Modeling Heat & Moisture Transfer in Building Envelopes using WUFI®

WUFI®-ORNL/IBP is a computer-based model for simulating the one-dimensional hygrothermal (heat and moisture) behavior of building assemblies. WUFI is a powerful tool for estimating the likelihood for condensation to occur within walls, ceilings, and other assemblies. This model was jointly developed by Oak Ridge National Laboratory (Oak Ridge, TN) and the Fraunhofer Institute for Building Physics (Holzkirchen, Germany).

[The] WUFI-ORNL/IBP Model is a transient, one-dimensional heat and mass transfer model that can be used to assess the heat and moisture distributions for a wide range of building material classes and climatic conditions found in North America.

—Andre Desjarlais, Oak Ridge National Laboratory, et. al.*

Before the availability of WUFI, the Glaser Method was used to determine if and where a dew point condition existed in a building assembly. If no dew point was indicated, the assembly was considered "safe" from condensation problems. If a dew point was indicated, the designer could specify an appropriate vapor retarder and recalculate.

The primary shortcoming of the Glaser Method is that it assumes the building assembly is in steady-state with the environment. In essence, it assumes that the design temperatures and humidities will remain constant; furthermore, the design temperatures and humidities are normally chosen for the annual extremes for a particular location. These assumptions are "conservative": if no dew point problems are predicted, the designer is assured that condensation will not be an issue.

However, these assumptions often led to false positive errors: that is, the Glaser Method predicted dew point problems when, in fact, there were none. The errors resulted because building assemblies never reached steady-state conditions with the environment. These false positive results occurred mainly with building materials which had relatively high inertia to the transfer of heat and/or moisture.

For example, dew point calculations frequently predicted condensation problems with closed-cell spray polyurethane foam (SPF), when experience indicated otherwise. Reliance on the Glaser Method would result in avoiding many SPF applications which were actually perfectly "safe."

WUFI, on the other hand, does not assume steady-state conditions. Instead of a calculation based on one extreme climatic condition, WUFI calculates temperature and moisture profiles through the building assembly for every hour of an entire year. WUFI, thereby, takes into account materials which have high hygrothermal inertia.

Using WUFI is a multi-step process. In the first step, the designer needs to input the construction of the building assembly. This involves specifying the building materials used in the assembly, their physical properties, and the order in which they are installed. WUFI provides a substantial database of materials and properties for the designer.

Secondly, the designer specifies the time period of calculation (usually this is one year but different periods may be used).

Thirdly, the designer must specify exterior and interior conditions. WUFI has over 50 U.S. and Canadian cities preprogrammed into its database. The designer may select the coldest or hottest typical climatic year (i.e., the extreme tenth percentile hottest and coldest years for the last 30 years). WUFI then uses actual climatic data for the selected city. Interior conditions can be adjusted for variable moisture loads and temperatures.

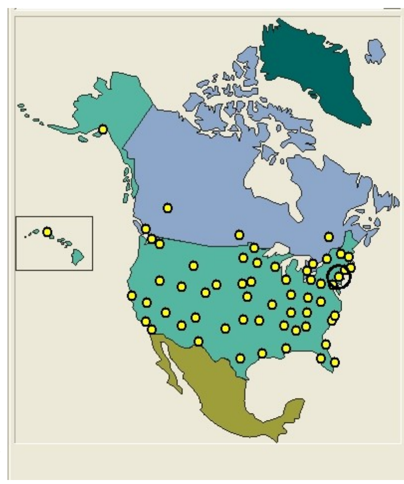

Figure 1. The WUFI database includes climate information from over 50 cities in North America.

Once all of the appropriate information is inputted into WUFI, the simulation is run. The primary WUFI output is a "real time" picture of the thermal and moisture profiles as conditions change through the year (or other simulation period).

*Karagoizis, Kuenzel, Holm and Desjarlais, "An Educational Hygrothermal Model WUFI-ORNL/IBP," undated article.

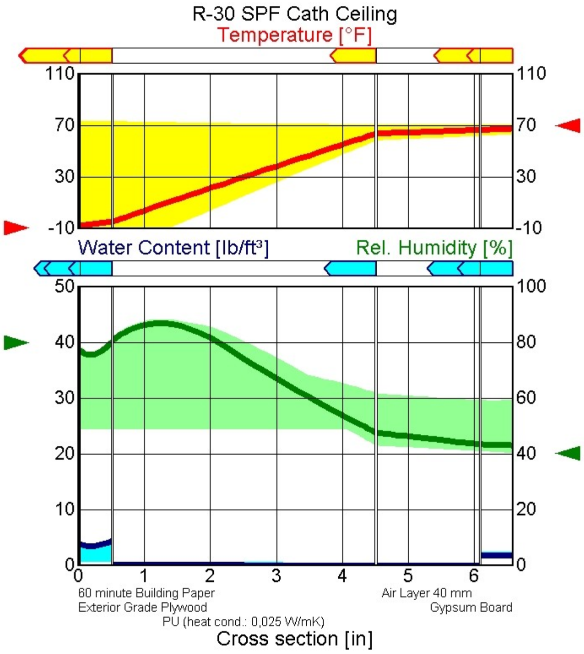

Figure 2: Typical WUFI simulation. Top (yellow) graph represents the temperature profile, bottom (green/blue) graph is the moisture/humidity profile. The dark curves (red and dark green) are the current profiles, the shaded regions (yellow and light green) represent the range of earlier profiles. This simulation was an R-30 SPF cathedral ceiling, north facing, in Edmonton, Alberta. This simulation was run from October 1 to March 2 of the "coldest" typical year.

In Figure 2 above, a conventional dew point calculation (Glaser Method) would indicate a false positive condensation problem, suggesting the need for a vapor retarder or an alternate construction. The WUFI simulation indicates there is no condensation problem and a vapor retarder is unnecessary.

The WUFI model is adept at comparing "what-if" scenarios. For example, the Figure 3 shows two simulations, side by side. The left-hand chart shows profiles for an R-30 cathedral ceiling which is composed of two inches of SPF and a 3 1/2-inch glass fiber batt (on the warm side). The right-hand chart shows the profiles of the same R-30 cathedral ceiling using only SPF insulation. The simulation was for a north facing assembly in Edmonton, Alberta.

WUFI simulations produce a wealth of data which may be formatted and studied in a variety of ways. Designers can use this powerful tool to reliably determine how a particular building assembly will perform under transient moisture and thermal drives; this is a capability lacking with former design methods.

Deer Ridge Consulting utilizes WUFI to assist designers and advise our customers on satisfactory designs, while avoiding potential problems.

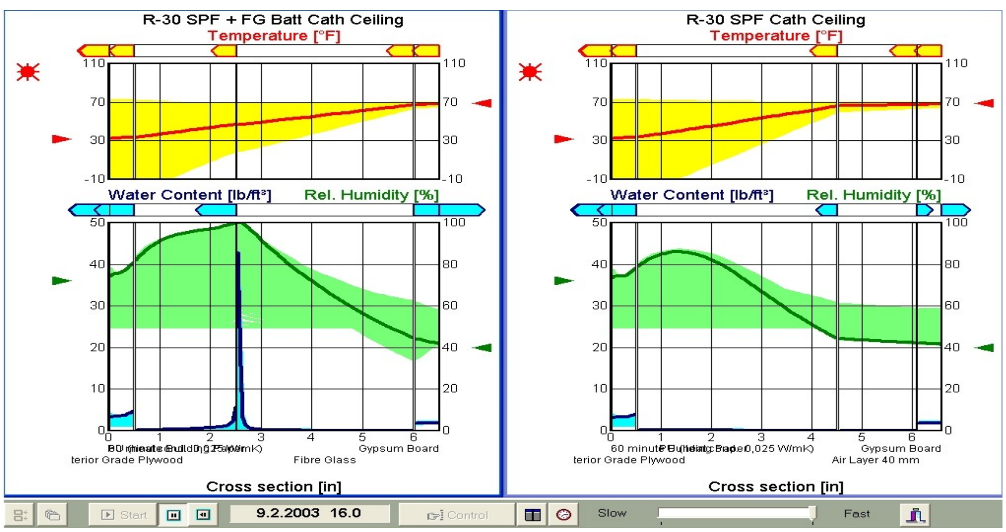

Figure 3: "What-If" Scenario. Note high humidity levels in the left-hand chart and the blue spike indicating a high water content. The conclusion is that condensation is a potential problem in the SPF-glass fiber batt assembly whereas the all-SPF assembly is "safe."

Additional information may be obtained from the Oak Ridge National Laboratory web site at:
www.ornl.gov/sci/btc/apps/moisture/

or the Fraunhofer Institute for Building Physics web site at:
www.hoki.ibp.fhg.de/wufi/wufi_frame_e.html

Deer Ridge Consulting, Inc.
505 Deer Ridge Lane
Ararat, VA 24053
276-755-9162 **www.deer-ridge-consulting.com**