

PREPARATION OF THE THIRD EDITION OF THE NATIONAL PROGRAM
PLAN FOR THE THERMAL PERFORMANCE OF BUILDING
ENVELOPE SYSTEMS & MATERIALS

ABSTRACT

Eugene Stamper
New Jersey Institute of Technology
Department of Mechanical Engineering
Newark, New Jersey 07102

The Research Coordinating Committees (RCC) of the Building Thermal Envelope Coordinating Council (BTECC) have appointed sub-committees charged with preparation of the chapters of the latest edition of the National Program Plan (NPP). This paper outlines the scope of the material to be presented in the NPP and presents a progress report on those chapters where the research needs are delineated.

The chapters are being written on: (a) Thermal Performance of whole Buildings, (b) Moisture Control in Buildings, (c) Heat and Mass Transfer Elements, (d) Air Infiltration and Ventilation, (e) Roofing Design and Construction, (f) Fenestration, thermal performance and daylighting, (g) Materials.

Research needs are enumerated for Whole Buildings, moisture control, heat and mass transfer.

The Third Edition of the National Program Plan
for the Thermal Performance of Building
Envelope Systems and Materials

by Eugene Stamper

New Jersey Institute of Technology
Newark, New Jersey 07102

INTRODUCTION

The Third Edition of the National Program Plan for the Thermal Performance of Building Envelope Systems and Materials will update the two previous plans. The first was issued jointly by the U.S. Department of Energy and the Department of Commerce in January, 1979¹. The second plan was released by Oak Ridge National Laboratory² in March 1982. The objectives of each document were to describe the research, development and verification activities required to produce the technical data, test procedures, guidelines, and consensus standards needed by manufacturers, designers, and builders to produce buildings of high energy efficiency. Concurrently these buildings are required to meet safety, durability, habitability, and economic objectives. Another objective was to accelerate the transfer of research results and new technology so that they could become part of the building design process and be utilized in the building construction.

BACKGROUND

The first National Program Plan (NPP) was produced by a team of government engineers and scientists. Recognizing the need for broader participation, DOE/ORNL formed a committee consisting of representatives from manufacturers, consulting engineers, and academia to review the original program plan. This committee made a number of recommendations relative to the scope, format, and program emphasis of the NPP. It also suggested that the second release of the NPP include greater cooperation between the public and private sectors in the planning and execution of energy conservation research, in the retrieval and dissemination of technical information and in the preparation of standards and regulations. These recommendations were incorporated in the second NPP².

A large number of industry, academic, and government experts prepared technical material for that revision. The second plan recognized that the development of new products

should be exclusively the role of industry, especially beyond the demonstration and working model stages.

Another important recommendation of the committee reviewing NPP1¹ was that there should be a Coordinating Council with broad participation which would act as a planning body and clearing house for research in the areas of building envelope research. This council now exists as the Building Thermal Envelope Coordinating Council (BTECC). Membership in BTECC consists of individuals, trade associations, manufacturers, and design professionals.

Responsibility for the preparation of the third edition of the National Program Plan on the Thermal Performance of Building Envelope Systems and Materials has been assigned to BTECC through a grant by Oak Ridge National Laboratory.

BTECC organized itself into Research Coordinating Committees (RCC's). Each RCC was given responsibility for writing a chapter of the NPP and formed sub-committees specifically charged with writing individual chapters. Participation has been quite broad and diverse.

ORGANIZATION OF THE NATIONAL PROGRAM PLAN

The major sections of the NPP are chapters on (a) Moisture Control in Buildings, (b) Roofing Design and Construction, (c) Air Infiltration and Ventilation, (d) Thermal Performance of Whole Buildings, (e) Fenestration, and daylighting, (f) Heat and Mass Transfer Measurements, (g) Materials.

The current scope represents a broadening of that of the previous NPP, since it now includes air infiltration³, indoor air quality⁴, passive solar heating⁵, and natural lighting⁶. These were excluded in NPP2. Life safety as affected by the design of the thermal envelope was also excluded in NPP-2 and is part of the scope of this document.

Whole Building Energy Performance

Building energy research has focused primarily on materials, equipment, as well as applications of renewable energy systems. These strategies need to be complemented with an understanding of how a building works as a whole, and how the interaction of building and occupants affect the whole building energy performance. Individual parts may be highly energy efficient, but when placed within the context of whole buildings, the results may not yield an effective energy solution. The whole may be more or less than the sum of the parts.

Research on Whole Building Energy Performance (WBEP) attempts to understand how the energy interactions within the whole building are as well understood as energy flows related to building elements. The research generates knowledge and data about the energy performance of whole buildings and enables designers and builders to provide cost effective solutions to the multitude of design alternatives.

NPP2 was one of the first documents to address WBEP research. In addition references (8), (9), (10) have reported on the importance of WBEP research.

The focus of WBEP research is to attempt to develop energy insights about buildings that lead towards significant improvements in energy efficient buildings beyond current levels. It is hoped that this research will result in significant building innovations and new knowledge about WBEP will emerge. It is anticipated that new forms of buildings and processes will emerge which are not yet perceived.

The term whole building is used to focus attention on the end product - a building. Inquiries into WBEP must recognize that the decision making processes, whether related to parts of sub-systems, building design, method of financing, priority setting, and building use, involve many people; design professional, contractors, owners, and finance institutions. Objectives are to understand the interrelationship between people, laws, which influence WBEP, to understand the interactions between sub-systems and climate occupant, as well as the impact of time requires a systems view of the process and the product. Interaction between systems is shown in Figure 1.

The components of WBEP research are:

1. Building sub-systems
2. Performance monitoring systems
3. Occupants systems interactions
4. Innovative building systems
5. The decision making system

1. Building Sub-Systems

This research focuses on major sub-systems such as:

1. structural sub-systems
2. envelope sub-systems, (roof, wall, floor, earth contact
3. interior partitions
4. mechanical systems and their controls
5. electrical systems and their controls

These systems must be viewed within the context of the building programming plan. Program plan issues include buildings configuration, surface to volume ratio, broad internal space organization and other design features such as atria and buffer spaces.

Interactions of each of the systems mentioned with each other and with climate can have major effects on building energy use. Some research in this area is underway, but more effort is needed.

2. Performance Monitoring

There have been a great number of buildings monitored in varying levels of detail. Recent advances and cost reductions in microprocessor technology have made it practical to study WBEP using data from detailed metering of buildings.

It must also be recognized that the design of monitoring systems and the use of monitoring results differ depending on the user of the information. For example, Utilities use the data for load forecasting and assessment of conservation strategies, professional societies used it as a basis for developing conservation standards and for developing design practise manuals. Architects and engineers use it for justifying and developing design decisions, manufacturers use the data for further development of products, contractors use it to develop marketing strategies and quality control measures, government may have the data for development of policy and determining priorities for further research.

3. Occupant-Systems Interaction

Occupant (including operating personnel) interaction with building sub-systems are related to environment qualities. Research in this area involves the disciplines of biology, psychology, and sociology. Initial research might focus on, "what is the difference in WBEP between an occupied and unoccupied building"? Further research might explore why supposedly identical buildings in the same climate perform so differently.

4. Innovative Building Systems

Up to now we have concerned ourselves with buildings more or less as we currently know them. There are on the horizon ideas, concepts and prototypes which suggest innovations in the building industry. These include:

Smart buildings. Buildings which sense and control physical sub-systems in response to measured, programmed, or observed conditions.

(b) Dynamic buildings. Buildings which anticipate changes in environmental conditions and modify their thermo physical properties and orientation according to predetermined optimal conditions.

(c) Community Scaled Energy Systems. Some systems, (water, energy conversion) may serve a small group of buildings while others serve communities or neighborhoods.

5. The Regulatory System

Laws, codes, regulations, and standards regulate the design, construction, and use of buildings. Research in this area focuses on the regulatory agencies and devices influence WBEP. How do zoning laws inhibit efficient WBEP? How do utilities influence building design, construction, and operation, and how does this influence manifest itself in WBEP?

6. The Decision Making System

We need to understand what WBEP information is currently used by various types of decision makers. If WBEP information is not used, why not?

MOISTURE CONTROL IN BUILDINGS

The main scope of this section of the NPP is to help organize research on moisture control in buildings with the aim of eliminating or minimizing the energy and material effects of moisture, and of optimizing comfort effects on the indoor environment.

The effect of normal living by a family of 4 has been estimated to produce 15 to 25 pounds of water per day. The 25 pound figure is associated with older homes. Simultaneously, the increased emphasis on energy conservation has resulted in much tighter home construction. Windows are tighter, doors are better fitting and vapor retarders are now the norm.

While moisture effects on materials research has a long history, is only relatively recently that moisture effects on construction indicate that moisture migration and change in state have induced deterioration, much of it hidden. Research needs to be directed at change in design and

construction procedures and also look at the degradation of materials over their lifetime.

External sources of moisture are precipitation and ground water. When combined with wind, moisture can penetrate exterior siding, even though the integrity of the siding may be intact. Ground water fed by hydrostatic pressure induces flow through cracks with migration of water over relatively large distances. The fundamental question is: If there is moisture where will it go and what will it do to the construction on individual materials and an interacting combinations of materials.

Recent Research

Luikov (1966)(11) described a mathematical approach to calculation of simultaneous moisture and heat flows through porous materials. Bomberg (1974) (12) and Anderlurd (1974) (13) developed computerized moisture analysis methods. This work was further advanced in Sweden by Andersson (14) and in Finland by Kohonen and Maatta (15). They require large amounts of material property data not currently available for most materials. Researchers in New Zealand use an approach to modeling which is simpler (Cunningham) (16).

Moisture Research Needs

Research in moisture is classified according to location within a home (a) attic spaces, (b) low slope roofs, (c) earth coupled spaces, and then looks at moisture management and needed instrumentation and measurement techniques. In this paper only some of these research needs will be highlighted.

- (a) Attic Spaces Based on detailed measurement carried out at Princeton University, Harrje (17), Dutt (18), and Cleary (19), and by Burch et.al (20) an assessment was made of further attic research needs. After a field survey to determine the percentage of U.S. housing stock affected by attic condensation problems, a model for predicting seasonal variation in roof moisture content needs to be developed. The model would then be verified through field experiments and ultimately develop design guidelines.

(b) Earth Coupled Spaces

These include basements, crawl spaces, slab on grade buildings and earth sheltered buildings. In each of these there is a potential for moisture gain throughout the year. The moisture problems

are related to the type of building foundation, climate, site conditions, and technique used during construction.

1. Field surveys to determine typical conditions in earth coupled spaces.
2. Development of ventilation strategies. If outdoor humid air migrates into the basement, increased ventilation will exacerbate the problem. If the outdoor humidity conditions are favorable and moisture comes through the walls or floor, increased ventilation will help.
3. Understanding air circulation patterns between basements and upper levels of the house.
4. Air quality is affected by release of radon through earth contact surfaces and by growth of molds and spaces.
5. Development of mathematical models.
6. Lab and field testing to determine effects of ground cover and slope, building design, location of vapor retarders.

(c) Instrumentation and Measurement

1. New instruments for needed measurement of relative humidity. There are many such instruments, but the accurate ones are relatively expensive.
2. Moisture content sensors of adequate accuracy and small enough so that the use of the sensor doesn't change the moisture characteristics of the building component.
3. Surface moisture measurement. No commercial instruments are currently available.
- (4) Measurement of moisture transport. There is no moisture equivalent of a heat flow meter.

HEAT AND MASS TRANSFER

Tests for steady state temperature conditions are used to measure R values, thermal transmittance (U), thermal conductivity (k). Field and laboratory measurement of these parameters differ in that exterior walls of real buildings seldom attain steady state conditions.

Laboratory measurements currently used include guarded hot plates (ASTM C177), and heat flow meters (ASTM C177).

Guarded hot boxes (ASTM C976) are used to measure heat transfer coefficients of composite wall systems. Currently, guarded hot box and calibrated hot box test methods are being altered to include testing of windows. It is not clear whether current standards are specific enough to assure that laboratories following test procedures will get reliable results.

In an effort to determine the variation of test results from one laboratory to another, a round robin for calibrated and guarded hot boxes was conducted in the early 1980's. Each laboratory tested 4 inch thick polystyrene beadboard. The measured resistances varied by $\pm 8\%$ at the 95% confidence level.

What is needed now is a similar round robin on composite wall assemblies. It is expected that the variance will be greater, but it is not possible to predict whether existing techniques are adequate for complex composite wall assemblies.

When walls and windows are added to composite walls, current ASTM test methods, can not be used to measure average heat transmission values. Since doors and windows represent a large percentage of the heat loss or gain through walls, methods to accurately measure heat transfer coefficients are needed. These tests will also produce results to verify analytical models.

As innovative walls systems are developed, additional testing will be needed to confirm analytical models. comparative tests will identify those walls with the most desirable features for reducing heat loss.

Steady State Research Needs

Steady state thermal performance evaluation requires both analytical and laboratory investigations. Specifically required are:

- (1) upgrading of laboratory test procedures to ensure that laboratories following prescribed procedures will achieve accurate results.
- (2) an industry wide round robin to determine heat transfer through composite wall assemblies.
- (3) a laboratory test method for measuring heat transmission through windows, doors, and wall assemblies containing windows and doors.
- (4) development and testing of innovative wall assemblies.

- (5) compilation of a data base of thermal properties of building materials going beyond those currently listed in ASHRAE Handbooks.
- (6) compilation of a data base of composite wall system performance, useful for comparison of alternative wall systems and to verify analytical models.

Dynamic Heat Transfer Through Walls

There have been few tests done on dynamic heat transfer through walls. Currently, dynamic predictions are made in computer models by solving one dimensional transient heat transfer equations. These make use of either response factors, or conduction transfer functions. These calculation methods need to be verified.

Several existing hot box facilities are available for conducting dynamic tests, but there are not accepted test methods for evaluating dynamic thermal performance of wall systems. The Construction Technology Laboratory of the Portland Cement Association has the most extensive test program on dynamic thermal performance (21). Their tests provide information on steady state and dynamic response to selected thermal conditions. These and other tests in application to the temperature cycles applied during these tests.

Dynamic Thermal Research Needs

Analytical, laboratory, and field investigations are required. Specifically, tasks should include the following:

- (1) Development of test procedures for dynamic thermal performance of full size building envelope sub-systems. Eventually, air leakage and moisture build up effects should be included.
- (2) Field investigations of existing buildings should be initiated. In site heat flux measuring techniques are required.
- (3) Coordination of walls tested in the laboratory and those tested in the field is important to try to verify laboratory test methods.
- (4) Analytical models should be checked against field and laboratory tests.

- (5) Test results must be tabulated in ways useful to building designers.
- (6) A test facility is needed which will allow for variation of outdoor temperature while indoor temperature float.

Bridges/Breaks/Penetrations/Anomolies

These anomolies can be sources of significant energy losses in buildings. Furthermore, they can contribute to serious moisture problems, and their impact on human comfort and occupant health is also of concern

Because of gaps in knowledge in Building Envelope, Thermal Anomolies (BETA's) their total impact is unknown. There is need for research in:

- (1) Collection and dissemination of information on BETA's. Specifically work done outside of the USA needs to be collected in an orderly fashion.
- (2) Integration of existing technical research on economics, materials, and performance evaluation of general and specific BETA's.
- (3) Conducting a study of construction practices to identify and characterize as many BETA's as possible.
- (4) Perform steady state and transient analytical studies on these BETA's.
- (5) Study the real costs of these BETA's and of proposed solutions to BETA problems.
- (6) Set up and maintain a complete catalog for Beta information including identification and description information, existing cost data, suggested modifications.
- (7) Establish an educational program for transfer of results.

Roof Moisture Measurements

The techniques for conducting moisture surveys on existing roof systems requires measurements to decide if and where there is appreciable water under a membrane.

Non-intrusive techniques are currently in use. These include infrared imaging, capacitance, and nuclear.

Needed Research Includes

- (1) Development of instruments for quantitative measurement of moisture in roof systems. These instruments should be able to detect moisture changes in small volume elements. Capacitance based probes seem to have the promise.
- (2) Calibration probes and standard procedures for carrying out calibration of moisture probes needs to be developed.
- (3) Experiments need to be designed that provide the base data needed to understand the phenomena behind roof related moisture problems.

REFERENCES

- (1) National Program Plan for the Thermal Performance of Building Envelope Systems and Materials DOE/CS-0059 Jan, 1979.
- (2) National Program Plan for the thermal Performance of Building Envelope Systems and Materials, ORNL/Sub-7973 March, 1982.
- (3) H.D. Ross - "Air Infiltration in Buildings (Revised)" - International Energy Agency (IEA), DOE/CS-0099D, 1982.
- (4) Environmental Protection Agency "Proceedings of Workshop on Indoor Air Quality", Washington, Dec 3-5, 1980.
- (5) Lawrence Berkeley Laboratory Draft Interim Report, "National Program Plan for Passive Solar Heating and Cooling, LBL - 8066, University of California, December 1978.
- (6) Lawrence Berkeley Laboratory/Department of Energy Draft Daylighting Program Plans "LBL-127733, University of California.
- (7) National Bureau of Standards, Reducing the Nations Fire Losses: The Research Plan, Center for Fire Research, January, 1976.
- (8) Subcommittee on Energy Development and Applications, of the Committee on Science and Technology, U.S. House of Representatives - Ninety Seventh Congress - July 22, 1982 - "Building Energy Research".
- (9) Proceedings of "Building Energy Research Workshop" Science applications Inc. - U.S. House of Representatives, Ninety Eight Congress, May, 1983.

- (10) "Architectural Research Priorities" American Institute of Architects, Architectural Research Council 1984.
- (11) Luikov, A.V. - Heat and Mass Transfer in capillary porous bodies Pergamon Press, 1966.
- (12) Bomberg, Mar - Moisture Flow through Porous Building Materials - Division of Building Technology Fund Inst. of Tech., Fund, Sweden, 1974.
- (13) Anderlund, Gunnar - Transient one-dimensional heat and moisture transport in building technology. Institute for Building Technology, Chalmers Univ. Goteborg, Sweden, 1974.
- (14) Andersson-Ann-Charlotte, Moisture Transfer in Building Materials Div. of Building Tech, Fund Inst. of Tech., Fund, Sweden, 1974.
- (15) Kohonen, R & Matta, J - Transient analysis of the thermal and moisture behavior of building constructions - Technical Research Centre of Finland, VTT, Espoo, Finland, 1983.
- (16) Cunningham, M.J.A., New Analytical Approach to the long term behavior of moisture concentrations in Building and Environment Vol. 18, no. 3, pp 117-124, 1983.
- (17) Harrje, D.T., Gibson, R.G., Dutt, G.S., Hans, G., Field Measurement of Seasonal Wood Variations in Residential Attics - Princeton University Center for Energy and Environmental Studies, Princeton Univ., 1984.
- (18) Dutt, G.S., "Condensation in Attics: Are Vapor Barriers Really the Answer?", Energy and Buildings - The Netherlands Vol. 2, 1979.
- (19) Cleary, P., "Moisture Control by Attic Ventilation - An in-sites study - ASHRAE Technical Paper, 1984.
- (20) Burch, D.M., Lemay, M.R., Rain, B.J., Validation of an Attic Condensation Model" ASHRAE Transactions Vol. 90, Part 2, 1984.
- (21) Van Geem, M.G., Calibrated Hot Box Test Results Data Manual - Volume I", Construction Technology Laboratories, Portland Cement Association, Skokie Ill, 1984 - 336 pages.

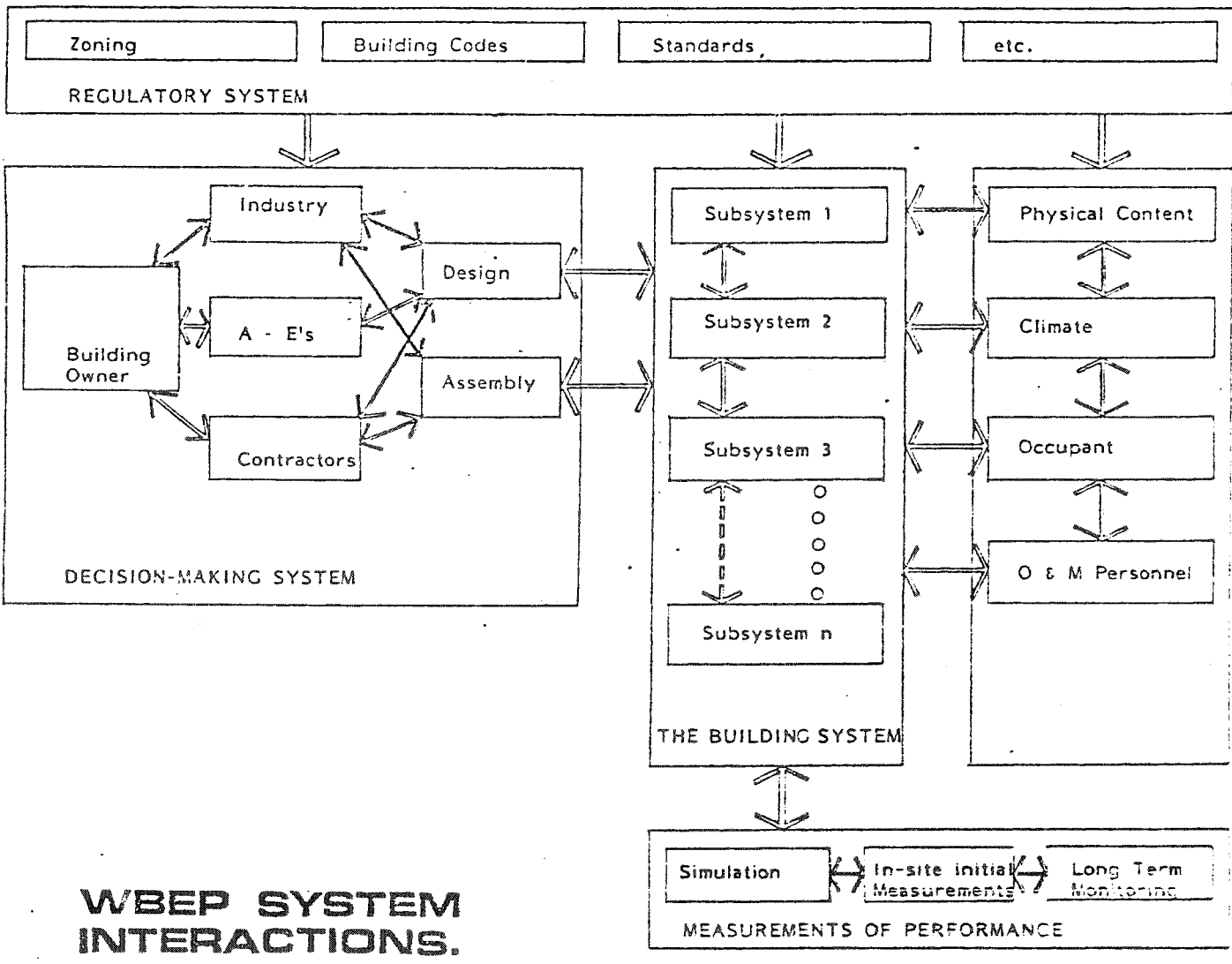


Figure 1: WBEP System Interactions