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Rehabilitation Guidelines 1984

11 Guideline for Residential Building Systems Inspection

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DEPARTMENT OF HOUSING
AND URBAN DEVELOPMENT

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Prepared for the
Division of Building Technology
Department of Housing and Urban Development
under Contract HC-5662

by
Building Technology Incorporated
Silver Spring, Maryland
and
University Research Corporation
Chevy Chase, Maryland

September 1984

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reflect the views or policies of the
Department of Housing and Urban Development
or the U.S. Government

FOREWORD

Our purpose in publishing the rehabilitation guideline series is to encourage the rehabilitation and conservation of our older building stock. By making our existing stock safe, sound, and functional, we can very significantly aid in achieving our national housing goals and revitalizing our urban areas. We are emphasizing and encouraging rehabilitation and conservation because they represent the most cost-effective way to add to and maintain our Nation's housing supply.

For some time, we have known that building codes which were established primarily for new construction actually served to impede rehabilitation projects. These new guidelines were developed so State and local officials could voluntarily adopt and use them in conjunction with existing codes in the inspection and approval of rehabilitated properties.

This guideline is designed to evaluate the rehabilitation potential of existing one-to four-family small residential buildings by inspecting the site exterior components, interior components, structural, electrical, plumbing, and Heating, Ventilating, Air Conditioning systems. I believe that this addition to the guideline series will prove useful to many who are involved in the building rehabilitation process.

Samuel R. Pierce, Jr.
Secretary
U.S. Department of Housing
and Urban Development

Acknowledgments

The authors of this Guideline were William Brenner and David Hattis of Building Technology Incorporated and Richard Stephan, Ken Frank, and Gerard Diaz (who also took the majority of the photographs) of the University Research Corporation. William Brenner was the project manager. The authors gratefully acknowledge the following technical reviewers: George Schoonover, Eugene Davidson, Joseph Wintz, Richard Ortega, Nick Gianopulos, Robert Santucci, James Wolf, and Thomas Fean.

The Rehabilitation Guideline Series

This Guideline is the eleventh in a series of *Rehabilitation Guidelines* prepared in response to the requirements of the Housing and Community Development Amendments of 1978. The first ten Guidelines cover the following topics:

1. The *Guideline for Setting and Adopting Standards for Building Rehabilitation* describes methods for identifying regulatory problems in a community, and recommends ways to amend, modify, or supplement existing regulations to encourage rehabilitation.

2. The *Guideline for Municipal Approval of Building Rehabilitation* presents specific recommendations for dealing with rehabilitation within municipal building departments.

3. The *Statutory Guideline for Building Rehabilitation* contains enabling legislation that can be directly adopted by communities to provide more effective regulation.

4. The *Guideline for Managing Official Liability Associated with Building Rehabilitation* addresses the liability of code officials involved with the administration and enforcement of rehabilitation.

5. The *Egress Guideline for Residential Rehabilitation* lists design alternatives for the components of egress that are regulated by current codes such as number and arrangement of exits, corridors, and stairs, travel distance, dead-end travel, and exit capacity and width.

6. The *Electrical Guideline for Residential Rehabilitation* outlines procedures for conducting inspections of electrical systems in existing buildings, and presents solutions to common problems associated with electrical rehabilitation.

7. The *Plumbing DWV Guideline for Residential Rehabilitation* presents criteria and methods for inspecting and testing existing drain, waste, and vent (DWV) systems, relocating fixtures, adding new fixtures to existing DWV systems, extending existing DWV systems, and installing new DWV systems in existing buildings.

8. The *Guideline on Fire Ratings of Archaic Materials and Assemblies* contains the fire ratings of building materials and assemblies that are no longer listed in current building codes or related reference standards. Introductory material discusses flame spread, the effects of penetrations, and methods for determining the ratings of assemblies not listed in the guideline.

9. The *Guideline for Structural Assessment* addresses the methods and approaches used to evaluate structural systems in existing buildings. It covers masonry, wood, steel, and concrete structural systems and components.

10. The *Guideline on the Rehabilitation of Walls, Windows, and Roofs* recommends procedures for rehabilitating and preserving walls, windows, and roofs in historic buildings.

The *Rehabilitation Guidelines* are available from HUD USER, P.O. Box 280, Germantown, Maryland 20874. Phone (301) 251-5154.

Contact HUD USER for cost and ordering information.

Table of Contents

Introduction

This Guideline is designed to help evaluate the rehabilitation potential of existing one- to four-family small residential buildings. It may be used by anyone with a basic knowledge of building construction, particularly small contractors, builders, and others involved in the rehabilitation process.

The Guideline contains information on assessing site conditions, exterior and interior building components, and structural, electrical, plumbing, and HVAC systems. The Guideline's appendices contain reproducible building inspection forms, a list of recommended inspection tools, and sources of additional information.

Use the Guideline in conjunction with The Secretary of the Interior's Standards for Rehabilitation when dealing with historic properties that qualify for federal investment tax credits. The Standards are available from the Preservation Assistance Division, National Park Service, Washington, D.C. 20240.

How to Use the Guideline

Read through the Guideline to become acquainted with its format and approach. It is written in two parts. Part I is the architectural inspection, which covers the site (Chapter 1), building exterior (Chapter 2), and building interior (Chapter 3). This phase of the inspection will be similar for every building. Part II is the systems inspection, which covers the structural system (Chapter 4), electrical system (Chapter 5), plumbing system (Chapter 6), and HVAC system (Chapter 7). All common system types are covered in these chapters, so each building inspection will vary depending on the systems found.

Reproduce the building inspection forms in Appendix A for use during the on-site inspection. General building data and site layouts, elevations, and floor plans should be recorded first; this information will form the general basis for later rehabilitation decisions. Then record the size, capacity, and condition/needed repairs information for each building component. This will provide the specific data on exactly what needs to be repaired or replaced.

Numerous tests (printed in italic type) are described in the text. Appendix B lists tools and equipment needed for the inspection process and for carrying out most of these tests. (Note, however, that some tests require specialized equipment and may also require trained personnel.) Appendix C provides ordering information for all publications referenced in the text.

Conducting the Site Inspection

Once at the site, conduct a brief "walk-through" of the building and its surroundings. Note the property's overall appearance and condition. If it has been well maintained it is far less likely to have serious problems. Next, examine the quality of the building's design and construction, and that of its neighborhood. There is no substitute for good design and sound, durable construction. Finally, assess the building's functional layout. Does the building "work," or will it have to be significantly altered to make it marketable?

Look for signs of dampness and water damage. Water is usually a building's biggest enemy, and a dry building will rarely have problems with wood decay, subterranean termites, or rusted and corroded equipment.

After completing the initial walk-through, begin the formal inspection process as follows:

- Part I, Architectural Inspection. Inspect the site, building exterior, and building interior in accordance with Chapters 1, 2, and 3. Use the tests described in Chapters 2 and 3 when appropriate. Record all pertinent data on the building inspection forms copied from Appendix A.

- Part II, Systems Inspection. Inspect the structural, electrical, plumbing, and HVAC systems in accordance with Chapters 4, 5, 6, and 7. Use the tests described in each chapter as necessary. Record the size, capacity, and other relevant information about each system or component on the building inspection forms copied from Appendix A.

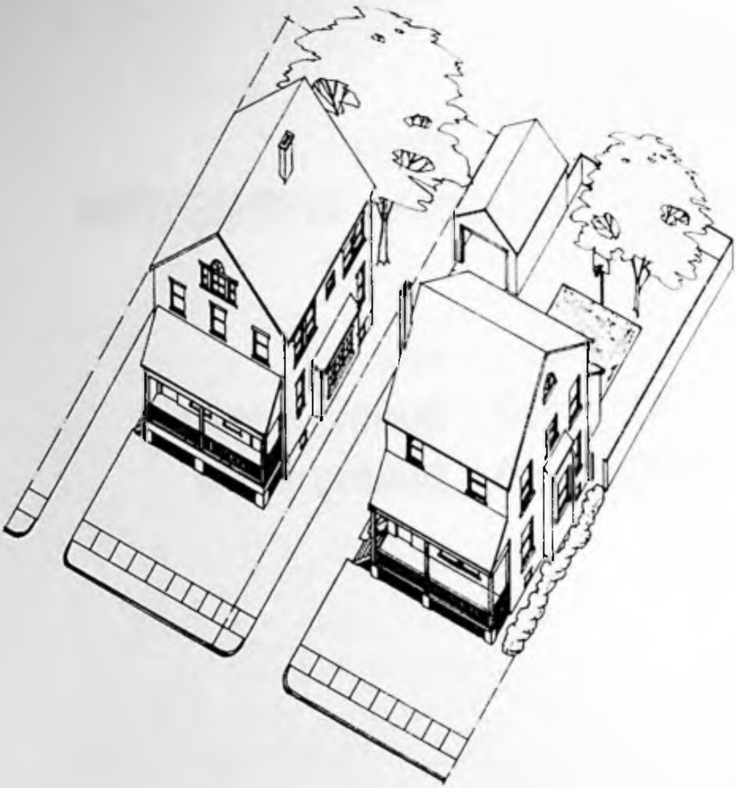
The inspection may be completed in one visit or over several, depending upon the property's condition, weather, problems of access, and the use of tests or expert help in the inspection process.

Further Information

This Guideline provides the basic information for assessing the rehabilitation potential of one- to four-family residential buildings. It does not attempt to establish specific rehabilitation standards, since these will vary according to the local housing market and state and local regulatory concerns.

Information on building assessment and rehabilitation beyond the scope of this Guideline is listed in Appendix C, and includes publications on code-related matters, technical assessment procedures, energy retrofit, historic preservation, and home renovation.

PART I
ARCHITECTURAL INSPECTION



Chapter 1
Site

Begin the rehabilitation inspection by thoroughly examining the property's drainage, landscaping, and outbuildings. Their condition may have a profound impact on the total costs of the rehabilitation project, yet they are often overlooked or not fully considered in the initial building assessment. Regrading, tree removal, the replacement of sidewalks and driveways, and the repair of outbuildings can all add substantially to rehabilitation expenses and may make the difference between a profitable and an unprofitable rehab project.

Record all pertinent site information on the inspection sheets copied from Appendix A.

1.1 Drainage

Observe the drainage pattern of the entire property, and adjacent properties as well. The ground should slope away from all sides of the building, and downspouts, surface gutters, and drains should all direct water away from the foundation. (Most problems with moisture in basements are caused by poor site drainage--see Section 3.1.) Window wells, basement stairwells, and other areaways should be properly drained; look for signs of ponding and poor drainage in such places. In rural sites, check drainage in and around the septic field (see Section 6.7).

Poor site drainage leads to a variety of problems, in this case a wet basement.

1.2 Site Improvements

Well-maintained landscaping and other site improvements are important for the resale or rental value of a property, and may be difficult to replace or repair. Inspect the following:

- Plantings. Note the location and physical condition of all trees and shrubbery. Those that are overgrown may need pruning or trimming; in some cases they may be overgrown to the extent that they will have to be removed. Removing large trees can be particularly costly. Check where overhanging branches may interfere with the chimney's draft, damage utility wires, and deposit leaves and twigs in roof gutters and drains. When trees or shrubbery exhibit disease or infestation, consult with a qualified expert.

Observe the solar shading characteristics of all site plantings: do they provide protection from the summer's sun and allow the winter sun to warm the building? Large deciduous trees located to the south and west of a building can do both, and a special effort should be made to retain and protect such trees where they exist.

- Fences. Fences are usually installed to provide physical or visual privacy. Examine their plumbness and overall condition. Inspect wood fences for signs of rot or insect infestation, and metal fences for rust. Inspect all gates and their associated hardware for proper operation and clearance.

- Lighting. Examine all outdoor lighting elements to determine their physical condition and functional safety. Exposed wiring should be run in conduit; underground wiring should be type UF (see Section 5.3). Fixtures, switches, and outlets should be properly covered and protected from moisture penetration.

- Paved areas. Inspect all sidewalks, driveways, and patios. If they are made of concrete and are in poor condition, they may have to be replaced. Asphalt driveways and walkways can usually be resurfaced or sealed, and brick or stone pavers relaid. When considering the repair or replacement of such site elements, pay particular attention to existing property lines and easements.

The concrete driveway is intact but has settled several inches. The only permanent solution is to replace this section.

- Steps. Inspect the condition of all exterior steps and stairways. Check wooden steps for proper support and strength, and for rot and insect infestation. Deteriorated concrete steps are difficult to repair and usually have to be replaced. All steps should be level, have a consistent rise-to-run ratio, and three or more steps should normally have a handrail. All publicly used steps should be properly lighted.

- Retaining walls. Inspect the physical condition of all retaining walls. Look for evidence of settlement, heaving by frost or tree roots, horizontal movement or sliding, or tilting. Check for weep holes. It may be possible to push tilted walls back into proper position by removing some of the soil behind the wall and applying horizontal pressure to the wall with jacks or levers. Otherwise, tilted walls should be rebuilt unless outward motion has obviously stopped and tilting is not severe. Walls damaged by other causes must be dealt with on a case-by-case basis. In most instances, rebuilding of part or all of a damaged wall will be required.

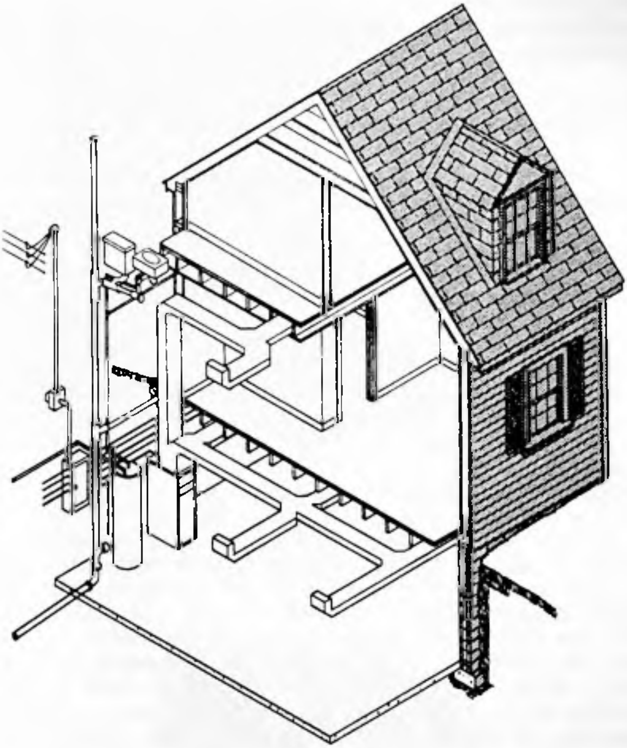
The outward movement of the upper part of this retaining wall can be halted only by structural reinforcement. Simply patching the crack will not solve the problem.

1.3 Outbuildings

Examine detached garages, storage sheds, and other outbuildings for their condition in the same general way the primary building is inspected. Check each building's water shedding capability and the adequacy of its foundations. On the interior, look for water staining on the roof or walls. Wood frame structures should be thoroughly inspected for rot and insect infestation. Check also that all doors function properly and that doors and windows provide adequate weather protection and security to the building. Make sure that small outbuildings have sufficient diagonal wind bracing and are properly tied down in high wind areas.

1.4 Yards and Courts

For urban properties, yards and courts provide light and ventilation to interior rooms. The adequacy of the light provided is a function of the dimensions of the yard or court, as well as the color of surrounding walls. Check these characteristics, as well as zoning and building code requirements pertaining to light, ventilation, and privacy screening for yards and courts shared by two or more dwelling units. Such requirements may affect the reuse of the property and their implications should be understood, preferably before the property is purchased.



Chapter 2
Building Exterior

After the site inspection has been completed, systematically inspect the building's exterior for its physical condition and weathertight integrity. Begin either at the foundation and work up, or at the roof and work down. Examine the quality and condition of all exterior materials, and look for patterns of damage or deterioration that should be further investigated during the interior inspection. Determine the building's architectural style and note what should be done to maintain or restore its integrity and character. See Chapter 4 for assessing all structural components of the building.

Additional information on the evaluation and treatment of historic building exteriors is presented in the HUD Guideline on the Rehabilitation of Walls, Windows, and Roofs and the Secretary of the Interior's Standards for Rehabilitation.

Record all information about the building exterior on the inspection sheets copied from Appendix A.

2.1 Foundation Walls and Piers

Foundation walls and piers in small residential buildings are usually made of masonry and should be inspected for cracking, deterioration, moisture penetration, and structural adequacy. See Sections 4.1 and 4.2 for the inspection of these masonry elements. Wood posts and columns should be inspected in accordance with Section 4.5, and concrete foundations and piers in accordance with Section 4.7.

2.2 Exterior Wall Cladding

Exterior walls above the foundation may be covered with a variety of materials, including wood siding or its aluminum and vinyl substitutes, wood or asbestos cement shingles, stucco, and brick or stone masonry. These materials are designed to serve as a weather-tight, decorative skin and in warm climates should be light in color to reduce heat absorption. All wood elements should be checked for fungal and insect infestation at exposed horizontal surfaces and exterior corner joints in accordance with Section 4.5. Inspect exterior claddings as follows:

A second layer of shingles has filled the former gap between roof and siding, causing the siding to deteriorate.

- Exterior wood elements. Inspect all painted surfaces for peeling, blistering, and checking. Paint-related problems may be due to vapor pressure beneath the paint, improper paint application, or excessive paint buildup. Corrective measures for these problems will vary from the installation of moisture vents to complete paint removal. Mildew stains on painted surfaces do not hurt the wood and may be cleaned with a mildew remover.

- Aluminum and vinyl siding. Aluminum and vinyl siding may cover up decayed or insect-infested wood but otherwise are generally low maintenance materials. Check for loose, bent, cracked, or broken pieces. Inspect all caulked joints, particularly around window and door trim. Many communities require that aluminum siding be electrically grounded; check for such grounding.

- Asbestos cement shingles. Like aluminum and vinyl siding, asbestos cement shingles may cover decayed or insect-infested wood. Check for loose, cracked, or broken pieces, and inspect around all window and door trim.

The stucco is beginning to erode on this structure due to a poor roof drainage detail. A longer scupper would solve this problem.

- Stucco. Check stucco for cracks, crumbling sections, and areas of water infiltration. Old and weathered cracks may be caused by the material's initial shrinkage or by earlier building settlement. New, sharp cracks may indicate movement behind the walls that should be investigated. Refer to Section 4.3 for problems of masonry walls. It is difficult to match the color of stucco repairs to the original stucco, so plan to repaint surrounding stucco work where sections are mended.

- Brick or stone veneers. Inspect veneers for cracking, mortar deterioration, and spalling. Refer to Sections 4.1 and 4.3 for the inspection of aboveground masonry walls.

Exterior walls on older buildings usually contain no thermal insulation. Examine behind the cladding when possible to determine the presence of insulation, if any, and assess the potential for insulating the exterior walls during the rehabilitation. See the thermal efficiency tests listed in Section 3.10.

2.3 Windows and Doors

Windows and doors are the most complex exterior elements of the building and should be inspected from the outside as follows:

- Exterior doors should be examined for their overall operation and fit, and the functionality of their hardware. Note the degree of physical security the door and its lockset offer.

The glazing putty in this window is deteriorated in some locations. Repairs will be time consuming, but replacing the window would seriously alter the building's character.

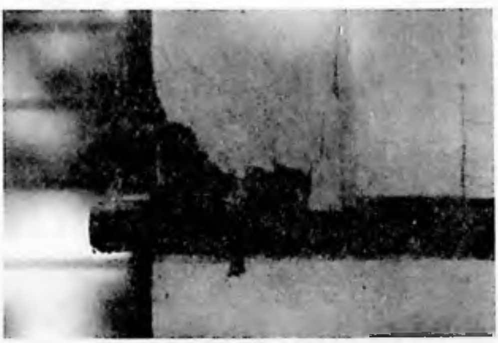
- Windows should be inspected for the exterior condition of their frames, sills, and sash. Their interior condition, operation, and hardware will be examined during the interior inspection. The glazing compound or putty around glass panels in wood or steel sash should be examined especially carefully--this is often the most vulnerable part of the window, and its repair is time consuming.

- Storm windows and doors should be examined for weathertightness and overall condition and fit. Check the condition of all screen and glass inserts; if they are in storage, locate, count, and inspect them.

2.4 Decks, Porches, and Balconies

Decks, porches, and balconies are exposed to the elements to a greater extent than other parts of a building and are therefore more susceptible to deterioration. Inspect for the following conditions:

- Physical condition. Examine all porch, deck, and balcony supports for signs of loose or deteriorated components. See Section 4.5 for the inspection of wood structural components. Masonry or concrete piers should be checked for plumb and stability in accordance with Section 4.2. Make sure that structural connections to the building are secure and protected against corrosion or decay.



A rotted corner post on a screened porch. In this case, the rotted section of the post and a small section of the floor beneath it were removed and replaced with sound wood.

Examine floors for signs of deflection and deterioration. Where the floor or deck is close to the level of the interior floor, look for signs of water infiltration at the door sill, and check for positive pitch of the floor or deck away from the wall.

- Exterior railings and stairs. Shake all railings vigorously to check their stability, and inspect their fastenings. Most codes require railings to withstand a horizontal force of 50 pounds per linear foot, and require that porches, balconies, and decks located more than 30 inches above grade have guard rails not less than 42 inches high and intermediate rails that will not allow the passage of an object 9 inches in diameter. Every stair with over three steps should have a handrail located 30 to 34 inches above the stair. Stairs should be level, structurally stable, and of consistent riser height and tread length.

2.5 Pitched Roof Coverings

Pitched roofs are best inspected when direct access is gained to all their surfaces. Use binoculars to inspect roofs that are inaccessible or that can't be walked on. Look for deteriorated or loose flashing, signs of damage to the roof covering, valleys and gutters clogged with debris, and related problems. Check the condition of the roof covering as follows:

- Asphalt shingles. Asphalt or "composition" shingles have a service life of about 20 years, depending on their weight, quality, and exposure. When they begin to lose their granular covering and start to curl, they should be replaced. No more than two layers of asphalt shingles should normally be in place at any one time.

- Wood shingles or shakes. This type of covering has a normal life expectancy of 25-30 years, but durability varies according to wood species, thickness, the slope of the roof, and whether or not shingles are made of heartwood. As wood shingles age, they dry, crack and curl, or in damp locations, rot. Replace all shingles when more than a third show signs of deterioration.

- Metal roof coverings. Metal can last 50 years or more if properly painted or otherwise maintained. Metal roofs may be made of galvanized iron or steel, copper, or lead; each material has its own unique wearing characteristics. Inspect all metal roofs for signs of rusting or pitting, corrosion due to galvanic action, and loose or leaking seams and joints. If the roof is historic or relatively complex, consult a metal roof specialist.

- Slate, clay tile, and asbestos cement shingles. These roof coverings are extremely durable and, if of high quality and properly maintained, may last the life of the structure. All are brittle materials, easily broken, and should not be walked on during the inspection. Use binoculars to look for missing, broken, or slipping pieces. Slate is particularly susceptible to breakage by ice or ice dams in the winter, and should therefore be especially well drained. Moss will sometimes grow on asbestos cement shingles, and should be removed with a cleaner to prevent capillary water leaks. Slate, clay tile, and asbestos shingles should be repaired or replaced by a qualified roofer.

This slate roof should be carefully investigated since it has a makeshift repair. Other problems include the chimney, which is too low, and the vent pipe, which is too narrow.

Examine the underside of the roof later during the interior inspection.

2.6 Flat Roof Coverings

A roof that is level or slightly pitched is called a flat roof. Problems in flat roofs are common and more difficult to diagnose than pitched roofs because the path of water leakage through flat roofs is often quite hard to trace. Look for signs of ponded water due to either improper drainage or sagging of the roof deck. If the cause is a sagging deck, it should be structurally corrected before it worsens. Flat roofs are expensive to repair, so extra care should be taken in their examination.

Inspect the flashing and joints around all roof penetrations, including drains, soil stacks, chimneys, skylights, hatchways, antenna mountings, and other roof-mounted elements. Note if metal flashings need painting or reanchoring, and if asphaltic or rubber flashings are brittle or cracked. Check parapet wall caps and flashing for signs of damage due to wall movement.

Examine all portions of the roof covering. Look for signs of previous repairs that may indicate trouble spots. Inspect flat roof coverings as follows:

- Built-up roof. Built-up roofs are composed of several layers of roofing felt lapped and cemented together with bituminous material protected by a thin layer of gravel or stone. Built-up roofs vary greatly in life span, but those used in residential buildings usually last about 20 years, depending on their quality, exposure, and the adequacy of their

The built-up roof and flashings in this photograph are in poor condition. Patching may work temporarily, but the roof and flashings should be replaced.

  drainage. Look for cracking, blistering, alligatoring, and wrinkling, all of which may indicate the need for roof replacement or repair. Consult an experienced roofer for a further evaluation if you are in doubt.

  Test: An infrared scanner can be used to detect areas of moisture in built-up roofs. Once located, *these areas can be more thoroughly checked with a moisture meter or a nuclear meter. Such a test must be performed by a trained roof inspector and is normally used to determine areas that need replacement on very large roofs.*

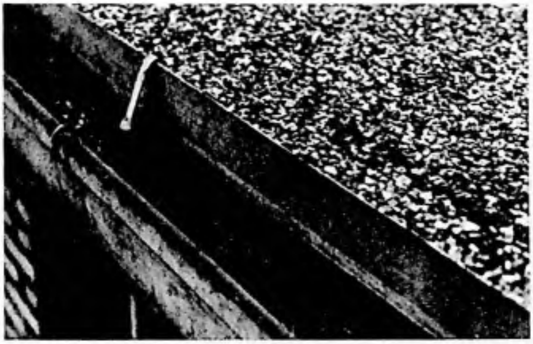
- Roll roofing. Roll roofing consists of an asphalt-saturated granule-covered roofing felt that is laid over the roof deck, and provides only single- or two-ply coverage. Inspect roll roofing for cracking, blistering, surface erosion, and torn sections. Seams are the most vulnerable part of roll roofing, and should be carefully checked for separation and lifting.

- Metal roof coverings. See metal roof coverings in Section 2.5.

The underside of the flat roof should be examined during the interior inspection. If it is inaccessible, look for signs of water leakage on interior ceilings and walls.

2.7 Skylights

From the exterior, check all skylights for cracked or broken lites, adequate flashing, and rusted or decayed frames. Skylights will be checked again during the interior inspection.



The gutters on this flat roof are deteriorating largely because of the accumulated detritus that they hold. They should be cleaned, and perhaps reinspected.

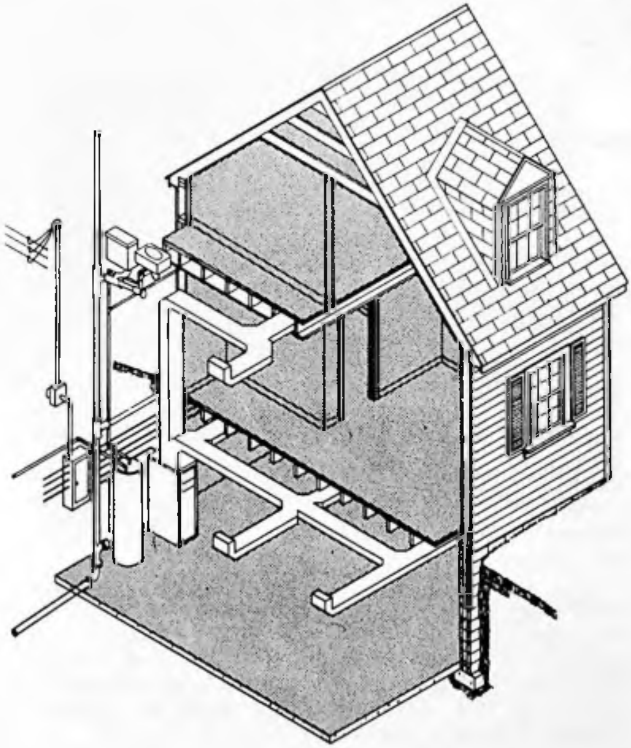
2.8 Gutters, Downspouts, and Drains

Check the physical and functional condition of all gutters, downspouts, and drains. Gutters should slope uniformly. Check the capacity of the drainage system: one square inch of downspout or drain cross section is usually needed for every 100 square feet of roof surface draining into it. At least one downspout is usually needed for each 40 feet of gutter.

2.9 Chimneys

Chimneys should project at least two feet above the highest part of a pitched roof and four feet above a flat roof (minimum heights may vary slightly; check your local code).

Flues should not be smaller in size than the discharge of the appliance they serve. The minimum flue area for chimneys connected to fireplaces is normally 50 square inches for round linings, 64 square inches for rectangular linings, and 100 square inches for an unlined chimney. Be extremely cautious about unlined chimneys. Check your local code.



Chapter 3
Building Interior

Following the inspection of the site and the building's exterior, move indoors and systematically inspect all interior spaces, including the basement or crawl space, finished rooms, halls and stairways, storage spaces, and the attic. Begin either at the lowest level and work up or at the attic and work down. Examine the overall quality and condition of the building's construction and finish materials. If the interior has unique woodwork or other stylistic features, consider how they may be incorporated to best advantage in the building's reuse. Look for patterns of water damage or materials deterioration that indicate underlying problems in the structural, electrical, plumbing, or HVAC systems. These systems will be inspected separately after the interior inspection is completed.

Record all pertinent information about the building interior (including floor-to-floor heights and other dimensions) on the inspection sheets copied from Appendix A.

3.1 Basement or Crawl Space

The basement or crawl space is often the most revealing area in the building, and usually provides a general picture of how the building works. In most cases, the structure is exposed overhead, as are the heating distribution system, plumbing supply and DWV lines, and the electrical branch circuit wiring. Examine the basement as follows:

- Moisture. One of the most common problems in small residential structures is a wet basement. Examine walls and floors for signs of water penetration such as dampness, water stains, peeling paint, efflorescence, and rust on exposed metal parts. In finished basements, look for rotted or warped wood paneling and doors, loose floor tiles, and mildew stains.

  Determine the source of any moisture that may be present. It may come through the walls or cracks in the floor, or from backed up floor drains, leaky plumbing lines, or a clogged air conditioner condensate line. If moisture appears to be coming through the walls, reexamine the roof drainage system and grading around the exterior of the building (the problem could be as simple as a clogged gutter). Look for unprotected or poorly drained window wells, leaking exterior faucets, and signs of leakage in the water supply line near the building (see Section 6.1 for water distribution system problems). If foundation walls are cracked, examine them in accordance with Section 4.2.

  If the basement or crawl space is merely damp or humid, the cause simply may be lack of adequate ventilation, particularly if the building has earthen floors. In such a case, consider how to best correct this condition when the building is rehabilitated.

- Fungal and insect infestation. Look for signs of fungal growth on wood, particularly in unventilated crawl spaces. Inspect all foundation walls, piers, columns, joists, beams, and sill plates for signs of termites and other wood inhabiting insects in accordance with Section 4.5.

Termite infestation is most common in basements and crawl spaces, particularly near foundation walls. Probe all suspect areas thoroughly.

- Thermal insulation. Examine the amount and type of insulating material, if any, above unheated basements and crawl spaces. Determine the proper amount of insulation the space requires, and whether additional insulation can or should be added. Check for adequate vapor barriers.

- Structural, electrical, plumbing, and HVAC systems. Understand enough about the layout of each system to make an informed inspection of the remainder of the building's interior. A more complete assessment of these systems will be performed later.

  - Note the type of structural system (wood frame, masonry bearing wall, etc.). Locate main support columns and posts, major beams, and bearing walls.

  - Find the main electrical panel box, if it is in the basement, and note how the branch circuits are generally distributed. Note also the type of wiring that is used.

  - Trace the path of the main water supply line, and check the composition of all piping materials.

- Observe the general location of the heating/ cooling unit, if it is in the basement, and the general layout of the HVAC distribution system.

3.2 Interior Spaces, General

This section deals with inspection procedures that are common to all interior spaces, including finished attics and basements. Examine each space as follows:

- Walls and ceilings. Check the general condition of all surfaces, ignoring cosmetic imperfections. Look for large cracks and peeling paint or wall-paper. Note signs of exterior water penetration or interior leakage. Whenever possible, probe behind wallpaper, paneling, ceiling tiles, and other coverings for problems that may have been concealed but not corrected.

  Look for sags and bulges in old plaster work. Gently tap and push on the plaster; if an area sounds hollow or feels flexible, it is a good indication that the plaster has separated from its wood lath backing and its keys are broken. It may be best to replaster or resurface the entire wall or ceiling if such areas are found.

  Wall and ceiling cracks are usually caused by building settlement, deflection or warping of wood structural elements, or small seasonal movements of building components due to temperature and humidity variations. Seasonal movements will make some cracks regularly open and close; these may be filled with a flexible, paintable sealant, but otherwise cannot be effectively repaired. Cracks due to settlement, deflection, or warping can be repaired if movement has stopped, as is often the case. Large wall and ceiling cracks may indicate structural problems. See Sections 4.1 through 4.3 for cracks associated with masonry wall problems and Section 4.5 for cracks associated with structural wood framing problems.

  Inspect drywall-covered walls and ceilings by checking for nail popping, joint cracks, and other signs of poor attachment or workmanship.

  Examine paneled walls by pushing or tapping on the paneling to determine if it is securely attached. Look for delamination of veneers. If the paneling is obviously not original, try to look behind it to see what problems may be covered up.

Lift suspended ceiling panels and observe above them. Check the condition of the original ceiling, if any. Tiled ceilings should be examined similarly. On top floors, inspect for ceiling penetrations that may form thermal by-passes to the unconditioned spaces above.

- Floors. Examine the floor's finish or covering. Inspect all hardwood floors to determine if they will need cleaning or sanding. If sanding is required, be sure to check (by removing a floor register or piece of baseboard trim) how much the floor thickness has been reduced by previous sandings. Too much sanding will expose the floor nails.

  Inspect resilient floors and carpeting for their overall condition and quality. If they are to be replaced, check that their floor underlayment is sound.

  If the floor feels springy or unstable, inspect it in accordance with Section 4.5.

- Interior doors. Inspect the condition of doors and door frames. Check all door hardware for finish, wear, and proper functioning. Binding doors or out-of-square frames usually indicate building settlement (see Section 4.2).

- Windows. Inspect window sash and frames for damage and deterioration. Operate each window to determine its smoothness, fit, and apparent weathertightness. Check for the presence and condition of adequate security hardware. Examine the functioning of sash cords and weights in double hung windows. Open windows above the ground floor (or others not fully inspected from the outside) and check their exterior surfaces, frames, and sills. Operate all combination storm windows and check their weathertightness and physical condition.

  Test: Air infiltration through windows and doors can be checked by the test method described in ASTM E783, "Field Measurement of Air Leakage Through Installed Windows and Doors." The test should be performed by a mechanical engineer.

Consider window-related code requirements for natural light, ventilation, and egress capability. Most codes require the following:

- Natural light. Habitable rooms should be provided with natural light by means of exterior glazed openings. The area required is a percentage of the floor area, usually 10 percent.

- Ventilation. Habitable rooms should be provided with operable windows. Their required opening size is a percentage of the floor area, usually 5 percent. A mechanical ventilation system may usually be provided in lieu of this requirement.

- Egress. Every sleeping room should have at least one operable window or exterior door for emergency egress or rescue. Egress windows should have a minimum net clear opening of 5.7 square feet, with a clear height of at least 24 inches, a clear width of at least 20 inches, and a sill height not more than 44 inches above the floor.

• Closets. Inspect all closets for condition and usability. It is best that they have a clear depth of at least 24 inches. Check all shelving and hanging rods for adequate bracing.

• Trim and finishes. Examine baseboards, sills, mouldings, cornices, and other trim for missing or damaged sections or pieces. Replacement trim may no longer be readily obtainable, so determine if trim can be salvaged from more obscure locations in the building. If the presence of lead-based paint is suspected, plan to repaint, cover, or remove it. Wall paper tightly affixed to the wall may be painted over or skim-coated with plaster.

• Convenience outlets and lighting. Look for signs of inadequate or unsafe electrical service. Generally speaking, each wall should have at least one convenience outlet and each room one switch-operated outlet or overhead light. Examine the condition of outlets and switches, and feel them for overheating. Make sure they are mounted on outlet boxes and that light fixtures are securely attached to walls or ceilings.

Test: Operate switches and look for dimmed or flickering lights that indicate electrical problems somewhere in the circuit. The electrical system will be reexamined more thoroughly later in the inspection.

- HVAC source. Locate the heating, cooling, or ventilating source for every room. If there is a warm air supply register but no return, make sure doors are undercut one-inch for air flow.

Check the heating source in every room. This particular heater, when tested, was operable and safe.

Test: With the HVAC system activated, check the heat source in each room and make sure it is functioning. The HVAC system will be more completely examined later in the inspection.

- Skylights. Examine the undersides of all skylights for signs of leakage and water damage. Inspect skylight components for damage, deterioration, and weathertightness.

3.3 Bathrooms

Examine bathrooms in accordance with the procedures for other interior rooms, and additionally inspect:

- Electrical Service. Wherever possible, switches and outlets should not be within arm's reach of the tub or shower. Consider installing ground fault circuit interrupters (GFCIs) in the outlets.

Test: Check the condition and operation of all *switches, outlets, and light fixtures. Check the operation of the exhaust fan, if one is present.*

- Plumbing. Examine all exposed plumbing parts for leaking or signs of trouble. Inspect the lavatory for secure attachment and support. Decide what fixtures should be replaced.

  Test: Check the condition and operation of the lavatory, toilet, tub, and shower.

  A common problem in bathrooms is leakage around tubs and showers. If possible, inspect the ceiling below each bathroom for signs of water damage or recent patching and painting.

  Test: Check for a faulty shower pan by covering the shower drain tightly and filling the shower base with about an inch of water. Look for signs of water leakage on the ceiling below. The presence of excessive caulking around the shower base or drain may indicate attempts to remedy a shower pan leak by preventing water from reaching the pan. This is only a temporary solution, and the pan should be properly repaired.

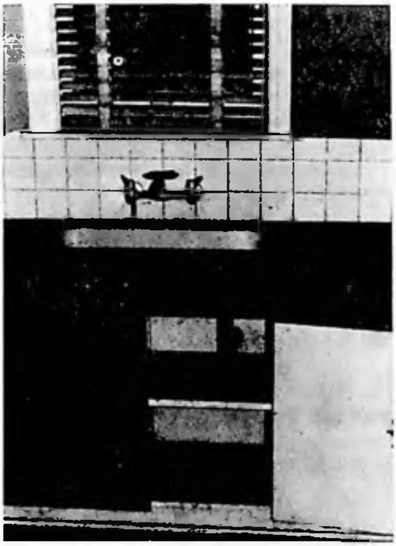
- Ceramic tile. Look for damaged or missing tiles, or tiles that have been scratched, pitted, or dulled by improper cleaning. Check the condition of all grouted and caulked joints. If a portion of the tile is defective or missing, all tile may have to be replaced since finding additional tiles of matching size, color, and texture may be impossible.

- Ventilation. The bathroom should be ventilated by either a window or exhaust fan. Poor ventilation will be indicated by mildew on ceiling and walls. If an exhaust fan is present, it should be properly ducted to the attic or exterior.

3.4 Kitchens

Examine kitchens in accordance with the inspection procedures for other interior rooms, and additionally inspect:

- Counters and cabinetry. Check counter tops for cracks or food traps, and examine kitchen cabinets carefully for signs of vermin infestation. Look for missing, broken, or damaged hardware and cabinet parts. Check doors and drawers for smooth operation, and wall cabinets for secure attachment. Compare the cost of replacement to the cost of reconditioning.



This kitchen cabinetry is plain but adequate. Rehabilitation of kitchen areas is often based largely on marketing needs.

- Electrical Service. Determine the adequacy and safety of electrical service to the kitchen. As a guide, new residential buildings are usually required to have a ground fault circuit interrupter (GFCI) on all outlets in close proximity to the sink, at least one 20 amp/120 volt circuit for portable kitchen appliances, and separate circuits for each major appliance as follows:

Refrigerator	20 amp/120 volt
Dishwasher	20 amp/120 volt
Garbage Disposal	20 amp/120 volt
Range	40 amp/240 volt

Test: Operate all electrical appliances simultaneously, including exhaust fans, to determine that they are connected and can run steadily without overloading their circuits.

- Plumbing. Visually inspect the condition of the sink for chips, scratches, and stains. Decide if it should be replaced. Check faucets for corrosion and proper operation. Make sure an air gap exists between the faucet and the flood rim to prevent possible back-siphoning.

Test: Turn the faucets on and off several times and look for drips and leaks in both the supply and drainage lines. Fill the sink and check that it drains promptly. Operate the disposal and dishwasher, listening and watching for smooth operation. Look for leaks in plumbing connections and check for the existence of an air vent for the dishwasher. Check the spray hose. Decide if either appliance should be replaced.

- Ventilation. See that exhaust fans are ducted to the outside and not to a cupboard, attic, crawl space, or wall. Ducts should be free of grease build-up.

Test: Operate exhaust fans and vented range hoods to determine if they are functional and whether they should be kept or replaced.

3.5 Storage Spaces

Inspect all closets and other storage spaces for cleanliness, functionality, proper lighting, and means of adequate ventilation.

3.6 Stairs and Hallways

Inspect stairs and hallways as follows:

- Light. Stairs and hallways should be well lighted and have three-way light controls. Public stair and hallway lights in multifamily buildings should be operated from centralized house controls.

Test: Check the operation of all stair and hallway lights.

- Smoke detectors. Stairs and hallways are the appropriate location for smoke detectors. Detectors should be located on or near the ceiling, near the heads of stairs, and away from corners.

Test: Check the operation of all smoke detectors by activating them with a smoke source or by pushing their test buttons.

- Stair handrails and guard rails. Hand rails located 30 to 34 inches above the stair nosing are normally required on at least one side of all stairs with three or more risers; guard rails are required on open sides of stairways and should have intermediate rails which will not allow passage of an object 9 inches in diameter. Shake all railings vigorously to check their stability, and inspect their fastenings.

- Stair treads and risers. Check that all treads and risers are secure and of uniform size and spacing. As a guide, stairs in new residential buildings must have a maximum rise of 8 inches and a minimum run of 9 inches. Inspect the condition and fastening of all stair coverings.

- Stair width and clearance. Stairs should normally have a minimum head room of 6'-6" and width of 3'-0". For multifamily buildings, check the local housing code for minimum widths of public hallways and stairs.

The rotted supports beneath this stair were insufficiently repaired by scabbing on small blocks of wood. The supports should be replaced and the source of moisture investigated.

- Structural integrity of stairs. Check that all stairs are structurally sound. Examine basement stairs where they meet the floor and where they are attached to the floor joists above.

3.7 Laundries and Utility Rooms

Laundry areas and utility rooms in small residential buildings are usually located in the basement or off the kitchen. Inspect them as follows:

- Laundries. Look for leaks or kinks in plumbing connections to the washer, and examine electrical or natural gas connections to the dryer. Inspect dryer venting and make sure it exhausts to the outside and is not clogged or otherwise restricted.

  Examine the laundry tub, if one exists, and decide if it should be replaced. Check its plumbing and its capacity to handle discharged water from the washer.

  In multifamily laundry areas, examine floors and walls for water damage. The laundry should have a floor drain. Determine if the laundry is of proper size and in the proper location for the planned rehabilitation.

  Test: Operate washers and dryers and observe their functioning. Listen for noise that indicates excessive wear. Determine if they should be replaced.

- Furnace rooms. Rooms containing fuel-burning equipment should not be located off a sleeping room in a single family residence, and must be in a publicly accessible area in a multifamily building. Check local code requirements for applicable fire safety and combustion air criteria. Inspect all HVAC equipment in accordance with Chapter 6.

3.8 Fireplaces and Flues

Inspect fireplaces and flues as follows:

- Fireplaces. Inspect the fire box for deterioration or damage. Check the damper, if one exists, and its operation. Make sure the hearth is of adequate size to protect adjacent combustible building materials, if any.

  Test: Burn some newspaper to check the draw. Discoloration around the mantel may indicate a smoky fireplace with poor draw.

- Flues. Check the flue lining in masonry chimneys. It should be tight along its entire length. Linings should be intact, unobstructed, and appropriate for the fuel type. A mirror may be helpful for examining flues. Consult a chimney expert if the integrity of the flue is in doubt. Analyze unlined chimneys for the possible installation of metal liners. See Section 7.2 for clearances around smoke pipes.

- Smoke pipe connections. Check that the smoke pipes from furnaces, water heaters, stoves, and related devices are tightly connected to the chimney and that they do not enter a fireplace flue. See additional requirements in Section 7.2

The structural condition of chimneys should be inspected in accordance with Section 4.4.

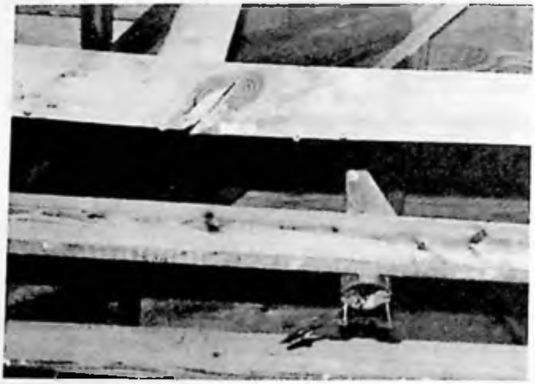
3.9 Attics

Attics are defined here as unconditioned spaces between the roof and the ceiling or walls of the building's inhabited rooms. In small residential buildings with pitched roofs, this is usually a partially or fully accessible space. In buildings with flat roofs, this space may be inaccessible or virtually nonexistent. Inspect all accessible attic spaces as follows:

- Roof leaks. Look for signs of water leakage from the roof above, and try to locate the source of leakage by tracing its path. This may be difficult to do beneath built-up roofs, since water may travel horizontally between layers of roofing materials. Determine the extent of any damage and the probable cost of repairs.

- Ventilation. Check for adequate attic ventilation. Approximately one square foot of net free vent area should be provided for every 300 square feet of attic space. All vents should be properly screened and free of obstruction. Signs of inadequate ventilation are rusted nails, wet or rotted roof sheathing, and excess heat build-up. Additional ventilation may be added by installing vents under the soffits, on the roof, or in gable ends.

- Thermal insulation. Examine the amount and type of existing insulating material. Check to see that faced insulation has been installed face-side down, and that vapor barriers are properly located between the ceiling and the first layer of insulation. Determine the proper amount of insulation the attic should have, and whether additional insulation is needed. Insure that insulation is held away from recessed lighting fixtures, and inspect spaces around vents, stacks, ducts, and wiring for thermal by-passes. Inspect attic doors or access hatches, heating or cooling ducts that pass through the attic, and whole-house attic fans for thermal bypasses.



This split ceiling joist can be easily repaired by proping it back in place and bolting new structural pieces to each side.

- Exhaust ducts and plumbing stacks. Insure that all exhaust ducts and plumbing stacks continue through the roof and do not terminate in the attic, and are not broken or damaged.

- Structural conditions. Inspect the roof structure in accordance with Section 4.5.

Where attics exist but are inaccessible, consider providing access to them through ceilings or gable ends. In flat roof buildings with no attic space, look for vents below the eaves and, if possible, open one or more of them. Probe the ventilating cavity to determine the amount of existing insulation and free air space it contains, and try to assess the general condition of surrounding building components.

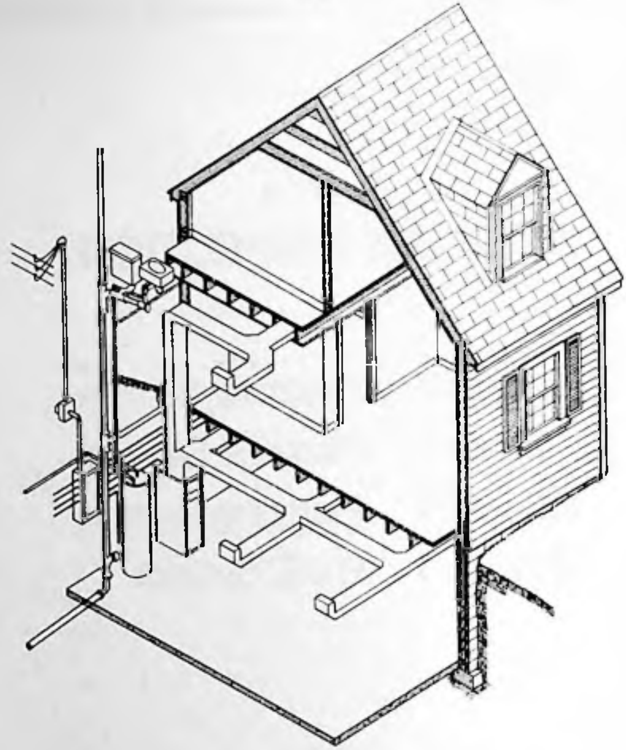
3.10 Whole-Building Thermal Efficiency Tests

Several whole-building tests can be performed to help evaluate the thermal efficiency of the building envelope:

Test: A building pressurization test can be used to determine air infiltration and exfiltration. This involves pressurizing the building with a fan, then using a smoke candle to detect air leakage through exterior building components. The test is particularly useful for "tightening up" an older building. See ASTM E779, "Practice for Measuring Air Leakage by the Fan Pressurization Method." A tracer gas test may also be used; see ASTM E741, "Practice for Measuring Air Leakage Rate by the Tracer Dilution Method." Such tests are usually performed by an energy specialist or an HVAC serviceman.

Test: A hand-held infrared scanner can be used to detect building "hot spots" due to interior air leakage or excessive heat loss through uninsulated building components. This test should be performed in cold weather when the building is heated; the greater the differential between inside and outside temperatures, the more accurate the results. Infrared scanners are commercially available; their use varies by manufacturer. Thermography can be used for the same purpose, but it requires much more expensive equipment and a trained operator. Thermographic tests should be performed by an energy specialist, mechanical engineer, or others with the proper training and equipment.

PART II
SYSTEMS INSPECTION



Chapter 4
Structural System

The majority of small residential buildings do not have inherent structural problems. Even many nineteenth century buildings, which often show signs of settlement, may have only minor structural faults that can be readily remedied. Major structural problems, when they do occur, are usually quite obvious. It is the less obvious problems that require careful inspection and informed diagnosis, because they will determine the extent of structural rehabilitation required and the costs of potential repairs. Such problems are often detected through a pattern of symptoms rather than any one symptom. This chapter describes signs of structural distress, deterioration, and damage by material type: masonry (the most difficult to assess), wood, iron and steel, and concrete.

Further information on structural assessment is provided in the HUD Guideline for Structural Assessment. To determine the capacity of the building's structural system, see Figure 4.1.

Record all pertinent structural information on the inspection sheets copied from Appendix A. Use only the sections relevant to the building being inspected.

4.1 Masonry, General

All exposed masonry should be inspected for cracking, spalling, bulging, bowing, leaning, and mortar deterioration. Before beginning a detailed masonry inspection, determine which walls are load-bearing and which are not. Usually this can be done by examining the beams and joists in the building's basement or crawl space or attic. Note also whether the walls are solid masonry or masonry cavity, or whether they are non-structural brick or stone veneer. The overall quality of the building's construction, and often that of its neighborhood, will be a good indicator of the quality of its masonry.

There may be a substantial difference in the masonry walls in buildings built during the last 40 to 50 years compared to those constructed earlier. Walls became thinner as designers began to exploit more effectively the compressive strength of masonry with the use of higher strength units and mortars. This came at the expense of flexibility, and such walls are often more brittle than their massive ancestors, and therefore more subject to stress-induced damage.

Tests: Two methods of testing are sometimes useful for assessing masonry. Probe holes can be drilled through the joints or masonry units with a masonry bit and probed with a stiff wire (or, if available, a fiber optic device) to determine a wall's thickness and the adequacy of its mortar. The probe holes are patched after the investigation is completed. A hammer test can be used for determining the structural soundness of masonry units and their bond to the mortar. The masonry is tapped lightly with a hammer and the resonance of the sound produced is evaluated. Three ASTM tests may also be useful: ASTM E518, "Test Method for Flexural Bond Strength in Masonry;" ASTM E447, "Test Method for Compressive Strength of Masonry Prisms;" and ASTM E519, "Test Method for Diagonal Tension in Masonry Assemblages." See a *qualified masonry consultant for the proper use of these tests on existing masonry.*

- Masonry cracking. Although masonry can elastically deform 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 the 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, differential movement between building materials, expansion of salts, and the bulging or leaning of walls. These problems are more fully discussed in Sections 4.2 and 4.3 below.

A common masonry wall crack probably caused by thermal or moisture expansion. If possible, monitor such cracks over a period of time to see if they're active. Active cracks should be sealed with a flexible sealant; inactive cracks may be remortared.

Cracks should always be 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 (a pocket lens may be useful for such an examination). Correlate the width of larger cracks to the age of the building. A 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 per year. In each case the cause and treatment may differ.

Figure 4.1
Assessing Structural Capacity

Unless there is obvious overloading, significant deterioration of important structural components, or additional loading is anticipated, there is usually little need to verify the building's structural design or to recompute its structural capacity. A thorough visual inspection of its structural components is all that is normally necessary. On some occasions, however, ceilings or other building elements may have to be opened for a selective inspection of critical structural members. A sufficient number of members must be examined to afford a reasonable assurance that they are representative of the total structure.

Record the dimensions of all major structural elements on the inspection sheets copied from Appendix A.

Test: A laboratory test may be helpful for determining the strength of a masonry wall section or some other structural component. A representative sample of the material or component in question must be removed from the structure for this test, which should be performed under the guidance of a qualified structural engineer and conducted by a certified testing laboratory. Refer to the ASTM tests listed in Sections 4.1, 4.6, and 4.7.

If doubt remains about the buildings's structural capacity after visual inspection and laboratory tests, or if during the building's rehabilitation its structural loading is to be dramatically increased, a quantitative analysis should be made of all the structural members involved. Simple calculations may be made in accordance with Parker and Ambrose's Simplified Engineering for Architects and Builders or, when wood-supported spans are involved, the use of the span tables in the One and Two Family Dwelling Code or the local building code may be sufficient. More complex calculations should be performed by a qualified structural engineer. See the HUD Guideline for Structural Assessment, pages 11-13, for additional guidance on this subject.

Test: 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 movements may take a half year or more to measure, but diurnal movements can be recorded over a few days. Hand measurements can also be made of crack movements, but these will be less precise and require repeated field visits.

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 or caulking; remortaring cyclical cracks will hold them open and cause more cracking.

When masonry problems exist, it is advisable to procure the services of a structural engineer. If problems appear to be due to differential settlement, a soils engineer may be required.

- Mortar deterioration. The two important qualities of mortar are its ability to bond to masonry and its internal strength. A sign of poorly made mortar may be random cracking at the bond joint. Until about the end of the nineteenth century, the standard mortar for masonry was a mixture of sand and pure lime or lime-possolan-sand. These low strength mortars gave masonry the ability to absorb considerable strain. Accordingly, the tendency to crack was reduced and when cracks did appear in the mortar joints, they were to a great extent capable of chemical reconstitution or "self-healing." Thus the age of the building may be a good clue in evaluating its mortar problems; older mortar (or mortar of any age that uses hydrated lime) will be softer and may require repointing, but otherwise may be responsible for a sound wall.

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 repoint the joints. Repointing should be performed with mortar of a composition similar to or compatible with the original mortar. The use of high strength mortar to repoint 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.

Test: To determine the composition (percentage of lime and other materials) of the existing mortar, remove a sample and have it chemically analyzed by a testing laboratory. This should be done under the supervision of a qualified structural engineer.

- 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 stop of its own accord 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.

The brick shown here is highly spalled from the effects of excessive moisture penetration and subsequent freezing. The damage cannot be repaired, although individual bricks can be replaced and the mortar repointed. The new mortar should be of the same composition as the old.

Very little can be done to correct existing mechanical and chemical damage except to replace the brick. Mechanical deterioration can be slowed or stopped by directing water away from the masonry surface and by repointing mortar joints to slow water entry into the wall. Surface sealants are rarely effective and may hasten deterioration by trapping moisture or soluble salts that inevitably does penetrate the wall, which in turn causes further spalling. Chemical deterioration can be slowed or stopped by adding a dampproof course (or injecting a dampproofing material) into the brick wall just above the ground line. Consult a specialist for this type of repair.

4.2 Masonry Foundations and Piers

Inspect stone, brick, or concrete block foundations for signs of the following problems (this may on occasion require some digging around the foundation):

- Problems Associated with Differential Settlement. Uneven (differential) settlement can be a major structural problem in small residential buildings, although 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 usually 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

An extreme case of structural failure in a masonry wall due to foundation settlement. The wall and foundation must be completely rebuilt.

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.

Should strengthening of the foundation be required, 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 is continuing and cracking is extensive, it is possible that only underpinning can rectify the problem. Older buildings with severe settlement problems may be very costly to repair. Seek the advice of a structural or soils engineer in such cases.

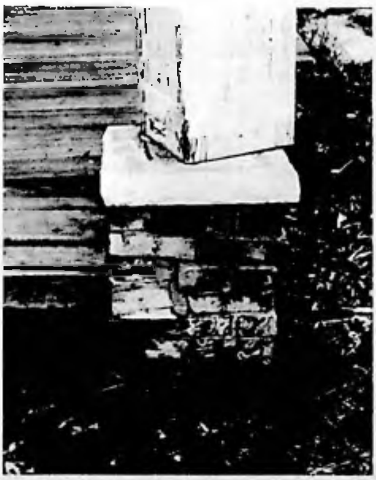
- <u>Problems Associated with Masonry Piers.</u> Masonry piers are often used to support internal loads on small residential buildings or to support projecting building elements such as bay windows, porches, and additions. In some cases they support the entire structure. Piers often settle differentially,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

  - <u>Settlement or rotation of the pier footing,</u> which causes 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 4.5). Masonry walls located over settled piers will crack (see Section 4.2).

- Frost heaving of the footing or pier, a condition caused by the lack of an adequate footing or one of insufficient depth. This will result in raising or tilting the pier, and in structural movement above it similar to that caused by settlement or rotation of the footing. Such a condition is most common under porches.

- Physical deterioration of the pier, due to exposure, poor construction, or overstressing. Aboveground piers exposed to the weather are subject to freeze-thaw cycles and, occasionally, physical damage. 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.

- Loss of bearing, of beams, joists, or floors, due to the above conditions or due to movements of the structure itself.



This pier has been overstressed by movement of the porch and column. The entire assembly should be rebuilt.

Piers should be examined for plumbness, signs of settlement, physical condition, and their adequacy in accepting bearing loads. Check their width to height ratio; it 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), they can be supplemented by the addition of adjacent supports.

- Cracking Associated with Drying Shrinkage in Concrete Block Foundation Walls. Shrinkage of concrete block walls as they dry in place often results in patterns of cracking similar to those 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. Such cracks are often mistaken for settlement cracks, although shrinkage cracks usually occur in the middle one-third of the wall and the footer beneath them remains intact (this is not observable unless the slab is broken away). Shrinkage cracking is rarely serious, and in an older building may have been previously repaired. If the wall is unsound, its structural integrity can be restored by pressure injecting concrete epoxy grout into the cracks or by adding pilasters.

- Bowing or Horizontal Cracking of the Foundation Wall. The bowing or horizontal cracking of brick or concrete block foundation walls may be caused by improper backfilling, 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, bowing or horizontal cracking may have occurred during the original construction and been compensated for at that time. Such distress, however, is potentially serious since it indicates that the vertical supporting member (the foundation wall) 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. 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.

4.3 Above-Ground Masonry Walls

Inspect above-ground stone, brick, or concrete block walls for signs of the following problems:

- Brick Wall Cracking Associated with Thermal and Moisture Movement. Above-ground brick walls expand in warm weather (particularly if south- or west-facing) 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 ends of 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 offsets 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 often present only cosmetic problems. After their cause has been determined, they should be repaired with a flexible caulking or 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, and may require the installation of expansion joints.

• Brick Wall Cracking 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. Such distress includes:

  - 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 (iron can expand to many times its original thickness) and displaces it. 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.

These conditions usually can be corrected by repairing or replacing corroded metal components and by repairing and repointing the masonry. Where cracking is severe, portions of the wall may have to be reconstructed.

- Wall Cracking or Displacement Associated with the Structural Failure of Building Elements. Structure-related problems, aside from those caused by differential settlement or earthquakes, 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 them. 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.

Despite the loss of masonry, this arch is intact and can be repaired with matching bricks.

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 that join in an inverted "V" above the opening's midpoint. Correcting such problems usually means replacing failed components and rebuilding the area above the opening.

Occasionally masonry arches fail because the walls that surround them cannot provide an adequate counterthrust to the arch action. This sometimes happens on windows that are too close to the corners of a wall or bay. In such cases, the masonry arch pushes the unbraced wall outward, causing it to crack above the opening near or just above the spring of the arch. When this occurs, the end walls must be strengthened.

- 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 if 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.

- Cracking due to overloading (or interior movement), which is fairly uncommon, but may be caused by a point load (often added during an alteration) bearing on a wall of insufficient thickness.. If the member is concealed, such a problem will be difficult to investigate, but the addition of interior wall supports or bracing may correct the source of the problem by relieving the load.

- Cracking due to ground tremors from nearby construction, heavy vehicular traffic, or earthquakes, which is roughly vertical in direction and occurs more toward the center of the building. Buildings exhibiting such cracking should be treated on a case-by-case basis, since possibly serious structural damage has taken place. Consult a structural engineer experienced in such matters.

• Bulging of Walls. 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. Whole-wall bulging 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 since 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 outwards.

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 masonry walls of many older buildings are examples of such ties (check with local ordinances on the use of such ties). Small bulges in the outer masonry course can often be pinned to the inner course or dismantled and rebuilt.

- Leaning of Walls. Masonry walls that lean (invariably outward) represent a serious, but uncommon, condition that is usually caused by poor design and construction practices, particularly inadequate structural tying or poor foundation work. When tilting or leaning occurs, it is often associated with parapets and other upper wall areas, especially those with heavy masonry cornices cantilevered from the wall. Leaning can produce separation cracking on the end walls and cracking on the interior wall face along floors, walls, and ceilings. Leaning walls can sometimes be tied back to the structure and thereby restrained. In such cases, the bearing and connections of interior beams, joists, floors, and roof should be examined.

When large areas or whole walls lean, rebuilding the wall, and possibly the foundation, may be the only answer.

Test: A wall is usually considered unsafe if it leans to such an extent that a plumb line passing through its center of gravity does not fall inside the middle one-third of its base. In such an event, consult a structural engineer.

- Problems Associated with 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. Common problems peculiar to brick veneer walls are:

  - Cracks caused by wood frame shrinkage, which are most likely to be found around fixed openings where the independent movement of the veneer wall is restrained. These cracks are also formed early in the life of the building and can be repaired by repointing.

  - Bulging, which is caused by inadequate or deteriorated ties between the brick and the wall to which it is held.

  - 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 (see Section 4.3), 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 caulk or 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. Typical parapet problems include:

  - Horizontal cracking at the roof line, due to differential thermal movement between it and the wall below (which is exposed to moderating interior temperatures). The parapet may eventually lose all bond except from friction and its own weight, and may be pushed out by ice formation on the roof.

A deteriorated parapet wall that badly needs repointing. Fortunately, the wall has not yet exhibited serious movement, but will if left unrepaired.

- 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 present) which, when followed by freeze-thaw cycles, causes masonry spalling and mortar deterioration.

Carefully examine all parapet walls. Check their coping and flashing for watertightness and overall integrity. In some cases, structurally unsound parapets can be stabilized and their moisture and thermal movements brought under control by the addition of expansion joints, while in others, the wall may require extensive repair or rebuilding.

All repairs should include adequate expansion joints.

- 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 for further appraisal. Hollow masonry units should be examined for internal cracking, where possible, by cutting into the wall. Such units may need replacement if seriously damaged. Masonry walls plastered on the fire side may have been sufficiently protected and will have suffered few, if any, ill effects.

4.4 Chimneys

Chimneys, like parapets, have greater exposure to the weather than most building elements, and have no lateral support from the point where they emerge from the roof. Common problems are:

- Differential settlement of the chimney, caused by inadequate foundations. 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. Consult a structural engineer.

- Deterioration of masonry near the top, 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 that cracks and breaks after several years. Check the cap and repair or replace it if necessary.

- Leaning of the chimney where it projects above the roof, due to deteriorated mortar joints caused 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 repointed, and unstable chimneys or those with a noticeable lean should be dismantled and rebuilt. Chimney-mounted antennas should be removed if they appear to be causing structural distress.

A deteriorated chimney cap. Mortar, rather than concrete, is often improperly used (as it was here) to cap the chimney. The masonry below will eventually deteriorate unless the cap is replaced.

4.5 Wood Structural Components

Wood structural components in small residential buildings are often directly observable only in attics or basements. Elsewhere they are concealed by fixed 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 (see Sections 4.2 and 4.3).

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. The three types of problems commonly associated with such components in small residential buildings are 1) deflection and warping, 2) fungal and insect attack, and 3) fire. Inspect for these problems as follows:

- Deflection, Warping, and Associated Problems. Some deflection of wood structural components or assemblies is common in older buildings and can normally be tolerated unless it causes loss of bearing or otherwise weakens connections, or opens watertight joints in roofs or other critical locations. Deflection can be arrested by the addition of supplemental supports or strengthening members, but 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 and will usually cause only superficial damage, although connections may be loosened and occasionally there may be a loss of bearing.

  Look for the following problems associated with wood structural components:

  - 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. Check 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. Each case must be diagnosed separately. 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 remodelings 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

The floor sag is caused by settlement of a basement support. It may be possible to jack the floor and its adjacent wall into a level position, but this should be done slowly and with caution.

supporting walls that have been removed, missing joist hangars, 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.

Test: Roll a marble or similar heavy round object over suspect floor areas to determine their direction and degree of slope, if any.

- 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. Correction, if desired, will be difficult since the whole structural assembly surrounding the stair has deformed. Look for signs of a supporting wall below the opening that has been removed. Where this has occurred, structural modification or the addition of a supporting column may be required.

- Floor sagging beneath door jambs, resulting from improper support below the jamb. This is rarely a structural concern, although if need be, additional bracing can be added (with some difficulty if above a finished ceiling) between the joists where the sag occurs.

- 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 problem that can be repaired only by breaking into the wall. See Sections 4.2 and 4.3 for cracking caused by differential settlement or masonry wall problems.

- Sagging in sloped roofs, resulting from too many layers of roofing material or inadequate bracing. 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. Check for all these conditions.

- Spreading of the roof downward and outward, due to inadequate tying. This is an uncommon but a potentially serious structural problem. Look for missing collar beams, inadequate tying of rafters and ceiling joists at the eaves, or inadequate tying of the ceiling joists (which act as a tension member) from one side of the roof to the other. Spreading can be halted by adequate bracing or tying, but there may be damage to masonry walls below the eaves (see Section 4.3). It is possible that the roof can be jacked back to its proper position. See a structural engineer.

- Deflection of flat roofs, due overspanning, 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 if it causes water to pond on the roof, thereby creating unacceptable dead loads. In both cases, the roof will have to be strengthened or releveled.

• Fungal and Insect Attack. The moisture content of properly protected wood structural components in buildings usually does not exceed 10-15%, which is well below the 25-30% required to promote decay by the fungi that cause rot or promote attack by many of the insects that feed on or inhabit wood. Dry wood will never decay.

Inspect 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.

Test: Probe all suspect wood with a sharp instrument and check its moisture content with a moisture meter. Wood with a meter reading over 20-25% 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. An excellent publication on the identification and control of wood-damaging organisms is A Guide to the Inspection of Existing Homes for Wood-Inhabiting Fungi and Insects (see Appendix C).

Exterior building areas or components that should be checked are:

- Places where wood is in contact with the ground, such as wood pilings, porch and deck supports, porch lattices, wood steps, adjacent fences, and nearby wood piles.

A common location of fungal and insect infestation is where wood door frames touch concrete or earth at grade.

- Foundation walls that might harbor shelter tubes, including cracks on the surface of the walls themselves.
- Frames and sills around basement or lower level window and door frames, 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 areas or components to be checked for rot or infestation are:

- Spaces around or within interior foundation walls and floors, crawl spaces, piers, columns, or pipes which 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.
- Wood frame basement partitions.
- 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.

Damage to wood from fungal or insect attack usually can be repaired at a reasonable cost by replacing or adding supplemental support to affected components, after the source of the problem has been corrected. Damage is rarely severe enough to seriously alter the structural stability of a building, although individual members may be badly deteriorated. Consult an exterminator when evidence of insect attack is found.

- Fire Damaged Wood. When exposed to fire, wood first "browns," then "blackens," then ignites and begins to char at a steady rate. The charred portion of the wood loses its structural strength, but the clear wood beneath does not unless it undergoes prolonged heating.

The remaining strength of wood exposed to fire can be determined by removing the char and estimating the size and strength of the new cross section. Damaged structural members may be reinforced by bolting additional structural members in a configuration that restores their original design strength. Consult a structural engineer before repairing major structural beams or girders.

This fire damaged wood should be carefully probed to determine the extent of charring. In this case, the wood was replaced.

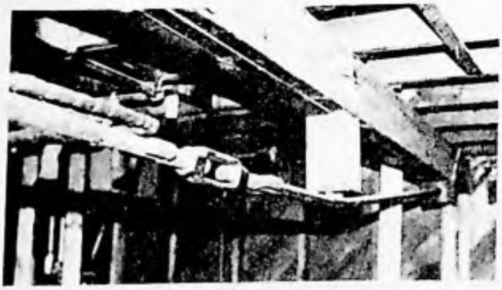
4.6 Iron and Steel Structural Components

Metal structural components used in small residential buildings are usually limited to beams and pipe columns in basements, angles over small masonry openings, and beams over long spans elsewhere in the structure. These components are almost always made of steel, although in buildings erected before 1890-1900 they may be of cast or wrought iron. Cast iron is weaker in tension than steel, but when found in small buildings is rarely of insufficient strength if not deteriorated or damaged.

Problems with iron and steel structural components usually center on corrosion. Inspect them as follows:

- 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 acids that lower the pH of rain water, thereby accelerating corrosion. Check all embedded iron and steel to determine its condition.

Make sure lintels have adequate bearing. Corrosion can also displace surrounding masonry; see Section 4.3.



The tie rod shown here was probably added in the building's mid-life to prevent spreading of the sidewalls. Consult a structural engineer before altering such an assembly.

- Columns should be checked for adequate connections at their base and top, and for corrosion at their base if it rests on ground level. Eccentric (off-center) loading or noticeable tilting of columns should be remedied.

- Beams should be checked for bearing, adequate connections to the structure, and deflection. Bearing can be significantly reduced on pilasters, piers, or columns in differentially settled buildings; inspect such conditions carefully (see Section 4.2). Beams in small residential buildings rarely deflect. If deflection is found, however, the cause should be determined and supplemental supports or plates should be added to correct the problem.

- Fire damage to iron and steel structural components should be carefully inspected. Iron and steel rapidly lose their load-bearing capacity when exposed to fire, and will undergo considerable expansion and distortion. In general, a structural iron or steel member that remains in place with negligible or minor distortions to its web, flanges, or end connections should be considered serviceable. Sagging or bent members, or those with a loss in bearing capacity should be replaced or reinforced with supplemental plates.

Test: When the quality or composition of an iron or steel structural component is in doubt, a small sample of the metal (called a "coupon") may be removed from a structurally unimportant location and sent to a *testing laboratory for evaluation. The sample should be tested in accordance with ASTM E8, "Tension Testing of Metallic Materials," and ASTM E9, "Compression Testing of Metallic Materials at Room Temperature." Such work should be performed under the auspices of a structural engineer.*

4.7 Concrete Structural Components

Concrete is commonly used for grade or below-grade level floors and for footings in small residential buildings. It may also be used for foundations, floors above grade, porches or patios built on grade, exterior steps and stoops, and occasionally as a precast or poured-in-place lintel or beam over openings in masonry. In foundations and floor slabs, concrete is usually only "reinforced" to the extent that it contains wire mesh to control cracking; spalling due to corroded reinforcing, therefore, is rarely found.

Failure of a concrete lintel and sill due to differential settlement of the building. Permanent repairs will be quite expensive. Note the makeshift shoring of the lintel.

Inspect for the following:

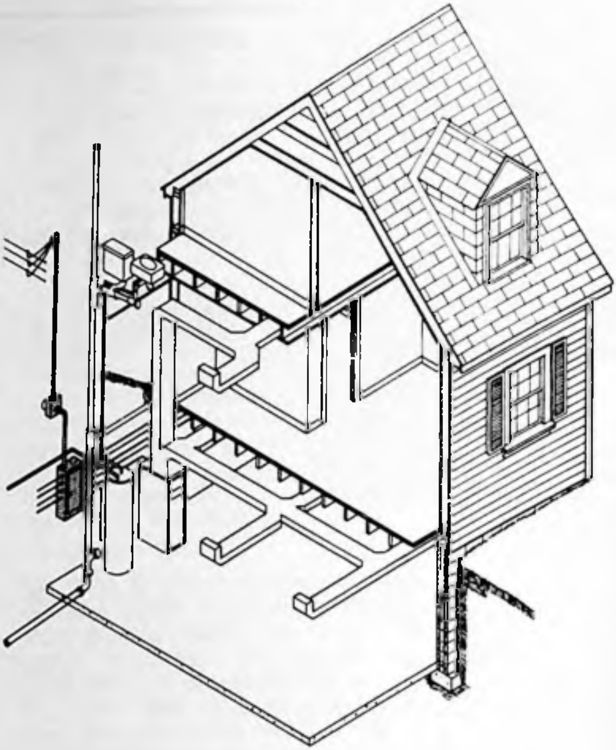
- Cracking at corners or openings in concrete foundations below masonry exterior walls, due to drying shrinkage of concrete walls that are prevented from contracting by the mass of the masonry above. This cracking will occur early in the life of the building. Minor cracks can be filled with mortar and major cracks by concrete epoxy grout.

- Cracking of interior slabs on grade, which is usually due to shrinkage or minor settlement below the slab. If cracking is near and parallel to foundation walls, it may be caused by movement of the walls or footers (see Section 4.2). Cracking can also result from soil swelling beneath the slab, a condition that may be caused by water from clogged or broken basement or footer drains. Rarely is such cracking structurally harmful to the building.

- Cracking of exterior concrete elements, such as porches, patios, and steps is usually due to heaving from frost or nearby tree roots, freeze-thaw cycles, settlement, or a combination of these conditions. It is compounded by the use of deicing salts. Such cracking rarely presents a structural problem to the building, but is often a practical problem that can best be remedied by replacing the concrete and providing the new work with more stable support. Cracks in existing concrete elements that are not seriously deteriorated may be cyclical and can be filled with a flexible sealant.

- Fire damage to concrete structural components should be thoroughly evaluated. Concrete heated in a building fire will lose some compressive strength, although when its temperature does not exceed 550°F most of its strength eventually will be recovered. If the concrete surface is intact, it can usually be assumed to be in adequate condition. Superficial cracking can be ignored. Major cracks that could influence structural behavior are generally obvious and should be treated on a case-by-case basis. Cracks can be sealed by injecting concete epoxy grout. Paints are available to restore the appearance of finely cracked or crazed concrete surfaces.

Tests: Two specialized tests may sometimes be useful for estimating the quality, uniformity, and compressive strength of in-situ concrete. The first is the Windsor Probe, a device that fires a hardened steel probe into concrete. See ASTM C 803, "Standard Test for Penetration Resistance of Hardened Concrete". The second test is the Schmidt Hammer, which measures the rebound of a hardened steel hammer dropped on concrete. See ASTM C 805, "Test for Rebound Number of Hardened Concrete." ACI 201.R, "Guide for Making a Condition Survey of Concrete in Service," and ACI 503.4, "Standard Specification for Repairing Concrete with Epoxy Mortars," may also be useful references when dealing with concrete problems.



Chapter 5
Electrical System

Electrical systems for small residential buildings are usually simple in concept and layout. Primary components are the service entry, panel box, 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 panel box between the service entry and the existing box. Existing circuits can continue to use the existing box, and new circuits can be fed through the new box.

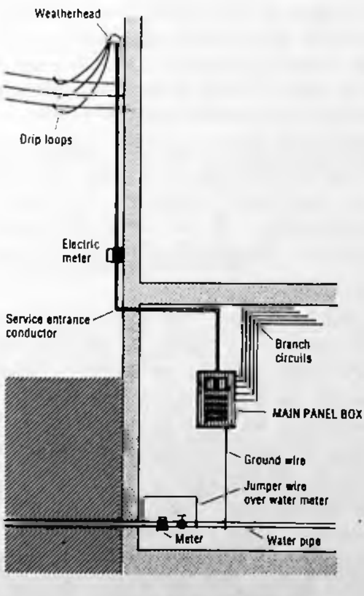
The electrical systems of buildings built prior to about 1940 may require overhaul or replacement, depending on rehabilitation plans. Parts of these older systems may function very adequately, however, and can often be retained if rehabilitation is not extensive.

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 persons experienced in residential electrical work, and preferably a qualified electrician.

The safety standards for the following assessment procedures are generally based on the requirements of the National Electrical Code. Certain exceptions to these requirements may be found in the HUD Electrical Guideline for Residential Rehabilitation.

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

Record all pertinent information about the electrical system on the inspection sheets copied from Appendix A.



Typical electrical service entry and main panel box for a single family residence.

Figure 5.1
Assessing Electrical Service Capacity (Ampacity)

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

1) 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 panel box (this should be performed only with the power to the building disconnected). If all conductors are unmarked, have an electrician evaluate them.

2) The ampere rating on the panel box or service disconnect switch, as listed on the manufacturer's data plate.

3) 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 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.

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 wire gage may be used (with power to the building disconnected) to measure the wire size, 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.

Record the ampacity of the building service and each of the branch circuits on the inspection sheets copied from Appendix A.

5.1 Service Entry

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

- 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.

- Service entrance conductor. Insure that the service entrance conductor has no splices and that its insulation is completely intact. If the main panel box 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.

5.2 Main Panel Box (Service Equipment)

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

- Physical condition and location. Check the overall condition of the panel box. Water marks or rust on a box mounted inside the building may indicate water infiltration along the path of the service entrance conductor. Panel boxes mounted outdoors should be watertight and tamperproof. Boxes mounted indoors should be located as closely as possible to where the service entrance conductor enters the building, and should be easily accessible.

The panel box 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 panel box. 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 panel box (as marked on the manufacturer's data plate) should match the voltage of the incoming electrical service.

  Test: The actual voltage rating of the incoming electrical service can be checked with a voltmeter. This test should be performed by an electrician.

- Grounding. Verify that the panel box is properly grounded. Its grounding conductor should normally be clamped to the metal water service inlet pipe between the exterior wall and the water meter. If it is attached on the other side of the meter, the meter should be jumped to insure proper electrical continuity to 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. Insure 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.

  Test: An electrical ground (resistance-to-ground) test may be used to determine whether the electrical system is well grounded to earth. The test requires the use of an ohmeter 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 wire, which should have 20 amp protection. Large appliances such as ranges, electric water heaters, and central air conditioners may require 30 amp service, which is normally supplied by #10 wire. Aluminum wire must be two sizes larger in each case. See Figure 5.1 for determining wire size.

Make sure that no circuit has a fuse or breaker with a higher ampere rating than its wiring is designed to carry. Look near the panel box 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.

Many older residential buildings have more than one fuse box. Check that all supplementary overcurrent devices are located in metal boxes, and that they are not in the vicinity of easily ignitable materials.

5.3 Branch Circuits

The earliest 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 acceptable wiring system, and one still found fairly often in houses built prior to 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. Knob and tube wiring is often replaced during rehabilitation, but if it is properly installed and in good condition, it is a safe wiring system and legal in most localities. The greatest

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

problem with such wiring is its insulation, which turns dry and brittle with age and often falls off on contact, leaving the wire exposed. When such conditions exist, replace the wire. 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.

- 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.

- 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, and water heaters. Check the size and length of all branch circuit wiring against the requirements of the local electrical code.

  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 panel box, 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.

  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 varies by manufacturer.

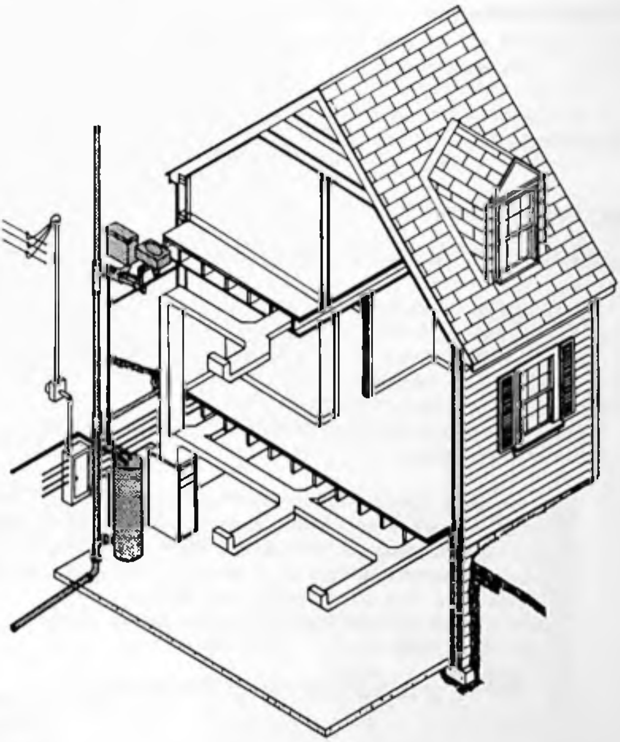
The armored cable and junction box are in good condition and can be reused, even if the lighting fixture is relocated.

- Condition and safety. Check that all wire types and equipment are installed properly in accordance with good practice. Check conductors' exposure to possible damage or abrasion. Look for proper fastening, clearance, and frayed or damaged insulation.

  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.

  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. Note whether knob and tube wiring splices are mechanically twisted, soldered, and taped, as required. 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 "CU-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, or flickering lights. All such conditions should be corrected.



Chapter 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.

If after checking the plumbing system it appears to be functioning properly, consider the effects of additional loads that may be imposed upon the system by renovations or modifications that might be planned for the building. The HUD Plumbing DWV Guideline for Residential Rehabilitation describes ways the existing DWV system may be reused or added to.

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

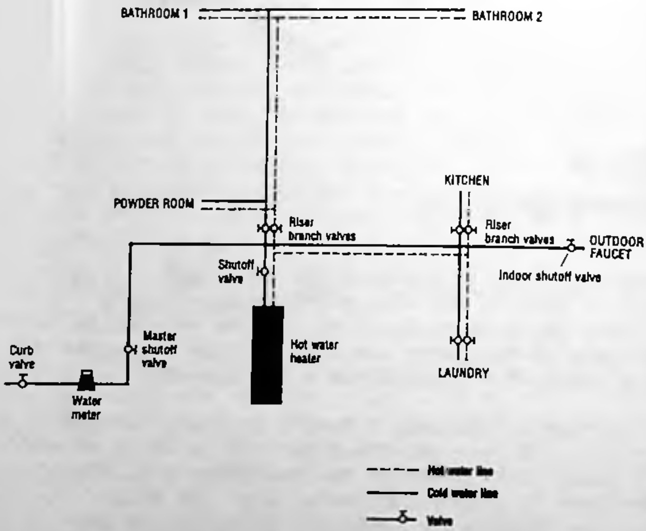
Record all pertinent information about the plumbing system on the inspection sheets copied from Appendix A.

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



Typical water distribution system schematic for a single family residence.

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	Size of copper pipe (type K)
1	1 to 1-1/4 inch	3/4 to 1 inch
2	1-1/4 to 1-1/2 inch	1 to 1-1/4 inch
3, 4	1-1/2 to 2 inch	1 to 1-1/4 inch

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

	Minimum Pipe Size	Minimum Flow Rate (gpm)	Minimum Flow Pressure (psi)
Kitchen sink	1/2"	2.5	8
Lavatory	3/8"	2	8
Shower	1/2"	3	8
Bathtub	1/2"	4	8
Toilet	3/8"	3	8
Dishwasher	1/2"	2.75	8
Laundry	1/2"	4	8
Hose bib	1/2"	2.5	8

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 gage 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). Record these capacities on the inspection sheets copied from Appendix A.

If the service entry is correctly sized but water flow is low throughout the building, the problem 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 the buildup occurs faster in hot water.

If new fixtures are to be added to the distribution system, have a plumber determine if 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.

10 feet away from the sanitary sewer or located on a plane one foot above it. Mains made of galvanized steel last about 20-30 years under normal soil and water conditions, although joints may leak sooner. If the building is approaching or over 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 undergound 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 if 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).

- <u>Master shutoff valve</u>. A master shutoff valve should be located where the house service main enters the building. 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.

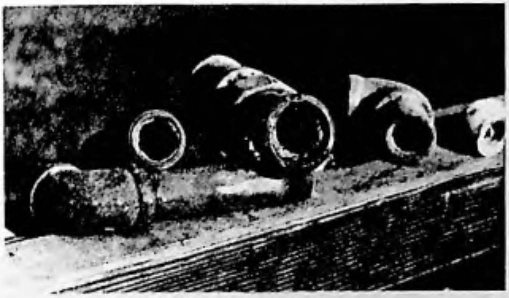
- Water meter. The water meter is normally the property of the municipal water company and may be located near the street, adjacent to the house, or within the house. Check the meter connections and supports, and inspect for adjacent plumbing constrictions that may reduce the building's water pressure.

6.2 Interior Water Distribution

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.

  - Galvanized steel piping is subject to rusting and the accumulation of mineral deposits more 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



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

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.

- 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.

- 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).

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. 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; 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 hot water heater.

- 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 if the piping remains exposed to freezing and whether any planned alterations or insulating 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 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

Figure 6.2

Assessing Drain, Waste, and Vent (DWV) Capacity

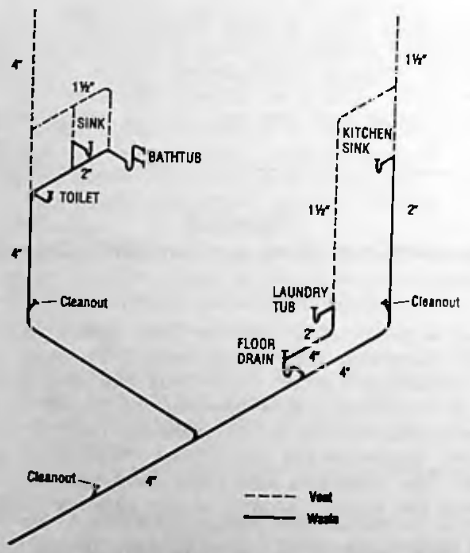
The installed capacity of an existing DWV system can be estimated by measuring the size of each DWV stack and finding the allowable number of fixtures that can drain into it. This is a relatively simple process and should be performed in accordance with the information given in the HUD Plumbing DWV Guideline for Residential Rehabilitation, pages 13-14. The guideline also gives examples of acceptable practices for adding fixtures to the existing DWV system.

Record the DWV capacity on the inspection sheets copied from Appendix A.

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 if 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, by obstructions in the venting system, or by the lack of a vent. In this case, first check for the presence of S-traps under the fixture—these may cause the self-siphonage and are no longer allowed by plumbing codes. If S-traps are not present, thoroughly check the venting system (see below). 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. They should be unobstructed and



Typical drain, waste, and vent (DWV) piping schematic for a single family residence.

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

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. See the HUD Plumbing DWV Guideline for Residential Rehabilitation, page 19. Check vent lines for damage caused by building movement or settlement, or 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.

- 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. 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.

Test: Test the waste drainage system by discharging several fixtures simultaneously and look for "boiling" or backup in the lowest fixture in the building. This indicates a clogged or malfunction-

ing 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) 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.

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 7 to 10 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 10 to 15 years. They have a low recovery rate and thus require a larger storage tank.

The dates of manufacture are usually listed on the data plate (often in a simple code in the serial number; 0575, for instance, would mean manufactured in May 1975), and since water heaters are usually installed within several months of manufacture, the age of the tank can often be approximated. Plan to replace any tanks that are near the end of their life expectancy. Assess hot water heater capacity in accordance with Figure 6.3.

Figure 6.3
Assessing Hot Water Heater Capacity

Hot 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 lower recovery rate. Lower recovery rates can be compensated for by the provision of larger storage capacity.

Use the table below to estimate required water heater size, as measured by storage capacity. Record the capacity on the inspection sheets copied from Appendix A.

Number of dwelling units	Storage Capacity: Oil- or gas-fired	Storage Capacity: Electric
1	40 gallons @ 40,000 BTU	50-60 gallons
2	60-80 gallons @ 40,000 BTU	80-100 gallons
3, 4	60-80 gallons @ 100,000 BTU	100-140 gallons

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

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

  Test: 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 must therefore be entirely replaced. Heavy rusting of the tank interior indicates that the tank should be replaced, although the presence of some sediment and rust is normal, and the tank should be drained

This hot water tank had a threaded plug where its pressure relief valve should be, an unsafe condition that should be corrected immediately.

regularly to remove it. 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 (but 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: The pressure relief valve should be tested by pressing the test lever, but since it may stick open, do not perform this test without having a replacement valve available.

The soot that has accumulated below the draft hood of this hot water heater indicates a severely clogged flue or chimney.

- Fuel burning components. On gas-fired and oil-fired tank water heaters, check the flue for upward pitch, 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.

  Test: Check that the burners have an adequate supply of combustion air by using a draft gage or match to test the draft. Test the operation of the shutoff valve by extinguishing and relighting the pilot light.

  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.

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 3 to 4 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° on the water gage; if it does, the aquastat needs adjustment.

  Check for the presence of a temperature/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 to a floor drain or the building's exterior, depending on local code requirements.

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

6.6 Water Wells and Equipment

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

- Location. 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 from a septic tank and 100 feet from any part of the absorption field.

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

- Depth and casing. Most localities now require wells to be over 50 feet 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.

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 flow is preferable) with a peak flow capacity of 12 gallons per minute.

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.

Record well capacity on the inspection sheets copied from Appendix A.

- Pumps. Two kinds of deep well pumps are in common use, the jet pump and the submersible pump. Jet pumps are 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 (submerged) at the bottom of the well casing, 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, and 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 pounds per square inch range (usually 20-40 psi, 30-50 psi, or 40-60 psi).

Test: Check the pressure tank and switch by running the water and seeing if 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.

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, since 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, since 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 water tight and, for a single-family house, have a minimum capacity of 1000 gallons. If properly maintained, it should have been pumped every several years. Ask to see the tanks 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.

Figure 6.5
Assessing Septic Capacity

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

Single Family # of Bedrooms	Multi-Family One Bedroom Each	Capacity in Gallons
1-2		750
3		1000
4	2 units	1200
5-6	3	1500
	4	2000

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

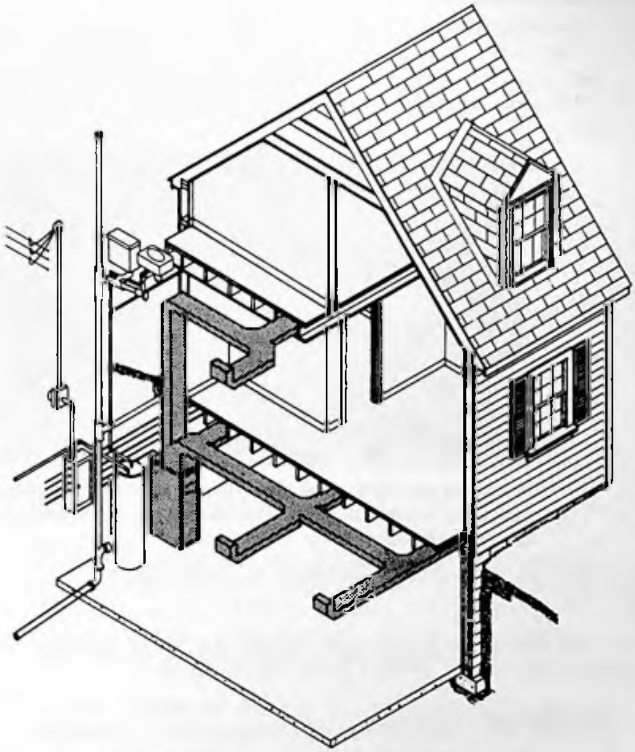
Test: Test the absorption field's capacity by running water into several plumbing fixtures for 30 to 60 minutes and observing the trap in the lowest building fixture. If the water in the trap "boils," backs-up, or makes a gurgling sound, the absorption field is clogged or inadequately sized. In either case, it will probably have to be replaced. See a local septic system specialist to determine replacement needs.

Record the septic system capacity on the inspection sheets copied from Appendix A.

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.

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.

- 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.

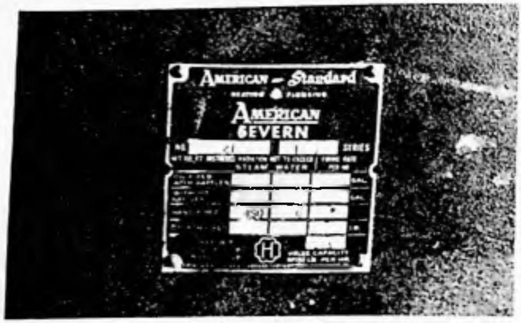


Chapter 7
HVAC System

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.

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.



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

Assess heating and cooling capacity as described in Figure 7.1.

Record all pertinent information about the HVAC system on the inspection sheets copied from Appendix A.

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.

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

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 two ways:

1) 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 unit cycles on and off) and compare this to outside temperatures. This procedure, while inexact, should give some idea of the system's potential capacity.

   In most cases the system can be assumed to have sufficient capacity since it has a history of use. Check with present or former building tenants on this matter.

   Of more concern to the rehabber may be 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.

2) 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 load. These loads can be calculated by 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 TEMPERATURE)*

* Based on R11 walls, R19 ceiling, and double glazing

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 BTUs).

These estimates should be followed by a complete load calculation after rehabilitation needs are firmly established. Record the system's heating and cooling capacity on the inspection sheets copied from Appendix A.

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. Multifamily 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 multizone systems by operating the HVAC system in all its modes and noting if distribution is adequate in each zone (see also Sections 7.3 and 7.4, below). Consider zoning needs for the planned reuse of the building. Refer to the NEEB "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems."

- Master switch. Every fuel-burning system should have a master switch that serves as an emergency shut-off for the burner. Master switches are usually located near the burner unit or, preferably, near the top of the stairs leading to the basement. 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.

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

In hot water heating systems that 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 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, 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.

- Fuel supply. Gas supply lines should be made of black iron or steel pipe (some jurisdictions allow copper lines with brazed connections). Shut-off valves should be easily accessible and all piping well-supported and protected.

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

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 tanks normally have a 550, 1000, or 1500 gallon capacity; basement tanks are usually restricted to a 275 gallon 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 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 gage and see if it works. Decide if the tanks should be replaced.

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.

- Physical 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 puff-back 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 cut-off to make sure it's on, press the *reset button, and try again. If it still doesn't light, call a serviceman.*

Once the unit is 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 blueish in color. Note if 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 serviceman 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, "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. 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 smoke pipes entering the chimney.

  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: Feel near the draft diverter or use a draft gage or CO tester 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

The vent shown here is made of improper materials and is incorrectly located on a side wall. It should be completely removed and replaced with an installation that meets the local code.

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

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.

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's 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 have been either replaced or converted to forced air. They are big, bulky, and easily recognizable. Lacking a mechanical means of moving air, such systems are inefficient and heat unevenly and are generally considered archaic. Plan to completely 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. 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 7.8). 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 7.5 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. A simple test for positive detection of heat exchanger cracks involves placing a smoke candle beneath the heat exchanger, and then activating the system. Air leaks in the exchanger will cause smoke to be emitted from the warm air supply registers. A CO tester may also be used to detect combustion gases.*

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°-120°F), 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°F, 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°F). 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, and for dirt buildup 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.

  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 is 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 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 or return ducts; check them in accordance with Section 7.10.

7.4 Forced Hot Water (Hydronic) Heating Systems

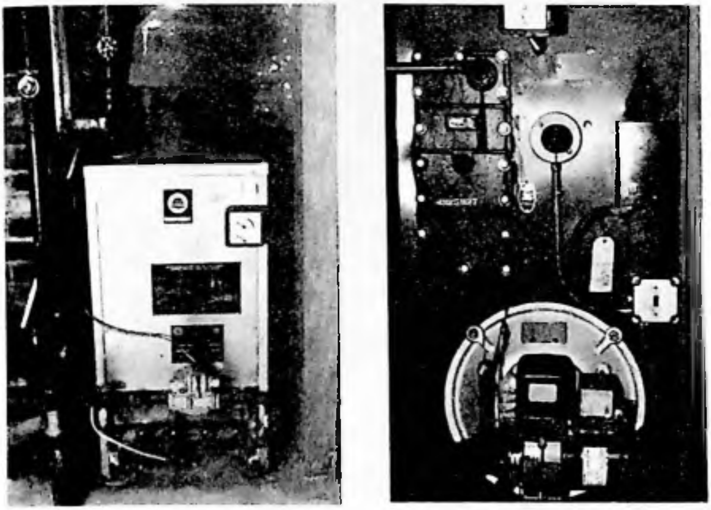
Hot water heating systems, like warm air systems, are of two types, forced or "hydronic," and gravity. Gravity systems are sometimes found in older single-family houses, but in most cases such systems have been replaced or converted to a forced hot water system. Gravity systems have no water pump and use bulky 3-inch 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 should normally be replaced during the rehabilitation process.

Forced hot water systems are usually heated by gas- or oil-fired boilers. Occasionally they may be immersion-heated by 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 7.5 for additional information on electrical resistance heating equipment.

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

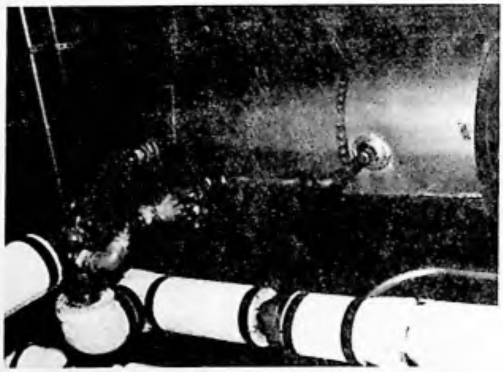
- Boiler. Most hot water and steam heating systems have steel boilers with a service life of about 20 years. Cast iron boilers, which are less common, have a service life of about 30 years. Old cast iron boilers converted from coal-fired units may last much longer but are usually quite inefficient. Inspect all boilers for signs of corrosion and leakage.



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

Test: Run the boiler for a half hour or more and check for leaks again. 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 which 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; air can often be added to the tank by a standard bicycle pump.



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

- Boiler controls. All boilers should be equipped with a pressure gage, a pressure relief valve, and a pressure reducing valve. The pressure gage indicates the water pressure within the boiler, which should normally be between 12 and 22 psi. A temperature gage may be included in the pressure gage. 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. 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. 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. The pressure relief valve should be mounted on the boiler.

Test: The pressure relief valve should be tested, 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.

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 pressure and speed. It should be located adjacent to the boiler on the hot water distribution piping. The pump may be operated in one of the following three ways:

1) 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.

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

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

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

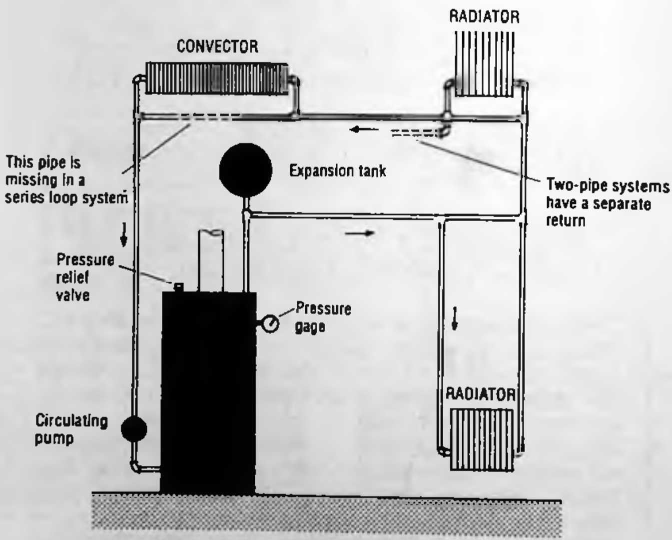
Test: Determine which kind of device controls the pump, and check its operation. Inspect the condition and operation of the pump itself. Listen for smooth operation; a loud pump may have bad bearings or a faulty motor. Inspect the seal between the motor and the pump housing for signs of leakage. Examine 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 be one of three types: series-loop, one-pipe, and two-pipe.

In a series loop, 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 via a diverter fitting, which is used to regulate the amount of hot water entering it.



One-pipe forced hot water heating system.

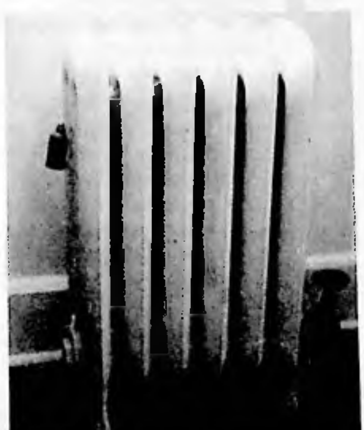
Two-pipe systems use separate pipes for supply and return water, which assures a very small temperature differential between radiators, regardless of their location. Individual room control is possible with both one-pipe and two-pipe systems, although a change in the valve adjustment on one radiator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

- Radiators and control valves. Radiators are of three types: cast iron (which in most cases are



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.

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 which are extremely durable and can normally 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 insure 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 them. Such heating is normally trouble-free, unless there are major structural problems that damage distribution piping and joints.

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 shut-off 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.

7.5 Steam Heating Systems

Steam heating systems are no longer installed in small residential buildings, but are still found 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 upkeep, 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 7.5).

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

  Test: Activate the boiler and observe the water level gage, which indicates the level of the water in the boiler. The gage should normally read about half full, but the actual level of the water is not critical as long as the level is showing. If the gage is full of water, the boiler is flooded and water must be drained from the system. If the gage 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 gage 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 gage; if the gage is too dirty to judge the water level, remove and clean it.

  The high-pressure limit switch turns off the burner when the boiler pressure exceeds a preset level, usually 5-7 psi. 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.

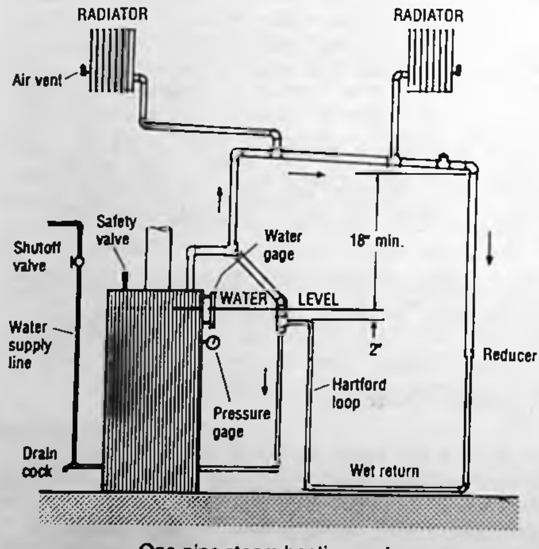
  Test: Lower the water level in the boiler and see if the low water cut-off turns off the burner.

  The pressure relief valve is designed to discharge when the boiler pressure exceeds 15 psi.

- 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 (which is evacuated 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 must therefore be pitched no less than one-inch in ten feet in the direction of the boiler to insure 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



One-pipe steam heating system.

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 shut-off valves that are not fully closed or open. Inspect the physical 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 of the interior inspection).

- 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; they can also be replaced by convectors. Radiators should be located on outside walls whenever possible.

Test: Activate the system and inspect the physical 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

Electrical resistance heating elements are commonly 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 7.4 and 7.5, and in heat pumps as described in Section 7.9. They incorporate one or more heavy duty heating ele- ents that are actuated by sequence relays on and from the thermostat. The relays start heating element at 30-second intervals, which inates surges on the electrical power system. arm air and heat pump systems, electric ating elements are normally located in the urnace 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 and generally trouble-free devices are often used as supplementary heating units, or as sole heat sources in houses where heating is only occasionally required. They may have one or more electric heating elements, depending on their size, which 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 blade 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 deter-

mine the cause, or have the system tested by an electrician.

- Baseboard heaters. Baseboard heaters rarely malfunction, but their 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."

7.7 Central Air Conditioning Systems

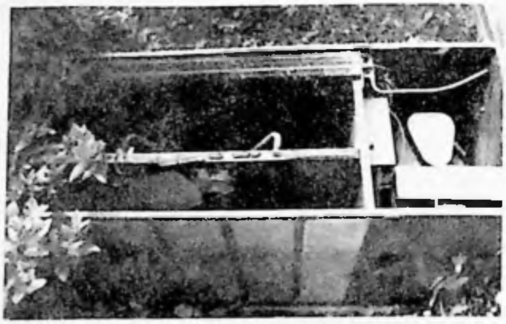
Central air conditioning systems are defined here as electrically operated refrigerant type systems used for cooling and dehumidification. (Evaporative coolers are described in Section 7.10, and gas-absorption systems are described in Section 7.8.) Heat pumps are similar to central air conditioners, 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 60°F; below that temperature, the systems can be damaged when operated.

There are two types of central air conditioning systems, integral and split. In the integral system, all mechanized components—compressor, condensor, evaporator, and fans--are contained in a single unit. The unit may be located outside the building (usually on the roof) 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 condensor 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 condensor. The compressor "pumps" refrigerant gas under great pressure through a condensor coil, where it gives up heat and becomes a liquid. The heat is exhausted to the outside air by the condensor fan. Compressors have a service life of 5 to 10 years, depending on the maintenance they receive, and are the most critical component in the air conditioning system.



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 condensor coils are to the left.

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 condensor fan should start simultaneously with the compressor. After several minutes of operation, the air flowing over the condensor should be warm. If it isn't, either the compressor is faulty or there is not enough refrigerant in the system.

If the compressor, condensor, and condensor 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, particularly on the condensor 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 just inside the building or adjacent to the units.

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 back to the evaporator. Check both lines for signs of damage and make sure the insulation is intact on the larger line; on the 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.

- Evaporator (condensing coil). 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. 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. There it is directed to a condensate drain line that empties in a house drain or somewhere on 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 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 to 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 serviceman 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.

- Distribution duct work 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 may occasionally 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 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 physical 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 spit 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 dampers, 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. Check also for the following problems:

- Auxiliary heater failure. Electric resistance auxiliary heaters are designed to activate (usually in stages) below about 30° when the heat pump cannot produce enough heat to satisfy the thermostat. Examine the physical 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 either by a faulty heater element, faulty relays, or a faulty thermostat.

- 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.

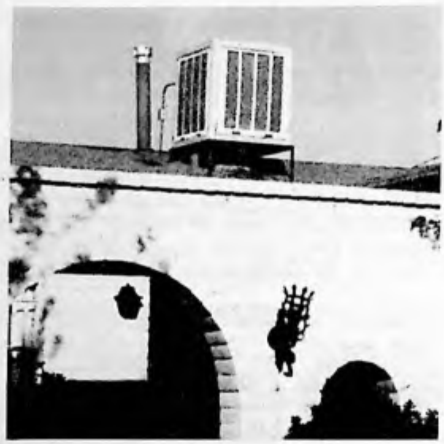
  Test: The pressure sensor may malfunction, and on units so equipped, it can be tested in the heating mode by temporarily placing an obstruction on the exhaust side of the coil and observing whether or not the coil begins to heat (defrost) within a short period of time.

- 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).

Test: Check the reversing valve when the outside temperature varies enough to cause the heat pump to change modes. If the system doesn't reverse, the reversing valve is faulty.

7.10 Evaporative Cooling Systems

Evaporative cooling systems are simple and economical devices that use wetted pads or screens to cool, through evaporation, air passed through them. Such systems can only be used in dry climates where evaporation readily takes place and where dehumidifcation is not required.



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

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 in 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 easily be removed with bleach. Some systems counteract this 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 if 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.

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 (usually located on the humidifier housing). Humidifiers can be of several types:

- Stationary pad, where 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, where 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, where water is broken into small particles by an atomizing device and released into the supply or return air ductwork.

Inspect the humidifier's physical 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. Insure 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 condensor coils may be "combed."

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

Test: Operate each window unit long enough 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 physical condition of the whole house or attic fan, if one is present. Inspect fan motors for signs of overheating and examine fan belts for signs of wear. Check all operating controls and associated electrical wiring.

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 open completely when the fan is running, and if exterior louvers on attic fans are weather-protected and screened.

Appendix A

Inspection Record

Note: Full-size copies of these inspection forms may be ordered at a nominal price from Building Technology Incorporated, 1109 Spring Street, Silver Spring, MD 20910 Phone (301) 588-5020

____
building name/location

____

____

Lot size______________________ Zoning classification______________

Year building built______________ Setback requirements:

Date of alterations______________ Front yard__________________

______________ Side yard__________________

Total building area______________ Rear yard__________________

Applicable building codes__________ Height limitation______________

______________________________ Other______________________

General comments:

____

____

____

____

____

____

____

____

SITE PLAN

Note the following on the site plan:

- North arrow
- Lot lines
- Building outline
- Drainage direction(s)
- Outbuildings
- Sidewalks and driveways
- Plantings
- Fences and walls
- Utility lines
- Water well, if any
- Septic system, if any
- Drawing scale

Provide dimensions for all major site components

ELEVATIONS

Note the following on each elevation:

- All exterior doors and windows
- Important architectural details
- Floor to floor heights
- Material types
- Direction of view
- Drawing scale

Supplement with exterior photographs as appropriate

FLOOR PLAN

Note the following on each floor plan:

- North arrow
- Floor level
- Wall thicknesses
- Wall materials
- Exterior dimensions
- Window sizes
- Door widths and swings
- Room dimensions
- Plumbing fixtures
- HVAC equipment
- Kitchen cabinetry
- Scale

Show major structural elements in colored pencil

INSPECTION CHECKLIST

(Complete only those elements pertinent to the building being inspected)

1 SITE

data	condition/needed repairs
1.1 Drainage	
Window well sizes ______	______
Basement stairwell size ______	______
1.2 Site Improvements	
Types of plantings ______	______
______	______
Fence dimensions ______	______
Lighting types ______	______
Driveway dimensions ______	______
Sidewalk widths ______	______
Step dimensions ______	______
Retaining walls ______	______
1.3 Outbuildings	
Garage dimensions ______	______
Shed dimensions ______	______
Other ______	______
1.4 Yards and Courts	
Areaway dimensions ______	______
Lighting dimensions ______	______
Access ______	______

2 BUILDING EXTERIOR

data	condition/needed repairs
2.1 Foundation Walls & Piers	
See Sections 4.1 & 4.2 for masonry	____________
See Section 4.7 for concrete	____________
See Section 4.5 for wood	____________
2.2 Exterior Wall Cladding	
Cladding material____________	____________
Thermal insulation____________	____________
2.3 Windows & Doors	
Door types____________No.___	____________
Window types____________No.___	____________
Storm wind. type____________No.___	____________
Storm door type____________No.___	____________
2.4 Decks, Porches, Balconies	
Size(s)____________	____________
Flooring material(s)____________	____________
Railing height(s)____________	____________
2.5 Pitched Roofs	☐ Replace ☐ Retain
Covering type____________	____________
Flashing type____________	____________
2.6 Flat Roofs	☐ Replace ☐ Retain
Covering type____________	____________
Flashing type____________	____________

	data	condition/needed repairs
2.7	Skylights	
	Size(s)________________	________________
	________________	________________
2.8	Gutters, Downspouts, & Drains	☐ Replace ☐ Retain
	Gutter size(s)________________ (1 sq in per 100 sq ft of roof)	________________
	Downspout size(s)________________ (one downspout per 40 ft of gutter)	________________
2.9	Chimneys	
	Ht. above roof________________	________________
	Flue size(s)________________	________________

3 BUILDING INTERIOR

data	condition/needed repairs
3.1 Basement/Crawl Space	
Floor height ______	______
Floor matl. ______	______
Wall matl. ______	______
Insulating matl(s). ______	______
3.2 Interior Spaces	
Room ______	______
Dimensions ______ Ht. ______	______
Ceil./wall matl(s). ______	______
Floor matl. ______	______
Door size(s) ______	______
Window size(s) ______ ______	______
Closet size(s) ______ ______	______
Trim ______	______
No. 120V outlets ____ ;240V outlet ☐	______
Heat source ______	______
Skylights ______	______
Room ______	______
Dimensions ______ Ht. ______	______
Ceil./wall matl(s). ______	______
Floor matl. ______	______
Door size(s) ______	______
Window size(s) ______ ______	______
Closet size(s) ______ ______	______
Trim ______	______
No. 120V outlets ____ ;240V outlet ☐	______
Heat source ______	______
Skylights ______	______

data	condition/needed repairs
Room ________	________
Dimensions ________ Ht. ______	________
Ceil./wall matl(s). ________	________
Floor matl. ________	________
Door size(s) ________	________
Window size(s) ______ ______	________
Closet size(s) ______ ______	________
Trim ________	________
No. 120V outlets ___ ;240V outlet ☐	________
Heat source ________	________
Skylights ________	________
Room ________	________
Dimensions ________ Ht. ______	________
Ceil./wall matl(s). ________	________
Floor matl. ________	________
Door size(s) ________	________
Window size(s) ______ ______	________
Closet size(s) ______ ______	________
Trim ________	________
No. 120V outlets ___ ;240V outlet ☐	________
Heat source ________	________
Skylights ________	________
Room ________	________
Dimensions ________ Ht. ______	________
Ceil./wall matl(s). ________	________
Floor matl. ________	________
Door size(s) ________	________
Window size(s) ______ ______	________
Closet size(s) ______ ______	________
Trim ________	________
No. 120V outlets ___ ;240 V outlet ☐	________
Heat source ________	________
Skylights ________	________

data	condition/needed repairs
3.3 Bathroom	
Dimensions__________ Ht.________	____________________
Ceil./wall matl.________________	____________________
Floor/wall matl.________________	____________________
Window size______ Ht. fr. fl.____	____________________
Closet size(s)_________ ________	____________________
Heat source__________________	____________________
120V outlet ☐; GFCI protected ☐	____________________
Lavatory: Replace ☐ Retain ☐	____________________
Toilet: Replace ☐ Retain ☐	____________________
Tub/Shower: Replace ☐ Retain ☐	____________________
Ventilation source______________	____________________
Dimensions__________ Ht.________	____________________
Ceil./wall matl.________________	____________________
Floor/wall matl.________________	____________________
Window size______ Ht. fr. fl.____	____________________
Closet size(s)_________ ________	____________________
Heat source__________________	____________________
120V outlet ☐; GFCI protected ☐	____________________
Lavatory: Replace ☐ Retain ☐	____________________
Toilet: Replace ☐ Retain ☐	____________________
Tub/Shower: Replace ☐ Retain ☐	____________________
Ventilation source______________	____________________

data	condition/needed repairs
3.4 Kitchen	
Dimensions_____ Ht._____	_____
Ceil./wall matl._____	_____
Floor covering_____	_____
Window size(s)_____ _____	_____
Counter space, l.f._____	_____
Overhd. cabinets, l.f._____	_____
Undercounter cabinets, l.f._____	_____
Heat source_____	_____
No. of 120V outlets_____	_____
Sep. 120V 20 amp refrig. outlet ☐	_____
240V range outlet ☐ gas outlet ☐	_____
Dishwasher (20 amp): Replace ☐ Retain ☐	_____
Disposal (20 amp): Replace ☐ Retain ☐	_____
Exhaust fan: Replace ☐ Retain ☐	_____
_____: Replace ☐ Retain ☐	_____
3.5 Storage Spaces	
Location_____ Size_____	_____
Location_____ Size_____	_____
Location_____ Size_____	_____
3.6 Stairs/Hallway	
Ceil./wall matl._____	_____
Floor matl._____	_____
Three-way light control ☐	_____
Smoke detector ☐	_____
Handrail ht._____ railing ht._____	_____
Tread/riser dim._____	_____
Stair width_____ Head room_____	_____
Structural integrity_____	_____

data	condition/needed repairs
3.7 Laundry/Utility Room	
Ceil./wall matl.________	________
Floor covering________	________
Plumbing connections adequate ☐	________
Dryer Vent ☐	________
Laundry tub: Replace ☐ Retain ☐	________
Floor drain present ☐	________
Washer: Replace ☐ Retain ☐	________
Dryer: Replace ☐ Retain ☐	________
240V. outlet ☐ Gas outlet ☐	________

3.8 Fireplaces/flues

Location	Opening Size	Depth	
________	________	________	________
________	________	________	________

3.9 Attic	
Ht. of highest point________	________
Means of access________	________
Ventilation, clear area________s.f.	________
Signs of roof leakage________	________
Type of insulation______Depth___	________
3.10 Whole Building Thermal Efficiency Tests	
Conduct pressurization test ☐	________
Scan exterior for heat loss ☐	________

4 STRUCTURAL SYSTEM

data	condition/needed repairs
4.1 Masonry, General	
Load-bearing walls are:	________________
	________________
	________________
4.2 Masonry Foundations and Piers	
Foundation wall mat.________	________________
Wall thickness________	________________
Pier mat.________	________________
Pier size(s)________	________________
Pier spacing________	________________
Depth of footings________	________________
Structural problems ☐	________________
4.3 Above-Ground Masonry Walls	
Wall mat(s).________	________________
Wall thickness________	________________
Support over openings________	________________
________________	________________
Thermal/moisture cracking ☐	________________
Freeze/thaw, corrosion cracking ☐	________________
Structural failure cracking ☐	________________
Wall bulging ☐	________________
Wall leaning ☐	________________
Brick veneer plroblems ☐	________________
Parapet wall problems ☐	________________
Fire damage problems ☐	________________
4.4 Chimneys	
Chimney mat.________	________________
Depth of footings________	________________
Structural problems ☐	________________

data	condition/needed repairs
4.5 Wood Structural Components	
Framing type ______ (balloon, platform, timber frame)	______
Floor members ______ size ______ spacing	______
Floor substrate matl. ______	______
Wall members ______ size ______ spacing	______
Wall substrate matl. ______	______
Ceiling members ______ size ______ spacing	______
Roof members ______ size ______ spacing	______
Roof substrate matl. ______	______
Deflection/warping problems ☐	______
Signs of fungal/insect attack ☐	______
Fire damage problems ☐	______
4.6 Iron & Steel Structural Components	
Lintels, Columns, & Beams	______
______ size ______ location	______
______ size ______ location	______
______ size ______ location	______
Lintel problems ☐	______
Column/beam problems ☐	______
Fire damage problems ☐	______

data	condition/needed repairs
4.7 Concrete Structural Components	
Slabs, Lintels, Walls	______________
________ ____________	______________
size location	
________ ____________	______________
size location	
________ ____________	______________
size location	
Foundation cracking problems ☐	______________
Interior slab-on-grade problems ☐	______________
Exterior concrete problems ☐	______________
Fire damage problems ☐	______________

5 ELECTRICAL SYSTEM

data | condition/needed repairs

5.2/5.2 Service Entry ☐ Replace ☐ Retain

Capacity from street_______Amps ____________________

_______Volts ____________________

Overhead wire clearance________ ____________________

Electric meter adequate ☐ ____________________

Service entrance conductor adequate ☐ ____________________

5.3 Main Panel Box ☐ Replace ☐ Retain

Main Circuit Breaker_______Amps ____________________

_______Volts ____________________

Grounded to______________ ____________________

No. of 15 Amp fuses/cir. brks.____ ____________________

No. of 20 Amp fuses/cir. brks.____ ____________________

No. of 25 Amp fuses/cir. brks.____ ____________________

No. of 30 Amp fuses/cir. brks.____ ____________________

No. of 40 Amp fuses/cir. brks.____ ____________________

Overcurrent protection adequate ☐ ____________________

5.4 Branch Circuits ☐ Replace ☐ Retain

Circuit No.	Wire Gage	Wire Capacity	Area Served	

Circuits grounded to panel box ☐ ____________________

Wire insulation in good condition ☐ ____________________

Aluminum wire used ☐ ____________________

6. PLUMBING

data | condition/needed repairs

6.1 Service Entry ☐ Replace ☐ Retain

Curb valve location________ ________

Line size______ Matl.______ ________

Shutoff valve operable ☐ ________

Water meter location________ ________

6.2 Interior Water Distribution Lines ☐ Replace ☐ Retain

Pipe Size	Pipe Matl.	Fixtures Served	

Thermal protection adequate ☐ ________

6.3 DWV Piping ☐ Replace ☐ Retain

Pipe Size	Pipe Matl.	Fixtures Served	

Vents, drains, and traps operable ☐ ________

data	condition/needed repairs
6.4/6.5 Hot Water Heater	☐ Replace ☐ Retain
Type________ Age______	____________
Storage Capacity____ Gal.____	____________
Recovery Rate________	____________
Plumbing components adequate ☐	____________
Fuel burning components adequate ☐	____________
Controls adequate ☐	____________
6.7 Water Well	
Location________	____________
Depth of casing________	____________
Pump type________ Age____	____________
Capacity____ GPM Depth____	____________
Pressure tank adequate ☐	____________
6.8 Septic System	
Location________	____________
Tank capacity________ Gal.	____________
Age of system________	____________
Size of drain field________	____________
Grease trap clean ☐	____________

7 HVAC SYSTEM

data	condition/needed repairs
7.1 Thermostatic Controls	☐ Replace ☐ Retain
Location(s) ________	________
________	________
Master switch operable ☐	________
7.2 - 7.6 Heating System	☐ Replace ☐ Retain
Location ________	________
Fuel type ________	________
Fuel storage capacity ________	________
System type ________	________
Age of heating unit ________	________
BTU/hr output ________	________
Room ventilation adequate ☐	________
Physical condition adequate ☐	________
Operation adequate ☐	________
Venting/draft adequate ☐	________
Distribution system adequate ☐	________
Controls adequate ☐	________
7.7 - 7.10 Cooling System	☐ Replace ☐ Retain
Location ________	________
System type ________	________
Age of cooling unit ________	________
Cooling capacity in tons ________	________
Electric service reqd. ________	________
Physical condition adequate ☐	________
Operation adequate ☐	________

data	condition/needed repairs
7.11 Humidifier	☐ Replace ☐ Retain
Humidifier type_______________	______________________
Physical condition adequate ☐	______________________
Operation adequate ☐	______________________
7.12 Unit Air Conditioners	☐ Retain ☐ Replace

Location	Capacity in Tons	Volts	Amps	
______	______	____	____	______________________
______	______	____	____	______________________
______	______	____	____	______________________
______	______	____	____	______________________

7.13 Whole House & Attic Fans	☐ Retain ☐ Replace
Location_______________	______________________
Capacity in cubic ft/min._______	______________________

Appendix B

Inspection Tools

A variety of tools are useful for inspecting and assessing existing buildings. The most essential of these are:

- Writing materials, including a clipboard with inspection sheets (see Appendix A) or notebook and graph paper.

- Tape measures of two lengths: 25-foot wide-blade retracting steel tape and 100-foot or longer steel tape.

- Screwdrivers, pliers, and adjustable wrench.

- Sharp probe, such as a knife, awl, or pick, for probing decayed or infested wood (see Section 4.5).

- Flashlight, for unlit areas, especially basements and attics.

- Marble, or other round object, for determining the levelness of floors and their direction of slope (see Section 4.5).

- Binoculars, to examine inaccessible exterior surfaces (see Chapter 2).

- Ladder, five- or six-foot folding type, and a 20'-30' extension ladder.

- Circuit tester, for testing circuits and ground connections (see Sections 5.2 and 5.3).

- Compass, for determining building orientation.

- Canvas bag, for carrying much of the above material.

Other items that may be extremely useful include:

- Hammer, for sounding masonry and concrete materials and for breaking into concealed spaces (see Chapter 4).

- Crowbar, for prying up or removing building elements to examine behind them.

- Level, for determining levelness and plumb of walls, floors, pipes, and other building elements (see Chapters 4, 6, and 7).

- Plumb bob, for determining the plumb of exterior walls (see Chapter 4).
- Marking chalk, for marking measurement lines.
- Pocket lens, for examining masonry cracks and other surface imperfections (see Section 4.1).
- Draft gage, for testing the draft on heating equipment (see Chapter 7).
- Thermometer(s), for testing heating and cooling equipment (see Chapter 7).
- Camera, with appropriate attachments, for recording exterior elevations, site features, and interior details.
- Stethescope, for locating exterior ground water leaks (see Section 6.1).
- Penetrant dye, for testing septic systems (see Section 6.7).
- Smoke candle, for testing heat exchangers (see Section 7.3).
- Mirror, for examining chimney flues and furnaces (see Section 3.8).
- Wire gauge, for determining electrical wire sizes (see Sections 5.2 and 5.3).
- Moisture meter, for determining the moisture content of wood and masonry (when used with wood, it is very useful for determining the likelihood of rot or insect infestation) (see Section 4.5).
- Voltmeter/ammeter, for measuring circuit voltage and amperage (see Sections 5.2 and 5.3).
- Shovel, for examining foundations (see Section 4.2).
- Dye capsules, for checking septic systems (see Section 6.7).
- Joint movement indicator, for determining crack movements over time (see Section 4.1).
- CO tester, for checking for the presence of carbon monoxide (both permanent and disposable testers are commercially available) (see Section 7.2).

Appendix C

References

The CABO One and Two Family Dwelling Code is the most widely accepted model code in the United States for one and two family dwellings. It can serve as a useful building assessment guide because it contains many of the minimum building requirements normally applied to existing as well as new residential buildings. It also provides span and working stress tables for wood joists and rafters, which are useful for checking the adequacy of wood structural components. The CABO code can be obtained from the Council of American Building Officials, 5205 Leesburg Pike, Falls Church, VA 22041 (phone 703-931-4533) or from any of the model code organizations.

Several of the HUD Rehabilitation Guideline publications are also useful for building assessment:

- The Egress Guideline for Residential Rehabilitation (Number 5).
- The Electrical Guideline for Residential Rehabilitation (Number 6).
- The Plumbing DWV Guideline for Residential Rehabilitation (Number 7).
- The Guideline on Fire Ratings of Archaic Materials and Assemblies (Number 8).
- The Guideline for Structural Assessment (Number 9).
- The Guideline on the Rehabilitation of Walls, Windows, and Roofs (Number 10).

These guidelines, and the HUD publications listed below, are available from HUD User, P.O. Box 280, Germantown, MD 20874 (phone 301-251-5154). They are also available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

The BOCA Basic/National Existing Structures Code contains much of the material presented in the above guidelines, as well as other useful information. It is available from Building and Code Administrators International, Inc., 4051 W. Flossmoor Road, Country Club Hills, IL 60477.

The National Electrical Code should be used as a reference for all electrical work. It can be obtained from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, or from any of the model code organizations.

The following technical publications are recommended as a supplement to this Guideline:

- A Guide to the Inspection of Existing Homes for Wood-Inhabiting Fungi and Insects, Michael P. Levy, U.S. Department of Housing and Urban Development.

- Simplified Engineering for Builders and Architects, Parker and Ambrose, John Wiley and Sons.

- Diagnosing and Repairing House Structure Problems, Joseph P. McNeill, VanNostrand Reinhold Company.

- Load Calculation for Residential Winter and Summer Air Conditioning (Manual J), Air Conditioning Contractors of America (1228 17th Street, N.W., Washington, D.C. 20036).

Publications useful for assessing the energy efficiency of existing residential buildings include:

- Insulation Manual for Homes and Apartments, 2nd Edition, NAHB Research Foundation (P.O. Box 1627, Rockville, MD 20850).

- Applying Cost-Effective Energy Standards in Rehabilitation Projects, U.S. Department of Housing and Urban Development.

- Conserving Energy in Older Homes, U.S. Department of Housing and Urban Development.

- Energy Conserving Features in Older Homes, John Burns, U.S. Department of Housing and Urban Development.

- In the Bank ... Or Up the Chimney, U.S. Department of Housing and Urban Development.

Residential buildings of historic merit, particularly those that qualify for federal rehabilitation investment tax credits, should be rehabilitated in accordance with The Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings, available from the Preservation Assistance Division, National Park Service, Washington, D.C. 20240. Other highly useful preservation publications include:

- Conservation of Historic Buildings, Bernard M. Fielden, Butterworth Scientific, Toronto and London.

- The Repair and Maintenance of Houses, Melville and Gordon, Estates Gazette Limited (151 Wadour Street, London W1V4BN).

- The Restoration Manual, Orin M. Bullock, Jr., VanNostrand Reinhold Company.

- Historic Preservation in Small Towns, Ziegler and Kidney, American Association for State and Local History (1400 Eighth Avenue South, Nashville, TN 37203).

Good home inspection publications include:

- The Complete Book of Home Inspection, Norman Becker, McGraw Hill.

- Principles of Home Inspection, Joseph G. McNeill, VanNostrand Reinhold Company.

- Conducting Housing Inspections, Community Revitalization Training Center (5530 Wisconsin Avenue, Chevy Chase, MD 20015).

- Basic Housing Inspection, U.S. Public Health Service.

The following publications are useful general references for rehabilitating houses:

- Home Renovation, Ching and Miller, VanNostrand Reinhold Company.

- Bob Vila's This Old House, Bob Vila, E.P. Dutton.

- The Old House Journal New Compendium, Poore and Labine, Dolphin Books.

- Home Improvements Manual, Reader's Digest Association, Inc.

- Rehabbing for Profit, Jerry Davis, McGraw-Hill.

The following test standards are referenced in this Guideline:

- ACI 201. R, "Guide for Making a Condition Survey of Concrete in Service."

- ACI 503.4, "Standard Specification for Repairing Concrete with Epoxy Mortars."
- ASTM C803, "Standard Test for Penetration Resistance of Hardened Concrete."
- ASTM C805, "Test for Rebound Number of Hardened Concrete."
- ASTM D2157, "Test Method for Effect of Air Supply on Smoke Density in Flue Gasses from Burning Distillate Fuels."
- ASTM E8, "Tension Testing of Metallic Materials."
- ASTM E9, "Compression Testing of Metallic Materials at Room Temperature."
- ASTM E447, "Test Method for Compressive Strength in Masonry Prisms."
- ASTM E518, "Test Method for Flexural Bond Strength in Masonry."
- ASTM E519, "Test Method for Diagonal Tension in Masonry Assemblages."
- ASTM E741, "Practice for Measuring Air Leakage Rate by the Tracer Dilution Method."
- ASTM E779, "Practice for Measuring Air Leakage by the Fan Pressurization Method."
- ASTM E783, "Field Measurement of Air Leakage Through Installed Windows and Doors."
- NEEB, "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems." (National Environmental Balancing Bureau, 8224 Old Courthouse Road, Vienna, VA 22180).

More detailed test methods are described in "Selected Methods for Condition Assessment of Structural, HVAC, Plumbing, and Electrical Systems in Existing Buildings" (NBSIR 80-2171), National Bureau of Standards (Washington, D.C. 20234).

The American Society of Home Inspectors is the professional organization that establishes home inspector qualifications and develops recommended home inspection standards. For information about this organization, write ASHI, Inc., 655 15th Street, N.W., Suite 320, Washington, D.C. 20005, or call (202) 842-3096.

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