Environments for the Chemically Sensitive as Models for Healthy Building Construction: Issues of Ventilation

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INTRODUCTION

Multiple Chemical Sensitivity Syndrome (MCS, also known as Environmental Hypersensitivity, 20th-Century Disease, and Environmental Illness or EI) is a controversial and little understood medical condition. As these various names suggest, MCS involves a heightened sensitivity to toxic chemicals now commonly found in the environment such as pesticides and formaldehyde. Such hypersensitivity also often extends to naturally occurring irritants such as wood resins, molds and pollens. Symptoms such as headaches, nausea, disorientation, and lack of muscle control are similar to those of the more familiar Sick Building Syndrome. Unlike Sick Building Syndrome, however, the symptoms tend to be persistent and not specific to any single immune response.[1]

At the current time there is no clearly established etiology and no known cure for MCS, which leaves isolation from potential irritants as the strongest course of action and the provision of a 'healthy house' or safe haven environment the best therapy. This fact makes the MCS community's work at securing shelter an intriguing study in the architectural issues of health and the indoor environment. Without resolving the status of MCS in the medical arena it is quite plausible to grant these individuals a heightened ability to perceive the presence of suspected irritants and hence to respect the commitment with which they pursue the task of creating 'safe haven' environments for themselves.

This paper reports on an ongoing project of documenting such refuge environments, focusing on the issue of ventilation. Control of indoor air quality through ventilation picks up where source control through careful materials selection leaves off, making ventilation one of the most highly considered design issues of these extreme case environments. As with the issue of materials selection, designing to optimize general and/ or dedicated ventilation produces distinctive architectural forms and construction assemblies. These case studies bring the issues of air motion and stagnation, humidity and biological activity, materials offgassing and assemblies detailing into focus. They offer guiding examples of the sorts of indoor air quality design principles now emerging in advanced practice in general.

BACKGROUND

The research has involved both the documentation of physical structures and interviews with the clients, builders, and the occasional architects involved in their creation. Eleven projects have been documented. Of these, five houses and

Fig. 1. The Pitman house porch, seen from the south.

one apartment building are discussed here, representing several different climates across the United States and Canada.

The differences between climates show up strongly in the issue of ventilation. One house with an overriding connection to the outdoors is located in Wimberley, Texas, a resort town noted for its mild climate and good air quality. A second house accommodates seasonal swings from closed to open living reflective of the temperate climate of central Indiana. The remainder of the work is located in and around Ottawa, Ontario, where bitter winters demand sealed buildings and mechanical ventilation.

CASE STUDY DWELLINGS

1) The Pitman House, Wimberley, Texas[2]

This house in the hot and sometimes humid climate of the Texas hill country is a dramatic example of designing for outdoor living. Passive ventilation strategies in large measure give the home its form and ambiance.

The plan is a free interpretation of a dog run cabin, a vernacular common to the South. Two log cubes sit within an immense screened porch enclosure; one cube houses only the sleeping rooms and the other the living, dining and study areas as well as a kitchen area and bath. The entire structure is raised approx. eight feet off grade in part to catch the breeze without having to clear away the native scrub cedar forest.

The house is oriented east / west with the primary entry and porch orientation to the south. This orientation faces into the prevailing southern summer breeze. The effect of the breeze is amplified by the inflection of the two cabins, which together act as a wind scoop directing air through the center of the screened enclosure. Corners of the cabins touch the northern wall, creating a smaller opening to the north that can be effectively closed off in the winter with storm windows. With the northern winds directed around the house rather than through it, the central area of the porch is habitable year round without additional storm windows to enclose it.

The desire to facilitate air movement and thus prevent stagnation is evident inside the cabins as well. The living cabin is treated as a single, interconnected volume. The living/ dining space are open to above, while the study is treated as a loft above the kitchen area. To avoid creating a pocket of still air above the sink at the rear of the kitchen, a transfer grille is cut through to the loft above. In the same way, the kitchen storage space features open shelving to allow for air movement.

Isolated from the house stands a two story structure housing a garage on the first floor and a storage room above. The garage sealed off from the floor above and vented through ductwork passing through the storage area to the roof. This keeps the garage under negative pressure and provides an outlet for offgassing from the automobiles that would otherwise seep up into the family's stored belongings. In keeping with the spirit of the house cloths are primarily dried on the line outside.

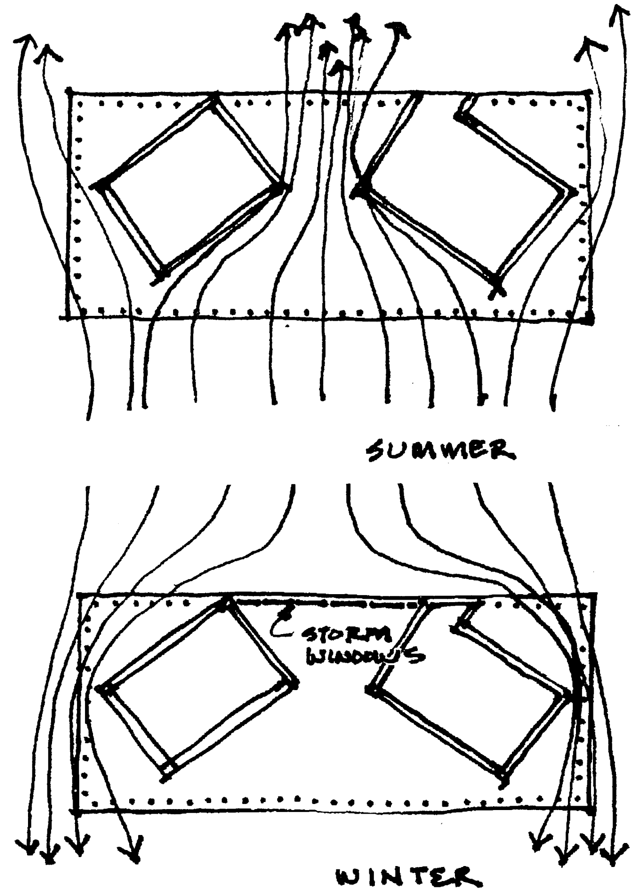

Fig. 2. Pitman house diagrams showing wind flow patterns. The cabins act to direct wind through the porch in the summer, while a small number of storm windows effectively shelter the porch in the winter.

The house is without a built-in mechanical system; in part because the climate allows it an in part because Sue Pitman did not want forced air or the ductwork associated with it, for fear of it becoming a breeding ground for mold. Instead, ceiling fans aid natural ventilation both inside and out. Winter heating is provided by movable electric/oil space heaters. Two similarly portable dehumidifiers operate in the summer; one in the closet dedicated to good cloths and linen and the second to dry out the comforter on the master bed. The bed is dehumidified in the bedroom during the day and rolled out onto the porch in the evening.

2) The Bower House and Haltom House/ Healthy House Institute Model Home. Unionville, Indiana[3]

These projects presented as one are the work of John Bower, who began building 'healthy houses' when his wife became chemically sensitive and is now recognized as an authority on the subject.

Taken together, these structures represent a catalog of state of the art mechanical strategies for superinsulated houses. The main house employs a heat recovery system while John's freestanding office uses exhaust only ventilation. Each sub-system tends to be independent of the others, a strategy that allows experimentation and the ability to pick and choose each component, in exchange for slightly higher cost and complexity.

Ventilation air is handled independently of heating and cooling, and is circulated through the house in a clearly defined loop. A filtration system draws air through all closets, the master bath and the kitchen, and supplies it in the center of the house into the living room. This arrangement is the inverse of a typical all-air system; supply is central and general and the exhaust locations are specific. The filter package is mounted above the hall ceiling and contains a pre-filter, absorption filter, and HEPA filter, together designed to handle pollen, mold spores and occasional wood smoke from the neighbors. The ductwork is oversized to reduce noise, compensating for the omission of potentially problematic duct linings.

A Heat Recovery Ventilator (HRV) is cut into this loop, exhausting the air taken from the kitchen and master bath and providing replacement air upstream of the filters. The HRV is a dual core unit with the fan located in the exhaust stream, an important feature for those sensitive to the offgassing of the electric motor. The core is aluminum rather than plastic for the same reason, and removable for cleaning. Given the superinsulated envelope, heating and air conditioning needs are minimal and are each supplied independently. Heating is supplied by hydronic/ electric baseboard heaters and A/C by a heat pump with its supply register mounted in the living room adjacent to the supply from the filtration loop, so that the cooled air will be intrained and dispersed with the filtered air.

Independent fans exhaust air from the range hood, the master bath, and the laundry. These fans, as well as those of the dryer and the central vacuum system, depressurize the house and require that a window be cracked open for make-up air during their operation. All of the exhaust ports are laid out on the leeward sides of the structures, away from intakes and operable windows. The central vacuum system is worth noting as a part of the basic clean-air infrastructure of the house; a feature repeated elsewhere. The garage also uses an exhaust fan on a timer activated by the garage door opener. This clears the garage of offgassing from the automobile as

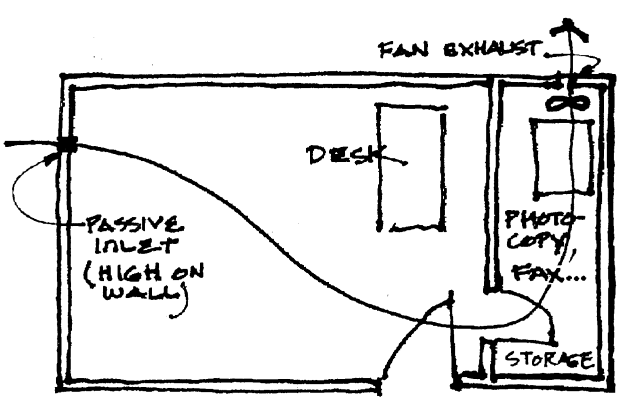

Fig. 3. Bower office structure diagram showing exhaust only ventilation strategy.

it cools down. Finally, John's wife uses glass enclosed boxes with their own fans and charcoal filters at both her computer desk and reading table.

Bower's office is housed in a separate structure, too small to justify the expense of a heat exchanger. Here, an exhaust only ventilation strategy draws air through a passive inlet port mounted high on the office wall. It passes through the office to the potentially more contaminated storage and equipment room and out via a small fan. This office presents a clear example of a coordinated arrangement of pollution sources and air flow paths in order to direct the air first through clean spaces, then to less critical spaces and out.

3) The Sunnyhill Research Center, Goodwood, Ontario[4]

This unfinished project is designed to serve both as a primary residence and a retreat center for people with MCS. The retreat features individual accommodations for six guests sharing common facilities such as a large kitchen. As a shared residence for a variety of chemically sensitive people, each with potentially different sensitivities expressed in differing degrees, Sunnyhill is unique among the structures documented. The design must allow for sensitive people to coexist in close proximity, a constraint reinforced by the limited budget and harsh climate that precludes a more individuated complex of buildings. Untested as the solution is in its unfinished state, the resulting design is based in large measure on strategies of controlled ventilation.

The center is located in rural farming country outside of Toronto, Ontario. Agricultural land is typically avoided by MCS victims because of the likelihood of incidental exposure to agricultural pesticides. This site was selected as a compromise; the farming in the area is less active than in other potential environs of Toronto and the site itself is on a windswept hill. Airborne pollen is also a typical concern of MCS victims, including the center's founder, Bruce Small. Small reasoned that the medical profession was better at treating conventional allergies than MCS, so that given the choice between the city and this site, he chose the relatively pollen rich air of the site.

The most interesting physical expression of the strategy of dedicated ventilation is in the kitchen, where cooking odors have the potential of overtaking the carefully maintained purity of the center. The kitchen is designed to support camaraderie amongst otherwise isolated clients and is prominently located on the main floor, overlooking the double height activity room below. This connection is mediated by glass, keeping the cooking segregated. More importantly, this idea of containment is extended to the individual appliances. Each of two ovens is fully encased in a vented cabinet structure. These in turn sit in an alcove exhausted by a continuous hood along its length.

4) The CMHC Demonstration House for the Environmentally Hypersensitive, Ottawa, Ontario[5]

As an adaptation of conventional factory built low-cost housing, this project explores the potential advantages of prefabrication; both in terms of cost and environmental quality control. Rather than eliminating all potential irritants from the basic envelope construction the design emphasizes a sophisticated system of interconnected exhaust plenums that keep both the storage areas and the interstitial spaces of the envelope under negative pressure. In keeping with this focus on air movement, the house features a prototypical integrated HVAC/air filtration system with several novel features. As with Sunnyhill, the success of these innovations is still conjectural.

Heating and ventilation systems are separate, though the same electric boiler provides heat for both. Space heating is delivered through a hydronic radiant floor system, which avoids the danger of creating and circulating 'fried dust' and works well with the choice of ceramic tile as a hygienic flooring. The boiler also provides domestic hot water, supplies a heating coil within the ventilation unit, and supplies exposed water pipes within a drying closet. The drying closet is especially notable; it is more energy efficient than an electric dryer while eliminating the need for fabric softeners, which are often offensive to a person with MCS. The humid exhaust air from the closet is lint-free enough to be exhausted through the heat exchanger.

Fresh air for the house is brought through a series of filters to the heat exchanger and supplied to the bedroom and living room. Return air is collected through the plenum system and returned to the heat exchanger. Ventilation in the bedroom

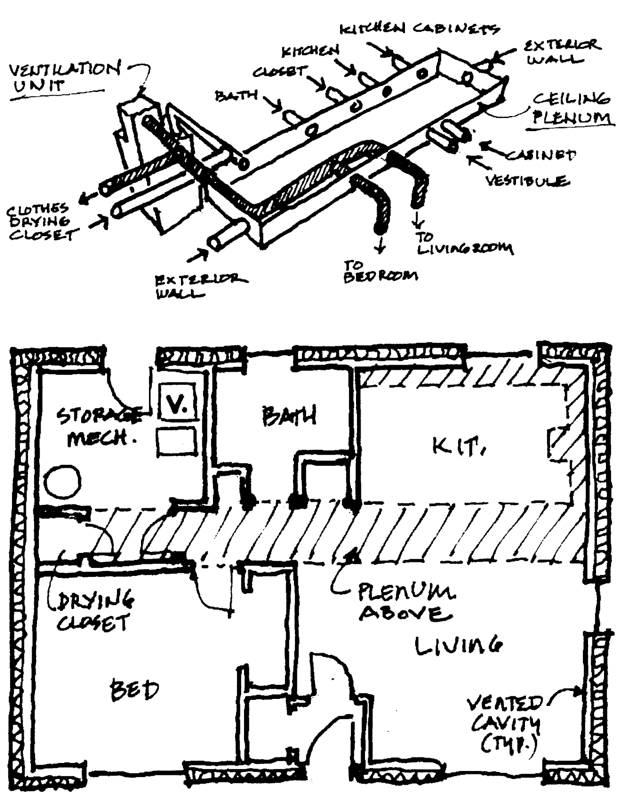

Fig. 4. CMHC demonstration house plan and ventilation plenum schematic diagram.

is given special attention, using a "displacement" or stratified ventilation strategy in which low volume air is introduced close to the floor and exhausted at the ceiling. In theory, the stale air rises via natural buoyancy, lowering the volume and fan power requirements while stirring up less dust and creating fewer drafts. The room is also kept under positive pressure, further insuring its cleanliness.

A return air plenum runs the length of the house in a lowered soffit. This spine gathers air from the kitchen, bath and closets, the kitchen cabinets, a glass multipurpose cabinet in the living room, and the exterior wall cavity. The cavity is the result of a two layer superinsulation strategy where an insulation cavity is created by outriggers, the primary structural framing is brought inside the vapor barrier and this inner cavity is left free of insulation to provide space for electrical chases etc. The plenum is ducted into the heat exchanger in the mechanical room, which has a gasketed door to insure both acoustic and stale air containment. Venting both the kitchen cabinets and the wall cavity are unique to this project.

7) Barhaven Community Housing for the Environmentally Hypersensitive, Ottawa, Ontario[6]

This recently completed low income housing is by far the most architecturally radical of these examples in its reconsideration of issues of design. As with the cold climate structures examined, this apartment building is compact and superinsulated, requiring a well worked out mechanical air movement system. The project takes an opposite approach to construction cavities from the CMHC house, seeking to eliminate them altogether. As a result of this elimination of interstitial space the ventilation system is completely exposed. The resulting ductwork is notable both for its layout and detailing, together allowing for complete periodic disassembly and cleaning.

Ducted, forced air heating uses an electric boiler on the first floor with a hydronic heating coil to eliminate the possibility of creating "fried dust." Prior to heating, air is filtered by a customizable rack of filters adaptable to individual needs. After being heated, the air is delivered around the perimeter of the first and second floors in ductwork suspended from the exposed concrete ceiling of the first floor.

Return air is drawn through the entry vestibule, the storage under the stairs, the bathrooms and mechanical rooms, the cloths closet, from behind the refrigerator, and through a vented glass cabinet/ work surface that divides the living room from the kitchen. This arrangement effectively flushes all of the storage space of the house except the shelves under the kitchen counter, which are left open to promote air circulation. At a larger scale, the plan is organized to minimize corridors and to create an open stair volume, both to promote the free movement of air.

A heat recovery ventilator in the second floor mechanical room exhausts the return air stream through a cupola that gathers together all of the roof penetrations for the building. Replacement air is drawn in through an intake in the gable end wall and inserted in line before the filtration. Exhaust lines for the dryer and for a central vacuum system that was provided for but not purchased run in the slab on grade and exit on the leeward side of the building, away from any operable windows.

One surprising difference from the other examples is that the range hood is not independently exhausted. Instead, a standard ductless filter captures cooking fumes and puts the air back into the kitchen, where it is eventually taken up by the exhaust located over the refrigerator. This is a low cost solution to the heat loss and system imbalancing that independent fans create. Though in theory less than ideal, to date none of the residents have complained about excessive cooking odors being a source of irritation.

6) The Nelms House, near Carp, Ontario[7]

This superinsulated country house features careful zoning and elaborate mechanical ventilation. The ventilation system is an early experiment in the types of ducted fresh air systems seen in each of the other superinsulated houses discussed here. This is in part a reflection on the builder Oliver Drerup, known nationally in Canada as a spokesperson for the government's R-2000 advanced construction education program.

The house is located on twenty five acres of well drained non-agricultural land with exceptional air quality. It is superinsulated and oriented to take advantage of passive solar gains. The additional space heating required is provided by an electric boiler and delivered through fin tube radiation.

The fresh air system is separate from the heating system. Air is brought into the house through a dormer on the roof. It passes by two electrostatic filters and over a fan coil unit, where it is heated in part by a closed glycol loop drawing heat via a heat pump from the house exhaust. As noted in other cases, an important feature of this fan coil unit is that the fan is mounted outside of the air stream, keeping the air stream clean. The heat recovery system has been tinkered with several times since the house was built; the owner joked that the first HRV, an air to air exchanger custom fabricated by the contractor, produced the acoustic sensation of living in a wind tunnel.

Tempered fresh air is distributed to every room in the house and stale air is collected through the baths, kitchen (from behind the oven and refrigerator), and laundry. This air is then ducted into the mechanical room, where it is exhausted past the heat pump. The mechanical room also serves as the exhaust plenum for the central vacuum system. This solves the problem of depressurization discussed in other examples: Though the heat pump is less efficient than the air to air heat exchangers used elsewhere, it does allow the exhaust air from the central vacuum to be stripped of some of its heat. Also, the mechanical room can be kept at a constant negative pressure regardless of the amount of air being dumped into it, which prevents contaminants from being drawn back into the house. Only the down-draft exhaust from the island mounted kitchen range is exhausted directly to the exterior.

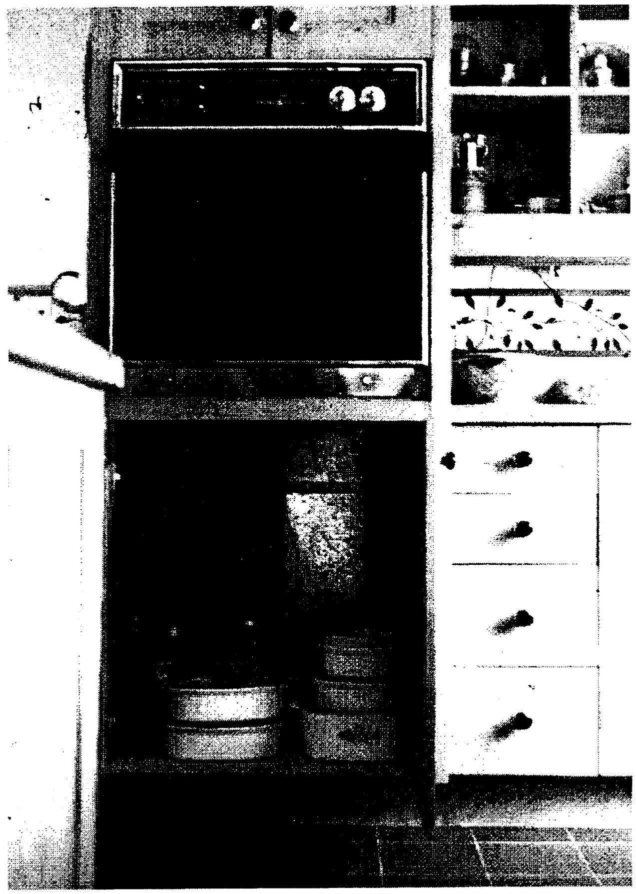

Fig. 5. Nelms house. An exhaust air duct ventilating the casework behind the built-in oven is visible below the oven.

In the Nelms' house perhaps more emphatically than in any other, the owners stressed the difference that this well balanced and thoroughly commissioned fresh air system made in their lives. The ability to leave the ventilation system on twenty four hours a day, continually flushing the house while saving enough heat to make it affordable, seemed to them to be central to the recovery of Catherine's health after years of serious illness.

CONCLUSION

The general debate about designing for indoor air quality often breaks into two competing camps; one arguing for source control through such things as careful materials selection, and the other arguing for increased ventilation. These houses for the environmentally hypersensitive pursue both strategies simultaneously, showing them to be complimentary. The fundamental ventilation lesson that these dwellings offer is that air motion is something to be designed. Beyond this the solutions mushroom in response to different climates and situations.

Where the topic of materials selection highlights chemical irritants such as formaldehyde, the primary objective of these ventilation strategies is to guard against mustiness, which more generally signals mold and mildew problems that can in fact be equally problematic to a sensitive individual. Venting the refrigerator so that slime doesn't grow in the condensation pan is perhaps the most graphically instructive example of this attunement. Practices such as this are pure common sense with potentially broad applicability.

Ventilation also calls attention to those things that are not specifically part of the building that can either be offensive themselves or carry in odors from the outside. Printed matter is often very irritating to a chemically sensitive person. Here we have seen books stored in ventilated cabinets and read in ventilated reading boxes. Cloths closets and other storage areas are typically designed with similar care.

Also, the primary consideration for the majority of these houses is the quality of the air outside rather than in. Several of the life histories represented here are tied to growing up on farms and being exposed to heavy concentrations of pesticides as a result. Not only do these houses shun urban air, they avoid rural agricultural settings as well.

The choice of either passive or mechanized ventilation strategies also strongly reflect the climates represented. On the passive side, these houses offer generally applicable examples of open air living arrangements, wind responsive building orientation, proper placement of openings for direct air flow, and the ways that open systems can be tuned to respond to varying conditions. On the mechanical side, we see houses that can completely shut themselves off from the outside during "bad air" days, that zone plan and section from clean to contaminated based on air flows, and that introduce sophisticated banks of filters that can be tuned to individual needs.

On a small scale, the treatment of storage space reiterates the basic formal differences between passive and active control. Sue Pitman's house opens shelving up to promote maximum air circulation. John Bower places everything behind glass, in some cases vented.

One of the most prescient features of the active systems is the articulation of dedicated exhaust paths; adding the refrigerator, closets, cabinets and garage to the range hood and toilet as areas to be exhausted. Central vacuuming systems present yet another tree of ductwork.

Finally, each of the colder climate houses matches the air tightness of the envelope with sophisticated ways of making penetrations through it to admit fresh air. These houses have been built by people who in several instances were make sick by the first generation of superinsulated housing and are now on the forefront of solving superinsulation's problems. They are pioneering the next generation of heat recovery equipment and possibly even presaging the general use of sophisticated air filtration equipment in residential settings.

NOTES

1 Interview with Claudia Miller, Univ. of Texas Health Science Center, San Antonio. See Ashford, Nicholas and Claudia Miller, *Chemical Exposures: Low Levels and High Stakes*. New York; Van Nostrand Reinhold. 1991.

2 Interview with Susan Pitman. No architect involved.

3 Interviews with John and Lynn Bower, Healthy House Institute. Interviews also with Ron Haltom and with Melany Lyle, MCS victims and "healthy house" owners. See Bower, John. *Healthy House Building: A Design and Construction Guide*. Bloomington; The Healthy House Institute. 1993.

4 Interview with Bruce Small, Green Eclipse Inc.. No architect involved.

5 Interview with Virginia Salares and Peter Russell, Research Division, Canadian Mortgage and Housing Company, principal investigators.

6 Interviews with Philip Sharp, architect, and Oliver Drerup, contractor.

7 Interviews with Catherine and John Nelms, clients, and Oliver Drerup, designer and builder.