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Document Name: HI BTS-2000: Method to Determine Efficiency of Commercial Space Heating Boilers

CFR Section(s): 10 CFR 431.86

Standards Body: Hydronics Institute

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

BTS-2000

TESTING STANDARD

Method to Determine

EFFICIENCY OF COMMERCIAL SPACE HEATING BOILERS

HYDRONICS INSTITUTE DIVISION OF AHRI

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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.

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TABLE OF CONTENTS

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, twisters 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/ft^3

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 (CO_2) **-** 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% ± 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% ± 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 Water Manometer	0.1"hg 0.1" water	±0.2" hg ±0.2" water	0 - 5" hg 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
	Gas	Manometer	0.1" water	±0.1" water	0 - 10" water
Weight or Flow	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
	Feedwater	Flow Meter	0.25% of hourly rate	±0.25% of hourly rate	As Needed
Time	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 tappings 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:

Gross Outputs	Pipe Sizes
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.

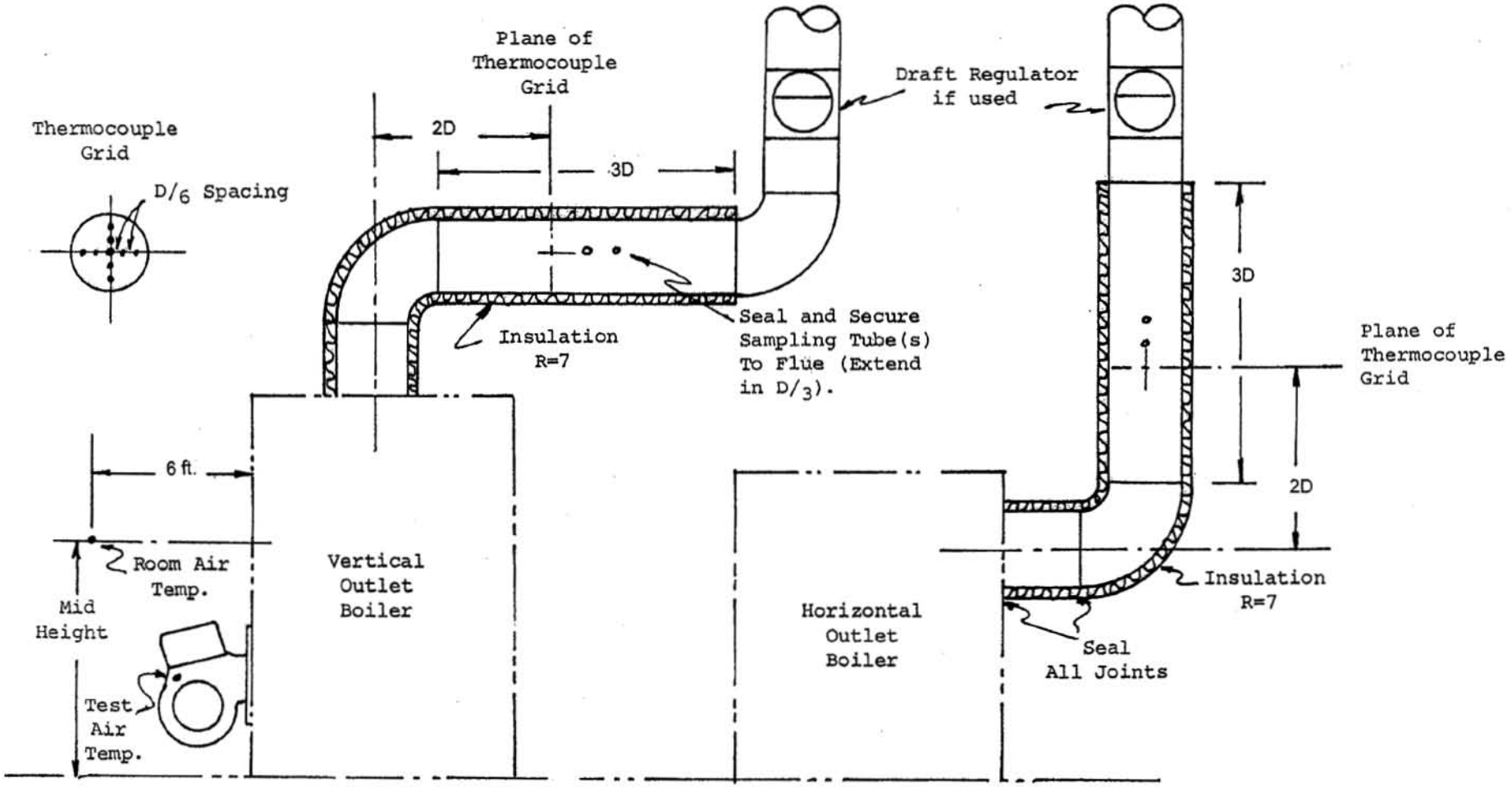
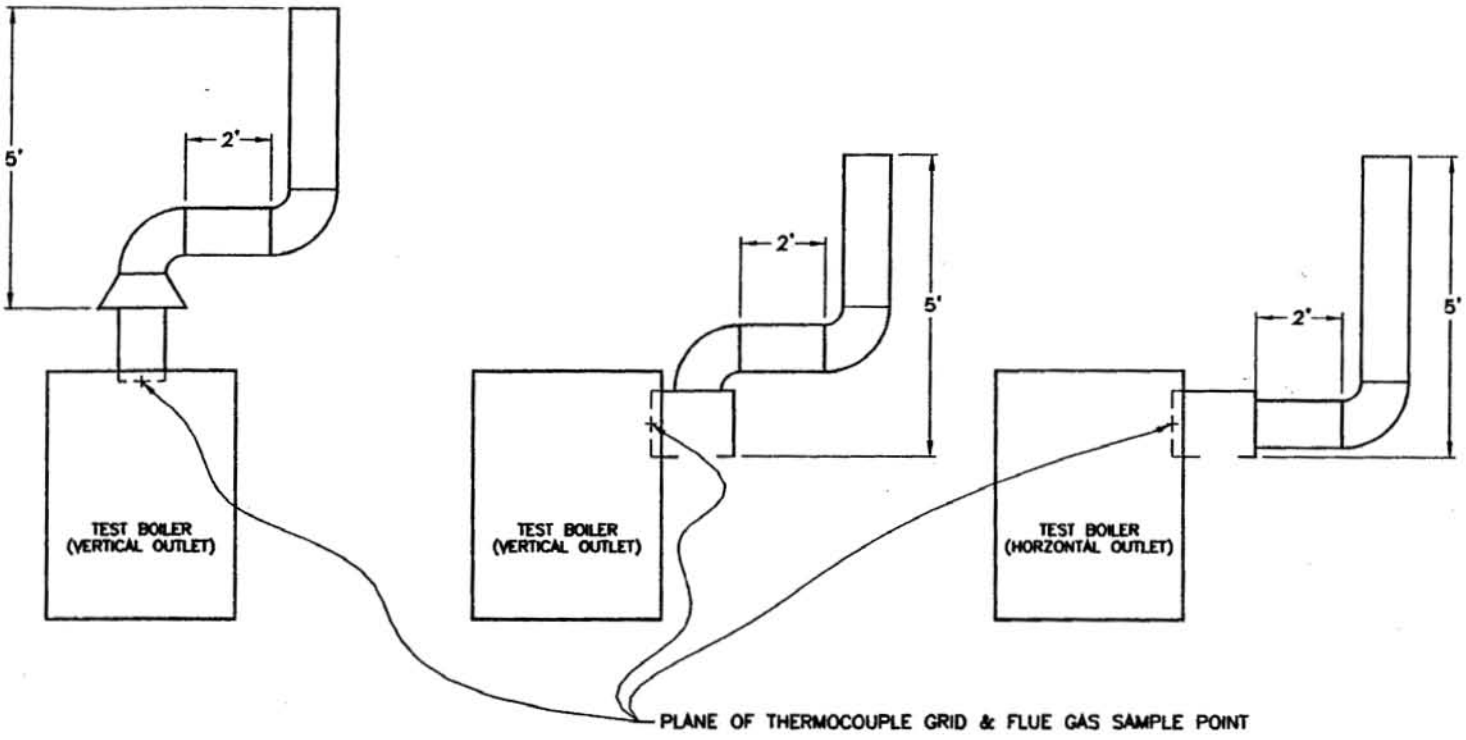
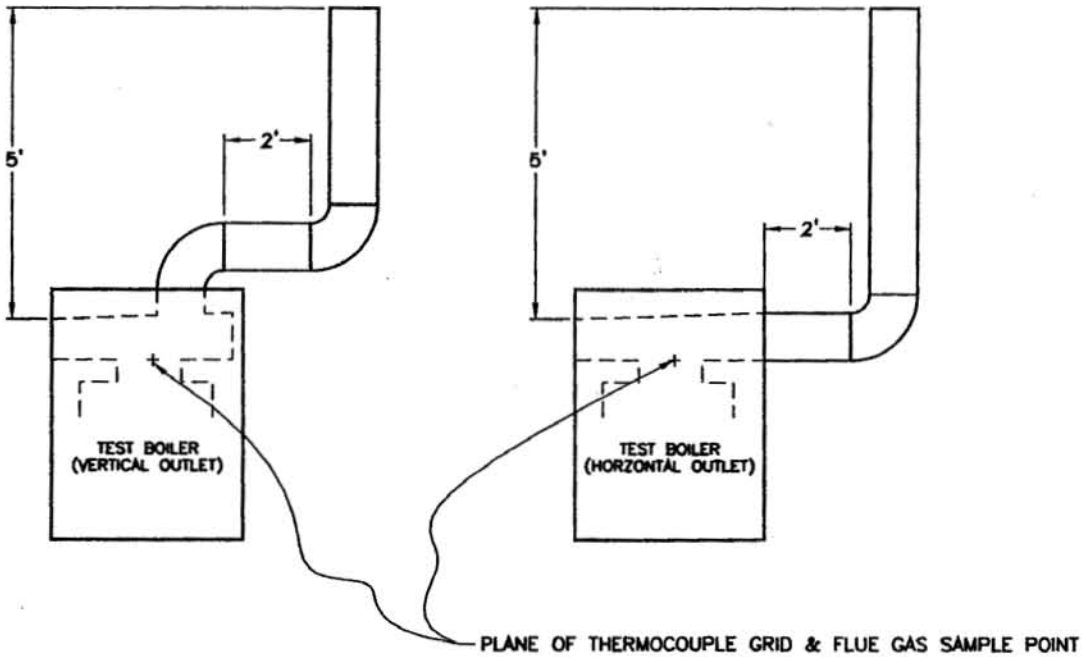


Figure 1 – TEST FLUE FOR OIL OR POWER GAS FIRING

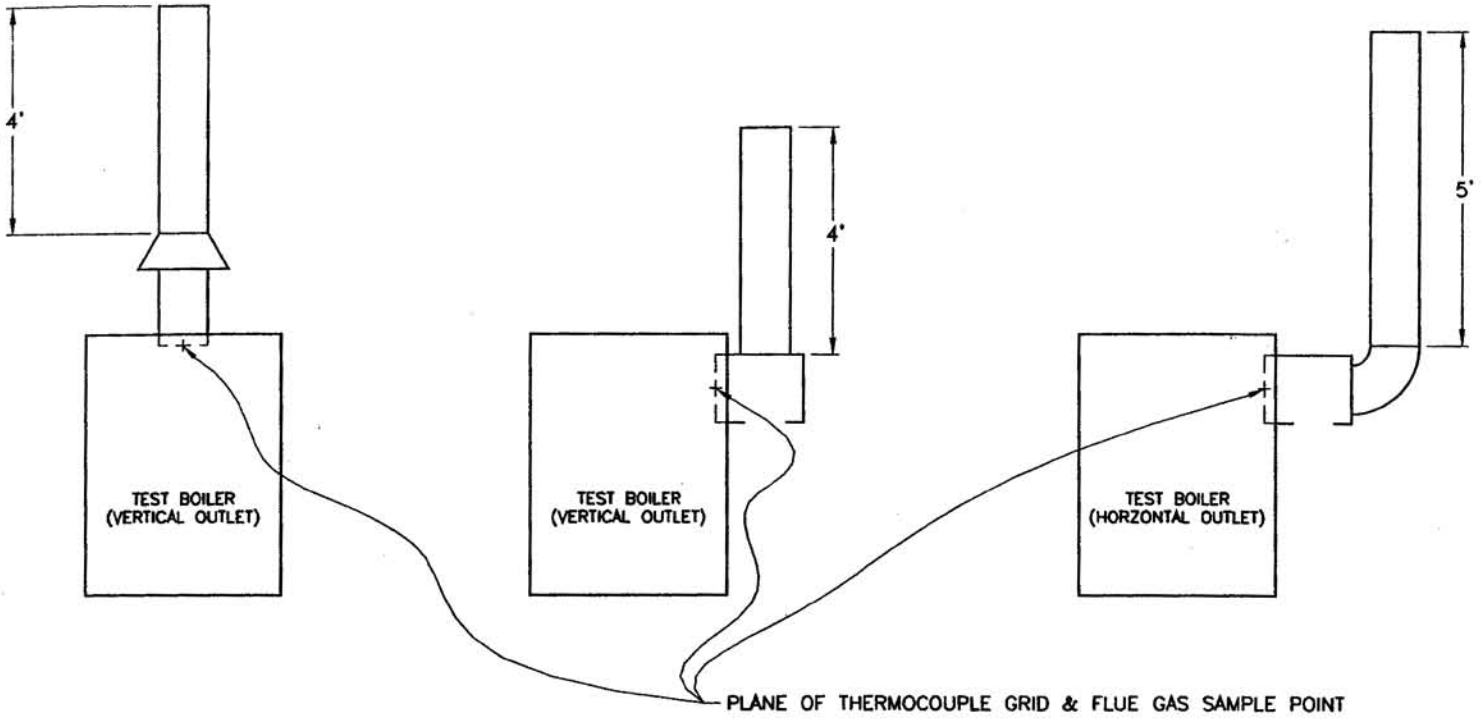


EXTERNAL DRAFT HOOD



BUILT-IN DRAFT HOOD

Figure 2A – TEST VENTS FOR NATURAL DRAFT ATMOSPHERIC GAS-FIRED BOILERS WITH INPUT RATINGS OF 400,000 Btuh OR LESS



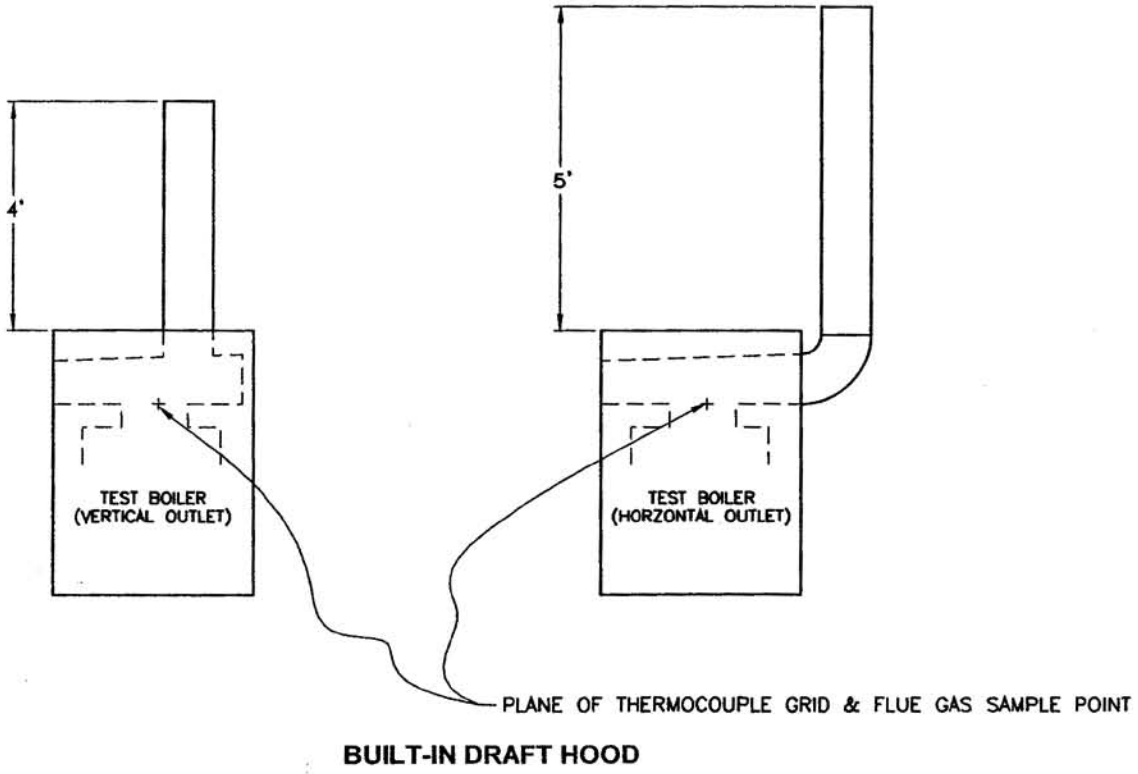


Figure 2B – TEST VENTS FOR NATURAL DRAFT ATMOSPHERIC GAS-FIRED BOILERS WITH INPUT RATINGS OVER 400,000 Btuh

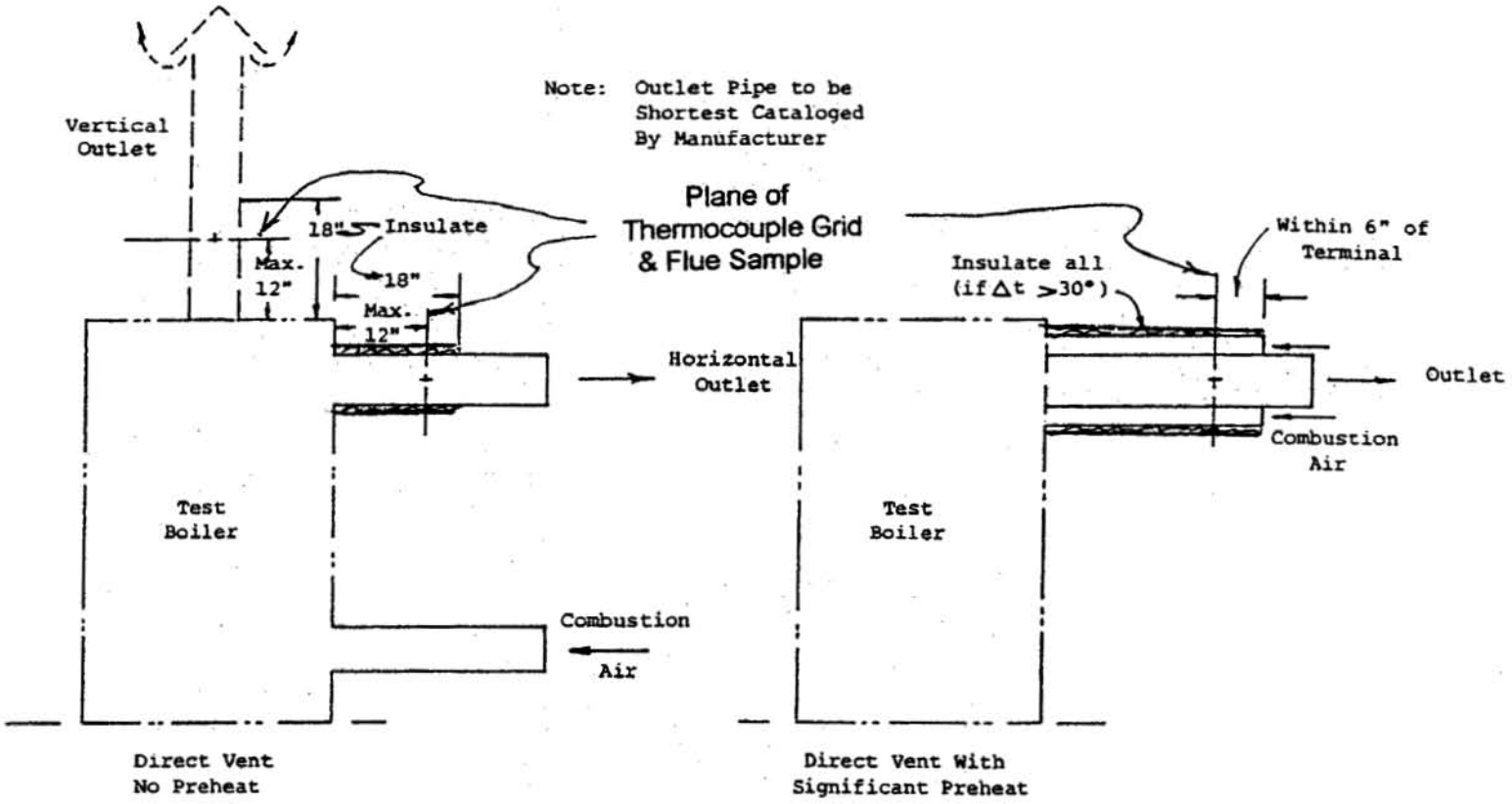


Figure 3a – TEST FLUES FOR DIRECT VENT UNITS

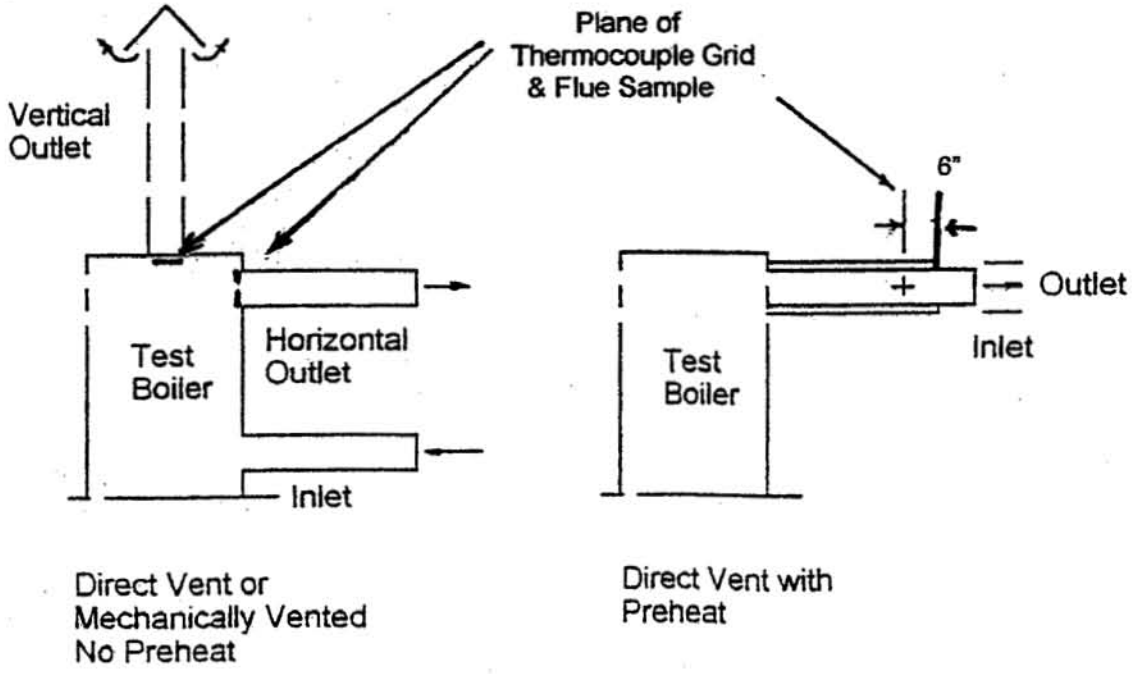


Figure 3b – TEST VENTS FOR DIRECT VENT & MECHANICAL VENTED BOILERS

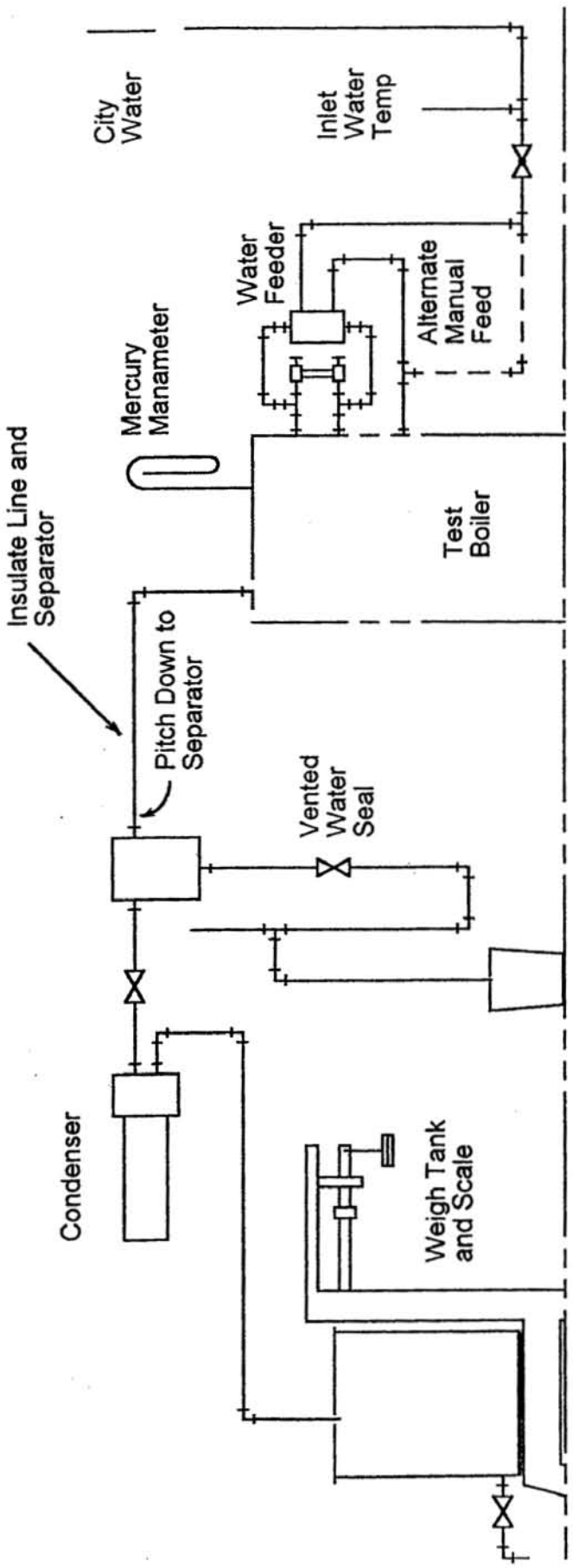


Figure 4A – SUGGESTED PIPING ARRANGEMENT FOR STEAM BOILERS
-CONDENSATE MEASUREMENT-

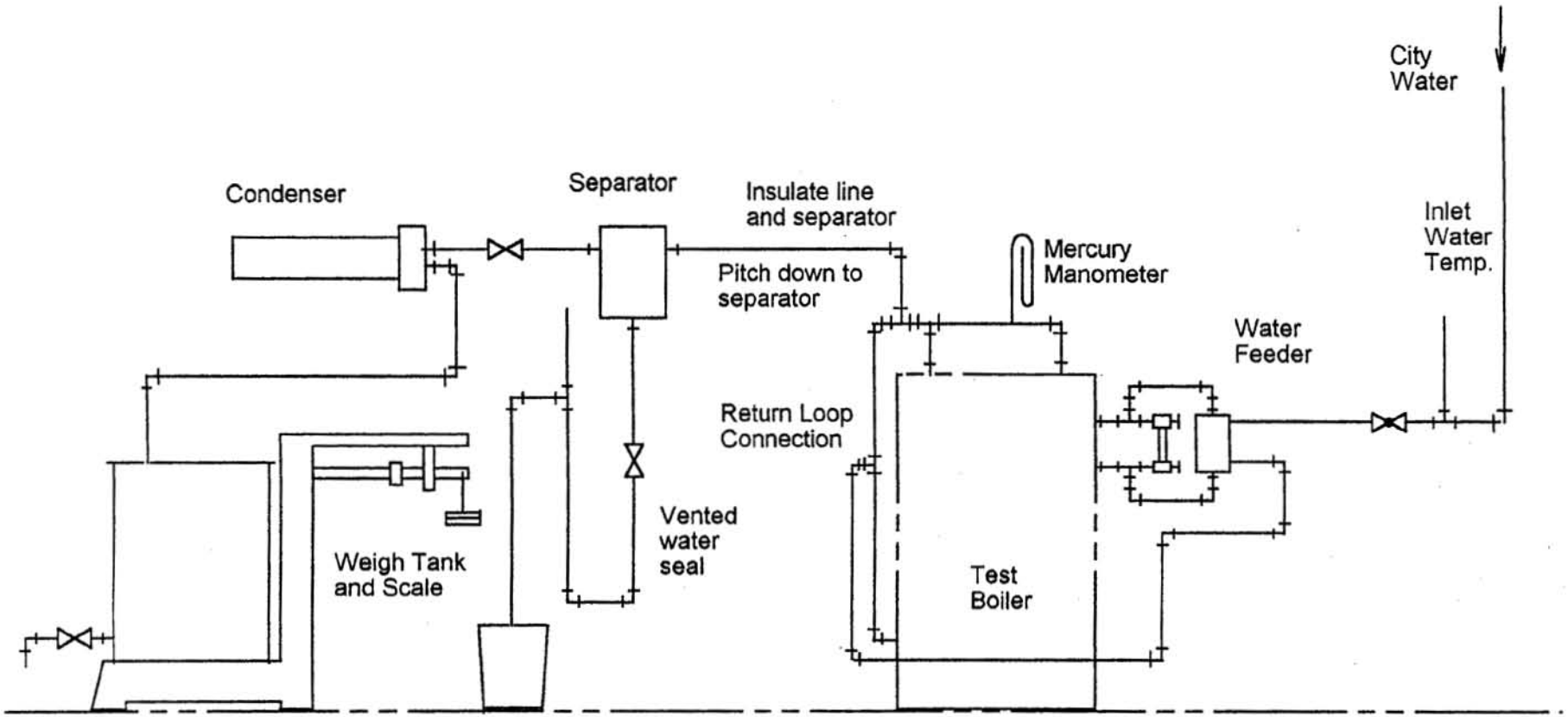


Figure 4B – ALTERNATE ARRANGEMENT FOR STEAM BOILERS WITH RETURN LOOP CONNECTION
-CONDENSATE MEASUREMENT-

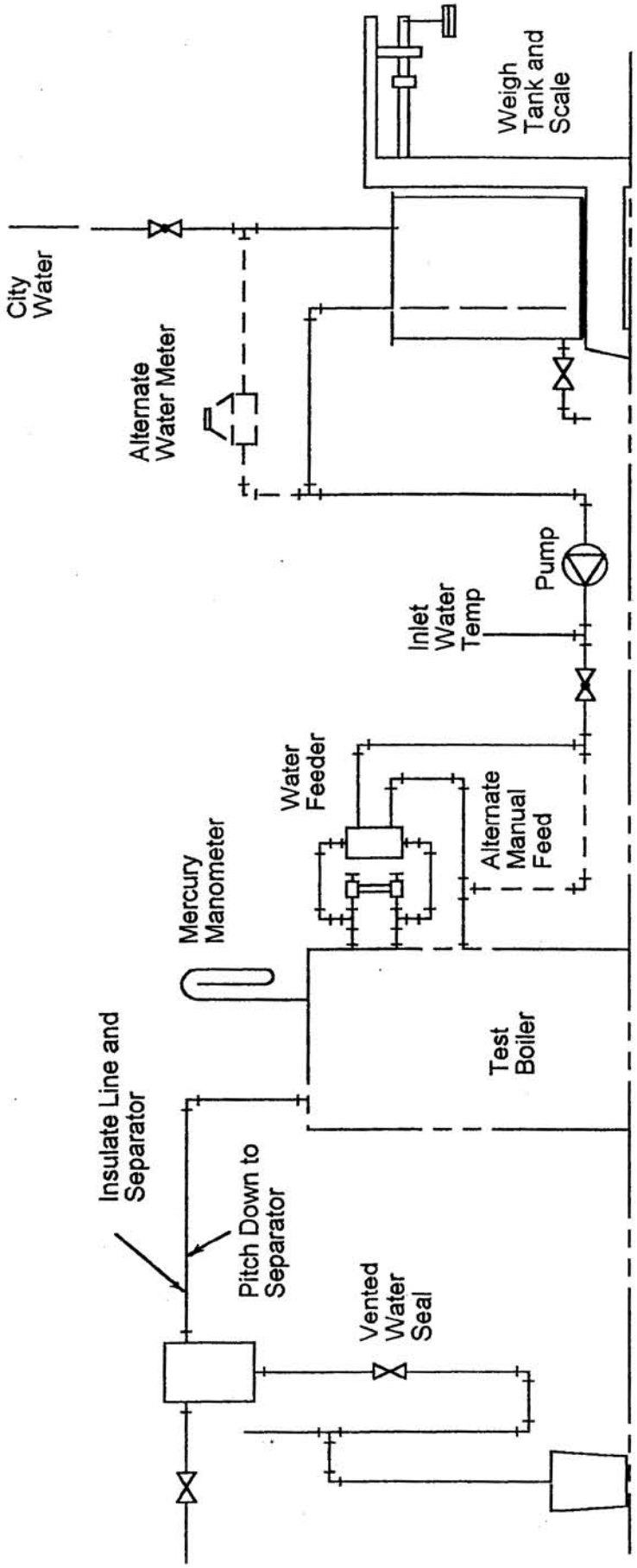


Figure 5A – SUGGESTED PIPING ARRANGEMENT FOR STEAM BOILERS FEEDWATER MEASUREMENT

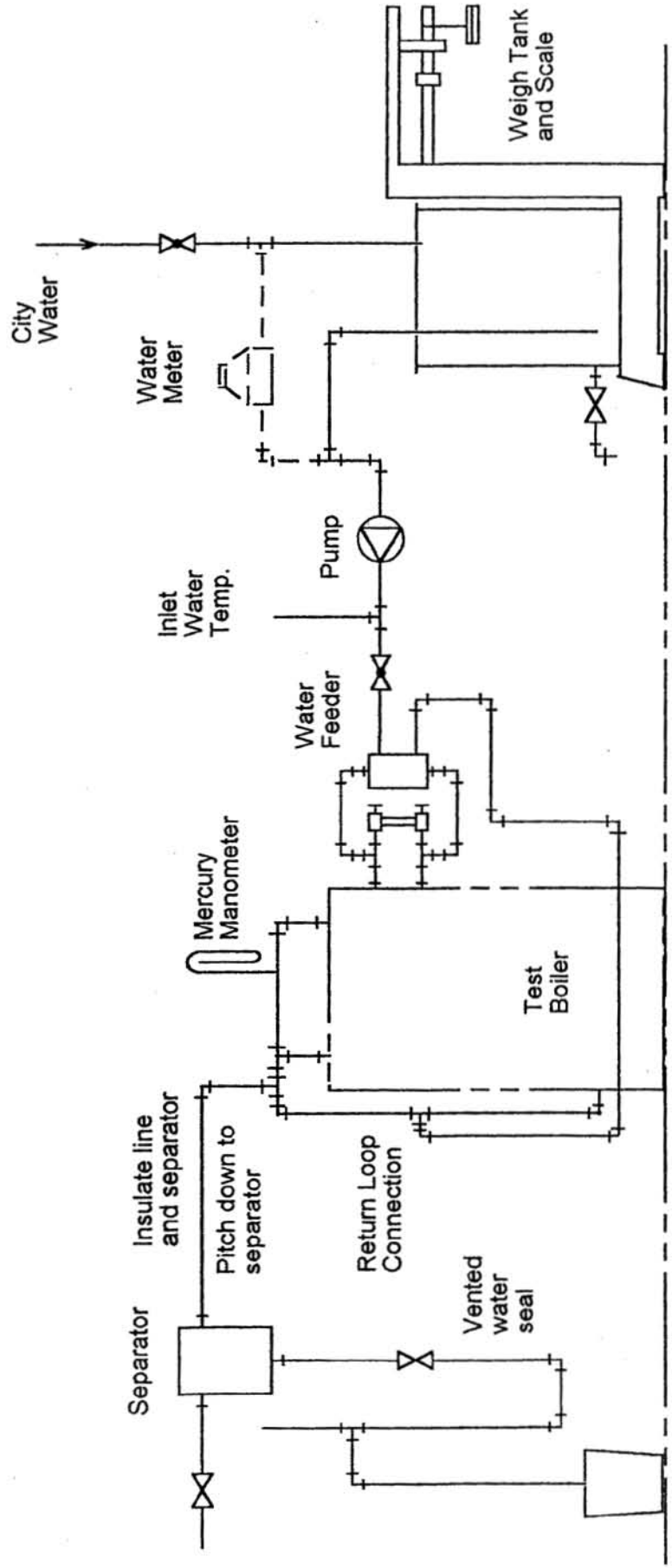


Figure 5B – ALTERNATE ARRANGEMENT FOR STEAM BOILERS WITH RETURN LOOP CONNECTION

-FEEDWATER MEASUREMENT-

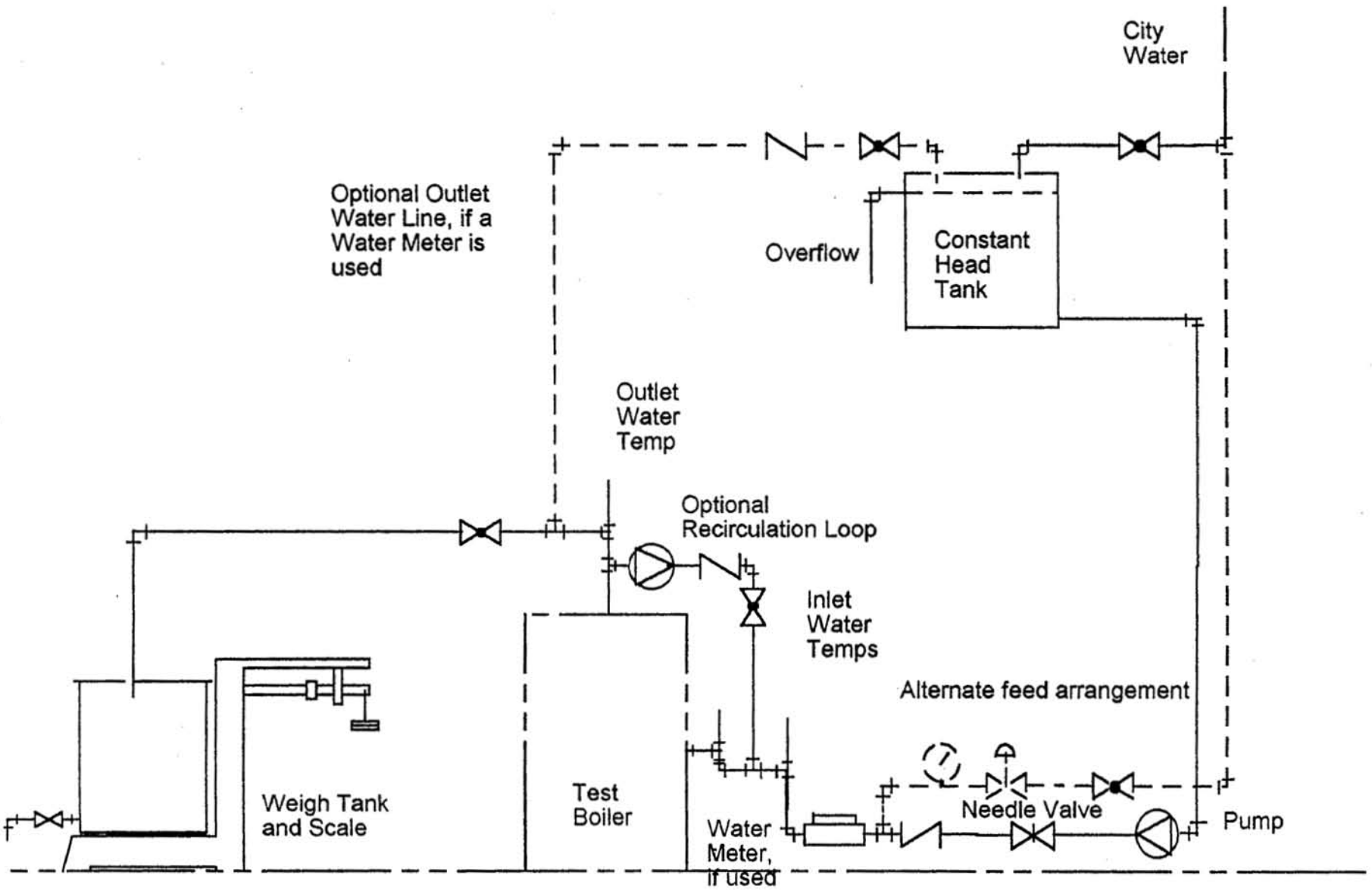


Figure 6 – SUGGESTED PIPING ARRANGEMENT FOR HOT WATER BOILERS

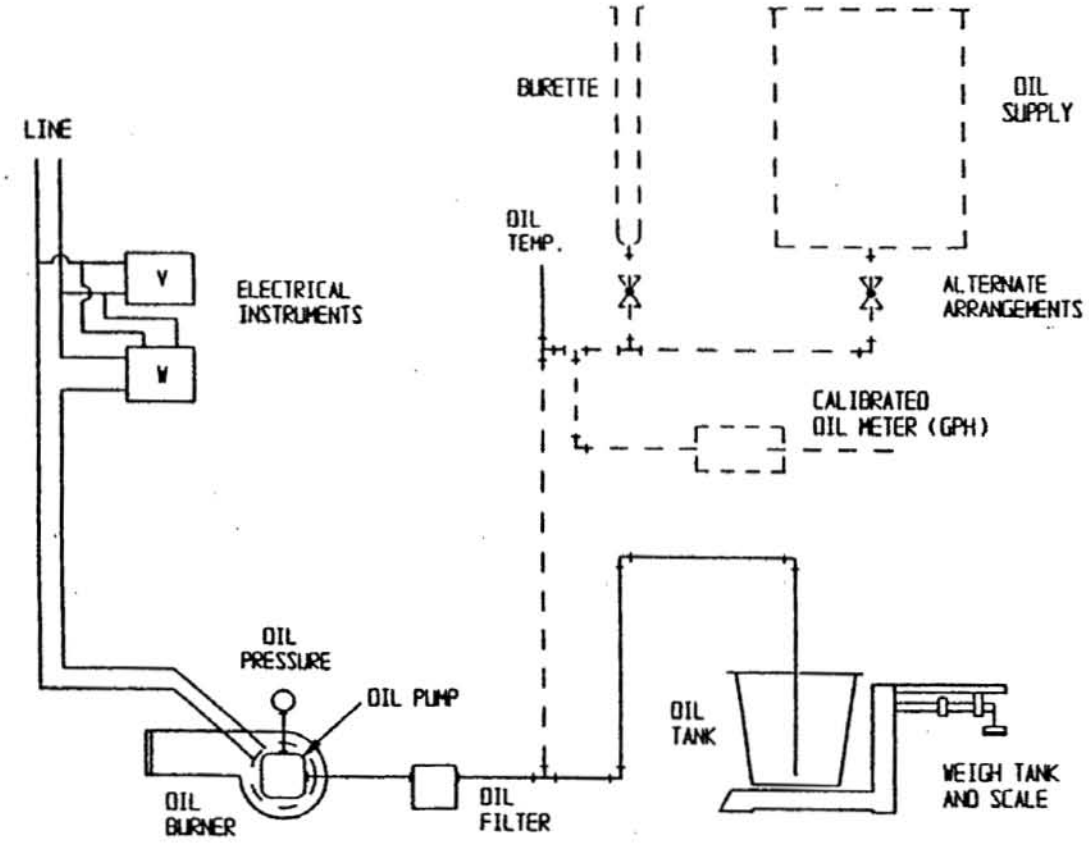


Figure 7 – SUGGESTED OIL BURNER TEST SETUP

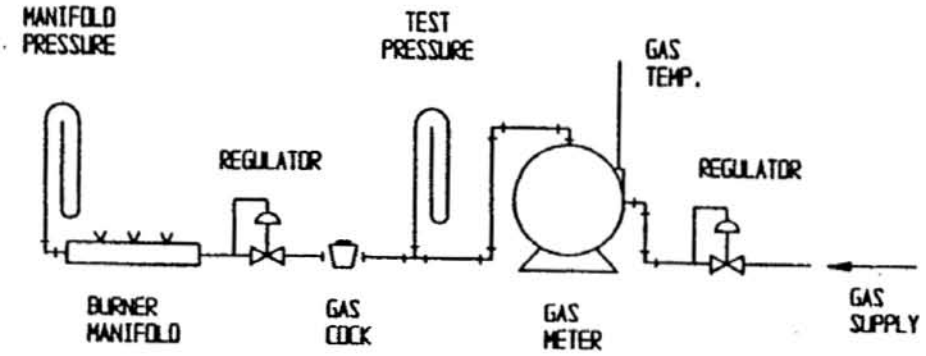
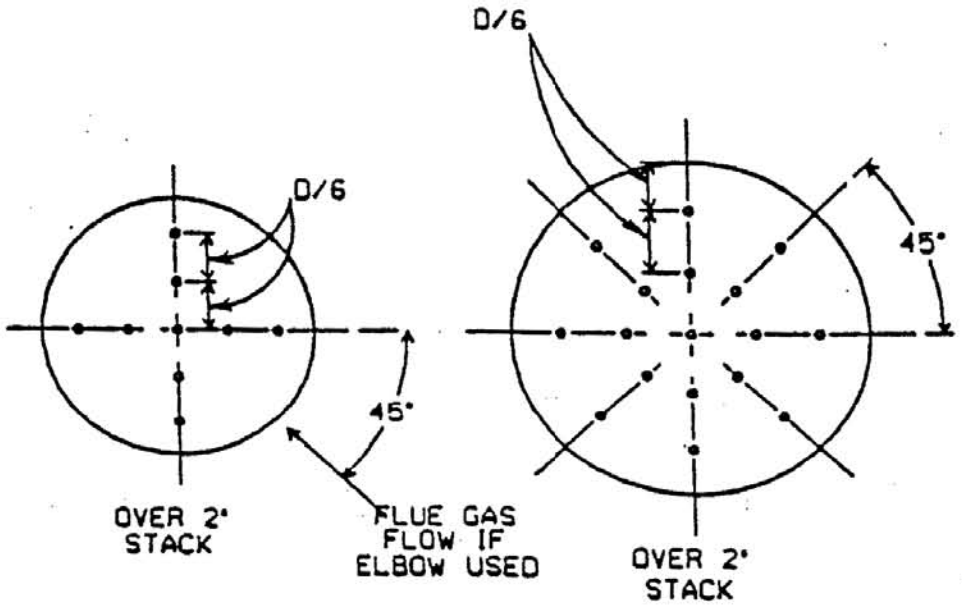
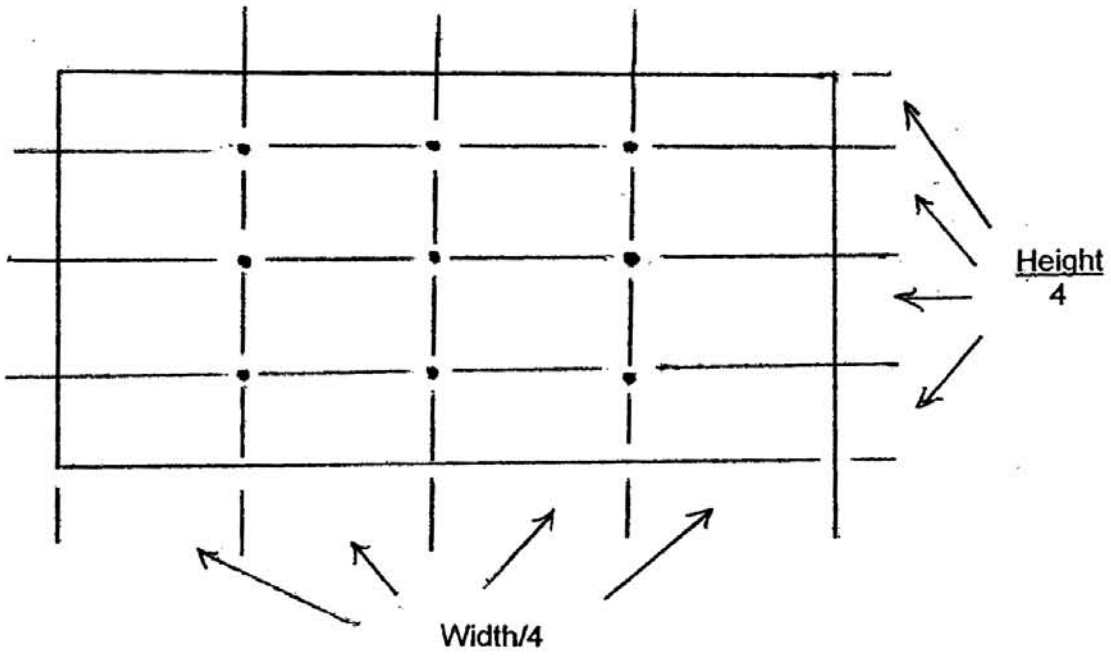


Figure 8 – SUGGESTED ATMOSPHERIC GAS BURNER TEST SETUP

Figure 9 – THERMOCOUPLE GRID



THERMOCOUPLE GRID & ARRANGEMENTS



7.6 APPLICATION OF ADDITIONAL INSTRUMENTS (Steam)

7.6.1 Steam Pressure

A mercury manometer or water manometer of sufficient size, shall be connected to the steam space of the boiler.

7.6.2 Feed Water

The piping connecting the feedwater supply to the return tapping of the boiler shall be of adequate size and shall contain a valve approximately two feet from the boiler. A needle valve is recommended for this purpose, or an automatic feedwater regulator may be incorporated in the system. A thermometer or thermocouple shall be located approximately one foot ahead of the inlet side of the valve. (See Figures 4 and 5), unless conduction or convection affects the temperature, in which case the thermometer can be moved far enough away to prevent this problem.

7.7 APPLICATION OF ADDITIONAL INSTRUMENTS (Water)

7.7.1 Water Temperatures

The inlet and outlet water temperatures shall be measured by thermometers or thermocouples located within one foot from the boiler.

7.7.2 Water Measurement

7.7.2.1 The outlet water may be collected in a covered tank and weighed.

7.7.2.2 The feedwater may be pumped from a weigh tank.

7.7.2.3 A calibrated water meter may be used.

8.0 TEST CONDITIONS

8.1 TEST UNIT

8.1.1 A standard boiler, or a prototype boiler, shall be used, erected in accordance with the manufacturer's directions. All openings shall be sealed as specified by the manufacturer to prevent the leakage of air.

8.1.2 Insulated Jacket

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

8.1.3 Cleaning of Boiler

The internal wet surfaces of the boiler shall be clean. The heating surface of the boiler may be cleaned before each test.

8.1.4 Tests for Determining Gross Output

8.1.4.1 Steam only boilers, or steam and water boilers, shall be tested as steam boilers. In addition, the water version of a steam and water boiler may be tested as a water boiler.

8.1.4.2 Water only boilers shall be tested as water boilers.

8.1.4.3 If a boiler is to have more than one input or output rating, separate tests are required.

8.2 FUEL

8.2.1 Oil

The fuel used shall be No. 2 (light) fuel oil. For boilers with firing rates in excess of 5 gph, rating tests may be made with No. 4, 5 or 6 (heavy) fuel oil. All fuel oil shall comply with ASTM D396-90A Specifications for Fuel Oils. No. 2 fuel oil shall be supplied at room temperature. Heavy oil shall be supplied at the temperature specified by the manufacturer.

8.2.2 Fuel Oil Analysis

A representative sample of the fuel oil of approximately one quart shall be taken and analyzed to an accuracy of ±1% for its heat value, hydrogen, carbon, pounds per gallon, and API gravity, according to the methods specified by ASTM D396-90A Specifications for Fuel Oils.

8.2.3 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 calorific value.

8.3 SELECTION OF BURNERS

Boilers for use with a burner of a given draft type (natural, forced, induced draft) shall be tested with a burner of this type. The burner shall be installed in accordance with the manufacturer's directions.

8.4 TEST CONDITIONS - STEAM OR WATER

8.4.1 Draft

8.4.1.1 Natural Draft

8.4.1.1.1 Light Oil or Power Gas
The draft in the firebox shall be maintained at the manufacturer's specification with a maximum variation during the test of ± 0.01 inches of water.

8.4.1.1.2 Heavy Oil or Power Gas
The draft in the firebox shall be adjusted to induce the admission of the necessary secondary air and shall be maintained at specified condition.

This may be done with the secondary air damper in a wide open position.

8.4.1.2 Forced Draft

8.4.1.2.1 Light Oil, Heavy Oil or Power Gas - The pressure in the flue connection shall be maintained at the manufacturer's specified condition, with a maximum variation of ± 0.02 inches of water.

8.4.1.3 Atmospheric Gas
The draft shall be as established by a 4-ft. or 5-ft. stack attached to the draft hood outlet, as specified in 7.2.2.1 and 7.2.2.2. If the manufacturer provides a dedicated venting arrangement, the boiler shall be tested with the arrangement having the least draft loss.

8.4.1.4 Outdoor Boiler
Pressure in the stack connection shall be maintained at 0.00 (+ 0.02, - 0.00) inches of water, unless the manufacturer requests a higher pressure. This higher pressure shall then be determined in a preliminary test with the standard venting means in place. All tests will then be conducted at the higher pressure ± .02 inches of water.

8.4.1.4.1 Outdoor Boiler Venting Systems
A gas-fired boiler for outdoor installation with a venting system provided as part of the boiler must be tested with the venting system in place.

8.4.2 Flue Gas Temperatures

8.4.2.1 Light Oil or Gas
The flue gas temperature during the test shall not vary more than a total of 2% of the flue gas temperature at the start of the test.

8.4.2.2 Heavy Oil
The flue gas temperature during the test shall not vary more than a total of 3% of the flue gas temperature at the start of the test.

8.4.2.3 Gas-Designed Boilers

8.4.2.3.1 Atmospheric Gas with Draft Hood
The flue gas temperature during the test shall not vary more than a total of 2% of the flue gas temperature at the start of the test.

8.4.2.3.2 Direct Vent, Direct Exhaust and Fan Assisted Boilers
The flue gas temperature during the test shall not vary more than a total of 2% of the flue gas temperature at the start of the test.

8.4.3 Air Temperature

The Test Air Temperature, measured at the burner inlet, shall be within ± 5°F of the room ambient temperature. The room ambient temperature shall be measured within 6 ft. of the front of the unit at mid height.

8.4.4 CO_2 In Flue Gas

The oil or power gas burner shall be adjusted to within ± 0.1% of the CO_2 specified by the manufacturer.

8.4.5 Smoke

The smoke readings shall not exceed #1 for light oil or #4 for heavy oil during any test.

8.4.6 CO in Flue Gas

The burner shall not produce CO to exceed .04% (air free basis), for natural gas or propane fired units.

8.5 ADDITIONAL TEST REQUIREMENTS FOR WATER

8.5.1 Water Temperatures

8.5.1.1 Non-Condensing Boilers
The inlet temperature shall be 35°F to 80°F, and the outlet temperature shall be 180°F ± 2°F. A higher outlet water temperature may be used when specified by a manufacturer.

8.5.1.1.1 For tubular boilers that require a greater flow rate to prevent boiling, a recirculating line can be installed as shown in Figure 6. The temperature rise through the boiler itself shall not be less than 20°F. The temperature rise from feedwater inlet to outlet and the outlet water temperature shall meet the requirements of 8.5.1.

8.5.1.2 Condensing Boilers
For condensing boilers, the outlet temperature shall be 180°F ± 2°F and the inlet temperature shall be 80°F ± 5°F at all times during the test.

8.5.2 Water Measurement

The water shall be weighed, and recorded at regular intervals during the test. A calibrated water meter may be used, but it shall be calibrated immediately prior to starting the test or series of tests. The difference between the actual flow rate and the meter reading shall not be greater than 3%.

8.6 ADDITIONAL TEST REQUIREMENTS FOR STEAM

8.6.1 Steam Pressure

Tests may be made at atmospheric pressure or at pressure not exceeding 2 psi gauge. Pressure may be developed by throttling with a valve beyond the separator.

8.6.2 Output

8.6.2.1 The output of boilers may be determined by condensing the steam and weighing the condensate, or by weighing feedwater.

8.6.2.2 The condensate or the feedwater shall be weighed and recorded at regular intervals during the test. The use of two scales is permissible. The condensate and water from the separator shall be cooled or covered effectively to prevent re-evaporation.

8.6.2.3 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.

8.6.2.4 A calibrated water meter may be used, but it shall be calibrated immediately prior to starting the test or series of tests. The difference between the actual flow and the meter reading shall not be greater than 3%.

8.6.3 Moisture in Steam

The moisture in the steam shall not exceed 2% of the water fed to the boiler during the test.

9.0 TEST PROCEDURE

9.1 THERMAL EFFICIENCY TEST

A test shall be conducted at 100% ± 2% of the manufacturer's nameplate input to the boiler. The test of a boiler with an oil or power gas burner shall be conducted at the same percentage of CO_2 in the flue gases and draft recommended by the manufacturer. This test shall be conducted with oil as the fuel, unless the boiler is only to be rated with gas.

9.1.1 Steam Test

9.1.1.1 Warm-Up Period

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

9.1.1.1.2 The burner shall be adjusted to the desired firing rate. Oil or power gas burners shall be adjusted to produce the required draft and CO_2 as specified by the manufacturer.

9.1.1.1.3 Tests may be made at atmospheric pressure or a steam pressure not exceeding 2 pounds gauge. Pressure may 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.

9.1.1.1.4 Readings (Recording of Observations) may be started as soon as steaming occurs. Once started, readings shall continue uninterrupted at 15 minute intervals.

9.1.1.1.5 To start, the fuel scale shall be balanced, or the gas or oil meter read, and measurement of evaporation, or feedwater (by scale or meter) shall be started. The water line, as indicated by the gauge glass, shall be maintained throughout the testing period at the level catalogued by the manufacturer, ± 1 ".

9.1.1.1.6 A state of equilibrium shall have been reached when consistent readings are obtained during a 30 minute period.

9.1.1.2 Test Period

9.1.1.2.1 The test period shall start when a state of equilibrium has been reached, and the last reading of the warm-up period plus a separator water weight shall be the first reading of the test period. No further burner adjustment shall be made.

9.1.1.2.2 Test conditions as specified in Section 8 shall be maintained throughout the test period and shall be observed and recorded at each 15 minute interval as specified in Section 10.

9.1.1.2.3 The test period shall be at least one hour if the condensate is measured or two hours if feedwater is measured and shall end with a regularly scheduled 15 minute reading plus a separator water weight.

When feedwater is measured, the water line at the end of the test shall be within ± 1/4" of the starting level.

9.1.2 Water Test

9.1.2.1 Warm-Up Period

9.1.2.1.1 With all required test apparatus properly connected, and with the boiler and piping filled with water such that water flows through the system, the burner shall be started and the system warmed up until the outlet water temperature approaches 180°F.

9.1.2.1.2 The burner shall be adjusted to the desired firing rate. Oil or power gas burners shall be adjusted to produce the required draft and CO_2 as specified by the manufacturer.

9.1.2.1.3 The water flow rate shall be adjusted until the inlet water temperature is within 35°F to 80°F while maintaining the outlet water temperature at 180°F ± 2°F.

9.1.2.1.4 For condensing boilers the outlet temperature shall be 180°F ± 2°F and the inlet temperature shall be 80°F ± 5°F at all times during the test.

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

9.1.2.1.6 To start, the water and fuel scales shall be balanced, or the gas, oil, or water meter read, and measurement of flows shall be started.

9.1.2.1.7 A state of equilibrium shall have been reached when consistent readings are obtained during a 30 minute period.

9.1.2.2 Test Period

9.1.2.2.1 The test period shall start when a state of equilibrium has been reached, and the last reading of the warm-up period shall be the first reading of the test period. No further burner adjustment shall be made.

9.1.2.2.2 Test conditions which are specified in Section 8 shall be maintained throughout the test period, and shall be observed and recorded at each 15 minute interval as specified in Section 10.

9.1.2.2.3 The test period shall be at least two hours and shall end with a regularly scheduled 15 minute reading.

9.2 COMBUSTION EFFICIENCY TEST

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

9.2.2 The boiler shall be fired until equilibrium has been established as indicated by three consecutive sets of consistent readings at 15 minute intervals. For condensing boilers condensate shall be collected for the 30 minute period. The data shall be recorded as specified in Section 10.

10.0 DATA TO BE RECORDED

10.1 THERMAL EFFICIENCY

10.1.1 For steam or water tests the following items shall be recorded on Form 715 before the start of test:

- Date of Test
- Manufacturer
- Boiler Model Number
- Name of Person Conducting Test
- Barometric Pressure (steam & natural gas only)
- Gas manifold pressure
- Gas line pressure at meter
- Burner Model Number & Manufacturer
- Nozzle description and oil pressure
- Oil Analysis - H, C, API Gravity, lb./gal. and Btu/lb.
- Gas temperature
- Gas Btu/ ft^3
- Combustion Chamber Size
- Combustion Chamber Material

10.1.2 For steam tests the following data shall be recorded on Form 715 at 15 minute intervals:

- Time, Minutes/seconds
- Separator water weight, lb. (start and end only)
- Steam Pressure, " Hg.
- Steam Temperature, °F (if used)
- Flue Gas Temperature, °F
- Draft in Firebox, In. Water
- Smoke Reading, Bacharach Number (oil)
- Room Air Temperature (start and end only)
- Condensate collected, or water fed, lb.
- Fuel Weight or volume, lb. (oil) ft^3 (gas)
- Inlet Water Temperature, °F
- Test Air Temperature, °F
- Draft in Smoke Pipe, In. Water
- Flue Gas CO_2, %
- Flue Gas CO (gas)

10.1.3 For water tests the following data shall be recorded on Form 715 at 15 minute intervals:

- Time, Minutes
- Fuel Weight or volume, lb. (oil) ft^3 (gas)
- Flue Gas Temperature, °F
- Draft in Firebox, In. Water
- Flue Gas Smoke Reading, Bacharach
- Test Air Temperature
- Water fed lb.
- Outlet Water Temperature, °F
- Inlet Water Temperature, °F
- Draft in Smoke Pipe, In. Water
- Flue Gas CO_2, %
- Flue Gas CO (gas)
- Room Air Temperature (start and end only)

10.1.4 For condensing boiler water tests the following additional data shall be recorded at 30 minute intervals:

- Flue Condensate Weight, lb.

10.2 COMBUSTION EFFICIENCY TEST

10.2.1 For steam or water tests the following data shall be recorded before start of test:

- Date of Test
- Manufacturer
- Boiler Model Number
- Burner Model Number & Manufacturer
- Nozzle Description & Oil Pressure
- Name of Person Conducting Test
- Barometric Pressure (steam & natural gas only)
- Oil Analysis – H, C, API Gravity, lb/gal & Btu/lb
- Gas Btu/ ft^3
- Gas Line Pressure and Temperature

10.2.2 For steam or water tests the following data shall be recorded on Form 715 at 15 minute intervals:

- Time, Minutes/Seconds
- Boiler Outlet Water Temperature, °F, or Steam Pressure, "Hg.
- Test Air Temperature, °F
- Draft in Smoke Pipe, In. Water (oil & power gas)
- Flue Gas Smoke Reading, Bacharach Number (oil)
- Flue Gas CO, % (gas) (start and end only)
- Room Air Temperature
- Fuel weight or volume lb.(oil), or ft^3(gas)
- Boiler Room Temperature, °F
- Flue Gas Temperature, °F
- Draft in Firebox, In. Water (oil & power gas)
- Flue Gas CO_2, %
- Flue Condensate Weight, lb. (condensing)

10.2.3 For condensing water boilers, the following data shall be recorded for the 30 minute period:

Flue condensate weight, lb.

10.2.4 Final test calculations shall be recorded on Form 721 and compared with the original test data.

TEST LOG SHEET

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

Manufacturer	
Boiler Model No.	
Test No. & Date	
Test Conducted by	
Oil — Nozzle Size	
Oil — Pressure	
Burner OEM and Number	
Barometer	
Gas — Pressure at Meter	
Gas — Temperature at Meter	
Combustion Chamber — Size, L x W x H	
Combustion Chamber — Material	

06.07 **Hydronics Institute Division of GAMA** Form 721

GAS or OIL-FIRED HEATING BOILER TEST REPORT SHEET

Company Name

Boiler Model Number

Cast Iron ☐ Steel ☐ Copper ☐ | Outdoor ☐ | Natural Draft ☐ Forced Draft ☐ Atmospheric ☐

Burner (OEM, Name, Number, Type)

Fuel Oil No. Calorific Value Btu/Lb. Lb/Gal.

Carbon % hydrogen % A.P.I. Gravity at °F

Gas Calorific Value Btu/Lb.

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	Lb./Sq. In.		
INPUT	9. Firing Rate, Test	G.P.H.		
	10. Total Fuel Burned	Cu. Ft. or Lb.		
	11. Total Heat Input	Btu		
COMBUSTION	12. Carbon Dioxide (CO_2)	%		
	13. Oxygen (O_2) – Oil	%		
	14. Carbon Monoxide – Gas	%		
	15. Flue Gas Temperature	°F		
	16. Test Air Temperature	°F		
	17. Net Flue Gas Temperature	°F		
DRAFT	18. In Flue Pipe	In. Water		
	19. Overfire	In. Water		
	20. Draft Loss	In. Water		
LOSSES	21. In Dry Flue Gases	%		
	22. Moisture in Flue Gases	%		
	23. Combustion Loss	%		
	24. Radiation and Unaccounted For	%		
STEAM AND WATER	25. Feedwater Temperature	°F		
	26. Steam or Outlet Water Temperature (Measured)	°F		
	27. Water Temperature Rise (Measured)	°F		
	28. Equivalent Steam Temp. *	°F		
	29. Latent Heat *	Btu/Lb.		
	30. Moisture in Steam *	%		
	31. Total Condensation or Water Heated	Lb.		
	32. Water from Separator *	Lb.		
	33. Total Latent Heat *	Btu		
	34. Total Heat in Liquid *	Btu		
OUTPUT	35. Total Output	Btu		
	36. Combustion Efficiency	%		
	37. Overall Efficiency	%		
	38. Output Rate	Btu/Hr.		
	39. Outdoor Boiler-Overall Efficiency	%		
	40. Outdoor Boiler-Output Rate	Btu/Hr.		

41. Heat Release Rate at Rated Input Btu/Cu. Ft. | Net Firebox Volume Cu. Ft.

Laboratory Name | Test Conducted by

* Steam test only

11.0 CALCULATION OF RESULTS

11.1 THERMAL EFFICIENCY TEST

The following items shall be calculated and recorded on an appropriate form:

11.1.1 Barometric Pressure, P_B, in inHg. Required for steam tests. Correct mercury readings for temperature and latitude. It is not necessary to correct aneroid readings.

11.1.2 Steam Pressure (absolute), P_{SAT}, in inHg

$$P_{SAT} = P_B + P_S$$

where:

P_B = barometric pressure, inHg
P_S = test steam pressure, inHg gage

11.1.3 Heat Input, Q_{IN},

11.1.3.1 Heat Input, Q_{IN}, in Btu/h for oil-fired boilers

$$Q_{IN} = \frac{W_F \times HHV}{t_T}$$

where:

W_F = weight of fuel, lb.
HHV = higher heating value, Btu/lb.
t_T = test duration, hr

11.1.3.2 Heat Input, Q_{IN}, in Btu/h for gas-fired boilers

$$Q_{IN} = \frac{W_V \times C_S \times HHV}{t_T}$$

where:

W_V = metered volume of gas, ft^3
C_S = correction factor to be applied if the gas, as metered, is not at standard temperature and pressure. (See Appendix A)
HHV = higher heating value, Btu/ft^3
t_T = test duration, hr

11.1.4 Loss in Dry Flue Gases, L_S, for oil, in percent.

$$L_S = \frac{4CO_2 + O_2 + 700}{3(CO_2 + CO)} \times \frac{C \times C_p(T_{F,SS} - T_A)}{HHV}$$

where:

CO_2 = percentage by volume of carbon dioxide in the flue gas, %
C = carbon content of the oil, %
$T_{F,SS}$ = steady state flue temperature, °F
T_A = test air temperature, °F
CO = percentage by volume of carbon monoxide in the flue gas, %

HHV = higher heating value of the oil, Btu/lb.
C_p = specific heat of air, 0.24 Btu/lb. °F
O_2 = percentage by volume of oxygen may be measured, or calculated per:

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

where:

CO_2 = percentage by volume of carbon dioxide in the flue gas, %
C = carbon content of the oil, %
H = hydrogen content of the oil, %

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

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

where:

T_A = test air temperature, °F
$T_{F,SS}$ = steady state flue temperature, °F
H = hydrogen content of the oil, %
HHV = higher heating value of the oil, Btu/lb.

11.1.6 Flue losses

11.1.6.1 Gas Fired Boilers

Calculate flue loss, L_f, in percent of heat input rate

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

where:

P = dry constituents in flue gases from stoichiometric combustion, SCF per 1000 Btu of gas burned
T = total constituents in flue gases from stoichiometric combustion, SCF per 1000 Btu of gas burned

$$C_1 = \frac{PU}{1000}\left[16.2\left(T_f - T_r\right) + 6530\ln\left(\frac{T_r}{T_f}\right) + 1.41\times10^6\left(\frac{1}{T_r} - \frac{1}{T_f}\right)\right]$$

$$C_2 = \frac{P}{10}\left(1 - \frac{U}{100}\right)\left[9.47\left(T_f - T_r\right) + 3470\ln\left(\frac{T_r}{T_f}\right) + 1.16\times10^6\left(\frac{1}{T_r} - \frac{1}{T_f}\right)\right]$$

$$C_3 = \frac{P}{10}\left(\frac{U - CO_2}{CO_2}\right)\left[9.46\left(T_f - T_r\right) + 3290\ln\left(\frac{T_r}{T_f}\right) + 1.07\times10^6\left(\frac{1}{T_r} - \frac{1}{T_f}\right)\right]$$

$$C_4 = \left[\frac{T - P}{10} + 0.00174hA\left(1 + \frac{P}{A}\left(\frac{U - CO_2}{CO_2}\right)\right)\right]\left[19.86\left(T_f - T_r\right) + 7500\ln\left(\frac{T_f}{T_r}\right) + 1194\left(\sqrt{T_r} - \sqrt{T_f}\right)\right]$$

where:

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

CO_2 = CO_2 in flue gases, percent of total dry constituents in the flue gas
H = relative humidity of the air supplied for combustion, percent/100
P = dry constituents in flue gases from stoichiometric combustion, SCF per 1000 Btu of gas burned
T = total constituents in flue gases from stoichiometric combustion, SCF per 1000 Btu of gas burned
T_f = flue gas temperature, degree R
T_r = room temperature, degrees R
U = ultimate (CO_2) of flue gas, percent

Variable	Value
A	9.4
P	8.47
T	10.42
U	11.9

11.1.6.2 Oil Fired Boilers

Calculate flue loss, L_f, in percent of heat input rate

$$L_f = L_S + L_L$$

where:

L_S = Loss in Dry Flue Gasses, %
L_L = Loss Due to Moisture, %

11.1.7 Equivalent saturated steam temperature, T_{SAT}, in °F, is taken from Table 2, "Properties of Saturated Steam", at the absolute steam pressure.

11.1.8 Latent heat of vaporization at the equivalent saturated steam temperature, h_{fg}, in Btu/lb, is taken from Table 2, "Properties of Saturated Steam" at the absolute steam pressure.

11.1.9 Moisture in Steam, M, in percent

11.1.9.1 If steam is condensed and weighed.

$$M = \frac{100 W_S}{W_S + W_C}$$

11.1.9.2 If feedwater is measured.

$$M = \frac{100 W_S}{W}$$

where:

W_S = weight of water in separator, lb.
W_C = weight of steam condensed, lb.
W = weight of water fed, lb.

11.1.10 Latent Heat, Q_L, in Btu/h , Steam test

11.1.10.1 If condensate is collected.

$$Q_L = \frac{h_{fg} \times W_C}{t_T}$$

11.1.10.2 If feedwater is measured.

$$Q_L = \frac{h_{fg} \times (W - W_C)}{t_T}$$

where:

h_{fg} = latent heat of vaporization at test absolute steam pressure, Btu/lb
W_C = weight of steam condensed, lb.
T_t = test duration, hr
W_S = weight of water in separator, lb.
W = weight of water fed, lb.

11.1.11 Heat in Liquid, Q_S, in Btu/h

11.1.11.1 Steam test if condensate is weighed

$$Q_S = \frac{C_p (W_C + W_S)(T_{SAT} - T_{IN})}{t_T}$$

11.1.11.2 Steam test if feedwater is weighed

$$Q_S = \frac{W \times C_p (T_{SAT} - T_{IN})}{t_T}$$

where:

W_C = weight of steam condensed, lb.
W_S = weight of water in separator, lb.
W = weight of water fed, lb.
T_{SAT} = test saturated steam temperature, °F
T_{IN} = inlet water temperature, °F
T_t = test duration, hr
C_p = average specific heat of water, Btu/lb.°F

11.1.11.3 Water test

$$Q_S = \frac{W \times C_p (T_{OUT} - T_{IN})}{t_T}$$

where:

W = weight of water fed, lb.
T_{OUT} = outlet water temperature, °F
T_{IN} = inlet water temperature, °F
t_T = test duration, hr
C_p = specific heat of water, Btu/lb.°F

11.1.12 Gross Output, Q_{OUT}, in Btu/h

11.1.12.1 Steam Thermal Efficiency Test

$$Q_{OUT} = Q_L + Q_S$$

11.1.12.2 Water Thermal Efficiency Test

$$Q_{OUT} = Q_S$$

where:

Q_L = latent heat in the steam produced, Btu/h
Q_S = sensible heat in the liquid, Btu/h

11.1.13 Thermal Efficiency, $Effy_T$, in percent

$$EffyT = \frac{100Q_{OUT}}{Q_{IN}}$$

where:

Q_{OUT} = gross output, Btu/h
Q_{IN} = heat input, Btu/h

11.1.14 Non-Condensing Combustion Efficiency, $Effy_{SS}$, in percent

$$Effy_{SS} = 100 - L_f$$

where:

L_f = flue loss, %

11.1.15 Radiation and Unaccounted for Loss, L_U, in percent

$$L_U = Effy_{SS} - Effy_T$$

where:

$Effy_{SS}$ = Combustion Efficiency, %
$Effy_T$ = Thermal Efficiency, %

11.1.16 Draft Loss for Natural Draft Boilers

$$D_L = D_F - D_{OF}$$

where:

D_F = Draft in the flue pipe, inches water
D_{OF} = Draft in the fire box, inches water

11.1.17 Condensing boiler - Latent heat gain due to condensation under steady state conditions, $L_{G,SS}$, expressed as a percent

$$L_{G,SS} = \frac{100h_{fg} \times M_{C,SS}}{Q_{IN}}$$

where:

100 = conversion factor to express a decimal as a percent
h_{fg} = latent heat of vaporization of water, 1053.3 Btu/lb. at 70°F
$M_{C,SS}$ = condensate mass collected, pounds/hr.
Q_{IN} = heat input, Btu/hr.

11.1.18 Condensing boiler - Steady state heat loss due to hot condensate going down the drain, $L_{C,SS}$, expressed as a percent

$$L_{C,SS} = \frac{L_{G,SS}\left[C_p\left(T_{F,SS} - T_A\right) - 0.45\left(T_{F,SS} - T_A\right)\right]}{h_{fg}}$$

where:

$L_{G,SS}$ = latent heat gain due to condensation under steady state conditions, %
C_p = specific heat of water, Btu/lb. °F
$T_{F,SS}$ = flue gas temperature, °F
T_A = test air temperature, °F
0.45 = specific heat of water vapor, Btu/lb. °F
h_{fg} = latent heat of vaporization of water, 1053.3 Btu/lb. at 70°F

11.1.19 Condensing boilers - Steady state combustion efficiency, $Effy_{SS}$, expressed as a percent

$$Effy_{SS} = 100 - \left(L_f - L_{G,SS} + L_{C,SS}\right)$$

where:

$L_{G,SS}$ = latent heat gain due to condensation under steady state conditions, %

$L_{C,SS}$ = steady state heat loss due to hot condensate going down the drain, %

L_f = flue loss, %

11.1.20 Outdoor Boiler Thermal Efficiency, $Effy_{T,O}$, in percent

- Water Boiler

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

- Steam Boiler

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

where:

$Effy_{SS}$ = combustion efficiency, indoor, %
L_U = radiation and unaccounted for loss, %
T_{OUT} = outlet steam or water temperature, °F
42 = assumed average outdoor temperature, °F
T_A = test air temperature, °F
T_{SAT} = test saturated steam temperature, °F

11.1.21 Outdoor Boiler Gross Output, $Q_{OUT,O}$ in Btu/h

$$Q_{OUT,O} = \frac{Q_{IN} \times Effy_{T,O}}{100}$$

where:

Q_{IN} = heat input, Btu/h
$Effy_{T,O}$ = outdoor thermal efficiency, %

11.2 COMBUSTION EFFICIENCY TEST

11.2.1 Non-Condensing Combustion Efficiency

The items 11.1.4, 11.1.5 and 11.1.6.2 shall be calculated for oil boilers and 11.1.6.1 shall be calculated for gas boilers. Section 11.1.14 shall be used to calculate the combustion efficiency.

11.2.2 Condensing Combustion Efficiency

The items 11.1.6.1 , 11.1.17, and 11.1.18 shall be calculated for gas boilers. Section 11.1.19 shall be used to calculate the combustion efficiency.

12.0 TEST REPORT

12.1 Individual test results shall be reported on Form 721.

TABLE 2: Properties of Saturated Steam

Absolute Pressure		Temperature	Latent Heat	Absolute Pressure		Temperature	Latent Heat
in Hg	psi	°F	btu/lb	in Hg	psi	°F	btu/lb
27.6	13.57	208.0	972.9	31.6	15.52	214.7	968.5
.7	13.61	208.1	972.8	.7	15.57	214.9	968.4
.8	13.66	208.3	972.7	.8	15.61	215.0	968.3
.9	13.71	208.5	972.6	.9	15.66	215.2	968.2
28.0	13.75	208.7	972.5	32.0	15.71	215.4	968.1
.1	13.80	208.8	972.4	.1	15.76	215.5	968.1
.2	13.85	209.0	972.2	.2	15.81	215.7	968.0
.3	13.90	209.2	972.1	.3	15.86	215.9	967.9
.4	13.95	209.4	972.0	.4	15.91	216.0	967.8
.5	14.00	209.5	971.9	.5	15.96	216.2	967.7
.6	14.05	209.7	971.8	.6	16.00	216.3	967.6
.7	14.10	209.9	971.7	.7	16.05	216.5	967.5
.8	14.15	210.1	971.6	.8	16.10	216.6	967.4
.9	14.20	210.2	971.4	.9	16.15	216.8	967.3
29.0	14.24	210.4	971.3	33.0	16.20	217.0	967.2
.1	14.29	210.6	971.2	.1	16.25	217.1	967.1
.2	14.34	210.8	971.1	.2	16.30	217.3	967.0
.3	14.39	210.9	971.0	.3	16.35	217.4	966.9
.4	14.44	211.1	970.9	.4	16.40	217.6	966.8
.5	14.49	211.3	970.8	.5	16.45	217.7	966.7
.6	14.54	211.4	970.7	.6	16.50	217.9	966.6
.7	14.59	211.6	970.5	.7	16.54	218.0	966.5
.8	14.64	211.8	970.4	.8	16.59	218.2	966.4
.9	14.69	212.0	970.3	.9	16.64	218.3	966.3
30.0	14.73	212.1	970.2	34.0	16.69	218.5	966.2
.1	14.78	212.3	970.1	.1	16.74	218.7	966.1
.2	14.83	212.4	970.0	.2	16.79	218.8	966.0
.3	14.88	212.6	969.9	.3	16.84	219.0	965.9
.4	14.93	212.8	969.8	.4	16.89	219.1	965.8
.5	14.98	212.9	969.7	.5	16.94	219.3	965.7
.6	15.03	213.1	969.6	.6	16.99	219.4	965.6
.7	15.07	213.3	969.5	.7	17.04	219.6	965.5
.8	15.12	213.4	969.4	.8	17.09	219.7	965.4
.9	15.17	213.6	969.2	.9	17.14	219.9	965.3
31.0	15.22	213.7	969.1	35.0	17.19	220.0	965.2
.1	15.27	213.9	969.0	.1	17.23	220.1	965.1
.2	15.32	214.1	968.9	.2	17.28	220.3	965.0
.3	15.37	214.2	968.8	.3	17.33	220.4	964.9
.4	15.42	214.4	968.7	.4	17.38	220.6	964.8
.5	15.47	214.6	968.6	.5	17.43	220.7	964.7

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

APPENDIX A

This Appendix is not part of this standard but is included for information purposes only.

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

Dry gas utilizing a dry test meter:

Inch Pounds:
$$C_S = \frac{P_g(459.7 + T_{std})}{P_S(459.7 + T_g)} \quad \text{(A-1a)}$$

International System of Units (metric):
$$C_S = \frac{P_g(273.15 + T_{std})}{P_S(273.15 + T_g)} \quad \text{(A-1b)}$$

Saturated gas utilizing a wet test meter:

Inch Pounds:
$$C_S = \frac{(P_g - P_{wv})(459.7 + T_{std})}{(P_S - P_{wvs})(459.7 + T_g)} \quad \text{(A-2a)}$$

International System of Units (metric):
$$C_S = \frac{(P_g - P_{wv})(275.15 + T_{std})}{(P_S - P_{wvs})(275.15 + T_g)} \quad \text{(A-2b)}$$

where:

P_g = absolute pressure of gas being metered (barometric pressure plus gas pressure in meter, inHg (kPa)
P_S = standard absolute pressure, inHg (kPa)
T_g = temperature of gas in meter, °F (°C)
T_{std} = standard temperature, °F (°C)
P_{wv} = water vapor pressure at T_g, inHg (kPa)
Pwvs = water vapor pressure at T_{std}, inHg (kPa)

NOTE: For water vapor pressures, see *ASHRAE Handbook - 1993 Fundamentals*, Chapter 6, Table 3.

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

$$C_f = \frac{P_S - P_{wvs}}{P_S}$$

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

$$C_f = \frac{P_S}{P_S - P_{wvs}}$$