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Design and construction of low-cost prototypical dwellings for Environmentally Hypersensitive occupants: A case study

Author and Project Architect

Phillip Sharp OAA MRAIC RIBA
Associate Professor, Carleton University
Phillip Sharp Architect Limited
68 Hopewell Avenue
Ottawa, Ontario
K1S 2Z1

Project Sponsor

Barrhaven United Church
Non-Profit Housing Inc.
3013 Jockvale Road
Nepean, Ontario
K2C 3H2

Project Consultants

Buchan, Lawton, Parent Ltd.
Consulting Engineers
5370 Canotek Road
Ottawa, Ontario
K1J 9E6

Drerup Armstrong Limited
Contractors and Specialist
Construction Consultants
P.O. Box 130 Carp, Ontario
K0A 1L0

The general issues of Hypersensitivity as they affect the construction of dwelling environments have been covered in Oliver Drerup's invited paper. This paper will therefore deal primarily with the design of a specific building complex.

LOCATION AND CLIMATE

The development is built in the Barrhaven community of the **City of Nepean**, within the greater Regional Municipality of Ottawa/Carleton, Ontario, Canada. It is located at 45 degrees latitude with temperatures ranging from +86 degrees F (30 degrees C) in summer to -15 degrees F (-26 degrees C) in winter.

COMMUNITY CONTEXT

The dwellings for the Environmentally Hypersensitive form part of a larger **non-profit community** for handicapped residents, senior citizens, and support families together with professional care facilities, sponsored by the Barrhaven United Church congregation. Integrated with a conventional suburban neighbourhood, it acts as a **catalyst for social and environmental responsibility**. It allows many people who would otherwise be institutionalized to live within the community at large.

GOVERNMENT PARTICIPATION

All levels of government have co-operated in the development of this project. **Municipal and Regional authorities** have allowed zoning and Building Code variations and have agreed to eliminate chemical spraying. The **Provincial Government**, through the **Ministry of Housing**, has enthusiastically supported the development of these dwellings and has provided funding guarantees within its non-profit housing program. The **Federal Government**, through **Canada, Mortgage and Housing Corporation**, has made research and testing facilities available. At all levels, the project promises to **influence future legislation.**

OBJECTIVE

Our objective was to provide a prototypical complex of dwellings designed to provide **safe, healthy environments** for those who suffer from the effects of **chemical emissions, dust and moulds**, within the limitation of a conventional social housing budget.

PRECEDENCE

We started with an exhaustive review of existing publications and research and an analysis of numerous private houses which had been custom built with specific hypersensitivities in mind. We found no precedence for the problems encountered in low-cost, multi-unit accommodation.

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DESIGN STRATEGY

As our dwellings were to cater to the widest possible range of occupants we eliminated from consideration materials or assemblies that appeared to cause problems at any level of sensitivity and it soon became apparent that nearly all conventional low-cost housing solutions were suspect.

Following this initial exploration, we developed the following strategy:

1. Minimize the extent of exterior envelope to reduce the area of insulation and vapour barrier required, both of which are particularly expensive in low-hazard materials.

Super-insulate this reduced external envelope to conserve energy and allow the economic use of electric heat sources.

2. Eliminate from the interior environment materials that are known to off-gas potential irritants. Test all other materials selected for use, on a panel of acutely sensitive volunteers.

3. Where undesirable materials cannot be avoided (for performance or budgetary requirements), isolate them from exposure to the interior space and where possible ventilate to the outside air.

4. Eliminate all below grade accommodation, basements, and crawlspaces as potential sources of damp and mould.

5. Eliminate wall cavities and all other dead air spaces in the interior structure, around appliances, and in the heating and ventilation systems where dust and mould can collect and not be easily removed.

6. Provide balanced ventilation, heating, cooling and air cleaning systems that effectively eliminate negative effects of the outdoor environment.

7. Mechanically ventilate all storage areas and closets as well as areas where cooking and cleaning functions are performed.

8. Group all facilities requiring plumbing services or containing major appliances around central mechanical rooms to reduce service runs. Where possible, expose all such plumbing services and the backs of appliances within the mechanical rooms to allow for regular inspection, cleaning, and maintenance.

9. Provide glazed ventilated cabinets or fume cupboards to isolate television, telephone, home computer and other such appliances and equipment as well as books and other items unavoidably containing off-gassing materials, from the main living spaces.

10. Wherever possible use single-material assemblies and components that do not require additional applied finishes.

GENERAL PLANNING

The owners "need and demand study" dictated a unit mix of two one-bedroom, three two-bedroom, and two three-bedroom dwellings. The two and three bedroom units are planned as back to back two-storey rowhouses, with the two one-bedroom units being single storey bachelor apartments, stacked one above the other, each with separate ground floor access.

The resulting two-storey complex is almost square in plan consisting of six structural planning modules. On the second floor, plans interlock, with the larger three-bedroom end units overlapping the ground floor plan of the two bedroom units.

DETAILED UNIT PLANNING

For the purposes of this paper, we will examine a typical two-bedroom dwelling. The one and three bedroom units follow similar principles.

Individual dwellings are planned around the location of their own storage/mechanical rooms. Kitchens, laundries and bathrooms vent directly into these rooms where plumbing, appliance extracts and the backs of major appliances are exposed for regular cleaning and maintenance, eliminating a major source of dust and mould.

Ground Floor

The entry lobby, under negative pressure, acts as an airlock to the dwelling itself. It is large enough to allow residents to conveniently change from outdoor to indoor footwear and leave their outer clothing in a ventilated closet before entering the living room. A free-standing hardwood cabinet with sliding glass doors on both sides separates the living room from the kitchen and provides mechanically ventilated dust-free shelf space for television, telephone and any other off-gassing, dust-burning electronic devices, as well as for kitchen items and books. Contaminated air rising from the back of the refrigerator is also evacuated by the ventilation duct serving this cabinet. A door allows access to the base and rear of the refrigerator for regular cleaning and maintenance, eliminating another source of dust and mould. Kitchen fittings consist of solid maple "butcher-block" countertops on maple frames, open shelves above and below, with provisions for roll-out metal cabinets. Additional kitchen storage can be provided as pantry shelving in the adjacent storage/mechanical room. A short hallway separates the kitchen from a laundry/half-bathroom facility. An open staircase with storage below, opens off the living room and leads to the second floor.

Second Floor

The second floor is planned around an open rectangular stair hall giving direct access to bedrooms, walk-in closet, bathroom and upper mechanical/storage room. Bedrooms are intended purely as sleeping spaces. All clothes are hung or stored in an open rack and tray system within a completely separate closet/dressing room.

HEATING AND VENTILATION

Following detailed exploration of mechanical installations shared by the entire complex, each dwelling now has its own self-contained systems to avoid any possibility of cross-contamination.

The primary system, ducted forced air heating, is served by an electric boiler, hydronic heating coil and a fan with the motor remote from supply and return air streams, all housed in the ground floor mechanical room. Return air, mixed with preconditioned fresh air, passes through filters which are capable of adaptation to meet occupants specific needs. This clean, filtered air is delivered to the kitchen/dining room, living room, entrance lobby, and bedrooms, through one continuous exposed duct diminishing in diameter from 12" to 4", suspended from the perimeter of the ground floor ceiling.

The secondary system consists of a heat recovery ventilator (HRV) housed in the second floor mechanical room which exhausts foul air from the entrance lobby, storage areas, closets, laundry, kitchen, bathroom, glazed cabinet, and both mechanical rooms on a continuous basis to the outdoors, through a roof-top enclosure. Continuous fresh air, drawn through gable end wall intakes, is delivered by the HRV, pre-heated and pre-filtered, to the return air duct of the primary system.

Ducts in both systems were acid-etched and washed to remove all traces of oil resulting from manufacturing or fabrication processes, and are demountable for periodic cleaning, if necessary.

PLUMBING AND MISCELLANEOUS MECHANICAL SYSTEMS

Plastic soil and waste pipes, used for cost reduction, are limited to the interior of the negatively-pressurized mechanical rooms or to underslab installations. All other pipes and fittings are copper or plated brass. Domestic hot water is electrically heated. A central vacuum system, exhausted to the outside air, is installed in each unit. Tenants provide their own canisters.

ELECTRICAL SYSTEMS

Power is supplied to each ground floor mechanical room through below-slab conduit. As there are no conventional cavity stud walls, power and lighting circuits are run in surface-mounted, galvanized metal wire-molds with baked-enamel finish. The wire-molds are capable of being placed under negative pressure and evacuated to the mechanical rooms. All lamp holders are ceramic, with glass globes or exposed decorative light bulbs.

ENERGY EFFICIENCY

This project, through compact planning, high levels of insulation, airtight construction, and effectively designed heating and air handling systems, goes well beyond R-2000 Standards. It is expected that the average unit will cost less than $180.00 per year (Canadian) to heat in spite of continuous air exchange. This is less than one third of the cost of heating a conventional dwelling in this part of Canada.

Although it draws on the conventional Hydro-Electric power grid, the project is ideally suited to the application of heat pumps (as originally envisaged, but abandoned through limited capital cost budget).

MATERIALS AND CONSTRUCTION

Hardwood and concrete products devoid of all additives (industrial detergents for air entrainment, plasticisers, curing agents, etc.) were selected as the major structural, constructional, and finishing materials.

Footings, foundations and ground floor slab on grade are in-situ concrete.

The dense 4" thick ground floor slab effectively isolates a polyethylene moisture/soil gas barrier and expanded polystyrene insulation from the interior space.

The second floor consists of precast concrete slabs, formed using organic soap as a release agent.

Both floor slabs are ground and polished to reveal their aggregate pattern, and sealed with a penetrating Sodium Silicate water repellent solution which hardens the surface and prevents cement from dusting.

Load bearing and party walls are dense, smooth surface, self finishing concrete blocks bedded in shale-based structural mortar, and providing a 1 hour fire rating with an STC of 53. Accent blocks were achieved with naturally occurring coloured sand. Exposed blocks were treated with a sodium silicate solution as described for floor slabs.

Load-bearing exterior block walls are lined on the outside with polyethylene vapour barrier, 2" x 8" out-rigger stud framing filled with additive-free rock wool insulation held in place with woven olefin fabric air/moisture barrier, and clad with prefinished hardboard siding.

Non-bearing gable end walls are 2" x 8" wood stud framing insulated and clad as for the exterior block walls. The interior sheathing is 5/8 " fire rated gypsum board with aluminum foil backing exposed to the inside as a vapour barrier sealed with aluminum tape and finished with 3/4 " x 4" tongue and grooved basswood.

Windows are double-glazed units in aluminum frames and sashes with baked enamel finish. Mechanical construction junctions sealed with aluminum tape. More energy efficient, low-emissive units (incorporating metallic foils) were rejected in favour of gaining a wider spectrum of natural daylight.

Roof construction consists of preformed, pre-finished sheet steel on wood purlins and trusses, rock wool insulation, and a fire-rated ceiling membrane consisting of 2 layers of 5/8 " gypsum board isolated from the interior space by taped aluminum foil backing, lined with 3/4" x 4" tongue and groove basswood.

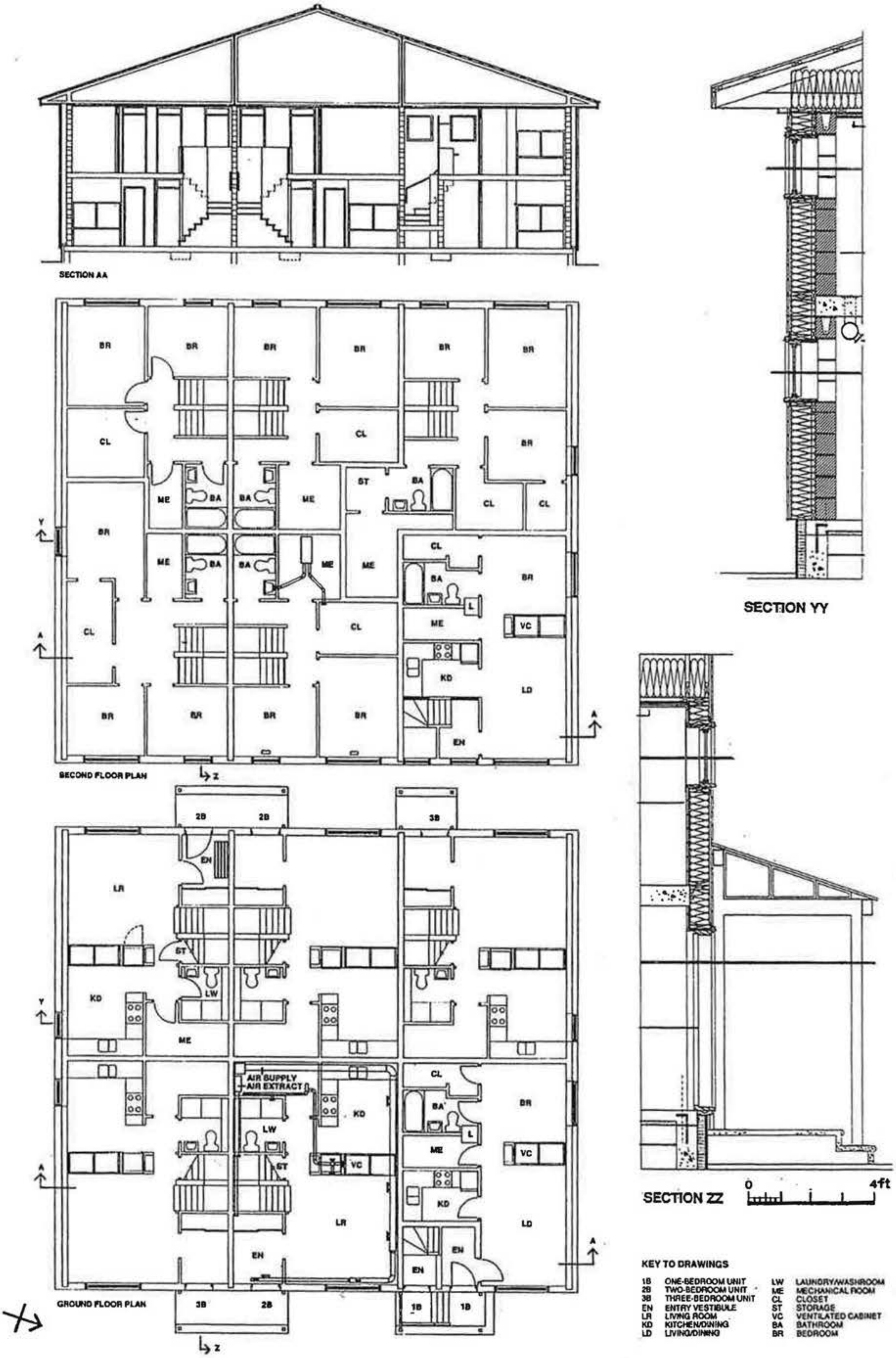
Interior partitions throughout are vertical planks of 2" x 6" tongue and groove basswood in rebated and mitred top and bottom plates.

Doors are framed and panelled poplar with panelled or glazed transoms.

Staircases are fabricated throughout in red maple.

All wood assemblies are either mechanically fastened or employ white glue only.

Wood surfaces subject to wear or handling are finished with water-based sealers.



KEY TO DRAWINGS

1B	ONE-BEDROOM UNIT	LW	LAUNDRY/WASHROOM
2B	TWO-BEDROOM UNIT	ME	MECHANICAL ROOM
3B	THREE-BEDROOM UNIT	CL	CLOSET
EN	ENTRY VESTIBULE	ST	STORAGE
LR	LIVING ROOM	VC	VENTILATED CABINET
KD	KITCHEN/DINING	BA	BATHROOM
LD	LIVING/DINING	BR	BEDROOM

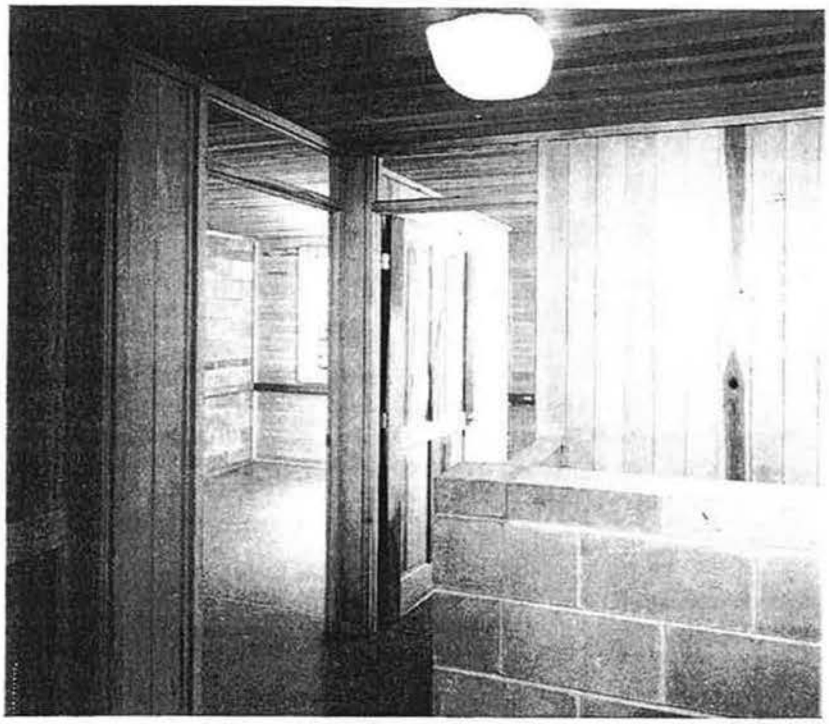
PROTOTYPICAL LOW-COST MULTI-UNIT DWELLINGS FOR THE ENVIRONMENTALLY HYPERSENSITIVE

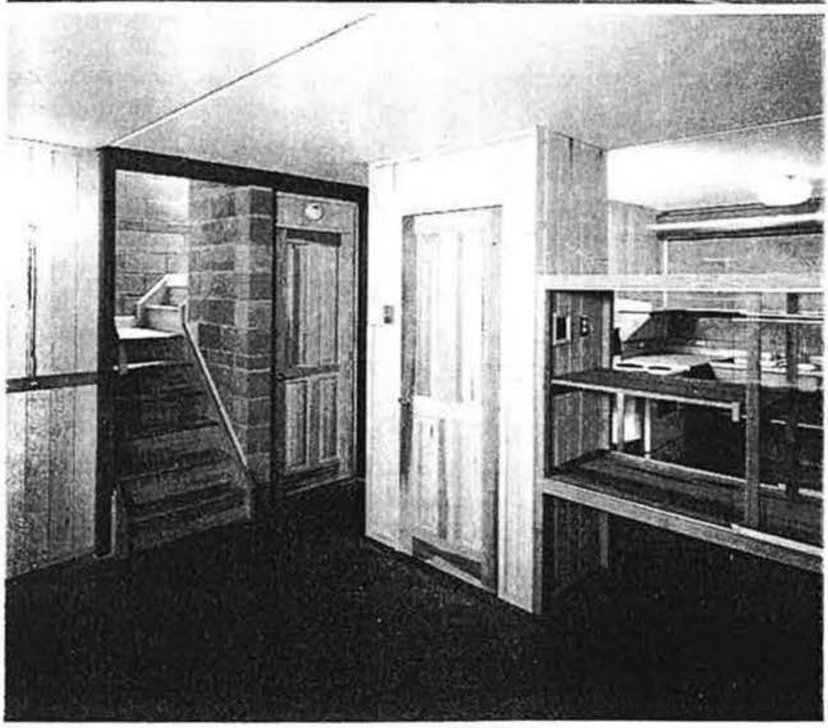
PHILLIP SHARP ARCHITECT LIMITED

CONCLUSIONS

The project was occupied at the end of April, 1993. It is too soon to draw any reliable conclusions but residents seem to be highly appreciative both from the standpoint of their health and well-being and of the quality and simplicity of their surroundings.

The author anticipates publishing a detailed case-history and generic specifications based upon this project. The publication will incorporate any recommendations arising from an on-going monitoring program.





The lessons embodied in this project are applicable to the design of **housing environments generally.** Elimination of pollutants leads naturally to simple easily maintainable components and assemblies that evolve directly from the use of basic **unadulterated materials.**

This in turn leads to planning the entire building around modules inherent in such materials and assemblies, resulting in an economy of means which, combined with the necessity for impeccable site management, can result in less waste and a general concern for more **sustainable development.**

Control of indoor air quality inevitably calls for the application of **energy conservation** measures and more stringent envelope design.

Taken to its natural conclusion, serious consideration of healthy living environments, in the fullest sense, demands an attitude to design based upon **first principles** and not upon mere stylistic whim.

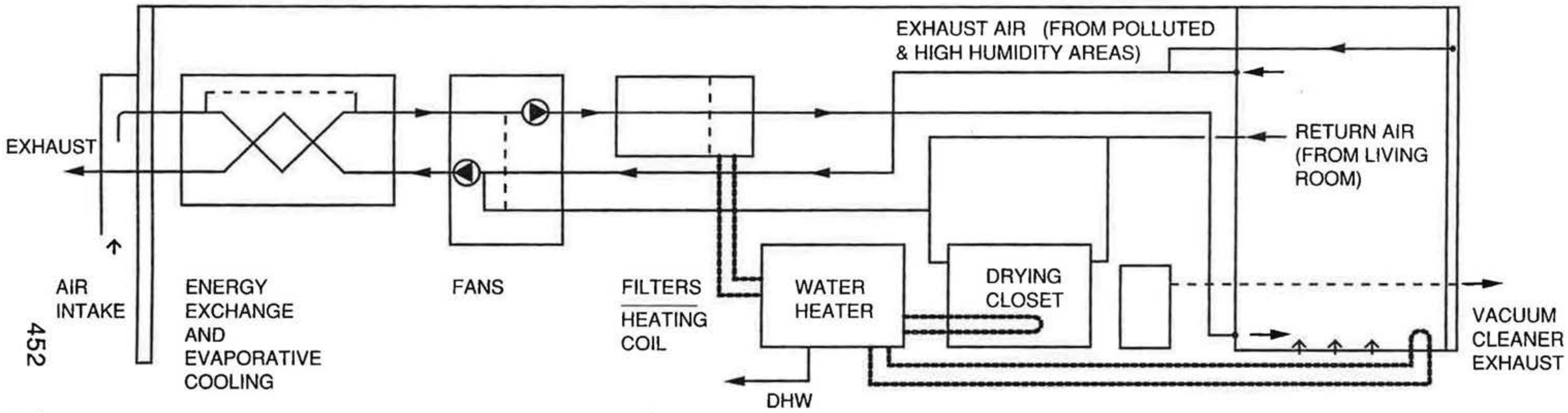
It calls for the pursuit of an ethical lifestyle where "**more**" is replaced by "**better**" and "**enough**".

Upper left:
Interior, Second Floor

Lower left:
Interior, Ground Floor

RESIDENTIAL INTEGRATED ENVIRONMENTAL CONTROL SYSTEM (SUITABLE FOR HOUSES FOR PEOPLE WHO ARE ENVIRONMENTALLY HYPERSENSITIVE)

PETER RUSSELL : RESEARCH DIVISION, CANADA MORTGAGE AND HOUSING CORPORATION, OTTAWA



VERY HIGH INDOOR AIR QUALITY
- AIR SUPPLY TO BED & LIVING ROOMS
- EXHAUST FROM BATHROOM & KITCHEN
- PARTICLE FILTERS
- GASEOUS ABSORBANT FILTER
- STRATIFIED VENTILATION
- DEPRESSURIZED CLOSETS AND WALLS

RELIABILITY
- HIGH QUALITY COMPONENTS
- FAIL SAFE DESIGN

AFORDABILITY
- LOW OPERATING COST
- SIMPLE MAINTENANCE
- NO FRILL CONSTRUCTION

ENERGY EFFICIENCY
- HIGHLY INSULATED BUILDING ENVELOPE
- ENERGY RECOVERY (WITH BY-PASS)
- LOW OPERATING TEMPERATURE
- RADIANT FLOOR HEATING
- EVAPORATIVE COOLING
- VARIABLE AIRFLOW RATES
- INTEGRAL DRYING CLOSET

LOW NOISE
- HIGH QUALITY FANS
- AIRTIGHT UTILITY ROOM

ADAPTABILITY
- MODULAR DESIGN