ANSI/AHRI Standard 1500

2015 Standard for

Performance Rating of Commercial Space Heating Boilers

Air-Conditioning, Heating, and Refrigeration Institute

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IMPORTANT

SAFETY DISCLAIMER

AHRI does not set safety standards and does not certify or guarantee the safety of any products, components or systems designed, tested, rated, installed or operated in accordance with this standard/guideline. It is strongly recommended that products be designed, constructed, assembled, installed and operated in accordance with nationally recognized safety standards and code requirements appropriate for products covered by this standard/guideline.

AHRI uses its best efforts to develop standards/guidelines employing state-of-the-art and accepted industry practices. AHRI does not certify or guarantee that any tests conducted under its standards/guidelines will be non-hazardous or free from risk.

Note:
This standard supersedes AHRI Hydronics Institute Standard BTS-2000 Rev. 06.07.

INFORMATIVE NOTE

AHRI CERTIFICATION PROGRAM PROVISIONS

Scope of the Certification Program (See Section 2 for Scope of the Standard)

The certification program includes all gas- and oil-fired steam and hot water Heating Boilers with inputs ranging from 300,000 Btu/h to 2,500,000 Btu/h. Models within a model series, or individual boiler models, having inputs over 2,500,000 Btu/h may be included in the program at the Participant's option.

Certified Ratings

The following certification program ratings are verified by test:

All steam boilers, and hot water boilers from 300,000 Btu/h up to and including 2,500,000 Btu/h.

1. Thermal Efficiency, % (required)
2. Combustion Efficiency, % (optional)

Hot water boilers above 2,500,000 Btu/h.

1. Combustion Efficiency, % (required)
2. Thermal Efficiency, % (optional)

Price $10.00 (M) $20.00 (NM)
Printed in U.S.A.

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PERFORMANCE RATING OF COMMERCIAL SPACE HEATING BOILERS

Section 1. Purpose

1.1 *Purpose*. The purpose of this standard is to establish for Commercial Space Heating Boilers: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

1.1.1 *Intent*. This standard is intended for the guidance of the industry, including manufacturers, designers, installers, contractors and users.

1.1.2 *Review and Amendment*. This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 *Scope*. This standard applies to gas and oil-fired steam and hot water Packaged Boilers, as defined in Section 3, that have an Input Rating equal to or greater than 300,000 Btu/h, that are:

2.1.1 A steam boiler designed to operate at or below a steam pressure of 15 psig; or

2.1.2 A hot water boiler designed to operate at or below a water pressure of 160 psig and a temperature of 250 °F; or

2.1.3 A boiler that is designed to be capable of supplying either steam or hot water, and designed to operate under the conditions in Sections 2.1.1 and 2.1.2 of this scope.

2.2 Products covered under this standard are for use in heating or space conditioning applications, utilize any means of natural or mechanical draft configurations, and may be intended for installation in either indoor or outdoor environments.

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the *ASHRAE Terminology* website (https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology) unless otherwise defined in this section.

3.1 *Barometric Draft Regulator*. A balanced damper device attached to the vent connector to control draft (negative pressure).

3.2 *Boiler*. A closed direct fired pressure vessel intended for use in heating water or generating steam to be used external to itself.

3.2.1 *Atmospheric Boiler*. A Packaged Boiler with a gas Atmospheric Burner and that operates with a non-positive Vent static pressure.

3.2.2 *Condensing Boiler*. A Boiler which will, during the laboratory tests prescribed in this standard, condense part of the water vapor in the flue gases and which is equipped with a means of collecting and draining this condensate from the heat exchange section.

3.2.3 *Direct Vent Boiler*. A Boiler (indoor) with the means or instructions for all air for combustion to be derived directly from the outdoors.

3.2.4 *Heating Boiler.* A 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 steam pressure; a low-pressure hot water Boiler operates at or below 160 psig water pressure and 250 °F water temperature.

3.2.5 *Non-condensing Boiler.* A Boiler that is not a Condensing Boiler.

3.2.6 *Outdoor Boiler.* A Packaged Boiler with integral venting means, factory assembled, weather-proofed, and wired for use out of doors.

3.2.7 *Packaged Boiler.* A Boiler that is shipped complete with Burner and controls.

3.3 *Btu.* British Thermal Unit.

3.4 *Burner.* A device for the introduction of fuel and primary air into a Firebox at the desired velocities.

3.4.1 *Atmospheric Burner.* A Burner for the final conveyance of a mixture of gas and air at atmospheric pressure, to the combustion zone. Air at atmospheric pressure is injected into the Burner by a jet of gas.

3.4.2 *Non-atmospheric Burner.* A Burner which supplies air for combustion at a pressure exceeding atmospheric pressure, or a Burner which depends on the draft induced by a fan incorporated in the Boiler, or a fan-powered Burner which depends on the natural draft developed by a chimney for proper operation, or a pulse combustion Burner.

3.5 *Choke Damper.* A Damper placed within the Vent Connector or vent pipe for regulating the flow of gases.

3.6 *Combustion Efficiency.* 100% less the losses due to (1) dry flue gas, (2) incomplete combustion, and (3) moisture formed by combustion of hydrogen.

3.7 *Condensate, Flue.* Liquid formed by the condensation of moisture in the flue gases.

3.8 *Condensate, Steam.* Liquid formed by the condensation of steam.

3.9 *Draft.* A pressure difference that causes gases or air to flow through a chimney, Vent or Boiler. Draft is the ambient pressure minus the pressure in the Vent or Firebox. Although draft represents a negative pressure, it is always expressed as a positive value.

3.10 *Draft Hood.* A non-adjustable device, either built into or external to the Boiler, that is designed to (1) provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the Draft Hood, (2) prevent a back draft from entering the Firebox, and (3) neutralize the effect of stack action of the chimney or gas vent upon the operation of the Boiler.

3.11 *Draft Regulator.* See “Barometric Draft Regulator.”

3.12 *Efficiency, Combustion.* See "Combustion Efficiency".

3.13 *Efficiency, Thermal.* See "Thermal Efficiency".

3.14 *Feedwater.* The water that is heated, cooled, or blended as needed and supplied to the Boiler test fixture.

3.15 *Firebox.* The space provided within the Boiler for combustion of the fuel.

3.16 *Flue, Boiler.* The passage(s) within a Boiler through which combustion products pass from the Firebox of the Boiler to the Draft Hood inlet opening on a Boiler equipped with a Draft Hood or to the outlet of the Boiler on a Boiler not equipped with a Draft Hood.

3.17 *Flue Collar.* That portion of a Boiler designed for attachment of a Draft Hood, Vent Connector, or continuous open passageway to the outdoors for the purpose of removing Flue or Vent Gasses.

3.18 *Flue Gas.* Products of combustion plus excess air in the Boiler Flue or heat exchanger.

3.19 *Flue Temperature.* The temperature of the Flue Gases, before dilution.

3.20 *Gross Output.* The output determined from thermal efficiency test data, in terms of Btu/h, under the conditions and limitations stipulated by this standard.

3.21 *Heating Value, Gas.* Amount of heat produced by the complete combustion of a unit quantity of fuel. This standard only uses the gross or higher heating value, which is obtained when all the products of combustion are cooled to the temperature existing before combustion, the water vapor formed during combustion is condensed, and all the necessary corrections to standard conditions have been made in accordance with Appendix E. The gas heating value is expressed in Btu/cubic foot at standard conditions of water vapor saturation, temperature of 60 °F and a pressure of 30" of mercury.

3.22 *Heating Value, Oil.* The higher heating value determined per ASTM D240-09 or ASTM D4809-09a and Section C3.2.1.1, Fuel Oil Analysis.

3.23 *Input Rating.* The maximum Btu/h or gph input located on the Boiler rating plate.

3.24 *Net Rating.* The recommended amount of installed radiation to be served by the Boiler, based on the normal allowance for piping and pickup losses.

3.25 *Oil.* Light oil refers to No. 2 oil, and heavy oil refers to Nos. 4, 5, and 6 oil, as defined in ASTM D396-14a.

3.26 *Published Rating.* A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal size and type (identification) produced by the same manufacturer. The term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.26.1 *Standard Rating.* A rating based on tests performed at Standard Rating Conditions.

3.27 *Rating Conditions.* Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

3.27.1 *Standard Rating Conditions.* Rating Conditions used as the basis of comparison for performance characteristics.

3.28 *Secondary Air.* Air for the purpose of aiding combustion, admitted beyond the Burner port or ports.

3.29 *"Shall" or "Should".* "Shall" or "should" shall be interpreted as follows:

3.29.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.29.2 *Should.* "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.30 *Superheat.* The temperature of steam in excess of its saturation temperature.

3.31 *Thermal Efficiency.* The ratio of the heat absorbed by the water or the water and steam to the higher heating value in the fuel burned.

3.32 *Ultimate Carbon Dioxide (CO_2).* 11.9% CO_2 for natural gas, 15.6% CO_2 for No. 2 fuel oil, 15.8% CO_2 for No. 4 fuel oil, 16.3% CO_2 for No. 5 fuel oil, and 16.7% CO_2 for No. 6 fuel oil. These numbers are used in the

standard to state the maximum percentage of carbon dioxide obtainable in the flue gas under stoichiometric combustion.

3.33 *Vent.* A passageway used to convey flue gasses from Boilers or their Vent Connectors to the outdoors.

3.34 *Vent Connector*. The pipe or duct that connects a Boiler to a Vent or chimney (sometimes called breaching).

3.35 *Vent Gases.* Products of combustion from Boilers, plus excess air and dilution air added to the Flue Gases after leaving the heat exchanger.

Section 4. Test Requirements

4.1 *Test Requirements*. Published Ratings shall be verified by tests conducted in accordance with the test method described in Appendix C and at the Rating Conditions in Section 5.

4.1.1 *Equipment.* Boilers shall be tested using all components as recommended by the manufacturer.

Section 5. Rating Requirements

5.1 *Standard Ratings*. Standard Ratings shall be established at the Standard Rating Conditions specified in Section 5.3.

Combustion Efficiency is a required Standard Rating for hot water boilers with an Input Rating greater than 2,500,000 Btu/h.

Thermal Efficiency is a required Standard Rating for all steam boilers and for hot water boilers with an Input Rating less than or equal to 2,500,000 Btu/h. Indoor Boilers shall report the indoor boiler Thermal Efficiency and Outdoor Boilers shall report the outdoor boiler Thermal Efficiency.

5.2 All Standard Ratings shall be verified by tests in accordance with Section 5.

5.2.1 *Values of Standard Ratings*.

Combustion Efficiency shall be expressed to the nearest tenths of a percent.

Thermal Efficiency shall be expressed to the nearest tenths of a percent.

5.2.2 *Values of Optional Standard Ratings*.

Gross Output shall be expressed to the nearest 1,000 Btu/h.

Net Ratings are determined by dividing the Gross Output by the piping and pickup factor listed in Table 1, and rounding out to the nearest 1,000 Btu/h. Steam square feet (sq ft) shall be determined by dividing the rounded steam Net Rating by 240. It shall be catalogued to either the nearest sq ft or the nearest 5 sq ft.

Table 1. Net Rating Calculation		
Gross Output, Btu/h	Steam Factor[1]	Water Factor
≤ 1,255,000	1.333	1.150
1,255,000 to 1,839,000	$1.5462 - [(2.353 \cdot 10^{-7}) \cdot Q_{OUT}] + [(5.2086 \cdot 10^{-14}) \cdot {Q_{OUT}}^2]$	
1,840,000 to 1,939,000	$1.3268 - [(2 \cdot 10^{-8}) \cdot Q_{OUT}]$	
≥ 1,940,000	1.288	
Notes: 1. Round calculated steam factors to three decimal places.		

5.3 *Standard Rating Conditions*. The conditions of test for Standard Ratings shall be established at the Standard Rating Conditions specified in this section.

5.3.1 *CO_2 or O_2 in Flue Gas.*

5.3.1.1 *Oil and Non-atmospheric Gas Burners*.

5.3.1.1.1 *Specified CO_2 or O_2 Level*. If the CO_2 or O_2 level is specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted to within ±0.1% of the specified level. The setup shall also meet the requirements of Sections 5.3.2 and 5.3.3, and input rate as required to comply with Section C4.1.

5.3.1.1.2 *Specified CO_2 Range*. If a CO_2 range is specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted to within 0.2% of, but no greater than, the maximum CO_2 level that is within the specified range and that also meets the requirements of Sections 5.3.2 and 5.3.3, and input rate as required to comply with Section C4.1.

5.3.1.1.3 *Specified O_2 Range*. If an O_2 range is specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted to within 0.2% of, but no less than, the minimum O_2 level that is within the specified range and that also meets the requirements of Sections 5.3.2 and 5.3.3, and input rate as required to comply with Section C4.1.

5.3.1.1.4 *No Specified CO_2 or O_2 Level or Range*. If there is no CO_2 or O_2 level or range specified in the manufacturer's instructions shipped with the boiler, the burner system shall be adjusted to within ±0.2% of the CO_2 level closest to 8% that also meets the requirements of Sections 5.3.2 and 5.3.3, and input rate as required to comply with Section C4.1.

5.3.1.2 *Atmospheric Burners*. Adjust the input rate as required to comply with Section C4.1.

5.3.2 *Smoke*. The smoke readings shall not exceed #1 for light oil or #4 for heavy oil during any test (see Section C2.5.4).

5.3.3 *CO in Flue Gas*. The Burner shall not produce CO to exceed 400 ppm (air free basis), for natural gas or propane fired units.

5.3.4 *Vent Pressure for Boilers with Positive Vent Pressure and Non-atmospheric Burner*. If a minimum positive vent pressure is specified in the manufacturer's instructions shipped with the boiler, that pressure, within the greater of ± 0.02 inches of water or 10% of the specified vent pressure shall be established before testing and data collection begins.

5.3.5 *Water Temperatures for Hot Water Boilers.*

5.3.5.1 *Non-condensing Boilers*. The inlet temperature (Figure C9, point A) shall be 35°F to 80°F, and the outlet temperature (Figure C9, point C) shall be 180°F ± 2°F. A higher outlet water temperature shall be used when specified by a manufacturer.

5.3.5.2 *Condensing Boilers*. For condensing boilers, the outlet temperature (Figure C9, point C) shall be 180°F ± 2°F and the inlet temperature (Figure C9, point A) shall be 80°F ± 5°F at all times during the test.

5.3.5.3 *Optional Recirculating Loop*. For Boilers that require a greater flow rate to prevent boiling, a recirculating line shall be installed as shown in Figure C9. The temperature rise through the boiler itself (between points B and C in Figure C9) shall not be less than 20°F. The temperature rise from inlet (Figure C9, Point A) to the outlet (Figure C9, Point C) shall meet the requirements of Section 5.3.5.1 or 5.3.5.2 as applicable.

5.3.6 *Steam Pressure*. Tests shall be made at atmospheric pressure or at the pressure required to comply with Section 5.3.7, not exceeding 15 psi gauge. If necessary, pressure shall be developed by throttling with a valve beyond the separator.

5.3.7 *Moisture in Steam*. During a thermal efficiency test, the moisture in the steam shall not exceed 2% of the water fed to the boiler during the test.

5.3.8 *Air Temperature*. The room ambient temperature shall be between 30 and 100 °F at any time during the test at each data collection point required by Section C5.

5.3.9 *Ambient Humidity*. The relative humidity of the room for Condensing Boilers shall not exceed 80 percent when recorded at the interval defined by Section C5.

Section 6. Minimum Data Requirements for Published Ratings

6.1 *Minimum Data Requirements for Published Ratings*. As a minimum, Published Ratings shall include all Standard Ratings as specified in Section 5.1. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with ANSI/AHRI Standard 1500." Claims to ratings outside the scope of this standard shall not imply or claim compliance with ANSI/AHRI Standard 1500.

Section 7. Marking and Nameplate Data

7.1 *Marking and Nameplate Data*. As a minimum, the nameplate shall display the manufacturer's name, model designation, and maximum Btu/h or gph input (Input Rating).

Section 8. Conformance Conditions

8.1 *Conformance.* While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's *Purpose* (Section 1) and *Scope* (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

APPENDIX A. REFERENCES - NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

A1.1 *ASHRAE Handbook Fundamentals*, 2013, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.2 *ASHRAE Terminology*, https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology, 2015, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.3 ASME PTC-19.11 – 2008, *Steam and Water Sampling, Conditioning, and Analysis in the Power Cycle*, ASME, Two Park Avenue, New York, NY 10016-5990, U.S.A.

A1.4 ASTM Standard D240 - 09, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter*, ASTM International, 2009, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, U.S.A.

A1.5 ASTM Standard D396 – 14a, *Standard Specification for Fuel Oils*, ASTM International, 2013, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, U.S.A.

A1.6 ASTM Standard D2156 – 09, *Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels*, ASTM International, 2013, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, U.S.A.

A1.7 ASTM Standard D4809 – 09a, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)*, ASTM International, 2009, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, U.S.A.

A1.8 ASTM Standard D5291 – 10, *Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants*, ASTM International, 2010, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, U.S.A.

APPENDIX B. REFERENCES - INFORMATIVE

B1 Listed here are standards, handbooks and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

B1.1 *Empirical Specific Heat Equations Based Upon Spectroscopic Data*, Sweigert and Beardsley, State Engineering Experiment Station of the Georgia School of Technology, Volume I, No. 3, June 1938.

B1.2 *Thermodynamic Properties of Steam*, Keenan and Keyes, 1969.

APPENDIX C. METHODS OF TESTING FOR RATING COMMERCIAL SPACE HEATING BOILERS – NORMATIVE

C1 *Instruments*. Instruments which meet the minimum requirements shown in Table C1 shall be used.

C1.1 *Calibration*. Instruments shall be calibrated to a recognized standard at regular intervals.

Table C1. Instruments

Property Measured	Item Measured	Informative Note: Example of Instrument Type	Minimum Resolution	Minimum Accuracy	Informative Note: Approximate Range of Readings
Temperature	Room Air	Thermometer, Thermocouple, RTD	1°F	±1°F	30 - 100°F
	Test Air	Thermometer, Thermocouple, RTD	1°F	±1°F	30 - 100°F
	Inlet Water	Thermometer or RTD	0.2°F	±0.2°F	40 - 125°F
	Outlet Water	Thermometer or RTD	0.2°F	±0.2°F	130 - 220°F
	Flue Gas	Thermocouple Grid	2°F	±2°F	80 - 650°F
	Gas	Thermometer or RTD	0.5°F	±0.5°F	30 - 100°F
Pressure	Atmospheric	Barometer	0.05 in Hg	±0.05 in Hg	28 - 31 in Hg
	Steam	Manometer, Bourdon Tube Gage	Greater of 0.1 in H_2O or 10% of observed value	Greater of ±0.1 in H_2O or ±10% of observed value	0 – 30 psi
	Firebox	Draft Gage	Greater of 0.02 in H_2O or 10% of observed value	Greater of ±0.02 in H_2O or ±10% of observed value	As needed
	Vent	Draft Gage	0.01 in H_2O	±0.01 in H_2O	0 - 0.5 in H_2O
	Flue/Vent Connector	Draft Gage	0.01 in H_2O	±0.01 in H_2O	0 - 0.5 in H_2O
	Fuel Gas	Manometer	≤14 in H_2O: 0.1 in H_2O >14 in H_2O: 0.01 psi	≤14 in H_2O: ±0.1 in H_2O >14 in H_2O: ±0.05 psi	0 - 14 in H_2O 0.5 - 15 psi

Table C1. Instruments (continued)

Property Measured	Item Measured	Informative Note: Example of Instrument Type	Minimum Resolution	Minimum Accuracy	Informative Note: Approximate Range of Readings
Weight or Flow	Oil	Scale, Burette or Flow Meter	0.25% of hourly rate	±0.25% of hourly rate	Sized for Rated Flow
	Gas	Volume Meter	Greater of 1 ft^3 or 0.25% of hourly rate	±1% of hourly rate	Sized for Rated Flow
	Water or Steam Condensate	Scale or Water Meter	Greater of 0.5 lb or 0.25% of hourly rate	Greater of ±0.5 lb or ±0.25% of hourly rate	Sized for Rated Flow
	Flue Condensate	Scale	Greater of 0.05 lb or 0.5% of measured weight	Greater of ±0.05 lb or ±0.5% of measured weight	As Needed
	Separator Moisture	Scale	0.1 lb	±0.1 lb	As Needed
Time	Test Period	Stopwatch	1 second/h	±1 second/h	0 - 3 h
Gas Chemistry	Carbon Dioxide	CO_2 Tester or Meter	0.1% CO_2	±0.1% CO_2	0 - 15% CO_2
	Carbon Monoxide	CO Tester or Meter	1 ppm	Greater of ±10 ppm or ±5% of reading	0 – 500 ppm CO
	Oxygen	O_2 Tester or Meter	0.1% O_2	±0.1% O_2	0 - 20% O_2
Gas Optics	Smoke	Smoke Spot Bacharach	1 Smoke Spot	±½ Smoke Spot	0 – 7
Heating Value	Natural Gas	Calorimeter or Gas Chromatograph	2 Btu/ft^3	± 1% of reading	970 – 1100 Btu/ft^3
	Oil	See Section C3.2.1.1	See Section C3.2.1.1	± 1% of reading	18500 – 20500 Btu/lb (#2 oil)
Humidity	Relative Humidity	Psychrometer	5%	± 5% of full scale	10 – 90%

C2 *Apparatus*.

C2.1 *Test Room or Area*. The test location shall be of sufficient size to permit easy access to all parts of the test unit and instrumentation, as well as to maintain relatively stable ambient conditions. Adequate electrical, water and drainage facilities are required. A chimney, or vent with induced draft fan, as well as provisions for supplying sufficient air for combustion are required.

C2.2 *Vent Connection*.

C2.2.1 *Test Vent for Boilers with Non-Atmospheric Gas or Oil Burners Meeting the Following Criteria: 1) With Negative Vent Pressure, or 2) With Positive Vent Pressure and that are Not Direct Vent Boilers, as Defined in Section 3.*

Note: If the boiler has positive vent pressure and is a Direct Vent Boiler, see Section C2.2.2.

All vent pipe connections shall be carefully sealed before the insulation is applied. A minimum of R-7 foil-faced insulation suitable for the temperature shall be applied as shown in Figure C1. The plane of the thermocouple grid and flue gas sampling points shall be located at the points shown in Figure C1. If dilution air is introduced into the flue gasses before the plane of the thermocouple and flue gas sampling points in the vent, utilize an alternate plane of thermocouple grid and flue gas sampling point located downstream from the heat exchanger and upstream from the point of dilution air introduction. (See Figure C1).

A barometric damper shall not be installed if the boiler has positive vent pressure.

C2.2.1.1 *Horizontal Discharge*. When the vent gases discharge horizontally, attach an elbow, sized to fit, directly to the flue collar or, if a sizing adapter is specified by the manufacturer's instructions shipped with the boiler, the elbow shall be sized to fit the adapter. Adding pipe between the flue collar and the elbow is allowed, if it is necessary for the test vent to clear obstructing boiler parts. Attach a vertical length of vent pipe, 3 pipe diameters long to the elbow. Additional vent length may be used if the installation complies with Section 5.3.4.

C2.2.1.1.1 *Additional Requirements for Horizontal Discharge with Negative Vent Pressure*. If a draft regulator is used, it shall be attached to the end of this vertical vent pipe, following the draft regulator manufacturer's instructions. If additional vent height or a mechanical draft inducer is needed to obtain the minimum draft specified in the manufacturer's installation instructions shipped with the boiler, it shall be attached to the end of the vertical vent pipe or to the draft regulator, if used.

C2.2.1.2 *Vertical Discharge*. When the vent gases discharge vertically, attach an elbow, sized to fit, directly to the flue collar or, if a sizing adapter is specified by the manufacturer's instructions shipped with the boiler, the elbow shall be sized to fit the adapter. Adding pipe between the flue collar and the first elbow is allowed, if it is necessary for the test vent to clear obstructing boiler parts. Attach a horizontal length of vent pipe 3 pipe diameters long to the elbow. Attach a second elbow, oriented up, to the end of the horizontal length of vent pipe. Additional vent length may be used if the installation complies with Section 5.3.4.

C2.2.1.2.1 *Additional Requirements for Vertical Discharge with Negative Vent Pressure*. If a draft regulator is used, it shall be attached to the vertical outlet of the second elbow, following the draft regulator manufacturer's instructions. If additional vent height or a mechanical draft inducer is needed to obtain the minimum draft specified in the manufacturer's installation instructions shipped with the boiler, it shall be attached to the vertical outlet of the second elbow or to the draft regulator, if used.

C2.2.2 *Test Vent for Boilers with Gas or Oil Non-Atmospheric Burners and with Positive Vent Pressure and that are Direct Vent Boilers, as Defined in Section 3.*

Note: If the boiler has positive vent pressure and is not a Direct Vent Boiler, see Section C2.2.1.

The test vent shall be the minimum length and type specified by the manufacturer's instructions shipped with the boiler and shall be attached to the flue collar. If the minimum vent length is not specified in the manufacturer's instructions shipped with the boiler, a 5 ft. vent pipe shall be attached. The vent diameter shall be sized to connect directly to the test boiler flue collar, unless a different size vent is required by the manufacturer's instructions shipped with the Boiler. A barometric damper shall not be installed (see Figure C4).

All vent pipe connections shall be carefully sealed before the insulation is applied. A minimum of R-7 foil-faced insulation suitable for the temperature shall be applied as shown in Figure C4. The plane of the thermocouple grid and flue gas sampling points shall be located in the vent at the

points shown in Figure C4 for boilers with preheat or boilers without preheat. The alternate plane of thermocouple grid and flue gas sampling shall be used if dilution air is introduced into the flue gasses before the plane of the thermocouple and flue gas sampling points in the vent. This alternate plane of thermocouple grid and sampling point shall be located downstream from the heat exchanger and upstream from the point that dilution air is introduced. Vent insulation is not required, if the plane of the thermocouple grid and flue gas sampling is located at a point before the flue gasses enter the vent (see Figure C4).

C2.2.3 *Atmospheric Boilers*. The boiler Vent Connector or Draft Hood flue collar shall be connected to an uninsulated sheet-metal vent sized to fit the Vent Connector or Flue Collar or, if a sizing adapter is specified by the manufacturer's instructions shipped with the boiler, it shall be sized to fit the adapter. If elbows are used, they shall be of the 90-degree (1.57 rad) and four-piece sheet-metal type. The vent pipe shall have a reasonably smooth inner contour. The vent pipe shall be arranged as follows:

C2.2.3.1 *For Boilers with a Maximum Input Rating of 400,000 Btu/h or Less*. When the Vent Gases discharge horizontally, a 2 ft. section of horizontal vent pipe, an elbow and a vertical section of vent pipe shall be attached to the Draft Hood or external draft diverter outlet, or in the absence of an external draft control device, to the Vent Connector. The height of the vertical section shall be 5 ft. as measured from the highest point of the vent connector or, if there is an external draft control device, from the draft control device outlet. When Vent Gases discharge vertically, an elbow shall first be attached directly to the vent connector or, if there is an external draft control device, directly to the draft control device outlet (see Figure C2).

C2.2.3.2 *For Boilers with a Maximum Input Rating Over 400,000 Btu/h*. When the Vent Gases discharge horizontally, an elbow and 5 ft. of vertical Vent pipe, measured from the end of the elbow, shall be attached to the Draft Hood or external draft diverter outlet, or in the absence of an external draft control device, to the Vent Connector. When Vent Gases discharge vertically, 4 ft. of vertical pipe, measured from point of attachment, shall be attached to the Draft Hood or external draft diverter outlet, or in the absence of an external draft control device to the Vent Connector (see Figure C3).

C2.2.4 *Additional Requirements for Condensing Boilers*. The vent pipe installation shall not allow Flue Condensate formed in the Vent 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 shall be included in the vent pipe installation without disturbing normal Flue Gas flow. Additional precautions shall be taken to facilitate uninterrupted flow of Flue Condensate during the test. Flue Condensate collection-containers shall be a smooth, non-porous material such as glass or polished stainless steel, so removal of interior deposits can be easily made. The collection-container shall have a vent opening to the atmosphere.

C2.2.5 *Additional Requirements for Outdoor Boilers*. If the manufacturer provides more than one outdoor venting arrangement, the Boiler shall be tested with the arrangement having the least draft loss.

C2.3 *Steam Piping (Thermal Efficiency Test)*. A typical set-up is shown diagrammatically in Figures C5 through C8. Connect to the boiler risers as specified in the manufacturer's instructions shipped with the boiler. If not specified, the risers shall be taken full size from regular steam outlet tapings and combined into a header. The risers shall be connected by piping of adequate size to either an effective separator or a throttling steam calorimeter in the outlet piping.

If a separator is used, this piping shall pitch downward to the separator, and from the separator downward to the condenser or exhaust outlet. A vented water seal shall be placed in the drain from the separator.

The separator or throttling steam calorimeter and the piping connecting it to the boiler shall be well insulated. Provision shall be made for temperature measurement in the outlet piping if output due to

superheat is to be claimed. Steam Condensate or feedwater shall be measured with a totalizing water meter or weighed.

When using a throttling steam calorimeter in place of a steam separator, adhere to the recommended installation instructions supplied by the manufacturer of the calorimeter being used. The use of a throttling steam calorimeter shall require the measurement of feedwater during the test.

C2.4 *Water Piping (Thermal Efficiency Test)*. A typical test set-up is shown diagrammatically in Figure C9. The amount of water heated by the boiler shall be measured using a water meter or one or more weigh tanks mounted on scales, measuring either the boiler feedwater or the boiler outlet water. Water from the boiler must enter the run of a first tee and exit from the side outlet of the tee. The remaining connection of the tee shall be plugged. Outlet water temperature shall be measured in the run of a second tee located 12 ±2 pipe diameters downstream from a first tee located no more than the greater of 12 inches or 6 pipe diameters from the outlet of the boiler. The temperature measuring device shall extend into the water flow at the point of exit from the side outlet of the second tee. The second tee outlet must face up or must have connected pipe fittings that face up. All outlet piping from the boiler to the temperature measurement shall be wrapped with R-7 insulation. See Figure C10.

Inlet water temperature shall be measured in the run of a tee and the temperature measuring device shall extend into the water flow at the point of exit from the side of the tee outlet (see Figure C9, Point A). The tee shall be located no more than the greater of 12 inches or 6 pipe diameters from the inlet of the boiler.

Except as specified in Section 5.3.5.3, no other water connections are allowed between the water meter and the boiler. The connection between the water meter and boiler shall be leak free.

Pipes shown in Figure C10 shall be sized for a water velocity between 2 and 6 feet per second at the boiler's maximum gross output. The water velocity shall be calculated based on the water flow rate and nominal pipe cross-sectional area.

C2.5 *Application of Instruments (Steam and Water)*.

C2.5.1 *Flue Gas Temperature Measurement*. The average temperature of boiler flue gases shall be taken downstream from the boiler heat exchanger and before any dilution air is introduced. The flue gas temperature shall be taken using a thermocouple grid constructed as shown in Figure C12 installed in a plane perpendicular to the flow of flue gas as shown in Figures C1, C2, C3, or C4, as appropriate. Thermocouples in the grid shall be made from thermocouple wire no larger than 22 gauge and shall be connected in parallel. Where there is a possibility the thermocouples could receive direct radiation from the burner flame, thermocouple radiation shields must be applied.

C2.5.1.1 *Round pipe.* A nine (9) thermocouple grid constructed as shown in Figure C12 shall be used in round pipe up to and including 24 inches in diameter. A seventeen (17) thermocouple grid constructed as shown in Figure C12 shall be used in round pipe over 24 inches in diameter.

C2.5.1.2 *Rectangular measurement plane*. A three-by-three, nine (9) thermocouple grid constructed with uniform spacing as shown in the example in Figure C12 shall be used in rectangular openings up to and including 24 inches of width. For rectangular openings over 24 inches in width, use a three-by-six, eighteen (18) thermocouple grid constructed with uniform spacing based on the example in Figure C12. For the purpose of this requirement, width is the longest side dimension in the flue cross-section.

C2.5.2 *Flue Gas Sampling*. All instruments inserted to sample flue gas shall be carefully sealed. Flue gas sampling shall be conducted downstream from the flue gas thermocouple grid and at a location prior to the ingress of any dilution air.

When taking flue gas samples from a round pipe, the samples shall be collected using an open end tube projecting into the pipe ¼ to ½ of the pipe diameter or an alternate sampling tube shall be

used to obtain an average flue gas sample. When taking flue gas samples from a rectangular plane, the samples shall be collected using a sampling tube located so as to obtain an average flue gas sample.

C2.5.3 *Draft Measurement.* A draft measurement instrument shall be connected to a tube located in the vent downstream of the thermocouple grid and downstream from the entry of any dilution air into the flue gas. The tube shall project into the vent ¼ to ½ the diameter of the pipe. A similar tube projecting into the firebox beyond the inside of the front or rear wall shall be used when a firebox pressure is specified by the manufacturer.

C2.5.4 *Smoke Measurement, Oil*. The smoke measuring device shall be connected to an open end tube located as shown in Figure C1. It shall project into the flue ¼ to ½ of the pipe diameter. It shall be installed in the opening provided for the draft gauge sampling tube for the time required to obtain the smoke sample.

The smoke spot reading shall be evaluated in accordance with ASTM D2156-09.

C2.5.5 *Fuel Burned.*

C2.5.5.1 *Oil*. The fuel oil shall be fed to the burner using a measuring means meeting the requirements of Section C1. If oil is fed to the burner from a tank resting on a scale, a siphon connection from the oil supply to the burner shall be used to permit free play of the scale (see Figure C11).

C2.5.5.2 *Gas*. Gas shall be fed to the burner through a wet or dry gas meter.

C2.6 *Application of Additional Instruments (Steam).*

C2.6.1 *Steam Pressure*. A pressure measuring instrument shall be connected to the steam space of the boiler.

C2.6.2 *Feed Water*. The piping connecting the feedwater supply to the return tapping of the boiler shall be of adequate size and shall contain a valve approximately two feet from the boiler. A temperature measuring instrument shall be located approximately one foot ahead of the inlet side of the valve. (See Figures C5 through C8), unless conduction or convection affects the temperature, in which case the instrument shall be moved far enough away to prevent these from affecting the temperature.

C2.6.3 *Moisture in Steam*. Moisture in the steam shall be determined by separating out the moisture, condensing it and calculating the percent moisture with either the feedwater or steam weight, in accordance with Sections C7.2.9.1 and C7.2.9.2, or by using a throttling steam calorimeter as described in Non-mandatory Appendix B of ASME PTC-19.11-2008, and the percent moisture calculated in accordance with Section C7.2.9.3.

C2.7 *Application of Additional Instruments (Water).*

C2.7.1 *Water Temperature*. The inlet and outlet water temperatures shall be measured at the locations specified in Section C2.4 and shown in Figures C9 and C10.

C2.7.2 *Water Measurement.*

C2.7.2.1 Water measurement shall be accomplished by one of the methods described in this section.

C2.7.2.1.1 Outlet water shall be collected in a covered tank and weighed.

C2.7.2.1.2 Feedwater shall be pumped from a weigh tank.

C2.7.2.1.3 A calibrated, totalizing water meter meeting the requirements of Section C2.7.2.2 shall be used to measure feedwater.

C2.7.2.2 *Calibration Requirements for a Water Met*er. A calibrated water meter used to measure feedwater shall meet at least one (1) of the following requirements:

C2.7.2.2.1 The water flow meter shall be calibrated to meet the accuracy and resolution requirements specified in Section C1 for "Water."

C2.7.2.2.2 A flow meter that does not meet the minimum accuracy required by Section C1 shall meet the following conditions:

C2.7.2.2.2.1 The meter shall not be used at flow rates, or under other conditions, outside of the meter manufacturer's specifications. The water flow rate recorded by the water flow meter shall be verified immediately prior to starting the test or series of tests using a scale(s) and stop watch meeting the requirements of Section C1. The water flow rate used to verify the water flow meter shall be the same as that required to perform the efficiency test ± 10%.

C2.7.2.2.2.2 During this verification, the water weighed shall be accumulated prior to the test over a period of not less than the following:

Minimum Weigh Period (seconds) = (1438 ÷ V) + 400

V = flow rate observed using meter, Gal/min

C2.7.2.2.2.3 The water flow rate recorded by the water flow meter shall not deviate from the water flow rate determined using the scale(s) by more than 3.0%.

C2.7.2.2.2.4 A correction factor for the water flow meter shall be calculated from the above measurements and used to determine the actual water flow during the test.

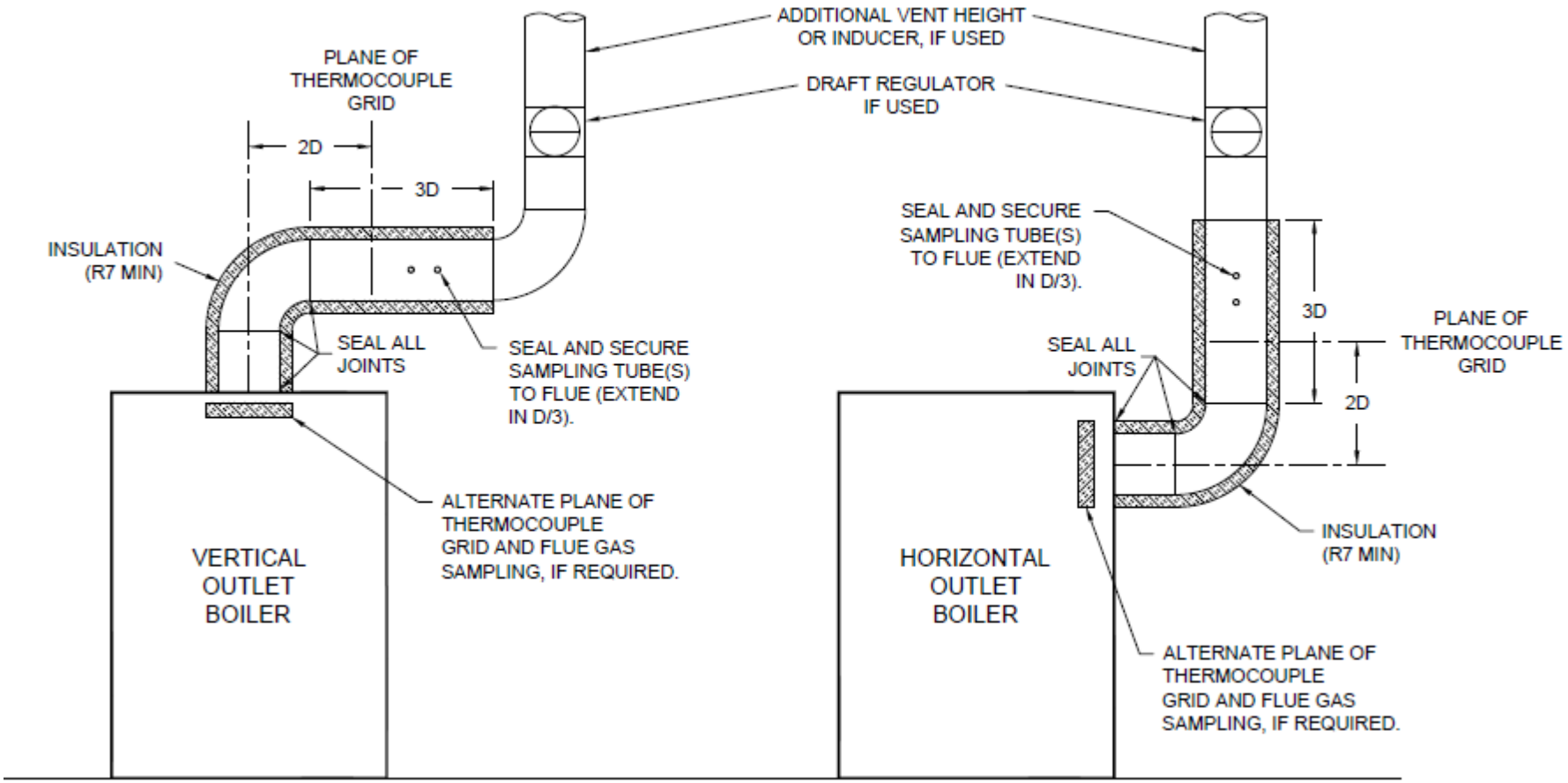
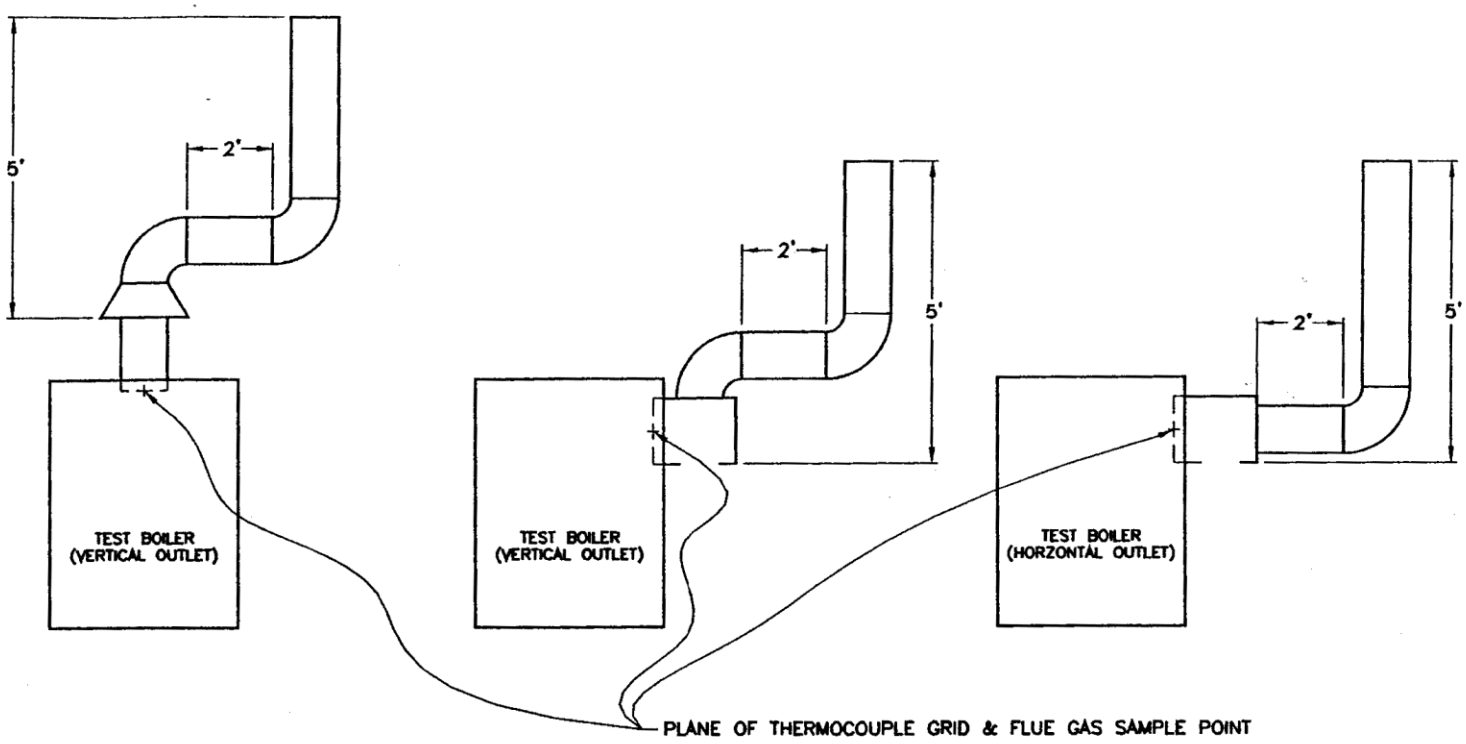


Figure C1. Test Vent for Boilers with a Gas or Oil Non-atmospheric Burner and with Negative Vent Pressure

and

Test Vent for Boilers with a Gas or Oil Non-atmospheric Burner and with Positive Vent Pressure and that are <u>not</u> Direct Vent Boilers, as Defined in Section 3 (if it is a Direct Vent Boiler, See Figure C4)



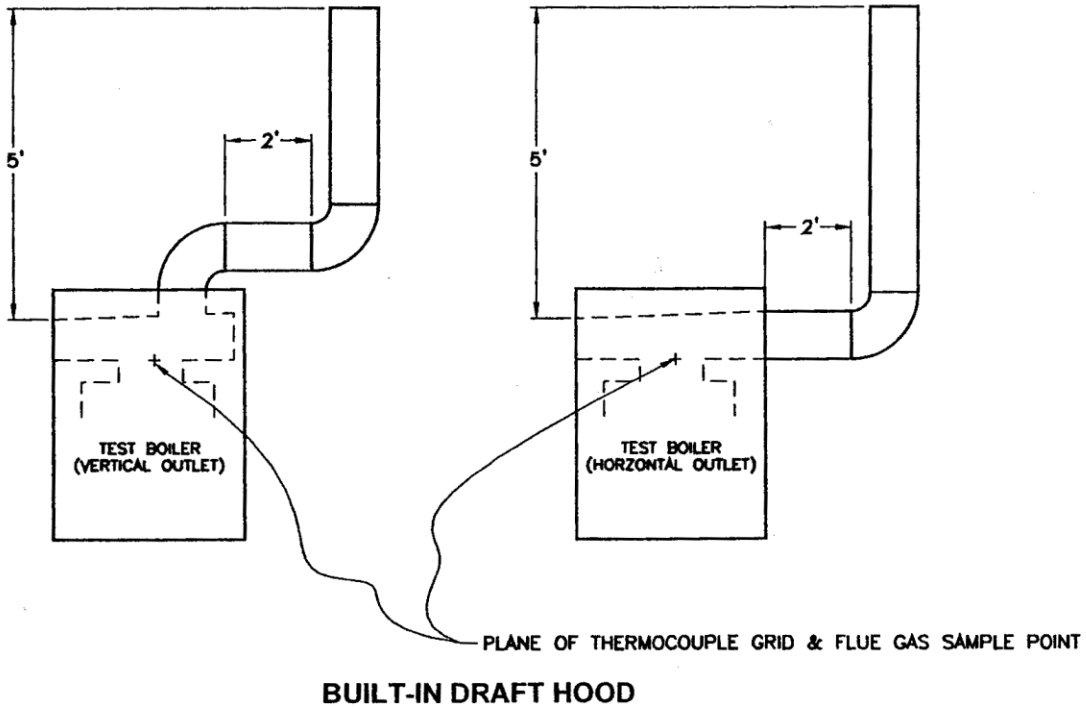
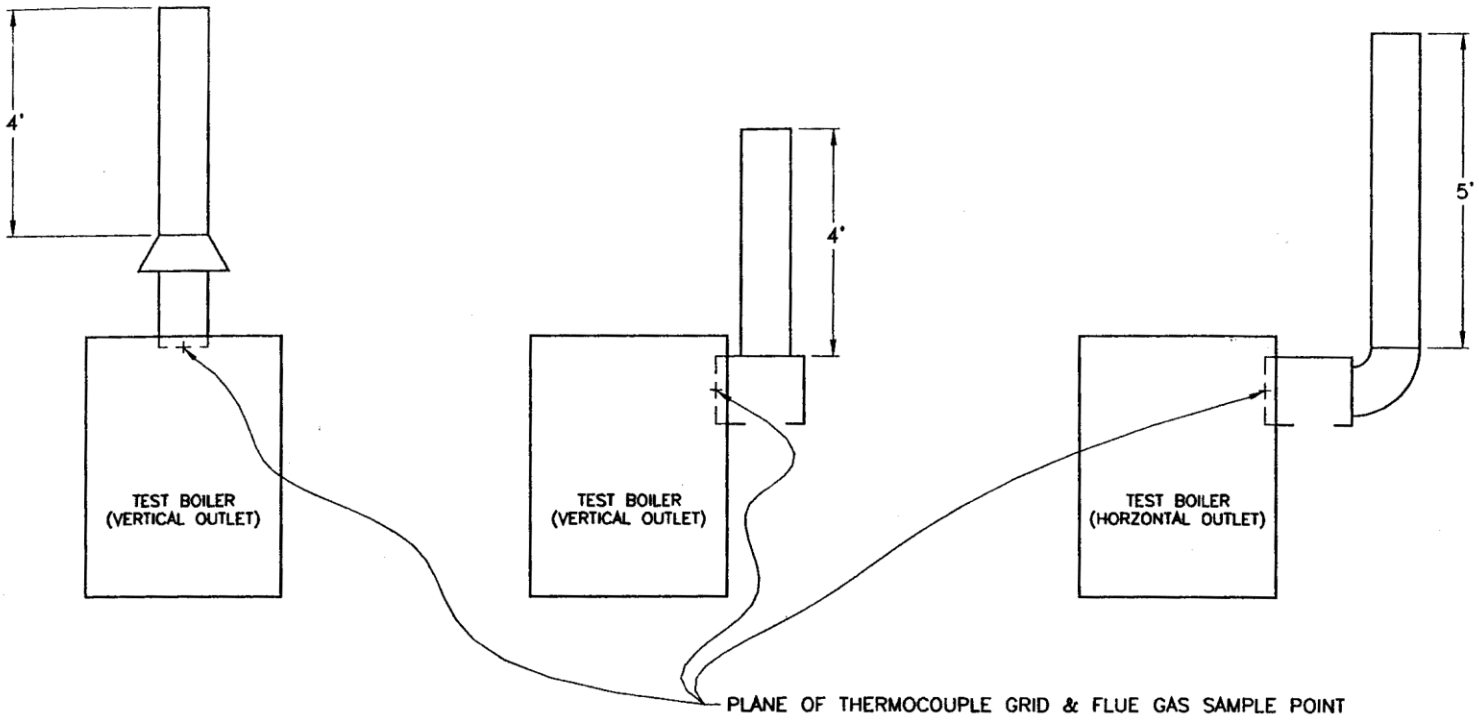


Figure C2. Test Vent for Atmospheric Boiler with an Input Rating of 400,000 Btu/h or Less

Note: Dimensions shown are in feet.



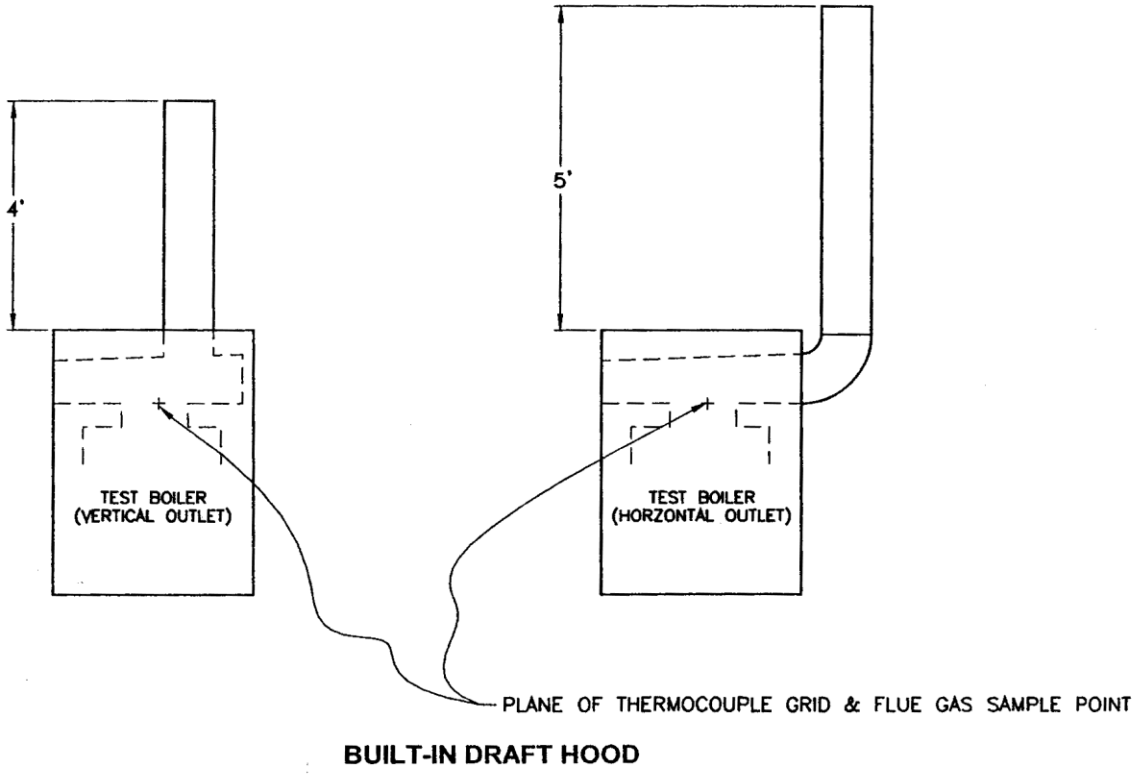
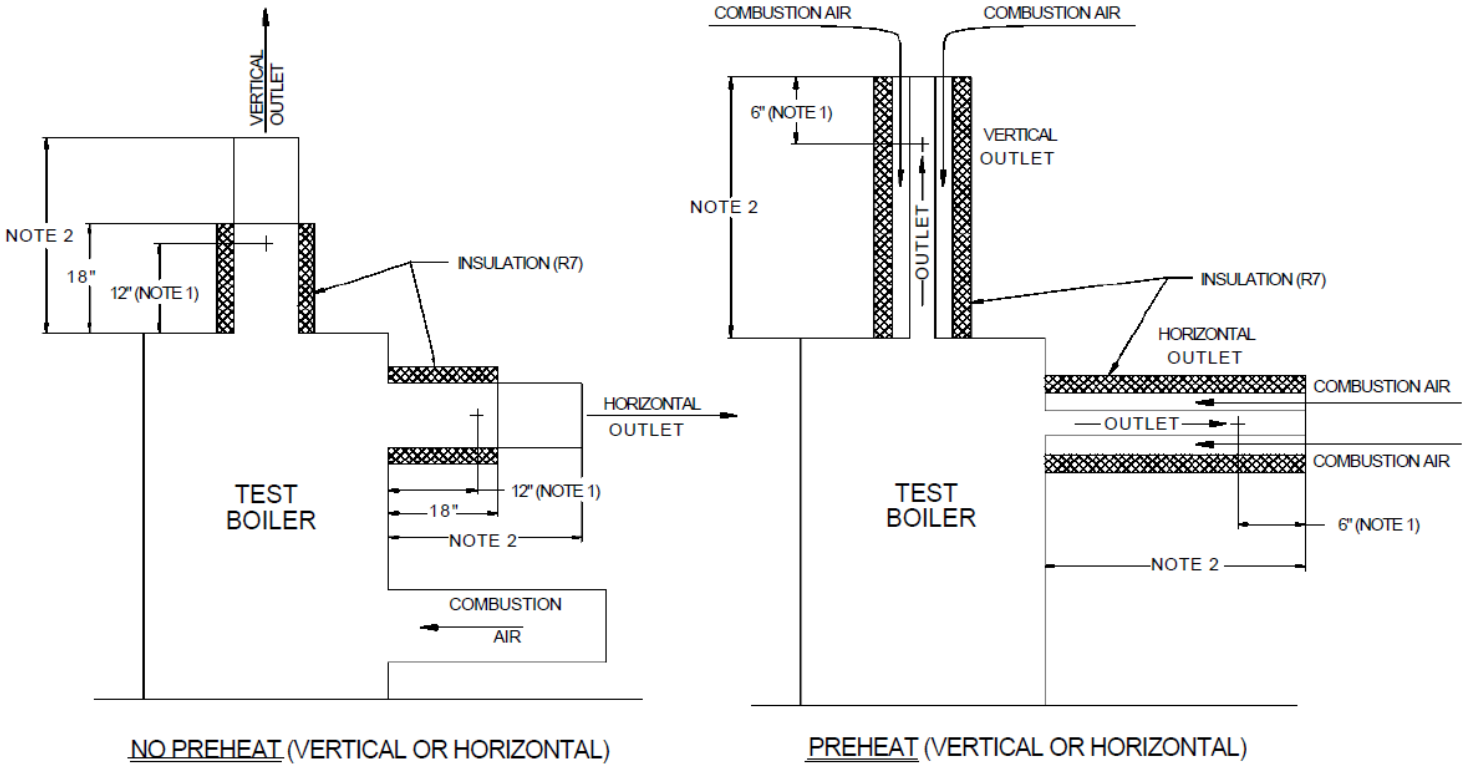
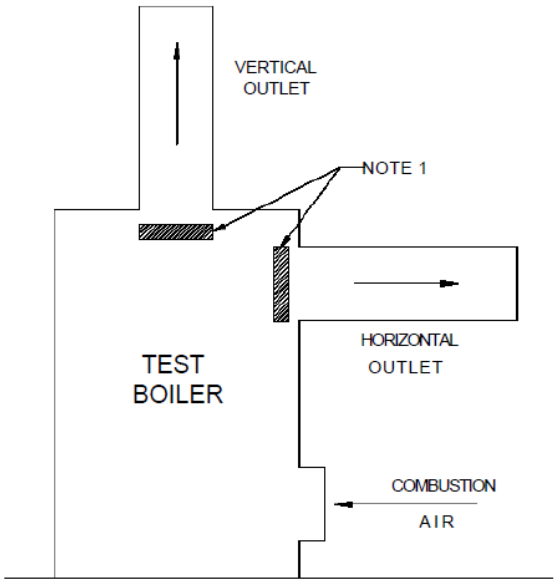


Figure C3. Test Vent for Atmospheric Boiler with an Input Rating Greater than 400,000 Btu/h

Note: Dimensions shown are in feet.



NOTES:
1. PLANE OF THERMOCOUPLE GRID AND FLUE SAMPLE.
2. MINIMUM VENT LENGTH SPECIFIED IN SECTION C2.2.2



ALTERNATE PLANE OF THERMOCOUPLE GRID AND FLUE GAS SAMPLING LOCATION, IF REQUIRED TO OBTAIN FLUE GAS SAMPLE BEFORE DILUTION AIR IS INTRODUCED.

Figure C4. Test Vent for Direct Vent Boilers (as Defined in Section 3) with a Gas or Oil Non-atmospheric Burner and with Positive Vent Pressure

(if not a Direct Vent Boiler, see Figure C1)

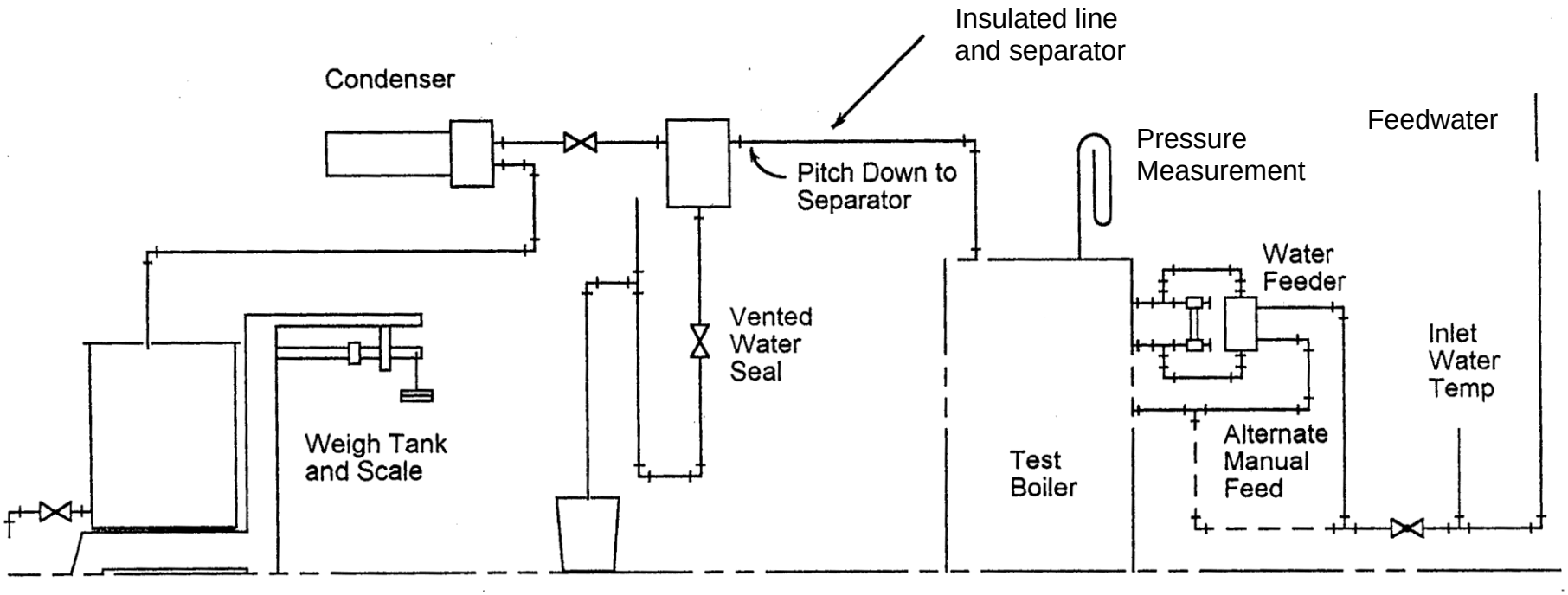


Figure C5. Suggested Piping Arrangement for Steam Boilers, Condensate Measurement

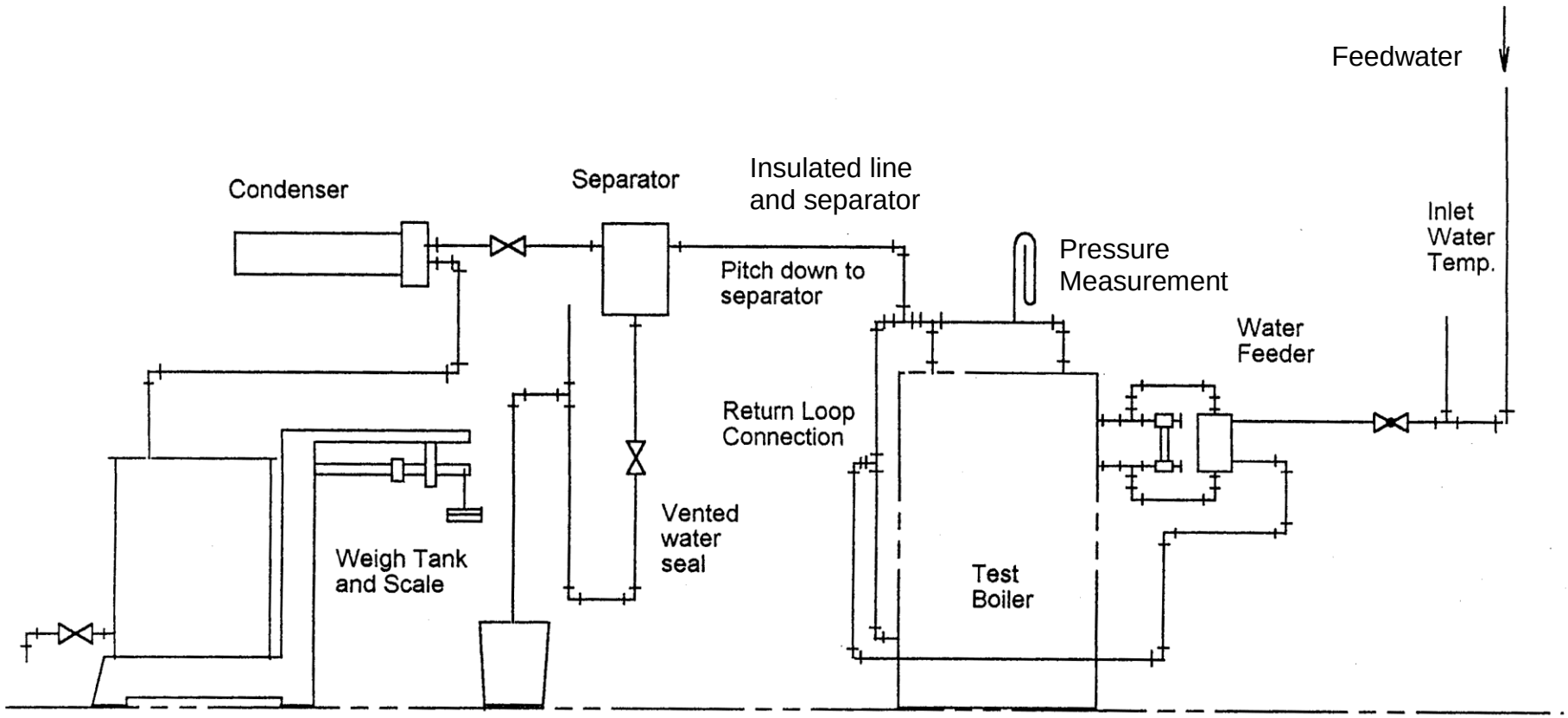


Figure C6. Suggested Piping Arrangement for Steam Boilers with Return Loop Connection, Condensate Measurement

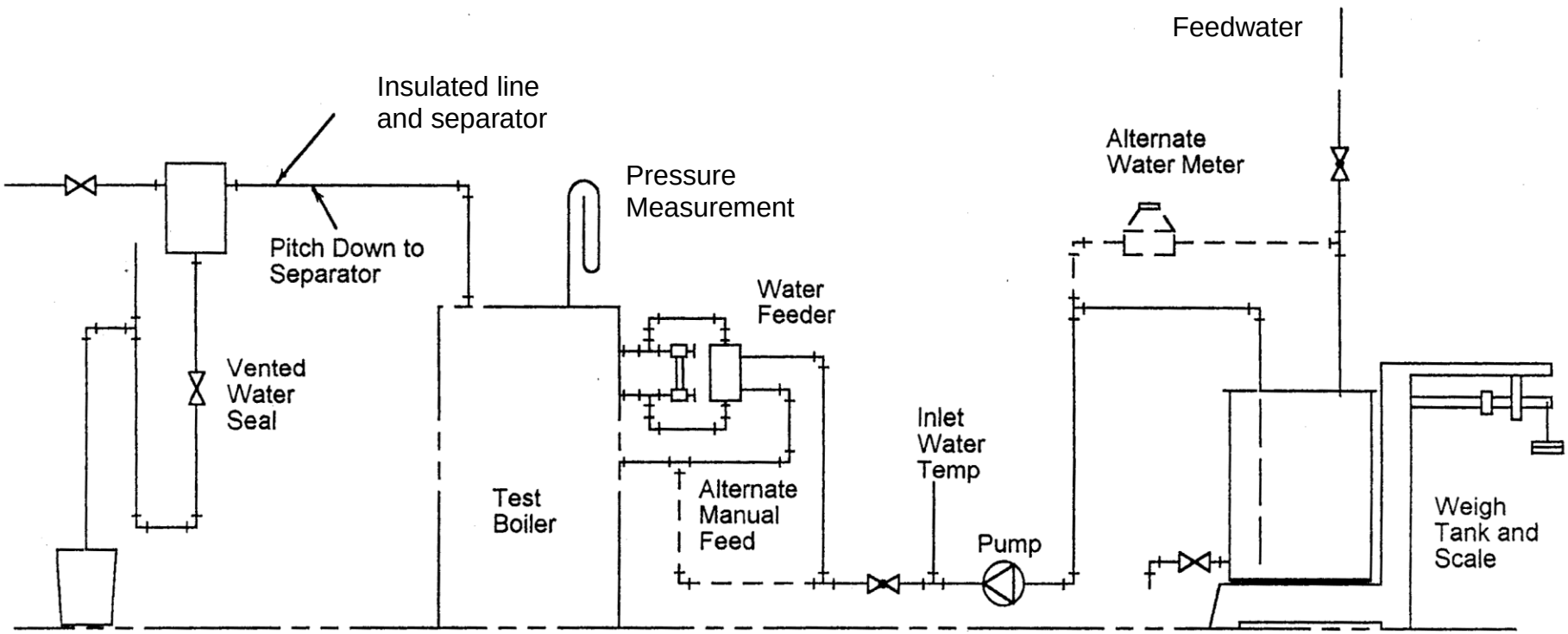


Figure C7. Suggested Piping Arrangement for Steam Boilers, Feedwater Measurement

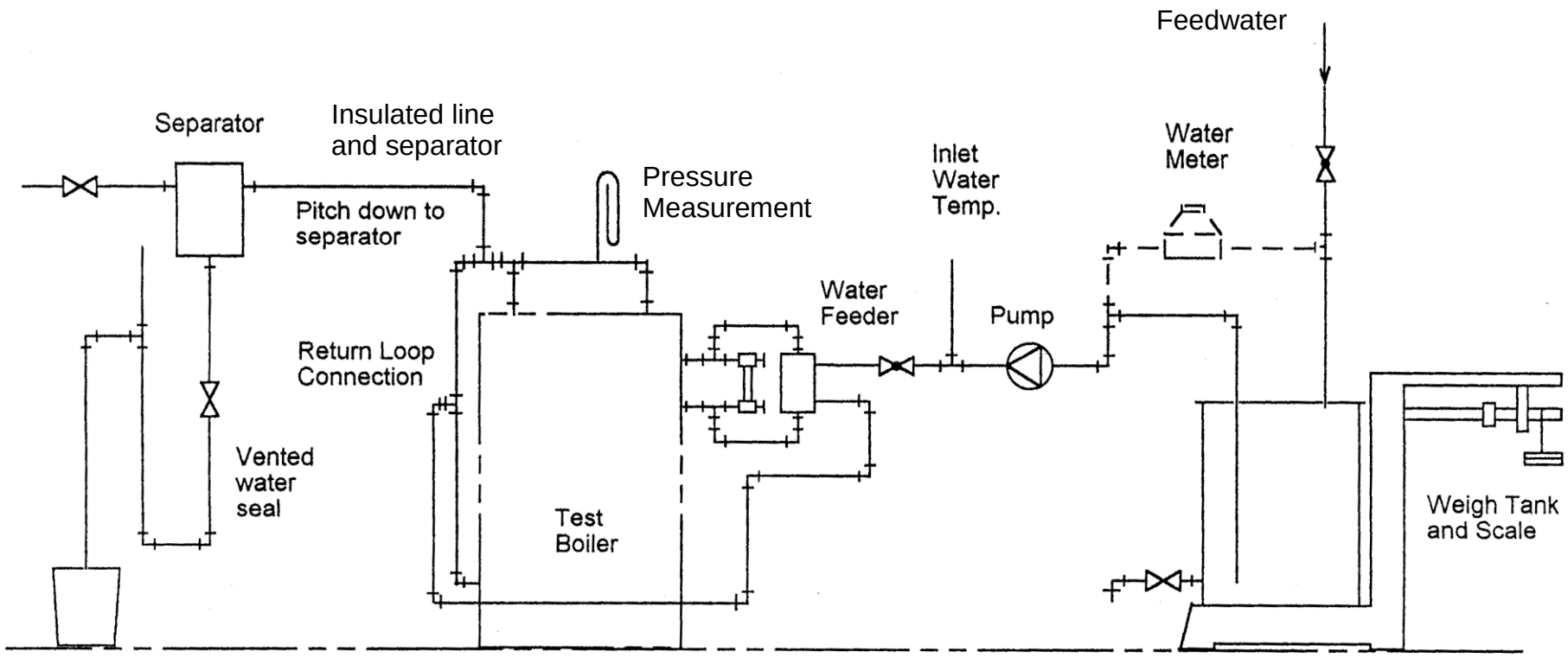


Figure C8. Alternate Arrangement for Steam Boilers with Return Loop Connection, Feedwater Measurement

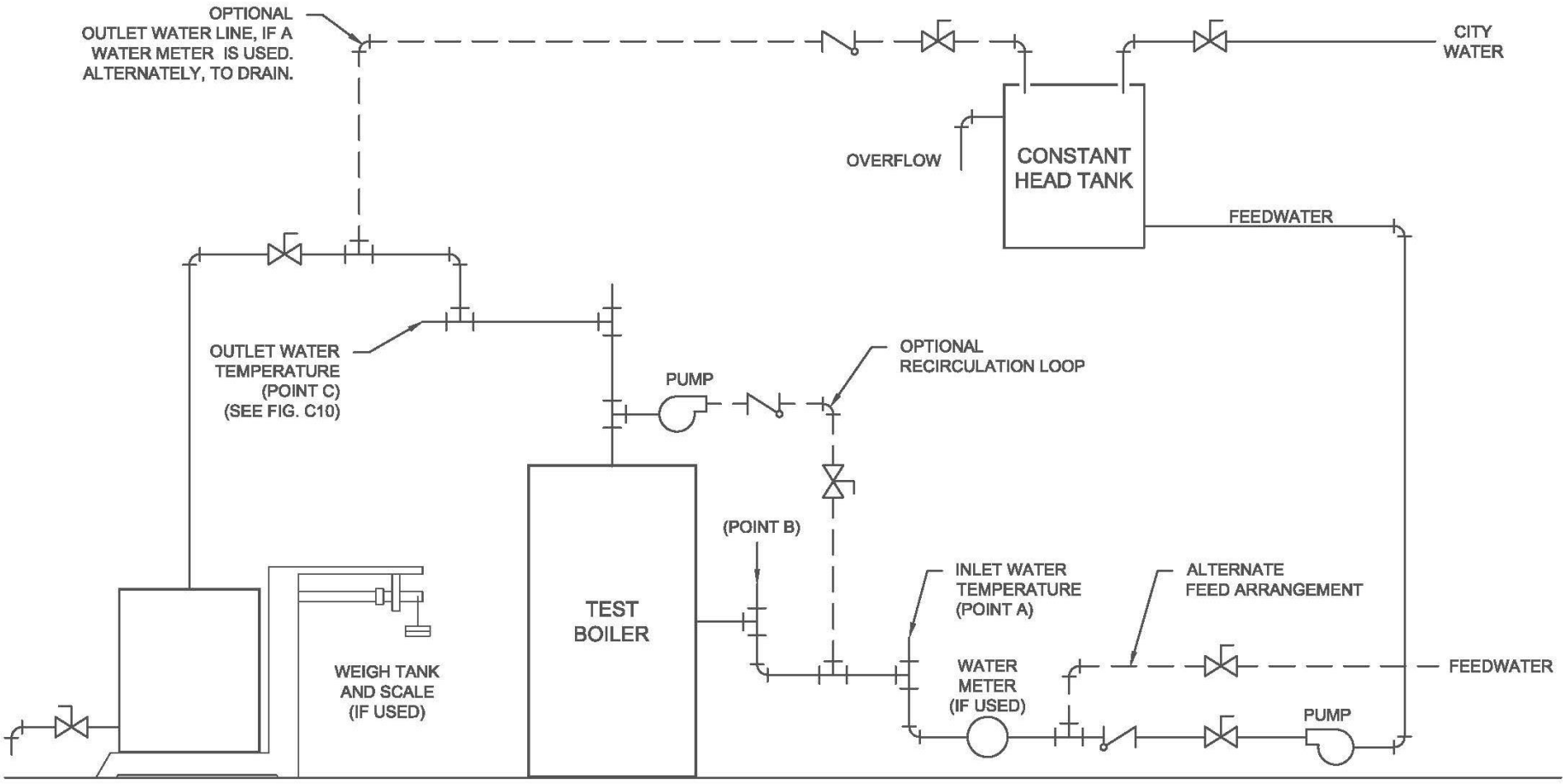


Figure C9. Suggested Piping Arrangement for Hot Water Boilers

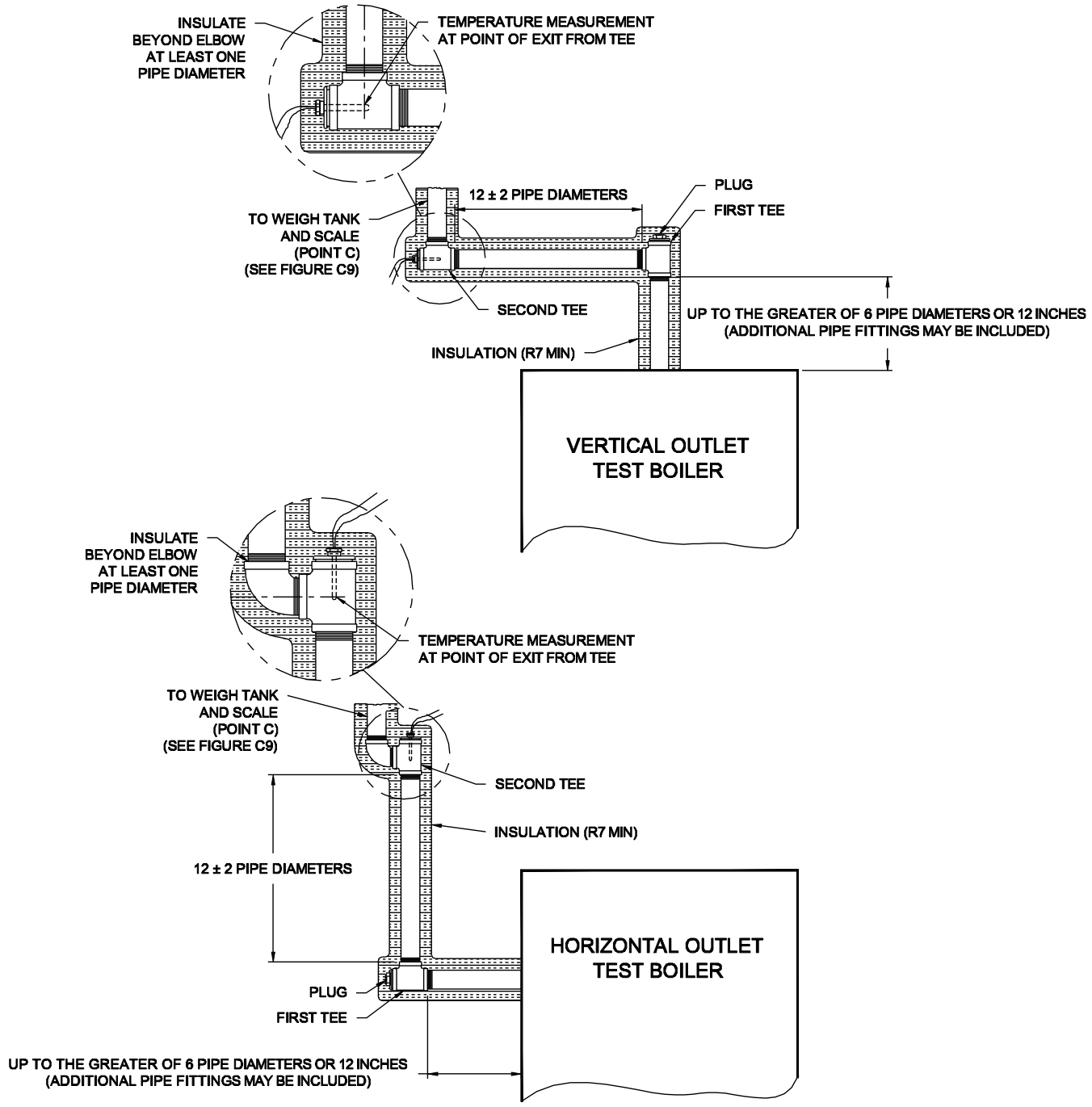


Figure C10. Required Piping Arrangement for Hot Water Boilers

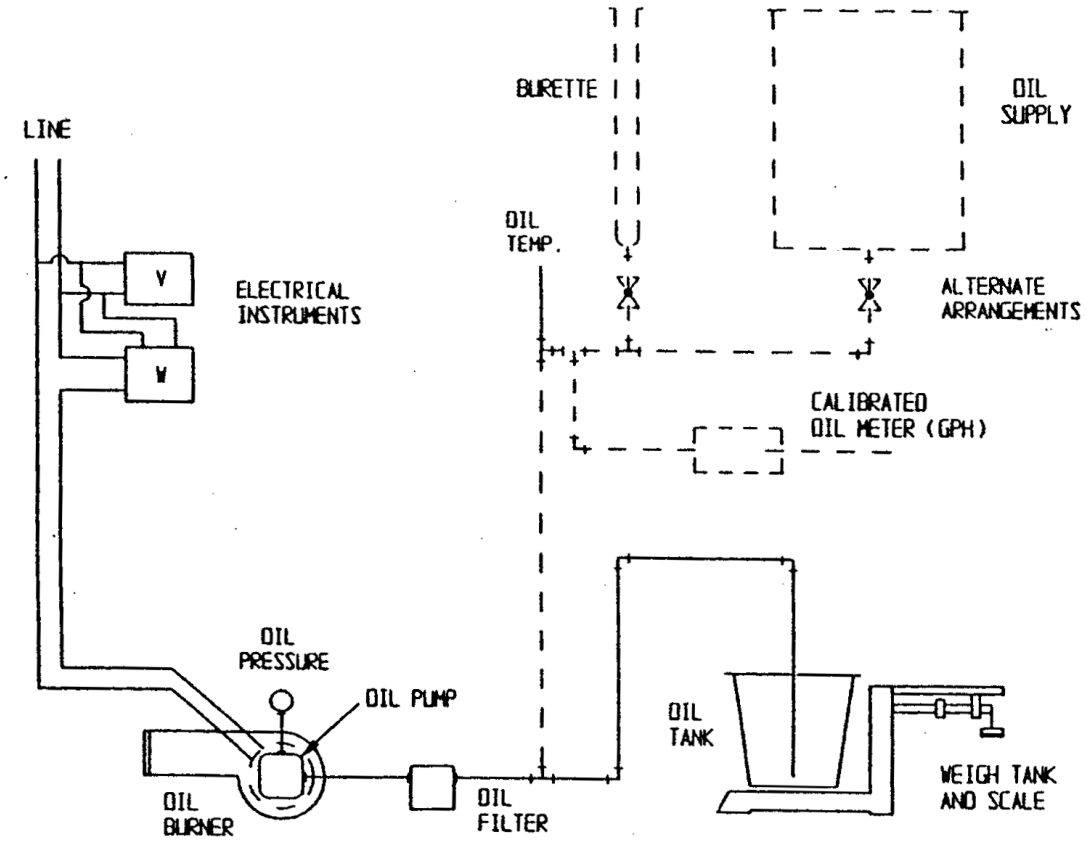
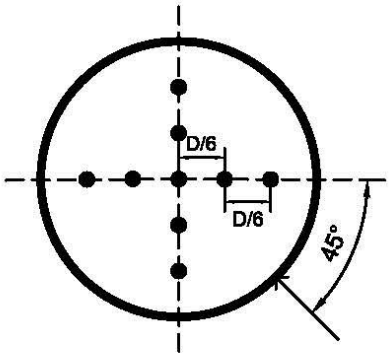


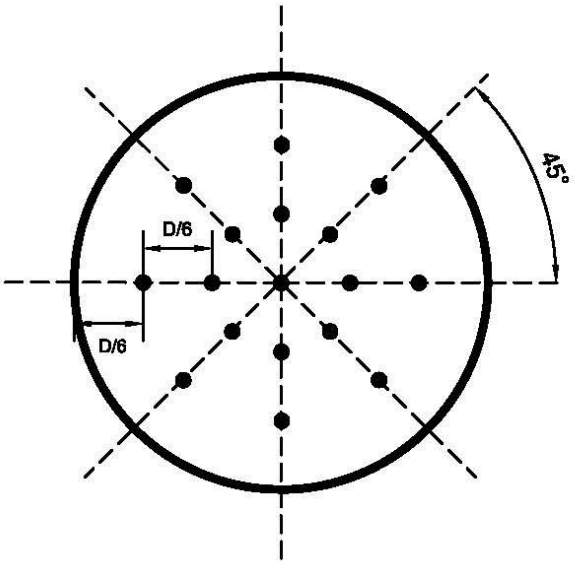
Figure C11. Suggested Oil Burner Test Setup

(Installed in a plane perpendicular to the flow of flue gas)



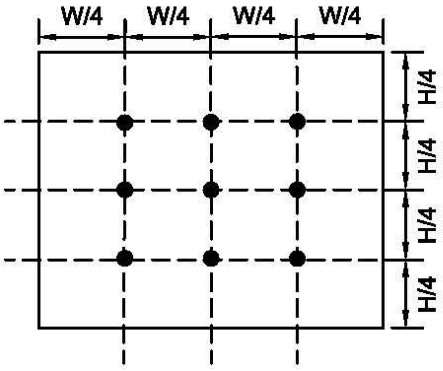
Up to & including 24 inches
Diameter (D)

Nine (9) Thermocouple Grid



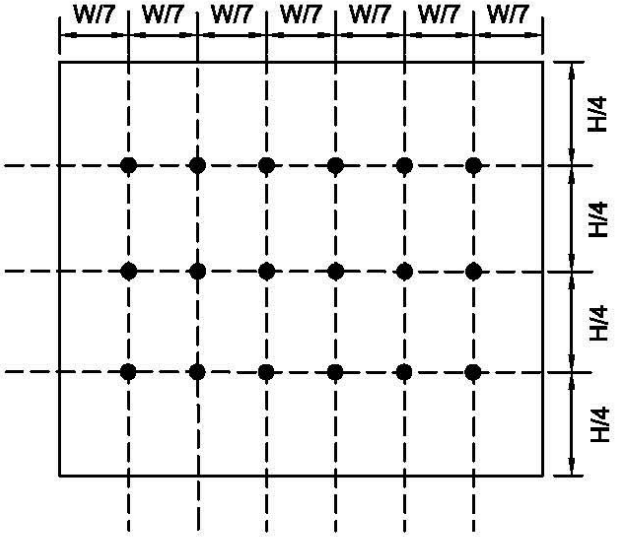
Over 24 inches Diameter (D)

Seventeen (17) Thermocouple Grid



Width (W) and Height (H)
Up to & including 24 inches

Nine (9) Thermocouple Grid



Width (W) or Height (H) Over 24 inches

Eighteen (18) Thermocouple Grid

Figure C12. Thermocouple Grid

C3 *Test Conditions*.

C3.1 *Test Unit*. A standard Boiler, or a prototype Boiler, shall be used, erected in accordance with the manufacturer's instructions shipped with the boiler. All openings shall be sealed as specified by the manufacturer's instructions shipped with the boiler to prevent the leakage of air.

C3.1.1 *Insulated Jacket*. The insulated flush jacket, catalogued or furnished with the Boiler shall be in place during the test. If a production jacket is unavailable, a prototype jacket shall be fabricated for the test. The insulation thickness and spacing as specified shall be maintained.

C3.1.2 *Cleaning of Boiler*. The internal wet surfaces of the Boiler shall be cleaned as specified by the manufacturer's instructions shipped with the boiler.

C3.1.3 *Tests for Determining Gross Output and Efficiency*.

C3.1.3.1 Steam only Boilers shall be tested as steam Boilers.

C3.1.3.2 Hot Water only Boilers shall be tested as a hot water Boilers.

C3.1.3.3 Steam and hot water boilers claiming the same efficiency as a steam and as a hot water boiler shall be tested as a steam boiler.

C3.1.3.4 Steam and hot water boilers claiming a different efficiency as a steam or as a hot water boiler shall be tested both as a steam boiler and as a hot water boiler.

C3.2 *Fuel*.

C3.2.1 *Oil*. Boilers with an Input Rating up to and including 5 gph shall use No. 2 (light) fuel oil. Boilers with an Input Rating in excess of 5 gph shall use No. 2 (light) fuel oil, or No. 4, 5 or 6 (heavy) fuel oil, when their oil supply temperatures are specified in the manufacturer's instructions shipped with the boiler. All fuel oil shall comply with ASTM D396-14a. No. 2 fuel oil shall be supplied at room temperature.

C3.2.1.1 *Fuel Oil Analysis*. A representative sample of the fuel oil of approximately one quart shall be taken and analyzed to an accuracy of ±1% for the following values:

C3.2.1.1.1 Heating Value, per ASTM D240-09 or ASTM D4809-09a;

C3.2.1.1.2 Hydrogen and carbon content, per ASTM D5291-10, and;

C3.2.1.1.3 Density in pounds per gallon and API gravity, according to the methods specified by ASTM D396-14a.

C3.2.2 *Gas*. The test gas shall be natural gas. The actual higher Heating Value shall be determined to an accuracy of ±1% by use of a calorimeter, gas chromatography, or by using bottled gas of a known heating value.

C3.3 *Installation of Burner*. The burner shall be installed in accordance with the manufacturer's instructions shipped with the Boiler.

C3.4 *Vent and Firebox Pressure*. The draft shall be as established by the vent system specified in Section C2.2. If the manufacturer provides a dedicated venting arrangement, the boiler shall be tested with the arrangement having the least draft loss. If a firebox pressure is specified in the manufacturer's instructions shipped with the boiler, make the adjustment in accordance with those instructions.

C3.4.1 *Negative Vent Pressure (Draft)*. The draft shall be as established by the vent system specified in Section C2.2. If the manufacturer provides a dedicated venting arrangement, the

boiler shall be tested with the arrangement having the least draft loss. If a firebox pressure is specified in the manufacturer's instructions shipped with the boiler, make the adjustment in accordance with those instructions.

C3.4.2 *Outdoor Boiler*. Outdoor boilers shall be installed as specified in the manufacturer's instructions shipped with the boiler. If the manufacturer provides a dedicated venting arrangement, the boiler shall be tested with the arrangement having the least draft loss.

C3.5 *Flue Gas Temperature*. The flue gas temperature during the test shall not vary from the flue gas temperature measured at the start of the Test Period, as defined in Section C4, when recorded at the interval defined by Section C5 by more than the limits prescribed in Table C2.

Table C2. Limits of Flue Gas Temperature Variation During Test

Boiler Type	Non-condensing	Condensing
Gas	±2%	Greater of ±3% or ±5 °F
Light Oil	±2%	
Heavy Oil	Greater of ±3% or ±5 °F	

C3.6 *Air Temperature*. The test air temperature, measured at the Boiler air inlet, shall be within ± 5°F of the room ambient temperature when recorded at the interval defined by Section C5. The room ambient temperature shall be measured within 6 ft of the front of the unit at mid height.

C3.7 *Ambient Humidity*. The ambient humidity shall be measured at the room ambient temperature location specified in Section C3.6.

C3.8 *Water Measurement for Hot Water Boilers*. The water shall be weighed or measured using a totalizing water meter meeting the requirements of Section C2.7.2.2, and recorded at regular intervals during the test.

C3.9 *Output Measurement for Steam Boilers*.

C3.9.1 The output of boilers shall be determined by weighing or using a totalizing water meter to measure the steam condensate or Feedwater. The condensate and water from the separator shall be cooled or covered effectively to prevent re-evaporation.

C3.9.2 The water from the separator shall be weighed and recorded at the beginning and end of the test. If condensate is collected and weighed, the separator water weight is added when calculating heat in the liquid. If Feedwater use is measured, the separator water weight is subtracted when calculating the latent heat.

C3.9.3 If a totalizing water meter is used, it shall meet the requirements of Section C2.7.2.2.

C4 *Test Procedure.*

C4.1 *Thermal Efficiency Test*.

C4.1.1 *Steam Test.* Informative Note: The conduct of this test may require that a continuous feed system be used to maintain a consistent water level.

C4.1.1.1 *Warm-up Period.*

C4.1.1.1.1 With all required testing apparatus properly connected, and with boiler water at normal level, the burner shall be started and the system warmed up until steaming occurs.

C4.1.1.1.2 Oil or Non-atmospheric gas shall be adjusted to produce the required firebox pressure and CO_2 or O_2 as described in Section 5.3.1.

Tests shall be conducted at atmospheric pressure or at the minimum steam pressure required to comply with Section 5.3.6. If necessary, pressure shall be developed by throttling with a valve located beyond the separator. This valve shall be set before the test is started and not changed during the test.

C4.1.1.1.3 Prior to collecting data, all fuel, condensed steam and feedwater scales shall be balanced, or, if totalizing flow meters are used, the starting readings shall be recorded at the beginning of data collection. The water level shall be maintained within the range specified in the manufacturer's instructions shipped with the boiler. If no water level is specified in the instructions shipped with the boiler, the water level shall be maintained within ± 1 inch of the water level indicated on the boiler or, if no water level is indicated on the boiler, a level 3 ± 1 inches above the highest fired surface.

C4.1.1.1.4 Steady-state shall have been reached when three consecutive readings have been recorded at 15-minute intervals that confirm:

- Input is within 2% of the Input Rating, and;
- Steam pressure varies no more than 5%.

C4.1.1.2 *Test Period.*

C4.1.1.2.1 The test period shall start when a steady state has been reached, and the last reading of the warm-up period plus a separator water weight shall be the first reading of the test period. No further burner adjustment shall be made. For non-atmospheric burners, the average of all CO_2 or O_2 readings during the test period shall not differ from the first reading by greater than the tolerance specified in Table C3.

Table C3. Flue Gas Measurement Tolerance

Fuel	If $\%CO_2$ is measured	If $\%O_2$ is measured
Gas	±0.3%	±0.5%
Fuel Oil	±0.3%	±0.4%

C4.1.1.2.2 Test conditions as specified in Sections 6 and C3 shall be maintained throughout the test period and shall be observed and recorded at each 15 minute interval as specified in Section C5.

C4.1.1.2.3 The test period shall be one hour if the Steam Condensate is measured or two hours if Feedwater is measured and shall end with a regularly scheduled 15 minute reading plus a separator water weight. When feedwater is measured, the water line at the end of the test shall be within ± ¼ in of the starting level. The total Heat Input measured during the Test Period shall be within ± 2% of the boiler Input Rating.

C4.1.2 *Water Test.*

C4.1.2.1 *Warm-up Period.*

C4.1.2.1.1 With all required test apparatus properly connected, and with the boiler and piping filled with water such that water flows through the system, the burner shall be started and the system warmed up until the outlet water temperatures described in Section 5.3.5 are achieved.

C4.1.2.1.2 Oil or Non-atmospheric gas burners shall be adjusted to produce the required firebox pressure and CO_2 or O_2 as specified in Section 5.3.1.

C4.1.2.1.3 The water flow rate shall be adjusted to achieve the water temperatures described in Section 5.3.5.

C4.1.2.1.4 Readings (Recording of Observations) may be started as soon as the water temperature conditions are met. Once started, readings shall continue uninterrupted at 15 minute intervals.

Prior to collecting data, all fuel and water scales used shall be balanced, or, if totalizing flow meters are used, the starting readings shall be recorded at the beginning of data collection.

C4.1.2.1.5 Steady state shall have been reached when three consecutive readings at 15-minute intervals confirm that:

- Input is within 2% of the Input Rating;
- Water temperatures are within the limits described in Section 5.3.5, and;
- Non-condensing boiler inlet water temperature is within the temperatures described in Section 5.3.5 and within +/- 10 °F of the first reading.

C4.1.2.2 *Test Period.*

C4.1.2.2.1 The test period shall start when a steady state has been reached, and the last reading of the warm-up period shall be the first reading of the test period. No further burner adjustment shall be made. For non-atmospheric burners, the average of all CO_2 or O_2 readings during the test period shall not differ from the first reading by greater than the tolerance specified in Table C3 in Section C4.1.1.2.1.

C4.1.2.2.2 Test conditions which are specified in Sections 6 and C3 shall be maintained throughout the test period, and shall be observed and recorded at each 15 minute interval as specified in Section C5.

C4.1.2.2.3 The test period shall be one hour for Condensing Boilers or 30 minutes for Non-condensing Boilers and shall end with a regularly scheduled 15 minute reading. The total Heat Input measured during the Test Period shall be within ± 2% of the boiler Input Rating.

C4.2 *Combustion Efficiency Test*.

C4.2.1 A combustion test is performed in a manner similar to the thermal efficiency test described above except that output is not measured.

C4.2.2 The Boiler shall be fired until steady state has been established as defined in Section C4.1.1.1.4 for steam boilers or Section C4.1.2.1.5 for hot water boilers. For condensing boilers

condensate shall be collected for the 30 minute period. The data shall be recorded as specified in Section C5.

C5 *Data to be Recorded*. Data shall be recorded in accordance with the requirements in Table C4. Example data logs and test report sheets are available in Appendix F.

Table C4. Data to be Recorded Before and During Testing

Item Recorded	Thermal Efficiency Test		Combustion Efficiency Test	
	Before Test	Every 15 minutes[1]	Before Test	Every 15 minutes[1]
Date of Test	X		X	
Manufacturer	X		X	
Boiler Model Number	X		X	
Burner Model Number & Manufacturer	X		X	
Nozzle description	X		X	
Oil Analysis - H, C, API Gravity, lb/gal and Btu/lb	X		X	
Gas Manifold Pressure	X		X	
Gas line pressure at meter	X		X	
Gas temperature	X		X	
Barometric Pressure (Steam and Natural Gas Only)	X		X	
Gas Heating Value, Btu/ft^3	X		X	
Time, minutes/seconds		X		X
Flue Gas Temperature, °F		X		X
Pressure in Firebox, in H_2O (if required per Section C3.4)		X		X
Flue Gas Smoke Spot Reading (oil)		X		X
Room Air Temperature		X		X
Fuel Weight or volume, lb (oil) or ft^3 (gas)		X		X
Inlet Water Temperature, °F		X		X
Test Air Temperature, °F		X		X

Table C4. Data to be Recorded Before and During Testing (continued)					
Item Recorded		Thermal Efficiency Test		Combustion Efficiency Test	
		Before Test	Every 15 minutes[1]	Before Test	Every 15 minutes[1]
Draft in Vent, in H_2O (oil and non-atmospheric gas)			X		X
Flue Gas CO_2 or O_2, %			X		X
Flue Gas CO, ppm			X		Start and End only
Relative Humidity, % (Non-condensing Boilers)					Start and End only
Relative Humidity, % (Condensing Boilers)			X		X
Flue Condensate Weight, lb (Condensing Boilers only)					Every 30 minutes
STEAM	Separator water weight, lb		At a minimum at Start and End		
	Steam Pressure, in Hg		X		X
	Steam Temperature, °F (if used)		X		
	Condensate collected, or water fed, lb		X		
WATER	Outlet Water Temperature, °F		X		X
	Water fed, lb		X		
	Recirculating Loop Temperature (Figure C9, Point B), °F (if used)		X		X
Notes: 1. "X" in this column indicates that required data shall be recorded every 15 minutes during the test. Other frequencies are otherwise noted.					

C6 *Symbols and Subscripts*. The symbols and subscripts used in this standard are as follows:

A = Air required for complete combustion, SCF per 1,000 Btu of gas burned
C = Carbon content of the oil, % by weight
$C_{p,air}$ = Specific heat of air = 0.24 Btu/lb·°F
$C_{p, H2O}$ = Average specific heat of water = 1.000 Btu/lb·°F
C_S = Correction factor to be applied if the gas, as metered, is not at standard temperature and pressure. (See Appendix E)
CO = Percentage by volume of carbon monoxide in the flue gas, %
CO_2 = CO_2 in flue gases, percent of total dry constituents in the flue gas
D = Vent pipe diameter, in
$Effy_{SS}$ = Combustion Efficiency, %
$Effy_T$ = Indoor Boiler Thermal Efficiency, %
$Effy_{T,O}$ = Outdoor Boiler Thermal Efficiency, %
F_W = Feedwater flow rate, gal/h

H = Hydrogen content of the oil, % by weight
HHV_{oil} = Oil Higher Heating Value, Btu/lb
HHV_{gas} = Gas Higher Heating Value, Btu/ft^3
$h_{fg,TSAT}$ = Latent heat of vaporization at the saturated steam temperature
$h_{fg,70}$ = Latent heat of vaporization of water at 70°F = 1053.3 Btu/lb
h_g = Enthalpy of saturated steam at steam pipe pressure, Btu/lb
h_{tg} = Latent heat of vaporization of saturated water at steam pipe pressure, Btu/lb
$L_{C,SS}$ = Steady state heat loss due to hot Flue Condensate going down the drain, %
L_f = Flue loss, % of heat input rate
$L_{G,SS}$ = Latent heat gain due to condensation under steady state conditions, %
L_L = Loss due to moisture, %
L_s = Loss in dry flue gases, %
L_U = Radiation and unaccounted for loss, %
M = Moisture in steam, %
$M_{C,SS}$ = Flue Condensate mass collected, lb/h
O_2 = Percentage by volume of oxygen, %
$O_{2,\ meas}$ = Measured percentage by volume of oxygen, %
P = Dry constituents in flue gases from stoichiometric combustion, SCF per 1,000 Btu of gas burned
P_B = Barometric pressure, in Hg
P_g = Absolute pressure of gas being metered (barometric pressure plus gas pressure in meter), in Hg
P_S = Test steam pressure, in Hg gage
P_{SAT} = Steam pressure (absolute), in Hg
P_{std} = Standard absolute pressure, in Hg
P_{wv} = Water vapor pressure at T_g, in Hg
P_{wvs} = Water vapor pressure at T_{std}, in Hg
Q_{IN} = Heat input, Btu/h
Q_L = Latent heat in the steam produced, Btu/h
Q_{OUT} = Gross Output, Btu/h
$Q_{OUT,O}$ = Outdoor Boiler Gross Output, Btu/h
Q_S = Sensible heat in the liquid, Btu/h
RH = Relative humidity of the air supplied for combustion, %/100 (the number entered shall be between 0 and 1)
T = Total constituents in flue gases from stoichiometric combustion, SCF per 1,000 Btu of gas burned
T_A = Test air temperature, °F
T_{cal} = Correct steam calorimeter temperature, °F
$T_{F,abs}$ = Absolute flue gas temperature, degrees R
$T_{F,SS}$ = Steady state Flue Temperature, °F
T_g = Temperature of gas in meter, °F
T_{IN} = Inlet water temperature, °F
T_{OUT} = Outlet water temperature, °F
$T_{r,abs}$ = Absolute room temperature, degrees R
T_{SAT} = Saturated steam temperature, either measured or taken from Appendix D at the absolute steam pressure, P_{SAT}, °F
T_{std} = Standard temperature, °F
t_T = Test duration, h
U_{gas} = Ultimate CO_2 of Flue Gas for natural gas, percent
U_{oil} = Ultimate CO_2 of Flue Gas for fuel oil, percent
V = Volume of water fed, gal
W = Weight of water fed, lb
W_C = Weight of steam condensed, lb
W_F = Weight of fuel, lb
W_S = Weight of water in separator, lb

W_V = Metered volume of gas, ft^3
ρ = Feedwater density, lb/gal
100 = Conversion factor to express a decimal as a percent
0.45 = Specific heat of water vapor, Btu/lb·°F
42 = Assumed average outdoor temperature, °F

C7 *Calculation of Results.*

C7.1 *Averaging and Totaling of Recorded Values*. All data shall be recorded as prescribed in Section C5.

C7.1.1 *Measurements to be Averaged (Mean) Over the Test Period*. For the following parameters (if recorded), the average (mean) of the values recorded during the test period shall be used for the calculations in this section:

C7.1.1.1 Room Air Temperature
C7.1.1.2 Test Air Temperature
C7.1.1.3 Inlet Water Temperature
C7.1.1.4 Outlet Water Temperature
C7.1.1.5 Flue Gas Temperature
C7.1.1.6 Fuel Gas Temperature
C7.1.1.7 Atmospheric Pressure
C7.1.1.8 Steam Pressure
C7.1.1.9 Steam Temperature
C7.1.1.10 Gas Pressure
C7.1.1.11 Flue Gas CO_2
C7.1.1.12 Flue Gas CO
C7.1.1.13 Flue Gas O_2
C7.1.1.14 Relative Humidity

C7.1.2 *Measurements to be Totaled Over the Test Period*. For the following parameters (if recorded), the sum of the values recorded during the test period shall be used for the calculations in this section. If a totalizer is used (or required) on a respective instrument, then the value measured at the end of the test period shall be used for the calculations in this section:

C7.1.2.1 Time
C7.1.2.2 Fuel Weight or Volume
C7.1.2.3 Flue Condensate Weight
C7.1.2.4 Steam Separator Weight
C7.1.2.5 Steam Condensate Collected
C7.1.2.6 Water Volume or Weight

C7.2 *Thermal Efficiency Test*. The following items shall be calculated and recorded on an appropriate form:

C7.2.1 *Barometric Pressure, P_B, in in Hg*. Required for steam and gas tests. Correct mercury readings for temperature and latitude. It is not necessary to correct aneroid readings.

C7.2.2 *Steam Pressure (absolute), P_{SAT}, in in Hg*.

$$P_{SAT} = P_B + P_S \quad \text{C1}$$

C7.2.3 *Heat Input, Q_{IN}, in Btu/h.*

C7.2.3.1 *For oil-fired Boilers*.

$$Q_{IN} = \frac{W_F \cdot HHV_{oil}}{t_T} \quad \text{C2}$$

C7.2.3.2 *For gas-fired Boilers.*

$$Q_{IN} = \frac{W_V \cdot C_S \cdot HHV_{gas}}{t_T} \quad \text{C3}$$

C7.2.4 *Loss in dry flue gases, L_S, for oil, %*

$$L_S = \frac{4CO_2 + O_2 + 700}{3(CO_2 + CO)} \cdot \frac{C \cdot C_{p,air}(T_{F,SS} - T_A)}{HHV_{oil}} \quad \text{C4}$$

Where:

CO_2 = Percentage by volume of carbon dioxide in the flue gas, %, shall be measured, or calculated per:

$$CO_2 = U_{oil} \cdot \frac{(20.9 - O_{2,meas})}{20.9} \quad \text{C5}$$

O_2 = Percentage by volume of oxygen, either use $O_{2,meas}$ or calculated per:

$$O_2 = 21\left[1 - \left(\frac{CO_2}{100}\right) \cdot \left(\frac{4.8C + 11.3H}{C}\right)\right] \quad \text{C6}$$

U_{oil} = Ultimate CO_2 of flue gas, %, which is:
= 15.6% for No. 2 fuel oil
= 15.8% for No. 4 fuel oil
= 16.3% for No. 5 fuel oil
= 16.7% for No. 6 fuel oil

C7.2.5 Loss Due to Moisture Formed by Combustion of Hydrogen, L_L, for oil, in percent

$$L_L = \frac{9H[1090 - T_A + (0.46T_{F,SS})]}{HHV_{oil}} \quad \text{C7}$$

C7.2.6 Flue Losses

C7.2.6.1 *Gas-fired Boilers.* Calculate flue loss, L_f, in percent of heat input rate

$$L_f = \frac{1}{379}(C_1 + C_2 + C_3 + C_4) + 5.04(T - P) \quad \text{C8}$$

Where:

$$C_1 = \frac{P \cdot U}{1000}\left[16.2\left(T_{F,abs} - T_{\text{r,abs}}\right) + 6530\ln\left(\frac{T_{r,\text{abs}}}{T_{F,abs}}\right) + 1.41 \cdot 10^6 \cdot \left(\frac{1}{T_{r,\text{abs}}} - \frac{1}{T_{F,abs}}\right)\right] \quad \text{C9}$$

$$C_2 = \frac{P}{10}\left(1 - \frac{U}{100}\right)\left[9.47\left(T_{F,abs} - T_{r,\text{abs}}\right) + 3470\ln\left(\frac{T_{r,\text{abs}}}{T_{F,abs}}\right) + 1.16 \cdot 10^6 \cdot \left(\frac{1}{T_{r,\text{abs}}} - \frac{1}{T_{F,abs}}\right)\right] \quad \text{C10}$$

$$C_3 = \frac{P}{10}\left(\frac{U - CO_2}{CO_2}\right)\left[9.46\left(T_{F,abs} - T_{r,\text{abs}}\right) + 3290\ln\left(\frac{T_{r,\text{abs}}}{T_{F,abs}}\right) + 1.07 \cdot 10^6 \cdot \left(\frac{1}{T_{r,\text{abs}}} - \frac{1}{T_{F,abs}}\right)\right] \quad \text{C11}$$

$$C_4 = \left[\frac{T - P}{10} + 0.00174RH \cdot A\left(1 + \frac{P}{A}\left(\frac{U - CO_2}{CO_2}\right)\right)\right] \cdot \quad \text{C12}$$

$$\left[19.86\left(T_{F,abs} - T_{r,\text{abs}}\right) + 7500\ln\left(\frac{T_{F,abs}}{T_{r,\text{abs}}}\right) + 1194\left(\sqrt{T_{r,\text{abs}}} - \sqrt{T_{F,abs}}\right)\right]$$

Where:

A = 9.4 SCF per 1,000 Btu of gas burned
CO_2 = CO_2 in flue gases, percent of total dry constituents in the flue gas, shall be measured, or calculated per:

$$CO_2 = U_{gas} \cdot \frac{\left(20.9 - O_{2,meas}\right)}{20.9} \quad \text{C13}$$

$O_{2,meas}$ = measured O_2 in flue gases, %
P = 8.47 SCF per 1,000 Btu of gas burned
T = 10.42 SCF per 1,000 Btu of gas burned
U_{gas} = Ultimate CO_2 of the flue gas = 11.9%

C7.2.6.2 *Oil-fired Boilers.* Calculate flue loss, L_f, in percent of heat input rate

$$L_f = L_s + L_L \quad \text{C14}$$

C7.2.7 **S**aturated steam temperature, T_{SAT}, in °F, shall either be equal to the measured steam temperature or taken from Appendix D, "Properties of Saturated Steam", at the absolute steam pressure, P_{SAT}.

C7.2.8 Latent heat of vaporization at the saturated steam temperature, $h_{fg,\ TSAT}$, in Btu/lb, shall be taken from Appendix D, "Properties of Saturated Steam" at the absolute steam pressure, P_{SAT}.

C7.2.9 *Moisture in Steam, M, %.*

C7.2.9.1 If steam is condensed and weighed:

$$M = \frac{100W_S}{W_S + W_C} \quad \text{C15}$$

C7.2.9.2 If feedwater is measured:

$$M = \frac{100 W_S}{W} \quad \text{C16}$$

C7.2.9.3 If a throttling steam calorimeter is used:

$$M = \frac{h_g - 1150.4 - 0.485(T_{cal} - 212)}{h_{tg}} \cdot 100 \quad \text{C17}$$

C7.2.10 *Latent Heat, Q_L, in Btu/h, Steam test.*

C7.2.10.1 If condensate is collected:

$$Q_L = \frac{h_{fg,TSAT} \cdot W_C}{t_T} \quad \text{C18}$$

C7.2.10.2 If feedwater is measured:

$$Q_L = \frac{h_{fg,TSAT} \cdot (W - W_S)}{t_T} \quad \text{C19}$$

C7.2.11 *Heat in liquid, Q_S, in Btu/h.*

C7.2.11.1 Steam test if condensate is weighed:

$$Q_S = \frac{C_{p,H2O}(W_C + W_S)(T_{SAT} - T_{IN})}{t_T} \quad \text{C20}$$

C7.2.11.2 Steam test if feedwater is weighed:

$$Q_S = \frac{W \cdot C_{p,H2O}(T_{SAT} - T_{IN})}{t_T} \quad \text{C21}$$

C7.2.11.3 Water test:

$$Q_S = \frac{W \cdot C_{p,H2O}(T_{OUT} - T_{IN})}{t_T} \quad \text{C22}$$

W = weight of water fed, lb (Measured or calculated from C7.2.11.3.1)

C7.2.11.3.1 Water volume to weight conversion:

$$W = V \cdot \rho \quad \text{C23}$$

Where:

$$\rho = \frac{\left(-7.36376 \cdot 10^{-5} \cdot T_{IN}{}^{2} + 0.002427088 \cdot T_{IN} + 62.48442\right)}{7.48052} \quad \text{C24}$$

C7.2.12 *Gross Output, Q_{OUT}, in Btu/h.*

C7.2.12.1 *Steam Thermal Efficiency Test.*

$$Q_{OUT} = Q_L + Q_S \quad \text{C25}$$

C7.2.12.2 *Water Thermal Efficiency Test.*

$$Q_{OUT} = Q_S \quad \text{C26}$$

C7.2.13 *Thermal Efficiency, $Effy_T$, %.*

$$Effy_T = \frac{100 \cdot Q_{OUT}}{Q_{IN}} \quad \text{C27}$$

C7.2.14 *Non-condensing Combustion Efficiency, $Effy_{SS}$, %.*

$$Effy_{SS} = 100 - L_f \quad \text{C28}$$

C7.2.15 *Radiation and unaccounted for loss, L_U, %.*

If $Effy_T > Effy_{SS}$:

$$L_U = 0 \quad \text{C29}$$

If $Effy_T \leq Effy_{SS}$:

$$L_U = Effy_{SS} - Effy_T \quad \text{C30}$$

C7.2.16 *Condensing Boiler - latent heat gain due to condensation under steady state conditions, $L_{G,SS}$, %.*

$$L_{G,SS} = \frac{100 \cdot h_{fg} \cdot M_{C,SS}}{Q_{IN}} \quad \text{C31}$$

C7.2.17 *Condensing Boiler - steady state heat loss due to hot condensate going down the drain, $L_{C,SS}$, %.*

$$L_{C,SS} = \frac{L_{G,SS}\left[C_{p,H2O}\left(T_{F,SS} - T_A\right) - 0.45\left(T_{F,SS} - T_A\right)\right]}{h_{fg}} \quad \text{C32}$$

C7.2.18 *Condensing Boiler – Steady state Combustion Efficiency, $Effy_{SS}$, %*

$$Effy_{SS} = 100 - (L_f - L_{G,SS} + L_{C,SS}) \quad \text{C33}$$

C7.2.19 *Outdoor Boiler Thermal Efficiency, $Effy_{T,O}$, %.*

C7.2.19.1 *Hot Water Boiler.*

$$Effy_{T,O} = Effy_{SS} - L_U\left(\frac{T_{OUT} - 42}{T_{OUT} - T_A}\right) \quad \text{C34}$$

C7.2.19.2 *Steam Boiler.*

$$Effy_{T,O} = Effy_{SS} - L_U\left(\frac{T_{SAT} - 42}{T_{SAT} - T_A}\right) \quad \text{C35}$$

C7.2.20 *Outdoor Boiler Gross Output, $Q_{OUT,O}$, in Btu/h.*

$$Q_{OUT,O} = \frac{Q_{IN} \cdot Effy_{T,O}}{100} \quad \text{C36}$$

C7.3 *Combustion Efficiency Test.*

C7.3.1 *Non-condensing Combustion Efficiency*. The items in Sections C7.2.4, C7.2.5 and C7.2.6.2 shall be calculated for oil boilers and C7.2.6.1 shall be calculated for gas boilers. Section C7.2.14 shall be used to calculate the combustion efficiency.

C7.3.2 *Condensing Combustion Efficiency*. The items in Sections C7.2.6.1, C7.2.16, and C7.2.17 shall be calculated for gas boilers. Section C7.2.18 shall be used to calculate the combustion efficiency.

APPENDIX D. PROPERTIES OF SATURATED STEAM – NORMATIVE

Table D1. Properties of Saturated Steam

Absolute Pressure		Temperature	Latent Heat	Absolute Pressure		Temperature	Latent Heat
in Hg	psi	°F	Btu/lb	in Hg	psi	°F	Btu/lb
27.6	13.57	208.0	972.9	31.4	15.42	214.4	968.7
.7	13.61	208.1	972.8	.5	15.47	214.6	968.6
.8	13.66	208.3	972.7	.6	15.52	214.7	968.5
.9	13.71	208.5	972.6	.7	15.57	214.9	968.4
28.0	13.75	208.7	972.5	.8	15.61	215.0	968.3
.1	13.80	208.8	972.4	.9	15.66	215.2	968.2
.2	13.85	209.0	972.2	32.0	15.71	215.4	968.1
.3	13.90	209.2	972.1	.1	15.76	215.5	968.1
.4	13.95	209.4	972.0	.2	15.81	215.7	968.0
.5	14.00	209.5	971.9	.3	15.86	215.9	967.9
.6	14.05	209.7	971.8	.4	15.91	216.0	967.8
.7	14.10	209.9	971.7	.5	15.96	216.2	967.7
.8	14.15	210.1	971.6	.6	16.00	216.3	967.6
.9	14.20	210.2	971.4	.7	16.05	216.5	967.5
29.0	14.24	210.4	971.3	.8	16.10	216.6	967.4
.1	14.29	210.6	971.2	.9	16.15	216.8	967.3
.2	14.34	210.8	971.1	33.0	16.20	217.0	967.2
.3	14.39	210.9	971.0	.1	16.25	217.1	967.1
.4	14.44	211.1	970.9	.2	16.30	217.3	967.0
.5	14.49	211.3	970.8	.3	16.35	217.4	966.9
.6	14.54	211.4	970.7	.4	16.40	217.6	966.8
.7	14.59	211.6	970.5	.5	16.45	217.7	966.7
.8	14.64	211.8	970.4	.6	16.50	217.9	966.6
.9	14.69	212.0	970.3	.7	16.54	218.0	966.5
30.0	14.73	212.1	970.2	.8	16.59	218.2	966.4
.1	14.78	212.3	970.1	.9	16.64	218.3	966.3
.2	14.83	212.4	970.0	34.0	16.69	218.5	966.2
.3	14.88	212.6	969.9	.1	16.74	218.7	966.1
.4	14.93	212.8	969.8	.2	16.79	218.8	966.0
.5	14.98	212.9	969.7	.3	16.84	219.0	965.9
.6	15.03	213.1	969.6	.4	16.89	219.1	965.8
.7	15.07	213.3	969.5	.5	16.94	219.3	965.7
.8	15.12	213.4	969.4	.6	16.99	219.4	965.6
.9	15.17	213.6	969.2	.7	17.04	219.6	965.5
31.0	15.22	213.7	969.1	.8	17.09	219.7	965.4
.1	15.27	213.9	969.0	.9	17.14	219.9	965.3
.2	15.32	214.1	968.9	35.0	17.19	220.0	965.2
.3	15.37	214.2	968.8				

Table D1. Properties of Saturated Steam (continued)							
Absolute Pressure		Temperature	Latent Heat	Absolute Pressure		Temperature	Latent Heat
in Hg	psi	°F	Btu/lb	in Hg	psi	°F	Btu/lb
35.5	17.43	220.7	964.7	48.5	23.82	237.4	953.9
36.0	17.68	221.5	964.2	49.0	24.07	238.0	953.5
36.5	17.93	222.2	963.8	49.5	24.31	238.5	953.1
37.0	18.17	222.9	963.3	50.0	24.56	239.1	952.8
37.5	18.42	223.6	962.9	50.5	24.80	239.6	952.4
38.0	18.66	224.3	962.4	51.0	25.05	240.2	952.1
38.5	18.91	225.0	962.0	51.5	25.29	240.7	951.7
39.0	19.16	225.7	961.5	52.0	25.54	241.3	951.3
39.5	19.40	226.3	961.1	52.5	25.79	241.8	951.0
40.0	19.65	227.0	960.7	53.0	26.03	242.3	950.6
40.5	19.89	227.7	960.2	53.5	26.28	242.9	950.3
41.0	20.14	228.3	959.8	54.0	26.52	243.4	949.9
41.5	20.38	229.0	959.4	54.5	26.77	243.9	949.6
42.0	20.63	229.6	959.0	55.0	27.01	244.4	949.3
42.5	20.87	230.2	958.6	55.5	27.26	244.9	948.9
43.0	21.12	230.9	958.2	56.0	27.50	245.4	948.6
43.5	21.37	231.5	957.8	56.5	27.75	245.9	948.3
44.0	21.61	232.1	957.4	57.0	28.00	246.4	947.9
44.5	21.86	232.7	957.0	57.5	28.24	246.9	947.6
45.0	22.10	233.3	956.6	58.0	28.49	247.4	947.3
45.5	22.35	233.9	956.2	58.5	28.73	247.9	946.9
46.0	22.59	234.5	955.8	59.0	28.98	248.3	946.7
46.5	22.84	235.1	955.4	59.5	29.22	248.8	946.3
47.0	23.08	235.7	955.0	60.0	29.47	249.3	946.0
47.5	23.33	236.3	954.6	60.5	29.71	249.8	945.7
48.0	23.58	236.9	954.2	61.0	29.96	250.3	945.3

Note: Basic values taken from "Thermodynamic Properties of Steam" by Joseph H. Keenan and Frederick G. Keyes.

APPENDIX E. CORRECTION FACTORS FOR HEATING VALUES OF FUEL GASES – NORMATIVE

Correction factor, C_S, applied to the higher heating value (HHV) for a fuel gas when it is metered at temperature and/or pressure conditions other than the standard conditions on which the value of HHV is based.

Dry gas utilizing a dry test meter:

$$C_S = \frac{P_g\left(459.7 + T_{std}\right)}{P_{std}\left(459.7 + T_g\right)} \quad \text{E1}$$

Saturated gas utilizing a wet test meter:

$$C_S = \frac{\left(P_g - P_{wv}\right)\left(459.7 + T_{std}\right)}{\left(P_{std} - P_{wvs}\right)\left(459.7 + T_g\right)} \quad \text{E2}$$

Note: For water vapor pressures, see *ASHRAE Handbook - 2013 Fundamentals*, Chapter 1, Table 3.

If the value of HHV is based on a dry condition and the gas is metered with a wet test meter, its value must also be reduced by a correction factor, C_f, of:

$$C_f = \frac{P_{std} - P_{wvs}}{P_{std}} \quad \text{E3}$$

Conversely, if the value is based upon a saturated condition and the gas is metered dry, its value must be increased by a factor of:

$$C_f = \frac{P_{std}}{P_{std} - P_{wvs}} \quad \text{E4}$$

APPENDIX F. SAMPLE TEST REPORT FORMS – INFORMATIVE

BOILER TEST LOG SHEET

TIME	WATER, □ lb □ Gal			FUEL		Steam Pressure, in Hg	TEMPERATURE, °F					DRAFT or PRESSURE, in H_2O		FLUE GAS, %	
HH:MM or MM:SS	Condensate or Water Feed	Difference Between Readings	Separator	Weight of Oil Tank or Gas Meter Reading	Difference Between Readings		Feed Water	Steam or Outlet Water	Room Air	Test Air	Flue Gases	Fire Box	Breach	CO_2 or O_2	Smoke or CO
Total															
Average															

Oil		Test Conducted by	Test No. & Date	Boiler Model No.	Manufacturer
Pressure	Nozzle Size				

Gas		Barometer	Burner OEM and Number
Pressure at Meter	Temperature at Meter		

GAS or OIL-FIRED HEATING BOILER TEST REPORT SHEET

Company Name				
Boiler Model Number				
Cast Iron ☐ Steel ☐ Copper ☐ Stainless Steel ☐		Outdoor ☐		
Atmospheric Burner ☐ Non-atmospheric Burner ☐ Negative Pressure Vent ☐ Positive Pressure Vent ☐ Oil ☐ Gas ☐				
Burner (OEM, Name, Number, Type)				
Fuel Oil No.	Heating Value	Btu/lb	lb/Gal	
Oil % Carbon	% Hydrogen			
Gas	Heating Value	Btu/ft^3		
GENERAL	1. Test Number			
	2. Date of Test			
	3. Duration of Test	hrs		
	4. Barometric Pressure (Corr.) *	in Hg		
	5. Boiler Gauge Pressure *	in Hg		
	6. Steam Pressure (Absolute) *	in Hg		
	7. Nozzle (Make, Rating, spray Angle) – Oil			
	8. Oil Pressure	psi		
INPUT	9. Firing Rate, Test	GPH		
	10. Total Fuel Burned	ft^3 or lb		
	11. Total Heat Input	Btu		
COMBUSTION	12. Carbon Dioxide (CO_2)	%		
	13. Oxygen (O_2), if measured – Required for Oil	%		
	14. Carbon Monoxide	%		
	15. Flue Gas Temperature	°F		
	16. Test Air Temperature	°F		
	17. Net Flue Gas Temperature	°F		
DRAFT OR PRESSURE	18. Breach/Vent	in H_2O		
	19. Firebox	in H_2O		
LOSSES	20. In Dry Flue Gases	%		
	21. Moisture in Flue Gases	%		
	22. Combustion Loss	%		
	23. Radiation and Unaccounted For	%		
STEAM AND WATER	24. Feedwater Temperature	°F		
	25. Steam or Outlet Water Temperature (Measured)	°F		
	26. Water Temperature Rise (Measured)	°F		
	27. Equivalent Saturated Steam Temp. *	°F		
	28. Latent Heat *	Btu/lb		
	29. Moisture in Steam *	%		
	30. Total Condensation or Water Heated	□lb □Gal		
	31. Water from Separator *	lb		
	32. Total Latent Heat *	Btu		
	33. Total Heat in Liquid *	Btu		
OUTPUT	34. Total Output	Btu		
	35. Combustion Efficiency	%		
	36. Thermal Efficiency	%		
	37. Gross Output	Btu/h		
	38. Outdoor Boiler-Thermal Efficiency	%		
	39. Outdoor Boiler-Gross Output	Btu/h		
Laboratory Name		Test Conducted By		

* Steam test only