, Sizing. Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methods.

Mounting. Verify equipment is correctly supported and installed in the structure.
Ventilation. Chapter 24, Fuel Gas, in the 2015 IRC is extracted from the 2015 edition of the International Fuel Gas Code (IFGC) and contains specific combustion air and ventilation requirements for gas-fired appliances, such as boilers. Boilers can be vented with a conventional chimney system or through a balanced flue system for direct venting through the wall. Review the construction documents and verify that the ventilation system has been installed in accordance with manufacturer installation instructions.

— 2015 IRC, Section G2407 (304), Combustion, Ventilation, and Dilution Air. The section numbers appearing in parentheses after each section number are the section numbers of the corresponding text in the IFGC. Air for combustion, ventilation, and dilution of flue gases for appliances installed in buildings should be provided by application of one of the methods prescribed in Section G2407.5 through G2407.9 of the IRC. Outdoor air should be introduced in accordance with one of the methods prescribed below:

1. G2407.6 (304.6), Outdoor Combustion Air. Outdoor combustion air provided through opening(s) to the outdoors. The minimum dimension of air openings should not be less than 3 inches. Review and confirm that the construction documents specify the combustion air opening(s) meet one of the methods below.
   - G2407.6.1 (304.6.1), Two-Permanent-Openings Method. Section R703.4 Flashing. Approved corrosion resistant flashing should be applied in shingle fashion to prevent entry of water into the wall cavity or penetration of water to the building structural framing components.
   - G2407.6.2 (304.6.2), One-Permanent-Opening Method. Within 12 inches of the ceiling (top of enclosure) and appliance have clearances of at least 1 inch from the sides and back and 6 inches from the front of the appliance directly communicating with the outdoors or through a vertical or horizontal duct to the outdoors or spaces that freely communicate with the outdoors with a minimum free area of 1 square inch per 3000 Btu/h of total input rating of all appliances located in the enclosure and not less than the sum of the areas of all vent connectors in the space.

2. G2407.9 (304.9), Mechanical Combustion Air Supply. Where combustion air is provided by a mechanical air supply system, the combustion air should be supplied from the outdoors at a rate not less than 0.35 cubic feet per minute per 1000 Btu/h of total input rating of all appliances located within the space.

— 2015 IRC, Sections M1801and G2426.1, General. Fuel-burning appliances shall be vented to the outdoors in accordance with their listing and label and manufacturer’s installation instructions. Venting systems shall consist of approved chimneys or vents, or venting assemblies that are integral parts of labeled appliances.

— 2015 IRC, Section G2427.4, Type of Venting System to be Used. The type of venting system to be used should be in accordance with Table G2427.4. See the following table.

<table>
<thead>
<tr>
<th>Type of Venting System to be Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appliances</td>
</tr>
<tr>
<td>— Listed Category I appliances</td>
</tr>
<tr>
<td>— Listed appliances equipped with draft hood</td>
</tr>
<tr>
<td>— Appliances listed for use with Type B gas vent</td>
</tr>
<tr>
<td>— Type B gas vent (Section G2427.6)</td>
</tr>
<tr>
<td>— Chimney (Section G2427.5)</td>
</tr>
<tr>
<td>— Single wall metal pipe (Section G2427.7)</td>
</tr>
<tr>
<td>— Listed chimney lining system for gas venting (Section G2427.5.2)</td>
</tr>
<tr>
<td>— Special gas vent listed for these appliances (Section G2427.3.2)</td>
</tr>
<tr>
<td>— Listed direct-vent appliances should be installed in accordance with the manufacturer’s instructions and Section G2427.8.</td>
</tr>
<tr>
<td>— As specified or furnished by manufacturers of listed appliances</td>
</tr>
</tbody>
</table>

— 2015 IRC, Sections G2427.8, Venting System Termination Location. The location of the venting system termination should conform to the requirements for Type B gas vents specified in Section G2427.8.

— 2015 IRC, Section G2427.9, Condensation Drainage. Condensate drainage system should be installed to collect and dispose of condensate from venting system.
Fuel Supply

— 2015 IRC, Section G2420, Gas Shutoff Valves. Piping systems should be provided with shutoff valves that are constructed of materials compatible with the piping and should comply with the standard that is applicable for the pressure and application as specified by ANSI/ASME® Valve Standards. Shutoff valves should be accessible and should not be located in furnace plenums or concealed locations.

— 2015 IRC, Section G2421, Flow Controls. Line pressure regulators should be listed as complying with ANSI Z21.80 and should be accessible and installed where the boiler is designed to operate.

— 2015 IRC, Section G2422, Appliance Connections. Gas-fired boilers should be fuel supply connectors should be protected against physical damage and installed in accordance with manufacturer’s instructions. The boiler should be connected to the gas supply piping system by one of the following:
  - Rigid metallic pipe and fittings
  - Corrugated stainless steel tubing

• Hydronic Piping and Distribution Systems. Review the construction documents and confirm the specified sizes, capacities, and R-value of insulation.

— 2015 IRC, Section M2101. Hydronic piping should be installed per M1308 and M2101. Materials should conform to Table M2101.1. Pipe and fittings should be rated for use at the operating temperature and pressure of the hydronic system. Piping Supports should be of material and strength adequate to support the piping and should be supported at intervals not exceeding the spacing specified in Table M2101.9 (see table below).

Hanger Spacing Intervals

<table>
<thead>
<tr>
<th>Piping Material</th>
<th>Maximum Horizontal Spacing (ft)</th>
<th>Maximum Vertical Spacing (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSClosed-cell rigid</td>
<td>4</td>
<td>10a</td>
</tr>
<tr>
<td>CPVC (1 ¼ inch)</td>
<td>4</td>
<td>10a</td>
</tr>
<tr>
<td>Copper or copper alloy pipe</td>
<td>4</td>
<td>10a</td>
</tr>
<tr>
<td>Copper or copper alloy pipe, with every eighth pipe</td>
<td>4</td>
<td>10a</td>
</tr>
<tr>
<td>M203.2.1, Slab-on-grade.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M203.2.2, Suspended floor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEX less than 1 inch pipe</td>
<td>2.67</td>
<td>4</td>
</tr>
<tr>
<td>PP more than 1 ¼ inches</td>
<td>4</td>
<td>10a</td>
</tr>
<tr>
<td>PVC</td>
<td>4</td>
<td>10a</td>
</tr>
</tbody>
</table>

• Flashing/Moisture Control. Verify that the design and specification of the weather-resistive covering, water-resistive barrier, and drainage are specified on the construction documents and meet applicable codes.

— 2015 IRC, Section R303.6, Outside Opening Protection. Air exhaust and intake openings that terminate outdoors should be protected against corrosion-resistant screens, louvers, or grills having a minimum opening size of ¼ inch (6 millimeters) and a maximum opening size of 1 inch (25 millimeters). In any direction. Openings should be protected against local weather conditions. Outdoor air exhaust and intake openings should meet the provisions for exterior wall opening protection in accordance with this code.

— 2015 IRC, Section R703.4, Flashing. Approved corrosion-resistant flashing should be applied shingle-fashion to prevent water from entering wall cavities or from penetrating into building structural framing components. Self-adhered flashing must comply with AAMA® 711. Fluid-applied membranes used as flashing in exterior walls should comply with AAMA 714. The flashing should extend to the surface of the exterior wall finish or to the water-resistive barrier. For this code, approved corrosion-resistant flashings should be installed at all wall and roof intersections.

• Potable Water System Protection. Verify that potable water connections to the equipment are correct.

— 2015 IRC, Section P2902.1, General. A potable water supply system should be designed and installed as to prevent contamination from non-potable liquids, solids, or gases being introduced into the potable water supply. Connections should not be made to a potable water supply in a manner that could contaminate the water supply or provide cross-connection between the supply and a source of contamination except where approved methods are installed to protect the potable water supply. Cross-connections between an individual water supply and a potable public water supply should be prohibited.

• Mechanical System Ducts. If ducts are employed as part of the installation, review the construction documents and confirm the specified R-value of insulation for air ducts.
Insulation

- **2015 IECC/IRC, Section R403.4/N1103.4. Mechanical system piping insulation.** Mechanical system piping capable of carrying fluids >105°F or <55°F must be insulated to at least R-3.
  - **R403.4.1/N403.4.1 Protection of piping insulation.** Piping insulation exposed to weather must be protected from damage caused by sunlight, moisture, equipment, and wind. The protection cannot be provided by adhesive tape.

- **2015 IECC/IRC, Section R403.3.1/N1103.3.1, Ducts. Insulation.**
  - Supply and return ducts installed in attics should be insulated to R-8 if ducts are >3 inches in diameter or to R-6 if ducts are <3 inches in diameter.
  - Supply and return ducts installed in other portions of the building should be insulated to R-6 if ducts are >3 inches in diameter R-4.2 if ducts are <3 inches in diameter.
  
    **Exception:** Ducts or portions thereof located completely inside the building thermal envelope.

- **Duct Leakage/Air Sealing.** Review the construction documents and confirm that the appropriate level of duct sealing is used based on the code to be applied. Be aware that current codes require duct tightness beyond just mechanical sealing of joints and that leakage be verified via field testing, and supporting documentation be provided to the code official. The code official should consider transmitting the jurisdictional requirements during the plan review phase.

  - **2015 IECC/IRC, Section R403.3.2/N1103.2.2, Sealing.** Ducts, air handlers, and filter boxes should be sealed. Joints and seams should comply with the International Mechanical Code (IMC) or IRC, Section M1601.4.1, as applicable.

  **Exceptions:**
  1. Application of air-impermeable spray foam products should be permitted without additional joint seals.
  2. For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), additional closure systems should not be required for continuously welded joints and seams, and locking-type joints and seams of other than the snap-lock and button-lock types.

Existing Buildings and Replacement. New boilers that are part of an addition shall comply with new construction sections of the code. An exception is, when ducts are used as part of an existing heating and cooling system and are extended to an addition, a duct system with less than 40 linear feet in unconditioned spaces does not need to be tested. Replacement boilers should be installed in accordance with relevant standards including ACCA Standard 5: HVAC Quality Installation, Specification and the ACCA’s Technician’s Guide for Quality Installations, and ACCA Standard 9: HVAC Quality Installation Verification Protocols.7

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1. American Society of Mechanical Engineers (ASME) Combustion Side Control (CSC) – 1
2. American Society of Mechanical Engineers (ASME) and American National Standard Institute (ANSI) as directed in Table G2420.1.1.1 of the IRC.
5. AAMA – American Architectural Manufacturers Association L (Underwriters Laboratory) is a global independent safety science company that certifies, validates, tests, inspects, audits, and advises and trains.

Field Inspection:

Per the **IECC, Section R104, Inspections.** Construction or work for which a permit is required is subject to inspection. Construction or work is to remain accessible for inspection purposes until the inspection is complete and the work approved. Required inspections include footing and foundation, framing and rough-in work, plumbing rough-in, mechanical rough-in, and final inspection.

Per the **IRC, Section R109, Inspections.** The wording is somewhat different in that, for onsite construction, from time to time the building official, upon notification from the permit holder or his agent, can make, or cause to be made, any necessary inspections. Further details are provided for inspections regarding the foundation, plumbing, mechanical, gas and electrical, floodplain, frame and masonry, and final inspection. Any additional inspections are at the discretion of the
This section provides details for inspecting to the specific provisions for gas-fired boilers where one or more specific type of inspection per the IECC or IRC may be necessary to confirm compliance. The mechanical rough-in and/or final inspection would be most likely the inspections to confirm code compliance for “gas-fired boilers.”

Inspections should provide verification in the following areas:

- Boiler is properly located and mounted, and connections are made per approved construction documents. Proper clearances are maintained for hazardous or noxious fumes.
- Verification that appropriate thermostats and outside-air heating-water-reset controls are installed per approved construction document.
- Confirmation that shutoff valves are readily accessible and that piping is properly installed and insulated, including pipe hangers at correct spacing.
- All intake and exhaust openings are properly located and flashed to prevent moisture incursion.
- If employed, radiant system is installed in accordance with manufacture’s installation instructions and R-values of insulation meet the approved R-value per construction documents.
- If ducts are used in the installation, verify that joints and seams in ductwork are properly sealed, and the duct tightness report is complete and has been submitted per jurisdictional requirements.
- Verify that pumps are listed and labeled and conform to approved construction documents.

Technical Validation(s):

This section provides additional information and helpful resources

- To ensure optimal boiler installations, refer to the following guides:

- For additional information and illustrations on boiler controls, see:
  — Boiler Reset Control Overview (ESC): http://cleanboiler.org/learn-about/boiler-efficiency-improvement/efficiency-index/boiler-reset-control/
  — Illustrations of boiler reset controls can be seen at: http://cleanboiler.org/learn-about/boiler-efficiency-improvement/efficiency-index/boiler-reset-control/

  Author: Air-Conditioning Heating and Refrigeration Institute
  Publication Date: April 2009

  Author: PNNL
  Publication Date: September 2013

  Author: PNNL
  Publication Date: September 2013

  Author: CARB
  Publication Date: November 2013

  Author: American Society of Mechanical Engineers
  Publication Date: January 2012
Case Studies

   
   **Author(s):** PNNL  
   **Organization(s):** PNNL  
   **Publication Date:** September, 2013  
   
   Case study of a DOE Zero Energy Ready Home in west Connecticut that scored HERS 39 without solar PV. The 3,000 ft2 two-story home has R-33 double-walls, R-72 flat roof with closed-cell foam and blown cellulose, an ERV, and LED lighting.

   
   **Author(s):** PNNL  
   **Organization(s):** PNNL  
   **Publication Date:** September, 2013  
   
   Case study of a DOE Zero Energy Ready in Long Island, NY, that scored HERS 43 without PV. This 5,088 ft2 custom home has R-25 double-stud walls, a vaulted roof with R-40 blown cellulose, R-10 XPS under slab, a hydro air system with 91% efficient boiler for forced air and radiant floor heat, and 100% LED lights.

3. **New Whole-House Solutions Case Study: The Performance House: A Cold Climate Challenge Home, Old Greenwich, Connecticut**
   
   **Author(s):** CARB  
   **Organization(s):** CARB  
   **Publication Date:** November, 2013  
   
   Case study about a high performance test home incorporating best practices for energy efficiency.

4. **Technology Solutions Case Study: Optimizing Hydronic System Performance in Residential Applications, Ithaca, New York**
   
   **Author(s):** CARB  
   **Organization(s):** CARB  
   **Publication Date:** November, 2013  
   
   Case study about maximizing efficiency of hydronic systems in single and multifamily buildings.

References and Resources*

1. **2009 IECC - International Energy Conservation Code**
   
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** January, 2009  
   
   Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

2. **2009 International Mechanical Code**
   
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** January, 2009  
   
   Code containing 2009 ICC language for mechanical draft systems.

3. **2009 IRC - International Residential Code for One and Two Family Dwellings**
   
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** January, 2009  
   
   Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.
2012 IECC - International Energy Conservation Code
Author(s): International Code Council
Organization(s): ICC
Publication Date: January, 2012
Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

5. 2012 International Mechanical Code
Author(s): International Code Council
Organization(s): ICC
Publication Date: April, 2011
Internationally, code officials recognize the need for a modern, up-to-date mechanical code addressing the design and installation of mechanical systems through requirements emphasizing performance. The International Mechanical Code®, in this 2009 edition, is designed to meet these needs through model code regulations that safeguard the...

6. 2012 IRC - International Residential Code for One and Two Family Dwellings
Author(s): International Code Council
Organization(s): ICC
Publication Date: January, 2012
Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

7. 2015 IECC - International Energy Conservation Code
Author(s): International Code Council
Organization(s): ICC
Publication Date: May, 2014
Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

8. 2015 International Mechanical Code
Author(s): International Code Council
Organization(s): ICC
Publication Date: May, 2014
Standard addressing the design and installation of mechanical systems through requirements emphasizing performance, public health, and safety.

9. 2015 IRC - International Residential Code for One and Two Family Dwellings
Author(s): International Code Council
Organization(s): ICC
Publication Date: May, 2014
Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

Author(s): International Code Council
Organization(s): ICC
Publication Date: November, 2017
Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems, and service water heating systems in homes and commercial businesses.

11. 2018 International Mechanical Code
Author(s): International Code Council
Organization(s): ICC
Publication Date: August, 2017
Standard addressing the design and installation of mechanical systems through requirements emphasizing performance, public health, and safety.

12.
2018 IRC - International Residential Code for One and Two Family Dwellings
Author(s): International Code Council
Organization(s): ICC
Publication Date: August, 2017
Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

13. ACCA Manual D - Residential Duct Systems
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: December, 2013
Standard outlining industry procedure for sizing residential duct systems.

14. ACCA Manual J - Residential Load Calculation
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: January, 2011
Standard covering equipment sizing loads for single-family-detached homes, small multi-unit structures, condominums, town houses and manufactured homes.

15. ACCA Manual S - Residential Equipment Selection
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: April, 2013
Standard covering sizing strategies for all types of cooling and heating equipment, as well as how to use comprehensive manufacturer's performance data on sensible, latent, or heating capacity for various operating conditions.

16. ACCA Standard 12: Home Evaluation and Performance Improvement
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: July, 2014
This Standard establishes the minimum requirements to evaluate a residence with regards to energy efficiency, water conservation, occupant comfort, and indoor air quality.

17. ACCA Standard 5: HVAC Quality Installation Specification
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: January, 2015
Standard providing a universally accepted definition for quality installation for residential and commercial heating, ventilating, and air conditioning applications.

18. ACCA Standard 9: HVAC Quality Installation Verification Protocols
Publication Date: January, 2016
Document detailing the requirements, roles, and obligations for participants in an organized effort, ensuring that HVAC installations comply with the ANSI/ACCA 5 QI – 2010 (HVAC Quality Installation Specification) QI Standard.

19. ASHRAE Handbook - Fundamentals
Author(s): ASHRAE
Organization(s): ASHRAE
Publication Date: January, 2017
Guidebook covering basic principles and data used in the HVAC&R industry.

20. Boilers, Baseboard Radiation, Finned Tube (Commercial) Radiation, and Indirect-Fired Water Heaters
Author(s): Air-Conditioning Heating and Refrigeration Institute
Organization(s): Air-Conditioning Heating and Refrigeration Institute
Publication Date: April, 2009
This directory contains the I=B=R Ratings for cast-iron, steel, aluminum and copper boilers, baseboard and finned tube radiation, indirect-fired water heaters, effective as of the date of this publication.

21.
Building America Best Practices Series Volume 12: 40% Whole-House Energy Savings in the Cold and Very Cold Climates
Author(s): Baechler, Gilbride, Hefty, Cole, Love
Organization(s): Pacific Northwest National Laboratory, Oak Ridge National Laboratory
Publication Date: February, 2011
Guide describing measures that builders in the cold and very cold climates can take to build homes that have whole-house energy savings of 40% over the Building America benchmark with no added overall costs for consumers.

22. Controls and Safety Devices for Automatically Fired Boilers
Author(s): American Society of Mechanical Engineers
Organization(s): American Society of Mechanical Engineers
Publication Date: January, 2012
Standard covering requirements for the assembly, installation, maintenance, and operation of controls and safety devices on automatically operated boilers directly fired with gas, oil, gas-oil, or electricity, having fuel input ratings under 12,500,000 Btu/hr.

23. EIA Residential Energy Consumption Survey 2009
Author(s): EIA
Organization(s): EIA
Publication Date: January, 2009
Federal statistics about national energy consumption in residential homes.

24. How to Perform a Heat-Loss Calculation Part I
Author(s): Holladay
Organization(s): Green Building Advisor
Publication Date: April, 2012
Website blog with guidance about calculating heat-loss.

Author(s): International Code Council
Organization(s): ICC
Publication Date: January, 2012
Standard document with information about the international fuel gas code.

Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: January, 2009
Standard technical manual with information about HVSC balancing, testing air and hydronic systems.

27. Measure Guideline: Condensing Boilers - Control Strategies for Optimizing Performance and Comfort in Residential Applications
Author(s): Arena
Organization(s): CARB, Steven Winter Associates, SWA
Publication Date: May, 2013
Document intended for designers and installers of hydronic heating systems interested in maximizing the overall system efficiency of condensing boilers when coupled with baseboard convectors. It is applicable to new and retrofit projects.

28. Measure Guideline: Condensing Boilers - Optimizing Efficiency and Response Time During Setback Operation
Author(s): Arena
Organization(s): CARB, Steven Winter Associates, SWA
Publication Date: February, 2014
Report providing step-by-step instructions for heating contractors and hydronic designers for selecting the proper control settings to maximize system performance and improve response time when using a thermostat setback.

29. Modern Hydronic Heating for Residential and Light Commercial Buildings
Author(s): Siegenthaler
Organization(s): Delmar CENGAGE Learning
Publication Date: January, 2012
Book with in-depth information about hydronic systems for residential and commercial buildings.

Author(s): RESNET
Organization(s): RESNET
Publication Date: January, 2013
RESNET standards aimed to ensure that accurate and consistent home energy ratings are performed by accredited home energy rating providers through their raters nationwide.

31.
**NFPA 54: National Fuel Gas Code**
Author(s): National Fire Protection Association  
Organization(s): National Fire Protection Association  
Publication Date: January, 2018  
*Code outlining minimum safety requirements for the design and installation of fuel gas piping systems in homes and other buildings.*

32. **Technician's Guide for Quality Installation**  
Author(s): Air Conditioning Contractors of America  
Organization(s): ACCA  
Publication Date: January, 2010  
The Technician's Guide equips practitioners with the knowledge to properly implement all of the measurement procedures required in the HVAC QI Specification.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.*

**Contributors to this Guide**  
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