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HEALTHY HOUSE CONSTRUCTION

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INTRODUCTION

The model demonstration house described in this paper was designed to optimize occupant health by minimizing indoor air pollution. This was accomplished by the use of three primary principles: ELIMINATION, SEPARATION, AND VENTILATION.[1] Pollutant source strength reduction has come to be regarded as the most effective method of reducing indoor pollution.[2] This is often easily achieved by ELIMINATING potentially polluting materials wherever possible, and using more benign low outgassing materials instead. Since it would be very difficult (and expensive) to ELIMINATE all potentially polluting materials, the second principle of SEPARATION was used to isolate some materials (like insulation) from the actual living environment. The use of these two principles alone can lead to a fairly inert structure, however the third principle of VENTILATION remains important to supply the occupants with sufficient fresh air for respiration and to remove or dilute pollutants generated by the occupants. As a secondary means of maintaining good indoor air quality, air filtration was also utilized. While VENTILATION and filtration can be used to remove or dilute pollutants emitted from the building structure, the first two principles are generally more effective and less costly approaches. The design and construction of this project is completely documented in a forthcoming book[3] and a recently released video[4].

BASIC DESIGN

The three bedroom, two bath ranch house contains 1568 square feet. The 24' X 24' two car garage is detached to prevent exhaust fumes from entering the living space. The garage has an electric overhead door opener. This allows a driver to open the overhead door from inside the automobile rather than having to get out and be exposed to automobile exhaust gases. The styling of the house is contemporary. It has three walk-in closets, an entry closet, a large closet in the hall, and a laundry closet. Built-ins include a display case, bookcase, and pantry. Built-in cabinetry allows potentially offensive objects to be stored where they will not affect the occupants (e.g., Books are often contaminated with mold and a glass doored bookcase will effectively isolate them from a mold sensitive person.)

The house is located in a relatively unpolluted area of southern Indiana. It is constructed in an airtight manner with a fresh air ventilation system that can be totally controlled by the occupants. Incorporating an energy efficient heat recovery ventilator, the fresh air system can be temporarily turned off in the event of an occasional severe outdoor pollution problem. The air filtration package was incorporated as a means of "polishing" the air in the house, rather than as a primary means of cleaning up very polluted air.

This house includes several features not normally found in houses being built today: superinsulation, steel framing, healthy materials, fresh air supply, water and air filtration systems,

etc. The house also incorporates passive solar design features such as large south facing windows. This helps minimize the use of the electric heating system.

Besides insuring good indoor air quality, one of the priorities that was established early in the design process was to utilize readily available and cost effective construction materials wherever possible, rather than expensive and exotic hard-to-find products. Therefore, nearly all of the components are available locally in most parts of North America or by mail-order. Another priority was to create a house that would be attractive and have a conventional appearance.

FOUNDATION

The health aspects associated with foundation construction primarily concern radon entry and mold. Radon is a known carcinogen, and damp foundations, or cold concrete slabs, can result in mold growth, a common allergen. While termite infestation will not be a concern in this house with its steel frame, toxic termiticides applied around the foundation of a wood framed structure have resulted in significant health problems that have caused many people to abandon their homes.[5]

Non-toxic ceramic tile floors are used throughout the house, so the most practical and cost effective foundation was a concrete slab on grade. It is well insulated (R-20 perimeter and under-slab) so it is warm to walk on and won't be prone to mold growth. While many people may find it unusual to have ceramic tile floors in all of the rooms (even closets), tile can yield a very attractive, and long lasting floor. While it has a higher initial cost than many of the alternatives, its durability makes it cost effective over life of the house. Easy to clean natural fiber area rugs can be used for accents.

Since it is difficult to predict if radon levels will be elevated once a house has been completed,[6] a sub-slab radon removal tube was incorporated as a part of the foundation system as a precautionary measure. When the house was finished, the indoor radon level was measured to be >.5 pCi/l. (similar to the ambient outdoor level) so it was not necessary to attach a fan to the radon removal tube and activate the system. The low radon level is attributed to the fact that the monolithic floor slab has all penetrations well sealed. The radon in the soil is in effect SEPARATED from the living space.

FRAMING

One of the more unusual aspects of this house is its steel frame. Steel stud walls were used to make the house termite resistant. It will, therefore, never need to be treated with potentially toxic termiticides. In most parts of the United States, the termites are of the subterranean type, a species that usually cannot travel very far from the soil.[7] Because of this, the termites cannot get up to the conventional wood framing that was used for the roof system. Wood was used in the roof to simplify the construction, but in climates where other species of termites are a pest, steel rafters or trusses could be substituted. At the time the frame was erected (mid-1991) steel studs were slightly more costly than wood studs but the overall cost increase was offset by the savings of not needing to treat for termites. Due to price increases in wood framing lumber (fall 1992), steel studs are now lower in cost.[8]

A superinsulated exterior double wall system yields an R-value of 33. The cathedral roof system is also superinsulated (R-38) and vented per current design standards. The roof was framed with rafters rather than trusses so that the house could have cathedral ceilings in all of the rooms. The central hall and two of the closets are the only rooms that have lowered flat ceilings. The sloped ceilings make the rooms feel more spacious.

The steel studs used for partition walls are not load bearing. In other words, they only support the weight of the drywall, not the roof. Therefore, they are made of lighter gauge material. These studs are not only less costly but they can be assembled quickly with a crimping tool.

ENCLOSING THE STRUCTURE

Long lasting metal roofing and siding with baked enamel finishes were used because of their low maintenance qualities and the fact that baked-on finishes generally have minimal outgassing characteristics.[9] The long sheets of metal roofing are deigned to be both attractive and easy to attach, and the installed cost is similar to fiberglass shingles over a plywood deck. The exterior walls are covered with horizontal aluminum siding. Entry doors are insulated steel units and all windows are triple glazed. The window frames incorporate a thermal break so that "sweating" will not be a problem. Located just off the kitchen is a 12' X 16' redwood deck. Redwood was used to avoid the use of chemically treated lumber which often contains arsenic compounds.

AIRTIGHT DRYWALL APPROACH (ADA)

ADA is a relatively simple technique that can be used to make a house virtually airtight.[10] Airtight houses have many advantages: better energy efficiency, less hidden moisture problems, and most importantly, occupant control of indoor air. Unfortunately, many of the early airtight houses had air quality problems because they had no fresh air supply system. A mechanical ventilation system is a strict requirement in an airtight house. An airtight house with a controlled ventilation system will often have more fresh air flowing through it than a conventional house. The fresh air system used in this house also has the advantage of high tech filtration.

ADA uses the drywall and drywall tape to form an air barrier between the living space and the insulation, the sheathing, and the outdoors. Foil backed drywall was used as both a moisture barrier and a pollutant barrier, so no poly moisture barrier was needed. Special construction details were used around windows, doors, electrical boxes and plumbing penetrations to make them airtight.

HEATING, VENTILATION, AND AIR CONDITIONING

In superinsulated houses, the heating and air conditioning requirements are very low.[11] This house is heated with low temperature, low polluting hydronic baseboard units. These heaters are self-contained and operate electrically. Conventional high temperature resistance heaters have been found to pyrolyze house dust that falls on them and release submicron aerosols into the air.[12] While baseboard heaters may not be as energy efficient as a heat pump, they are much lower in initial cost, and are maintenance free. Air conditioning is handled by a very quiet, energy efficient, ductless, split system.

One of the most important features of the house is the ventilation system. A whole house, energy efficient, heat recovery ventilator (HRV) is used to exhaust stale air to the outdoors and simultaneously bring in fresh air. The ductwork is designed to pull stale air from all the closets, and deposit the fresh air in the living room. The interior doors are undercut to allow the air to circulate from the living room into other rooms, into closets, thus resulting in a circulation pattern throughout the house that is reversed from conventional HVAC design. This allows the living areas to be flushed of pollutants prior to the storage areas. All of the ductwork is metal and it is within the conditioned space, so it doesn't need to be insulated. The HRV and the filtration unit are also within the conditioned space (above the hall ceiling) for easy access.

The filtration system contains a prefilter to remove relatively large particles and an activated carbon filter to remove any gaseous contaminants in the air. It also employs a very high efficiency HEPA filter that is capable of removing 99.97% of any particles such as house dust,

mold spores, or pollen. The filter unit can be operated to recirculate and clean the indoor air even when the fresh air system is temporarily turned off.

The house also has three exhaust fans: one in each bathroom, and a kitchen range hood. These are capable of moving larger volumes of air than the central ventilation system in order to clear out specific rooms as needed. During operation they result in the house being under a slight negative pressure which causes the air flows in the HRV to become unbalanced. The homeowners are instructed that the exhaust fans will operate more efficiently if a window is cracked open to relieve the depressurization. In a house with a conventionally aspirated combustion appliance, like a natural gas water heater or furnace, depressurization could result in backdrafting or spillage,[13] but this house is all-electric. There is also an exhaust fan in the garage. The water heater is an energy efficient electric model. A roof top solar collector is used to reduce the demand for electricity.

INTERIOR WORK

The materials directly exposed to the living space must be carefully selected to minimize indoor pollution. All interior trim and doors are solid hardwood (tulip poplar) finished with a clear environmental sealant. Hardwood was selected over more common softwood because some hypersensitive individuals have been found to react to the natural aroma of softwood lumber.[14] One bedroom contains solid wood wainscoting, making it suitable for use as a den or home office.

The kitchen and bathroom cabinetry is a designer style steel product with a baked enamel finish. The manufacturer has recently begun offering a special version for sensitive individuals that uses metal rather than wood and mastic stiffening within the doors. Door hinges and drawer rollers will be degreased upon request. Several colors are available and the exteriors are textured like many refrigerators. Kitchen countertops are made of non-toxic and hygienic stainless steel. A radiant glass top electric range reduces pollutants generated by open gas burners or conventional electric burners. The dishwasher is extremely energy efficient, and there is a central vacuum system.

Plumbing fixtures are made of low outgassing materials such as porcelain on steel, vitreous china, and stainless steel. Faucets contain a minimum of plastic parts, and a whole house water filtration system is included. It contains a sediment filter and an activated carbon filter. Toilets are efficient low flow models. Water supply lines are copper, soldered with lead-free solder. Closet shelves and organizers are made of metal wire with a baked epoxy finish. The paints and finishes are specially designed products that are suitable for hypersensitive individuals. The off-white walls and sand colored ceramic tile compliment the natural woodwork. Doors and woodwork were finished in advance in order to minimize outgassing indoors once the house was closed up. The drywall joint compound was also designed for hypersensitive people.

SUMMARY

This house was carefully designed as a system and many of the components interact. The room layout was planned around keeping all of the ductwork within the conditioned space. Cost considerations were balanced with comfort, energy efficiency, and long lasting, low maintenance materials. The design of the roof system was influenced by cost, energy efficiency, appearance, and moisture control. Air quality is maintained by using non-polluting materials, separating materials such as insulation from the living space, ventilation, and filtration.

The heating, air conditioning, and ventilation systems operate independently of each other to give the homeowners maximum control. Occupant control of indoor air quality is an important new

concept. We usually have more control of our stereos and automobiles than of the air in our homes.

The indoor air of the finished house should be suitable for most individuals who are hypersensitive or have severe allergies. Therefore, it will provide an extremely clean environment for the healthy person who wishes to remain that way.

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