5 Electrical System

Electrical systems for small residential buildings are usually simple in concept and layout. Primary components are the service entry, panelboard, and branch circuits. In unaltered buildings built since about 1940, the electrical system is likely to be intact and safe, although it may not provide the capacity required for the planned reuse of the building. Electrical capacity can be easily increased by bringing additional capacity in from the street and adding a larger panelboard between the service entry and the existing panel. Existing circuits can continue to use the existing panel and new circuits can be fed through the new panel.

The electrical systems of small residential buildings built prior to about 1940 may require overhaul or replacement, depending on rehabilitation plans and the condition of the electrical system. Parts of these older systems may function very adequately and they can often be retained if the rehabilitation is not extensive and the load-carrying capacity is adequate.

A thorough and informed assessment of the electrical system will determine the extent to which it can be reused. This assessment should be conducted only by a qualified electrician who is experienced in residential electrical work.

When universal design is a part of a rehabilitation, consult HUD publication *Residential Remodeling and Universal Design* for detailed information about electrical devices.

Assess the capacity of the building's existing electrical service in accordance with Figure 5.1.

The safety standards for the following assessment procedures are generally based on the requirements of the *National Electrical Code*.

5.1 Service Entry

Inspect for the following conditions in the electrical service between the street and the main panelboard:

- **Overhead wires.** Check that overhead wires from the street are no lower than 10 feet above the ground, not in contact with tree branches or other obstacles, and not reachable from nearby windows or other accessible areas. Make sure that the wires are securely attached to the building with insulated anchors, and have drip loops where they enter the weatherhead. Spliced connections at the service entrance should be well wrapped, and bare wires from the street should be replaced by the utility company. Wires should not be located over swimming pools.
- **Electric meter.** Check that the electric meter and its base are weatherproof, and that the meter is functional, has not been tampered with, and is securely fastened. Advise the utility company of any problems with the meter.
- **Seismic vulnerability.** If the building is in a seismic zone, check the electrical service for vulnerability to differential movement between the exterior and interior. Look for flexible connections.
- **Service entrance conductor.** Ensure that the service entrance conductor has no splices and that its insulation is completely intact. If the main panelboard is located inside the building, the conductor's passage through the wall should be sealed against moisture. Where aluminum conductors are used, their terminations at all service equipment should be cleaned with an oxide inhibitor and tightened by an electrician or replaced with equal capacity copper conductors. When it is necessary to replace an overhead service entry, have it replaced with an underground service entry.
- **Type of power available.** Not every jurisdiction provides the same kind of electrical power. Philadelphia, for example, has two-phase electrical power in some locations rather than the more common single-phase. Check with the power company to determine the characteristics of the power available.

5.2
Main Panelboard (Service Equipment)

The main panelboard is the distribution center for electric service within the building and protects the house wiring from overloads. Inspect the panelboard as follows:

- **Condition and location**. Check the overall condition of the panelboard. Water marks or rust on a panel mounted inside the building may indicate water infiltration along the path of the service entrance conductor. Panelboards mounted outdoors should be watertight and tamper proof. Panels mounted indoors should be located as closely as possible to where the service entrance conductor enters the building and should be easily accessible. The panelboard should have a workable and secure cover.
- **Amperage rating**. The amperage rating of the main disconnect should not be higher than the amperage capacity of the service entrance conductor or the panelboard. If the rating is higher (indicating unapproved work has been done), more branch circuits may be connected to it than the service entrance conductor is capable of supplying. This is a serious hazard and should be corrected.
- **Voltage rating.** The voltage rating of the panelboard (as marked on the manufacturer's data plate) should match the voltage of the incoming electrical service.

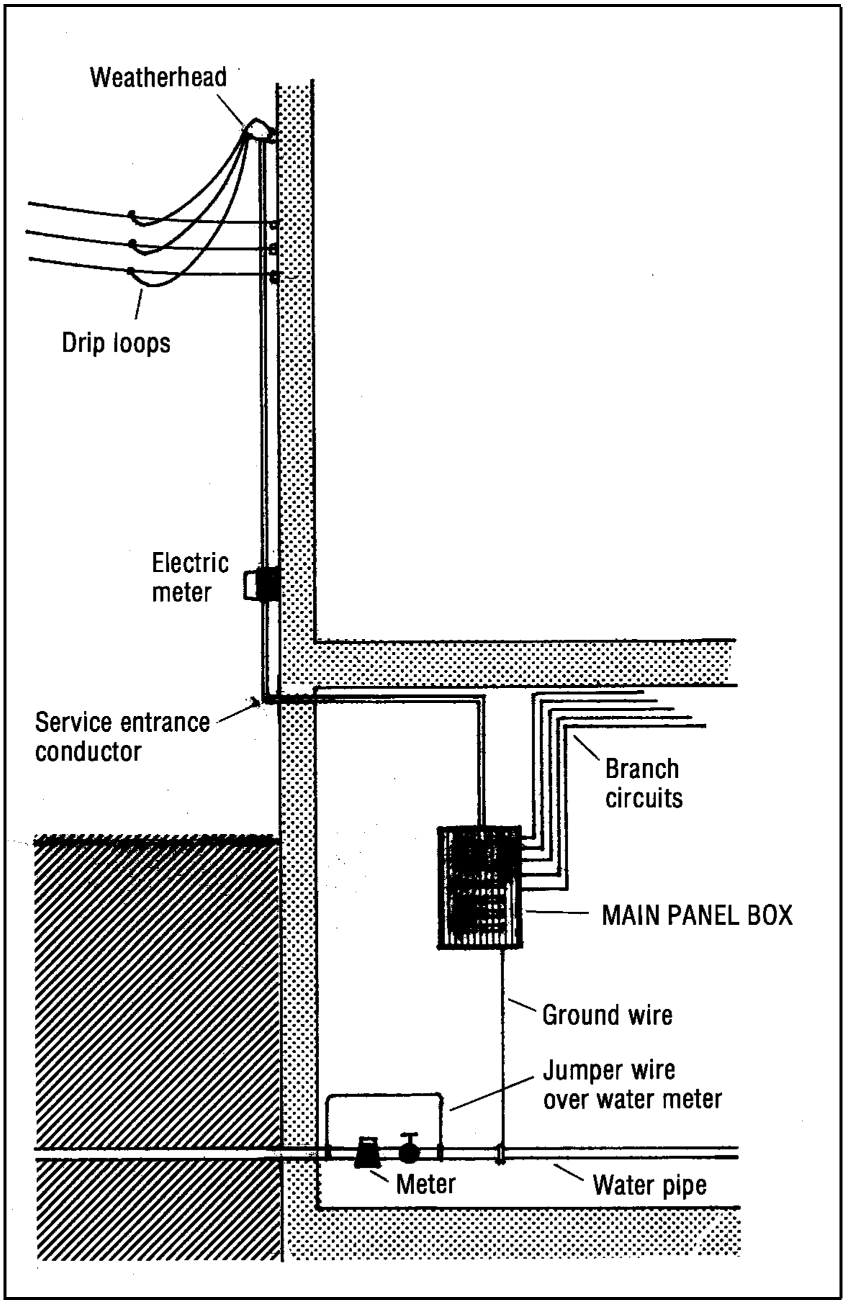
Figure 5.1
Assessing Electrical Service Capacity (Ampacity)

To determine the capacity (measured in amperes) of the building's existing electrical service at the main panelboard, check the following:

- The ampacity of the service entry conductor, which may be determined by noting the markings (if any) on the conductor cable and finding its rated ampacity in the *National Electrical Code*, Table 310-16, or applicable local code. If the service entry conductor is in conduit, look for markings on the conductor wires as they emerge from the conduit into the panelboard. If all conductors are unmarked, have an electrician evaluate them.
- The ampere rating on the panelboard or service disconnect switch, as listed on the manufacturer's data plate.
- The ampere rating marked on the main circuit breaker or main building fuse(s). This rating should never be higher than the above two ratings; if it is, the system should not be used until it is evaluated by an electrician.

The building's service capacity is the lowest of the above three figures. Once the service ampacity has been determined, compare it to the estimated ampacity the building will require after rehabilitation. If the estimated ampacity exceeds the existing ampacity, the building's electrical service will need upgrading. The method for estimating required ampacity is found in the *National Electrical Code*, Article 220.

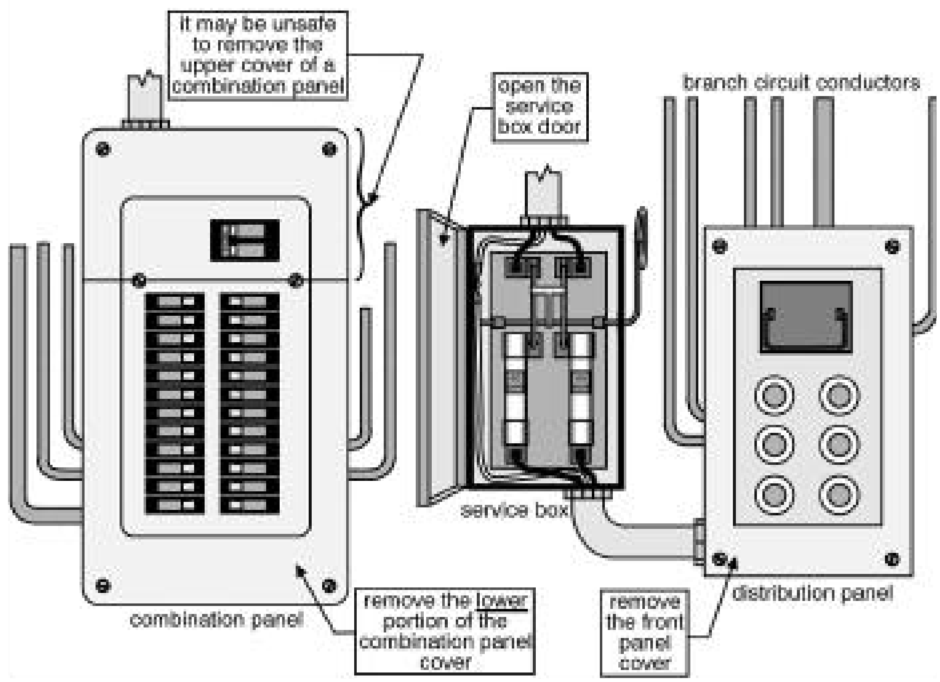
Similarly, the service capacity of each branch circuit can be determined by checking the markings on each branch circuit conductor. If no markings can be found, a plastic wire gauge may be used to measure the wire size (with the power disconnected), although an experienced person can often determine the size by eye. Find the ampere rating of the conductor, either by its markings or wire size, in the *National Electrical Code*, Table 310-16, or applicable local code.



Typical electrical service entry and main panelboard for a single family residence. This type of grounding applies only if the water pipe is metal. If the water pipe is plastic, a separate driven ground rod is required.

Test: The actual voltage rating of the incoming electrical service can be checked with a voltmeter. This test should be performed by an electrician. Usually three service conductors indicates 120/240 volt current, and two conductors indicates 120 volt current.

- **Grounding.** Verify that the panelboard is properly grounded. Its grounding conductor should run to an exterior grounding electrode or be clamped to the metal water service inlet pipe between the exterior wall and the water meter. If it is attached on the house side of the meter, the meter should be jumpered to ensure proper electrical continuity to the earth. Make sure that the ground conductor is securely and properly clamped to the pipe—often it is not, and occasionally it is disconnected altogether. Ensure also that the grounding conductor is not attached to a natural gas pipe, to an inactive pipe that may be cut off on the exterior side of the wall, or to a pipe that is connected to a plastic water service entry line. If the grounding conductor is attached to an exterior grounding electrode driven into the earth, verify that the electrode is installed in accordance with local code. Many older buildings will have the ground connected to the cold water pipe. If this is the case and the building needs to conform to the current code, an alternate ground is required.



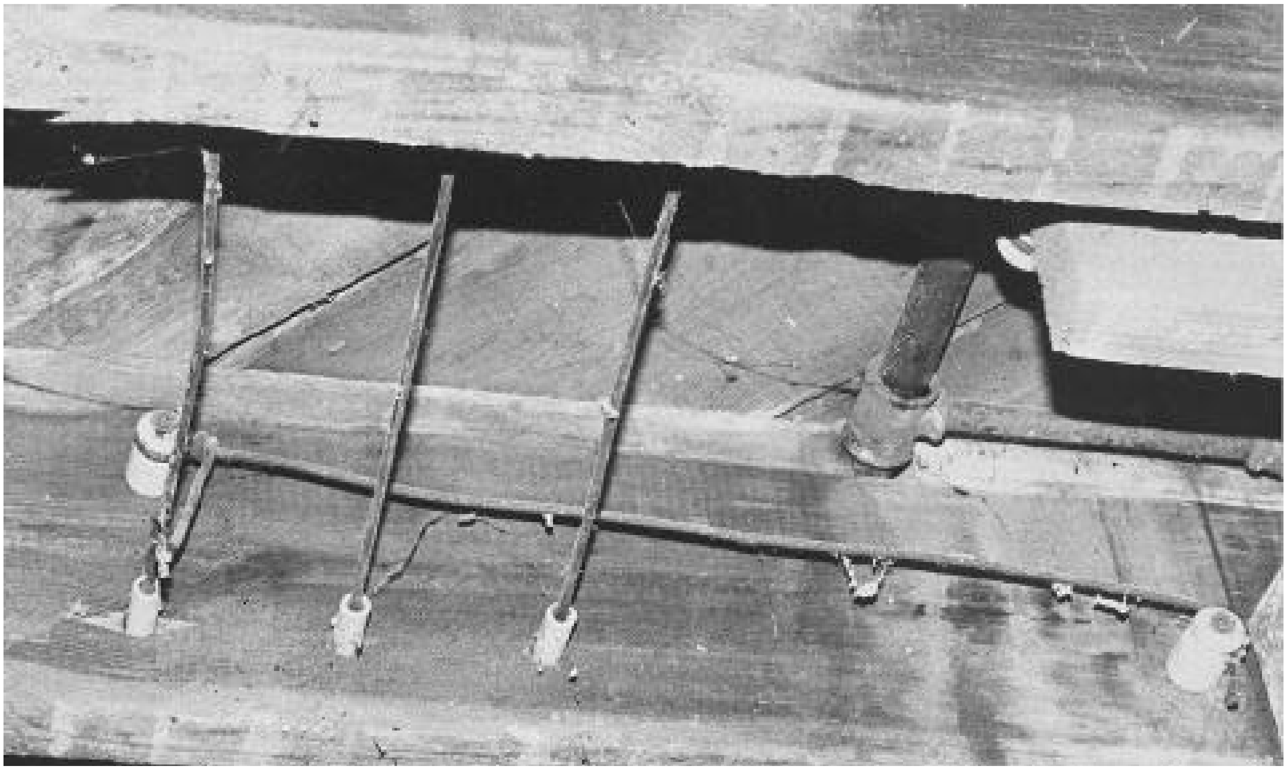
Typical service equipment

Test: An electrical ground (resistance-to-ground) test may be used to determine whether the electrical system is well grounded to the earth. The test requires the use of an ohmmeter and should be performed by an electrician.

- **Overcurrent protection.** Check the rating of the fuse or circuit breaker for each branch circuit. The amperage of the fuse or circuit breaker should not exceed the capacity of the wiring in the branch circuit it protects. Most household circuits use #14 copper wire, which should have 15 amp protection. There may be one or more circuits with #12 copper wire, which should have 20 amp protection. Large appliances, such as electric water heaters and central air conditioners, may require 30 amp service, which is normally supplied by #10 copper wire. If there is an electric range, it would require a 40 or 50 amp service with #6 copper wire. Central air conditioning equipment will have an overcurrent protection requirement on the nameplate. Aluminum wire must be one size larger than copper wire in each case (e.g., #14 to #12), but it should not be used for 15 and 20 amp circuits. See Figure 5.1 for determining wire size.

  Make sure that no circuit has a fuse or circuit breaker with a higher ampere rating than its wiring is designed to carry. Air conditioners and other equipment with motors may have circuit breakers up to 175 percent ampacity of the conductor rating to allow for starting current. Look near the panelboard for an inordinate number of new or blown fuses, or breakers taped in the "on" position. Be suspicious of 20 or 25 amp fuses on household lighting circuits. These are signs of frequent overloads and inadequate electrical service. Other indications of overloading are the odor of burned insulation, evidence of melted insulation, discolored copper contact points in the fuse holders, and warm fuses or circuit breakers.

Test: Flip all circuit breakers on and off manually to make sure they are in good operating condition. A commercially available circuit breaker and resistance tester, which can simulate an overload condition, can be used to test each breaker. Such a test should be performed by an electrician. Note



This knob and tube wiring is in good condition except for a piece of broken insulation (top of photograph).

that this test is not recommended for computers, VCRs, clocks, and many similar devices.

Many older residential buildings have more than one panelboard or fused devices. Check that all supplementary overcurrent devices are located in metal boxes and that they are not in the vicinity of easily ignitable materials. All panelboards must have covers. It should be possible to turn off all electrical power to a dwelling from a single location.

5.3 Branch Circuits

The oldest types of residential wiring systems are seldom encountered today. They include open wires on metal cleats, wiring laid directly in plaster, and wiring in wooden molding. These systems proved quite hazardous. The oldest wiring system that may still be acceptable, and one still found fairly often in houses built before 1930, is “knob and tube.” This system utilizes porcelain insulators (knobs) for running wires through unobstructed spaces, and porcelain tubes for running wires through building components such as studs and joists. Note whether knob and tube wiring splices are mechanically twisted, soldered, and taped, as required. Knob and tube wiring should be replaced during rehabilitation; but if it is properly installed, needs no modification, has adequate capacity, is properly grounded, has no failed insulation, and is otherwise in good condition, it can be an acceptable wiring system and is still legal in many localities. Check with local building code officials. Also check the terms and conditions of the home insurance policy in force to see if knob and tube wiring is excluded. The greatest problem with such wiring is its insulation, which turns dry and brittle with age and often falls off on contact, leaving the wire exposed.

The armored cable and junction box are in good condition and can be reused, even if the lighting fixture is relocated.

Insulation that can be seen to have failed also will likely have failed where wiring is concealed. If any failed insulation is observed, the knob and tube wiring should be replaced.

Other approved wire types include:

- **NM** (non-metallic) cable, often called by the trade name "Romex," a plastic covered-cable for use in dry locations (older NM cable may be cloth covered).
- **NMC,** similar to NM but rated for damp locations.
- **UF** (underground feeder), a plastic-covered waterproof cable for use underground.
- **AC** (armored cable), also called BX, a flexible metal-covered cable.
- **MC** (metal-clad cable), a flexible metal-covered cable with a green insulated ground conductor.
- **EMT** (electrical metallic tubing), also called "thinwall," a metal conduit through which the wires are run in areas where maximum protection is required.

Check branch circuits for the following:

- **Marking.** The function of each branch circuit should be clearly and legibly marked at its disconnect, fuse, circuit breaker, or on the directory on the panelboard.
- **Connected loads.** Trace branch circuit conductors to determine that their connected load does not exceed their rating (e.g., a 30 amp clothes dryer connected to a 20 amp circuit). Generally speaking, each dwelling unit should have two to four 15 amp circuits for lighting and convenience outlets; two 20 amp circuits for appliances in the kitchen, dining, and laundry areas; and separate circuits of appropriate ampacity for large appliances such as dryers, ranges, disposals, dishwashers, and water heaters. See Section 3.4 for additional kitchen electrical service information. Check the size and length of all branch circuit wiring against the requirements of the local electrical code. Buildings built before 1980 may be considered to have an inadequate number of circuits because present day codes require a separate laundry circuit and a separate circuit for the bathroom receptacle. For air conditioning units, many local codes will allow one wire size smaller than called for in the disconnect.

  Test: A voltmeter may be used to measure voltage drop due to excessive branch circuit length, poor wiring connections, or undersized wire. Measurements must be made under a connected load. This test should be performed by an electrician.

- **Grounding.** It is best that all circuits be grounded to the panelboard, but this was not required by the *National*

Electrical Code prior to 1965. Do not assume that circuits in metal cable are grounded without testing each outlet. Also, do not assume that three-prong plug convenience outlets are connected to ground. Remove each one to observe the presence of a connected ground wire. Check to see whether GFI (ground fault interruption) type receptacles have been installed in laundries, kitchens, and bathrooms, and test their operation. These types of receptacles were not required before 1990, but are easily installed as replacements.

Test: Commercially available circuit analyzers can be used for checking the following circuit conditions: open ground, open hot, open neutral, hot/ground reversed, hot/neutral reversed. Operation of these analyzers varies by manufacturer.

- **Condition and safety.** Check that all wire types and equipment are installed properly in accordance with good practice. Check the conductors' exposure to possible damage or abrasion. Look for proper fastening, clearance, and frayed or damaged insulation. Make certain that all wire splices are made in work boxes and that all boxes for splices and switches have cover plates. Check all exterior receptacles to make sure they are of the waterproof type.

Test: A megohm test may be used for detecting deteriorated insulation. It requires a Megger tester and operates at high voltage. With the electrical service disconnected, branch circuits should read at least one megohm to ground. If lights or appliances are connected to the circuit, readings should be at least 500,000 ohms. This test should be performed by an electrician. A visual inspection of insulation on accessible circuits will usually determine whether additional tests should be performed by an electrician.

Look for unprotected wire runs through ducts and other inappropriate areas. Inspect for evidence of "handyman tampering" (e.g., unconventional splices), and if found in one location, expect it to be more widespread. Check for surface-mounted lamp cord extension wiring. It is dangerous and must be removed. It is best to remove all unused wiring or wiring that will be abandoned during rehabilitation work to avoid future confusion or misuse.

- **Aluminum wire.** Aluminum wire was used in residential buildings primarily during the 1960s and early 1970s. Inspect with local code requirements in mind. Be sure that aluminum wire is attached only to approved devices (marked "CO-ALR" or "ICU-AL") or to approved connectors. Problems with aluminum wiring occur at connections, so feel all cover plates for heat, smell for a distinctive odor in the vicinity of outlets and switches, and look for sparks and arcing in switches or outlets and for flickering lights. Also check for the presence of an oxide inhibitor on all aluminum wire connections. All such conditions should be corrected. Aluminum wire should not be used on 15 and 20 amp circuits. Whenever possible, aluminum wire and its devices should be replaced with copper wire and devices appropriate for copper. If aluminum wiring is not replaced, it must be frequently inspected and maintained.
- **Smoke Detectors.** Check to see if buildings have functioning smoke detectors. Detectors should be wired to a power source, and also should contain a battery. Most likely, buildings built before 1970 will not have detectors, but they should be added.

6
Plumbing System

A thorough assessment of the plumbing system will determine the extent to which it, like the electrical system, can be reused. Older piping in particular may require replacement, but other parts of the system may function very adequately and can be retained if rehabilitation is not extensive. Also see Sections 3.3 and 3.4 for additional plumbing information.

If the plumbing system appears to be functioning properly after checking, consider the effects of additional loads that may be imposed on the system by any rehabilitation that might be planned for the building.

Assess the capacity of the building's existing plumbing system in accordance with Figure 6.1.

6.1
Water Service Entry

Inspect the following water service components:

- **Curb valve** (also known as the curb cock or curb stop). The curb valve is located at the junction of the public water main and the house service main, usually near the street. Locate it and check its accessibility and condition. The curb valve is usually the responsibility of the municipal water department.
- **House service main.** The house service main begins at the curb valve and ends at the inside wall of the building at the master shutoff valve. The main is normally laid in a straight run between the two and its location can thereby be traced. Codes require that the main be at least 10 feet (3 m) away from the sanitary sewer or located on a plane one foot above it. Mains made of galvanized steel last about 20 to 30 years under normal soil and water conditions, although joints may leak sooner. If the building is approaching or more than 40 years old, consider replacing the main.

  Test: Leaks in the main can be detected by inspecting for unexplained sources of ground water over the path of the main or by listening with a stethoscope for underground water flow. Stop all water flow inside the building before using this device. If the water meter is located near the street, leaks in the service main can also be detected by turning off all water in the building and watching the meter to see whether it continues to register a water flow.

Check the main where it enters the building; older lines are sometimes made of lead.

  Test: If a lead main is found, have the water analyzed and replace the piping if lead content exceeds 50 parts per billion (0.05 ppm).

- **Master shutoff valve.** A master shutoff valve should be located where the house service main enters the building. If the water meter is located inside the building, look for another water meter outside of the building and two shutoff valves, one on the street side and one on the house side. If a valve appears corroded or damaged, have a plumber check to see that it is operable and not frozen into the open position. The shutoff valve should include a bleed valve for draining the building's interior distribution piping.
- **Water meter**. The water meter is normally the property of the municipal water company and may be located near the street, adjacent to the house, or within the house. Check the meter connections and supports, and inspect for adjacent plumbing constrictions that may reduce the building's water pressure. If the water meter is located inside the house, look for two shutoff valves, one on the street side and one on the house side of the meter.
- **Seismic vulnerability.** If the building is in seismic zones 3 or 4 (California and portions of Alaska, Arkansas, Hawaii, Idaho, Missouri, Montana, Nevada, Oregon, Utah, Wyoming, and Washington), check the water service for vulnerability to differential movement where the piping enters the building. Look for adequate clearance.

Figure 6.1
Assessing Water Supply Capacity

The minimum size of the water service entry should be approximately as follows:

Number of dwelling units served	*Size of galvanized steel pipe (NPS/DN)*	*Size of type K copper pipe (NPS/DN)*
1	1 to 1-1/4 inch (25 to 32 mm)	3/4 to 1 inch (20 to 25 mm)
2	1-1/4 to 1-1/2 inch (32 to 40 mm)	1 to 1-1/4 inch (25 to 32 mm)
3, 4	1-1/2 to 2 inch (40 to 50 mm)	1 to 1-1/4 inch (25 to 32 mm)

The following minimums should generally apply to fixture supply pipes within the building (these are code minimums; 15 psi [103 kPa] at each fixture is preferable to the lower figures listed here):

	Minimum pipe size (NPS/DN)	*Minimum flow rate*	*Minimum flow pressure*
Kitchen sink	1/2" (15 mm)	2.5 gpm (9.5 L/min)	8 psi (55 kPa)
Lavatory	3/8" (10 mm)	2.0 gpm (7.5 L/min)	8 psi (55 kPa)
Shower	1/2" (15 mm)	3.0 gpm (11.5 L/min)	8 psi (55 kPa)
Bathtub	1/2" (15 mm)	4.0 gpm (15 L/min)	8 psi (55 kPa)
Toilet	3/8" (10 mm)	3.0 gpm (11.5 L/min)	8 psi (55 kPa)
Dishwasher	1/2" (15 mm)	2.75 gpm (10.5 L/min)	8 psi (55 kPa)
Laundry	1/2" (15 mm)	4.0 gpm (15 L/min)	8 psi (55 kPa)
Hose bib	1/2" (15 mm)	2.5 gpm (9.5 L/min)	8 psi (55 kPa)

Test: The capacity of the interior water distribution piping should be checked by running the water in all the fixtures in a fixture group (such as a bathroom) and observing whether water flow is adequate. Water flow can be more precisely tested at each fixture by using a water pressure gauge to determine the fixture's pressure in psi, or by clocking the time it takes to fill a gallon jug from each fixture (e.g., a kitchen sink faucet should be able to fill a gallon jug in 24 seconds; that is, 60 seconds divided by 2.5 gpm).

If the service entry is correctly sized but water flow is low throughout the building, the problem will either be the jurisdiction's water pressure or it will be somewhere between the building inlet and the first fixtures on the line. Check for external restrictions in the supply main, such as undersized piping (particularly around the water meter), partially closed valves, or kinks in the piping. If there are no apparent external restrictions, the piping is probably clogged by rust and/or mineral deposits and should be replaced. If water flow is low in only one set of fixtures, examine the fixture risers in a like manner and inspect plumbing fixtures for flow restrictors, clogged aerators, or malfunctioning faucets. If water flow is lower in hot water faucets than cold, suspect problems with the water heater or, more likely, buildup of rust and mineral deposits in the supply lines, since this buildup occurs faster in hot water.

If new fixtures are to be added to the distribution system, have a plumber determine whether the existing piping can carry the additional load by checking the size and condition of the piping and calculating the water demands of the fixture(s) to be added.

6.2 Interior Water Distribution

All piping, regardless of composition, should be checked for wet spots, discoloration, pitting, mineral deposits, and leaking or deteriorated fittings. Fixture risers tend to remain in better condition than supply mains, so their inspection is not as critical. The water flow from all fixtures should be checked.

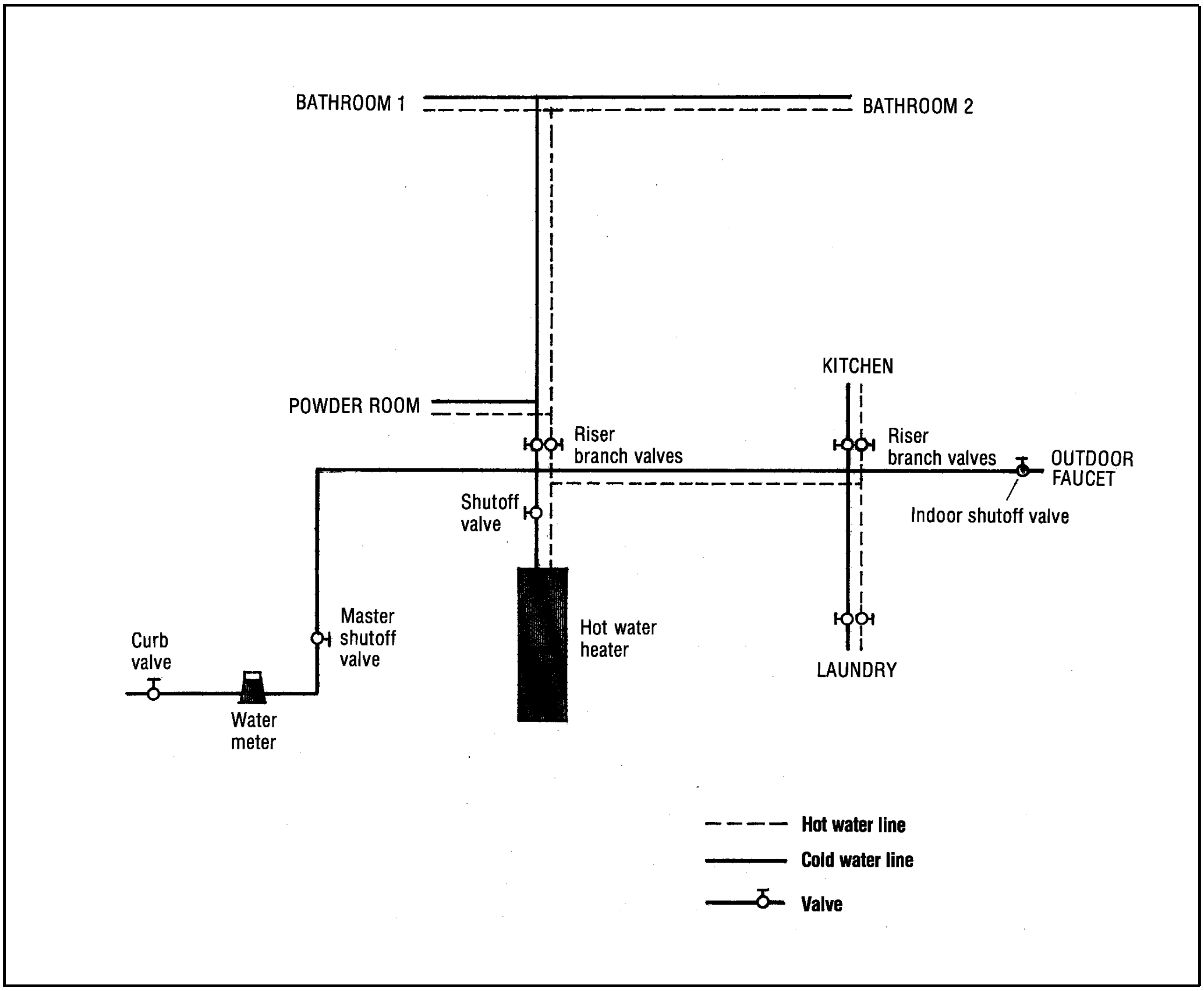
Test: To check water flow, run several plumbing fixtures at once and observe the flow rate at the smallest spout. Rusty water indicates that galvanized steel is present somewhere in the line or, if it only appears from the hot water side, that there is rust in the water heater.

Inspect the following water distribution components:

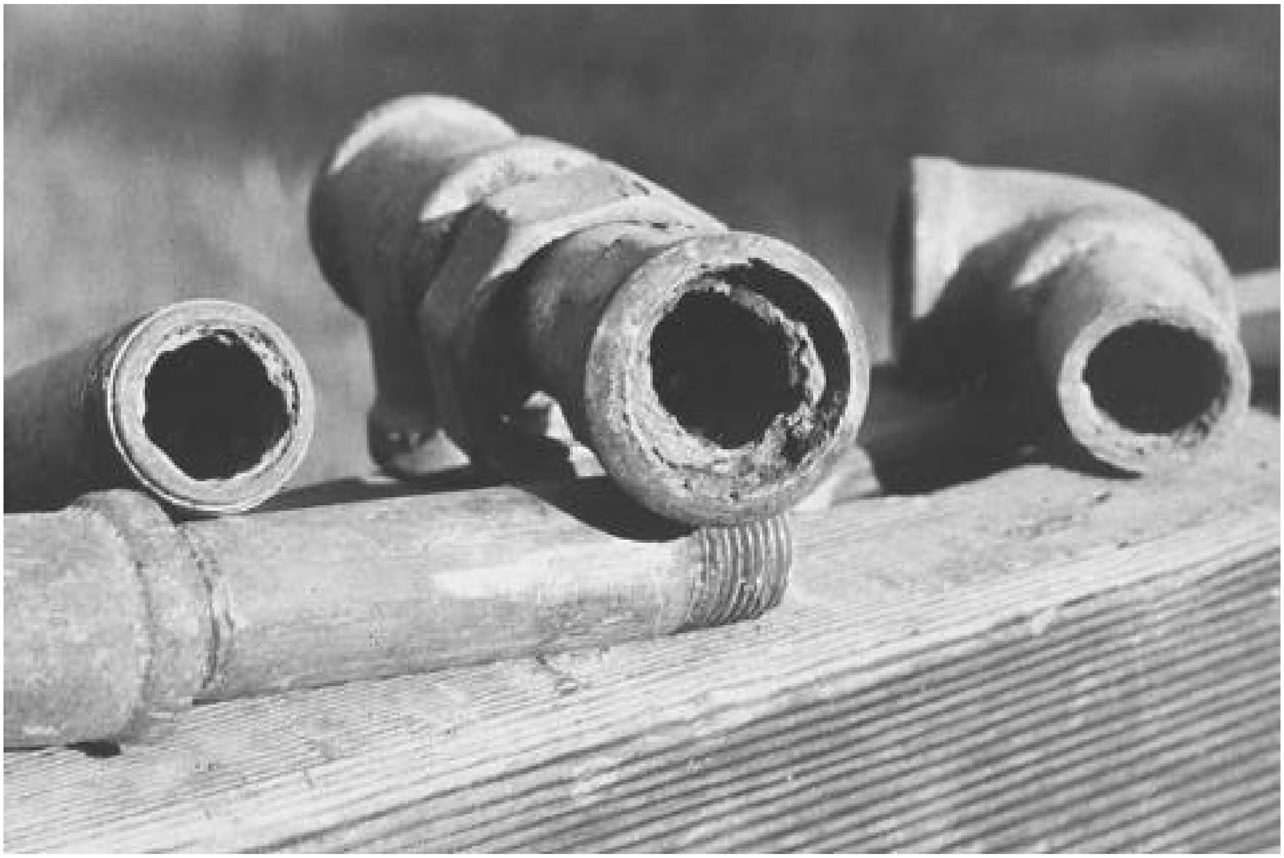
- **Distribution piping.** Distribution piping consists of supply mains and fixture risers.

Most supply mains can be inspected from the basement or from crawl spaces, but the fixture risers are usually concealed within walls and cannot be readily examined. The two most important factors in assessing distribution piping are the piping's material and age.

Test: Pressure test any piping suspected of having leaks.



Typical water distribution system schematic for a single-family residence



Galvanized pipe sections removed from an older house. Mineral deposits and corrosion within the pipe had severely reduced water flow to the plumbing fixtures.

❑ ***Galvanized steel piping*** is subject to rusting and accumulating more mineral deposits than most other piping materials. Depending on the quality of the pipe and its joints and the mineral content of the water it carries, the service life of galvanized steel piping is anywhere from 20 to 50 years. Rusted fittings and rust-colored water, particularly from hot water lines, are signs of advanced deterioration. Low rates of flow and low water pressure are likely to be caused by galvanized steel piping clogged with rust and mineral deposits. During rehabilitation, if galvanized steel piping is exposed, consider replacing it.

❑ ***Brass piping*** is of two varieties, yellow and red. Red is more common and has the longer service life—up to 70 or more years. The service life of yellow brass is about 40 years. Old brass piping is subject to pinhole leaking due to pitting caused by the chemical removal of its zinc content by minerals in the water. Often, water leaking from the pinhole openings will evaporate before dripping and leave whitish mineral deposits. Whitish deposits may also form around threaded joints, usually the most vulnerable part of a brass piping system. Brass piping with such signs of deterioration should be replaced.

❑ ***Copper piping*** came into widespread use in most parts of the country in the 1930s and has a normal service life of 50 or more years. Copper lines and joints are highly durable and usually not subject to clogging by mineral deposits. Such piping need not be replaced unless there are obvious signs of deterioration, leakage, or restriction of water flow. Leakage usually occurs near joints and at supports.

❑ ***Plastic piping*** (ABS, PE, PB, PVC, and CPVC) is a relatively new plumbing material and, if properly installed, supported, and protected from sunlight and mechanical damage, should last indefinitely. However, there are several class action lawsuits pending at this time concerning polybutylene pipe and fittings used inside and outside buildings. Funds resulting from these suits are controlled by local jurisdictions. Check with local authorities or consumer advocate groups for details. Some codes restrict the use of plastic piping. Consult the local building official.

Some newer buildings use a manifold off the water main to distribute cold water and a manifold off the water heater to distribute hot water. From the manifold, flexible plastic pipes are snaked through floors and walls to each plumbing fixture. Check manifolds closely for signs of corrosion and leaks. When testing water flow, all the fixtures off a manifold should be run at the same time.

❑ ***Lead piping*** may be found in very old structures and may pose a health hazard to building occupants.

Test: If lead piping is found, have the water analyzed for lead content and replace the piping if lead content exceeds 50 parts per billion (0.05 ppm).

❑ ***Mixed metal piping*** that is a mixture of galvanized steel and copper or brass piping is a sign of potential trouble and should be closely inspected for corrosion due to galvanic action. Where pipes of dissimilar metals are connected, be certain a dielectric coupling separates them. Also, metal pipes and dissimilar metal supports need to be separated to avoid corrosion. Check connections to plumbing and HVAC equipment, such as water heaters and boilers, to be certain that pipes and connections are the same metal or, if of different metals, that a dielectric coupling separates them. No separation is needed between metal and plastic pipe.

- **Thermal protection.** Examine all water distribution lines for exposure to freezing conditions and look for signs of previous water damage from burst joints or piping. Determine whether the piping remains exposed to freezing and whether any planned rehabilitation work will block the moderating effects of the building's interior temperature from any part of the piping. Consider the costs and benefits of insulating hot water lines during the building's rehabilitation.

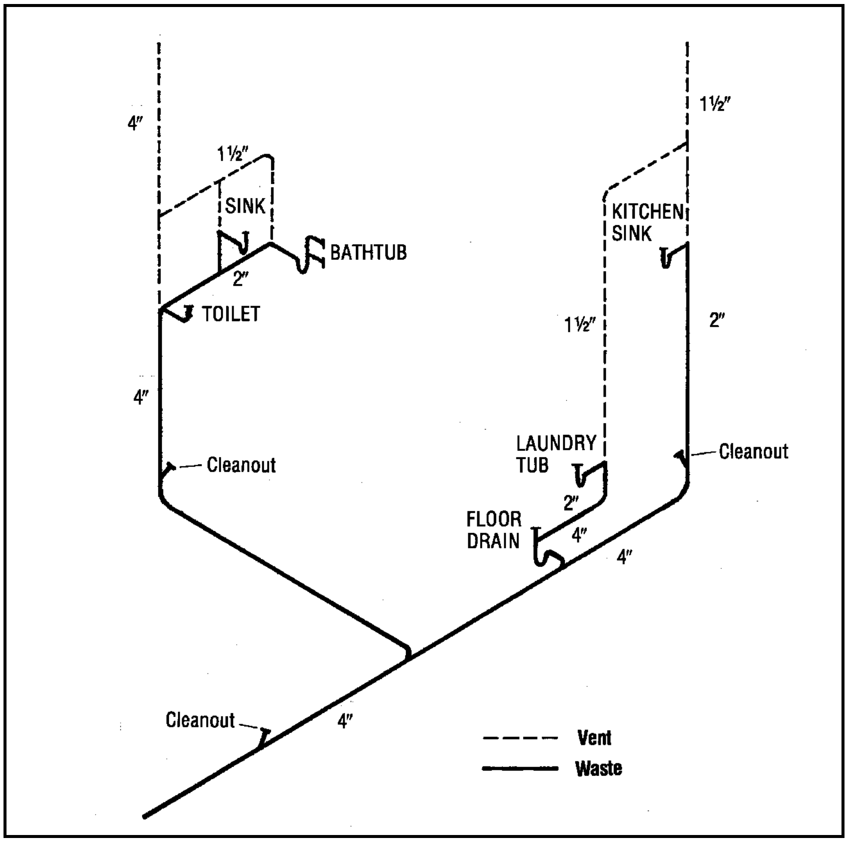
6.3 Drain, Waste, and Vent Piping

Determine drain, waste, and vent (DWV) capacity as described in Figure 6.2. Inspect the DWV piping as follows:

- **Fixture traps.** Fixture traps are generally U-shaped and designed to hold a water seal that blocks the entry of sewer gasses through the fixture drain. Check all fixture drains for evidence of water seal loss; such drains usually emit the odor of sewer gas. The water seal in water closets can be visually verified, while other fixtures can be checked with a dipstick.

  Test: Refill any empty traps and discharge their fixtures to determine whether the water seal was lost due to a plumbing malfunction or through evaporation due to lack of use. If, after operation, the traps are again "pulled," the problem is caused either by self-siphonage because of improper plumbing design, obstructions in the venting system, or the lack of a vent. In this case, first check for the presence of S-traps under the fixture, which may cause the self-siphonage and are no longer allowed by plumbing codes. If S-traps are not present, thoroughly check the venting system. Even if all plumbing fixtures are to be replaced, this assessment process should be performed to reveal problems in the overall system.

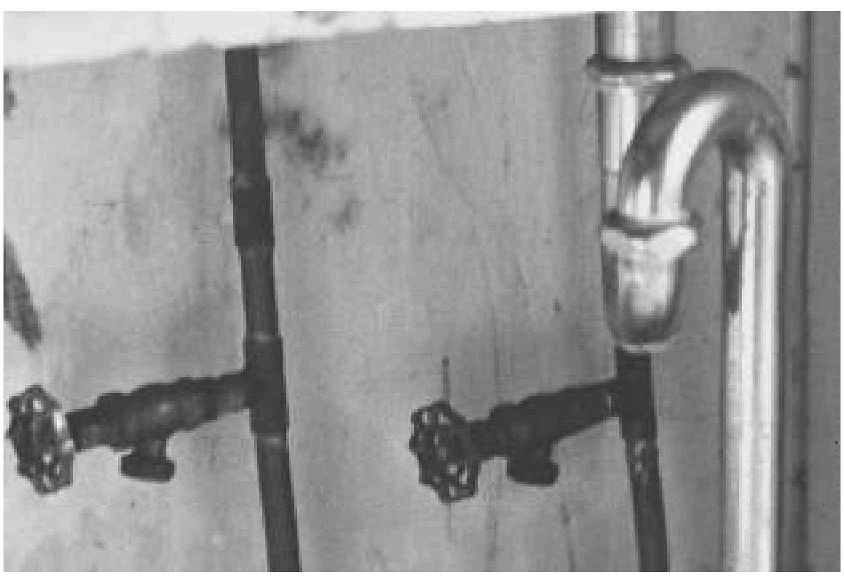
- **Vents.** Vents equalize the atmospheric pressure within the waste drainage system to prevent siphoning or "blowing" of the water seals in the building's fixture traps. Vents



Typical DWV piping schematic for a single-family residence

should be unobstructed and open high enough above the roof to prevent snow closure. Vents that terminate outside an exterior wall or terminate near a building opening (such as a dormer window) are prohibited by building codes, although under certain conditions they may be acceptable. Check vent lines for damage caused by building movement or settlement or by the sagging of individual building components.

Test: Discharge several fixtures simultaneously while observing fixture traps; water movement greater than one inch in the trap indicates inadequate or obstructed venting that must be corrected. Also, fill a sink, lavatory, or tub with water and listen to the fixture drain. If a gurgling sound is heard, it usually indicates a venting problem.



An S-trap that can cause self-siphonage and loss of the water seal. All such traps should be replaced.

Figure 6.2 Assessing DWV Capacity

The installed capacity of an existing DWV system can be estimated by measuring the size of each DWV stack and, using the local plumbing code, finding the allowable number of fixtures that can drain into it. This is a relatively simple process.

- **Drain lines.** Drain lines direct waste water from the fixture trap through the building to the sewer. Because the waste drainage system operates by gravity, drain lines must be of adequate size and slope to function properly. Minimum slope should be 1/8 inch per foot (1:00) Cleanouts should be located near the juncture of all main vertical drain pipes that enter the building drain. Check for low spots on long horizontal runs caused by inadequate support, and for damage or distress caused by building settlement or movement. Check also for drains with pipes of dissimilar metals that are not separated by a dielectric coupling to prevent corrosion. Metal pipes with dissimilar metal supports need to be separated to avoid corrosion.

  Test: Test the waste drainage system by discharging several fixtures simultaneously. Look for "boiling" or backup in the lowest fixture in the building. This indicates a clogged or malfunctioning main building drain between the building and the public sewer. Most often such a problem is caused by tree roots that have clogged the line.

  Test: Oil of peppermint or smoke can be used to check the hydraulic integrity of DWV systems by inserting either substance in the system (the oil through a roof vent, the smoke through a trap) and then checking throughout the structure for signs of a pungent odor or smoke. This test should be performed by a plumber.

- **House trap.** Some communities require the installation of a house trap on the building drain. This trap is usually located inside the building by the foundation wall. It is U-shaped and requires a separate vent that terminates outside the foundation wall. Inspect the trap cleanout and check to see that the vent is unobstructed from the outside.

Figure 6.3
Assessing Hot Water Heater Capacity

Water heater capacity is determined by the heater's storage capacity and its recovery rate, or the time it takes to reheat the water in its tank. Recovery rates vary with the type of fuel used. Generally, gas- or oil-fired heaters have a high recovery rate and electric heaters have a low recovery rate. Low recovery rates can be compensated for by the provision of larger storage capacity.

Water heaters are sized according to the number of people living in the house and the type of heat source used:

Gas

30 gallon (115 L)	3 to 4 people
40 gallon (150 L)	4 to 5 people
50 gallon (190 L)	5 and more people

Electric

40 to 42 gallon (115 to 160 L)	3 to 4 people
50 to 52 gallon (190 to 200 L)	4 to 5 people
65 gallon (250 L)	5 and more people

Oil

30 gallon (115 L)	any number of people

A qualified plumber or mechanical engineer should determine the size of replacement units based on rehabilitation plans.

If a spa or whirlpool bath is in the house and the water is heated by either gas or electricity, an additional capacity of 10 gallons (40 L) is needed.

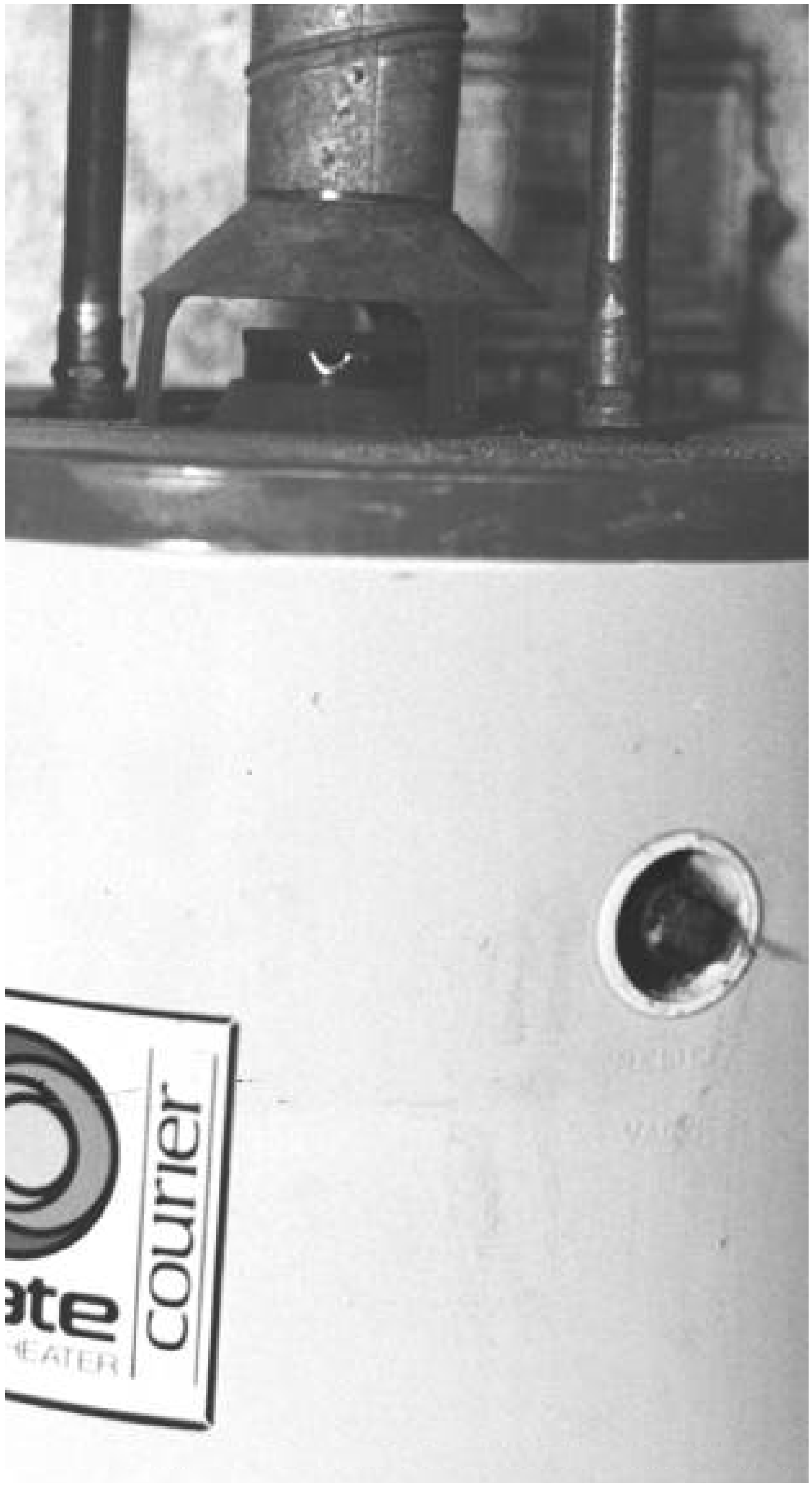
6.4 Tank Water Heaters

Tank water heaters consist of a glass-lined or vitreous enamel-coated steel tank covered by an insulated sheet metal jacket. They are gas-fired, oil-fired, or electrically heated.

- **Gas-fired tank water heaters** have an average life expectancy of about 11 to 13 years and a high recovery rate.
- **Oil-fired heaters** have an average life similar to that of gas-fired heaters. Their recovery rate is also high.
- **Electric water heaters** have a longer service life—about 14 years. They have a low recovery rate and thus require a larger storage tank.

Dates of tank manufacture are usually listed on the data plate (often in a simple 1995 code in the serial number; 0595, for instance, would mean manufactured in May 1995), and since water heaters are usually installed within several months of manufacture, the age of the tank often can be approximated. Plan to replace a tank near the end of its life expectancy. Assess water heater capacity in accordance with Figure 6.3. Inspect tank water heaters as follows:

- **Plumbing components.** Check that the hot and cold water lines are connected to the proper fittings on the tank; often they are reversed, causing a loss of fuel efficiency. There should be a shutoff valve on the cold water supply line. Heavy mineral or rust



This water heater tank had a threaded plug where its temperature-pressure relief valve should have been, an unsafe condition that should be corrected immediately.

deposits around the tank fittings are usually a sign that the tank is nearing the end of its service life.

Test: If the tank's age or general condition cannot be determined from observation, consider having a plumber drain some water from the tank and inspect for sediment and rust.

Check for signs of leakage on the bottom of the tank, such as rust or water stains on or near fuel burning components or on the floor. Leaking tanks cannot usually be repaired and, therefore, must be replaced entirely. Heavy rusting of the tank interior indicates that the tank should be replaced, although the presence of some sediment and rust is normal. The tank should be drained regularly to remove this normal amount of sediment and rust. Check for the existence of a temperature/pressure relief valve on top of the tank or on the hot water line leading from the tank (it should not be on the cold water line), and for a discharge pipe that extends from the valve to a few inches from the floor or to a floor drain or the building exterior, depending on local code requirements.

Test: If necessary, the pressure relief valve can be tested by pressing the test lever, but since it may stick open, do not perform this test without having a replacement valve available and the necessary tools for replacement.

The soot that has accumulated below the draft hood of this water heater indicates a severely clogged flue or chimney, or more commonly, back-drafting caused by insufficient make-up air.

- **Fuel-burning components.** On gas- and oil-fired tank water heaters, check the flue for upward pitch (1/4 inch per foot [1:50] minimum with no flat spots), tightness of the fittings, and overall condition and integrity. A clogged flue or chimney will deposit soot on top of the tank under the draft hood. On oil-fired water heaters, check for a barometric damper in the flue and verify that it moves freely.

  Test: Check that the burners have an adequate supply of combustion air by using a draft gauge or match to test the draft.

  Inspect the ignition components and look for clogged burners and signs of flashback, such as soot on the heater near the burner. The fuel burning components can be repaired or replaced, but consider the cost-effectiveness of such repairs in terms of the expected remaining service life of the water heater.
- **Seismic vulnerability.** If the building is in seismic zones 3 or 4 (California and portions of Alaska, Arkansas, Hawaii, Idaho, Missouri, Montana, Nevada, Oregon, Utah, Wyoming, and Washington), check the water heater for the presence of seismic bracing to the floor or other structural member.

6.5 Tankless Coil Water Heaters (Instantaneous Water Heaters)

Tankless coil water heaters consist of small diameter pipes coiled inside of or in a separate casing adjacent to a hot water or steam boiler. They are designed for a specific rate of water flow, usually three to four gallons per minute. Since demand for domestic hot water can easily exceed this flow, such heaters often have an associated storage tank to satisfy periods of high demand. Thus the recovery rate of a tankless coil water heater is instantaneous for low demand and will vary for high demand depending on the size of the storage tank, if any. The life expectancy of a tankless coil water heater is limited only by the possible long-term deterioration of its coils and by the service life of the boiler to which it is attached. Since the boiler must operate through the summer in order for the water heater to function, such water heaters are usually considered inefficient.

Check tankless coil water heaters as follows:

- **Plumbing components.** Inspect the plumbing connections and joints around the heater mounting plate for rust, water stains, and mineral deposits. Tighten the mounting plate and repair the connections if required.

  Test. Turn on the hot water in two or more plumbing fixtures to check the water flow. If it is low, suspect a buildup of mineral deposits within the coil. Such deposits can often be flushed from the coil by a plumber.
- **Controls.** Inspect the functioning of the aquastat (device that activates the boiler when heat is needed for producing hot water).

  Test: Run hot water until the boiler fires. Boiler water temperature should not drop below 180 ºF (82 ºC) on the water gauge; if it does, the aquastat needs adjustment.

  Check for the presence of a pressure relief valve on the hot water side of the coil or on the auxiliary storage tank. The valve should be connected to a discharge pipe that extends to a few inches from the floor, or the building's exterior, depending on local code requirements.

  Test: The relief valve should be tested by pressing the test lever, but as it may stick in the open position, the test should not be performed without having a replacement valve available and the necessary tools for replacement.

6.6 Water Wells and Equipment

Assess well capacity as described in Figure 6.4. Check water wells and equipment as follows:

- **Location and water quality.** Wells that supply drinking water should be located uphill from the building supplied and from any storm or sanitary sewer system piping. Codes usually require that the well be a minimum of 50 feet (15 m) from a septic tank and 100 feet (30 m) from any part of the absorption field; however, local codes may have different separation distances based on the percolation rates of the local soils. Well water can be more corrosive than city water and may contain radon.

Test: Water should be analyzed for the presence of bacterial contamination, for its mineral content, and for the presence of radon. The local health department normally will provide such an analysis. There should be no measurable coliforms.

- **Depth and casing.** Most localities now require wells to be more than 50 feet (15 m) in depth and encased in a steel, wrought iron, or plastic pipe. The casing should extend several inches above its surrounding concrete cover, which should slope away from and completely protect the casing. The casing should be tightly sealed where the pump and power lines enter it and protected from flooding and other threats to its sanitary integrity.
- **Pumps.** Two kinds of deep well pumps are in common use, the jet pump and the submersible pump. A jet pump is mounted above the well casing, and two pipes should extend into it; if there is only one pipe leading into the casing, the well is less than 25 feet deep and may not meet code. Submersible pumps are located at the bottom of the well casing (submerged) and a single discharge pipe and an electrical supply cable extend from the top of the casing. The life expectancy of deep well pumps is 10 years or longer, depending on the type. Submersible pumps are usually the most long lasting and trouble free. Check that pump and plumbing components at the well are protected from freezing.
- **Pressure tank and switch.** A tank under low air pressure (a hydropneumatic tank) should be located in either the well house or the building's basement. This tank regulates water pressure and flow; when air pressure is lost (as air is absorbed in the water over time), the tank becomes waterlogged and causes the pump to be activated every time water is used. Look for this condition; it can be remedied by pumping air back into the tank. Newer tanks contain an air bag. A pressure switch on the tank keeps the water pressure within a predetermined 20 psi (140 kPa) range (usually 20 to 40 psi [140 to 275 kPa], 30 to 50 psi [205 to 345 kPa], or 40 to 60 psi [275 to 415 kPa]).

Test: Check the pressure tank and switch by running the water and seeing whether the pump activates at the lower pressure limit and stops at the upper pressure limit. If pressure slowly goes down in the tank without water being drawn from the system, the tank or some other part of the system is leaking, and the problem should be found and corrected.

Pressure tanks and switches have an average life expectancy of 5 to 10 years, but may last much longer. Check the tank for the presence of a pressure relief valve.

Figure 6.4
Assessing Well Capacity

A water well serving a single-family residence should be capable of sustaining at least a 4-gallon-per-minute flow (a 5- to 7-gpm [19 to 26 L/min] flow is preferable) with a peak flow capacity of 12 gpm (45 L/min).

Test: To check the well's capacity, run water simultaneously from several faucets for 30 minutes or more. Note pressure fluctuations, if any. Near the end of the test, look for mud or cloudiness in the water; this indicates that the well has insufficient capacity for normal use.

Wells serving more than one residence should have proportionately larger capacities. A more exacting capacity test can be performed by a well specialist.

6.7 Septic Systems

Assess septic system capacity as described in Figure 6.5. Check septic systems as follows:

- **Location and layout.** Septic systems should be located downhill from the building. No storm water should be directed into the septic system, as this can flood it and force solids into the absorption field, thereby destroying the field. Sufficient room should exist on the property to relocate the absorption field, which has an average life expectancy of 20 to 30 years under proper use. Do everything possible to determine the layout of the existing septic system, as the absorption field should not be disturbed by new construction and vehicular traffic, or covered by fill. The field often can be located by the presence of greener vegetation in dry summer weather or by melting snow in winter.
- **Septic tank.** The septic tank should be watertight and, for a single-family house, have a minimum capacity of 1000 gallons (3800 L). If properly maintained, it should have been pumped every several years. Ask to see the tank's pumping records. Lack of periodic pumping will cause solids to be carried into the absorption field, clogging the leaching beds and shortening their useful life.
- **Absorption field.** The absorption field should be adequately sized to handle its service loads without clogging or overflowing. Try to locate the original design information and service records for the system. If the company that serviced the installation can be identified,

Figure 6.5 Assessing Septic Capacity

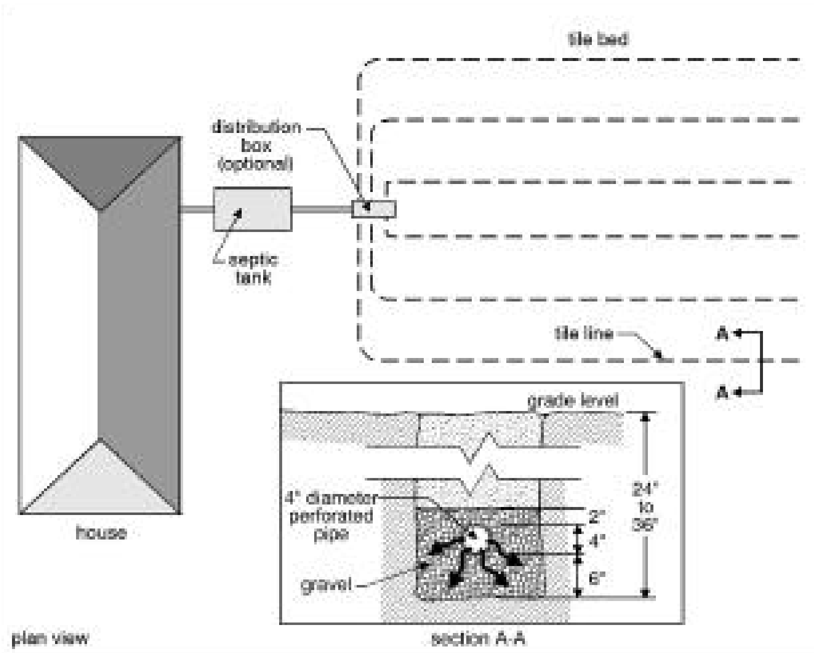
Plumbing codes normally require the following septic tank capacities (check the local code for exact requirements):

Single-family, number of bedrooms	*Multi-family, one bedroom each*	*Capacity*
1 to 2	--	750 gallons (2840 L)
3	--	1000 gallons (3785 L)
4	2 units	1200 gallons (4545 L)
5 to 6	3 units	1500 gallons (5680 L)
	4 units	2000 gallons (7570 L)

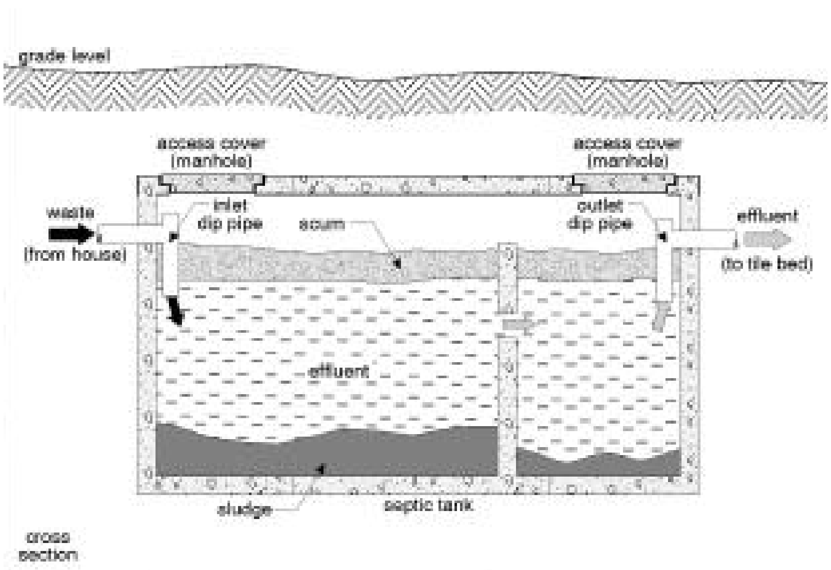
The capacity of the septic system's absorption field depends on its layout and on the percolation qualities of the surrounding soil.

> Test: The absorption field's capacity should be checked by running water into several plumbing fixtures for 30 to 60 minutes and observing the trap in the lowest building fixture. If the water in the trap "boils," backs up, or makes a gurgling sound, the absorption field is clogged or inadequately sized. In either case, it will probably have to be replaced. See a local septic system specialist to determine replacement needs. It is very difficult to test septic systems where the house has been vacant for 30 days or more.

Other signs of a clogged absorption field are the presence of dark green vegetation over the leaching beds throughout the growing season (caused by nutrient-laden wastes being pushed up through the soil), wet or soggy areas in the field, or distinct sewage odors. These signs all indicate the probable need to replace the absorption field.



Example of a typical septic system layout with a detail of the absorption field piping



Cross section of a typical two-compartment septic tank

check with that company about the system's condition. If a renovation that adds bedrooms is being considered, verifying the system's existing capacity is critical to determining what additional work is needed. A qualified plumber or mechanical engineer should determine the capacity of the system based on the renovation plans.

- **Grease trap.** Some houses have grease traps in the septic system to prevent grease from getting into and clogging the absorption field. This trap should be inspected for grease buildup.

  Test: To check whether runoff on the site is coming from the absorption field, put dye capsules in the waste water and return later to check the color of any runoff.

6.8 Gas Supply in Seismic Regions

Inspect the following features of the gas service:

- **Service entrance.** If the building is in seismic zones 3 or 4 (California and portions of Alaska, Arkansas, Hawaii, Idaho, Missouri, Montana, Nevada, Oregon, Utah, Wyoming, and Washington), check the gas service for vulnerability to differential movement where the piping enters the building. Look for adequate clearance or for flexible connections.
- **Emergency shutoff.** If the building is in seismic zone 4 (portions of Alaska and California, and small parts of Idaho, Montana, and Wyoming), look for an automatic emergency shutoff valve for the entire house.

7
HVAC System

Most HVAC (heating, ventilating, air conditioning) systems in small residential buildings are relatively simple in design and operation. They consist of four components: controls, fuel supply, heating or cooling unit, and distribution system. Each component must be evaluated for its physical and functional condition and its adequacy in terms of the building's planned reuse. The adequacy of heating and cooling is often quite subjective and depends upon occupant perceptions that are affected by the distribution of air, the location of return air vents, air velocity, the sound of the system in operation, and similar characteristics. For this reason, past energy use should not be used as the basis for estimating future energy use.

This chapter describes inspection procedures for oil- and gas-fired warm air, hot water, and steam heating systems; electric resistance heaters; chilled air and evaporative systems; humidifiers; unit air conditioners; and attic fans.

When inspecting the HVAC system, look for equipment service records and read all equipment data plates. Whenever possible, ask building occupants about the HVAC system's history of performance. Always try to observe equipment in actual operation.

When universal design is a part of a rehabilitation, consult HUD publication *Residential Remodeling and Universal Design* for detailed information about HVAC controls.

HVAC systems have used asbestos-bearing insulation on piping, ducts, and equipment, and may have lead-based paint on piping and equipment such as radiators. When inspecting the HVAC system, pay particular attention to the presence of these hazardous materials.

Assess heating and cooling capacity as described in Figure 7.1.

7.1
Thermostatic Controls

Residential HVAC controls consist of one or more thermostats and a master switch for the heating or cooling unit. Inspect them as follows:

- **Thermostats.** Thermostats are temperature-sensitive switches that automatically control the heating or cooling system. They normally operate at 24 volts. Thermostats should be located in areas with average temperature conditions and away from heat sources such as windows, water pipes, or ducts. For a thermostat that controls both heating and cooling, a location near the return air grille is ideal.

  Test: Check each thermostat by adjusting it to activate the HVAC equipment. Then match the temperature setting at which activation occurs with the room temperature as shown on the thermostat's thermometer.

  Take off the thermostat cover and check for dust on the spring coil and dirty or corroded electrical contact points. Newer thermostats have a mercury switch in lieu of electrical contacts. Plan to replace worn or defective thermostats.

  There may be more than one thermostat in each living unit. Sometimes two thermostats separately control the heating and cooling system, and sometimes the living unit is divided into zones, each with its own thermostat. Multi-family buildings with a central HVAC system will be divided into at least one zone per living unit and buildings with electric baseboard heat may have a thermostat in every room or on every heating unit.

  Test: Check the functioning of multi-zone systems by operating the HVAC system in all its modes and noting whether distribution is adequate in each zone (see also Sections 7.3 and 7.4). Consider the zoning needs for the planned rehabilitation of the building. Refer to the National Environmental Balancing Bureau's *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems or the Associated Air Balance Council's MN-4*, ABBC Test and Balance Procedures.

- **Master switch.** Every gas- and oil-burning system should have a master switch that serves as an emergency shutoff for the burner. Master switches are usually located near the burner unit or, if there is a basement, near the top of the stairs.

  Cooling system controls also may include a master switch, which in the “off” position will not allow the compressor to start, as well as a switch allowing only the circulating fan to operate.

Figure 7.1
Assessing Heating and Cooling Capacity

The capacity of an existing heating or cooling system, as measured by its ability to heat or cool a specific building or space, can be determined in either of two ways:

- **Field test.** Properly sized heating and cooling systems should operate at full capacity at normal yearly outside temperature extremes and should be slightly undersized for unusual outside temperature extremes. It is rare, however, that they can be checked under such conditions.

  Test: Operate the heating system on the coolest possible day and the cooling system on the warmest possible day (within the limitations of the inspection period). Note how "hard" the system is working to maintain the preset indoor temperature, as indicated by how often the system cycles on and off, and compare this to outside temperatures. This procedure, while inexact, may provide some idea of the system's potential capacity.

  When the system has a history of continuous use, maintenance, and repair, it can be assumed to have sufficient capacity. However, check with present or former building tenants on this matter.

  Of more concern is the fuel efficiency of the system. Ask the local utility company or fuel distributor for records of past fuel consumption and consider this in the overall assessment of the HVAC system.

- **Design calculation**. An HVAC system's capacity can be more accurately determined by noting its heating or cooling output (in tons or BTUs) from information on the manufacturer's data plate and comparing it to the building's heating and cooling loads. These loads can be calculated using the Air Conditioning Contractors of America's Manual J or similar load calculation guide.

  A rough estimate of a building's required heating equipment size in BTUs per hour (BTUH) can be obtained by using the following formula:

  BTUH = .33 x [square footage of building to be heated] x [difference between outside and inside design temperatures]

  The factor of .33 in this formula is based on R11 exterior walls, an R19 ceiling at the top floor or roof, and double-glazed windows.

  A rough estimate of a building's required cooling equipment size, in tons, can be made by dividing the floor area by 550 (each ton equals 12,000 BTUH). Tonnage is not an adequate measure of cooling capacity in a dwelling of three or more floors with the air handling unit located on the lowest floor, with such a layout, the top floor can never be properly cooled.

  These estimates should be followed by a complete load calculation after rehabilitation needs are firmly established.

Test: Operate all master and emergency shut-off switches when the burner is in operation to see whether they deactivate the unit.

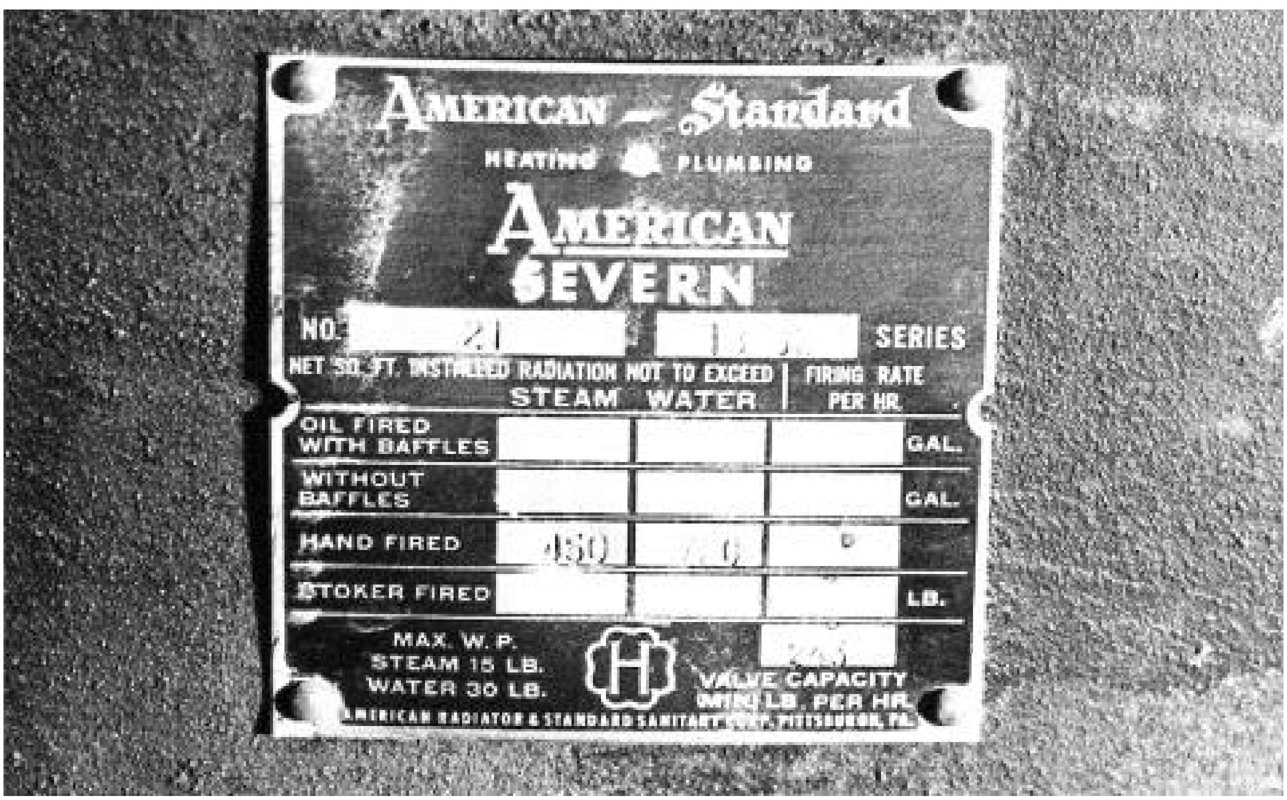
In hot water heating systems that also are used to generate domestic hot water, the thermostat controls the circulating pump rather than the burner (see Section 7.4).

7.2 Fuel-Burning Units, General

Oil- or gas-fired furnaces and boilers provide heat to the majority of small residential buildings. Such fuel-burning units, whether they are part of a warm air or a hot water system, should be inspected as follows:

- **Location, clearances, and fire protection.** Check that the unit meets local fire safety regulations. No fuel-burning unit should be located directly off sleeping areas or close to combustible materials.
- **Data plate and service records.** Locate the data plate on each unit and note its date of manufacture, rated heating capacity in BTUs per hour, fuel requirements, and other operational and safety information. Examine the service records of oil-fired units. These should be attached to the unit or available from the oil distributor or company that last serviced the unit.
- **Seismic vulnerability.** If the building is in seismic zones 3 or 4 (California and portions of Alaska, Arkansas, Hawaii, Idaho, Missouri, Montana, Nevada, Oregon, Utah, Wyoming, and Washington), check fuel-burning equipment for the presence of seismic bracing to the structure.
- **Fuel supply.** Gas supply lines should be made of black iron or steel pipe (some jurisdictions allow copper lines with brazed connections). Shutoff valves should be easily accessible and all piping well-supported and protected.

  Oil tanks should be maintained in accordance with local code or the recommendations of the National Fire Protection Association. All tanks must be vented to the outside and have an outside fill pipe. Buried



Record all pertinent information from the manufacturer's data plates on HVAC equipment. It will be useful in assessing the equipment's capacity later.

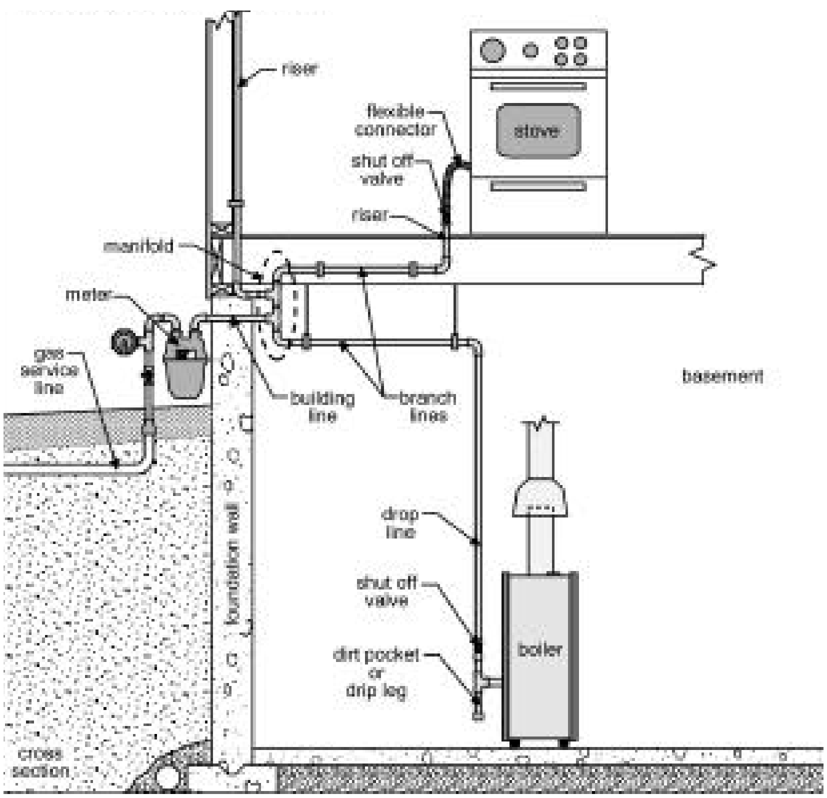
tanks normally have a 550, 1000, or 1500 gallon (2080, 3785, or 5680 L) capacity; basement tanks are usually restricted to a 275 gallon (1040 L) capacity, with no more than two tanks allowed. Tanks must be located at a minimum of seven feet from the furnace and should be adequately supported and free of interior rust. Outside tanks at grade should have an adequate supporting base.

Oil tanks often begin to leak after about 20 years, when the bottom of the tank corrodes from moisture that has condensed inside the tank and settled to the bottom. Feel along the undersides and probe the interiors for such leakage. Look for an oil level gauge and see whether it works. Decide whether the tanks should be replaced. See also the information on buried oil tanks in Section 1.2.

Check the oil supply line to the furnace; it should be equipped with a filter and protected from accidental damage and rupture.

- **Ventilation and access.** Make sure the fuel-burning unit has adequate combustion air and is easily accessible for servicing with at least three feet clear on each side of the unit requiring service. Check the local code for requirements. Also check equipment manufacturer's guidelines for makeup air, especially where furnaces and boilers are enclosed in a finished basement or closet. A general rule is to provide one inch of free area across the width of the door to the furnace or boiler room or closet for every 1000 BTUH (300 W) of heating. The free area needed should be divided: roughly half at the bottom of the door and half at the top. A grille can also be used in the door.
- **Condition.** Open all access panels and examine the external and internal condition of each unit. On hot air furnaces, look for signs of rust from basement dampness or flooding, and, if an air conditioning evaporator coil is located over the furnace, look for rust caused by condensate overflow. On hot water boilers, look for rust caused by dampness and by leaking water lines and fittings. If possible, check the condition of the interior refractory lining on all oil-fired units.
- **Ignition and combustion.** Observe the ignition and combustion process.

Test: Step away from the unit while someone else turns up the thermostat. Look for a puffback in oil-fired units or flames licking under the cover plate of a gas-fired unit; both indicate potential hazards that must be corrected. If the unit doesn't light, check the master switch or emergency



Gas piping terminology

Look for signs of corrosion around and within oil storage tanks and check the operation of the oil level gauge. Use a dipstick to check for signs of condensation in the tank.

shutoff to make sure it's on, press the reset button, and try again. If it still doesn't light, call a service technician.

Once the unit has been activated, closely observe the combustion process. In oil-fired units, the flame should be clear and clean, and have minimal orange-yellow color. Flame height should be uniform.

Gas-fired units should have a flame that is primarily bluish in color. Note whether the flame lifts off the burner head; this indicates that too much air is being introduced into the mixture. Check gas burners for rust and clogged ports. Soot build up is a sign of inefficient combustion. In oil-fired units, look for soot below the draft regulator, on top of the unit's housing, and around the burner. The odor of smoke near the unit is another sign of poor combustion.

Test: Consider having a service technician perform a flue gas analysis to determine the unit's combustion efficiency. This test requires the use of a flue gas analyzer and should be performed in accordance with ASTM D2157, *Standard Test Method for Effect of Air Supply on Smoke Density in Flue Gasses from Burning Distillate Fuels*.

- **Venting and draft.** Check the smoke pipe between the unit and the chimney. It should have a slight upward pitch with no sags, preferably a minimum of 1/4 inch per foot. Inspect the pipe for corrosion holes, the tightness of its fittings, and the tightness of its connection to the chimney. Check for signs of soot build up in the smoke pipe. Consult local code requirements about the minimum size, required clearance from combustible materials, and number of

This barometric draft regulator should swing freely and open somewhat as the heating unit warms up.

smoke pipes entering the chimney. Newer, higher efficiency furnaces are not as prone to backdrafting because of forced or reduced draft systems. When these systems are used with existing old flues, flues tend to fail early. Check for evidence of rust or leaking in the exhaust flue.

Gas-fired units have a draft diverter that is located either on the exhaust stack of a boiler or built into the sheet metal casing of a furnace.

Test: Have a service technician run the furnace or boiler through a complete cycle, then with a match or candle conduct a simple smoke test of the draft at or near the diverter. A draft gauge or CO tester can be used to detect an outward flow of hot exhaust gas; this indicates a hazardous draft problem that must be corrected.

Proper draft is critical to the efficient operation of an oil-fired unit. A barometric draft regulator is required above the unit or on the smoke pipe. Inspect for open joints or cracks that allow excess air to enter the combustion chamber or the smoke pipe. All such openings should be sealed. The damper of a barometric draft regulator should be level, free of rust, and not damaged or altered. Improper draft from an oil furnace could cause a build up of carbon monoxide gas in occupied spaces. Have old flues cleaned by a chimney sweep or HVAC service technician. Have a deteriorated flue replaced.

Test: Check the draft regulator by observing its motion when the heating unit is in operation. It should open as the heating unit warms up. The draft regulator is adjusted during the combustion efficiency test.

- **Operation.** The operation of the fuel-burning unit will depend on the type of heating system in which it is used. See Section 7.3 for the operation of gas- and oil-fired warm air systems and Section 7.4 for the operation of gas- and oil-fired hot water and steam systems.

7.3 Forced Warm Air Heating Systems

Warm air heating systems are of two types, forced air or gravity. Gravity systems are occasionally still found in older single-family houses, but most gravity systems either have been replaced or converted to forced air. Gravity systems are big, bulky, and easily recognizable. Lacking a mechanical means of moving air, such systems are inefficient and heat unevenly, can be dangerously hot, and are generally considered archaic. Plan to replace them unless there are overriding reasons for doing otherwise.

Most forced warm air systems use natural gas or fuel oil as a heat source, but some systems use electric resistance heaters or heat pumps. These heaters replace the heat exchanger and burner found in gas- and oil-fired furnaces or supplement the heat output of heat pumps (see Section 7.9). Electric resistance heating systems have no moving parts and require no adjustment. The circulation blower and air distribution ductwork for electric resistance heating systems (and heat pumps) are identical to those of gas- and oil-fired warm air systems and should be checked as described below. See Section 7.6 for additional information on electrical resistance heating equipment.

Assess the condition of forced warm air heating systems as follows:

- **Heat exchanger.** The heat exchanger is located above the burner in gas- and oil-fired furnaces and separates the products of combustion from the air to be heated. (There is no heat exchanger in an electrically heated furnace.) It is critical that the heat exchanger be intact and contain no cracks or other openings that could allow combustion products into the warm air distribution system. Visual detection of cracks, even by heating experts, is a difficult and unreliable process.

  Test: Look for signs of soot at supply registers and smell for oil or gas fumes. Observe the burner flame as the furnace fan turns on; a disturbance or color change in the flame may indicate air leakage through the exchanger. Operate the furnace for several minutes and then feel the furnace frame for uneven hot spots. Similarly, another simple test requires turning on the fan only and placing a lighted match or candle in the heat exchanger enclosure. If there are leaks, the flame will flicker. A CO tester may also be used to detect combustion gases. For any of these tests, consult a heating contractor or HVAC service technician.

  Look for rust on the exchanger—a major cause of premature exchanger failure is water leakage from humidifiers or blocked air conditioner condensate lines. Check for other signs of water leakage.

  The durability of the heat exchanger determines the service life of the furnace. Furnaces installed since the 1950s normally have a useful life of 25 years or less. Older furnaces with cast iron heat exchangers may last much longer.

- **Furnace controls.** Gas- and oil-fired furnaces have two internal controls, a fan control and a high-temperature limit control. (Furnaces with electric resistance heating coils have high temperature limit controls and air flow switches.) The fan control prevents cold air from being circulated through the system. It is a temperature-sensitive switch, completely independent of the thermostat, and turns the furnace blower on and off at preset temperatures. When the thermostat calls for heat, the furnace burner is turned on. After the heat exchanger warms to a preset temperature (usually 110 to 120 ºF [43 to 49 ºC]), the fan control activates the blower. The thermostat will shut off the burner when the building warms to the thermostat setting, and when the heat exchanger cools to about 85 ºF (29 ºC) the fan control will switch off the blower.

  Test: Observe the above sequence; if it is faulty, the fan control should be adjusted or replaced.

  The high-temperature limit control is a safety device that shuts the burner off if the heat exchanger gets too hot (the control is usually set at about 175 ºF). Should the burner automatically turn off before the blower is activated, either the blower, the fan control, or the high-temperature limit control is faulty and should be adjusted or replaced.

- **Circulation blower.** Remove the blower cover and inspect the blower motor and fan. Look for proper maintenance and oiling. Check for wear or misalignment of the fan belt, if any, and for dirt build up on the motor or fan.

  Test: When the system is operating, listen for unwarranted blower noise and determine its cause.

- **Distribution system and controls.** The distribution system is made up of supply and return ducts, filters, dampers, and registers. Supply and return ducts may be made of sheet metal, glass fiber, or other materials. Glass fiber ducts are self-insulated, but sheet metal ducts are usually not insulated except where they pass through unheated (or uncooled) spaces (see Sections 3.1 and 3.9). Sheet metal ducts are occasionally insulated on the inside; determine the presence of insulation by tapping on the duct and listening for a dull sound. Check ducts for open joints and air leakage wherever the ducts are exposed. Examine them for dirt build up by removing several room registers and inspecting the duct. Ducts can be cleaned by a heating contractor. If there is a flexible connection between the furnace and the duct work, check it for tears and openings. There should be no openings in return ducts in the same room as a combustion furnace.

Air filters are usually located on the return side of the furnace next to the blower, but they may be found anywhere in the distribution system. Check for their presence and examine their condition.

Supply ducts are often provided with manual dampers to balance air flow in the distribution system. Locate them by looking for small damper handles extending below the ductwork. Check their operation. In zoned systems, automatically controlled dampers may be located in the ductwork, usually near the furnace.

Test: The operation of all dampers should be checked by activating each thermostat, one at a time. If the dampers are working properly, air should begin to circulate in each zone immediately after its thermostat has been activated.

Check the location of supply and return registers in each room. Warm air registers are most effective when positioned low on the exterior wall; cold air registers when located high on the walls or in the ceiling. Return registers should be on opposite sides of the room from supply registers. If return registers are located in a hallway or a different room, make sure intervening doors are undercut by about one inch.

Test: When the furnace blower is on, check the air flow in all supply and return registers. Remove and inspect registers that appear blocked. Listen for sounds emanating from the ductwork and determine their source.

Humidifiers may be located in the supply ducts. They should not be located in return air ducts because the moist air will pass through the heat exchanger and evaporator coil, rendering the humidification ineffective and corroding the heat exchanger. Check humidifiers in accordance with Section 7.11.

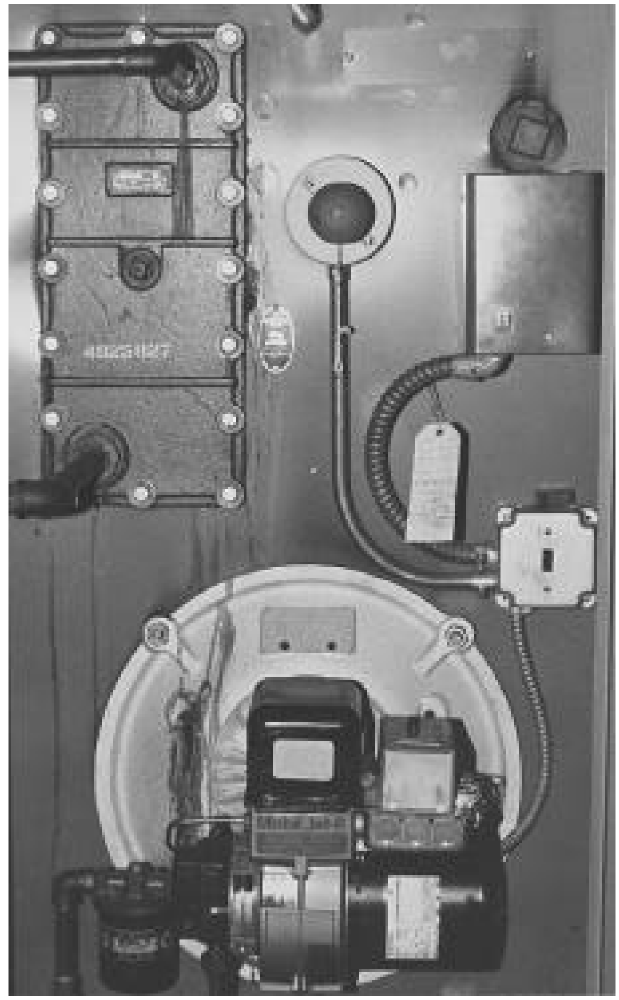
7.4 Forced Hot Water (Hydronic) Heating Systems

Hot water heating systems, like warm air systems, are of two types, forced or “hydronic” and gravity. Gravity systems are sometimes found in older single-family houses, but in most cases such systems have been replaced or converted to a forced hot water system. Gravity systems have no water pump and use larger piping. They tend to heat unevenly, are slow to respond, and can only heat spaces above the level of their boiler. Like gravity warm air systems, they are considered inefficient and normally should be replaced during the rehabilitation process.

Forced hot water systems are usually heated by gas- or oil-fired boilers. Occasionally they may use immersion-type electric resistance heating coils. These coils replace the burner found in gas- and oil-fired boilers. The hot water pump and distribution piping for electrically heated systems are similar to those of gas- and oil-fired hot water systems and should be checked as described below. Refer to Section 7.6 for additional information on electrical resistance heating equipment.

Assess the condition of forced hot water heating systems as follows:

- **Boiler.** Most hot water and steam heating systems have steel boilers with a service life of about 20 years. Cast iron boilers, which are less

The hot water boiler on the left is gas-fired; the one on the right, oil-fired. Both have standard pressure and temperature gauges.

common, have a service life of about 30 years. Old cast iron boilers converted from coal-fired units may last much longer but are usually quite inefficient. Inspect all boilers for signs of corrosion and leakage.

Test: Run the boiler for one-half hour or longer and check for leaks. Occasionally a boiler fitting will leak slightly before it warms up, expands, and returns to a watertight fit. Don't confuse condensation droplets on a cold boiler with water leaks.

- **Expansion tank.** The expansion tank is usually located above the boiler (although it may be in the attic) and is connected to the hot water distribution piping. Most tanks are compression-type tanks that are designed to permit heated water to expand against a cushion of pressurized air within the tank. When the tank loses air, it becomes "waterlogged" and expansion cannot be accommodated. Instead, water discharges from the boiler's pressure relief valve each time the system heats up. Check for such a condition. Waterlogged expansion tanks should be drained and repressurized. This should be done by a heating or plumbing contractor.
- **Boiler controls.** All boilers should be equipped with a pressure gauge, a pressure relief valve, and a pressure-reducing valve. The pressure gauge indicates the water pressure within the boiler, which

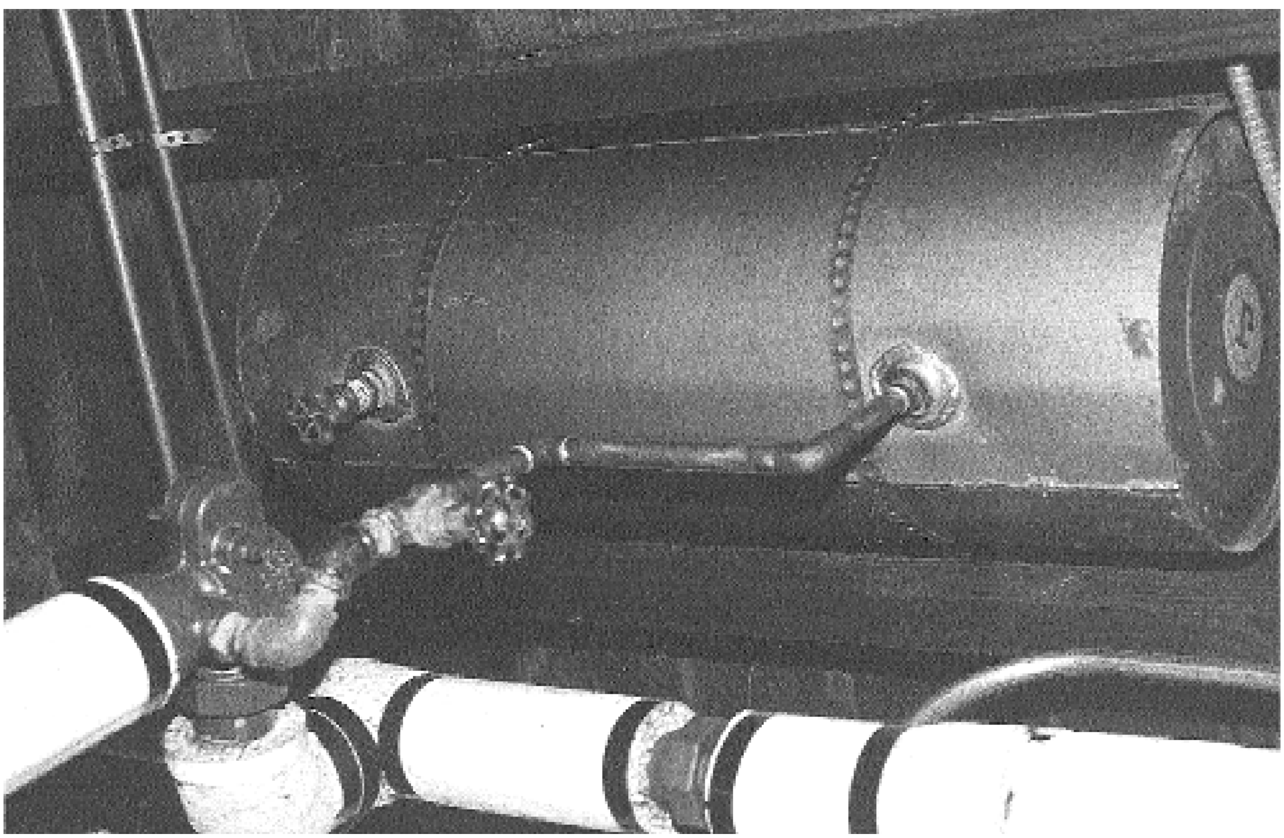
should normally be between 12 and 22 psi (83 to 153 kPa). A temperature gauge may be included in the pressure gauge. The pressure-reducing valve (actually a water make-up valve) adds water to the system from the domestic water supply when the boiler pressure drops below 12 psi (83 kPa). Pressure readings lower than 12 psi indicate a faulty valve that should be adjusted or replaced.

The pressure relief valve should discharge water from the system when the boiler pressure reaches 30 psi (207 kPa). Look for signs of water near the valve or below it on the floor. High pressure conditions are usually due to a waterlogged expansion tank. If the boiler also generates domestic hot water, high pressure may be caused by cracks in the coils of the water heater, since the domestic water supply pressure usually exceeds 30 psi (207 kpa). The pressure relief valve should be mounted on the boiler.

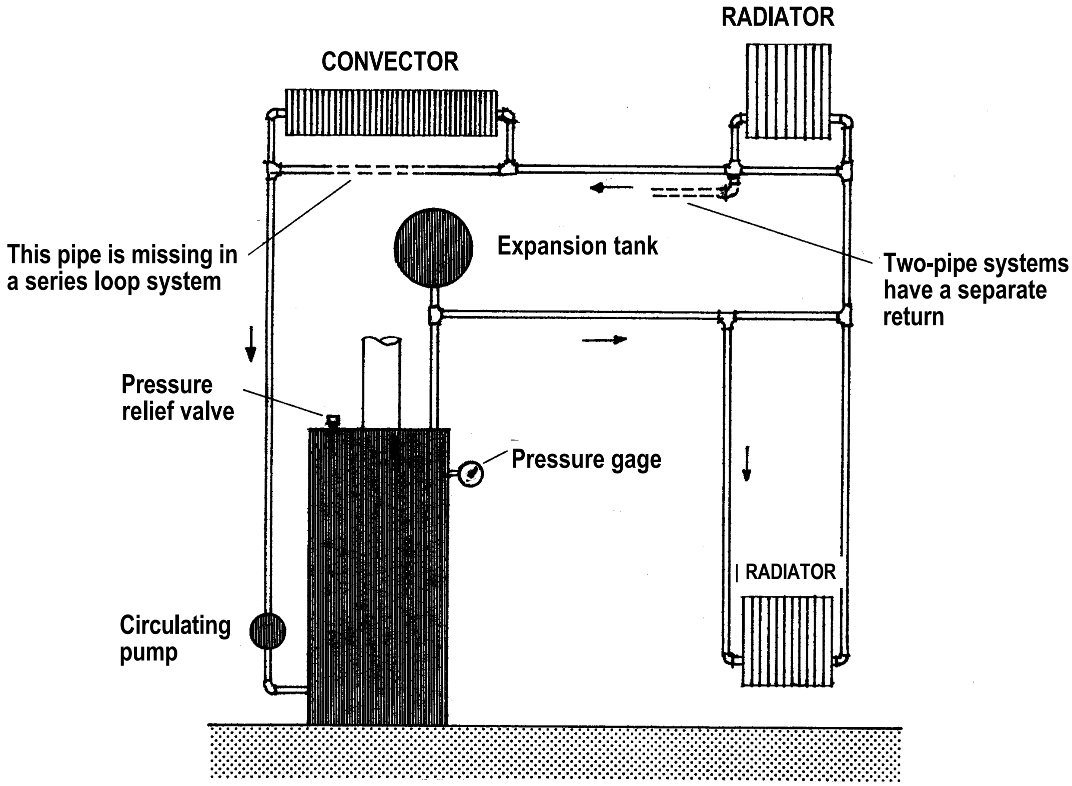
Test: As a last resort, the pressure relief valve may be tested by a service technician. But since it may be old or clogged and become stuck in the open position, the test should not be performed without having a replacement valve on hand and the proper tools for removing and reinstalling the valve and extension pipe.

Hot water boilers should have a high-temperature limit control or aquastat that shuts off the burner if the boiler gets too hot. Check for such a control.

- **Circulating pump and controls.** The circulating pump forces hot water through the system at a constant flow rate, usually stated in gallons per minute (gpm). It should be located adjacent to the boiler on the return pipe near the boiler. The pump may be



This hot water expansion tank is located above the boiler. Look for signs of leakage in expansion tanks.



One-pipe forced hot water heating system

operated in one of the following four ways:

❑ ***Constant-running circulator,*** in which the pump is controlled by a manual switch. The pump is usually turned on at the beginning of the heating season and runs constantly until it is turned off at the end of the heating season. The boiler is independently activated by the thermostat as heat is required.

❑ ***Aquastat-controlled circulator,*** which turns the pump on and off at a preset boiler temperature (normally 120 °F [49 °C]). Like the constantly running circulator, the burner is independently activated by the thermostat as heat is required.

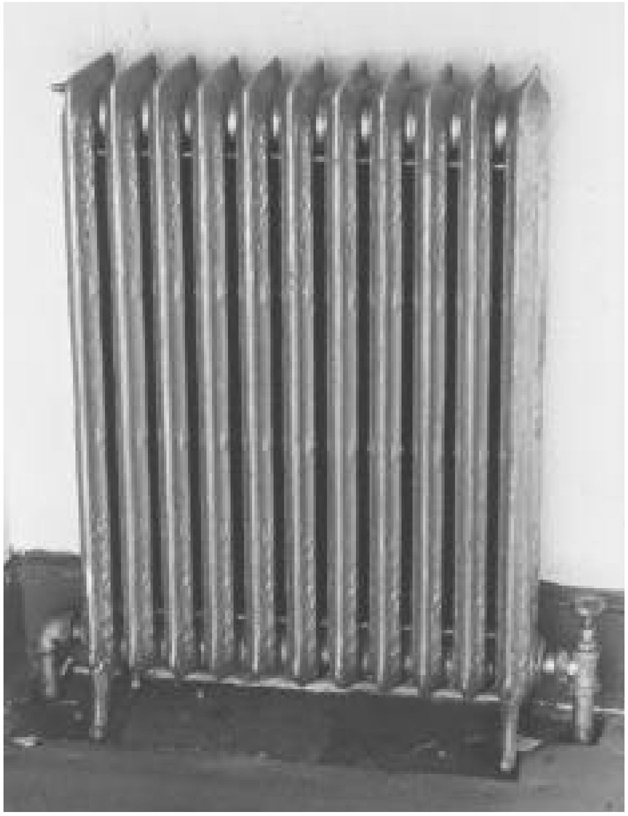
❑ ***Thermostat-controlled circulator,*** in which water is maintained at a constant temperature in the boiler by an aquastat.

❑ ***Relay-controlled circulator,*** in which the pump is activated (via a relay switch) whenever the boiler is activated by the thermostat.

Test: Determine which kind of device controls the pump and check its operation. Inspect the condition and operation of the pump itself. Listen for smooth operation; a loud pump may have bad bearings or a faulty motor. Inspect the seal between the motor and the pump housing for signs of leakage. Examine the condition of all electrical wiring and connections. Feel the return line after the system has been operating for a short time; it should be warm. If it isn't, the pump may be faulty.

In heating systems used for generating domestic hot water, the thermostat will control the circulating pump and an aquastat will control the burner. See Section 6.5.

■ **Distribution piping**. The forced hot water distribution system consists of distribution piping, radiators, and control valves. Distribution piping may



The hot water radiator on the left has a bleed valve at its top left corner. The steam radiator on the right has an air vent.

be one of three types: series-loop, one-pipe, and two-pipe.

In a **series-loop system**, radiators are connected by one pipe directly in a series. Since the last radiator will receive cooler water than the first, downstream radiators should be progressively larger. Alternatively, series-loop systems may be divided in small zones to overcome this problem.

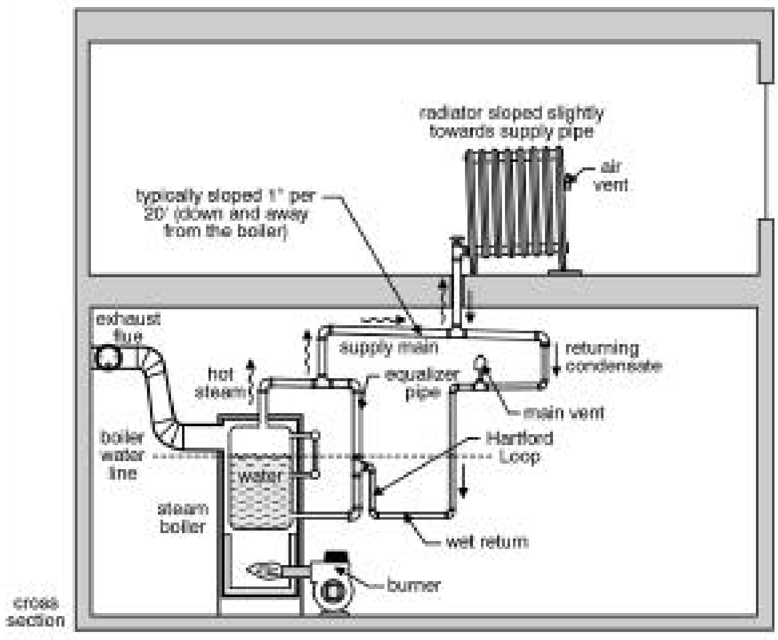
One-pipe systems differ from series-loop systems in that their radiators are not connected in series. Instead, each radiator is separately attached to the water distribution pipe with a diverter fitting, which is used to regulate the amount of hot water entering it.

Two-pipe systems use separate pipes for supply and return water, which ensures a small temperature differential between radiators, regardless of their location. Individual room control is possible with both one-pipe and two-pipe systems, although a change in the valve adjustment on one radiator will affect the performance of others downstream.

Distribution piping should be checked for leaks at valves and connections. Inspect such piping as outlined in Section 6.2 for domestic water supply piping. Make sure pipes are properly insulated in unheated basements, attics, and crawl spaces. See Sections 3.1 and 3.9.

When the distribution piping is divided in zones, each zone will have either a separate circulation pump or a separate electrically operated valve.

Test: Check the operation of all zone valves by activating each thermostat, one at a time. If hot water is being distributed properly to each zone, the radiators in that zone should be warm to the touch within several minutes. Locate all valves, inspect their electrical wiring and connections, and look for signs of leakage.



One-pipe parallel flow steam heating system

- **Radiators and control valves.** Radiators are of three types: cast iron (which in most cases are free standing but sometimes are hung from the ceiling or wall, convector (which may have a circulating fan), and baseboard. Older residential buildings usually have cast iron radiators that are extremely durable and normally can be reused, although they are less efficient than convectors. Baseboard radiators are considered the most desirable for residential use because they are the least conspicuous and distribute heat most evenly throughout the room. Radiators should be located on outside walls whenever possible.

  Test: Activate the system and look for signs of water leakage. Feel the surfaces of all radiators to ensure that they are heating uniformly; if they are not, bleed them to remove entrapped air. Examine the fins of all convectors for dirt and damage. These fins can be "combed" straight. Check the condition of all radiator control, safety, and bleed valves and make sure they are operational. Often the valves need tightening or their packing needs replacing.

- **Radiant panel heating.** Hot water distribution piping may be embedded in floors, walls, and ceilings to provide radiant heating. Because the piping is embedded, it can only be inspected by looking for signs of water leakage or rust on the floor or wall surfaces that cover the piping. Such heating is normally trouble free, unless there are major structural problems that damage distribution piping and joints, or unless piping includes copper pipe and steel pipe that are not separated by a dielectric coupling.

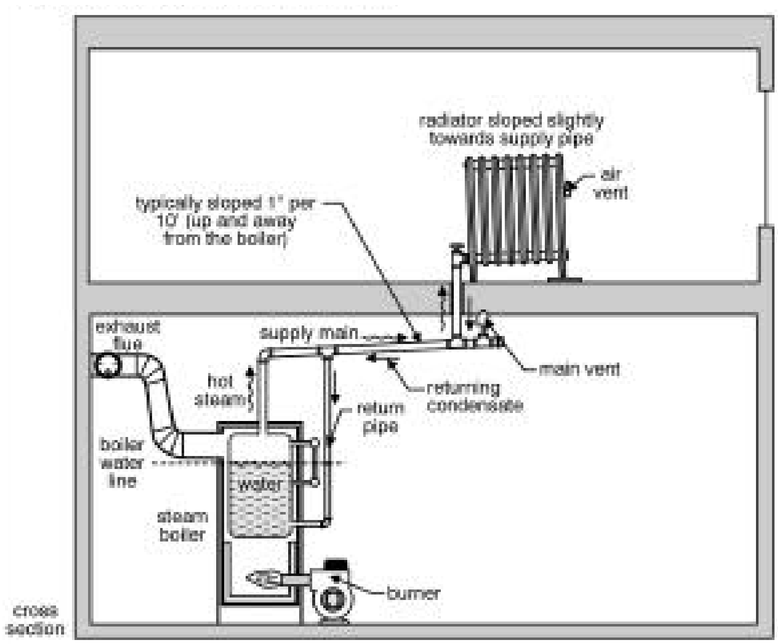
  Test: Operate radiant heating systems to determine their functional adequacy. Radiant surfaces should be warm to the touch within several minutes. Check the condition of the shutoff valves for each distribution zone and the main balancing valves near the boiler and look for signs of leakage. Inspect the expansion tank and air vent (if any) in accordance with the subsection on expansion tanks (above). If the system appears to be in good condition but heating is not adequate, consider having a service technician pressure test the distribution piping for a period of up to 24 hours. If a drop in pressure occurs, there is a leak. When a leak is detected, have the service technician flush the piping to check for galvanic corrosion.

7.5 Steam Heating Systems

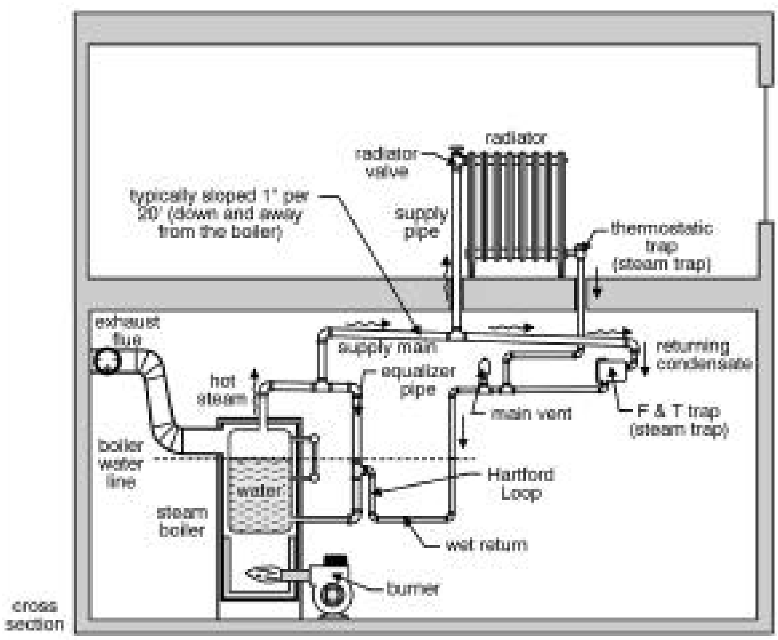
Steam heating systems are seldom installed now in small residential buildings but are still common in many older ones. They are simple in design and operation, but require a higher level of maintenance than modern residential heating systems. Unless the steam system is in good working order and adequate plans can be made for its up keep, consider replacing it with a more maintenance-free system.

Assess the condition and operation of steam heating systems as follows:

- **Boiler.** Steam boilers are physically similar to hot water boilers and should be inspected similarly. See Section 7.4.



One-pipe counterflow steam heating system



Two-pipe steam heating system

- **Boiler controls.** Unlike hot water boilers, steam boilers operate only about three-fourths full of water and at much lower pressures, usually 2 to 5 psi. Steam boilers should be equipped with a water level gauge, a pressure gauge, a high-pressure limit switch, a low water cut-off, and a safety valve.

  Test: Activate the boiler and observe the water level gauge that indicates the level of the water in the boiler. The gauge should normally read about half full, though the actual level of the water is not critical as long as the level is showing. If the gauge is full of water, the boiler is flooded and water must be drained from the system. If the gauge is empty, the boiler water level is too low and must be filled (either manually through the fill valve or automatically through the automatic water feed valve, if the boiler has one). Unsteady, up and down motion of water in the gauge means the boiler is clogged with sediment or is otherwise operating incorrectly and must be repaired. The clarity of the boiler water should be noted when checking the gauge; if the gauge is too dirty to judge the water level, remove and clean it. This test and any resulting work should be done by a service technician.

  The high-pressure limit switch turns off the burner when the boiler pressure exceeds a preset level, usually 5 to 7 psi (35 to 48 kPa). It is connected to the boiler by a pigtail-shaped pipe. The low water cut-off shuts down the burner when the boiler water level is too low.

Test: Lower the water level in the boiler and see whether the low water cutoff turns off the burner. Usually this test should be performed by a service technician.

The pressure relief valve is designed to discharge when the boiler pressure exceeds 15 psi (103 kPa).

- **Distribution piping.** The steam distribution system consists of distribution piping, radiators, and control valves. Distribution piping may have either a one-pipe or two-pipe configuration.

  In a **one-pipe system,** steam from the boiler rises under pressure through the pipes to the radiators. There it displaces air by evacuation through the radiator vent valves, condenses on the radiator's inner surface, and gives up heat. Steam condensate flows by gravity back through the same pipes to the boiler for reheating. The pipes, therefore, must be pitched no less than one inch in ten feet in the direction of the boiler to ensure that the condensate does not block the steam in any part of the system. All piping and radiators must be located above the boiler in a one-pipe system.

  In a **two-pipe system,** steam flows to the radiators in one pipe and condensate returns in another. A steam trap on the condensate return line releases air displaced by the incoming steam. If the condensate return piping is located below the level of the boiler, it should be brought back up to the level of the boiler and vented to the supply piping in a "Hartford Loop." This prevents a leak in the condensate return from emptying the boiler. Two-pipe systems can be balanced by regulating the supply valves on each radiator, and may be converted for use in a hot water heating system (although new, larger-size return piping usually must be installed).

  Distribution piping should be checked for leaks at all valves and connections. Make sure all piping is properly pitched to drain toward the boiler. "Pounding" may occur when oncoming steam meets water trapped in the system by improperly pitched distribution piping or by shutoff valves that are not fully closed or fully open. Inspect the condition of all piping as outlined in Section 6.2 for domestic water supply piping. Make sure pipes are properly insulated in unheated basements, attics, and crawl spaces. See Sections 3.1 and 3.9.

- **Radiators and control valves.** Steam radiators are made of cast iron and are usually free standing. They are quite durable and, in most cases, can be reused. Radiators should be located on outside walls whenever possible.

  Test: Activate the system and inspect the condition of all radiators. Look for signs of water leakage. Feel their surfaces to make sure they are heating uniformly; if they are not, check the radiator air vents and supply valves on a one-pipe system and the radiator supply valves and the steam trap on the condensate return on a two-pipe system. Often air vents need cleaning and supply valves need tightening, or valve packing needs to be replaced. "Pounding" near the radiator can often be cured by lifting one edge of the radiator slightly; this reduces condensate blocking in the pipes.

7.6 Electric Resistance Heating

Electric resistance heating elements commonly are used in heat pump systems, wall heaters, radiant wall or ceiling panels, and baseboard heaters. They are less frequently used as a heat source for central warm air or hot water systems. Such heating devices usually require little maintenance, but their operating costs should be carefully considered when planning the building rehabilitation.

Assess the condition of all electric resistance heating devices by activating them and inspecting as follows:

- **Electric resistance heaters.** Electric resistance heaters are used in warm air and hot water systems as described in Sections 7.3 and 7.4, and in heat pumps as described in Section 7.9. They incorporate one or more heavy duty heating elements that are actuated by sequence relays on demand from the thermostat. The relays start each heating element at 30-second intervals, which eliminates surges on the electrical power system. In warm air and heat pump systems, electric heating elements are normally located in the furnace or heat pump enclosure, but they may be located anywhere in the ductwork as primary or secondary heating devices.

Inspect the condition of all electric resistance heaters, including their wiring and connections.

Test: If possible, observe the start up of the heating elements. Their failure to heat up indicates either a burnt-out element or a malfunctioning relay.

- **Electric wall heaters.** These compact devices are often used as supplementary heating units or as sole heat sources in houses for which heating is only occasionally required. They may have one or more electric heating elements, depending on their size, and should be inspected as described above. Wall heaters often have a small circulation fan; check its condition and operation and look for dirt build up on the fan blades and motor housing. Inspect all electrical wiring and connections.
- **Radiant wall and ceiling panels.** Electric heating panels that are embedded in wall or ceiling surfaces cannot be directly inspected, but all radiant surfaces should be examined for signs of surface or structural damage.

  Test: If the panels do not provide heat when the thermostat is activated, check the thermostat, circuit breaker, and all accessible wiring to determine the cause or have an electrical continuity test performed by an electrician.
- **Baseboard heaters.** Baseboard heater heating fins can be damaged and become clogged with dust. Remove heater covers and inspect for such problems. Bent heating fins can often be restraightened by "combing." The thermostat may be on an adjacent wall or in the unit itself.

7.7 Central Air Conditioning Systems

Central air conditioning systems are defined here as electrically operated refrigerant-type systems used for cooling and dehumidification. (Evaporative coolers are described in Section 7.10 and gas-absorption systems are described in Section 7.8.) Heat pumps are similar to central air conditioners, but are reversible and can also be used as heating devices; they are described in Section 7.9. Air conditioning systems should be tested only when the outside air temperature is above 65 ºF (18 ºC); below that temperature, the systems will not operate properly and may shut down due to safety controls.

There are two types of central air conditioning systems: integral and split. In the **integral system,** all mechanized components—compressor, condenser, evaporator, and fans—are contained in a single unit. The unit may be located outside the building with its cold air ductwork extending into the interior, or it may be located somewhere inside the building with its exhaust air ducted to the outside.

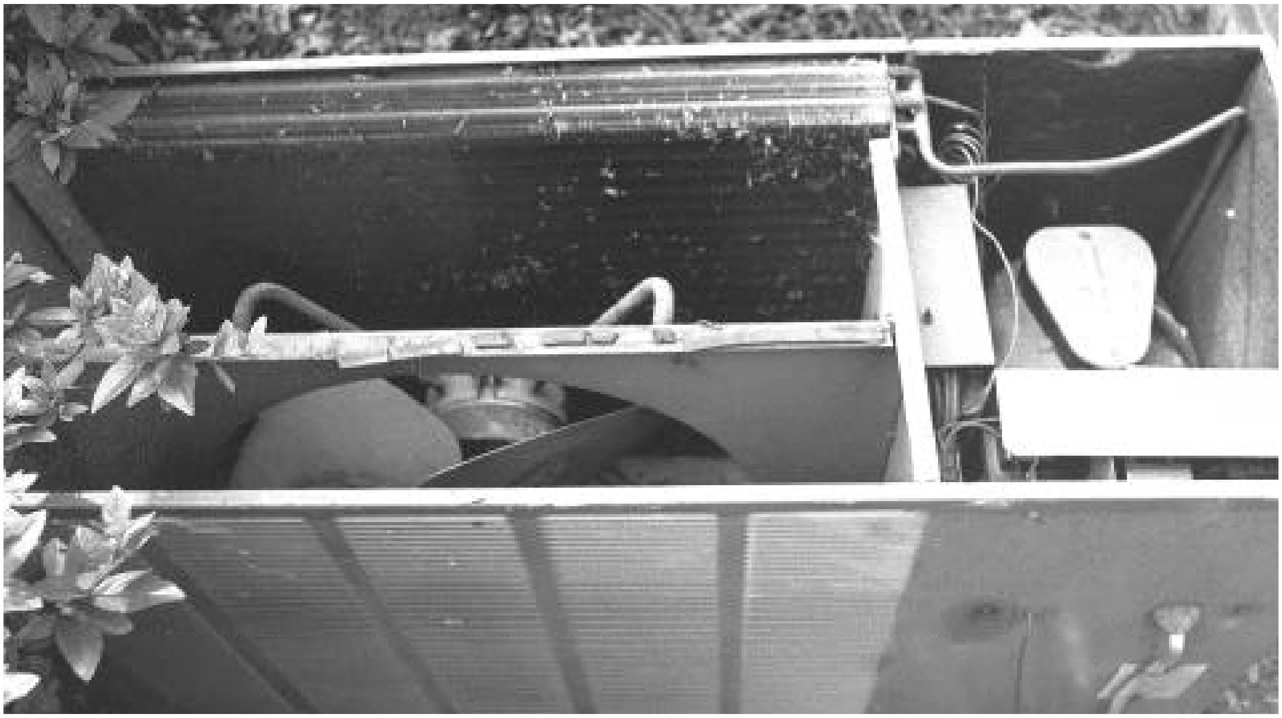
In the **split system,** the compressor and condenser are located outside the building and are connected by refrigerant lines to an evaporator inside the building's air distribution ductwork. Split systems in buildings heated by forced warm air usually share the warm air system's circulating fan and ductwork. In such cases, the evaporator is placed either directly above or below the furnace, depending on the furnace design.

Assess the condition of central air conditioning systems as follows:

- **Compressor and condenser.** The compressor pumps refrigerant gas under high pressure through a condenser coil, where it gives up heat and becomes a liquid. The heat is exhausted to the outside air by the condenser fan. Compressors have a service life of 5 to 15 years, depending on the maintenance they receive, and are the most critical component in the air conditioning system.

  Test: Activate the system and observe the operation of the compressor. It should start smoothly and run continuously; noisy start up and operation indicates a worn compressor. The condenser fan should start simultaneously with the compressor. After several minutes of operation, the air flowing over the condenser should be warm. If it isn't, either the compressor is faulty or there is not enough refrigerant in the system.

  If the compressor, condenser, and condenser fan are part of a split system and are located in a separate unit outside, check the air flow around the outside unit to make sure it is unobstructed. Look for dirt and debris inside the unit,

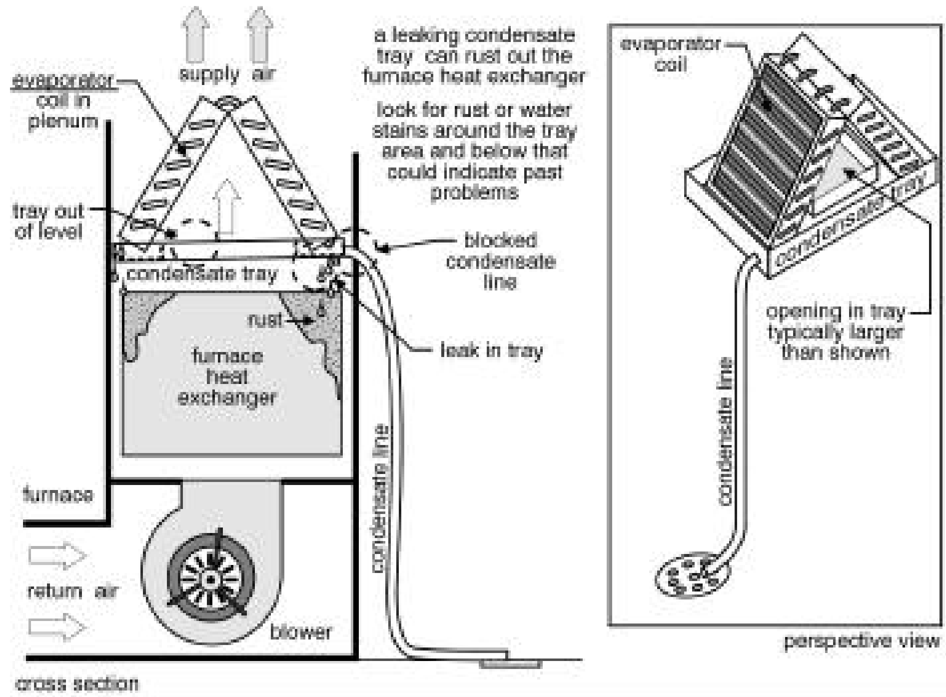


Looking down into an outdoor compressor unit with the top cover removed. The compressor is on the upper right, controls are on the lower right, and the fan and condenser coils are to the left.

particularly on the condenser coils and fins, and inspect all electrical wiring and connections. The unit should be level and well-supported, and its housing intact and childproof. An electrical disconnect switch for use during maintenance and repairs should be located within sight of the unit.

Integral systems located somewhere on or in the building should have their compressors placed on vibration mountings to minimize sound transmission to inhabited building spaces.

- **Refrigerant lines.** Refrigerant lines form the link between the interior and exterior components of a split system. The larger of the two lines carries low pressure (cold) refrigerant gas from the evaporator to the compressor. It is about the diameter of a broom handle and should be insulated along its entire length. The smaller line is uninsulated and carries high pressure (warm) liquid refrigerant to the evaporator. Check both lines for signs of damage and make sure the insulation is intact on the larger line. On its exterior, the insulation should be protected from ultraviolet damage by a covering or by white paint. Sometimes a sight glass is provided on the smaller line; if so, the flow of refrigerant should look smooth through the glass. Bubbles in the flow indicate a deficiency of refrigerant in the system. Frost on any exposed parts of the larger line also indicates a refrigerant deficiency.
- **Seismic vulnerability.** If the building is in seismic zones 3 or 4 (California and portions of Alaska, Arkansas, Hawaii, Idaho, Missouri, Montana, Nevada, Oregon, Utah, Wyoming, and Washington), check roof-mounted compressor and condenser units for the presence of seismic bracing to the structure.
- **Evaporator.** The evaporator is enclosed in the air distribution ductwork and can only be observed by removing a panel or part of the furnace plenum. High pressure liquid refrigerant enters the evaporator and expands into a gas, absorbing heat from the surrounding air.



Leaking condensate tray

Air is pushed past the evaporator coil by the system's circulation blower; in the process, water vapor from the air condenses on the evaporator coil and drips into a drain pan. From there, it is directed to a condensate drain line that may sometimes include a condensate pump. The drain line empties into a house drain or directly to the building's exterior.

Examine the ductwork around the evaporator for signs of air leakage and check below the evaporator for signs of water leakage due to a blocked condensate drain line. Such leakage can present a serious problem if the evaporator is located above a warm air furnace, where dripping condensate water can rust the heat exchanger (see Section 7.3), or above a ceiling, where it can damage the building components below. Follow the condensate line and make sure that it terminates in a proper location. If there is a pump on the line, check its operation.

In split systems where the evaporator is located in an attic or closet, the condensate drain pan should have an auxiliary condensate drain line located above the regular drain line or an auxiliary drain pan that is separately drained. The connection of a condensate drain line to a plumbing vent in the attic may violate local codes. Check for such violations.

Test: If the evaporator coil can be exposed, inspect it for frost build up after about 30 minutes of operation. Frost is an indication of inadequate air flow due to dirt on the coil or a deficiency of refrigerant in the system. Check to see if water is discharging from the condensate drain line. If it is not, either the evaporator coil is not working properly or the drain line is clogged.

Test: Central air conditioning systems can be tested by an HVAC service technician to determine their overall condition and operational efficiency. This test requires a variety of specialized equipment and involves: 1) testing the pressure in the refrigerant lines, 2) taking amperage readings on the compressor, and 3) taking temperature readings of the air passing over the condenser and the evaporator coils, and correlating these readings with ambient outside temperature conditions.

- **Geothermal heating and cooling system.** Geothermal systems are relatively new and operate similarly to air-to-air heat pump systems, but differ in design and installation. What might be considered the condenser are pipes buried in the ground in dry wells or other in-ground systems suitable for transferring or displacing heat. The system is closed and its piping is PVC so corrosion is not a potential problem. Geothermal systems are normally installed without a back up or emergency heating system and all their components except the buried coils are usually inside the house. For more information, consult the *Geothermal Heat Pumps: Introductory Guide* published by the International Ground Source Heat Pump Association. A geothermal heating and cooling system can be operated in a heating or cooling mode under any outside temperature. Although expensive to install, they normally are efficient and economical to operate.

  Test: Observe the operation of the system in both heating and cooling modes if possible. Visually inspect the well field header piping and pumps. Pressure test the well field. Tests should be conducted by a service technician.

- **Distribution ductwork and controls.** Cool air distribution ductwork and controls, including zone controls, should be inspected similarly to those for forced warm air heating systems, as described in Section 7.3.

7.8 Central Gas-Absorption Cooling Systems

Gas-absorption cooling systems occasionally may be found in older residential buildings. Such systems use the evaporation of a liquid, such as ammonia, as the cooling agent and, like a gas refrigerator, are powered by a natural gas or propane flame.

Test: A gas-absorption system operates under several hundred pounds of pressure and should be tested by a specialist. The local gas or fuel supplier probably maintains the unit; ask for an evaluation of the system. Meanwhile, operate the system. It should start smoothly and run quietly.

Examine the condition of the system's exterior and interior components. Inspect ductwork in accordance with Section 7.3.

7.9 Heat Pumps

Electric heat pumps are electrically operated, refrigerant-type air conditioning systems that can be reversed to extract heat from outside air and transfer it indoors. Heat pumps are normally sized for their air conditioning load, which in most parts of the country is smaller than the heating load. Auxiliary electric heaters are used to provide the extra heating capacity the system requires in the heating season.

Like air conditioning systems, heat pumps can be either split or integral. Integral systems located outside the building should have well-insulated air ducts between the unit and the building. If located on or within the building, they should be mounted on vibration isolators, be thermally protected, and have an adequate condensate drainage system.

Inspect heat pumps by the procedure described in Section 7.7 for central air conditioning systems. Testing in one mode is usually sufficient. However, do not operate air-to-air heat pumps in temperatures below 65 ºF (18 ºC) on the cooling cycle and above 55 ºF (13 ºC) on the heating cycle. In both conditions the amount of work the heat pump has to do to achieve interior comfort temperatures is not enough to really test the heat pump's ability to perform. Check also for the following problems:

- **Auxiliary heater failure.** Electric resistance auxiliary heaters are designed to activate (usually in stages) below about 30 ºF (-1 ºC) outdoor temperature when the heat pump cannot produce enough heat to satisfy the thermostat. Examine the condition of all auxiliary heaters in accordance with Section 7.6.

  Test: If possible, activate the auxiliary heaters to observe their operation. Operating failures may be caused by a faulty heater element, faulty relays, a faulty thermostat, or a faulty reversing valve.

- **Improper defrosting.** During cold, damp weather, frost or ice may form on the metal fins of the coil in an outdoor unit. Heat pumps are designed to defrost this build up by reversing modes either at preset intervals or upon activation by a pressure sensing device.

Test: The pressure sensor may malfunction, and on units so equipped, it can be tested in the heating mode by temporarily placing an obstruction on the exhaust side of the coil and observing whether the coil begins to heat (defrost) within a short period of time.

- **Faulty reversing valve.** In most heat pumps, a reversing valve changes modes from heating to cooling (some heat pumps use a series of dampers instead) when the thermostat is changed.

Test: Check the reversing valve when the outside temperature varies enough to be able to run the heat pump in the opposite modes. Change the thermostat. If the system doesn't reverse, the reversing valve is faulty.

7.10 Evaporative Cooling Systems

Evaporative cooling systems are simple and economical devices. They pass air through wetted pads or screens and cooling takes place by evaporation. Such systems can only be used in dry climates where evaporation readily

A roof-mounted evaporative cooler. This type of cooling unit is relatively simple to inspect, repair, and maintain.

Installation of this air conditioner destroyed the structural integrity of the bearing wall between the two windows.

takes place and where dehumidification is not required.

Evaporative coolers consist of evaporator pads or screens, a means to wet them, an air blower, and a water reservoir with a drain and float-operated water supply valve. These components are contained in a single housing, usually located on the roof, and connected to an interior air distribution system. In **wetted-pad coolers,** evaporator pads are wetted by a circulating pump that continually trickles water over them; in **slinger coolers,** evaporator pads are wetted by a spray; and in **rotary coolers,** evaporator screens are wetted by passing through a reservoir on a rotating drum.

The water in evaporative coolers often contains algae and bacteria that emit a characteristic "swampy" odor. These can be removed easily with bleach. Some systems counteract this pattern by treating the water or by continually adding a small amount of fresh water.

Inspect evaporative cooling systems by examining the condition of each component. Note whether evaporative pads need cleaning or replacement. Look for signs of leakage and check the cleanliness and operation of the water reservoir, float-operated supply valve, and drain.

Test: Activate the system and listen for unusual sounds or vibrations. Inspect all distribution ductwork as described in Section 7.3 and evaluate the system's overall ability to cool the building.

If the building is in seismic zones 3 or 4 (California and portions of Alaska, Arkansas, Hawaii, Idaho, Missouri, Montana, Nevada, Oregon, Utah, Wyoming, and Washington), check the evaporative cooler for the presence of seismic bracing to the structure.

7.11 Humidifiers

Humidifiers are sometimes added to warm air heating systems to reduce interior dryness during the heating season. They are installed with the air distribution system and are controlled by a humidistat that is usually located in the return air duct near the humidifier housing. The humidifier should not be located in a return air duct (see Section 7.3). Humidifiers can be of several types:

- **Stationary pad,** in which air is drawn from the furnace plenum or supply air duct by a fan, blown over an evaporator pad, and returned to the air distribution system.
- **Revolving drum,** in which water from a small reservoir is picked up by a revolving pad and exposed to an air stream from the furnace plenum or supply ductwork.
- **Atomizer,** in which water is broken into small particles by an atomizing device and released into the supply air ductwork.
- **Steam,** in which water is heated to temperatures above boiling and then injected into the supply air duct.

Inspect the humidifier's condition. Take off the unit's cover and check for mineral build up on the drum or pad. Examine the humidifier's water supply and look for signs of leakage, especially at its connection with the house water supply. Check all electrical wiring and connections.

Test: Activate the humidifier by turning up the humidistat. It should only operate when the furnace fan is on, the system is in the heating mode, and the indoor humidity is lower than the humidistat setting.

7.12 Unit (Window) Air Conditioners

Unit air conditioners are portable, integral air conditioning systems without ductwork. Inspect their overall condition and check the seal around each unit and its attachment to the window or wall. Ensure that it is adequately supported and look for obstructions to air flow on the exterior and for proper condensate drainage. Make sure all electrical service is properly sized and that each unit is properly grounded. Bent fins on the condenser coils may be "combed."

Test: Operate each window unit for a long enough period to determine its cooling capacity; after several minutes, the air from the unit should feel quite cool. It should start smoothly and run quietly. Check for water dripping from the condensate discharge on the exterior side of the unit.

7.13 Whole House and Attic Fans

Check the location and condition of the whole house or attic fan, if one is present (see Section 3.9). Inspect fan motors for signs of overheating and examine fan belts for signs of wear. Check all operating controls and associated electrical wiring and check to see that the attic fan thermostat is set at about 95 ºF (35 ºC).

Test: Activate whole house and attic fans and observe their operation. They should start and run smoothly and be securely fastened to their frames. Note whether the louvers below a whole house fan are open completely when the fan is running and whether exterior louvers on attic fans are weather protected and screened.