Preface

by Heinz R. Trechsel[1]

PURPOSE OF THE MANUAL

In ASTM Manual MNL 18, *Moisture Control in Buildings,*[2] Mark Bomberg and Cliff Shirtliffe, in their chapter "A Conceptual System of Moisture Performance Analysis," make the case for a rigorous design approach that "should involve computer-based analysis of moisture flow, air leakage, and temperature distribution in building elements and systems." In the Preface to the same manual, I state that one objective of Manual 18 is to help establish moisture control in buildings as a separate and essential part of building technology.

In 1996, the Building Environment and Thermal Envelope Council (BETEC)[3] conducted a Symposium on Moisture Engineering. The symposium presented an overview of the current state-of-the-art of moisture analysis and had a wide participation of building design practitioners. The consensus of the participants was that moisture analysis was now practical as a design tool, and that it should be given preference over the simple application of the prescriptive rules. However, it was also the consensus that the architect/engineer community was not ready to fully embrace the analytical approach. Thus, both the building research and the broader building design community recognized the need for moisture analysis and for a better understanding of currently available moisture analysis methods.

The concerns for moisture control in buildings have increased significantly since the early 1980s. One sign of the increased concern is the number of research papers on moisture control presented at the DOE/ASHRAE/BETEC conferences on "Thermal Performance of Exterior Envelopes of Buildings" from 8 in 1982 to 17 in 1992 and to 27 directly related to moisture in 1998. Another measure is that the Building Environment and Thermal Envelope Council held four conferences/symposia from 1991 through 1999, and only two between 1982 and 1990.

In response to these developments ASTM Committees C16 on Thermal Insulation and E06 on Performance of Buildings have agreed to co-sponsor the preparation and publication of this new manual to expand and elaborate on the relevant chapters of MNL 18: Chapter 2, "Modeling Heat, Air, and Moisture Transport through Building Materials and Components," and Chapter 11, "Design Tools." The objective of this manual, then, is to familiarize the wider building design community with typical moisture analysis methods and models and to provide essential technical background for understanding and applying moisture analysis.

THE CURRENT PRESCRIPTIVE RULES TO PREVENT MOISTURE PROBLEMS IN BUILDING ENVELOPES

In 1948, the U.S. Housing and Home Finance Agency (a forerunner of the current Federal Housing Administration) held a meeting attended by representatives of build-

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[2] *Manual on Moisture Control in Buildings, ASTM MNL 18,* Heinz R. Trechsel, Editor, Philadelphia, 1994.
[3] The Building Environment and Thermal Envelope Council is a Council of the National Institute of Building Sciences, Washington, DC.

ing research organizations, home builders, trade associations, and mortgage finance experts on the issue of condensation control in dwelling construction.[4] The focus of the meeting was on vapor diffusion in one- and two-family frame dwellings in cold weather climates. The consensus and result of that meeting was the Prescriptive Rule to place a vapor barrier (now called a vapor retarder) on the warm side of the thermal insulation in cold climates. The meeting also established that a vapor barrier (retarder) means a membrane or coating with a water vapor permeance of one Perm or less. One Perm is 1 $g/h{\cdot}ft^2{\cdot}in.Hg$ (57 $ng/s{\cdot}m^2{\cdot}Pa$). The rule was promulgated through the FHA Minimum Property Standards.[5] It still is referenced unchanged in some construction documents.

The 1948 rule was based on the assumption that diffusion through envelope materials and systems is the governing mechanism of moisture transport leading to condensation in and eventual degradation of the building envelope. Since 1948, and particularly since about 1975, research conducted in this country and abroad has brought recognition that infiltration of humid air into building wall cavities and the leakage of rainwater are significant, in many cases governing mechanisms of moisture transport. Accordingly, the original simple rule with a limited scope has been expanded to include air infiltration and rainwater leakage, and to cover other climates and building and construction types. The current, expanded prescriptive rules can be summarized as follows:

- install a vapor retarder on the inside of the insulation in cold climates,
- install a vapor retarder on the outside of the insulation in warm climates,
- prevent or reduce air infiltration,
- prevent or reduce rainwater leakage, and
- pressurize or depressurize the building so as to prevent warm, moist air from entering the building envelope.

The current expanded rules have greatly increased the validity and usefulness of the prescriptive rules. However, the rules still do not fully recognize the complexities of the movement of moisture and heat in building envelopes. For example:

- The emphasis on either including or deleting a separate vapor retarder is misplaced, and the contribution of the hygrothermal properties of other envelope materials on the moisture flow are not considered. In fact, incorrectly placed vapor retarders may increase, rather than decrease, the potential for moisture distress in building envelopes.
- Climate as the only determining factor is inadequate to establish whether a vapor retarder should or should not be installed. Indoor relative humidity and the moisture-related properties of all envelope layers must also be considered.
- The two climate categories "cold" and "warm" have never been adequately or consistently defined, and large areas of the contiguous United States do not fall under either cold or warm climates, however defined. For example, ASHRAE,[6] in 1993, used condensation zones based on design temperatures. For cold weather, Lstiburek[7] suggests 4000 Heating Degree Days or more, and the U.S. Department of Agriculture[8] uses an average January temperature of 35°F or less. For warm climates, ASHRAE[9] established criteria based on the number of hours that the wet bulb temperature exceeds certain levels, Odom[10] suggests average monthly latent load greater than

[4] Conference on Condensation Control in Dwelling Construction, Housing and Home Finance Agency, May 17 and 18, 1948.

[5] HUD Minimum Property Standards for One- and Two-Family Dwellings, 4900.1, 1980 (latest edition).

[6] ASHRAE, *Handbook of Fundamentals,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, 1993.

[7] Lstiburek, J. and Carmody, J., "Moisture Control for New Residential Buildings," *Moisture Control in Buildings, MNL 18,* H. R. Trechsel, Ed., American Society for Testing and Materials, Philadelphia, 1994.

[8] Anderson, L. O. and Sherwood, G. E., "Condensation Problems in Your House: Prevention and Solutions," Agriculture Information Bulletin No. 373, U.S. Department of Agriculture, Forest Service, Madison, 1974.

[9] ASHRAE, *Handbook of Fundamentals,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, 1997.

[10] Odom, J. D. and DuBose, G., "Preventing Indoor Air Quality Problems in Hot, Humid Climates: Design and Construction Guidelines," CH2M HILL and Disney Development Corporation, Orlando, 1996.

average monthly sensible load for any month during the cooling season, and Lstiburek[11] suggests defining warm climate as one receiving more than 20 in. (500 mm) of annual precipitation and having the monthly average outdoor temperature remaining above 45°F (7°C).

Over the last 20 years or so, building researchers have tried to refine the definitions of cold and warm climates. Except for the efforts of Odom and Lstiburek (for which the jury is still out), not much progress has been made. In the meantime, much progress has been made in the development of analytical methods to predict surface relative humidities, moisture content, and even the durability performance of building envelope materials.

The above suggests that the prescriptive rules alone will not assure that building envelopes are free of moisture problems. Accordingly, and consistent with the consensus of the 1996 BETEC Symposium participants, we must look to job specific moisture analysis methods and models for the solution to reduce or eliminate moisture problems in building envelopes. This does not mean that the traditional prescriptive rules should be ignored or that they should be violated without cause. They should, however, be used as starting points, as first approximations, to be refined and verified by moisture analysis. This, then, is analogous to the practice in structural design, where, for example, depth-to-span ratios are used as first approximations, to be refined by analysis. Which is, very much simplified, what Bomberg and Shirtliffe advocate in Manual 18.

ANALYTICAL METHODS AND MODELS AND THEIR LIMITATIONS

The progress made in the development of computer-based analysis methods, or models since the publication of MNL 18 in 1994, has been spectacular. At last count, there exist now well over 30 models that analyze the performance of building envelopes based on historical weather data, and new and improved models are being developed as this manual goes to press. The models vary from simplified models useable by building practitioners on personal computers to sophisticated models that require specially trained experts and that run only on mainframe computers.

The simpler models may or may not include the effect of moisture intrusion due to air and water infiltration. The more sophisticated models are excellent tools for building researchers and, as a rule, include the effects of rainwater leakage and air infiltration. As mentioned above, air infiltration and water leakage are significant causes of moisture distress in building envelopes. This would seem to imply that only models that include these two factors are useful to the designer. However, this is not necessarily so for the following reasons:

- The input data for air infiltration and water leakage are unreliable. Infiltration and leakage performance data for various joint configurations and for entire systems are generally unknown. Also, much of the performance of joints depends on field workmanship and quality control over which the designer seldom has significant control.
- Air infiltration and rainwater leakage, unlike diffusion, occur at distinct leakage sites. These are seldom evenly distributed over the entire building envelope. Accordingly, the effect of air and water leaks are bound to be localized with the locations unknown at the design stage.
- Both air and water leaks are transitional in nature, with durations measured in hours, days, or weeks. Rainwater leakage depends on wind direction, and rainfalls one day may not fall again during the next day or week. Air infiltration depends on wind direction. Moist air moves into the envelope one day; the next day dry air may enter the envelope and wetting turns to drying. In contrast, diffusion mechanisms operate generally on a longer time horizon, frequently for weeks, months, or over an entire season.

Although models that include air infiltration and rainwater leakage are excellent research tools, models that do not include these transport mechanisms are still most

[11] Lstiburek, J., "Builder's Guide for Hot-Humid Climates," Westford, 2000.

useful for the designer/practitioner provided that their limitations are recognized and proper precautions are taken to reduce or eliminate air infiltration and water leakage.

The use of moisture analysis alone does not guarantee moisture-resistant buildings. Careful detailing of joints and the use and proper application of sealants and other materials are necessary. The issues of field installation and field quality control, mentioned above, must be addressed adequately by the designer and specification writer. For example, for more complex and innovative systems, specifying quality control specialists for inspecting and monitoring the installation of envelope systems in Section 01450 and specifying that application only be performed by installers trained and approved or licensed by the manufacturer will go a long way towards reducing moisture problems in service. Also important are operation and maintenance, both for the envelope and for the mechanical equipment. Face-sealed joints need to be inspected and repaired at regular intervals. If pressurization or depressurization are part of the strategy to reduce the potential for moisture distress, documentation of proper fan settings is critical. However, these concerns are outside the scope of this manual and will not be discussed further.

Moisture analysis is still an evolving art and science. While great advances have been made in the development of reliable and easy-to-use models and methods, some input data needed for all the models are still limited:

Weather Data

Appropriately formatted data are available only for a restricted number of cities. However, it is generally possible to conduct the analysis for several cities surrounding the building location and to determine the correctness of the assumptions with great confidence. Also, the data currently available were developed for determining heating and cooling load calculations; their appropriateness for moisture calculations has been questioned. Chapter 2 of this manual provides new weather data specifically developed for moisture calculations.

Material Data

Data on the hygrothermal properties of materials are available only for a limited number of generic materials. A major effort is currently under way by ASHRAE and by the International Energy Agency to develop the necessary extensive material database. Some of the most recent material data are included in Chapter 3 of this manual.

Failure Criteria

Reliable failure criteria data are available only for wood and wood products, and even for these the significant parameter of length of exposure has not been studied to the desirable degree. Chapter 4 of this manual discusses these criteria.

Despite these concerns about the application of moisture models, designs based on rigorous analysis are bound to be far more moisture resistant than designs based on the application of prescriptive rules alone. The authors of this manual hope that it will encourage building practitioners and students to conduct moisture analysis as an integral part of the design process. The more widespread use of moisture analysis to develop building envelope designs will then in turn provide an added incentive for model developers to improve their models, for producers to develop the necessary data for their materials, and for researchers to establish new databases on weather data better suited for moisture calculations.

CONCLUSIONS

One objective of this manual is to provide the necessary technical background for the practitioner to understand and apply moisture analysis. In addition, two models are discussed in detail to familiarize the practitioner with the conduct of typical computer-based analysis. The selection of the two models is based on ready availability and on ease of operation. The two models are included on a CD ROM disk enclosed in the pocket at the end of the manual. Also included on the disk are two programs to convert various properties of air. Based on the information provided, the reader should be able to start his or her own hands-on training in moisture analysis.

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Editor

Acknowledgments

THIS MANUAL IS NOT THE WORK of a single person. It is the result of cooperation between the authors of individual chapters, a small army of reviewers, staff support people, and the editor, all working together.

Thus, my utmost thanks to the authors who prepared their chapters. Each one is a leading expert in his field, and the chapters are at the forefront of the current state-of-the-art in moisture analysis. Next, I want to thank the reviewers, who generously gave of their time and whose comments and suggestions improved the individual chapters and the utility of the manual. The names of the reviewers are listed below. My appreciation also goes to the executive committees of the two sponsoring ASTM Committees, C16 on Thermal Insulation and E06 on Performance of Buildings.

Aside from the technical inputs mentioned above, the manual would not have been born without the untiring support of ASTM's staff: Kathleen Dernoga and Monica Siperko, who shepherded the preparation of the Manual through all its phases and provided much needed administrative support; and David Jones, who capably edited the final drafts of the individual chapters. To all of them my most sincere thanks and appreciation.

Our special thanks also to Mr. Rob Davidson of the Trane Company and to Dr. Carsten Rode of the Technical University of Denmark for their permissions to reproduce the conversion programs. Also to Dr. James E. Hill, Deputy Director of the Building and Fire Research Laboratory at the National Institute of Standards and Technology in Gaithersburg, Maryland, to Prof. Dr. -Ing. habil. Dr. h.c. mult. Dr. E.h. mult. Karl Gertis, of the Fraunhofer Institute für Bauphysik in Holzkirchen, Germany, and to Dr. Andre Desjarlais of Oak Ridge National Laboratory at Oak Ridge, Tennessee, for their permission to reproduce the two moisture analysis programs. I'm also much indebted to Mr. Christopher Meyers of the Engineering Field Activity Chesapeake, Naval Facilities Engineering Command for coordinating the four programs and preparing a user friendly interface for the CD-ROM.

Finally, but by no means least, I was encourged by two good friends to prepare this manual long before the first word was ever written. Ev Shuman of Pennsylvania State University and Reese P. Achenbach, formerly Chief of the Building Environment Division at the National Institute of Standards and Technology, assisted me in formulating the initial plan for the manual. Both are no longer among us. However, their suggestions have, to a large degree, shaped the manual you hold in your hands. My thanks to them.

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