Appendix A— The Effects of Fire on Structural Systems

Introduction

Building fires, which normally reach temperatures of about 1000 ºC, can affect the load-bearing capacity of structural elements in a number of ways. Apart from such obvious effects as charring and spalling, there can be a permanent loss of strength in the remaining material and thermal expansion may cause damage in parts of the building not directly affected by the fire.

In assessing fire's effects, the main emphasis should be placed on estimating the residual load-carrying capacity of the structure and then determining the remedial measures, if any, needed to restore the building to its original design for fire resistance and other requirements. Obviously, if weaknesses in the original design are exposed, these should be corrected.

All building materials except timber are likely to show significant loss of strength when heated above 250 ºC, strength that may not recover after cooling. Thus, it is useful to estimate the maximum temperature attained in a fire. Molded glass objects soften or flow at 700 or 800 ºC. Metals form drops or lose their sharp edges as follows: 300 to 350 ºC for lead, 400 ºC for zinc, 650 ºC for aluminum and alloys, 950 ºC for silver, 900 to 1000 ºC for brass, 1000 ºC for bronze, 1100 ºC for copper, and 1100 to 1200 ºC for cast iron. There are also the well-known color changes in concrete or mortar. The development of red or pink coloration in concrete or mortar containing natural sands or aggregates of appreciable iron oxide content occurs at 250 to 300 ºC and, normally, 300 ºC may be taken as the transition temperature. Table A-1 provides specifics.

Making an analysis of the damage and assessment of the necessary repairs may be possible within a reasonable degree of accuracy, but final acceptance may depend on proof by a load test, where performance is generally judged in terms of the recovery of deflection after load removal.

Table A–1
Fire-Induced Color Change in Concrete

The temperature within a slab may continue to rise after the fire has ended and some of the maxima were attained after the end of the heating period.

Heating period, hours	*Maximum surface temperature*		*Maximum depth of concrete showing characteristic change*			
	ºF	*ºC*	*Pink or red 300 ºC*	*Fading of red, friability 600 ºC*	*Buff 600 ºC*	*Sintering 1200 ºC*
1	1742	950	56 mm	19 mm	0	0
2	1922	1050	100 mm	38 mm	6 mm	0
4	2246	1230	140 mm	63 mm	25 mm	3 mm
6	2282	1250	170 mm	90 mm	38 mm	6 mm

1
Timber

Timber browns at about 120 to 150 ºC, blackens around 200 to 250 ºC, and emits combustible vapors at about 300 ºC. Above a temperature of 400 to 450 ºC (or 300 ºC if a flame is present), the surface of the timber will ignite and char at a steady rate. Table A-2 shows the rate of charring.

Analysis and Repair

Generally, any wood that is not charred should be considered to have full strength. It may be possible to show by calculation that a timber section or structural element subjected to fire still has adequate strength once the char is removed. Where additional strength is required, it may be possible to add strengthening pieces. Joints that may have opened and metal connections that may have conducted heat to the interior are points of weakness that should be carefully examined.

2
Masonry

The physical properties and mechanisms of failure in masonry walls exposed to fire have never been analyzed in detail. Behavior is influenced by edge conditions and there is a loss of compressive strength as well as unequal thermal expansion of the two faces. For solid bricks, resistance to the effects of fire is directly proportional to thickness. Perforated bricks and hollow clay units are more sensitive to thermal shock. There can be cracking of the connecting webs and a tendency for the wythes to separate. In cavity walls, the inner wythe carries the major part of the load. Exterior walls can be subjected to more severe forces than internal walls by heated and expanding floor slabs. All types of brick give much better performance if plaster is applied, which improves insulation and reduces thermal shock.

Analysis and Repair

As with concrete, it is possible to determine the degree of heating of the wall from the color change of the mortar and bricks. For solid brick walls without undue distortion, the portion beyond the pink or red boundary may be considered serviceable and calculations should be made accordingly. Per-forated and hollow brick walls should be inspected for the effects of cracks indicating thermal shock. Plastered bricks sometimes suffer little damage and may need repairs only to the plaster surfaces.

3
Steel

The yield strength of steel is reduced to about half at 550 ºC. At 1000 ºC, the yield strength is 10 percent or less. Because of its high thermal conductivity, the temperature of unprotected internal steelwork normally will vary little from that of the fire. Structural steelwork is, therefore, usually insulated.

Table A–2
Char Rate of Timber

A column exposed to fire on all faces should be assumed to char equally on all faces 1.25 times faster than the rates shown. Linear interpolation or extrapolation for periods between 15 and 90 minutes is permissible.

Species	*Charring after 30 minutes*	*Charring after 60 minutes*
All structural species except those below	20 mm	40 mm
Western red cedar	25 mm	50 mm
Oak, utile, kerving (gurgun), teak, greenheart, jarrah	15 mm	30 mm

Apart from losing practically all of its load-bearing capacity, unprotected steelwork can undergo considerable expansion when sufficiently heated. The coefficient of expansion is 10^{-5} per degree Celsius. Young's modulus does not decrease with temperature as rapidly as does yield strength.

Cold-worked reinforced bars, when heated, lose their strength more rapidly than do hot-rolled high-yield bars and mild-steel bars. The differences in properties are even more important after heating. The original yield stress is almost completely recovered on cooling from a temperature of 500 to 600 ºC for all bars but on cooling from 800 ºC, it is reduced by 30 percent for cold-worked bars and by 5 percent for hot-rolled bars.

The loss of strength for prestressing steels occurs at lower temperatures than that for reinforcing bars. Cold-drawn and heat-treated steels lose a part of their strength permanently when heated to temperatures in excess of about 300 ºC and 400 ºC, respectively.

The creep rate of steel is sensitive to higher temperatures and becomes significant for mild steel above 450 ºC and for prestressing steel above 300 ºC. In fire resistance tests, the rate of temperature rise when the steel is reaching its critical temperature is fast enough to mask any effects of creep. When there is a long cooling period, however, as in prestressed concrete, subsequent creep may have some effect in an element that has not reached the critical condition.

Analysis and Repair

In general, a structural steel member remaining in place with negligible or minor distortions to the web, flanges, or end connections should be considered satisfactory for further service. Exceptions are the relatively small number of structures built with cold-worked or tempered steel, where there may be permanent loss of strength. This may be assessed using estimates of the maximum temperatures attained or by on-site testing. Where necessary, the steel should be replaced, although reinforcement with plates may be possible. Microscopy can be used to determine changes in microstructure. Since this is a specialized field, the services of a metallurgist are essential.

4 Concrete

Concrete's compressive strength varies not only with temperature but also with a number of other factors, including the rate of heating, the duration of heating, whether the specimen was loaded or not, the type and size of aggregate, the percentage of cement paste, and the water/cement ratio. In general, concrete heated by a building fire always loses some compressive strength and continues to lose it on cooling. However, where the temperature has not exceeded 300 ºC, most strength eventually is recovered.

Because of the comparatively low thermal diffusivity of concrete (of the order of 1 mm/s), the 300 ºC contour may be at only a small depth below the heated face. Concrete's modulus of elasticity also decreases with temperature, although it is believed that it will recover substantially with time, provided that the coefficient of thermal expansion of the concrete is on the order of 10^{-5} per degree Celsius (but this varies with aggregate). Creep becomes significant at quite low temperatures, being of the orders of 10^{-4} to 10^{-3} per hour over the temperature range of 250 to 700 ºC, and can have a beneficial effect in relaxing stresses.

Analysis and Repair

- **Effective cross section.** Removal of the surface material down to the red boundary (see Table A-1) will reveal the remaining cross section that can be deemed effective. Compression tests of cores can indicate the strength of the concrete, yielding a value for use in calculations.
- **Cracks.** Most fine cracks are confined to the surface. Major cracks that could influence structural behavior are generally obvious. A wide crack or cracks near supports may mean there has been a loss of anchorage of the reinforcement.
- **Reinforcing steel.** Provided that mild steel or hot-rolled high-yield steel is undistorted and has not reached a temperature above about 800 ºC, the steel may be assumed to

have resumed its original properties except that cold-worked bars will have suffered some permanent loss.

- **Prestressing steel.** It is likely that prestressing steel will have lost some strength, particularly if it has reached temperatures over 400 °C. There will also be a loss of tensile stress. These effects can be assessed for the estimated maximum temperature attained.

In some situations, the replacement of a damaged concrete structural member may be the most practical and economic solution. Elsewhere, the repair of the member, even if extensive, will be justified to avoid inconvenience and damage to other structural members.

Where new members are connected to existing ones, monolithic action must be ensured. This calls for careful preparation of the concrete surfaces and the continuity of reinforcing steel. For repair, the removal of all loose friable concrete is essential to ensure adequate bonding. Extra reinforcement should be fastened only by experienced welders.

New concrete may be placed either by casting in forms or by the gunite method. With the latter, it may be possible to avoid increasing the original dimensions of the member. The choice of method will depend on the thickness of the new concrete, the surface finish required, the possibility of placing and compacting the concrete in the forms, and the degree of importance attached to an increase in the size of the section.

Large cracks can be sealed by injecting latex solutions, resins, or epoxies. Various washes or paints are available to restore the appearance of finely cracked or crazed surfaces.

Appendix B—Wood-Inhabiting Organisms

This material is excerpted from *A Guide to the Inspection of Existing Homes for Wood Inhabiting Insects*, by Michael P. Levy and published by the U.S. Department of Housing and Urban Development (HUD).

Wood is a porous material and will absorb moisture from the air. Moisture is attracted to the walls of the tubes that make up the wood. As walls absorb moisture, the wood swells. If the humidity is kept at 100 percent, the walls become saturated with water. The moisture content at which this occurs is the fiber saturation point, which is approximately 30 percent by weight for most species used in construction. Fungi will only decay wood with a moisture content above the fiber saturation point. To allow a safety margin, wood with a moisture content above 20 percent is considered to be susceptible to decay. Wood in properly constructed buildings seldom will have a moisture content above 16 to l8 percent. Thus, wood will only decay if it is in contact with the ground or wetted by an external source of moisture, such as rain seepage, plumbing leaks, or condensation. **Dry wood will never decay.** Also, the drier the wood, the less likely it is to be attacked by most types of wood-inhabiting insects.

Wood-inhabiting fungi are small plants that lack chlorophyll and use wood as their food source. Some fungi use only the starch and proteins in the wood and don't weaken it. Others use the structural components, and as they grow, they weaken the wood, which eventually becomes structurally useless. All fungi require moisture, oxygen, warmth, and food. The keys to preventing or controlling growth of fungi in wood in buildings are to either keep the wood dry (below a moisture content of 20 percent) or to use preservative-treated or naturally resistant heartwood or selected species.

Wood-inhabiting insects can be divided into those that use wood as a food material—termites and wood-boring beetles, for example—and those that use it for shelter—carpenter ants and bees, for example. Damage is caused by immature termites called nymphs, by the larvae or grubs of the wood-boring beetles, and by the adults in ants and bees.

Some wood-inhabiting organisms are found in all parts of the country, others are highly localized. Some, although common, cause very little structural damage. The following is a description of the major wood-inhabiting fungi and insects in the United States.

- **Surface molds and sapstain fungi.** Surface molds or mildew fungi discolor the surface of wood, but do not weaken it. They are generally green, black, or orange and powdery in appearance. The various building codes allow the use of framing lumber with surface molds or mildew, providing that the wood is dry and not decayed. Spores (or seeds) of surface molds or mildew fungi grow quickly on moist wood or on wood in very humid conditions. They can grow on wood before it is seasoned, when it is in the supplier's yard or on the building site, or in a finished house. When the wood dries, the fungi die or become dormant, but they do not change their appearance. Thus, wherever surface molds or mildew fungi are observed on wood in a building, it is a warning sign that at some time the wood was moist or humidity was high.

  Surface molds and mildew fungi are controlled by eliminating the source of high humidity or excess moisture, for example by repairing leaks, improving ventilation in attics or crawl spaces, or installing soil covers. Before taking corrective action, the source of the moisture that allowed fungus growth must be determined. If the wood is dry and the sources of moisture are no longer present, no corrective action need be taken.

  Sapstain or bluestain fungi are similar to surface molds, except that the discoloration goes deep into the wood. They color the wood blue, black, or gray and do not weaken it. They grow quickly on moist wood and do not change their appearance when they die or become dormant. They usually occur in the living tree or before the wood is seasoned, but sometimes they grow in the supplier's yard, on the building site, or in a finished house. In the latter case, they are normally associated with rain seepage or leaks. Stain fungi are a warning sign that at some time the wood was moist. Control is the same as for surface molds or mildew fungi.

- **Water-conducting fungi.** Most decay fungi are able to grow only on moist wood and cannot attack adjacent dry wood. Two brown-rot fungi, *Poria incrassata* and *Merulius lacrymans,* are able to conduct water for several feet through root-like strands or rhizomorphs, to moisten wood and then to decay it. These are sometimes called water-conducting or dry-rot fungi. They can decay wood in houses very rapidly, but fortunately they are quite rare. *Poria incrassata* is found most frequently in the Southeast and West. *Merulius lacrymans* occurs in the Northeast. Both fungi can cause extensive damage in floors and walls away from obvious sources of moisture. Decayed wood has the characteristics of brown rotted wood except that the surface of the wood sometimes appears wavy but apparently sound, although the interior may be heavily decayed. The rhizomorphs that characterize these fungi can be up to an inch in diameter and white to black in color, depending on their age. They can penetrate foundation walls and often are hidden between wood members. The source of moisture supporting the fungal growth must be found and eliminated to control decay. Common sources include water leaks and wood in contact with or close to the soil: for example, next to earth-filled porches or planters. Where the fungus grows from a porch, the soil should be removed from the porch next to the foundation wall to prevent continued growth of the fungus into the house. *Poria incrassata* normally occurs in new or remodeled houses and can cause extensive damage within two to three years.

- **Brown-rot and white-rot fungi.** The fungi often produce a whitish, cottony growth on the surface of wood. They grow only on moist wood. The fungi can be present in the wood when it is brought into the house or can grow from the spores that are always present in the air and soil. Wood attacked by these fungi should not be used in construction.

  Wood decayed by brown-rot fungi is brittle and darkened in color. As decay proceeds, the wood shrinks, twists, and cracks perpendicular to the grain. Finally, it becomes dry and powdery. Brown-rot is the commonest type of decay found in wood in houses.

  Wood decayed by white-rot fungi is fibrous and spongy and is bleached in color. Sometimes it has thin, dark lines around decayed areas. The wood does not shrink until decay is advanced.

  These fungi can be controlled by eliminating the source of moisture that allows them to grow, for example by improving drainage and ventilation under a house, repairing water leaks, or preventing water seepage. When the wood dries, the fungi die or become dormant. Spraying wood with chemicals does not control decay. If the moisture source cannot be eliminated, all the decayed wood should be replaced with pressure-treated wood.

- **White-pocket rot.** White-pocket rot is caused by a fungus that attacks the heartwood of living trees. Decayed wood contains numerous small, spindle-shaped white pockets filled with fungus. These pockets are generally 3 to 13 mm long. When wood from infected trees is seasoned, the fungus dies. Therefore, no control is necessary. White-pocket rot generally is found in softwood lumber from the West Coast.

- **Subterranean termites.** Subterranean termites normally damage the interior of wood structures. Shelter tubes are the most common sign of their presence. Other signs include structural weakness of wood members, shed wings or warmers, soil in cracks or crevices, and dark or blister-like areas on wood. The major characteristics of infested softwood when it is broken open are that damage is normally greatest in the softer springwood and that gallery walls and inner surfaces of shelter tubes have a pale, spotted appearance like dried oatmeal. The galleries often contain a mixture of soil and digested wood. Termites usually enter houses through wood in contact with the soil or by building shelter tubes on foundation walls, piers, chimneys, plumbing, weeds, etc. Although they normally maintain contact with the soil, subterranean termites can survive when they are isolated from the soil if they have a continuing source of moisture. Heavy damage by subterranean termites (except Formosans) does not normally occur during the first five to 10 years of a building's life, although their attack may start as soon as it is built. Subterranean termites can be controlled most effectively by the use of chemicals in the soil and foundation area of the house, by breaking wood-soil contact, and by eliminating excess moisture in the house. When applied properly, these chemicals will prevent or control termite attack for at least 25 years.

- **Formosan subterranean termites.** Formosan subterranean termites are a particularly vigorous species of subterranean termite that has spread to this country from the Far East. They have caused considerable damage in Hawaii and Guam and have been found in several locations on the United States mainland. It is anticipated that they could eventually become established along southern coasts, the lower East and West Coasts, in the lower Mississippi Valley, and in the Caribbean.

  The most obvious characteristics that distinguish Formosan subterranean termite swarmers from those of native species are their larger size (up to16 mm compared to 9 to 13 mm) and hairy wings (compared with smooth wings in other subterraneans). Soldiers have oval shaped heads, as opposed to the oblong and rectangular heads of native soldiers. Formosan termites also produce a hard material called carton, which resembles sponge. This is sometimes found in cavities under fixtures or in walls adjacent to attacked wood. Other characteristics—and control methods—are similar to those for native subterranean termites. However, Formosan subterranean termites are more vigorous and can cause extensive damage more rapidly than do native species. For this reason Formosans should be controlled as soon as possible after discovery.

- **Drywood termites.** It is quite common for buildings to be infested by drywood termites within the first five years of their construction in southern California, southern Arizona, southern Florida, the Pacific area, and the Caribbean. Swarmers generally enter through attic vents or shingle roofs, but in hot, dry locations, they can be found in crawl spaces. Window sills and frames are other common entry points.

  Drywood termites live in wood that is dry. They require no contact with the soil or with any other source of moisture. The first sign of drywood termite infestation is usually piles of fecal pellets, which are hard, less than 1 mm in length, with rounded ends and six flattened or depressed sides. The pellets vary in color from light gray to very dark brown, depending on the wood being consumed. The pellets, eliminated from galleries in the wood through round kick holes, accumulate on surfaces or in spider webs below the kick holes. There is very little external evidence of drywood termite attacks in wood other than the pellets. The interior of damaged wood has broad pockets or chambers that are connected by tunnels that cut across the grain through springwood and summerwood. The galleries are perfectly smooth and have few, if any, surface deposits. There are usually some fecal pellets stored in unused portions of the galleries. Swarming is another sign of termite presence.

  It normally takes a very long time for the termites to cause serious weakness in house framing. Damage to furniture, trim, and hardwood floors can occur in a few years. The choice of control method depends on the extent of damage. If the infestation is widespread or inaccessible, the entire house should be fumigated. If infestation is limited, spot treatment can be used or the damaged wood can be removed.

- **Dampwood termites.** Dampwood termites of the desert Southwest and southern Florida are rarely of great danger to structures. Pacific

Coast dampwood termites can cause damage greater than subterranean termites if environmental conditions are ideal.

Dampwood termites build their colonies in damp, sometimes decaying wood. Once established, some species extend their activities to sound wood. They do not require contact with the ground, but do require wood with a high moisture content. There is little external evidence of the presence of dampwood termites other than swarmers or shed wings. They usually are associated with decayed wood. The appearance of wood damaged by dampwood termites depends on the amount of decay present. In comparatively sound wood, galleries follow the springwood. In decayed wood, galleries are larger and pass through both springwood and summerwood. Some are round in cross section, others are oval. The surfaces of the galleries have a velvety appearance and are sometimes covered with dried fecal material. Fecal pellets are about 1 mm long and colored according to the kind of wood being eaten. Found throughout the workings, the pellets are usually hard and round at both ends. In very damp wood, the pellets are often spherical or irregular, and may stick to the sides of the galleries.

Dampwood termites must maintain contact with damp wood. Therefore, they can be controlled by eliminating damp wood. Treatment of the soil with chemicals can also be used to advantage in some areas.

- **Carpenter ants.** Carpenter ants burrow into wood to make nests, but do not feed on the wood. They commonly nest in dead portions of standing trees, stumps, logs, and sometimes wood in houses. Normally they do not cause extensive structural damage. Most species start their nests in moist wood that has begun to decay. They attack both hardwoods and softwoods. The most obvious sign of infestation is the large reddish-brown to black ants, 6 to 13 mm long, inside the house. Damage occurs in the interior of the wood. There may be piles or scattered bits of wood powder (frass), which are very fibrous and sawdust-like. If the frass is from decayed wood, pieces tend to be darker and more square ended. The frass is expelled from cracks and crevices, or from slit-like openings made in the wood by the ants. It is often found in basements, dark closets, attics, under porches, and in crawl spaces. Galleries in the wood extend along the grain and around the annual rings. The softer springwood is removed first. The surfaces of the galleries are smooth, as if they had been sandpapered, and are clean. The most effective way to control carpenter ants is to locate the nest and kill the queen in colonies in and near the house with insecticides. It is sometimes also helpful to treat the voids in walls, etc. For current information on control, an entomologist should be contacted.

- **Wood-boring beetles, bees, and wasps.** There are numerous species of wood-boring insects that occur in houses. Some of these cause considerable damage if not controlled quickly. Others are of minor importance and attack only unseasoned wood. Beetles, bees, and wasps all have larval, or grub, stages in their life cycles, and the mature flying insects produce entry or exit holes in the surface of the wood. These holes, and sawdust from tunnels behind the holes, are generally the first evidence of attack that is visible to the building inspector. Correct identification of the insect responsible for the damage is essential if the appropriate control method is to be selected. The characteristics of each of the more common groups of beetles, bees, and wasps are discussed in the following table which summarizes the size and shape of entry or exit holes produced by wood-boring insects, the types of wood they attack, the appearance of frass or sawdust in insect tunnels, and the insect's ability to reinfest wood in a house.

To use the table, match the size and shape of the exit or entry holes in the wood to those listed in the table; note whether the damaged wood is a hardwood or softwood and whether damage is in a new or old wood product (evidence of inactive infestations of insects that attack only new wood will often be found in old wood; there is no need for control of these). Next, probe the wood to determine the appearance of the frass. It should then be possible to identify the insect type. It is clear from the table that there is often considerable variation within particular insect groups. Where the inspector is unsure of the identity of the insect causing damage, a qualified entomologist should be consulted.

- **Lyctid powder-post beetles.** Lyctids attack only the sapwood of hardwoods with large pores: for example, oak, hickory, ash, walnut, pecan, and many tropical hardwoods. They reinfest seasoned wood until it disintegrates. Lyctids range from 3 to 7 mm in length and are reddish-brown to black. The presence of small piles of fine flour-like wood powder (frass) on or under the wood is the most obvious sign of infestation.

Even a slight jarring of the wood makes the frass sift from the holes. There are no pellets. The exit holes are round and vary from 1 to 1.5 mm in diameter. Most of the tunnels are about 1.5 mm in diameter and loosely packed with fine frass. If damage is severe, the sapwood may be completely converted to frass within a few years and held in only by a very thin veneer of surface wood with beetle exit holes. The amount of damage depends on the level of starch in the wood. Infestations are normally limited to hardwood paneling, trim, furniture, and flooring. Replacement or removal and fumigation of infested materials are usually the most economical and effective control methods. For current information on the use of residual insecticides, the

Table B-1
Characteristics of Wood-Inhabiting Organisms

Shape and size (inches) of exit/entry hole	*Wood type*	*Age of wood attacked*	*Appearance of frass in tunnels*	*Insect type*	*Reinfest*
round, 0.5 to 1.5 mm	softwood & hardwood	new	none present	ambrosia beetles	no
round, 0.8 to 1.5 mm	hardwood	new & old	fine, flour-like, loosely packed	lyctid beetles	yes
round, 0.8 to 2.5 mm	bark/sapwood interface	new	fine to course, bark colored, tightly packed	bark beetles	no
round, 0.8 to 1.5 mm	softwood & hardwood	new & old	fine powder and pellets, loosely packed; pellets may be absent and frass tightly packed in some hardwoods	anobiid beetles	yes
round, 2.5 to 7 mm	softwood & hardwood (bamboo)	new	fine to course powder, tightly packed	bostrichid beetles	rarely
round, 1.5 to 7 mm	softwood	new	course, tightly packed	horntail or woodwasp	no
round, 13 mm	softwood	new & old	none present	carpenter beetle	yes
round-oval, 3 to 10 mm	softwood & hardwood	new	course to fibrous, mostly absent	round-headed borer	no
oval, 3 to 13 mm	softwood & hardwood	new	sawdust-like, tightly packed	flat-headed borer	no
oval, 6 to 10 mm	softwood	new & old	very fine powder and tiny pellets, tightly packed	old house borer	yes
flat oval 13 mm or more or irregular surface groove, 6 to 13 mm wide	softwood & hardwood	new	absent or sawdust-like, course to fibrous; tightly packed	round or flat headed borer	no

inspector should contact the extension entomologist at his nearest land grant university or a reputable pest control company.

- **Anobiid beetles.** The most common anobiids attack the sapwood of hardwoods and softwoods. They reinfest seasoned wood if environmental conditions are favorable. Attacks often start in poorly heated or ventilated crawl spaces and spread to other parts of the house. They rarely occur in houses on slab foundations. Anobiids range from 3 to 7 mm in length and are reddish-brown to nearly black. Adult insects are rarely seen. The most obvious sign of infestation is the accumulation of powdery frass and tiny pellets underneath infested wood or streaming from exit holes. The exit holes are round and vary from 1.5 to 3 mm in diameter. If there are large numbers of holes and the powder is bright and light colored like freshly sawed wood, the infestation is both old and active. If all the frass is yellowed and partially caked on the surface where it lies, the infestation has been controlled or has died out naturally. Anobiid tunnels are normally loosely packed with frass and pellets. It is normally 10 or more years before the number of beetles infesting wood becomes large enough for their presence to be noted. Control can be achieved by both chemical and non-chemical methods. For current information on control of anobiids, the inspector should contact the extension entomologist at his nearest land grant university or a reputable pest control company.
- **Bostrichid powderpost beetles.** Most bostrichids attack hardwoods, but a few species attack softwoods. They rarely attack and reinfest seasoned wood. Bostrichids range from 2.5 to 7 mm in length and from reddish-brown to black. The black polycaon is an atypical bostrichid and can be 13 to 25 mm in length. The first signs of infestation are circular entry holes for the egg tunnels made by the females. The exit holes made by adults are similar, but are usually filled with frass. The frass is meal-like and contains no pellets. It is tightly packed in the tunnels and does not sift out of the wood easily. The exit holes are round and vary from 2.5 to 9 mm in diameter. Bostrichid tunnels are round and range from 1.5 to 10 mm in diameter. If damage is extreme, the sapwood may be completely consumed. Bostrichids rarely cause significant damage in framing lumber and primarily affect individual pieces of hardwood flooring or trim. Replacement of structurally weakened members is usually the most economical and effective control method.
- **Old house borer.** This beetle infests the sapwood of softwoods, primarily pine. It reinfests seasoned wood, unless it is very dry. The old house borer probably ranks next to termites in the frequency with which it occurs in houses in the mid-Atlantic states. The beetle ranges from 15 to 25 mm in length, and is brownish-black in color. The first noticeable sign of infestation by the old house borer may be the sound of larvae boring in the wood. They make a rhythmic ticking or rasping sound, much like a mouse gnawing. In severe infestations the frass, which is packed loosely in tunnels, may cause the thin surface layer of the wood to bulge out, giving the wood a blistered look. When adults emerge (three to five years in the South, five to seven years in the North), small piles of frass may appear beneath or on top of infested wood. The exit holes are oval and 6 to 10 mm in diameter. They may be made through hardwood, plywood, wood siding, trim, sheetrock, paneling, or flooring. The frass is composed of very fine powder and tiny blunt-ended pellets. If damage is extreme, the sapwood may be completely reduced to powdery frass with a very thin layer of surface wood. The surfaces of the tunnels have a characteristic rippled pattern, like sand over which water has washed. Control can be achieved by both chemical and non-chemical methods. For current information on control of the old house borer, the inspector should contact the extension entomologist at his nearest land grant university or a reputable pest control company.

- **Carpenter bees.** Carpenter bees usually attack soft and easy-to-work woods, such as California redwood, cypress, cedar, and Douglas fir. Bare wood, such as unfinished siding or roof trim, is preferred. The only external evidence of attack is the entry holes made by the female. These are round and 9 mm in diameter. A rather course sawdust-like frass may accumulate on surfaces below the entry hole. The frass is usually the color of freshly sawed wood. The presence of carpenter bees in wood sometimes attracts woodpeckers, which increases the damage to the surface of the wood. The carpenter bee tunnels turn at a right angle after extending approximately an inch across the grain of the wood, except when entry is through the end of a board. They then follow the grain of the wood in a straight line, sometimes for several feet. The tunnels are smooth-walled. It takes several years of neglect for serious structural failure to occur. However, damaged wood is very unsightly, particularly if woodpeckers have followed the bees. The bees can be controlled by applying five to 10 percent carbaryl (Sevin) dust into the entry holes. Several days after treatment, the holes should be plugged with dowel or plastic wood. Prevention is best achieved by painting all exposed wood surfaces.

- **Other wood-inhabiting insects.** There are several other species of insects that infest dying or freshly felled trees or unseasoned wood, but that do not reinfest seasoned wood. They may emerge from wood in a finished house or evidence of their presence may be observed. On rare occasions, control measures may be justified to prevent disfigurement of wood, but control is not needed to prevent structural weakening.

❏ ***Ambrosia beetles.*** These insects attack unseasoned sapwood and heartwood of softwood and hardwood logs, producing circular bore holes 0.5 to 3 mm in diameter. Bore holes do not contain frass, but are frequently stained blue, black, or brown. The insects do not infest seasoned wood.

❏ ***Bark beetles.*** These beetles tunnel at the wood/bark interface and etch the surface of wood immediately below the bark. Beetles left under bark edges on lumber may survive for a year or more as the wood dries. Some brown, gritty frass may fall from circular bore holes 1.5 to 2.5 mm in diameter in the bark. These insects do not infest wood.

❏ ***Horntails (wood wasps).*** Horntails generally attack unseasoned softwoods and do not reinfest seasoned wood. One species sometimes emerges in houses from hardwood firewood. Horntails occasionally emerge through paneling, siding, or sheetrock in new houses; it may take four to five years for them to emerge. They attack both sapwood and heartwood, producing a tunnel that is roughly C-shaped in the tree. Exit holes and tunnels are circular in cross-section and 1.5 to 7 mm in diameter. Tunnels are tightly packed with course frass. Frequently, tunnels are exposed on the surface of lumber by milling after the development of the insect.

❏ ***Round-headed borers.*** Several species are included in this group. They attack the sapwood of softwoods and hardwoods during storage, but rarely attack seasoned wood. The old house borer is the major round-headed borer that can reinfest seasoned wood. When round-headed borers emerge from wood, they make slightly oval to nearly round exit holes 3 to 10 mm in diameter. Frass varies from rather fine and meal-like in some species to very course fibers like pipe tobacco in others. Frass may be absent from tunnels, particularly where the wood was machined after the emergence of the insects.

❏ ***Flat-headed borers.*** These borers attack sapwood and heartwood of softwoods and hardwoods. Exit holes are oval, with the long diameter 3 to 13 mm. Wood damaged by flat-headed borers is generally sawed after damage has occurred, so tunnels are exposed on the surface of infested wood. Tunnels are packed with sawdust-like borings and pellets, and tunnel walls are covered with fine transverse lines somewhat similar to some round-headed borers. However, the tunnels are much more flattened. The golden buprestid is one species of flat-headed borer that occurs occasionally in the Rocky Mountain and Pacific Coast states. It produces an oval exit hole 5 to 7 mm across, and may not emerge from wood in houses for 10 or more years after infestation of the wood. It does not reinfest seasoned wood.

If signs of insect or fungus damage other than those already described are observed, the inspector should have the organism responsible identified before recommending corrective measures. Small samples of damaged wood, with any frass and insect specimens (larvae or grubs must be stored in vials filled with alcohol), should be sent for identification to the entomology or pathology department of the state land grant university.

Appendix C—
Life Expectancy of Housing Components

The following material was developed for the National Association of Home Builders (NAHB) Economics Department based on a survey of manufacturers, trade associations, and product researchers. Many factors affect the life expectancy of housing components and need to be considered when making replacement decisions, including the quality of the components, the quality of their installation, their level of maintenance, weather and climatic conditions, and intensity of their use. Some components remain functional but become obsolete because of changing styles and tastes or because of product improvements. Note that the following life expectancy estimates are provided largely by the industries or manufacturers that make and sell the components listed.

Appliances	*Life in Years*
Compactors	10
Dishwashers	10
Dryers	14
Disposal	10
Freezers, compact	12
Freezers, standard	16
Microwave ovens	11
Electric ranges	17
Gas ranges	19
Gas ovens	14
Refrigerators, compact	14
Refrigerators, standard	17
Washers, automatic and compact	13
Exhaust fans	20

Source: Appliance Statistical Review, April 1990

Bathrooms	*Life in Years*
Cast iron bathtubs	50
Fiberglass bathtub and showers	10–15
Shower doors, average quality	25
Toilets	50

Sources: Neil Kelly Designers, Thompson House of Kitchens and Bath

Cabinetry	
Kitchen cabinets	15–20
Medicine cabinets and bath vanities	20

Sources: Kitchen Cabinet Manufacturers Association, Neil Kelly Designers

Closet Systems	
Closet shelves	Lifetime

Countertops	
Laminate	10–15
Ceramic tile, high-grade installation	Lifetime
Wood/butcher block	20+
Granite	20+

Sources: AFPAssociates of Western Plastics, Ceramic Tile Institute of America

Doors	
Screen	25–50
Interior, hollow core	Less than 30
Interior, solid core	30-lifetime
Exterior, protected overhang	80–100
Exterior, unprotected and exposed	25–30
Folding	30–lifetime
Garage doors	20–50
Garage door opener	10

Sources: Wayne Dalton Corporation, National Wood Window and Door Association, Raynor Garage Doors

Electrical

Electrical	Life in Years
Copper wiring, copper plated, copper clad aluminum, and bare copper	100+
Armored cable (BX)	Lifetime
Conduit	Lifetime

Source: Jesse Aronstein, Engineering Consultant

Finishes Used for Waterproofing

Paint, plaster, and stucco	3–5
Sealer, silicone, and waxes	1–5

Source: Brick Institute of America

Floors

Oak or pine	Lifetime
Slate flagstone	Lifetime
Vinyl sheet or tile	20–30
Terrazzo	Lifetime
Carpeting (depends on installation, amount of traffic, and quality of carpet)	11
Marble (depends on installation, thickness of marble, and amount of traffic)	Lifetime+

Sources: Carpet and Rug Institute, Congoleum Corporation, Hardwood Plywood Manufacturers Association, Marble Institute, National Terrazzo and Mosaic Association, National Wood Flooring Association, Resilient Floor Covering Institute

Footings and Foundation

Poured footings and foundations	200
Concrete block	100
Cement	50
Waterproofing, bituminous coating	10
Termite proofing (may have shorter life in damp climates)	5

Source: WR Grace and Company

Heating Ventilation and Air Conditioning

Heating Ventilation and Air Conditioning	Life in Years
Central air conditioning unit (newer units should last longer)	15
Window unit	10
Air conditioner compressor	15
Humidifier	8
Electric water heater	14
Gas water heater (depends on type of water heater lining and quality of water)	11–13
Forced air furnaces, heat pump	15
Rooftop air conditioners	15
Boilers, hot water or steam (depends on quality of water)	30
Furnaces, gas- or oil-fired	18
Unit heaters, gas or electric	13
Radiant heaters, electric	10
Radiant heaters, hot water or steam	25
Baseboard systems	20
Diffusers, grilles, and registers	27
Induction and fan coil units	20
Dampers	20
Centrifugal fans	25
Axial fans	20
Ventilating roof-mounted fans	20
DX, water, and steam coils	20
Electric coils	15
Heat Exchangers, shell-and-tube	24
Molded insulation	20
Pumps, sump and well	10
Burners	21

Sources: Air Conditioning and Refrigeration Institute, Air Conditioning, Heating, and Refrigeration News, Air Movement and Control Association, American Gas Association, American Society of Gas Engineers, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Safe Aire Incorporated

Home Security Applicances

Home Security Applicances	Life in Years
Intrusion systems	14
Smoke detectors	12
Smoke/fire/intrusion systems	10

Insulation

For foundations, roofs, ceilings, walls, and floors	Lifetime

Sources: Insulation Contractors Association of America, North American Insulation Manufacturers Association

Landscaping

Wooden decks	15
Brick and concrete patios	24
Tennis courts	10
Concrete walks	24
Gravel walks	4
Asphalt driveways	10
Swimming pools	18
Sprinkler systems	12
Fences	12

Sources: Associated Landscape Contractors of America, Irrigation Association

Masonry

Chimney, fireplace, and brick veneer	Lifetime
Brick and stone walls	100+
Stucco	Lifetime

Sources: Brick Institute of America, Architectural Components, National Association of Brick Distributors, National Stone Association

Millwork

Stairs, trim	50–100
Disappearing stairs	30–40

Paints and Stains

Paints and Stains	Life in Years
Exterior paint on wood, brick, and aluminum	7–10
Interior wall paint (depends on the acrylic content)	5–10
Interior trim and door paint	5–10
Wallpaper	7

Sources: Finnaren and Haley, Glidden Company, The Wall Paper

Plumbing

Waste piping, cast iron	75–100
Sinks, enamel steel	5–10
Sinks, enamel cast iron	25–30
Sinks, china	25–30
Faucets, low quality	13–15
Faucets, high quality	15–20

Sources: American Concrete Pipe Association, Cast Iron Soil and Pipe Institute, Neil Kelly Designers, Thompson House of Kitchens and Baths

Roofing

Asphalt and wood shingles and shakes	15–30
Tile (depends on quality of tile and climate)	50
Slate (depends on grade)	50–100
Sheet metal (depends on gauge of metal and quality of fastening and application)	20–50+
Built-up roofing, asphalt	12–25
Built-up roofing, coal and tar	12–30
Asphalt composition shingle	15–30
Asphalt overlag	25–35

Source: National Roofing Contractors Association

Rough Structure	*Life in Years*
Basement floor systems	Lifetime
Framing, exterior and interior walls	Lifetime

Source: NAHB Research Foundation

Shutters	
Wood, interior	Lifetime
Wood, exterior (depends on weather conditions)	4–5
Vinyl plastic, exterior	7–8
Aluminum, interior	35–50
Aluminum, exterior	3–5

Sources: A.C. Shutters, Inc., Alcoa Building Products, American Heritage Shutters

Siding	
Gutters and downspouts	30
Siding, wood (depends on maintenance)	10–100
Siding, steel	50–Lifetime
Siding, aluminum	20–50
Siding, vinyl	50

Sources: Alcoa Building Products, Alside, Inc., Vinyl Siding Institute

Walls and Wall Treatments	
Drywall and plaster	30–70
Ceramic tile, high grade installation	Lifetime

Sources: Association of Wall and Ceiling Industries International, Ceramic Tile Institute of America

Windows	
Window glazing	20
Wood casement	20–50
Aluminum and vinyl casement	20–30
Screen	25–50

Sources: Best Built Products, Optimum Window Manufacturing, Safety Glazing Certification Council, Screen Manufacturers Association

Appendix D—References

The American Society of Home Inspectors (ASHI) 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 (phone 202 842 3096), http://www.ashi.org.

Useful home inspection publications include:

Becker, Norman. 1993. *The Complete Book of Home Inspection.* New York: McGraw-Hill, Tab Books.

Boroson, Warren, and Ken Austin. 1993. *The Home Buyer's Inspection Guide*. New York: John Wiley & Sons.

Burgess, Russell W. 1999. *Real Estate Home Inspection.* 3d ed. Chicago, Illinois: Dearborn Financial Publishing Group, Real Estate Education Company.

Carson, Alan, and Robert Dunlop. 1999. *Inspecting a House: A Guide for Buyers, Owners, and Renovators*, 2d ed. New York: Stoddart Publishing Company.

Carson Dunlop & Associates Limited. 1998. *The Illustrated Home*. Toronto, Ontario: Carson Dunlop & Associates Limited. Available from Carson, Dunlop & Associates, 120 Carlton Street, Suite 407, Toronto, Ontario M5A4K2, Canada (phone 800 268 7070), http://www.carsondunlop.com

________.1998. *Home Reference Book.* Toronto, Ontario: Carson Dunlop & Associates Limited. Available from Carson, Dunlop & Associates, 120 Carlton Street, Suite 407, Toronto, Ontario M5A4K2, Canada (phone 800 268 7070), http://www.carsondunlop.com

Irwin, Robert. 1995. *The Home Inspection Troubleshooter*. Chicago, IL: Dearborn Financial Publishing Group, Real Estate Education Company.

Scutella, Richard M., and Dave Heberle. 1994. *Home Buyer's Checklist, A Foolproof Guide to Finding the Perfect House*, 2d ed. New York: McGraw-Hill, Tab Books.

Traister, John E. 1997. *Home Inspection Handbook*. Gordon and Breach Publishing Group, Craftsman House Books.

Ventolo, William L. 1995. *Your Inspection Guide*. Chicago, IL: Dearborn Financial Publishing Group, Real Estate Education Company.

The CABO *One and Two Family Dwelling Code* and its successor, the *International Residential Code for One- and Two-Family Dwellings*, are the most widely used and accepted residential building codes in the United States and can be used for comparing conditions in existing structures against current code requirements. They also provide span and working stress tables for wood joists and rafters, which are useful for checking the adequacy of wood structural components.

International Code Council, Inc. 2000. *International Residential Code for One- and Two-Family Dwellings.* Falls Church, VA: International Code Council, Inc. Available from any of the three model code organizations: Building Officials and Code Administrators International, Inc., 4051 West Flossmoor Road, Country Club Hills, IL 60478-5795 (phone 703 799 2300), http://www.bocai.org; Southern Building Code Congress International, Inc., 900 Montclair Road, Birmingham, AL 35213-1206 (phone 205 591 1853), http://www.sbcci.org; and International Conference of Building Officials, 5360 Workman Mill Road, Whittier, CA 90601-2298 (phone 800 423 6587), http://www.icbo.org.

The *National Electrical Code* should be used as a reference for all electrical work.

National Fire Protection Association (NFPA). 2000. *National Electrical Code*. Quincy, MA: National Fire Protection Association. Available from NFPA, Batterymarch Park, Quincy, MA 02269 (phone 617 770 3000), http://www.nfpa.org.

The following publications are useful general references for rehabilitating houses:

Ching, Francis D. K., and Miller, Dale E. 1983. *Home Renovation*. New York: John Wiley & Sons.

Litchfield, Michael W. 1997. *Renovation: A Complete Guide*. New York: Sterling Publishing.

Nash, George. 1996. *Renovating Old Houses*. Newtown, CT: Taunton Press.

Vila, Bob, and Hugh Howard. 1999. *Bob Vila's Complete Guide to Remodeling Your Home: Everything You Need to Know about Home Renovation from the Number One Home Improvement Expert*. New York: Harper Collins, Avon Books.

Residential buildings of historic significance should be rehabilitated in accordance with the following:

Heritage Preservation Services, National Park Service (NPS). 2000. *The Secretary of the Interior's Standards for Rehabilitation and Illustrated Guidelines for Rehabilitating Historic Buildings*. Washington, DC: National Park Service. Available from NPS, Washington, DC 20240, http://www.nps.gov or full text online at http://www2. cr.nps.gov/tps/tax/rhb/stand.htm.

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

U.S. Department of Housing and Urban Development (HUD). 1982. *Applying Cost-Effective Energy Standards in Rehabilitation Projects*. Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20849 (phone 800 245 2691), http://www.huduser.org.

________. 1981. *Conserving Energy in Older Homes: A Do-It-Yourself Manual*. Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20849 (phone 800 245 2691), http://www.huduser.org.

________. 1982. *Energy Conserving Features in Older Homes*. Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20849 (phone 800 245 2691), http:// www.huduser.org.

________. 1977. *In the Bank or Up the Chimney: A Dollars and Cents Guide to Energy-Savings Home Improvement*. Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20849 (phone 800 245 2691), http://www.huduser.org.

________. 1996. *Rehabilitation Energy Guidelines for One-to-Four Family Dwellings*. Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20849 (phone 800 245 2691), http:// www.huduser.org.

Wilson, Alex and John Morrill. 2000. *Consumer Guide to Home Energy Savings*. 6th ed. Washington, DC: American Council for an Energy Efficient Economy.

The following publications are referenced in this Guideline:

Air Conditioning Contractors of America (ACCA). *Residential Load Calculation* (Manual J). Washington, DC: Air Conditioning Contractors of America. Available from ACCA, 1712 New Hampshire Avenue, NW, Washington, DC 20009 (phone 202 483 9370), http:// www.acca.org.

Ambrose, James E. 2000. *Simplified Engineering for Architects and Builders*. New York: John Wiley & Sons.

Federal Emergency Management Agency (FEMA). 1999. *Taking Shelter from the Storm: Building a Safe Room Inside Your House* (FEMA 320). 2d ed. Washington, DC: Federal Emergency Management Agency. Available from FEMA Publications, P.O. Box 2012, Jessup, MD 20794-2012 (phone 800 565 3896), http:// www.fema.gov.

________. 1996. *Design Manual for Retrofitting Flood-Prone Residential Structures* (FEMA-114). Washington, DC: Federal Emergency Management Agency. Available from FEMA Publications, P.O. Box 2012, Jessup, MD 20794-2012 (phone 800 565 3896), http:// www.fema.gov.

Gypsum Association. 1999. *Design Data—Gypsum Products* (GA-530). Washington, DC: Gypsum Association. Available from Gypsum Association, 810 First Street, NW, Washington, DC 20002 (phone 202 289 5440), http://www.gypsum.org.

Institute for Business and Home Safety (IBHS). 1998. *Is Your Home Protected from Hurricane Disaster? A Homeowner's Guide to Hurricane Retrofit.* Boston: Institute for Business and Home Safety. Available from IBHS, 175 Federal Street, Suite 500, Boston, MA 02110-2222 (phone 617 292 2003), http://www.ibhs.org.

________. 1999. *Is Your Home Protected from Earthquake Disaster? A Homeowner's Guide to Earthquake Retrofit*. Boston: Institute for Business and Home Safety. Available from IBHS, 175 Federal Street, Suite 500, Boston, MA 02110-2222 (phone 617 292 2003), http:// www.ibhs.org.

________. 1999. *Is Your Home Protected from Hail Damage? A Homeowner's Guide to Roofing and Hail*. Boston: Institute for Business and Home Safety. Available from IBHS, 175 Federal Street, Suite 500, Boston, MA 02110-2222 (phone 617 292 2003),http://www.ibhs.org.

International Conference of Building Officials (ICBO). 1997. *Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings*. Appendix Chap. 1 in Uniform Code for Building Conservation. Whittier, CA: International Conference of Building Officials. Available from ICBO, 5360 Workman Mill Road, Whittier, CA 90601-2298 (phone 800 423 6587), http:// www.icbo.org.

International Ground Source Heat Pump Association (IGSHPA). 1997. *Geothermal Heat Pumps: Introductory Guide*. Stillwater, OK: International Ground Source Heat Pump Association. Available from IGSHPA, 490 Cordell South, Oklahoma State University, Stillwater, OK 74078-8018 (phone 800 626 4747), http:// www.igshpa.okstate.edu

Lightning Protection Institute (LPI). *Installation Code* (LPI-175). Arlington Heights, IL: Lightning Protection Institute. Available from LPI, 3335 North Arlington Heights Road, Suite E, Arlington Heights, IL 60004 (phone 847 577 7200), http://www.lightning.org.

National Association of Home Builders Remodelers Council and Single Family Small Volume Builders Committee (NAHB). 1996. *Residential Construction Performance Guidelines for Professional Builders and Remodelers.* Washington, DC: National Association of Home Builders. Available from NAHB, 1201 15th Street, NW, Washington, DC 20005 (phone 202 822 0200), http://www.nahb.org.

National Concrete Masonry Association (NCMA). 1997. *Sound Transmission Class Ratings for Concrete Masonry Walls* (Tek Note 13-1). Herndon, VA: National Concrete Masonry Association. Available from NCMA, 2302 Horse Pen Road, Herndon, VA 20171 (phone 703 713 1900), http:// www.ncma.org.

National Fire Protection Association (NFPA). 1997. *Standard for the Installation of Lightning Protection Systems* (NFPA 780). Quincy, MA: National Fire Protection Association. Available from NFPA, Batterymarch Park, Quincy, MA 02269 (phone 617 770 3000), http:// www.nfpa.org.

National Institute of Building Sciences (NIBS). 1996. *Guidance Manual: Asbestos Operations and Maintenance Work Practices*. Washington, DC: National Institute of Building Sciences. Available from NIBS, 1090 Vermont Avenue, NW, Washington, DC 20005-4905 (phone 202 289 7800), http:// www.nibs.org.

________. 1995. *Lead-Based Paint Operation and Maintenance Work Practices Manual for Homes and Buildings*. Washington, DC: National Institute of Building Sciences. Available from NIBS, 1090 Vermont Avenue, NW, Washington, DC 20005-4905 (phone 202 289 7800), http://www.nibs.org.

Partnership for Advancing Technology in Housing (PATH). 1998–. *The Rehab Guide*. Vol. 1, *Foundations* (HUD 8590), vol. 2, *Exterior Walls* (HUD 8751), vol. 3, *Roofs* (HUD 8702), vol. 4, *Windows and Doors* (HUD 8724), vol. 5, *Partitions, Ceilings, Floors and Stairs* (HUD 8798), vol. 6, *Kitchens and Baths* (HUD 8796), vol. 7, *Electrical/Electronics*, vol. 8, *HVAC/Plumbing*

(HUD 8797), vol. 9, *Site Work*. Washington, DC: U.S. Department of Housing and Urban Development (HUD). Available from HUD User, P.O. Box 6091, Rockville, MD 20848 (phone 800 245 2691), http:// www.huduser.org or full text online at Path Net, http://www.pathnet.org.

Underwriters Laboratories (UL). 1994. *Installation Requirements for Lightning Protection Systems* (UL 96A). Northbrook, IL: Underwriters Laboratories. Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096 (phone 847 272 8800), www.ulstandardsinfonet. ul.com.

________. 1994. UL *Standard for Safety for Lightning Protection Components* (UL 96). Northbrook, IL: Underwriters Laboratories. Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096 (phone 847 272 8800), http://www.ulstandardsinfonet.ul.com.

U. S. Department of Housing and Urban Development (HUD). 1996. *Residential Remodeling and Universal Design: Making Homes More Comfortable and Accessible* (HUD 07107). Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20848 (phone 800 245 2691), http:// www.huduser.org.

________. 1995. Lead–Based Paint Inspections. Chap. 7 in *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing*. Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20848 (phone 800 245 2691), http:// www.huduser.org.

________. 1997. *Nationally Applicable Recommended Rehabilitation Provisions.* Washington, DC: U.S. Department of Housing and Urban Development. Available from HUD User, P.O. Box 6091, Rockville, MD 20848 (phone 800 245 2691), http://www.huduser.org.

The following test standards are referenced in this Guideline:

American Concrete Institute (ACI). 1992. *Guide for Making a Condition Survey of Concrete in Service* (ACI 201.1R-92). Farmington, MI: American Concrete Institute. Available from ACI, P.O. Box 9094, Farmington, MI 48333, http://www.aciint.org.

________. 1994. *Guide for Evaluation of Concrete Structures Prior to Rehabilitation* (ACI 364.1R-94). Farmington, MI: American Concrete Institute. Available from ACI, P.O. Box 9094, Farmington, MI 48333, http://www.aciint.org.

________. 1997. *Standard Specification for Repairing Concrete with Epoxy Mortars* (ACI 503.4-92). In Four Epoxy Standards (ACI 503.1-92). Farmington, Michigan: American Concrete Institute. Available from ACI, P.O. Box 9094, Farmington, MI 48333, http://www.aciint.org.

American Society for Testing and Materials (ASTM). 1997. *Standard Test Method for Penetration Resistance of Hardened Concrete* (ASTM C803/X803M-97e1). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1997. *Standard Test Method for Rebound Number of Hardened Concrete* (ASTM C805-97). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1999. *Standard Test Method for Effect of Air Supply on Smoke Density in Flue Gasses from Burning Distillate Fuels* (ASTM D2157-94 (1999)). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1999. *Standard Test Method for Tension Testing of Metallic Material* (ASTM E8-99). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1989. *Standard Test Method of Compression Testing of Metallic Materials at Room Temperature* (ASTM E9-89ae1). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1999. *Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements.* (ASTM E90-99). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1996. *Standard Method of Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine* (ASTM E492-90(1996)e1). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1999. *Standard Test Methods for Flexural Bond Strength of Masonry* (ASTM E518-99). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1993. *Standard Test Method for Diagonal Tension (Shear) in Masonry Assemblages* (ASTM E519- 81(1993)e1). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1995. *Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution* (ASTM E741-95). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1999. *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* (ASTM E779-99). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1993. *Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors* (ASTM E783-93). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

________. 1996. *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Difference* (ASTM E1105-96). West Conshohocken, PA: American Society for Testing and Materials. Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428 (phone 610 832 9500), http://www.astm.org.

American Society of Civil Engineers (ASCE). 1990. *Guideline for Structural Condition Assessment of Existing Buildings* (ASCE 11-90). Reston, VA: American Society of Civil Engineers. Available from ASCE, 1801 Alexander Bell Drive, Reston, VA 20191-4400 (phone 703 295 6300), http://www.asce.org.

Associated Air Balance Council (AABC). 1999. *AABC Test and Balance Procedures* (MN-4). Washington, DC: Associated Air Balance Council. Available from AABC, 1518 K Street, NW, Washington, DC 20005 (phone 202 737 0202), http://www.aabchq.com.

National Environmental Balancing Bureau (NEBB). 1998. *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems*, 6th ed. Gaithersburg, MD: National Environmental Balancing Bureau. Available from NEBB, 8575 Grovemont Circle, Gaithersburg, MD 20877-4121 (phone 301 977 3698) http://www/nebb.org.

Appendix E— Inspection Record

Building Name/Location

____

____

____

Lot size ____________________

Year building built ____________________

Total building area ____________________

Applicable building codes ____________________

Setback requirements: ____________________

Front yard ____________________

Side yard ____________________

Rear yard ____________________

Other ____________________

Zoning classification ____________________

Date of alterations ____________________

Height limitation ____________________

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 or marker

Inspection checklist

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		
1.5 Flood Region		
❑ Flood risk zone (see local authorities)		

2—Building Exterior

	Data	Condition/needed repairs
2.1 Foundation Walls and Piers		
See Sections 4.1 and 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 and Doors		
Door types	No.	
Window types	No.	
Storm window 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		
2.7 Skylights		
Size(s)		

	Data	Condition/needed repairs
2.8 Gutters, Downspouts and 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		
Height above roof		
Flue size(s)		
2.10 Parapets and Gables		
❑ Requires structural inspection		
2.11 Lightning Protection		
❑ Protection required		

3—Building Interior

	Data	Condition/needed repairs
3.1 Basement/Crawl Space		
Floor height		
Floor material		
Wall material		
Insulating materials		
3.2 Interior Spaces		
Room		
Dimensions	Height	
Ceiling/wall material(s)		
Floor material		
Door size(s)		
Window size(s)		
Closet size(s)		
Trim		
No. 120V outlets	❑ 240V outlet	
Heat source		
Skylights		
Room		
Dimensions	Height	
Ceiling/wall material(s)		
Floor material		
Door size(s)		
Window size(s)		
Closet size(s)		
Trim		
No. 120V outlets	❑ 240V outlet	
Heat source		
Skylights		

	Data	Condition/needed repairs
Room		
Dimensions	Height	
Ceiling/wall material(s)		
Floor material		
Door size(s)		
Window size(s)		
Closet size(s)		
Trim		
No. 120V outlets	❑ 240V outlet	
Heat source		
Skylights		

Room		
Dimensions	Height	
Ceiling/wall material(s)		
Floor material		
Door size(s)		
Window size(s)		
Closet size(s)		
Trim		
No. 120V outlets	❑ 240V outlet	
Heat source		
Skylights		

	Data		Condition/needed repairs
Room			
Dimensions	Height		
Ceiling/wall material(s)			
Floor material			
Door size(s)			
Window size(s)			
Closet size(s)			
Trim			
No. 120V outlets	❑ 240V outlet		
Heat source			
Skylights			

3.3 Bathroom

Dimensions	Height		
Ceiling/wall material(s)			
Floor/wall material(s)			
Window size	Height from floor		
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
Dimensions	Height			
Ceiling/wall material(s)				
Floor/wall material(s)				
Window size	Height from floor			
Closet size(s)				
Heat source				
❑ 120V outlet	❑ GFCI protected			
Lavatory:	❑ Replace	❑ Retain		
Toilet:	❑ Replace	❑ Retain		
Tub/shower:	❑ Replace	❑ Retain		
Ventilation source				

3.4 Kitchen

			Data	Condition/needed repairs
Dimensions	Height			
Ceiling/wall material				
Floor covering				
Window size(s)				
Counter space, l.f.				
Overhead 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		
Other:	❑ Replace	❑ Retain		

	Data			Condition/needed repairs
3.5 Storage Spaces				
Location	Size			
Location	Size			
Location	Size			
3.6 Stairs/Hallway				
Ceiling/wall material				
Floor material				
❑ Three-way light control				
❑ Smoke detector				
Handrail ht.	Railing ht.			
Tread/riser dim.				
Stair width	Head room			
Structural integrity				
3.7 Laundry/Utility Room				
Ceiling/wall material				
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 Fireplace/flues				
Opening Location	Size	Depth		

	Data	Condition/needed repairs
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		
3.11 Sound Transmission Control		
❑ Conduct sound transmission tests		
3.12 Asbestos		
❑ Evidence of asbestos		
3.13 Lead		
❑ Evidence of lead-based paint		
❑ Water test conducted		
3.14 Radon		
❑ Radon test conducted		
3.15 Tornado Room		
❑ Requires structural inspection		

4—Structural System

	Data	Condition/needed repairs
4.1 Seismic Resistance		
❑ Requires structural inspection		
4.2 Wind Resistance		
❑ Requires structural inspection		
4.3 Masonry, General		
Load bearing walls are:		
4.4 Masonry Foundations and Piers		
Foundation wall material		
Wall thickness		
Pier material		
Pier size(s)		
Pier spacing		
Depth of footings		
❑ Structural problems		
4.5 Above-ground Masonry Walls		
Wall material(s)		
Wall thickness		
Support over openings		
❑ Thermal moisture cracking		
❑ Freeze/thaw, corrosion cracking		
❑ Structural failure cracking		
❑ Wall bulging		
❑ Wall leaning		
❑ Brick veneer problems		
❑ Parapet wall problems		
❑ Fire damage problems		

	Data	Condition/needed repairs
4.6 Chimneys		
Chimney materials		
Depth of footings		
❑ Structural problems		
4.7 Wood Structural Components		
Framing type (balloon, platform, timber frame)		
Floor members	size spacing	
Floor substrate material		
Wall members	size spacing	
Wall substrate material		
Ceiling members	size spacing	
Roof members	size spacing	
Roof substrate material		
❑ Deflection/warping problems		
❑ Signs of fungal/insect attack		
❑ Fire damage problems		
4.8 Iron and Steel Structural Components		
Lintels, Columns and Beams		
size	location	
size	location	
size	location	
❑ Lintel problems		
❑ Column/beam problems		
❑ Fire damage problems		

	Data		Condition/needed repairs
4.9 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

5.1 Service Entry	❑ Replace	❑ Retain	
Capacity from street	Amps:	Volts:	
Overhead wire clearance			
❑ Electric meter adequate			
❑ Service entrance conductor adequate			
5.2 Main Panelboard	❑ Replace	❑ Retain	
Main circuit breaker	Amps:	Volts:	
Grounded to			
❑ 15 Amp fuses/circuit breakers		No.	
❑ 20 Amp fuses/circuit breakers		No.	
❑ 25 Amp fuses/circuit breakers		No.	
❑ 30 Amp fuses/circuit breakers		No.	
❑ 40 Amp fuses/circuit breakers		No.	
❑ Overcurrent protection adequate			

	Data	Condition/needed repairs

5.3 Branch Circuits

❑ Replace ❑ Retain

Circuit No.	Wire Gage	Wire Capacity	Area Served	Condition/needed repairs

❑ Circuits grounded to panel box

❑ Wire insulation in good condition

❑ Aluminum wire used

6—Plumbing

Data | **Condition/needed repairs**

6.1 Water Service Entry

❑ Replace ❑ Retain

Curb valve location

Line size | Material

❑ Shutoff valve operable

Water meter location

6.2 Interior Water Distribution Lines

❑ Replace ❑ Retain

Pipe size	Pipe material	Fixtures served

❑ Thermal protection adequate

6.3 DWV Piping

❑ Replace ❑ Retain

Pipe size	Pipe material	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			
6.6 Water Well			
Location			
Depth of casing			
Pump type	Age		
Capacity	GPM	Depth	
❑ Pressure tank adequate			
6.7 Septic system			
Location			
Tank capacity	Gal.		
Age of system			
Size of drain field			
❑ Grease trap clean			
6.8 Gas Supply in Seismic Regions			
❑ Service entrance has adequate clearance/flexible connection			
❑ Has automatic emergency shutoff valve			

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	
	Electric service reqd.	
	❑ Physical condition adequate	
	❑ Operation adequate	
7.11 Humidifier	❑ Replace ❑ Retain	
	Humidifier type	
	❑ Physical condition adequate	
	❑ Operation adequate	

	Data	Condition/needed repairs

7.12 Unit air conditioners ❑ Replace ❑ Retain

Location	Capacity in Tons	Volts	Amps

7.13 Whole House and Attic Fans

❑ Replace ❑ Retain

Location

Capacity in cubic ft/min.

Additional Notes

U.S. Department of Housing and Urban Development
HUD USER
P.O. Box 6091
Rockville, MD 20849

FIRST CLASS MAIL
POSTAGE & FEES PAID
HUD
Permit No. G-795

Official Business
Penalty for Private Use $300

February 2000