indoor air technologies inc.
CANADA: 2344 Haddington Cres., Box 22038, Sub 32 Ottawa, Canada K1V 0W2
USA: 1201 North Market St., Box 1347, Wilmington, De., U.S.A. 19899-1347
Phone: 1 613 731 2559 or 1 800 558 5892 Fax: 1 613 733-9394
e-mail: ae977@freenet.carleton.ca Web URL: http://www.cyberus.ca/~dsw/iat

ECHO System for Basements

INTRODUCTION

Homeowners looking for more space are all too familiar with the cold, damp and dingy basement. Now the Enclosure Conditioned Housing (ECHO) System^{TM}, winner of the 1994 Ottawa-Carleton Home Builders' Technology Award, has helped you create the 'perfect basement' in your own home. With this System you have
- *depressurized, ventilated and drained sub floors which can be finished like floors upstairs,*
- *depressurized, ventilated and drained perimeter walls,*
- *mechanical, variable rate heat, recovery house ventilation,*
- *house depressurization testing capability.*

The ECHO System insulation, ventilation, dehumidification and water drainage system is incorporated in specially constructed basement perimeter stud walls and sub floors. ECHO System ventilation and drainage technology keeps building and insulation materials dry in what might otherwise be damp and musty basement floor and perimeter wall cavities.

The System eliminates foundation water leakage. Its continuous, depressurized envelope cavity prevents soil and building material moisture, gases and mold spores from entering the living space. Its energy efficient, variable speed blower, provides extra house ventilation when you need it.

Here is how it is done. First, in an existing finished basement, old insulation, studs and carpets are removed in the areas to be finished with the System. Next, cracks in the foundation walls are air-sealed. Then the ECHO System perimeter stud walls and/or raised sub-floors are constructed. The ECHO raised floor is hollow yet has a thermal resistance of R4 or more, depending upon the thickness chosen. This floor is drained either by a standard floor drain or by a hole(s) to the sub-slab. It is sealed at the edges where there is no connected ECHO wall. Sub-slab depressurization may have been included. This prevents soil gas entry in areas not covered by the ECHO sub-floor. It can also help to keep the slab from being damp, and exhaust humidity from existing stud walls. ECHO perimeter stud walls were fully insulated (air can move through batt insulation, and glass and mineral fibers are not damaged by water), contain R2000 electrical outlets, are sealed at the top and either connected to an ECHO sub-floor or sealed and drained at the slab.

The complete perimeter stud wall - raised floor assembly is exhausted to the outside by a continuous duty blower. The System was pressure-tested and leaks sealed before drywall installation. This ensures complete venting of the wall-floor assembly at the lowest possible exhaust rates for the System layout and foundation type. After the drywall was installed, the System was commissioned and certified, setting the minimum exhaust rate for continuous enclosure venting, and higher rates for house ventilation and dehumidification.

The performance of an ECHO System is monitored on an ongoing basis with a differential pressure gauge. Exhaust rate adjustment enables maintenance of a negative pressure of at least 1 Pascal under seasonal weather changes with the lowest possible ventilation rate. A radon monitor can be used for additional optimization of System soil gas mitigation.

indoor air technologies inc.

CANADA: 2344 Haddington Cres., Box 22038, Sub 32 Ottawa, Canada K1V 0W2
USA: 1201 North Market St., Box 1347, Wilmington, De., U.S.A. 19899-1347
Phone: 1 613 731 2559 or 1 800 558 5892 Fax: 1 613 733-9394
e-mail: ae977@freenet.carleton.ca Web URL: http://www.cyberus.ca/~dsw/iat

ECHO System for Basements

THEORY

We are all familiar with the fact that a tiny pin prick in a balloon allows its air to escape. Similarly, the radon log shown in Figure 1 illustrates that tight sealing of a foundation (even ECHO sealing) will not prevent radon entry into a basement. Such entry will occur whenever there is a driving pressure inward, equally before and after the ECHO System sealing was installed no matter how tight the seal. Hence, prevention of contaminated air flow through an ECHO wall or subfloor into the living space requires that the ECHO System be maintained at a lower pressure than the living space.

To achieve ECHO System depressurization, both ECHO wall and building 'stack or buoyancy pressures' must be overcome by a blower flow-induced pressure drop across the poly (or drywall) and subfloor plywood separating the system from the living space. The blower-induced pressure drop is a function of system exhaust rate and equivalent leakage area (ELA).

Preventing significant gaseous molecular 'back' diffusion from a depressurized ECHO wall imposes requirements for ECHO System drywall finishing tightness.

(A) Stack or buoyancy pressures

Stack or buoyancy pressures arise from air density differences which in turn arise from temperature differences. Stack pressures are calculated as

$$\Delta p_s = \rho_i \, g \, (h-h_n) \, (T_i-T_o)/T_o \quad \ldots \quad (1)$$

where

Δp_s = pressure difference due to stack effect, Pa
ρ = air density (about 1.2 kg/m^3 for indoor conditions)
g = gravitational constant (9.81 m/s^2)
h = height of observation, m
h_n = height of neutral pressure, m
T = absolute air temperature, ^{o}K
i = inside
o = outdoors (when calculating building stack);
behind ECHO wall insulation (when calculating ECHO stack)

Neglecting any resistance to air flow within the structure

$$\Delta p_s = 0.04 \text{ Pa}/(\Delta K.\Delta m) \quad \ldots \quad (2)$$

Since the soil is colder than the living space year-around (e.g., 8-9 ^{o}C at foundation depth; -3 to 0 ^{o}C at the surface in winter and near average air temperatures in summer), temperatures between the insulation and the foundation wall are always colder than in the living space. Exhausting building air through the cavity has a slight warming effect. On average the cavity air temperature behind the insulation is ~10 ^{o}C and ECHO wall stack pressures offset System depressurization by some 0.5 Pa.

Building stack effect pressures further offset (or augment during building air-conditioning in hot weather) ECHO system depressurization. The amount depends upon both building envelope leakage quantities and leakage locations. For example, an ECHO System covering a block wall will be more affected by building stack effect than one over a poured concrete foundation. A two storey house with a tight envelope or a chimney leading from the basement will produce greater offsetting pressures on the system than a house with a leaky envelope or an open furnace make-up air duct. In theory, a two storey house might induce stack pressures up to ~4 Pa. In practice, combined house and ECHO stack pressures on ECHO cavities range between 0 and 2 Pa, summer to winter.

As a result, an ECHO System depressurization of 1 Pa will offset stack pressures during the non-heating season - a period when mold and material offgasing are generally highest. A 1 Pa depressurization will also offset heating season stack effect in many installations most of the time. However, in some houses, a 2-3 Pa depressurization will be required in cold weather. In homes with concrete block foundation walls, higher ECHO System depressurization may coincidentally depressurize the block cavities. If so, the entry of block and soil gases into the house via block ‘chimneys’ and through small cracks in the top of the wall will also be prevented. Again, such depressurization will have to be higher in winter.

(B) Equivalent leakage area

The tighter the ECHO System is constructed, the lower the ELA and the lower the exhaust rate required to achieve a particular depressurization target.

For typical construction leaks, the ELA can be calculated using

$$ELA = (Q / Cd) * (\rho_a / 2 * \Delta p)^{0.5} \quad (3)$$

where

- ELA = equivalent leakage area (m^2)
- Q = flow (m^3/s)
- Cd = discharge coefficient = 0.65 for small openings
- Δp = pressure difference (Pa)
- ρ_a = air density (kg/m^3)

Comparison can be made to construction norms for tightness using normalized leakage area

$$ELA_n = ELA/\text{ECHO System surface area coverage} \quad (4)$$

indoor air technologies inc.
CANADA: 2344 Haddington Cres., Box 22038, Sub 32 Ottawa, Canada K1V 0W2
USA: 1201 North Market St., Box 1347, Wilmington, De., U.S.A. 19899-1347
Phone: 1 613 731 2559 or 1 800 558 5892 Fax: 1 613 733-9394
e-mail: ae977@freenet.carleton.ca Web URL: http://www.cyberus.ca/~dsw/iat

ECHO System for Basements

The ECHO blower capacity of 40 L/s has been chosen to remove soil moisture from ECHO cavities as fast it might enter an older basement (no poly under the slab), with a basement air relative humidity of 40%. This capacity also allows the ECHO System to be used as a house ventilation system for up to 5 occupants at minimum code requirements, drawing outdoor air in via above-ground envelope leaks and openings.

A 40 L/s rate coincidentally dilutes typical building pollutants to acceptable levels while dehumidifying the cavity under typical summer indoor/outdoor conditions. The standard ECHO System blower installation provides such a ventilation rate when operated on high speed. The ECHO blower can also be operated as the ventilation system at lower rates when there are fewer than 5 occupants while providing basement air pollutant mitigation at source.

An exhaust of 5 L/s will depressurize a tight ECHO System behind the poly by 2 Pa relative to the basement living space (up to 50% of this Δp occurs across the drywall alone). From Eq. (3), this equates to an ELA in the ECHO construction of 42 cm^2 (6.5 in^2). Conversely, a leaky ECHO system will depressurize by 1 Pa at an exhaust flow of 40 L/s.[1] This equates to an ELA of 477 cm^2.

Normalizing these ELAs for a system covering 150 m^2 of perimeter wall and slab, a tight system ELA_n is 0.3 cm^2/m^2, and a leaky system ELA_n is 3.2 cm^2/m^2. By way of comparison, a typical house envelope ELA_n is 1.5 cm^2/m^2 and a tight house envelope ELA_n is 0.5 cm^2/m^2. An experienced ECHO System contractor can usually achieve an ECHO System ELA_n of 0.3 cm^2/m^2 for poured concrete foundation walls. In the case of block wall foundations, some system leakage will occur via block cavities. Such leakage can be reduced by air sealing at the top of the block wall wherever access is possible. Block wall depressurization is useful since cavities can harbor mold growth and be conduits for soil gas entry.

(C) Molecular diffusion

Trace amounts of contaminant gases can escape from a depressurized ECHO System into the house through a phenomenon known as molecular diffusion. The quantities of cavity gases entering the house via diffusion depends upon the system ELA, tightness of the drywall, and the system exhaust rate.

Molecular diffusion of a gas is calculated from

$$M_d = D * (\rho_2 - \rho_1) *A/L \quad (5)$$

where

---

[1] A leaky system can arise due to foundation leakage as well as leaky ECHO construction. For example, poured concrete foundations produce tighter systems than block wall or rubble mound foundations.

M_d = mass transfer of a gas or vapour due to diffusion
D = mass diffusivity for the gas in air
$\rho_2 - \rho_1$ = partial density gradient of the gas
A = cross sectional area over which diffusion takes place
L = length over which diffusion occurs

Mass diffusivity of a gas varies inversely with the square root of its molecular weight. Thus, the mass diffusivity coefficient D for radon is 0.46 times that for ethanol. For methane, D is 1.7 times that for ethanol.

Diffusion of a gas from an ECHO wall is countered by its convective mass transfer back into the wall. Convective transfer is calculated using

$$M_c = C_1 * Q \quad (6)$$

where

M_c = mass transfer due to convection (mg/s)
C_1 = concentration of the gas (mg/m^3)
Q = flow (m^3/s)

For example, an ECHO cavity may contain mold gases entering from the soil. For a tight ECHO system (poly ELA = 42 cm^2, drywall ELA = 84 cm^2), mass transfer of ethanol (a microbial offgas, D = 11.9) due to diffusion in still air would create a concentration in the living space of ~ 0.1% of the cavity concentration with the drywall in place and a cavity exhaust rate of 5 L/s. With only the poly in place, the living space concentration would be some 6% of the cavity concentration. It should be noted that since diffusion entry from the ECHO cavity is not through still air, but upstream through air currents, these values are overestimates.

For a leaky ECHO System (poly ELA = 477 cm^2, drywall ELA = 954 cm^2), mass transfer of ethanol due to diffusion would create a concentration in the living space of ~ 0.2% of the cavity concentration with the drywall in place and a cavity exhaust rate of 40 L/s. With only the poly in place, the living space ethanol concentration with a leaky ECHO System would be some 16% of the cavity concentration.

From the above, it can be seen that diffusion of gases is likely to be unimportant for properly built, finished and commissioned ECHO System construction.

(D) Water vapour transfer

Unperturbed soil (e.g., under foundation wall footings) generally has high water content. This soil moisture passes through concrete via capillary action. Once inside a conventionally finished basement, it is trapped inside stud wall and subfloor cavities, and under carpets. Stack effect pressures prevent circulation of house air through these cavities (except in air conditioned houses

indoor air technologies inc.

CANADA: 2344 Haddington Cres., Box 22038, Sub 32 Ottawa, Canada K1V 0W2
USA: 1201 North Market St., Box 1347, Wilmington, De., U.S.A. 19899-1347
Phone: 1 613 731 2559 or 1 800 558 5892 Fax: 1 613 733-9394
e-mail: ae977@freenet.carleton.ca Web URL: http://www.cyberus.ca/~dsw/iat

during hot weather when it does little good), eliminating convective transport. This leaves diffusion.

For a water vapour concentration of 9600 mg/m^3 in a stud wall cavity, a drywall leakage area ELA = 1000 cm^2, and a living space concentration of 6,000 mg/m^3 , moisture transfer via diffusion into the basement living space would be at the rate of less than 0.7 mg/s.[2] Over a day this equates to 60 gm of water. Moisture entry through foundations (excluding leakage) typically ranges between 2.5 and 10 kg/day (the entry rate rate reduces as indoor relative humidity increases). Hence, diffusion has negligible impact on removing the soil moisture entering wall and subfloor cavities, and even 'dry' finished basements can become moldy.

On the other hand, the convective removal used by an ECHO System is effective. For example, for a cavity air moisture concentration of 9,600 mg/m^3 and a living space moisture concentration of 6,000 mg/m^3, convection removes between 18 mg/s to 144 mg/s (1.6 and 12.4 kg/day) for ventilation rates of 5 and 40 L/s, respectively - rates of removal comparable to basement moisture entry rates.

---

[2] A water vapour concentration of 9600 mg/m^3 equates to 100 % relative humidity in air at 10ºC or 60% RH in air at 20ºC. A water vapour concentration of 6000 mg/m^3 equates to 40% relative humidity in air at 20ºC.