LE PLAN VERT DU CANADA
CANADA'S GREEN PLAN

ADVANCED HOUSES PROGRAM
PROGRAMME DE MAISONS PERFORMANTES

DESIGN AND PERFORMANCE OF THE MANITOBA ADVANCED HOUSE

PREPARED FOR:

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EXECUTIVE SUMMARY

The Manitoba Advanced House is one of ten homes constructed across Canada as part of the Advanced Houses Program. Its purpose is to demonstrate and evaluate innovative housing technologies for reducing energy consumption, conserving water, improving indoor air quality, facilitating home recycling and reducing construction waste. Built in Winnipeg in 1992, the house contains a number of innovative products, systems and design concepts, some of which were developed specifically for it. To assess the performance of the Manitoba Advanced House, an intensive monitoring program was established which tracked energy usage, water consumption, indoor air quality and numerous other variables.

The results of the monitoring program indicated that the energy consumption of the Manitoba Advanced House exceeded its original design target. However, following a detailed analysis of the data, it was concluded that over three-quarters of the predicted overconsumption was attributable to inherent limitations of the computer software used to design the house in 1992. The analysis suggested that if current versions of the software had been available at that time, the house would have been designed in a more energy efficient manner and lower energy usage would presumably have resulted.

Nonetheless, the analysis clearly showed that the Manitoba Advanced House is an extremely energy efficient structure. For example, it would only consume 44% to 48% of the energy of an equivalent, new Manitoba home, or 60% of that of an R-2000 house. It was also concluded that the energy usage could have been further reduced by: upgrading the envelope airtightness, simplifying the ventilation system, using windows with insulated frames, modifying the design of the greywater heat recovery system and switching to smaller, more efficient electric motors, blowers and water pumps.

Extensive indoor air quality testing demonstrated that the collective impact of the various indoor air quality control measures used in the house (such as a high quality mechanical ventilation system, an 85% efficient bag filter and an activated charcoal filter, sealed combustion appliances and the elimination or containment of various potential pollutants) was very successful. Measured pollutant levels in the house were well below the recommended Health and Welfare Canada exposure guidelines as well as being lower than those measured in comparable, new conventional and R-2000 houses. The measured per capita water consumption in the Manitoba Advanced House averaged 100 l/day•person, which is well below reported levels for conventional residences, although this was due in part to the lifestyle of the homeowners who were very conscientious about water usage.

Finally, a large number of observations, experiences and insights gained during the design, construction and operation of the Manitoba Advanced House were documented.

RÉSUMÉ

La Maison performante du Manitoba compte parmi les dix maisons construites sur tout le territoire du Canada dans le cadre du Programme de la maison performante. Ce programme vise à faire la démonstration et l'évaluation de techniques d'habitation novatrices permettant de diminuer la consommation énergétique, de faire des économies d'eau potable, d'améliorer la qualité de l'air intérieur, de favoriser le recyclage domestique et de réduire les déchets de la construction. Construite en 1992 dans la ville de Winnipeg, la maison comprend plusieurs produits, systèmes et modèles de conception à la fine pointe de la technologie, dont certains qui ont été conçus spécialement pour ce genre d'habitation. Dans le but d'évaluer le rendement donné par la Maison performante du Manitoba, on a mis sur pied un programme intensif de surveillance destiné à faire des relevés de l'usage énergétique, de la consommation d'eau potable, de la qualité de l'air intérieur et de divers autres variables.

Les résultats obtenus à l'aide du programme de surveillance indiquent que la consommation énergétique de la Maison performante du Manitoba excède l'objectif original. Toutefois, à la suite d'une analyse détaillée des données recueillies, on en est venu à la conclusion que plus des trois quarts de la quantité prévue d'énergie surconsommée étaient attribuables aux limites du logiciel utilisé en 1992 lors de la conception. Ainsi, si l'on avait pu utiliser à cette époque les versions actuelles du logiciel, il aurait sans doute été possible de concevoir une maison favorisant davantage l'efficacité énergétique, ce qui aurait probablement résulté en une utilisation énergétique moindre.

Néanmoins, l'analyse a clairement démontré que la Maison performante du Manitoba constituait une structure qui favorisait hautement l'efficacité énergétique. Par exemple, elle ne consommait que 44 à 48 % de l'énergie d'une maison neuve équivalente du Manitoba, ou que 60 % de l'énergie d'une Maison R-2000. On a également conclu qu'il aurait été possible de réduire davantage la consommation énergétique en renforçant l'étanchéité de l'enveloppe, en simplifiant le système de ventilation, en recourant à des fenêtres munies de cadres isolés, en modifiant la conception de l'appareil de récupération de la chaleur à partir des eaux ménagères et en se tournant vers des appareils électriques plus petits et plus efficaces dans le cas des moteurs, des ventilateurs soufflants et des pompes à eau.

Une vérification approfondie de la qualité de l'air intérieur a mis en lumière l'effet fructueux des mesures combinées de contrôle de cette qualité qui ont pris la forme d'un système mécanique de ventilation de grande qualité, d'un dépoussiéreur à sacs filtrants et d'un filtre à charbon actif efficaces à 85 %, d'appareils hermétiques à combustion, ainsi que de l'élimination ou du confinement des divers polluants possibles. Les niveaux de pollution mesurés étaient bien en deçà de ceux recommandés par Santé Canada dans les lignes directrices relatives aux niveaux acceptables d'exposition. De même, ils étaient inférieurs à ceux rencontrés dans les maisons neuves ou les Maisons R-2000 comparables. La consommation d'eau potable par personne évaluée dans la Maison performante du Manitoba atteignait une moyenne de 100 l/jour-personne, un niveau bien moins élevé que ceux rapportés dans les maisons classiques, bien que ce résultat soit attribuable en partie au style de vie des propriétaires de la maison qui prenaient grand soin de leur consommation d'eau.

En dernier lieu, on a pu documenter une grande partie des observations, des expériences et des constatations faites lors de la conception, de la construction et du fonctionnement de la Maison performante du Manitoba.

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SECTION 1
THE MANITOBA ADVANCED HOUSE

1.1 INTRODUCTION

The Manitoba Advanced House is one of ten houses constructed across Canada as part of the Advanced Houses Program. Its purpose is to demonstrate and evaluate various innovative housing technologies for reducing energy consumption, conserving water, improving indoor air quality, facilitating home recycling and reducing construction waste.

Design of the Manitoba Advanced House began in late 1991 and construction commenced the following spring. The final components and systems were installed in 1994 after which the house was sold and eventually occupied in July, 1994. To evaluate the performance of the home, an intensive monitoring program was put into place in the summer of 1994 and maintained until the fall of 1995.

1.2 CONTENTS OF THIS REPORT

The primary purpose of this report is to document the findings of the monitoring program created for the Manitoba Advanced House. However, it also contains extensive information, analysis and insights which were generated from other elements of the project. It also contains additional background information on the design and construction of the house as well as some general technical comments on Advanced Houses. Finally, it provides brief summaries of a few non-monitoring aspects of the project, such as the technology transfer program which has successfully passed on many of the lessons learned to both industry and consumers.

As much as possible, this report has been written to provide useful information to the reader which can, it is hoped, be applied to other houses regardless of whether they are conventional, R-2000 or Advanced Houses. The reader will notice that this report focuses on information and knowledge, rather than on the presentation of raw data. Interpretation of the monitoring data has been maximized so as to provide a concise summary of what was learned from the design, construction and operation of the home.

Since new and innovative technologies were extensively employed in the Advanced Houses Program, many of the products and systems used were not readily available through normal commercial channels. As such, their costs were often radically different from what might be expected if they were more widely available. For this reason, cost was not a dominant factor in the selection or rejection of candidate technologies. As a result, determination of the costs and the cost-effectiveness of the various technologies is not a major focus of this report.

The intended audiences for this report includes house designers, conservation program officials, software developers, equipment and product manufacturers, utility representatives and researchers.

1.3 BACKGROUND

1.3.1 The CANMET Advanced Houses Competition

The Advanced Houses Program was conceived by the Canadian Centre for Mineral and Energy Technology (CANMET), the research and development arm of Energy, Mines and Resources Canada (now Natural Resources Canada). Its objectives were to demonstrate and evaluate technologies to reduce energy consumption and minimize the environmental impact of new housing by fostering research and development of innovative building products, technologies and techniques; testing innovative products and systems in regional field trials conducted in Advanced Houses across the country; and encouraging adoption of successful products and concepts by the residential construction industry.

A unique feature of the Advanced Houses Program was that it was structured as a design competition and carried out in two stages. The first stage, announced in 1991, invited proposals from builders, developers, design teams, etc. to prepare a conceptual house design capable of meeting a detailed set of technical requirements for energy, indoor air quality, water conservation, recycling, etc. From the approximately 40 original entries, a total of 16 entries were selected to prepare detailed proposals under the second stage. These proposals had to contain detailed descriptions of how the Advanced Houses Technical Requirements were to be met, computer projections of energy usage, working drawings of the proposed house, descriptions of how the project was to be managed and all funding provisions. From this group, ten proposals were ultimately selected for construction. The winners, selected from across the country, were officially announced in February, 1992. One of these successful proposals was that prepared by the Manitoba Home Builders' Association for construction of the "Manitoba Advanced House" in Winnipeg.

1.3.2 Advanced House Design Criteria

All Advanced Houses were required to meet detailed design criteria specified in the "Advanced Houses Program Technical Requirements" (Dumont 1992), summarized below:

Energy Performance Target - The total energy consumption target for each house was calculated on the basis of its size and the severity of the local climate. It was established to equal about one-half that of the (then) R-2000 target. In addition, specific sub-targets were created for space heating, space cooling, domestic hot water heating, appliances, lighting and outdoor electrical usage. These targets and sub-targets are discussed in more detail in Section 4.

Water Usage Target - The Technical Requirements mandated the use of low-consumption toilets, showerheads, faucet aerators, clothes-washing machines and water-efficient landscaping.

Recycling - Each house was required to make provision for composting of kitchen waste and storage of recyclable products such as paper, metal and glass.

Ecomanagement - Wherever possible, recycled materials were to be used for construction. In addition, a waste management plan had to be established to reduce the amount of waste generated during construction of the house. The use of EcoLogo products was also encouraged.

Indoor Environment - Measures had to be incorporated into the house to maintain good air quality, thermal comfort and control noise which would be produced by the house's mechanical equipment.

1.4 DESIGN PHILOSOPHY

Each design team was encouraged to adopt a particular design philosophy which they felt was most appropriate to their physical environment and the local home-buying market. In the case of the Manitoba Advanced House, the emphasis was placed on practicality of components and systems. Essentially, the house was designed as an evolutionary rather than a revolutionary structure, i.e., one which could maximize the performance of products and systems which were commercially available while still recognizing the harshness of the climate and the conservative nature of the local home-buying public. Using this philosophy, the final design was developed. With only a few, minor exceptions, the completed structure was the same as that described in the final design.

1.5 DESCRIPTION OF THE MANITOBA ADVANCED HOUSE TEAM

A project of this magnitude obviously requires the dedication and effort of a large number of people with a wide variety of skills. In this particular case the Project Manager, the Manitoba Home Builders' Association, was able to assemble such a team and also draw on the contributions of many of its member firms.

Project Team

Project Manager: Manitoba Home Builders' Association.
Responsibilities: Overall project management, coordination, scheduling and financial control.

Builder: Manitoba Home Builders' Association.
Responsibilities: Construction and marketing of the home.

Designers, Engineers and Consultants: UNIES Ltd. and Appin Associates Ltd.
Responsibilities: Design of the advanced features, energy analysis and production of detailed working drawings.

Major Sponsors

The funding partners for the Manitoba Advanced House were:

Canadian Imperial Bank of Commerce
Centra Gas Manitoba
City of Winnipeg
Environment Canada (Environmental Innovations Program)
Ladco Co. Ltd.
Manitoba Energy & Mines
Manitoba Home Builders' Association
Manitoba Hydro
Natural Resources Canada

Also, approximately 50 suppliers provided products or services, frequently at a considerable discount, to the project.

1.6 TECHNOLOGY TRANSFER

In addition to its research and evaluation components, a major objective of the Advanced Houses Program was to publicize the project and transfer useful and useable information to consumers, industry groups, government departments, utilities and other interested parties. In the case of the Manitoba Advanced House, this resulted in a number of initiatives which began during the construction phase in 1992 and continue to this day. In most instances, these efforts focused on transferring the lessons learned to the various audiences.

Seminars - Important lessons from the design and construction of the Manitoba Advanced House have been incorporated into a number of industry and consumer-directed seminars. For example, in 1994 Manitoba Hydro and Manitoba Energy and Mines sponsored a series of nine, four-hour "Energy Saver" seminars around the province which were attended by about 360 people. These discussed all aspects of energy efficiency in new home construction and included numerous findings from the Manitoba Advanced House. In 1996, Manitoba Energy and Mines sponsored a similar series of nine province-wide "New Home Workshops" which drew more extensively on Advanced House materials and were attended by 167 people. In addition, Advanced House material has been incorporated into the existing "R-2000 Builder's Workshop" offered by the Manitoba R-2000 Program and into the "Residential Mechanical Ventilation Courses" offered by the Heating, Refrigeration and Air-Conditioning Institute of Canada (HRAI). Since construction began on the Manitoba Advanced House in 1992, 11 two-day R-2000 Builder's Workshops and two, one-day updates have been delivered in Manitoba along with about 12 HRAI courses. Average workshop attendance was about 20 people which means approximately 260 builders and 240 mechanical installers have been exposed to information from the project. In addition, a handful of speciality seminars have been delivered to audiences such as the Manitoba Lung Association. Thus, the total number of people who have attended these various industry and consumer seminars is well in excess of one thousand.

Tours/Open House - Numerous tours and Open Houses were conducted prior to the house being sold and occupied. Although a good head count was not maintained, it is conservatively estimated that well in excess of 3,000 people toured the home. A walk-through guide was also prepared and distributed to highlight the major features as people toured the home.

Fact Sheets - A series of 9 detailed fact sheets were prepared by Appin Associates for general distribution which discussed specific subjects ranging from the building envelope used in the Manitoba Advanced House to in-home recycling to water conservation. A complete set of the fact sheets is attached is Appendix A. One thousand copies were produced and distributed at seminars, by the project partners and through the Manitoba Energy and Mines Information Centre.

Brochure - A full-colour brochure, also attached in Appendix A was prepared which summarized the major features of the house. This was given out during house tours, at various seminars and by the project partners. An estimated 5,000 to 10,000 copies have been distributed to date.

Articles - A number of newspaper, magazine and trade journal articles have been written about the Manitoba Advanced House or about specific features of the house. A partial listing of these includes: "Winnipeg Real Estate News" newspaper (three articles), "Specifics" magazine, "1992 Parade of Homes" magazine, "Manitoba Business" magazine, "Winnipeg Free Press" newspaper, "Homes and Cottages" magazine, "Popular Science" magazine and "Fine Homebuilding" magazine.

Video - A 12.5 minute video was produced by Appin Associates which describes the project and the unique features of the house. One hundred copies were prepared and have been distributed to the project partners, industry groups and various interested parties.

Television Appearances - Appearances were made by project personnel on four occasions on public and private television stations in Winnipeg to talk about the project and discuss the Advanced Houses Program in general.

SECTION 2
DESCRIPTION OF THE HOUSE AND ITS ADVANCED FEATURES

2.1 INTRODUCTION

This Section describes the overall design of the house and provides brief overviews of its major systems and components. For each of these descriptions, comments are provided with respect to the technology's observed performance including recommendations as to whether it would be used if the house were designed again - in light of the lessons which have been learned.

It should be appreciated that the recommendations in this Section have been prepared for houses intended to meet the very rigorous Advanced House Technical Requirements. They do not necessarily apply to houses intended to meet less ambitious design goals, such as those used for conventional or R-2000 houses. Also, the recommendations in this report are directed solely at those technologies used in the Manitoba Advanced House. It is possible that other products, systems or technologies, not used in this project, might perform equally well or better. Finally, the recommendations in this Section do not reflect the fact that some of the design strategies may have indirect economic or environmental benefits (such as societal or utility savings), which go beyond those experienced by the homeowners.

Mindful of the fact that many of the products and systems used were not readily commercially available, only the most general comments are offered on the costs or cost-effectiveness of the design features.

2.2 HOUSE LOCATION AND GENERAL DESIGN

The Manitoba Advanced House was constructed in the Richmond West sub-division of Winnipeg. Architecturally, it is a two storey, 186 m^2 (2000 ft^2) structure with a two-car attached garage and is generally similar to other houses in the vicinity. A set of the original design drawings are available from Natural Resources Canada.

Design of the house's major energy-related features was carried out with the aid of the HOT2000 Version 6.02 energy analysis software and the WINDOW Version 3.1 glazing analysis program. These two software packages were used to perform numerous simulations both to verify compliance with the house's energy target and to optimize the design and prevent over-design.

2.3 CLIMATE

A few words are in order regarding the climate since the house's energy target was a function of the severity of the climate and also to give the reader a general sense of local conditions. Winnipeg has a cold, dry climate with relatively severe winters. It experiences 5889 celsius heating degree days per year (10,679 fahrenheit) and has a 97.5% winter design temperature of -33 °C (-27 °F). Precipitation averages 53 cm (21") per year and summer daytime relative humidity levels are typically in the range of 30% to 60%. The summer dry bulb design temperature is 30 °C (86 °F).

2.4 DETAILED HOUSE DESCRIPTION AND COMMENTARY

2.4.1 Building Envelope

The stringency of the Advanced Houses energy target dictated an extremely airtight and well-insulated building envelope. Since the design team had many years of successful experience with this type of construction, it was felt that the performance of the envelope could be maximized with little technical risk. The major features of the building envelope are summarized in Table 1 and described in more detail below along with a general evaluation of their performance and recommendations on their future use. Features which were deemed to be prototypes in the project are labelled as such.

Wall System (Prototype)

Description and Comments: Since the house was designed as a two-storey structure, a large percentage of the total envelope area consisted of above-grade walls. Therefore, an extremely well-insulated wall system was required. After considering conventional, stick-built double-wall construction, an innovative new system was selected. The exterior walls are constructed using a factory-built, split-stud system consisting of inner 38x64 (2x3) and outer, load-bearing 38x89 (2x4) studs connected by thin, metal pins. Plywood is used for the top and bottom plates and the rough-openings of windows and doors. The total face-to-face thickness of the studs was 305 mm (12"). Details of the wall construction are shown on Drawing A12 in Appendix B. Wall insulation consists of the Blown-In-Batt (BIB) system, using mainly glass fibre insulation - although some cellulose was used in a few locations. The nominal RSI value of the wall is 8.10 (R-46) with very few thermal bridges. Possibly because both the wall framing and insulation systems were new to the Manitoba market, a few minor installation problems were encountered. For example, glass fibre insulation had to be used in place of the originally intended cellulose fibre because of excessive settling of the latter in the thick cavities, despite the installer's use of a maximum density setting on the blowing equipment. The installer reported that he had never encountered this problem with walls of lesser thickness. Also, a minor problem was encountered with spillage of insulation between stud cavities during installation. To permit a sufficient insulation density to be produced by the blower, the wall system had to be compartmentalized by installing cardboard strips between the inner and outer studs at each stud location to create separate cavities. The insulation was then successfully blown into each cavity. No problems with bulging of the drywall were observed.

Recommendations: Recommended (both the wall framing system and the BIB insulation). However, further investigation is warranted to determine the cause of the settlement problems experienced with the cellulose insulation. Also, with an open cavity wall system of this type, consideration has to be given to containing the insulation during installation if a blown-in insulation such as glass fibre or cellulose is used.

TABLE 1
SUMMARY OF ENVELOPE CONSTRUCTION

ENVELOPE COMPONENT	DESCRIPTION
Wall construction	Factory-built, split-stud wall system. Blown-In-Batt glass fibre insulation, nominal RSI 8.10 (R-46). Stucco exterior.
Basement construction	Cast-in-place concrete. Batt and rigid glass fibre insulation. Nominal above-grade wall RSI 5.64 (R-32), below-grade wall RSI 7.20 (R-41), slab RSI 1.76 (R-10).
Ceiling construction	Truss roof, blown cellulose insulation, nominal RSI 10.57 (R-60).
Windows	Quadruple-glazed with two suspended films, 3 low-E coatings, insulating spacers and metal-clad wood frames.
Doors	Steel insulated doors, inward-opening with exterior weatherstripping, no storm doors.
Air barrier	EAT (Easy Air Tightness): combination of sealed 6-mil polyethylene, header wraps, gaskets and urethane foam.
Header sealing method	House wrap sealed to exterior wall polyethylene and to sill plate.
Cantilever sealing method	House wrap sealed to exterior wall polyethylene and to sill plate.
Partition wall at ceiling sealing method	Sealed polyethylene.
Window and door rough-opening sealing method	Urethane foam.
Electrical outlet sealing method	Plastic, airtight, electrical boxes with snap-on covers to seal to wall polyethylene.
Vapour barrier	6-mil polyethylene.

Foundation System

Description and Comments: The foundation uses a relatively conventional cast-in-place concrete wall and floor slab, as shown in Drawings A11 to A13 in Appendix B. A conventional concrete foundation was viewed as important for builder acceptance while the very high insulation levels provided the thermal performance needed to meet the energy target. Nominal insulation levels are RSI 5.64 (R-32) interior over the full wall height, RSI 1.59 (R-8) over the exterior, below-grade portions of the walls and RSI 1.76 (R-10) underneath the floor slab along with sealed 6 mil polyethylene to control air leakage. The interior RSI 5.64 (R-32) batts (consisting of RSI 2.11 batts placed vertically in the wood framing and RSI 3.52 batts placed horizontally between the framing and the foundation wall) were relatively cheap and easy to install. Thermal bridges were also eliminated. The exterior insulation system (extending from the footings to grade) provides a high quality capillary break with a side benefit of offering extra thermal resistance. In excess of three years have now elapsed since the house was constructed and the basement has not experienced any water leaks and the floor slab has remained remarkably crack free. In contrast, conventional houses in the Winnipeg area frequently leak water and almost always experience slab cracking, often to a significant degree. The use of underslab insulation has also made the floor quite comfortable. However, one problem which developed may have been aggravated by the underslab insulation. The house has proven to be vulnerable to overheating in the summer (see pg. 18). Since it does not contain a mechanical cooling system, the only opportunity that would normally exist to cool the house would be to circulate house air through the basement where it could dissipate some of its heat through the slab. With the use of underslab insulation, this opportunity does not exist.

Recommendations: Recommended. However, the use of underslab insulation eliminates the opportunity for free cooling during the summer using the underlying soil, which may increase the need for mechanical cooling.

Airtightness System and Vapour Barrier Protection

Description and Comments: The airtightness system used in the house was termed EAT (Easy Air Tightness) and consists of a hybrid of sealed, CGSB 51.34 polyethylene over the walls and ceiling, house wrap air retarder wraps around the floor headers, foamed-in-place polyurethane in the window and door rough-openings and airtight electrical boxes on exterior surfaces. The system was selected because it combined the best features of both the traditional "poly" approach and the ADA system, in terms of performance, cost and ease-of-use. Overall, the EAT system has worked quite well and was not particularly expensive. Some problems were experienced maintaining quality control at the sill plate. From an architectural perspective, the projections for windows, etc. complicated the air barrier detailing. In retrospect, it probably would have been easier to design the house in a more box-like fashion and then add the projections outside the air barrier. The biggest problem

encountered with the airtightness system was created by the large number of penetrations through the envelope for the ventilation and make-up air ductwork. These consisted of: a large fresh air duct supplying the HRV, dryer make-up air and range make-up air (and believed to be the major problem area), HRV exhaust ducts and the ducts for the three exhaust fans. The results of the initial airtightness test, conducted prior to installation of the ductwork penetrations, gave an air change rate at 50 Pascals of 0.78 ac/hr_{50}. After the penetrations were installed, this increased to 1.17 ac/hr_{50}.
Recommendations: Recommended, however the EAT system could be improved somewhat to reduce costs while still providing comparable performance. Also, some of the ductwork and resulting penetrations (such as the large fresh air duct) could have been eliminated or reduced in size which would further improve performance.

Windows
Description and Comments: The windows were designed specifically for the Manitoba Advanced House and use quadruple-glazing with three low-E coatings, two suspended films, krypton-filled spaces, insulated spacer bars and pre-finished, exterior metal-clad wood frames. They were selected from amongst several competing designs by evaluating their thermal performance using WINDOW Version 3.1. Maximum thermal resistance and relatively high solar gains were the desired objectives. After installation, one or two of the sealed units had to be replaced, otherwise no problems were encountered with the windows. However, the homeowners (both seniors) reported that the family room and ensuite both felt cold on occasion during the winter. This may have been partly because both rooms contain large expanses of glazing, although teething problems with the heat distribution and control systems may have been contributing factors.
Recommendations: Recommended, although the cost of production windows is unknown.

Doors
Description and Comments: The house uses steel insulated doors, inward-opening with exterior weatherstripping and no storm doors. Glass inserts in the doors are constructed to the same standard as the windows described above. Overall the doors have worked well. However, the front door has experienced some freezing problems in colder weather (-25 °C), along the exterior weatherstripping, possibly due to the door having been forced at some point by intruders - which may have damaged the frame. Note that inward-opening doors can be opened even when snow is piled against the door, however this necessitates locating the weatherstripping on the cold side of the door which can cause it to lose much of its flexibility in colder weather. The freezing problem was also aggravated by the house being occasionally pressurized during the 1994/95 winter by the clothes dryer supply air system (see pg. 19). The other doors in the house appear to have performed satisfactorily.
Recommendations: Recommended.

2.4.2 Mechanical Systems

The major features of the space heating, domestic hot water (DHW), ventilation and heat recovery systems are summarized in Table 2.

Heating System

Description and Comments: The space heating system is integrated with the DHW system and uses a sealed combustion, natural gas hot water tank as its energy source. Although numerous high-efficiency natural gas furnaces are commercially available for space heating, most DHW tanks are low to mid-efficiency devices. Therefore an integrated system was selected to permit high-efficiency DHW heating. The tank manufacturer's claimed seasonal efficiency is 94%. The house is divided into four heating zones, three air and one hydronic. The three air zones are supplied by a single air handler and each zone has a separate fan coil. Hot water flow to each zone is controlled by a separate zone thermostat operating an automatic valve. The single hydronic zone (the hobby room) is individually controlled by an automatic valve on the hot water line to the baseboard heater. Some problems were experienced with the hot water tank, although most of these were related to installation deficiencies, such as incorrect slope on the vent line. Ice build-up underneath the exhaust outlet occurred in very cold weather which resulted in plugging of the exhaust outlet on several occasions and automatic shut-down of the tank. Ground clearance is only about 25 cm (12"). After discussions with the manufacturer, a number of changes were made to the installation in the fall of 1995. These consisted of a) replacement of the original concentric inlet/exhaust with a separate inlet and exhaust, b) relocation of the air inlet to the opposite side of the house (to shorten the total length of piping and reduce the overall pressure drop of the system and prevent excessive cool-down of the exhaust gases), c) adjustment to the slope of the exhaust line so it drains back to the tank along its entire length (the 25 cm outdoor portion drained to the exterior) and d) insulation of the outdoor portion of the exhaust vent. The success of these measures had not been fully evaluated at the time of writing. Another problem which occurred was that the original condensate drain line had to be replaced because of corrosion.

The heat distribution system used in the house was judged as too complex from design, installation and maintenance perspectives. The three air handler zones were included for experimental purposes. However, this required separate coils, automatic valves, relief valves, thermostats, water temperature thermometers, ductwork access hatches, etc. for each zone. During the post-construction review of the house, it was also decided that a better air handler (fan/motor combination) should have been selected. The existing unit has proven to be noisier than desired despite the use of duct insulation, vibration isolators and other noise control measures.

TABLE 2
SUMMARY OF THE MECHANICAL SYSTEMS

MECHANICAL SYSTEM COMPONENT	DESCRIPTION
Heating system	Sealed combustion, natural gas hot water heater, nominal efficiency 94%, supplying heat through three fan coils and one hydronic baseboard.
Domestic hot water heating	Uses water from the space heating tank; insulating piping system with timer-controlled circulation pump.
Domestic hot water preheating	Greywater heat recovery system using a custom-built, prototype double-wall storage/heat transfer tank.
Ventilation system	Heat Recovery Ventilator (80% efficient) and intermittent use, high-capacity exhaust fans in the bathrooms.
Range exhaust	High-capacity exhaust hood, side curtains, make-up air blower.
Fireplace	Direct-vent natural gas unit with glow-bar ignition, approximately 70% efficient.

At the maximum air flow rate, power consumption by the air handler was found to be excessive (663 Watts), although at reduced flow the power draw was more reasonable (typically 175 W to 350 W). However, the reduced power consumption was achieved by lowering the power factor, not dropping the amperage - a point which may be of concern to electric utilities. The fan energy requirements in the Technical Requirements specify that the combined electrical power consumption of the warm-air heating and Heat Recovery Ventilator should not exceed 0.75 Watts per litre per second (W•s/l) of combined flow. In the Manitoba Advanced House, the corresponding value was 1.21 W•s/l if both devices are operating at high speed. More energy efficient motors, for both devices, would have been desirable.

Recommendations: The integrated hot water tank is recommended. However, the required ground clearance underneath the exhaust vent should be increased to allow more room for ice build-up. The other modifications to the system, detailed above, are also recommended. The heat distribution system is not recommended for houses of the size as the Manitoba Advance House. The house should have been designed as a single air zone. Heat distribution problems could have been controlled using proper balancing although better labelling of the balancing dampers and improved homeowners' instructions may have been desirable. The air handler arrangement is not recommended. A quieter, more energy efficient air handler should have been used (see "Ventilation System (HRV)" below).

Ventilation System (HRV)

Description and Comments: The ventilation system consists of an off-the-shelf Heat Recovery Ventilator (HRV) plus a number of high-capacity exhaust fans (discussed in "Ventilation System (Exhaust Fans)" below). The HRV has a nominal efficiency of about 80% and was chosen for this reason. An attempt was made to upgrade its performance by using higher efficiency motor/fan sets, however this could not be orchestrated with the manufacturer. Based on the monitoring data, most of which for the HRV was collected during the period from October, 1994 to April, 1995 (i.e., the heating season), the HRV was only operated 22% of the time by the homeowners, or 5.3 hours/day. Their utilization of the system was highest in the shoulder seasons and lowest during the winter. Overall, the HRV has worked very well. However, it was installed somewhat different from that recommended by the manufacturer. In a conventional installation, the control system draws the supply air from inside the house when the HRV is in defrost mode, thereby depressurizing the house since the exhaust air stream is not affected. In the Manitoba Advanced House, a by-pass duct was added between the exhaust and supply air streams so that during defrost the "indoor" air drawn in by the supply blower was taken from the exhaust air stream thereby preventing depressurization of the house. Since defrost mode only represents a small portion of the total operating time, the energy and air quality implications of this change are minor. Fresh air for the HRV is supplied through a large common duct which also supplies air for the dryer heat exchanger and range make-up air. This turned out to be a rather cumbersome arrangement which has degraded the overall airtightness of the building as the result of leakage through the ductwork. Further, this ductwork increases the building's overall thermal losses since it has a relatively large surface area and is rather poorly insulated with RSI 0.5 (R-3), nominal, compared to the rest of the building envelope. In retrospect, more insulation should have been used since it essentially is controlling heat loss between the indoor and outdoor air.

Another limitation of the ventilation system is the excessive amounts of energy required for air distribution, since the HRV discharges into the heating system ductwork and requires the air handler to operate for proper distribution. The HRV control system consists of an on/off switch in the basement, which proved an inconvenient location. High speed/low speed operation should have been manually controlled. It should be noted that conventional dehumidistats commonly used to control high speed/low speed operation on HRVs are regarded by the monitoring team as notoriously inaccurate. The use of a high-efficiency HRV, rather than a mid-efficiency unit, was regarded as a very cost-effective way to improve the overall energy performance of the house. Also, the HRV size and the mechanical ventilation rate could have been reduced from those specified in CSA F326 given the other air quality control measures used in the house. However, a more formal procedure for quantifying these changes needs to be developed.

Recommendations: In general, the ventilation system was judged to have worked satisfactorily, although some opportunities for improvement were identified. For example, an improved method of distributing ventilation air, so as to use less energy, would be desirable. Possible solutions include: Electrically Commutated Motors (or equivalent) for the air handler, use of a dedicated ductwork system for the ventilation air and a simplified distribution system using inter-zone transfer fans. The HRV control system could also have been simplified and improved. For example, a centrally located switch or dial, clearly labelled and incorporating some type of display providing feedback on the ventilation rate would have been ideal. From a design optimization perspective, the house demonstrated the value of using high rather than mid-efficiency HRVs, particularly if they can be used in lieu of envelope upgrades since these are generally much more expensive. Upgrading from a mid to high-efficiency HRV adds about 20%, or $450 (retail) to the total system cost while increasing the overall heat recovery from about 60% to near 80%. These advantages are most pronounced in larger houses since the mechanical ventilation load can represent a larger portion of the total energy load than in smaller houses. These observations are particularly relevant for houses built under the R-2000 Program or the National Energy Code for Houses (NECH). Also, procedures need to be developed to permit reductions in HRV size and ventilation rate when other indoor air quality control measures are employed. Finally, the thermal resistance of the HRV duct insulation should have been higher to reduce duct losses and improve the overall HRV system efficiency.

Ventilation System (Exhaust Fans)

Description and Comments: In addition to the HRV, the house also contains three intermittent-use exhaust fans as part of the ventilation system. These were installed to provide high-capacity exhaust capability to the main pollutant-generating zones of the house. The fans are physically located in the basement to reduce noise in the rooms which they serve and to ease sealing of the duct penetrations through the envelope (since they are accessible from grade). The fans draw from the main floor hobby room and the two second floor bathrooms. Unfortunately, the duct runs for the latter two rooms are absurdly long because the overall complexity of the mechanical system made it difficult to find a simple route for the ductwork through partition walls, etc. In retrospect, these two fans should have been installed so as to exhaust directly through the main walls on the second floor with the fans and penetration points located either in the floor system (of the second floor) or in separate duct chases. In retrospect, it also was concluded that intermittent-use bathroom exhaust fans do not have to be particularly quiet since they provide very effective acoustic masking of bathroom adventures. Another concern with the exhaust fans is the long-term effectiveness of the backdraft dampers. Most dampers used in such applications are rather crude with unknown performance and life expectancy. Although the design team was not aware of any detailed performance data, they felt an improved design was probably warranted.

Recommendations: The exhaust fan arrangement is recommended but with qualifications. The exhaust fans should have been located in the rooms which they serve and ducted directly out through the walls (but not into the attic since it is too vulnerable). An improved design for residential exhaust dampers may also be needed.

Domestic Hot Water Heating

Description and Comments: A major concern of the design team was to minimize DHW heating energy since this is one area which has received comparatively limited attention by most designers of low-energy housing. The DHW system used in the Manitoba Advanced House is integrated with the space heating system and draws its water directly from the hot water tank. There is also a DHW circulation loop, with fully insulated water lines (using slip-on foam sleeves) and a timer-controlled circulation pump. The system has worked very well to date. The pipe insulation is an inexpensive method of reducing DHW system losses, particularly because of the continuous circulation feature of the system. If the circulation system were to be operated continuously, the line losses would be about 2000 kilowatt-hours per year (kWh/year), although about half of this would occur during the heating season and hence offset the heating load. As an aside, if the house had been designed as an all-electric structure, an alternative DHW system using a large, electric tank and off-peak power would probably have been used.

Recommendations: Recommended.

Greywater Heat Recovery System (Prototype)

Description and Comments: This is one of the prototype systems developed especially for the Manitoba Advanced House and is described and analyzed in more detail in a separate report (Proskiw 1995), the major details of which are summarized here. The greywater system was included to meet the previously-stated objective of minimizing DHW energy consumption. It recovers energy from waste water which would otherwise be lost and uses it to preheat the incoming mains water before it reaches the primary DHW heating system. Using data gathered from field tests performed on the prototype, coupled with an analysis of the maximum theoretical savings achievable by such systems, a thermal simulation model was developed which is capable of predicting the performance of greywater systems for various design configurations and operational conditions. The analysis showed that the maximum possible savings which could be achieved by an ideal greywater system are a function of the inlet water and greywater temperatures, DHW tank setpoint, DHW load and tank efficiency. A general procedure was also developed for estimating the maximum theoretical savings for specific applications. Using typical values for the input parameters, the analysis found that the maximum theoretical savings which a residential greywater heat recovery system could achieve would be about 50% of a typical family's annual DHW load. The simulation model was also used to predict the technically achievable savings from various greywater systems, i.e., the savings which would result using an actual, rather than ideal, system. Using typical operating and environmental conditions, the practical performance limit for a greywater system was found to be about 42% of the annual DHW load. Such a system would be similar to the prototype used in the Manitoba Advanced House but with increased tank insulation, reduced greywater mass, increased cold water mass and an increased heat transfer coefficient between the cold water and greywater. The impact of a number of design and operational variables was also studied using the model and categorized as having either a minor or major impact on system performance. Minor variables were found to be: tank insulation levels (provided a minimum level is used), greywater mass and room temperature. Major variables were: cold water mass, cold water inlet temperature, greywater temperature, DHW tank setpoint, AU1 (the overall heat transfer coefficient between the cold water and the greywater), the greywater and cold water flow rates (acting together) and the greywater flow rate (acting in isolation). It was also concluded that the success of a greywater heat recovery system depends as much, or more, on proper selection of the application as it does on the design of the system. Ideal applications are those which have large DHW loads and have not, or can not, take advantage of conservation measures designed to reduce DHW consumption.

Recommendations: Recommended. Although this technology is still at a relatively early stage of development, we believe it has significant potential for wide-scale application. In many respects its evolutionary state is akin to that which Heat Recovery Ventilators were in 15 years ago.

BGHRV (Prototype)

Description and Comments: The Below-Grade Heat Recovery Ventilator is a novel concept which was included for both research and demonstration purposes. In its most general form, it uses an exhaust air stream from the house to reduce below-grade foundation losses by ducting the air into the existing weeping tile system around the perimeter of the structure. The version installed in the Manitoba Advanced House uses attic air as the energy source (since all other significant exhaust air streams employ heat recovery) and ducts it into the sump pit. Since the weeping tiles also enter the sump pit (above the water trap), the heated air is free to flow around the foundation. Unfortunately, the system is designed to blow attic air into the weeping tiles whenever the temperature in the attic is sufficiently high (approx. 40 °C), regardless of the season. The system in the Manitoba Advanced House has experienced problems due to leakage of humid sump air into the attic resulting in significant attic condensation. This occurred due to the failure of a motorized duct damper in the attic to seal properly. Overall, the attempt to use attic air as the source of heat was too problematic. It was concluded that the best energy source for a BGHRV would be an exhaust air stream from a conventional exhaust-only ventilation system which does not utilize heat recovery. Although attic air is available at higher temperatures than exhaust air, this only occurs for a limited portion of the year. Also, the practical problems of drawing attic air through the house to the sump pit, and the repercussions of reverse air leakage into the attic, make the use of the attic as an energy source unnecessarily risky.

Recommendations: The BGHRV concept is worthy of further investigation, but in more appropriate applications, such as houses with exhaust-only ventilation without heat recovery.

Natural Gas Range Exhaust and Make-Up Air System

Description and Comments: To demonstrate a method of providing range make-up air in houses with spillage-susceptible appliances, a dedicated make-up air blower system was installed. The natural gas range uses a high-capacity exhaust hood, complete with side curtains to improve capture efficiency. To prevent excessive depressurization of the house, a make-up air blower complete with electric preheater was installed. Make-up air is ducted to the back of the refrigerator compartment so waste heat from the refrigerator's condenser coils can provide further preheating of the make-up air and aid heat dissipation from the refrigerator. However, based on our experiences with the house the range make-up air system cannot be judged a success. The make-up air preheater was very expensive and the controls are problematic (actually, they are not a problem because the homeowners hardly ever use the system). The concept of bringing make-up air to the backside of the fridge has also been very troublesome. The fridge compartment tends to get hot in the summer causing concern to the homeowners because the fridge runs somewhat longer than it otherwise would. If used in the winter, the make-up air system causes cold drafts in the kitchen near the fridge.

Recommendations: The make-up air system originally installed is not recommended because of the excessive cost, complexity and problems which it created. For other houses, upgrading spillage susceptible appliances to non-spillage susceptible types, and installing a good soil gas barrier if needed, would likely be cheaper than providing make-up air. There would also be significant energy savings.

Cooling System (Prototype)

Description and Comments: As an experiment, the house was designed without a mechanical cooling system to see if this significant capital cost could be eliminated. Although the house has a large amount of south-facing glazing, it also makes extensive use of external overhangs to reduce summer gains. In addition, exterior window shade screens were provided which block out most of the incident solar radiation when installed. Energy efficient lighting was also used to reduce the internally generated heat. Despite these measures, the house

overheated in its first two summers of operation. Basically, once the house got hot, it stayed hot. Part of the explanation for the overheating problem is believed to be the result of the very high levels of basement insulation, particularly under the floor slab. In a conventional house, without underslab insulation, this would constitute a source of coolness which could be distributed to the rest of the house by the air circulation system. In the Manitoba Advanced House, the use of RSI 1.76 (R-10) insulation under the entire slab precluded this option. The addition of a portable dehumidifier in the late summer of 1994 improved comfort levels somewhat. Nonetheless, a mechanical cooling system will probably be retrofitted into the house. Alternative, low-energy cooling systems which could have been considered include a ground-coupled water loop under the basement floor connected to a coil in the ductwork (although the extra fan energy would have to be considered) or a heat pump DHW preheater which uses indoor air as a source of energy for domestic hot water heating.
Recommendations: Overheating has proven to be a major problem. Some form of active cooling system would be considered for future houses built in this fashion.

Dryer Heat Exchanger

Description and Comments: To recover some of the energy used by the clothes dryer, a commercial-grade, stainless steel heat exchanger was installed on the dryer outlet which preheats the incoming make-up air using the dryer's exhaust air. Unfortunately, the system has proved to be expensive to construct and has suffered numerous teething problems such as cold drafts, noise, etc. Maintenance of the heat exchanger (to remove lint from the heat exchanger surface) has been difficult at best and the physical space taken up by the unit and associated ducting is considerable. Give the modest energy requirements of the dryer, the whole system is now regarded as unnecessary.
Recommendations: Not recommended.

Fireplace

Description and Comments: The fireplace selected for the house is a direct-vent, natural gas unit with a glow-bar ignition system and a claimed efficiency of 70%. Although this is lower than the efficiency of the heating system, market forces dictated that a fireplace had to be included in the house. An analysis was carried out during the design phase to estimate the energy impact of a standing pilot versus a glow-bar ignition. This showed that the energy consumption of a standing pilot was of the same relative magnitude as the total heating load of the house! Hence the decision to use a glow-bar. Another concern with the fireplace is air leakage. After installation, the unit was checked during the routine airtightness test and no significant leakage could be detected. However, the homeowners have reported some comfort problems near the fireplace which they attribute to air leakage even though they subsequently sealed the air intake/exhaust vent. Some small holes were also sealed in an attempt to alleviate the problem. It is now believed that the fireplace creates a cool zone

in the room during the winter because the inner glass surface of the fireplace becomes quite cold and creates a radiation sink. Outdoor air circulates by thermosyphon action through the air inlet into the combustion chamber and out through the air exhaust loop even when the unit is not in operation. This keeps the glass surface relatively cold.
Recommendations: Further study of direct-vent fireplaces is recommended to identify their impact on comfort levels as the result of radiation from the house interior to the cold surface of the glass. Also, it might be appropriate for the standards body responsible for fireplaces to consider including performance tests on air leakage as part of their test procedure. Finally, glow-bar ignition systems are strongly recommended over standing pilot units.

2.4.3 Lighting and Electrical System

The overall installed lighting levels in the house were about one-third higher than suggested in the Commentary of the Advanced Houses Technical Requirements: 10.6 Watts per square metre (W/m^2) vs. the recommended 8 W/m^2. However, the average lighting output was superior to the suggested values: 46 lumens/W vs. the recommended value of 40 lumens/W.

Fluorescent Lighting
Description and Comments: T-8 bulbs with electronic ballasts were used in various locations. Generally, they have been found to give good colour rendition. However, the homeowners report some television interference problems in the family room.
Recommendations: Recommended.

Dimmable Ballasts
Description and Comments: These were used on some of the T-8 fluorescents lights. However, they were quite expensive, averaging about $200 each vs. $30 to $40 for a conventional, non-dimming electronic ballast, although current costs are believed to be lower.
Recommendations: Recommended for demonstration purposes only, at these prices.

Compact Fluorescent Lighting
Description and Comments: These were used in the hall and various other locations. They have worked well although their initial cost is significant.
Recommendations: Recommended for high utilization fixtures.

Halogen Lighting
Description and Comments: These were used in select fixtures. A 50 W, 2000 hour halogen bulb with screw base costs approximately $10 (although costs are quite variable) versus 50¢ for a conventional incandescent bulb. They provide good colour rendition and appear well suited to task lighting.

Recommendations: Recommendation for demonstration purposes only, at these prices.

EMF Control Measures

Description and Comments: As an experiment, the house was built with features to reduce the strength of electromagnetic fields (EMF). The most significant measure consisted of isolating the houses's electrical system from the water mains to reduce spurious ground current flows through the plumbing system. However, tests on the effectiveness of the system were inconclusive because the background magnetic field strength in the house was very low. Based on a review of the literature, the concept appears to have merit.
Recommendations: Further study recommended.

2.4.4 Indoor Air Quality Control

Air Filtration

Description and Comments: Controlling concentrations of airborne particulates was seen as a goal which could be relatively easily attained by applying commercial/industrial technology to a residential application. The air handling system contains an 85% efficient bag filter (based on particulate removal capability), suspended vertically along with a 25 mm (1") thick pre-filter. The bag filter would probably represent overkill for most consumers since it is quite large and has a high pressure drop which imposes a significant energy penalty on the air handler. The vertical installation which was used complicated the ductwork although horizontal installation kits were subsequently found to be available. A less efficient filter, say a 40% to 60% efficient unit, would have simplified the installation and still provided a quantum leap over a conventional furnace filter which only has an efficiency of about 5%. If the air handler flow rates could have been reduced, the pressure drop (and hence air handler energy requirements) would have also declined. The cost of replacement filters is under $100 and the recommended replacement schedule is once per year which could prove expensive for many consumers. However, it is worth noting that the measured particulate levels in the Manitoba Advanced House were quite low suggesting that the bag filter achieved its objectives (see Section 8). Since a filter essentially converts electricity into cleaner air, it is probably worthwhile to use an energy efficient furnace motor in conjunction with high performance filtration because of the filter's high pressure drop.
Recommendations: Recommended with qualifications. Only homeowners with severe air quality concerns should need an 85% bag filter. However, many might be able to benefit from mid-efficiency units (40% to 60%). These are less expensive and easier to incorporate into the ductwork system but would still represent a major improvement over conventional furnace filters whose efficiency is only about 5%. Energy efficient furnace motors are also recommended in conjunction with high performance filters to control energy costs.

Activated Charcoal Filter
Description and Comments: A 25 mm (1") thick charcoal filter was installed in the air handler ductwork. Based on comments made during the open house period, potential users need to understand that charcoal filters remove odours and gaseous chemicals from the air, not dust. The recommended replacement schedule for the filter is once per year which could be a little expensive for some consumers.
Recommendations: Recommended for people with chemical sensitivities.

Hobby Room
Description and Comments: The hobby room was intended to be used for those activities which might produce unusual levels of pollutants inside the house such as hobbies, smoking or even functions related to the use of the room as a home office. It is served by an exhaust-only ventilation system which depressurizes it relative to the rest of the house when the door to the room is closed. Pollutants produced can therefore be contained within the room. Pressure differential testing confirmed that the room is depressurized once the door is closed.
Recommendations: Recommended, the concept is especially useful for people with chemical sensitivities and in houses which contain both smokers and non-smokers.

Low Emission Finishes
Description and Comments: Because of concerns about particleboard off-gassing, a waterborne, acrylic, low emission finish ("Crystal Aire") was used on the edges of exposed particleboard on the kitchen cabinets. This product seals the surfaces and absorbs VOCs (volatile organic compounds). Application of the product proved to be rather labour intensive (partially because it was a special order), even under factory conditions. This could probably be improved upon with more widespread use of the product. The sealer appears to be working effectively because measured VOC levels are low.
Recommendations: Recommended, with qualifications. Sealers of this type are probably best suited for problem areas. For complete cabinet/furniture sets, alternate approaches (such as low emission pressed board products) might be cheaper.

Cabinet Exhaust System
Description and Comments: Since some odour-and-pollutant-generating products generally have to be kept in the house, one of the kitchen cabinets was equipped with an outlet to the exhaust side of the HRV. This depressurizes the cabinet space and prevents odours and pollutants from escaping into the house. Although no testing was done, the concept appears to be workable. It is suitable for storage bins and cabinets containing potential pollutants (paints, finishes, etc.), compost pails, etc. Some design guidelines on enclosure tightness are required.

Recommendations: Recommended. However, design guidelines need to be established.

Closet Return Air Grilles

Description and Comments: In several rooms, the heating system return air grilles in several rooms were located in closets so that pollutants emitted by clothes could be removed before they entered the room. The return air is then circulated through the air filtration system. The concept has worked well although grille placement is important. To prevent clothes or dry-cleaning plastic bags from getting sucked against the grille face, the grilles have to be located on either the back wall of the closet or on the end wall above the clothes. It also works best with open shelving such as the metal grille type.

Recommendations: Recommended.

2.4.5 Water Conservation

Low Flow Showerheads

Description and Comments: To reduce both water and DHW energy consumption, various types of low flow showerheads were used in the house. They appear to be working satisfactorily, even though their measured flow rates were slightly above that permitted in the Technical Requirements (see Section 9).

Recommendations: Recommended.

Infrared Faucets

Description and Comments: With these devices, water flow is activated by the presence of the user's hand near a sensor on the faucet which automatically turns off the faucet when the hand is removed. The units are very expensive for a residential application (approx. $200). They are also rather troublesome when filling containers with water since the sensor shuts off the faucet because the container is not interpreted as a source of heat. Another problem is that the faucet sometimes stays on if the sun happens to be shining on the sensor head.

Recommendations: Not recommended, other than for special needs applications (e.g., handicapped).

Double-Flush Toilet

Description and Comments: One of the largest consumers of water in a house is a conventional toilet. Since one of the toilets used in the house was a conventional unit, a special water-saving kit was retrofitted onto the unit. The kit, which is commercially available, permits two different volumetric flush rates to be selected by the user, depending on the need. However, flow rates were measured under both conditions and found to be very similar: low volume flush rate 15.0 litres (3.3 I.G.) per flush, high volume rate 16.3 l (3.6 I.G.) per flush. It should be noted though, that the unit installed for the test had been

adjusted for minimum savings at low flow since the house was expected to be heavily loaded with people during the demonstration phase.
Recommendations: Recommended, if further testing can demonstrate water savings.

Pressure-Flush Toilets
Description and Comments: These toilets use pressurized water rather than gravity for their operation. Unfortunately, the units installed in the house proved to be very troublesome. The high pressure water hose ruptured on two or three occasions, always at the same spot, resulting in water damage to the house. Presumably a redesign of the faulty component would solve the problem. The unit is also quite noisy and can be rather startling to the unsuspecting.
Recommendations: The current design is not recommended. A better alternative might be a gravity-fed, ultra-low flow toilet.

Reduced Turf
Description and Comments: Depending on the landscaping plan, grass and plantings can be a huge consumer of water particularly in semi-arid regions such as the prairies. Indigenous plants and other ground coverings were used for landscaping with only minimal use of conventional turf. This has worked very well and the plants appear to be drought resistant. Visually, the yard stands out relative to others in the neighbourhood which make extensive use of conventional turf. There is some debate whether this is a positive or negative feature.
Recommendations: Recommended.

2.4.6 Resource Conservation
Stone/Glass Drainage
Description and Comments: To demonstrate a practical application for recycled glass, a mixture of 30% recycled glass and 70% stone was used in lieu of the conventional pea gravel beneath the floor slab and for the drain stone over the weeping tiles around the perimeter of the foundation. Processing of the waste glass was a bit of a problem, although there was no shortage of waste glass. Otherwise the system worked fine. A sieve analysis was conducted on a sample of the mixture which showed that it met the requirements in the National Building Code. Surprisingly, there were no safety or handling problems with the stone/glass mixture, in fact it could be comfortably handled with bare hands. Any type of clear or coloured glass can be used.
Recommendations: Recommended. However, some additional research is needed to determine the appropriate stone/glass ratio; perhaps 100% glass could be used.

Floor Trusses and Beams
Description and Comments: Several measures were taken to reduce the amount of large

dimensioned lumber normally found in new homes. The main floor uses 305 mm (12") deep open web floor trusses with a 16 mm (5/8") tongue and groove, exterior-grade plywood sub-floor. The main floor beam consists of a 2-ply microlaminated built-up wood beam. The second floor uses 302 mm (11 7/8") deep plywood "I" joists with a 16 mm (5/8") tongue and groove, exterior-grade plywood sub-floor. These types of floor trusses have the advantages of being more dimensionally uniform, less susceptible to shrinkage and are more resource efficient. No problems were encountered during construction or operation.
Recommendations: Recommended.

Recycled Furniture
Description and Comments: As a demonstration, several of the furniture pieces used for display purposes were recycled, repaired and refinished for the project. It is believed that the costs were a little expensive; otherwise the recycled furniture worked fine.
Recommendations: Recommended, although the use of recycled furniture is largely a matter of personal choice.

Cork Flooring
Description and Comments: Cork flooring (a sustainable product), coated with a urethane finish, was used in the living and family rooms. The cork surface sustained some damage during the open house phase of the project (when traffic levels were quite high at times) and seems to be particularly vulnerable to women's spike heels.
Recommendations: Recommended for low traffic applications.

Pine Shake Roof
Description and Comments: Pine shakes were used on the house, rather than conventional petrochemical-based asphalt shingles. To date, no roof leaks or other problems have been encountered. The roof has experienced at least one torrential downpour, with no problems. The appearance is very pleasing.
Recommendations: Recommended, although experience is limited to date.

2.4.7 Household Recycling
Multiple-Bin Recycler
Description and Comments: This device, which can be likened to a laundry chute - only for recyclables, permits products to be transferred from the kitchen directly to storage bins in the basement. It has a selectable control which allows the user to dial the type of product being recycled (e.g., glass, aluminum, etc.) so that the chute directs the product into one of four bins. The device works great, is relatively inexpensive and was extremely popular with visitors during the open house. The only complaint is that it has to be mounted in the bottom shelf which requires the user to bend down every time the recycler is used. Also, the benefit

of a multiple bin selector would be lost if there is no need to sort recyclables (as is the case for the recycling program which the City of Winnipeg recently introduced).
Recommendations: Recommended, although a re-design of the unit is required so the opening can be installed at counter level.

Kitchen Compost Storage
Description and Comments: To expedite recycling of kitchen waste, this unique design feature was included. It consists of a pail in a sealed storage bin in the kitchen which is fed through a hole in the counter-top. The bin is emptied through an access hatch outdoors. The outside access was a little expensive to construct (since everything had to be hand built) and caused some nuisance problems during construction. In retrospect, the design should have used a through-the-counter opening with a clean edge (e.g., commercial kitchen style) with an indoor access door and storage compartment depressurized by the HRV. The pail could still be installed tight under the counter with the re-design.
Recommendations: Recommended, but with indoor access provided to empty the compost pail, and with the storage space depressurized.

2.4.8 Appliances
Natural Gas Range
Description and Comments: The range is a conventional type, i.e., it vents directly into the living space and does not use a sealed combustion arrangement. No air quality problems have been observed or reported to date.
Recommendations: Recommended, although further research on range venting is warranted.

Natural Gas Dryer
Description and Comments: A standard natural gas clothes dryer was installed. No problems were encountered although the dryer heat recovery system, discussed on pg. 19, should have been eliminated.
Recommendations: Recommended.

Power Indicator
Description and Comments: Research has shown that homeowners can successfully control their household energy consumption when they receive continuous, real-time feedback on their energy usage. This novel product displays information on electrical energy usage using an optical tap which is affixed to the utility power meter. The concept is good, although the product used on the Manitoba Advanced House could be improved. The optical pick-up is tricky to position and is susceptible to dislodgement from pedestrians. Also, the display is far too complicated for most people to program and read. A simpler system which provides a highly visible, qualitative indication of power usage would be preferable.

Recommendations: Not recommended for general use until an improved and simplified version is developed.

Natural Gas Refuelling Station

Description and Comments: An electrically driven, natural gas refuelling station, for use with a natural gas vehicle, was also included in the design. The refuelling station was installed for the open house period only and was not used other than for demonstration purposes. However, this limited experience showed that careful attention has to be paid to code requirements for installation. The system is intriguing but will require a careful analysis, particularly of the amount of electrical energy needed to compress the gas since this can be considerable.

Recommendations: Recommended, with qualifications. Further research and analysis is required before a more detailed commentary can be provided.

SECTION 3
CONSTRUCTION OF THE MANITOBA ADVANCED HOUSE

3.1 CONSTRUCTION SCHEDULE

This Section briefly reviews the construction phase of the project. Construction of the Manitoba Advanced House began in the spring of 1992. Although the house was not totally finished, it was officially opened on September 11, 1992 and kept available for public display for approximately six months. Substantial completion of the house did not occur until about July, 1994.

3.2 DESIGN CHANGES

A set of the original design drawings are available from Natural Resources Canada. In general, construction of the house proceeded in accordance with the original design. The only significant changes between the original design and the finished house were:

- The original landscaping design, which used extensive amounts of plantings, bushes and trees, was greatly simplified to save costs.
- The exterior water collection system and sump water recycling system were eliminated to save costs.
- The asphalt shingles, which were originally planned for the entire roof, were replaced with pine shakes to reduce the use of a non-renewable, oil-based resource.
- The range make-up air heater, originally intended to use a glycol loop running through a heat exchanger and drawing heat from the space heating hot water tank, was replaced with an electric duct heater (to save costs and reduce complexity).
- The attic exhaust air heat recovery system was grossly simplified, so that rather than extracting heat from the attic to use in the DHW preheat system, it was simply ducted into the house's weeping tiles. This reduced costs and complexity and only had a minor impact on the overall performance of the DHW preheat system.
- A few minor interior architectural changes were also made.

3.3 OVERALL COMMENTS ON THE CONSTRUCTION PROCESS

From a technical perspective, the construction schedule was compressed too much in an effort to meet the official opening date. Although the house was largely (but not substantially) finished for the opening, the pace of activity, the density of tradesmen in the house at any given moment during the final few weeks, and the need to make numerous on-the-spot decisions on complex issues, created problems, extra costs and quality control implications.

It is also felt that extra costs were incurred as the result of the accelerated schedule. During the construction of a conventional house, the pace of construction can be increased (to some extent) because all of the required steps are relatively well defined since most houses differ only in their architectural features. In the case of an Advanced House, which tends to be much more complex and integrated (such that a decision affecting one part of the house can have far-reaching consequences), this becomes much more problematic. Many of these problems could have been eliminated or somewhat reduced in magnitude if the initial design could have been tendered to get a more accurate estimate of the total costs, and then modified as appropriate, before construction began. With the Manitoba Advanced House, this resulted in increased construction costs, particularly for the mechanical systems.

The mechanical system also used many components designed for the commercial, as opposed to the residential, market. Commercial-grade products are often much more expensive than their residential counterparts because they are designed to higher standards in order to survive the more arduous operating conditions of commercial establishments. Examples of commercial products which were used included: the dryer heat exchanger, some of the blower controls, the electric pre-heat coils for the make-up air system, etc.

In addition, any design which incorporates so many unique features is particularly vulnerable to problems which were not considered or anticipated at the design stage. It would have been very beneficial to have had the opportunity to "sleep on the design" to identify opportunities and thereby reduce costs, improve performance, reduce conflicts, etc. Although a firm figure is not available, it is estimated that the accelerated construction schedule, coupled with the inability to calmly review the initial design, probably added significantly to the total cost of the house. Future projects of this sort would benefit greatly from the availability of extra time at the design stage even though this may create conflicts with the project's overall schedule.

SECTION 4
TECHNICAL COMPLIANCE AND PERFORMANCE PREDICTIONS

4.1 INTRODUCTION

This Section describes the detailed calculation of the energy target for the Manitoba Advanced House and provides a brief overview of the major technical criteria contained in the Advanced Houses Technical Requirements. It also compares the energy target to the predicted energy consumption calculated during the design phase of the project. Detailed comparisons between the program targets and the measured performance of the house are contained in later Sections.

Prior to reviewing this material, some comments are required on the process by which compliance with the energy target was determined. From a technical perspective, the most important objective of the Advanced Houses Program was to push the limits of residential energy efficiency technology by establishing a quantitative energy performance target which all Advanced Houses had to be designed to meet. The energy target, as defined in the Technical Requirements, is the sum of six individual sub-targets for: space heating, space cooling, domestic hot water heating, appliances, lighting and the outdoor electrical loads. It is calculated based on house size, occupancy, climate and the type of space heating fuel which is used. This approach is similar, although more comprehensive, to that employed by the R-2000 Program which uses an energy performance target for the space heating and domestic hot water loads only. Also, the Advanced Houses energy target is about 50% of the R-2000 energy target.

4.2 TECHNICAL COMPLIANCE CHECKLIST

Appendix C contains the detailed Technical Compliance Checklist which summarizes the major features of the Manitoba Advanced House with respect to the Technical Requirements.

4.3 ENERGY DESIGN AND ANALYSIS SOFTWARE

The Advanced Houses Program required candidate houses to be evaluated using a suitable energy analysis model, supported as necessary by other software and engineering calculations. Most design teams, including the Manitoba team, used HOT2000 since it is used extensively by the R-2000 Program for compliance verification, and has been used in numerous studies of residential energy performance. HOT2000 was first developed about ten years ago and has been continuously refined since that time. During the design phase of the project, the latest edition of the program then available was used - Version 6.02. However, to perform the analysis described in this report, a more recent edition of HOT2000, Version 7.10, was employed. This uses some significantly different procedures and algorithms to calculate many key components of a house's energy usage, most notably the air infiltration/mechanical ventilation model, the thermal bridging of opaque elements and the DHW load. Ostensibly, the accuracy of Version 7.10 (i.e., its ability to predict energy usage) is superior to that of Version 6.02. While improved accuracy is highly desirable, it creates a problem from an analysis perspective because Version 7.10 tends to predict higher energy usage than Version 6.02.

As a result, a house designed to meet the Advanced Houses energy target, when analyzed using Version 6.02, would likely not meet the target when analyzed with Version 7.10. The effects and implications of this issue will become apparent when they are discussed in more detail in Section 6.

4.4 ENERGY TARGET AND PREDICTED ENERGY CONSUMPTION

The target and sub-targets for the Manitoba Advanced House are shown in Table 3. The energy target is a function of climate, specifically the number of heating degree-days. The predicted total energy consumption estimated using HOT2000 Version 6.02 with default weather data, was 17,156 kilowatt-hours, equivalent, per year (kWh_e/yr). For comparison purposes, the R-2000 energy target was also calculated for the house and found to be 30,773 kWh_e/yr.

TABLE 3
ENERGY TARGETS

	ENERGY TARGET (kWh_e/yr)	PREDICTED ENERGY CONSUMPTION USING HOT2000 VERSION 6.02 (kWh_e/yr)
Space heating (Qs)	7,303	5,934
Space cooling (Qc)	0	0
Domestic Hot Water (Qw)	5,520	3,167
Appliances (Qa)	3,838	7,520
Lighting (Ql)	352	352
Outdoor electrical usage (Qo)	183	183
Total	17,196	17,156

4.5 OTHER ENERGY-RELATED GOALS

Airtightness

The airtightness goals specified in the Technical Requirements were the same as those of the R-2000 Program: the Normalized Leakage Area (NLA) could not exceed 0.7 cm^2/m^2 or the air change rate at 50 Pascals (Pa) could not exceed 1.5 ac/hr_{50}.

Ventilation System

All mechanical ventilation systems had to be designed and installed in accordance with CSA F326 "Residential Mechanical Ventilation Systems". This is the same requirement used by the R-2000 Program.

Fan Energy

For houses with forced-air heating systems, the electrical power consumption for the combination of the heating system and HRV could not exceed 0.75 W•s/l of combined air flow. Higher values (energy use per unit air flow) were permitted for houses without forced-air systems.

Lighting

Aside from the lighting target, which was calculated on the basis of house volume, the Technical Requirements also specified that the total installed electrical lighting capacity could not exceed 8 W/m^2 and that the average lighting output for all fixtures had to be greater than 40 lumens/W.

4.6 INDOOR ENVIRONMENT

Another goal of the program was to improve the quality of the indoor environment, specifically in terms of air quality, thermal comfort and noise. As discussed in Section 2, low emission products and finishes were to be used wherever possible along with a high quality ventilation system. Also, every attempt was to be made to meet the "Exposure Guidelines for Residential Indoor Air Quality" developed by Health and Welfare Canada. Results of the indoor air quality testing are discussed in Section 8.

4.7 WATER CONSUMPTION

The Technical Requirements did not contain an overall, quantified water usage target for the entire house. Rather, a set of five requirements for fixture water usage, appliance type and landscaping were specified. The Manitoba Advanced House was designed to satisfy these criteria. To check the installed performance, water flow rates were measured after the house had been completed. The results are discussed in Section 9.

4.8 ENVIRONMENTAL FEATURES

The Technical Requirements specified that provision be made for recycling (compost as well as household products), recycled materials had to be used in the construction process wherever possible, construction waste be minimized through a waste control program and that no insulation products which contained fluorocarbons could be used in the design of the house.

SECTION 5
MONITORING PROGRAM

5.1 BACKGROUND

A key aspect of the Manitoba Advanced House project was development of a detailed, custom-designed, monitoring program to provide feedback on the performance of the house relative to its targets, other Advanced Houses and to conventional houses, particularly those in Manitoba. Monitoring was performed by Proskiw Engineering Ltd. of Winnipeg, with the assistance of Howell-Mayhew Engineering Ltd. of Edmonton, the National Monitoring Coordinator for the Advanced Houses Program, along with SAR Engineering of Vancouver.

5.2 OBJECTIVES

The primary objectives of the Manitoba Advanced House monitoring program were to:

1. Determine the overall energy consumption of the house and its major components during a one year monitoring period.
2. Compare the measured energy consumption with the predicted energy usage and comment upon the differences between the two.
3. Assess the indoor air quality of the structure, relative to objective standards and other houses.
4. Evaluate the performance of the various prototypes and other unique features which were incorporated into the house.
5. Provide an overall commentary on the performance of the house and offer recommendations on how it could be improved in future Advanced Houses.

5.3 DESCRIPTION OF THE MONITORING PROGRAM

The monitoring program consisted of three phases, which extended over both the occupied and unoccupied periods:

Phase 1. Continuous monitoring, for the entire monitoring period, of several key variables.

Phase 2. A series of once-only tests conducted on the various prototypes and innovative features.

Phase 3. Indoor air quality measurements performed during both the occupied and unoccupied periods.

The monitoring program employed a system designed to record several dozen key performance variables using manual meter readings, spot measurements and Sciemetric Instruments 641 and 321 Data Acquisition Systems (DAS) operating under the control of Co-Pilot software. Detailed data processing was performed using custom-built EXCEL spreadsheets. Variables which were monitored were mainly those associated with energy usage and included zone temperatures, environmental conditions (solar, temperature, relative humidity), gas and electricity usage, electrical motor operation, HRV operation, etc. This is described in more detail in the "Manitoba Advanced House Monitoring Plan", attached in Appendix D.

Results of the monitoring program are presented in Section 6 (energy performance), Section 7 (once-only tests) and Section 8 (indoor air quality).

SECTION 6
ENERGY PERFORMANCE

6.1 OVERVIEW

This Section of the report analyzes the measured energy performance of the Manitoba Advanced House and compares it to both the predicted performance and to the performance of conventional and energy efficient (R-2000) houses. The analysis focuses on overall house performance, with less of an emphasis on the behaviour of individual components since these are more strongly influenced by the homeowners' unique lifestyle. In contrast, the effects of occupancy can be accounted for, to some extent, when dealing with the complete house.

Energy consumption was monitored for a one-year period extending from Sept. 1, 1994 to Sept. 1, 1995. During this time the house was occupied by two adults. Weather during the period was comparatively mild relative to long-term averages, with 5,492 celsius heating degree-days being encountered, relative to the long-term average of 5,889.

6.2 ANALYSIS PROCEDURE

The energy analysis used a combination of measured energy consumption data and other related information collected during the monitoring period coupled with a series of computer simulations performed using HOT2000 version 7.10. The modelling used the following process. Building data (component areas, construction details, etc.) were entered into HOT2000 using information collected from the construction drawings and knowledge of the house. Information on the operational characteristics of the house (i.e., actual weather, interior temperatures, ventilation system usage, base loads, occupancy, etc.) were then entered. Table 4 summarizes the data sources for the major input variables.

Once the initial data input had been completed, results of the HOT2000 simulations were compared to the actual energy usage measured during the monitoring period using data from the natural gas and electrical meters. The HOT2000 input data was then adjusted to reconcile the measured and predicted results to achieve an exact match. This process of reconciling input variables has been successfully used in other studies to evaluate the performance of many types of houses. Obviously, if the model (consisting of HOT2000 and the input data) exactly captured reality, then the predicted energy usage would have exactly equalled the measured usage. This did not occur, nor does it ever occur in exercises of this type. The major difficulty is deciding which input variable(s) to modify since it is always possible to force a perfect match using a sufficiently intrusive procedure. However, there has to be a rationale for modifying the inputs. In other studies in which this approach has

TABLE 4
SOURCES OF HOT2000 INPUT DATA

COMPONENT	SOURCE OF DATA
Envelope areas and RSI values	Construction drawings
Window RSI values and shading coefficients	Enermodal Engineering (1993)
Envelope airtightness	Airtightness test
Interior temperatures	DAS[1] (continuously monitored)
Outdoor temperature	DAS[1] (continuously monitored)
Solar radiation (horizontal)	DAS[1] (continuously monitored)
Wind	Winnipeg International Airport data
Ventilation system air flow rates	DAS[1] (continuously monitored)
Ventilation system electrical usage	DAS[1] (continuously monitored)
HRV efficiency	HVI[2] test data
Total indoor electrical load	House meters
Indoor lighting electrical load	House meters
Indoor appliance electrical load	House meters
Outdoor electrical load	House meters
Domestic hot water consumption	House meters
Greywater system efficiency	Predicted using greywater model
Heating system efficiency	Manufacturer's data
DHW system efficiency	Manufacturer's data

Notes:
1. DAS = data acquisition system.
2. HVI = Home Ventilating Institute.

been employed, indoor temperature has been used as the reconciliation variable since it has a major impact on the space heating load, and is generally poorly defined since explicitly measured data is seldom available.

In the case of the Manitoba Advanced House, the interior temperatures were very well defined since they were continuously monitored at five locations throughout the house. Likewise, component RSI values, ventilation system usage and many other variables were known. Considering this, it was decided to use the steady-state efficiency of the space heating system as the reconciliation variable, since the efficiency of the unit actually installed in the house had not been explicitly measured.

6.3 MEASURED ENERGY CONSUMPTION

The measured energy consumption of the house was determined using data from the main utility meters installed on the natural gas and electrical lines, along with supplementary data provided by the sub-meters installed on various end-use devices. This data is summarized in Table 5. The total energy consumption of the Manitoba Advanced House during the monitoring period of Sept. 1, 1994 to Sept. 1, 1995 was 20,463 kWh_e/yr (if the natural gas used to heat the garage is excluded - the heater was installed because the garage was used as a display area during the open house) or 21,099 kWh_e/yr (if the garage heat is included). The former value was used for the energy analysis because the measured energy consumption exclusive of the garage heat is considered the more representative way to express total energy usage. Usage of the garage heater was regarded as a discretionary end-use dictated by lifestyle, similar to a barbecue for example.

6.4 COMPARISON OF MEASURED AND THE PREDICTED, ACTUAL TOTAL ENERGY USAGE

Using inputs obtained from the sources listed in Table 4 coupled with the actual occupancy and utilization data, the total energy consumption predicted by HOT2000 Version 7.10 was 20,615 kWh_e/yr. This compared very well to the actual measured energy use of 20,463 kWh_e/yr. The difference between the two was only 152 kWh_e, or 0.7% of the actual measured energy consumption, indicating that the modelling process had achieved a good capture of the house.

6.5 COMPARISON BETWEEN MEASURED ENERGY USAGE AND THE ENERGY TARGET

Providing an honest assessment of the house's energy performance requires far more than simply comparing the actual, measured consumption with the actual, predicted consumption. In essence, both of these data points are only applicable to the unique circumstances generated by the homeowners' individual lifestyle, the actual weather during the monitoring period, etc. To provide a more representative assessment, these unique variables have to be replaced with standardized inputs that are representative of average, rather than unique, conditions.

TABLE 5

MEASURED ENERGY CONSUMPTION FROM SEPT. 1, 1994 (SELECTED DATA)

PERIOD	NATURAL GAS (kWh_e/yr)			ELECTRICITY (kWh/yr)						
ENDING	TOTAL	GARAGE	STOVE	TOTAL	EXTERIOR	HRV	INTERIOR LIGHTS	CLOTHES WASHER	FRIDGE	RANGE
Sept. 1/94	0	0	0	0	0	0	0	0	0	0
Oct. 15/94	289	0	48	n/a	17	7	37	10	60	10
Oct. 21/94	723	0	57	570	20	22	47	10	70	10
Nov. 1/94	1186	0	87	810	24	41	66	10	80	10
Nov. 17/94	1851	0	112	1170	29	74	92	10	n/a	10
Nov. 28/94	2517	0	123	1450	38	198	109	10	115	10
Nov. 29/94	2575	0	124	1480	39	101	111	10	115	10
Dec. 10/94	3269	0	142	1780	57	121	135	10	135	10
Dec. 21/94	4484	550	161	2170	117	123	170	10	145	10
Jan. 12/95	5901	636	193	2900	133	135	314	10	175	0
Feb. 1/95	7174	636	258	3420	134	144	n/a	10	195	10
Mar. 1/95	9055	636	273	4130	139	152	n/a	10	235	10
Apr.15/95	10733	636	298	4990	171	158	359	10	285	10
May 9/95	11745	636	339	5720	177	173	405	10	315	10
Jun. 8/95	12381	636	369	6120	208	184	430	15	365	10
Sept. 1/95	13799	636	465	7300	362	300	536	25	540	15

n/a = Reading not available.

After considering various approaches to this problem, it was decided that the measured energy usage could best be compared to the energy target using either of two approaches:

Method 1) Default Energy Target and Default Conditions - With this approach, the energy target, calculated using default weather, is compared to the predicted energy consumption of the reconciled house modelled with default weather, occupancy, base loads, ventilation system utilization, etc. This method of comparison removes the influence of unique occupancy and weather, and replaces them with more representative, average behaviour and conditions. The default energy target for the Manitoba Advanced House was 17,196 kWh_e/yr, whereas the predicted energy consumption, using the reconciled house model and default occupancy, base loads, etc. was 26,222 kWh_e/yr, calculated using HOT2000 Version 7.10. Thus, with this method of comparison, the house's actual energy consumption exceeded the energy target by 53%.

Method 2) Actual Energy Target and Actual Conditions - This approach compares the energy target, calculated using the target equation and the actual weather during the monitoring period, to the actual, measured energy usage of the house. It has the advantage of not requiring any mathematical modelling, and therefore eliminates this potential source of error. However, it constitutes somewhat of an "apples and oranges" comparison since the target implicitly assumes average occupancy patterns, base loads, ventilation rates, etc. and not the unique ones which actually occurred. The energy target for the house, calculated using actual weather was 16,710 kWh_e/yr, whereas the actual measured consumption was 20,463 kWh_e/yr. Therefore, using this method of comparison, the house's energy consumption exceeded the target by 22%.

The different targets and predicted energy uses, calculated using the default and actual conditions described above, are summarized in Table 6.

Both methods of comparing the energy targets and measured consumption indicate that the house consumed more energy than anticipated. The different values for the overconsumption (53% using Method 1 and 22% using Method 2), reflect the influence of occupant lifestyle. During the monitoring period, the Manitoba Advanced House was occupied by two adults (vs. the two adults and two children assumed for the default occupancy) who lived a relatively low-energy lifestyle. Usage of lighting, appliances, ventilation, etc. were comparatively low. Their residency resulted in energy usage which was closer to the energy target than would be expected for a more typical family.

TABLE 6
SUMMARY OF ENERGY TARGETS AND ENERGY USE

	CALCULATED USING DEFAULT CONDITIONS (kWh_e/yr)	CALCULATED USING ACTUAL CONDITIONS (kWh_e/yr)
Energy Target	17,196	16,710
Predicted Energy Use (HOT2000, Version 6.02)	17,156	not calculated
Predicted Energy Use (HOT2000, Version 7.10)	26,222	20,615
Actual Measured Energy Use	20,463	

6.6 PREDICTED ENERGY CONSUMPTION USING DEFAULT INPUTS

Using this logic, it was concluded that the most accurate and representative method of evaluating the annual, energy consumption of the Manitoba Advanced House was to use Method 1 - the reconciled house, with the standard input default values specified in the Advanced Houses Program Technical Requirements, modelled using HOT2000 Version 7.10. A copy of the HOT2000 output of the final, reconciled design is attached in Appendix E. This was used for all subsequent analyses.

Figure 1 shows the variation in the gross and net space heating loads during the year (the net load is defined as the gross load minus the contribution from solar and internal gains). The energy balance for the space heating load is shown in Fig. 2, while Fig. 3 illustrates the distribution of total energy usage throughout the year. In keeping with the previous comments, Figs. 1 to 3 use default values for occupancy, temperatures, appliance usage, ventilation, etc. as well as average weather conditions, thereby removing the uniqueness of the actual occupancy and weather during the monitoring period.

6.7 WHY DID THE ENERGY CONSUMPTION EXCEED THE ENERGY TARGET?

The actual energy consumption of the Manitoba Advanced House not only exceeded its target, but also the originally predicted energy consumption (by 9,066 kWh_e/yr or 53%). Why? To answer this question, considerable effort was expended to find the causes of the overconsumption. Fortunately, the analysis provided considerable insight into the behaviour of the house and how the performance of future ultra low-energy homes could be improved.

Fig. 1

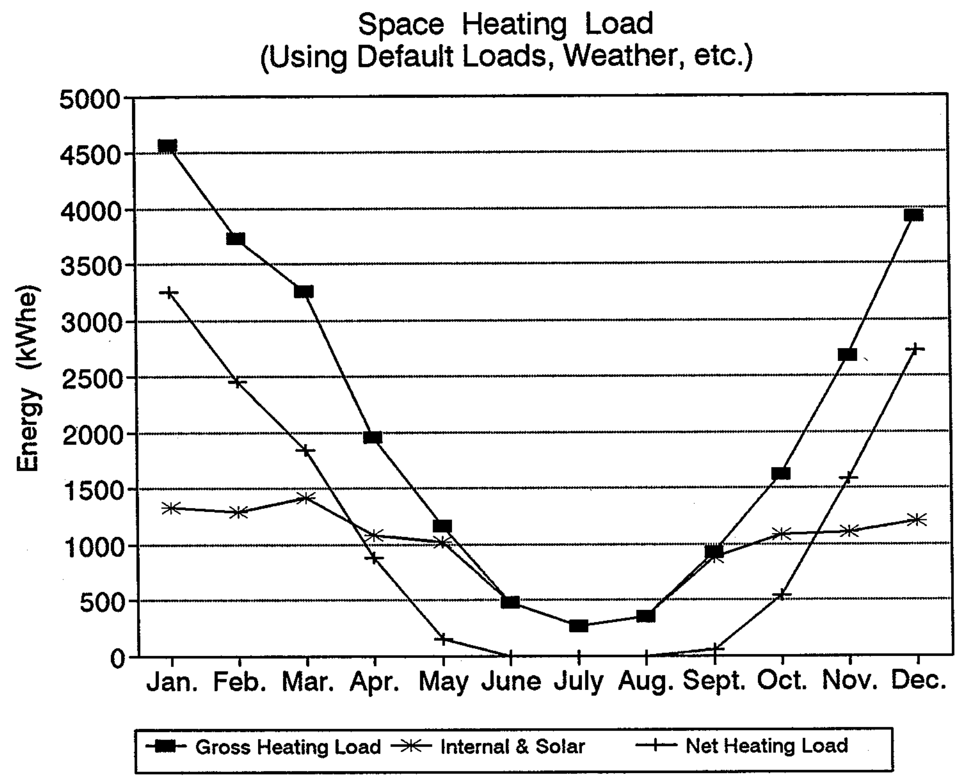

Space Heating Load
(Using Default Loads, Weather, etc.)
Energy (kWhe)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
Gross Heating Load
Internal & Solar
Net Heating Load

Fig. 2

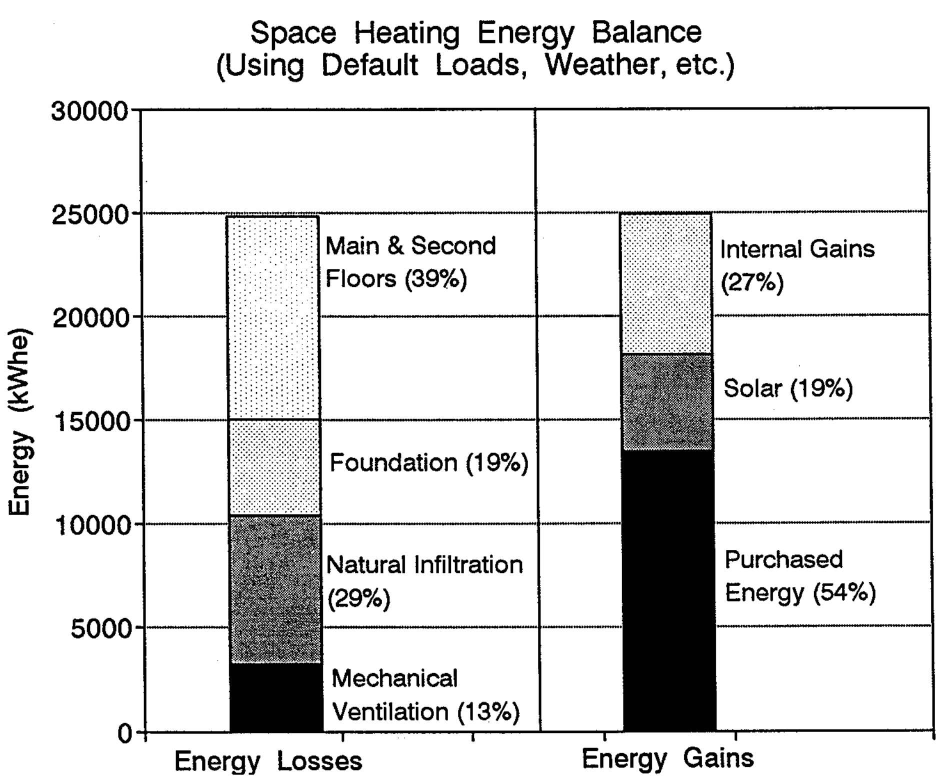
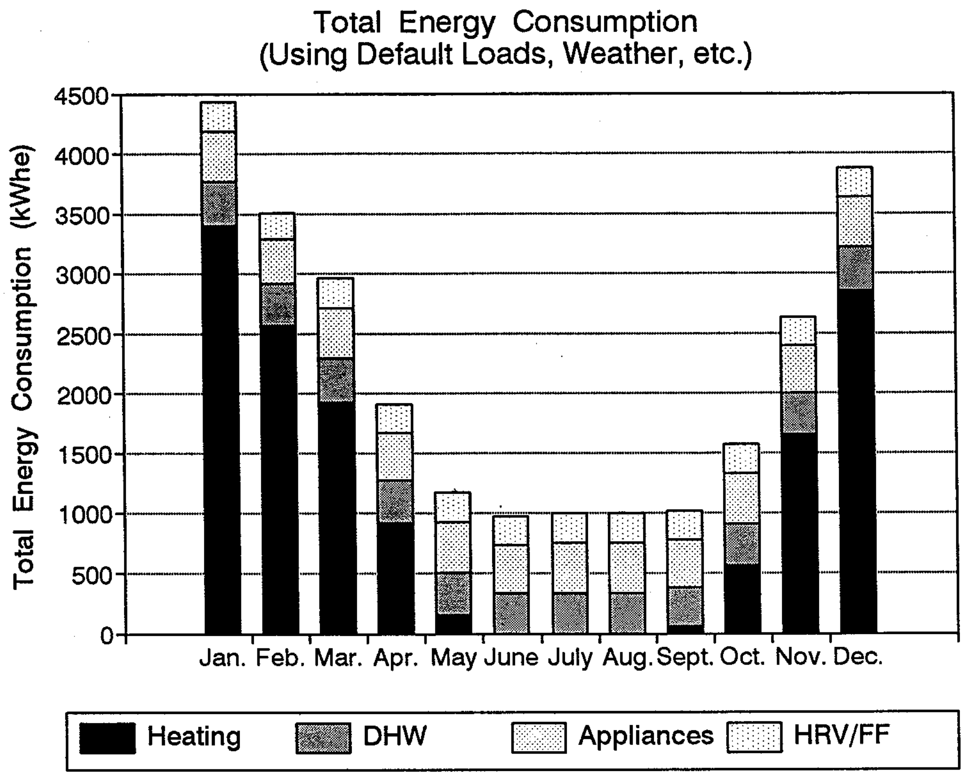

Space Heating Energy Balance
(Using Default Loads, Weather, etc.)
Energy (kWhe)
30000
25000
20000
15000
10000
5000
0
Main & Second Floors (39%)
Foundation (19%)
Natural Infiltration (29%)
Mechanical Ventilation (13%)
Internal Gains (27%)
Solar (19%)
Purchased Energy (54%)
Energy Losses
Energy Gains

Fig. 3



Notes:

1. "Appliances" includes interior and exterior appliances and lighting energy.
2. "HRV/FF" includes HRV and furnace fan blower energy.

Table 7 compares the total energy usage predicted using HOT2000 Version 6.02 with the total energy consumption predicted using HOT2000 Version 7.10 (using the reconciled house data). This shows that the major source of the overconsumption was space heating (actual/predicted = 2.37) and to a lesser extent DHW heating (actual/predicted = 1.34).

TABLE 7
COMPARISON OF ORIGINALLY PREDICTED AND AS-BUILT ENERGY USAGE

COMPONENT	ENERGY USAGE (kWh_e/yr)		AS-BUILT / ORIGINAL
	ORIGINAL DESIGN (USING HOT2000 VERSION 6.02)	AS-BUILT HOUSE (USING HOT2000 VERSION 7.10)	
Space heating	5,934	14,093	2.37
Domestic hot water heating	3,167	4,248	1.34
Appliances	7,520	7,881	0.98
Lighting	352		
Outdoor electrical use	183		
Total	17,156	26,222	1.53

The combined energy consumption for lighting, appliances and outdoor electrical use was very similar to the amount assumed in the original design. Examining the data more closely, lighting consumed 52% more energy than anticipated in the original design while exterior energy use was almost double that expected. However, appliance use was lower than anticipated. Measured fan energy usage was also higher than expected, so actual, estimated values were used for modelling the as-built house.

The space heating load was analyzed in more detail by comparing the gross annual heat loss of each component (walls, windows, etc.), as originally calculated during the design phase using HOT2000 Version 6.02, with those predicted using HOT2000 Version 7.10. These results are shown in Table 8. Note that the sum of the gross component heat losses are different from the values for total energy usage shown in Table 7 because the latter includes the effects of solar, base load and occupant gains.

Reviewing the ratios of results (as-built/original) in Table 8, two components stand out as having contributed significantly to the overprediction: ventilation and windows.

Ventilation - The "ventilation" load in HOT2000 includes both natural air leakage and mechanical ventilation. By modifying the inputs in the HOT2000 Version 7.10 simulation to produce the same net ventilation load predicted by Version 6.02, it was determined that ventilation contributed 6,094 kWh_e/yr of the 9,066 kWh_e/yr overprediction, or 67.2%. Initially, it had been suspected that this was due to the slightly poorer-than-anticipated airtightness which was actually achieved. To meet the energy target, the house had been designed assuming an airtightness of 0.75 ac/hr_{50}, which is one-half the maximum permitted in the Technical Requirements. The blower door test conducted just prior to occupancy indicated that the actual airtightness was 1.17 ac/hr_{50}. This latter value was input into the Version 7.10 simulation and re-run. This showed that the extra leakiness of the building envelope was responsible for 1,494 kWh_e/yr of the 9,066 kWh_e/yr overprediction, or 16.5%. The remainder of the ventilation overprediction, 4,600 kWh_e/yr (50.7% of the total),

TABLE 8
COMPONENT HEAT LOSSES

COMPONENT	COMPONENT HEAT LOSS (kWh_e/yr)		AS-BUILT / ORIGINAL
	ORIGINAL DESIGN (USING HOT2000 VERSION 6.02)	AS-BUILT HOUSE (USING HOT2000 VERSION 7.10)	
Ceiling	1,617	1,296	0.80
Walls	3,178	3,430	1.08
Doors	826	1,022	1.24
Exposed floors	125	125	1.00
Basement walls above grade	338	587	1.74
Windows	3,293	4,448	1.35
Upper basement walls	347	354	1.02
Lower basement walls	940	956	1.02
Floor perimeter	1,160	1,092	0.94
Floor centre	1,346	1,307	0.97
Ventilation	3,946	10,568	2.68
Total	17,116	25,185	1.47

was attributed to the different algorithms which are used to model ventilation in HOT2000 Versions 6.02 and 7.10. The former uses the Shaw model while the latter uses the newer, AIM-2 procedure, which is believed to be more accurate.

Windows - The windows contributed approximately 1,155 kWh_e/yr, or 13%, to the total energy overconsumption. Window performance is determined by the overall thermal resistance of the unit, its shading coefficient and the air leakage. Values for the window's thermal resistance and shading coefficient were originally evaluated using WINDOW Version 3.1, and the results then used to perform the HOT2000 simulations. Subsequent to completion of the house, more detailed determinations were performed by Enermodal Engineering Ltd. using VISION3 and FRAME 3.0 (1993). This indicated that the thermal resistance of the windows was somewhat lower than predicted by WINDOW, possibly because of FRAME's more rigorous analysis of the frame geometry. Since the solar gains predicted by the two versions of HOT2000 were virtually identical, the window's contribution to the total house energy overprediction was attributed to the lower-than-anticipated thermal resistance. However, it should be recognized that this resulted from a change in the model used to predict performance, not that the windows performed poorer.

Other envelope components (such as the basement walls below grade, exterior walls and the doors) performed slightly poorer than originally predicted, although their collective impact was relatively minor. Most of this was attributed to the use of actual, rather than nominal, thermal resistance values in HOT2000 Version 7.10 .

The remaining factor contributing to the energy overconsumption was the domestic hot water heating system. Reviewing the HOT2000 results, the DHW system was responsible for 1,081 kWh_e/yr, or 12%, of the overconsumption. Two key components determine the performance of the DHW system: the water heating efficiency and the recovery efficiency of the greywater system. The latter was analyzed by modelling the system using the finite difference greywater heat recovery model described in Section 2 with the default loads assumed for the final HOT2000 Version 7.10 simulation. This showed that the originally assumed recovery efficiency of 48% (which had been estimated at the design phase using engineering calculations) was somewhat optimistic. The greywater model indicated that the actual recovery efficiency would be about 40%. The second contributor to the overconsumption of DHW was the lower-than-anticipated heating efficiency. The original HOT2000 Version 6.02 analysis predicted an annual hot water heating efficiency of 94% whereas the Version 7.10 analysis predicted 84%. It was concluded that the 12% energy overprediction attributable to DHW heating could be equally divided between the poorer-than-expected performance of the greywater system and the lower efficiency of the DHW system.

Table 9 summarizes the estimated contribution to the energy overprediction of all the items discussed above. Overconsumption is defined as the difference between the total annual energy consumption predicted using HOT2000 Version 7.10 (26,222 kWh_e/yr) with reconciled, default inputs and that predicted by HOT2000 Version 6.02 (17,156 kWh_e/yr) with default inputs.

TABLE 9
SUMMARY OF ENERGY OVERCONSUMPTION

COMPONENT		OVERCONSUMPTION (kWh_e/yr)
Ventilation	- Higher air change (modelling difference)	4,600 (50.7%)
	- Looser building envelope	1,494 (16.5%)
Windows	- Lower thermal resistance (modelling difference)	1,155 (12.7%)
Miscellaneous envelope components (modelling differences for the thermal resistance of basement walls above grade, walls, doors, etc.)		735 (8.1%)
DHW	- Lower heating system efficiency (modelling difference)	541 (6.0%)
	- Lower greywater system performance	541 (6.0%)
Total		9,066 (100%)

It is apparent that the major reason the energy consumption of the Manitoba Advanced House was greater than expected was due to differences in how the original house design was modelled relative to how the final, as-built structure was modelled. Modelling differences for the ventilation load (50.7%), DHW heating (6.0%), windows (12.7%) and the miscellaneous envelope components (8.1%) were responsible for 78% of the total overconsumption.

However, the manner in which these differences manifested themselves in the design needs to be explained. Part of the intent of the design process was to create a house which had a predicted energy consumption which met the energy target, but did not significantly undershoot it. HOT2000 Version 6.02 and WINDOW 3.1 were the primary analysis tools used to determine compliance and they indicated that this goal had been achieved. The final energy analysis, performed using HOT2000 Version 7.10, VISION3, FRAME 3.0 predicted that this goal had not been met. Presumably the latter models are more accurate. Aside from containing algorithms and procedures which are generally regarded as superior to their predecessors, they were also able to predict the measured energy consumption of the actual house with surprising accuracy (0.7% difference). In essence, this means that had HOT2000 Version 7.10, VISION3 and FRAME 3.0 been available during the design phase of the Manitoba Advanced House, the structure would have been designed in a much more energy efficient manner than actually occurred.

6.8 COMPARISON BETWEEN THE MANITOBA ADVANCED HOUSE AND CONTEMPORARY MANITOBA HOUSES

Once the predicted energy consumption (using actual weather, occupancy, base loads, etc.) had been reconciled to the measured usage, a series of additional HOT2000 simulations were performed to assess the Manitoba Advanced House relative to newly constructed, conventional houses in the province and to these same houses upgraded to various other standards. For the most part, these simulations used default conditions to represent how the Manitoba Advanced House would perform under typical conditions, as opposed to the unique conditions of the monitoring period. The results are summarized in Table 10 and Fig. 4 using a variety of Energy Use Indices (EUI) which factor out the influence of weather, house size and occupancy.

Data for the newly constructed houses was obtained from two recently completed studies in which audits, airtightness tests, detailed occupancy surveys, etc. were performed on 23 natural gas-heated houses and 39 all-electric houses in Manitoba (Proskiw 1996, Proskiw 1994). These houses were selected to provide representative samples of the two house types. Their predicted energy performance was estimated using an energy bill reconciliation process similar to that described herein for the Manitoba Advanced House. EUI values are shown for conventional houses as they are currently built and operated, and (for the natural gas-heated houses only) these same structures upgraded to the 1995 National Building Code (NBC), the NECH and the R-2000 standard. These two house samples were modelled using HOT2000 Version 6.03. This is a special developmental edition of the program which contains the AIM-2 ventilation model plus other features which were ultimately incorporated into Version 7.10. HOT2000 Version 6.03 and Version 7.10 tend to predict total annual energy consumption reasonably closely. It should also be noted that several of the conventional houses used supplemental wood heating - the contribution from which is not included in the data in Table 10 since only purchased energy is shown.

The results in Table 10 are presented for a variety of ventilation system utilization rates (VSU). This is defined as the average, annual utilization of the mechanical ventilation rate. For example, a VSU of 20% would indicate that the ventilation system was operated at design capacity for 4.8 hours per day (4.8/24). System utilization is a key factor which

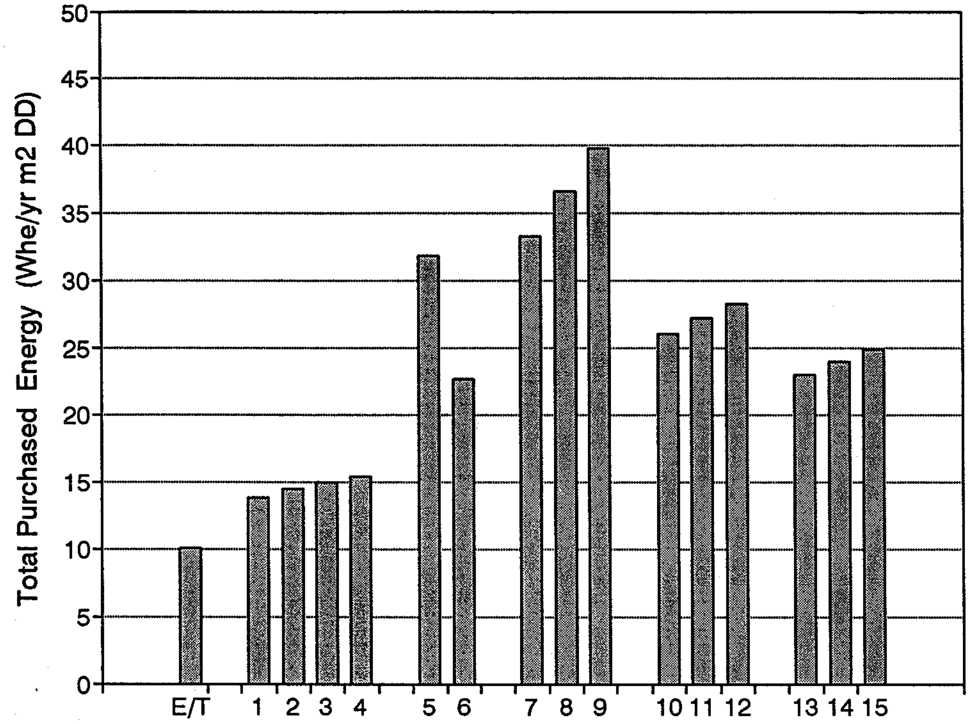
TABLE 10
COMPARATIVE ENERGY USE INDICES

TYPE OF HOUSE	VSU[1]	SPACE HEATING				DHW		TOTAL PURCHASED ENERGY		
		$\frac{kWh_e}{yr}$	$\frac{kWh_e}{yr \bullet m^2}$	$\frac{kWh_e}{yr \bullet DD}$	$\frac{Wh_e}{yr \bullet m^2 \bullet DD}$	$\frac{kWh_e}{yr}$	$\frac{kWh_e}{yr \bullet person}$	$\frac{kWh_e}{yr}$	$\frac{kWh_e}{yr \bullet m^2}$	$\frac{Wh_e}{yr \bullet m^2 \bullet DD}$
Energy Target	100%	9274	32	1.57	5.45	5520	1380	17,196	60	10.1
Manitoba Advanced House	100%	16,934	59	2.88	9.96	4248	1062	26,222	91	15.4
Manitoba Advanced House	20%	14,513	50	2.46	8.53	4248	1062	23,712	82	13.9
Manitoba Advanced House	50%	15,444	53	2.62	9.08	4248	1062	24,666	85	14.5
Manitoba Advanced House	80%	16,346	57	2.78	9.61	4248	1062	25,590	89	15.0
Gas-heated, conventional	Existing	29,452	122	4.99	20.7	6293	2003	44,716	188	31.8
All-electric, conventional	Existing	18,399	84	2.83	12.8	5041	1455	32,161	149	22.7
Gas-heated, 1995 NBC	20%	31,351	131	5.31	22.1	6293	2003	46,820	197	33.3
Gas-heated, 1995 NBC	50%	34,662	145	5.87	24.6	6293	2003	51,350	216	36.6
Gas-heated, 1995 NBC	80%	37,877	159	6.42	26.9	6293	2003	55,782	235	39.8
Gas-heated, NECH	20%	22,904	94	3.88	16.0	5166	1609	36,925	154	26.0
Gas-heated, NECH	50%	23,335	96	3.95	16.3	5166	1609	38,532	160	27.2
Gas-heated, NECH	80%	23,772	98	4.03	16.6	5166	1609	40,138	167	28.3
Gas-heated, R-2000	20%	18,136	76	3.07	12.8	4981	1530	32,307	136	23.0
Gas-heated, R-2000	50%	18,445	77	3.12	13.1	4981	1530	33,729	142	24.0
Gas-heated, R-2000	80%	18,563	78	3.14	13.2	4981	1530	34,953	147	24.9

Note:
1. VSU = ventilation system utilization rate.

Fig. 4

Total Purchased Energy Use



E/T - Advanced House energy target
1, 2, 3, 4 - Manitoba Advanced House (VSU = 20%, 50%, 80% & 100%)
5, 6 - Conventional natural gas houses, conventional all-electric houses
7, 8, 9 - Natural gas houses, upgraded to the 1995 NBC (VSU = 20%, 50% & 80%)
10, 11, 12 - Natural gas houses, upgraded to the NECH (VSU = 20%, 50% & 80%)
13, 14, 15 - Natural gas houses, upgraded to R-2000 (VSU = 20%, 50% & 80%)

has a significant impact upon both energy usage and energy costs. Typical VSU rates for conventional houses are generally quite low, around 5% or less, whereas those of R-2000 type houses are much higher. For example, one monitoring study of HRV usage in R-2000 houses in Winnipeg found that HRVs were used an average of 80% of the time (Proskiw 1992a). In the case of the Advanced House Program, a VSU value of 100%, at the installed flow capacity, was used - even though it is very unlikely that most houses would ever be operated at such a high ventilation rate. To provide a more representative description of the house's performance, additional simulations were performed of the Manitoba Advanced House with ventilation system utilization rates of 20%, 50% and 80% (at the installed flow capacity of 70 l/s).

The results in Table 10 and Fig. 4 show that while the Manitoba Advanced House did not meet its energy target, its energy consumption was still significantly less than that of equivalent, conventional or R-2000 houses being built in Manitoba, or to these same houses upgraded to either the 1995 NBC or NECH.

Manitoba Advanced House relative to conventional houses - Relative to gas-heated houses currently being constructed in the province, the total purchased energy consumed by the Manitoba Advanced House, expressed on a size and weather-normalized basis ($Wh_e/yr \bullet m^2 \bullet DD$), would equal 44% to 48% of that consumed by an equivalent gas-heated home (depending on the ventilation rate). However, this represents somewhat of an "apples and oranges" comparison since the VSU of the conventional houses is very low, and to increase the rate to that of the Manitoba Advanced House would significantly increase their total energy consumption. The higher ventilation rate in the Manitoba Advanced House would translate into superior indoor air quality relative to that in the conventional houses. Energy Use Indices for the all-electric houses are lower than those of gas-heated houses because of the 100% conversion efficiency of electric heat, the fact that all-electric houses are generally better insulated and because of the prevalence of wood heating (most all-electric houses are in rural areas). Also, it should be recognized that "conventional" Manitoba houses are, for the most part, constructed in a reasonably energy efficient fashion relative to homes in other regions of the country, both in terms of insulation levels and airtightness. For example, the 1990 cross-country survey of airtightness showed that Manitoba houses were the most airtight in Canada.

Manitoba Advanced House relative to the 1995 NBC - The only energy-related impact which the 1995 NBC would have on the design of conventional houses in Manitoba would be to require a significantly improved mechanical ventilation system, specifically one which is properly sized and is capable of continuous operation. This presumably would result in higher mechanical ventilation rates than are currently being experienced in new homes. However, the degree to which the ventilation rate would increase is unknown. Since very few natural gas heated homes are equipped with HRVs, higher ventilation rates would have a major impact on energy usage. If comparisons are made at equivalent VSU rates, the total purchased energy consumed by the Manitoba Advanced House would be 38% to 42% of that of natural gas-heated homes built to the 1995 NBC.

Manitoba Advanced House relative to the NECH - The NECH requirements for Manitoba include higher thermal insulation levels and better windows than are currently being used, an HRV and various other features to limit energy usage. One effect of the HRV is that much higher mechanical ventilation rates can be economically sustained, relative to the very low levels now used in conventional houses. The total purchased energy usage of the Manitoba Advanced House would be about 53% of that of natural gas-heated homes built to the NECH.

Manitoba Advanced House relative to the R-2000 standard - The R-2000 standard will usually result in a home which is slightly more energy efficient than that produced by the NECH. Insulation levels are slightly higher and the house will be more airtight. The total purchased energy consumed by the Manitoba Advanced House would be 60% of that of natural gas-heated homes built to the R-2000 standard.

6.9 OVERALL PERFORMANCE OF THE HEATING SYSTEM

Neither the steady-state nor seasonal efficiency of the hot water tank were explicitly measured. The reconciliation exercise (described above) between measured and predicted energy consumption suggested that the seasonal efficiency was approximately equal to the manufacturer's reported value. However, this is an indirect determination of efficiency and the actual value could be significantly different. A concern which has arisen since completion of the house is the ability of the tank to operate in a full condensing mode and hence achieve its rated performance. Condensing appliances achieve their highest performance when they are able to lower the products of combustion to sufficiently low temperatures, about 40 °C to 50 °C (104 °F to 122 °F), that significant condensation occurs and the latent heat of evaporation is released. In the case of a condensing hot water tank, when the tank is supplying space heating the temperature of the return water from the coils can be above this level, thereby limiting the amount of condensation and lowering the system performance. Similarly, the greywater heat recovery tank would increase the average temperature of supply water to the hot water tank during the entire year, which might reduce the tank's efficiency. The magnitude of these effects is unknown.

Some additional, qualitative comments on the heating system can also be made. Temperature levels in the four zones in the house were quite consistent, although the homeowners did report a cold spot in the family room (likely the result of radiant losses to the glass face of the fireplace and by air leakage). However, the heating system has displayed some problems, most notably the vent blockage/appliance shut-down discussed in Section 2. Also, the plumbing system serving the four zones is far too complex and expensive. In retrospect, the three air zones could have been replaced by a single zone with an air handler and the single zone served by the hydronic baseboard could have been provided with an electric baseboard heater. Another improvement which could have been made would have been to use a smaller, quieter, more efficient air handler. The existing unit is excessively noisy and consumes too much energy.

6.10 OVERALL PERFORMANCE OF THE DHW SYSTEM

The HOT2000-predicted, annual efficiency of the DHW system was 84%, somewhat less than the 95% steady-state efficiency of the hot water heater. This difference was due to tank losses during the non-heating portion of the year and the thermal losses from the DHW piping. The greywater heat recovery system, although it did not perform quite as well as originally anticipated, was judged a success. The finite difference model indicated that the system is supplying about 40% of the DHW load. However, DHW usage was very low in the Manitoba Advanced House, so the results may not be indicative of those which would be experienced in other houses.

6.11 OVERALL PERFORMANCE OF THE VENTILATION SYSTEM

The purpose of the ventilation system is to assist in providing good indoor air quality. As will be discussed in Section 8, the measured levels of pollutants in the Manitoba Advanced House were generally quite low, despite an HRV utilization of only 22%. Note that the homeowners' usage of the HRV was highest in the shoulder seasons (spring and fall) and lowest during the winter.

With respect to heat recovery performance, the rated sensible recovery efficiency of the HRV was 80% at 0 °C and 77% at -25 °C. The actual measured efficiency of the unit, using the data collected by the DAS was 81% (based on 250 days of data; Sept. 1/94 to May 9/95). However, the HRV system efficiency, which includes the effects of losses between the appliance and the outdoors, was only 60%. This reinforces the importance of reducing the amount of ducting on the cold side of the HRV and of using high insulation levels on the ductwork (discussed in Section 2). Overall, the ventilation system has to be judged as very successful. However, it could have been improved, and the cost reduced somewhat, by simplifying parts of the system, most notably the exhaust fans' ducting, and by increasing insulation levels on the HRV ductwork.

6.12 SUMMARY COMMENTS ON ENERGY PERFORMANCE

The most important objective of the Advanced Houses Program was to acquire a better understanding of how energy efficient houses built to such rigorous standards actually perform, especially from an energy perspective. The monitoring program and detailed energy analysis which followed have highlighted some important lessons in this regard. These are summarized below. In many instances, the knowledge gained applies not only to Advanced Houses, but also to those designed to less rigorous standards, such as the R-2000 Standard or the NECH.

Total Energy Consumption - The monitoring and energy analysis conducted on the Manitoba Advanced House indicated that it exceeded its energy target by 53%, or 9,066 kWh_e/yr, based on default occupancy patterns, weather and base loads. However, over three-quarters (78%) of this overconsumption was due to limitations of the computer software originally used to design the house in 1992. The current (1996) versions of the software are believed to be more accurate and, had they been available in 1992, would have resulted in a more efficient design for the house. Nonetheless, despite the overconsumption, the Manitoba Advance House is an extremely energy efficient structure which would consume only 44% to 48% of the energy of a conventional new home, or 60% of that of an equivalent R-2000 house.

Ventilation/Infiltration - Ventilation and air infiltration constitute the largest single energy load in the house, despite having an envelope which was tighter than that required by the Technical Requirements and the use of a very energy efficient HRV. Based on the final HOT2000 analysis (using default occupancy, base loads and weather), air infiltration and mechanical ventilation comprise 29% and 13% respectively of the gross heating load of the house. To reduce these values, a tighter building envelope and higher HRV system efficiency would be required. A more realistic airtightness target for future Advanced Houses would be one-half of that now specified, i.e., 0.75 ac/hr_{50}. This is especially important in two or three storey houses where the stack effect is larger due to their greater height and in northern locations where the colder temperatures increase the stack effect because of the larger indoor-to-outdoor temperature differentials. To improve the ventilation system efficiency, more effort would have to be devoted to reducing heat loss and air leakage from the HRV ductwork (see "Mechanical Systems" below) and reducing electrical consumption by improving the motor/fan efficiency and the duct layout. Also, the mechanical ventilation load assumes continuous operation of the system. By incorporating air quality control measures (air filtration, proper materials selection, etc.), much lower ventilation rates could be used without compromising occupant health.

Windows - The overall thermal performance of the windows used in the Manitoba Advanced House is excellent. However, a close examination of their thermal properties suggests opportunities for improvement. While the thermal resistance of the sealed glass unit is quite high, the "weak spot" is the frames, which are a conventional wood frame design without any supplemental insulation. The impact is particularly pronounced in the Manitoba Advanced House because of its extensive use of small windows in which the frames constitute a large percentage of the total window area. Further, casual examination of many high performance windows now on the market indicates that for many of these, the frames also are the limiting factor in their design. An important component of any future Advanced Houses would be windows which have better insulated frames.

Mechanical Systems - The excess complexity of the mechanical systems not only added to the construction costs, but decreased the house's energy performance. The complex ductwork system (particularly the large, fresh air duct supplying the HRV, dryer heat exchanger and range make-up air, and the BGHRV duct running from the attic to underneath the floor slab) degraded the measured airtightness of the house despite attempts to seal the ductwork. Further, the ductwork increased the overall building's thermal losses since it had a relatively large surface area and was rather poorly insulated compared to the rest of the envelope. In retrospect, the dryer heat exchanger and range make-up air could have been eliminated which would have permitted a much smaller, more energy efficient ductwork system. As a general recommendation, future Advanced Houses should be designed with mechanical systems which are as simple as possible. Further, commercial-grade products and tradesmen should be used cautiously since they are often much more expensive than comparable residential-grade products and services.

Domestic Hot Water Heating - More research is needed to find effective means to supply and/or reduce the DHW load in Advanced Houses. Heating appliance efficiencies are often lower than anticipated while water conservation strategies can be circumvented by the homeowner's lifestyle. One technology which shows considerable promise, is greywater heat recovery. The system used in the Manitoba Advanced House, although not having the benefit of design tools which could have improved its performance (and which were subsequently developed), still provided a significant portion of the annual DHW load.

Electrical Motors - The electrical usage of continuous or quasi continuous-operating motors should be reduced in future Advanced Houses since this can represent a major energy load. In the Manitoba Advanced House, the main loads were: the main circulation blower, the HRV, the space heating circulation pump and the DHW circulation pump. Their total electrical consumption over the one year monitoring period was 1846 kWh, 300 kWh, 654 kWh and 426 kWh, respectively. Collectively, these four devices consumed 44% of the total monitored electrical consumption in the house. Further, this does not include the electrical consumption, albeit small, of the intermittently used air-handling devices (the three exhaust fans, range exhaust fan and the range make-up air fan). The main circulation blower could also have been downsized if a simpler, single-zone ductwork layout had been used instead of the complex three zone layout.

Lights and Appliances - Lighting and exterior electricity usage were higher than expected while appliances usage was lower than anticipated. Overall, energy usage for lighting and appliances (both interior and exterior) were equal to the amount budgeted in the energy target. Consumption by the white appliances was generally low, for example the refrigerator used 540 kWh/yr whereas comparably sized devices in the EnerGuide Directory consume 500 to 1000 kWh/yr (1995).

Fireplace - Gas consumption by the fireplace was extremely small because it was used very infrequently and employed a glow-bar ignition system as opposed to a standing pilot. However, as discussed in Section 2, there appears to be some discomfort created by the fireplace's presence in the room as the result of radiation to its cold glass surface plus a small amount of air leakage.

Cooling - Better design tools are needed to assess the potential for overheating in Advanced Houses. Overheating has proven to be a problem in the house for a few weeks every summer, despite the use of solar shade screens. Some form of mechanical cooling system is definitely required. Unfortunately, existing design tools for estimating the severity of the overheating problem are not really designed for structures of this type and their accuracy is questionable. The annual cooling load would probably be modest but the absence of any "coolness" within the house (because the basement is so well insulated), dictates the need for a mechanical cooling system.

Envelope Performance - Other than the components discussed above (airtightness and windows), the thermal envelope of the Manitoba Advanced House has performed very well. The exterior wall system, basement insulation system, attic insulation, etc. have, with only minor exceptions, delivered as promised. Further, increasing insulation levels beyond those used would produce only marginal benefits but would increase costs significantly.

SECTION 7
ONCE-ONLY TESTS

7.1 INTRODUCTION

As discussed in Section 5, the monitoring program also included a series of "once-only tests" to investigate the performance of specific components or systems:

- o Range hood exhaust system
- o Exterior wall wood moisture content
- o Heating system ductwork
- o Hobby room displacement ventilation

7.2 RANGE HOOD EXHAUST SYSTEM TESTS

The Manitoba Advanced House uses a natural gas range which, like most appliances of this type, vents directly into the interior space. The range's design is relatively conventional: four top burners and an oven, all with spark ignition systems. To vent the products of combustion an overhead range hood is provided which exhausts directly to the outdoors using a hood-mounted exhaust fan. The venting system is fairly conventional and the overall range/venting system is similar to those found in thousands of Canadian homes.

A concern with systems of this type is whether the range venting system is capable of adequately removing the products of combustion with sufficient efficiency that spillage into the living space would be minimized. In a house with low levels of air leakage, such as the Manitoba Advanced House, this is particularly important because natural air leakage plays a minor role in removing contaminants. Excessive depressurization by the venting system also needs to be considered. In theory, virtually any range venting system can be made to work if a sufficiently high exhaust flow rate is used. However, as the exhaust rate is increased the level of depressurization also increases. This raises the possibility of combustion spillage and backdrafting and accelerates the infiltration of radon and other soil gases, especially if the range hood operates for extended periods.

Thus, the two fundamental design criteria for residential range hood ventilation systems are mutually exclusive: a high exhaust capacity so contaminants can be efficiently captured versus the need to limit exhaust capacity to prevent excessive depressurization. A preliminary literature review was carried out to explore this subject and it revealed that most of the focus has been on the first issue, namely how to provide sufficient exhaust capacity. Unfortunately, little information was found on how to reconcile these two competing design goals.

Recognizing this conflict, a series of tests were designed and carried out in the Manitoba Advanced House to:

1. Explore the performance of a conventional, and an improved, overhead hood venting system for a natural gas range.
2. Develop a general understanding of the exhaust flow rates needed to vent the products of combustion for different range operating configurations.
3. Estimate the percentage of new houses which would be exposed to potentially excessive depressurization by range exhaust systems operating at flow rates sufficient to remove the products of combustion.

The tests conducted were intended as an *initial* exploration only, and not an exhaustive examination of residential kitchen ventilation. It was hoped they would provide some insight and provide direction for future research.

7.2.1 Test Method

The basic issue investigated was whether excessive spillage into the living space occurred from the range while the exhaust system was operating, in its various configurations. To study the problem, a novel test method was developed which used a smoke generator to visualize the heat plume rising up from the range while it was in operation. The range consisted of four natural gas burners and an oven. The generator ejected smoke into a cooking pot which was located on a burner, or in the oven (as appropriate). The smoke plume could then be observed rising from the pot to determine how effectively it was captured by the range hood. "Excessive spillage" was arbitrarily defined as having occurred when more than 10% of the smoke plume was not captured by the range hood and entered the living space. The amount of spillage was determined subjectively by two observers. A video record was also made of the tests. Tests were conducted in several configurations: with the smoke generator positioned on the front and back burners, and in the oven; with various numbers of burners operating; with and without side curtains on the range; and with the exhaust hood operating at various air flow rates. The results are summarized below.

7.2.2 Spillage From Front vs. Back Burners

The amount of spillage was significantly reduced when a rear burner was used rather than a front burner, particularly when side curtains were also in place. With rear burners the thermal plume was easily captured by the hood whereas with a front burner, a higher exhaust flow rate was needed to prevent spillage. Part of this is explained by the geometry of exhaust hoods. The back burners are usually directly underneath the exhaust grille of the hood whereas the front burners are positioned at the front edge of the hood, or beyond. Extending the hood further out would create an obstruction, while raising the hood (to remove the obstacle) would reduce its overall effectiveness because of the greater distance from the cooking surface. Front burners were also found to be more vulnerable to "wave spillage", which is created when someone walks past the range. Behind the moving person, two vortices are created which disturb the otherwise stable airflow patterns around the range. This results in a significant increase in spillage for several seconds until the thermal plume is recaptured by the exhaust hood.

7.2.3 Single vs. Multiple Burner Operation

The use of multiple burners increased the amount of spillage from the single burner on which the smoke generator was positioned relative to the amount of spillage observed when only a single burner was functioning. Presumably the operation of the additional burners either overwhelmed the exhaust hood or distorted the airflow underneath the hood such that plume capture was retarded.

7.2.4 Side Curtains

Side curtains were found to significantly reduce the amount of spillage which occurred, particularly from the back burners. Their presence reduced the amount of sideways spillage and also increased the local air velocity across the operating burner permitting better plume capture. The curtains extended from the top of the range to the underside of the hood, and out from the back wall 30 cm (12"). For the tests, simple cardboard replicates were used while the final curtains installed with the range were removable units manufactured from tempered glass.

7.2.5 Required Range Hood Exhaust Flow Rate

Arguably, this is the most important issue in the design of a range hood exhaust system since it has to balance the need to adequately exhaust pollutants with the desire to minimize depressurization of the house. Therefore, a series of trials were conducted to determine the minimum exhaust flow rate, as measured at the hood, necessary to limit spillage to no more than 10%. Five different operating conditions were tested and the required exhaust rates measured. Two of these involved use of the oven, which exhausted out through the top of the range near the back of the unit. The test results are shown in Table 11, along with the results of an analysis which calculated the percentage of new, Manitoba houses which would experience more than 5 Pa of depressurization at each flow rate. Five Pascals is generally regarded as the maximum depressurization which a naturally aspirated appliance can sustain without being vulnerable to combustion spillage or backdrafting. These results are based on a recent survey of the airtightness of 22 newly constructed, gas-heated houses in Manitoba (Proskiw 1996). For all the configurations studied, the required range hood exhaust rate necessary to control spillage to under 10% could cause combustion spillage in the majority of new, Manitoba houses if they were equipped with naturally aspirated combustion appliances (which most are). New houses in Manitoba are typically more airtight than those built in any other part of Canada. Therefore applying this analysis to other parts of the country would show a smaller percentage of houses vulnerable to combustion spillage caused by the range exhaust system. It should also be remembered that these results were produced from tests on a single (albeit typical) range/hood configuration and would vary with different ranges, hood designs, installation geometries, etc.

TABLE 11
MINIMUM EXHAUST FLOWS NECESSARY TO LIMIT RANGE SPILLAGE TO 10% IN NEW MANITOBA HOMES

CONFIGURATION	MINIMUM REQUIRED EXHAUST RATE	PERCENT OF NEW MANITOBA HOMES WHICH WOULD BE DEPRESSURIZED MORE THAN 5 Pa
One back burner on, no side curtains	104 l/s (220 cfm)	77%
One back burner on, side curtains	75 l/s (160 cfm)	55%
Two back burners on, side curtains	104 l/s (220 cfm)	77%
Oven on, side curtains	90 l/s (190 cfm)	68%
Oven on, no side curtains	>104 l/s (220 cfm)	>77%

7.2.6 Duct Leakage

Duct leakage was not explicitly measured during the tests, but in the course of performing the trials it was recognized that leakage could be an important factor in the overall determination of indoor air quality. With most residential range exhaust systems, the ductwork is positively pressurized. Therefore leakage from the ductwork will be into the house. Unfortunately, most residential ductwork systems are very leaky. For example, measurements of the leakage in positively pressurized residential ductwork systems have shown that the total leakage can exceed one-half of the total air flow entering the duct. If this were occurring with a range hood system, it would effectively degrade the efficiency of the range hood by one-half (but decrease the probability of combustion spillage/backdrafting).

7.2.7 Rangetop vs. Oven Operation

Another issue which became apparent during the trials is that further study and research needs to be directed to the relative contributions to air quality degradation by the rangetop and the oven. The total combined input of the rangetop burners will generally be several times that of the oven, therefore one might assume that they would represent the greater potential threat to air quality. However, the oven tends to be operated for extended periods of time while the rangetop burners are often used for relatively short periods. Therefore, it is unclear what the relative contributions of pollutants are from these two sources.

7.3 EXTERIOR WALL WOOD MOISTURE CONTENT

The main walls of the Manitoba Advanced House were constructed with an innovative split-stud system consisting of an inner 38x64 (2x3) stud and an outer, load-bearing 38x89 (2x4) stud connected by thin, metal pins. Wall insulation consists of blown-in glass fibre or cellulose installed using the BIB system. Sealed 6 mil polyethylene serves as the air/vapour barrier. Because the BIB system applicator injects a small amount of a latex binder onto the insulation at the time of installation, some concerns had been expressed that wood framing members might be vulnerable to rot. Therefore, a number of wall cavities in the house were instrumented at the time of construction with 24 sets of permanently embedded wood moisture content (WMC) probes. The pins were installed in both glass fibre and cellulose cavities, on north and east walls (where the threat due to wood rot was deemed to be the greatest), inner and outer studs, and in both main floor and second floor cavities (since the former would be exposed primarily to air infiltration forces and the latter to air exfiltration). All WMC measurements were temperature-corrected using data from thermocouples installed along isotherms with the moisture pins.

The wood used for the wall studs in the Manitoba Advanced House was dry at installation. Random measurements of the stud WMC, made during construction of the house (July, 1992), showed typical values of 10% to 13%. For comparison purposes, the National Building Code requires all lumber used for residential construction have a moisture content which does not exceed 19% at the time of installation. Wood with a WMC of 19% or less is generally considered dry. In practice, the threat due to wood rot begins to slowly increase when the WMC increases above 19% and reaches a maximum value at about 30%.

WMC measurements made using the permanently embedded moisture pins were made on a number of occasions up until July, 1995. In all cases, the WMC readings were found to be stable and generally well below the level at which the wood might be vulnerable to wood rot. Only a single reading exceeded 19% (19.7%). The conclusion drawn from these tests is that the wall system did not experience elevated moisture levels which might ultimately lead to wood rot (in a house located in a cold, relatively dry prairie climate). Further, the moisture introduced by the BIB system into the wall cavities did not pose a threat to the wood studs.

7.4 HEATING SYSTEM DUCTWORK

Various air flow rate, static pressure and power measurements were made on the heating system ductwork and blower to provide information on its operating characteristics. Static pressure measurements were made at 11 locations throughout the system to determine the pressure drop due to various components, in particular the bag filter and charcoal filter. Air flow rate measurements were made using 25 point traverses of the ductwork along with supply grille velocity measurements to determine overall air flow rates and the magnitude of the system duct leakage. Measurements were made at three different settings of the air handler speed control (full, half and low speed). For each flow condition, the electrical usage of the air handler motor was also measured. Although the results of these tests are specific only to the Manitoba Advanced House, certain observations resulted which could have more general application.

7.4.1 Duct Leakage

Duct leakage was defined as the percentage of the total air flow delivered by the main blower which leaked out of the supply ductwork prior to reaching its intended destination, the supply air grilles in the various zones. The flow rate measurements showed that duct leakage was surprisingly high, varying from 33% to 53% of the total air flow depending on the speed of the main blower. This occurred despite considerable effort being made to seal the ductwork using a commercial-grade paint-on mastic and duct tape. A full explanation of why the duct leakage was so high has not been developed. An obvious implication of this finding is residential forced air system design procedures, which assume zero duct leakage, can at best only roughly approximate the actual performance of a system. It could also partly explain complaints about cold rooms in houses with forced air heating systems.

7.4.2 Filter Pressure Drop

The Manitoba Advanced House uses an 85% efficient bag filter and a charcoal filter, both located on the upstream side of the circulation blower. Since both only provide filtration when the blower is operating, the extra pressure drops created by their presence need to be considered since this increases electricity consumption. The static pressure measurements showed that the two filters created the single largest pressure drop in the ductwork system, varying from 50% of the total system static when the blower operated at high speed to 65% at low speed. The non-linearity in response was caused by the different flow characteristics of the ductwork (which behaves like an orifice flow device) and the filters (which correspond more to laminar flow devices). Since the power required to operate the blower is proportional to the pressure drop, this means that a significant portion of the total electrical requirements of the blower is created by the filters. This can be a very important factor in the design of modern heating and ventilating systems since they are designed to operate on a quasi-continuous basis.

7.4.3 Power Requirements of the Main Circulation Blower

The main circulation blower uses an infinitely variable speed controller. The electrical power draw of the motor was measured and found to vary from 660 W at high speed, to 371 W at half speed and to 197 W at low speed. Part of the power reduction was achieved through a drop in the power factor (from 0.98 at high speed, to 0.77 at half speed, to 0.70 at low speed). Given that the air handling system is designed for continuous operation, these characteristics permit a significant reduction in electrical consumption (70%) when the unit is operated at low speed. To put these numbers into perspective, a 463 W saving (660 W - 197 W) would represent over 4,000 kWh per year (ignoring the fact that some of this will offset the space heating load) if the blower were operated continuously. This represents about one-quarter of the total, annual energy budget of the Manitoba Advanced House (i.e., both natural gas and electricity)! It should be noted that conventional furnace motors, such as the Permanently Split Capacitor (PSC) type, do not demonstrate such large reductions in power consumption because their efficiencies fall off at lower speeds. Thus, while they may only be moving a fraction of the air that they move at high speed, their electrical consumption is barely reduced.

7.5 HOBBY ROOM DISPLACEMENT VENTILATION

The hobby room was one of the novel air quality control strategies used in the Manitoba Advanced House. This was designated as a room in which odour or pollutant-generating activities, such as a hobby or home office, could be located without significantly affecting the remaining air quality in the rest of the house. The room was equipped with an exhaust to the HRV as well as a separate exhaust fan ducted directly outside. The intent of this design is that with the (non-weatherstripped) door closed and the HRV and/or exhaust fan operating, the room can be depressurized such that there will be no air movement from the room to the rest of the house. Some concern had been expressed as to whether any significant level of depressurization could be achieved of an internal zone within a house. Therefore, tests were conducted to determine the level of depressurization which could be sustained under these conditions. The exhaust flow rates, measured at the grilles, were 7 l/s (15 cfm) to the HRV and 61 l/s (129 cfm) through the exhaust fan. The results are summarized in Table 12.

The tests showed that the HRV was not able to provide significant room depressurization while the exhaust fan comfortably depressurized the room relative to the house. With only the exhaust fan operating and the HRV off, the HRV exhaust became an air inlet to the room. The last test configuration (exhaust fan on, HRV grille sealed and the door sill taped), represents an optimum configuration in which ventilation is provided by the exhaust fan and the door is weatherstripped. In this configuration, a substantial level of depressurization was achieved which effectively precluded the transfer of any pollutants to the house as long as the door was closed. The use of weatherstripping would permit the system to work even better. Nonetheless, the conclusion drawn from these tests is that the hobby room concept is valid and can be incorporated into a normal house design with relative ease.

TABLE 12
HOBBY ROOM DEPRESSURIZATION

CONFIGURATION	ROOM-TO-HOUSE PRESSURE DIFFERENTIAL (Pa)
HRV on	-0.2
Exhaust fan on	-2.5
HRV and exhaust fan on	-3.2
Exhaust fan on, HRV grille sealed, door sill taped	-11.2

SECTION 8
INDOOR AIR QUALITY

8.1 INDOOR AIR QUALITY MEASURES

A key feature of the Manitoba Advanced House was the indoor air quality control measures incorporated into the design, as summarized in Table 13. These included a variety of mechanical systems and design features which were selected to both limit the amount of pollutants introduced into the living space and to remove those which did enter.

To evaluate the overall impact of these control measures, two rounds of indoor air quality testing were performed in June, 1994 (just prior to occupancy) and in April, 1995 (approximately one year after occupancy). During these tests, the concentrations of several pollutants were determined using either spot (instantaneous) measurements or with longer term (7 day) dosimeters. The results are summarized in Table 14 along with the relevant exposure guidelines published by Health and Welfare Canada (HWC 1989). For several pollutants, exposure guidelines are expressed using both the Acceptable Short-Term Exposure Range (ASTER) and the Acceptable Long-Term Exposure Range (ALTER). The ASTER is the concentration range that a person could be exposed to over a specified short time period without undue risk to their health. The ALTER is the concentration range that a person could be exposed to over a lifetime without undue risk to their health.

Carbon dioxide (CO_2) levels were measured on a continuous basis for a six month period between March, 1995 and August, 1995 (see Table 15) and by spot checks using gas detection tubes. The mean concentration recorded during the period of continuous monitoring, which is considered to be the more representative, was 571 ppm - well below the Health and Welfare Canada guideline of 3500 ppm. However, what makes these results particularly interesting is that the homeowners intentionally operated the HRV so as to control the CO_2 concentrations to roughly 600 ppm. The CO_2 sensor, located in the master bedroom, had an output display which the homeowners used as an indicator to turn the HRV on or off. Using this control strategy, the average mechanical ventilation rate provided by the HRV was estimated at 16 l/s (33 cfm). The design flow rate for the house, as calculated using CSA F326, was 70 l/s (148 cfm). Therefore, the average utilization of the HRV, based on the design flow rate, was 22%, or 5.3 hours per day. Despite this relatively low utilization, CO_2 concentrations were kept at reasonable levels, acknowledging that the occupancy levels were relatively low (two adults, occasionally away for several days - during which the HRV was turned off).

TABLE 13
SUMMARY OF THE INDOOR AIR QUALITY CONTROL MEASURES IN THE MANITOBA ADVANCED HOUSE

AIR QUALITY CONTROL MEASURE	PROVIDES PROTECTION AGAINST
Continuous mechanical ventilation (Heat Recovery Ventilator)	All airborne pollutants (chemicals, particulates, odours, moisture, etc.)
Intermittent mechanical ventilation (various exhaust fans)	All airborne pollutants (chemicals, particulates, odours, moisture, etc.)
High-capacity kitchen range hood with side curtains	Natural gas products of combustion, cooking by-products
Sealed combustion appliances used for space heating, DHW and fireplace	Combustion spillage and backdrafting from natural gas appliances
High-efficiency (85%) bag filter	Particulates
Activated charcoal filter	Chemicals and odours
Airtight below-grade construction	Radon, soil gas and soil moisture
Airtight above-grade construction	Outdoor-based pollutants (car exhausts, chemicals, particulates, etc.)
Natural fabrics for carpets and upholstery	Chemicals (mainly Volatile Organic Compounds)
Solid wood cabinetry (wherever possible)	Chemicals (mainly Volatile Organic Compounds)
Sealed particleboard surfaces	Chemicals (mainly Volatile Organic Compounds)
Open metal closet shelving	Chemicals (mainly Volatile Organic Compounds)
Cabinet exhausts	Chemicals stored in cabinets
Closet return air grilles	Odours and chemicals originating from clothes
Hobby room	Various pollutants originating from hobby room activities

TABLE 14
SUMMARY OF INDOOR AIR QUALITY RESULTS

POLLUTANT	MEASUREMENT PERIOD	EXPOSURE GUIDELINES[1]	MEASURED CONCENTRATION		ASSESSMENT
			UNOCCUPIED	OCCUPIED	
Formaldehyde (HCHO)	one week	0.05 ppm (target level)[2] 0.10 ppm (action level)[2]	0.042 ppm 0.047 ppm[3]	0.01 ppm 0.01 ppm[3]	Very satisfactory performance
Radon (Rn)	one week	100 mWL[4]		4 mWL	Very satisfactory performance
Particulates	one week	100 $\mu g/m^3$ (ASTER) 40 $\mu g/m^3$ (ALTER)	12 $\mu g/m^3$	<5 $\mu g/m^3$	Very satisfactory performance
Total Volatile Organic Compounds (TVOC)	one week	0.3 mg/m^3 (target level)[5] 1.0 mg/m^3 (action level)[5]	0.05 mg/m^3	0.15 mg/m^3	Very satisfactory performance
Carbon dioxide (CO_2)	spot	3500 ppm (ALTER)	500 ppm 600 ppm 600 ppm[3]		Very satisfactory performance
Carbon monoxide (CO)	spot	11 ppm (8 hour) 25 ppm (1 hour)	< 5 ppm (4 measurements)[3]		Very satisfactory performance
Nitrogen dioxide (NO_2)	spot	0.25 ppm (ASTER) 0.05 ppm (ALTER)	< 0.5 ppm		Unknown, level below detection limit of sampler
Ozone (O_3)	spot	0.12 ppm (ASTER)	< 0.05 ppm (3 measurements)[3]		Very satisfactory performance
Sulphur dioxide (SO_2)	spot	0.38 ppm (ASTER) 0.019 ppm (ALTER)	< 0.2 ppm		Satisfactory performance
Total air change rate (ac/hr)		not applicable	0.28 ac/hr	0.22 ac/hr	not applicable

Notes:
1. From "Exposure Guidelines for Residential Indoor Air Quality", Health and Welfare Canada (HWC 1989), unless noted.
2. The "target level" represents the long-term objective whereas the "action level" is the point at which immediate action should be taken to reduce pollutant levels.
3. Multiple measurements made per monitoring period.
4. "mWL" = milliWorking Levels; 100 mWL is equivalent to 800 Bq/m^3 (Becquerels per cubic metre).
5. From the recommended, but non-mandatory, target concentration guidelines for selected contaminants in ASHRAE draft Standard 62-1989R (August 1996).

TABLE 15
MEAN CO_2 CONCENTRATIONS
(CONTINUOUSLY MONITORED DATA)

MONTH	MEAN CO_2 CONCENTRATION (ppm)
March/95	772
April/95	678
May/95	732
June/95	450
July/95	386
Aug/95	411
MEAN	571

8.2 INDOOR TEMPERATURES AND RELATIVE HUMIDITY

Indoor temperatures were monitored on a continuous basis at five locations in the house during the monitoring period: the master bedroom and second bedroom on the second floor, the living room and family room on the main floor and in the basement. For the HOT2000 analysis, a single, average temperature was used for each level, as summarized in Table 16. Interior relative humidity (RH) levels were continuously recorded using a sensor located in the exhaust air duct leading to the HRV. Unfortunately, reliability problems occurred with the data collection system such that only about seven months of data was obtained. Average comparative data is also shown in Table 16 for the five, occupied Advanced Houses across the country (Cooper and Mayhew, 1996).

The temperature data shows that temperatures within the house were generally quite uniform, with a variation of only about 1 °C to 2 °C between the mean temperatures on the three levels. This is viewed as a positive indication that the house was able to operate in a reasonably balanced manner from a thermal perspective. Relative humidity levels were generally within, or slightly below, the range of 30% to 55% recommended by Health and Welfare Canada (1989) for winter conditions. However, these levels are mainly indicative of the homeowners' utilization of the ventilation system, rather than the house itself.

TABLE 16
MEAN MONTHLY TEMPERATURES AND RELATIVE HUMIDITY LEVELS

MONTH	BASEMENT TEMPERATURE (°C)	MAIN FLOOR TEMPERATURE (°C)	SECOND FLOOR TEMPERATURE (°C)	RELATIVE HUMIDITY (%)
Sept/94	20.8	22.4	22.4	
Oct/94	20.9	21.8	20.8	45%
Nov/94	20.6	21.2	19.7	28%
Dec/94	20.1	20.7	19.1	25%
Jan/95	19.8	20.4	18.3	24%
Feb/95	20.1	20.9	19.2	22%
March/95	20.1	21.2	19.9	22%
April/95				
May/95	20.7	22.3	21.9	35%
June/95	23.0	25.2	25.1	
July/95	22.7	23.9	23.9	
Aug/95	22.9	24.3	24.0	
MEAN	21.1	22.2	21.3	
COMPARATIVE DATA FOR FIVE, OCCUPIED ADVANCED HOUSES				
Mean House Temperatures:	23.2 °C (summer)	20.4 ° (winter)		
Mean Basement Temperatures:	21.8 °C (summer)	19.5 ° (winter)		
Mean Relative Humidity Levels:	47% (summer)	29% (winter)		

8.3 COMPARISON WITH CONVENTIONAL AND R-2000 HOUSES

Comparisons were also made between the indoor air quality in the Manitoba Advanced House with that measured in four conventional and 16 R-2000 houses monitored during the Flair Project in the late 1980s (Proskiw 1992b). These houses used technology which typified conventional and R-2000 construction in Manitoba. A summary of these results is shown in Table 17 along with some comparative data for all the Advanced Houses.

When the pollutant concentrations in Table 17 are compared to those in Table 14, it is apparent that the indoor air quality in the Manitoba Advanced House was quite good relative to either conventional or R-2000 houses. Formaldehyde, radon, particulate and carbon dioxide concentrations were all lower in the Manitoba Advanced House while levels of nitrogen dioxide were below the detection limit of the measurement system.

TABLE 17
TYPICAL POLLUTANT CONCENTRATIONS IN OTHER TYPES OF HOUSES

POLLUTANT	MANITOBA HOUSES		ALL ADVANCED HOUSES	
	CONVENTIONAL	R-2000	TEST #1	TEST #2
Formaldehyde (HCHO)	0.068 ppm	0.060 ppm	0.046 ppm[1]	0.058 ppm[1]
Radon (Rn)	10 mWL	7 mWL		
Particulates	33 $\mu g/m^3$	38 $\mu g/m^3$		
Nitrogen dioxide (NO_2)	0.0044 ppm	0.0040 ppm		
Carbon dioxide (CO_2)	800 ppm	600 ppm	495 ppm[2]	552 ppm[2]

Notes:
1. Test #1 conducted during the unoccupied period, Test #2 conducted during the occupied period.
2. Test #1 conducted during the summer, Test #2 conducted during the winter.

8.4 OVERALL ASSESSMENT OF THE INDOOR AIR QUALITY

The air quality testing demonstrated that the collective impact of the indoor air quality control measures in the Manitoba Advanced House was very successful at maintaining low pollutant concentrations and generally providing a high quality living space, from an air quality perspective. Measured pollutant concentrations were generally well below the Health and Welfare Canada exposure guidelines and lower than those measured in comparable new, conventional and R-2000 houses in the same city. With respect to the radon data, it should also be noted that Winnipeg is regarded as being an area of high radon concentrations, so the very low measured concentrations are particularly interesting.

Although there are numerous other pollutants known to exist in the indoor residential environment and whose concentrations were not measured, the results from the testing were very encouraging and demonstrated that the control measures were quite successful at their intended function.

SECTION 9
WATER CONSUMPTION

9.1 FIXTURE FLOW RATES

The flow rates of various fixtures were determined during the house's unoccupied period. In addition, the overall water usage of the house was measured during the monitoring period for comparison to published data. The fixture flow rate results are summarized in Table 18 along with the Advanced House and R-2000 water usage requirements (for comparison). The house's compliance with the water usage requirements in the Technical Requirements are summarized in Table 19.

TABLE 18
FIXTURE WATER FLOW RATES

FIXTURE	MEASURED FLOW (l/min)	ADVANCED HOUSE REQUIREMENT (l/min)	R-2000 REQUIREMENT (l/min)
Kitchen sink faucet (single)	4.4	see note 1	8.3
Kitchen sink faucet (double)	15	see note 1	8.3
Basement sink faucet	12	see note 1	8.3
Main floor bathroom sink faucet	4.4	see note 1	8.3
Second floor bathroom sink faucet	5.2	see note 1	8.3
Second floor bathtub	12	none	none
Second floor shower - low flow - high flow	 2.4 11	 none 10	 none 10
Ensuite sink faucet	5.5	see note 1	8.3
Ensuite whirlpool	36	none	none
Ensuite shower - low flow - high flow	 2.1 12	 none 10	 none 10

Notes:
1. Sink faucets are required to have aerators, however no quantitative requirement exists.

TABLE 19
COMPLIANCE WITH WATER USAGE REQUIREMENTS

ADVANCED HOUSES TECHNICAL REQUIREMENT	MANITOBA ADVANCED HOUSE	COMPLIES WITH TECHNICAL REQUIREMENTS?
Toilets: water usage can not exceed 7 litres/flush	One of three toilets measured; water usage 16 litres/flush.	No
Showerheads: water flow rate can not exceed 10 litres/minute at 551 kPa	The two showers exceeded target by 10% and 20%, respectively.	No
Faucets: must be equipped with faucet aerators	All faucets equipped with aerators.	Yes
Landscaping: must be designed to minimize the use of water	Extensive use of vegetation with low water requirements, minimal turf.	Yes
Clothes washing machine: model with low water consumption per cycle must be chosen	Low usage model chosen.	Yes

9.2 TOTAL WATER USAGE

The total (indoor and outdoor) measured water consumption of the Manitoba Advanced House during the one year monitoring period was 73,000 litres. This is equivalent to 200 l/day or 100 l/day•person for the two homeowners in the house. The vast majority of this is believed to have been consumed indoors. The Technical Requirements quotes an American reference which gives an average indoor water consumption of approximately 300 l/day•person. Therefore, despite the fact that not all the technical requirements were met, the average per capita measured water consumption in the Manitoba Advanced House was about one-third that of a conventional house. However, water usage is heavily dependent upon lifestyle and the two homeowners were very conscientious about conserving water.

SECTION 10
CONCLUSIONS AND RECOMMENDATIONS

10.1 ENERGY CONSUMPTION

The monitoring program and energy analysis indicated that, under average operating conditions, the Manitoba Advanced House would exceed its energy target by 53%, or 9,066 kWh_e/yr. However, over three-quarters (78%) of this overconsumption was due to limitations of the computer software used to design the house in 1992. The analysis suggested that if current versions of the software had been available at that time, the house would have been designed in a more energy efficient manner and lower energy usage would presumably have resulted. Nonetheless, the Manitoba Advanced House is an extremely energy efficient structure which would only consume 44% to 48% of the energy of an equivalent conventional, new natural gas Manitoba home, or 60% of that of an R-2000 house. To further improve its energy performance, the following changes could be made to the design:

- The airtightness could be improved from the final value of 1.17 ac/hr_{50}. This could probably be achieved by reducing the air leakage through the supply air ductwork system.
- The HRV system efficiency could be improved by using smaller diameter, better insulated ductwork for the ventilation system.
- Some form of insulated frames, rather than conventional wood frames could be used for the windows.
- The greywater heat recovery system could be re-designed to increase its energy recovery capability.
- Smaller and more energy efficient motors, blowers and pumps sets could be used for the heating system's air handler, the HRV and the water circulation pumps.

10.2 INDOOR AIR QUALITY

The collective impact of the indoor air quality control measures incorporated into the house (high quality mechanical ventilation, 85% efficient bag filter, activated charcoal filter, sealed combustion appliances and elimination/containment of various potential pollutants) was very successful at maintaining low pollutant concentrations. Measured pollutant levels were well below the Health and Welfare Canada exposure guidelines and were also lower than those measured in equivalent, conventional and R-2000 houses.

10.3 WATER CONSERVATION

The measured per capita water consumption was 100 l/day•person, well below reported levels for conventional residences, although this was due in part to the lifestyle of the homeowners who were very conscientious about water usage.

10.4 RECYCLING AND ECOMANAGEMENT

The various measures intended to encourage recycling and ecomanagement were, in most cases, judged as successful and easy to use. No major problems were encountered and they were favourably received by tradesmen working on the house and by the public during the open house period.

10.5 TECHNOLOGY SPECIFIC CONCLUSIONS AND RECOMMENDATIONS

Exterior Wall System - The exterior walls were constructed using a factory-built split stud system and insulated with Blown-In-Batt glass fibre insulation with a nominal thermal resistance of RSI 8.10 (R-46). No major problems were encountered during construction, thermal performance met expectations and monitoring indicated acceptably low wood moisture content levels in the studs.

Foundation - The relatively conventional concrete basement, insulated with high levels of interior, exterior and underslab insulation performed in a very satisfactory manner. In contrast to most houses in the same general area, there has been no water penetration or slab cracking problems. However, the presence of underslab insulation precluded using the basement as a free source of cooling during the summer.

Air and Vapour Barrier Protection - The air/vapour barrier system used in the house employed sealed polyethylene, air retarder header wraps, polyurethane foam at penetrations and airtight electrical boxes. Overall, the system worked quite well and at reasonable cost. The only major problem encountered was created by the leaky supply air ductwork, which increased the initial, measured airtightness from 0.78 ac/hr_{50} to the final value of 1.17 ac/hr_{50}.

Windows - The windows consisted of quadruple-glazed sealed units with triple low-E coatings, krypton-filled spaces, insulating spacer bars and wood frames. Overall, their performance was excellent. However, heat losses were slightly higher than had been anticipated during the design phase because of limitations in the software used to analyze the performance of the windows. One area in which the windows could be improved would be through use of insulated frames, rather than the conventional wood frames.

Doors - The steel insulated doors, with glass inserts constructed to the same standard as the house windows, generally worked satisfactorily.

Mechanical System - Overall, the mechanical system was too complex, expensive and used too much space in the house. Some of the components provided little, if any, benefit and could have been eliminated or simplified without major adverse effect upon performance.

Space Heating System - The condensing, natural gas boiler generally provided a comfortable living space. However, the unit suffered from exhaust vent blockage caused by ice build-up which resulted in automatic shut-down of the unit on several occasions. The four heating zones used in the house could have been replaced by a single air zone and one baseboard-heated zone. This would have saved construction costs and simplified the mechanical system. Also, a smaller, quieter and more energy efficient air handler should have been used.

Ventilation System - Measured pollutant levels in the house were very low which indicates that the mechanical ventilation system achieved its primary objective of maintaining good indoor air quality. The system could have been improved by using smaller, simpler and better insulated ductwork between the HRV and the outdoors, a more energy efficient distribution system for the ventilation air and unitary exhaust fans which exhausted directly out through exterior walls rather than using long duct runs to exhaust air down to the basement and out through the floor headers.

Continuous Circulation Blowers and Pumps - The four devices intended for continuous or quasi-continuous operation (heating system air handler, HRV, space heating circulation pump and DHW circulation pump) consumed 44% of the total electrical load during the monitoring period. The use of more efficient electric motors, blowers and pumps could have reduced this load - possibly to a significant degree. Also, improved mechanical system design would have permitted lower utilization of these devices.

Domestic Hot Water Heating System - The integrated DHW system, which draws hot water from the space heating tank, has performed well. However, additional research is needed to find effective means to supply and/or reduce the DHW load in Advanced Houses. One technology which shows considerable promise is greywater heat recovery.

Greywater Heat Recovery - The prototype, custom-built system used in the Manitoba Advanced House was estimated to have supplied about 40% of the DHW load, despite not having benefit of the design tools subsequently developed as part of this project. With the knowledge gained, the system could be easily re-designed to both increase the amount of recovered heat and reduce costs. Greywater heat recovery is regarded as a technology with considerable promise and one worth developing further.

Below-Grade Heat Recovery System - The BGHRV concept, which ducts exhaust or attic air into the drainage system around the house, is regarded as having some potential. However, it would be better suited to houses which do not have an HRV, and can thus use the warm exhaust air from the ventilation system as the source of heat.

Natural Gas Range Exhaust and Make-up Air System - The make-up air system installed in the house was too complex, expensive and problem-prone. The conclusion drawn from this experience was that, for many houses, it would be easier and cheaper to solve the problem of providing make-up air to houses with spillage-susceptible appliances by changing the appliances to non spillage-susceptible types, rather than providing a make-up air system with its attendant complexities. Performance tests conducted on the range hood demonstrated that: hood capture of the thermal plume was enhanced when back burners were used rather than front burners, multiple burners increased the amount of spillage compared to a single burner, and side curtains significantly reduced spillage. Finally, the tests showed that the required hood exhaust rate necessary to control spillage from the range would be sufficiently high that combustion spillage would occur in the majority of new, Manitoba homes if equipped with naturally aspirated appliances.

Cooling - Overheating has been a problem in the Manitoba Advanced House despite the use of exterior solar shade screens. Some form of mechanical cooling is required. Further, better design tools are needed to assess the potential for overheating in Advanced Houses.

Dryer Heat Exchanger - Attempts to save energy using a commercial-grade heat exchanger proved to be expensive and futile. The heat exchanger should have been eliminated or replaced with a grossly simpler system.

Fireplace - The direct-vent, natural gas fireplace has generally worked well although it appears that the unit can create a localized cool spot in the room due to thermosyphoning of outdoor air through the fireplace which cools the glass face of the unit. In addition, there may be a small amount of air leakage through the fireplace. The choice of a glow-bar ignition system, rather than a standing pilot, saved a great deal of energy. It is recommended that the thermosyphoning and air leakage issues be investigated in more detail.

Lighting and the Electrical System - The T-8 fluorescent lights with electronic ballasts and the compact fluorescents have worked well and provided good colour rendition. The dimmable ballasts (used on some of the T-8 lights) and halogen lights were found to be quite expensive, when originally purchased. The electromagnetic field control measures incorporated into the house were relatively easy to install. However, tests on their effectiveness proved inconclusive because the background magnetic field strength in the house was very low.

Air Filtration System - The 85% efficient bag filter proved very effective at controlling particulate levels in the house, however the pressure drop across the filter was large and needs to be considered (from an energy perspective) if the technology is being considered for future houses. For many homeowners, a slightly less efficient filter (40% to 60%) would prove adequate and yet still represent a major improvement over a conventional 5% efficient furnace filter.

Hobby Room - The concept of depressurizing one room or zone with an exhaust-only ventilation system to control migration of pollutants generated in that area to the rest of the house, proved successful. It would be especially useful for people with chemical sensitivities and in houses which contain both smokers and non-smokers.

Low Emission Finishes, Cabinet Exhaust System and Closet Return Air Grilles - All of these measures were judged as relatively easy to use and effective at improving indoor air quality. However, application of the low emission finishes to the kitchen cabinetry was somewhat labour intensive, although this could be reduced in a mass-production environment.

Water Conservation Devices - The low flow showerheads appear to have worked satisfactorily even though their water flow rates were slightly greater than those specified in the Technical Requirements. The infrared faucets, while popular from a demonstration perspective, were quite expensive and would only be economical for people with special needs. Water usage of the double-flush toilet was well above that specified in the Technical Requirements, while the pressure flush toilet leaked repeatedly causing damage to the house. The landscaping system, using indigenous plants and minimal turf, worked well although costs have to be monitored carefully when using this approach.

Resource Conservation - The resource conservation measures were generally quite effective. The stone/glass drainage system under the floor slab and over the weeping tile was very successful and posed no handling problems. The use of open web floor trusses, microlaminated built-up wood beams and plywood "I" joists were all successful. The cork flooring system worked well although it proved a little vulnerable to damage during the very high traffic levels encountered in the open house period. The pine shake roof was also very successful, and aesthetically pleasing with no functionality problems.

Household Recycling Devices - The multiple bin recycler work very well, although a re-design of the unit would be beneficial so the opening could be located at counter level to make it more convenient to use. The kitchen compost storage device was also judged as successful although a modified design would be preferred in which indoor access was provided to permit the compost pail to be emptied from the indoors, and the storage space depressurized to control odours.

Power Indicator - The power indicator, designed to provide an instantaneous read-out of electrical energy usage, was judged as a good concept with potential commercial application. However, the unit installed in the Manitoba Advanced House was too complicated for most people to easily program and read. Also, it uses an optical pick-up on the electrical meter which proved to be susceptible to dislodgement.

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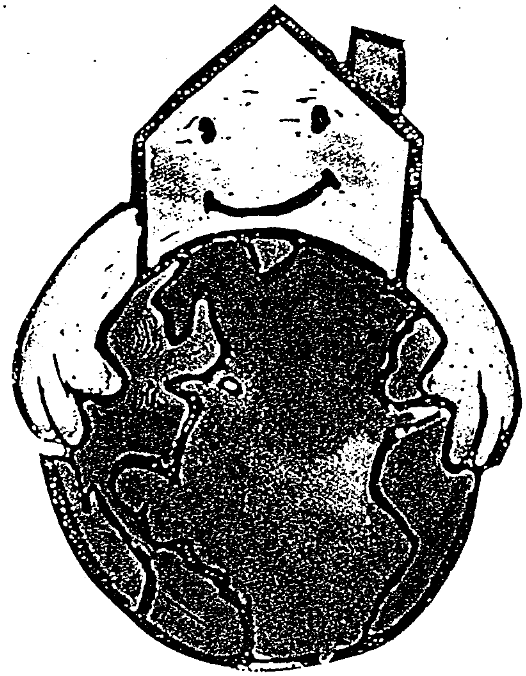
APPENDIX A



MANITOBA ADVANCED HOUSE

Developing new approaches to energy-efficient, environmentally sensitive housing

MANITOBA ADVANCED HOUSE PARTNERS

Manitoba Home Builders' Association
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Environment Canada
Manitoba Energy and Mines
The City of Winnipeg
Centra Gas Manitoba
Manitoba Hydro
Ladco Co. Ltd.
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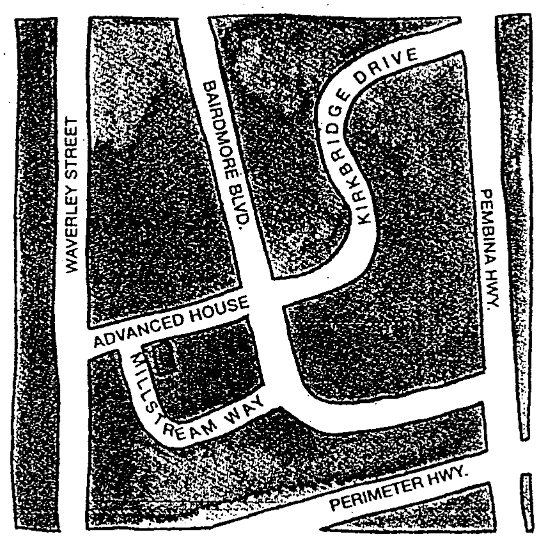

ADVANCED HOUSES PROGRAM

For more information contact:
Manitoba Home Builders' Association
Box B 231-1120 Grant Avenue
Winnipeg, Manitoba
R3M 2A6
Tel: (204) 477-5110
Fax: (204) 477-5139

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THE ADVANCED HOUSE PROGRAM

The Advanced House Program is an Energy, Mines and Resources Canada initiative in partnership with the Canadian Home Builders' Association.

The program is challenging Canadian home builders, manufacturers, utilities and others to explore homes for a more sustainable future – homes built on a solid foundation of energy-efficient, environmentally sensitive construction practices.

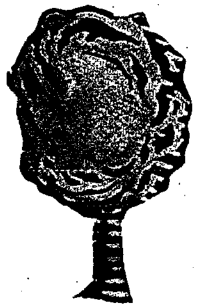
A SHARED VISION

The Manitoba Advanced House Project is coordinated by the Manitoba Home Builder's Association. It is a team effort involving industry, utilities and government.

The Manitoba Advanced House is one of eleven winning proposals selected in a national competition. These eleven projects will act as a catalyst in developing a new generation of more energy-efficient and environmentally responsible homes.

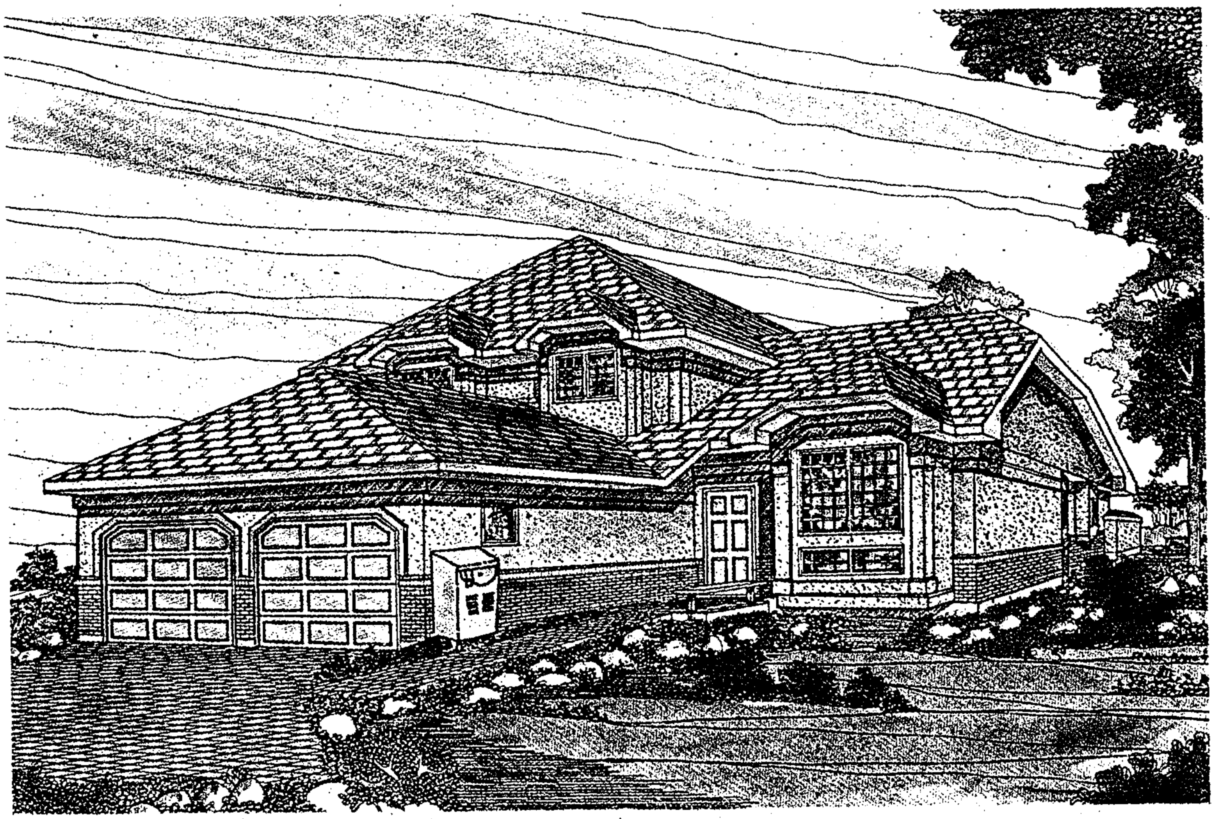
LEARNING TOGETHER

The Manitoba Advanced House will be open to the public until the fall of 1993. Consumers and the building industry can tour the home and participate in workshops to learn about the home's innovative ideas and products. For details about open house hours or the workshops, contact the Manitoba Home Builders' Association at 477-5110.



After being open to the public, the Advanced House will be sold to private owners. Extensive monitoring will be conducted on the occupied house for one year.

The performance of the home's innovative technologies and products will be assessed. Results will be shared with the public and the building industry across Canada and around the world.



We wish to acknowledge the co-operation of the following suppliers:

Basement, garage, front step slab: St. Andrews Concrete Finishers Ltd.

Brick Installer: Len's Masonry

Cabinets: Kitchen Craft of Canada Ltd.

Cellular Phone Services: Cantel

Ceramic Tile: Torino Tile

Closet Organizers: For Space Sake

Damp Proofing: Peter Kohut

Designers: Appin Associates; UNIES Ltd.; BOGE & BOGE; TPR Mechanical

Driveways and Walkways: Barkman; R & D Construction

Drywall Products: The Synkoloid Co. of Canada

Drywall: Loewen Drywall; Westroc

Electrical: Sussex Electrical

Electronic Equipment: Advance Electronics

Excavating: Frick Construction Ltd.

Exhaust Fans: ECCO Heating Products

Financing: Canadian Imperial Bank of Commerce

Floor trusses/Microlam/Lumber: Dominion Lumber

Flooring: H.I. Carpeting; Floorevery

Foundation: Otto Zacharias

Framing: Solstice Enterprises

Furnishings and Accessories: Faveri's; Workshop Designs; Interior Illusions

Garage Door: Red River Overhead Door

Garage Heater: Wholesale Heating

Glass/gravel mix and concrete: Supercrete

Heating Coils & Circulation Pumps: Hydron-aire Ltd.

Heating: Pellaers Ventilation

House Performance Monitoring: Proskiw Engineering

Insulation: B. Plett Enterprises; Fiberglas Canada; Dow Canada Inc.

Interior Designers: Jan Ash Design; Joy Meyers-Piske Design

Interior Finishing Material: Woodlands Supply Ltd.

Kitchen Light Box: Gateway Kitchen & Bath Centre Ltd.

Kitchen Range Hood/Switches: Broan Manufacturing

Landscaping: McEwan Bros.

Lifebreath Heat Recovery Ventilator: Heat Saver Distributors, Nutech Energy Systems

Light Fixtures: Superlite

Locks: Weiser

Major Electrical Appliances/Bulbs/ Motors: G.E. Canada

Paint: Buhle Painting; Northern Paint

Piles: Provincial Piling

Plumbing Fixtures and Faucets: Crane Canada Ltd.; Derksen Plumbing

Recycled Glass: Manitoba Soft Drink Recycling

Roof Trusses and Microlam: All Fab Building Components

Roofing: Prairie Shake Roofing

Sealants: G.P. Johnson Ltd.

Security System/Control Valves: Honeywell

Sewer and Water Services Installer: Double A Construction

Site Supervisor: J.P. Koop Construction

Steel: Cowin Steel

Stucco Detail: D. Popiel Siding

Stucco: Hubatka Bros. Contracting

Sub-Floor Construction: L.H. Koop Construction

Survey: Pollock & Wright Land Surveyor

Wall Studs System: Ten Lives

Windows: Wilmar Windows

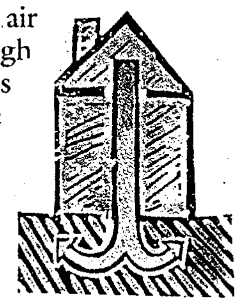
The Manitoba Advanced House is a 2,000 sq. ft., two-storey home. It is located in south Winnipeg at the corner of Kirkbridge (east of Waverley) and Millstream. Features of the home include:

ENERGY EFFICIENT BUILDING SHELL

- High attic insulation levels (R-60) provided by cellulose insulation made from recycled newsprint.
- A unique "split-stud" wall system containing above average levels (R-45) of blown-in insulation.
- Special electrical boxes in exterior walls and ceilings that eliminate drafts.
- Most windows face south to take advantage of Manitoba's sunny winters.
- Windows that gain more energy than they lose, even on the north side of the house! Added benefits include improved comfort, no condensation and blockage of ultra-violet light from the sun that fades fabrics and furniture.
- Removeable solar screens that cover windows during summer to prevent overheating without blocking views.
- Exterior insulation on foundation walls to reduce the potential for structural and water seepage problems.
- Rigid foam insulation under the entire basement floor slab to reduce heat loss, dampness and improve comfort.

ENERGY EFFICIENT MECHANICAL SYSTEM

- A hi-efficiency natural gas hot water tank with air handler that heats both the home and water for cooking, showers, dish-washing, clothes washing, etc.
- Air circulation through the home using motors and fans that are much more efficient than standard units.
- An innovative heat exchange system that preheats incoming fresh water with water drained from the clothes washer, dish-washer, showers and sinks.
- Insulated water pipes; hot water pipes to reduce heat loss and cold water pipes to prevent condensation.
- A programmable electronic control system that provides flexibility and energy savings in operating the heating, ventilation, lighting and security systems.
- Separate thermostats that create four zones to allow heating as required by the occupants.
- A heat recovery ventilator to exhaust stale air while preheating incoming fresh air.
- A system to exhaust warm air from the attic down through the basement drainage tiles and into the soil to reduce heat loss around the basement.



- An easy-to-read electronic monitor provides occupants with feedback about how much electricity they are using. The monitor gives the rate of present and past usage and can predict the monthly electrical bill.

ENERGY EFFICIENT LIGHTING

- Attractive, energy-efficient fluorescent and halogen lighting fixtures are used through most of the house. Incandescent lighting is restricted to fixtures that are seldom used.
- Extensive use of special dimmer and automatic light switches to save energy and increase convenience for the occupants.

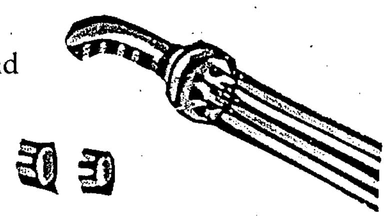
ENERGY EFFICIENT APPLIANCES

- Appliances that are among the most energy-efficient and water conserving models available.
- A natural gas range with a specially designed hood to vent cooking odors directly to the outdoors.
- Recovery of heat from the exhaust air of the natural gas dryer.

INDOOR AIR QUALITY

- Paints, flooring, adhesives and countertops that meet rigorous standards to reduce "off-gassing" of chemical pollutants that may be harmful.
- A very effective "bag" filter and charcoal filter to remove contaminants and odors in the indoor air.
- Special sealing of the basement floor to prevent the entry of radon.

WATER CONSERVATION



- Water-efficient toilets, showerheads and faucets that reduce water usage without sacrificing performance.
- Landscaping with native and drought tolerant plants that reduce watering requirements, provide summertime shade and create a comfortable, attractive "micro-climate".
- A system to collect and store water from the roof and basement sump for later use in watering the lawn.

HOUSEHOLD RECYCLING

- A special kitchen-to-basement recycling chute and bins to make sorting and storing recyclable materials easy.
- A large storage bin for kitchen wastes that prevents odor problems while providing easy access from the outdoors to a backyard composter.

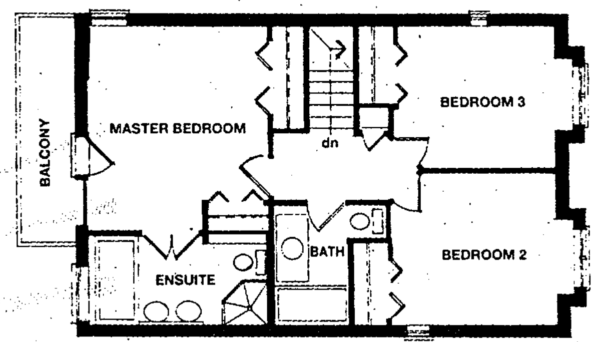
CONSTRUCTION WASTE MANAGEMENT

- Pine roof shakes that require little energy to manufacture, come from a renewable resource and have a long life expectancy (30 to 50 years).
- Backfill around the basement's drainage system that is a mixture of gravel and recycled glass.
- Engineered wood products such as split-stud wall framing, floor trusses, roof trusses and laminated wood beams that use small dimension lumber. This lessens the need to harvest old-growth forests.

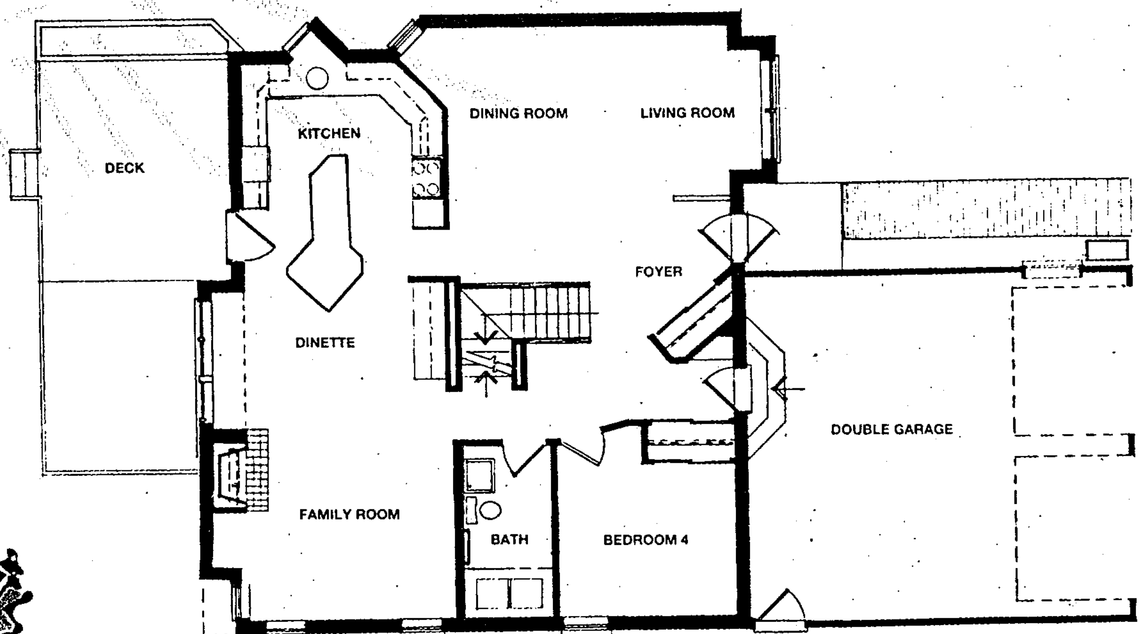
OTHER FEATURES

- An electrical system that incorporates measures to reduce the effects of electromagnetic fields.
- An indoor timer to control vehicle block heaters and interior warmers.
- A barrier-free main floor for wheelchair access.
- Pieces of display furniture that are recycled by recovering and refinishing.
- A natural gas vehicle refueling station that a homeowner can use to fill their low-pollution, natural gas vehicle.
- An easy-to-locate direct vent natural gas fireplace with no pilot light, provides clean, convenient, energy-efficient comfort.

Southern Exposure



second floor plan



main floor plan

THE MANITOBA ADVANCED HOUSE FLOOR PLAN

Good reasons to build...

A Better Building Envelope

▼▼▼▼▼▼▼▼▼▼

Builders often refer to the parts of a home that separate heated living space from the great outdoors as the building envelope. A proper building envelope features high levels of insulation, good quality windows and doors, and low air leakage. This results in a more durable, comfortable and energy-efficient home.

This is the 1st in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.

THE BUILDING BLOCKS OF HOME DESIGN

It is important that the right choices be made when planning your new home or addition because future upgrading of the building envelope is expensive. In reality however, some builders are more concerned with minimizing construction costs rather than long-term operating costs. This means you could be offered a lower purchase price, but you may end up paying higher costs for energy and maintenance.

SELECTING A PROFESSIONAL

Choose a home designer, builder or contractor that is knowledgeable about building well-insulated, sealed and ventilated homes.

An easy way to locate qualified professionals is to contact the Manitoba R-2000 Home Program for a list of certified builders. This program is a partnership between the home building industry, utilities, governments, financial institutions and others. The R-2000 Home Program promotes the construction of homes offering homebuyers the maximum in comfort, quality, energy savings and environmental benefits.

Under this program, the plans for your home will be evaluated to ensure that your home achieves a minimum "energy performance target". The home will also be inspected and tested during construction to insure that it meets or exceeds the established standards.

Contact the Manitoba R-2000 Home Program by calling 945-4335 in Winnipeg, or toll-free 1-800-282-8069 (extension 4335).

AIR-TIGHT HOMES AND INDOOR AIR QUALITY

There is a popular misconception that a home should deliberately have a "leaky" building envelope to avoid moisture or air quality problems. Research proves otherwise.

A leaky home is at the mercy of the weather to replace stale, indoor air with fresh air from the outdoors. For example, cold, windy days can cause too much ventilation resulting in uncomfortable drafts, low humidity and high heating bills. On the other hand, mild, calm days can result in poor ventilation, causing odours and other pollutants to linger. A leaky building envelope can also cause moisture to accumulate in the structure of the home leading to expensive, long-term damage.

Good indoor air quality in air-tight homes is achieved through the use of a well-designed ventilation system. This system continuously exhausts stale air, and replaces it with fresh outdoor air that can be heated, cooled, humidified or filtered before it is circulated.

For more information about choosing a mechanical system and indoor air quality, please refer to fact sheets #3 and #4 respectively, in this series.

TIP

To check the quality of how well the building envelope is sealed, insist that your builder conduct a ***blower door*** *test.* (A) *(See diagram next page.) This test uses a large fan fitted into an exterior door frame. It measures the rate at which air can be exhausted from the home. An excessive air flow rate means that there are cracks and openings in the building envelope that require further sealing. Specify that this testing be done in*

A Better Building Envelope

accordance with the standard CAN/CGSB-149.10-M86 "Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method."

BUILDING CONSIDERATIONS

The following tips walk you through the building process to help you make good design and construction decisions before you build.

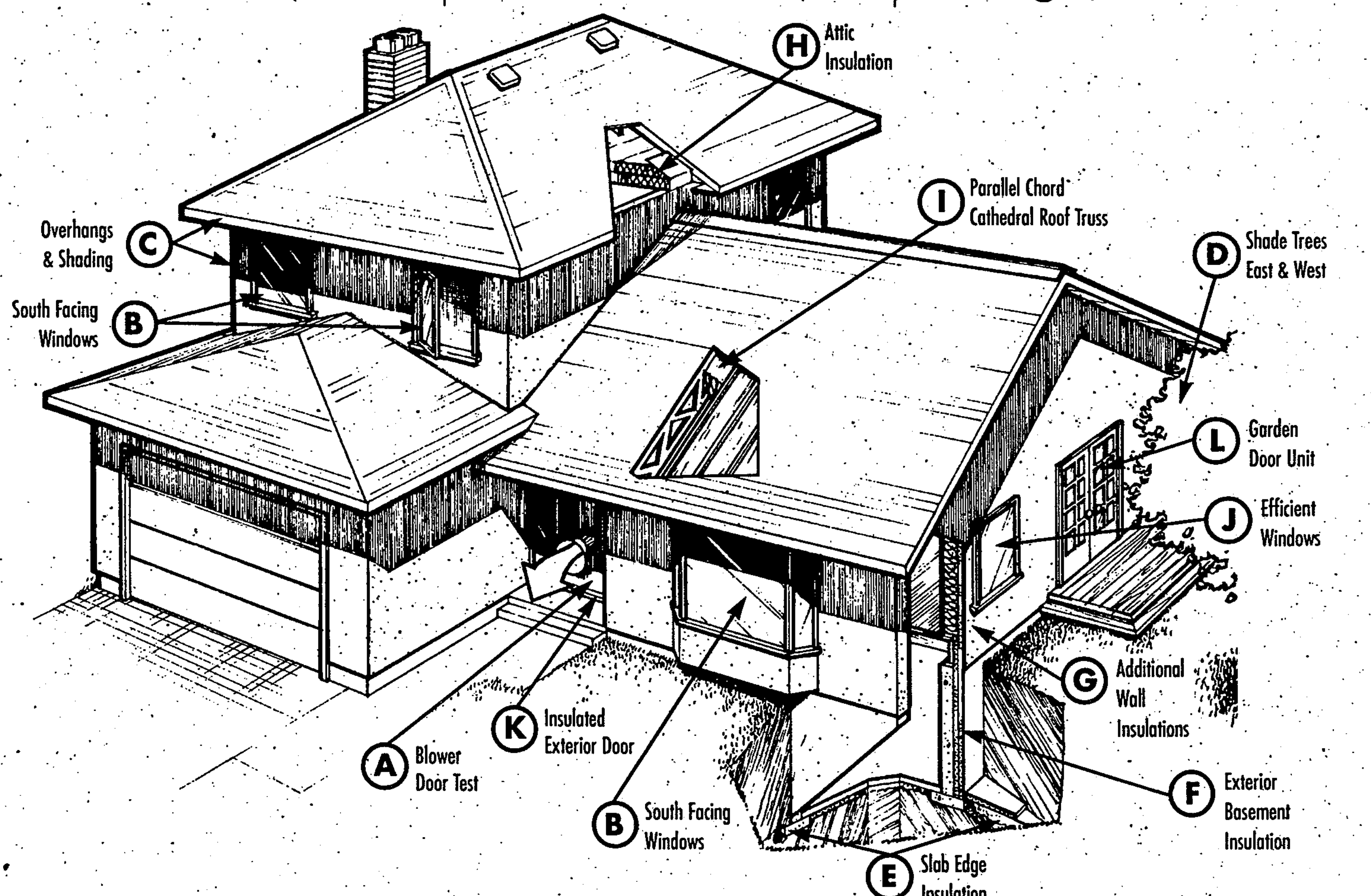
... DESIGN CONSIDERATIONS

The construction cost and heat loss from the building envelope is affected by the home's overall layout.

- A 2-storey house has less wall and roof area relative to its floor area than a bungalow, reducing building and heating costs.
- On a sloped site, consider a split level. A two or three-storey layout works well on the downhill side; restrict the height to one level on the uphill side.
- Bi-levels offer considerable interior living space at a reasonable cost.
- For bungalows, consider whether you really need a full basement; consider building a partial basement and use the money saved to expand the main floor living and storage areas.
- Avoid excessively complicated floor plans since they can be tricky to insulate and seal properly.
- Avoid locating doors on a side of the house which faces the prevailing wind.
- Design an unheated air-lock or mud room adjacent to outside doors as a means of controlling heat loss.

... SITE CONSIDERATIONS

- Pick a building site that enables you to take advantage of passive solar energy. Orient the majority of windows in the home to within 30 degrees of due south. (B)
- To avoid overheating, don't have too much south-facing window area. A rule-of-thumb is to limit south-facing glazing between 6% to 9% of the total floor area, including the basement of the home. (B)
- Ask your designer to include proper overhangs on south-facing windows to control over heating during the summer. (C)



A Better Building Envelope

- Use trees, louvres or screens to shade east or west-facing windows which are difficult to shade with overhangs. (D)
- Orient the home and windows to use prevailing wind for natural ventilation.

INSULATION

If you are building in a remote or ortherly area, or if you must use a ostly fuel source to heat your home, t is particularly important to achieve igh insulation levels. Follow the values n tables 1, 2, and 3 recommended by Vanitoba Energy & Mines.

... BASEMENT FLOORS

- It is cost-effective to add a 1 meter (3.3 feet) width of RSI-0.88 (R-5.0) rigid insulation under the perimeter of the basement floor even though it is seldom included in standard home specifications. (E)
- If the entire basement is to be used as living space, insulate under the entire basement floor for greater comfort.

CAUTION!

An insulated floor slab may increase the risk of foundation shifting if the soil is frost-sensitive or if the foundation is shallow. Find out if there have been problems with shallow basements in the vicinity of your lot.

... BASEMENT WALLS

You have the option of choosing between interior or exterior basement wall insulation methods. Insulating from the interior is more common because it is less costly to achieve high insulation values. It also makes it easy to finish the basement as living space.

Despite these advantages, consider the benefits of exterior insulation: (F)

TABLE 1 ***RECOMMENDED BASEMENT WALL INSULATION VALUES.***

Home Heat Source	Southern Manitoba	Northern Manitoba*
Natural Gas or Ground Source Heat Pump	•RSI-3.5 (R-20) Interior •RSI-2.1 (R-12) Exterior	•RSI-4.2 (R-24) Interior •RSI-3.2 (R-18) Exterior
Electricity, Oil, Propane, Wood	•RSI-4.2 (R-24) Interior •RSI-3.2 (R-18) Exterior	•RSI-4.2 (R-24) Interior •RSI-3.2 (R-18) Exterior

Source: Manitoba Energy and Mines
* North of the 53rd parallel

- reduces potential for structural damage since basement walls are not subject to large temperature swings and freeze/thaw cycles,
- adds to the thermal mass of the home,
- eliminates concealed condensation and water leakage problems,
- enables the contractor to insulate and seal the junction between the floor framing and basement wall better, and
- does not take away valuable interior living space.

... EXTERIOR WALLS

Exterior wall insulation is typically placed between the studs of a standard 38 x 140 mm (2 x 6 in.) wall. There are several different types that can be used: (G)

- RSI-3.5 (R-20) batt-type insulation. Even higher insulation values can be achieved by the addition of insulated sheathing, attached to the outside of the wall framing.
- Loose-fill cellulose or fibreglass insulation can be mixed with an adhesive and sprayed into the open exterior walls before the interior finish is applied. Commonly called 'blown-in-blanket' (BIB), this method can provide more uniform insulation levels and reduced air leakage.
- There are several different styles of panel wall systems that use a rigid foam insulation core. These systems offer uniform insulation levels and quick installation, but may make electrical wiring and other services more difficult to install.

TIP

Investigate the performance of new insulation systems such as spray-application methods and panel-wall systems. Find out how many homes your builder has built using these methods and ask for references of satisfied customers.

TABLE 2 ***RECOMMENDED EXTERIOR WALL INSULATION VALUES.***

Home Heat Source	Southern Manitoba	Northern Manitoba
Natural Gas or Ground Source Heat Pump	•RSI-3.5 (R-20)	•RSI-4.6 (R-26)
Electricity, Oil, Propane, Wood	•RSI-4.6 (R-26)	•RSI-4.9 (R-28)

Source: Manitoba Energy and Mines

... ATTICS

Attics are easy to insulate with high levels of low-cost batt-type or blown insulation. (H) Either fibreglass or cellulose insulation that complies to the appropriate CSA or CGSB standards, is acceptable.

... CATHEDRAL AND SLOPED CEILINGS

It is difficult and expensive to achieve high insulation levels in a cathedral or sloped ceiling. They are also prone to moisture problems since it can be awkward to seal against air leaks and ventilate properly.

Energy-efficient alternatives to cathedral ceilings include:

- taller walls with a flat ceiling and standard roof truss system, or
- parallel chord or scissor truss roof systems which are easier to insulate and still achieve a sloped ceiling. (I)

Make sure that the builder specifies a minimum insulation value of RSI-4.9 (R-28) for any sloped ceiling in your home design.

... WINDOWS AND DOORS

The heating and cooling requirements of your home, and your comfort, will be influenced by the number, size, type and location of the windows and doors in the design.

Select windows that are at least triple-glazed with an air space of 13 to 16 mm. (1/2 to 5/8 in.) between the glazings. (J)

To further reduce heat loss and resist condensation, consider any combination of the following options in the window design:

- insulating spacers between the layers of glazing,
- low-e (low-emissivity) coatings on the glazing layers, and
- gas-filled units with an inert gas such as argon between the layers of glazing.

TIP

Low-e coatings can be tailored to match the orientation with some brands of windows. For example, consider specifying a low-e coating that maximizes solar heat gain on south-facing windows. With east and west-facing windows choose a low-e coating that blocks solar heat gain to avoid overheating and comfort problems.

Also, remember to:

- compare the maintenance, durability, aesthetics and cost of the various window frame materials that are available such as wood, aluminum, PVC and fibreglass;
- for operable windows, choose casement and awning windows since they tend to have better seals than sliders;
- consider local manufacturers who have developed products for our harsh climate; and,
- be sure to compare the warranties offered by different manufacturers.

Choose pre-hung, insulated exterior doors. (K) These units have a better, more durable air seal and much higher insulating value than any ordinary wood door. If you decide to install a sliding patio door unit, choose a one with an effective, durable seal. French or garden door units are the better alternative. (L)

TABLE 3 ***RECOMMENDED ATTIC INSULATION VALUES.***

Home Heat Source	Southern Manitoba	Northern Manitoba
Natural Gas or Ground Source Heat Pump	•RSI-7.1 (R-40)	•RSI-8.8 (R-50)
Electricity, Oil, Propane, Wood	•RSI-7.1 (R-50)	•RSI-8.8 (R-60)

Source: Manitoba Energy and Mines

A Better Building Envelope

TIP

A new certification label is starting to appear on some brands of windows. Sponsored by the Canadian Window and Door Manufacturers Association (CWDMA), this label will indicate the window's Energy Rating (ER) which is based on an 'average' Canadian home.

Window ER numbers range from –50 to +15. Windows with high positive ER numbers perform best.

Common Building Envelope Terms

RSI (metric) and R (imperial) Insulation Values:
a measurement of the ability of a material to resist heat transfer.

Air Leakage:
the uncontrolled flow of air into (infiltration) and out of (exfiltration) a home through cracks and other unintentional openings.

Air-Vapour Barrier:
a material used to restrict the flow of air and water vapour from inside a home to the outdoors.

High Performance Window:
windows that are very energy-efficient due to features such as multiple glazing, low-e coatings, gas-fills, insulating spacers, good weather seals and efficient frame and sash design.

Glazing:
the sheets of glass or plastic film used in a window, skylight, patio door, etc.

Thermal mass:
the ability of materials in a home to absorb and store heat.

For more information about building a better building envelope, contact:

Manitoba Energy and Mines Information Centre
1395 Ellice Avenue, Suite 360
Winnipeg, MB R3G 3P2

Call 945–4154 in Winnipeg or toll-free throughout Manitoba at 1–800–282–8069

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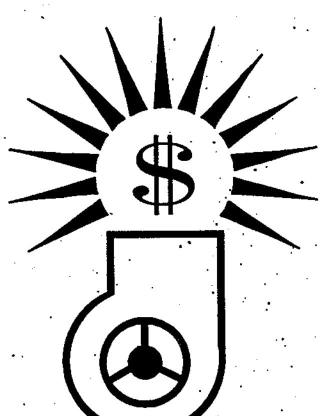
A guide to...

Efficient Mechanical Systems

The mechanical system provides space heating, air conditioning, water heating, and ventilation. Systems with lower installation costs are often less efficient, increasing operating costs, while not providing the best comfort or air quality. This fact sheet outlines choices that you can discuss with your builder to improve comfort and provide long-term savings.

This is the 3rd in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.



DARE TO COMPARE ENERGY SOURCES

Start planning your home heating system by comparing the energy sources available in your area.

... NATURAL GAS

Natural gas is the most common heating choice for new homes in Manitoba. It is:

- clean burning
- affordable

and is available in most larger communities in southern Manitoba. Centra Gas is expanding their gas network; call to see if there are plans to service your site in the future.

... ELECTRICITY

Electricity is the second most common heating choice. It is:

- generated in Manitoba
- from renewable resources

with prices among the least expensive in Canada. However, electricity is currently about 60% more expensive than natural gas in homes with an average heating requirement. In future years, this price gap is predicted to shrink.

... PROPANE

Propane heating systems are an option for homes where natural gas is not available and electric heat is not desired. In some northern Manitoba communities, propane is piped directly to homes. For most people however, supply is dependent upon a delivery truck.

Unfortunately, propane prices are less stable and generally more expensive than electricity prices. This makes it a more costly fuel source unless you use a high-efficiency heating system.

Converting to natural gas from propane service is usually quick and inexpensive. If you know natural gas is going to be available in the future, propane would be a good choice.

... OIL

Oil is rarely considered a preferred option for new home heating in Manitoba. Similar to propane, oil prices are less stable and usually more expensive than electricity prices.

... WOOD

Wood can be a good choice as a supplemental heat source for your home. In rural areas where firewood sources are plentiful and inexpensive it could be the only heat source you need. However, it will take time and effort to gather the wood and tend the fire.

Inefficient wood-burning equipment can be a significant source of air pollution. Give preference to products that have been certified as meeting the U.S. Environmental Protection Agency (EPA) or Canadian CSA-B415 Emission Standards.

Stoves that burn pellets manufactured from wood or agricultural crop residues are increasing in popularity. While these heating systems are more efficient than the conventional wood-burning variety, long-term, reasonably-priced fuel supplies can be hard to find.

TIP

Talk with an insurance agent to see if installing wood-burning equipment will affect the cost of your home insurance policy. Look for salespeople and installers that are certified under the Wood Energy Technical Training (WETT) program.

Efficient Mechanical Systems

CONSIDER THE SPACE HEATING OPTIONS

Once you have made a decision about what kind of energy source to use, choose a heating unit and distribution system that works best for your home.

Verify that a heat loss calculation will be done for your home to ensure that a properly-sized heating system is installed. A common mistake is to specify an over-sized heating system. This can result in significant comfort problems.

TIP

Your builder should use the CSA Standard F280 "Determining the Required Capacity of Residential Space Heating and Cooling Appliances". Ask for a copy of your home's heat loss calculation.

There are three main categories of heating systems: forced air, radiant and baseboard convection systems.

... *FORCED AIR SYSTEMS*

with a furnace ...

Most new homes in Manitoba are built with forced-air systems where air, heated by a furnace, is distributed through the home by ductwork. These moderately priced systems can be fuelled by natural gas, electricity, oil, propane or even wood.

With a forced-air system:

- it is easy to heat, cool, filter or humidify air for the entire home;
- the air can be quickly warmed after a temperature setback; and
- ductwork can double as part of the home's ventilation system.

Ductwork must be properly sized and the joints sealed for the system to operate at maximum efficiency. Ask your builder to follow "Residential Air System Design Standards" published by the Heating, Refrigerating and Air-conditioning Institute of Canada (HRAI).

TIP

You may have to adjust the air flow to each room for different comfort levels. Adjust the balancing dampers located in the basement ductwork or on the registers in each room.

with a ground source heat pump (GSHP) ...

A forced air system can use an electric GSHP to extract energy from the earth or groundwater to heat your home. Most of these systems can be adapted to also provide hot water for washing, cleaning and cooking—or even heat hot tubs and swimming pools!

A GSHP can:

- lower heating costs by up to 60% compared to conventional electric heat,
- lower water heating costs by about 50%, and
- reduce air conditioning costs by about 20%.

But be prepared for high installation costs. This type of system also requires a stable source of groundwater or enough space on your lot to accommodate a circuit of underground piping.

TIP

Ensure that the GSHP is designed and installed in accordance with CSA Standard C445 "Design and Installation of Earth Energy Heat Pump Systems for Residential and Other Small Buildings".

or with an integrated space and water heater (ISWH) ...

Systems which combine space and water heating are becoming popular. Some are based on a space heating boiler that is adapted to also provide domestic hot water. Others use a storage tank water heater that provides hot water for both domestic needs and space heating.

An ISWH usually has a higher overall efficiency than a separate furnace and water heater. This type of system is worth considering if you are planning to build a very energy-efficient home with a small to moderate space heating requirement.

... *RADIANT HEATING SYSTEMS*

Radiant heating systems use electric panels, cables or hot water piping, concealed by the ceiling or floor, to radiate warmth to objects and surfaces in a room. These systems offer high comfort levels. Without supply or return grills to contend with, furniture arranging is more flexible.

Keep in mind that you will still require ductwork for a ventilation system to circulate, filter and humidify fresh air, or air-condition your home. This makes a radiant heating system more expensive to install than a conventional forced-air system.

TIP

Ground source heat pumps, integrated space and water heaters, and radiant heating systems are not common in Manitoba. Be sure to shop around for knowledgeable designers and installers. To avoid disappointment or costly mistakes, always obtain references from the builder or contractor you are considering.

... BASEBOARD CONVECTION SYSTEMS

Baseboard convection systems are long, slender units that are typically installed under the windows of exterior walls. Using an electric element or water heated by a natural gas, electric, oil, or propane burner, cold air enters the bottom of the unit and rises out of the top after being heated. A significant advantage of these systems is that they enable temperature control in your home on a room-by-room basis. A major drawback is that baseboard heaters make furniture placement more restrictive.

Inexpensive electric element baseboard heaters are the most common type in this category. However, their high operating temperatures can heat dust causing odour and indoor air pollution problems. Hot water systems operate at lower temperature avoiding this problem but are more expensive to install and maintain.

If you are considering a baseboard convection system, remember that you will also require ductwork for a ventilation system to circulate, filter and humidify fresh air or air-condition your home.

TIP

Specify wall-mounted, electronic line-voltage thermostats to sense room temperatures when using baseboard convection heaters. Ordinary thermostats mounted on the heaters are not as accurate, and often permit large temperature swings.

A LOOK AT AIR-CONDITIONING SYSTEMS

Building a well-designed, energy-efficient home will reduce or even eliminate the need for air-conditioning in our climate. Before you explore air conditioning options, refer to the 1st fact sheet in this series, *Good reasons to build... A Better Building Envelope.*

Central air-conditioners are the popular choice for new homes. Be sure that a properly-sized unit is installed because bigger isn't better. It might be tempting to pick an over-sized unit to cool your home quickly, but the unit will do little to reduce the relative humidity level making your home feel "clammy".

Ask your builder to size the unit using the CSA Standard F280 "Determining the Required Capacity of Residential Space Heating and Cooling Appliances". Properly sized equipment will run continuously on hot, humid days. This will significantly reduce the relative humidity making your home more comfortable.

To minimize operating costs:

- choose a central air conditioner with a minimum Seasonal Energy Efficiency Rating (SEER) of 10 or better.

To minimize noise problems:

- locate the unit away from sensitive areas such as bedroom windows and decks; and
- give preference to models with features such as extra sound insulation or a quiet compressor.

A LOOK AT HOT WATER HEATING SYSTEMS

In most homes, the water heater is the second largest consumer of energy next to the space heating system. By choosing energy-efficient:

- water heating equipment, and
- appliances (see fact sheet #5 *Investing in... Energy-Efficient Appliances*)

and installing:

- water-efficient taps and showerheads (see fact sheet #7 *How to make... Your Home Water Wise*)

You will significantly reduce hot water demand in your home and save money.

You can choose from two types of water heating systems:

- a tank that heats and stores the water, or
- an instantaneous tankless heater.

The storage tank heater is the most common choice, and is usually fuelled by the same energy source (e.g. natural gas, electricity, propane or oil) as the space heating system.

Use the following checklist to help you choose a water heating system, and ask your builder to follow the installation tips for maximum benefits:

reduce standby losses...

Confirm that your water heater meets or exceeds minimum energy efficiency levels specified by CGA or CSA:

Fuel Source	Standard
natural gas or propane	CAN 1-4.1
electric	CAN/CSA-C191
oil	CAN/CSA-B211

Efficient Mechanical Systems

A Install heat traps where the water lines connect to the tank. This keeps the hot water in the insulated tank rather than in the piping until the hot water is needed.

B Insulate the first metre (3.3. feet) of piping from the water heater.

Size the Water Heater Correctly...

C Use the manufacturer's guidelines to choose a tank sized to meet the needs of your family. If you are planning to include energy-efficient and water-conserving appliances and fixtures in the home, your hot water demand will be lower.

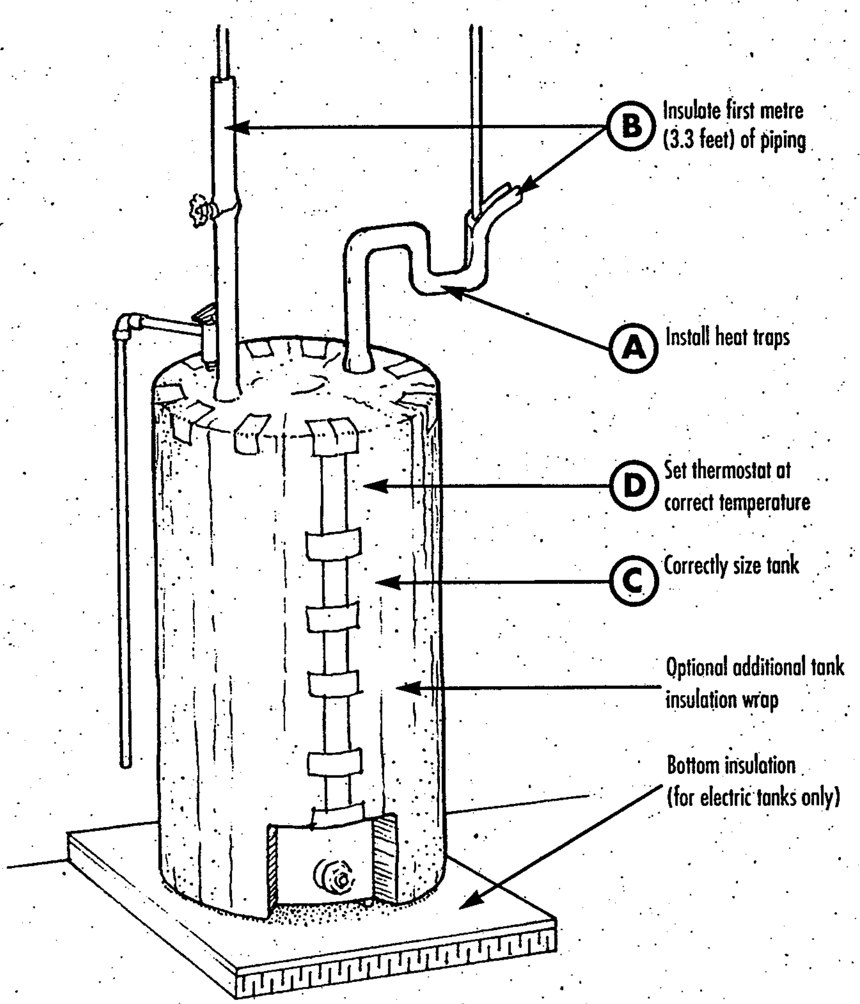
Locate the Water Heater Close to the Demand...

Minimize heat loss from the piping by locating the hot water heater close to the major hot water users in the house (e.g. bathrooms, kitchen, laundry room).

Set the Water Heater to the Correct Temperature...

D Set the thermostat:

- on natural gas, oil and propane water heaters between 50°C – 55°C (122°F – 131°F); and
- on electric units between 55°C – 60°C (131°F – 140°F).



There is little advantage to setting the temperature high. It wastes energy, reduces the life of the tank and poses a serious threat to safety from scalds.

TIP

For natural gas, oil or propane water heaters, consider an induced-draft or direct-vent unit that exhausts directly to the outdoors through a horizontal vent. These models will improve efficiency and reduce the risk of combustion gas entering the home.

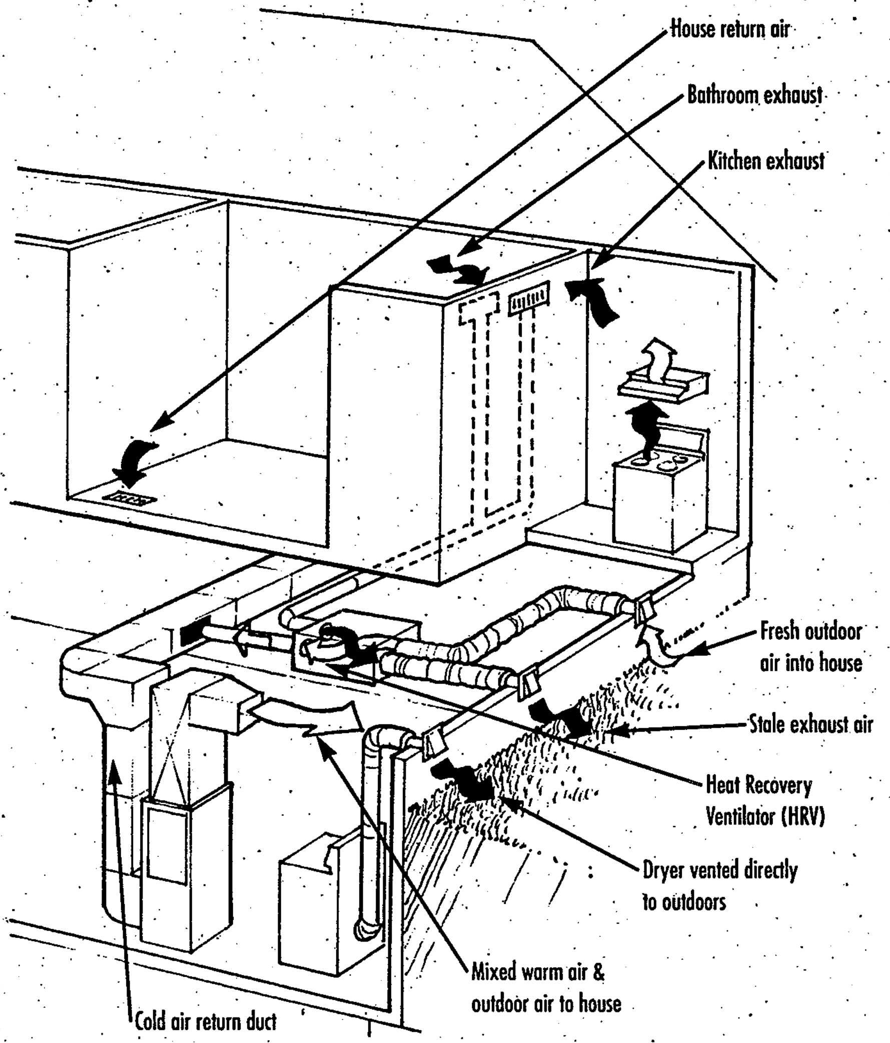
A LOOK AT VENTILATION SYSTEMS

All new homes should have a properly designed mechanical ventilation system to supply fresh air and exhaust stale air. Superior indoor air quality can be achieved by a system that:

- provides balanced air flow in and out of the home,
- runs at a continuous low level,
- exhausts air from high pollution areas (e.g. bathrooms, kitchen, workshop, etc.),
- supplies outdoor air at comfortable temperatures to the living space, and
- has variable speed control.

Air quality in a home is also affected by the construction materials used, furnishings, filtration system, and so forth. See fact sheet #4 in this series, *The inside story... Indoor Air Quality,* for more tips on this topic.

Efficient Mechanical Systems



... THE HEAT RECOVERY VENTILATOR (HRV)

Ventilation systems that best meet the criteria listed on the previous page use a HRV. These systems remove stale air from rooms in the house through ductwork. In a continuous flow, the stale air passes through the HRV and is exhausted to the outdoors, as the incoming fresh air from the outdoors is warmed and circulated through the house.

When a HRV is used in conjunction with a forced air system, the incoming fresh outdoor air is ducted to the furnace. The furnace fan is set to run continuously at a low speed to distribute the air but can be switched to high speed either manually or automatically if more ventilation is needed. For radiant and baseboard convection systems, an independent ducting system is required to distribute the outdoor air.

TIP

Ensure that your builder uses a mechanical contractor trained by the Heating Refrigeration & Air Conditioning Institute of Canada (HRAI). Ask that the system meets the CSA Standard F-326 "Residential Mechanical Ventilation Systems". The HRV should have a minimum of 65% sensible heat recovery efficiency.

... CENTRAL EXHAUST SYSTEM

A central exhaust system uses a variable-speed fan to draw stale air from rooms in the house into ductwork that exhausts to the outdoors. An outside air intake, connected to the return-air side of the furnace, brings in the fresh air for distribution to all rooms.

The incoming air in this system is not preheated. This can lead to comfort problems making it tempting to operate the system less often. This can result in not enough ventilation to control moisture, odour and other indoor pollutants.

Central exhaust systems cost less to install but more to operate than a system with an HRV. Fortunately, they can be easily converted to a heat recovery ventilator at a later date.

... INDIVIDUAL EXHAUST FANS

The least expensive and least effective method to ventilate a new home is to use individual exhaust fans vented to the outdoors in kitchens and bathrooms. If you plan to use individual exhaust fans choose:

- models that operate quietly (i.e. less than 1.5 sone rating).

And, at least one fan on the upper floor should be capable of continuous, low speed operation.

Homes that only have individual exhaust fans for ventilation should have an outdoor air intake connected to the return air duct of the forced-air furnace. This will ensure that some fresh air is distributed to all rooms in the house when the furnace operates.

TIP

Use a timer switch on bathroom exhaust fans so that the fan can run for a while after a shower or bath, to remove moisture.

Efficient Mechanical Systems

TIP

All ventilation systems require regular maintenance. Be sure to:

- *clean or replace filters regularly,*
- *vacuum exhaust fan blades and grilles,*
- *check inlet and exhaust hood openings for obstructions, and*
- *lubricate fan motors periodically.*

TIP

A dehumidistat automatically turns a HRV to high speed if the relative humidity inside your home gets too high. This control can also be used to operate a central exhaust fan system or individual exhaust fans.

Glossary of Common Heating/ Ventilating Terms

Backdrafting:
a potentially dangerous situation where combustion gases from a furnace, boiler, water heater or fireplace escape into the home rather than flowing to the outdoors via the chimney.

BTU per hour:
a unit of measure for sizing that capacity of heating systems. One BTU (British Thermal Unit) is about equal to the amount of heat generated by burning a common wood match.

CGA
Canadian Gas Association

CSA
Canadian Standards Association

Combustion Equipment:
heating equipment that burns a fuel with air to produce heat (e.g. gas, oil, propane, wood, coal, etc.).

Coefficient of Performance (COP):
the ratio of total energy delivered by a heat pump to the total energy consumed.

Direct Vent:
equipment which draws combustion air directly from the outdoors via a sealed duct and exhausts the by-products of combustion to the outdoors through another sealed vent.

Domestic Hot Water:
hot water used for household purposes such as cooking, cleaning, showering, etc.

Ductwork:
round or rectangular tubing that is used to supply or remove air from the spaces in a home.

Earth Energy System:
another name for a ground source heat pump.

Heat Loss Calculation:
detailed calculations used to determine the required capacity of a heating system to offset the heat lost from a home during the coldest part of a typical heating season.

Heat Trap:
a simple piping arrangement or device designed to prevent hot water from rising from a storage tank.

Sone:
a unit of loudness used to rate how much noise an exhaust fan generates (a fan rated at 2 sones makes half the sound of one at 4 sones).

Standby Loss:
the heat lost by a hot water tank and piping to the surrounding air.

Ton of Cooling:
a term used to describe the cooling capacity of an air conditioner or heat pump. Describes the cooling effect generated by the melting of one ton of ice in a 24-hour period.

For more information about effective and efficient heating and ventilation systems, contact:

- your builder or heating and ventilation contractor
- Manitoba Hydro or Winnipeg Hydro
- Centra Gas
- your local propane, fuel oil or wood heating dealer,

or the

Manitoba Energy and Mines Information Centre
1395 Ellice Avenue, Suite 360
Winnipeg, MB R3G 3P2

Call 945-4154 in Winnipeg or toll-free throughout Manitoba at 1-800-282-8069

This Fact Sheet was produced by the Manitoba Advanced House Project

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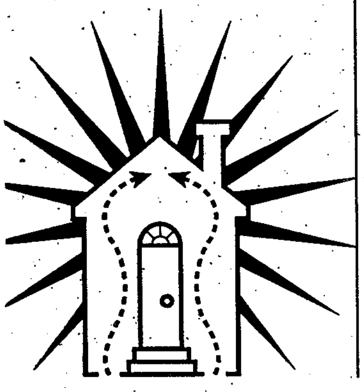
The inside story...

Indoor Air Quality

Many people spend a lot of their time indoors in northern climates. For most, this time is spent at home. If our homes have poor air quality, it can contribute to our family's ill-health. This fact sheet outlines how indoor air pollution can occur and helps you to take some practical, affordable steps to minimize exposure to common indoor air pollutants.

This is the 4th in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.



WHY IS INDOOR AIR QUALITY IMPORTANT?

Many people are concerned about outdoor air quality, but few realize that the air indoors may be more hazardous.

When the quality of air inside a home is poor, it will have an effect on the health of every living thing inside it—from humans to pets. Vulnerable people such as the elderly, the infirm and children are particularly at risk from chronic, low-level exposure to indoor air contaminants.

The way the body responds to indoor air pollutants is a function of the individual's metabolic ability to tolerate or withstand the effects of the irritant, or combination of irritants, that are present. These physical responses can be immediate or develop over a period of time.

WHAT HEALTH EFFECTS CAN BE PRODUCED?

The medical profession is becoming more aware of the range of possible health effects from poor indoor air quality. Since many contaminants enter the body through breathing, physical symptoms often include respiratory and flu-like conditions, as well as headaches, dizziness, fatigue, skin disorders and other problems.

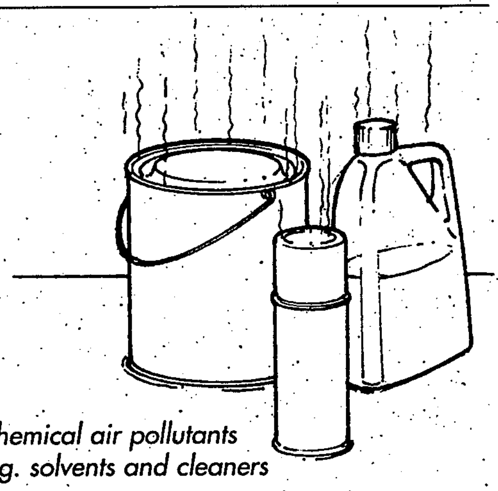
Exposure to contaminants can also cause indirect effects by making people vulnerable to other diseases, aggravating existing health problems or causing increased sensitivity to other environmental conditions.

There are a small percentage of people who are extremely intolerant or hyper-sensitive to pollutants, even at very low levels. The Canadian Housing Information Centre in Ottawa (see last page) can provide more detailed indoor air quality information and publications to individuals and medical practitioners.

WHERE DO INDOOR AIR QUALITY POLLUTANTS COME FROM?

Indoor air pollutants arise from biological and chemical sources within the home or from the outdoors. The most common types are listed in the table below:

Sources of Common Indoor Air Pollutants
Biological
dust mites
pollen
animal dander
bacteria
fungi
Chemical Gases and Particulates
carbon dioxide (CO^2) and odours from occupants
combustion gas spillage from furnaces, water heaters, ranges and fireplaces
gases released from building materials, furniture, fabrics, floor coverings, carpets, paints and caulking as they dry, or age
gases from cleaning products, pesticides & hobby supplies
ozone from electrical equipment
vapours from hairspray, perfume and other personal care products
radon and other soil gases

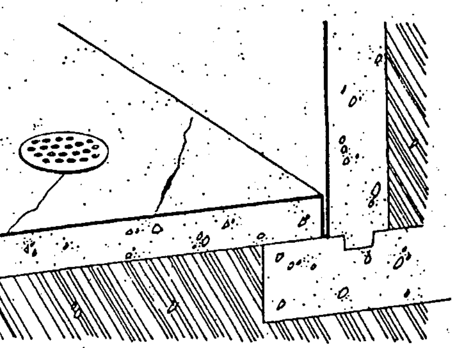


Chemical air pollutants e.g. solvents and cleaners

Indoor Air Quality

THE ROLE OF HUMIDITY

Humidity is the most common indoor air quality problem, particularly in new homes for the first few years as construction materials dry. If the humidity is too high, it can produce conditions that favour the growth of moulds and fungi.



Damp basements are a common source of mould and fungi problems

On the other hand, low humidity can dry the mucus membranes and irritate the respiratory system. It is quite acceptable to use humidifiers to eliminate dry conditions, but remember to maintain them properly and clean them regularly to prevent bacterial growth. Never vent a clothes dryer indoors, especially natural gas and propane models.

Health Canada recommends that the relative humidity inside homes be maintained between 30% and 80% in the summer, and 30% to 55% in winter. The easiest and most efficient way to monitor indoor humidity levels is with an electronic hygrometer. These devices can be purchased from home electronics stores for under $50. Make sure the model you choose has an accuracy rating of ±5% relative humidity or better. This information will be printed on the back of the package.

If you need to correct a humidity problem, contact the Manitoba Energy & Mines Information Centre in Winnipeg (see last page) or a heating and ventilation specialist, for advice.

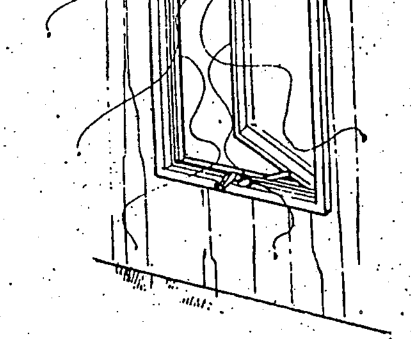
HOW TO AVOID INDOOR AIR POLLUTION PROBLEMS

... FROM EXTERNAL AIR POLLUTION SOURCES

Avoid sites close to or downwind from known external sources of pollution such as:

- high traffic zones, railways or airports,
- landfill sites, and/or
- factories or businesses that generate fumes such as dry cleaners or gas stations.

Smoke from nearby wood burning chimney's can also be a nuisance under certain weather conditions. Locate outdoor air intakes away from the neighbors driveway and exhaust vents.



Many indoor pollutants are from external sources

If you choose a rural site for your home, remember that seasonal agricultural activities (e.g. dust; pollen; pesticide drift) may cause reactions. Choose a treed site, plant shelter belts, or wildlife corridors to minimize your exposure to these kinds of contaminants.

... FROM GROUND WATER SOURCES

Avoid sites that are:

- poorly drained, or
- have a high water table.

If your site has these characteristics, ensure that your builder pays extra attention to dampproofing and drainage or you may end up with a wet basement, and mould and mildew problems.

... FROM INTERNAL SOURCES

choose building materials and new furnishings wisely ...

Request low-emission building materials in your building specifications. For example, ask your contractor to:

- use water-based paints on interior surfaces that meet or exceed the Environment Canada Environmental Choice standards (EcoLogo) for emissions,

Look for EcoLogo-approved paint

Indoor Air Quality

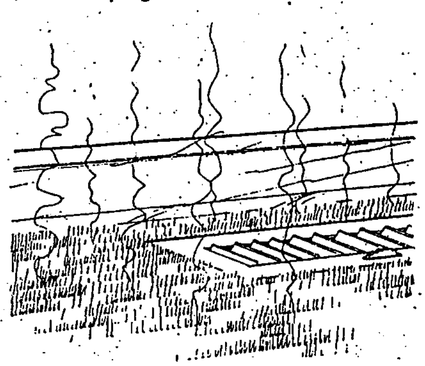
- apply water-based floor adhesives or a product that does not contain volatile organic compounds (VOC's), and
- use water-based or VOC-free sealing products to cover any exposed edges of particleboard in kitchen cupboards or bathroom vanities.

AND CONSIDER INVESTING IN...

- carpets that have been manufactured without glues or underpads, or natural fibre broadloom such as wool, which has not been as chemically pre-treated as man-made fibres,
- natural fibre cotton or wool area rugs,
- hard surface flooring such as hardwood, ceramic tile or cork for high traffic areas and bedrooms, and
- kitchen cabinets made from wood products that are formaldehyde-free.

TIP

The R-2000 Home Program now requires builders to make more use of materials with recycled content and/or reduced emission levels. For a complete list of R-2000 building features, contact the Manitoba Energy & Mines Information Centre (see last page).

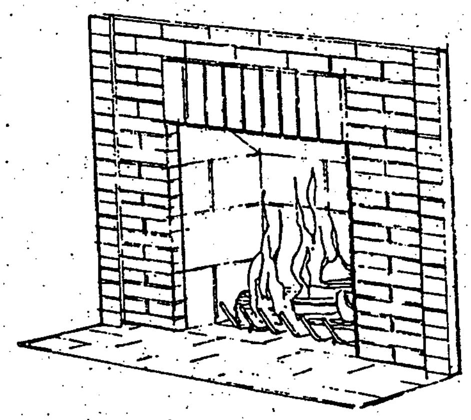


Select carpets, paint and other construction material that emit fewer pollutants

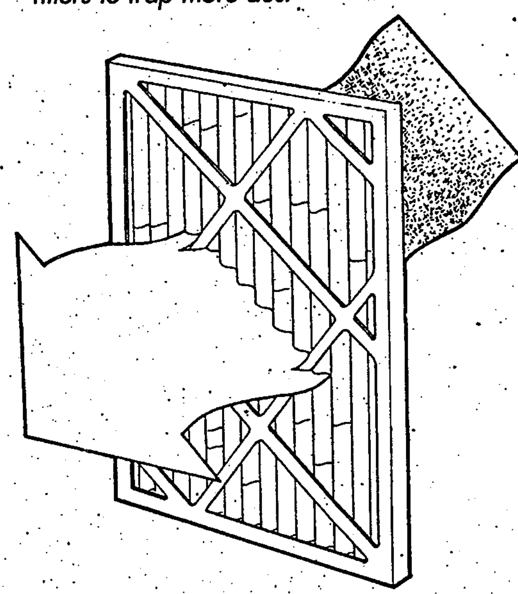
PAY ATTENTION TO THE VENTILATION SYSTEM ...

- Insist that the ventilation system is designed and installed in accordance with the CSA Standard "F326–Residential Mechanical Ventilation Systems". This will ensure that your home has an effective ventilation system to exhaust stale, moist air and distribute fresh, outdoor air throughout your home.
- Choose a ventilation system contractor who has been trained and certified by the Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI).
- Install return air ducts in bedroom closets to draw air through clothing and vent irritants such as perfume, cigarette smoke or dry cleaning solvents from the fibres. Consider venting a "hobby room" separately from the rest of the house to remove fumes.
- To trap fine particles in the ductwork, replace a standard disposable furnace filter with a pleated or extended surface disposable filter.
- For greater performance, talk to your contractor about installing an electrostatic air cleaner.
- Ask for clear, written information on how to operate and maintain the ventilation system.
- Ensure that your contractor is following the current Manitoba Building Code concerning radon reduction measures, or have the house tested for radon levels by a professional. Obtain a copy of "Radon: An Interim Guide for Manitoba Homeowners" from Manitoba Environment. Call 945-4422 in Winnipeg or toll-free throughout Manitoba at 1-800-282-8069.

Be alert to spillage of combustion gases into the home from the furnace, water heater, wood stove or fireplace



Use pleated or extended surface disposable furnace filters to trap more dust



Indoor Air Quality

- After construction, have the furnace ductwork professionally cleaned to remove trapped dust, dirt and debris.

AND MODIFY YOUR HOUSEKEEPING ROUTINE ...

- Install a central vacuum system that exhausts to the outdoors. Conventional canister and upright vacuums stir up biological contaminants which can be irritating to people with sensitivities.
- Avoid aerosol products that spray a mist of minute chemical particles into the air. These droplets can be easily inhaled and enter the bloodstream through the lungs.
- Simplify your cleaning routine. You'd be surprised to see how well a little dish soap or soft cleanser can clean, or how vinegar and water makes windows sparkle!
- Do not use chemical air fresheners that mask odours. A dish of vinegar in a room works wonders to absorb smells, and a simmering pan of cinnamon and water on the stove, makes a terrific potpourri!
- Substitute lemon juice or vinegar for ammonia when cleaning.

LOCATE A KNOWLEDGEABLE PROFESSIONAL

Be sure to work with a firm that takes your concerns about indoor air quality seriously. Since this is an emerging field, it may be a bit challenging to find a designer or builder with knowledge about indoor air quality issues and the building practices that can minimize the effects.

Your best bet is to contact builders that are registered with the Manitoba R-2000 Home Program, and heating and ventilation contractors that have received Residential Mechanical Ventilation System Installation training through the Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI).

COMMON INDOOR AIR QUALITY TERMS

COMBUSTION GASES:
the by-products resulting from the burning of natural gas, propane, oil or wood.

ELECTROSTATIC AIR CLEANER:
an electronically operated filter device used to remove dust and other airborne particles from the air.

EXFILTRATION:
air that leaks from inside a home to the outdoors.

INFILTRATION:
air that leaks from the outdoors into a home.

RELATIVE HUMIDITY:
the actual amount of moisture in air at a given temperature compared to the maximum amount it could retain. The ratio is expressed as a percentage.

VENTILATION:
the supply of fresh outdoor air and removal of stale indoor air from a home by natural or mechanical means.

VOLATILE ORGANIC COMPOUNDS (V.O.C.)
carbon containing chemical compounds; from glues, solvents, paints, plastics, pressed wood products, etc., that enter the air and can cause health problems.

For more information about indoor air quality issues, contact:

Canadian Housing Information Centre
Canada Housing and Mortgage Corporation
700 Montreal Road
Ottawa, ON K1A 0P7

or the

Manitoba Energy and Mines Information Centre
1395 Ellice Avenue, Suite 360
Winnipeg, MB R3G 3P2

Call 945–4154 in Winnipeg or toll-free throughout Manitoba at 1-800-282-8069

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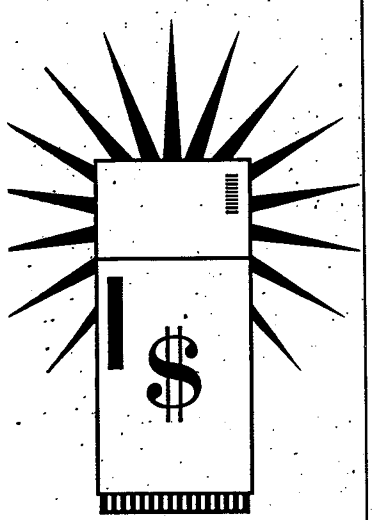
5 Investing in...

Energy-Efficient Appliances

Major appliances in the kitchen, laundry and utility room use 10 to 15% of the energy consumed in the home. This fact sheet will help you select new energy-efficient appliances and use them more wisely in the future.

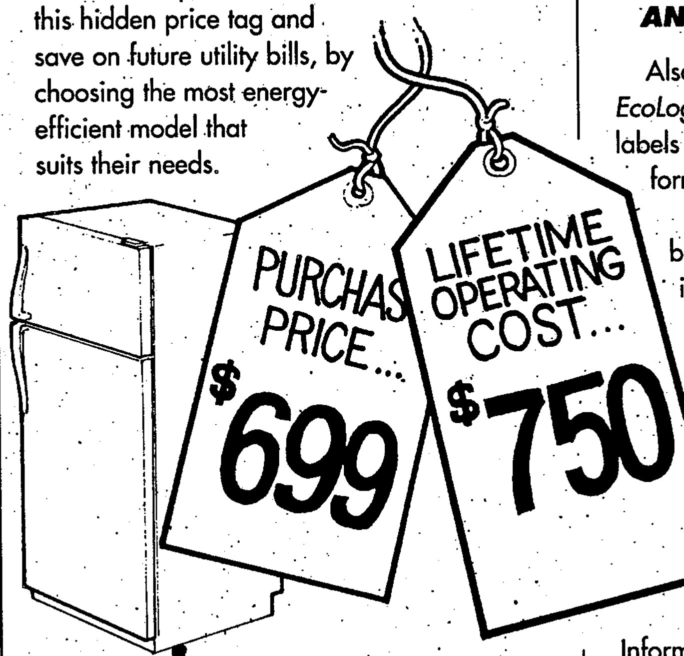
This is the 5th in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.



ONE APPLIANCE: TWO PRICE TAGS

The purchase price factors into every new appliance decision. But we often forget about the money that will be spent to operate it, during the long time that we own it. This can be significant.

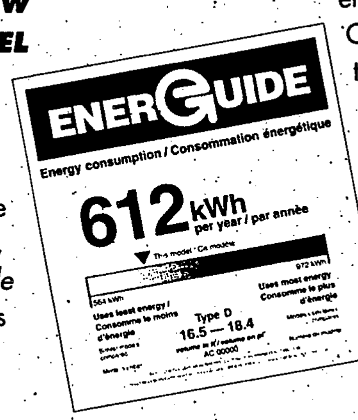
The operating costs of a major appliance can exceed the original price that was paid. A wise consumer will minimize this hidden price tag and save on future utility bills, by choosing the most energy-efficient model that suits their needs.



COMPARISON SHOPPING MADE EASY

... WITH THE NEW ENERGUIDE LABEL

Comparing the energy-efficiency of appliances has never been easier. Look for the redesigned, rectangular, black & white *EnerGuide* label on new appliances sold in Canada.



In addition to providing the annual energy consumption for the product, the label now provides a scale which identifies how the appliance performs in comparison to other models of comparable type and size.

- Choose models with the lowest annual energy consumption rating to obtain the greatest long-term savings.

... WITH POWER SMART AND ECOLOGO LABELS

Also watch for the *Power Smart* and *EcoLogo* labels on new appliances. These labels identify the top energy-efficient performers in each category of appliance.

If the appliance showroom seems boggling, do some homework before visiting the store. Consult the EnerGuide Directory for the energy consumption ratings of all major appliances sold in Canada. For a copy, contact Manitoba Hydro, Winnipeg Hydro or the Manitoba Energy & Mines Information Centre.

SEAL OF ENERGY EFFICIENCY POWER SMART™

Take this fact sheet with you when you shop. Consider mixing brands of appliances for maximum energy savings.

ENVIRONMENTAL CHOICE · CHOIX ENVIRONNEMENTAL

Contact your electric or gas utility for further assistance about energy-efficient appliance features.

Energy Efficient Appliances

CHOOSING KITCHEN APPLIANCES

... THE REFRIGERATOR

Building design notes ...

Ask your contractor or kitchen designer to locate the refrigerator:

- away from direct sunlight, dishwashers, ranges and heating ducts, and
- close to counters to help minimize door opening time.

There needs to be sufficient air circulation around a refrigerator for it to operate efficiently. Check the size of the planned enclosure against the fridge manufacturer's recommendations to ensure the required clearance is provided.

Prepare for shopping ...

Use these guidelines to pick the right size of refrigerator for your family:

Size of Household Refrigerator	Capacity
1 – 2 people	12 cu. ft.
3 – 4 people	14 – 17 cu. ft.

Add 2 cu.ft. for each additional person

People are most familiar with refrigerators that have a top-mounted freezer. These appliances are moderately priced, come in a wide variety of sizes, and offer more features than other types of refrigerators. Some energy-efficient models reverse the order. The refrigerator is put at eye level to minimize bending, and the freezer is put on the bottom.

Side-by-side models allow you to put the items you use most often at eye level. With a slightly larger freezer than the top-mounted style, this style of refrigerator costs more to purchase and operate, especially if you want an ice and water dispenser.

Listen to different models operating before you buy. Some new refrigerators are noisier than the old ones, which could prove to be annoying once it is in your home.

and make further long-term savings ...

- The refrigerator should operate at 3°C (37°F) and the freezer at −18°C (0°F); use an accurate refrigerator thermometer to determine each temperature and adjust the cooling controls accordingly.
- Some refrigerators have an energy saver switch to control condensation; consult your owner's manual on its proper use.
- Clean the cooling coils and the evaporation tray under the fridge every 6 months.
- Defrost manual refrigerators when the frost on the freezer compartment walls accumulates to about 1/4 of an inch or more.

TIP

Planning to dispose of an old fridge or freezer that contains CFC's? Landfills in Manitoba will no longer accept these appliances unless they bear a sticker, applied by a qualified refrigeration or cooling expert, that verifies it is CFC-free. For more information, contact the Manitoba Ozone Protection Industry Association, in Winnipeg, at 338–0804.

...FREEZER

Prepare for shopping ...

The larger the freezer the more energy is consumed. Gear freezer capacity to the number of people in your family. Allow 4.5 cu. ft. of space per person.

Chest freezers are more efficient than upright models. Buy the most energy-efficient model to minimize the hidden price tag over time.

Keep the freezer in a cool, indoor room and allow 2 – 3 inches of clearance around it for adequate air circulation. Do not keep the freezer in an unheated area such as a porch or garage. The compressor could become damaged.

and make further long-term savings ...

- Operate the freezer at −18°C.
- Defrost the freezer twice a year for best results.

TIP

Are you losing energy through a poor refrigerator or freezer door seal?

Open the door and place a $2.00 bill across the edge or face of the appliance. If the bill pulls out easily when the door is closed, the door needs to be adjusted or the door gasket replaced.

Another method to check a door seal is by placing a lit flashlight inside the appliance. Close the door and turn off the room light. If you see light from within, the seal is poor.

Energy Efficient Appliances

... THE RANGE

Building design notes ...

Consider a natural gas rough-in package for the kitchen, even if you intend to use an electric range. For about a $200 investment it makes a switch to gas easier in the future, and becomes an added feature when selling your home.

All kitchen odours, moisture and other pollutants require ample ventilation to minimize indoor air pollution. For more information about reducing sources of indoor air pollution, consult fact sheet #4 in this series, *The inside story... Indoor Air Quality*, for more tips on this topic.

Prepare for shopping ...

If you've ever wondered about the differences between natural gas and electric cooking, here are some features of both.

Compared to a natural gas range, an energy-efficient electric range:

- is less expensive to purchase but costs more to operate,
- is less likely to need repairs,
- has burners that will bring large pots of liquid to a boil more quickly, and
- is available in a sleek, smoothtop design.

However;

- it does not respond as quickly as gas and does not have as precise temperature control, and
- it poses a greater risk of burns from accidentally touching hot surfaces.

On the other hand, the new natural gas range has improvements over older models:

- the electronic ignition has replaced the pilot light,
- sealed burners are much easier to clean, and
- oven capacities have increased.

Optional electronic time and temperature controls on electric and gas ranges make cooking more precise. But remember: the more complex the operating technology, the higher the repair bill if breaks down.

TIP

If you are debating whether to purchase a self-cleaning oven, consider that this feature costs loss to operate than purchasing chemical cleaners.

and make further long-term savings...

- When cooking small amounts of food, use the microwave, toaster oven or slow cooker.
- An electric kettle saves 50% of the energy needed to boil water on the stove.
- Activate the self-cleaning feature while the oven is hot after cooking rather than when the oven is cool.

... A DISHWASHER

Prepare for shopping ...

Most of the energy consumed by dishwashers goes into heating the water. Be sure to choose a model that has a low *EnerGuide* rating and:

- includes a short cycle or "econo wash" feature and air-dry option,
- has a booster heater or "sani" setting to raise the water temperature apart from the hot water heater, and
- has adjustable racks to accommodate fuller loads, and
- requires less detergent for dish washing.

Many efficient dishwashers operate very quietly, which is a great feature for open-plan homes. Visit a dealer with functional display models to compare noise levels.

and make further long-term savings...

- Wash dishes only when you have a full load.
- Rinse dishes soon after eating and use the dishwasher's short "econo" cycle for cleaning.

Energy Efficient Appliances

CHOOSING LAUNDRY ROOM APPLIANCES

... THE WASHING MACHINE

Prepare for shopping ...

Clothes washers get a lot of use, adding up to high operating costs over the lifetime of the appliance. Pick a model that has a low *EnerGuide* rating and offers energy-saving features such as:

- cold wash and rinse cycles,
- adjustable water levels, and
- a "Suds Saver" cycle to conserve water, energy and detergent.

TIP

Look for more front loading (horizontal axis) washing machines in Canada soon. This very energy-efficient style of washing machine has been popular in Europe for years. It uses less water, spins faster to reduce drying time and is said to be easier on clothes.

and make further long-term savings...

- Always use the cold water rinse cycle unless the garment care label says otherwise.
- Remember to lower the water level setting for small loads.

... A CLOTHES DRYER

Building design notes ....

The dryer can be a source of indoor air pollution and moisture; always vent it to the outside.

Consider these tips when designing the laundry room:

Do:

- Locate the dryer on an outside wall to reduce the amount of ductwork needed.
- Use metal ductwork with as few elbows as possible.
- Choose an exhaust outlet with a damper.
- Consider adding a clothes dryer hook-up to your natural gas rough-in package.

Do not:

- Locate the exhaust under a window or overhang, or where condensation or dripping can create an ice hazard in winter.
- Use flexible plastic ducting which can collect lint and increases the risk of fire.

Prepare for shopping ...

The clothes dryer is a long-term investment. Choose a model that offers energy-saving features such as:

- sensors that turn off the dryer when the clothes are dry, and
- a "cool-down" or perma-press cycle that shuts off the heat before the end of the cycle.

Pick an electric model with a low *EnerGuide* rating, or look for a gas dryer that would cost much less to operate but may cost slightly more to purchase and install.

and make further long-term savings...

- Dry clothes in consecutive loads to utilize the retained heat effectively.
- Clean the lint filter before every load. Clean the exhaust hose, vent pipe, hood, damper and exhaust port twice a year for optimum performance and reduced risk of fire.
- Make a conscious decision to dry clothes outdoors on a clothesline, in spring, summer and fall.

For more information about choosing and using energy-efficient appliances, contact:

- an appliance dealer or retailer
- your builder or contractor
- Manitoba Hydro or Winnipeg Hydro
- Centra Gas

or the

Manitoba Energy and Mines Information Centre
1395 Ellice Avenue, Suite 360
Winnipeg, MB R3G 3P2

Call 945–4154 in Winnipeg or toll-free throughout Manitoba at 1–800–282–8069

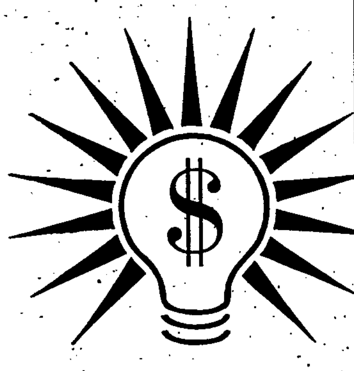
This Fact Sheet was produced by the Manitoba Advanced House Project

Research & Co-ordination: Appin Associates Wordsmith: EnviroScribe Consulting, Winnipeg Illustrations: David Morrow Illustration/Design Design: Doowah Design Inc. 12/95

Bright ideas about...
Efficient Home Lighting

Lighting is often neglected in home design. A little extra planning can pay big dividends and enhance the comfort, appearance and safety of your home. This fact sheet provides some advice about how to choose efficient lights, fixtures and controls that will reduce your electricity bills and the impact on the environment.

This is the 6th in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.



BASIC LIGHTING TIPS

Indoor light has an effect on our emotional well being, particularly during the darkness of winter. A well-designed lighting system combines ample natural light from windows or skylights, with energy-efficient lighting technologies.

Notice how you respond to indoor lighting. Some kinds of artificial light may feel warm and pleasing, while others may irritate you.

The lights in your home serve the purpose of:

- *general lighting* that is diffused or indirect illumination for a large area or room,
- concentrated *task lighting* for close work or activities such as cooking or reading, and
- *accent lighting* to highlight objects and surfaces.

When shopping for lights, take time to make decisions. Ask a lighting specialist to help you create a pleasant environment with the right balance of light sources. Check out lighting catalogues at the store, to see energy-efficient fixtures that aren't on display.

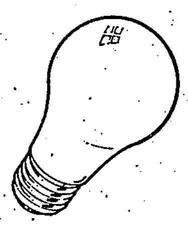
A variety of energy-saving lighting products are described in this fact sheet. Use this for reference when you talk to your builder, or take it with you to the store.

CHOOSE THE RIGHT LIGHT SOURCE

Become familiar with the large assortment of light bulbs and fixtures on the market.

Incandescent bulbs

The ordinary incandescent light bulb may be inexpensive to purchase, but it isn't energy-efficient and it doesn't last long. Keep this bulb for general illumination and task lights that are used less than 4 hours a day.



When buying incandescent bulbs, look for:

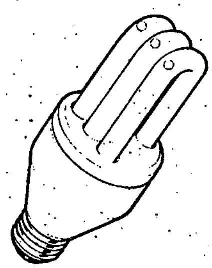
- reduced wattage 34, 52, and 90 watt bulbs to replace 40, 60 and 100 watt bulbs without a noticeable reduction in light.

TIP

'Long-life' or 'extended-life' incandescent bulbs use the same amount of energy as standard bulbs. They last longer because they emit 30% less light. These products can be used in lights that are hard to reach, but a compact fluorescent bulb is the more energy-efficient choice.

Compact Fluorescent Bulbs

A compact fluorescent light bulb consumes up to 75% less energy than an incandescent bulb and lasts up to 10 times longer. These energy-efficient products have a pleasing quality of light and conveniently replace standard screw-in incandescent bulbs.



Compact fluorescent bulbs range in price between $15 and $25. Use these products in lights that are used more than 4 hours a day to get the best value for your investment.

Keep these points in mind when purchasing compact fluorescents:

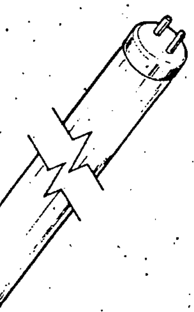
- A compact fluorescent bulb is slightly larger than an incandescent. Some lamps may need an extended harp for the shade to allow a compact fluorescent to fit.
- Your lighting dealer might display only a few lighting fixtures for compact fluorescent bulbs. You can choose from more styles if you ask to see the manufacturers' catalogues. Usually a special order can be arranged.

Efficient Home Lighting

TIP
Because of Manitoba's cold winters, compact fluorescent bulbs should not be used in outdoor fixtures.

Fluorescent Tubes

Fluorescent tubes have been around for a while for good reason. Using 60% to 80% less energy than incandescent bulbs and lasting up to twenty times longer, they are still considered a good choice for valance lighting; kitchen counter top lighting; or for general illumination for extended periods of time.

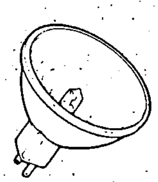


The *deluxe warm white* fluorescent tube produces more natural and flattering colour than the common cool-white variety. Compare each type at the store before you buy.

The 'T-8' fluorescent tube and electronic ballast is another option. These products cost more, but produces even greater energy savings and a pleasing quality of light.

Halogen bulbs

Halogen bulbs produce a bright, clear light. They cost more to purchase than incandescent bulbs, but will last two to four times longer.



Use halogen bulbs in:

- task or accent lighting fixtures designed especially for compact halogen bulbs, or
- as a direct replacement in fixtures designed for incandescent flood and spot light bulbs.

SAVE FURTHER WITH LIGHTING CONTROLS

Lighting controls can be used around the home to create a certain mood or improve security. These products can also help to achieve even further energy savings.

... INDOORS

Dimmers

Save energy and extend the life of incandescent bulbs with dimmer switches. Choose from:

- wall-mounted or plug-in models.

Look for the *Power Smart* or *EcoLogo* seal on the product label.

Timers

If you are going on vacation or just out for the evening, use inexpensive light timers for home security. Choose from models that:

- plug into a wall outlet to control table or floor lamps, or
- replace a light switch with a permanent timing device that has a variety of on/off settings.

Delayed on/off switches and occupancy sensors

If lights are left on in unoccupied rooms, replace the wall switch with:

- a delayed on/off switch to turn off the lights after a predetermined period, or
- an occupancy sensor which turns on the lights in the presence of motion.

Trilight switches

Consider a trilight when purchasing a table or floor lamp with an incandescent bulb. Instead of just an on/off switch, these lamps have high, medium, and low light intensities.

... AND OUTSIDE

Photocells

A light-detecting photocell is commonly used outdoors for convenience. It will turn a light on at dusk, and turn it off with the sunrise in morning.

Motion detectors

The motion detector is another energy saving control for outdoor lighting. Instead of leaving entrance or yard lights on all night for security, this device turns them on only when activated by movement.

For more energy-efficient lighting information and ideas, contact:

- your builder or electrical contractor
- lighting, electrical or home improvement centres
- Manitoba Hydro or Winnipeg Hydro,

or the

Manitoba Energy and Mines Information Centre
1395 Ellice Avenue, Suite 360
Winnipeg, MB R3G 3P2

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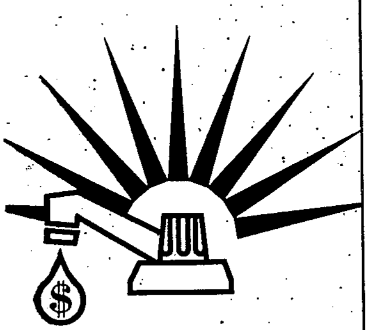
How to make...
Your Home Water Wise

▼▼▼▼▼▼▼▼▼▼

Whether you plan to purchase a new home or renovate an old one, it makes economic and environmental sense to use water efficiently. This fact sheet outlines the need for domestic water conservation and identifies where savings can be made, easily and effectively.

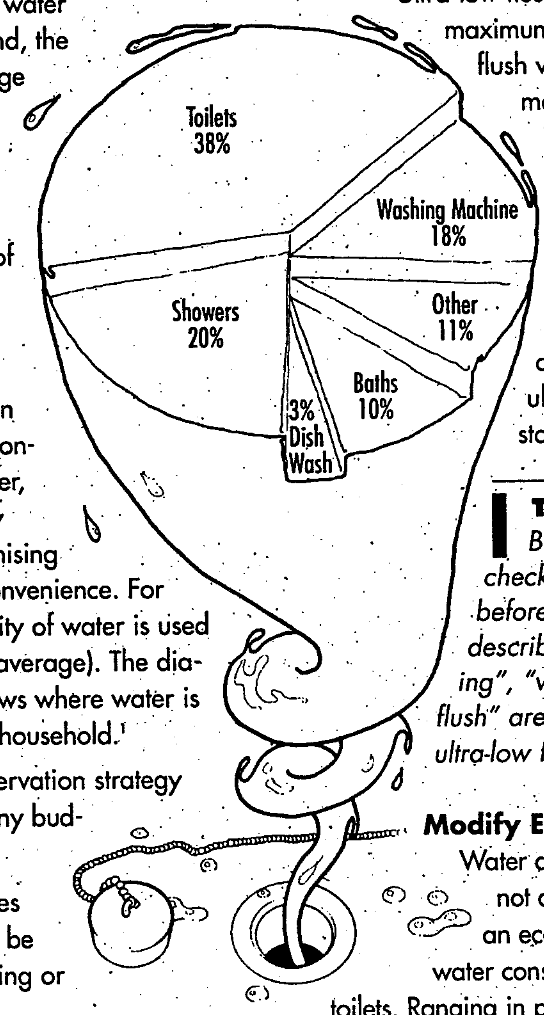
This is the 7th in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.



As the 1990's progress, Manitobans are developing a new attitude towards our natural resources.

Water has always been perceived to be plentiful but it is limited. The water supply is at or near capacity in many communities. In others, underground aquifers can not replenish themselves in proportion with the demand, while some water supplies have been found to be contaminated and unfit for consumption.

Still, the demand for water grows. With this demand, the cost of water and sewage treatment services increase with the development of new areas and the maintenance and upgrading of existing service.



There are a lot of things you can do to reduce water use, lessen the impact on the environment, and save on water, sewer and even energy bills—without compromising quality, reliability or convenience. For most homes, the majority of water is used indoors (over 90% on average). The diagram on this page shows where water is consumed in a typical household.[1]

A home water conservation strategy can be tailored to fit any budget:

- water-efficient fixtures and appliances can be selected when building or renovating,
- inefficient fixtures can be modified or replaced, and
- water-wasting habits can be changed!

To help you make informed decisions, use this brief guide to home water conservation. Keep it handy for quick reference, and take it with you when you shop.

▶ A HOMEOWNERS GUIDE TO WATER EFFICIENT PRODUCTS

Install Ultra-Low Flush (ULF) Toilets

Ultra-low flush or 'ULF' toilets use a maximum of 6 litres of water per flush without sacrificing performance. Ordinary toilets use 15 to 25 litres per flush.

- Insist that your builder or plumbing contractor install CSA-approved ULF toilets.
- The selection of affordable brands and styles of ultra-low flush toilets is constantly improving.

TIP

Buyer beware! Double-check toilet water ratings before you buy. Some models described as "water conserving", "water-efficient" or "low-flush" are not as water-efficient as ultra-low flush models.

Modify Existing Toilets

Water displacement devices are not as effective as ULF's but are an economical way to reduce water consumption with conventional toilets. Ranging in price from $10 to $25, choose from:

[1] Indoor water use by residential single-family homes and apartments, based on a Wardrop/TetrES study for the City of Winnipeg, 1992

- toilet tank dams,
- dual-flush levers that provide a full or partial flush, or
- early-closure flapper valves.

TIP
Over time, a silent leak through the toilet flapper valve can waste large volumes of water. Place toilet tank dye tablets or a few drops of food colouring in the toilet tank. Wait a while. If colour is found in the bowl before flushing, check for leaks and repair promptly.

Use Water-Saving Showerheads

New water-efficient showerheads are a good investment. Look for models that are rated 11 litres/minute or less. Models bearing the *EcoLogo* provide even greater savings at 9.5 litre/minute or less.

Water-saving showerheads range in price from $10 to $30. Products are available with spray patterns that vary from wide and soft to narrow and invigorating. Keep your showers short!

TIP
Here's how to judge a water-wasting shower:
Turn the tap on fully. Activate the shower. Quickly place a 2 litre milk carton under the showerhead. If the carton is full in 8 seconds or less, you need a water-saving showerhead!

Install Water-Saving Faucets & Aerators

In the kitchen and bathroom, save water by:

- purchasing new water-saving fixtures, or
- replacing aerators on existing faucets for $5 – $10.

Models with flow rates of about 5 to 9 litres per minute will perform well and provide substantial savings. Save even more by turning off the tap while brushing your teeth!

TIP
New to the market are water-saving infrared on/off faucets that turn on/shut off in the presence or absence of an object. Although expensive, these products are particularly useful for people who have difficulty grasping taps.

Look for Water-Conserving and Energy-Efficient Appliances

Energy-efficient clothes and dish washing appliances often use less water. Always ask to see the *EnerGuide* or *EcoLogo* label to compare different brands and models to make the best choice.

For example, when purchasing a new clothes washer, choose a water-wise model. Look for features such as:

- adjustable water levels, and
- a "suds saver" cycle that holds rinse water for the next wash.

Front-loading tumble clothes washers use 30% less water than the conventional top-loading style.

Reduce dishwasher water use by choosing a model that has:

- a short cycle or "econo wash" feature, and
- adjustable racks to accomodate fuller loads.

For more information, read fact sheet #5, *Investing in... Energy-Efficient Appliances.*

Plan and Maintain a Water-Saving Landscape

Most of the water applied to lawns, gardens and flower beds is wasted through evaporation, runoff or overwatering in spring or summer.

Try these water-saving lawn care tips to reduce the need for frequent watering:

- Cut the grass longer (about 75 mm or 3 inches in height).
- Water early in the morning when the wind is light or in the evening, if necessary.
- Place a tin can or rain gauge near the sprinkler when watering. Move the hose or turn off the tap when you've captured an inch of water.

Xerixscaping refers to water conservation through creative landscaping techniques. Whether designing a new yard or simply taking care of one, try to fit these tips into your plans and routine:

- Reduce the amount of grass around the yard and replace it with native trees, shrubs, grasses, flowers, decks, patios and walkways.
- Apply mulch to flower beds, trees, shrubs and the vegetable patch to slow evaporation.
- Use above ground or buried drip irrigation systems.
- Collect rainwater and water with a watering can.

For more water saving information and ideas, contact:

- your builder or plumbing contractor
- home improvement centres
- garden centres

or the

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Winnipeg, MB R3G 3P2

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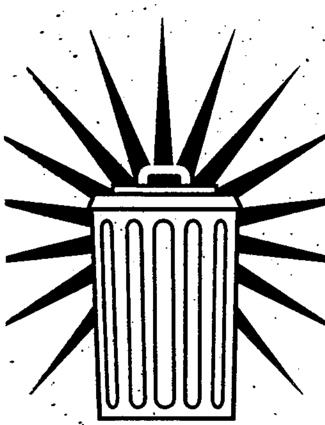
A guide to...
Household Waste Management

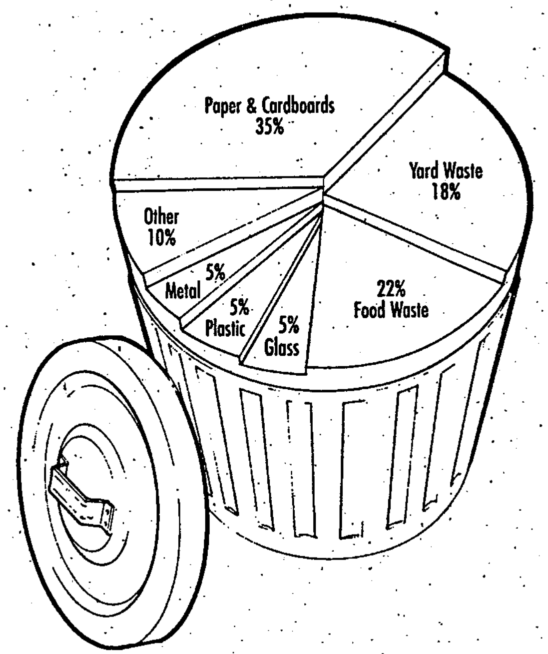
Many of us once thought natural resources would last forever and landfill space was 'free'. That era is over and this fact sheet is designed to help you reduce and wisely dispose of the waste that is generated in your home. Much of yard waste and food waste can be composted. Much of paper and cardboard, glass, metal and plastic can be recycled.

This is the 8th in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.



THE TYPICAL HOUSEHOLD WASTE PROFILE

It's easier to manage wastes when you know what you generate. These are the kinds of waste that the average home creates:



In the not-so-distant future, scarcity of resources, limited space for landfills and the cost of municipal solid waste management will force us all to reduce the waste we generate.

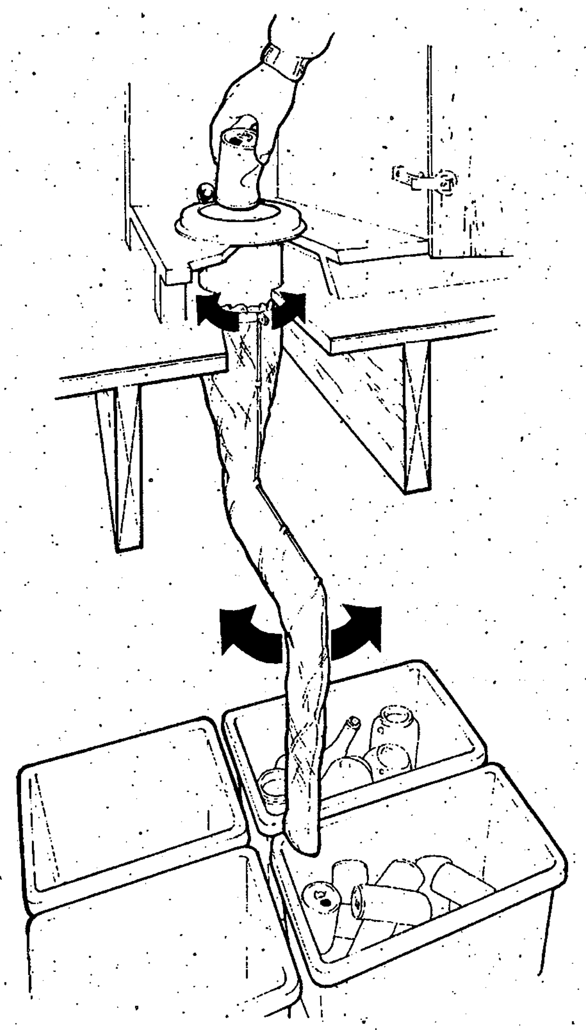
INCLUDE WASTE MANAGEMENT IN THE KITCHEN DESIGN

... FOR RECYCLING

For convenience, include a recycling centre in the kitchen. Kitchen manufacturers are designing new styles all the time; be sure to shop around.

In small kitchens, a recycling chute saves valuable space. Materials are directed down to bins in a basement storage closet below.

A recycling centre can also be put in a large closet or utility room near the kitchen.



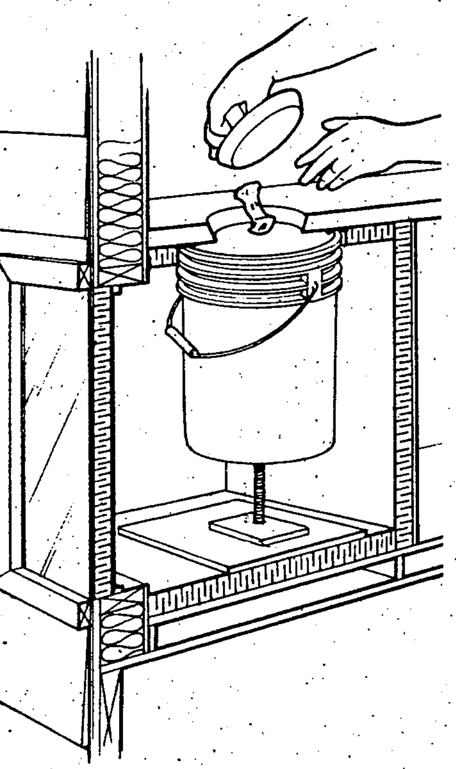
Kitchen cabinet to basement recycling chute

Household Waste Management

... FOR ORGANIC WASTE

Have an odour-free compost receptacle. Organic kitchen scraps are dropped through a hole in the countertop, to a compost pail in a compartment below. Insulate the receptacle and put a door on the outside wall, for outdoor removal and emptying.

If limited yard space prevents a regular compost pile, see if the under-sink cabinet can accommodate a small vermicompost bin for red earth worms.



Under counter compost storage system

... AND REDUCE THE VOLUME OF WASTE PICKED UP FOR DISPOSAL

Be prepared! As bag-limit or user-pay municipal waste systems become the way of the future, trash compactors and garbage disposers will help to reduce the volume of waste you send to the landfill.

- A built-in trash compactor reduces the volume of non-recyclable waste by 1/2 or more.
- A garbage disposer or garburator beneath the sink grinds food wastes into tiny bits before travelling to the sewage treatment plant. (Note: Not recommended for septic systems.)

Make a lifetime commitment to solid waste management. The information in this facts sheet shows how simple it can be.

REDUCE SOLID AND HAZARDOUS WASTE

... THROUGH BETTER PURCHASING HABITS

Start to reduce the waste you produce by following a few basic rules when you shop.

Do:

- buy products that are:
  - concentrated (e.g. laundry products, juice)
  - refillable (e.g. enviro-packs)
  - bulk (e.g. spices, dry goods)
  - minimally packaged (e.g. boxless tooth paste)
- purchase products that contain recycled material like:
  - toilet paper, tissue and paper towels
  - green garbage bags
  - re-refined motor oil
- avoid harsh chemical products and use less toxic cleaners such as:
  - baking soda, washing soda, borax
  - vinegar or lemon juice
  - biodegradable soap
  - hydrogen peroxide as a bleach alternative
- take your own reusable shopping bags or boxes to the store

Don't:

- buy single-serving foods and beverages

TIP

Sharpen your shopping skills! The Environmentally-Friendly Grocery Challenge teaches consumers to make wise environmental choices when shopping. The program is available to all Manitobans. Call the Manitoba Association of Home Economists in Winnipeg at 784–1272, or your regional Manitoba Agricultural Extension Office for more information.

Photo: A. Downey-Franchuk

Household Waste Management

REUSE

Think about the durability and life span of products when you shop. Purchase good quality reusable items such as:

- diapers, hankies, napkins,
- rechargeable batteries, and
- picnic supplies & lunch kits.

and give old things new life ...

One man's garbage is another man's gold. Look at the groups who want your donation — and some will even come by to get it!

- **Save:**
  - cartons & boxboard, buttons, popsicle sticks, toilet rolls, produce baskets, etc.
  - scraps of wool, fabric and carpet

  For:
  - day cares, nursery schools and nursing homes
- **Save:**
  - books

  For:
  - second hand book stores, and charitable sales
- **Save:**
  - clothing and linens

  For:
  - thrift shops, Goodwill, Salvation Army, and theatrical groups
- **Save:**
  - small appliances
  - housewares
  - furniture

  For:
  - second hand stores, and the Canadian Diabetes Association
- **Save:**
  - building materials & supplies

  For:
  - the Habitat Re-Store
- **Save:**
  - old records and photographs
  - vintage memorabilia

  For:
  - local museums and archives (Winnipeg & some surrounding communities; call for pick-up details)

RECYCLE

... NON-HAZARDOUS WASTES

These materials are collected for recycling in Manitoba (local markets may vary):

- tin, steel & aluminum cans, foil
- coloured & clear glass
- all types of paper, magazines, boxboard, corrugated cardboard
- PET, milk jug, #1, #2, #5, #7 plastic
- milk & egg cartons
- plastic shopping bags
- tires

RECOVER

... AND START COMPOSTING

Start a compost heap in the backyard or use a vermicomposter indoors. Either way, you will turn organic kitchen and yard wastes into nutrient-rich humus, that is great for the garden.

- Visit the "Compost Trail" of innovative composting technologies at Winnipeg's Fort Whyte Centre for Environmental Education, 989-8350, or the Fort Whyte Nature Company at the Forks Market, 943-BIRD.

Two municipal composting programs are available to the residents of Winnipeg:

- the "Leaf it to Us" leaf composting program in the fall, and
- the Christmas tree chipping program in January.

Contact the City of Winnipeg for details.

COLLECTION OPTIONS TO SUIT EVERY BUDGET

Location	Depots	Collection
City of Winnipeg	• Call the City of Winnipeg Waste Reduction Hotline for information (986-4777)	City-wide curbside residential
Across Manitoba	• Local recycling organizations & groups for information (925-3777) • Manitoba Association Regional Recyclers (1-204-857-7919) • Manitoba Environment Manitoba Products Stewartship Program (945-8761)	Some curbside service available in small communities; contact the Recycling Council of Manitoba

Household Waste Management

DISPOSE OF HAZARDOUS WASTE PROPERLY

Don't harm sanitation workers, damage the septic system, threaten water supplies and poison wildlife by improperly throwing household hazardous wastes (HHW) away.

One way to recognize household hazardous wastes is by the warning symbol(s) on product labels:

Flamable

Corrosive

Toxic

Explosive

Automotive batteries, used car oil, fluorescent light ballasts (pre-1980), smoke detectors, propane tanks and expired prescription drugs are also considered hazardous.

When you have some HHW to dispose of, save it, label it, and store it safely in the garage or shed for the next household hazardous waste collection depot in your area.

Household Hazardous Waste Depots are held:

- in Winnipeg, on Saturdays, from 9 a.m. to 4 p.m. at:

  55 Trottier Bay (off Chevrier Blvd)

- in the R.M. of Montcalm, on Tuesdays, from 10 a.m. to 3 p.m. at the:

  Manitoba Environmental Centre 2 km. west of Hwy 75 on Hwy 14

- and at the request of rural communities – planning guides for these one-day events are available from the Manitoba Hazardous Waste Management Corporation.

For more information about:

...general waste management contact:
The City of Winnipeg Waterworks, Waste Disposal Department
Call 986-3333 in Winnipeg; visual ear for the deaf, 986-2149
or, call your rural municipality office.

...provincial recycle initiatives contact:
The Recycling Council for Manitoba
Call 925-3777 in Winnipeg

...household hazardous waste collection depots contact:
The Manitoba Hazardous Waste Management Corporation
Call 945-1863 in Winnipeg

This Fact Sheet was produced by the Manitoba Advanced House Project

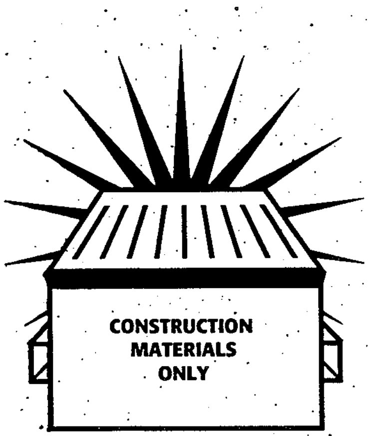
Research & Co-ordination: Appin Associates Wordsmith: EnviroScribe Consulting, Winnipeg Illustrations: David Morrow Illustration/Design Design: Doowah Design Inc. 12/95

Changing attitudes about...

Construction Waste

A lot of waste is generated when building a new house or renovating an old one. But with a little forethought and planning, you can ensure that materials will be used more efficiently, construction waste will be reduced, and that money will be saved too!

This is the 2nd in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.



THE NEED FOR CHANGE

With over 5,000 lbs of waste generated in the construction of a typical new home[1], it is no wonder that residential building and demolition debris makes up 12% to 30% of total landfill waste.

Some waste is unavoidable. But a lot can be avoided by using construction materials more efficiently, and diverting useful items or recyclable materials from disposal altogether.

Contractors pass waste hauling expenses and tipping fees onto their clients. Reducing waste at source lowers waste disposal costs. Using building materials more efficiently means budgetary and environmental savings as well. And a reduction in the volume of waste requiring disposal will extend the life span of an existing landfill, and save a lot of tax dollars.

Recycling markets have emerged for drywall, concrete, and masonry in other communities in Canada. Unfortunately, the response in Manitoba has been slow. By demanding alternatives and voicing concerns, homeowners like you will help motivate the building industry to become accountable for the volume of waste that is produced. You can also make a difference by encouraging your local municipality to foster and develop markets for construction wastes much closer to home.

CHOOSING AND WORKING WITH ARCHITECTS, BUILDERS AND CONTRACTORS

When designing your home and drawing up plans, work with an architect, builder or drafting company that designs homes to take advantage of standard building material dimensions. If you work with a designer who has computer aided design (CAD) capabilities, it is easier to quickly adjust room dimensions to obtain the most efficient use of building products such as lumber, plywood and drywall. Be informed. There are many suggestions for better construction waste management in this fact sheet. Make waste minimization one of your screening criteria when interviewing contractors. Pick a company who will break from convention and minimize job-site waste.

[1]Toronto Home Builders Association

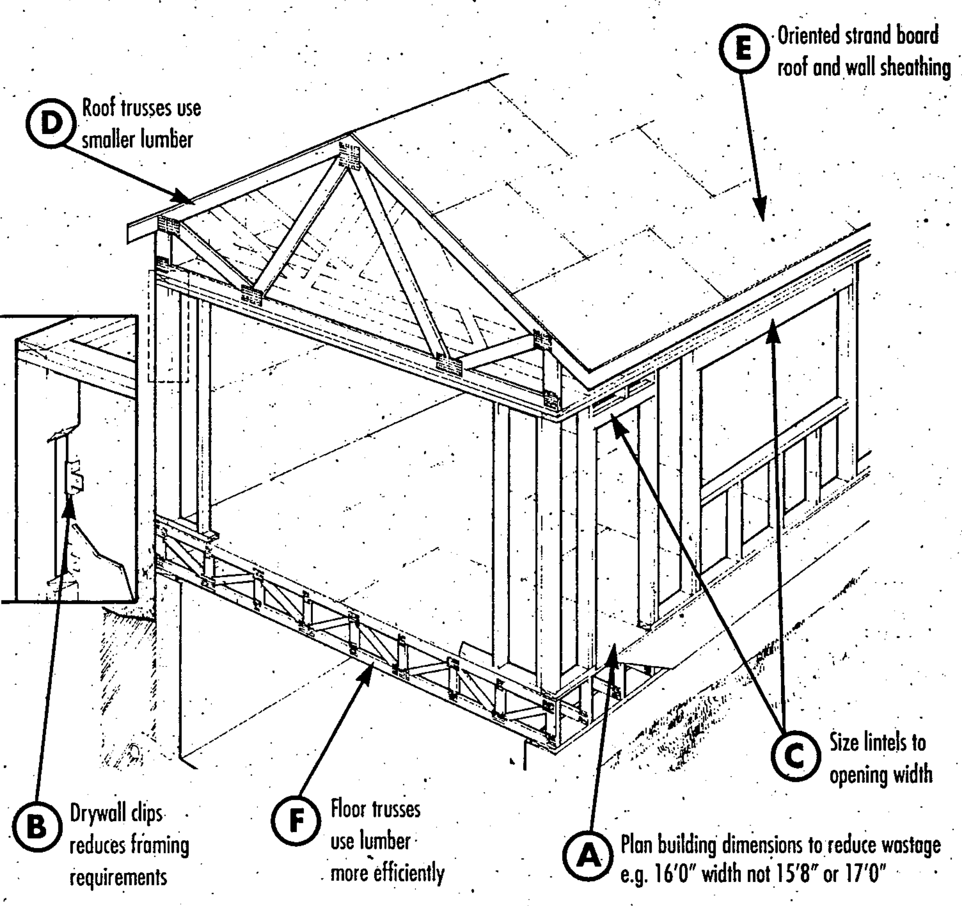
Construction Waste

▸ PLAN TO USE MATERIALS MORE EFFICIENTLY ...

Some construction wastes can be avoided by using certain building techniques or particular materials in the design. Talk about these options with your builder and include as many of the suggestions as possible in your specifications. Look for ideas in the illustration below.

A HOMEOWNER'S CHECKLIST ...

- Lumber and plywood is sold in standard sizes; lumber lengths come in 2′ increments and plywood comes in 4′ x 8′ sheets. Trimming and cutting wood products creates a lot of waste. Optimize the use of dimension lumber, subflooring and sheathing by adjusting room dimensions to multiples or even fractions of standard sized materials. (A)
- Reduce the lumber requirements for interior corners by using drywall clips. (B)
- Properly size lintels over door and window openings. (C)
- Use prefabricated roof trusses which are constructed from small dimension and/or reused off-cut lumber. (D)
- Specify oriented strand board (OSB) for wall and roof sheathing. Only fast growing trees are harvested for these products. (E)
- Further reduce the use of large dimension, old growth forest products by using open web or I-beam floor trusses and engineered lumber for lintels and beams. (F)



▸ MAKE BETTER PURCHASING DECISIONS

A CONTRACTOR'S CHECKLIST ...

- Tell suppliers that you no longer want to purchase over-packaged materials and supplies.
- Encourage suppliers to deliver products in reusable containers.
- Be aware of the range of environmentally-friendly and/or recycled building products on the market. For example plastic/wood products for trim and exterior decks; recycled tire paving stones for walkways; and cellulose insulation made from recycled newspapers.
- Backfill under the basement slab and around the foundation with a 50% old glass to 50% granular backfill mixture.
- Order precut studs to avoid waste.
- Support the local economy and reduce shipping and handling costs. Purchase locally made windows, cabinets, stonework and brick products.
- Avoid ordering too much material. Double-check estimates.

Construction Waste

REDUCE SITE WASTE

A CONTRACTORS CHECKLIST ...

- Properly store and handle materials to prevent weather damage and loss.
- Make a central location for cutting lumber and sorting off-cuts. It will be easier to find pieces for bridging and blocking later.
- Place scrap pieces of drywall between the studs of interior walls. This will increase the thermal mass and reduce the amount of waste on-site.
- Use scrap batt insulation around windows and doors or add surplus insulation to the attics.

REUSE

A HOMEOWNER'S CHECKLIST ...

- Use salvage materials where possible, such as hardwood flooring, lumber products like studs, beams and posts, or reclaimed brick.
- Keep everything from old cabinets to plumbing fixtures; electrical switches to eavestrough for a yard sale; or look in the Yellow Pages under "Building Materials – Used" for businesses who will buy or trade salvaged materials.
- In Winnipeg, the Habitat Re-Store will pick-up used items from your home. Call 233–5160 for information.

RECYCLE

A HOMEOWNER'S CHECKLIST ...

- Hire sub-contractors that will remove and recycle their own waste materials.
- Ask the contractor to separate cardboard waste on-site. Look in the Yellow Pages under "Recycling" for handlers of corrugated cardboard.
- Save all untreated and unpainted wood scraps for the fireplace or wood stove.
- Call the Recycling Council of Manitoba at 925–3777, to learn of markets for construction wastes in Manitoba. Discuss these possibilities with your contractor.

TAKE CARE OF HAZARDOUS WASTES

A HOMEOWNER'S AND CONTRACTOR'S CHECKLIST ...

- Specify in your contract that all hazardous construction waste be properly handled and disposed of off-site. Wastes containing residues of glues and adhesives, paints, thinners and caulking products should not be buried around your home when the lot is graded.

A CONTRACTOR'S CHECKLIST ...

- Use leftover paint as primer for other jobs. Extend the life of solvents – allow solids to settle from used solvent.
- It is an offense to dispose of waste paint or solvent improperly. Talk to your paint supplier or the Manitoba Hazardous Waste Management Corporation at 945–1863, for advice.

For more information about construction waste management, contact:

Canada Mortgage and Housing Corporation
4th Floor, 10 Fort Street
Winnipeg, MB
R3C 1C4
983–5600

for relevant information available at the Canadian Housing Information Centre.

The Manitoba Home Builder's Association
Unit 1 – 1420 Clarence Avenue
Winnipeg, MB
R3T 1T4
925–2560

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Planning ahead for a...

Natural Gas Vehicle

For environmental and economic reasons, natural gas is being considered as one alternative to automobile fuel. Since we will be hearing more about natural gas vehicles (NGV's) in the future, this fact sheet provides some background information to help you decide if natural gas fuel is for you.

This is the 9th in a series of nine informative fact sheets about energy-efficient, environmentally conscious options for new homes and renovation projects.

WHY USE NATURAL GAS FOR CAR FUEL?

Natural gas produces less carbon dioxide (a greenhouse gas), and less carbon monoxide than other petroleum fuels, making it an attractive contender as a future automotive fuel.

New car manufacturers are starting to make some bi-fuel models which operate on either natural gas or gasoline. Otherwise, the conversion of most existing cars can be done quite easily.

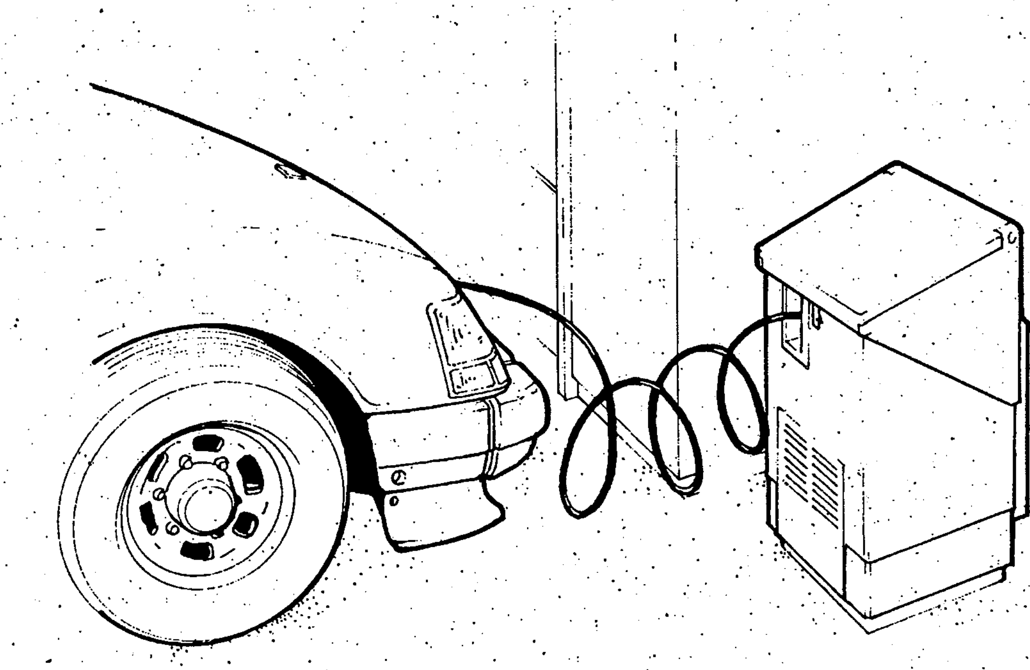
Natural gas vehicle conversion is a suitable option for urban commuters who purchase a lot of fuel. At current fuel prices, natural gas costs about half the price of gasoline per litre.

Centra Gas will be renting vehicle fuel tanks to customers and providing a list of certified mechanics who are familiar with natural gas conversions. Choose between a bi-fuel system (natural gas/gasoline), or make a complete conversion to natural gas.

No additional maintenance is required for a natural gas vehicle. It is recommended that you service your vehicle according to the owner's manual.

There are a few limitations to both conversion options. Use this chart to help you compare.

THE BI-FUEL VEHICLE	THE DEDICATED NATURAL GAS VEHICLE
more refueling options	restricted range for travel
smaller fuel tank	better mileage and performance
refuel at home or away	limited remote refueling stations
estimated cost: $1500 - $3000	estimated cost: $1500 - $3000



Home Refueling Device - When the vehicle's tank is full, natural gas supply automatically shuts off

Natural Gas Vehicle

WHAT IS A HOME REFUELING APPLIANCE?

Home-refueling appliances will be available to lease so that you can refuel your NGV car(s) conveniently. Eventually, fast-fill public refueling stations will be built in Winnipeg and Brandon, for gas-ups away from home.

The compressor for a NGV home refueling appliance is located outside the garage but the refueling control panel and fuel hose are found in the garage. It takes about 5 hours to fill the equivalent of 20 litres of gasoline but the control panel can be programmed to activate refueling overnight – for convenience and/or better fuel rates, if available.

- You can plan ahead for a home refueling appliance by having a gas line roughed-in to a new garage. Request a copy of the building specifications from Centra Gas.
- A refueling appliance will make about as much noise as a central air conditioner. Find a suitable place for it so the sound does not cause a nuisance.

TIP

Through the Market Development Incentive Program (MDIP) offered by Natural Resources Canada, $500 grants can be applied towards NGV vehicle conversions as well as the purchase and installation of natural gas residential refueling appliances. Factory produced natural gas vehicles are eligible for an additional $500 grant, for a total of $1000 per vehicle. Call 1-613-995-0955, for details.

For more information about Natural Gas Vehicles and home refuelling stations, contact:

Centra Gas
444 St. Mary Avenue
Winnipeg, MB R3C 3T7
925-0741

or the

Manitoba Energy and Mines Information Centre
1395 Ellice Avenue, Suite 360
Winnipeg, MB R3G 3P2

Call 945-4154 in Winnipeg or toll-free throughout Manitoba at 1-800-282-8069

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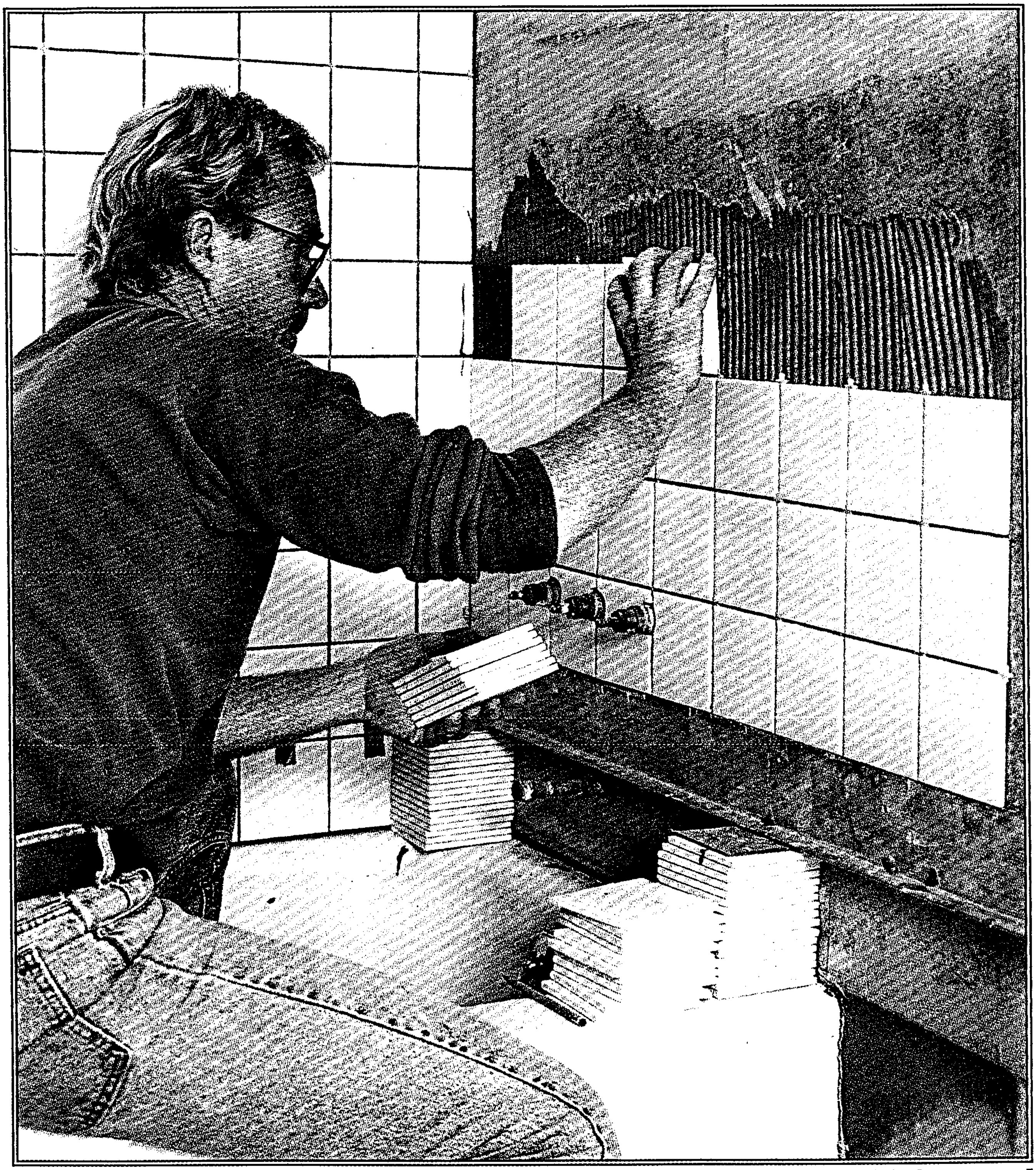


Tiling a Tub Surround

Energy-Saving Details

A demonstration house in Canada shows new approaches to energy-efficient, environmentally sensitive construction

Total energy cost: $800 a year. Every system in the Manitoba Advanced House was chosen according to its impact on the environment. The pine roofing is recyclable and produced with less energy than asphalt roofing. The synthetic stucco mitigates air and water infiltration, and the energy-efficient windows hold heat inside in winter while keeping it out in summer.

by Kip Park

Canada has the highest energy use per capita of any country in the world. That's not unexpected, given the country's climate. In Winnipeg, Manitoba, for example—said to have the coldest winters of any capital city outside of Siberia—temperatures can drop as low as -48°F. But in summer, temperatures can soar: The highest recorded in this prairie city of 600,000 is 108°F. That kind of climate boosts both space-heating and air-conditioning costs.

During the oil embargo of the mid-1970's, the Canadian government started the R-2000 Home Program. Houses built to R-2000 standards consumed half the energy of the typical houses being built at the time. The reduction was achieved by increasing insulation, reducing air leakage, improving window performance, using more efficient heating systems and installing a mechanical ventilation system, usually a heat-recovery ventilator (HRV).

But the R-2000 homes still used too much energy. So in 1991, Energy, Mines and Resources Canada started the Advanced House program and proposed building as many as 10 low-energy, environmentally "green" homes across the country to showcase cutting-edge and traditional technologies to chop energy bills to one-quarter of those attributed to a typical house built in 1975.

The program targeted not only space-heating and air-conditioning costs but all energy use, including embodied energy, the amount of energy it takes to produce, manufacture, distribute, install, operate and, eventually, dispose of everything that goes into a house. Advanced House techniques and technology are available from Manitoba Energy and Mines Info Center (Suite 360 Ellice Center, 1395 Ellice Ave., Winnipeg, Man. R3G 0G3; 204-945-4154).

The Advanced House had to be comfortable and convenient to live in, not forcing major changes in lifestyle. And its design had to have market appeal. There's little point in advancing technology if no one is going to buy and use it.

Energy conservation can be stylish and practical—In the fall of 1992, the Manitoba Home Builders Association (231-1120 Grant Ave., Winnipeg, Man. R3M 2A6; 204-477-5110) was the first group in Canada to construct and open an Advanced House (photo, above). According to computer simulations, it would cost about $800 a year to heat, cool, ventilate and provide domestic hot water in Manitoba's Advanced House. That's far from the $2,400 for a typical 1975 house. Both figures include about $200 a year for standby utility charges, fees to keep electrical and natural-gas lines running into the house.

Monitoring sensors and thermocouples were installed around the foundation and in wall cavities to measure moisture and temperature levels; the performance of the home was scrutinized closely through the fall of 1994.

The 1,859-sq. ft., four-bedroom Manitoba Advanced House demonstrates to contractors and tradespeople that it doesn't take a genius to conserve materials and energy. To the public, it shows that energy conservation can be stylish as well as practical and comfortable.

Reducing waste and using whiskey bottles—A major concern throughout construction was the amount of construction waste. It's been estimated that as much as 20% of materials going into landfills is construction waste. Transporting that waste to landfills is an energy cost in itself. Creating landfills eats up valuable and productive land.

"We wanted to reduce the amount of waste as much as possible," said co-designer and home-energy analyst John Hockman of Appin Associates of Winnipeg (472 Academy Road, Winnipeg, Man. R3N 0C7; 204-488-4207). So the floor plan was designed to minimize construction-material waste (by using full 4x8 sheets wherever possible, for instance), and scrap lumber was used for blocking. Suppliers were advised that all packaging materials had to be made of recycled materials or be capable of being recycled.

On the roof, pine shakes (Prairie Shake Roofing, 885 Century St., Winnipeg, Man. R3H 0M3; 204-786-0813) were used instead of asphalt shingles, which require large amounts of nonrenewable energy to produce. Pine shakes cost about 15% more than asphalt shingles, but they have a life expectancy of 30 to 50 years, after which they can be recycled.

The fill under the foundation and over the plastic drain pipes, or weeping tiles, is an indication of the imagination used. About 30% of the fill is empty whiskey bottles, smashed and pulverized on-site when tumbled in a concrete mixer with pea gravel. "We expected some problems with sharp edges of broken glass," said consulting engineer Gary Proskiw, the other designer of the house and head of Proskiw Engineering Ltd. (1666 Dublin Ave., Winnipeg, Man. R3H 0H1; 204-633-1107), which has extensive experience in residential-energy use. "The only problem we did encounter was the smell. It was like a distillery."

The ground-up bottles reduced the amount of gravel required: Gravel must be transported, cleaned and sifted, all of which consume energy. So Canada's energy use was reduced slightly by whiskey drinkers.

Split-stud walls add insulation space—Predictably, there are high levels of insulation in the Manitoba house: R-60 in the ceiling, R-42 on poured-concrete basement walls and rigid insulation under the entire basement-floor slab, totaling R-10. The 12-in. thick exterior walls have an R-value of 46. The walls are a split-stud system (photo, bottom right, where the exterior 2x4s are separated from the interior 2x3s by 6-in. long, ¼-in.-dia. metal rods. Manufactured by Ten Lives Industries (60 Heaton Ave., Winnipeg, Man. R3B 3E3; 204-956-2860), these wall trusses are easier to install than a site-built double wall. The wall trusses use less lumber than a double wall, yet the trusses are stiffer because of the metal rods, which conduct less heat through walls than a full stud. In conventional wall systems, about 18% of the wall area is made up of studs; a 2x6 stud has an insulating value of about R-7.

The high-performance thermal envelope features rim joists covered with housewrap (photo, bottom left), which adheres to the structure with acoustical sealant. On the interior side, a 6-mil polyethylene air/vapor barrier is sealed to the housewrap (drawing, right). The barrier is nearly hole-free: it goes up the wall and into the joist cavities, where it's stapled to the joist faces only.

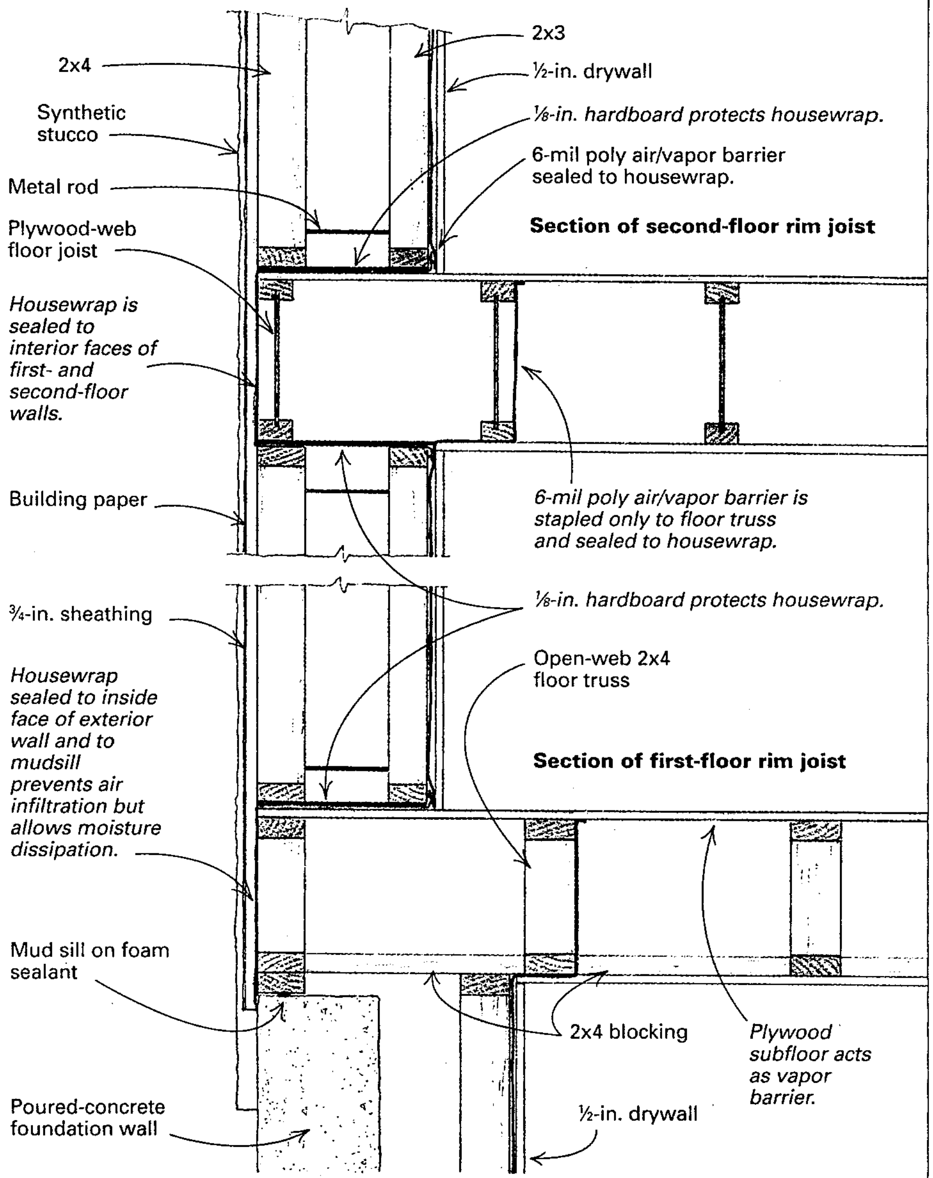
The combination of housewrap and air/vapor barrier is engineered for a cold climate. The poly stops moisture from entering the wall, and the housewrap stops air from flowing in or out, yet it allows any moisture in the wall to escape.

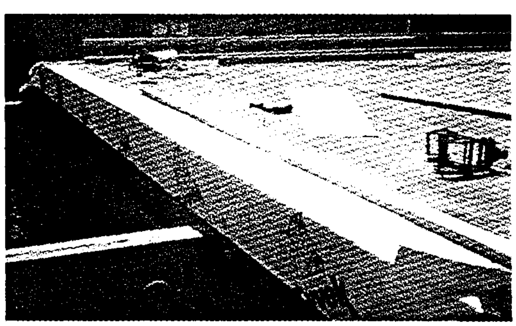
The air/vapor barrier is sealed to the electrical boxes, which have adhesive gaskets (Nu-Tek Plastics Inc., 25-11151 Horseshoe Way, Richmond, B. C. V7A 4S5; 604-272-5550). The Manitoba Advanced House, when tested with a blower door, had an air-change rate (ach50) of 0.78 per hour at 50 Pascals; requirements call for 1.5 ach50 (the tightest house in Canada, also in Winnipeg, had less than 0.20 ach50 when it was built in 1982).

Conserving natural resources—Very little large-dimension lumber was used in the Manitoba Advanced House. "The largest pieces

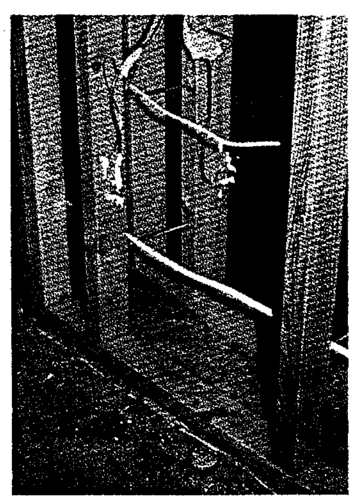
Controlling infiltration at the rim joist.

This combination of housewrap on the rim joist and air/vapor barrier on the inside faces of the walls and the floor trusses prevents wintertime indoor humidity from accumulating in the rim-joist cavity. The housewrap blocks air infiltration but allows any moisture that sneaked past the air/vapor barrier to escape. Acoustical sealant was used because it bonds well to the poly materials and eliminates staple holes.





Wrapping the rim joist in Tyvek and then sealing the vapor barrier to it traps interior air but allows moisture to escape.

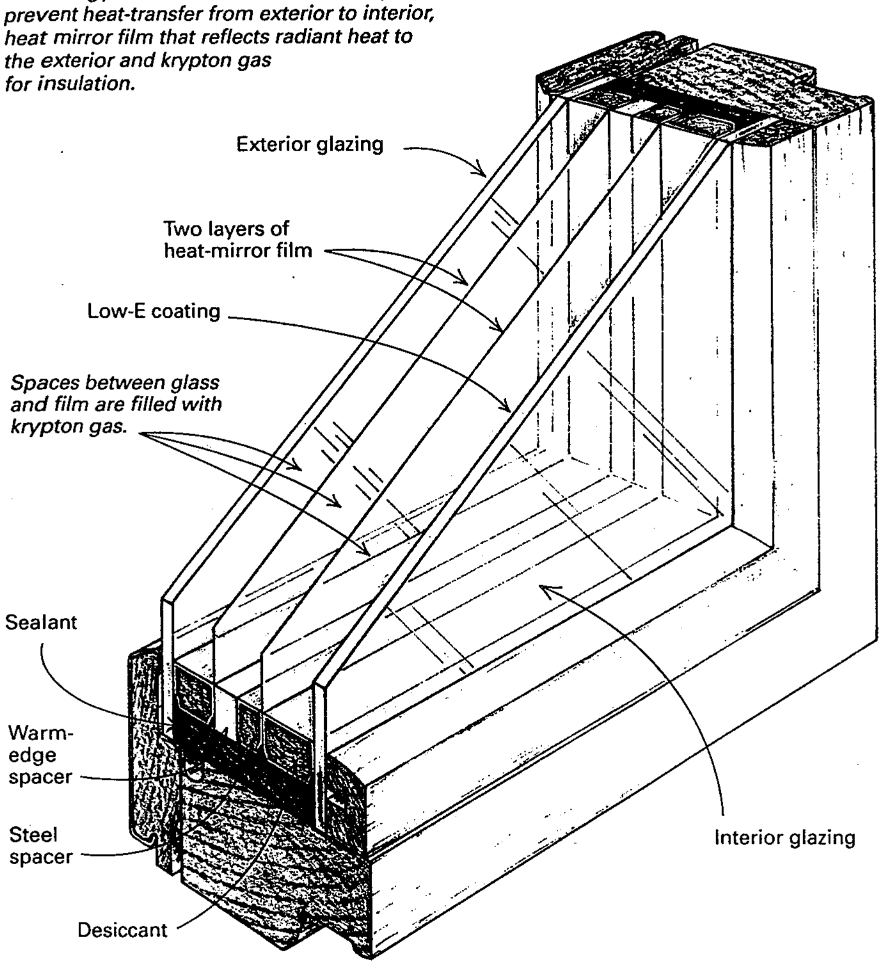


Manufactured wall trusses, 2x4s and 2x3s joined with metal rods, allow for 12 in. of insulation. The metal rods stiffen walls and reduce thermal bridging.

Photos this page: John Hockman and Gary Proskiw

High-efficiency window.

Willmar's R Plus XII windows were used throughout the Manitoba Advanced House not only for their R-12 center-of-glass insulating value but also for their low-E coatings on three surfaces. The energy-efficient features include a spacer to prevent heat-transfer from exterior to interior, heat mirror film that reflects radiant heat to the exterior and krypton gas for insulation.



of lumber are 8-ft. long 2x8s," said Glenn Buchko, executive director of the Manitoba Home Builders Association, which acted as general contractor for the project. The 2x8s were in the garage-door headers.

The first-floor joists are open-web trusses made of 2x4s; the second-floor joists have finger-jointed cords and a plywood web. Why use two different trusses? The open-web joists allowed for large ducts and conduits; the closed-web joists use less material. Both types of truss "dramatically reduced our need for large-dimension lumber, thus lowering the demands we impose on our forests," said Buchko.

Water conservation is also a major factor in the Manitoba Advanced House. Water-efficient toilets, shower heads and faucets reduce water usage without sacrificing performance. Low-flush toilets use about 1.5 U. S. gallons per flush, compared with 3.5 gallons for conventional toilets.

Infrared sensors (Crane Canada Inc., 5850 Cote-de-Liesse Road, Montreal, Quebec H4T 1B2; 514-735-3592) on bathroom water faucets automatically turn water on and off when hands are removed from beneath the faucet.

Landscaping includes drought-resistant native plants, which are adapted to Manitoba's dry summers. These plants reduce watering requirements and provide summertime shade and a comfortable, attractive climate around the house.

There's even a system to collect and store rainwater from the roof and from the sump pit for use in watering the lawn and garden.

Windows for all seasons—The Manitoba Advanced House is oriented to maximize passive-solar heat gain—but with a difference. The program called for window treatments that would control summertime overheating. The most energy-efficient windows in Canada, Willmar's R Plus XII (drawing, above), were installed throughout (Willmar Windows, 485 Watt St., Winnipeg, Man. R2L 2A5; 204-668-8230). They're considered quadruple-glazed, though two of those glazings are actually Heat Mirror 88 film, which reflects radiant heat while it transmits 88% of the light, suspended between two panes of glass. The inner light has an additional soft low-E coating, and the air spaces are filled with krypton gas. A special spacer-bar system was developed to keep the edges of the lights warmer than conventional-window edges, and center-of-glass insulation values hit R-11.5. R Plus XII windows cost about one-third more than conventional double-glazed windows.

To prevent solar overheating in summer, all windows are equipped with removable solar screens, which block about 30% of solar radiation. That reduces the cooling load by more than one-third and, when combined with the house's ventilation system, also eliminates the need for air conditioning.

Heating and ventilating—On the mechanical side, a 94% efficient natural-gas water heater with a custom-built air handler (Mor-Flo Industries Inc., division of American Water Heater Group, P. O. Box 4056, Johnson City, Tenn. 37602; 615-283-8000) heats both the home (forced hot air) and the domestic hot water. The unit's high efficiency is achieved in part by circulating warm greywater, the wastewater from such things as washing machines and dishwashers, through a heat exchanger (drawing, facing page) to preheat water going to the boiler.

Indoor-air quality is maintained by a heat-recovery ventilator (HRV), which preheats incoming air. The modified Lifebreath 195 HRV (Nutech Energy Systems Inc., 511 McCormick Blvd., London, Ont. N5W 4C8; 519-457-1904) mixes fresh air with return air, and all air is then filtered through an 85% efficient bag filter to remove dust and fine particulate matter. The air then passes through an activated-charcoal filter to remove odors and chemicals before it is heated and distributed.

The home is divided into four heating zones—all forced hot air except for hot-water baseboard in the fourth bedroom, which I'll explain in a minute—allowing one area of the home to receive fresh, heated air, while another (unoccupied) area still can receive fresh, unheated air. To ensure high air quality and to prevent the chronic problem of mold growth in cold closets, return-air vents, which pull stale air from the room, are installed in all bedroom closets. The location of these vents improves overall air quality, too. "Clothing can be a significant source of indoor-air pollution because of chemicals used in dry cleaning," Proskiw noted. "Here, we're eliminating them at the source."

The fourth bedroom, on the main floor, can be used as a den, a hobby room or a smoking room. It has its own separate exhaust-air system, so any noxious odors or chemicals produced by hobbies or smoking are exhausted directly outside. For the same reason, this is the room heated with hot-water baseboards.

Great care was taken in selecting materials used inside the home to ensure good indoor-air quality. For instance, the technical requirements as issued by Energy, Mines and Resources required that products containing urea-formaldehyde-based resin glues, such as the chipboard used in the kitchen cabinets, be sealed to limit formaldehyde outgassing. Indoor air could not contain any more than 0.05 parts per million of formaldehyde.

Using less electricity—"There are two major factors affecting the energy performance of any iouse—the structure itself and the people who ive in it," said Hockman. In the Manitoba Advanced House, a Power Sentry power-usage ndicator was installed above a desk in the kitchen to show present and cumulative use of electricity (Northwest Extension Inc., 15 Central Way #201, Kirkland, Wash. 98033; 206-828-9190). The power-usage indicator also presents data in dollars and cents.

In other installations, this type of information system, which makes homeowners aware of just now much electricity is being used at any moment, has resulted in an immediate 10% to 20% reduction in consumption. "It's an awareness hing," said Proskiw.

The appliances by General Electric are among he most energy-efficient models on the market. The clothes washer is rated at 74kwh per month, compared with conventional washers that can use 150kwh. The refrigerator is rated at 55kwh compared with similarly sized conventional units hat can use as much as 85kwh per month.

Artificial lighting was considered important because Winnipeg receives only about eight hours of daylight per day during December. High-efficiency fluorescent and halogen lighting fixtures are used throughout most of the house. Less-efficient incandescent lighting is restricted to fixtures that are seldom used, such as closet lights, because the incandescent lights are a lot less expensive. The Manitoba Advanced House also makes extensive use of dimmers and automatic ight switches to promote energy savings and to ncrease convenience.

In Winnipeg's cold winter climate, engine-block heaters and and vehicle-interior warmers keep cars from freezing up. Because these comfort devices use lots of electricity, an indoor timer automatically switches on the heaters about two hours before vehicles will be used.

Future repercussions—There are a multitude of features in the Manitoba Advanced House, many of them simple in concept. "All the features had to be as practical as possible, with the widest potential application," said Hockman. "This type of house will be aimed at the mainstream in the very near future."

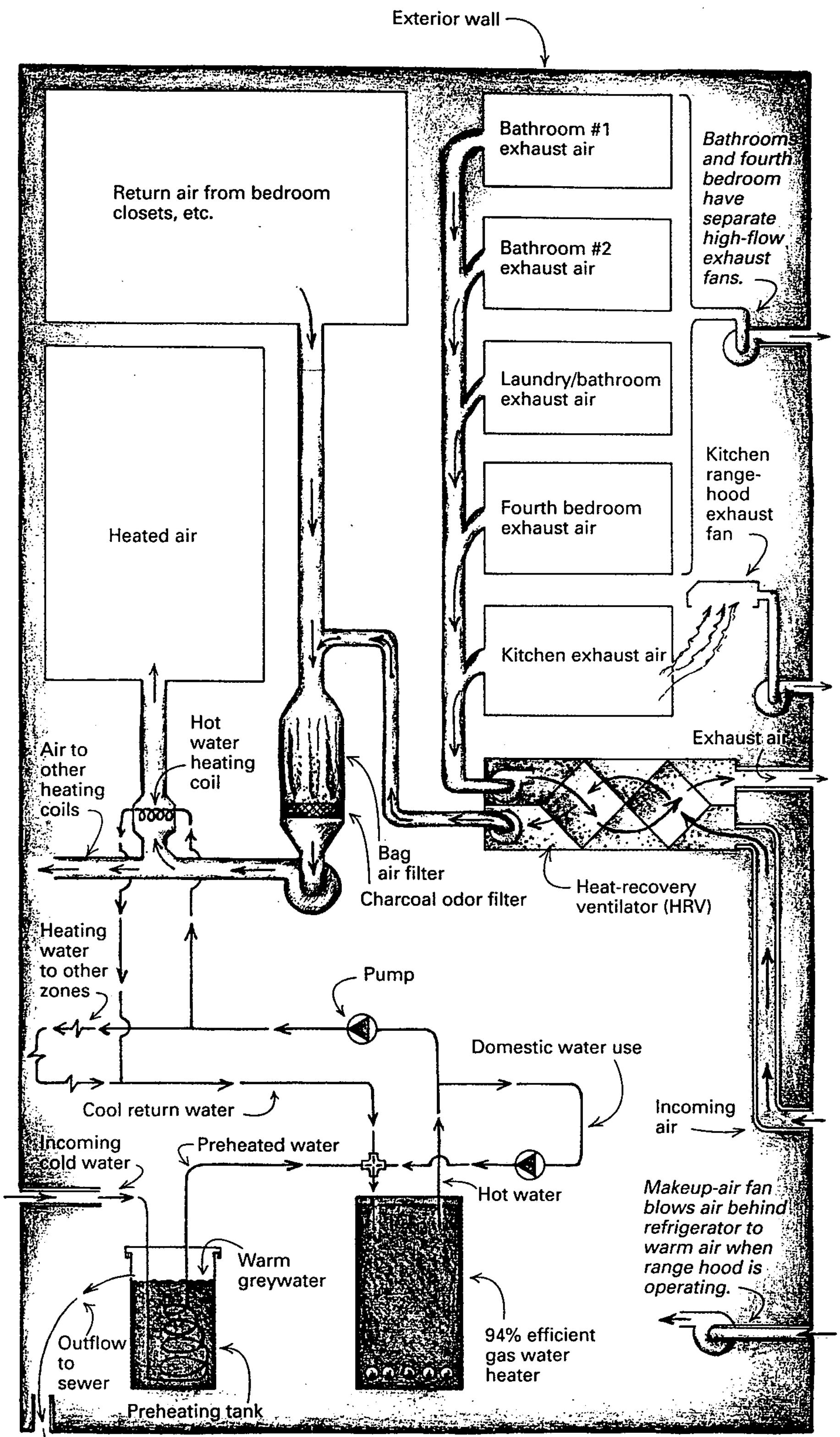
The principles learned and demonstrated in he Manitoba Advanced House eventually could be transferred to the renovation industry. Because much of the technology incorporated n the Manitoba Advanced House is cutting-edge, t is, therefore, expensive. The lessons learned in Winnipeg, however, will help that technology develop further, and the cost of renovating existing homes will drop.

Although its monitoring systems made the Manitoba Advanced House about 25% more expensive than a conventionally constructed home, the house is truly a demonstration that energy-efficient, environmentally friendly, "green" houses are practical and ready to stand the test of he marketplace. □

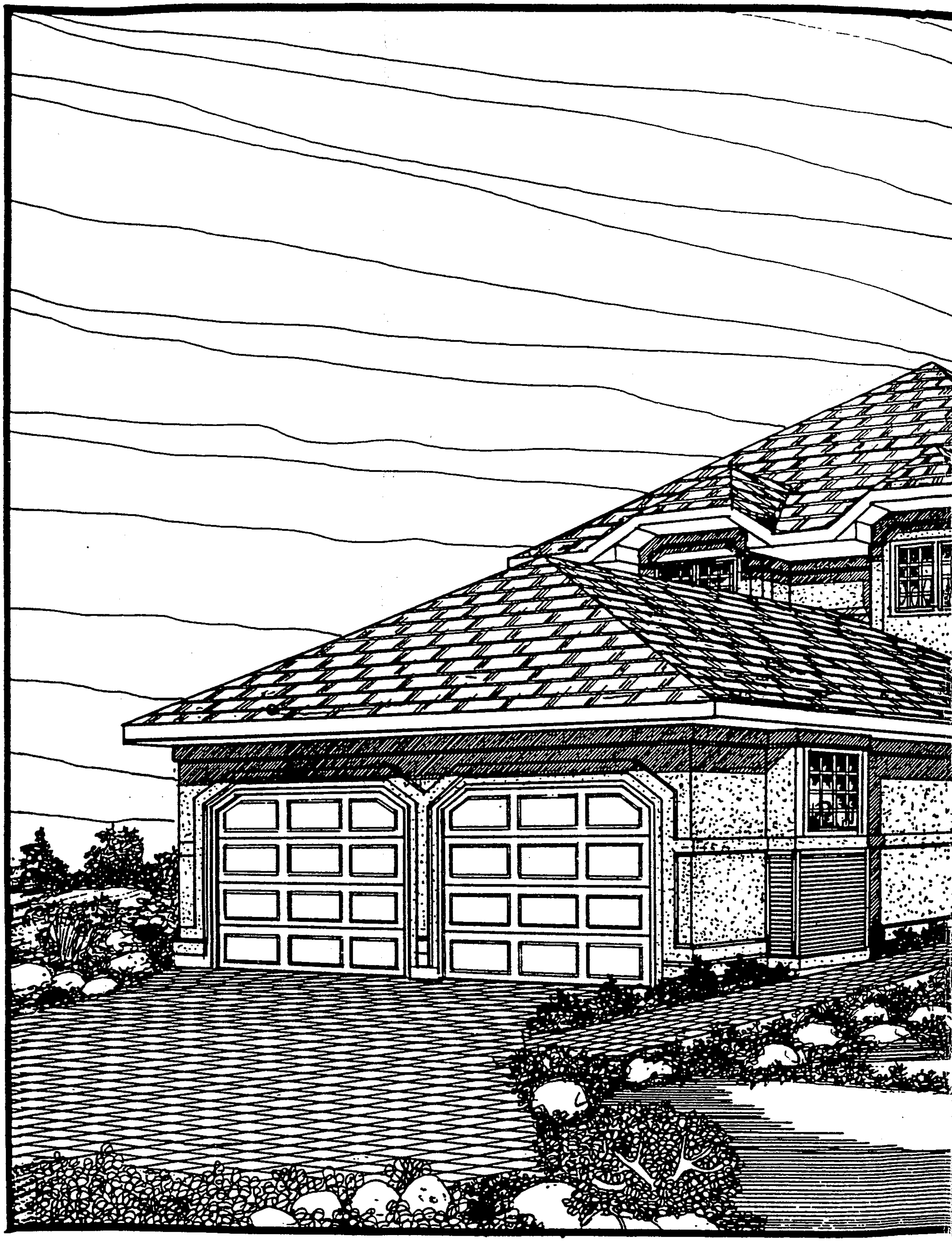
Kip Park lives in Winnipeg, Manitoba, and he writes about housing, construction and energy-technology issues. Photo by the author except where noted.

An energy-efficient heating and ventilating system.

Using one-third the energy of a typical house built in 1975, the Manitoba Advanced House incorporates heat-capturing devices, energy-efficient appliances and multiple heating zones. Incoming water is warmed in a custom-built preheater that captures heat from dishwasher and laundry wastewater; the preheated water then goes to a highly efficient gas water heater and is distributed to the domestic hot water and the heating system. The ventilating system, required in the airtight Manitoba house, pulls outdoor air through a heat-recovery ventilator, which warms the air with the residual heat of stale air that's exhausting from the house. The warmed incoming air mixes with recirculated indoor air and is filtered twice, then sent to one of four separate heating/ventilating zones. All fan motors are more efficient than conventional fan motors.

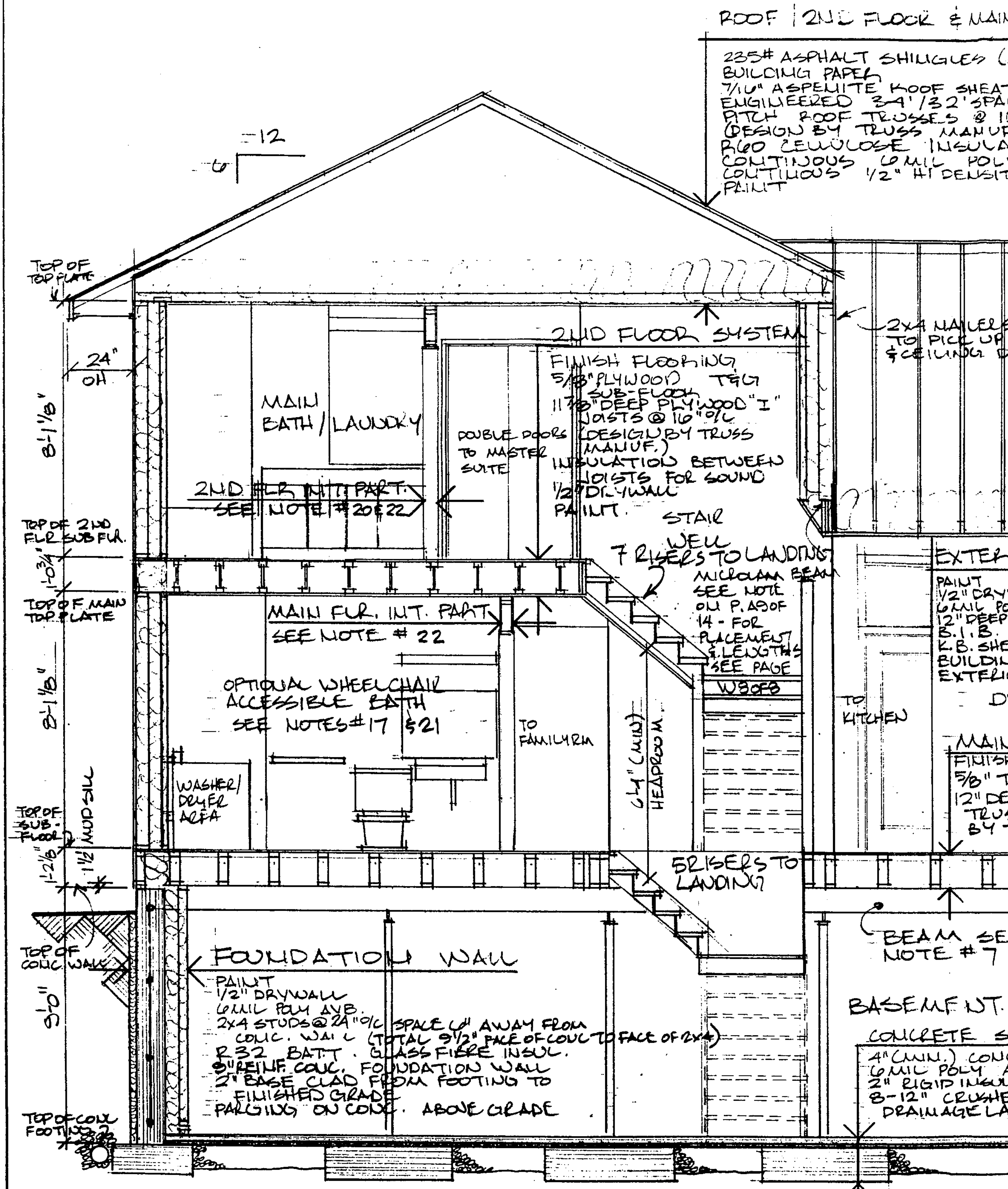


APPENDIX B



MHBA ADVANCED HOUSE NORTH ELE

VATION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235# ASPHALT SHINGLES
BUILDING PAPER
7/16" ASPENITE ROOF SHEAT
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R60 CELLULOSE INSULA
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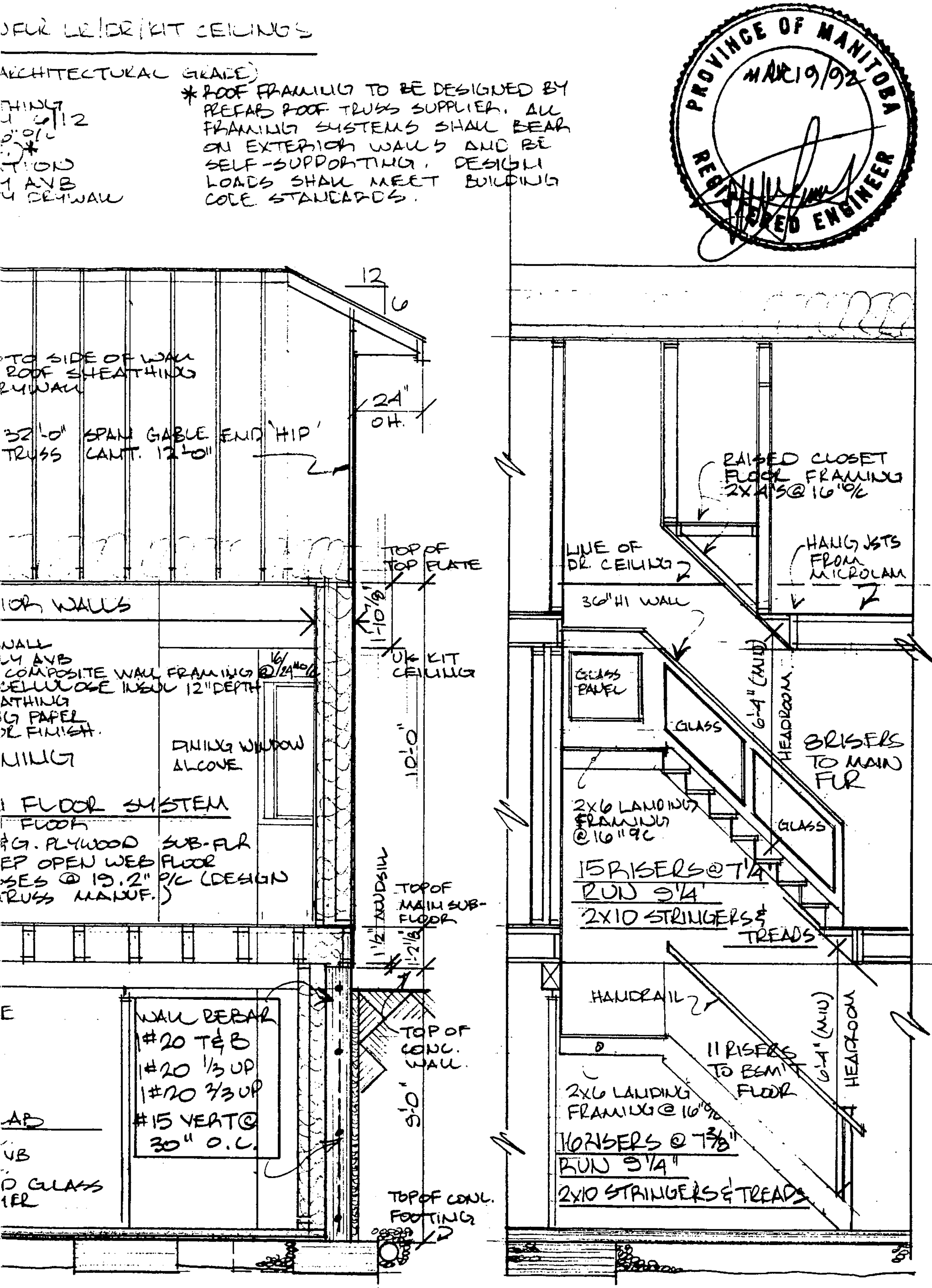
PAINT
12
6
TOP OF TOP PLATE
24" OH
8'-1 1/8"
MAIN BATH / LAUNDRY
DOUBLE DOORS TO MASTER SUITE
2ND FLOOR SYSTEM
FINISH FLOORING
5/8" PLYWOOD T&G SUB-FLOOR
11 7/8" DEEP PLYWOOD "I" JOISTS @ 16" o/c (DESIGN BY TRUSS MANUF.)
INSULATION BETWEEN JOISTS FOR SOUND
1/2" DRYWALL
PAINT
2X4 NAILER TO PICK UP & CEILING
2ND FLR INT. PART. SEE NOTE #20 & 22
TOP OF 2ND FLR SUB FLR.
STAIR WELL
7 RISERS TO LANDING
MICROLAM BEAM SEE NOTE ON P. A9 OF 14 - FOR PLACEMENT & LENGTHS SEE PAGE
W8OF8
TOP OF MAIN TOP PLATE
MAIN FLR. INT. PART SEE NOTE # 22
EXTER
PAINT
1/2" DRYW
6MIL PO
12" DEEP
B.I.B.
K.B. SHE
BUILDIN
EXTERI
8'-1 1/8"
OPTIONAL WHEELCHAIR ACCESSIBLE BATH SEE NOTES #17 & 21
TO FAMILY RM
6'-4" (MIN) HEADROOM
TO KITCHEN
MAIN
FINISH
5/8" T
12" DE
TRUS
BY
WASHER/ DRYER AREA
TOP OF SUB-FLOOR
MUDSILL
1-2 1/8
1 1/2
5 RISERS TO LANDING
BEAM SEE NOTE #7
TOP OF CONC. WALL
FOUNDATION WALL
PAINT
1/2" DRYWALL
6MIL POLY AVB.
2x4 STUDS @ 24" o/c SPACE 6" AWAY FROM CONC. WALL (TOTAL 9 1/2" FACE OF CONC TO FACE OF 2x4)
R32 BATT. GLASS FIBRE INSUL.
8" REINF. CONC. FOUNDATION WALL
2" BASE CLAD FROM FOOTING TO FINISHED GRADE
PARGING ON CONC. ABOVE GRADE
9'-0"
BASEMENT
CONCRETE S
4" (MIN.) CONC
6MIL POLY A
2" RIGID INSUL
8-12" CRUSHE
DRAINAGE LA
TOP OF CONC FOOTING

SECTION.



STAIRS DETAIL

APPROVED | PAGE A11 OF 14

DRAWN J. BECKMAN

SCALE: DO NOT SCALE DIMENSIONS GOVERN.

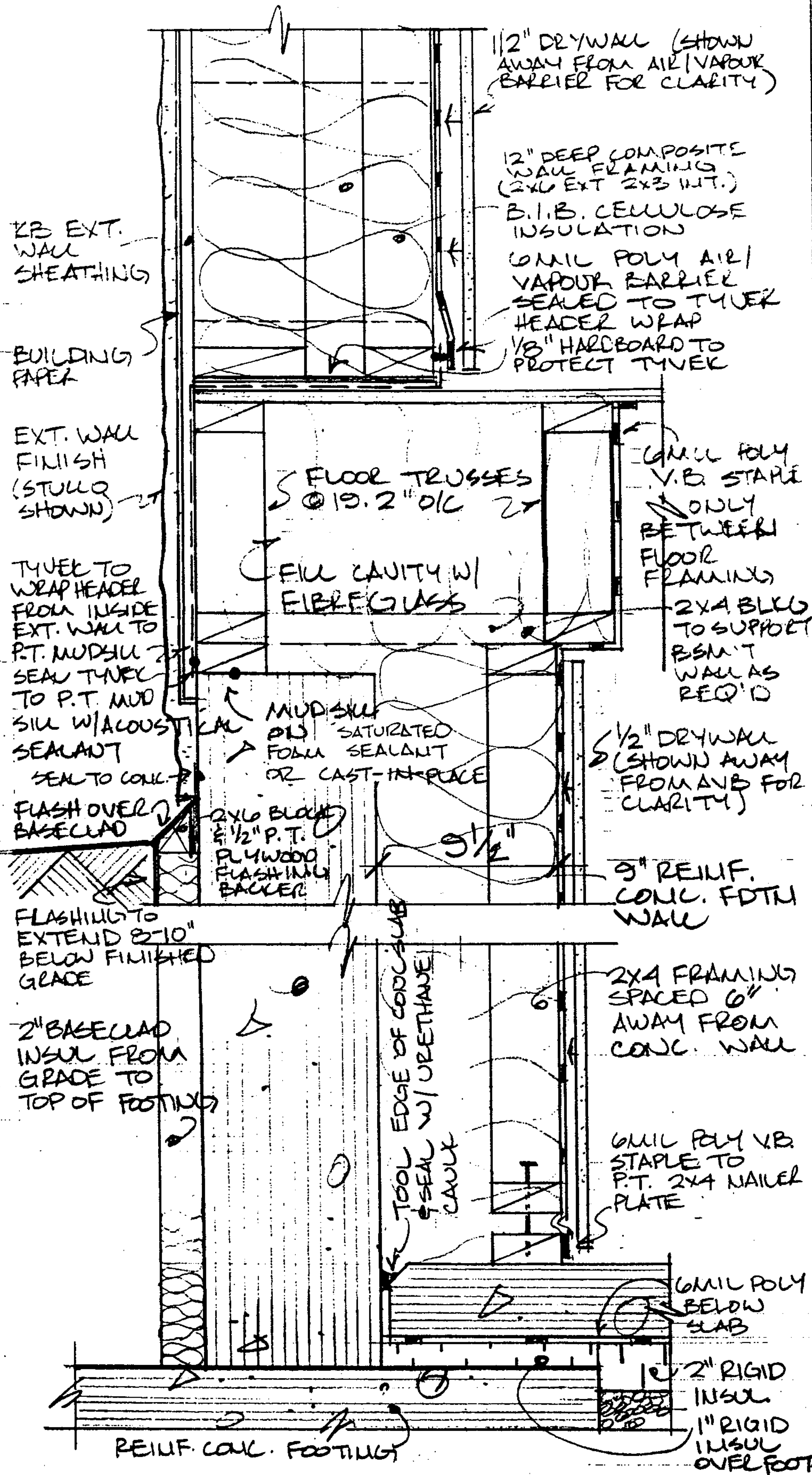
DATE JAN 8/92

REV 2 03.92

ADVANCED HOUSE
CROSS SECTIONS

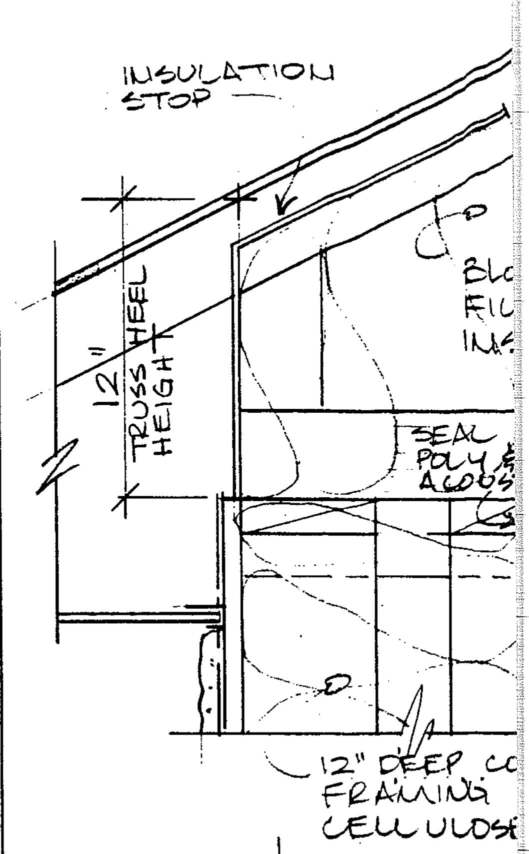
MANITOBA HOME BUILDERS ASSOCIATION

UNIES LTD | APPIN ASSOC.

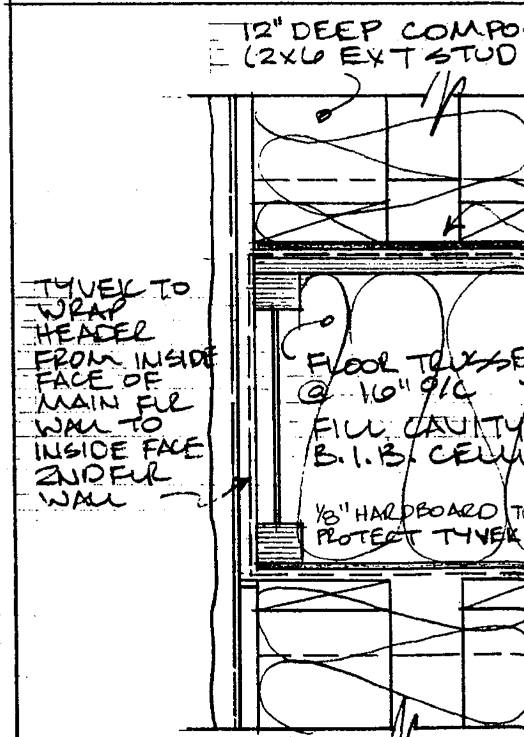


MAIN FLOOR HEADER DET'L

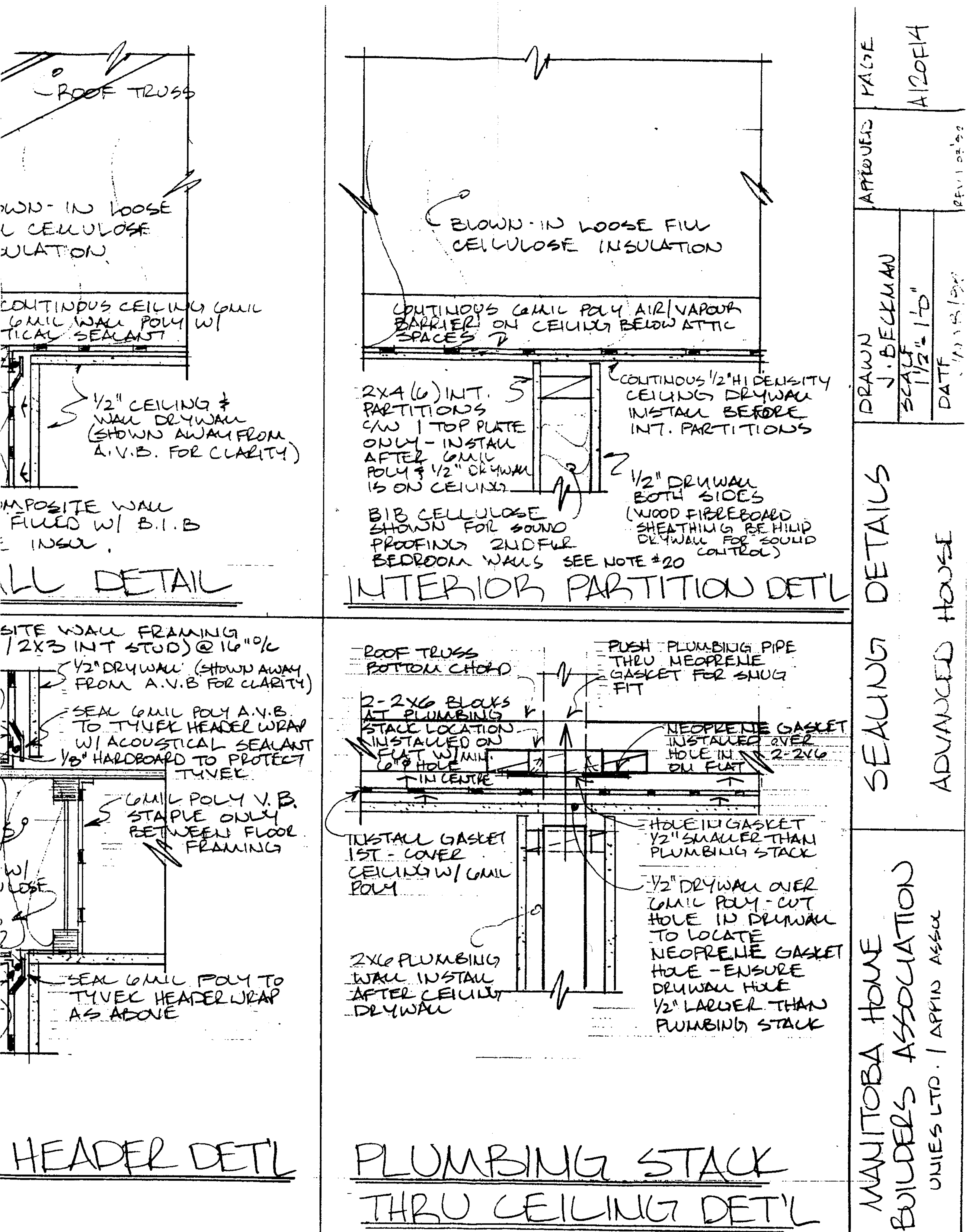
BSM'T FRAMING DETAIL



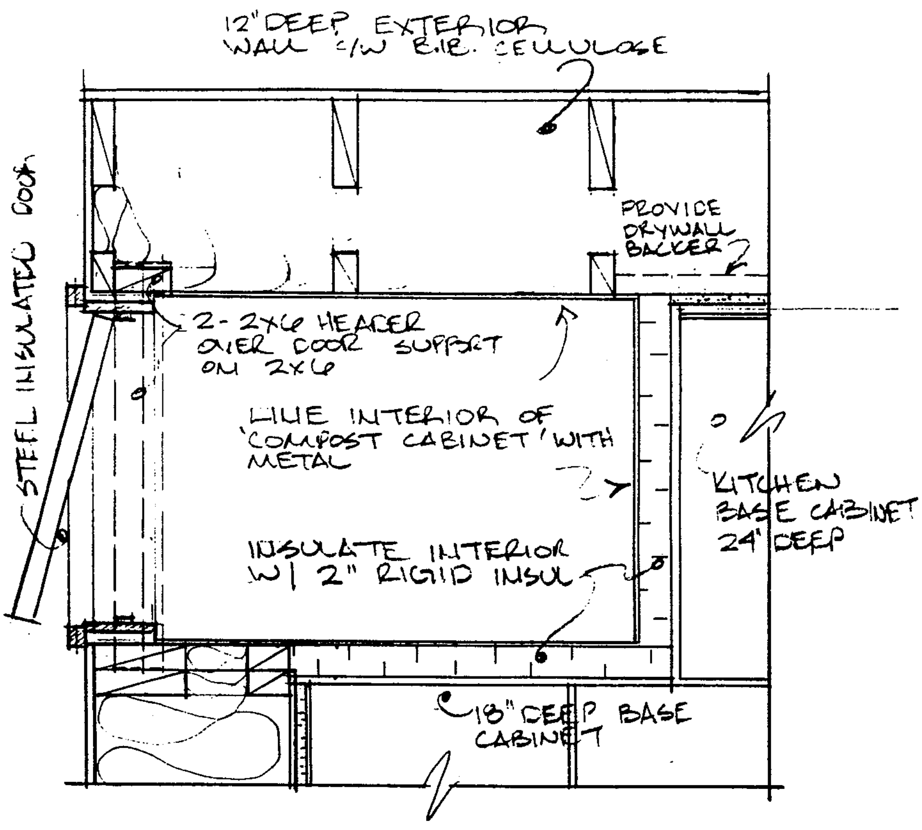
ROOF / EXT. WA

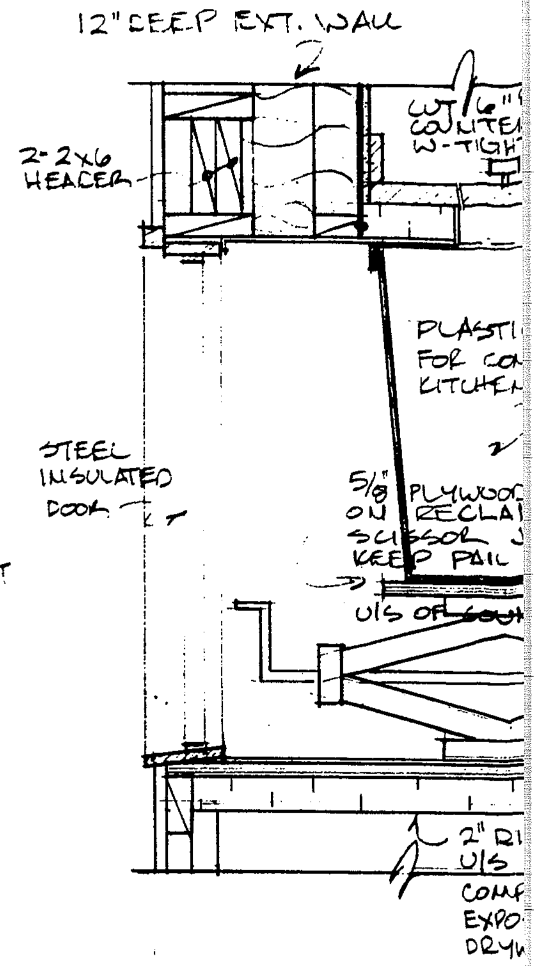


2ND FLOOR

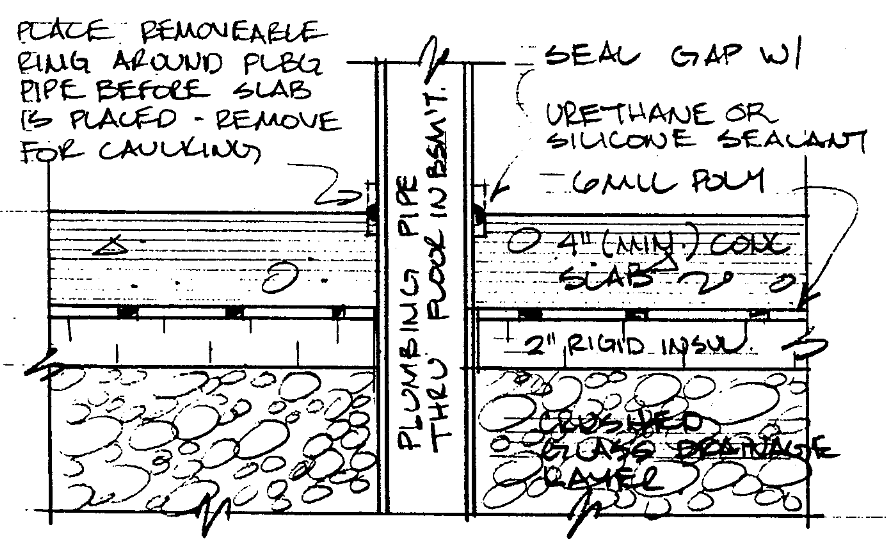


ROOF TRUSS
CONTINUOUS CEILING 6MIL
6MIL WALL POLY W/
TICAL SEALANT
1/2" CEILING & WALL DRYWALL (SHOWN AWAY FROM A.V.B. FOR CLARITY)
MPOSITE WALL FILLED W/ B.I.B
INSUL.
LL DETAIL
BLOWN-IN LOOSE FILL CELLULOSE INSULATION
CONTINUOUS 6MIL POLY AIR/VAPOUR BARRIER ON CEILING BELOW ATTIC SPACES
CONTINUOUS 1/2" HI DENSITY CEILING DRYWALL INSTALL BEFORE INT. PARTITIONS
2X4 (6) INT. PARTITIONS C/W 1 TOP PLATE ONLY - INSTALL AFTER 6MIL POLY & 1/2" DRYWALL IS ON CEILING
1/2" DRYWALL BOTH SIDES (WOOD FIBREBOARD SHEATHING BEHIND DRYWALL FOR SOUND CONTROL)
BIB CELLULOSE SHOWN FOR SOUND PROOFING 2ND FLR BEDROOM WALLS SEE NOTE #20
INTERIOR PARTITION DET'L
SITE WALL FRAMING
/2X3 INT STUD) @ 16" O/C
1/2" DRYWALL (SHOWN AWAY FROM A.V.B FOR CLARITY)
SEAL 6MIL POLY A.V.B. TO TYVEK HEADER WRAP W/ ACOUSTICAL SEALANT
1/8" HARDBOARD TO PROTECT TYVEK
6MIL POLY V.B. STAPLE ONLY BETWEEN FLOOR FRAMING
SEAL 6MIL POLY TO TYVEK HEADER WRAP AS ABOVE
HEADER DET'L
ROOF TRUSS BOTTOM CHORD
2-2X6 BLOCKS AT PLUMBING STACK LOCATION INSTALLED ON FLAT W/ MIN 6" Ø HOLE IN CENTRE
PUSH PLUMBING PIPE THRU NEOPRENE GASKET FOR SNUG FIT
NEOPRENE GASKET INSTALLED OVER HOLE IN 2-2X6 ON FLAT
INSTALL GASKET 1ST - COVER CEILING W/ 6MIL POLY
HOLE IN GASKET 1/2" SMALLER THAN PLUMBING STACK
1/2" DRYWALL OVER 6MIL POLY - CUT HOLE IN DRYWALL TO LOCATE NEOPRENE GASKET HOLE - ENSURE DRYWALL HOLE 1/2" LARGER THAN PLUMBING STACK
2X6 PLUMBING WALL INSTALL AFTER CEILING DRYWALL
PLUMBING STACK THRU CEILING DET'L
SEALING DETAILS
ADVANCED HOUSE
MANITOBA HOME BUILDERS ASSOCIATION
UNIES LTD. / APPIN ASSOC
DRAWN J. BECKMAN
SCALE 1 1/2" = 1'-0"
DATE
APPROVED
PAGE A12 of 14

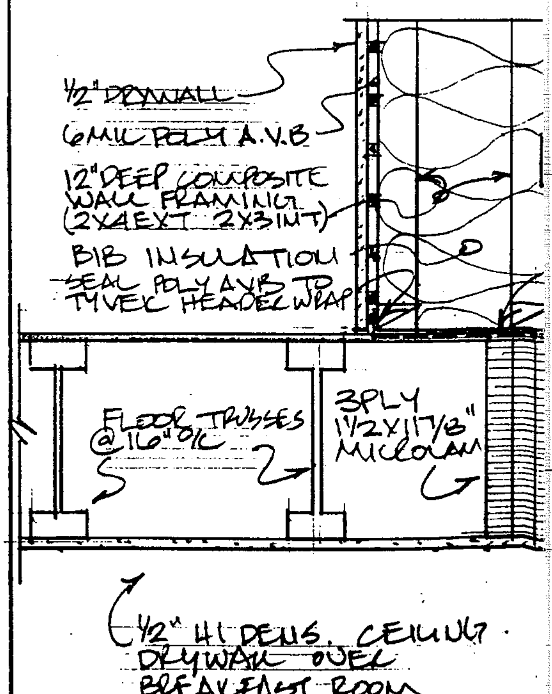




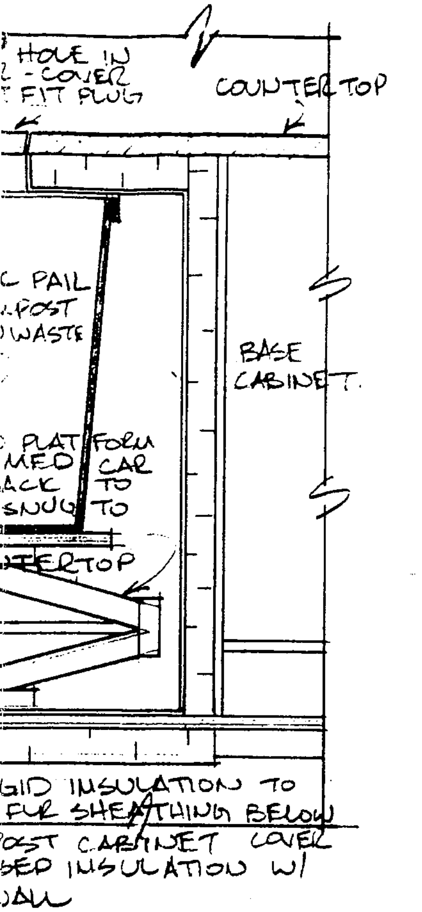
PLAN VIEW - COMPOST CABINET - S



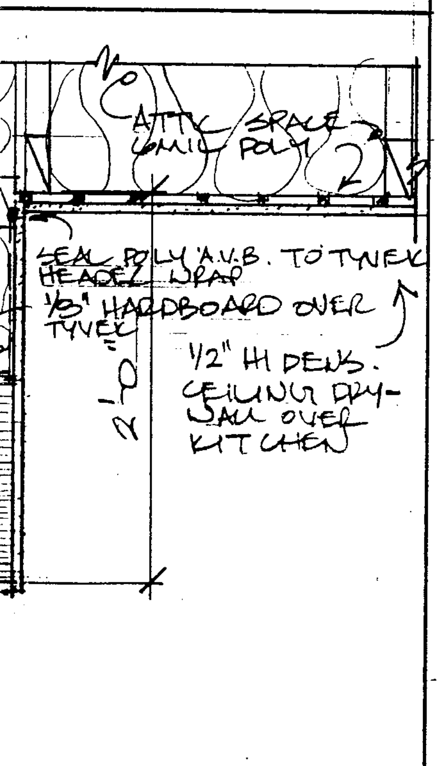
PLUMBING THRU BSM'T FUR SLAB DET'L.



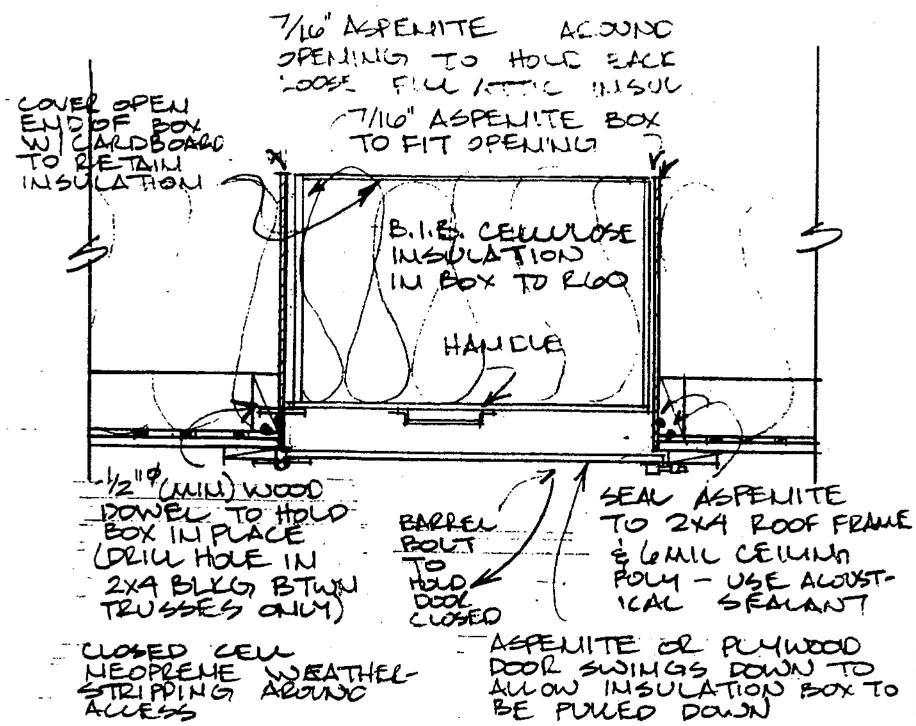
POLY DET'L @ 2ND



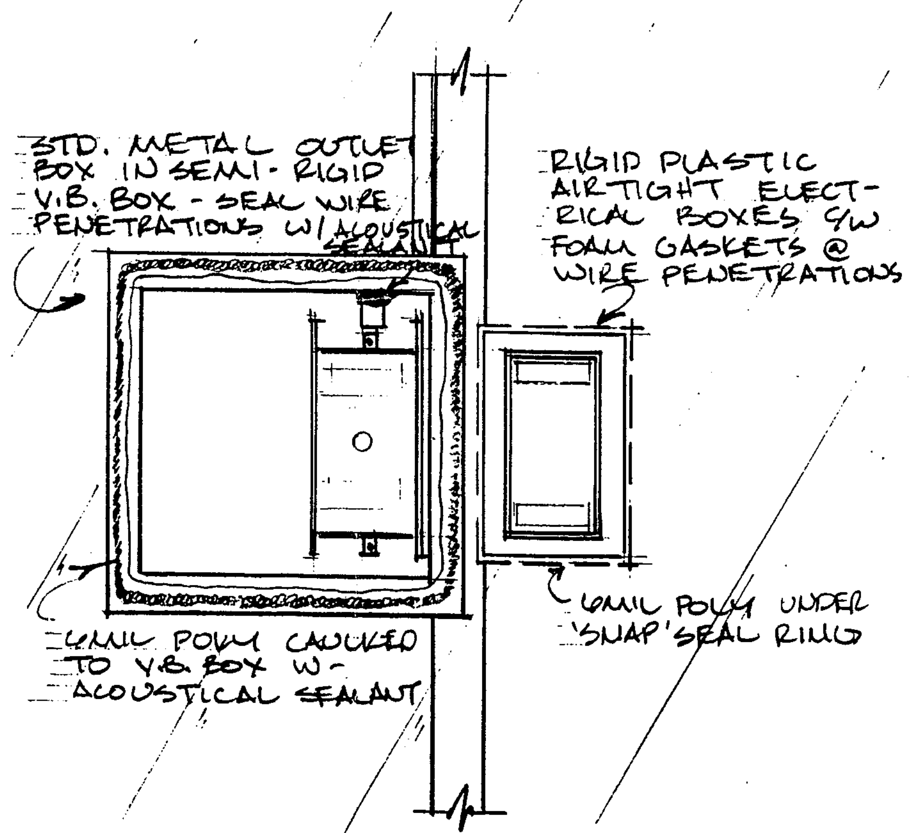
ECTION



FUR MICROLAM



ATTIC ACCESS DETAIL



ALTERNATE EXTERIOR WALL ELECTRICAL DETAIL

APPROVED | PAGE A13 OF 14

REV 01 06 92

DRAWN J. BECKMAN

SCALE 1" = 1'0"

DATE JAN 8/92

ADVANCED HOUSE VARIOUS DETAILS

MANITOBA HOME BUILDERS ASSOCIATION

UNIES LTD / APPIN ASSOC.

APPENDIX C

CHECK LIST FOR ADVANCED HOUSES TECHNICAL REQUIREMENTS

Robert S. Dumont
Building Science Division
Saskatchewan Research Council
15 Innovation Boulevard
Saskatoon, Saskatchewan
S7N 2X8

September 9, 1992

INTRODUCTION

This check list follows the numbering scheme used in the Technical Requirements(1). For further information regarding the check list, refer to the Technical Requirements. Please note that this check list should be returned within 10 days of receipt to Robert Dumont at the above address. If information is missing or unknown, leave the item blank. A followup questionnaire will be sent at the time of completion of the house.

Advanced House Location

Street Address 420 KIRKBRIDGE DRIVE

City WINNIPEG

Prov MANITOBA

Postal Code R3T 5R1

Name of person filling out this form GARY PROSKIW

Telephone (204) 633-1107

CHECK LIST

2.0 MINIMUM ENVELOPE AIR LEAKAGE REQUIREMENTS

Air tightness test attached? Yes X No ____ Pending _____

Result of air tightness test: 0.78 air changes/hr @ 50 Pa

0.43 cm^2/m^2 normalized leakage area

If not done, state approximate date on which test will be done: A FINAL TEST WILL BE DONE IN OCT/92

3.0 VENTILATION SYSTEMS AND EQUIPMENT

HRAI installer's report attached? Yes ___ No X — INSTALL. NOT COMPLETE

If not done, state approximate date on which report will be submitted: OCT/92

Is insulated ductwork between HRV and outdoors less than 2 metres? Yes ___ No X — INSTALLATION NOT COMPLETE

If answer is no, state length of ductwork and insulation level on ducts.

Length (m) ______
Insulation Value (RSI) ______

Does innovative ventilation equipment have laboratory test results to back performance claims? Yes ___ No X

If answer is no, when will report be submitted? SUMMER/93

Is all ductwork carrying conditioned air located inside the conditioned envelope of the building? Yes X No ___

If the answer is no, please attach pressure test report on the ductwork, or indicate the approximate date on which the test report will be submitted. ______________

If the answer is no, please indicate the insulation levels used on the ductwork. ______________

4.0 COMBUSTION EQUIPMENT

Does all combustion equipment meet provisions of Technical Requirements? Yes X No ____

Does wood heating apparatus meet current State of Oregon emission requirements? (See Resource Book for listing of approved apparatus.) Yes ___ No ____ NO WOOD HEATING

5.0 ENERGY PERFORMANCE TARGETS

Please fill in the Table with the appropriate numbers.

ENERGY PERFORMANCE SUMMARY
(Annual Figures)

	Target (kWh)	Prediction (kWh)
Space Heating	7303	5934
Space Cooling	0	0
Domestic Water Heating	5520	3167
Appliances	3838	7520
Lighting	352	352
Outdoor Electrical Usage	183	183
Totals	17,196	17,156

6378

State following house characteristics:

Volume of House (m^3) 721.8

Number of Bedrooms 4

Surface/volume factor 0.79

Occupant factor 0.9

Type of space heating system

electricity	______
natural gas	X
oil	______
propane	______
solar	______
other (please state)	______

Has the revised HOT-2000 or other energy analysis program calculation been submitted? Yes X No____

Has RSI 3.5 (R20) insulation been specified for all heated water storage tanks? Yes___ No X

R-16 ON POLARIS

Has RSI 0.5 (R2.9) insulation been specified for all inlet and outlet water piping for one metre from the water heater? Yes X No___

5.5 APPLIANCES

State the Energuide electrical consumption for each of the following appliances (kWh/yr): (In the absence of Energuide ratings, give the manufacturer's projected annual consumption)

Refrigerator	864	
Stove	205	← AFTER DEDUCTING 75 kwh/yr FOR HEAT RECOVERY
Clothes washer (excluding hot water)	96	
Clothes dryer	528	← AFTER DEDUCTING 612 kwh/yr FOR HEAT RECOVERY
Dishwasher (excluding hot water)	864	

Heat distribution System

Furnace fan(s)	______	} 1971
Furnace combustion gas exhaust fan	______	
Furnace electronics	______	
Circulating pumps	______	

Heat recovery ventilator

Fans	946
Electric defrost unit	0

Additional major electrical loads(Specify)

1. VARIOUS BLOWERS 1000
2. ______ ______

Do appliances meet minimum capacity requirements?

Refrigerator or refrigerator/freezer (440 L)	Yes X No___	479 l
Stove Minimum 4 burners; minimum 60 litres volume	Yes X No___	127 l
Clothes washer; minimum tub capacity 60 litres	Yes X No___	77 l
Clothes dryer: minimum 140 litres volume	Yes X No___	153 l
Dishwasher; minimum 150 litres volume	Yes___ No___	} NOT LISTED IN ENERGUIDE

5.6 LIGHTING

Is the installed lighting for the house(including movable lamps) less than 8 W/m^2? Yes___ No___

Is the average lighting output for all fixtures less than 40 lumens/watt? Yes___ No___

State the lighting density W/m^2. ____________

State the average lumens/watt. ____________

5.8 PEAK ELECTRICAL CONSUMPTION CONTROL

Does house use grid-connected electric resistance heating? Yes____ No X

If answer is yes, what type of load management controller is used? Give manufacturer and model number ________________

In areas where the January design temperature is below -20°C, is a timer located inside the house to control the automobile block heater? Yes X No______

Not Applicable___

5.9 FAN ENERGY

Will heat recovery ventilator fans meet the requirement of 1.2 W/L/s of air flow capacity? (Systems without forced air heating.) Yes____ No______

Not applicable X

State predicted W/L/s consumption rate. ________________

Will the fans for the combined warm air heating and heat recovery ventilator system meet the requirement of 0.75 W/L/s of air flow capacity? (Systems with forced air heating.) Yes____ No__X__

Not applicable___

State predicted W/L/s consumption rate. __1.54__ 108 / (148.3 / 2.12)

6.0 WATER USAGE

Do the toilets meet the 7 litre or less per flush requirement? Yes__X__ No__X__ 2 @ 6 l/FLUSH

State water usage per flush (L)____________ ← 1 @ 17 l/FLUSH + ≃ 8½ l/FLUSH (DUAL FLUSH)

Do the shower heads meet the 10 litre/minute or less flow requirement at a water pressure of 551 kilopascals (80 psig)? Yes__X__ No______

State water flow per shower head. __10 l/min @ 85 psi__

Do sink faucets have aerators? Yes__X__ No______

Has the landscaping for the house been chosen so as to reduce the outdoor water usage of the house by 50%. Attach list of water conserving measures. Yes__X__ No______

- MINIMAL TURF
- INDIGINOUS PLANTS
- GROUND MATS / BARK CHIPS

Has a low water consumption per cycle washing machine been chosen? Yes__X__ No______

State water consumption per cycle (L) __128-188 l__

MINIMUM — MAXIMUM

7.0 RECYCLING

Has the kitchen been laid out to include space for a 10 litre compost container and a volume sufficient to hold a blue box container (508x394x305 mm)? Yes X No ____ ← IN BASEMENT CONNECTED TO KITCHEN VIA CHUTE

Has an outdoor compost bin with a minimum volume of 150 litres been specified? Yes X No ____

8.0 ECOMANAGEMENT

Has a construction waste management plan been designed? Yes X No ____

Has a construction waste management plan been implemented? Yes X No ____ Pending ____

Has construction waste management plan been submitted? Yes ____ No X

How will scrap gypsum board be handled?

Recycled NO ← NO LOCAL FACILITIES

Used as interior thermal mass NO ← DUMB IDEA

9.0 ECOLOGO PRODUCTS

Provide a list of ECOLOGO approved products that are used in the house:

1. CELLULOSE INSULATION
2. HRV
3. PAINT
4. ____
5. ____
6. ____

Are any insulation products being used that contain fluorocarbons with an ozone depletion factor greater than 0.05? Yes______ No__X__

9.0 INDOOR ENVIRONMENT

9.1 Air quality

Has house questionnaire detailing the building materials been completed? Yes______ No_______ Pending__X__

Have products known to contain urea-formaldehyde based resin glues been excluded? Yes______ No__X__
(Products include interior grade particle board, medium density fibreboard, and interior grade plywoods such as oak, birch, mahogany.)

If answer is no, is documentation attached to show that the product can meet the target guideline of 0.05 ppm formaldehyde when the room is ventilated at design conditions? Yes__X__ No_______ Pending____

ALL PARTICLEBOARD USED IN CABINETRY WAS PAINTED WITH 2 COATS OF "CRYSTAL-AIR"

Have the federal-provincial air quality guidelines been accounted for in the selection of materials and equipment for the house? (See Resource Book for a summary of the air quality guidelines.) Yes__X__ No_______

Thermal Comfort

Have air supply vents been positioned to minimize drafts? Yes__X__ No_______

Have glass areas been chosen so as to

minimize thermal discomfort from large cold window surfaces? Yes_X_ No____

Noise

Has air moving equipment been chosen, located, and/or acoustically isolated so that the ASHRAE noise criteria (NC) equal to 25 to 30 or less is met? Yes_X_ No____

State measures used:

Flexible mounting of air moving equipment Yes_X_ No____

Flexible connectors between equipment and ducts Yes_X_ No____

Acoustic lining of ducts Yes_X_ No____

Acoustic isolation of mechanical room Yes____ No_X_

Humidification equipment

Has provision been made to maintain a minimum of 30% relative humidity in the house throughout the heating season? Yes_X_ No____ Pending____

References

1. Dumont, R.S. Saskatchewan Research Council, Advanced Houses Program Technical Requirements. CANMET Buildings Group, Efficiency and Alternative Energy Technology Branch, Energy, Mines, and Resources Canada, Ottawa, Ontario, 1992 (39 pp)

c:\crit\checklist

APPENDIX D

ONE-TIME AND SHORT TE

Local Monitoring Coordinator: Gary Proskiw Telephone: 1 204 633-1107 Faxphone: 1 204 632-1442				MANITOBA AD	
BUILDING ENVELOPE	**COMPONENT**	**MONITORED PARAMETER**	**CoPilot CODES**	**MONITORING OBJECTIVE**	
Outside Conditions	Envelope	Horizontal radiation	SOLhor	Determine heat loss coefficient Compare with long term trends	Effect of solar Correlation witl HOT2000 attic
		Outside temperature	Tout	Determine envelope heat loss	Wall, window, Correlation witl HOT2000 attic
		Outside RH and temperature	RHout	Determine HRV enthalpic efficiency	Enthalpic effici
			Trhout	Determine moisture added to inside	
Inside Conditions	Second floor	Temperature - S, master bedroom	T2mbed	Determine envelope heat loss	Wall, window, using weighted associated witl Bin and graph with other adva
		Temperature - NW bedroom	T2bed		
	First floor	Temperature - S, kitchen	T1kitc		
		Temperature - N, entry	T1entr		
		Temperature - N, hobby room	T1hobb		
	Basement	Temperature	Tb		
Adjoining Spaces	Attic - east and west	Temperature	Tatice	Determine envelope heat loss	Ceiling heat lo HOT2000 attic Adjoining wall l
			Taticw		
	Garage		Tgar		
Wood Moisture Content	Wall framing	Wood moisture content and temperature at top and bottom of inner and outer stud	na	Evaluate performance of framing/ insulation combination and susceptibility of framing members to wood decay	Document resı of houses in Fl Mark XIV Proje
Attic Reclaim System	Inlet duct	Temperature from attic	Tatico	Determine energy to weeping tile	Document resı
	Sump	Temperature to sump	Tsmpin		

RM TESTS NOT INCLUDED

Manitoba Advanced House
4/5/94

VANCED HOUSE - Monitored Parameters

Analog Channels: 38
Counter Channels: 07
Digital Channels: 13

TYPE OF ANALYSIS	MONITORING PROTOCOL	METHOD	SAVE RATE	TYPE OF SENSOR
gains on balance point n attic temperature for use with model	Locate sensor at roof peak in unobstructed area	DAS - A	Hourly	Pyranometer
door and ventilation heat loss n attic temperature for use with model	Locate sensor in shaded area on north-east side of house	DAS - A	Hourly	Shielded thermistor
ency	Locate RH sensor in HRV supply air duct, close to outside wall	DAS - A	Hourly	RH sensor
	Locate temperature sensor next to RH sensor	DAS - A	Hourly	Thermistor
door and ventilation heat loss	Locate sensor mid-height on wall adjoining closet	DAS - A	Hourly	Shielded thermistor
values based on heat loss	Locate sensor mid-height on wall adjoining linen closet	DAS - A	Hourly	Shielded thermistor
each temperature zone	Locate sensor mid-height on wall adjoining desk	DAS - A	Hourly	Shielded thermistor
all temperatures for comparison	Locate sensor mid-height on angled wall adjoining closet	DAS - A	Hourly	Shielded thermistor
nced houses	Locate sensor mid-height on wall adjoining bathroom	DAS - A	Hourly	Shielded thermistor
	Locate sensor mid-height in center of basement	DAS - A	Hourly	Shielded thermistor
s	Locate sensor mid-height in center of east attic	DAS - A	Hourly	Shielded thermistor
model	Locate sensor mid-height in center of west attic	DAS - A	Hourly	Shielded thermistor
eat loss	Locate sensor mid-height on wall adjoining house	DAS - A	Hourly	Shielded thermistor
lts and compare to performance	Locate sensors in north wall, main floor, cellulose insulation	Manual	Monthly	Moisture pins and thermocouples
air Energy Demo/CHBA	Locate sensors in east wall, main floor, cellulose insulation	Manual	Monthly	
ct	Locate sensors in east wall, main floor, fiberglass insulation	Manual	Monthly	
	Locate sensors in north wall, second floor, cellulose insulation	Manual	Monthly	
	Locate sensors in east wall, second floor, fiberglass insulation	Manual	Monthly	
	Locate sensors in east wall, second floor, cellulose insulation	Manual	Monthly	
lts	Locate sensor in inlet duct of attic reclaim system	DAS - A	Hourly	Thermistor
	Locate sensor in sump	DAS - A	Hourly	Thermistor

MECHANICAL SYSTEMS	COMPONENT	MONITORED PARAMETER	CoPilot CODES	MONITORING OBJECTIVE	T
Energy Supply to Space Heating and DHW Systems	Gas space/DHW tank	Gas consumption	NGgwt	Determine input energy	Integrated syste Energy balance Verify technical HOT2000 fan in
		Electric consumption	EEgwt		
	Space heating pump		EEshp		
	Space heating fan		EEshf		
	DHW circulation pump		EEdhwp		
	Attic reclaim fan		EEatcf		
Energy Demand from Space Heating and DHW Systems	Fan coils (3)	Water flow from hot water tank to coils	Vshc	Determine output energy for space heating	Integrated syste Energy balance
		Supply temperature from hot water tank	Tshs		
		Return temperature to hot water tank	Tshr		
	Preheat tank	Outlet temperature from preheat tank	Tphot	DHW total preheat contribution, including greywater [illegible]	Verify technical HOT2000 DHW
	Domestic hot water	Water flow	Vdhw	Determine total DHW output energy	Combination DH Energy balance Verify technical
		Temperature of cold service water	Tcw		
		Temperature of hot water to house	Tdhw		
Ventilation System	Heat recovery ventilator (HRV)	Fan electrical consumption	EEhrvf	Determine HRV efficiency Determine moisture added to inside air Evaluate indoor RH levels	Sensible and en for HOT2000 Pr Verify technical
		Supply air flow rate to house	Fsup		
		Exhaust air flow rate from house	Fexh		
		Supply air temperature to core	Tsupin		
		Supply air temperature from core	Tsupou		
		Exhaust air temperature to core	Texhin		
		Exhaust air temperature from core	Texhou		
		Exhaust air temperature at hood	Texhhd		
		Exhaust air RH to core	RHexh		
		Flow during defrost mode	Fdef		
		Thermocouple junction temperature	Tjnc	Determine thermocouple temperatures	None required
	Range hood	Exhaust air flow from house	Frgf	Determine fan electrical consumption and volume of exhaust air	Energy balance HOT2000 infiltra Verify technical
		Exhaust temperature	Texhrg	Determine stove utilizability factor	
	Range make-up air	Preheat coil on/off status, power draw	EEmaph	Determine input energy	
	Range make-up air fan	Fan on/off status, power draw	EEmaf		
	Ensuite exhaust fan		EEensf		
	Bathroom exhaust fan		EEbthf		
	Hobby room fan		EEhobf		

...M TESTS NOT INCLUDED

Manitoba Advanced House
4/5/94

...PE OF ANALYSIS	MONITORING PROTOCOL	METHOD	SAVE RATE	TYPE OF SENSOR	
...m efficiency	Connect sensor to detect on/off voltage signal from gas valve Determine gas flow constant with a manual measurement	DAS - D	Hourly	Voltage status sensor	
...requirement ...put	Status will be the same as gas valve status. Measure duty cycle and measure power draw using a Wattmeter.	CoPilot	Hourly	None required	DONE
	Connect sensor in line dedicated to space heating pump	DAS - D	Hourly	~~Watt transducer~~ VSR	DONE
	Connect sensor to detect on/off voltage signal from fan or pump control. Measure power draw using a Watt meter.	DAS - A	Hourly	V~~oltage status sensor~~	DONE
		DAS - D	Hourly	Voltage status sensor	DONE
		DAS - D	Hourly	Voltage status sensor	DONE
...m efficiency	Locate sensor in supply line to, or return line from, exchanger	DAS - C	Hourly	Fluid meter with pulse output	
	Locate sensors in supply line to fan coil	DAS - A	Hourly	Thermistor probe	
	Locate sensors in return line from fan coil	DAS - A	Hourly	Thermistor probe	
...requirement ...model	Locate sensor at outlet from preheat tank	DAS - A	Hourly	Thermistor probe	
...W tank efficiency ...and DHW demand	Locate sensor in cold water line to preheat tank	DAS - C	Hourly	Fluid meter with pulse output	
	Locate sensor at entry point of service water to house	DAS - A	Hourly	Thermistor probe	
...requirement	Locate sensor after mixing valve in hot water line to house	DAS - A	Hourly	Thermistor probe	
...thalpic system efficiency inputs ...ogram ...equirement	Locate sensor in line dedicated to HRV	DAS - D	Hourly	kWh meter with pulse output	DONE
	Locate sensor in warm side supply duct	DAS - A	Hourly	Pitot array and transducer	
	Locate sensor in warm side exhaust duct	DAS - A	Hourly	Pitot array and transducer	
	Locate sensor at fresh air intake to HRV	DAS - A	Hourly	Thermocouple grid	
	Locate sensor at fresh air outlet from HRV	DAS - A	Hourly	Thermocouple grid	
	Locate sensor at exhaust air intake to HRV	DAS - A	Hourly	Thermocouple grid	
	Locate sensor at exhaust air outlet from HRV	DAS - A	Hourly	Thermocouple grid	
	Locate sensor as close to outside wall as possible	DAS - A	Hourly	Thermocouple grid	
	Locate sensor in warm side exhaust duct	DAS - A	Hourly	RH sensor	
	Locate sensor at defrost air inlet to HRV	DAS - A	Hourly	Pitot array and transducer	
	Locate sensor inside DAS near thermocouple channels	DAS - A	Not required	Thermistor	
...tion model ...equirement	Locate sensor in exhaust air duct	DAS - A	Hourly	Pitot array and transducer	
	Measure in center of range hood exhaust duct	DAS - A	Hourly	Thermistor	
	Connect sensor to detect on/off voltage signal from preheat coil and fan control. Measure power draw using a Wattmeter.	DAS - D	Hourly	Voltage status sensor	—
		DAS - D	Hourly	Voltage status sensor	DONE
		DAS - D	Hourly	Voltage status sensor	DONE
		DAS - D	Hourly	Voltage status sensor	DONE
		DAS - D	Hourly	Voltage status sensor	DONE

M TESTS NOT INCLUDED

Manitoba Advanced House
4/5/94

PE OF ANALYSIS	MONITORING PROTOCOL	METHOD	SAVE RATE	TYPE OF SENSOR	
ntilation rates	Locate sensors in master bedroom	DAS - A	Short-term	CO2 sensor	
s	Locate sensors in family room	DAS - A	Short-term	CO2 sensor	
	As specified in the Advanced Houses Indoor Environment Monitoring Requirements	Manual	Short-term	As specified in Indoor Environment Monitoring Requirements	
door RH levels	Locate sensor in relay panel installed near electrical service	Manual	Continuous	Runtime meter	
PE OF ANALYSIS	**MONITORING PROTOCOL**	**METHOD**	**SAVE RATE**	**TYPE OF SENSOR**	
	Locate sensor in electrical service line to panel	DAS - C	Hourly	kWh meter with pulse output	
equirements	Locate submeter in line dedicated to refrigerator	Manual*	Monthly	kWh meter	
0 defaults	Locate submeter in line dedicated to dishwasher	Manual*	Monthly	kWh meter	
	Locate submeter in line dedicated to clothes washer	Manual*	Monthly	kWh meter	
	Connect sensor to detect on/off voltage signal from dryer control Measure power draw using a Wattmeter	DAS - D	Hourly	Voltage status sensor	DONE
	Locate sensor in exhaust line from dryer	DAS - A	Hourly	Thermistor	
	Locate sensor in line dedicated to clothes dryer supply fan	Manual*	Monthly	kWh meter	
equirement	Locate submeter in line dedicated to lighting	Manual*	Monthly	kWh meter	
Validate HOT2000 default	Locate sensor in line dedicated to outside consumption	DAS - C	Hourly	kWh meter with pulse output	
s	Locate sensor in line dedicated to vehicle refueler compressor	Manual*	Monthly	kWh meter	
	Measure power draw using a Wattmeter	Manual	One-time	Wattmeter	DONE
	Locate sensor in gas line to house	DAS - C	Hourly	Gas meter with pulse output	
	Locate submeter in gas line to oven	DAS - C	Hourly	Gas meter with pulse output	
	Connect sensor to detect on/off voltage signal from gas valve Determine gas flow constant with a manual measurement	DAS - D	Hourly	Voltage status sensor	
	Connect sensor to detect on/off signal from electric switch Determine gas flow constant with a manual measurement	DAS - D	Hourly	Voltage status sensor	
	Locate sensor in gas line to garage heater	DAS - C	Hourly	Gas meter with pulse output	
	Locate sensor in gas line to vehicle refueler	Manual*	Monthly	Gas meter	
	Obtain by subtracting all other used from total	Calculate	As required	Not required	
equirement	This is house meter installed by local utility	Manual	Monthly	Utility water meter	
	Locate submeter to measure total outside consumption	Manual*	Monthly	Water meter	
	Locate submeter to measure water from sump	Manual*	Monthly	Water meter	
	Locate submeter to measure water from outside tank	Manual*	Monthly	Water meter	

PE OF ANALYSIS	MONITORING PROTOCOL	METHOD	SAVE RATE	TYPE OF SENSOR
	Install according to senor connection diagram in senor documentation manual	DAS - A	Hourly	Resistor
		DAS - A	Hourly	Resistor

ONE-TIME AND SHORT TEF

INSIDE ENVIRONMENT	COMPONENT	MONITORED PARAMETER	CoPilot CODES	MONITORING OBJECTIVE	T
Air Quality and Comfort	Ventilation system and source control measures	Carbon dioxide (CO_2)	CO2bed	Verify acceptable exposure levels	Correlate with w
			CO2fam	Determine system effectiveness	Document resul
		Other parameters as specified in the Advanced Houses Indoor Environment Monitoring Requirements	na	Determine source strengths	
	Humidifier	On/off status		Determine ontime	Correlate with in
UTILITIES	**COMPONENT**	**MONITORED PARAMETER**	**CoPilot CODES**	**MONITORING OBJECTIVE**	**T**
Electrical Service	Total house	Electrical consumption	EEhse	Determine input energy	Energy balance
	Refrigerator		na		Verify technical
	Dishwasher		na		Validate HOT20
	Clothes wasner		na		
	Clothes dryer		EEdryr		
		Temperature - exhaust air	Tdryxh	Determine utilizapility factor	Energy balance
	Dryer supply fan	Electrical consumption	na	Determine input energy	
	Inside lights		na		Verify technical r
	Outside circuits		EEout		Energy balance:
	Vehicle refueler	Compressor electrical consumption	na		Document result
	Monitoring system	Electrical consumption	na	Determine contribution to space gains	Energy balance
Gas Service	Total gas consumption	Natural gas consumption	NGhse	Determine input energy	Energy balance
	Stove		NGstve		
	Dryer		NGdryr		
	Fireplace		NGfire		
	Garage heater		NGgar		
	Vehicle refueler		na		
	Barbecue		na		
Water Service	Total house	Water consumption	na	Determine total water consumption	Verify technical r
	Outside water		na	Determine outside water consumption	
	Water from sump		na	Determine contribution from sump	Document results
	Water from outside tank		na	Determine contribution rainwater	
MONITORING SYSTEM	**COMPONENT**	**MONITORED PARAMETER**	**CoPilot CODES**	**MONITORING OBJECTIVE**	**TY**
Monitoring Hardware	Data acquisition unit	Voltage constant	Vconst	Verify operation of DAU	None required
		Resistance constant	Rconst		

APPENDIX E

```
****************************************
*                                      *
*              HOT2000                 *
*           Version 7.10b              *
*              CANMET                  *
*      Natural Resources CANADA        *
*           Apr 30, 1995               *
*          Reg. # CD000172             *
****************************************
```

File = E:\001\REPORTS\AHCASE31.HDF

Weather Data for WINNIPEG, MANITOBA

Builder Code =
Data Entry by: GP   Date of entry 20/01/1996

Client name: Manitoba Advanced House
Street address:
City: Winnipeg   Region: Manitoba
Postal code: Telephone:

*** GENERAL HOUSE CHARACTERISTICS ***

House type: Single detached
Number of storeys: Two storeys
Wall construction: Platform frame, double stud wall
Year House Built: 1992
Wall colour: White 0.25 Value .250
Plan shape: Square Front orientation North

SOIL TYPE: Normal conductivity: dry sand, loam, clay, low water table

HOUSE THERMAL MASS LEVEL: (A) Wood frame construction, 12.5 mm (0.5 in.) gyproc walls and ceiling, wooden floor

Effective mass fraction 1.000

Occupants : 2 Adults for 50.0 % of the time
2 Children for 50.0 % of the time
0 Infants for .0 % of the time

Sensible Internal Heat Gain From Occupants = 2.40 kWh/day

*** HOUSE TEMPERATURES ***

Heating Temperatures	Main Floor	= 69.8 F
	Basement	= 68.0 F
	TEMP. Rise from 69.8 F	= 6.3 F

Basement is- Heated: Yes Cooled: No Separate T/S: No

Indoor design temperatures for equipment sizing
Heating = 71.6 F
Cooling = 75.2 F

*** FOUNDATION CONSTRUCTION CHARACTERISTICS ***

Foundation Construction	Attachment Sides	Insulation Placement	Volume Ft3
Full Basement	None	Interior	9538.0

*** WINDOW CHARACTERISTICS ***

Direc-tion	Seq #	Loc. Code	# of Windows	Type	Window Width Ft	Window Height Ft	OverHang Width Ft	Header Height Ft	SHGC	Curtain Factor
South	1	M1	2	00	2.350	5.340	2.00	.67	.3414	1.000
	2	M1	4	01	2.480	2.000	2.00	.00	.2601	1.000
	3	D2	1	00	2.210	5.920	2.00	2.67	.3404	1.000
	4	D4	2	00	2.420	5.920	2.00	1.20	.3442	1.000
	5	M1	3	00	2.350	2.670	4.00	1.00	.3249	1.000
	6	M1	3	00	2.350	3.390	4.00	4.00	.3319	1.000
	7	M1	4	00	1.675	2.670	3.00	1.00	.3096	1.000
	8	M1	1	00	2.350	2.670	1.00	.50	.3249	1.000
	9	M1	1	00	2.350	3.350	4.00	3.50	.3316	1.000
	10	B1	3	300224	2.350	2.000	1.00	1.00	.3802	1.000
East	1	M1	1	00	1.210	1.210	2.00	9.00	.2543	1.000
	2	M1	2	00	2.680	2.040	2.00	9.00	.3193	1.000
	3	M1	1	01	2.380	5.000	2.00	2.00	.2995	1.000
North	1	M1	2	00	4.000	3.390	1.00	2.00	.3479	1.000
	2	M1	1	01	6.620	2.670	2.00	1.00	.3137	1.000
	3	M1	1	00	6.620	4.000	2.00	4.00	.3613	1.000
West	1	M1	1	00	1.210	1.210	2.00	.67	.2543	1.000
Southwest	1	M1	2	01	2.020	4.000	3.00	2.67	.2812	1.000

*** WINDOW PARAMETER CODES SCHEDULE ***

	Code	Description (Glazings, Coatings, Fill, Spacer, Type, Frame)
1	300224	Triple/Triple with 1 coat, Clear, 13 mm Air, Insulating, Slider with sash, Vinyl, ER* = -6.8, Eff. R= .51

Window Standard Energy Rating estimated for assumed dimensions, and
Air tightness type: CSA - Fixed; Leakage rate = .25 m3/hr/m

*** USER-DEFINED WINDOW CODES SCHEDULE ***

	Code	Description	Window Type
1	00	A/H fixed	Picture
2	01	A/H awnings/casement	Hinged

*** USER-DEFINED WINDOW CODES: DATA ***

	Code	R -Values Centre of Glass	Edge of Glass	Frame	Frame Ht. In	Centre of Glass SHGC
1	00	9.300	7.400	2.700	1.6	.400
2	01	9.300	7.400	2.600	2.8	.400

*** BUILDING PARAMETER DETAILS ***

CEILING COMPONENTS

	Construction Type	Code Type	Roof Slope	Heel Ht. Ft	Section Area Ft2	R-Value R
C1	Attic/Hip	211	6.00 / 12	.67	645.70	58.43
C2	Attic/Gable	211	6.00 / 12	.67	467.60	58.28

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Inter.	Height Ft	Perim. Ft	Area Ft2	R-Value R
	Main Walls								
M1	111	101	N/A	1	2	8.60	245.8	2113.88	43.62
M2	0000000000	N/A	N/A	0	0	1.00	29.0	29.00	60.00
	Basement Walls above grade								
B1	112	N/A	N/A	1	0	2.00	63.1	126.20	31.14
B2	0000000000	N/A	N/A	1	1	1.00	126.2	126.20	35.00
	Upper Basement Walls								
1	113	N/A	N/A	1	0	2.00	126.2	252.40	40.18
	Lower basement walls								
1	113	N/A	N/A	1	0	5.68	126.2	716.82	41.18

FLOORS

	Seq #	Construction Type	Section Area Ft	R-Value R
Exposed or overhanging floors	1	0000000000	70.00	46.00
Full Depth Floor Perimeter	1	311	369.60	11.67
Full Depth Floor Centre	1	311	610.00	11.67
Floors above Basement	1	4512008300	1054.00	5.08

DOORS

	Location	Type	Height Ft	Width Ft	Gross Area Ft2	R-value R
D1	M1	Steel polyurethane core	7.00	3.63	25.41	6.47
D2	M1	Steel polyurethane core	7.00	3.26	22.82	6.47
D3	M1	Steel polyurethane core	7.00	3.63	25.41	6.47
D4	M1	Steel polyurethane core	7.00	6.28	43.96	6.47

*** Interior Floor PARAMETER CODES SCHEDULE ***

	Code	Description (Str., typ/size, Spac., Ins1, 2, Int, Sheath, Ext., Drop Floors)
1	4512008300	Composite wood joist, 38 x 302 mm (2 x 11.875 in), 487 mm (19 in), None, None, Carpet & underpad, Waferboard/OSB 15.9 mm (5/8 in), None, No

*** USER-DEFINED STRUCTURE CODES SCHEDULE ***

	Code	Description
1	211	R-60 cellulose, truss 16" o/c
2	111	R-46, 12", A/H double stud
3	112	A/G bsmt. wall, R-32
4	113	B/G bsmt. wall, R-41
5	311	

*** Lintel PARAMETER CODES SCHEDULE ***

	Code	Description (Type, Material, Insulation)
1	101	Double, Wood, Same as wall framing cavity

*** USER-DEFINED LINTEL CODES SCHEDULE ***

	Code	Description
1	L1	
2	L02	

Roof Cavity Inputs

Gable Ends	Total Area	77.9	Ft2
Sheathing Material: Plywood/Part. bd 9.5 mm (3/8 in)		.47	R
Exterior Material: Hollow metal/vinyl cladding		.62	R
Sloped Roof	Total Area	1244.7	Ft2
Sheathing Material: Plywood/Part. bd 12.7 mm (1/2 in)		.63	R
Roofing Material: Asphalt shingles		.44	R

Roof colour: Medium brown 0.84 — Absorptivity: .840

Total cavity volume 2706.6 Ft3 — Ventilation rate .50 ACH/hr

*** BUILDING ASSEMBLY DETAILS ***

CEILING COMPONENTS

Loc	Construction Code	Nominal R	System R	Effective R
C1	211	60.39	58.84	58.43
C2	211	60.39	58.84	58.28

WALL COMPONENTS

Loc	Construction Code	Nominal R	System R	Effective R
Main Walls				
M1	111	45.96	43.77	43.62
Basement Walls above grade				
B1	112	31.82	31.14	31.14
Upper Basement Walls				
1	113	38.96	40.18	40.18
Lower basement walls				
1	113	38.96	41.18	41.18

FLOORS

Component	Seq #	Construction Code	Nominal R	System R	Effective R
Full Depth Floor Perimeter	1	311	10.01	11.67	11.67
Full Depth Floor Centre	1	311	10.01	11.67	11.67
Floors above Basement	1	4512008300	.00	5.08	5.08

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(Ft2)	R Window	(Shutter)
South					
M1	2	00	25.10	6.44	
M1	4	01	19.84	4.56	
D2	1	00	13.08	6.41	
D4	2	00	28.65	6.54	
M1	3	00	18.82	5.95	
M1	3	00	23.90	6.15	
M1	4	00	17.89	5.55	
M1	1	00	6.27	5.95	
M1	1	00	7.87	6.14	
B1	3	300224	14.10	2.74	
East					
M1	1	00	1.46	4.50	
M1	2	00	10.93	5.80	
M1	1	01	11.90	5.31	

```
Fan and Preheater Power at  32.0 F                          =   108. Watts
Fan and Preheater Power at -13.0 F                          =   108. Watts
PreHeater Capacity:                                         =     0. Watts
Sensible Heat Recovery Efficiency at  32.0 F                =    80. %
Sensible Heat Recovery Efficiency at -13.0 F                =    77. %
Total Heat Recovery Efficiency in Cooling mode              =    25. %

Low Temperature Ventilation Reduction                       =     1. %
Low Temperature Ventilation Reduction: Airflow Adjustment=       1 cfm (    .7 %)

Vented combustion appliance depressurization limit =  10.0 Pa.

Ventilation Supply Duct
 Location : Basement         Type : Ext. insulated Sheet metal
 Length      15.0 Ft         Diameter     10.0 In
 Insulation     4.0 R        Sealing Characteristics : Sealed

Ventilation Exhaust Duct
 Location : Basement         Type : Flexible
 Length       5.0 Ft         Diameter      6.0 In
 Insulation     4.0 R        Sealing Characteristics : Sealed
```

*** AIR LEAKAGE AND VENTILATION SUMMARY ***

```
F326 Required continuous ventilation rate               =  148.3 cfm (  .35 ACH)
Central Ventilation Rate ( Balanced )                   =  148.3 cfm (  .35 ACH)
Total house ventilation is Balanced

Gross Air Leakage and Ventilation Energy Load              =  70.542 Mil.BTU
Seasonal Heat Recovery Ventilator Efficiency               =  73.238 %
Estimated Ventilation Electrical Load: Heating Hours       =   2.967 Mil.BTU
Estimated Ventilation Electrical Load: Non-Heating Hours =      .261 Mil.BTU
Net Air Leakage and Ventilation Energy Load                =  37.551 Mil.BTU
```

*** SPACE HEATING SYSTEM ***

```
PRIMARY Heating Fuel             : Natural Gas
Equipment    : Condensing furnace/boiler
Manufacturer                     : Mor-Flo/American
Model                            : Polaris
Output Capacity                  =    93999.7 BTU/hr

Steady State Efficiency          =  95.4 %

Fan Mode : Continuous             Fan Power     225. watts
```

*** DOMESTIC WATER HEATING SYSTEM ***

```
PRIMARY Water Heating Fuel     : Natural Gas
Water Heating Equipment        : Condensing
Energy Factor                  :    .860

Manufacturer                   :
Model                          :
Tank Capacity =   33.3 Imp Gal     Tank Blanket Insulation     .0 R
```

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -27.4 F	=	1.63 BTU/hr/Ft3	= 41494. BTU/hr
Including credit for HRV	=	1.16 BTU/hr/Ft3	= 29541. BTU/hr

Gross Space Heating Load	= 85.951 Mil.BTU
Usable Internal Gains	= 23.159 Mil.BTU
Usable Internal Gains Fraction	= 26.9 %
Usable Solar Gains	= 16.001 Mil.BTU
Usable Solar Gains Fraction	= 18.6 %
Auxiliary Energy Required	= 45.925 Mil.BTU
Space Heating System Load	= 45.925 Mil.BTU
Furnace/Boiler Seasonal efficiency	= 94.7 %
Furnace/Boiler Annual Energy Consumption	= 48.139 Mil.BTU

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption	= 37.1 Imp Gal /day
Hot Water Temperature	= 131.0 F
Estimated Domestic Water Heating Load	= 12.124 Mil.BTU
PRIMARY Domestic Water Heating Energy Consumption	= 14.450 Mil.BTU
PRIMARY System Seasonal Efficiency	= 83.9 %

*** BASE LOADS SUMMARY ***

	kwh/day	Annual kWh
Interior Lighting	3.0	1095.0
Appliances	10.1	3686.5
Other	.0	.0
Exterior use	.5	182.5
HVAC fans		
HRV/Exhaust	2.6	946.1
Space Heating	5.4	1971.0
Space Cooling	.0	.0
Total Average Electrical Load	21.6	7881.1

R-2000 Energy Efficient Lighting Credits

Area	Credit (kwh/yr)	Applied
Kitchen	110	Yes
Main hallway	70	Yes
Living room	65	Yes
Family room	65	Yes
Dining room, or bedroom, or entrance, or bathroom, or other finished room	17	Yes
Utility or laundry room, or other unfinished room	9	Yes

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(Ft2)	R Window	(Shutter)
North					
M1	2	00	27.12	6.67	
M1	1	01	17.68	5.64	
M1	1	00	26.48	7.19	
West					
M1	1	00	1.46	4.50	
Southwest					
M1	2	01	16.16	4.92	

*** BUILDING PARAMETERS SUMMARY ***

Component	Area (Ft2) Gross	Net	Effective R	Heat Loss Mil.BTU	% Annual Heat Loss
ZONE 1 : ABOVE GRADE					
Ceiling	1113.30	1113.30	58.37	4.422	5.14
Main Walls	2142.88	1792.39	43.81	11.708	13.62
Doors	117.60	75.86	6.47	3.487	4.06
Exposed floors	70.00	70.00	46.00	.426	.50
South windows	161.43	161.43	5.92	8.116	9.44
East windows	24.30	24.30	5.45	1.325	1.54
North windows	71.28	71.28	6.55	3.237	3.77
West windows	1.46	1.46	4.50	.097	.11
Southwest windows	16.16	16.16	4.92	.976	1.14
		ZONE 1 Totals:		33.794	39.32
INTER-ZONE Heat Transfer : Floors Above Shallow and Full Basement	1054.00	1054.00	5.08	9.447	

ZONE 2 : SHALLOW / FULL BASEMENT

Basement Walls above grade	252.40	238.30	33.07	2.003	2.33
South windows	14.10	14.10	2.74	1.429	1.66
Upper Basement Walls	252.40	252.40	40.91	1.207	1.40
Lower basement walls	716.82	716.82	40.91	3.263	3.80
Full Depth Floor Perimeter	369.60	369.60	11.67	3.726	4.34
Full Depth Floor Centre	610.00	610.00	11.67	4.460	5.19
				=========	=======
		ZONE 2 Totals:		16.089	18.72

Ventilation

House Volume	Air Change	Heat Loss Mil.BTU	% Annual Heat Loss
25485.2 Ft3	.520 ACH	36.068	41.96

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area = 5527.4 Ft2
Air Leakage Test Results at 50 Pa.(0.2 in H2O) = 1.17 ACH
Equivalent Leakage Area @ 10 Pa. = 52.4 in2

Terrain Description		Height	Ft
@ Weather Station :	Open flat terrain, grass	Anemometer	32.8
@ Building site :	Suburban, forest	Bldg. Eaves	18.0

Local Shielding- Walls: Heavy
Flue : Light local shielding

Leakage Fractions - Ceiling: .200 Walls: .650 Floors: .150

Normalized Leakage Area @ 10 Pa. = .0095 in2/ft2
Estimated Airflow to cause a 5 Pa Pressure Difference = 114 cfm
Estimated Airflow to cause a 10 Pa Pressure Difference = 178 cfm

*** F326 VENTILATION REQUIREMENTS ***

Kitchen,living,dining:	3 rooms @ 10 cfm	= 30 cfm
Bedrooms:	1 rooms @ 20 cfm	= 20 cfm
Bedrooms:	2 rooms @ 10 cfm	= 20 cfm
Bathrooms:	3 rooms @ 10 cfm	= 30 cfm
Other habitable rooms:	2 rooms @ 10 cfm	= 20 cfm
Basement Rooms:		20 cfm

*** CENTRAL VENTILATION SYSTEM ***

System Type : Heat recovery ventilator (HRV)
Manufacturer: Nutech
Model Number: 195 DCS

Tank Location : Basement

Pilot Energy .0 BTU/hr Flue Diameter .0 In

*** FAN OPERATION SUMMARY (kWh) ***

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	869.7	109.9	.0
Neither	76.4	1861.1	.0
Cooling	.0	.0	.0
Total	946.1	1971.0	.0

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	=	51185. MJ	=	14218.2 kWh
Ventilator Electrical Consumption: Heating Hours	=	3131. MJ	=	869.7 kWh
Estimated Annual DHW Heating Energy Consumption	=	15246. MJ	=	4234.9 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	=	69562. MJ	=	19322.8 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	=	118559. MJ	=	32933.0 kWh
(Credit included for Energy Efficient Lighting)	=	1210. MJ	=	336.0 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

Fuel	Space Heating	Space Cooling	DHW Heating	Appliances	Total
Natural Gas (MCF)	48.1	.0	14.5	.0	62.6
Electricity (kWh)	2840.7	.0	.0	5040.4	7881.1

*** MONTHLY ENERGY PROFILE ***

Month	Energy Load Mil.BTU	Internal Gains Mil.BTU	Solar Gains Mil.BTU	Aux. Energy Mil.BTU	HRV Eff. %
Jan	15.585	2.237	2.280	11.068	75.5
Feb	12.755	2.017	2.368	8.370	76.1
Mar	11.105	2.239	2.597	6.270	76.5
Apr	6.689	2.180	1.500	3.009	76.0
May	3.965	2.240	1.222	.503	72.2
Jun	1.630	1.409	.221	.000	66.6
Jul	.922	.890	.031	.000	61.7
Aug	1.205	1.125	.080	.000	66.3
Sep	3.177	2.089	.909	.179	72.1
Oct	5.526	2.287	1.399	1.840	75.1
Nov	9.139	2.195	1.555	5.389	76.9
Dec	13.386	2.250	1.839	9.297	76.2
Annual	85.084	23.159	16.001	45.925	73.2

*** FOUNDATION AND VENTILATION ENERGY PROFILE ***

Month	Heat Loss (Mil.BTU) Crawl Space	Slab	Shallow/ Full	Air	Temperature (Deg F) Crawl Space	Basement	Air Change Rate Natural	Total
Jan	.000	.000	1.117	7.320	.0	67.5	.219	.574
Feb	.000	.000	.844	5.822	.0	67.2	.211	.566
Mar	.000	.000	.632	4.848	.0	67.0	.199	.554
Apr	.000	.000	.304	2.612	.0	67.1	.180	.535
May	.000	.000	.051	1.317	.0	67.6	.151	.506
Jun	.000	.000	.000	.420	.0	68.5	.117	.472
Jul	.000	.000	.000	.139	.0	70.1	.087	.442
Aug	.000	.000	.000	.299	.0	69.9	.099	.454
Sep	.000	.000	.018	1.073	.0	68.3	.148	.503
Oct	.000	.000	.186	2.145	.0	68.0	.169	.524
Nov	.000	.000	.544	3.934	.0	67.8	.193	.548
Dec	.000	.000	.938	6.139	.0	67.7	.209	.564
Annual	.000	.000	4.634	36.068	.0	68.1	.165	.520

*** SPACE HEATING SYSTEM PERFORMANCE ***

Month	Space Heating Load Mil.BTU	Furnace Input Mil.BTU	Pilot Light Mil.BTU	Indoor Fans Mil.BTU	Heat Pump Input Mil.BTU	Total Input Mil.BTU	System Cop
Jan	11.068	11.602	.000	.571	.000	12.173	.947
Feb	8.370	8.773	.000	.516	.000	9.289	.947
Mar	6.270	6.572	.000	.571	.000	7.143	.947
Apr	3.009	3.155	.000	.553	.000	3.707	.947
May	.503	.527	.000	.571	.000	1.098	.947
Jun	.000	.000	.000	.553	.000	.553	.000
Jul	.000	.000	.000	.571	.000	.571	.000
Aug	.000	.000	.000	.571	.000	.571	.000
Sep	.179	.188	.000	.553	.000	.741	.947
Oct	1.840	1.928	.000	.571	.000	2.499	.947
Nov	5.389	5.649	.000	.553	.000	6.202	.947
Dec	9.297	9.745	.000	.571	.000	10.316	.947
Ann	45.925	48.139	.000	6.725	.000	54.865	.947

*** MONTHLY ESTIMATED ENERGY CONSUMPTION BY DEVICE (Mil.BTU) ***

	Space Heating Primary	Space Heating Secondary	DHW Heating Primary	DHW Heating Secondary	Lights & Appliances	HRV & FANS	Air Conditioner
Jan	11.602	.000	1.295	.000	1.439	.845	.000
Feb	8.773	.000	1.180	.000	1.299	.764	.000
Mar	6.572	.000	1.296	.000	1.439	.845	.000
Apr	3.155	.000	1.227	.000	1.392	.818	.000
May	.527	.000	1.228	.000	1.439	.845	.000
Jun	.000	.000	1.150	.000	1.392	.818	.000
Jul	.000	.000	1.160	.000	1.439	.845	.000
Aug	.000	.000	1.150	.000	1.439	.845	.000
Sep	.188	.000	1.122	.000	1.392	.818	.000
Oct	1.928	.000	1.188	.000	1.439	.845	.000
Nov	5.649	.000	1.188	.000	1.392	.818	.000
Dec	9.745	.000	1.266	.000	1.439	.845	.000
Total	48.139	.000	14.450	.000	16.938	9.953	.000

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Energy units: MIL.BTU = Million British Thermal Units (3413 BTU = 1 kWh)

The calculated heat losses and energy consumptions are only estimates, based upon the data entered and assumptions within the program. Actual energy consumption and heat losses will be influenced by construction practices, localized weather, equipment characteristics and the lifestyle of the occupants.