
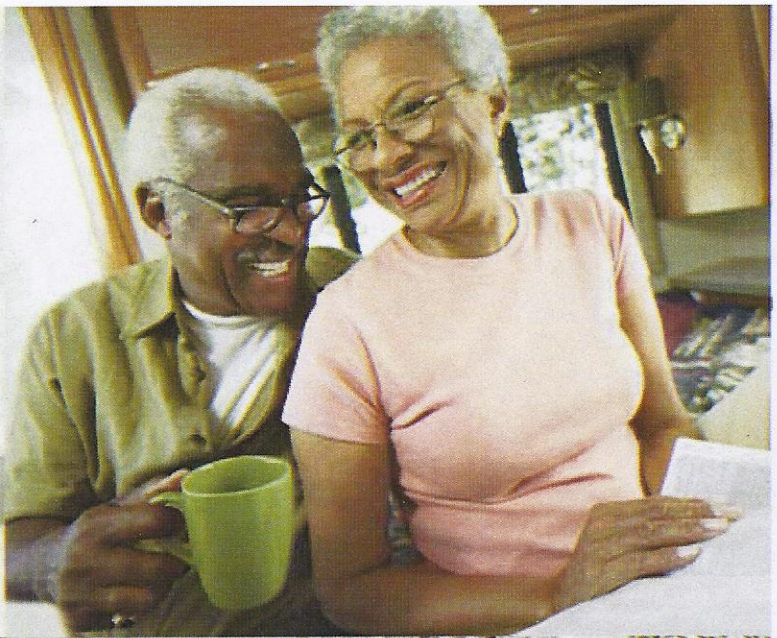
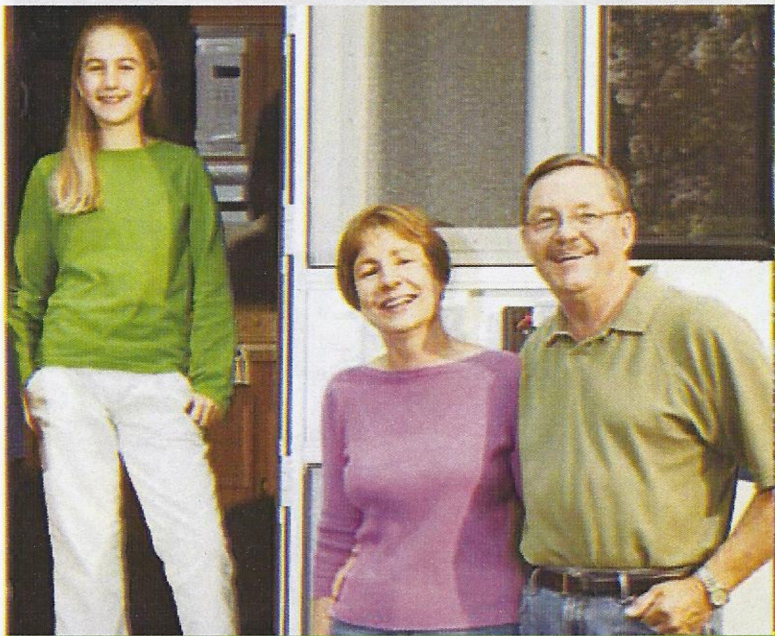
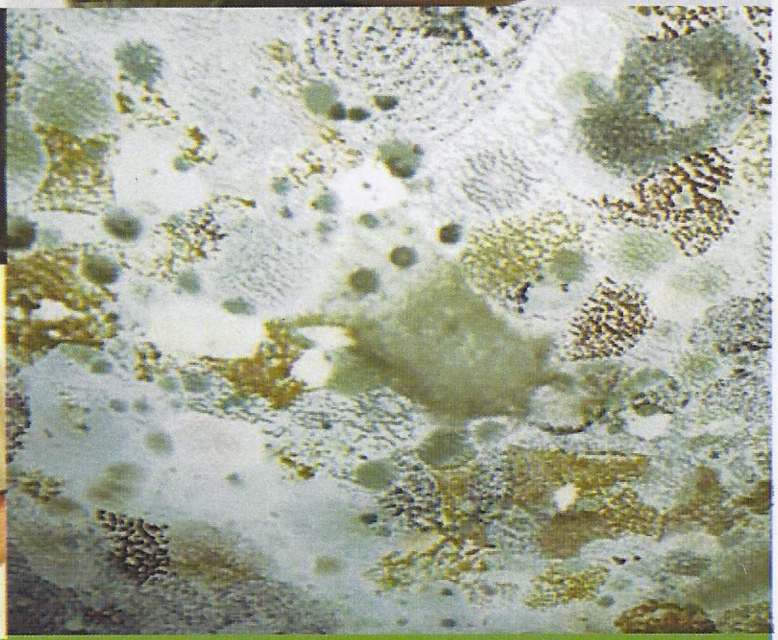

U.S. Department of Health and Human Services
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Safety and Health in Manufactured Structures

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Safety and Health in Manufactured Structures

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Centers for Disease Control and Prevention

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Preface

Millions of people in America live in manufactured structures—a range of units that includes manufactured homes, travel trailers, camping trailers, and park trailers. Manufactured structures are used for long-term residence; for temporary housing following disasters; for recreational and travel purposes; and also for classrooms, day care centers, and workplaces. Housing is a primary purpose of these structures, with manufactured homes accounting for 6.3% of the housing units in the U.S. and housing 17.2 million persons. Manufactured homes offer flexibility and affordability, and comprise an important part of the U.S. housing stock.

Whether used for long-term housing or for short-term shelter following a disaster, for classrooms or for offices, manufactured structures should be safe and healthy for the people who live, work, study, and play in them. With Americans spending the vast majority of their time indoors, it is vital that buildings protect occupants from the elements and provide privacy, comfort, and peace of mind. At the same time, these structures should not present risks to occupant's health and safety due to design, construction, or maintenance problems.

This report identifies and summarizes safety and health issues in manufactured structures based on a wide expanse of research. The end result is a thorough characterization of health and safety hazards in manufactured structures, along with mitigation strategies and discussions of opportunities for health/safety enhancements and at-risk populations.

Many of the hazards discussed in this report are not unique to manufactured structures, while other issues have been identified as particular problems for this form of housing. Further, when manufactured structures are used as interim housing following a disaster, additional health/safety issues can arise. The specific topics covered in this report are an introduction to manufactured structures, fire safety, moisture and mold, indoor air quality (IAQ), pests and pesticides, siting and installation, utilities, postdisaster housing, and potential opportunities for future enhancements.

The health and safety hazards related to fire safety, moisture and mold, IAQ, pests and pesticides, and other issues generally fall into the categories of design, construction, and maintenance. Thus, for an issue like effective moisture management to prevent mold and related problems, strategies range from good product selection in the design phase to proper grading of the site during construction all the way to regular maintenance of the building envelope after many years of service. Most other health and safety hazards are similar in nature, with multiple parties playing an important role in managing risks from the design of the manufactured home through its use as a home for years to come.

Fortunately, the challenges of managing health and safety risks in manufactured structures are well documented, along with appropriate strategies and solutions. This report documents and summarizes this information, with the intent of serving as a comprehensive resource to inform discussions and future decisions regarding the design, construction, maintenance, and deployment of manufactured structures in the United States.

I wish to thank the working group participants from the Centers for Disease Control and Prevention, U.S. Department of Housing and Urban Development, Federal Emergency Management Agency, U.S. Department of Education, New York City Office of Emergency Management, and Harvard School of Public Health; the expert consultants who reviewed the draft document during the Safe and Healthy Manufactured Structures meeting on October 17, 2008; and subject-matter experts who reviewed and commented on several drafts of the document. I believe that these recommendations provide essential guidance on the safe and healthy use of manufactured structures.

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how they consumed their energy. Studies have shown that energy savings of 5%-15% are possible with direct feedback systems that provide the home owner with real-time feedback on energy use in the home (Darby 2006). These feedback systems, sometimes referred to as dashboards, are able to provide information on such items as instantaneous whole-house electricity use, demand, and pricing; individual appliance electricity consumption; and even recommendations on ways to reduce energy consumption.

Water Conservation

Low-flow Toilets and Fixtures

Conserving water also conserves energy that would otherwise be used to treat and pump water to homes. Toilets account for approximately 30% of water used in a home and represent an excellent opportunity for water savings (U.S. Environmental Protection Agency 2008b). Federal regulations currently limit the volume of water used per flush to 1.6 gallons, and products are now available "with a water flushing device capable of adequately flushing and cleaning the bowl" (per HUD Code) that use far less water than this. Toilets with EPA's WaterSense label use 1.28 gallons per flush (gpf) or less, saving at least 25% of the water used per flush. WaterSense labeled dual flush toilets, which have a full volume flush for solids and a reduced volume flush for liquids, use 1.6 gpf or less at full volume and 1.1 gpf or less at reduced volume. Flushless urinals and flushless composting toilets are also available, but are prohibited by HUD Code, which requires water flushing devices be installed.

Low-flow devices can also be specified at sinks and shower heads. Water used in sinks accounts for about 15% of water used in a home, and faucets with the WaterSense label can reduce flow by 30% or more while delivering comparable performance (U.S. Environmental Protection Agency 2008c). Showers account for approximately 17% of indoor water use, and showerhead flow is capped by federal mandate at 2.5 gpm at 80 psi. The EPA is currently developing a specification for a WaterSense showerhead that will consider such input as consumer perception, safety, and performance while achieving lower flow rates. In the meantime, low-flow showerheads are available, as well as showerheads that slow to a trickle when hot water reaches them, assuring that no extra water is wasted as home owners wait for a shower to warm.

Plumbing Improvements: Centralized, Home Runs with Polyethylene (PEX)

Shortened plumbing runs save water and energy by reducing the amount of water wasted while waiting for hot water to arrive at the intended destination. Because of the relatively small footprint of manufactured homes, there are inherent water use efficiencies built into the homes. Today, cross-linked PEX tubing is specified in most manufactured homes, and the small cross-diameter of this tubing reduces the amount of water wasted in waiting for hot water to arrive. Where not common practice, central location of the water heater and specification of a central manifold with individual or "home" runs to each water fixture can further reduce water heating demands and water consumption.

Water Catchment

Recently, manufactured home designs have begun to incorporate water-catchment systems. For instance, a model green manufactured home collects rain water with a metal roof that is sloped from both ends to the center. Currently, water harvested from the catchment system can be used for meeting landscaping needs, but future modifications to the system could also enable the water to be used for flushing toilets.

Optimizing Indoor Air Quality and Mechanical Ventilation

Significant strides have been made to improve indoor air quality in manufactured homes. Changes have been made in the HUD Code to control pollutants at the source as well as to ensure that whole-house ventilation is provided to facilitate a healthy indoor environment. Providing good indoor air quality has been and will continue to be an iterative process as manufacturers and regulators respond to the evolving body of science on this topic as well as the introduction of new materials and consumer products that may compromise air quality.

Controlling Pollutants and Potential Problems at the Source

While HUD Code has a history of being proactive in addressing indoor air quality (e.g., incorporating regulations related to formaldehyde, requiring mechanical ventilation), further opportunities exist to go beyond code in providing a healthier indoor environment. By attention to detail during construction and careful selection of such items as building materials and adhesives, manufacturers can greatly influence indoor air quality of homes. Opportunities for improving indoor air quality that can be achieved during the manufacturing process include the following:

- Providing for passive radon mitigation systems (piping, presence of electrical outlet for a fan installation if necessary) in the built units. Radon mitigation, which is not covered in the HUD Code, is especially important for units on basements and/or units that will be situated in high radon areas. Appendix F of the International Residential Code has guidance on radon control methods.

- Ensuring that separation between exhaust terminations and ventilation intakes is at least 10 feet (minimum permitted by ASHRAE 62.2, which is more restrictive than HUD Code's 3-foot allowance)
- Location of tightly sealed ducts within conditioned space.
- Ensuring that composite wood products (including products used in floors, walls, and cabinets) conform to CARB standards, which are more stringent than HUD Code (Composite Panel Association 2008).
- Installing low- or no-VOC carpets.
- Using no-VOC paints for interior finish.
- Use of soy adhesives and resins as an alternative to urea-formaldehyde and phenol-formaldehyde adhesives.
- Avoiding interior vapor retarders in hot-humid climates.
- Following model building code prescriptions for flashing of building openings, intersections, and penetrations (e.g., 2009 IRC Section R703.8).

Optimizing Mechanical Ventilation

All HUD Code homes are required to specify mechanical ventilation systems, including whole-house, kitchen exhaust, and bathroom exhaust systems. While the ventilation specifications of the HUD Code are more progressive than those of most site-built building codes, there is still room for improvement. For example, HUD Code does not address the use of intermittent whole-house ventilation or permissible sound levels for ventilation equipment. Maintaining low sound levels for supply and exhaust fans increases the likelihood that occupants will not override the operation of specified mechanical ventilation systems.

Manufacturers that desire to provide indoor air quality in accordance with the latest consensus-based specifications may look to ASHRAE 62.2 for guidance on these and other indoor air quality concerns not addressed within HUD Code. ASHRAE 62.2 has now been adopted by reference in the state residential building codes of California and Maine and is also a prerequisite of the LEED for Homes green building rating system. Adoption of ASHRAE 62.2 is currently being considered by the Manufactured Housing Consensus Committee, which is responsible for maintaining and updating the HUD Code. It should be mentioned that while ASHRAE 62.2 provides a more thorough ventilation specification reference, its minimum ventilation rates can be lower than HUD Code rates, depending on the number of bedrooms and conditioned floor area. Assuming that outdoor air contains lower pollution concentrations than indoor air, higher ventilation rates should result in better air quality. A notable exception to this premise is when introduction of outdoor air increases the humidity level of the indoor air to levels that are conducive for condensation and mold growth.

While providing higher ventilation rates generally results in better indoor air quality, it can also carry a severe energy penalty associated with ventilation fan energy use as well as energy required to condition the outdoor air to indoor set points. Neither ASHRAE 62.2 nor the HUD Code address the energy use of ventilation equipment, which is an important consideration given that ventilation distribution systems alone can consume as much as 3100 kWh annually in manufactured homes (assuming 350-watt central blower operates continuously for ventilation distribution) (Lubliner et al. 2005). Manufacturers have multiple options for specifying energy efficient mechanical ventilation systems. If specifying a whole-house exhaust-based ventilation system, specification of Energy Star exhaust fans can be a very economical choice (e.g., payback of 1.2 years and savings of 580 kWh per year when operated continuously versus a builder-grade exhaust fan, assuming $0.11/kWh). "Smart" versions of this system ventilate only as much as needed to meet a certain target air exchange rate, and "take credit" for time periods when exhaust fans are run for bath exhaust too.

Specification of heat and energy recovery ventilators (HRVs and ERVs), which precondition outdoor air with exhausted indoor air before introducing it into the space, can provide another energy efficient option for mechanical ventilation. A recent DOE study used building energy simulations to show that total heating and cooling energy savings of HRVs over other mechanical ventilation systems in a cold climate manufactured home can range between 500 and 2000 kWh (Lubliner et al. 2005). The energy efficiency of central fan integrated systems, which introduce fresh outdoor air into the return plenum of the central duct system, can be improved by ensuring that the central fan is powered by an electronically commutating motor (ECM). An ECM operates at a higher efficiency than a traditional permanent split capacitor motor, offering up to 70% savings when operated continuously (Canada Mortgage and Housing Corporation 2005).

As mentioned above, mechanical ventilation for homes that undergo air sealing and lack sufficient natural ventilation is critical. Providing for outdoor air exchange with indoors can help control indoor humidity and exhaust airborne chemicals and pollutants. Fresh ventilation air is also filtered in many systems to remove dust and other particulates. These essential health/safety benefits of mechanical ventilation will only be realized, however, if the systems are allowed to run by the residents. Therefore, systems that are reasonably quiet and energy efficient to operate, as well as automated, are important for occupant health and safety.

DESIGNING FOR DURABILITY AND DISASTER

Manufactured homes, park trailers, and travel trailers are often used to provide emergency and short-term housing in the wake of natural disasters that have destroyed or damaged housing units. Because manufactured homes and trailers are sited in areas where natural disasters occur, it is prudent to ensure that their construction is sufficient to withstand the recurrence of the natural disasters, within reason. HUD Code and state regulations have responded to natural disasters by increasing their stringency, with favorable results (Grosskopf and Cutlip 2006). Nevertheless, opportunities still exist for improving the durability and disaster resistance of manufactured homes, and thereby improving occupant health and safety.

Floods

Protecting Manufactured Homes from Floods and Other Hazards (Federal Emergency Management Agency 2009), provides guidance for installation of manufactured homes in flood hazard areas. This resource may be supplemented by state-specific requirements, and provides foundation specifications that will help in avoiding a complete structural loss from flooding. In addition to thoughtful siting and providing an adequate foundation to resist flood forces, manufactured homes can be built with flood-resistant materials that will permit them to weather flood events more successfully. When building for flood resistance, assemblies and materials should be selected that can withstand water immersion, do not provide a food source for mold, and dry easily. For example, a wall assembly consisting of the following materials (in order from exterior to interior) would serve this purpose (Louisiana State University Agricultural Center 2008a):

- Cladding: vinyl or fiber cement siding, furred out from sub layers.
- Insulation: rigid foam insulation.
- Building wrap.
- Sheathing: non-paper-faced gypsum.
- Framing: steel studs with empty cavity that can be opened at top and bottom to allow drying.
- Interior finish: non-paper-faced gypsum and latex paint.

Similarly, the insulation, structure, and finishes of the floor system may be selected to permit faster drying and decrease the chance of permanent damage from flooding events. Placing ducts in conditioned space instead of the underbelly of the manufactured home should also permit a faster and less costly recovery from flood damage. Locating ducts in the conditioned envelope also helps keep them free of pests, which aids in maintaining a healthy indoor environment.

Termites

Inspections of manufactured homes after the Florida hurricanes of 2004 revealed that many of the damaged homes had sustained termite damage and wood rot that compromised their structural integrity (Jordan 2004). When locating a manufactured home in a location with high termite pressure (generally coincident with hot-humid climates), specification of termite-resistant materials for structural framing and sheathing is a good choice. In fact, Hawaii now requires that termite-resistant materials (e.g., light-gauge steel framing, pressure-treated lumber, or masonry) are used for all structural members in site-built homes.

Insulation materials treated with borates (which are nontoxic to humans) are now available that provide further termite resistance in the walls. If a borate-treated rigid foam insulation is specified for the flood resistant wall described previously, this wall would also function as a termite-resistant assembly.

Termites thrive in warm, moist conditions where a cellulosic food source is available. Removal of cellulosic debris from around the foundation will minimize food sources. Ensuring that foundations stay dry by addressing any plumbing leaks and installing gutters and drain spout extensions of at least three feet in length can help to remove sources of moisture. Regular inspection is also an important component of combating termites.

In terms of health/safety benefits of these termite prevention measures, keeping the home's structure intact is the main benefit. Preventing termites from compromising the home's structural integrity is crucial for the home to withstand strong external forces (e.g., hurricanes) and keep the residents safe.