

BTS-2000

TESTING STANDARD

Method to Determine

EFFICIENCY OF COMMERCIAL

SPACE HEATING BOILERS

HYDRONICS INSTITUTE DIVISION OF AHRI
35 RUSSO PLACE • BERKELEY HEIGHTS • NEW JERSEY 07922

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PREFACE

This Second Edition of the *BTS-2000 Testing Standard, Method to Determine Efficiency of Commercial Heating Boilers*, published by The Hydronics Institute Division of AHRI, revises the January 2001 edition to be consistent with the U.S. Department of Energy efficiency test procedures for commercial boilers. This standard was previously part of The Hydronics Institute, Inc., Testing and Rating Standard for Heating Boilers, sixth Edition, June 1989.

This Standard applies to heating boilers having inputs of 300 MBh and larger.

Inquiries regarding this Standard should be addressed to:

Hydronics Institute Division of AHRI
35 Russo Place
P.O. Box 218
Berkeley Heights, New Jersey 07922-0218

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Arlington, VA 22201

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1.0 PURPOSE

The purpose of this Standard is to specify methods and procedures for determining performance of heating boilers.

2.0 SCOPE

This Standard applies to gas and oil-fired steam and hot water boilers with inputs equal to or greater than 300 MBh.

3.0 DEFINITIONS OF TERMS USED IN THIS STANDARD

baffle - a device installed in a boiler to direct or restrict the flow of gases through the boiler. Devices known as turbulators, spinners, twistors and deflectors are special types of baffles.

base - a structure used beneath a boiler to increase furnace volume.

boiler - a closed direct fired pressure vessel intended for use in heating water or generating steam to be used external to itself. As used in this Standard, this includes boiler-burner units or packaged boilers.

boiler-burner unit - a combination of boiler, burner, combustion chamber design (if required) and controls, marketed as a unit.

boiler, condensing - 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.

boiler, gas-designed – as used in this standard, a boiler that meets the scope of Z21.13/CGA 4.9 standard and is not intended to be capable of being converted to oil firing. This includes the following:

- (a) atmospheric burner with draft hood
- (b) direct vent
- (c) direct exhaust
- (d) fan assisted burner
 - forced draft
 - induced draft
 - negative or positive draft at the vent connection

boiler, modular - a steam or hot water heating assembly consisting of a grouping of individual boilers called modules, intended to be installed as a unit with no intervening stop valves. Modules may be under one jacket or may be individually jacketed. The individual modules shall be limited to a maximum input of 400,000 Btuh (117.24 kW)(gas), 3 gph (3.15 mL/s) (oil), or 115 kW (electric).

breaching - the duct used for conveying the products of combustion from the outlet of the boiler to the chimney or vent.

Btu - British Thermal Unit

burner - a device for the introduction of fuel and primary air into a furnace at the desired velocities, turbulence and concentration to establish and maintain proper ignition and combustion of the fuel.

burner, atmospheric - 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.

burner capacity: See "firing rate".

burner, power - 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.

calorific value (gas) - the total heating value of the gas in Btu/cubic foot at standard conditions of water vapor saturation, temperature of 60°F and a pressure of 30" of mercury.

calorific value (oil) - the higher heating value of the oil as fired in Btu per pound.

choke damper - a damper placed within the breaching or flue pipe for regulating the flow of gases.

combustion chamber - that portion of the firebox, which may be lined with heat resisting material, in which the initial combustion of fuel takes place.

combustion efficiency - 100% less the losses due to (1) Dry Flue Gas, (2) Incomplete Combustion, and (3) Moisture Formed by Combustion of Hydrogen.

condensate, flue - liquid formed by the condensation of moisture in the flue gases.

condensate, steam - liquid formed by the condensation of steam.

damper - a device used to control the flow of air or other gases.

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 combustion chamber, and (3) neutralize the effect of stack action of the chimney or gas vent upon the operation of the boiler.

draft loss - the pressure difference associated with the movement of flue gases through a boiler from the burner location in the firebox to the breaching connection.

draft regulator - a device for controlling the draft in the boiler.

efficiency-combustion - See "combustion efficiency".

efficiency-thermal - See "thermal efficiency".

firebox - the space provided within the boiler for combustion of the fuel.

firebox-net volume - See "net firebox volume".

firetube - a tube within a boiler having water or steam on the outside and products of combustion on the inside.

firing rate - the rated input required to develop the gross output of the boiler.

flue gas - the gaseous products of combustion in the breaching.

flue temperature - the temperature of the flue gases, before dilution.

forced draft - a method of forcing air into the combustion chamber by mechanical means to maintain a positive pressure in the firebox and breaching.

forced draft boiler-burner unit - a unit designed to operate with a positive pressure in the firebox and in the flue connection.

forced draft burner - a burner which is designed to operate with a positive pressure in the firebox and breaching and to force the products of combustion through the boiler by mechanical means.

furnace - See "firebox".

furnace volume - See "net firebox volume".

gross output - the output determined from thermal efficiency test data, in terms of Btuh, under the conditions and limitations stipulated by this Standard.

heat release rate - the heat input per cubic foot of net firebox volume, expressed in Btuh/ft³

heating value - See "calorific value".

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 hot water boiler operates at or below 160 psig water pressure and 250°F water temperature.

heating surface, primary - those surfaces exposed to flame or combustion gases on one side and steam or water on the other side. Water backed surfaces in contact with heated refractory surface may be considered primary heating surface.

heating surface, extended - metallic heat absorbing surface protruding beyond the tube, section, or boiler wall.

induced draft - a method of drawing air into the combustion chamber by mechanical means to maintain a negative pressure in the firebox.

induced draft boiler-burner unit - those designed to operate with a negative pressure in the firebox created by a fan located within the unit or in the breaching external to the unit.

instrument accuracy - the ability of an instrument to indicate or record a true value of a measured quantity.

manometer - an instrument for measuring pressures, usually consisting of a U-tube partly filled with liquid, generally water, mercury or light oil, and so constructed that the displacement of the liquid would indicate the pressure being exerted in a leg of the tube.

MBh - one thousand Btu/h.

mechanical draft - either forced draft or induced draft.

mechanical firing - other than hand firing.

modular boiler - "see boiler, modular".

natural draft boilers or boiler-burner units - those designed to operate with a negative pressure in the firebox and in the flue connection created by a chimney or the height of the unit itself, up to the draft control device.

net firebox volume - the space bounded by the walls and floor of the heat resisting material, if used, plus the space above that is bounded by the walls of the firebox and the first substantially horizontal plane of entry into the flues or between the sections of the boiler. Where no heat resisting material is used, it is the space bounded by the walls of the firebox.

net flue temperature - flue temperature minus room temperature.

oil - Light oil means No. 2 oil. Heavy oil means Nos. 4, 5, and 6 oil.

orsat - a gas analysis apparatus in which certain gaseous constituents are measured by absorption.

outdoor boiler - a boiler-burner unit with integral venting means, factory assembled, weather-proofed, and wired for use out of doors.

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.

packaged boiler - a boiler-burner unit factory assembled and wired.

room air - ambient temperature measured at mid height of the unit.

secondary air damper - an adjustable device which controls the admission of air to the gases of combustion for the purpose of aiding combustion.

spinner - a strip baffle with edges twisted into helical form.

square foot of steam radiation - the heat equivalent of 240 Btuh.

superheat - is the temperature of steam in excess of its saturation temperature.

test air temperature - is the temperature of the air for combustion being supplied to the burner from the room.

turbulator - See "baffle".

ultimate carbon dioxide (CO₂) - the maximum percentage of carbon dioxide obtainable in the flue gas under perfect combustion.

vent - the piping leading from the flue collector outlet of a forced draft boiler-burner unit or the fan outlet of a induced draft boiler to the area where flue gases are discharged. Also, the pipe connected to a gas-fired boiler to carry the products of combustion out of the building.

watertube - a tube within a boiler having the water or steam on the inside and heat supplied to the outside.

4.0 CLASSIFICATIONS

4.1 Only boilers of the following classifications are covered by this Standard.

4.1.1 Heating Medium

4.1.1.1 Steam

4.1.1.2 Water

4.1.2 Fuel

4.1.2.1 Oil

4.1.2.2 Gas

4.1.3 Trim

4.1.3.1 Boiler-burner unit

4.1.3.2 Packaged Boiler

4.1.4 Draft

4.1.4.1 Natural

4.1.4.2 Mechanical

4.1.4.2.1 Induced

4.1.4.2.2 Forced

4.1.5 Location

4.1.5.1 Indoor

4.1.5.2 Outdoor

4.1.6 Burner Type

4.1.6.1 Atmospheric

4.1.6.2 Power

5.0 TYPES OF TESTS

5.1 Thermal Efficiency Test

Shall consist of a test point conducted at $100\% \pm 2\%$ of the nameplate boiler input. The test shall yield a complete accounting of the energy input in terms of output and losses.

5.2 Combustion Efficiency Test

Shall consist of a test point conducted at $100\% \pm 2\%$ of the input to the boiler and shall yield an accounting of energy input in terms of products of combustion only.

6.0 INSTRUMENTS

6.1 Instruments which meet the minimum requirements shown in Table 1 shall be used.

Table 1: Instruments

Property Measured	Item Measured	Type	Minimum Graduation	Minimum Accuracy	Approximate Range of Readings
Temperature	Room Air	Thermometer or Thermocouple	1°F	±1°F	30 - 100°F
	Test Air	Thermometer or Thermocouple	1°F	±1°F	30 - 100°F
	Inlet Water	Thermometer or Thermocouple	0.2°F	±0.2°F	40 - 125°F
	Outlet Water	Thermometer or Thermocouple	0.2°F	±0.2°F	130 - 220°F
	Flue Gas	Thermocouple Grid	2°F	±2°F	300 - 650°F
Pressure	Atmospheric	Barometer	0.05" hg	±0.05" hg	28 - 31" hg
	Steam	Mercury Manometer	0.1"hg	±0.2" hg	0 - 5" hg
		Water Manometer	0.1" water	±0.2" water	0 - 5" water
	Fuel Oil	Bourdon Tube Gage	5 psi	±5 psi	50 - 350 psi
	Fire Box	Draft Gage	0.01" water	±0.01" water	0 - 0.5" water
	Vent	Draft Gage	0.01" water	±0.01" water	0 - 0.5" water
	Flue	Draft Gage	0.01" water	±0.01" water	0 - 0.5" water
Weight or Flow	Gas	Manometer	0.1" water	±0.1" water	0 - 10" water
	Oil	Scale, Burette or Flow Meter	0.25% of hourly rate	±0.25% of hourly rate	As Needed
	Gas	Volume Meter	0.25% of hourly rate	±0.25% of hourly rate	As Needed
	Water	Scale	0.5 lb	±0.5 lb	As Needed
	Condensate	Scale	0.5 lb	±0.5 lb	As Needed
	Separator Moisture	Scale	1 oz	±1 oz	As Needed
	Feedwater	Scale	0.5 lb	±0.5 lb	As Needed
Time	Feedwater	Flow Meter	0.25% of hourly rate	±0.25% of hourly rate	As Needed
	Test Period	Stopwatch	1 second/hr	±1 second/hr	0 - 3 hr
Gas Chemistry	Carbon Dioxide	Orsat or Meter	0.2% CO ₂	±0.1% CO ₂	0 - 15% CO ₂
	Carbon Monoxide	CO Tester or Meter	0.01% CO	±0.01% CO	0 - 0.05% CO
Gas Optics	Smoke	Smoke Spot Bacharach	1 Bacharach	±½ Bacharach	0 - 7

7.0 APPARATUS

7.1 TEST ROOM OR AREA

The test location should 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. Instruments shall be calibrated to a recognized standard at regular intervals.

7.2 FLUE CONNECTION

7.2.1 Oil and Power Gas, other than Direct Vent

A flue connection, the full size of the flue gas outlet collar, shall be used (see Figure 1). It shall include one elbow and a length of flue pipe that is at least three times the pipe diameter. All flue pipe connections shall be carefully sealed before the insulation is applied. A minimum of R-7 foil-faced insulation (R-7) suitable for the temperature shall be applied. An auxiliary choke damper may be placed in the piping downstream of the test flue pipe to develop proper draft during the test.

7.2.2 Gas-designed Boilers, other than Direct Vent

The boiler shall be connected to an uninsulated sheet-metal vent pipe the same size as the draft hood outlet, unless otherwise specified. Elbows shall be 90-degree (1.57 rad), four-piece sheet-metal elbows. The vent pipe shall have a reasonably smooth inner contour. The vent pipe shall be arranged as follows:

7.2.2.1 For Boilers with Input Ratings 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 outlet, or in the absence of a draft control device, to the flue collar. The height of the vertical section shall be 5 ft. as measured from the highest point of the flue collar or the draft control device opening. When vent gases discharge vertically, an elbow shall be attached to the outlet. (See Figure 2A)

7.2.2.2 For Boilers with Input Ratings Over 400,000 Btu/h

When the vent gases discharge horizontally, an elbow and 5 ft. of vertical vent pipe shall be attached to the draft hood or draft diverter outlet, or in the absence of a draft control device, to the flue collar. When vent gases discharge vertically, 4 ft. of vertical pipe shall be attached to the outlet. (See Figure 2B)

7.2.3 Boilers with Direct Vent

Direct vent units shall be provided with the minimum length vent configuration recommended by the manufacturer or a 5 ft. flue pipe if there are no recommendations. (See Figure 3)

7.2.4 Additional Requirements for Condensing Boilers

The flue pipe installation must not allow flue condensate formed in the flue pipe to flow back into the unit. An initial downward slope from the unit's exit, an offset with a drip leg, annular collection rings, or drain holes shall be included in the flue pipe installation without disturbing normal flue gas flow. Flue gases should not flow out of the drain with the flue condensate. Additional precautions shall be taken to facilitate uninterrupted flow of

condensate during the test. Collection-containers must be 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.

7.2.5 Additional Requirements for Outdoor Boilers

The integral venting means may have to be revised to permit connecting the test flue apparatus described above.

7.3 STEAM PIPING (Thermal Efficiency Test)

A typical set-up is shown diagrammatically in Figures 4 and 5. Risers may be taken full size from regular steam outlet tapings and combined into a header unless otherwise recommended by the manufacturer. The risers shall be connected by piping of adequate size to an effective separator in the outlet piping. 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 and the piping connecting it to the boiler shall be well insulated as no allowance can be made for the heat loss from them. Provision shall be made for a thermometer or thermocouple in the outlet piping if output due to superheat is to be claimed. Condensate can be collected in a tank and weighed, or the feedwater can be weighed.

7.4 WATER PIPING (Thermal Efficiency Test)

A typical test set-up is shown diagrammatically in Figure 6. The water outlet shall be taken from the regular boiler water outlet and carried to a swing joint above a weigh tank, or tanks, mounted on a scale, or scales. The piping shall be arranged so that the water may be collected in a tank or discarded. As an alternate, the feedwater may be pumped out of a weigh tank mounted on a scale. Provision shall be made as shown for a thermometer or thermocouple located in a tee approximately one foot from the outlet of the boiler. Piping shall be thoroughly insulated in the areas shown, since no allowance can be made for heat losses in the piping. The water inlet shall be connected to the return connection of the boiler. Provision shall be made for a thermometer or thermocouple located in a tee within one foot from the inlet of the boiler.

Recommended pipe sizes to be used for water tests are as follows:

<u>Gross Outputs</u>	<u>Pipe Sizes</u>
Up to - 400 MBh	1"
400 - 800 MBh	1-1/4"
801 -1,300 MBh	1-1/2"
1,301 - 2,400 MBh	2"
2,401 - 3,750 MBh	2-1/2"
3,751 - 7,500 MBh	3"

7.5 APPLICATION OF INSTRUMENTS (Steam and Water)

7.5.1 Flue Pyrometry

Nine parallel connected thermocouples no larger in size than 22 gauge having equal length leads shall be used for measuring the average temperature of the flue gases. As an alternate, 17 thermocouples may be used. The couples shall be properly spaced to obtain an average reading as illustrated in Figure 9. Where there is a possibility that the thermocouples could receive direct radiation from the flame, use of a radiation shield is required.

7.5.1.1 Location**7.5.1.1.1 Oil or Power Gas Burner Natural Draft or Direct Exhaust**

The grid of nine (or 17) equally spaced thermocouples shall be installed in a plane perpendicular to the axis of the vent pipe, at a distance that is at least two times the diameter of the flue pipe measured from the centerline of the boiler outlet.

7.5.1.1.2 Direct vent (without combustion air preheat)**7.5.1.1.2.1 Gas-designed boilers**

The grid of nine (or 17) equally spaced thermocouples shall be installed in a plane perpendicular to the flow of flue gas at a suitable point immediately before the discharge from the boiler. (Fig. 3b)

7.5.1.1.2.2 Oil and Power Gas Burner

The grid of nine (or 17) equally spaced couples shall be installed in a plane perpendicular to the axis of the vent pipe, 12 inches from the boiler outlet. (Fig. 3a)

7.5.1.1.3 Direct Vent with Combustion Air Preheat

The grid of nine (or 17) equally spaced thermocouples shall be installed in a plane perpendicular to the axis of the vent pipe, within 6" of the vent or air intake terminal.

7.5.1.1.4 Draft Hood

The grid of nine (or 17) equally spaced thermocouples shall be installed in a plane perpendicular to the flow of flue gas and at a suitable point immediately before the discharge from the boiler.

7.5.2 Flue Gas Sampling

All instruments in flue connection must be carefully sealed.

7.5.2.1 Oil and Power Gas

Flue gas sampling tubes should be installed downstream of the thermocouple grid, as shown in Figure 1. If an open end tube is used, it shall project into the flue 1/4 to 1/2 of the pipe diameter. If other methods of sampling are used, the sampling tube shall be placed so as to obtain an average sample.

7.5.2.2 Gas Designed Boilers

Flue gas shall be sampled at a suitable point immediately before the discharge of the boiler.

7.5.3 Draft Gauges, Oil and Power Gas

The draft gauge shall be connected to a tube located downstream of the thermocouple grid. The tube shall project into the flue 1/4 to 1/2 of the pipe diameter. A similar tube shall be used to measure the draft in the firebox. It should project into the firebox beyond the inside of the front or rear wall.

7.5.4 Smoke Meter, Oil

The smoke meter shall be connected to an open end tube located as shown in Figure 1. It shall project into the flue 1/4 to 1/2 of the pipe diameter. It may be installed in the

opening provided for the draft gauge sampling tube for the time required to obtain the smoke sample.

7.5.5 Fuel Burned

7.5.5.1 Oil

The fuel oil shall be fed to the burner from a tank of adequate size, 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 5). As an alternative, a calibrated flow meter or burette may be used.

7.5.5.2 Gas

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

7.5.6 Chimneys

Tests for natural draft performance may be conducted with either natural or induced draft with means provided for controlling draft.