HYGROTHERMICS
»WATER IS FLUID, SOFT AND YIELDING. BUT WATER WILL WEAR AWAY ROCK.«

LAO TZU
The Hygrothermics Department specializes in the analysis of transient hygrothermal behavior of building materials, building components and constructions. This work also includes the conduct of laboratory materials testing and outdoor tests under defined conditions, along with creation and trials of new test procedures. A considerable portion of the activities in hygrothermics also consists of developing and applying numerical simulation models. The department’s long-standing experience with experimental and computational investigative methods permits a comprehensive assessment of ways of protecting building structures from moisture due to climatic impacts. It also permits targeted optimization of construction products, including development of new construction materials and building systems.

Assessing thermal and moisture protection of building structures involves analysis of the transient hygrothermal conditions in and on building materials and building components, and analysis of how these conditions affect usability. Assessment criteria include thermal and hygienic requirements (e.g. thermal insulation unimpaired by moisture, prevention of mold growth) and freedom of damage to building components (e.g. elimination of moisture accumulation, corrosion, frost damage or loss of strength). Along with hygrothermal material properties, ambient weather conditions and indoor air conditions play a major role as well. Accordingly, to ensure that a building is in proper working order, both the construction design and the selection of materials must be analyzed as a function of the respective climate zone and conditions of use.

The main goal of product development is to improve economic efficiency and durability while optimizing the thermal and moisture performance of construction products. The department’s core competence areas provide the foundation for this, aided by experimental facilities and hygrothermal simulation tools that are kept updated on an ongoing basis. An outstanding example of this kind of product development is the humidity controlled vapor retarder now available for sale in many countries.

Knowledge transfer includes worldwide seminars and the preparation of materials and documentation for the training of craftsmen, architects and engineers. Additional building blocks are participation in national and international standardization bodies (DIN, CEN, WTA, ASHRAE, ASTM) and involvement in international standard reference works for engineers such as e.g. the ASHRAE Handbook of Fundamentals. The immediate transfer of research findings to practical applications in the field usually takes place through lectures and publications held and presented in both German and English.

**FOCAL TOPICS**

- **CLIMATE-RELATED HEAT AND MOISTURE CONTROL**
- **PRODUCT DEVELOPMENT**
- **KNOWLEDGE TRANSFER**
F I E L D S

• THERMAL PARAMETERS AND LABORATORY CLIMATE SIMULATION
• HYGROTHERMAL PROPERTIES AND OUTDOOR DURABILITY TESTS
• DEVELOPMENT OF HYGROTHERMAL MODELS AND USER SOFTWARE
• MOISTURE CONTROL AND CONSTRUCTION IN OTHER CLIMATIC ZONES
Originally located exclusively in Holzkirchen, Germany, in May 2008 the department grew through the addition of the Stuttgart group on “thermal parameters and climate simulation.” This way, now all of the material parameters required for hygrothermal simulation can be determined within the department. Conversely, the steady state thermal testing methods in place in Stuttgart are supplemented by transient procedures introduced from Holzkirchen. Moreover, the departmental emphasis to date - on opaque building shells - is now supplemented through addition of transparent building components through certified test facilities in Stuttgart. Another benefit of the expansion is the linkage between computational and laboratory climate simulation. Hygrothermal simulations help calculate maximum thermal and moisture-related loads for building components under practical conditions; these loads provide a basis for accelerated weathering experiments in the laboratory. Conversely, the leakage rates measured in laboratory climate simulation due to manufacturing-related imperfections in the building components tested can serve as inputs for hygrothermal simulation calculations. This way, manufacturing quality can be factored into computational predictions of the behavior of building structures as a function of temperature and humidity conditions. These predictions provide the basis for estimations concerning the durability and the risk of damage or failure.

The accredited testing laboratory at our location in Holzkirchen measures the moisture-proofing qualities of materials in accordance with international product standards or technical approvals. The lab is also where all of the hygric material parameters are measured for computer simulations. It offers an opportunity to investigate climate-related moisture transfer and natural aging of construction materials, taking outdoor climate conditions into effect.

The WUFI® software family is a major asset to the department. In cooperation with partner institutions in Europe, North America and the Far East, models are developed to explain the hygrothermal behavior of building structures and prepared for use in a practical setting. This work also includes providing worldwide user seminars and specialized workshops.

Thanks to globalization, construction products native to one country are increasingly put to use in other climatic zones. Accordingly, a growing area of responsibility for the department is to provide moisture control assessments and to tailor these products to new climates. The same applies to the transfer of hygrothermal models to business areas beyond construction.

1 Test station for testing window air- and water-tightness.
2 Thermal bridge calculation for an aluminum facade structure.
3 Triple-chamber climate simulator for thermal (-30°C to 80°C) and humidity (5% to 95% RH) testing.
4 Removal of weathered wall test panels in an air-conditioned test hall to determine moisture content through weighing.
5 Nuclear magnetic resonance equipment used to determine the distribution of moisture in porous construction materials.
6 In-situ measurements of the adhesive strength of external insulation systems.
Thermal parameters – climate simulation
The thermal laboratory at the location in Stuttgart is recognized by the Deutsches Institut für Bautechnik (DIBt) as a testing facility under applicable building regulations (LBO / BRL) and is recognized as Notified Body No. 1004 for products under EN 14351-1 to the terms of the Construction Products Law (BauPG). It has been granted flexible accreditation under DIN EN ISO/IEC 17025 by the German Accreditation System for Testing (DAP) under accreditation no. DAP-PL-3743.27. Numerous parameters are identified for the characterization of insulation and construction materials, such as:
- Thermal conductivity
- Heat transfer resistance (R-value)
- Thermal transmittance (U-value)
- Heat dissipation
- Dimensional stability under thermal load conditions
- Compressive stress and tensile strength, adhesive strength
- Freeze-thaw cycle resistance
- Moisture absorption through vapor diffusion in temperature gradients
- Linear drag
- Air permeability
- Driving rain resistance
- Wind resistance

Other measurements carried out there include radiation-based, integral methods such as:
- Surface emissivity (thermal principle),
- Total energy transmission (calorimetric principle),
- Thermography of building components.
Also available are a variety of pieces of solar equipment for the measurement of usability of construction elements under exposure to the sun.

Hygrothermal properties – material behavior under moisture load conditions
The hygrothermal laboratory has been granted flexible accreditation by the German Council of Accreditation (DAR) under DIN EN ISO 17025. The testing includes determination of:
- Water vapor diffusion parameters (μ-value, s_d-value)
- Capillary water absorption (A-value)
- Reference moisture content (U_98)
- Sorption isotherms and moisture retention functions
- Capillary transport coefficients
- Apparent density and porosity
- Thermal and hygric material expansion

Methods are modified or developed in the context, for instance, of research projects to determine surface moisture on façades, or to develop standardized methods to identify the drying behavior of building materials. Outdoor experiments are also conducted on test walls and small-sized material specimens to investigate the aging behavior and durability of materials. Outdoor experiments are also used to identify the potential pollution of façade coatings and roofing tiles. Wall panels subjected to the elements on an east-west-oriented test stand can also be investigated and compared in terms of the moisture content under natural climate conditions.

Development of hygrothermal models and user software (WUFI® family)
Often, inadequate moisture protection leads to increased heat loss through transmission; but it can also cause damage to the building shell due to mold, frost, corrosion or decay. Most damage can be prevented, though, through careful planning and execution of moisture control design and the right choice of materials. Until now, moisture control has typically been thought of as protection against condensation in the winter. The traditional assessment method for condensation is the steady-state diffusion calculation commonly called Glaser method (EN ISO 13788). Yet this method is limited to winter-time condensation resulting from the diffusion of moisture from the interior space – while other factors such as the effects of driving rain or construction moisture are not considered.

Today, thanks to years of work spent developing hygrothermal simulation software, we can arrive at a realistic calculation of the hygrothermal storage and transport processes in multi-layer building components under real climate conditions. This enables a more comprehensive approach to moisture protection
of building envelope assemblies that includes phenomena such as:
- Drying of building moisture
- Absorption of driving rain
- Summertime condensation
- Condensation on exterior building components due to night-time over-cooling
- Rising damp
- Energetic impacts of moisture

Ever since licensing of the WUFI® software family began for external users in 1995, demand for this application has quickly grown worldwide. Intensive program maintenance ensures that the latest findings in the physics of construction are implemented, with material and climate databases updated on an ongoing basis. In cooperation with international research institutes, new models are also being developed, e.g. for the simulation of aging, corrosion or convection. In the future, these models hold promise to permit improved evaluation and assessment of hygrothermal simulation results.

Moisture control and construction in other climatic zones
The laws of nature may be the same everywhere, but building regulations and traditions in other countries vary considerably from those here in Germany. Often, the variations are a function of different climate conditions. While fireproofing and soundproofing function more or less the same regardless of climate, usually the specifications for heat insulation and moisture protection cannot be easily transposed from one country to another. Through numerous international projects and product-development initiatives and cooperation partnerships worldwide, the Hygrothermics Department has extensive expertise and tools at its disposal with which to assess moisture control design in buildings in all climate zones.

Its routine investigations include:
- Analysis of climate data and creation or review of meteorological data records for hygrothermal simulation
- Assessment of the risk of condensation through vapor diffusion from inside (e.g. cold regions and mountains) or from outside (e.g. tropical or subtropical areas) a structure
- Determination of the moisture load caused by drying building moisture and planning of measures to remedy this
- Assessment of the hygrothermal loads on the building shell due to precipitation and wind (e.g. driving rain) and the radiation of the sun
- Lifespan forecasting and durability assessments for building structures for other climate zones through comparison of hygrothermal loads in the target region with conditions in the country of origin.

Sample projects
- Development of a physical, regulatory and cultural guideline for use by German companies entering the Japanese market
- Planning of timber frame buildings optimized for climate conditions in Japan
- Investigation of the suitability and adaptability of insulated composite systems to climate conditions in India
- Measurement of vapor barriers for industrial halls in Russia
- Assessment and improvement of hygrothermal conditions in membrane roof construction of the airport building in Bangkok
- Hygrothermal optimization of wall panels for residential buildings in Dubai
- Review of the durability of façade systems under Irish climate conditions

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