THE ENCLOSURE CONDITIONED HOUSING (ECHO) SYSTEM: A NEW APPROACH TO BASEMENT DESIGN

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Concerns over hazardous soil gas and mold exposures combined with traditional basement problems of water leakage and cold floors suggested a new approach to basement design in which a sealed, ventilated and drained cavity system is built into the basement enclosure. This concept has been successfully demonstrated in the basement of a house built in Ottawa, Canada in the spring of 1988. Additional construction costs were modest and resulted in a thermally comfortable basement environment with excellent indoor air quality characteristics.

INTRODUCTION

Traditional building construction in cold climates involves excavation below the lowest level of frost penetration to pour footings for load bearing walls. These walls normally are of masonry material, at least below grade, although pressure-treated wood construction is sometimes used now. Basement floors are continuous slabs, poured between the walls and resting on crushed stone, sometimes with a sheet of polyethylene underneath. Water leakage is inhibited through proper landscaping, underground drainage at the footings, and retrofit crack-sealing. If ground water levels are high, sump pump wells are constructed. In spite of such measures, water leakage is common leaving some basements remaining unfinished and underutilized, and promoting fungal contamination.

In cold climates, basement floor slabs are cool year around. This problem often is addressed through carpeting and sometimes wooden subfloors. Even if there is no leakage, the cold concrete can get wet in summer from condensation, resulting in mold growth, odours, and rotting carpets, subfloors, etc.

Recently another basement problem has been identified - the entry of soil gas containing radioactive radon and, in some cases, methane or other potentially hazardous gases. This problem has been dealt with by sealing basement cracks and openings, however experience has shown that complete air-sealing of cracks is not practicable. More frequently, soil-gas exhaust systems are being installed for problem buildings. In this approach, exhaust pipes are located in the gravel below the slab or connected to the weeping tile. In some cases, soil gas exhaust systems have been located between several problem basements. However, the effectiveness of the technique is unpredictable because it relies on the creation of an air flow around the entire sub-grade basement enclosure through non-homogenous materials, often with voids and cracks.

THE ENCLOSURE CONDITIONED HOUSING SYSTEM

The approach of the Enclosure Conditioned Housing (ECHO) System is to create a sealed, ventilated, drained and moisture-resistant cavity system as part of the basement enclosure. This cavity effectively creates a barrier between the soil and the basement living space. The system, which has been patented in Canada and the United States, is illustrated in Figure 1.

An ECHO System™ has been constructed in Ottawa, Canada in the spring of 1988 in a 3700 sq. ft. (including a 1200 sq. ft. basement) two story, single family (3 occupants), detached house. This house is heated with a conventional-efficiency gas furnace, and it is air-conditioned and dehumidified electrically. This ECHO System was installed in the exterior walls and subfloor during the basement finishing process. Finishing, insulating and wiring the basement walls and building the subfloor cost $7500. Creating the sealed cavity plus installing a 50 L/s blower exhaust system cost an additional $1000. This compares to a total house and property cost of $270,000 (3%).

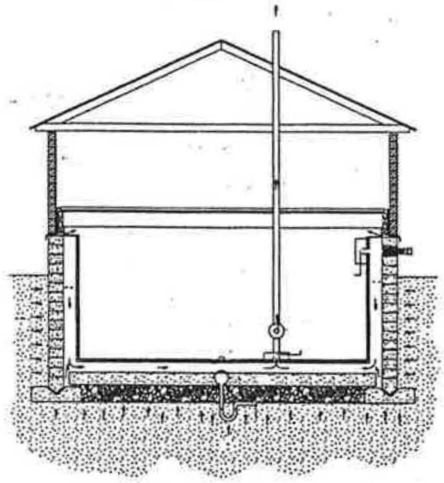

Fig. 1 The ECHO System™

RESULTS AND DISCUSSION

Following commissioning, cavity depressurization (2 Pa below basement space) was achieved for cavity exhaust rates as low as 28 L/s. Measurement of carbon dioxide concentrations outdoors and in the cavity and basement indicated that about 25 percent of the cavity ventilation air was coming from the living space.

Soil and Enclosure Gas Mitigation Characteristics

Radon progeny levels in the basement living space were measured continuously for several days on two occasions with a Thomson and Nielsen Radon Sniffer Working Level Meter and Data Logger. Radon progeny levels outdoors averaged 1.1 mWL. In both the 1988 and 1990 tests, illustrated in Fig. 2, the average radon progeny levels were lower in the basement than outdoors when the cavity ventilation system was on as is intended in the system design. This occurrence presumably was due both to the very efficient trapping and exhausting of radon in the cavity, and to the normal plating-out on interior surfaces of a portion of any progeny arising from radon gas entering the above-ground portion of the house. To demonstrate how the radon levels would be without an ECHO System, the cavity ventilation system was turned off for a several days. During that period radon progeny levels increased significantly and, as with conventional houses, varied widely (10 to 20 mWL range (100 to 200 Bq/m3 EER)).

Volatile organic compounds (VOCs) were sampled in 1988, and later in 1989, with pumps and tubes containing glass bead, Tenax, and Ambersorb sorbents in series, followed by thermal desorption, and FID and GC/MS analyses (1). Ethanol, limonene, pinene, toluene, benzene, and naphthalene were among the compounds identified. Toluene and benzene are common to indoor air, and are also present in small amounts in the Tenax. The limonene and pinene were thought to be associated with glued wood products. The naphthalene was found in the first test only, arising from some containers which were subsequently removed. The ethanol likely arose primarily from fungal growth.

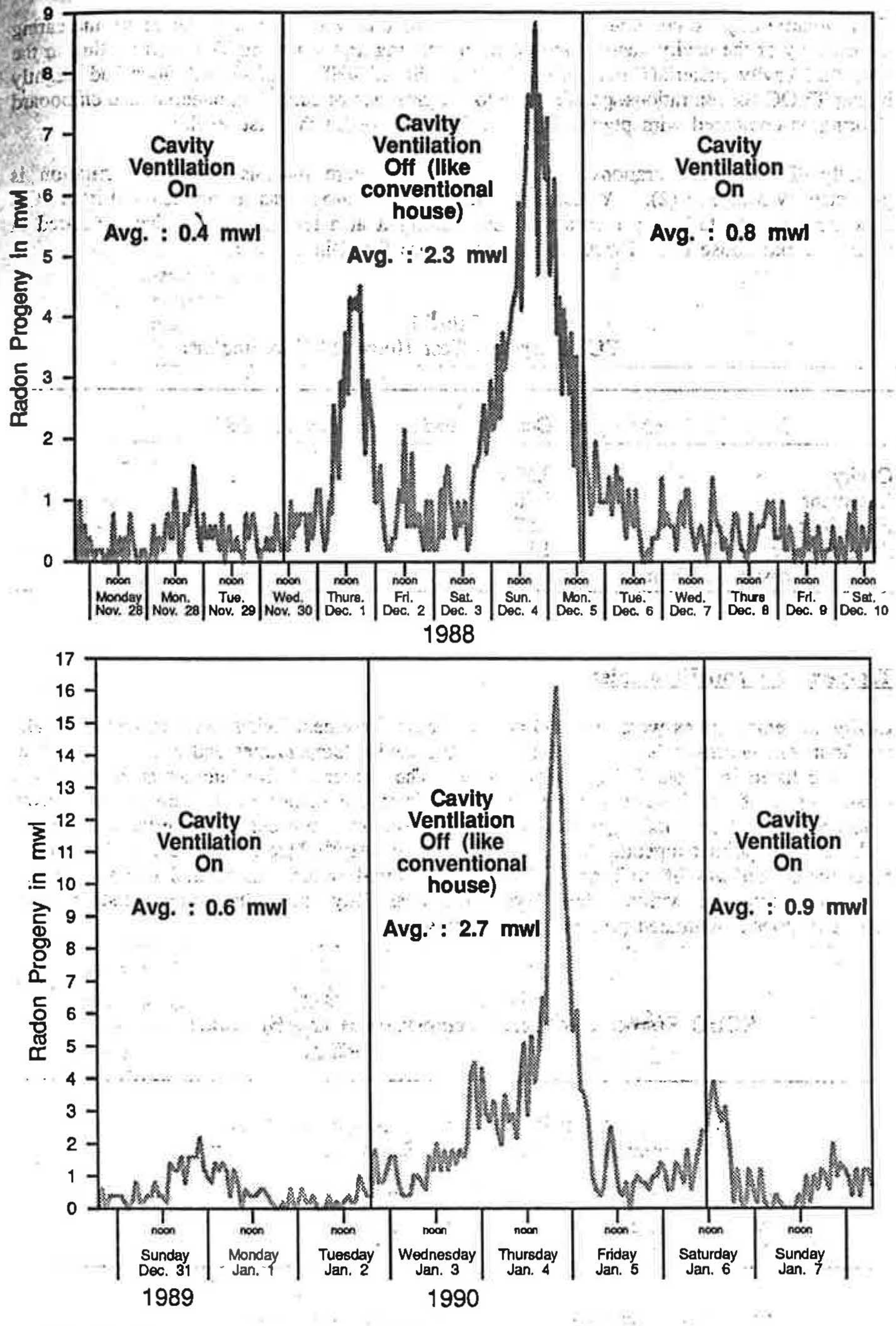

Fig. 2 Demonstration of the ECHO System Radon Mitigation Capability

Total volatile organic compound (TVOC) concentrations were highest in the cavity indicating the efficacy of the cavity ventilation system in trapping and removing VOCs originating in the enclosure cavity materials and perhaps in the soil as well. The second floor had slightly higher TVOC concentrations, possibly due to the presence of carpeting, underlay and chipboard flooring as compared with plywood and hardwood floor on the first level.

Initially, TVOC concentrations were in the range where mucous membrane irritation is predicted by Molhave (2). A year later, one of the locations was re-sampled and its TVOC concentration had fallen by a factor of four putting it at a level similar to that measured in a 15 year old house (1). TVOC concentrations are listed in Table 1.

Table 1
ECHO System Test House TVOCs (mg/m³)

	Oct. 12, 1988	Dec. 30, 1989
Cavity	2.50	
Basement	1.60	
First floor - kitchen	1.57	
Second floor - hall	1.81	
- master bedroom		0.55

Temperatures and Humidities

Cavity air temperatures were only 1-3 degrees below basement living space temperatures and the floor was warm to the touch. Basement and cavity temperatures and relative humidities (RH) are listed in Table 2 for two occasions. The higher relative humidities in the cavity versus those of the basement air would arise from the cooler cavity temperatures, from moisture released by building materials, and from soil moisture entry. Nevertheless, the dry bulb and dew point temperatures (T_{db} and T_{dp}, respectively) of the cavity were well separated so condensation was of no concern. In fact, an initial water leakage into one side of the cavity was dried up within a few days. The possibility exists that some moisture could collect in poorly ventilated portions of the cavity.

Table 2
ECHO System Test House Temperatures and Humidities

	July 14, 1988		August 18, 1988	
	Basement	Cavity	Basement	Cavity
T_{db} (F)	77.3	76.8	72	69
RH (%)	45.5	49.8	50	69
T_{dp} (F)	56.8	60.0	53	59

Table 3
ECHO System Test House Fungi

	Dec. 18, 1988 CFU/m3	Dec. 18, 1988 Genera	March 5, 1990 CFU/m3	March 5, 1990 Genera
Cavity	75	P	TNTC	Numerous
Basement	100	P	25	P
First floor - family room			113	P, NSI*
Second floor - hall	138	C	12	NSI*
- master bedroom			38	NSI*, P
- bedroom			12	NSI*
- bedroom			6	NSI
- TV room			0	

Table 4
Ottawa House Fungal Survey: March 21, 1988

	CFU/m3	Genera
5 Townhouses:		
#1 basement	300	A,C,M,P,U
bedroom	194	C,M,P,U
#2 basement	138	A,C,P
bedroom	50	A,C,P
#3 basement	189	A,C,P
bedroom	106	C,P
#4 basement	113	A,C,P
bedroom	69	C
#5 basement	231	A,C,P
House #1 basement	13	A,C,P
House #2 basement	206	A,P
bedroom	6	C

Table 5
Ottawa Complaint House Fungi

	CFU/m^3	Genera & species
House #1, Feb. 28, 1989		
- basement	175	A, NSI,P
- bedroom	38	NSI,C
House #2, April 12, 1989		
- basement	575	C,PV,V,AV,NSI,Ul
- bedroom	763	C,PV,AV,NSI,P
- master bedroom	325	A,PV,NSI,C

Legend (Tables 3, 4 and 5):

A	= Alternaria	AV	= Aspergillus versicolor
C	= Cladosporium	M	= Mucor
NSI	= non-sporulating isolates	*	= likely source is house plants
P	= Penicillium	PV	= Penicillium viridicatum
TNTC	= too numerous to count	U	= unknown

Mold Mitigation

Air-borne fungal propagules were collected on Biotest Rose Bengal Agar strips during the winters of 1988-89 and 1989-90 with an RCS sampler. These were incubated for a few weeks and then colonies were counted and genera and species identified. On both occasions basement air fungal counts were lower than those upstairs. In the first winter, the fungi were thought to arise from the green lumber, while a year later the primary source of the fungi was thought to be the numerous house plants. The family room sample, for example, was taken adjacent to a large plant which was shaken during the test. Counts and species on these two occasions are given in Table 3.

Fungal levels and species in the test house were considered to be of no concern according to the postulates of Miller (3). While numerous fungal propagules were present in the cavity, levels in the house fell substantially in the basement and elsewhere between the two test periods indicating that, as in the case of radon, none were entering the living space.

Comparison of test house fungal exposures with those measured in some other Ottawa houses illustrates the efficacy of the ECHO System in preventing fungal problems. Exposures of 200 to 300 CFU/m^3 in the basements of these other houses were common and well above the 25 CFU/m^3 measured in the test house basement. Some of these comparative measurements are provided in Tables 4 and 5 for basements and upstairs bedrooms.

CONCLUSIONS

The ECHO System represents a new approach in basement construction which addresses not only traditional basement problems of cold floors and odours, but also concerns about soil gas and mold exposures. The System can be constructed for little more than the cost of finishing the basement conventionally, yet experience has shown that its successful implementation is not automatic. This depends upon a clear understanding of system principles and adequate quality control during construction. When the System is successfully installed, high quality basement living space is provided at a fraction of the cost of the space upstairs.

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