Technical Series 99-123

ENVELOPE MOISTURE PERFORMANCE THROUGH INFILTRATION, EXFILTRATION AND DIFFUSION—EMPTIED

Introduction

Condensation in exterior walls is often a problem when indoor air is humidified in cold climates. The problem has persisted ever since the introduction of thermal insulation. To ensure that moisture performance is satisfactory most designers of walls for cold climates use these rules of thumb:

- install a very impervious vapour barrier on the warm side of the wall;
- unless there is an air space with ventilation to the exterior, avoid installing layers of material that are less than 10 times as pervious as the vapour barrier in a wall outside the vapour barrier;
- locate no more than one-third of the thermal resistance of the wall inward from the vapour barrier; and
- make the wall airtight.

These rules do not account for the following significant effects:

- the ability of different building materials to store various amounts of condensed moisture without harm;
- mass transport of moisture through walls by air movement, in addition to vapour diffusion; and
- the effects of variable exterior conditions on moisture in the wall through the year.

The list could go on to include:

- wetting of exterior surfaces by precipitation;
- solar heat inputs;
- latent heat effects as water condenses, freezes, vapourizes, or sublimates; and
- redistribution of moisture in walls by capillary forces and gravity.

However, many of the differences in performance of wall designs could be anticipated if designers could evaluate three of the additional effects: wetting of exterior surfaces by precipitation; solar heat inputs; and latent heat effects as water condenses, freezes, vapourizes, or sublimates.

EMPTIED is a computer program that makes enough simplifying assumptions to be practical for designers to use in order to compare the relative effects of different climates, indoor conditions, wall materials and airtightness on wall performance.

Get with the Program

EMPTIED was developed to take the following factors into account:

- The level of absolute humidity in the interior is relevant to moisture performance of walls.

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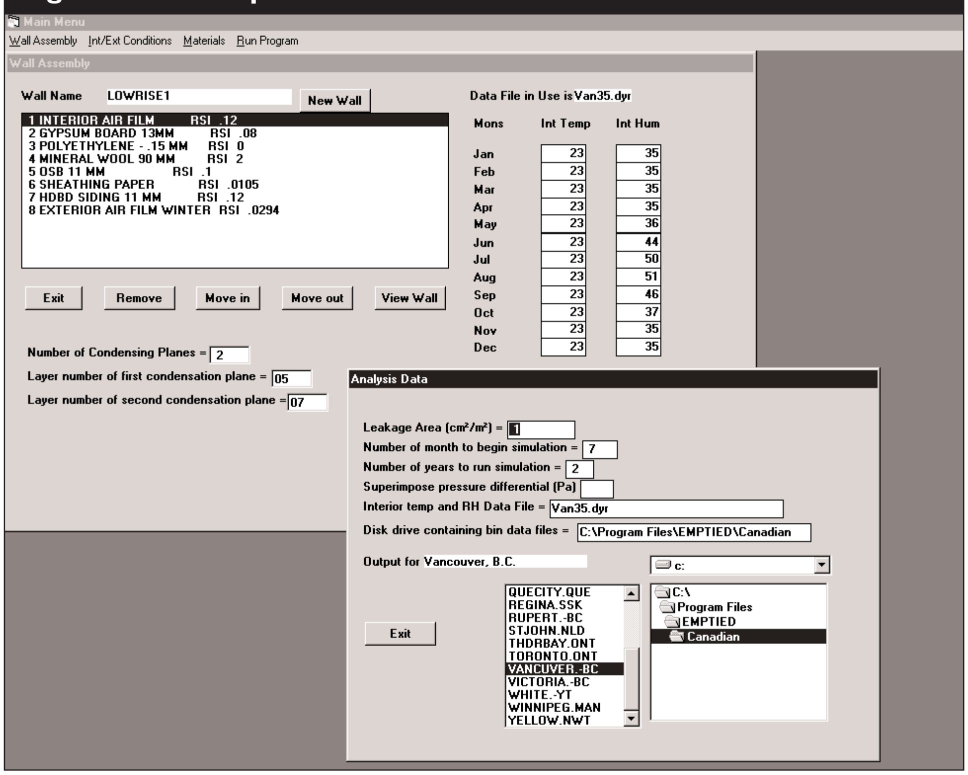
- As moisture enters a wall, either by air leakage or diffusion, if there are water absorptive materials in the wall that are at or below the dew point temperature of the indoor air, there will be condensation that will be stored until conditions change to favor drying.
- If materials below dew point temperature are non-absorptive or saturated, condensation will occur on the surfaces as ice or water, and may be removed (to the exterior, one hopes) or redistributed by downward flow.
- Conditions in the wall are not constant—each month is different, with different numbers of hours when the exterior conditions are within any particular range of temperature and humidity.
- Air leakage usually transports far more moisture into a wall than vapour diffusion. Most air-transported moisture is carried by air moving under relatively low pressure differences that occur most of the time, such as stack effect and superimposed fan pressures.
- Absolute prevention of condensation is not possible. However, if condensation is stored or removed without harm and does not accumulate from year to year, then performance is satisfactory.

EMPTIED takes the following information as inputs:

- Month-by-month indoor temperature and humidity conditions. The user can specify them or **EMPTIED** can calculate them assuming that humidity on the interior comes from ventilation air and normal occupancy, excluding mechanical humidification and unusual occupancies.
- Hourly bin data (counts of the number of hours in an average year that exterior conditions fall into particular combinations of temperature and humidity ranges) for exterior conditions. **EMPTIED** includes data for several North American cities so the user can select a city.
- Superimposed mechanical pressure or suction, if any (zero is the default).
- Equivalent leakage area per unit area of wall.
- Specifications for layers in the wall, including vapour resistance, maximum capacity for storage of moisture, thermal resistance, and thickness. **EMPTIED** supplies a menu of common materials with properties already specified, but the user can edit them and add new materials to the list.
- Identification of two layers in the wall where condensation is expected to occur.
- How many years to run the simulation, and what month to start with.

The data entry screens (but not the menus for selection of materials or other pre-defined data) are shown in Figure 1.

Figure 1: Main Input Screens



From this information, **EMPTIED** predicts condensation amounts using one-dimensional models for flows of air, moisture, and heat. Calculations are done month-by-month and bin-by-bin, and results are reported for each month. **EMPTIED** calculates temperatures, assuming steady state conditions for the duration of each bin, neglecting latent heat and heat transported by moving air. Air flows are calculated assuming that the driving force is superimposed pressure plus stack effect pressure over a one storey height (of 2.4 m—7 ft. 10 1/2 ft.) due to the temperature difference between interior and exterior for each bin.

Figure 2: Main Input Screen

Year 1
Wall type = LOWRISE1

Mon	Plane 1 - kg/m² Conden	Evap	Drain	Absorb	Plane 2 - kg/m² Conden	Evap	Drain	Absorb
Jul	0.0018	1.4468	0.0000	0.0000	0.0016	0.3244	0.0000	0.0000
Aug	0.0014	1.3438	0.0000	0.0000	0.0008	0.3307	0.0000	0.0000
Sep	0.0032	1.1612	0.0000	0.0000	0.0010	0.3497	0.0000	0.0000
Oct	0.0238	1.0120	0.0000	0.0000	0.0087	0.3526	0.0000	0.0000
Nov	0.1097	0.4819	0.0000	0.0000	0.0390	0.1647	0.0000	0.0000
Dec	0.1884	0.2096	0.0000	0.0000	0.0661	0.0669	0.0000	0.0000
Jan	0.2548	0.2272	0.0000	0.0276	0.0672	0.0737	0.0000	0.0000
Feb	0.0988	0.1477	0.0000	0.0000	0.0814	0.3595	0.0000	0.0000
Mar	0.0752	0.4046	0.0000	0.0000	0.0379	0.1333	0.0000	0.0000
Apr	0.0204	0.8569	0.0000	0.0000	0.0119	0.3043	0.0000	0.0000
May	0.0005	1.4170	0.0000	0.0000	0.0004	0.4856	0.0000	0.0000
Jun	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Output for Vancouver, B.C.
Interior Temp (°C) =Van35.dyr
Interior Dewpoint = Van35.dyr
Leakage Area (cm²/m²) = 1.00000

Plane 1 OSB 11 MM
Plane 2 HDBD SIDING 11 MM
Max Absorb Plane 1, kg/m² = 1.70
Max Absorb Plane 2, kg/m² = 0.00

Condensation Breakdown | Next Year | Previous Year | Graphs | Exit | Edit Wall

Print | Save to File

Vapour flows are calculated from the resistances specified for materials, the calculated temperatures, and resulting partial pressure of water vapour differences between layers, and between interior and exterior conditions, for each bin. Condensation is assumed to occur within the specified layers until their storage capacity is exhausted, and then to occur on the surfaces. If condensation during a month exceeds potential evaporation, stored moisture is carried over to the next month. However, moisture condensed on surfaces is assumed to be removed by drainage. Hours below freezing are reported for each layer. All layers are assumed to be dry to start with. The main screen that reports results, with links to graphs, subsequent years and a breakdown of condensation due to air leakage vs. diffusion is shown in Figure 2.

Clicking the **Condensation Breakdown** button produces the screen shown in Figure 3, where the amount of condensation due to vapour diffusion can be compared to that due to air leakage, and the number of hours each layer is below freezing in each month can be seen.

Clicking the **Graphs** button produces a bar graph showing amounts of condensation, amounts of stored condensation carried over to the next month, and amounts of surface condensation presumed to

Figure 3: Condensation Breakdown Report

CONDENSATION BREAKDOWN - AIR LEAKAGE - VAPOUR DIFFUSION
Condensation Breakdown applies to all years

Wall type = LOWRISE1

Mon	Plane 1 - kg/m² Air Lkge	Diffusion	Total	HAFZ	HBFZ	Plane 2 - kg/m² Air Lkge	Diffusion	Total	HAFZ	HBFZ
Jul	0.0018	0.0000	0.0018	744	0	0.0016	0.0000	0.0016	744	0
Aug	0.0014	0.0000	0.0014	744	0	0.0008	0.0000	0.0008	744	0
Sep	0.0032	0.0000	0.0032	720	0	0.0010	0.0000	0.0010	720	0
Oct	0.0238	0.0000	0.0238	744	0	0.0087	0.0000	0.0087	744	0
Nov	0.1097	0.0000	0.1097	720	0	0.0390	0.0000	0.0390	709	11
Dec	0.1884	0.0000	0.1884	744	0	0.0661	0.0000	0.0661	741	3
Jan	0.2548	0.0000	0.2548	733	11	0.0672	0.0000	0.0672	657	87
Feb	0.0988	0.0000	0.0988	672	0	0.0814	0.0000	0.0814	672	0
Mar	0.0752	0.0000	0.0752	744	0	0.0379	0.0000	0.0379	744	0
Apr	0.0204	0.0000	0.0204	720	0	0.0119	0.0000	0.0119	720	0
May	0.0005	0.0000	0.0005	744	0	0.0004	0.0000	0.0004	744	0
Jun	0.0000	0.0000	0.0000	720	0	0.0000	0.0000	0.0000	720	0

Output for Vancouver, B.C.
Interior Temp (°C) =Van35.dyr
Interior Dewpoint = Van35.dyr
Leakage Area (cm²/m²) = 1.0000

Plane 1 OSB 11 MM
Plane 2 HDBD SIDING 11 MM
Max Absorb Plane 1, kg/m² = 1.70
Max Absorb Plane 2, kg/m² = 0.00

Output Table | Next Year | Previous Year | Graphs | Exit | Edit Wall have drained from the wall, like the one shown in Figure 4. Next Year and Previous Year buttons produce a chart or graph corresponding to the one being displayed.

Software Limitations

EMPTIED has limitations that should be kept in mind. Initial moisture contents cannot be specified. Wind, sun, and rain are not taken into account. Air movement is taken to be the same through every layer, there are no convection loops within layers, or between the exterior and vented cavities. The maximum amount of moisture
a material can store safely is assumed to be the same amount at which condensation will start to occur on the surface. In reality, for some materials, the safe limit will be exceeded before condensation occurs on the surface. The user has to decide which two layers are most likely to be of interest. (Several runs specifying different layers, working from inside to outside may help.)

The user must also remember that surface condensation, instead of draining away out of the system as **EMPTIED** assumes, may soak into porous materials and remain. If these limitations are remembered, misleading interpretations of the results can be avoided, and most inaccuracies will be conservative.

Implications for Industry

EMPTIED is Windows-based and can be added to the toolbox of any designer who cares to go beyond the established rules of thumb. Once data is entered a typical run takes less than a minute. Because of **EMPTIED**'s limitations, it should not be expected to predict or explain absolute amounts of moisture in a wall, but it does offer an excellent comparative tool capable of addressing the following questions. If you have a wall design that you know from experience performs well in particular conditions, you can ask what will happen to performance if you:

- build it in another city with a different climate;
- humidify the interior in winter for comfort or by change to a humid occupancy;
- add insulation to the interior to reduce energy consumption and retain exterior appearance;
- modify components or add insulation for the next project; and
- add air conditioning (**EMPTIED** reports reverse condensation when the exterior is hotter and more humid that the interior).

On the other hand, if you have a wall that is not performing well, **EMPTIED** can help you compare the following approaches to improving the situation:

- adding insulation and cladding to the exterior;
- reducing air leakage;
- using vapour-barrier paint on the interior; and
- dehumidifying the interior.

For example, Figure 4 shows an Output Condensation Graph for a wall and minimum interior humidity in Vancouver. Figure 5 shows what **EMPTIED** predicts for the same wall and minimum interior humidity for Yellowknife.

Varying one input condition with **EMPTIED**, (such as interior humidity, or equivalent leakage area) will allow you to determine where a wall is most sensitive to changes in input parameters. For example, condensation amounts are apt to increase very sharply over a narrow range of leakage areas, without being very sensitive to changes in air leakage outside that range, while varying amounts of insulation make less dramatic differences.

The only cost associated with use of **EMPTIED** is the time it takes for the user to become acquainted with the program, gather input information and run an analysis. Other programs that evaluate annual moisture storage cycles in different assemblies are far more expensive and time consuming. They are practical only for large or unusual buildings, while EMPTIED is simple enough to use for any project warranting architectural design.

It has to be said that **EMPTIED** is like an eccentric colleague whose manners are rough, and whose dress is a little unconventional, but whose insights are valuable. It is less graceful than many Windows programs. **EMPTIED** has quirks that will be unexpected and frustrating initially (but also harmless). It is well worth the effort required to get acquainted.

Figure 4 : Output Condensation Graph

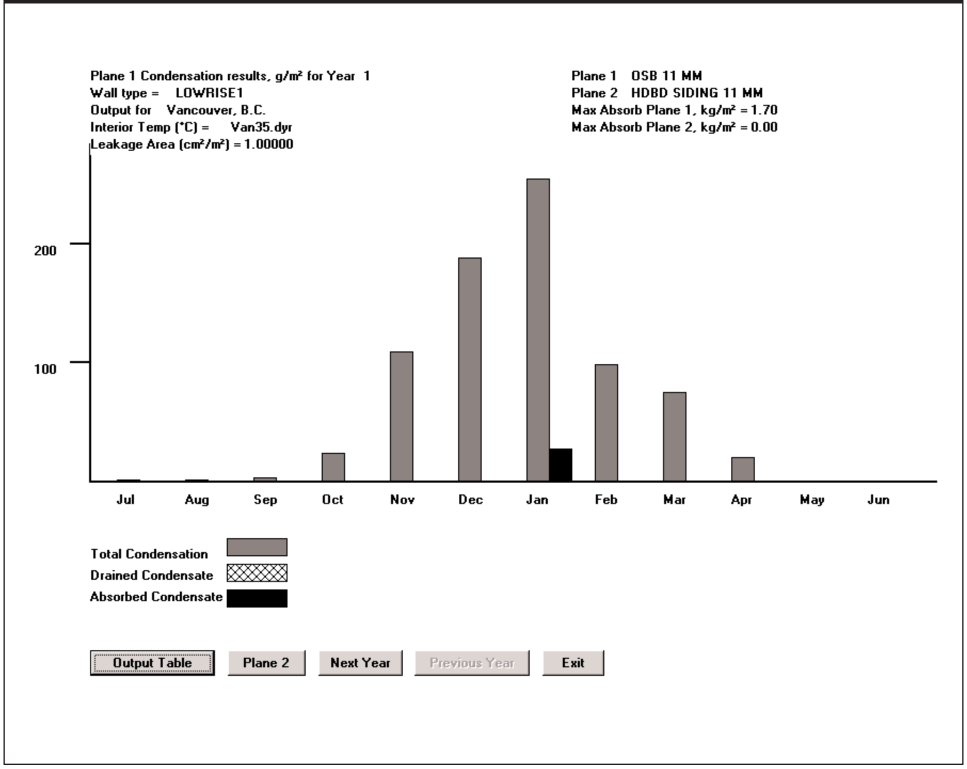
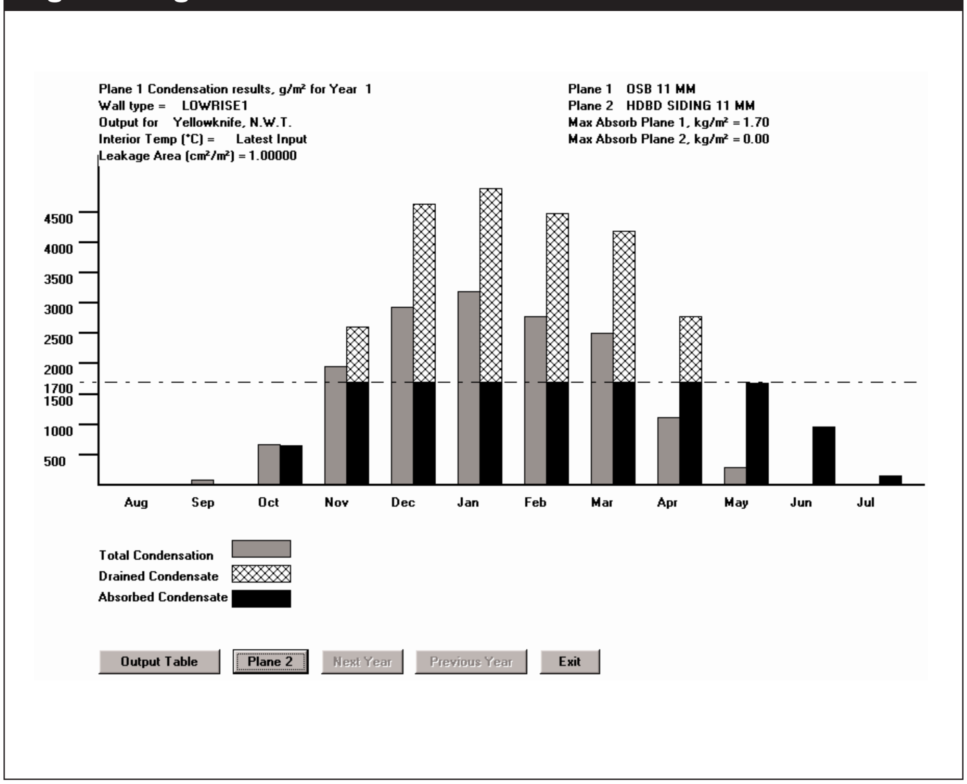


Figure 5: Figure 4 Re-calculated for Yellowknife



Project Manager: Jacques Rousseau

Program: EMPTIED (Version 3)

Research Consultants: Program designed by Handegord & Company and TROW Consulting Engineers Ltd. Windows version developed by IRC Building Sciences Group

A copy of this program and an operator's manual are available from CMHC by e-mail request to Jacques F. Rousseau jroussea@cmhc-schl.gc.ca

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