

Chapter 6: Structural System

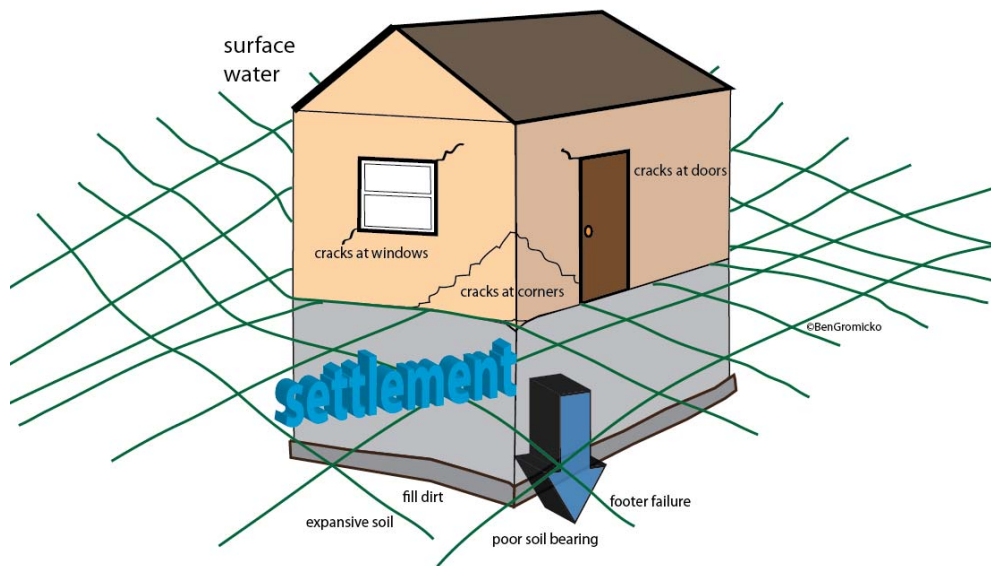
This chapter goes over structural problems that may be found in a house. Many different types of cracking in numerous building materials are described. Most homes do not have major structural problems, but some do. In a well-maintained and kept, modern residential building, there may likely be no major structural problems. 19th-century buildings, that often show



This chapter describes signs of structural distress, deterioration and damage by material type: masonry (the most difficult to assess), wood, iron, steel and concrete.

Assessing structural capacity. A thorough visual home inspection of its structural components is all that is normally necessary to verify the building's structural design or its structural integrity. Unless there is

obvious overloading, significant deterioration of important structural components, or additional loading is anticipated, there is usually little need for engineering evaluations.

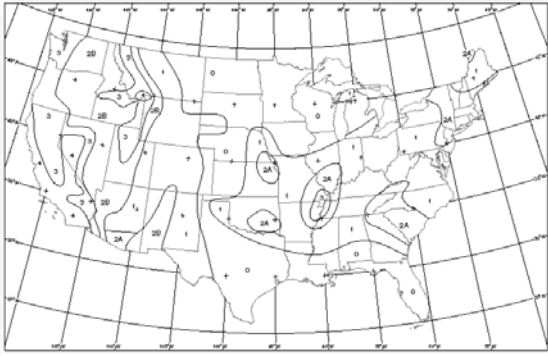


signs of settlement, may have only minor structural faults that can be readily remedied. Major structural problems, when they do develop, are usually quite obvious. It is the less obvious problems that require careful inspection and informed diagnosis. Such problems are often detected through a pattern of symptoms rather than any one symptom.

If the building's structural loading will be dramatically increased by such things as a new water bed, installation of a stone kitchen countertop, tile flooring, or heavy stove and oven, a quantitative analysis should be made of all the structural members involved. Simple calculations may be made or the

local building code may be sufficient. More complex calculations could be performed by a qualified structural engineer.

6.1 Seismic Resistance



If the building is in seismic zones 2B, 3, and 4 (California, Idaho, Nevada, Oregon, Washington, and portions of Alaska, Arizona, Arkansas, Hawaii, Missouri, Montana, New Mexico, Utah, and Wyoming), have a structural engineer **check the following conditions** for structural vulnerability. (Note that wood frame buildings with brick or stone veneer are still considered wood frame.)

- Wood frame buildings that are not physically anchored to their foundations. Such buildings may be vulnerable to shifting or sliding.
- Wood frame buildings and wood framed portions (porches, for example) or other buildings when they are supported above ground on either short wood studs (cripple walls) or on piers of stone, masonry or concrete.

Such buildings may be vulnerable to tilting or falling over.

- Un-reinforced and inadequately reinforced masonry buildings. Such buildings may be vulnerable to total or partial collapse due to inadequate reinforcement or to inadequate anchorage of roofs and walls to the floors.

- Buildings of any type that have irregular shapes. Such buildings may be vulnerable to partial collapse.

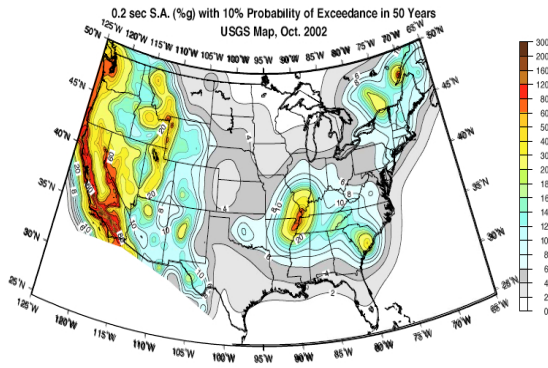
- Wood frame and masonry buildings with more than one story above grade where the story at grade is a large unobstructed open space, such as a garage. Such buildings may be vulnerable to collapse of the story at grade.



- Wood frame and masonry buildings with more than one story above grade that are constructed on sloping hill-sides, and buildings of any type of construction and height that are constructed on steep slopes of 20 degree or more. Such

buildings may be vulnerable to sliding.

If the building is in seismic zone 2A (Connecticut, Massachusetts, Rhode Island, South Carolina, and portions of Georgia, Illinois, Indiana, Kansas, Kentucky, Maine, New Hampshire, New Jersey, New York, North Carolina,



Oklahoma, Pennsylvania, Tennessee, Vermont, and Virginia) and has more than two stories above grade, consider having a structural engineer check for the last two conditions (large unobstructed open space at grade and sloped sites).

Buildings not of wood frame or masonry construction, such as stone, adobe, log, and post and beam structures, as well as buildings with more than one type of construction in any seismic zone, should be investigated by a structural engineer to determine their seismic vulnerability.

Masonry bearing wall buildings in seismic zones 2B, 3, and 4 should be investigated by a structural engineer for the presence of rein-forcing steel.

Have a structural engineer check the anchorage of wood framed structures to their foundations and investigate all such structures supported on cripple walls or piers in seismic zones 2, 3, and 4.

In all seismic zones, a structural engineer should investigate buildings with more than one story above grade where the story at grade is a large unobstructed open space or the building is on a sloping hillside and in seismic zones 2B, 3, and 4 buildings with an irregular shape.

6.2 Wind Resistance

Hurricanes are large, slow moving, damaging storms characterized by gusting winds from different directions, rain, flooding, high waves and storm surges. The coasts of the Gulf of Mexico, the south- and mid-Atlantic coast, the coastal areas of Puerto Rico, the U.S. Virgin Islands and Hawaii as well as the U.S. territories of American Samoa and Guam are vulnerable to hurricanes in the late summer and early fall. Winter storms along the mid- and north-Atlantic coast can be more damaging than hurricanes because of their greater frequency, longer duration, and high erosion impacts on the coastline. Even in states not normally considered susceptible to extreme windstorms, there are areas that experience dangerously

high winds. These areas are typically near mountain ranges and include the Pacific Northwest coast. Other extreme wind areas include the plains states, which are especially subject to tornadoes.

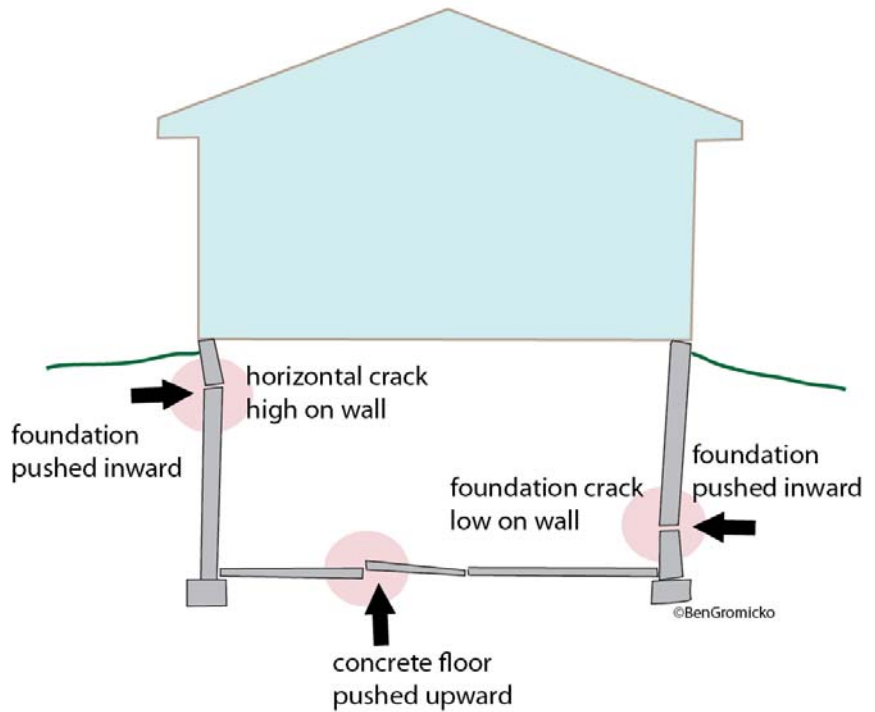
In addition to the direct effects of high winds and winter on buildings, hurricanes and other severe storms generate **airborne debris** that can damage buildings.

Debris. Debris, such as small stones, tree branches, roof shingles and tiles, building parts and other objects, is picked up by the wind and moved with enough force to damage and even penetrate windows, doors, walls and roofs. When a building's exterior envelope is breached by debris, the building can become pressurized, subjecting its walls and roof to much higher damaging wind pressures. In general, the stronger the wind, the larger and heavier the debris it can carry and the greater the risk of severe damage.



If the building is in a hurricane or high-wind region, consider having a structural engineer check its structural system for continuity of load

path, including resistance to uplift forces. If there is an accessible attic, improper attachment of the roof sheathing to the roof-framing members can be checked by looking for unengaged or partially engaged nails. Hurricane hold-down clips for joists, rafters, and trusses should be present at the exterior wall. Examine the gable end walls and the roof trusses for lateral bracing. Check to see whether the exterior wall and other load-bearing



walls are securely attached to the foundation.

6.3 Masonry

A homeowner should know which walls are load-bearing and which are not. Usually this can be understood by examining the beams and joists in the building's basement or crawl space or attic. All exposed masonry should be monitored for cracking, spalling, bowing (bulges vertically), sweeping (bulges horizontally), leaning and mortar deterioration.

Masonry cracking. Monitoring the masonry walls of the house is needed. Although masonry can deform elastically over long periods of time to accommodate small amounts of movement, large movements normally cause cracking. Cracks may appear along the mortar joints or through the masonry units. Cracking can result from a variety of problems: differential settlement of foundations; drying shrinkage (particularly in concrete block); expansion and contraction due to ambient thermal and moisture variations; improper support over openings; the effects of freeze-thaw cycles; the corrosion of iron and steel wall reinforcement, differential movement between building materials; expansion of salts and; the bulging or leaning of walls.

Cracks should always be further evaluated to determine their cause and whether corrective action is required.



Look for signs of movement. A clean crack indicates recent movement; a dirty or previously filled crack may be inactive. **Correlate the width of larger cracks to the age of the building.** A one-half-inch crack in a new building may be a sign of rapid settlement, but in a building 50 years old, it may indicate a very slow movement of only 1/100 of an inch (0.25 mm) per year.

Crack movement can be measured with a commercially available joint movement indicator. This device is temporarily fastened over the crack and a scribe records movement over a period of time.

Cyclical. Cyclical movements may take six months or more to measure, but diurnal movements can be recorded over a few days. Cracks associated with thermal expansion and contraction may open and close with the season. These are cyclical cracks, which may gradually expand as accumulating mortar debris jams them farther apart after each cycle. Such cracks should be cleaned and protected by flexible sealants. Re-mortaring cyclical cracks will hold them open and cause more cracking.

When there are major masonry problems, it is advisable to hire a structural engineer. If problems appear to be due to differential

settlement, a soils engineer also may be required.

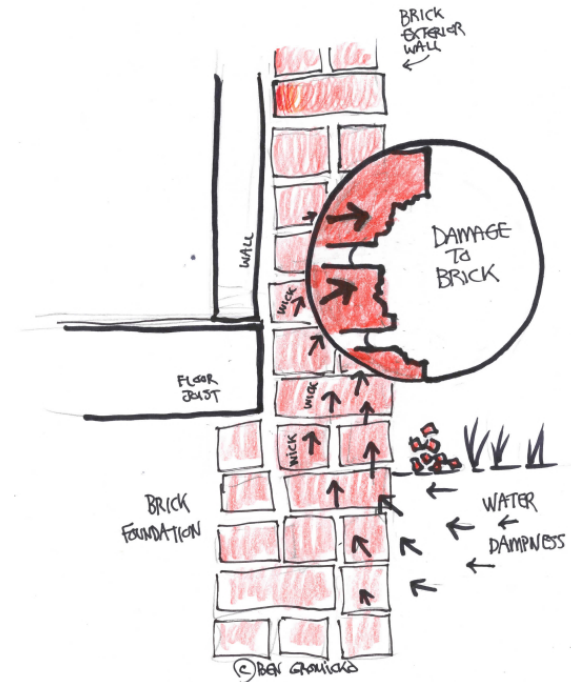


Mortar deterioration. The age of the building may be a good clue in evaluating its mortar problems. The two important qualities of mortar are its ability to bond to masonry and its internal strength. Older mortar (or mortar of any age that uses hydrated lime) will be softer and may require pointing, but otherwise may be responsible for a sound wall.

Moisture. Most often, mortar deterioration is found in areas of **excessive moisture**, such as near leaking downspouts, below windows and at tops of walls. In such cases the remedy is to redirect the water flow and point the mortar joints. Pointing should be performed with mortar of a composition similar to or compatible with the original mortar. The use of high strength mortar to point mortar of a lower strength can do serious damage to the masonry since the pointing can't "flex" with or act in a similar way to the rest of the joint.

It is useful to remember that mortar acts as a drainage system to equalize hydrostatic pressure within the

masonry. Nothing should be done to reduce its porosity and thereby block water flow to the exterior surface.



Deterioration of brick masonry units. The spalling, dusting or flaking of brick masonry units may be due to either mechanical or chemical damage. **Mechanical** damage is caused by moisture entering the brick and freezing, resulting in spalling of the brick's outer layers. Spalling may continue or may stop on its own after the outer layers that trapped the interior moisture have broken off. **Chemical** damage is due to the leaching of chemicals from the ground into the brick, resulting in internal deterioration. External signs of such deterioration are a dusting or flaking of the brick. Very little can be done

to correct existing mechanical and chemical damage except for actually replacing the brick. Mechanical deterioration can be slowed or stopped by directing water away from the masonry surface and by pointing mortar joints to slow water entry into the wall.

6.4 Masonry Foundations and Piers

At your foundation walls (either stone, brick, concrete, or concrete block foundations) look for these following problems:



Uneven settlement.

Uneven (or differential) settlement can be a major structural problem in small residential buildings. Serious settlement problems are relatively uncommon. Many signs of masonry distress are incorrectly diagnosed

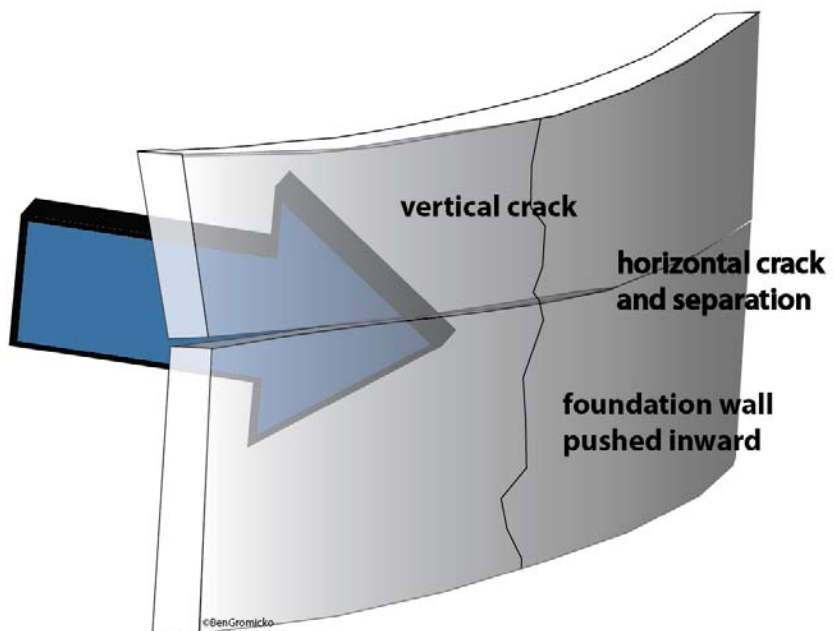
as settlement-related when in fact they are due to moisture and thermal movements.

Indications of differential settlement are vertical distortion or cracking of masonry walls, warped interior and exterior openings, sloped floors, and sticking doors and windows.

Settlement most often occurs early in the life of a building or when there is a dramatic change in underground conditions. Often such settlement is associated with improper foundation design, particularly inadequate footers and foundation walls.

Other causes of settlement are:

- soil consolidation under the footings
- soil shrinkage due to the loss of moisture to nearby trees or large plants
- soil swelling due to inadequate or blocked



- surface or house drainage
- soil heaving due to frost or excessive root growth
- gradual downward drift of clay soils on slopes
- changes in water table level
- soil erosion around footers from poor surface drainage, faulty drains, leaking water mains or other underground water movements (occasionally, underground water may scour away earth along only one side of a footer, causing its rotation and the subsequent buckling or displacement of the foundation wall above)
- soil compaction or movement due to vibration from heavy equipment, vehicular traffic, or blasting, or from ground tremors (earthquakes).

Gradual differential settlement over a long period of time may produce no masonry cracking at all, particularly in walls with older and softer bricks and high lime mortars; the wall will elastically deform instead. More rapid settlements, however, produce cracks that taper, being largest at one end and diminishing to a hairline at the other, depending on the direction and location of settlement below the wall.

Cracking is most likely to occur at corners and adjacent to openings, and usually follows a rough diagonal along mortar joints (although individual masonry units may be split). Settlement cracks (as opposed to the similar-appearing shrinkage cracks

that are especially prevalent in concrete block) may extend through contiguous building elements such as floor slabs, masonry walls above the foundation, and interior plaster work.

Tapering cracks, or cracks that are nearly vertical and whose edges do not line up, may occur at the joints of projecting bay windows, porches, and additions. These cracks indicate differential settlement due to inadequate foundations or piers under the projecting element. Often settlement slows a short time after construction and a point of equilibrium is reached in which movement no longer occurs.

Minor settlement cracking is structurally harmful only if long-term moisture leakage through the cracks adversely affects building elements. Large differential settlements, particularly between foundation walls and interior columns or piers, are more serious because they will cause movements in contiguous structural elements such as beams, joists, floors, and roofs that must be evaluated for loss of bearing and, occasionally, fracture.

Repair. If the foundation needs repair, it can be accomplished by the addition of new structural elements, such as pilasters, or by **pressure-injecting concrete epoxy grout** into the foundation wall. If movement continues and cracking is extensive, it is possible

that the problem can only be rectified by underpinning. Older buildings with severe settlement problems may be very costly to repair.

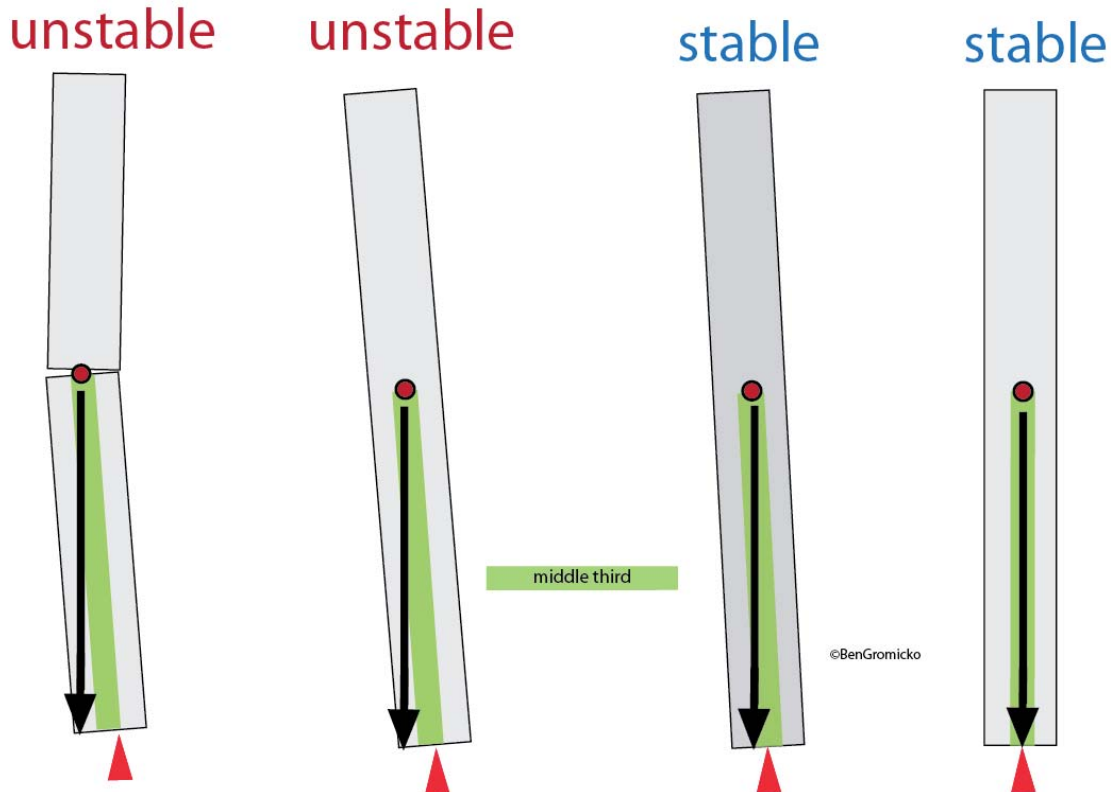
Masonry piers. Masonry piers are often used to support internal loads on small residential buildings or to support projecting building elements such as bay windows, porches, and additions. In some cases they support the entire structure. Piers often settle differentially and over a long period of time (particularly when they are exposed to the weather) they tend to deteriorate.

Pier problems:

- Piers should be plumb, without major settlement, in good condition and

adequate in accepting bearing loads. Their width to height ratio, which should not exceed 1:10. Those that are deficient should be repaired or replaced. When appearance is not a factor (as is often the case), piers can be supplemented by the addition of adjacent supports.

- Settlement or rotation of the pier footing can cause a lowering or tilting of the pier and subsequent loss of bearing capacity. Wood frame structures adjust to this condition by flexing and redistributing their loads or by sagging (see Section 6.7). Masonry walls located over settled piers will crack.



- Frost heaving of the footing or pier, a condition caused by the lack of an adequate footing or one of insufficient depth can raise or tilt a pier. This could show up as movement similar to that caused by settlement or rotation of the footing. Such a condition is most common under porches and decks.

- Aboveground piers exposed to the weather are subject to freeze-thaw cycles and subsequent physical damage. Deterioration of the pier could be caused by exposure, poor construction, or overstressing. Piers for many older residential structures are often of poorly constructed masonry that deteriorates over the years. A sign of overstressing of piers is vertical cracking or bulging.

- Problems with piers can result in problems with bearing of wooden components. Structural wooden components can lose bearing when piers move or deteriorate.

- **Cracking.** Cracking can form from the drying shrinkage in concrete block foundation walls. The shrinkage of concrete block walls as they dry in place often results in patterns of cracking similar to that caused by differential settlement: **tapering cracks** that widen as they move diagonally upward. These cracks usually form during the building's first year and in existing buildings will appear as "old" cracks and exhibit no further movement. Although such cracks are often mistaken for settlement cracks, **shrinkage** cracks

usually occur in the middle one-third of the wall and the footer beneath them remains intact. Shrinkage cracking is rarely serious, and in an older building may have been repaired previously. If the wall is unsound, its structural integrity sometimes can be restored by pressure-injecting concrete epoxy grout into the cracks or by adding pilasters.

- **Sweeping or horizontal cracking** of the foundation walls. The sweeping or horizontal cracking of brick or concrete block foundation walls may be caused by improper backfilling, vibration from the movement of heavy equipment or vehicles close to the wall or by the swelling or freezing and heaving of water saturated soils adjacent to the wall. Like drying shrinkage, sweeping or horizontal cracking may have occurred during the original construction and been compensated for at that time. Such distress, however, is potentially serious as it indicates that the vertical supporting member (the foundation wall) that is carrying a portion of the structure above is "bent" or "broken." It may be possible to push the wall back into place by careful jacking, and then reinforcing it with the addition of interior buttresses or by pressure-injecting concrete epoxy grout into the wall. If outside ground conditions allow, the wall can be relieved of some lateral pressure by lowering the ground level around the building.

Soil. When **expansive soils** are suspected as the cause of the cracking, examine the exterior for sources of water such as broken leaders or poor surface drainage. Suspect frost heaving if the damage is above local frost depth or if it occurred during an especially cold period.

6.5 Above-Ground Masonry Walls



For above-ground masonry walls, look for:

Brick wall cracking associated with thermal and moisture movement.

Aboveground brick walls expand in warm weather (particularly if facing south or west) and contract in cool weather. This builds up stresses in the walls that may cause a variety of cracking patterns, depending on the configuration of the wall and the number and location of openings. Such cracks are normally cyclical and will open and close with the season. They will grow wider in cold weather and narrower in hot weather. Look for cracking at the corners of long walls, walls with abrupt changes in cross section (such as at a row of windows), walls with abrupt turns or jogs, and in transitions from one- to two-story walls. These are the weak points that have the least capacity for stress.

Common moisture and thermal movement cracking includes:

- Horizontal or diagonal cracks near the ground at piers in long walls due to horizontal shearing stresses between the upper wall and the wall where it enters the ground. The upper wall can thermally expand but its movement at ground level is moderated by earth temperatures. Such cracks extend across the piers from one opening to another along the line of least resistance. This condition is normally found only in walls of substantial length.
- Vertical cracks near the end walls due to thermal movement. A contracting wall does not have the tensile strength to pull its end walls with it as it moves inward, causing it or the end walls to crack vertically where they meet.
- Vertical cracks in short off-sets and setbacks caused by the thermal expansion of the longer walls that are adjacent to them. The shorter walls are “bent” by this thermal movement and crack vertically.
- Vertical cracks near the top and ends of the facade due to the thermal movement of the wall. This may indicate poorly bonded masonry. Cracks will tend to follow openings upward.
- Cracks around stone sills or lintels caused by the expansion of the masonry against both ends of a

tight-fitting stone piece that cannot be compressed.

Cracks associated with thermal and moisture movement are usually only cosmetic problems: After their cause has been determined, they should be repaired with a flexible sealant, since filling such cyclic cracks with mortar will simply cause the masonry to crack in another location. Cracks should be examined by a structural engineer.

- Brick wall cracking can be associated with **freeze-thaw cycles** and **corrosion**. Brick walls often exhibit distress due to the expansion of freezing water or the rusting of embedded metals.

Look for:

- **Cracking** around sills, cornices, eaves, chimneys, parapets, and other elements subject to water penetration, which is usually due to the **migration of water** into the masonry. The water expands upon freezing, breaking the bond between the mortar and the masonry and eventually displacing the masonry itself. The path of the water through the wall is indicated by the pattern of deterioration.

- Cracking around iron or steel **lintels**, which is caused by the expansive force of corrosion that builds up on the surface of the metal. This exerts great pressure on the surrounding masonry and displaces it, since corroded iron can expand to many times its original

thickness. Structural iron and steel concealed within the masonry, if exposed to moisture, can also corrode, and cause cracking and displacement of its masonry cover. Rust stains usually indicate that corrosion is the cause of the problem. Check to make sure the joint between the masonry and the steel lintel that supports the masonry over an opening is clear and open. If the joint has been sealed, the sealant or mortar should be removed.

These conditions usually can be corrected by repairing or replacing corroded metal components and by repairing and pointing the masonry. Where cracking is severe, portions of the wall may have to be reconstructed. Cracks should be further examined by a structural engineer.

- Wall cracking or displacement associated with the structural failure of building elements. Structure-related problems, aside from those caused by differential settlement or earth-quakes, are usually found over openings and (less commonly) under roof eaves or in areas of structural overloading.

Such problems include:

- Cracking or displacement of masonry **over openings**, resulting from the deflection or failure of the lintels or arches that span the openings. In older masonry walls

with wood lintels, cracking will occur as the wood sags or decays. Iron and steel lintels also cause cracking as they deflect over time. Concrete and stone lintels occasionally bow and sometimes crack.

Masonry arches of brick or stone may crack or fail when there is wall movement or when their mortar joints deteriorate. When such lintel deflections or arch failures occur, the masonry above may be supporting itself and will exhibit step cracks beginning at the edges of the opening and joining in an inverted "V" above the opening's midpoint. Correcting such problems usually means replacing failed components and rebuilding the area above the opening.

- Cracking or outward displacement under the eaves of a pitched roof due to failure in the horizontal roof ties that results in the roof spreading outward. The lateral thrust of the roof on the masonry wall may cause it to crack horizontally just below the eaves or to move outward with the roof. The roof will probably be leaking as well. When this occurs, examine the roof structure carefully to ascertain whether there is a tying failure. If so, additional horizontal ties or tension members will have to be added and, if possible, the roof pulled back into place. The damaged masonry can then be repaired. The weight also can be transferred to interior walls. Jacking of the ridge and rafters is possible too.

- Masonry walls sometimes show signs of **bulging** as they age. A wall itself may bulge, or the bulge may only be in the outer wythe. Bulging often takes place so slowly that the masonry doesn't crack, and therefore it may go unnoticed over a long period of time. The bulging of the whole wall is usually due to thermal or moisture expansion of the wall's outer surface or to contraction of the inner wythe. This expansion is not completely reversible because once the wall and its associated structural components are "pushed" out of place, they can rarely be completely "pulled" back to their original positions.

The effects of the cyclical expansion of the wall are cumulative, and after many years the wall will show a detectable bulge. Inside the building, separation cracks will occur on the inside face of the wall at floors, walls, and ceilings. Bulging of only the outer masonry wythe is usually due to the same gradual process of thermal or moisture expansion: masonry debris accumulates behind the bulge and prevents the course from returning to its original position. In very old buildings, small wall bulges may result from the decay and collapse of an internal wood lintel or wood-bonding course, which can cause the inner course to settle and the outer course to bulge outward.

Bulging of walls. When wall bulges occur in solid masonry walls, the walls may be insufficiently tied to the structure or their mortar may have lost its bond strength. Large bulges must be tied back to the structure; the star-shaped anchors on the exterior of masonry walls of many older buildings are examples of such ties (check with local building ordinances on their use). Small bulges in the outer masonry course often can be pinned to the inner course or dismantled and rebuilt.

Leaning of walls. Masonry walls that lean represent a serious, but uncommon, condition that is usually caused by poor design and construction practices, particularly inadequate structural tying or poor foundation work.

Brick veneer walls. Brick veneer walls are subject to the forces of differential settlement, moisture-and thermal- related cracking and the effects of freezing and corrosion.

Look for:

- Cracks caused by frame shrinkage, which are most likely to be found around fixed openings where the independent movement of the veneer wall is restrained.
- Bulging, which is caused by inadequate or deteriorated ties between the brick and the wall that it is held upon.
- Vertical cracking at corners or horizontal cracking near the ground caused by thermal movement of the

wall, which is similar to that in solid masonry or masonry cavity walls, but possibly more pronounced in well-insulated buildings because of the reduction in the moderating effect from interior temperatures. Thermal cracks are cyclic and should be filled with a flexible sealant. Where there is severe cracking, expansion joints may have to be installed.

Problems associated with parapet walls. Parapet walls often exhibit signs of distress and deterioration due to their full exposure to the weather, the splashing of water from the roof, differential movement, the lack of restraint by vertical loads or horizontal bracing, and the lack of adequate expansion joints.

At parapets:

- Horizontal cracking at the roof line due to differential thermal movement between the roof line and the wall below, which is exposed to moderating interior temperatures. The parapet may eventually lose all bond except that due to friction and its own weight and may be pushed out by ice formation on the roof.
- Bowing due to thermal and moisture expansion when the parapet is restrained from lengthwise expansion by end walls or adjacent buildings. The wall will

usually bow outward since that is the direction of least resistance.

- Overhanging the end walls when the parapet is not restrained on its ends. The problem is often the most severe when one end is restrained and the other is not.
- Random vertical cracking near the center of the wall due to thermal contraction.
- Deterioration of parapet masonry due to excessive water penetration through inadequate coping or flashing, if any, which when followed by freeze-thaw cycles causes masonry spalling and mortar deterioration.
- Fire damage to brick masonry walls. Masonry walls exposed to fire will resist damage in proportion to their thickness. Examine the texture and color of the masonry units and probe their mortar. If they are intact and their basic color is unchanged, they can be considered serviceable. If they undergo a color change, consult a qualified structural engineer. Hollow masonry units should be examined for internal cracking, where possible, by cutting into the wall. Such units may need replacement if seriously damaged.

6.6 Chimneys

If you have a chimney, look at it. Chimneys have greater exposure to

the weather than most building elements, and have no lateral support from the point where they emerge from the roof. Problems can develop at any point in time as the house ages.

Look:

- An inadequate foundation can cause differential settlement of the chimney, but the foundation is underground and not readily visible. If the chimney is part of an exterior wall, it will tend to lean away from the wall and crack where it is joined to other masonry. In some cases, the chimney can be tied to the building.



- A chimney sweep can monitor the chimney structure for you. Masonry at the top of the chimney stack can deteriorate due to a deteriorated cap that allows water into the masonry below and exposes it to freeze-thaw cycles. This cap is often made of a tapered layer of mortar, called a cement wash, which cracks and breaks after several years. If the cap is mortar and the chimney has a

hood, repair the mortar. If the cap is mortar and the chimney does not have a hood, replace the mortar with a stone or concrete cap. If the cap is stone or concrete, repair it or replace it.



- The chimney could lean where it projects above the roof due to deteriorated mortar joints caused either by wind-induced swaying of the chimney or by sulfate attack from flue gases and particulates within the chimney when the chimney is not protected by a tight flue liner. Deteriorated mortar joints should be pointed, and unstable chimneys or those with a noticeable lean should be dismantled and rebuilt.

6.7 Wood Structural Components



Wood structural components in small residential buildings are often directly observable only in attics, crawl spaces, or basements. Elsewhere they are concealed by floor, wall and ceiling materials. Common signs of wood structural problems are sloping or

springy floors, wall and ceiling cracks, wall bulges, and sticking doors and windows, although many such problems may be attributable to differential settlement of the foundation or problems with exterior masonry bearing walls.

The four types of problems commonly associated with such components in small residential buildings are (1) deflection and warping, (2) fungal and insect attack, (3) fire, and (4) connection failure and improper alteration.

When failures in wood structural components occur, they usually involve individual wood members and rarely result in the failure of the entire structure. Instead, an elastic adjustment takes place that redistributes stresses to other components in the building.

Deflection, warping, and associated problems. Some deflection of wood structural components or assemblies is common in older buildings and normally can be tolerated. Once permanently deflected, a wood structural component cannot be straightened.

Warping of individual wood components almost always takes place early in the life of a building. It will usually cause only superficial damage.



With wood, look for:

- **Floor sagging** near stairway openings due to gradual deflection of the unsupported floor framing. This is a common problem in older houses and usually does not present a structural problem.

- **Floor sagging** beneath doorjamb resulting from improper support below the jamb. This can be a structural concern. If needed, additional bracing can be added between the joists where the sag occurs.

- **Loss of bearing** in beams and joists over foundation walls, piers or columns due to movements caused by long-term deflection of the wood beams or joists, differential movements of the foundation elements, localized crushing or wood decay. Monitor the bearing and connections of all exposed structural elements that are in contact with the foundation and look for symptoms of bearing failure where these elements are concealed, such as bowing or sloping in the floor above, and cracking or tilting of foundation walls, piers and columns.

- **Sagging, sloping, or springing** of floors due to foundation settlement, excessive spans, cut or drilled structural elements, overloading, or removal of supporting walls or columns on the floor above or below. In older buildings, columns or walls that helped support or stabilize the floor above may have been removed during a

previous alteration; conversely, partitions, bathrooms, kitchens, or similar remodeling may have been placed on a floor not designed to support such additional loads. Depending on the circumstances, sagging, sloping or springing floors may be anything from an annoyance to an indication of a potentially serious structural problem. Check below the floor for adequate supports and bearing and for sound connections between structural elements. Look for signs of supporting walls that have been removed, missing joist hangers and for inappropriate cuts or holes in joists for plumbing, electric, or HVAC lines or ducts. Also look for signs of insect or fungal attack.

- **Cracking in interior walls** around openings, which may be caused by inadequate, deflected or warped framing around the openings; differential settlement or; on the interior of masonry load-bearing walls, by problems in the exterior masonry wall. Cracking due to framing problems is usually not serious, although it may be a cosmetic concern that can be corrected only by breaking into the wall.

- **Sagging in sloped roofs** resulting from too many layers of roofing material, failure of fire retardant plywood roof sheathing, inadequate bracing or undersized rafters. Sometimes three or more layers of shingles are applied to a roof,

greatly increasing its dead load. Or, when an attic story has been made into a habitable space or otherwise altered, collar beams or knee walls may have been removed. A number of factors, such as increases in snow and wind loads, poor structural design and construction errors result in undersized rafters. Look for all these conditions.

- **Failure of Fire Retardant Plywood (FRP)** used at party walls between dwelling units in some townhouses, row houses and multiple dwellings is not uncommon. Premature failure of the material could be due to excessive heat in the attic space. On the exterior, sagging of the roof adjacent to a party wall often is apparent. On the interior, check for darkening of the plywood surface, similar to charring, as an indication of failure that requires replacement of the FRP with a product of comparable fire resistance and structural strength.

- **Spreading of the roof downward and outward** due to inadequate tying. Look for missing collar beams, inadequate tying of rafters and ceiling joists at the eaves, or inadequate tying of ceiling joists that act as tension members from one side of the roof to the other. Altered trusses can also cause this problem. Check trusses for cut, failed or removed members, and for fasteners that have failed, been completely removed or partially disconnected. Spreading can be halted by adequate bracing or tying, but there may be damage to masonry walls below the eaves (see Section 6.5). It is

possible that the roof can be jacked back to its proper position.

- **Deflection of flat roofs** due to too great a span, overloading, or improper support of joists beneath the roof. This is a common problem and is usually of no great concern unless it results in leaking and subsequent damage to the structure, or unless it causes water to pond on the roof, thereby creating unacceptable dead loads. In both cases, the roof will have to be strengthened or leveled.

- **Fungal and insect attack.** The moisture content of properly protected wood structural components in buildings usually does not exceed 10 to 15 percent, which is well below the 25 to 30 percent required to promote decay by the fungi that cause rot or to promote attack by many of the insects that feed on or inhabit wood. Dry wood will never decay. Check all structural and non-structural wood components for signs of fungus and insect infestation, including wood stains, fungi, termite shelter tubes, entry or exit holes, signs of tunneling, soft or discolored wood, small piles of sawdust or "frass" and related signs of infestation.

You can probe all suspect wood with a sharp instrument. Building inspectors check moisture content with moisture measurement devices. Wood with a meter reading

of more than 20 to 25 percent should be thoroughly examined for rot or infestation. Sound wood will separate in long fibrous splinters, but decayed wood will lift up in short irregular pieces.



Exterior components:

- Shelter tubes can be found at foundation walls, in the cracks and corners.
- Where wood is in contact with the ground, such as wood pilings, porch and deck supports, porch lattices, wood steps, adjacent fences and nearby woodpiles.
- Frames and sills around basement or lower level window and doorframes and the base of frames around garage doors.
- Wood framing adjacent to slab-on-grade porches or patios.
- Wood near or in contact with roofs, drains, window wells or other areas exposed to periodic wetting from rain or lawn sprinklers, etc.



Interior:

- Wood frame basement partitions.
- Spaces around or within interior foundation walls and floors, crawl spaces, piers, columns or pipes that might harbor shelter tubes, including cavities or cracks.

- The sill plate that covers the foundation wall, and joists, beams, and other wood components in contact with it.
- Baseboard trim in slab-on-grade buildings.
- Subflooring and joists below kitchen, bathroom, and laundry areas.
- Roof sheathing and framing in the attic around chimneys, vents and other openings.

6.8 Iron and Steel Structural Components

Metal structural components used in residential homes are usually limited to beams and pipe columns in basements, angles over small masonry openings and beams over long spans. These components are almost always made of steel.



Problems with iron and steel structural components usually center on **corrosion**. Monitoring is needed.

Lintels and other embedded metal components in exterior masonry walls can corrode and in time become severely weakened themselves. Rain and snow often contain carbonic, sulfuric, nitric or hydrochloric acid that lowers the pH of rain water, thereby accelerating corrosion. Check the areas of

embedded iron and steel. Corrosion can also displace surrounding masonry by popping off mortar joints at brick walls, for example.



Columns should be checked for adequate connections at their base and top, and for corrosion at their base if they rest at ground level.

6.9 Concrete Structural Components

Concrete is commonly used for grade and below-grade level floors and for footings. Concrete also may be used for foundations, beams, floors above grade, porches or patios built on grade, exterior stairs and stoops, sills, and occasionally as a precast or poured-in-place lintel or beam over masonry openings. Concrete structural components are reinforced. Welded steel wire mesh is used in floors at and below grade, patios built on grade, walks and drives, and short-span, light-load lintels. All other concrete structural components usually are reinforced with steel bars.



Look for:

Cracking at corners or openings in concrete foundations below masonry exterior walls due to drying shrinkage of concrete walls. This cracking will occur early in the life of the building.

Minor cracks can be filled with mortar and major cracks with concrete epoxy.

Cracking of interior slabs on grade is usually due to shrinkage or minor settlement below the slab. If cracking is near and parallel to foundation walls, it may have been caused by the movement of the walls or footers. Cracking can also result from soil swelling (expanding) beneath the slab, a condition that may be caused by water from clogged or broken basement or footer drains. Cracking of exterior concrete elements, such as porches, patios, and stairs, is usually due to heaving from frost or nearby tree roots, freeze-thaw cycles or settlement.

6.10 Inspection Standards

The inspector shall inspect the basement, the foundation, the crawlspace and visible structural components. The inspector shall report any general indications of foundation movement that are observed by the inspector, such as but not limited to sheetrock cracks, brick cracks, out-of-square doorframes or floor slopes.

Inspectors do not perform engineering or architectural services. Inspectors do not report upon the adequacy of any structural system or component.

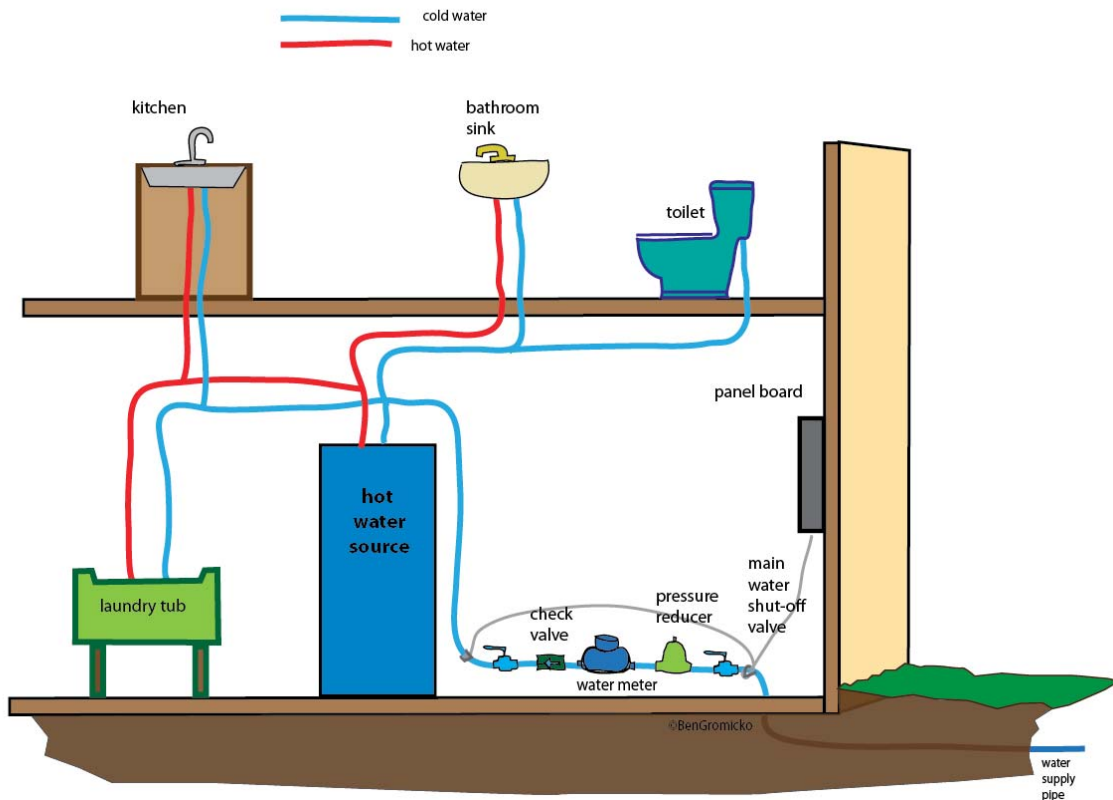
Chapter 7: Plumbing System

7.1 Water Service Entry

Curb valve. A homeowner should know where the curb valve is located. It is the way for the main water supply

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.

Main water shutoff valve. A master shutoff valve should be located where the house service main enters the building. If the water meter is not located inside the



to be turned off. It is typically located at the junction of the public water main and the house service main, usually at the street. The curb valve is usually the responsibility of the municipal water department.

building, the water meter will likely be outside in an underground crock. Home inspectors typically do not test this main valve during a visual-only inspection.

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. 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.



7.2 Interior Water Distribution



All piping, regardless of composition, should be monitored for wet spots, discoloration, pitting, mineral deposits and leaking or deteriorated fittings.



Distribution piping. Distribution piping consists of supply mains and fixture risers. Most supply pipes can be seen from the basement or from crawl spaces, but the riser pipes are usually concealed within walls and cannot be readily examined.

The two most important factors in understanding distribution piping are the material and age.

Galvanized steel piping is subject to rusting and accumulating more mineral deposits than most other piping materials. 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. If galvanized steel piping is found, 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. Leakage usually occurs near joints.

Plastic piping (ABS, PE, PB, PVC, CPVC and PEX) 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 (PB pipe) and fittings. Funds resulting from these suits are controlled by local jurisdictions. Check with local authorities or consumer advocate groups for details.

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.

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

7.3 Drain, Waste, and Vent Piping



Fixture traps. Fixture traps are designed to hold a water seal that blocks the entry of sewer gasses into the house interior through the fixture drain. Watch for clogs and water leaks at water traps.

Vents. Vents equalize the atmospheric pressure within the waste drainage system to prevent siphoning of the water seals in the building's fixture traps. Vents should be unobstructed and open above the roof.

Drain lines. Drain lines direct wastewater from the fixture trap through the building to the sewer or septic system. Monitor for water drips and leaks particularly located at loose cleanout fittings.

7.4 Tank Water Heaters

Tank water heaters consist of a glass-lined or vitreous enamel-coated steel tank covered by an

insulated metal jacket. They are gas-fired, oil-fired or electrically heated.



- Gas-fired tank water heaters have an average life expectancy of about 6 to 12 years and a fairly 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 an estimated service life of 5 to 10 years. They have a low recovery rate and thus require a larger storage tank.

Plan to replace a tank that is near the end of its life expectancy.



Watch for signs of leakage on the bottom of the tank, such as rust or water stains at fuel burning components or on the floor. Leaking tanks cannot usually be repaired and, therefore, must be replaced entirely.

As part of a maintenance plan, the tank should be drained regularly to remove sediment and rust.



Check the temperature/pressure relief valve (sometimes on the top or on the side of the tank), and for a discharge pipe that extends from the valve to a few inches from the floor, a floor drain or the building exterior, depending on local code requirements. This pipe should never be dripping or leaking water.



Monitor for soot or carbon deposits. Any soot or carbon that has accumulated below the draft hood of a water heater may indicate a restricted flue or chimney, or more

commonly, back-drafting caused by insufficient make-up air.

7.5 Domestic Coil Water Heaters (with Boilers)

Tankless domestic coil water heaters consist of small diameter pipes coiled inside of or in a separate casing adjacent to a hot water boiler. They are designed for a rate of water flow, usually three to four gallons per minute. The recovery rate of a domestic coil water heater is instantaneous for low demand and will vary for high demand. The life expectancy of a domestic coil water heater is limited only by the deterioration of its coils and by the service life of the boiler to which it is attached.



Monitor tankless coil water heaters by checking its performance (ability to produce hot water on demand) and by checking the area where the coil is attached to the boiler. Over time water

may start to leak from the gasket area or the bolts at the front mounting plate where the tankless coil is located at the boiler.

Monitor the plumbing connections and joints around the heater mounting plate for rust, water stains and mineral deposits.

7.6 Private Wells

Location and water quality. A homeowner should know the location of the well. Ideally wells that supply drinking water would be located uphill from the building and from any storm or sanitary sewer system piping. Standards 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. Local codes may have different separation distances based on the percolation rates of the local soils.

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 have inherent performance problems. 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.



Pressure tank. 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.

Water tests. Consider hiring a professional home inspector who provides water quality sampling and well inspections to annually test the water quality. Water should be analyzed for the presence of bacterial contamination and for its mineral content.

7.7 Septic Systems

Location and layout. The homeowner should know the layout of the existing septic system. The absorption field should not be disturbed by new construction and vehicular traffic or covered by fill, trees or dense vegetation. No storm water should be directed into the septic system. A typical system has an average life expectancy of 15 to 20 years under proper use.

Septic tank. If properly maintained, it should be pumped every two to three years. Keep records about pumping. Lack of periodic pumping will cause solids to be carried into the absorption field, clogging the leaching beds and shortening their useful life.

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.

7.8 Gas Supply in Seismic Regions

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), the gas service should not be vulnerable 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.

7.9 Inspection Standards

The inspector shall inspect and describe the water supply, drain, waste and main fuel shut-off valves, water main valve and shut-off valve. The inspector is not required to determine the size, temperature, age or life expectancy of the water heater source. Home inspectors are not septic system inspectors.