STANDARD

ANSI/ASHRAE Standard 103-2017
(Supersedes ANSI/ASHRAE Standard 103-2007)

Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers

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ANSI/ASHRAE Standard 103-2017, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers

NOTE

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FOREWORD

ASHRAE Standard 103 is an industry standard specifying the method of testing for determining the annual fuel utilization efficiency of residential and light commercial furnaces and boilers. Previous significant updates to the standard were published in 1993, when the content of the standard was aligned with the United States Department of Energy test procedures for rating furnaces and boilers, and in 2007. In the 2007 revision, attention was given to modern classes of two-stage and modulating equipment and to equipment whose performance is affected by post purge of the combustion chamber. Also, greater understanding and clarity regarding losses from equipment were incorporated into the standard.

This 2017 revision focuses on improving mandatory language and on incorporating SI units. While the project committee focused mostly on editorial improvements to these areas, they also made quality improvements to the test duct and plenum figure, the system number table, and figures for surface heat transfer coefficient and coefficient of radiation. This revision also adopts the 2013 Department of Energy change to the procedure section allowing for the optional procedures for condensing equipment (Section 9.10) to be extended to two-stage modulating controls.

1. PURPOSE

The purpose of this standard is to provide procedures for determining the annual fuel utilization efficiency of residential central furnaces and boilers.

2. SCOPE

2.1 This standard includes

a. a test method for cyclic and part-load performance,
b. methods for interpolating and extrapolating test data, and
c. calculation procedures for establishing seasonal performance.

2.2 This standard applies to central furnaces with inputs less than 225,000 Btu/h (65.92 kW) and boilers with inputs less than 300,000 Btu/h (87.90 kW), having gas, oil, or electric input, and intended for use in residential applications. This standard also applies to furnaces with inputs less than 225,000 Btu/h (65.92 kW) contained within the same cabinet with central air conditioners that have rated cooling capacities of 65,000 Btu/h (19.04 kW) or less. This standard applies to equipment that utilizes single-phase electric current or low-voltage DC current.

2.3 The procedures are intended to be used to compare energy consumption measures of various furnace and boiler models. They are not intended to provide an absolute measure of performance in any specific installation configuration, as the effects of heating system installation variables are not fully taken into account.

3. DEFINITIONS

air intake terminal: a device that is located on the outside of a building and is connected to a furnace or boiler by a system of conduits through which air for combustion is taken from the outside environment.

air shutter: an adjustable device for varying the amount of primary air entering the burner (atmospheric and power types).

annual fuel utilization efficiency (AFUE): the ratio of annual output energy to annual input energy, which includes any non-heating-season pilot input loss and, for gas- or oil-fired furnaces or boilers, does not include electric energy.

atmospheric burner: a device for the final conveyance of the gas, or a mixture of gas and air at atmospheric pressure, to the combustion zone.

automatic vent damper: an electrically operated or thermally actuated device installed downstream of the draft hood (see *stack damper*).

barometric draft regulator or barometric damper: a device designed to maintain a constant draft in a furnace or boiler.

boiler: a self-contained fuel-burning or electrically heated appliance for supplying low-pressure steam or hot water for space-heating application.

boiler, finned-tube: a boiler whose heat exchanger consists of only finned tubes.

boiler, low-pressure steam or hot water: an electric, gas, or oil-burning boiler designed to supply low-pressure steam or hot water for space-heating applications. A low-pressure steam boiler operates at or below 15 psig (103 kPa) steam pressure; a hot-water boiler operates at or below 160 psig (1.10 MPa) water pressure and 250°F (121°C) water temperature.

boiler outlet: the opening provided in a boiler for the exhaust of the flue gases from the combustion chamber.

condensing furnace or boiler: a unit that will, during the laboratory tests prescribed in this standard, condense part of the water vapor in the flue gases and is equipped with a means of collecting and draining this condensate.

control: a device used to regulate the operation of a piece of equipment; the device regulates the gas, air, water, or electrical supplies.

control, modulating: a manual control, an automatic step modulating control, or a two-stage control.

control, single-stage: a control that cycles a burner between the maximum heat input rate and OFF.

control, step modulating: a modulating control that cycles a burner between the reduced input rate and OFF if the heating load is light. If a higher heating load is encountered that cannot be met with the reduced input rate, the control goes into a modulating mode where it either gradually or incrementally increases the input rate to meet the higher heating load. At

that point, if a lower heating load is encountered, the control either gradually or incrementally decreases to the reduced input rate.

a. ***automatic modulating control:*** a step modulating control that is capable of controlling burner fuel input rate between the maximum and the minimum adjustable input rate in response to varying heating load without manual intervention.
b. ***manually adjusted modulating control:*** a step modulating control adjusted for reduced input at the time of installation of the furnace or boiler, set by the installer.

control, two-stage: a modulating control that both cycles a burner between reduced heat input rate and OFF and between the maximum heat input rate and OFF. It may also switch from OFF to reduced fire to high fire to OFF under certain load conditions.

direct exhaust system: a venting system supplied or recommended by the manufacturer and through which the products of combustion pass directly from the furnace or boiler to the outside and that does not employ a means of draft relief. This includes systems that have small air passages in the flue with an opening area that is not in excess of 10% of the cross-sectional area of the stack.

direct vent system: a system consisting of (a) a central furnace or boiler for indoor installation; (b) combustion air connections between the furnace or boiler and the outdoor atmosphere; (c) flue gas connections between the furnace or boiler and the vent cap; and (d) a vent cap for installation outdoors, supplied or specified by the manufacturer and constructed so that all air for combustion is obtained from the outdoor atmosphere and all flue gases are discharged to the outdoor environment.

draft hood: a device built into a gas-fired appliance, or external to it, which is designed to (a) provide for the ready escape of flue gases in the event of no draft, back draft, or stoppage beyond the draft hood; (b) prevent a back draft from entering the appliance; and (c) neutralize the effect of stack action of the chimney or gas vent on the operation of the appliance (see *integral draft diverter*).

excess air: air that passes through the combustion chamber and the furnace flues in excess of that which is theoretically required for complete combustion.

external static pressure (ESP): the difference between the static pressures measured in the discharge duct and return air openings (or return air duct when used for test). Measurements shall be made as close as possible to the air supply and return openings of the furnace and in all cases shall be made between the furnace openings and any restrictions or elbows in the test plenums or ducts (see Section 8.4.2.1.2).

flue: a conduit between the furnace or boiler outlet and the integral draft diverter, draft hood, barometric draft regulator, vent terminal, or any other point of draft relief.

flue damper: for the purposes of this standard, an electric or mechanical device installed upstream of the integral draft diverter, draft hood, barometric draft regulator, or vent terminal on a unit not equipped with a draft control device, which is designed to automatically open the venting system when the appliance is in operation and to automatically close off the venting system when the appliance is in a standby condition.

flue gases: all gases in the flue during combustion in the combustion chamber, including reaction products, inerts, and any excess air.

flue losses: the sum of sensible and latent heat losses above room temperature of the flue gases leaving the furnace or boiler.

forced draft: air forced into the combustion chamber by mechanical means.

furnace, forced-air or gravity type: an electric, gas, or oil-burning appliance designed to supply heat through a system of ducts with air as the heating medium. In an electric furnace, heat is generated by one or more electric resistance heating elements; in a gas or oil furnace, the heat is generated by combustion of the fuel and transferred to the air within a casing by conduction through heat exchange surfaces. Forced-air furnaces circulate the heated air by means of a fan or blower, whereas gravity furnaces depend primarily on natural convection.

furnace outlet: the opening provided in a furnace for the exhaust of the flue gases from the combustion chamber.

heating capacity (Q_{OUT}): the rate of useful heat output when operating under steady-state conditions.

higher heating value (HHV): the heat produced per unit of fuel when complete combustion takes place at constant pressure and the products of combustion are cooled to the initial temperature of the fuel and air and when the vapor formed during combustion is condensed. The higher heating value is expressed in Btu/lb (kJ/kg), Btu/ft^3 (kJ/m^3) for gaseous fuel, or Btu/gal (kJ/L) for liquid fuel.

ignition system: the system used to ignite the main burner flame, consisting of either a continuous pilot or a noncontinuous source (intermittent or interrupted ignition).

indoor furnace or boiler: a unit intended for installation indoors that communicates with the heated space. Jacket heat from the unit is retained within the heated space, and the air for draft control comes from the heated space.

induced draft: the process of drawing air into the combustion chamber by mechanical means.

infiltration parameter: that portion of unconditioned outside air drawn into the heated space as a consequence of loss of conditioned air through the exhaust system of a furnace or boiler (expressed as a decimal).

inlet damper: a type of electromechanical damper upstream of the burner combustion air inlet that is an integral part of the furnace or boiler and is designed to automatically open the airflow passage to the combustion air inlet of the burner box when the burner is ON and to automatically close off the air passage and restrict the airflow through the heat exchanger when the burner is OFF. For the purposes of this standard, it must close within 10 seconds.

input, reduced heat: see *reduced heat input rate*.

integral draft diverter: a device that is an integral part of a furnace or boiler and is designed to (a) provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft diverter; (b) prevent a back draft from entering the furnace; and (c) neutralize the effect of stack action of the chimney or gas vent upon the operation of the furnace. For the purposes of this standard, this does not include draft hoods.

isolated combustion system: a system where a unit is installed within the structure but is isolated from the heated space. A significant portion of the jacket heat from the unit is lost, and air for ventilation, combustion, and draft control comes from outside the heated space.

modulating furnace or boiler: a unit equipped with one of the modulating control arrangements defined herein such that the reduced input rate is equal to or less than 75% of the nameplate input rating (Q_{IN}).

nameplate input rating (Q_{IN}): the assigned maximum hourly input rate (Btu/h) as marked on the unit nameplate.

outdoor furnace or boiler: a unit intended for outdoor installation, equipped with a weatherized jacket and integral venting means, and labeled for outdoor installation.

plenum: an air compartment that is attached to, or is an integral part of, a forced-air furnace and that is designed to either distribute the heated air after it leaves the heat exchanger, in the case of a supply plenum, or to collect air that enters the return inlet in the case of a return plenum.

post purge: the design that permits the continued operation of the combustion blower in a power vented unit, power burner unit, or forced-draft unit for a period of time after the main burner is shut off for the purpose of venting of residual flue gas in the heat exchanger and the venting system.

power burner: a burner that supplies air for combustion at a pressure exceeding atmospheric pressure, or a burner that depends on the draft induced by a fan incorporated in the furnace or boiler, or a fan-powered burner that depends on the natural draft developed by a chimney for proper operation, or a pulse combustion burner.

power gas: see *power burner*.

reduced heat input rate ($Q_{IN,R}$):

a. For furnaces or boilers equipped with automatic modulating control, the measured steady-state input rate (or nameplate input rate as permitted by Section 9.1.2.2) resulting from the lowest factory-adjusted setting of the control.

b. For furnaces or boilers with manually adjustable modulating control**,** the measured steady-state input rate (or nameplate input rate as permitted by Section 9.1.2.2) resulting from burner operation at the manufacturer's recommended adjustment setting, or the midpoint setting (see Section 8.4.1.1.2).

residential application: an application in which a furnace or boiler provides comfort heating for single-family living quarters.

resistance heating element: the electrical conducting medium that is heated by an electric current and that also dissipates this heat into the air or a fluid.

stack: the portion of the exhaust system downstream of the draft diverter, draft hood, or barometric draft regulator.

stack damper: for purposes of this standard, an electrical or mechanical device installed downstream of the integral draft diverter, draft hood, or barometric draft regulator that is designed to automatically open the venting system when the appliance is in operation and to automatically close off the venting system when the appliance is in a standby condition. (See *automatic vent damper.*)

stack gases: the mixture of flue gases and air that enters at the draft diverter, draft hood, integral draft diverter, or barometric draft regulator.

vent limiter: a device that limits the flow of air from the atmospheric diaphragm chamber of a gas pressure regulator to the atmosphere. A vent limiter may be a limiting orifice or other limiting device.

vent pipe: passages and conduits in a direct vent system through which gases pass from the combustion chamber to outdoor air.

vent terminal: a device that is located on the outside of a building and is connected to a furnace or boiler by a system of conduits through which exhaust gases are discharged to the outside environment.

4. CLASSIFICATIONS

4.1 Product

4.1.1 Furnace.

4.1.2 Boiler.

4.2 Heating Medium

4.2.1 Air.

4.2.2 Water.

4.2.3 Steam.

4.3 Circulation

4.3.1 Gravity (air, steam).

4.3.2 Forced (air, water).

4.4 Energy Source

4.4.1 Gas.

4.4.2 Oil.

4.4.3 Electricity.

4.5 Burner Type

4.5.1 Atmospheric.

4.5.2 Power.

4.5.2.1 Natural draft.

4.5.2.2 Forced draft.

4.5.2.3 Induced draft.

4.5.2.4 Pulse combustion.

4.6 Ignition

4.6.1 Continuous pilot.

4.6.2 Intermittent or interrupted operating ignition for gas or oil.

4.7 Draft Equipment

4.7.1 Draft hood.

4.7.2 Draft diverter.

4.7.3 Barometric regulator.

4.7.4 None.

4.8 OFF-Cycle Devices

4.8.1 Stack damper.

4.8.2 Electromechanical inlet damper.

4.8.3 Electromechanical flue damper.

4.8.4 None.

4.9 Installation

4.9.1 Indoor Unit. Jacket heat from the unit is retained within the heated space.

4.9.1.1 Communication with the Heated Space. The air for combustion and draft control comes from the heated space.

4.9.1.2 Direct Vent. The unit is within the heated space, but the air for combustion is taken from outdoors.

4.9.1.2.1 With heat exchange, heat from the exhaust gases heats air for combustion using heat from the vent pipe (as in a counterflow heat exchanger configuration).

4.9.1.2.2 Without heat exchange.

4.9.1.3 Direct Exhaust System. This is a venting system supplied or recommended by the manufacturer through which the products of combustion pass directly from the furnace or boiler to the outside and which does not employ a means of draft relief.

4.9.2 Isolated Combustion System. This system is composed of units located within the structure that are isolated from the heated space. A significant portion of the jacket heat from the unit itself is lost, and air for ventilation, combustion, and draft control comes from outside the heated space.

4.9.3 Outdoor Unit. A unit intended for outdoor installation, equipped with a weatherized jacket and integral venting means, and labeled for outdoor installation.

4.10 Flue Gas

4.10.1 Condensing.

4.10.2 Noncondensing.

4.11 Control

4.11.1 Single stage.

4.11.2 Two-stage modulating.

4.11.3 Step modulating.

5. REQUIREMENTS

Annual fuel utilization efficiency (AFUE) of furnaces and boilers shall be determined using test data and assumed cyclic conditions. Tests are performed on complete units following test procedures specified in Section 9, and the heating seasonal efficiency is then calculated using the procedures in Section 11.

6. INSTRUMENTS

6.1 General. All instruments shall be in working order and calibrated periodically. Records of periodic calibration shall be kept and shall contain, at a minimum, the date of calibration, method of calibration, and reference standard used.

6.2 Temperature

6.2.1 Thermometers. Thermometers shall have an error no greater than ±1°F (± 0.55 °C).

6.2.2 Thermocouples. Thermocouples and their read-out instrumentation shall have an error no greater than ±2°F (1.1°C). Thermocouples shall be the bead type having a wire size no greater than No. 24 American wire gauge (AWG). Where there is a possibility that the thermocouples could receive direct radiation from the flame, use of a radiation shield is required. Installation of these radiation shields is described in Section 7.6, "Thermocouple Grids."

6.2.3 Thermocouple Grid. Thermocouples used in grids shall be those described in Section 6.2.2 and shall be made as described in Section 7.6. Location of thermocouple grids shall be in accordance with Section 8.2.1.5.

6.3 Pressure. Instruments for measuring gas, oil, air, water, and steam pressure shall be calibrated so that the error is no greater than the following:

a. Gas: ±0.2 in. of water (50 Pa)
b. Air: ±0.01 in. of water (2.5 Pa)
c. Steam: ±0.2 in. Hg (0.67 kPa)

6.4 Draft. Draft gages shall have an accuracy of ±0.005 in. of water (1.25 Pa). Minimum divisions on the draft gage shall be 0.005 in. of water (1.25 Pa).

6.5 Combustion Products. Stack and flue carbon dioxide (CO_2) shall be determined with an instrument providing a reading with an error no greater than ±0.1 percentage points.

6.6 Weight or Volume. The error associated with the measuring instruments shall not exceed ±0.5% of the quantity measured.

6.7 Time. The error associated with timing instruments shall not exceed ±0.5 seconds/h.

6.8 Smoke. Smoke measuring instruments shall comply with requirements for smoke meters as outlined in ASTM D2156[1].

6.9 Tracer Gas Mass Flow Rate. The instruments used to measure the tracer gas mass flow rate shall have an accuracy of ±2% of the value of the concentration measured.

6.10 Energy Flow Rate

6.10.1 Electricity. The error shall be no greater than 1%.

6.10.2 Gas. The error shall be no greater than 1%.

6.10.3 Oil. The error shall be no greater than 1%.

6.11 Higher Heating Value

6.11.1 Gas. The error shall be no greater than 1%.

6.11.2 Oil. The error shall be no greater than 1%.

7. APPARATUS

7.1 General. Furnaces and boilers shall be installed in the test room in accordance with their manufacturers' instructions unless required otherwise by a specific method of test. The

apparatus described below is used in conjunction with the furnace or boiler during testing. Each piece of apparatus shall conform to material and construction specifications and the reference standards cited.

Test rooms containing equipment shall have suitable facilities for providing the utilities necessary for performance of the test and be able to maintain conditions within the limits specified.

7.2 Furnaces

7.2.1 Ducts and Plenums

7.2.1.1 Gravity Central Furnaces. Build a vertical supply test plenum or extended casing and horizontal test ducts as shown in Figure 1.

7.2.1.2 Forced-Air Central Furnaces. Build a plenum and test duct for forced-air central furnaces as shown in Figure 2.

7.2.1.3 Electric Central Furnaces. Build equipment for electric central furnaces as shown in Figure 2.

7.2.2 Stacks and Flues without Stack Dampers

7.2.2.1 Gravity and Forced-Air Central Furnaces Equipped with Draft Hood or Integral Draft Diverter. Gravity and forced-air central furnaces equipped with a draft hood or a draft diverter shall be provided with a 5 ft (1.5 m) stack of a cross-sectional area or perimeter the same size as the furnace outlet, as shown in Figure 3. For furnaces equipped with an integral draft diverter, cover the stack with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. Provide the flue pipe of the draft-hood-equipped furnace with insulation having an R-value of 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil (see Figures 3c and 3d). Supply an elbow the same size as the furnace outlet on horizontally discharging draft diverters, and cover the draft diverter elbow with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 K/W$) and an outer layer of aluminum foil.

For furnaces equipped with integral draft diverters that are mounted in an exposed position (not inside the overall unit cabinet), cover the diverter box (excluding any openings through which draft relief flows) before the beginning of any test (including jacket loss test) with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. For units equipped with integral draft diverters that are enclosed within the overall unit cabinet, insulate the draft diverter box with insulation as described above before the cool-down and the heat-up tests as described in Sections 9.5 and 9.6, respectively. Do not apply the insulation for the jacket loss test (if conducted) described in Section 8.6 or the steady-state test described in Section 9.1. For furnaces equipped with a draft hood and an electromechanical burner box inlet damper or an electromechanical flue damper, cover the 5 ft test stack and the outer portion of the draft hood with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil before conducting the tracer gas measurements for determination of the OFF-cycle loss factor (K_L) described in Section 9.7.6.

7.2.2.2 Forced-Air Central Furnaces (Direct Vent and Direct Exhaust). Units not equipped with a draft hood or draft diverter shall be provided with the minimum-length vent configuration recommended by the manufacturer or a 5 ft flue pipe if there are no recommendations (see Figure 4). For a direct exhaust system, insulate the minimum-length vent configuration or the 5 ft (1.5 m) flue pipe with insulation having an R-value not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. For a direct vent, see Section 7.5 for insulation requirements.

For units with power burners, cover the flue collection box with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil before the cool-down and heat-up tests described in Sections 9.5 and 9.6, respectively. However, do not apply the insulation for the jacket loss test (if conducted) described in Section 8.6 or the steady-state test described in Section 9.1. For power-vented units, insulate the shroud surrounding the blower impeller with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil before the cool-down and heat-up tests. Do not apply the insulation for the jacket loss test (if conducted) or the steady-state test. Do not insulate the blower motor or block the airflow openings that facilitate the cooling of the combustion blower motor or bearings.

7.2.2.3 Oil-Fired or Power Gas Forced-Air Central Furnaces. Forced-air central furnaces shall be provided with a flue and elbows as shown in Figure 5. The flue and elbows shall be of the same cross-sectional area or perimeter as the furnace outlet and covered with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. There shall be no opening between the furnace and the point where the flue gas sample is to be taken and the flue gas temperature is to be measured. Provide means for adjusting draft. Additional stack height or a mechanical draft inducer is allowed. Adjustment of draft is to be done only on units with barometric draft control.

7.2.2.4 Condensing Furnaces, Additional Requirements. The flue pipe installation must not allow condensate formed in the flue pipe to flow back into the unit. An initial downward slope from the unit's exit, an offset with a drip leg, annular collection rings, or drain holes must be included in the flue pipe installation without disturbing normal flue gas flow, as specified in Section 7.2.2. Flue gases shall not flow out of the drain with the condensate.

7.2.2.5 Downflow Furnaces. Install the internal section of vent pipe the same size as the flue collar for connecting the flue collar to the top of the unit, if not supplied by the manufacturer. Do not insulate the internal vent pipe during the jacket loss test (if conducted) described in Section 8.6 or the steady-state test described in Section 9.1. Insulate the internal vent pipe before the cool-down and heat-up tests described in Sections 9.5 and 9.6, respectively, with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. If the vent pipe is surrounded by a metal jacket, insulate the metal jacket with insulation as described for the vent pipe above. Install a 5 ft (1.5 m) test stack of the same cross-sectional area or perimeter as the vent

pipe above the top of the furnace. Tape or seal around the junction connecting the vent pipe and the 5 ft test stack. Insulate the 5 ft (1.5 m) test stack with insulation having an R-value not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil (see Figure 3e).

7.2.3 Stacks and Flues with Stack Dampers

7.2.3.1 Units with Draft Hoods or Draft Diverters. Install the stack damper in accordance with the manufacturer's instructions. Install 5 ft of stack above the damper.

For units with an integral draft diverter, cover the 5 ft (1.5 m) stack with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. For units with draft hoods, insulate the flue pipe between the outlet of the furnace and the draft hood with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. For units with integral draft diverters that are mounted in an exposed position (not inside the overall unit cabinet), cover the diverter boxes (excluding any openings through which draft relief air flows) before the beginning of any test (including jacket loss test) with insulation having an R-value of not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. For units equipped with integral draft diverters that are enclosed within the overall unit cabinet, insulate the draft diverter box with insulation as described above before the cool-down and heat-up tests described in Sections 9.5 and 9.6, respectively. Do not apply the insulation for the jacket loss test (if conducted) described in Section 8.6 or the steady-state test described in Section 9.1.

7.2.3.2 Units with Barometric Draft Control. Provide means for adjusting draft as specified in Section 7.2.2.3. Additional stack height or a mechanical draft inducer is allowed. Install the stack damper per the manufacturer's instructions.

7.3 Gas and Oil-Fired and Electric Low-Pressure Steam and Hot-Water Boilers

7.3.1 Piping. See Figures 6, 7, 8, and 9 for typical piping arrangements for hot-water and steam boilers, including electric boilers.

7.3.2 Stacks and Flues, without Stack Dampers

7.3.2.1 Units with Draft Hoods or Draft Diverters. Provide low-pressure steam and hot-water boilers with draft hoods or integral draft diverters with the same flue and stack arrangements described in Section 7.2.2.1 and shown in Figure 3.

7.3.2.2 Boilers, Direct Vent, Direct Exhaust, and Condensing. Units not equipped with a draft hood or draft diverter shall be provided with the same flue and insulation arrangements described in Section 7.2.2.2.

7.3.2.3 Oil-Fired or Power Gas Boilers. Provide oil-fired or power gas low-pressure steam and hot-water boilers with the same flue arrangements described in Section 7.2.2.3 and shown in Figure 5.

7.3.2.4 Condensing Boilers, Additional Requirements. The flue pipe installation must not allow condensate formed in the flue pipe to flow back into the unit. An initial downward slope from the unit's exit, an offset with a drip leg, annular collection rings, or drain holes must be included in the flue pipe installation without disturbing normal flue gas flow, as specified in Section 7.2.2. Flue gases shall not flow out of the drain with the condensate.

7.3.3 Stacks and Flues on Units with Stack Dampers

7.3.3.1 Units with Draft Hoods or Draft Diverters. Provide boilers with the same stack and flue arrangements described in Section 7.2.3.1.

7.3.3.2 Units with Barometric Draft Control. Provide means for adjusting draft. Additional stack height or a mechanical draft inducer is allowed.

7.4 Units with Integral Dampers. Dampers supplied with the furnace or boiler, which are in the burner inlet or in the flue passages and which are opened by fan power and closed by gravity or spring power, shall be installed in the location and manner prescribed by the manufacturer. Such dampers shall not be considered to be flue dampers.

7.5 Direct Vent Systems, Insulation Requirements. For direct vent systems that are not designed to significantly preheat the incoming air, only the first 18 in. (0.46 m) of vent pipe downstream of the furnace outlet shall be insulated with a layer of insulation having an R-value not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil. For units designed to significantly preheat the incoming combustion air, cover all surfaces of the vent or air intake system exposed to ambient air with insulation having an R-value not less than 7 $ft^2 \cdot h \cdot °F/Btu$ (1.2 $m^2 \cdot K/W$) and an outer layer of aluminum foil where the combustion air temperature exceeds the room temperature by more than 30°F (16.7°C) (see Figure 4). Care should be taken not to block the air intake with insulation.

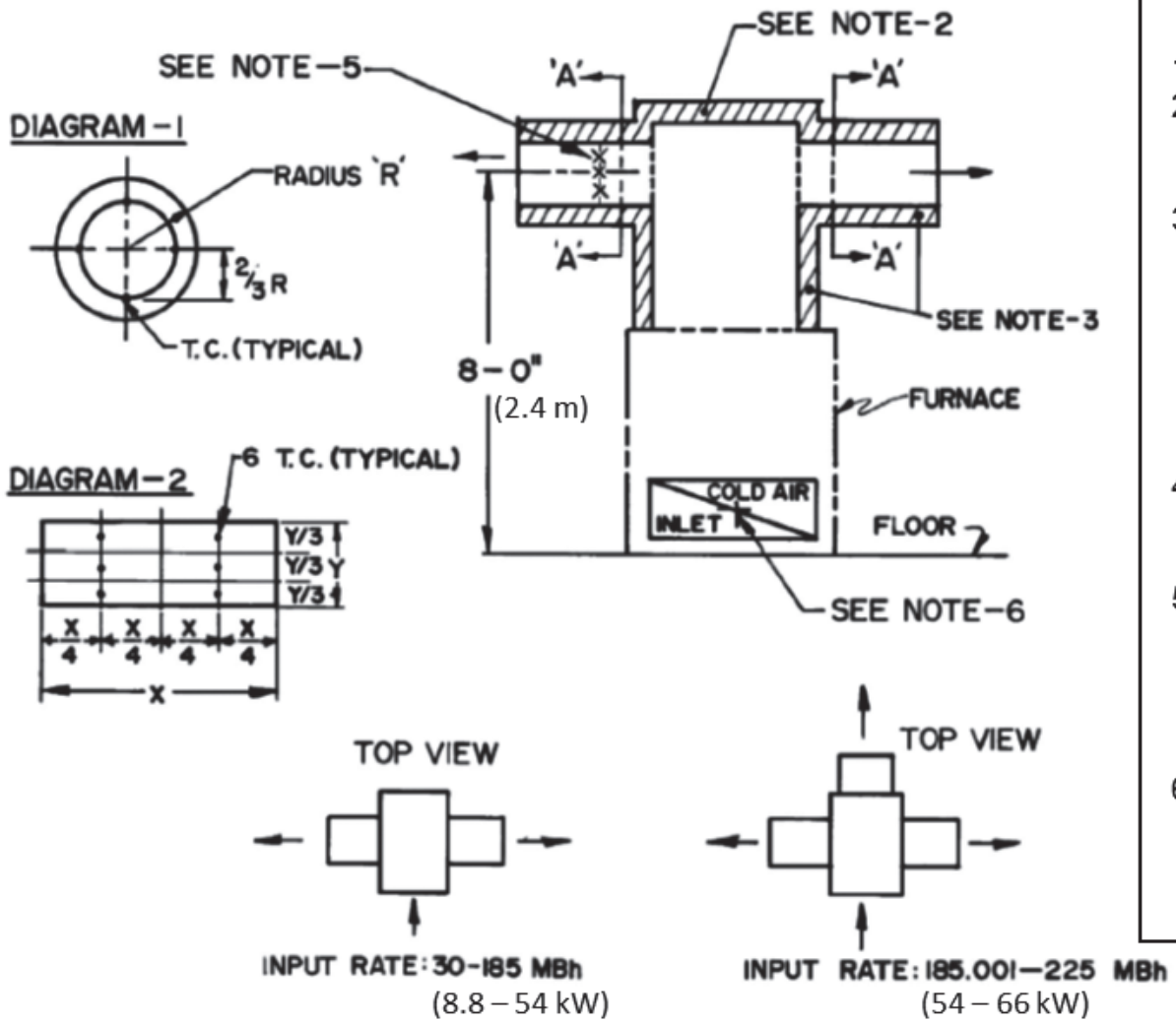
7.6 Thermocouple Grids. Thermocouple grids shall be constructed of either 5, 9, or 17 thermocouples of the type described in Section 6.2.2 and shown in Figure 10. The grid shall be in a test plane perpendicular to the axis of the test vent pipe. The thermocouple leads shall be equalized in length before wiring in parallel.

7.6.1 Flue and Stack. Arrange the thermocouples in a grid with one thermocouple in the center of the test stack and the remaining as shown in Figure 10. Location of the grid in the stack is described in Section 8. If there is a possibility that the thermocouples could receive direct radiation from the flame, install radiation shields on the flame side of the thermocouple only, and position the shields so that they do not touch the thermocouple junctions. If there is an indication that condensation forming in the flue or stack is contacting the thermocouples, provide means to protect the thermocouples from direct contact with the condensate.

7.6.2 Ducts. Thermocouple grids used in furnace outlet ducts shall be arranged as shown in Figures 1 and 2.

7.7 Electrical Measurement See Figure 11.

7.8 Condensate Collection. Condensate drain lines shall be attached to the unit as specified in the manufacturer's installa-



Notes for Figure 1:

1. Ducts removable at Section A-A.
2. Optional 2-in (5.1-cm) of insulation with K=0.27 Btu•in/(h•ft^2•°F) (1.53 W/(m^2•°C)).
3. Plenum and ducts shall be of the same shape as the plenum or casing collar. Horizontal ducts shall be 3-ft (91-cm) long and have an area of 0.75Q/111 (0.75Q/54), where Q is the input rating in Btu/h (kW) and 111 is 111 Btu/(in^2•h) (54 kW/(m^2)).
4. The average normal air temperature rise shall not exceed 130°F (54°C) above room temperature.
5. One thermocouple grid in each duct, placed 2-ft (61 cm) from outlet. Thermocouples to conform to requirements of Section 6.2.3 and be placed as shown in diagrams 1 and 2.
6. Each cold air inlet to contain a single No. 24 AWG bead. Thermocouple to be located in center of duct opening plane and be shielded from direct radiation.

FIGURE 1 Duct and plenum arrangement for gravity central furnaces (including direct vent).

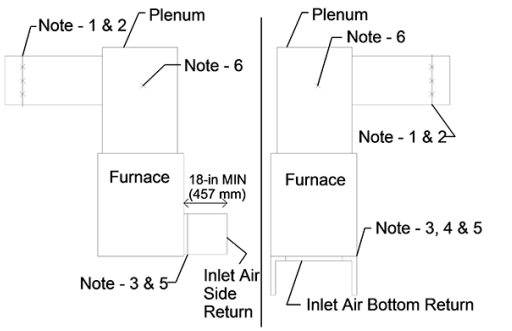


FIG-2A
Upflow Furnace - Side/Bottom Return, Utility Type

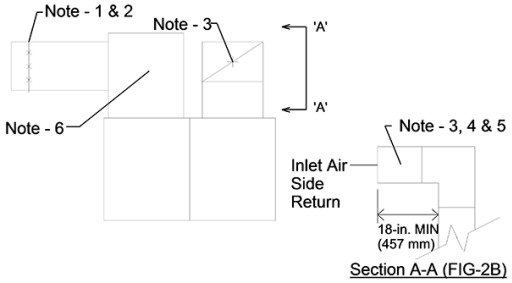


FIG-2B
Upflow Furnace - Basement Type

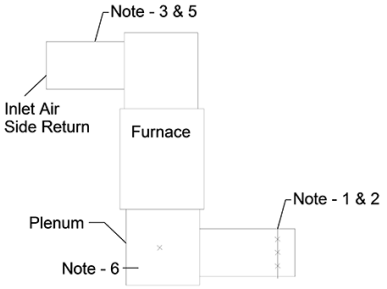


FIG-2C
Down Flow Furnace

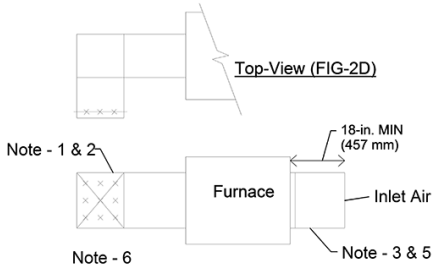


FIG-2D
Horizontal Furnace Duct

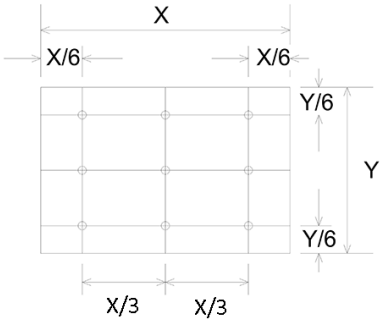


Diagram - 1

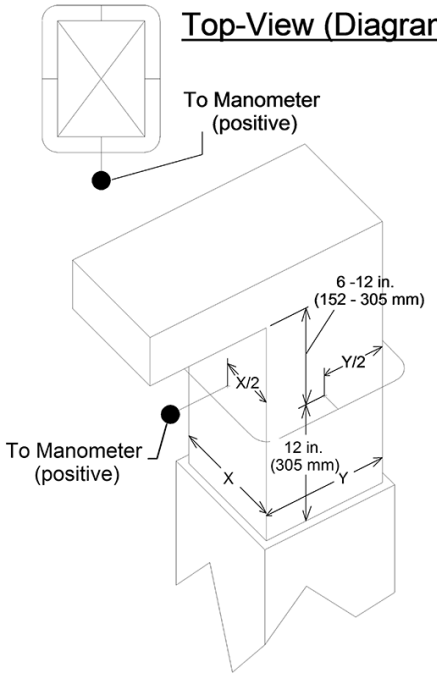


Diagram - 2

NOTES for Figure 2

1. Outlet air duct aspect ratio shall not exceed 4 to 1, and the duct area shall be that which gives a velocity between 900 and 1000 fpm (4.6 to 5.1 m/s).
2. Thermocouple grid shall be located in the test duct as close as possible to the plenum without any single thermocouple being able to see any part of the heating surface, or within 6 in. (152 mm) downstream of this minimum location. The duct shall extend at least 6 in. (152 mm) beyond the thermocouple grid. Thermocouple grid to be arranged as shown in diagram 1.
3. Remove all air filter(s) and locate inlet air thermocouple as described in section 8.2.1.5.
4. Test stand for upflow furnaces with bottom air return, shall met manufacturer's requirements for minimum return air opening and air flow per Note 1.
5. Inlet duct is not required, but can be used to straighten airflow or prevent re-circulation of supply air. Inlet ducts shall not exceed minimum length by more than 6 in. (152 mm) and shall not reduce inlet opening dimensions or add static to the unit. Static measurements are to be taken using the four pressure tap method as detailed in Note 6.
6. Unless an inlet duct is utilized as per Note 5, positive static measurement is taken from outlet plenum only with negative manometer input open to atmospheric conditions, a differential static shall not be taken from the inlet air side. Measurement points to consist of four (4) pressure taps, one placed within the duct on each side of the outlet plenum and connected together to average all 4 points at one sampling point at the positive input of the static pressure manometer as shown in Diagram – 2. This arrangement is the same for Figures 2A, 2B, 2C, and 2D by rotating Diagram – 2 to the outlet duct configuration of the figure. If an inlet duct is utilized, the same 4 point tap configuration is required to determine differential static by placing each tap in the geometric center of each side of the inlet duct and the single averaging point from the inlet duct connected to the negative input of the static pressure manometer. Pressure taps are recommended to consist of 0.25 in. (6.4 mm) diameter nipples soldered to a plate or the surface of the plenum centered over 0.04 in (1.0 mm) holes that are free of burrs and sharp edges.

FIGURE 2 Duct and plenum arrangement for gas, oil, and electric forced-air central furnaces (including direct vent).