

GUIDELINES FOR DESIGN AND CONSTRUCTION OF NEW HOMES WITH BELOW-GRADE UNDER-FLOOR SPACES

Version 1.0

October 30, 2003

DEVELOPED BY THE MOISTURE MANAGEMENT TASK FORCE

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INTRODUCTION

In March 2002 the Tri-County Health Department (TCHD) circulated a letter to building officials within their jurisdiction indicating a rise in 2001 of the number of calls from homeowners regarding mold in homes. TCHD indicated it was their opinion that current building codes do not adequately address the issues concerning moisture control as it relates to potential for mold growth.

In May 2002 TCHD called a meeting of the building officials at which TCHD presented information about mold, and three speakers invited by TCHD presented information on the topic from their perspective. The speakers included a building official (Tom Thompson), a private home inspector (Gary Hansen), and a forensic/structural engineer (Ed Fronapfel, PE). Representatives of the Home Builders Association of Metropolitan Denver (HBA) also attended. Discussion focused on potential for mold build-up in below-grade under-floor spaces¹ beneath structurally supported basement floors; in particular, beneath wood-decked floors. The group agreed that further meetings would be beneficial and agreed to allow HBA to host the next meeting in the hopes that more builders would be willing to participate.

¹ “Below-grade under-floor space” is defined as under-floor space located such that ventilation openings cannot be provided directly through an exterior wall.

In June 2002 the HBA hosted a meeting at which the consensus of the group was to work together to achieve the following goals and objectives:

- A. Identify potential causes of water infiltration/moisture build-up in below grade under-floor spaces.
- B. Determine if current codes adequately address the identified causes.
- C. Develop suggested alternative solutions to the identified problems.

It was agreed that a task force with a balanced representation from various disciplines and areas of expertise in the building industry would be formed and that the mission of the Task Force would be:

“To develop guidelines and proposed code amendments with the aim of offering building professionals in the design and construction of new homes some alternative methods to better manage moisture in and around below-grade under-floor spaces to reduce the potential for mold growth.”

The make up of the group was agreed upon, with each representative group suggesting who should serve from their group on the task force. The task force membership includes:

Builders/ Developers (4)

Justin Jones	Centex Homes
Jeff Vogel	Engle Homes
Mert Moret	Sanford Homes
Randy Rainey/Marc Grivas	U.S. Home Corporation

Building Scientists/Engineers (4)

Ed Fronapfel, P.E.	PIE
Joe Lstiburek, P. Eng., PhD.	Building Science Corp.
Steve Andrews	E-Star Colorado
Bob Barrett, P.E.	CTL Thompson, Inc.

Geotechnical Engineers (2)

Ron McOmber, P.E.	CTL Thompson, Inc.
Tim Spencer, P.E.	A.G. Wassenaar, Inc.

Building Officials (3)

Tom Thompson	City & County of Broomfield
Sam Dardano	City of Boulder
Steve Thomas	City of Cherry Hills

Health Officials (3)

Michele Kinshella
Chuck McCammon
John Martyny

TCHD
TCHD
National Jewish Center

Moderator

Kim Calomino

HBA of Metro Denver

The Moisture Management Task Force met periodically between July 2002 and October 2003 to discuss the issues. Minutes were prepared as the meetings progressed, and reviewed during subsequent meetings. These guidelines were developed based upon discussions at those meetings.

The guidelines are a primarily a packaging of the opinions and knowledge that are already found in the industry. It is not represented, however, as an exhaustive compendium of alternatives and potential solutions, nor is it the collective judgment of the Task Force that these guidelines contain the only viable measures and methods that can be employed to effectively manage moisture in and around crawlspaces and foundations. Neither does the Task Force by these guidelines issue an opinion on other measures and methods. The Task Force readily accepts that alternative methods can be effective.

ORGANIZATIONAL APPROACH

The Task Force decided that the first step would be the development of guidelines, followed by code language written as potential amendments to the code. The Task Force would also identify issues and develop suggestions as relates to occupancy and maintenance that could be included in an educational piece provided by builders to homeowners.

The group agreed that a two-thirds majority consensus of the Task Force members was necessary to proceed with any recommendations and recommended code amendment. Since local jurisdictions decide whether to adopt any recommended code language, the consensus was that this majority agreement would make it easier for building officials to gain approval within their local jurisdiction.

The Task Force approached the goals and objectives by brainstorming issues involved with Objective A first.

- A. Identify what is causing water infiltration/moisture build-up in below grade under-floor spaces to occur.

The Task Force then divided these causes into three groups based on the alternatives and potential solutions: Surface Drainage, House Design and Construction Practices, and Occupant Issues.

Discussion subsequently focused on sequential potential solutions for the potential causes. When existing code provisions could be readily identified, those provisions and potential code amendments were discussed, relevant to the specific cause and potential solution. In this manner the Task Force approached objectives B and C:

- B. Determine if current codes adequately address the problem.
- C. Develop suggested solutions and code amendments to address the problem.

This report is organized to present potential causes, followed by the group's suggested solutions. It includes some background commentary, explaining rationales for both problems and solutions. Building officials within the group used this report and other information to provide model code language which was reviewed by the Task Force.

The following comprises the work of the Task Force beginning with a glossary of terms and phrases followed by recommended guidelines as pertain to surface drainage and house design and construction practices, and concluding with recommended information for homebuyers. The proposed code amendments exist as a separate document.

GUIDELINES FOR DESIGN AND CONSTRUCTION OF NEW HOMES WITH BELOW-GRADE UNDER-FLOOR SPACES

I. GLOSSARY

- A. Below-grade under-floor spaces: Under-floor spaces located such that ventilation openings cannot be provided directly through an exterior wall.
- B. At-grade under-floor spaces: Under-floor spaces located such that ventilation openings can be provided directly through an exterior wall.
- C. Area grading plan: An area grading plan should show final grade elevation for roads, lots, open space, detention ponds, and tract areas.
- D. Area underdrain system: Area underdrain systems consist of a network of solid or perforated pipes, generally placed in the base of sanitary sewer trenches within streets.
- E. Grading performance plan: Commonly referred to as a plot plan that shows the proposed surface water drainage patterns and elevations for any given lot.
- F. Grading certificate: A plot plan that shows actual surface water drainage patterns and elevations for any given lot as prepared by a land surveyor or engineer.
- G. Sealed (vapor barrier): Reasonably air tight.
- H. ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers.
- I. IRC: International Residential Code.

II. SURFACE DRAINAGE

- A. Area Grading Plan (for the overall site)

The task force believes that area grading plans should be required for all residential projects. These plans should address the following issues:

1. The impact of pre-existing drainage patterns should be considered. Such considerations should include existing floodplains, wetlands and irrigation ditches adjacent to lots as well as any known ground water.

2. The design should anticipate provisions for drainage swales to convey water away from foundations. The existing code calls for 2% minimum slope. Builders should do what they can with site specific conditions to create good drainage and, where appropriate and possible, strive to obtain more than the code requires.
3. The design should anticipate grades necessary to drain water away from foundations. These grades should be a minimum of 5% (maximum of 33%), and more where possible to a minimum of 10' away from the house. Where lot lines, walls, slopes or other physical barriers prohibit 6 inches of fall within 10 feet, drains or swales should be provided to ensure drainage away from the structure. The minimum slope should be provided in the site-specific soils report.
4. Upon completion of area grading any deviation from the area grading plan should be identified with an as-built survey and approved by the design engineer.
5. Plans for each lot should require platted drainage easements along lot lines.

B. Area Underdrain Systems

The Task Force believes area underdrain systems can help control subsurface water and provide a gravity discharge for foundation drain systems. Where underdrains are permitted and planned, they should be designed to allow maintenance (with cleanouts), and inspected during and after construction. Long-term maintenance responsibility should be defined.

C. Lot Specific Drainage Plans

The task force believes that lot-specific plot plan showing grading and drainage flows (grading performance plan) should be required as a part of the residential permit application process. At the time of C.O., a stamped Grading Certificate should verify this plan. These plans should address the following issues:

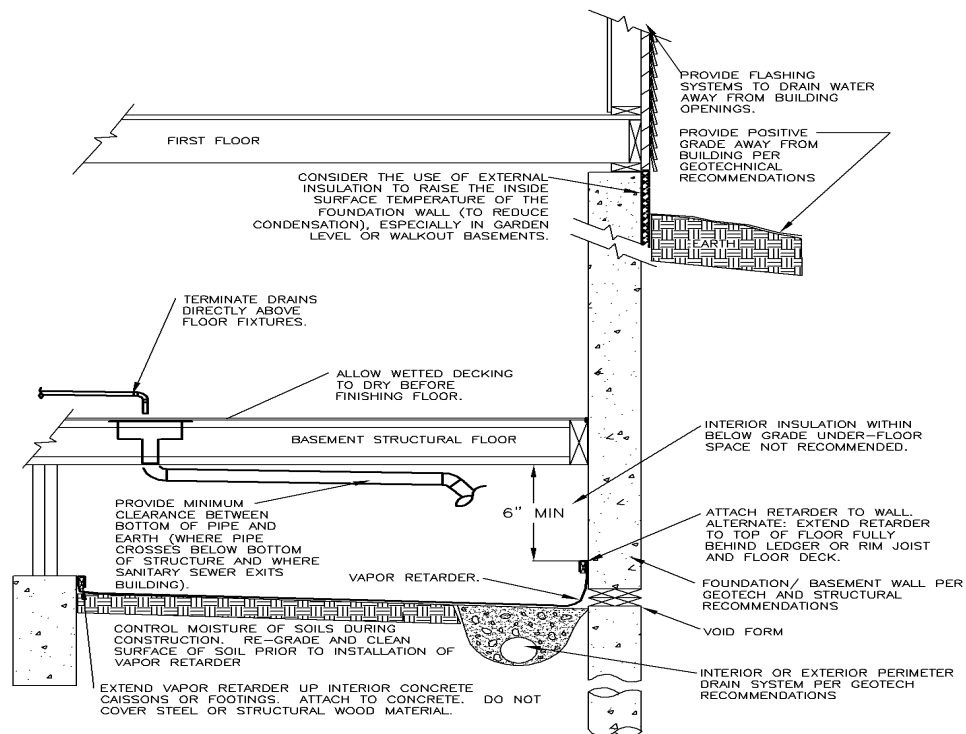
1. Drainage swales should be used to convey surface water away from foundations. The existing code calls for 2% minimum slope. Builders should do what they can with site specific conditions to create good drainage and, where appropriate and possible, strive to obtain more than code requires.
2. The plans should be verified to ensure agreement of the lot-specific drainage with the Area Grading Plan.

3. The plans should specify top of grade-beam/foundation elevation for the foundation.
4. The design should anticipate grades necessary to drain water away from foundations. These grades should be a minimum of 5% (maximum of 33%), and more where possible to a minimum of 10' away from the house. Where lot lines, walls, slopes or other physical barriers prohibit 6 inches of fall within 10 feet, drains or swales should be provided to ensure drainage away from the structure. The minimum slope should be provided in the site-specific soils report.

III. HOUSE DESIGN AND CONSTRUCTION

The Task Force believes that moisture management practices during home design and construction can reduce the potential for mold growth in below-grade under-floor spaces either before or after home occupancy. The measures identified below and included in Figure III include:

FIGURE III



A. Foundation Perimeter Drains

Perimeter drains—either interior and/or exterior—should be provided adjacent to the lowest concrete or masonry foundations that retain earth. Carefully follow the engineered foundation drainage system specifications. Generic recommendations:

1. At time of construction the drainage trench should have a positive slope to a sump pit or gravity discharge. The drain should be protected during installation of the sanitary sewer service or restored, if merited, after this installation.
2. The impact of the sewer service line should be considered in the design and construction of the drain to avoid directing foundation drain flow into the sewer trench except when a gravity discharge (underdrain) is provided in the sewer trench.
3. Perimeter drains should discharge in a sump pump pit. A pump should be installed unless the drains are provided with a gravity discharge daylighting at the ground surface or into an underdrain system. The discharge pipe for sump pumps should discharge at least five feet away from the foundation, to an area of positive drainage away from the foundation, or rely on other approved discharge method.

B. Excavation and Backfill

The soils report prepared for design of foundations should identify the degree of compaction required for foundation wall backfill and the minimum slope to achieve adequate drainage. The excavation outside the foundation should be back-filled with soil that is substantially free of organic material, construction debris, cobbles and soil clods in excess of 6 inches in diameter, boulders and frozen soils. The backfill should be placed in lifts and compacted in a manner that does not damage the foundation or the waterproofing or damp-proofing material.

1. Common Excavations. Where excavations include more than one house, special attention is required regarding compaction of the backfill between houses, or a specially engineered drainage system should be designed.
2. Ramp. Ramp backfill should be compacted to avoid excessive settlement and to reduce the likelihood that the ramp will become a conduit for surface water to flow toward the foundation. Suggestions: Ramp placement below swales between houses should be avoided. Ramp backfill outside the immediate foundation area should be compacted to higher degree than the backfill around the foundation.
3. Utility trenches. Water and sewer utility service trench backfill should be compacted to control settlement and reduce the

likelihood the trenches will provide a conduit for surface moisture to flow toward the foundation.

C. Wetting of Soils below Basement Floor during Construction

Measures should be incorporated to control moisture of soils in below-grade under-floor spaces and water in foundation drains during construction.

1. Standing water, snow or ice present in the basement excavation and foundation drain should be removed prior to installation of a vapor barrier and/or the floor deck.
2. Once roof-drain gutters are in place, install downspouts with extensions which discharge at least 5 feet away from the foundation, measured perpendicular to the foundation wall, or to an approved drainage system. If tip-ups with hooks are used, remove these hooks prior to occupancy so that extensions cannot be left in the “up” position after occupancy.
3. The excavation bottom should not be “dished out” such that any portion of the exposed soil is below the high point of the foundation drain trench. Any portion of the excavation bottom that is dished out should be provided with a positive flow to the sump pit.
4. At the time of construction, the surface of the below grade under-floor space should be graded to slope toward the sump pit or toward drain systems installed to control free water. The grading should not allow ponding of water.

D. Clearance below Floor Systems and Plumbing

At the time of construction, the minimum clearance below steel floor components (i.e., beams, joists, etc.), and plumbing lines (where practical) should be equal to the void height plus 4 inches. The site-specific soils report should provide recommendations for minimum clearance to control the likelihood that the clearance will be closed.

It is not possible to create clearance under sewer lines as they approach the service connection and exit the house. If it is necessary to trench below beams or plumbing lines in order to create the clearance, then these trenches should slope to the perimeter drain system.

Where clearance between the top of the sewer line and the bottom of the foundation wall is less than the void height, the engineered foundation plan should provide a block-out detail. When a block-out is necessary, coordination between foundation and plumbing trades is necessary. Match recommended void height beneath bottom of lowest point of wall and the sewer line.

E. Ground Preparation and Cover for below-grade under-floor spaces

1. The surface of the below-grade under-floor space should be graded to slope toward the sump pit or toward drain systems installed to control free water. The grading should not allow ponding of water.
2. IRC 408.4 requires removal of all debris from the dirt floor.
3. Placement of a minimum 10-mil un-reinforced polyethylene vapor retarder (or material with equivalent puncture protection) is recommended below all structurally-supported basement floors.
 - a. ASTM test method for vapor retarder as ground cover E154-99
 - b. Puncture pound force FTMS101C
 - c. 10-mil poly with 8.1 puncture pound force or greater is allowed (Two puncture tests are D1709 and D4397.)
 - d. The sheet material covering the entire dirt floor should be placed directly on the ground surface and attached to foundation walls above foundation void material, to interior caissons (below the post and/or plate) or footing pads, and plumbing lines. Laps should be continuously sealed. Methods to achieve this include chemically bonded joints, or joints lapped and taped with tape approved for use on exterior house wrap. The vapor retarder should either be placed behind the basement floor rim joist or ledger extending to top of the floor, or be terminated at least 6 inches below the rim joist and mechanically attached to the wall, and to all penetrations, in a continuous manner.
 - e. The sheet material should not be attached to horizontal surfaces such that condensate might drain to wood or corrodible metal surfaces.
4. Alternative systems may be considered based upon engineered design. These designs should consider use of non-cellulose framing systems (e.g., concrete and/or steel), ventilation, access, ground preparation, vapor retarding and insulation.

F. Wetting of Construction Materials during Construction

1. Construction materials should be protected from exposure to moisture in accordance with manufacturer's recommendations.

2. When basement floor decking has been placed and is wetted after placement, it should be allowed to dry. Suggested solution: leave off or remove at least two 4x8 sheets at opposite corners of the floor, and place a walk-able metal grate over the openings. If the decking remains wet after framing is complete, install temporary fans (power required) to dry the floor materials.

G. Downspout Termination

Consider overall drainage plan when locating downspouts. Install downspouts with extensions which discharge at least 5 feet away from the foundation, measured perpendicular to the foundation wall. If tip-ups with hooks are used, remove these hooks prior to occupancy so that extensions cannot be left in the “up” position after occupancy.

H. Landscaping

1. No landscaping requiring irrigation should be located within five feet of foundation walls.
2. Landscape edging should not interfere with the discharge of the roof drainage system.
3. Use of drought-tolerant landscaping is recommended.
4. Proper soil preparation below sod is critical to create water storage capacity, which reduces watering requirements. Soil preparation requirements should be determined based on site-specific soil conditions.
5. No valve boxes or drain valves should be placed within the backfill or within five feet of the foundation. Wherever possible, sprinkler lines should be installed with the same guideline.
6. Swales and surface drainage pathways around the house.
 - a. Don't plant trees in swales (drainage pathways).
 - b. Don't build retaining walls that would change drainage pathways.
 - c. Fences, including posts, should be constructed to minimize effects on drainage swales and pathways.
 - d. Landscaping edging should not interfere with the flow of surface water away from the foundation and/or along drainage pathways.

I. Insulation in below-grade under-floor spaces

It is not recommended that any insulation be placed between floor joists beneath the wood deck, or against the interior surface of the foundation wall. On a walkout basement wall, exterior insulation of the concrete foundation wall along

the walkout is recommended. The intent is to control the potential for condensation on any wood in contact with the concrete foundation wall. There may be other options for achieving this result.

J. Insulation in Basements

Exterior insulation is preferred to interior vinyl-faced fiberglass blankets. At present, reported mold problems in homes along the Front Range with vinyl-faced blankets are limited; when vinyl-faced blankets are used, holding the bottom edge of the blanket six inches above the floor is recommended. Potential best practice would be the use of either un-faced insulation or a 5-perm facing over any insulation product.

K. Ventilation of below grade under-floor spaces

Commentary:

The practices for ventilation of below-grade under-floor spaces have evolved, and differ among builders and with floor type. Current code requirements for ventilation (e.g., IRC 408) are for ventilating at-grade crawl spaces and do not address below-grade under-floor spaces.

For wood-decked floor systems, the most common ventilation practices include use of one in-line fan with one or more intake ducts (6-inch typical) terminated at the exterior (outdoor make-up air). The fans are typically controlled by a humidity sensor. The exhaust and intake ducts tend to be located based on convenience of the installer.

Where high humidity persisted, additional fans and/or intake vents have been installed, sometimes along with a vapor retarding ground cover. A few builders choose to use indoor air in lieu of outdoor air (with and without a vapor retarder) and report success.

There are several structural floor systems that do not incorporate the use of cellulose-based structural materials. These structural systems include concrete and steel/concrete composite systems. Some of these systems isolate the sub-floor space from the basement by not providing underfloor access. Typically, the only openings through the floors are sump or sanitary piping clean-out access. In both of these types of systems ventilation is not considered as critical as with wood-decked floor systems that include a door-type opening. Access into the below-grade under-floor space is required for wood-decked systems for maintenance and inspection. Penetrations through the floor should be sealed.

For slab-on-grade, slab on void, or steel/concrete decking systems which isolate the basement from the below-grade under-floor space, under-floor ventilation is not required for moisture control. However, below-floor ventilation may be

required for radon control, structural concerns (i.e., corrosion of steel), or for other reasons. The builder and home owner should understand that under these circumstances, the area below the floor system could be very humid, may contain organic material (especially in the soil), and may be at an appropriate temperature to support fungal growth. Therefore, the isolated space below an unventilated basement floor should be “sealed off” to as great an extent as possible.

“Passive” ventilation systems may be considered for “sealed” floor systems. Passive ventilation systems usually include a pipe that penetrates the basement floor and runs to the exterior of the building. Natural convection, or stack effect, can cause the below grade under-floor spaces to be depressurized. However, especially at high outside air temperatures, reverse stack effect may also slightly pressurize the below-grade under-floor spaces. The Task Force believes that the differential pressures which develop due to stack effect are very small; thus the impact of passive ventilation is probably negligible from either a positive or negative pressure perspective.

The Task Force acknowledges that ventilation is only one component of the measures necessary to control moisture in below-grade under-floor spaces. If the other system components discussed in this document (surface drainage, foundation drainage, vapor retarder, etc.) are installed and maintained correctly, then only very minimal ventilation is necessary. Under this condition, use of outdoor air for exhaust make-up is usually acceptable. On the other hand, the amount of ventilation described in this document is intended to mitigate potential humidity problems encountered in these below-grade under-floor spaces. It is not intended to provide sufficient airflow to remedy standing water from drainage problems or sources such as plumbing leaks. Nevertheless, the Task Force believes the best current practice is to include a vapor retarder and ventilation using indoor air for accessible below-grade under-floor spaces that use cellulose-based products. The Task Force acknowledges that other engineered systems can perform satisfactorily and believe code language should allow their use.

The introduction of outside air may affect below-grade under-floor air temperature and humidity more adversely than the introduction of conditioned indoor air. In the winter, unconditioned outside air cools the humid air in the below-grade under-floor space and surfaces near the intake duct. Condensation can form on the surface of the duct or in the vicinity of the duct termination. In the summer, the dewpoint temperature of indoor air (a measure of the air’s moisture content) is much lower than the daily high dewpoint temperature of the outdoor air. This is true in both air-conditioned and non-air conditioned homes.

The natural ventilation rate of at-grade crawl spaces using code mandated passive ventilation openings is roughly 1 air-change per hour. A continuously operating fan of 25 cfm would provide 1 air-change per hour ventilation rate for a 1000 ft² basement subfloor area (assumed depth of 18” beneath floor deck).

Note that at-grade, passively ventilated crawl spaces often “ventilate” up through the home; on an annualized basis, as much as $\frac{3}{4}$ of the air entering the crawl space vents may exit through the living space above. To reduce the same airflow pattern (from a below-grade under-floor space to the basement), the Task Force recommends the use of ventilation systems which will maintain a slight negative pressure in the under-floor space (with respect to the basement), and which operate continuously.

The rate of water vapor intrusion to a below-grade under-floor space may be considerably greater than that for an at-grade crawl space.

ASHRAE Standard 62.2 has been developed to address “Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. This standard requires the installation of “A mechanical exhaust system, supply system, or combination thereof... [for] whole-building ventilation with outdoor air” at a specified minimum rate. The minimum rate is calculated at: 7.5 cfm times the number of bedrooms, plus 1; plus 0.01 cfm per ft² of conditioned floor area. One way ASHRAE 62.2 can be met in most homes is by sizing the below-grade under-floor ventilation system in accordance with the standard, drawing make-up air for the under-floor exhaust from the conditioned, occupied space (e.g., via transfers through the basement floor) and operating the fan on a continuous basis.

This rate of ventilation will also exceed the “1 air-change per hour” rate of a passively ventilated, at-grade crawl space by a factor of about 2 to 3 times (e.g., for a four bedroom house with a 1000 square foot basement and 2000 square feet above grade). It is believed that this rate of ventilation is adequate to remove the additional water vapor intrusion expected within a below-grade under-floor space that includes a properly sealed ground cover. Some ventilation system designers may add a safety factor to the ASHRAE 62.2 recommended ventilation rate.

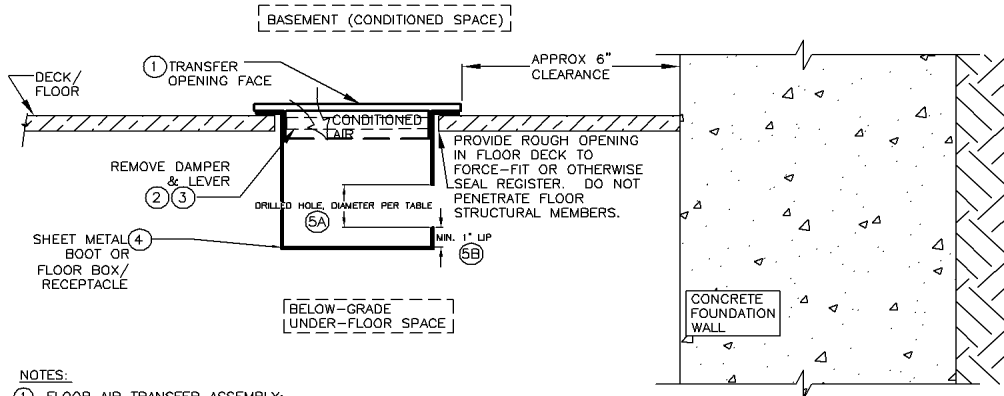
End Commentary

Active systems may utilize make-up air from the outside, or conditioned air from inside the house.

1. Active Ventilation of Below-grade Under-floor Spaces using indoor air: The Task Force recommends use of conditioned indoor air to mechanically ventilate below-grade under-floor spaces through floor transfer grills or manifold systems exhausted to the exterior. Systems should be professionally engineered and/or use power-vented or direct-vented combustion appliances to relieve potential for back-drafting of gas-fired appliances within the home. Suggested design details include:

- a. Fan sizing: Recommend reliance on ASHRAE 62.2 standard. Note that the proper selection of an exhaust fan requires the desired airflow rate and the desired static pressure capability. A nominal “50 cfm” fan will only produce 50 cfm at the manufacturer’s listed static pressure (usually 0”w.c.).
- b. Fan specifications: average bearing life should be no less than 5 years (44,000 hours).
- c. Fan installation: the fan’s vibration should be isolated from the building structure by use of flex connections, flexible duct or other means.
- d. Fan control: Continuous operation of the fan is recommended.
- e. Fan functionality: If the fan fails, a trouble light or alarm should alert the homeowner to repair or replace the fan.
- f. Fan discharge duct: Any pressurized ductwork within the house or under-floor space that carries exhaust air to the outdoors should be sealed.
- g. Transfer floor opening: Provide at least one transfer floor opening per 250 ft² of basement floor area (or fraction thereof), with air-flow opening restricted per Figure/Table III.K. Place an HVAC boot beneath the grills to serve as code-required “ashtray” (IRC M1601.4.3). Transfer floor openings should be sized and distributed to provide uniform cross ventilation; e.g., located one inlet per corner. Transfer floor openings may consist of conventional floor grilles or registers, but should have their cross-sectional flow area restricted in accordance with Figure/Table III.K.
- h. Floor opening size calculation procedure:
 1. Calculate the required exhaust rate.
 2. Determine the number of floor registers desired (based on floor geometry).
 3. Calculate the required exhaust rate per transfer.
 4. Determine the required opening size for each transfer (from Figure/Table III.K., below).

FIGURE III.K



NOTES:

- ① FLOOR AIR TRANSFER ASSEMBLY: STANDARD FLOOR REGISTER OR GRILLE WITH LONG DIM. PARALLEL TO FOUNDATION WALL. MODIFY AS FOLLOWS:
- ② DAMPER LEVER: REMOVE DAMPER ACTUATION LEVER (IF PRESENT).
- ③ DAMPER: REMOVE DAMPER IF PRESENT.
- ④ PROVIDE SHEET METAL "BOOT" OR FABRICATED "BOX", SAME SIZE AS GRILLE OR REGISTER FLANGE. BOOT OR BOX SHALL BE CAPPED BELOW FLOOR EXCEPT FOR HOLE IN SIDE:
- ⑤ PROVIDE CUT OR DRILLED SHARP EDGE HOLE IN SIDE OF BOOT OR BOX CLOSEST TO FOUNDATION WALL AS FOLLOWS:
 - ⓂA NET OPENING THROUGH TRANSFER: IN ACCORDANCE WITH TABLE, BELOW.
 - ⓂB BOOT OR BOX SHALL PROVIDE CODE INTENT FOR NON-COMBUSTIBLE RECEPTACLE FOR PLENUM AIR DEVICE AND SHALL HAVE MINIMUM 1" VERTICAL LIP.

ALL OPENINGS IN SIDE OF BOOT OR BOX SHALL BE THE SAME CROSS-SECTIONAL AREA +/- 10%.

NOT TO SCALE. DETAIL SHOWN IS SUGGESTED MEANS OF ACHIEVING SPECIFIED NET TRANSFER OPENING AREA AND RECEPTACLE. ALTERNATE MEANS OF ACHIEVING THESE GOALS MAY BE USED AT DESIGNER'S OPTION.

FREE AREA OF OPENING IN BOOT OR BOX	FREE AREA OF OPENING IN BOOT OR BOX
EXHAUST RATE PER TRANSFER OPENING	NET FREE AREA / HOLE DIAMETER
0 - 9 CFM	NOT APPLICABLE - TRANSFER AT LEAST 10 CFM THROUGH EACH OPENING
10 - 15 CFM	1.7 TO 2.6 SQ. IN. FREE AREA / (1-5/8" Ø drilled hole)
16 - 20 CFM	2.6 TO 3.7 SQ. IN. FREE AREA / (2" Ø drilled hole)
21 - 25 CFM	3.7 TO 4.7 SQ. IN. FREE AREA / (2-1/4" Ø drilled hole)
26 - 30 CFM	4.7 TO 5.8 SQ. IN. FREE AREA / (2-1/2" Ø drilled hole)

- i. Example: Assume a 4 bedroom, 2000 sq.ft. (above grade) home with a 1000 sq.ft. (below grade) basement:
 1. Calculate the required exhaust rate: (per ASHRAE 62.2): $CFM = 7.5*(4+1) + 0.01*(3000) = 67.5$ cfm.
 2. Determine the number of floor registers desired (based on floor geometry). Assume 5 transfers are required for the example home.

3. Calculate the required exhaust rate per transfer: $67.5 \text{ cfm} \div 5 = 14 \text{ cfm}$ per transfer.
4. Determine the required net floor opening size from Table IV.J: For 14 cfm (in the range of 10-15 cfm): use a $\geq 1 \frac{5}{8}'' \text{Ø}$ drilled hole.

Performance specification: When this type of active ventilation system is sized and installed properly (and adequately sized combustion air openings are installed in accordance with code for all atmospherically vented appliances), the negative pressure generated by the exhaust fan should be less than negative1 (-1) Pascals. For frame of reference, the level at which the typical atmospherically vented water heater might spill combustion gases into the adjacent space is between -5 and -10 Pascals.

The rationale for drawing exhaust air from the indoors acknowledges that the current code allows for the wide variety of exhaust appliances. A number of those appliances and pressure-impacting features are listed below, including the typical range of flows and possible negative pressures they can create. Any resulting negative pressure generated is *highly dependent* on the volume of air within the directly depressurized zone (e.g., wide-open basement vs. utility room, etc):

Feature/appliance	Cfm of exhaust	Potential pressure
Dryers in basements	150 cfm	-1 to -2 pascals
Basement bath fan	30 – 75 cfm	-0.5 to -1 Pa
Down-draft exhaust Fans	500 – 900 cfm	-2 to -8 Pa (depending on make-up air or not)
Whole-house fans (windows variable)	1000 – 3500 cfm	-5 to -50 Pa (latter w/ windows closed)
fireplace	100 – 500 cfm	-2 to -5 Pa
Return air ducts (using building cavities)	400 – 1200 cfm	-1 to -10 Pa

Note that the only way to determine the real-world impact of the above elements on depressurization in a combustion zone is to measure it. Estimation can't truly work, since the items may or may not be additive. When trying to estimate their impact on the pressure in any basement, one would have to factor in a) how leaky the basement is to the outdoors; b) how leaky the basement is to the house above

(door undercut, etc.); and c) the volumes of the respective spaces.

The Task Force believes that, with proper design, use of indoor air will not induce negative pressures in basements that are sufficient for concern. At the same time, the Task Force still recommends use of power-vented, direct-vented or sealed combustion appliances.

2. Active Ventilation of Below-grade Under-floors spaces using outdoor air: The use of unconditioned outside transfer air may be an acceptable alternative to the use of indoor air; especially in basements which are completely below grade (do not include garden level or walk-out basements unless insulated on the exterior surface of foundation wall). Suggested design details include:
 - a. Fan sizing: Recommend at least 2, but no more than 4 air-changes per hour. Note that the proper selection of an exhaust fan requires the desired airflow rate and the desired static pressure capability. A nominal “50 cfm” fan will only produce 50 cfm at the manufacturer’s listed static pressure (usually 0”w.c.).
 - b. Fan specifications: average bearing life should be no less than 5 years (44,000 hours).
 - c. Fan installation: the fan’s vibration should be isolated from the building structure by use of flex connections, flexible duct or other means.
 - d. Fan control: Various methods for fan control can be utilized. Such methods include continuous operation of the fan, use of humidity sensor or humidity sensor/thermostat. Choice of fan control method should be engineered, taking into account air exchange rate, vapor retarders, and other system components.
 - e. Fan functionality: If the fan fails, a trouble light or alarm should alert the homeowner to repair or replace the fan.
 - f. Air intake opening: Provide at least one air intake opening from the exterior. The opening should be located such that airflow from the opening to the exhaust fan will cross as much floor area of the below grade under-floor space as possible. The objective is to reduce the possibility for dead or stagnant air spaces to develop. Use of manifold air ducts (across one full side of a house) and manifold exhaust ducts (across the opposite side of the house) should be

considered. The intake duct should be insulated to prevent condensation on the duct. The insulation should be duct wrap insulation conforming with IRC M1601.2.1 with minimum R-4 insulation value and a vapor retarder covering. The location of the discharge of the duct should be directed away from any structural floor components, where condensation may form without damage. All ventilation manifolds and laterals located beneath the floor should be supported by the floor and suspended above grade by more than the height of the void form (plus 4”).

3. Conditioning of below-grade under-floor plenum air: Some designers may elect to provide heating, cooling and/or dehumidifying system(s) to condition the air within the below-grade under-floor space. Nothing in these recommendations should be construed to discourage that practice. However, the following precautions are recommended:
 - a. Exhaust of the below-grade under-floor plenum at the rate of at least 1 air-change per hour is recommended, except when a dehumidification system is installed.
 - b. Care should be taken to prevent contamination of occupied spaces due to circulation of air from unoccupied spaces. To achieve this, the Task Force recommends a separate system to condition the below-grade under-floor area.
 - c. The homeowner should be advised to inspect these systems frequently.

L. Corrosion

When appropriate, structural components should be designed to tolerate corrosion or should be protected against corrosion that may impair the strength or serviceability of the structure.

Steel members may deteriorate in particular service environments. This deterioration may appear either in external corrosion, which would be visible upon inspection, or in undetected changes that would reduce its strength. The designer should recognize these problems by either factoring a specific amount of damage tolerance into the design or providing adequate protection systems (e.g. coatings, cathodic protection) and/or planned maintenance programs so that such problems do not occur.

(Source: AISC Manual of Steel Construction, Ch. L, Sec. L5)

M. Building Envelope Flashing

Provide comprehensive flashing systems that drain water away from the building. In order to allow pan flashing at doors, patios or stoops should be one step (3 to 7 inches) below top of foundation wall. This is particularly important at doors on walkout basements with structurally supported floors.

N. Dryer Vents

Dryer vents should always extend to the exterior, and should be located at least 3 feet from openings (air intakes and windows).

O. Condensate, Water Heater and Humidifier Drains above structurally supported basement floors

All indirect drains should terminate directly above floor drains with the required air gap and a turn-down into the floor drain. (See IRC P2803)

P. Negative Pressure in Basements

1. Unsealed ductwork. IRC 2000 requires sealing of all ductwork. The Task Force recommends elimination of use of building cavities for return-air ducts, and reducing return-air duct system complexity. (Rationale: typical return ducts using building cavities are very leaky, which can lead to negative pressure in basements.) Instead of requiring return-air cavities in every room, allow transfer air grilles and jump-ducts as acceptable means of relieving pressure in bedrooms. An alternative approach that is currently being used by several performance-based programs (e.g., Engineered for Life, Environments for Living, Building America) is a design and installation package that results in less than 3 Pascals of air-pressure differential (room to hallways, with doors closed) with reference to outdoors.
2. Sealants: The Task Force recommends the use of mastic on all ductwork, including dryer vents, bath fan ducts, and all exhaust ducts. The task force discourages the use of cloth duct tapes and UL-listed 181b tapes on ductwork.

IV. HOMEOWNER AND MAINTENANCE ISSUES

Homeowners need to improve their knowledge of the moisture control system and their own important role in maintaining that system. Builders are encouraged to educate their buyers on their responsibilities and role in maintaining that system. The following key items are suggested for

communication to the homebuyer by the builder as part of an overall homeowner education package.

A. Excessive Irrigation

1. Limited watering. Irrigation water is the major source of water around foundations and other structures and should be controlled to reduce moisture introduction to the subsurface environment. This will also enhance likelihood of good performance of foundations and concrete flatwork.
2. Rain/moisture Sensors. When sprinkler systems are installed, the Task Force recommends the use of rain sensors tied to the sprinkler controller system to prevent the system from cycling on if sufficient precipitation or irrigation has occurred prior to activation of the irrigation cycle. This may be a code requirement in some building jurisdictions.
3. Once landscaping is established, the irrigation system timer should be adjusted to supply only sufficient water to maintain that landscaping.
4. No irrigation should occur within five feet of the foundation.

B. Termination and Maintenance of Gutters and Downspouts

1. The occupant should maintain extensions on all downspouts so that discharge occurs at least 5 feet away from foundations, as measured perpendicular to the foundation wall. Discharge should occur in an area where water can drain freely away from the foundation.
2. Gutters, downspouts and extensions should be kept free of leaves and other debris.
3. Downspouts generally should not be buried or terminate under the soil. Buried drains are susceptible to damage, freezing, and/or disconnection and are difficult to maintain. Where buried pipes are used, the occupant should maintain the piping and discharge outlet.

C. Landscaping

1. No landscaping requiring irrigation should be located within five feet of foundation walls.
2. Landscape edging should not interfere with the discharge of the roof drainage system.
3. Use of drought-tolerant landscaping is recommended.
4. Proper soil preparation below sod is critical to create water storage capacity, which reduces watering requirements. Soil

preparation requirements should be determined based on site-specific soil conditions.

5. No valve boxes or drain valves should be placed within the backfill or within five feet of the foundation. Wherever possible, sprinkler lines should be installed with the same guideline.
6. When landscaping installation is delayed erosion control measures need to be taken.
7. Maintain swales and surface drainage pathways around the house.
 - a. Don't plant trees in swales (drainage pathways).
 - b. Don't build retaining walls that would change drainage pathways.
 - c. Fences, including posts, should be constructed to minimize effects on drainage swales and pathways.
 - d. Landscaping edging should not interfere with the flow of surface water away from the foundation and/or along drainage pathways.

D. Knowledge and awareness of mechanical equipment operation

1. To protect the long-term durability of the structure, humidifiers are not recommended. If you do have a humidifier, set the controller such that the appliance maintains 30% RH or less, in order to avoid potential moisture problems.
2. When fans are provided to ventilate below-grade under-floor spaces they are an important component of the system used to control humidity and maintain proper airflow in the residence. Do not disconnect them. If a humidity sensor is installed, do not set it above 40% RH (relative humidity). Periodically check to see if ventilation fans and controllers are operating properly. If a fan fails, replace it. Do not cover the floor air-circulation vents as this could increase the amount of water vapor beneath the floor and lead to moisture problems.
3. Unvented combustion appliances generate moisture as a byproduct of the combustion process. In particular, unvented gas fireplaces should not be installed within conditioned spaces.
4. Homeowners should periodically check under-floor spaces beneath accessible subfloors for sewage leaks, integrity of the ground cover, condensation, standing water, etc.
5. Sump pumps should be checked regularly by pouring water into the sump to assure the pump operates properly.

6. Whole house fans should only be operated with the windows open.
 7. Evaporative coolers add moisture to the home's air and should only be operated with windows open. They require annual maintenance.
 8. Clothes dryers should always be vented directly to the exterior.
 9. Frequently check clothes and dish washer connection hoses for wear. Consider installing flexible steel connection hoses.
- E. Maintain integrity of the vapor retarder (ground cover) on the soil in order to minimize moisture-related problems.
1. It is normal for moisture to collect beneath the vapor retarder. If mold appears under the retarder, it should not be considered a defect.
 2. Never remove any portion of the vapor retarder material.
 3. Do not use the under-floor space for storage, as this would damage the vapor retarder.
 4. If there is standing water on top of the vapor retarder, this is a problem that needs to be examined by a professional.

F. Basement Finish

Because there are a number of expansive soils and moisture-related issues, finishing basements is generally not recommended. For example, application of linoleum or carpet floor finishes could cause moisture-related problems by reducing the drying potential of the floor assembly. Any blockage of the floor air-circulation vents could increase the amount of water vapor beneath the floor and lead to moisture problems.

If you do finish your basement, you or your builder/remodeler should be fully aware of the problems and accept the risks associated with that task, and carefully design, construct and maintain the basement finish "system" to control moisture.

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