



SATURN HYDRONIC SYSTEMS FIELD GUIDE



SATURN RESOURCE MANAGEMENT

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Saturn Hydronic Systems Field Guide

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The *Saturn Hydronic Systems Field Guide* includes procedures for evaluating
and servicing steam and hot-water space-heating systems.

The companion volume *Saturn Building Shell Field Guide* outlines procedures
for insulating, air-sealing, and improving the shading of existing homes.

The companion volume *Saturn Energy Auditor Field Guide* describes the
procedures used to analyze the performance of existing homes.

The companion volume *Saturn HVAC Field Guide* describes the procedures
used to evaluate and service forced air heating and cooling systems.

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Foreword

The Saturn *Hydronic Systems Field Guide* outlines specifications and procedures for improving the performance and efficiency of steam and hot-water space-heating systems in residential and light-commercial buildings. This guide encourages technicians and contractors to use a building-science-based approach to hydronic service.

We assume that the reader is experienced in working on hydronic systems. We don't cover every detail of every energy-conserving procedure in the interest of brevity and clear communication.

Chapter 1 outlines the whole-house approach we've found necessary to performing effective hydronic evaluation and service.

Chapter 2 addresses combustion safety and efficiency testing, as well as service to the combustion system.

Chapter 3 provides guidelines for evaluating and servicing the boiler's venting system.

Chapter 4 includes inspection and replacement standards for boilers.

Chapter 5 covers domestic water heating using the heating boiler or a stand-alone water heater.

Chapter 6 covers the use and maintenance of hot-water space-heating systems.

Chapter 7 focuses on steam heating distribution systems.

The Saturn *Field Guides* have benefitted greatly over the years from the generous feedback of our readers. Please help continue this process by sending us your comments and suggestions.

Special thanks to the U.S. Department of Energy, the National Renewable Energy Lab, and the Building Performance Institute for their support and contract management.

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TABLE OF CONTENTS

1: Hydronic Energy Efficiency and Service

Buildings Are Systems	13
Evaluating the Building Shell.....	14
Insulation	14
Air Leakage and Ventilation.....	16
Evaluating Hydronic Systems for Energy Efficiency.....	17
Boiler Sizing and Selection.....	18
Commissioning Hydronic Heating Systems.....	19

2: Evaluating Combustion and Venting

Essential Combustion Safety Tests	21
Leak-Testing Gas Piping	22
Carbon Monoxide	23
Causes of Carbon Monoxide	24
Carbon Monoxide Testing	24
Smoke and Carbon Monoxide Alarms	25
Worst-Case Testing for Atmospheric Venting Systems .	27
Measuring Chimney Draft.....	31
Eliminating Spillage and Improving Insufficient Draft ..	31
CAZ Isolation Testing for Open Combustion Appliances	33
Boiler Combustion Testing.....	33
Combustion Efficiency Testing and Adjustment	34
Critical Boiler-Testing Parameters	36
Other Relevant Boiler-Testing Parameters	37
Prescriptive Inspection of Gas Combustion Systems	38
Inspection.....	38
Maintenance and Adjustment	39
Evaluating and Improving Oil-Burner Efficiency.....	45
Oil-Burner Inspection.....	45

Oil-Burner Testing	46
Oil-Burner Controls	49
Oil-Burner Adjustment.....	50
Oil-Burner Maintenance and Visual Checks	50
Upgrading to Flame-Retention Burners	52

3: Combustion Air Supply and Exhaust Venting

Combustion Air and Venting Introduction	55
Classifying Combustion Air and Exhaust Arrangements	56
Combustion Air.....	56
Combustion Air from Living Space	57
Combustion Air from Outdoors	58
Sealed Combustion.....	60
Combustion Venting	62
Vertical Chimneys	64
Special Venting Considerations for Gas.....	71
Power Venters for Sidewall Venting	75
Applicable Codes and Standards	77

4: Choosing Boilers

Troubleshooting Boiler Failure	79
Overheating Failures	80
Corrosion Failures	80
Combustion Problems and Failures	81
Gas-Fired Boiler Installation	81
Testing New Gas-Fired Boilers.....	82
Oil-Fired Heating Installation.....	83
Testing New Oil-Fired Heating Systems	84
Combustion Boiler Replacement	85
Hot-Water Boiler Replacement.....	86
Steam-Boiler Replacement.....	88

5: Water-Heating Energy Savings

Determinants of Water-Heating Efficiency	91
Distribution Efficiency and Performance	92
Controlling Water Temperature and Pressure	92
Controlling Water Flow	93
Circulating Domestic Hot Water	94
Pipe Insulation	95
Selecting Storage Tanks	95
Corrosion Resistance of Tanks	95
Sizing Storage Tanks	96
Storage-Tank Insulation	97
Storage Water Heaters	97
Disadvantages of Gas Storage Water Heaters	97
Comparing Conventional Direct-Fired Gas to Electric Storage Water Heaters	98
Specifications for Gas Storage Water Heaters	101
Storage Water Heating Improvement	102
External Insulation Blankets	103
Instantaneous (Tankless) Direct-Fired Water Heaters	105
Instantaneous Control and Maintenance	106
Indirect-Fired Water Heaters	107
Efficiency and Performance	107
Cleaning Heat Exchangers	109
Solar Water Heating	109
Solar Hot-Water System Design	109

6: Hot-Water Space-Heating

Hot-Water Piping Systems	113
Initial Evaluation	114
Keeping Air out of the System	114
Removing Air from the System	114

Limiting Feedwater	115
Determining Fill Pressure	116
Expansion Tank Capacity	117
System and Zone Controls	118
Boiler Controls	118
Zone Controls	120
Radiator Control.....	122
Pumps	122
Pump Sizing.....	123
Downsizing Pumps.....	124
Smart Pumps.....	125
Pump Lubrication	125
Evaluating System Sizing	126
Final Maintenance and Troubleshooting	128

7: Steam Heat Distribution

Steam Boilers.....	129
Pressure Control.....	130
Boiler Water Quality	131
Boiler Controls	133
Flow of Steam, Air, and Condensate	135
Defeating Water Hammer.....	136
Reducing Bounce and Preventing Flooding	137
General Steam Distribution Improvements.....	137
Types of Steam Distribution Systems	138
One-Pipe Steam Systems	138
Two-Pipe Steam Systems	140

Converting Steam to Hot Water 142

Equivalent Direct Radiation (EDR)143

Major References147

List of Tables and Illustrations149

Index153

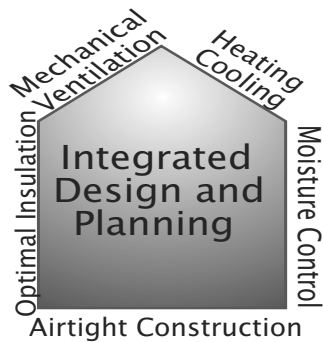
CHAPTER 1: *HYDRONIC ENERGY EFFICIENCY AND SERVICE*

Hydronics is the technology of heating with steam and hot water. As a hydronic technician, you can improve customer satisfaction, outshine your competition, and open new sales and marketing opportunities by specializing in energy efficiency.

This field guide outlines how to integrate energy-efficiency testing and improvements into your existing installation and service procedures in existing buildings.

1.1 BUILDINGS ARE SYSTEMS

A building's design should integrate the building shell with its hydronic heating system. A well-insulated and airtight home compliments a well-designed and installed hydronic heating system. And unfortunately, a drafty, unshaded, and poorly insulated home detracts from the performance of the system.



The building shell's poor thermal performance may overwhelm the hydronic heating system's during extreme weather, causing customer complaints. Sometimes the best solution to a customer complaint involves adding insulation or sealing air leaks rather than by trying to squeeze better performance out of the hydronic heating system.

We suggest that you become better educated on how buildings function as systems. Many hydronic heating contractors are now working with insulation contractors and other building trades to provide a more integrated energy-and-comfort packages for their customers.

1.2 EVALUATING THE BUILDING SHELL

The characteristics of the building shell determine the heating load of the building. Therefore, it's important to understand the basics of winter heat loss through buildings. Winter heat loss is driven by the temperature difference between indoors and outdoors.

A building's *thermal boundary* is a theoretical concept that combines resistance to heat flow through building materials and resistance to air leakage through the building shell.

1.2.1 Insulation

America's building industry has placed too little emphasis on the energy efficiency of the building shell. Insulation is the most valuable investment a building owner can make in constructing or renovating a building. Attic or roof-cavity insulation is extremely important in all climates to limit heat loss and heat gain through the vulnerable roof area. Wall insulation is also very important. Both attic and wall insulation are often inadequate for wise energy use because of installation flaws and insufficient insulation thickness. Floor or foundation insulation is simply neglected in most homes, causing excessive energy waste especially in cool climates.

The building shell is supported by wood, metal and other non-insulating materials. The building shell's thermal resistance then depends on an average of the insulation and structural materials, which is usually less than the nominal value of the installed insulation. For example, 15–30 percent of the surface of a framed wall is lumber and only 70–85 percent is insulated cavity. In the case of a 2-by-4 wall with R-11 insulation, the whole-wall R-value, accounting for this mix of materials on the surface of the wall is less than R-11. The whole-wall R-value can be reduced another 5–25 percent by installation flaws.

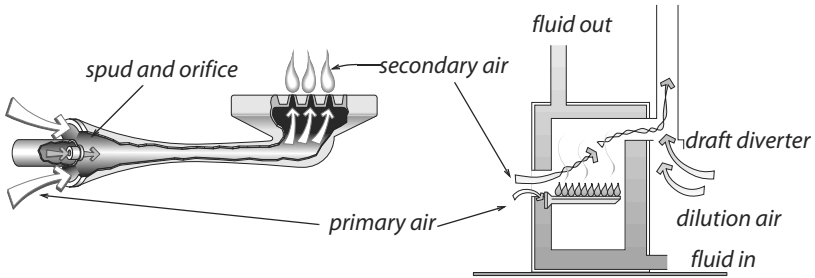
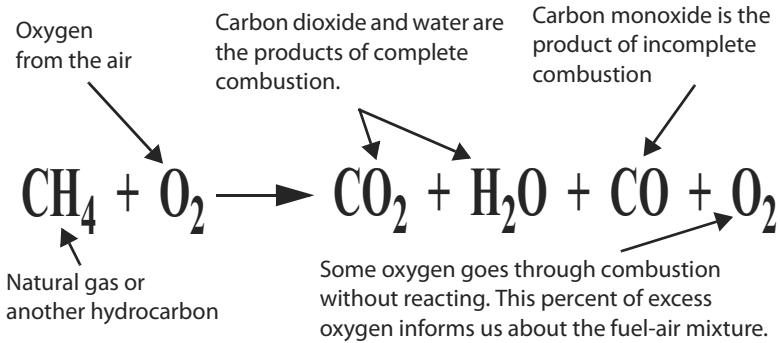
Thermal bridging describes the thermal-resistance effect of non-insulating materials like wood and metal within the ther-

mal boundary. Steel has a thermal conductance 200 times that of wood and aluminum has a thermal conductance of 900 times that of wood. These materials can have a dramatic effect on a building component's R-value. Thermal wall sheathing should be standard practice to reduce thermal bridging through wood and metal studs.

Convection is air movement within or around the insulation, which reduces its thermal resistance. Convection is a particular problem with walls because they are vertical like chimneys. Any voids or small channels, created during installation, encourage convection in wall cavities. This convection carries heat through or around the insulation. Careful cutting and fitting of batts and careful dense-packing of loose-fill insulation minimizes the potential for convection.

CHAPTER 2: EVALUATING COMBUSTION AND VENTING

The effective performance of burners and their venting systems is essential for safe and efficient combustion. The burners must not produce excessive carbon monoxide (CO), which is a poison. The venting system must convey the combustion gases outside the building.



Atmospheric, open-combustion gas burners: Combustion air comes from indoors in open-combustion appliances. These burners use the heat of the flame to pull combustion air into the burner. Dilution air, entering at the draft diverter, prevents over-fire draft from becoming excessive.

2.1 ESSENTIAL COMBUSTION SAFETY TESTS

The Building Performance Institute (BPI) requires that essential combustion safety tests be performed as part of all energy-con-

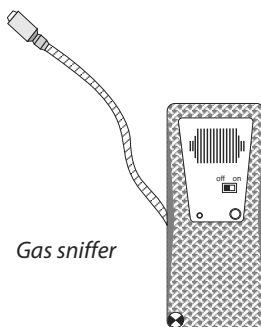
ervation work. BPI requires natural-gas leak-testing and CO testing for all appliances. For naturally drafting appliances, either a worst-case venting test or zone-isolation test is also necessary.

BPI considers naturally drafting appliances and venting systems to be obsolete for both efficiency and safety reasons. BPI recommends that naturally drafting appliances be replaced with modern sealed-combustion or power-vent combustion appliances, whenever possible. However there are some circumstances in which a sealed-combustion boiler may not operate safely. The boiler's location and the points of combustion air intake and exhaust gas discharge must be suitable for utilization of a modern venting systems in order to make the transition from atmospheric venting to sealed combustion or power venting.

2.1.1 Leak-Testing Gas Piping

Natural gas and propane piping systems may leak at their joints and valves. Find gas leaks with an electronic combustible-gas detector, often called a gas sniffer. A gas sniffer finds all significant gas leaks if used carefully. Remember that natural gas rises from a leak and propane falls, so position the sensor accordingly.

Sniff all valves and joints with the gas sniffer.



Gas sniffer

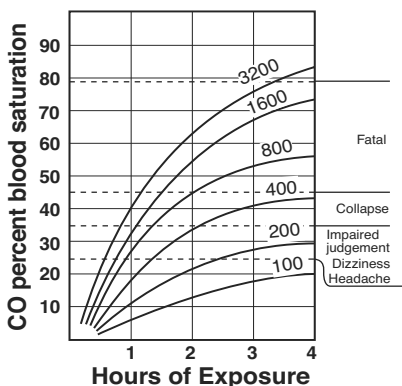
- ✓ Accurately locate leaks using a non-corrosive bubbling liquid, designed for finding gas leaks.
- ✓ All gas leaks must be repaired.
- ✓ Replace kinked or corroded flexible gas connectors.
- ✓ Replace flexible gas lines manufactured before 1973. The date is stamped on a date ring attached to the flexible gas line.

Local authorities may also require using the dials of the gas meter to detect leaks. The hand on the lowest-reading dial must not move in at least 30 minutes with all the pilots extinguished in a typical test.

2.2 CARBON MONOXIDE

Carbon monoxide (CO) is a product of incomplete combustion. CO is the largest cause of injury and death in the U.S. from gas poisoning, resulting in more than 500 deaths per year. Additional people are injured or sickened by lower concentrations of the gas. The symptoms of low-level CO exposure are similar to the flu, and may go unnoticed.

CO blocks the oxygen-carrying capacity of the blood's hemoglobin, which carries vital oxygen to the tissues. At low concentrations (5-to-50 ppm), CO reduces nerve reaction time and causes mild drowsiness, nausea, and headaches. Higher concentrations (50-to-3000 ppm) lead to severe headaches, vomiting, and even death if the high concentration persists. The effects of CO poisoning are usually reversible, except for exposure to very high levels, which can cause brain damage.



Effects of CO: This graph's curves represent different exposure levels in parts per million.

The EPA's suggested maximum 8-hour exposure is 9 ppm in room air. Room levels of CO at or above 9 ppm are usually associated with the use of malfunctioning combustion appliances within the living space, although cigarette smoking or automobile exhaust are also common CO sources.

CHAPTER 3: COMBUSTION AIR SUPPLY AND EXHAUST VENTING

Combustion air supply and exhaust venting are important to the safe flow of air and gases through the burners, heat exchanger, and chimney of a combustion boiler. Venting is a general term for the flues, chimney, and other passageways that exhaust combustion gases out of the building. If the venting system is faulty, combustion gases may spill into the building. If these gases contain carbon monoxide (CO), the health of residents is threatened.

3.1 COMBUSTION AIR AND VENTING

INTRODUCTION

Combustion air provides oxygen necessary for combustion. There are three common ways of providing combustion air.

1. Combustion air from the living space.
2. Combustion air from outdoors.
3. Sealed combustion.

The advantages of sealed combustion include the following.

- Reduced chance of exhaust products entering the living space.
- Reduced standby losses out the vent while the appliance is hot but not firing.
- No discomfort caused by pulling cold combustion air through the building.
- Potentially improved control over the fuel-air mixture.

3.1.1 Classifying Combustion Air and Exhaust Arrangements

NFPA standards currently permit all of the combustion-air methods described previously. See *"Applicable Codes and Standards"* on page 77. Because of the difficulties of controlling combustion air in other than sealed-combustion appliances, building codes attempt to address an infinite number of situations found in real-world buildings. The combustion appliances in these buildings may, at times, draw combustion air from indoors, outdoors, attics, crawl spaces, adjacent buildings, or even the appliance's chimney or another chimney.

In combination with the three ways of providing combustion air, there are four common ways of exhausting combustion gases to the outdoors.

1. Fan forced out the top of the building.
2. Fan forced out the side of the building.
3. Gravity (natural draft) up to the top of the building.
4. Natural draft out the side of the building.

Now we'll describe the code provisions, safety and energy conservation recommendations for each combination of combustion air supply and exhaust, organized by the three ways of supplying combustion air:

Each of the four venting options can be combined with any of these three combustion air options, producing 12 main approaches. First we'll describe the three ways of supplying combustion air.

3.2 COMBUSTION AIR

Combustion Air is essential for efficient and safe combustion. Combustion air can come from the living space or from outdoors.

3.2.1 Combustion Air from Living Space

This section discusses combustion air for non-sealed-combustion equipment installed in a room without dedicated outdoor air. Examples include typical boiler or water heater installation in a single family home.

Most older combustion appliances take their combustion air from indoors. This indoor air is replenished from leaks in the building shell. This arrangement requires a building to be leaky, which wastes energy and causes discomfort. As buildings are built and retrofitted to be less leaky, this combustion air is becoming less available, which deprives the vent of a free flow of air regardless to the type of vent used. This desirable problem is rendering this combustion-air option obsolete.

Table 3-1: Combustion Air From Indoors

Location	Air is Provided by:
Air taken from indoors if building conforms to air-volume requirements or infiltration estimate sections of NFPA 54.	Air leaks from outdoors are considered sufficient. No dedicated air supply required.
Confined space as defined by NFPA 54 (combustion appliance is in a small closet that is smaller than NFPA threshold)	Two direct openings between confined space and an adjacent indoor space, each opening having a minimum area of 100 in ² and sized at 1 in ² per 1000 Btuh. Combined volumes of combined space and rest of building must be ≥ 50 ft ³ per 1000 Btuh

Here is an example of sizing combustion air to another indoor area. The boiler and water heater are located in a confined space. The boiler has an input rating of 100,000 Btu/hour. The water heater has an input rating of 40,000 Btu/hour. Therefore, there should be 280 in² of net free area of vent between the mechani-

CHAPTER 4: CHOOSING BOILERS

Don't assume that older boilers are inefficient without testing them. Try to repair and adjust the existing boiler, before deciding to replace it. The distribution system is more often the cause of heating problems than the boiler anyway.

Older boilers and distribution systems may be repaired or retrofitted to improve their performance by knowledgeable technicians using modern testing equipment. Estimate the repair and retrofit costs for existing steam and hot-water systems and compare them to boiler-replacement cost before choosing between retrofit and replacement.

New boilers must be installed to manufacturer's specifications, following all applicable electrical, plumbing, mechanical, and fire codes. If the manufacturer's instructions or the code requirements are ignored, the warranty may be void and unsafe conditions may arise.

Replacement boilers should have a minimum Annual Fuel Utilization Efficiency (AFUE) of 80%. However prefer gas boilers with AFUEs of 90% if practical. High-efficiency boilers are power-vented or sealed-combustion units with health and safety benefits in addition to their superior performance and lower fuel usage.

4.1 TROUBLESHOOTING BOILER FAILURE

If an old boiler fails, the cause may be a system problem. Problems in the existing distribution system could cause the new boiler to malfunction or fail. Therefore try to find the failure's cause and evaluate the distribution system for compatibility with the new boiler.

4.1.1 Overheating Failures

Boiler overheating is usually caused by low water, sludge or lime buildup, over-firing, or inadequate distribution capacity.

- ✓ Make sure that both steam and hot-water new boilers have automatic fill valves and a low-water cutoffs.
- ✓ Check piping for sludge or lime deposits. Clean pipes with pressurized water and cleaning solutions if necessary.
- ✓ Make sure that the radiation (EDR) has capacity to service new boiler output.

4.1.2 Corrosion Failures

Boiler corrosion is usually caused by excessive make-up water, faulty water chemistry, or too-low return water temperature.

- ✓ Notice if the relief valve has been discharging. If so the system pressure is too high, usually because of a waterlogged expansion tank, inadequate expansion-tank capacity, exposure to high city water pressure, or excessive water temperature.
- ✓ Steam boilers may require water treatment to cope with their regular need for make-up water or blow-down.
- ✓ Some hot-water boilers use a glycol mix that may react with water for form sludge or acid. Look for sludge in near boiler piping or layered boiler or piping corrosion from acid.
- ✓ Return water temperature that is too low causes flue gases to condense, which corrodes boiler flues, vent connectors, and chimneys. Either replace the corroded boiler with a condensing boiler or install a piping bypass or mixing valve to maintain an adequate return water temperature.

4.1.3 Combustion Problems and Failures

Boiler combustion problems and failures are usually caused by negative pressure in the combustion zone, blocked venting, or leaky venting that weakens draft.

- ✓ Measure the pressure difference between the combustion zone and outdoors. Take steps to remove negative pressure in the combustion zone. See “*Worst-Case Testing for Atmospheric Venting Systems*” on page 27.
- ✓ Thoroughly inspect the chimney and vent connector for blockages, soot, and air leaks. Remove blockages and soot and repair air leaks.
- ✓ Make sure that the new boiler has sufficient combustion air by combustion testing during worst-case conditions. Oxygen and carbon monoxide levels should be within prescribed limits.
- ✓ Check the oil tank and oil piping for obstructions when replacing oil-fired boilers.

4.2 GAS-FIRED BOILER INSTALLATION

The goal of boiler replacement is to save energy and provide safer heating. The boiler replacement project should produce a gas-fired heating system in virtually new condition, even though existing components like the gas lines, chimney, or water piping may remain. Any necessary maintenance or repair on these remaining components must be part of the installation. Any design flaws in the original system should be diagnosed and corrected during the boiler replacement.

- ✓ A new boiler should have at least 80% AFUE and be power vented, or better yet, sealed-combustion. However if appropriate and safe to operate, gas boilers with AFUE ratings of over 90% are available.
- ✓ All new boilers should be installed with adequate clearances to facilitate maintenance.

CHAPTER 5: WATER-HEATING ENERGY SAVINGS

Heating domestic water typically accounts for between 12% and 25% of a building's energy costs. The water heater's efficiency, the storage tank's efficiency and the distribution system's efficiency together determine the energy consumption for domestic hot water.

Replacing water heating equipment presents numerous choices, especially for managers of multifamily buildings. Direct-fired storage water heaters are the most common water heater in single-family homes. Single-family and multifamily buildings with boilers often have indirect water heaters, which are powered by the same boiler used for space heat. Solar water heating is also viable option for both single-family and multifamily buildings.

5.1 DETERMINANTS OF WATER-HEATING EFFICIENCY

There are three types of efficiency that rate water heaters.

- Steady-state or recovery is the efficiency at which a combustion water heater heats water.
- Energy factor, which is a decimal less than one, represents the energy remaining in water coming out of the water heater divided by the energy input used to heat the water. The energy factor is always less than the steady-state efficiency because energy factor accounts for storage losses.
- System efficiency includes losses from the distribution system and so is the lowest of the three efficiencies. The water heating system efficiency is less than the energy factor because it accounts for distribution losses.

All the different water-heating systems have system-efficiency factors in common, including the following.

- System efficiency increases with decreases in stored water temperature to a minimum of 120°F.
- System efficiency decreases with increases in the distance of fixtures from the storage tank.
- System efficiency increases with increased insulation on hot-water storage tanks.
- System efficiency is directly related to the heat-source's steady-state efficiency.
- Continuous circulation is less efficient than timed circulation, which is less efficient than demand circulation.

5.2 DISTRIBUTION EFFICIENCY AND PERFORMANCE

Controlling water temperature, pressure, and flow are the essential for the performance, efficiency and longevity of all water-heating systems.

- ✓ Inspect faucets for hot-water leaks and repair leaks if found.
- ✓ Install a sediment filter on the incoming water service.
- ✓ Insulate all hot-water pipes.

Follow the recommendations below to improve water-heating performance and efficiency before considering other more expensive and complex options.

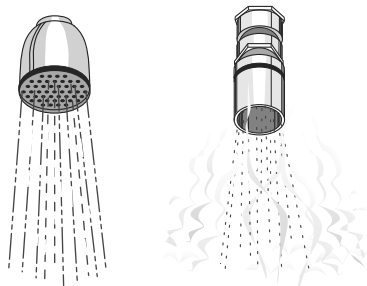
5.2.1 Controlling Water Temperature and Pressure

All decisions in any way related to water heating should prioritize the goal of delivering water to the tap at a temperature at a temperature between 115°F and 120°F. Colder water causes complaints, which leads to overheated water. Overheated water scalds residents, wastes energy, and damages faucet parts, leading to continuous leaks of heated water down the sewer. Overheated water also leads to more liming and corrosion compared to 120° water.

Excessive water pressure can damage tanks, coils, and fixtures and leads to excessive flow. Limit pressure to a level that serves the farthest fixtures satisfactorily, by adjusting the pressure-reducing valve to the minimum sufficient pressure. Install a pressure-reducing valve if none exists and water pressure is excessive.

5.2.2 Controlling Water Flow

Excessive water flow wastes energy and can overwhelm a water heater's capacity, especially in multifamily buildings. You can control flow at fixture with energy-saving showerheads, low-flow faucet aerators, or at the water heater with in-line flow controls.



Water-saving shower heads: The shower head on the left gives a laminar flow. The shower head on the right gives an atomized, steamy shower.

You can determine flow rate by measuring the time it takes to draw one-gallon into a calibrated container, such as a marked bucket or plastic milk jug. If the gallon flows in less than 20 seconds, your flow rate is more than 3 gallons per minute.

- ✓ Start a stopwatch at the same time you move the container underneath the shower or faucet, capturing its entire flow.
- ✓ Note the number of seconds required to draw a gallon, and divide 60 by that number to find gallons per minute.

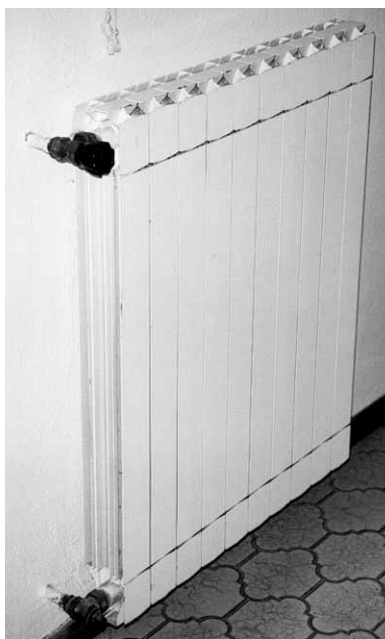
Consider these maximum flow rates to improve both the efficiency and performance of domestic water heating systems.

- 1.5 Gpm or less for shower heads
- 1.0 Gpm or less for bath and kitchen faucets (uncirculated)
- 0.5 Gpm for bath faucets in circulated systems

CHAPTER 6: *HOT-WATER SPACE-HEATING*

The hot-water distribution system consists of a pump, piping, and heat emitters in the heated rooms. The heat emitters transfer the heat to the space. Heat emitters include the following devices.

- Cast iron radiators.
- Baseboard convectors.
- Convectors, wall mounted or recessed.
- Fan coils.
- Radiant slabs.
- European-style flat-panel radiators.



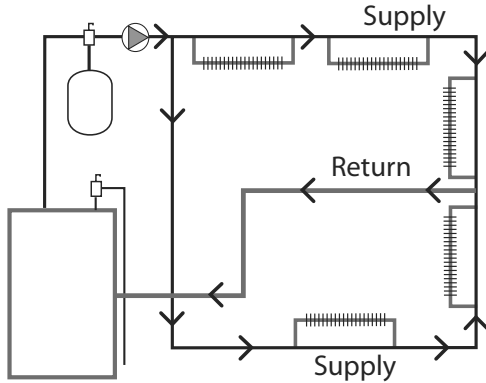
Panel radiator-convector:
European style radiator heats by both radiation and convection.

6.1 HOT-WATER PIPING SYSTEMS

Hot-water piping systems come in three basic types.

1. Series loops: Water goes through one heat emitter and into the others in a sequential water flow.
2. Parallel piping: Each radiator has a supply pipe and a return pipe.
3. Diverter tee systems: The diverter tee creates a single-pipe parallel system.

Split loop: When the series loop is split half the flow goes to one end of the system and half goes to the other, cutting the resistance in half. In this case, the return will have to carry twice the flow of one supply and must be sized accordingly.



6.2 INITIAL EVALUATION

Inquire about the system's performance at various times of the year in cold weather and mild weather because some systems provide just the right amount of heat at one outdoor temperature but overheat or underheat at other outdoor temperatures. Notice signs of poor heating performance like electric space heaters and open windows. If fuel bills are available, evaluate them and compare to other buildings, both efficient and inefficient ones.

6.3 KEEPING AIR OUT OF THE SYSTEM

Much overheating and underheating of buildings is caused by air in the hot-water distribution system. If air continually enters the system, corrosion of system components occurs over time. Air bubbles in the circulating water damages pumps. The air separator, air vent, the expansion tank, and the fill pressure are all important to good long-term air-free operation.

6.3.1 Removing Air from the System

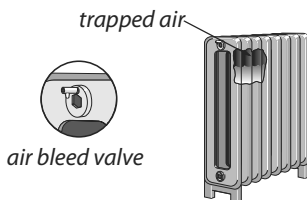
The air separator (or air eliminator) and air vent eliminate air from the system to protect pumps and ensure good water circulation. Air in heating water pipes is a common problem in hot-

water distribution systems, which causes damage to pumps and uneven distribution. Air is best vented at the point of minimum solubility where the water temperature is highest and water pressure is lowest. For a one or two storey building, this point of minimum solubility is immediately downstream of the boiler and on the suction side of the pump. For a taller building, the point of minimum solubility is at the top of the building, so install an air vent at the top of the system in taller buildings.

Bleed air from radiators and piping through air vents on piping or radiators.

6.3.2 Limiting Feedwater

When all the air is removed from the piping and water, new air must be prevented from entering. The main way new air enters hydronic systems is via new feedwater, which, regardless of its source — municipal or well — generally contains enough dissolved air to create air pockets. The solution is to prevent any of the air-free water from leaving the system. All water leaks, no matter how minor, must be eliminated.



Purging air: Trapped air collects at the hot-water system's highest parts. Bleeding air from radiators fills the radiator and gives it more heating surface area.

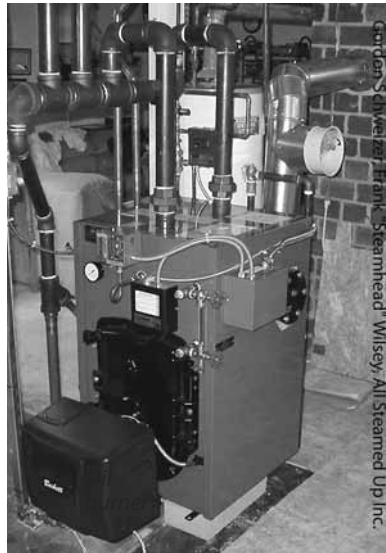
CHAPTER 7: STEAM HEAT DISTRIBUTION

A steam boiler boils water sending steam into steam mains, which pushes air out through air vents and/or return piping. The steam condenses delivering its heat inside radiators. The condensate (water) then returns to the boiler. To operate effectively, a steam system must be able to vent its air as the steam makes its way into piping and the condensate must be able to return to the boiler.

Buildings heated by steam tend to use more energy than buildings heated by hot-water systems when the steam is not properly distributed or controlled. Although the combustion efficiency of a few steam boilers for single-family homes has improved, the focus of energy-saving efforts should be on the steam distribution system rather than boiler replacement, unless the existing boiler is shown to be inefficient.

7.1 STEAM BOILERS

Steam boilers have an empty space at the top known as the steam chest or steam dome. The steam chest is the space where



Modern Steam Boiler: Generous near-boiler piping allows separation of water and steam.

the steam emerges from the boiler's water. Steam systems heat most effectively when their steam is dry, meaning that the steam contains little or no water droplets but only steam. Clean boilers have the best success at producing dry steam. *See also "Steam-Boiler Replacement" on page 88.*

7.1.1 Pressure Control

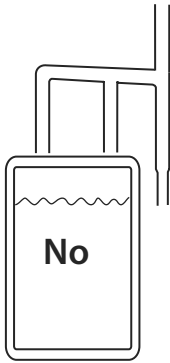
Steam systems should operate at the lowest steam pressure that heats the building satisfactorily. This maximum steam pressure should always be less than 2 psi on the boiler-pressure gauge. The operating pressure controller should activate the burner at around $\frac{1}{2}$ psi and deactivate the burner at between 1 and 2 psi.

Vapor systems, which are very low-pressure steam systems, operate at 12 ounces per square inch (0.75 psi) or less. Operating pressure controllers should activate the burner at around 4 ounces and deactivate the burner at between around 12 ounces in vapor systems.

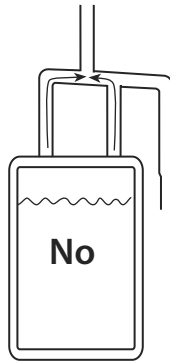
Operating pressure controllers turn the fire on and off at an adjustable pressure setting. There is a differential between the on-setting and off-setting to prevent short cycling. The differential may be fixed or adjustable. If the gas valve is short cycling, there is usually a problem with air being blocked from venting out of the system rather than a problem with the pressure controller. *See "Types of Steam Distribution Systems" on page 138.*

Not all systems have operating pressure controllers. Many systems have only a high-limit pressure control that is never needed because the high-limit pressure setting is considerably above the operating pressure of the system. The pressure never gets to the high limit because air is venting properly and the thermostat is satisfied long before the pressure reaches the high-limit setting.

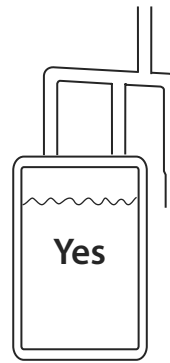
Wet steam is drawn up into piping



Steam streams oppose each other



Steam rises water drips down



Steam header piping: Separating dry steam from wet steam and droplets requires the correct header piping.

7.1.2 Boiler Water Quality

Boiler water quality is important for steam quality and boiler durability. Clean boiler water and a minimum of feedwater are the keys to good water quality.

Clean Boiler Water

Two types of impurities cause boilers to make wet steam.

1. Grease or oil.
2. Dirt or scale.

Dirty boiler water causes wet steam, excess condensate, and poor steam distribution. Grease or oil interfere with the evaporation of steam at the boiler's water line. Dirt and scale insulates the boiler vessel from the flame and creates uneven heating of the water. There are a few ways to evaluate the boiler water for dirt.

1. Watch the sight glass for bouncing of the water level, which is a sign of dirty boiler water.

A-1 EQUIVALENT DIRECT RADIATION (EDR)

Estimating radiator square feet EDR

Use Tables 1 through 5 to determine the square feet EDR of radiators or convectors when manufacturer's data is not available.

Figure 2 Cast iron baseboard



To determine EDR of radiator:

- 1 Measure length of baseboard
- 2 Read baseboard square feet (EDR) from **Table 2**

Table 2 Square feet EDR

Cast Iron Baseboard		Square feet per linear foot
Depth (inches)	Height (inches)	
2 1/2	10	3.40

Figure 3 Radiant convectors



To determine EDR of radiator:

- 1 Measure depth and height of radiator
- 2 Read square feet (EDR) from **Table 3**
- 3 Multiply table value times the number of radiator sections

Table 3 Square feet EDR

Radiant Convector		Square feet per section
Depth (inches)	Height (inches)	
5	20	2.25
7 1/2	20	3.40

Courtesy of The Hydronics Institute, Division of the Gas Appliance Manufacturers Association (GAMA) now part of the Air Conditioning, Refrigeration, and Heating Institute (ARHI)

A-1 EQUIVALENT DIRECT RADIATION (EDR)

Figure 4 Tubular radiators

To determine EDR of radiator:

- 1 Count the number of tubes (illustration is 5-tube radiator)
- 2 Measure height of radiator, floor to top
- 3 Read square feet (EDR) from **Table 4**
- 4 Multiply table value times the number of radiator sections



Table 4 Square feet EDR

Height (inches)	Tubular Radiation				
	3 Tube	4 Tube	5 Tube	6 Tube	7 Tube
14					2.67
17					3.25
20	1.75	2.25	2.67	3.00	3.67
23	2.00	2.50	3.00	3.50	
26	2.33	2.75	3.50	4.00	4.75
32	3.00	3.50	4.33	5.00	5.50
38	3.50	4.25	5.00	6.00	6.75

Figure 5 Columnar radiators

To determine EDR of radiator:

- 1 Count the number of columns (illustration is a 3-column radiator)
- 2 Measure height of radiator, floor to top
- 3 Read square feet (EDR) from **Table 5**
- 4 Multiply table value times the number of radiator sections



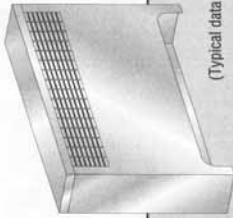
Table 5 Square feet EDR

Height (inches)	Columnar Radiation				
	1 column	2 column	3 column	4 column	5 column
14					4.00
17					4.00
18			2.25	3.00	5.00
20	1.50	2.00			5.00
22			3.00	4.00	6.00
23	1.67	2.33			
26	2.00	2.67	3.75	5.00	
32	2.50	3.33	4.50	6.50	
38	3.00	4.00	5.00	8.00	
44				10.00	
45		5.00	6.00		

Courtesy of The Hydronics Institute, Division of the Gas Appliance Manufacturers Association (GAMA) now part of the Air Conditioning, Refrigeration, and Heating Institute (ARHI)

A-1 EQUIVALENT DIRECT RADIATION (EDR)

Figure 6 Convertors, copper or cast iron
— estimated square feet EDR
for typical units



Copper convectors Cabinet dimensions (inches) (Typical data — EDR varies slightly with manufacturer)										Cast iron convectors Cabinet dimensions (inches) (Typical data — EDR varies slightly with manufacturer)					
Approx. Cabinet Depth (inches)	Approx. Cabinet Length (inches)	Cabinet height (inches)					Approx. Cabinet Depth (inches)	Approx. Cabinet Length (inches)	Cabinet height (inches)						
		18	20	24	26	32			38	18	20	24	26	32	38
4	20	10.4	11.3	13.1	13.3	14.0	14.6	4 (No. 3)	18	8.4	9.1	10.5	11.0	11.8	12.3
	24	12.8	13.9	16.1	16.4	17.2	17.9		23	10.9	11.8	13.5	14.2	15.2	15.9
	28	15.2	16.5	19.1	19.4	20.4	21.3		28	13.3	14.4	16.5	17.4	18.6	19.4
	32	17.6	19.1	22.1	22.5	23.6	24.6		33	15.8	17.1	19.7	20.6	22.1	23.0
	36	20.0	21.7	25.2	25.5	26.8	28.0		38	18.2	19.7	22.7	23.8	25.5	26.5
	40	22.4	24.3	28.2	28.6	30.0	31.3		43	20.6	22.3	25.7	26.9	28.9	30.1
	44	24.8	26.9	31.2	31.6	33.2	34.7		48	23.1	25.0	28.7	30.1	32.3	33.6
	48	27.2	29.5	34.2	34.7	36.4	38.0		53	25.5	27.6	31.8	33.3	35.7	37.2
	56	32.0	34.7	40.8	42.8	44.7	46.7		58	28.0	30.3	34.8	36.5	39.1	40.7
	64	36.8	39.9	46.3	46.9	49.2	51.4		63	30.5	33.0	37.9	39.7	42.5	44.3
6	20	15.3	16.3	18.4	18.8	19.7	20.6	6 (No. 5)	18	12.3	13.5	15.4	16.2	17.5	18.2
	24	18.9	20.1	22.7	23.1	24.2	25.4		23	15.9	17.4	19.9	20.9	22.6	23.5
	28	22.3	23.8	26.9	27.4	28.7	30.1		28	19.5	21.3	24.4	25.6	27.7	28.8
	32	25.8	27.6	31.1	31.7	33.3	34.8		33	23.1	25.2	28.9	30.4	32.9	34.1
	36	29.3	31.3	35.4	36.0	37.8	39.6		38	26.7	29.2	33.4	35.1	38.0	39.4
	40	32.8	35.1	39.6	40.3	42.3	44.3		43	30.3	33.1	37.9	39.8	43.1	44.7
	44	36.3	38.8	43.8	44.6	46.8	49.0		48	33.9	37.0	42.4	44.5	48.1	50.0
	48	39.8	42.6	48.1	48.9	51.3	53.8		53	37.5	40.9	46.8	49.2	53.3	55.3
	56	46.8	50.1	56.5	57.5	60.4	63.2		58	41.1	44.8	51.3	53.9	58.4	60.6
	64	53.8	57.6	65.0	66.1	69.4	72.7		63	44.7	48.7	55.8	58.7	63.5	65.9

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LIST OF TABLES AND ILLUSTRATIONS

Hydronic Energy Efficiency and Service

Blower door	16
Home air leakage values	16
Existing buildings and their heating loads	18

Evaluating Combustion and Venting

Atmospheric, open-combustion gas burners	21
Effects of CO	23
Testing Requirements for Combustion Appliances and Their Venting Systems.....	25
Flame roll-out	27
Worst-case depressurization	28
Maximum CAZ or Mechanical Room Depressurization for Various Appliances	29
Negative versus positive draft.....	30
Measuring draft	31
Draft Problems and Solutions	32
Combustion Standards for Gas Boilers.....	35
Carbon Monoxide Causes and Solutions.....	36
Primary air adjustment.....	36
Input in Thousands of BTU/hr for 1000 BTU/cu. ft. Gas ...	42
Gas meter dial	43
Measuring gas pressure.....	44
Barometric draft control	46
Combustion Standards – Flame-Retention Oil-Burners ...	47
Minimum Worst-Case Draft for Oil-Fired Appliances	48
Measuring oil-burner performance.....	48
Oil burner	51
Oil spray pattern and combustion chamber	52
Flame-retention burner.....	52

Combustion Air Supply and Exhaust Venting

Combustion Air From Indoors.....	57
Louvered mechanical room vent.....	58
Combustion Air Supplied to Mechanical Room from Outdoors.....	59
Fan-powered combustion air.....	59
Combustion Air for Sealed Combustion.....	61
Detecting gas spillage.....	63
Masonry chimneys.....	64
Clearances to Combustibles for Common Chimneys.....	65
All-fuel metal chimney.....	66
Two vent connectors joining chimney.....	67
Clearances to Combustibles for Vent Connectors.....	68
Vent Connector Diam. vs. Max. Horiz. Length.....	68
Areas of Round Vents.....	68
Chimney terminations.....	69
Roof Slope and B-Vent Chimney Height (ft).....	69
Flexible metal chimney liners.....	70
AGA venting categories.....	71
B-vent chimney liner.....	72
Characteristics of Gas Boilers.....	73
Fan-assisted gas heaters with vertical chimneys.....	74
Fan-assisted heaters with sidewall vents.....	74
Condensing boiler venting.....	75
Power venters.....	76
Guide to Venting Standards.....	78

Choosing Boilers

Combustion Standards for Gas-Burning Boilers.....	82
Oil heating system.....	83
Combustion Standards – Oil-Burning Appliances.....	85
Reset controller.....	87

Water-Heating Energy Savings

Water-saving shower heads	93
Demand hot-water circulation	94
Standard gas water heater	98
Standard oil water heater	98
Induced-draft water heaters	101
Sealed-combustion water heaters	101
Advanced gas water heater	102
Setting hot-water temperature	102
Water heater insulation	104
Sealed-combustion tankless water heater	105
Obsolete tankless water heater	105
Tankless coil	106
Immersed coil	107
Tankless coil	108
Immersed coil	108
Plate and shell heat exchanger	108
Storage tank versus mixing valve	108
Closed loop antifreeze system	111
Drainback system	111

Hot-Water Space-Heating

Panel radiator-convactor	113
Split loop	114
Purging air	115
Hot-water system components	116
Volume Multipliers for Type M Copper Pipe	118
Modern hot-water system controller	118
Zone valves	120
Zone pumps with zone controller	120
Manifold with zone valves	121
Boiler loop and low-temperature heat emitters	121
Thermostatic radiator valve	122
Pump and system curves	123
Three-piece pump	125

Supply Temperature & Heat-Emitter BTUH Capacity	126
Maximum Flow and BTUH Capacity of Pipe	127
Fiberglass pipe insulation	128

Steam Heat Distribution

Modern Steam Boiler	129
Steam header piping	131
Low-water cutoff	134
Condensate tank and feed pump	135
One-pipe steam systems	139
Two-pipe steam systems	140
Steam Orifice Sizing Table	142

INDEX

A

Acid solutions	
flushing heat exchangers	106
AFUE. See Annual Fuel Utilization Efficiency	
Air	
excluding from piping	114-116
flow of	135-137
purging	115
venting from steam systems	139-140
Air Conditioning Contractors of America	18
Air eliminator. See Air separator	
Air excluder. See Air separator	
Air leakage	
measuring, blower doors	16
Air separator	86, 114
Air shutters, oil	50
Air-leakage	
rates of	16
Air-sealing	
ventilation and	16
Alarms	
carbon monoxide	26
smoke	26-27
American Gas Association	
venting categories	71
Annual Fuel Utilization Efficiency	34, 71
Antifreeze system	
solar water heating	111
Automatic controls	
cutout controllers	87
cycle controllers	133
feeders	135
hot-water systems	118-122
low-water cutoff	134
oil burners	49-50

pressure controllers	130
reset controllers	87
steam boilers	133-135
thermostats	133
verifying functioning	20
zone	120-121
Automatic feeders	135

B

Barometric dampers	46, 76
Blower doors	16
test procedures	14-18
Boilers	
cleaning	131-132
combustion problems	81
commissioning	19-20
condensing	19
efficiency. See Steady-state efficiency	
evaluating water quality	131
failure	79-81
features	19
hot-water controls	118-122
installation	85-90
low-mass	107
power venting	19
replacement	79-89
selection	19
sizing	18, 86
steam, controls	133-135
steam, sizing	88-89
steam, water line	89
water quality	131-132
Building Performance Institute	21
Buildings	
as systems	13
heat loss	14-17
Burners	21-53
gas, servicing	21-22

nozzle for oil	50	from outdoors	58-60
oil	45-53	sealed combustion	60
C		Combustion appliance zone	
<hr/>			
Cad cell	48	isolation test	33
Carbon monoxide	23-26	worst-case test	29-31
alarms	26	Combustion chamber	53
causes of	24	Combustion efficiency. See Steady-state efficiency	
causes/solutions	36	Combustion testing	20, 34-37
effects	23-26	critical parameters	36-37
exposure limits	23-24	drilling holes	35
maximum level	34	oxygen level	34
maximum level in CAZ	25	worst-case test	27-31
standard for oil	35, 47, 82, 85	Combustion zone	
testing	24, 25	definition	27
Chimney liners		Combustion. See also Combustion testing	
insulating	70	Condensate	
sizing	70	flow of	135-137
Chimneys	64-72	one-pipe steam	138
all-fuel	66	receiver	140
clearances	65	two pipe systems	140
high-temperature plastic	73	Controls. See Automatic controls	
masonry specifications	64	Convection	15
measures to improve draft	32	Corrosion	
retrofit liners	69, 72	boiler failures and	80
termination	68	chimneys	80
types	64	prevention	114, 132
Circulators. See Pumps		storage tanks and	95
CO. See Carbon monoxide		water treatment and	80
Combustion		Cutout controls	87
inspecting gas systems	38-39	Cycle controllers	133
maintaining/adjusting gas systems	39-40	D	
oil standards	47, 85	<hr/>	
problems, boilers	81	Demand circulation	94
safety and efficiency	21-53	Direct vent. See Sealed combustion	
sealed	79	Domestic hot water	
the chemical process	21	boiler capacity and	89
Combustion air	57-60	Draft	
cfm requirements	27	measuring	31
evaluating	38	over-fire	47
fan-powered	59	positive	73
from indoors	57-58		

Drainback system 111

E-F

EDR. See Equivalent direct radiation

Efficiency

steady state 91

storage water heaters and 99-100

water heating 91-93

Energy factor 91, 98, 100

water heating 101, 103

Equivalent direct radiation

boiler sizing and 88

tables 143-145

Excess air

oil burners 47

Expansion tanks 86

capacity 117

Feeders

automatic 135

Feedwater

limiting 115-116

minimizing 132-133

Flame roll-out 27

Flame-retention burners 52

Flexible gas lines

safety of 22

Flue dampers. See vent dampers

Flue-gas analysis 46

G

Gas. See Natural gas

Gas burners

clocking gas meter 40

maintenance/service 21-22

operation of 21

Gas meters

clocking 40-43

Gas valves 44

modulating 106

H

Heat distribution

evenness of 20

Heat emitters

cleaning 128

types of 113

Heat load. See Heat loss

Heat loss 14-17, 18, 138

Heating systems

combustion safety 21-53

hot-water 123

oil-fired 45-53

steam 129-142

Hot-water space heat 113-128

components 116

curves 123

Hydronic systems

commissioning 19-20

definition 13

hot-water space heat 113-128

steam heat 129-142

I

Immersed coil 108

Indirect water heaters 107-108

Infiltration. See Air leakage

Instantaneous water heaters 105

Insulation 14-15

convection and 15

floor or foundation 14

loose-fill 15

pipe 87, 95, 95, 137

storage tanks and 97

water-heater blankets 103-104

J-M

Low-limit	87
Low-mass boilers	107
Low-water cutoff	134
Manifolds	121
Manometers	
digital	27
Manual J	18
Mixing valves	107, 108
Multifamily buildings	
storage tanks for	96

N-O

National Fire Protection Association	
standards	77
Natural gas	
adjusting pressure	43-44
heat content	43
input	37
leak testing	40
measuring input	40-43
pressure	37
NFPA. See National Fire Protection	
Association	
Oil burners	45-53
controls for	49-50
excess air	47
ignition	46
maintenance/adjustment	50-51
nozzles	50
parts of	51
performance	48
performance indicators	47, 82, 85, 118
spray pattern	52
Oil filters	50
Oil pressure	35, 47, 85
One-pipe steam	138-140
Orifices	
steam	141

Over-fire draft	47
Oxygen	
combustion testing and	34

P-Q

Pipe insulation	95
Piping systems	
excluding air	114-116
hot-water types	113
one-pipe steam	138-140
two-pipe steam	140-141
Power venters	19, 72, 75-77
Pressure	
control, steam	130
differential	130
fill, hot water	116-117
maximum steam	130
maximum vapor	130
Pressure controllers	130
Pressure relief valves	86, 116, 134
Pressure tank. See Expansion tank	
Primary air	
adjustment	36
Propane	71
finding leaks	22
Pumps	122-125
curves	123
downsizing	124-125
hydronic, installation	86
location in system	86
lubrication	125
sizing	123-124
solar systems and	110
throttling	124
trimming impellers	125
zone	121

R

Radiation	
boiler sizing and	18, 88, 143-145
Radiator valves	
thermostatic	122, 141

Radiators		Steam traps	129, 140-141
covers	137	failure	141
swapping	128, 138	switching to orifices	141
Reset controllers	87	Storage tanks	95-97, 108, 109
R-value	15	insulation	97
S		sizing	96
<hr/>			
Safety		Storage water heaters	97-100
pipe insulation and	95	efficiency	99-100
storage water heaters	99	improving	102-103
water-heater insulation and	103	insulating blankets	103-104
Sealed combustion	22, 60, 79	safety	99
water heaters	101, 105	specifications, replacement	101-102
Showers		T-V	
measuring flow	93	<hr/>	
Sizing		Tankless coil	108
storage tanks	96	Tankless water heaters	105
Smoke alarms	26-27	Tanks	
Smoke number	35, 47, 85	storage	95-97
Solar water heating	109-111	Thermal boundary	14
antifreeze systems	110-111	Thermal bridging	14
drainback systems	110	Thermal envelope. See Thermal	
Steady-state efficiency	34, 35, 47, 52,	boundary	
82, 88, 91		Thermal resistance	14
testing for	46	Thermal wall sheathing	15
Steam		Thermostatic radiator valves	122,
flow of	135-137	141	
orifices	141	Thermostats	133
pressure	130, 139	Two-pipe steam	140-141
pressure control	130	Valves	
quality of	129-133	mixing	107, 108
Steam chest	129	pressure relief	116
Steam dome	129	thermostatic radiator	122, 141
Steam heating systems	129-142	zone	120-121, 122
boiler replacement	88-90	Vapor systems	130
converting to hot water	142	Vent connectors	66-68
one-pipe	138-140	clearances	68
reducing excessive condensate	137	materials	66
two-pipe	140-141	specifications	67
water hammer	136	Ventilation	17
water quality	129-133	Venting	
Steam orifices		AGA categories	71
replacing steam traps	141	atmospheric	64-70

fan-assisted	71-73
for condensing furnaces	74
for new boilers	87
high-temperature plastic	73
power	19
power venting	22
problems	73
sealed combustion	22
sealed-combustion	74

W-Z

Water flow rate	
measuring	93
Water hammer	141
defeating	136
Water heaters	91-101
condensing	102
indirect	107-108
induced-draft	101
instantaneous	105
insulation blankets	103-104
oil fired	98
sealed combustion	101, 105
sealed-combustion	101
solar	109-111
storage	97-100
storage tanks	95-97
tankless	105
Water heating	
boiler capacity and	89
circulation	94
improving efficiency	91-93, 102-104
solar	109-111
Water quality	80, 129-133
Water softeners	106
Worst-case spillage test	27-31
Zone controls	120-121
Zone valves	120-121, 122