ANSI/AHRI Standard 1500-2024 (I-P)

Performance Rating of Commercial Space Heating Boilers

Approved American National Standard

ANSI

AHRI

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IMPORTANT

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Note:

This standard supersedes ANSI/AHRI Standard 1500-2015.

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Intent

This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors, and users.

Review and Amendment

This standard is subject to review and amendment as technology advances.

2024 Edition

This edition of AHRI Standard 1500, *Performance Rating of Commercial Space Heating Boilers*, was prepared by Hydronic Systems Standards Technical Committee. The standard was approved by the Heating Standards Subcommittee on 13 May 2024 and was approved as an American National Standard (ANS) on 3 June 2024.

Origin and Development of AHRI Standard 1500

The initial publication was ANSI/AHRI Standard 1500-2015, *Performance Rating of Commercial Space Heating Boilers*

Summary of Changes

AHRI Standard 1500-2024 (I-P) contains the following update(s) to the previous edition:

- Changes to definitions.
- Clarification of certain burner adjustment requirements for non-atmospheric boilers
- Removed humidity measurement requirement for non-condensing boilers
- Changed required measurement intervals for various metrics
- Added annual calibration requirement for all instrumentation
- Revised the inlet water temperature to align with 10 CFR 431 Subpart E Appendix A
- Revised calculations for determining steam output, including addition of superheat calculation coverage

Committee Personnel

Hydronic Systems Standards Technical Committee

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Bosch Thermotechnology Corp	Stephen Barnard	Primary Voter
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Triangle Tube Phase III Co. Inc.	Joshua Garrett	Primary Voter
Weil-McLain, a brand of WM Technologies, LLC	Mark Swanson	Primary Voter
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Hydronic Systems Standards Technical Committee Scope:

The Hydronic Systems Standards Technical Committee is responsible for the development and maintenance of AHRI standards and guidelines pertaining to boilers, indirect water heaters, and other hydronic system components.

Out of scope for this STC are water heaters and pool heaters not specifically part of a hydronic system.

This STC reports to the Heating Standards Subcommittee.

Heating Standards Subcommittee

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Heating Standards Subcommittee Scope:

The scope of the Heating Standards Subcommittee is standards and guidelines related to the end products that are part of the AHRI Heating Industry Sector. (The definition of and list of products associated with each sector are found on the AHRI website

This list represents the membership at the time the Standards Technical Committee and Standards Subcommittee were balloted on the final text of this edition. Since that time, changes in the membership may have occurred. Membership on these committees shall not in and of itself constitute an endorsement by the committee members or their employers of any document developed by the committee on which the member serves.

Heating Standards Consensus Body

Interest Category	Participant	Company	Voting Level
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	Jared Ledford	Olson Plumbing and Heating	Primary Voter
General Interest	Jim Kendzel	American Supply Association	Primary Voter
	Timothy Matthews	Lee Company	Primary Voter
	Aniruddh Roy	Energy Solutions	Primary Voter
Product Manufacturer	Paul Haydock	Carrier Corporation	Primary Voter
	Reza Mossavi	Viessmann Manufacturing Company (U.S.) INC.	Primary Voter
Regulatory Agency	Ronald Balneg	California Energy Commission	Primary Voter
Testing Laboratory	Caroline Henley	UL Solutions	Primary Voter
	Stephen Kowalski	Oak Ridge National Laboratory	Primary Voter

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PERFORMANCE RATING OF COMMERCIAL SPACE HEATING BOILERS

Section 1. Purpose

This standard establishes definitions, test requirements, rating requirements, minimum data requirements for *published ratings*, marking and nameplate data, and conformance conditions for commercial space *heating boilers*.

Section 2. 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

1) A steam *boiler* designed to operate at or below a steam pressure of 15 psig; or
2) A hot water *boiler* designed to operate at or below a water pressure of 160 psig and a temperature of 250°F or
3) A *boiler* that is designed to be capable of supplying either steam or hot water and designed to operate under the conditions described in this scope.

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

Section 3. Definitions

All terms in this document shall follow the standard industry definitions in the ASHRAE Terminology website unless otherwise defined in this section.

3.1 Expression of Provisions

Terms that provide clear distinctions between requirements, recommendations, permissions, options, and capabilities.

3.1.1 "Can" or "cannot"

Express an option or capability.

3.1.2 "May"

Signifies a permission expressed by the document.

3.1.3 "Must"

Indication of unavoidable situations and does not mean that an external constraint referred to is a requirement of the document.

3.1.4 "Shall" or "shall not"

Indication of mandatory requirements to strictly conform to the standard and where deviation is not permitted.

3.1.5 "Should" or "should not"

Indication of recommendations rather than requirements. In the negative form, a recommendation is the expression of potential choices or courses of action that is not preferred but not prohibited.

3.2 Standard Specific Definitions

3.2.1 Boiler

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

3.2.1.1 Atmospheric Boiler

A *packaged boiler* with a gas *atmospheric burner* and that operates with a non-positive *vent* static pressure.

3.2.1.2 Condensing Boiler

A *boiler* that condenses part of the water vapor in the *flue gases* during the laboratory tests prescribed in this standard, and that is equipped with a means of collecting and draining this condensate from the heat exchange section.

3.2.1.3 Direct Vent Boiler

A *boiler* (indoor) with the means or instructions for all air for combustion to be derived directly from the outdoors

3.2.1.4 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.

3.2.1.5 Non-condensing Boiler

A *boiler* that is not a *condensing boiler*.

3.2.1.6 Outdoor Boiler

A *packaged boiler* with integral venting means, factory assembled, weather-proofed, and wired for use out of doors.

3.2.1.7 Packaged Boiler

A *boiler* that is shipped complete with Burner and controls.

3.2.2 Boiler Flue

The passage(s) within a *boiler* where 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*.

3.2.3 British Thermal Unit (Btu)

A unit of heat. The amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

3.2.4 Burner

A device for the introduction of fuel and primary air into a *firebox* at specific velocities.

3.2.4.1 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.

3.2.4.2 Non-atmospheric 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 *boiler*, or a fan-powered *burner* that depends on the natural *draft* developed by a chimney for proper operation, or a pulse combustion *burner*.

3.2.5 Choke Damper

A damper placed within the *vent connector* or *vent* pipe for regulating the flow of gases.

3.2.6 Condensate

3.2.6.1 Flue Condensate

Liquid formed by the condensation of moisture in the *flue gases*.

3.2.6.2 Steam Condensate

Liquid formed by the condensation of steam.

3.2.7 Draft

A pressure difference that causes gases or air to flow through a chimney, *vent*, or *boiler* and is the ambient pressure minus the pressure in the *vent* or *firebox*. Represents a negative pressure and is always expressed as a positive value.

3.2.8 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 if *draft*, back *draft*, or stoppage beyond the *draft hood* are not present
2) prevent a back *draft* from entering the *firebox*
3) neutralize the effect of stack action of the chimney or gas *vent* upon the operation of the *boiler*

3.2.9 Draft Regulator

A balanced damper device attached to the vent connector to control draft (negative pressure).

Can be called “barometric draft regulator”.

3.2.10 Efficiency

3.2.10.1 Combustion Efficiency

100% less the losses due to dry flue gas, incomplete combustion, and moisture formed by combustion of hydrogen.

3.2.10.2 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.

3.2.11 Feedwater

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

3.2.12 Firebox

The space provided within the *boiler* for combustion of the fuel.

3.2.13 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*.

3.2.14 Flue Gas

Products of combustion plus excess air in the *boiler flue* or heat exchanger.

3.2.15 Flue Temperature

The temperature of the *flue gases*, before dilution.

3.2.16 Gross Output

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

3.2.17 Heating Value

3.2.17.1 Gas Heating Value

Amount of heat produced by the complete combustion of a unit quantity of fuel expressed in *Btu*/cubic foot at standard conditions of water vapor saturation, temperature of 60°F and a pressure of 30 in of mercury. This standard only uses the gross or higher heating value, that 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.

3.2.17.2 Oil Heating Value

The higher heating value determined per ASTM D240-09 or ASTM D4809-09a and Section C.3.2.2, Fuel Oil Analysis.

3.2.18 Input Rating

The maximum *Btu*/h or gph input located on the *boiler* rating plate.

3.2.19 Net Rating

The amount of installed radiation to be served by the *boiler*, based on the allowance for piping and pickup losses.

3.2.20 Oil Types

3.2.20.1 Heavy Oil

Nos. 4, 5, and 6 oil, as defined in ASTM D396-14a.

3.2.20.2 Light Oil

No. 2 oil as defined in ASTM D396-14a.

3.2.21 Published Rating

A statement of the assigned values of those performance characteristics, under stated *rating conditions*, where a unit can be chosen to fit the application. These values apply to all units of the same nominal size and type (identification) produced by the same manufacturer. This 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*.

3.2.21.1 Rating Conditions

Any set of operating conditions where a single level of performance results and causes only that level of performance to occur.

3.2.21.2 Standard Rating

A rating based on tests performed at *standard rating conditions*.

3.2.21.3 Standard Rating Conditions

Rating conditions used as the basis of comparison for performance characteristics.

3.2.22 Superheat

The temperature of steam above the saturation temperature.

3.2.23 Vent

A passageway used to convey *flue gases* from *boilers* or their *vent connectors* to the outdoors.

3.2.24 Vent Connector

The pipe or duct that connects a *boiler* to a *vent* or chimney.

3.2.25 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.

4.2 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 record the indoor *boiler thermal efficiency* and *outdoor boilers* shall record the *outdoor boiler thermal efficiency*.

5.2 Verification of Standard Ratings

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 1000 *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 1000 *Btu*/h. Steam square feet (sq ft) shall be determined by dividing the rounded steam *net rating* by 240. The *net rating* 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	1333	1150
1,255,000 to 1,839,000	$1546\ 2 - [(2{,}353 \cdot 10^{-7}) \cdot Q_{OUT}] + [(5{,}208\ 6 \cdot 10^{-14}) \cdot {Q_{OUT}}^2]$	
1,840,000 to 1,939,000	$1326\ 8 - [(2 \cdot 10^{-8}) \cdot Q_{OUT}]$	
≥ 1,940,000	1288	

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 meet the requirements of Section 5.3.2 and Section 5.3.3, and the *input rate* shall comply with Section C.4.1.

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 not greater than, the maximum CO_2 level that is within the specified range and that meets the requirements of Section 5.3.2 and Section 5.3.3, and the input rate shall comply with Section C.4.1.

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 not less than, the minimum O_2 level that is within the specified range and that meets the requirements of Section 5.3.2 and Section 5.3.3, and the input rate shall comply with Section C.4.1

5.3.1.1.4 Unspecified CO_2 or O_2 Level or Range

If no CO_2 or O_2 level or range is specified in the manufacturer's instructions shipped with the *boiler*, the *burner* system shall be adjusted to within ± 0.2% of the following default CO_2 level based on the fuel:

Natural Gas: 8.0%

#2 Oil: 11.0%

#4 Oil: 11.1%

#5 Oil: 11.5%

#6 Oil: 11.8%

If the requirements of Section 5.3.2, Section 5.3.3, or input rate adjustment cannot be met at the default CO_2, the burner system shall be adjusted as close as possible to the default CO_2, while simultaneously meeting all other requirements.

5.3.1.2 Atmospheric Burners

The input rate shall be adjusted to comply with Section C.4.1.

5.3.2 Smoke

The smoke readings shall not exceed #1 for *light oil* or #4 for *heavy oil* during any test (see Section C.2.5.4).

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 Inlet Temperature

The inlet temperature (Figure 9, point A) shall be 80°F ± 5°F, and the outlet temperature (Figure 9, 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 Optional Recirculating Loop

For *boilers* that require a greater flow rate to prevent boiling, a recirculating line shall be installed as shown in Figure 9. Maintain the inlet temperature at point B of Figure 9 at 140°F ± 5°F during the warm-up period and test period. The temperature rise through the *boiler* (between points B and C in Figure 9) shall not be less than 20°F. The temperature rise from inlet (Figure 9 Point A) to the outlet (Figure 9, Point C) shall meet the requirements of Section 5.3.5.1.

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 measured at each data collection point required by Section C.5. During a *non-condensing boiler* test, room ambient temperature shall be maintained between 65°F and 100°F at any time during the test. For a *condensing boiler* test, the room ambient temperature shall be maintained between 65°F and 85°F at any time during the test.

5.3.9 Ambient Humidity

The relative humidity of the room for *condensing boilers* shall be maintained below 80% when recorded at the interval defined by Section C.5.

Section 6. Minimum Data Requirements for Published Ratings

As a minimum, *published ratings* shall include all *standard ratings*. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 1500 (I-P)". All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of AHRI Standard 1500 (I-P)". *Application ratings* within the scope of the standard shall include a statement of the conditions under which the ratings apply.

Section 7. 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

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

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.

A.1. ASHRAE Handbook Fundamentals, 2021, ASHRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, USA.

A.2. ASHRAE Terminology. ASHRAE. Accessed January 14, 2022. https://www.ashrae.org/technical-resources/free-resources/ashrae-terminology.

A.3. ASME PTC-19.11 – 2008 (R2018), *Steam and Water Sampling*, Conditioning, and Analysis in the Power Cycle, 2018, ASME, Two Park Avenue, New York, NY 10016-5990, USA.

A.4. ASTM Standard D240 - 09, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter,* 2014, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA.

A.5. ASTM Standard D396 – 14a, *Standard Specification for Fuel Oils*, 2014, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA.

A.6. ASTM Standard D2156 – 09, *Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels*, 2018, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA.

A.7. ASTM Standard D4809 – 09a, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method),* 2012, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA.

A.8. ASTM Standard D5291 – 10, *Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants*, 2021, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA.

A.9. Lemmon, Eric W., Bell, Ian H., Huber, Marcia L, and McLinden, Mark O., *Thermophysical Properties of Fluid Systems*. Gaithersburg: National Institute of Standards and Technology, 2021. NIST Chemistry WebBook. DOI: https://doi.org/10.18434/T4D303**.** https://webbook.nist.gov/chemistry/.

APPENDIX B. REFERENCES - INFORMATIVE

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.

B.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.

B.2. Keenan, Joseph H. *Steam Tables: Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases.* New York, NY: J. Wiley and Sons, 1969.

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

C.1. Instruments

Instruments that meet the minimum requirements shown in Table 2 shall be used.

C.1.1. Calibration

Instruments shall be calibrated to a recognized standard annually.

Table 2 Instruments

Property Measured	Item Measured	Example of Instrument Type[1]	Minimum Resolution	Minimum Accuracy	Approximate Range of Readings[2]
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
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

Property Measured	Item Measured	Example of Instrument Type[1]	Minimum Resolution	Minimum Accuracy	Approximate Range of Readings[2]
	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 C.3.2.2	See Section C.3.2.2	± 1% of reading	18,500 – 20,500 *Btu*/lb (#2 oil)
Humidity	Relative Humidity	Psychrometer	5%	± 5% of full scale	10 – 90%

Notes:
1. The information in the Example of Instrument Type column is informative.
2. This information in the Approximate Range of Readings column is informative.

C.2. Apparatus

C.2.1. Test Room or Area

The test location shall permit access to all parts of the test unit and instrumentation, as well as to maintain stable ambient conditions. Electrical, water, and drainage facilities are required. A chimney, or *vent* with induced draft fan, as well as provisions for supplying air for combustion are required.

C.2.2. Vent Connection

C.2.2.1. Test Vent for Boilers with Non-Atmospheric Gas or Oil Burners

Test *vent* for *boilers* with non-atmospheric gas or oil *burners* shall meet one of the following criteria:

1) have negative *vent* pressure

2) have positive *vent* pressure and are not *direct vent boilers*, as defined in Section 3.2.1.3.

Note: *Boilers* that have positive *vent* pressure and are *direct vent boilers* are described Section C.2.2.2.

All *vent* pipe connections shall be sealed before the insulation is applied. A minimum of R-7 foil-faced insulation for the temperature shall be applied as shown in Figure 1. The plane of the thermocouple grid and *flue gas* sampling points shall be located at the points shown in Figure 1. If dilution air is introduced into the *flue gases* 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 1).

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

C.2.2.1.1. 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. Pipe can be added between the *flue collar* and the elbow if the test *vent* needs to clear obstructing *boiler* parts. Attach a vertical length of *vent* pipe, three pipe diameters long to the elbow. Additional *vent* length can be used if the installation complies with Section 5.3.4.

If used, a *draft regulator* 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*, the mechanical draft inducer shall be attached to the end of the vertical *vent* pipe or to the *draft regulator*, if used.

C.2.2.1.2. 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. Pipe can be added between the *flue collar* and the first elbow if the test *vent* needs to clear obstructing *boiler* parts. Attach a horizontal length of *vent* pipe three 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 can be used if the installation complies with Section 5.3.4.

If used, a *draft regulator* 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*, the mechanical draft inducer shall be attached to the vertical outlet of the second elbow or to the *draft regulator*, if used.

C.2.2.2. Test Vent for Boilers with Gas or Oil Non-Atmospheric Burners and with Positive Vent Pressure and that are Direct Vent Boilers

Note: *Boilers* that have positive *vent* pressure and are not *direct vent boilers* are described in Section C.2.2.1.

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 4).

All *vent* pipe connections shall be sealed before the insulation is applied. A minimum of R-7 foil-faced insulation for the temperature shall be applied as shown in Figure 4. The plane of the thermocouple grid and *flue gas* sampling points shall be in the *vent* at the points shown in Figure 4 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 gases* 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 gases* enter the *vent* (see Figure 4).

C.2.2.3. 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*. A sizing adapter specified by the manufacturer's instructions shipped with the *boiler*, shall be sized to fit the adapter. If used, elbows 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:

C.2.2.3.1. 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 2).

C.2.2.3.2. 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 3).

C.2.2.4. Additional Requirements for Condensing Boilers

The *vent* pipe installation shall not let *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 the *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 made. The collection-container shall have a *vent* opening to the atmosphere.

C.2.2.5. 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.

C.2.3. Steam Piping (Thermal Efficiency Test)

An example set-up is shown in Figure 5 through Figure 8. 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 a separator or a throttling steam calorimeter in the outlet piping.

All steam piping between the *boiler* and a point 12 in beyond the separator or throttling steam calorimeter shall be wrapped with R-7 insulation. Provision shall be made for temperature measurement in this outlet piping if output due to *superheat* is claimed. *Steam condensate* or *feedwater* shall be measured with a totalizing water meter or weighed.

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 shall be wrapped with R-7 insulation.

The separator or throttling steam calorimeter and the piping connecting to the *boiler* shall be well insulated. *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 manufacturer's recommended installation instructions of the calorimeter being used. The use of a throttling steam calorimeter shall require the measurement of *feedwater* during the test.

C.2.4. Water Piping (Thermal Efficiency Test)

An example conventional test set-up is shown in Figure 9. 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* shall 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 not more than the greater of 12 in or six 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 shall face up or shall 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 10.

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 9, Point A). The tee shall be located not more than the greater of 12 in or 6 pipe diameters from the inlet of the *boiler*.

Except as specified in Section 5.3.5.2, other water connections are shall not be used between the water meter and the *boiler*. The connection between the water meter and *boiler* shall be leak free.

Pipes shown in Figure 10 shall be sized for a water velocity between two and six 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.

C.2.5. Application of Instruments (Steam and Water)

C.2.5.1. 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 12 installed in a plane perpendicular to the flow of *flue gas* as shown in Figure 1, Figure 2, Figure 3, or Figure 4, as appropriate. Thermocouples in the grid shall be made from thermocouple wire not larger than twenty-two gauge and shall be connected in parallel. Thermocouples that receive direct radiation from the *burner* flame shall have thermocouple radiation shields applied.

C.2.5.1.1. Round pipe

A nine-thermocouple grid constructed as shown in Figure 12 shall be used in round pipe up to and including twenty-four inches in diameter. A seventeen-thermocouple grid constructed as shown in Figure 12 shall be used in round pipe over twenty-four inches in diameter.

C.2.5.1.2. Rectangular Measurement Plane

A three-by-three, nine thermocouple grid constructed with uniform spacing as shown in the example in Figure 12 shall be used in rectangular openings up to and including twenty-four inches of width. For rectangular openings over twenty-four inches in width, use a three-by-six, eighteen thermocouple grid constructed with uniform spacing based on the example in Figure 12. For this requirement, width is the longest side dimension in the flue cross-section.

C.2.5.2. Flue Gas Sampling

All instruments inserted to sample *flue gas* shall be 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 1/4 to 1/2 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 to obtain an average *flue gas* sample.

C.2.5.3. 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* 1/4 to 1/2 the diameter of the pipe. A 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.

C.2.5.4. Smoke Measurement, Oil

The smoke measuring device shall be connected to an open-end tube located as shown in Figure 1and shall project into the flue 1/4 to 1/2 of the pipe diameter. The smoke measuring device 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.

C.2.5.5. Fuel Burned

C.2.5.5.1. Oil

The fuel oil shall be fed to the *burner* using a measuring means meeting the requirements of Section C.1. 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 11).

C.2.5.5.2. Gas

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

C.2.6. Application of Additional Instruments (Steam)

C.2.6.1. Steam Temperature

Provision shall be made to measure the outlet steam temperature, T_{ST}, in the outlet piping if output due to *superheat* is claimed.

C.2.6.2. Steam Pressure

If output due to *superheat* is claimed, measure the outlet steam pressure, P_S, in the same location as the temperature instrument described in Section C.2.6.1. Otherwise, measure the steam pressure, P_S, in the steam space of the *boiler*.

C.2.6.3. Feed Water

The piping connecting the *feedwater* supply to the return tapping of the *boiler* shall contain a valve two feet from the *boiler*. A temperature measuring instrument shall be located one foot ahead of the inlet side of the valve (see Figure 5, Figure 6, Figure 7 and Figure 8), unless conduction or convection affects the temperature. In these cases, the instrument shall be moved far enough away to prevent these from affecting the temperature.

C.2.6.4. Moisture in Steam

Moisture in the steam shall be determined by separating out the moisture, condensing the moisture and calculating the percent moisture with either the *feedwater* or steam weight, in accordance with Equation 17 and Equation 18, or by using a throttling steam calorimeter as described in Non-mandatory Appendix B of ASME PTC-19.11, and the percent moisture calculated in accordance with Equation 19.

C.2.7. Application of Additional Instruments (Water)

C.2.7.1. Water Temperature

The inlet and outlet water temperatures shall be measured at the locations specified in Section C.2.4 and shown in Figure 9 and Figure 10.

C.2.7.2. Water Measurement

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

1) Outlet water shall be collected in a covered tank and weighed.
2) *Feedwater* shall be pumped from a weigh tank.
3) A calibrated, totalizing water meter meeting the requirements of Section C.2.7.2 shall be used to measure *feedwater*.

C.2.7.3. Calibration Requirements for a Water Meter

A calibrated water meter used to measure *feedwater* shall meet at least one of the following requirements:

1) The water flow meter shall be calibrated to meet the accuracy and resolution requirements specified in Section C.1 for water.
2) A flow meter that does not meet the minimum accuracy required by Section C.1 shall meet the following conditions:
    a) 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 a stopwatch meeting the requirements of Section C.1. The water flow rate used to verify the water flow meter shall be the same as that required to perform the efficiency test ± 10%.
    b) During this verification, the water weighed shall be accumulated prior to the test over a period of not less than the following:
        i) Minimum Weigh Period (seconds) = (1438 ÷ V) + 400
        ii) V = flow rate observed using meter, Gal/min
    c) 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%.
    d) 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.

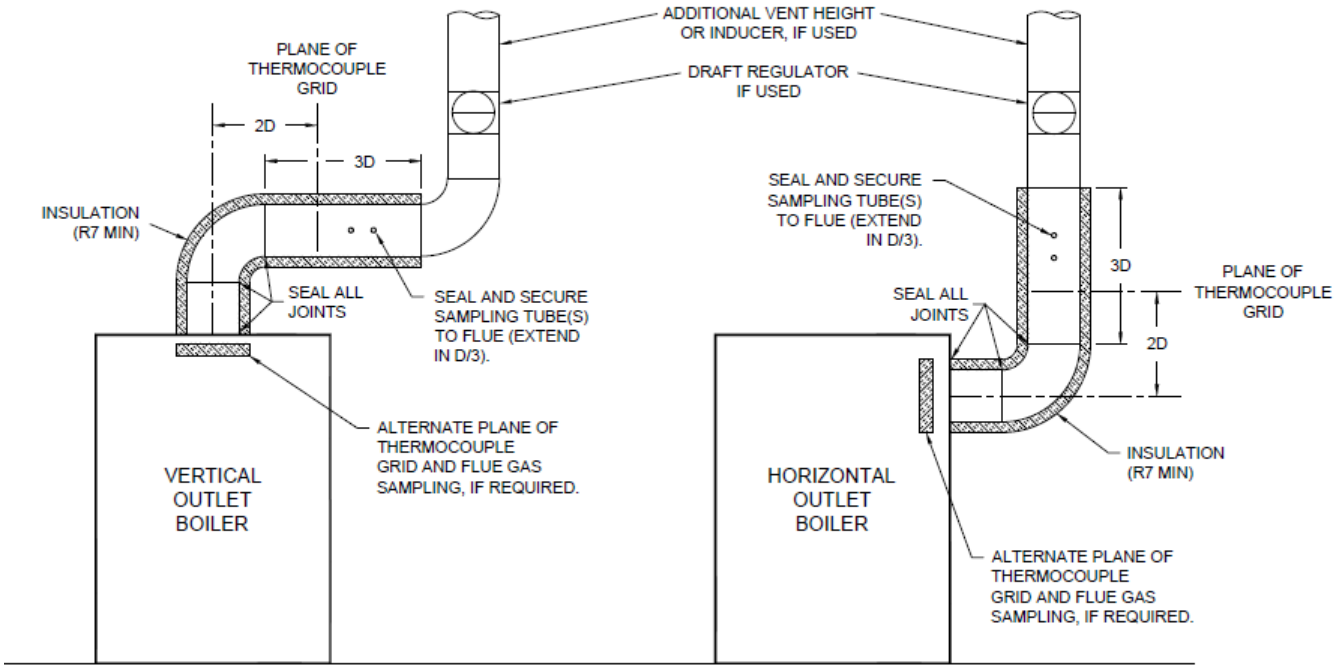
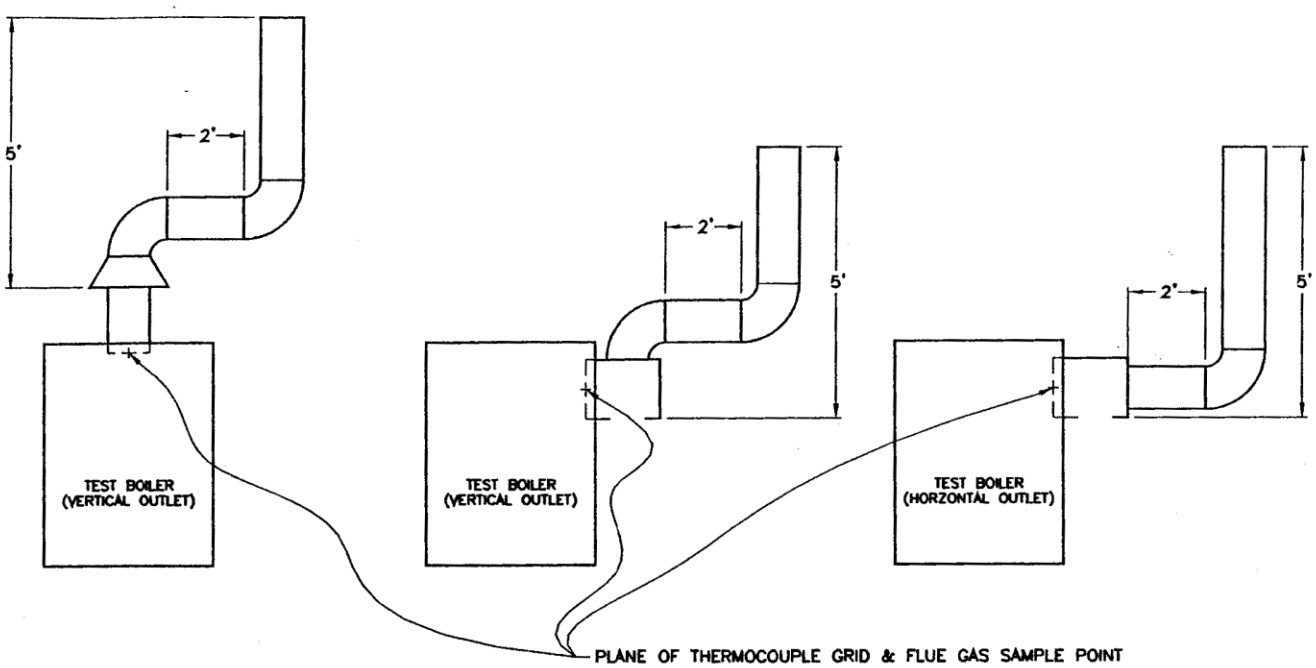


Figure 1 Test Vent for Boilers with a Gas or Oil Non-atmospheric Burner and with Negative Vent Pressure and Test Vent for Boilers with a Gas or Oil Non-atmospheric Burner and with Positive Vent Pressure and that are not Direct Vent Boilers



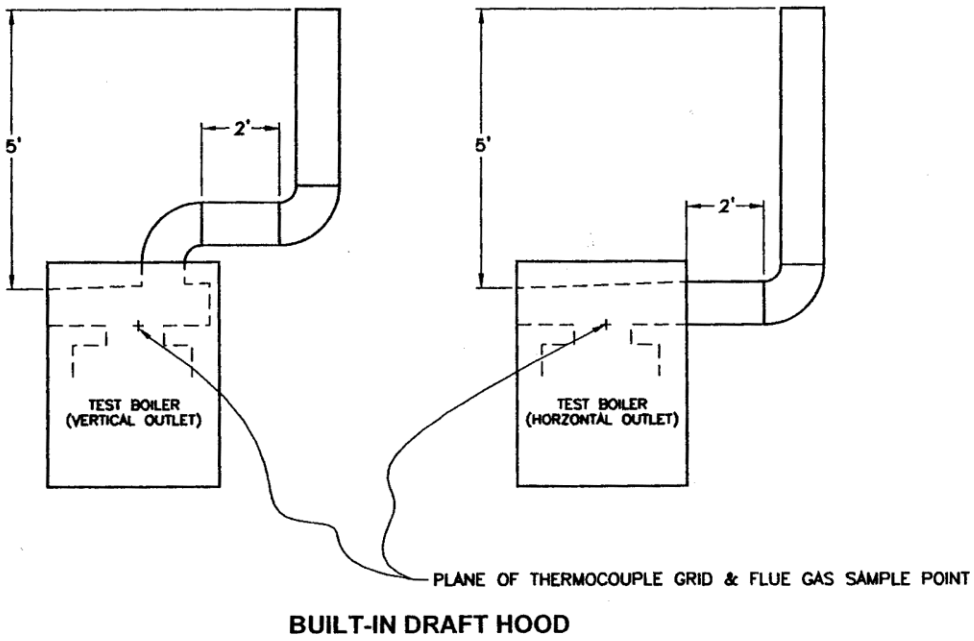


Figure 2 Test Vent for Atmospheric Boiler with an Input Rating of 400,000 Btu/h or Less

Note: Dimensions in Figure 2 are shown in feet.

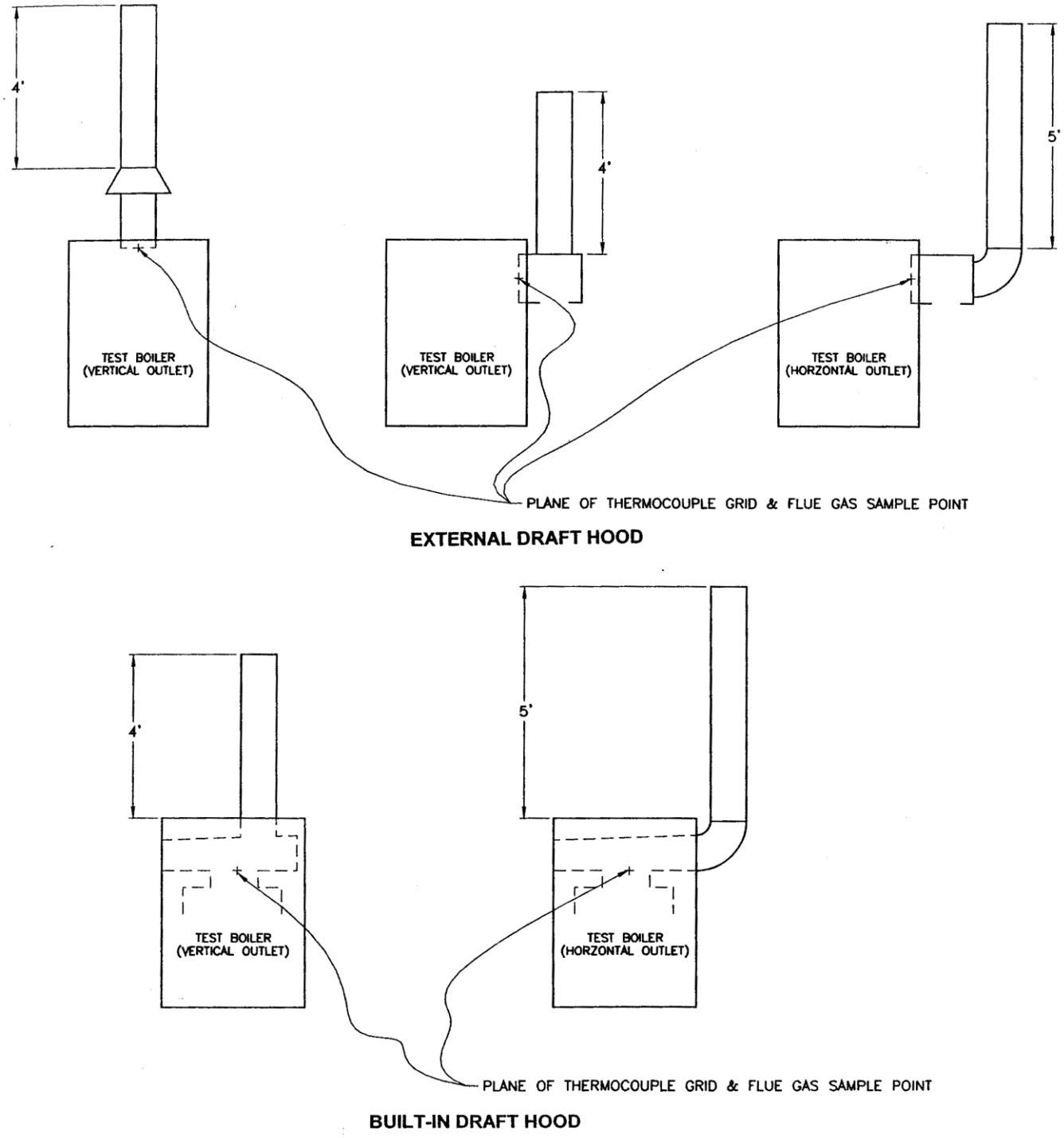


Figure 3 Test Vent for Atmospheric Boiler with an Input Rating Greater than 400,000 Btu/h

Note: Dimensions in Figure 3 are shown in feet.

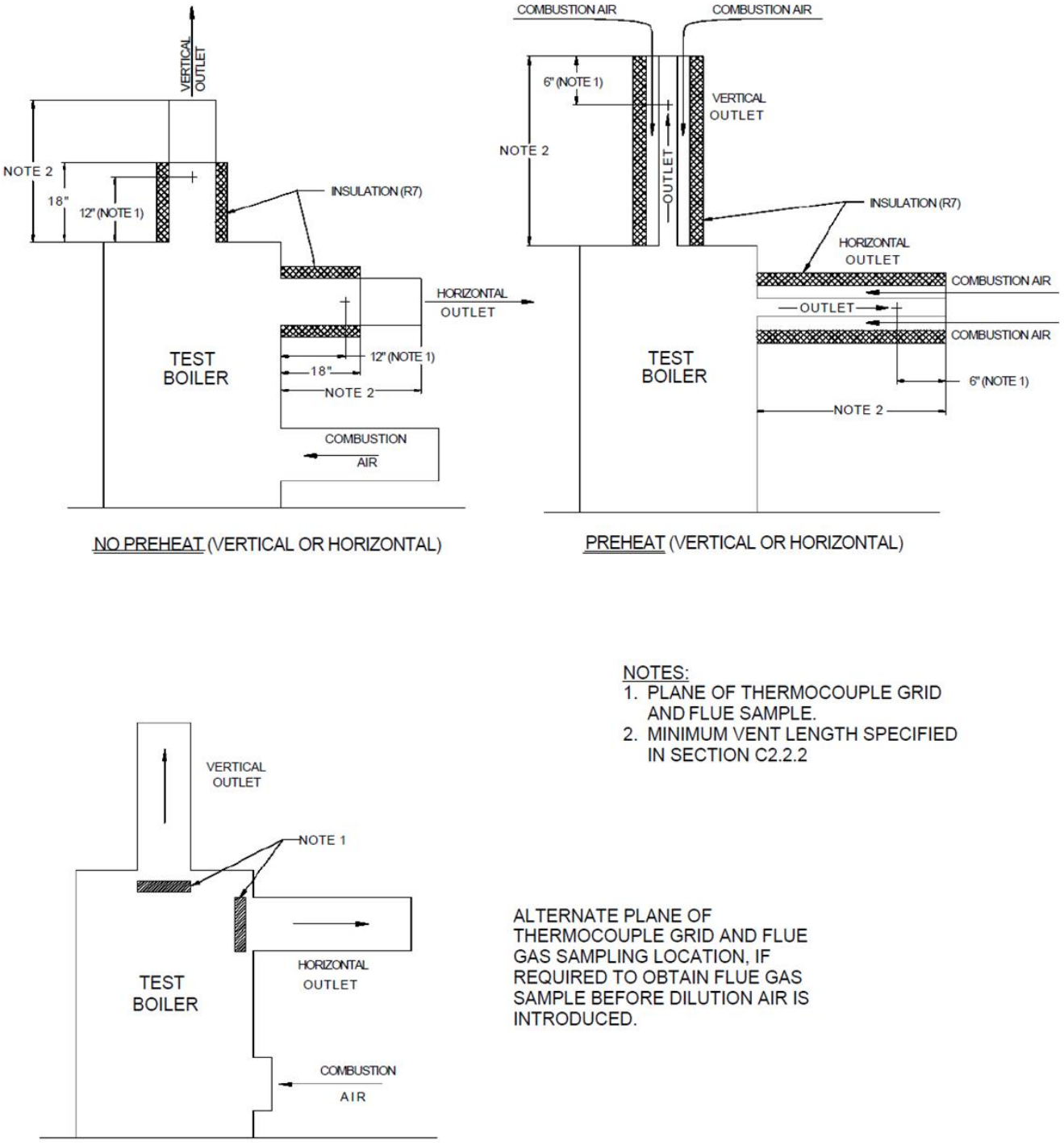


Figure 4 Test Vent for Direct Vent Boilers with a Gas or Oil Non-atmospheric Burner and with Positive Vent Pressure

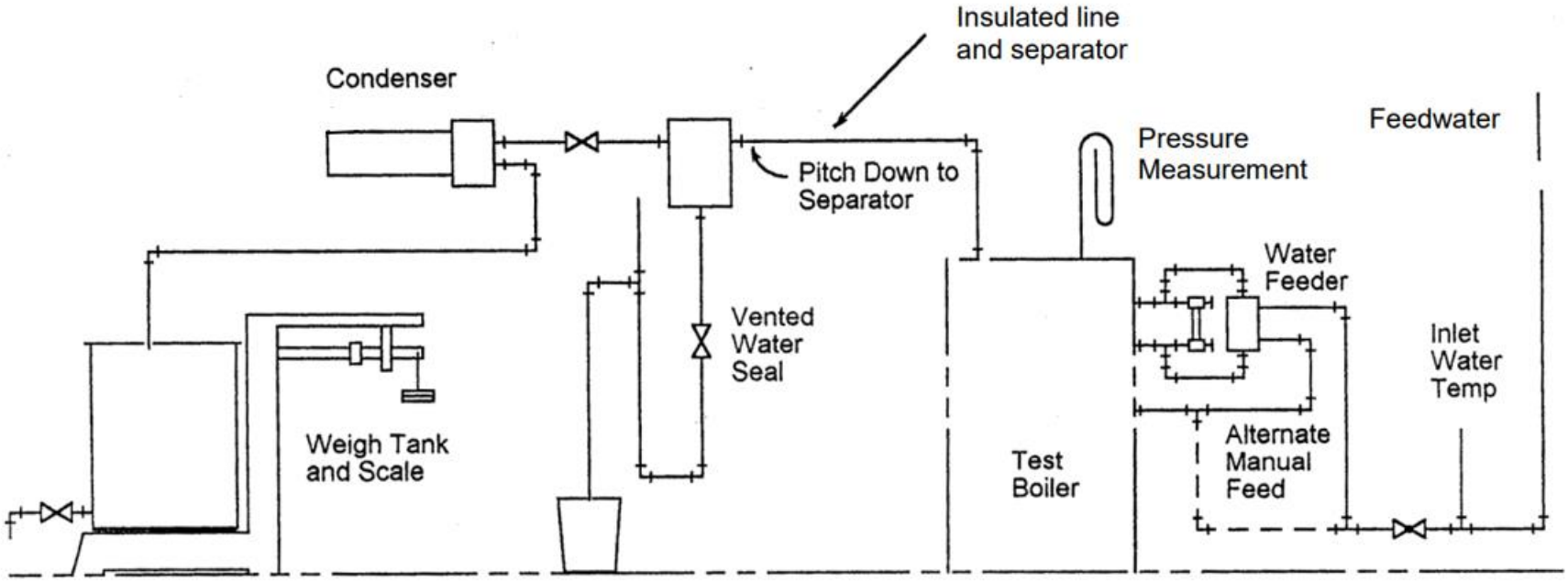


Figure 5 Example of a Piping Arrangement for Steam Boilers, Condensate Measurement (Informative)

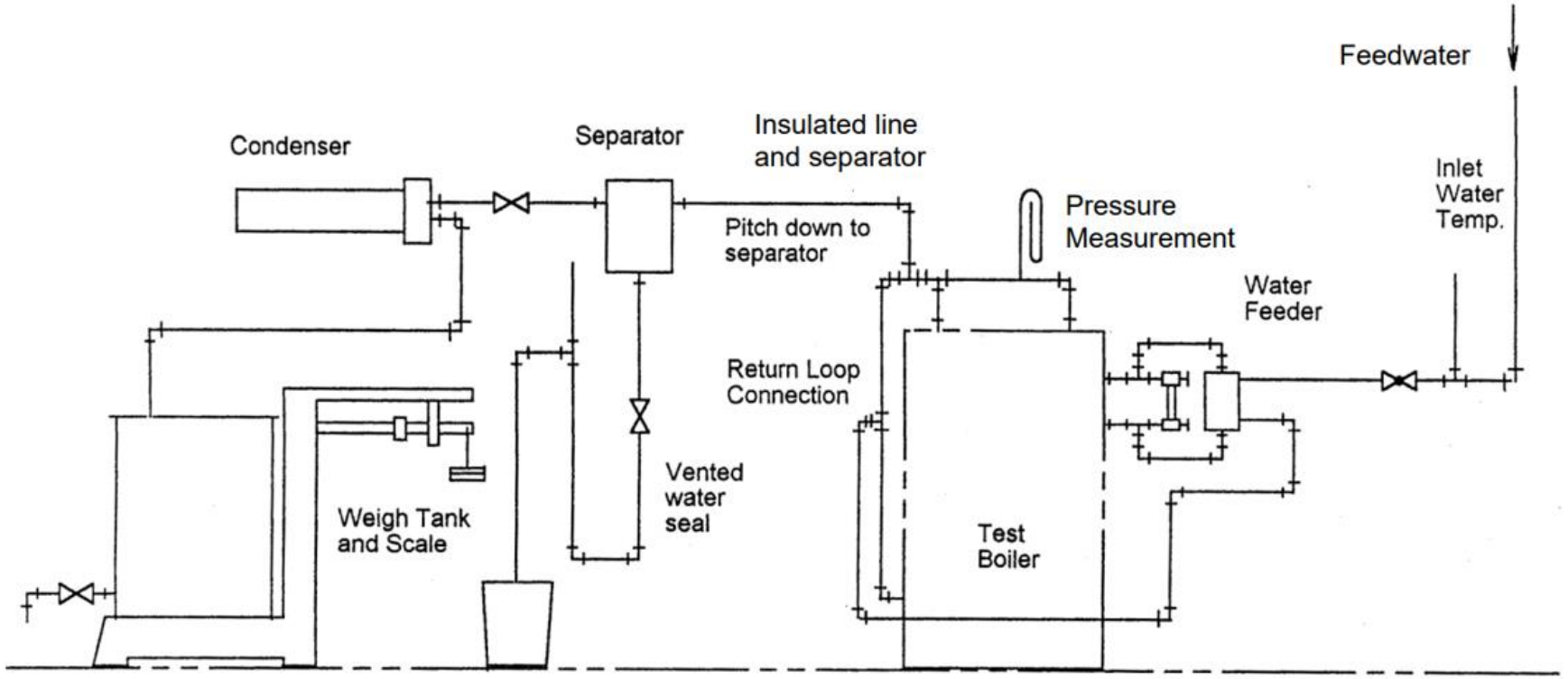


Figure 6 Example of a Piping Arrangement for Steam Boilers with Return Loop Connection, Condensate Measurement (Informative)

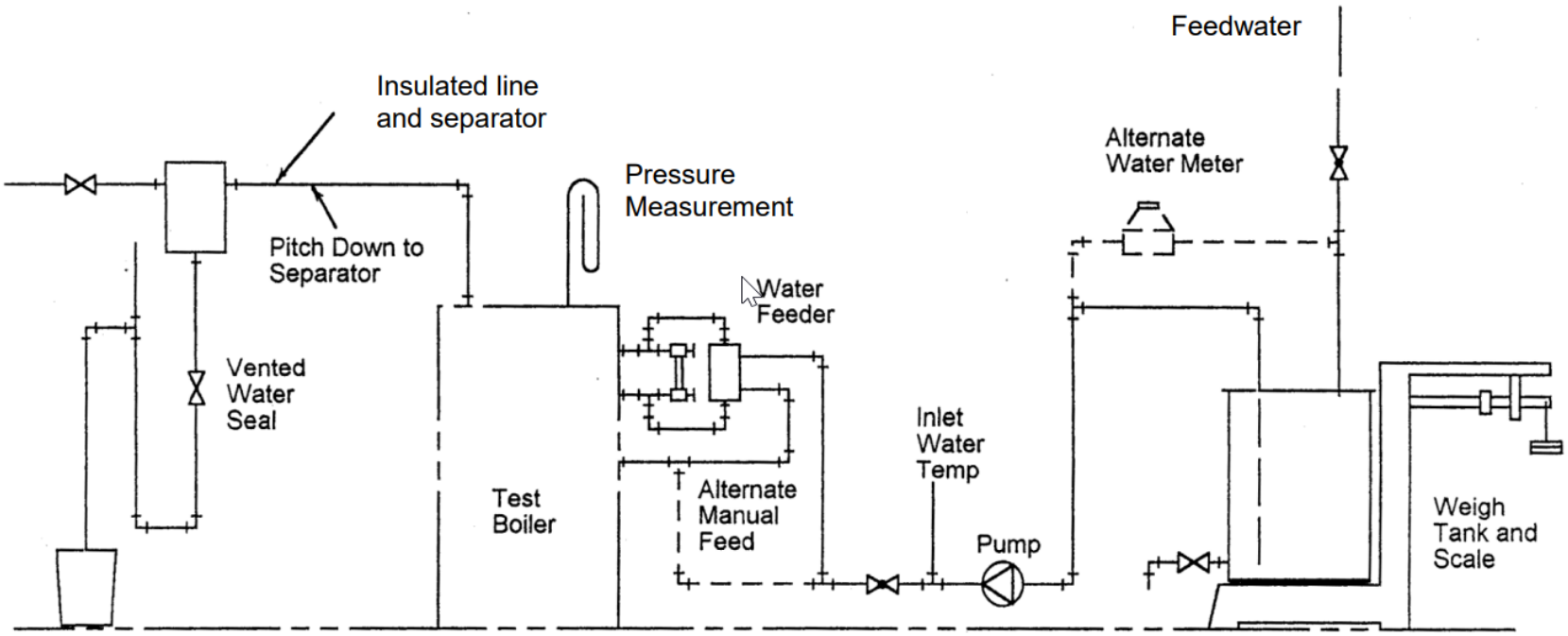


Figure 7 Example of a Piping Arrangement for Steam Boilers, Feedwater Measurement (Informative)

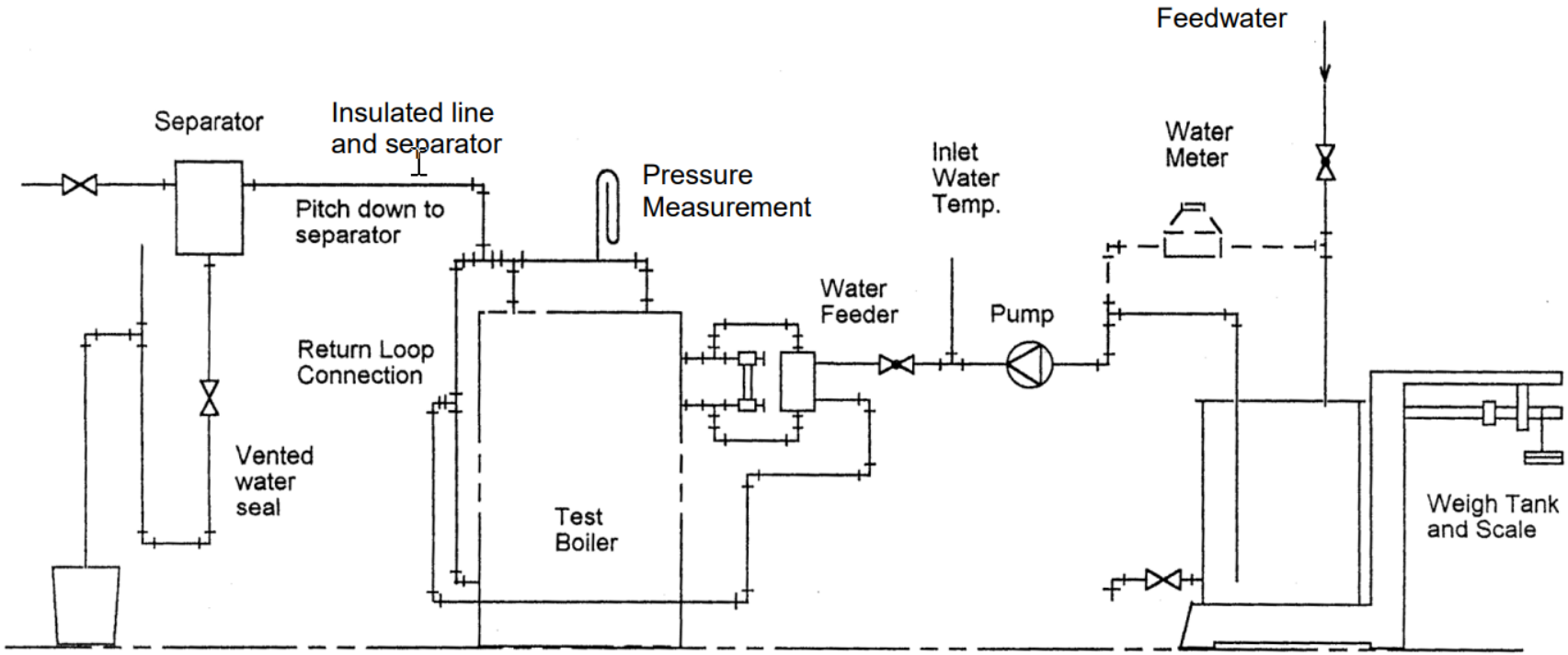


Figure 8 An Example of an Alternate Arrangement for Steam Boilers with Return Loop Connection, Feedwater Measurement (Informative)

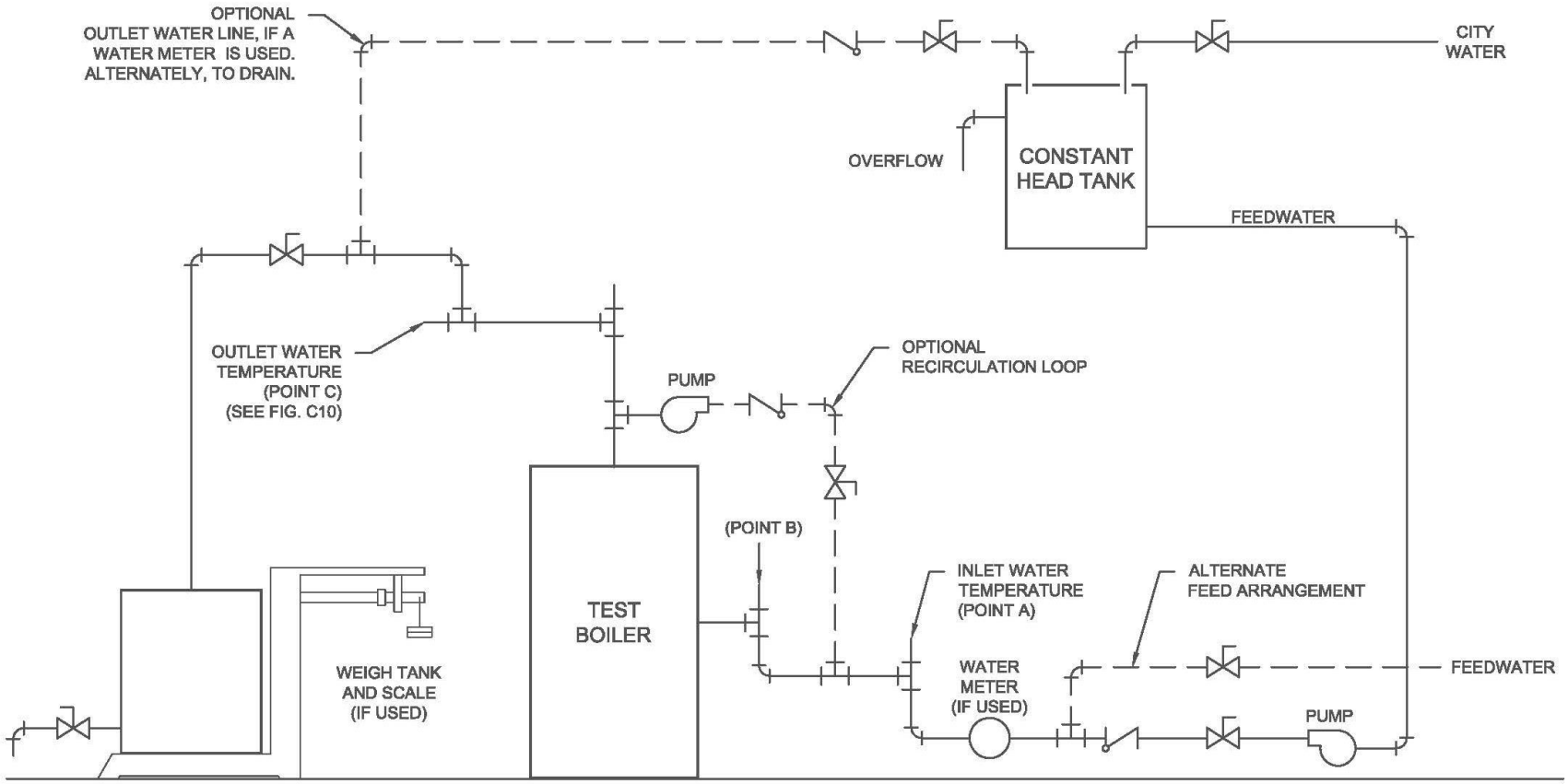


Figure 9 Example of a Piping Arrangement for Hot Water Boilers (Informative)

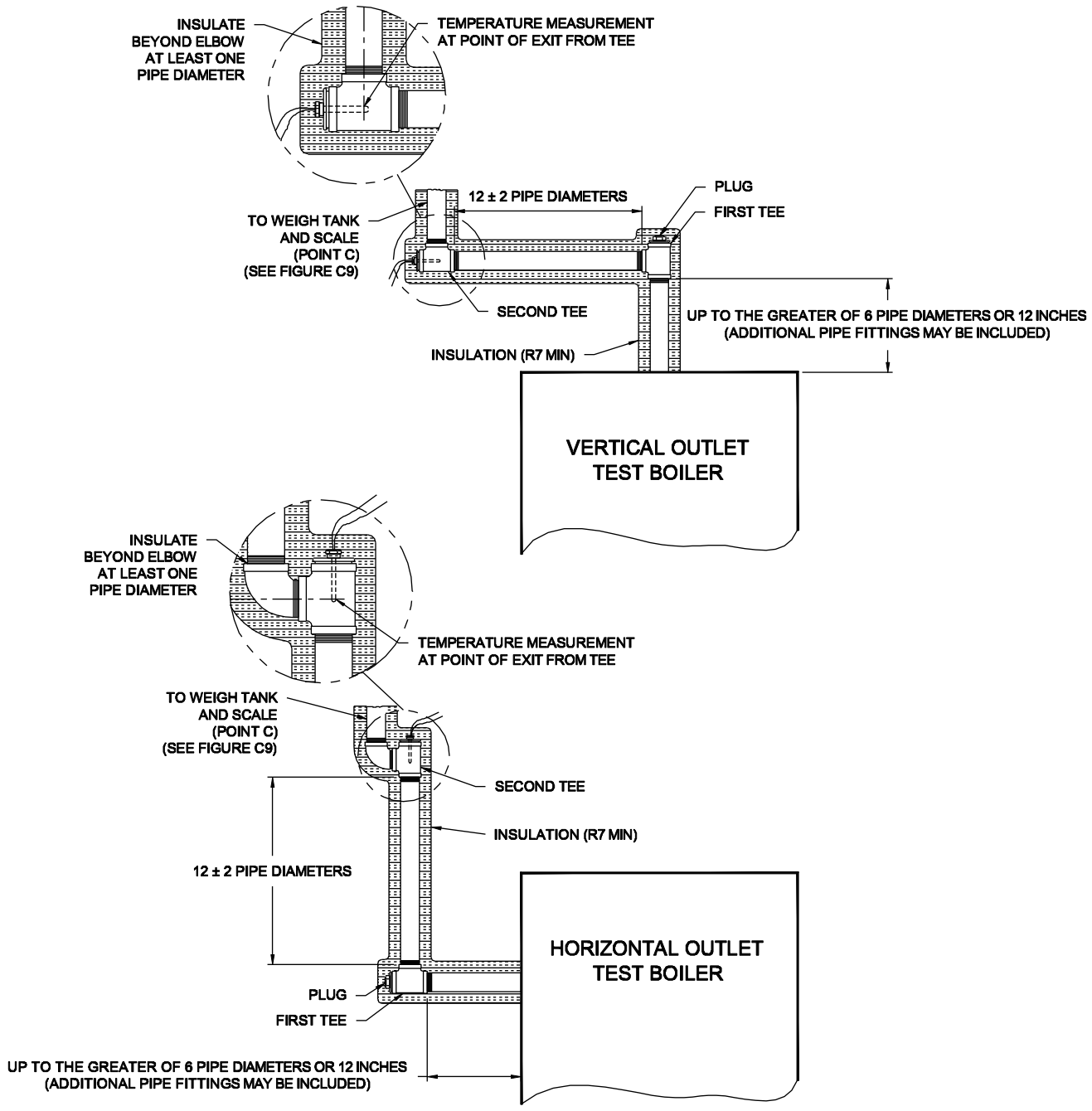


Figure 10 Required Piping Arrangement for Hot Water Boilers

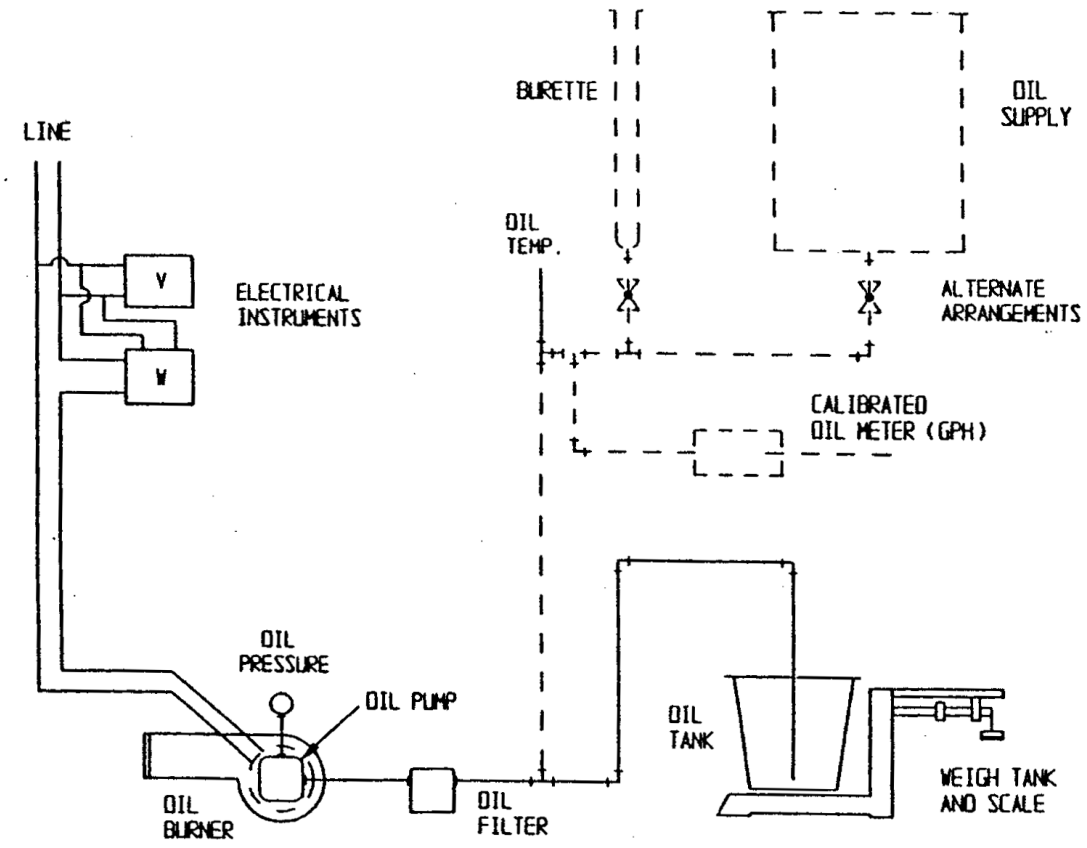


Figure 11 Example of an Oil Burner Test Setup (Informative)

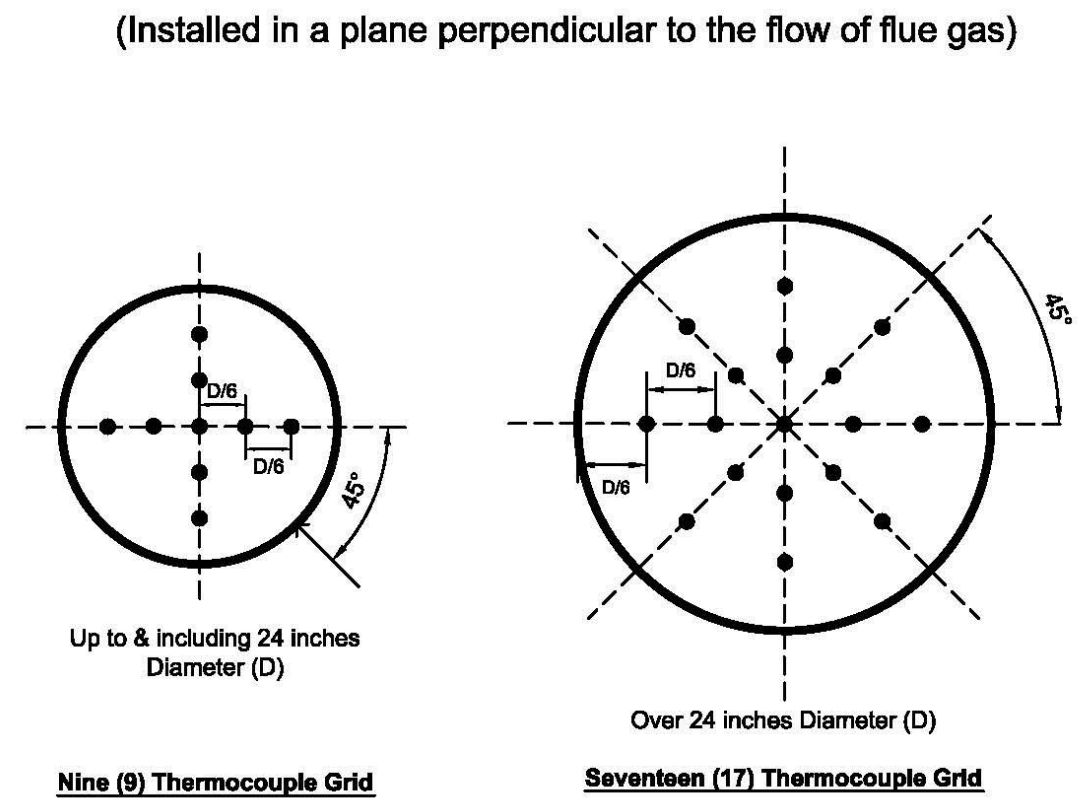


Figure 12 Thermocouple Grid

C.3. Test Conditions

C.3.1. 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.

C.3.1.1. Insulated Jacket

The insulated flush jacket catalogued or furnished with the *boiler* shall be in place during the test. If a production jacket is not provided, a prototype jacket shall be fabricated for the test. The insulation thickness and spacing as specified shall be maintained.

C.3.1.2. Cleaning of Boiler

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

C.3.1.3. Gross Output and Efficiency Tests

Tests for determining *gross output* and efficiency include:

1) Steam only *boilers* shall be tested as steam *boilers*.
2) Hot water only *boilers* shall be tested as hot water *boilers*.
3) Steam and hot water *boilers* claiming the same efficiency as steam and hot water *boilers* shall be tested as steam *boilers*.
4) Steam and hot water *boilers* claiming a different efficiency as steam or hot water *boilers* shall be tested both as steam *boilers* and hot water *boilers*.

C.3.2. Fuel

C.3.2.1. Oil

Boilers with an *input rating* up to and including 5 gph shall use *light oil* No. 2. *Boilers* with an *input rating* more than 5 gph shall use *light oil* No. 2, or *heavy oil* No. 4, 5 or 6, 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. *Light oil* No. 2 shall be supplied at room temperature.

C.3.2.2. Fuel Oil Analysis

A representative sample of the fuel oil of one quart shall be taken and analyzed to an accuracy of ± 1% for the following values:

1) Heating Value, per ASTM D240-09 or ASTM D4809-09a
2) Hydrogen and carbon content, per ASTM D5291-10
3) Density in pounds per gallon and API gravity, according to the methods specified by ASTM D396-14a

C.3.2.3. 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.

C.3.3. Installation of Burner

The *burner* shall be installed in accordance with the manufacturer's instructions shipped with the *boiler*.

C.3.4. Vent and Firebox Pressure

The *draft* shall be as established by the *vent* system specified in Section C.2.2. 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.

C.3.4.1. Negative Vent Pressure (Draft)

The *draft* shall be established by the *vent* system as specified in Section C.2.2. 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.

C.3.4.2. 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.

C.3.5. 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 C.4, when recorded at the interval defined by Section C.5 by more than the limits prescribed in Table 3.

Table 3 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	

C.3.6. 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 C.5. The room ambient temperature shall be measured within 6 ft of the front of the unit at mid height.

C.3.7. Ambient Humidity

The ambient humidity shall be measured at the room ambient temperature location specified in Section C.3.6.

Exception: At the option of the manufacturer, measurement of humidity can be omitted for *non-condensing boilers*. If this measurement is omitted, a value of 1.0 (100%) shall be assigned to RH in Equation 12.

C.3.8. Water Measurement for Hot Water Boilers

The water shall be weighed or measured using a totalizing water meter meeting the requirements of Section C.2.7.2 and recorded at regular intervals during the test.

C.3.9. Output Measurement for Steam Boilers

Output measurement requirements for steam *boilers* include:

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 to prevent re-evaporation.
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.
3) If used, a totalizing water meter shall meet the requirements of Section C.2.7.2.

C.4. Test Procedure

C.4.1. Thermal Efficiency Test

C.4.1.1. Steam Test

Note: The conduct of this test can require that a continuous feed system be used to maintain a consistent water level.

C.4.1.1.1. Warm-up Period

The following criteria shall be met during the steam test warm-up period:

1) With all required testing apparatus connected, and with *boiler* water at normal level, the *burner* shall be started, and the system warmed up until steaming occurs.
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.
3) 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.
4) 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 water level is not specified in the instructions shipped with the *boiler*, the water level shall be maintained within ± 1 in of the water level indicated on the *boiler* or, if water level is not indicated on the *boiler*, a level 3 ± 1 in above the highest fired surface.
5) Steady-state shall have been reached when three consecutive readings have been recorded at fifteen-minute intervals that confirm:
    a) Input is within 2% of the *input rating*
    b) Steam pressure varies not more than 5%

C.4.1.1.2. Test Period

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. Further *burner* adjustment shall not 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 more than the tolerance specified in Table 4.

Table 4 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%

1) Test conditions as specified in Section 6 and Section C.3 shall be maintained throughout the test period and shall be observed and recorded at each fifteen-minute interval as specified in Section C.5.

2) 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 fifteen-minute reading plus a separator water weight. When *feedwater* is measured, the water line at the end of the test shall be within ± 1/4 in of the starting level. The total heat input measured during the test period shall be within ± 2% of the *boiler input rating*.

C.4.1.2. Water Test

C.4.1.2.1. Warm-up Period

The following criteria shall be met during the water test warm-up period:

1) With all required test apparatus 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.
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.
3) The water flow rate shall be adjusted to achieve the water temperatures described in Section 5.3.5.
4) Readings (recording of observations) can be started as soon as the water temperature conditions are met. Once started, readings shall continue uninterrupted at fifteen- minute intervals.
5) 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.
6) Steady state shall have been reached when three consecutive readings at fifteen-minute intervals confirm that:
    a) Input is within 2% of the *input rating*
    b) Water temperatures are within the limits described in Section 5.3.5
    c) *Non-condensing boiler* inlet water temperature is within the temperatures described in Section 5.3.5 and within ± 10°F of the first reading.

C.4.1.2.2. Test Period

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. Further *burner* adjustment shall not 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 4 in Section C.4.1.1.2.

Test conditions that are specified in Section 4 and Section C.3 shall be maintained throughout the test period, and shall be observed and recorded at each fifteen-minute interval as specified in Section C.5.

The test period shall be one hour for *condensing boilers* or thirty minutes for *non-condensing boilers* and shall end with a regularly scheduled fifteen-minute reading. The total heat input measured during the test period shall be within ± 2% of the *boiler input rating*.

C.4.2. Combustion Efficiency Test

A combustion test is performed in the same manner as the *thermal efficiency* test described above except that output is not measured.

The *boiler* shall be fired until steady state has been established as defined in Section C.4.1.1.1(5) for steam *boilers* or Section C.4.1.2.1(5) for hot water *boilers*. For *condensing boilers* condensate shall be collected for the thirty-minute period. The data shall be recorded as specified in Section C.5.

C.5. Recorded Data

Data shall be recorded in accordance with the requirements in Table 5. Examples of data logs and test report sheets are provided in Appendix F.

Table 5 Data to be Recorded Before and During Testing

Item Recorded	*Thermal Efficiency* Test			*Combustion Efficiency* Test		
	Before Test	**Every one minute**	**Every fifteen minutes**	**Before Test**	**Every one minute**	**Every fifteen 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*/ft3	X	—	—	X	—	—
Time, minutes/seconds	—	X	—	—	X	—
Flue Gas Temperature, °F	—	X	—	—	X	—
Pressure in *Firebox*, in H2O (if required per Section C.3.4)	—	—	X	—	—	X
Flue Gas Smoke Spot Reading (oil)	—	—	X	—	—	X
Room Air Temperature	—	X	—	—	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
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

Item Recorded		*Thermal Efficiency* Test			*Combustion Efficiency* Test		
		Before Test	**Every one minute**	**Every fifteen minutes**	**Before Test**	**Every one minute**	**Every fifteen minutes[1]**
Flue Condensate Weight, lb (*Condensing Boilers* only)		—	—	—	—	—	Every thirty 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	—	—	X	—
	Condensate collected, or water fed, lb	—	—	X	—	—	—
WATER	Outlet Water Temperature, °F	—	X	—	—	X	—
	Water fed, lb	—	—	X	—	—	—
	Recirculating Loop Temperature (Figure 9, Point B), °F (if used)	—	—	X	—	—	X

"X" in the *thermal efficiency* fifteen-minute test column indicates that required data shall be recorded every fifteen-minutes during the test. Other frequencies are otherwise stated.

C.6. Symbols and Subscripts

The symbols and subscripts used in this standard are as follows:

A = Air required for complete combustion, SCF per 1000 *Btu* of gas burned

C = Carbon content of the oil, % by weight

$C_{p,air}$ = Specific heat of air = 0.24 *Btu*/lb·°F

Cp,sh = Specific heat of superheated steam at constant pressure, *Btu*/lb-F

$C_{p, H2O}$ = Average specific heat of water = 1000 *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

E_{ffySS} = *Combustion efficiency*, %

E_{ffyT} = Indoor *boiler thermal efficiency*, %

$E_{ffyT,O}$ = *Outdoor boiler thermal efficiency*, %

F+ = *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_g = Enthalpy of saturated steam at steam pipe pressure, *Btu*/lb

h_{sh} = Enthalpy resulting from *superheat*, *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 1000 *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

Pwvs = 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_{SS} = Steam output due to *superheat*, *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 1000 *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_{ST} = Measured steam temperature, °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

C.7. Calculation of Results

C.7.1. Averaging and Totaling of Recorded Values

All data shall be recorded as prescribed in Section C.5.

C.7.1.1. Measurements 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:

1) Room air temperature
2) Test air temperature
3) Inlet water temperature
4) Outlet water temperature
5) *Flue gas* temperature
6) Fuel gas temperature
7) Atmospheric pressure
8) Steam pressure
9) Steam temperature
10) Gas pressure
11) *Flue gas* CO_2
12) *Flue gas* CO
13) *Flue gas* O_2
14) Relative humidity

C.7.1.2. Measurements 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:

1) Time
2) Fuel weight or volume
3) *Flue condensate* weight
4) Steam separator weight
5) *Steam condensate* collected

6) Water volume or weight

C.7.2. Thermal Efficiency Test

The following items shall be calculated and recorded for the *thermal efficiency* test.

C.7.2.1. Barometric Pressure, PB, in in Hg

Required for steam and gas tests. Correct mercury readings for temperature and latitude. Correction of aneroid readings is not required.

C.7.2.2. Steam Pressure

For steam pressure (absolute), P_{SAT}, in in Hg see Equation 1.

$$P_{SAT} = P_B + P_S \quad \textbf{1}$$

C.7.2.3. Heat Input

For heat input, $_{QIN,}$ in *Btu*/h, see Equation 2 and Equation 3.

For oil-fired *boilers* see Equation 2.

$$Q_{IN} = \frac{W_F \cdot HHV_{oil}}{t_T} \quad \textbf{2}$$

For gas-fired *boilers* see Equation 3.

$$Q_{IN} = \frac{W_V \cdot C_S \cdot HHV_{gas}}{t_T} \quad \textbf{3}$$

C.7.2.4. Loss in Dry Flue Gases

For loss in dry *flue gases*, L_S, for oil, %, see Equation 4 through Equation 6.

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

Where:

CO_2 = Percentage by volume of carbon dioxide in the *flue gas*, %, shall be measured, or calculated per Equation 5.

$$CO_2 = U_{oil} \cdot \frac{\left(20{,}9 - O_{2,meas}\right)}{20.9} \quad \textbf{5}$$

O_2 = Percentage by volume of oxygen, either use $O_{2,meas}$ or calculated per Equation 6.

$$O_2 = 21\left[1 - \left(\frac{CO_2}{100}\right) \cdot \left(\frac{4.8C + 11.3H}{C}\right)\right] \quad \textbf{6}$$

U_{oil} = Ultimate CO_2 of *flue gas*, %, that 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

C.7.2.5. Loss Due to Moisture Formed by Combustion of Hydrogen

For loss due to moisture formed by combustion of hydrogen, L_L, and for oil, in percent. See Equation 7.

$$L_L = \frac{9H\left[1090 - T_A + \left(0.46T_{F,SS}\right)\right]}{HHV_{oil}} \quad (7)$$

C.7.2.6. Flue Losses

For flue losses see Equation 8 through Equation 14.

C.7.2.6.1. Gas-fired Boilers

Calculate flue loss, L_f, in percent of heat input rate. See Equation 8 through Equation 13.

$$L_f = \frac{1}{379}(C_1 + C_2 + C_3 + C_4) + 5{,}04(T - P) \quad \textbf{8}$$

Where:

$$C_1 = \frac{P \cdot U}{1000}\left[16{,}2\left(T_{F,abs} - T_{\mathrm{r,abs}}\right) + 6530\, ln\left(\frac{T_{r,\mathrm{abs}}}{T_{F,abs}}\right) + 1{,}41 \cdot 10^6 \cdot \left(\frac{1}{T_{r,\mathrm{abs}}} - \frac{1}{T_{F,abs}}\right)\right] \quad \textbf{9}$$

$$C_2 = \frac{P}{10}\left(1 - \frac{U}{100}\right)\left[9{,}47\left(T_{F,abs} - T_{r,\mathrm{abs}}\right) + 3470\, ln\left(\frac{T_{r,\mathrm{abs}}}{T_{F,abs}}\right) + 1{,}16 \cdot 10^6 \cdot \left(\frac{1}{T_{r,\mathrm{abs}}} - \frac{1}{T_{F,abs}}\right)\right] \quad \textbf{10}$$

$$C_3 = \frac{P}{10}\left(\frac{U - CO_2}{CO_2}\right)\left[9{,}46\left(T_{F,abs} - T_{r,\mathrm{abs}}\right) + 3290\, ln\left(\frac{T_{r,\mathrm{abs}}}{T_{F,abs}}\right) + 1{,}07 \cdot 10^6 \cdot \left(\frac{1}{T_{r,\mathrm{abs}}} - \frac{1}{T_{F,abs}}\right)\right] \quad \textbf{11}$$

$$C_4 = \left[\frac{T - P}{10} + 0.00174RH \cdot A\left(1 + \frac{P}{A}\left(\frac{U - CO_2}{CO_2}\right)\right)\right] \cdot \left[19.86\left(T_{F,abs} - T_{r,\mathrm{abs}}\right) + 7500\, ln\left(\frac{T_{F,abs}}{T_{r,\mathrm{abs}}}\right) + 1194\left(\sqrt{T_{r,\mathrm{abs}}} - \sqrt{T_{F,abs}}\right)\right] \quad \textbf{12}$$

Where:

A = 9.4 SCF per 1000 *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 Equation 13.

$$\mathrm{CO_2} = \mathrm{U_{gas}} \cdot \frac{\left(20.9 - \mathrm{O_{2,meas}}\right)}{20.9} \quad \textbf{13}$$

$O_{2,meas}$ = measured O_2 in *flue gases*, %

P = 8.47 SCF per 1000 *Btu* of gas burned

T = 10.42 SCF per 1000 *Btu* of gas burned

U_{gas} = Ultimate CO_2 of the *flue gas* = 11.9%

C.7.2.6.2. Oil-fired Boilers

Calculate flue loss, L_f, in percent of heat input rate. See Equation 14.

$$L_f = L_s + L_L \quad \textbf{14}$$

C.7.2.7. Saturated Steam Temperature

For saturated steam temperature, T_{SAT}, in °F, see Equation 15.

$$T_{SAT} = 0.000173842 \cdot {P_S}^3 - 0.035155974 \cdot {P_S}^2 + 3.309466274 \cdot P_S + 139.7280185 \quad \textbf{15}$$

C.7.2.8. Latent Heat of Vaporization at Saturated Steam Temperature,

For latent heat of vaporization at saturated steam temperature, h_{fg}, T_{SAT}, in *Btu*/lb, see Equation 16.

$$h_{fg,TSAT} = 1.524143 \cdot 10^{-6} \cdot {P_S}^4 - 3.611355 \cdot 10^{-4} \cdot {P_S}^3 + 0.036602 \cdot {P_S}^2 - 2.440951 \cdot P_S + 1019.4644 \quad \textbf{16}$$

C.7.2.9. Moisture in Steam

For moisture in steam, *M*, %, see Equation 17 through Equation 19.

If steam is condensed and weighed see Equation 17.

$$M = \frac{100 W_S}{W_S + W_C} \quad \textbf{17}$$

If feedwater is measured see Equation 18.

$$M = \frac{100 W_S}{W} \quad \textbf{18}$$

If a throttling steam calorimeter is used, see Equation 19.

$$M = \frac{h_g - 1150.4 - 0{,}485(T_{cal} - 212)}{h_{tg}} \cdot 100 \quad \textbf{19}$$

C.7.2.10. Latent Heat in Steam

For heat in steam calculate using Equation 20 and Equation 21.

If condensate is collected calculate with Equation 20.

$$Q_L = \frac{h_{fg,TSAT} \cdot W_C}{t_T} \quad \textbf{20}$$

If *feedwater* is measured calculate with Equation 21.

$$Q_L = \frac{h_{fg,TSAT} \cdot (W - W_S)}{t_T} \quad \textbf{21}$$

C.7.2.11. Output Due to Superheat

For output due to *superheat*, *Btu*/h, calculate with Equation 22 and Equation 23.

C.7.2.11.1. Specific Heat of Superheated Steam at Constant Pressure

For specific heat of superheated steam at constant pressure, determine $C_{P,SH}$, *Btu*/lb-F, as follows:

Where T_{ST} is not measured or is less then T_{SAT}:

$C_{P,SH} = 0$

Where T_{ST} is greater than T_{SAT}:

$C_{P,SH} = 0.482484$ *Btu*/lb-F

C.7.2.11.2. Output Due to Superheat

For output due to *superheat*, *Btu*/h, see Equation 22 and Equation 23.

If condensate is collected see Equation **22.**

$$Q_{SS} = \frac{C_{P,SH} \cdot W_C (T_{ST} - T_{SAT})}{t_T} \quad \textbf{22}$$

If *feedwater* is measured see Equation 23.

$$Q_{SS} = \frac{C_{P,SH} (W - W_S)(T_{ST} - T_{SAT})}{t_T} \quad \textbf{23}$$

C.7.2.12. Heat in Liquid

For heat in liquid, Q_S, in *Btu*/h, steam test if condensate is weighed, calculate with Equation 24.

$$Q_S = \frac{C_{p,H2O} (W_C + W_S)(T_{SAT} - T_{IN})}{t_T} \quad \textbf{24}$$

If *feedwater* is weighed for the steam test, calculate with Equation 25.

$$Q_S = \frac{W \cdot C_{p,H2O} (T_{SAT} - T_{IN})}{t_T} \quad \textbf{25}$$

Use Equation 26 to calculate for the water test.

$$Q_S = \frac{W \cdot C_{p,H2O} (T_{OUT} - T_{IN})}{t_T} \quad \textbf{26}$$

W = weight of water fed, lb (Measured or calculated from Equation 27)

Calculate with Equation 27 and Equation 28 for water volume to weight conversion:

$$W = V \cdot \rho \quad \textbf{27}$$

Where:

$$\rho = \frac{(-7.36376 \cdot 10^{-5} \cdot {T_{IN}}^2 + 0.002427088 \cdot T_{IN} + 62.48442)}{7.48052} \quad \textbf{28}$$

C.7.2.13. Gross Output

For *gross output*, Q_{OUT}, in *Btu*/h see Equation 29 and Equation 30.

For steam *thermal efficiency* test calculate with Equation 29.

$$Q_{OUT} = Q_L + Q_S + Q_{SS} \quad \textbf{29}$$

For water *thermal efficiency* test calculate with Equation 30.

$$Q_{OUT} = Q_S \quad \textbf{30}$$

C.7.2.14. Thermal Efficiency

For thermal efficiency, $Effy_T$, %, calculate with Equation 31.

$$Effy_T = \frac{100 \cdot Q_{OUT}}{Q_{IN}} \quad \textbf{31}$$

C.7.2.15. Non-condensing Combustion Efficiency

For non-condensing *combustion efficiency*, $Effy_{SS}$, %, calculate with Equation 32.

$$Effy_{SS} = 100 - L_f \quad \textbf{32}$$

C.7.2.16. Radiation and Unaccounted for Loss

For radiation and unaccounted for loss, L_U, %, see Equation 33 and Equation 34.

If $Effy_T > Effy_{SS}$ see Equation 33.

$$L_U = 0 \quad \textbf{33}$$

If $Effy_T \leq Effy_{SS}$ see Equation 34.

$$L_U = Effy_{SS} - Effy_T \quad \textbf{34}$$

C.7.2.17. Condensing Boiler Latent Heat Gain

For *condensing boiler* latent heat gain due to condensation under steady state conditions, $LG_{,SS}$, %, calculate with Equation 35.

$$L_{G,SS} = \frac{100 \cdot h_{fg} \cdot M_{C,SS}}{Q_{IN}} \quad \textbf{35}$$

C.7.2.18. Condensing Boiler Steady State Heat Loss

For *condensing boiler* steady state heat loss due to hot condensate going down the drain, $LC_{,SS}$, %, calculate with Equation 36.

$$L_{C,SS} = \frac{L_{G,SS}\left[C_{p,H2O}\left(T_{F,SS} - T_A\right) - 0{,}45\left(T_{F,SS} - T_A\right)\right]}{h_{fg}} \quad \textbf{36}$$

C.7.2.19. Condensing Boiler Steady State Combustion Efficiency

For *condensing boiler* steady state *combustion efficiency*, $Effy_{SS}$, %, calculate with Equation 37.

$$Effy_{SS} = 100 - (L_f - L_{G,SS} + L_{C,SS}) \quad \textbf{37}$$

C.7.2.20. Outdoor Boiler Thermal Efficiency

For *outdoor boiler thermal efficiency*, $Effy_{T,O}$, %, calculate with Equation 38 and Equation 39.

For hot water *boilers* see Equation 38.

$$Effy_{T,O} = Effy_{SS} - L_U \left(\frac{T_{OUT} - 42}{T_{OUT} - T_A}\right) \quad \textbf{38}$$

For steam *boilers* calculate with Equation 39.

$$Effy_{T,O} = Effy_{SS} - L_U \left(\frac{T_{SAT} - 42}{T_{SAT} - T_A}\right) \quad \textbf{39}$$

C.7.2.21. Outdoor Boiler Gross Output

For *outdoor boiler gross output*, $Q_{OUT,O}$, in *Btu*/h, calculate with Equation 40.

$$Q_{OUT,O} = \frac{Q_{IN} \cdot Effy_{T,O}}{100} \quad \textbf{40}$$

C.7.3. Combustion Efficiency Test

C.7.3.1. Non-condensing Combustion Efficiency

Equation 4, Equation 7 and Equation 14 shall be used to calculate for oil *boilers* and Equation 8 shall be used to calculate for gas *boilers*. Equation 32 shall be used to calculate the *combustion efficiency*.

C.7.3.2. Condensing Combustion Efficiency

Equation 8, Equation 33, Equation 34, and Equation 35 shall be used to calculate for gas *boilers*. Equation 36 shall be used to calculate the *combustion efficiency*.

APPENDIX D. PROPERTIES OF SATURATED STEAM - INFORMATIVE

Appendix D shows the properties of saturated steam. See Table 6.

Table 6 Properties of Saturated Steam

Absolute Pressure in Hg	Absolute Pressure psi	Temperature °F	Latent Heat *Btu*/lb	Absolute Pressure in Hg	Absolute Pressure psi	Temperature °F	Latent Heat *Btu*/lb
27,6	13.57	208.0	972.9	31.2	15.32	214.1	968.9
27.7	13.61	208.1	972.8	31.3	15.37	214.2	968.8
27.8	13.66	208.3	972.7	31.4	15.42	214.4	968.7
27.9	13.71	208.5	972.6	31.5	15.47	214.6	968.6
28.0	13.75	208.7	972.5	31.6	15.52	214.7	968.5
28.1	13.80	208.8	972.4	31.7	15.57	214.9	968.4
28.2	13.85	209.0	972.2	31.8	15.61	215.0	968.3
28.3	13.90	209.2	972.1	31.9	15.66	215.2	968.2
28.4	13.95	209.4	972.0	32.0	15.71	215.4	968.1
28.5	14.00	209.5	971.9	32.1	15.76	215.5	968.1
28.6	14.05	209.7	971.8	32.2	15.81	215.7	968.0
28.7	14.10	209.9	971.7	32.3	15.86	215.9	967.9
28.8	14.15	210.1	971.6	32.4	15.91	216.0	967.8
28.9	14.20	210.2	971.4	32.5	15.96	216.2	967.7
29.0	14.24	210.4	971.3	32.6	16.00	216.3	967.6
29.1	14.29	210.6	971.2	32.7	16.05	216.5	967.5
29.2	14.34	210.8	971.1	32.8	16.10	216.6	967.4
29.3	14.39	210.9	971.0	32.9	16.15	216.8	967.3
29.4	14.44	211.1	970.9	33.0	16.20	217.0	967.2
29.5	14.49	211.3	970.8	33.1	16.25	217.1	967.1
29.6	14.54	211.4	970.7	33.2	16.30	217.3	967.0
29.7	14.59	211.6	970.5	33.3	16.35	217.4	966.9
29.8	14.64	211.8	970.4	33.4	16.40	217.6	966.8
29.9	14.69	212.0	970.3	33.5	16.45	217.7	966.7
30.0	14.73	212.1	970.2	33.6	16.50	217.9	966.6
30.1	14.78	212.3	970.1	33.7	16.54	218.0	966.5
30.2	14.83	212.4	970.0	33.8	16.59	218.2	966.4
30.3	14.88	212.6	969.9	33.9	16.64	218.3	966.3
30.4	14.93	212.8	969.8	34.0	16.69	218.5	966.2
30.5	14.98	212.9	969.7	34.1	16.74	218.7	966.1
30.6	15.03	213.1	969.6	34.2	16.79	218.8	966.0
30.7	15.07	213.3	969.5	34.3	16.84	219.0	965.9
30.8	15.12	213.4	969.4	34.4	16.89	219.1	965.8
30.9	15.17	2136	969.2	34.5	16.94	219.3	965.7
31.0	15.22	213.7	969.1	34.6	16.99	219.4	965.6

Absolute Pressure in Hg	Absolute Pressure psi	Temperature °F	Latent Heat *Btu*/lb	Absolute Pressure in Hg	Absolute Pressure psi	Temperature °F	Latent Heat *Btu*/lb
31.1	15.27	213.9	969.0	34.7	17.04	219.6	965.5
34.8	17.09	219.7	965.4	48.0	23.58	236.9	954.2
34.9	17.14	219.9	965.3	48.5	23.82	237.4	953.9
35.0	17.19	220.0	965.2	49.0	24.07	238.0	953.5
35.5	17.43	220.7	964.7	49.5	24.31	238.5	953.1
36.0	17.68	221.5	964.2	50.0	24.56	239.1	952.8
36.5	17.93	222.2	963.8	50.5	24.80	239.6	952.4
37.0	18.17	222.9	963.3	51.0	25.05	240.2	952.1
37.5	18.42	223.6	962.9	51.5	25.29	240.7	951.7
38.0	18.66	224.3	962.4	52.0	25.54	241.3	951.3
38.5	18.91	225.0	962.0	52.5	25.79	241.8	951.0
39.0	19.16	225.7	961.5	53.0	26.03	242.3	950.6
39.5	19.40	226.3	961.1	53.5	26.28	242.9	950.3
40.0	19.65	227.0	960.7	54.0	26.52	243.4	949.9
40.5	19.89	227.7	960.2	54.5	26.77	243.9	949.6
41.0	20.14	228.3	959.8	55.0	27.01	244.4	949.3
41.5	20.38	229.0	959.4	555	27.26	244.9	948.9
42.0	20.63	229.6	959.0	56.0	27.50	245.4	948.6
42.5	20.87	230.2	958.6	56.5	27.75	245.9	948.3
43.0	21.12	230.9	958.2	57.0	28.00	246.4	947.9
43.5	21.37	231.5	957.8	57.5	28.24	246.9	947.6
44.0	21.61	232.1	957.4	58.0	28.49	247.4	947.3
44.5	21.86	232.7	957.0	58.5	28.73	247.9	946.9
45.0	22.10	233.3	956.6	59.0	28.98	248.3	946.7
45.5	22.35	233.9	956.2	59.5	29.22	248.8	946.3
46.0	22.59	234.5	955.8	60.0	29.47	249.3	946.0
46.5	22.84	235.1	955.4	60.5	29.71	249.8	945.7
47.0	23.08	235.7	955.0	61.0	29.96	250.3	945.3
47.5	23.33	236.3	954.6	-	-	-	-

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

E.1. Correction Factor

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

For the dry gas utilizing a dry test meter see Equation 41.

$$C_S = \frac{P_g(459.7 + T_{std})}{P_{std}(459.7 + T_g)} \quad \textbf{41}$$

For the saturated gas utilizing a wet test meter see Equation 42.

$$C_S = \frac{(P_g - P_{wv})(459.7 + T_{std})}{(P_{std} - P_{wvs})(459.7 + T_g)} \quad \textbf{42}$$

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, the value shall be reduced by a correction factor, C_f, shown in Equation 43.

$$C_f = \frac{P_{std} - P_{wvs}}{P_{std}} \quad \textbf{43}$$

Conversely, if the value is based upon a saturated condition and the gas is metered dry, the value shall be increased by a factor shown in Equation 44.

$$C_f = \frac{P_{std}}{P_{std} - P_{wvs}} \quad \textbf{44}$$

APPENDIX F. EXAMPLE TEST REPORT FORMS - INFORMATIVE

Appendix F provides example test report forms that can be used to record data. Figure 13 shows Example Boiler Test Log Sheet 1 and Figure 14 shows Example Boiler Test Log Sheet 2.

BOILER TEST LOG SHEET

TIME	WATER, □ lb □ Gal			FUEL		Steam Pressure, in Hg	TEMPERATURE, °F					DRAFT or PRESSURE, in H_2O		FLUE GAS, %		Oil		Test Conducted by	Test No. & Date	Boiler Model No.	Manufacturer
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	Pressure	Nozzle Size				
Total																					
Average																					

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

Figure 13 Example Boiler Test Log Sheet 1

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/ft³		
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	ft³ 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		

Figure 14 is only used for steam tests.

Figure 14 Example Boiler Test Log Sheet 2