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Performance Concept in Buildings

Opening Addresses, Rapporteur Reviews, And Discussions

Joint

RILEM-ASTM-CIB Symposium Proceedings

U.S.
PARTMENT
OF
COMMERCE
National
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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
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NATIONAL BUREAU OF STANDARDS Lawrence M. Kushner, *Acting Director*

Performance Concept in Buildings

Volume 2: Opening Addresses, Rapporteur Reviews, and Discussions

Proceedings of a Symposium Jointly Sponsored by the International Union of Testing and Research Laboratories for Materials and Structures (RILEM), the American Society for Testing and Materials (ASTM), and the International Council for Building Research Studies and Documentation (CIB)

Held at Philadelphia, Pa., May 2-5, 1972

Edited by

Bruce E. Foster: Secretary, Joint Symposium Committee

Building Research Division
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

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Foreword

For well over fifty years the National Bureau of Standards has directed a substantial effort toward developing requirements and methods of test for buildings, components, and materials. The members of its staff have also participated in the work of both domestic and international technical committees dealing with these fields of activity, including committees of the three organizations sponsoring this Symposium.

In recent years many of our research programs have emphasized the development of data and procedures needed for realization of the potential benefits promised by the formalized performance concept. Therefore, we welcome the opportunity to participate with colleagues throughout the world in the exchange of ideas and experience made possible by this Symposium. As a contribution to the Symposium, as evidence of our belief in the importance of its subject, and to make the information available to the building community, we are pleased to publish these Proceedings.

LAWRENCE M. KUSHNER
Acting Director

The Symposium was held in Philadelphia, Pennsylvania, May 3-5, 1972, at the headquarters building of the American Society for Testing and Materials. The attendance totaled 189 of which 19 were from Canada and 52 from other countries abroad.

On the afternoon preceeding the Symposium proper, May 2nd, ASTM Committee E-06 on Performance of Building Construction sponsored an informal, well-attended research review session. The program is given here:

Opening Remarks by Chairman, ASTM Committee E-06
R. W. Bletzacker, Director, The Ohio State University Engineering Experiment Station, Columbus, Ohio 43210

Presentations on Test Methods for Industrialized Buildings
by Members of the Staff of the Structures Section, Building Research Division, National Bureau of Standards, Washington, D.C. 20234

Introduction by Norman F. Somes, Assistant Chief, Structures Section

Case of a Wood Module System
N. F. Somes

Case of a Glass Fiber Reinforced - Plastic System
H. S. Lew

Case of a Steel Skin Honeycomb Paper Core System
J. H. Pielert

Case of a Concrete Box System
Felix Yokel

Summary Discussion - What Are Our Needs in Testing?
N. F. Somes

Powder-Actuated Fastenings of Exterior Perimeter Plates to Masonry Foundation Walls or Slabs
R. W. Henning, Ramset Fastening Systems*
289 Winchester Avenue, New Haven, Connecticut 06504

Committee E-06 Activities on Structural Performance of Joining and Fastening in Building Construction
E. G. Stern, Earle B. Norris Prof. of Wood Construction,
Virginia Polytechnic Institute, Blacksburg, Virginia 24060

Field Testing Device for Nails
R. R. Reeves, Canadian Forest Service, on leave to
Virginia Polytechnic Institute, Blacksburg, Virginia 24060

Structural Aspects of Fire Endurance Performance
R. W. Bletzacker, The Ohio State University
Columbus, Ohio 43210

The formal Symposium sessions were conducted using the rapporteur system. At the start of each technical session, a rapporteur presented a report which included a summary of the papers in the subject area of the session and a discussion of the viewpoints expressed. The rapporteur's discussion was not necessarily limited to the presentations or subject areas covered by the papers reviewed. Since the formal papers were available to all Symposium participants before the meeting, there was no need for authors to present their papers

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* Paper read by Professor Stern

during the technical session. However, authors were invited to present, from the floor, new data, or to comment or supplement the rapporteur's review. Following this, the meeting was thrown open from discussion by all attendees. Discussors were invited to submit written condensations of their remarks for inclusion in the printed Proceedings. Simultaneous translation into French was provided for all Symposium sessions.

The Symposium papers in English, and with abstracts also in French, appear in Volume 1 of the Proceedings. This second volume records much of the material presented during the eight Symposium sessions in Philadelphia. The printed discussions include only those submitted in written form, and these were required to be in condensed form. Addresses and affiliations of the discussors can be found in the list of registrants.

The Symposium Committee wishes to express its gratitude to the many people who contributed to the Symposium's success. First should be mentioned the authors of papers who produced the substance of the Symposium, and their secretaries who performed so ably in preparing the camera-ready copy. A debt is owed to the sixty-odd reviewers, most of whom were staff members of the Building Research Division of the National Bureau of Standards, who performed the concentrated paper review which made publication of papers possible on the very tight schedule required.

With regard to the Philadelphia gathering, we wish to thank Messrs. Finger and Wright for their excellent opening addresses. We are particularly gratified with the performance of the rapporteurs, Mrs. Saeterdal and Messrs. Atkinson, Allen, Achenbach, Christensen, Bergstrom and Hutcheon whose roles of synthesizing and summarizing the material in the papers and stimulating discussion furnished the key to the success of the sessions. Recognition is due also to Messrs. Robertson and Mielenz who assisted the symposium committee members in chairing technical sessions. Finally, and by no means least, we wish to thank Mrs. Lydwine Booth who furnished the simultaneous translation in French.

With regard to the management aspects, we are grateful to the Symposium Steering Committee which consisted of Richard Mielenz, Chairman, W. J. Bierens de Haan, Richard W. Bletzacker, W. T. Cavanaugh, Maurice Fickelson, and James R. Wright, and to the assistance of the U. S. National Committee for CIB, represented by S. M. Charlesworth.

For financial support, we recognize the National Science Foundation which, through the U.S. National Committee for CIB, made a substantial grant, the Building Research Division of the National Bureau of Standards which published the Proceedings, and our host, the American Society for Testing and Materials.

Credit for meeting and social arrangements in Philadelphia is due to Miss Joan McFadden, Manager, Meetings Department, ASTM, and her staff.

Chairman Jones and I wish to express our gratitude to our fellow members on the Symposium Committee, Messrs. Amstutz, Blachère Birkeland, and Sneck, and especially to the latter two who came to the United States last October to assist in the paper review and in finalizing the program.

Finally, on my part, I wish to thank Chairman Jones for his excellent leadership of the Committee, J. R. Wright for his full support in making it possible to marshal the resources of the NBS Building Research Division and so meet the publishing schedule, Miss Margaret Estabrook who assisted so capably in editing both volumes of the Proceedings and in particular the portions in French, and Mrs. Evelyn Granger who performed the necessary manuscript typing and contributed in other important ways to the development of the Proceedings.

BRUCE FOSTER, Secretary
Symposium Committee

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Abstract

Volume 2 records the proceedings of the Joint RILEM-ASTM-CIB Symposium on the Performance Concept in Buildings which was held in Philadelphia on May 2-5, 1972. Volume 1 contains the 82 papers accepted for the Symposium and was published prior to the meetings. This second volume contains the opening addresses; the reports of the rapporteurs, which include a review of the papers and a general discussion in each of six areas; such discussion as was submitted in writing; a general summary of the Symposium with conclusions drawn by the closing rapporteur; and statements by representatives of the three sponsoring organizations outlining the present and probable future activity of these organizations in furthering the performance concept in buildings. The subject matter covered in the papers includes physiological, anthropometrical, psychological, sociological, and economic human requirements and methods of evaluation; physical requirements and methods of evaluation in mechanical, acoustical, thermal, dimensional stability, compatibility, fire properties, and geometry areas; operation and maintenance requirements and methods of evaluation in such areas as maintenance, repair, replacement, and versatility; techniques and problems in applying the performance concept to design; and experience gained in application of the performance concept in design, building, and building use.

Key words: Buildings; components; design procedures; experience in use; materials; performance evaluation; performance requirements; user requirements.

SESSION I

Opening Remarks and General Addresses

Rudard A. Jones, Chairman
Small Homes Council -- Building
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A. Opening Remarks

Remarks for the Symposium Committee

Rudard A. Jones, Chairman

Good morning ladies and gentlemen. My name is Rudard Jones and I am from the University of Illinois at Urbana-Champaign. On behalf of the Symposium Committee, it is my privilege to welcome you to the opening session of the RILEM-ASTM-CIB Symposium on "The Performance Concept in Buildings." This is indeed a momentous occasion for it is the first time these three prestigious societies have met together to consider a subject of mutual interest. Shortly you will be officially welcomed by representatives of each of the sponsoring societies, but first some words about the conduct of the symposium and of this particular session.

Due to time limitations, and following customary practices, the introduction of session chairman, rapporteurs and speakers will be very brief. Each one is identified in the program. There will no open discussion during the first session. In the following sessions, the rapporteurs will present their comments on the preprinted papers and then the floor will be open for discussion. Chairmen will explain the conduct of each session in more detail as the symposium proceeds.

And now may I present Mr. William Cavanaugh, Managing Director of ASTM, who will welcome you for the host Society.

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PREMIERE SEANCE

Discours d'introduction et Allocutions Générales

Rudard A. Jones, Président
Conseil en Construction de petites maisons
Conseil en Recherches dans le Bâtiment
Université de l'Illinois à Urbana-Champaign

A. Discours d'introduction

Propos de la part du Comité du Colloque

Rudard A. Jones, Président

Bonjour Mesdames et Messieurs,

Je m'appelle Rudard Jones et je viens de l'Université de l'Illinois à Urbana-Champaign. Au nom du Cornité du Colloque, j'ai le plaisir de vous souhaiter la bienvenue à cette séance d'ouverture du Colloque RILEM-ASTM-CIB sur "La Notion de Performance dans le Bâtiment." C'est là en vérité un évènement important puisque c'est la première fois que ces trois Sociétés prestigieuses se sont réunies pour examiner un sujet d'intérêt commun. Des représentants de chacune des trois Sociétés vous souhoiteront vientôt officiellement la bienvenue, mais j'aimerois d'abord vous dire quelques mots au sujet de la conduite du colloque et plus particulièrement de cette séance.

A cause du manque de temps et comme il est d'usage, la présentation des présidents de séance, des rapporteurs et des auteurs sera très brève. Vous avez d'ailleurs déja pu les identifier d'après les notes dans le programme. Il n'y aura pas de discussion libre au cours de la première séance. Au cours des séances suivantes, les rapporteurs présenteront leurs commentaires sur les exposés publiés à l'avance et leur rapport sera suivi d'une discussion libre. Les présidents de séance expliqueront les modalités de travail en plus de détail au cours du Colloque.

Et maintenant, puis je vous présenter Monsieur William Cavanaugh, Directeur de l'ASTM qui vous souhaitera la bienvenue au nom de vos hôtes.

Remarks for the American Society for Testing and Materials

William T. Cavanaugh, Managing Director

On behalf of the President and the Board of Directors of ASTM, it is my pleasure and privilege to welcome all of you to this symposium and to the Headquarters of ASTM. We hope that your participation in this landmark meeting will be successful and most fruitful.

ASTM is pleased to be associated in this undertaking with the International Union of Testing and Research Laboratories for Materials and Structures (RILEM) and the International Council for Building Research Studies and Documentation (CIB). We look forward to continuing mutual participation in the development of techniques and concepts vital to the provision of adequate housing in most parts of the world.

Let me tell you a few things about ASTM. This Headquarters building is used entirely by the staff of the Society which consists of approximately 150 people. Our task here is to provide administrative, legal, and publications support to the 110 main ASTM committees and the thousands of subcommittees and task groups that develop ASTM consensus standards in almost all areas. Please feel at home here. Do not hesitate at any time to request assistance from any member of our staff. You will find them most cooperative and friendly.

As a result of the work carried on here, we know a great deal about standardization in America and the world. Many of our staff people would be delighted to meet with you as you may have the time to discuss any aspect of the vast world of standardization of which ASTM is such an important part. Many interesting things are happening in the United States and in your own countries, and we would be delighted to exchange views with you on these matters as time and circumstances may permit.

We feel additionally honored at your coming to our country and our Headquarters for this very important meeting since, very soon, we will begin a one-year observance of the 75th anniversary of the founding of ASTM. As some of you may already know, ASTM had its beginning really as part of an international standards organization. It is, therefore, most appropriate that in a very real sense this meeting is one of many important events that will take place during our anniversary year.

In closing, let me say we hope your visit to our country and to ASTM will prove to be most enjoyable and memorable. Please give us any opportunity to be of assistance or service to you.

Discours de la part de l'American Society for Testing and Materials

William T. Cavanaugh, Directeur

Au nom du Président et du Conseil d'Administration de l'ASTM, j'ai le plaisir et le privilège de vous souhaiter à tous la bienvenue à ce Collogue et au Quartier Général de l'ASTM. J'espère que votre participation dans cette réunion marquante sera des plus utiles et couronnée de succès.

L'ASTM est heureuse d'être associée à cette entreprise avec la Réunion Internationale des Laboratoires d'Essais et de Recherches sur les Matériaux et les Constructions (RILEM) et le Conseil International du Bâtiment pour la Recherche, l'Etude et la Documentation (CIB). Nous envisageons avec plaisir la continuation de notre participation dans la mise au point de techniques et de notions fondamentales essentielles pour permettre de fournir des habitations adéquates dans la plupart des parties du monde.

Je voudrais d'abord vous dire quelques mots au sujet de l'ASTM. Ce bâtiment, notre Quartier Général, est occupé entièrement par le personnel de la société, qui comprend environ 150 personnes. Notre tâche est de fournir l'appoint administratif, légal et éditorial aux 110 Comités principaux de l'ASTM et aux milliers de sous-comités et groupes de travail qui élaborent les normes agréées de l'ASTM dans presque tous les domaines. J'espère que vous vous sentirez chez vous ici. N'hésitez pas, je vous en prie, à demander l'aide des membres de notre personnel. Vous êtes assurés de leur coopération bienveillante.

Grâce au travail que nous faisons ici, nous avons de bonnes connaissances concernant la normalisation en Amérique et dans le monde entier. Parmi les membres de notre personnel, il y en a beaucoup qui aimeraient s'entretenir avec vous, si vous en avez le loisir, pour parler des nombreux aspects de ce vaste comaine de la normalisation dont l'ASTM est une partie importante. Bien des choses intéressantes sont en cours tant aux Etats-Unis que dans vos propres pays, et nous serions heureux d'établir avec vous un échange de vues sur ces questions si le temps et les circonstances le permettent.

Nous sommes d'autant plus honorés de votre présence dans notre pays et dans notre Quartier Général, que nous allons commencer bientôt une Année Commémorative du 75 ème anniversaire de la fondation de l'ASTM. Comme certains d'entre vous le savent déjà, l'ASTM avait débuté vraiment comme une partie d'un organisme international de normalisation. C'est pourqusi il est très opportun que cette réunion figure parmi les manifes tations importantes qui marqueront cette année d'anniversaire.

Pour finir, permettez moi de vous souhouter une visite mémorable et agréable à l'ASTM, et de vous dire combien nous serious heureux de nous mettre à votre disposition pour toutes questions ou services que vous pourriez nous demander.

Remarks for the International Union of Testing and Research Laboratories for Materials and Structures

Robert L'Hermite, Secretary General*

As Secretary General and as former President of RILEM, and as a member of the ASTM and f the CIB, I have several grounds for feeling pleased to see that the good understanding ınd the happy conjugation of the efforts of the three associations have led to the holding f this symposium in Philadelphia. And since we are the guests of the ASTM in Philadelphia, t is a special pleasure for me to recognize everything that the success of this inter-ational cooperation owes to the ASTM, and to thank it for having been good enough to assume he heavy task of organizing this meeting.

The Philadelphia symposium could, I venture to say, be regarded both as the impressive echnical conclusion to the twenty-sixth meeting of the Permanent Commission of RILEM that as just been held in Washington and the rendezvous resulting from a mutual decision on the art of our associations to come together in order to demonstrate that their activities are ot strictly parallel, that they are sometimes convergent, and always complementary.

Joint symposia, like the one we are holding today, in which the men of the laboratory nd builders get together and exchange ideas and experiences, represent a particularly use-ul and fruitful form of international cooperation. The topic of the present symposium is n a high level, for it touches on certain aspects of the philosophy of building and it has ts special place in the context of progress for economy and safety. It will certainly have mportant consequences for the future of our profession.

I cannot conclude without recalling what this meeting owes to the initiative of the late homas A. Marshall Jr., Managing Director of the ASTM, whose passing has been a great loss ot only to the ASTM, but to all those who had the opportunity to appreciate his spirit of ooperation and his ready understanding of all our problems. With his memory I shall associ-te the gratitude that we owe to his successor, William T. Cavanaugh, to Richard C. Mielenz, hom we in RILEM tend to consider almost one of us, to the President and to all those re-ponsible for the activities of the ASTM who have provided us in Philadelphia with all the acilities that we find here, as well as to my friends of the National Bureau of Standards, ames R. Wright and Bruce Foster.

* In Mr. L'Hermite's absence, read by Maurice Fickelson, Deputy Secretary General.

Propos de la part de la Réunion Internationale des Laboratoires d'Essais et de Recherche sur les Matériaux et les Constructions

Robert L'Hermite, Secrétaire Général**

J'ai plusieurs motifs de me montrer satisfait, comme Secrétaire Général et ancien Président de la RILEM, et comme membre de l'ASTM et du CIB, de voir que la bonne entente et l'heureuse conjugaison des efforts des trois associations aient abouti à la réunion de ce colloque de Philadelphie. Et puisque nous sommes, à Philadelphie, les hôtes de l'ASTM, il m'est agréable de reconnaître tout ce que la réussite de cette coopération internationale lui doit, et de la remercier d'avoir bien voulu assumer la lourde charge d'organiser cette réunion.

J'aurais tendance à voir dans le colloque de Philadelphie à la fois l'impressionnante conclusion technique fournie à la 26ème Réunion de la Commission Permanente de la RILEM, qui vient de se tenir à Washington, et le rendez-vous que se sont donné nos associations afin de démontrer que leurs activités ne sont pas strictement parallèles, qu'elles sont parfois convergentes, et toujours complémentaires.

Les colloques en commun, comme celui d'aujourd'hui, où les hommes de laboratoires et les constructeurs se rencontrent et se concertent, représentent une forme de coopération internationale particulièrement utile et fructueuse. Le thème du présent collogue est d'un niveau élevé, car il atteint certains aspects de la philosophie de la construction et il se place dans un sens particulier du progrès pour l'économie et la sécurité. Il aura certainement des conséquences importantes pour l'avenir de notre métier.

Je terminerai en rappelant qu'à l'origine de cette réunion se trouvait le regretté Thomas A. Marshall Jr., Managing Director de l'ASTM, dont la disparition a été une grande perte non seulement pour l'ASTM, mais pour tous ceux qui ont eu la chance d'apprécier son esprit de coopération et sa vive compréhension de tous nos problèmes. A son souvenir, j'associerai la gratitude que nous devons à son successeur, William T. Cavanaugh, à Richard C. Mielenz, que nous avons tendance à la RILEM de considérer comme un peu des nôtres, au Président et à tous les responsables de l'ASTM qui nous ont donné à Philadelphie toutes les facilités que nous y trouvons, ainsi qu'à mes amis du National Bureau of Standards, James R. Wright et Bruce Foster.

** En l'absence de M. L'Hermite, l'adresse était presentée par Maurice Fickelson, Député Secrétaire Général.

Remarks for the International Council for Building Research Studies and Documentation

Øivind Birkeland, Vice-President

The opening of this Symposium on the Performance Concept is, for CIB, a very happy event. It seems to be more and more generally accepted that the Performance Concept is a necessary tool if we wish to promote a development within building required for satisfying the demand for buildings of all kinds facing all nations of the world. And we find performance thinking very widely adopted even by building people who don't use the word performance.

It is the task of building research organizations to develop the performance concept into the tool we need.

CIB, being an organization of building research institutions, it is natural that performance thinking for a long time has been present in the pattern of work of CIB, in the papers presented at CIB congresses, and in the activities of the working commissions. Again and again it has been a theme for discussions within the Board of CIB. This pattern has been easily discernible even though the word performance has not always been used.

Likewise, as far as I understand, the performance concept has been considered an important part of the work within RILEM and ASTM. It seems natural, therefore, that ASTM, RILEM and CIB here have found common ground for collaboration. We in CIB are very happy for this mutual effort with ASTM and RILEM in the development of the performance concept. And, on behalf of CIB, I am glad to have this opportunity to express our best thanks for this cooperative work. Being one of CIB's representatives in the Organizing Committee for this Symposium, I have witnessed and participated in an unusually open and happy association. We have all worked toward one common goal in complete agreement with each other.

If this Symposium achieves its aim, it will present a worldwide picture of the situation regarding development of the performance concept. It is now up to you, the participants in this Symposium; to you, the authors of papers; and to you, the rapporteurs; whether we shall achieve this aim.

We in CIB hope that the very happy cooperation now existing may result in further joint ventures between our three organizations.

May I again, on behalf of CIB, express our sincere gratitude for the collaboration resulting in this Symposium. We are, of course, especially indebted to ASTM, the host of the Symposium, for the immense work they have contributed to make this Symposium possible.

Propos de la part du Conseil International du
Bâtiment pour la Recherche, l'Etude et la Documentation

Øivind Birkeland, Vice-Président

L'ouverture de ce Symposium sur le performance concept est pour le CIB un événement très heureux. En effet, il semble de plus en plus accepté que le performance concept est un outil dont nous ne pouvons nous passer si nous désirons, dans l'industrie du bâtiment, poursuivre ce développement dont dépend la possibilité pour nous de satisfaire la demande de constructions de tous genres, et de faire face à cette damande dans tous les pays du monde. Et nous constatons que le raisonnement en "performance" est largement répandu même chez les bâtisseurs qui généralement ne se servent pas du mot performance.

C'est la tâche des organisations de recherche du bâtiment de développer le performance concept pour en faire l'outil dont nous avons besoin.

Le CIB étant un organisme qui groupe des institutions de recherche du bâtiment, il est logique que le raisonnement en performance se soit, depuis longtemps déjà, manifesté dans le schéma de travail du CIB, dans les travaux et rapports présentés aux congrès du CIB et dans les activités des commissions de travail. Constamment, cette notion, ce concept, a fait l'objet de discussions au sein du Comité directeur du CIB. Cet aspect des choses a été très nettement visible, même si le mot performance n'a pas toujours été employé.

De la même manière, si j'ai bien compris, le performance concept a constitué une partie importante du travail effectué par la RILEM et l'ASTM. Il semble, ainsi, que ces trois organismes ASTM, RILEM et CIB ont trouvé ici un terrain commun de collaboration. Nous autres, du CIB, sommes très heureux de la collaboration avec ASTM et RILEM sur le développement du performance concept. Et, au nom du CIB, je suis content de pouvoir profiter de cette occasion pour dire tous nos remerciements pour cette collaboration. Etant moi-même un des représentants du CIB dans le Comité organisateur de ce Symposium, j'ai eu l'avantage de connaître un esprit de collaboration d'une franchise et d'une courtoisie exceptionnelles. Nous avons tous déployé nos efforts dans un but commun et dans une compréhension réciproque parfaite.

Si ce Symposium réalise ce qui est son but, cela reflétera à l'échelle mondiale la situation concernant le développement du raisonnement en performance. Il vous appartient maintenant à vous, participants à ce Symposium, à vous, auteurs des rapports, et à vous, rapporteurs, de faire en sorte que nous atteignions ce but.

Nous, du CIB, espérons que cette très réussie collaboration entraînera d'autres efforts communs entre nos trois organisations.

Permettez-moi d'exprimer une nouvelle fois mes remerciements de la collaboration qui a abouti à l'organisation de ce Symposium. Et ces remerciements s'adressent tout particuliérement à notre hôte, l'organisme ASTM, sans le travail immense duquel ce Symposium n'aurait pas été possible.

The Role of the Performance Concept in Operation BREAKTHROUGH

The Honorable Harold B. Finger
Assistant Secretary for Research and Technology
Department of Housing and Urban Development
Washington, D.C. 20410

1. Operation BREAKTHROUGH: Its Goals and Impact

Operation BREAKTHROUGH was first announced on May 8, 1969 -- almost to the day three years ago. Our goal was to accelerate the rate of change, of improvement in housing, to encourage innovation in housing systems, in land planning, and in providing opportunities for all people to live in well-designed communities. In this short time we have accomplished much of what we set out to do, and in many areas we have accomplished more than we expected. We have broken through many of the constraints to the improvements we were seeking.

1.1 In these three years, twenty states have passed mandatory statewide industrialized housing laws or general purpose building codes. Eight additional states have such legislation now pending. None of these laws was in effect before Operation BREAKTHROUGH was announced — and there is no doubt that Operation BREAKTHROUGH provided the stimulus to get them passed. These laws reassert State authority in the code area and are an essential part of our effort to overcome the limitations imposed by thousands of local building codes. We are now working with our national code organizations and the state code officials to encourage passage of model legislation that will provide for greater uniformity among the states and will provide a means for reciprocity in building regulation.

1.2 Building trade union actions have led to precedent setting labor agreements encouraging the building of housing in factories on an industrialized basis. These agreements include special factory wage levels instead of higher field wages, provide for larger proportions of lower skilled workers, provide minority training opportunities, and also permit work and jurisdictional rules to facilitate efficient industrial production of housing as distinguished from the arrangements used in field construction and assembly.

1.3 Transportation is the key link to large area markets for factory built housing. BREAKTHROUGH has worked with the transport industry, housing producers, other Federal agencies and state and local agencies to reduce truck tariffs, to reduce highway restraints and red tape, and to interest railroads in long range shipments at reasonable tariffs using standardized tie down hardware and flat beds to handle housing components. Some successes have already been achieved in reducing shipping cost. More are needed and work is continuing to achieve those further reductions.

1.4 A wide spectrum of financial institutions have been exposed to industrialized housing. These include mortgage bankers, insurance companies, commercial banks, savings and loan institutions, and the various governmentally established organizations involved in the mortgage market. This involvement of the established financial institutions is easing their concern with industrialized housing that had previously existed because of the lack of familiarity with the quality that can be achieved in such housing.

1.5 The management systems being used in Operation BREAKTHROUGH are being emulated by industry and even by other parts of Government. A need for more refined cost controls led Operation BREAKTHROUGH to develop an Industrialized Housing Cost Accounting System which, in a sense, married the most useful of field construction accounting to advance factory production cost accounting.

1.6 The model or prototype sites developed in Operation BREAKTHROUGH as well as the follow-on Phase III volume production projects have involved a large part of the Headquarters and Field organizations of the U. S. Department of Housing and Urban Development. Operation BREAKTHROUGH has, therefore, already provided a processing familiarity with industrialized and innovative housing approaches to a large part of the government organization responsible for housing. In addition, changes are being made in HUD processing to recognize the special requirements of industrialized housing as distinguished from the more traditionally on-site built housing.

1.7 All of the 50 states and many local communities have named special representatives for Operation BREAKTHROUGH. In this respect, Operation BREAKTHROUGH has been a pacesetter in involving State participation in housing and community development activities. Two hundred eighteen sites in 36 states and the District of Columbia were offered for prototype development. Some 12 more states have created State housing and/or finance agencies, along with the 20 statewide codes described above. In sum there has been a large-scale assumption of responsibility for housing at the State level.

1.8 BREAKTHROUGH design criteria and project surveillance require special precautions at the most common sources of accidents in the home (e.g., slippery tubs, glass doors, poorly lighted stairs, hazardous electrical plugs, etc.) and provide high standards for the building industry in effective control of quality during production.

1.9 New forms of building technology have undergone rigorous evaluation and testing and were found to be sound and feasible. These include sprayed fiberglas structure, stressed skin foamed plastic core structural panels, honeycomb core sheet metal skin structures, honeycomb core fiberglass skin structures, high rise structures of steel-framed factory modules, high rise structures of factory made concrete modules stacked checkerboard fashion, snap-in electrical inter-connections for panels and modules, and core modules efficiently packaging bathrooms, kitchens and heating/cooling units. The recent topping out of a 110 unit high rise building in 23 working days from the time erection of panels started on our Sacramento site is a technological achievement of which we are all proud.

1.10 The nine prototype projects taken as a group provide a national model for the effective use of land in varying urban and geographic settings. The volume production site plans are being reviewed to insure continuation of such quality development.

1.11 Two thousand nine hundred thirty eight units will have been constructed at the prototype sites by the conclusion of the prototype phase of the program. As of the end of April, 1199 of these units were erected and 101 occupied. With the possible exception of the complex Jersey City site, all of the prototype sites should be constructed by the end of this year.

Further, 10,900 units of special earmarked housing assistance subsidies have been allocated for follow-on volume production for other than the prototype sites. We expect that by the end of June, a total of 25,000 units will have been allocated. In addition, the development of 7,000 non-earmarked housing units are in process, of which many will be for middle or upper-middle income occupancy.

1.12 The initial marketing and occupancy of the prototype sites indicate that economic, social, and racial mixing of families is feasible if community design, living environment, and the amenities that indicate good living opportunities are available. Longer term evaluation of this social consequence of Operation BREAKTHROUGH is necessary for development of community planning policies.

1.13 And finally, I would like to come to the principal subject of this Conference. In preparing to evaluate the suitability of BREAKTHROUGH housing systems, it became apparent that certain of the systems could not be judged by normal prescriptive building codes because these systems differed substantially from conventional building methods which served as a basis for these codes. Further, we found that certain safety, durability, and livability issues in housing were not specifically addressed in most codes.

It was determined that performance measures were needed to encourage innovation and to evaluate new housing systems. In a remarkably short time, the National Bureau of Standards developed such an interim set of Performance Guide Criteria. A highly qualified committee of the National Academies of Sciences and Engineering reviewed the Guide Criteria. The resulting Criteria are serving as the basis for evaluating BREAKTHROUGH housing. These Guide Criteria are continuing to be evaluated and adjusted based on comments from various elements of the housing business and on results of BREAKTHROUGH testing. In addition, the concepts of the Performance Guide Criteria are being considered in the development of the Minimum Property Standards that are used as the basis for Federal mortgage insurance. The important point is that the Performance Criteria provide a new effective bench-mark for design efforts and evaluation of innovative technology and they provide a guide of good practice for improving code administration.

2. The Performance Basis for Evaluation of Housing Systems; Tool for Advancing the Industry

I would like now to go somewhat further into the performance basis for evaluation of housing systems, relying on the experience that we have had in Operation BREAKTHROUGH. I know that later discussion will go into this subject in more detail and, therefore, I will touch only on the broad conceptual aspects and further needs in this area.

We all realize that the building industry has been continually changing throughout the world and, here in the United States, it is changing and advancing faster than ever before largely as a result of the impetus of Operation BREAKTHROUGH. As the pace of these changes quickens and the sophistication of our industry advances, we find ourselves, in the United States and around the world, going beyond the familiar, the accepted methods, into new and largely untried concepts. This fact need not lead to frustration, for we possess the tool with which to continue advancement. This tool is the performance concept -- -- the performance basis for evaluating the suitability of these new building systems.

Current design criteria and building code provisions are to a large extent materials oriented, reflecting past and present design solutions and building techniques. Prescriptive specification requirements have made the evaluation of safety and durability a reasonably simple responsibility to discharge for already proven and established building concepts. Historically, these prescriptive specification requirements written into building codes have produced housing which is safe, sanitary, and durable.

There is, however, a learning process which we must all undertake which essentially takes us back to the basic requirements of shelter and its uses. As an example, an interior non-load bearing partition employing conventional framing and familiar surfacing materials may be adequate for its purpose if designed merely to resist some level of uniformly distributed horizontal load. Used in a situation in which we have prior experience, we take for granted that this conventional configuration will also permit normal household shelving to be attached and supported, will have acceptable acoustic properties, will withstand the normal wear and tear of human activities, can be easily repaired or re-decorated, will accomodate electrical wiring and perhaps plumbing piping, and will meet a number of fire safety requirements such as flame spread, smoke generation or endurance.

From designer to comsumer, we may not be as confident when presented with a new, an innovative, configuration. However, confidence can be re-established if the system performance attributes are made explicit, and if they are satisfied, regardless of the material or method of solution. These performance attributes whether they be for a material, component or system must always be defined in terms of their desired function.

3. Determination of User Needs and Wants

Since ultimately the function of buildings is to serve their occupants, performance requirements must be defined in terms of user needs and wants. We must bear in mind that user needs and wants range the spectrum from absolute necessities to desirable amenities and the entire spectrum of these needs and wants can never be fully satisfied. Thus, it will be necessary for us to determine those needs and wants which should be satisfied practically and economically. In some cases this determination can be easily made. For example, it is obvious that the occupants of a building must be protected against structural collapse.

In other cases the determination is not so easy since the present state of knowledge is insufficient to define all aspects of user requirements. Acoustic privacy and occupant anxiety due to structural vibrations and building motion are two areas in which user requirements can only be adequately defined after extensive research. There is then a complicating factor of trade-off, or optimization, of the built environment in such a way that within established technological and economic bounds, lower levels of performance in one area may be permitted in return for a higher level of performance in another area which is more important or desirable to the ultimate user.

4. From the Qualitative to the Quantitative

But user requirements are very often defined as qualitative statements of the attributes required of the built environment. Unfortunately, qualitative statements do not sufficiently define performance. Again, the user requirement for protection against structural collapse merely infers that the structural system of a building must have adequate strength to prevent a collapse of the building during its service life. Clearly, this statement does not provide sufficient information with which to evaluate performance since it has not been established what the required strength must be in order to demonstrate compliance with the user requirement.

Sufficient guidance for design, and information for acceptance, can only be provided when the performance requirement is quantitatively defined. This requires the establishment of the quantitative scientific engineering design statement which fulfills the meaning and intent of the qualitative human need. This aspect of the performance concept is the one which will try our technological resources if we are to establish acceptance levels based truly on required performance rather than comparability with traditionally accepted solutions.

5. Where to Set the Numbers? A Monumental Task

We realize the gravity of this situation in the Operation BREAKTHROUGH program when the Performance Guide Criteria were being developed. The state of the art was such that in many cases we were obliged to establish performance on the comparability principle and have seen the shortcomings and constraints implicit in this approach. I do not think it is rational to establish performance levels on the basis of the maximum characteristics evidenced by a family of products historically employed to perform a particular function in order to insure safety or durability. Nor does it seem rational to establish performance levels on the basis of the minimum characteristics evidenced by a family of products historically employed to perform a particular function since this must obviously be satisfactory since it has been acceptable.

Clearly, this aspect of establishing rational required performance levels is a monumental task. It is a problem faced by every technical discipline on the building team. I consider it not merely national in scope, but an area in which international cooperation and exchange of current research, and coordination of needed future research is essential if the performance concept is to keep pace with the current trend of new technologies in the building industry, let alone foster their introduction.

6. Evaluation for the Specified Performance

Ultimately, of course, regardless of the level of performance quantitatively established as required, a method must be identified by which compliance with the established performance level is demonstrated for new, untried systems. This method, or test, can cover the spectrum from the familiar engineering design calculations to highly sophisticated and, I might add, time consuming and expensive, full scale system physical testing. As with the establishment of performance levels, the determination and verification of compliance with required performance levels is an aspect of the performance concept which merits concerted effort, research and modernization.

The complexity of the evaluation process many times precludes the use of standardized tests which can be easily interpreted. Moreover, testing is many times performed as a supplement to a more comprehensive evaluation procedure which includes analysis and the application of sound engineering judgment. Many test procedures have become abstract to the point where they merely measure the relative characteristics of materials without ddressing the measurement of material performance in practical service. Consequently, nnovations tested to this synthetic environment may prove unacceptable in actual service.

Our whole family of test methods and procedures needs to be reevaluated in the light of heir ability to realistically forecast performance in actual service, for the goal is not erely to demonstrate compliance with a test method but to employ the test method as a ehicle with which to demonstrate compliance with a performance requirement. Beyond that ompliance demonstration, test data under service conditions are needed to establish a base f factual experience with new systems that will permit their use without retest to revalidate the performance levels for every minor design change made.

7. Global Cooperation in Evaluative Procedures

In the area of test methods and procedures, I also view international cooperation and nter-change as mandatory. Just as we are not aware of the innovations yet to come in the uilding industry which must be evaluated, we cannot at this time develop the acceptance rocedures in anticipation of their entry. Many test methods and procedures will be eveloped throughout the world in response to a particular problem or innovation, and it is nly by means of the exchange of this knowledge that we can all benefit from the work of thers, thereby contributing to our store of knowledge and experience and avoid "re-inventing he wheel," so to speak, on an individual basis. Each one of us must also strive for the apid inclusion of newly developed test methods and procedures into the recognized acceptance tandards of our respective countries, for only in that way can the acceptance of innovations e promulgated throughout the mainstream of our industry.

8. Conversion to Engineering Drawings and Specifications

But the performance concept is not readily interpreted by production line or field nspectors. Conversion must be made from performance statements to engineering drawings nd specifications that can be visually observed to assure compliance. Quality control rocedures are an essential element of such compliance assurance. Some elements of performance criteria cannot be converted to visual observations and more complex and systematic nspection and quality techniques must be implemented.

9. Not an Easy - But an Essential - Approach

I want to emphasize that the performance concept is not a simple approach to evaluating he suitability of building methods and systems. The combination of analysis combined with he trial and error process that has led us to such familiarity with our common building ystems (in this country the traditional wood frame house) and the prescriptive building odes that result are far easier to apply by a building regulatory agency and its inspectors. ut were we to rely on those methods, advancement in this multi-billion dollar industry ould continue at its snail's pace. Innovative methods would continue to be ruled out simply ecause no effective and speedy system was available to evaluate the suitability of those deas. That has been the case here in the United States. For example, our California uilding Department indicated that they had no basis for evaluating an innovative fiberglass-lastic housing system under their conventional codes. Only through the development and pplication of the performance concept, including the Performance Guide Criteria, the nalysis and testing that was conducted to assure compliance with the Criteria, and the uality assurance program that was established in the plant could the system be approved. t is the entire process and the management of that process that must be considered and eighed in establishing the performance approach for evaluating the suitability of housing ystems.

10. The Real Test: Is it a Good Place to Live?

I would like very much to go on and be more specific than I have been in presenting to ou examples of particular problems that we have faced in Operation BREAKTHROUGH. Time does ot allow that. Therefore, I have appended a few of the technical pages from a talk I had

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the honor of giving to The Royal Society in London last November. This will indicate a few of the actions we have taken in Operation BREAKTHROUGH in regard to the Performance Guide Criteria.

In the end the real test of any basis for evaluating housing systems must be the suitability of the community that is built. The real test is how the community satisfies the needs of its residents, and how well they respond by feeling a personal responsibility for the community. We have emphasized these factors in the Operation BREAKTHROUGH prototype sites. For those of you who have the opportunity to visit them, I believe you will agree with me when I say they are alive, vibrant, and fully indicate the community benefit of mixing housing systems, of designing for environmental concerns, of obtaining both racial and economic mix, of providing a good living environment. The real test is whether people who visit these sites will say "This is a good place to live." That must be the end objective of any basis for evaluating what we accomplish in this housing business.

The principal emphasis in this Conference is on performance of buildings. We have not yet defined the performance evaluation criteria to assure good community living environments. We have not yet verbalized the performance requirements for community designs including land planning, architecture of buildings and landscape, designs to benefit the environment and to derive benefits from the environment, guides that define leisure and recreational needs of all elements of the community -- -- we have not yet defined the performance criteria for good community living. I urge that we continue to work together to add all of those community performance evaluation factors to our efforts to develop building performance guides.

Thank you very much.

APPENDIX

1. Operation BREAKTHROUGH Performance Guide Criteria[1]

In preparing to evaluate the suitability of BREAKTHROUGH housing systems, it became apparent that certain of the systems could not be judged by normal prescriptive building codes because these systems differed substantially from conventional building methods which served as a basis for these codes. Further, we found that certain safety, durability, and livability issues in housing were not specifically addressed in most codes.

It was determined that performance measures were needed to encourage innovation and to evaluate new housing systems. In a remarkably short time, the National Bureau of Standards developed such an interim set of Performance Guide Criteria. A highly qualified committee of the National Academies of Sciences and Engineering reviewed the Guide Criteria. The resulting Criteria are serving as the basis for evaluating BREAKTHROUGH housing. These Guide Criteria are continuing to be evaluated and adjusted based on comments from various elements of the housing business and on results of BREAKTHROUGH testing. Some elements of these Criteria are discussed below.

1.1 Structures

Two aspects of structural performance are considered in the Guide Criteria: (1) Is the structure safe? (2) Does the structure perform well in service?

Structural safety is generally related to the structural attribute of adequate strength. Structural performance in-service is related to the attributes of adequate stiffness and rigidity and adequate resistance to local damage that may be caused under service conditions. Conventional structures, with which we have had extensive experience, generally possess these attributes; competition in the industry and user-rejection over the years have eliminated most undesirable attributes. However, this process is too slow in times of rapidly developing technology and changing needs and tastes. Further, the public could not afford the

[1] I would like to acknowledge the assistance of the staff of the National Bureau of Standards in preparing this material.

onsequences of the introduction of unsafe or otherwise unsatisfactory systems in great uantity. But neither can it afford to stall innovation by rejecting untried ideas. With nnovative, untried systems it is, therefore, necessary to introduce performance requireents which include areas not normally considered in the building codes.

One of the major problems we face is the lack of sufficient knowledge about the true uality of present methods. It became necessary to performance test traditional construcion elements of the BREAKTHROUGH systems to determine whether levels required by the riteria were actually greater than those now in acceptance for conventional systems. For xample, we tested a traditional house for drift by subjecting it to horizontal loads and ound that its performance level exceeded the Criteria requirements.

Figure 1 shows a typical example of an advanced structural system — the TRW system. ere is a test on a wall specimen containing a paper honeycomb core, a reinforced glass fiber kin, with an outer layer of gypsum board. It is obvious that performance testing was necesary to determine the strength and stiffness of this new system. Some specimens were tested n a normal dry state. Others were conditioned by wetting and steaming and then tested. In his case, failure loads for dry specimens ranged from 12 kip to 18 kip and of wet specimens rom 7 kip to 9.4 kip. Thus, conditioning reduced the load by about 50 percent. The reuired ultimate load capacity was 4 kip and the strength was deemed satisfactory.

Another difference between the Criteria and present codes is the inability of codes to easure the safety margins of innovative systems. Traditionally, safety margins take into ccount strength variability and deterioration with age. For untried systems, such paraeters must be estimated and evaluated. One example is the problem of evaluating the trength of structural adhesives. Many codes require mechanical fastening in addition to dhesives because the durability of adhesives is not known.

Evaluation included determination of time-fracture characteristics of materials by esting specimens to destruction under loads applied for various lengths of time and under arious temperatures and moisture conditions, including extreme conditions expected. The ame had to be done for the various adhesives and finally for structural subassemblies. As result of these tests, the original design had to be changed by connecting several modules ot previously connected in order to provide added racking resistance.

Another innovative system that had to be evaluated by testing is that of Republic Steel. his single-story system uses structural panels having a steel skin and paper honeycomb cores. ur confidence in analytical evaluation methods is not great enough to rely exclusively on alculation. Figure 2 shows a test on one of their roof panels. To simulate the most severe nvironmental condition, this panel was submerged in water for several days.

In this case, performance testing played an important role in system development. The irst test sample subjected to environmental conditioning showed serious deterioration in he bond between the skin and the core. Further study indicated that the adhesive used lost uch of its strength in wet conditioning. As a result of the test, another adhesive is now sed which performs well. The test also detected potential panel weakness caused by the plicing of core material. This led to recommendations for elimination or improvement of plicing. The testing in these previous examples not only evaluated proposed systems; the nformation gained substantially contributed to the improvement of that system.

Another system that was improved as a result of performance testing is the Shelley ystem. This system consists of 13-foot-wide and 53-foot-long concrete boxes weighing 6 tons each. These boxes are stacked in checkerboard pattern as shown in Figure 3.

The boxes, while reinforced, derive their structural strength from four ribs, each of hich consists of two columns with a beam at the ceiling level. Since grouting was to be voided, one-fourth inch thick neoprene bearing pads were planned for the column connection rom box-to-box. These pads also fulfill the function of equalizing bearing pressures and picking up the slack" from construction tolerances. Since reinforcement is not carried hrough this joint, except for a single steel dowel in the center of the column, the entire oad is transmitted through plain concrete bearing.

Stresses on plain concrete permitted by present codes would result in oversizing the column. Confining reinforcement was, therefore, provided to increase the bearing capacity of the concrete. The bearing strength of the concrete, in an improved joint consisting of a neoprene pad between two steel plates, was greatly increased and indeed the state-of-the-art in jointing techniques for precast concrete was advanced.

Examples of other structural performance tests include impact tests on walls and on floors and concentrated load tests for floors. All these tests simulate user activity. As systems become more innovative, more and more tests will have to be performed on full-scale three-dimensional modules and the test methods will have to be standardized.

Finally, something should be said about the evaluation process itself -- evaluation as a creative process, as conducted in BREAKTHROUGH.

The Housing Systems Producers in Operation BREAKTHROUGH have been free to seek innovativ solutions to housing production subject only to requirements for performance given in the BREAKTHROUGH criteria. It is, or course, essential that their plans and specifications be evaluated to achieve a high degree of assurance of the required performance. This activity is far different from the traditional code-checking of a building code department. The traditional prescriptive code says, for instance, that wall studs must be wood 2 x 4's on 16" centers, and the checker looks at the working drawings to see that they are. The performance specification says walls must not be damaged by occupancy loads. The BREAK-THROUGH criteria assist the designer and evaluator with some quantitative expressions for occupancy loads and damage, but still it is necessary to conceive potential mechanisms of damage, formulate the resistance to each mechanism and identify the critical loading configuration.

1.2 Materials and Durability

Simply stated, durability is the time-dimension of performance and, hence, is related to the aging process. Aging has a major influence on performance. The rate of aging is determined by the nature of the material in question, its compatibility with the adjoining materials and by such factors as exposure, climate, use and maintenance. The nature, intensity, and frequency of the aging factors acting alone or with others, often synergistically, produce changes which alter the performance characteristics of the material. The ability of a material, assembly, or structure to resist or, more often, adjust to the ambient forces for a normal period of time with normal usage becomes a necessary measure of performance. The cost/benefit ratio of durability and performance should be a prime consideration not only in the selection but also in the evaluation of materials which meet the performance criteria.

The preparation of the Guide Criteria clearly demonstrated that there are some developing technologies for which there is simply not enough knowledge for a full evaluation on a performance basis. We are currently working with the National Bureau of Standards on several long-range projects in an attempt to fill these knowledge gaps. For example, as indicated earlier, the rapidly expanding use of adhesives in buildings has outstripped the evaluation and testing knowledge. The major problem facing the adhesives industry is that of measuring and predicting the durability by laboratory tests. Although laboratory tests for various adhesive properties are specified in ASTM or Federal Test Methods, no existing test or series of tests provide information which adequately relates to durability and, hence, performance over the expected lifetime of the building.

Another subject of long-range research is plastics. The use of plastics on the structure's exterior in roofing, cladding, paints, coatings, sealants and caulk, and waterproofing systems has become common practice. Yet, at the current state-of-the-art of plastic technology, it is extremely difficult to predict with accuracy the long-term performance on the basis of short-term tests.

If certain parameters are known about various materials used in a building system, their behavior can be predicted with some degree of accuracy in any combination of use. This approach results in a tremendous simplification in the measurement of performance. The three parameters which should be determined are (1) the chemical and physical properties,

2) the changes which occur in these properties when exposed to the intended environment, nd (3) the compatibility of materials with other materials which make up the building ystem in question. While it is relatively easy to determine the pertinent properties of material and the interaction between or among materials, it is much more difficult to etermine the effects of time and exposure on those properties. We are working to develop riteria which consider all three parameters.

1.3 Fire Safety

est Method Inadequacies

The commonly accepted procedure for evaluating the fire endurance of elements in a uilding is the ASTM E119 Method, "Fire Test of Building Construction and Materials," a est adopted about 1908 and modified little since. As long as the materials and contructions being evaluated remained comparable to the ones for which it was developed, ne test method remained valid. With the use of new materials and constructions such as nose submitted in the BREAKTHROUGH program, we have found deficiencies in the test. For xample, there is no provision for a standard to test a load-bearing wall which has a fire xposure from both sides simultaneously.

We were faced with the problem that, in modular construction, loadbearing walls may be ubject to fire from both sides, yet no test furnaces were available to evaluate the perormance capability of the systems in question. The National Bureau of Standards developed n analytical heat transfer program using an iterative solution to evaluate the bearing alls with fire on both sides. Additionally, we believe we will have to develop a new et of criteria for the fire performance of double party walls found in modular construction nd not covered by the present codes.

There are other deficiencies in the E119 test method which have come to light and which ust be resolved. For example, the pressure in the test furnace is not defined. Whether ne furnace is operated under a positive or negative internal pressure makes a large differnce in the amount of gases and fumes coming through the construction. The pressure also ffects the degree to which fire penetrates the test construction.

Also, the standard E119 fire test makes no provision for measuring the amount of smoke nd toxic gases generated by the construction. In testing some walls made of fiberglasseinforced polyester, we found an intolerable amount of gases and smoke generated by the onstruction, even though they passed the E119 stipulated requirements. Yet another major eficiency is the lack of a defined method of evaluating construction with small fires. nis becomes especially significant as we become more innovative in the use of chemical nd plastic construction materials.

moke Detectors

Studies have been conducted of fire deaths in residences in the Province of Ontario, anada. The results indicated that 59 percent of the persons asleep at the time of the fire ould have been saved by an adequate smoke detection system. Studies by the National Fire rotection Association on residential fires in the United States have indicated that 52 ercent of the fatalities in these fires were caused by smoke inhalation and only 44 percent y burns. With these data in hand, it was relatively easy to decide that we should provide moke detection for safety in residential construction, even though detectors are not equired in any of the model codes. Specific criteria for residential detectors were not vailable. We therefore initiated a study of the mechanics of detectors and the state-ofhe-art to develop a set of criteria which would provide for an inexpensive residential etector. The criteria placed emphasis both on reliability and extended service life.

ife Safety System

The BREAKTHROUGH Criteria attempted to provide a system for life safety in fires, articularly in high-rise buildings, which would be equal to or better than those now in se. As a result, several new concepts were introduced in the form of new requirements hich do not exist in the current codes. The system consists of the following components:

detection, alarm, design of passageways and exiting, and control of materials.

An early warning system of either the smoke or product-of-combustion type is required. Detectors spaced on 30-foot centers are required in corridors. Since such corridors would be passable for a longer period of time, increases in travel distance were allowed above those normally permitted by the code.

Once a fire is detected, there must be an alarm. Most buildings have alarm systems which ring throughout the building but experience has shown these systems are not effective. When the alarm rings, no one feels an immediate presence of danger. Therefore, we went to a zoned system in which the alarm sounds on only the floor of the fire, the floor below and the floor above. When an inhabitant of the building hears the alarm of this system, he knows that danger is near.

Unfortunately, in our state of knowledge, there is no good indication as to whether the alarm system should be visual, or audible, or both. Although bells were required in the criteria,there is a growing body of opinion in the United States which holds that a voice type of system, with possibly flashing lights for directions in the corridors, should be used for greater effectiveness. This question should be investigated.

Many deaths due to fires have been the result of people fleeing their burning apartment and leaving the door open, allowing the fire to get into the corridor. In the case of a nursing home fire in Marietta, Ohio, about 30 people died because of the lack of self-closing doors. For this reason, all doors opening onto the corridor are required to be self-closing.

In addition, it was felt desirable to control smoke at its source by controlling the materials on the building surfaces. Therefore, criteria were added which place control on the smoke propagation properties of interior finish materials. These criteria are also not found in current codes.

1.4 Acoustics

Major property management firms report that noise transmission is one of the most serious problems facing managers of apartment buildings throughout the country. Managers and owners of apartments readily admit that market resistance is not only increasing as a result of excessive noise transmission but also that lack of both acoustical privacy and noise control are the greatest drawbacks to apartment living.

The basic noise problems are due primarily to lightweight building structures, poor acoustic design -- including site selection and arrangement of functional living spaces without regard to noise sources, poor workmanship which nullifies planned sound insulation, an increased use of mechanical appliances, and the greater concentration of people in smaller areas such as in high-rise apartments.

These are the problems that the BREAKTHROUGH acoustic criteria are intended to alleviate By citing lightweight building structures, increased mechanization, and the prevalence of high-rise construction as causes of the noise problem, there is no intent to deprecate these trends in architecture and construction. Rather, the intent is to point out that modern buildings require more specific attention to noise control than did the massive constructions of the past.

Without minimum standards, the consumer must purchase a dwelling unit on the basis of glorified phrases of praise by the salesman. It is not until after occupancy that the consumer knows whether his home is liveable. He will know <u>every day</u> whether his need for privacy or quiet is fulfilled. Every day he knows that there is little he can do to improve certain deficiencies without a great deal of expense -- some of which could have been corrected at a minimal cost during construction. One thing we learned in BREAKTHROUGH was that builders, or systems producers, are generally unaware of potentially inexpensive methods of acoustical improvements. Therefore, they think such improvements must be prohibitively expensive so the changes are avoided. Part of the confusion stems from a lack of clearly defined acoustical goals.

ɔals of Acoustic Criteria

The guide criteria developed for the design and evaluation of the acoustic environment f prototype housing in BREAKTHROUGH are intended to permit attainment of three distinct ut related goals:

-- Provision of a sufficiently quiet environment in which to live comfortably

-- Provision of acoustical privacy between dwelling units

-- Provision of acoustical privacy within a dwelling unit

Criteria which are suitable to all situations and environments would be virtually npossible to establish and very difficult to apply. Therefore, the intent was to establish riteria which would satisfy a majority of the occupants most of the time and yet would be asy to administer.

One significant problem is that these goals can be in conflict with one another. For xample, while it may be possible to design out the major source of outside noise, and, herefore, effectively meet the first goal, the newly attained quiet may well bring a new ntensity to the lack of privacy inside the structure. Inter-apartment noises that were reviously dulled by the conflicting outside noise now are clearly heard and the occupants' ntagonism and aggressions are directed at their fellow residents.

A most difficult problem is the provision of measures of the acoustic criterion. We re using the NC curves devised by L. L. Beranek which provide a single-figure rating for nterior noise levels. The following graphs show the curves as they plot speech interference nd annoyance (Figure 4). We are also using the Sound Transmission Class Normalized Isola-ion Class rating systems to better measure the difference in average sound pressure levels n rooms on opposite sides of a test partition (Figure 5). In order to assess the impact ound insulating properties of floor-ceiling constructions, we are using an adaption of the nternational Standard Organization method established by the American Society for Testing aterials.

I want to emphasize that the important thing is not the specific graphs or the many ating systems that are available, but rather the lack of available research on standards oncerning the real needs and desires of those who occupy our dwellings. For example, what s the degree of privacy desired by parents? Do they really want to be able to hear every-hing in order to feel their children are safe, or is there a higher level of priority ttached to reduction of bathroom and bedroom noises? Can both goals be achieved? At hat cost?

The last two graphs compare the BREAKTHROUGH criteria for inter-dwelling acoustics with our British criteria and show how closely matched the contours really are. Figure 6 shows striving for the highest normalized level of sound difference while Figure 7 shows a triving for the lowest impact sound pressure level.

It may be helpful to point out that our criteria go beyond those now required by the ormal HUD/FHA Minimum Property Standards (MPS). There, no requirements are given for artitions within a dwelling unit and none are given to ensure a quiet environment. In peration BREAKTHROUGH both requirements are stated. While the FHA Minimum Property tandards base compliance on laboratory tests, the Operation BREAKTHROUGH criteria are based n performance (field tests). Laboratory tests are used as a guide to determine in the esign stage whether compliance could be met.

The use of industrialized -- especially modular -- housing has its good and bad points, coustically speaking. One advantage is that the combined wall or floor/ceiling construc-ion that results usually has a minimum of coupling between the two interior surfaces and hus provides the potential for a superior partition. One drawback of modular housing can e illustrated in the case where a module for a garden apartment includes a partywall in he center of the module. This partywall might separate two living rooms, kitchens or what-ver. Because of the need to transport modules, the structural integrity of the module must e maintained.

Even though a wall can be constructed which in itself provides a high degree of sound isolation, one major coupling path exists -- the continuous floor under the partywall. Additionally, a flanking path sometimes exists in the void space between the first and second floor modules since the wooden floor does not attenuate sounds very well. These problems can be corrected by making a saw cut in the floor in the partywall cavity and providing a firestop as shown in Figure 8. A better location for the insulation is also shown.

Specific examples of the problems and progress of the BREAKTHROUGH systems can be illustrated by TRW and Material Systems, both of which use new, lightweight fiberglass reinforced plastic materials. Material Systems Corporation has partitions of chopped glass fiber reinforced polyester. Although this material is very lightweight and innovative from a building standpoint, the sound transmission loss of such partitions is very poor. A more massive material such as gypsum drywall must be added, especially to partywalls, to provide the proper sound attenuation. TRW, which has a fiberglass modular shell, has had to go to gypsum drywall laminated to their basic shell to satisfy both the sound attenuation levels and fire safety criteria.

The Townland System has a supported land system. Modules are placed on different levels of a multi-level frame which creates artificial land space. The vertical acoustical privacy is greatly enhanced by this separation of dwelling units.

A survey in New York City a few years ago indicated that occupants of apartments would be willing to pay an additional $15 a month for better acoustical quality -- a pretty strong statement coming from a city where prices are already very high.

Frankly, and despite consumer desires, the response of the housing system producer to the acoustical criteria of Operation BREAKTHROUGH has been mixed. The majority of the housing systems producers have been unwilling to spend even a minimal amount to increase the acoustical quality of the dwelling unit unless it is absolutely required in order to complete the Operation BREAKTHROUGH program. Much resistance has been met to incorporating even those items which can be done very inexpensively, e.g., vibration isolation of the garbage disposer from the sink, the dishwasher from the floor and plumbing, resilient pipe hangers, water hammer arresters, and design of duct work to minimize noise transmission. Many such simple modifications may cost only two or three dollars yet can be responsible for approximately a 10dB reduction in noise level.

The objective of HUD, quite understandably, is to see that every housing system producer is able to provide a product in a reasonable time and at a reasonable cost. It is our responsibility, perhaps our greatest challenge, to see that these production goals are achieved with high quality construction.

In Operation BREAKTHROUGH, it is doubtful that any housing system will meet all the criteria for acoustics. This does not imply that no progress has been made concerning acoustics in the building industry. More builders than ever before are now at least aware that acoustic quality in buildings is becoming an essential consumer requirement. A great deal of information can be drawn from the testing of Operation BREAKTHROUGH housing. At any rate, a number of the Operation BREAKTHROUGH housing systems should afford better acoustical privacy and better control over the noise than most of the homes built in the United States today.

2. Environmental Systems

The BREAKTHROUGH program has a real potential for significant advances in environmental quality in housing, if that quality is recognized as a legitimate responsibility on the part of the designer and builder. One of the most notable achievements of HUD-sponsored housing research has been the creation of the means by which building service system innovations can be evaluated and introduced into practice. The following sections portray specific examples of the accomplishments, lessons, benefits, and implications that have arisen from HUD-stimulated or supported research in the Building Transport System areas of plumbing, electrical distribution systems, total energy systems, physical distribution (elevators), solid waste, and aerobic waste treatment systems.

In plumbing, or hydro-sanitary systems, European developments have led to considerable use of new technology in ways not yet generally applied in the United States. In developing the BREAKTHROUGH criteria and selecting the system for prototype site development, we relied heavily upon European experience and technology. Our objective was not only to stimulate new technology but also to create an opportunity for the demonstration and acceptance of existing technological advances beyond the scope of our normal use.

2.1 Plumbing Innovations

For the purposes of this discussion, the term "innovation," in BREAKTHROUGH plumbing will be applied to the materials, methods, or techniques that are not indicated as allowable in the text of most present-day American plumbing codes. Specifically, BREAKTHROUGH includes:

a. Plastic piping (drain-waste-vent piping; water-distributing piping)

b. Single-stack drainage (designs derived from British single-stack drainage, and those from Swiss "Sovent" single-stack drainage)

c. Reduced-size venting and simplified venting (designs with dry vents of less than code-size, and designs with traditional stack vents or individual vents eliminated)

d Prefabricated assemblages of piping (incorporation of the plumbing designs into the modular approach for the whole room or the whole house in BREAKTHROUGH appears to have much more far-reaching significance than the types of spotty prefabrication of the recent past).

A number of the plumbing innovations appearing in the BREAKTHROUGH program appear to conflict with the "letter" of many codes. Among the features of the criteria that have made it possible to develop a favorable reaction to a number of such innovative proposals are the following:

a. The use of trap-seal retention and of maintenance of an effective barrier to deleterious fluid ejection as the criterion of vent-system performance, rather than the traditional $\pm$ 1 inch water column pressure criterion.

b. The use of load-supporting capability for the rims, sumps, supports, and water supply and drain connections of installed plumbing fixtures, as the criterion of the adequacy of the strength of the completed installation from the owner's and user's point of view.

c. The identification of deleterious accumulation of spilled water in certain locations as the criterion for determination of need for floor drains or other means of disposing of such water.

d. Criteria for avoiding deleterious ejection of detergent suds or buildup of excessive pneumatic pressures in the lower portions of sanitary DWV Systems.

e. Criteria for selecting realistic hydraulic test loads for evaluating innovative DWV or water-distributing systems.

f. Criteria relating to water quality that can affect pipe sizing or selection of materials, or that can determine the need for a water conditioning program.

g. A criterion that establishes a maximum and a minimum limit on available discharge rates of water outlets, under design load conditions. Although some codes exhibit a form of this criterion, experience in BREAKTHROUGH suggests that the code criteria may be largely misinterpreted or ignored.

h. A scheme for rating relative life expectancy for the various parts of a plumbing system.

i. Criteria for discharge effects.

j. Among other criteria that are not widely spelled out in plumbing codes, but which are included in the BREAKTHROUGH criteria, are criteria for minimization of fouling of DWV piping, criteria for system components, controlled-flow roof drainage, acoustical criteria, and fire criteria for plumbing walls, and pipe chases.

2.2 Prefabricated Electrical Distribution Systems

A possible "breakthrough" in prefabricated, complete electrical distribution systems for assembly line installation in modular housing units has been developed by the General Cable Corporation at the urging of Boise Cascade. These "spyder harnesses" consist of a central junction box or circuit breaker panel and network of predetermined legs using outlets and switches specifically designed for attachment in controlled high volume factory assembly lines, as shown in Figure 9.

These power distribution systems use conventional materials and components. The system incorporates a number of unique characteristics. For example, while the switches, outlets and other system elements are of conventional design, they are wired automatically and factory assembled in integral junction boxes ready for attachment and cover plate installation. This process is not only more economical than field fabrication of electrical distribution systems but it also appears to offer advantages in quality control, reliability and safety.

2.3 Emergency Electric Power and Heating

Electrical codes generally require provision of emergency power sources for special facilities like police/fire, and hospitals. However, this is generally not the case for multi-family, low- or high-rise dwellings.

The blackouts we have experienced in recent years have clearly demonstrated that it would be desirable to have such back-up in a broader range of types of facilities. Therefore, the BREAKTHROUGH criteria specifically require that standby electrical power (usually generated on-site) should be provided for multi-family housing buildings containing 60 or more living units in cases where the primary power source reliability indicates a 20 percent annual probability of frequent (six or more per year of more than 5 minute duration) or extended (six hours or more) failure of the customary power source.

These are only a few of the areas in which Operation BREAKTHROUGH is setting a performance basis for judging housing suitability. The objective is to encourage improvement and to provide a means of evaluating new concepts. Much remains to be done to make such approaches fully implementable but a good, solid start has been made.

2.4 Examples of Advanced Utility Demonstrations for the United States

In addition to concern for site planning and building system performance, Operation BREAKTHROUGH's prototype sites offer an opportunity to evaluate and demonstrate advanced utility systems to provide services essential to a residential community. Two of these are described below.

Total Energy

The recognized shortage of energy reserves have led to undesired conditions from both a livability and an economic standpoint. Two examples show this clearly:

In Washington, D.C., and Baltimore, Maryland, no new customer can obtain natural gas service if his requirements exceed 300,000 cubic feet per day. Also, the Boston Gas Company plans to import gas all the way from Algeria by tanker.

The severity of these conditions, combined with technological progress and potential cost savings, has caused a logical turn to total energy systems as a possible solution for new development. As a result, we will be installing a full-scale total energy system at the Jersey City, New Jersey, prototype site. It will provide all electrical services, hot and cold water for space heating and cooling, and domestic hot water for 500 dwelling units as well as for shopping facilities and primary grade school facilities. Carefully designed and operated, this system will utilize 65 to 70 percent of all the heat energy in the fuel consumed whereas large central electric generating stations usually convert only 35 to 40 percent.

However, unless the reduction in fuel cost for a total energy system more than offsets the higher first cost and maintenance cost as compared to the purchase of electricity from the local utility, the system would not be economically viable.

Virtually all utility companies use a sliding cost scale for electric energy. The electric rates for six of the cities in which we have prototype sites, as of August 1970, are shown in Figure 10. The individual home owner must pay the highest rate shown at the left of the graph, to offset both the greater distribution cost to residential customers, and also for the higher level of wasted energy that is characteristic of central generating stations. It is in these offsetting cost patterns that a total energy system may be able to attain a lower overall owning and operating cost for the whole spectrum of energy needs.

While the cost savings for individual homeowners may be significant, the dramatic savings potential becomes more obvious when the long-term energy requirements and the resulting estimates of the various savings of a total energy system are determined. Considering the use of total energy in new and redeveloped communities alone, from now until 1986, the potential savings in power generation facility capital costs is large, perhaps as high as $50 billion! Added to this would be a projected annual reduction of fuel imports by over $2.5 billion and a savings to the domestic consumer of some $3.8 billion annually in electrical costs that can now be attributed to waste energy. These numbers are based on estimates of the available market.

In addition to the specific financial savings, there would be important gains by reduced thermal pollution, reduced cooling water requirements, reduced combustion effluents -- perhaps by as much as 40 percent -- greatly increased recycling of solid wastes, reduced sewer water volume by as much as 80 percent for those units serviced by integrated utility systems, reduced noise pollution, and reduced maintenance requirements for individual units.

Solid Waste Disposal

Criteria for trash and garbage removal facilities recognize the principle that to be effective for multi-family buildings such systems must be adequate, safe and convenient to all the occupants. This is reflected in BREAKTHROUGH criteria in the following provisions:

a. Disposal facilities are required on each floor of high-rise buildings.

b. Vertical chutes large enough to assure good operation without blockage.

c. Compactors are required rather than incinerators to facilitate removal of trash from the building and to alleviate smoke pollution.

d. Fire-safe trash rooms are required.

The most significant demonstration effort concerned with solid waste is the installation of a pneumatic vacuum trash collection (PTC) system at the Jersey City site. In this system solid waste is collected at a central point through pneumatic tubes. The system is not a new technological advance since it is already in use in Sweden and the concept is used in other countries, but it is a perfect example of an innovation suited for use in the

United States but as yet unaccepted. We are trying to show that such a system has advantages and can become a major item in our environmental control program. Like the total energy system, potential financial and livability savings are considerable, and the most significant gains will come when these two systems, total energy and solid waste collection, are combined so the waste is recycled in the form of heat producing energy.

3. Conclusion

I am frequently asked whether the Operation BREAKTHROUGH effort has been justified, not only by the specific results such as those I have mentioned today, but also in relation to the priorities we face in the United States today. I think the answer is an unequivocal YES.

Were BREAKTHROUGH merely an attempt to help industry build more houses more efficiently, we would never have become involved with the program. My country faces a large number of major problems that are closely related. I said earlier that a home is more than a building. So, too, is the BREAKTHROUGH program a lot more than housing production. We are talking about communities, about recognizing the faults that are inherent in the institutions which currently dictate how we live, and where we live, and we are causing those institutions to change.

All change is not progress, but in this case I submit that the record will show that the American consumer, the homebuyer and renter, will have an expanded range of opportunities, that the individual will be better able, regardless of race or income, to find improved living conditions, and that the emphasis on housing production will have been supplemented by stronger emphasis upon quality and community in addition to assuring availability of the number of housing units we need.

I think this program will have addressed the major economic, social and institutional issues which are currently confronting not only housing production but also life in communities across the United States. I do not for a moment think that we will have solved all of those problems, but I do believe that we will have made a major contribution to their resolution.

For the European components of the BREAKTHROUGH program, and there are many, we are all grateful. For this opportunity to meet with you today, I am personally most honored and appreciative.

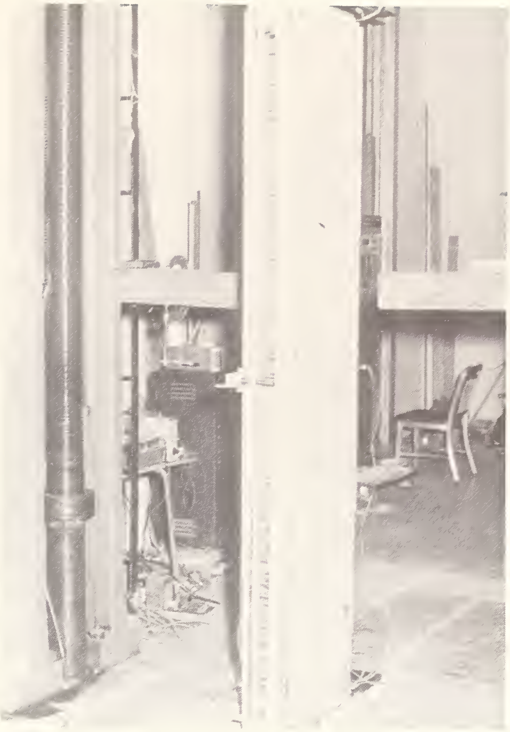
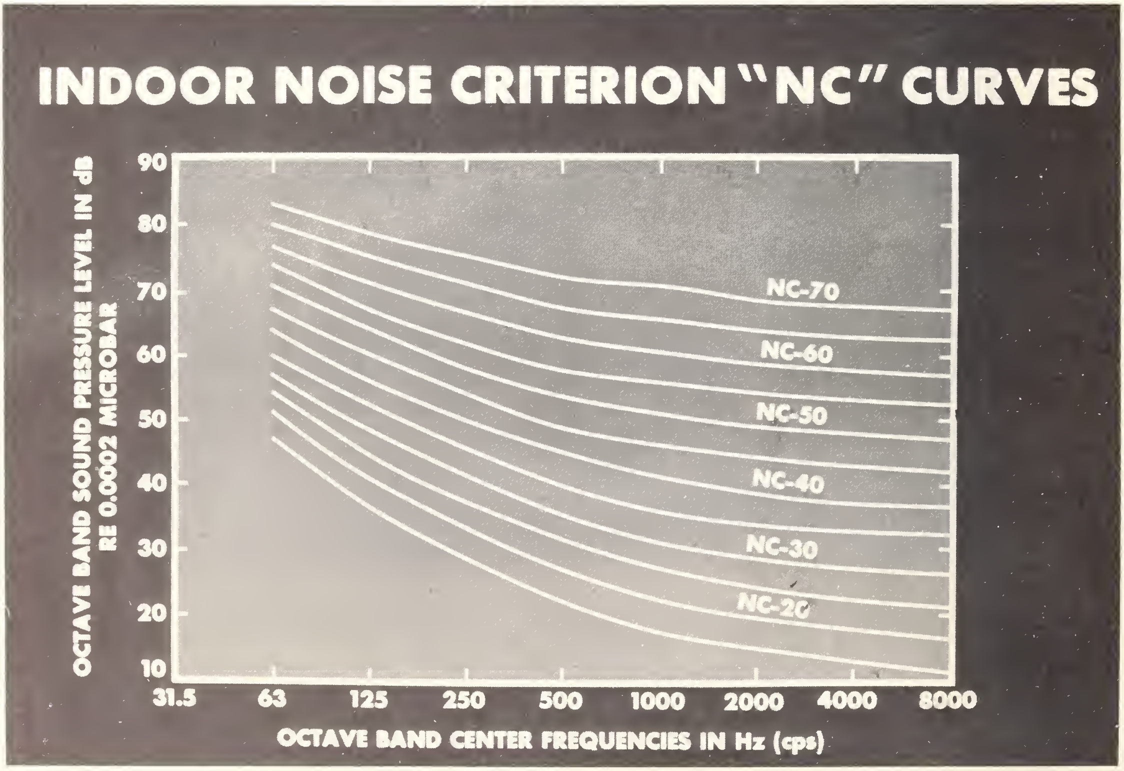


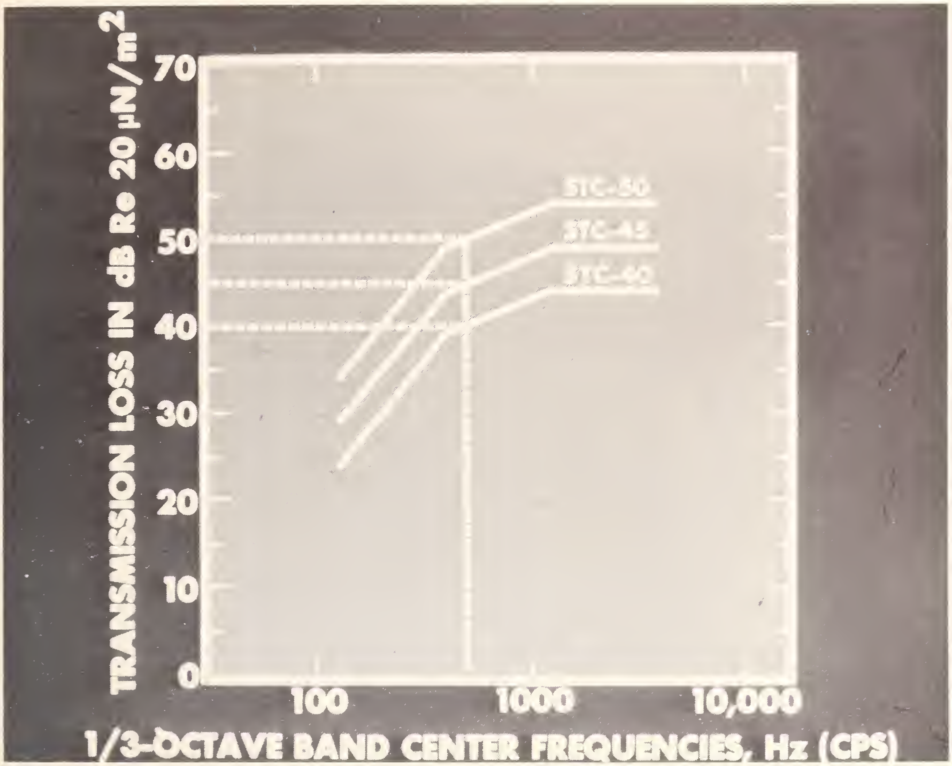
Figure 1

Figure 2

Figure 3

Figure 4





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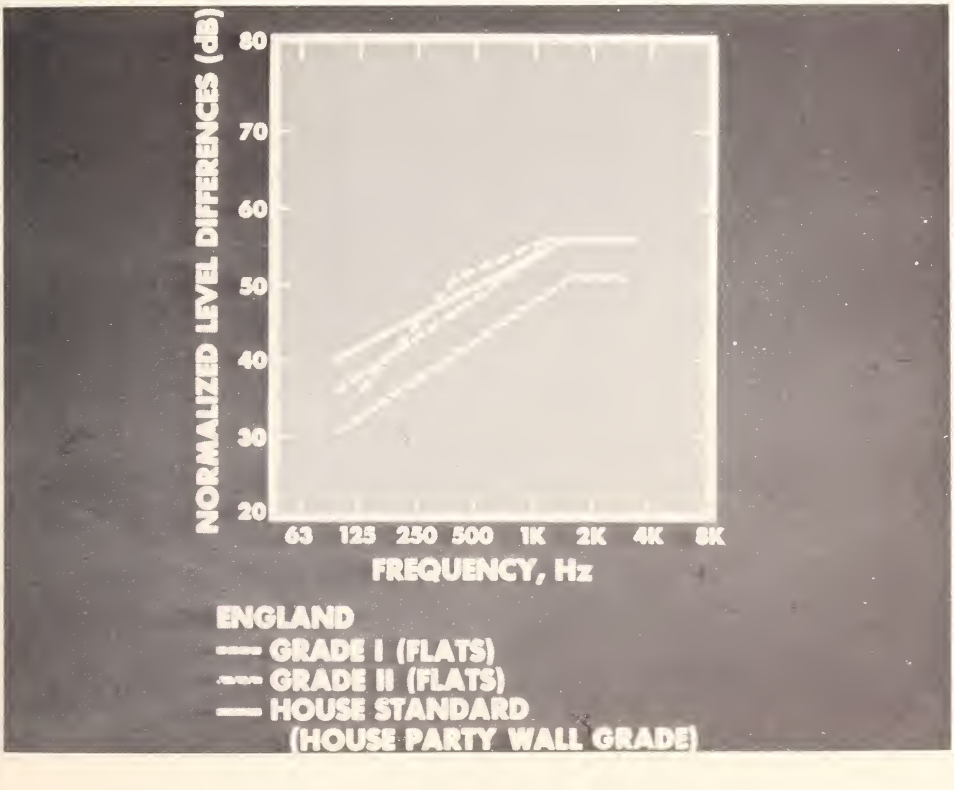

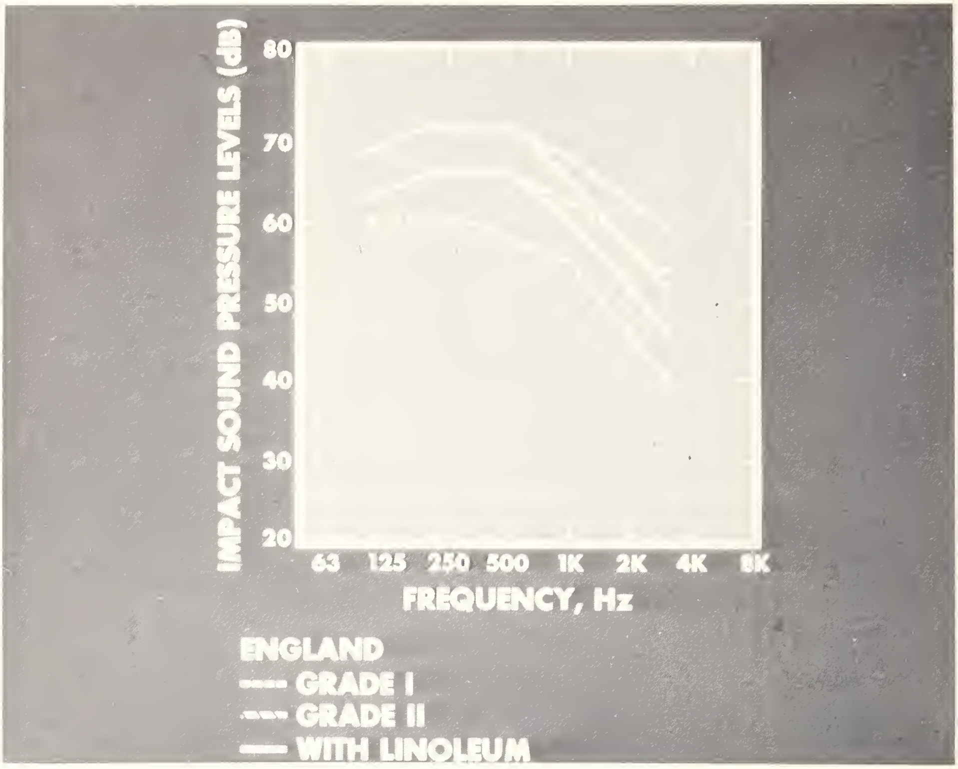

Figure 7

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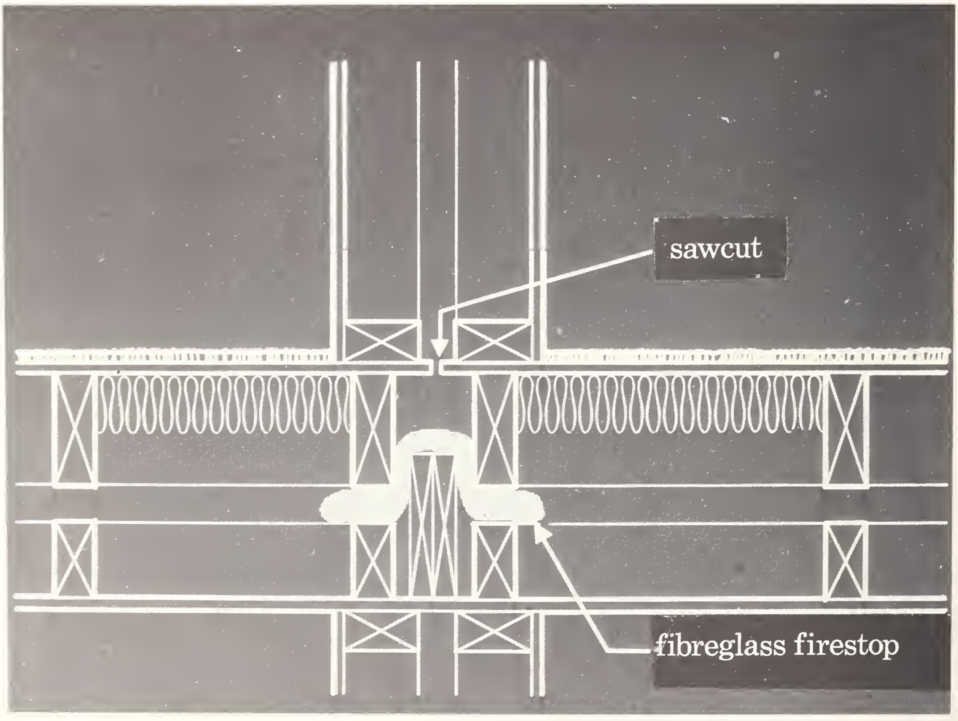


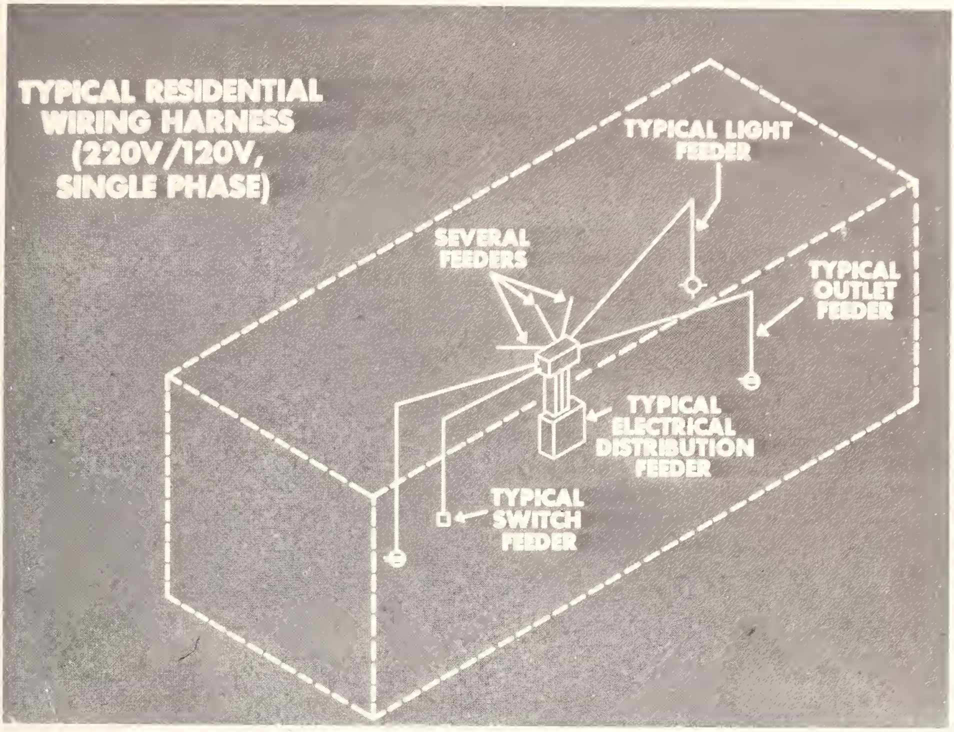
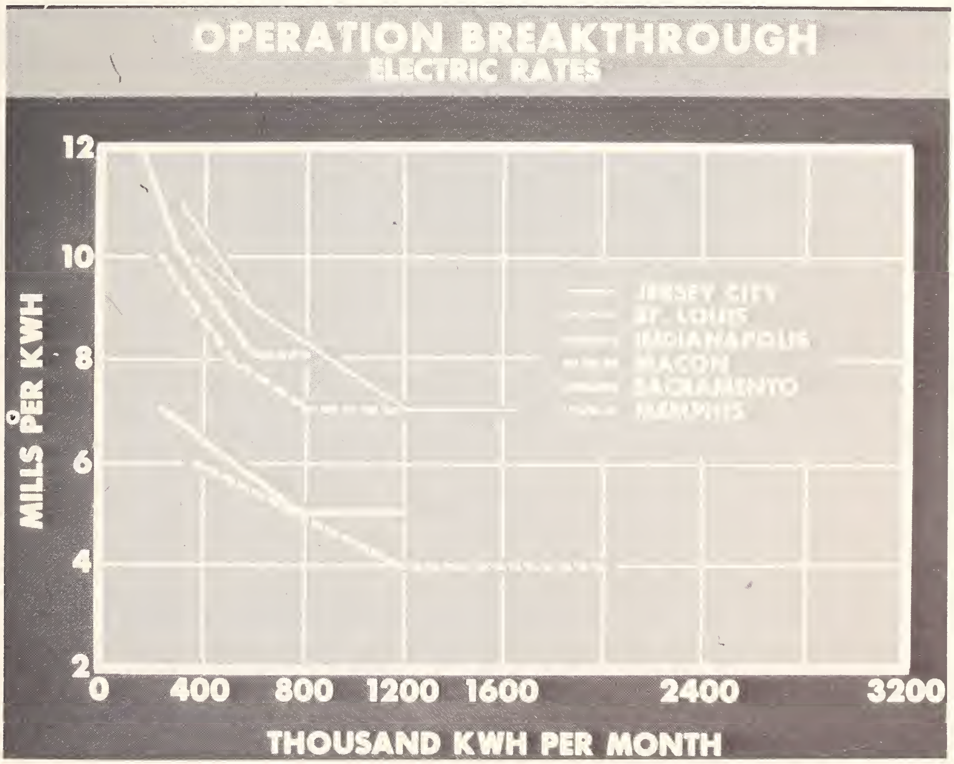


Figure 9

Figure 10



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B. Allocutions Générales

Le Rôle de la Notion de Performance dans l'Opération BREAKTHROUGH

l'Honorable Harold B. Finger
Sécretaire Assistant de la Recherche et la Technologie
Ministère du Logement et Développement Urbain
Washington, D.C.

1. L'Opération BREAKTHROUGH: Ses Buts et Sa Force

Le 8 mai verra le troisième anniversaire de la création de l'Operation BREAKTHROUGH. Notre but était d'accélérer le rhythme d'amélioration de l'habitat, de susciter des innovations dans les systèmes de construction, dans l'aménagement foncier et de donner à tous la possibilité d'habiter des communautés parfaitement conçues. Dans ce court laps de temps, nous avons réalisé presque tout ce que nous nous étions proposés et, dans de nombreux domaines, plus que nous ne l'attendions. Nous avons surmonté beaucoup d'obstacles qui s'opposent aux améliorations que nous cherchions.

1.1 Au cours de ces trois ans, vingt états ont promulgué soit des lois rendant le bâtiment industrialisé obligatoire sur l'étendue de leur territoire, soit des codes généraux de construction. De tels projets de loi sont maintenant en attente dans huit autres états. Il est évident que l'Opération BREAKTHROUGH a fourni le stimulus nécessaire pour la promulgation de ces lois puisqu'aucune de celles-ci n'étaient en vigeur avant sa création. Ces lois réaffirment l'autorité de l'état en ce qui concerne les codes de construction qui sont l'instrument essentiel permettant de surmonter les restrictions imposées par une myriade de codes locaux de construction. Nous travaillons avec nos organisations nationales et les organisations d'états s'occupant des codes de construction de susciter l'établissement d'une législation type qui apportera une plus grande harmonie entre les états et qui donnera la possibilité de règles réciproques dans la construction.

1.2 Pour la première fois, les initiatives des syndicats du bâtiment ont conduit à l'établissement des accords sur la main d'oeuvre permettant la construction industrialisée de logements. Ces accords permettent des niveaux de salaires industriels spéciaux au lieu des hauts salaires de la construction classique, l'emploi d'un plus grand nombre d'ouvriers non qualifiés, et l'instruction professionnelle des minorités. Ces accords fournissent également des codes de juridiction et de travail pour une production industrialisée efficace de bâtiments par opposition aux accords en usage dans le montage et la construction in situ.

1.3 Le transport est le maillon majeur aux marchés étendus pour des bâtiments préfabriqués. L'Opération BREAKTHROUGH en coopération avec l'industrie des transports, les fabricants de bâtiments, les services fédéraux, les services d'états et locaux ont essayé de réduire les tarifs routiers, les entraves routières et bureaucratiques. Ils ont amené les chemins de fer à accepter les expéditions à longue distance à un prix raisonnable en utilisant les wagons plats classiques et l'arrimage normal pour le transport des éléments préfabriqués. On est arrivé à certains résultats dans la réduction des frais d'expédition. Il en faut plus et on s'attache maintenant à obtenir des réductions plus importantes.

1.4 Une grande variété d'établissements financiers sont concernés par construction industrialisée: le crédit hypothécaire, les compagnies d'assurances, les banques commerciales, les caisses d'épargne et différents services administratifs. L'engagement de ces établissements financiers a diminué leurs craintes vis-à-vis de la construction industrialisée qui existaient auparavant en raison de leur ignorance de la qualité qui peut être obtenue dans ce domaine.

1.5 Les systèmes de gestion en usage dans l'Opération BREAKTHROUGH sont adoptés par l'industrie et même par d'autres services administratifs. La nécessité d'une vérification plus précise des prix a conduit l'Opération BREAKTHROUGH à mettre au point un système de comptabilité des prix du logement industrialisé qui, dans un sens, allie la comptabilité la plus utile de construction in situ à la comptabilité la plus avancée dans la production industrielle.

1.6 Une grande partie du personnel de l'état-major et des services de construction sur sites du Ministère du Logement et de l'Urbanisme s'est trouvé engagée dans l'aménagement de sites modèles ou prototypes de l'Opération BREAKTHROUGH aussi bien que dans son étape suivante, la Phase III concernant la production en masse. L'Opération BREAKTHROUGH a donc déjà fourni à une grande partie des services administratifs responsables du logement la connaissance des méthodes industrialisées et la façon d'aborder l'innovation en matière de logement. De plus, on observe des changements dans la façon dont HUD reconnaît les exigences particulières du bâtiment industrialisé par rapport à la construction plus classique in situ.

1.7 Les cinquante états sans exception et de nombreuses communautés locales ont désigné des représentants spéciaux pour l'Opération BREAKTHROUGH. A cet égard, L'Opération BREAKTHROUGH a été la cheville ouvrière de la participation au niveau de l'état dans le domaine du logement et de l'aménagement des communautés locales. Dans trente-six états et le District de Colombie deux cent dix-huit sites ont été proposés pour un aménagement type. Dans quelques douze autres états des services de logement et de financement aussi bien que les vingt codes de construction dont nous avons déjà parlé ont été mis sur pied. En résumé, il y a eu importante prise de responsabilité dans le logement au niveau de l'état.

1.8 Les normes du plan et la surveillance du projet dans le cadre de l'Opération BREAKTHROUGH exigent des précautions particulières en ce qui concerne les causes les plus fréquentes d'accidents dans le logement (c'est-à-dire, les baignoires glissantes, les portes vitrées, les escaliers obscurs, les prises de courant dangereuses, etc.) et fournissent des normes rigoureuses pour une vérification efficace de la qualité en cours de production dans l'industrie de la construction.

1.9 Grâce à une évaluation rigoureuse et à des essais on s'est aperçu que des nouvelles formes de technologie dans la construction étaient viables et réalisables. Elles comprennent: "sprayed fiberglass structure, stressed skin foamed plastic core structural panels, honeycomb core sheet metal skin structures, honeycomb core fiberglass skin structures, high rise structures of steel-framed factory modules, high rise structures of factory made concrete modules stacked checkerboard fashion, snap-in electrical inter-connections for panels and modules, and core modules efficiently packaging baths, kitchens and heating/cooling units." Le récent achèvement d'un grande ensemble de cent dix unités sur notre site de Sacramento vingt-trois jours après la première mise en place des panneaux est une réussite technique dont nous sommes tous fiers.

1.10 Les neuf projets prototypes pris dans leur ensemble fournissent un modèle national d'aménagement foncier efficace dans différents contextes géographiques. Les sites envisagés pour la production en masse sont en cours d'étude pour assurer la continuité d'aménagements d'une telle qualité.

1.11 Deux mille neuf cent trente-huit unités auront été construites dans les sites prototypes à la fin de la phase prototype du programme. A la fin d'avril, plus de 1199 de ces unités étaient construites et 101 étaient occupées. Tous les prototypes devraient être terminés à la fin de cette année à l'exception peut-être du site très complexe de Jersey-City.

En outre, 10.900 unités faisant partie d'une tranche spéciale de l'aide à l'habitat ont été affectées à la production en masse en plus des sites prototypes. Nous pensons qu'à la fin de juin 25.000 unités auront été affectées. De plus la construction de 7.000 unités de logements non affectées est en cours. Elles s'addressent aux moyens et hauts revenus.

1.12 Les premières mises sur le marché ainsi que l'occupation des sites prototypes indiquent que le mélange économique, social et racial est réalisable si l'aménagement communautaire et le cadre de vie, éléments de confort qui indiquent la possibilité d'une vie agréable, se trouvent disponibles. Une évaluation à plus longue échéance de l'influence sociologique de l'Opération BREAKTHROUGH est indispensable pour la mise au point d'une politique de planning communautaire.

1.13 Enfin, je voudrais en venir à l'objet principal de ce Colloque. En étudiant l'opportunité des systèmes de construction de l'Opération BREAKTHROUGH, il devint évident que certains de ceux-ci ne pouvaient être évalués d'après les codes de construction normaux et consacrés parce que ces systèmes s'écartaient essentiellement des méthodes classiques de construction qui étaient à la base de ces codes. En outre, nous nous sommes aperçus que certains problèmes de sécurité, de durée et de confort du logement n'étaient pas mentionnés de façon précise dans la plupart de ces codes.

Il a été établi que des mesures concernant la performance étaient nécessaires pour stimuler l'innovation et pour évaluer les nouveaux systèmes de construction. Dans un laps de temps particulièrement court, le National Bureau of Standards a mis au point un guide provisoire des critères de performance. Celui-ci a été révisé par un comité hautement qualifié des Académies Nationales des Sciences et de l'Ingénierie. Ces critères révisés servent de base à l'évaluation de la construction de l'Opération BREAKTHROUGH. Cependant, ils sont toujours en cours de révision et d'évaluation d'après les commentaires venant de différents éléments de l'industrie de la construction et également d'après les résultats des essais de l'Opération BREAKTHROUGH. De plus, on pense utiliser les concepts du Guide des Critères de Performance pour la mise au point des normes de propriété minimale qui servent de base à l'assurance hypothécaire fédérale. L'essentiel est que les critères de performance fournissent une étape nouvelle et efficace pour le plan et pour l'évaluation d'une technologie novatrice. Ils fournissent également une guide de bonne pratique pour l'amélioration de l'application des codes.

2. La Base de Performance Pour L'Evaluation des Systèmes de Construction; L'Outil du Progrès de L'Industrie

Je voudrais maintenant mentionner plus particulièrement la base de performance pour l'évaluation des systèmes de construction. Je sais que ce sujet sera discuté ultérieurement de façon plus approfondie, en conséquence, je me bornerai aux aspects conceptuels généraux et aux besoins futurs dans ce domaine.

Nous savons tous que l'industrie de la construction a été en perpétuel changement dans le monde. Ici aux Etats-Unis elle change et elle avance plus vite que jamais auparavant surtout à cause de l'impulsion qui lui est donnée par l'Opération BREAKTHROUGH. Au fur et à mesure que le rhythme de ces changements s'accélère et que progresse le perfectionnement de notre industrie, nous nous trouvons aller, aux Etats-Unis et ailleurs, au-delà des méthodes familières et consacrées vers des idées neuves et pratiquement inexploitées. Ceci ne doit pas nous décourager, car nous avons en main l'outil nécessaire pour aller de l'avant. Cet outil c'est la notion de performance, la base de performance pour évaluer la convenance de ces nouveaux systèmes de construction.

Les exigences courantes du plan et les dispositions des codes de construction s'appuient, dans une large mesure, sur des matériaux qui reflètent les solutions, passées et présentes, au plan et aux techniques de construction. Les exigences des spécifications consacrées ont fait de l'évaluation de sécurité et de durée une responsabilité suffisamment simple à écarter au profit de concepts de construction établis et qui ont fait leurs preuves. Historiquement, ces exigences des spécifications consacrées figurant dans les codes de construction ont permis de produire des logements sûrs, sains, et durables.

Il y a cependant un apprentissage que nous devons tous suivre et qui nous ramène aux exigences de base requises par l'"abri" et son utilisation. Par exemple, une cloison intérieure non-portante construite en matériaux classiques avec son revêtement familier peut remplir son but si elle est faite pour résister simplement à une certaine charge horizontale uniformément répartie. En l'utilisant dans un contexte connu nous partons du principe que cette cloison classique permettra d'y accrocher des étagères, qu'elle aura des propriétés acoustiques acceptables, qu'elle supportera l'usure normale des activités humaines, qu'elle pourra être facilement réparée ou repeinte, qu'elle permettra le passage de conduites électriques et peut être de conduites sanitaires et sera conforme aux règlements sur l'incendie tels que la propagation des flammes, la production de fumée et la résistance au feu.

Du projecteur à l'usager, nous pouvons ne pas avoir une telle confiance quand il s'agit de réalisations nouvelles et novatrices. Cependant la confiance peut revenir si les qualités des systèmes de performance sont rendues claires et si elles sont satisfaites, quel que soit le matériau ou la méthode de solution. Des qualités de performance, qu'elles soient pour un matériau, un composant ou un système doivent toujours être définies selon leur fonction.

3. Détermination des Exigences et des Desiderata de L'Usager

Puisque, en fin de compte, la fonction d'un bâtiment est d'être à la disposition de ces occupants, les exigences de performance doivent être définies selon les besoins et les desiderata des usagers. Nous ne devons pas perdre de vue que les besoins et les desiderata des usagers vont du strict nécessaire au plus grand confort. Nous ne devons pas oublier non plus que cette gamme de besoins et de desiderata ne pourra jamais être complètement satisfaite. Ainsi nous devrons déterminer ceux qui pourront être satisfaits de façon pratique et économique. Par exemple, il est évident que les habitants d'un immeuble devront être protégés contre l'écroulement structural.

Dans l'état actuel de nos connaissances il ne sera pas si facile dans d'autres cas de définir tous les aspects des exigences des usagers. La transmission du bruit et l'anxiété de l'occupant due aux vibrations et aux mouvements structurals sont deux domaines dans lesquels les exigences de l'usager ne peuvent être parfaitement connues qu'après de nombreuses recherches. Il se produit alors un facteur compliqué de troc, ou d'équilibre, de l'environnement construit de telle façon que dans les limites techniques et économiques établies, des niveaux plus bas de performance peuvent être autorisés en contre-partie pour un autre zone d'un niveau plus haut, qui est plus important ou plus souhaitable, pour l'utilisateur final.

4. Du Qualitatif au Quantitatif

Mais les exigences de l'usager sont très souvent définies comme critères <u>qualitatifs</u> des qualités requises de l'environnement construit. Malheureusement, les critères <u>qualitatifs</u> ne sont pas suffisants pour définir la performance. Encore une fois, le droit de l'usager à être protégé contre l'écroulement structural implique simplement que le système structural d'un bâtiment doit être suffisamment résistant pour éviter l'effondrement du bâtiment au cours de sa vie utile. Evidemment, ce critère ne fournit pas de données pour évaluer la performance puisque la résistance requise pour répondre aux exigences de l'usager n'a pas été établie.

Un guide suffisant pour le plan, et des données pour l'acceptation ne peuvent être fournis que lorsque les exigences de performance sont quantitativement définies. Cela exige l'établissement d'un critère de <u>plan d'ingénierie quantitatif, et scientifique</u> qui satisfasse le sens et le but du besoin humain <u>qualitatif</u>. Cet aspect du concept de performance est celui qui mettra à l'épreuve nos ressources technologiques si nous devons établir l'acceptation des niveaux basés réellement sur la <u>performance requise</u> plutôt que de l'assimiler à des solutions habituellement acceptées.

5. Où désigner des Chiffres? Une Tâche Monumentale

Nous avons compris la gravité de cette situation dans le programme de l'opération BREAKTHROUGH au moment où le Guide des critères de performance à été mis au point. L'état de l'art était tel que dans de nombreux cas nous avons été obligués d'établir la performance par comparaison et nous nous sommes aperçus des défauts et des contraintes implicites dans cette façon d'aborder le problème. Je ne crois pas qu'il soit rationnel d'établir les niveaux de performance sur la base des caractéristiques <u>maximum</u> mises en évidence par une série de produits traditionnellement utilisés pour remplir une fonction particulière en vue d'assurer la sécurité et la durée. Il ne semble pas plus rationnel d'établir les niveaux de performance sur la base des caractéristiques <u>minimum</u> mises en évidence par une série de produits traditionnellement utilisés pour remplir une fonction particulière qui est évidemment satisfaisante puisqu'elle a été acceptée.

Il est clair que cette façon d'établir des niveaux rationnels de performance requise est une tâche monumentale. Tous les technocrates de la construction ont à faire face à ce problème. Il me semble que c'est un domaine non seulement de portée nationale mais encore un domaine dans lequel la coopération internationale, l'échange d'information récente sur la recherche ainsi que la coordination des besoins futurs en recherche sont essentiels si la notion de performance doit se maintenir au niveau de la tendance actuelle des nouvelles techniques dans la construction industrielle, sans parler d'encourager leur introduction.

6. Evaluation Pour la Performance Spécifiée

Finalement, sans tenir compte des niveaux de performance quantitativement établis, comme il est exigé, une méthode doit être identifiée qui démontre la conformité avec le niveau de performance établi pour les systèmes nouveaux et non encore mis en oeuvre. Cette méthode ou l'essai, peut aller des calculs les plus simples aux plus compliqués des plans d'ingénierie et, je dois ajouter, aux systèmes d'essais physiques de l'échelle en vraie grandeur qui prennent du temps et de l'argent. Comme pour l'établissement des niveaux de performance, la fixation et la vérification de la conformité avec les niveaux requis de performance est un aspect du concept de performance qui mérite des efforts concertés, la recherche et la modernisation. La complexité du processus d'évaluation empêche bien des fois l'emploi de méthodes d'essai normalisées qui pourraient être facilement interprétées. En outre, les essais sont bien souvent exécutés en tant que supplement à une procédure d'évaluation plus complète qui comprend l'analyse et l'application d'un jugement technique sain. De nombreuses méthodes d'essai sont devenues abstraites au point qu'elles mesurent simplement les caractéristiques relatives des matériaux sans consigner les mesures de performance du matériau dans la pratique. En conséquence les innovations mises aux essais dans cet environnement synthétique peuvent se révéler inacceptables dans la pratique.

L'ensemble de nos méthodes d'essai et de procédures ont besoin d'être réévaluées à la lumière de leur capacité à prévoir de façon réaliste la performance dans la pratique, car le but n'est pas seulement de démontrer la conformité avec la méthode d'essai mais aussi d'employer celle-ci somme véhicule pour démontrer la conformité avec l'exigence de performance. Au-delà de cette démonstration de conformité, les données d'essai dans les conditions d'utilisation sont nécessaires pour établir une base d'expérience de fait avec les nouveaux systèmes qui permettra leur utilisation sans avoir à recommencer les essais pour valider à nouveau les niveaux de performance pour chaque changement mineur apporté au plan.

7. Coopération Globale Dans le Domaine de Procédures Evaluatives

Dans le domaine des méthodes d'essai et de procédures, je considère que la coopération internationale et les échanges sont obligatoires. Puisque nous ne connaissons pas les innovations futures dans l'industrie de la construction qui devront être évaluées, nous ne pouvons actuellement mettre au point les procédures d'acceptation en prévision de leur apparition. De nombreuses méthodes d'essai et de procédures seront mises au point dans le monde entier pour répondre à un problème particulier ou à une innovation et c'est seulement au moyen de cet échange de connaissances que nous pourrons tous profiter de travail des autres, contribuant ainsi à augmenter notre savoir et notre expérience et éviter d'avoir à "réinventer la roue", pour ainsi dire, sur une base individuelle. Chacun de nous doit aussi lutter pour l'inclusion rapide des méthodes d'essai et des procédures mises au point récemment dans les normes reconnues de nos pays respectifs, car c'est seulement de cette façon que l'acceptation des innovations pourra se répandre au coeur de notre industrie.

8. La Conversion en Dessins et Spécifications

Mais la notion de performance n'est pas facilement interprétée par les surveillants des chaînes de production ou in situ. La conversion des exigences de performance doit être faite en dessins et spécifications qui peuvent être visuellement observés pour assurer la conformité. Les procédures de vérification de la qualité sont un élément essentiel d'une telle assurance de conformité. Quelques éléments des critères de performance ne peuvent être convertis en observations visuelles et un ensemble plus complexe d'inspection systématique et de techniques de qualité doit être mis en oeuvre.

9. Le Concept n'est pas Facile Mais Il est essentiel

Je voudrais préciser que le concept de performance n'est pas seulement le fait d'aborder l'évaluation de l'opportunité des méthodes et des systèmes de construction. L'ensemble de l'analyse associée aux tâtonnements qui nous a conduit à une telle familiarité avec nos systèmes de construction communs (dans ce pays la maison traditionnelle à charpente de bois) et les codes prescriptifs de construction qui en résultent sont beaucoup plus faciles à appliquer par un service régulateur de construction et par ses inspecteurs. Mais si nous devions nous fier à ces méthodes, le progrès de cette industrie de plusieurs milliards de dollars continuerait à son pas d'escargot. Les méthodes novatrices continueraient à être tenues à l'écart simplement parce qu'aucun système efficace et rapide n'existait pour évaluer la convenance de ces idées. Ce fut le cas aux Etats-Unis. Par exemple, le ministère de la construction de Californie a indiqué qu'il n'avait aucune base pour évaluer un système de construction en fibre de verre-plastique selons leurs codes classiques. C'est simplement par la mise au point et l'application du concept de performance, y compris le Guide des critères de performance, l'analyse et les essais qui ont été faits pour assurer la conformité avec les critères ainsi que le programme d'assurance de la qualité qui a été établi à l'usine, que le système a pu être approuvé.

10. Le Véritable Essai: Est-ce que c'est un bon Endroit pour Vivre?

J'aimerais beaucoup continuer et être plus précis que je ne l'ai été, en vous présentant des exemples de problèmes particulier auxquels nous avons eu à faire face dans l'Opération BREAKTHROUGH. Le temps ne me le permet pas. En conséquence j'ai inclus quelques-unes des pages techniques du discours que j'ai eu l'honneur de présenter devant The Royal Society à Londres en novembre dernier. Ceci vous indiquera quelques-unes des mesures que nous avons prises dans l'Opération BREAKTHROUGH en ce qui concerne le Guide des critères de performance.

En fin de compte le véritable essai de toute base d'évaluation des systèmes de construction doit être la convenance de la communauté qui est construite. Le véritable essai est de savoir comment la communauté répond aux besoins de ses habitants et de savoir comment ils y réagissent par un sentiment de responsabilité personnelle pour la communauté. Nous avons mis l'accent sur ces facteurs dans les sites prototypes de l'Opération BREAKTHROUGH. Pour ceux d'entre vous qui ont eu l'occasion de les visiter, je pense qu'ils seront d'accord quand je dis que les sites sont vivants, vibrants, et qu'ils indiquent pleinement le profit que tire la communauté du mélange des systèmes de construction, des plans en relation avec l'environnement, de l'obtention des mélanges économiques et raciaux tout à la fois, d'un environnement vivable. Le véritable essai est de savoir si les gens qui visitent ces sites diront "Voilà un bon endroit pour vivre". Ceci doit être l'objectif final pour toute base d'évaluation de ce que nous avons fait dans cette industrie de la construction.

L'accent de ce Colloque a été mis sur la performance dans les bâtiments. Nous n'avons pas encore défini les critères d'évaluation de la performance pour assurer un bon environnement vivable pour la communauté. Nous n'avons pas encore traduit en paroles les exigences de performance pour les plans communautaires qui comprennent l'aménagement foncier, l'architecture des logements et des paysages, plans qui doivent faire bénéficier l'environnement et en tirer profit, des guides qui doivent définir les loisirs de tous les éléments de la communauté -- nous n'avons pas encore défini les critères de performance pour une vie communautaire agréable. Je vous en prie, continuons à travailler ensemble pour ajouter tous ces facteurs d'évaluation de la performance de la communauté à nos efforts pour mettre au point les guides de performance dans les bâtiments.

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The Performance Approach: History and Status

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Ladies and Gentlemen,

It is a distinct honor to have the opportunity to discuss with you the performance approach to the art and science of building.

There are two boundary conditions which should be noted before moving on, however. One is that this symposium is confined to building technology, even though two of the sponsoring organizations (RILEM and ASTM) extend in their concerns beyond building technology. The other boundary condition has to do with my own perspective. I am forced to rely heavily on experiences with the performance approach in the United States. I therefore apologize in advance for what may strike you as parochialism, and I ask your understanding.

1. An Old Concept

Almost invariably at symposia such as this someone makes the point that the performance concept represents nothing new. True. Performance, in fact, is an old idea.

At one point in our history we North Americans were decidedly performance-oriented. Indigenous populations from the Arctic to the dry, torrid regions of the Southwest not only satisfied needs of more shelter but attained symbolic performance as well. European settlers, after finding that some of their old building practices could not be easily transplanted to the New World, produced some of the most straightforward and adaptive architecture this continent has even seen. Then these white settlers sought some symbolic performance of their own. They turned their attention to books on Georgian architecture from abroad, and later, when their land became sovereign, they sought to integrate artifact with their new system of government and borrowed liberally from the republican Romans. Still later, in that episode, the Industrial Revolution, which transferred skill and intelligence to the machine, some of the white settlers became rich and others became aggrieved; and all turned to eclecticism for either cultural support of new found economic station or romantic escape from a dehumanized world.

The growth of building technology roughly paralleled the rise in general knowledge. New materials and techniques were developed, and the test of their acceptability was through comparison with old materials and techniques. We developed experiential models. We had found that a certain material did the job - in implicit performance terms - and we gravitated toward prescriptive building standards. They were a convenience. We did not have to go all the way back to the user, forever measuring how rationally and effectively his needs may have been accommodated, but merely to that brick wall which served him satisfactorily for centuries.

We depended on technological bounty and the implicit satisfaction of user needs, and long after the summer sun had quit and the evening air was cool, we sweltered in our bedrooms while primitive man, who followed principles we foolishly ignored, rested quite comfortably. Some of us were lucky enough to acquire various air-cooling mechanisms, but these things demand expensive energy infusions, and we have been warned of late that energy is a finite matter.

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There was one movement that promised remedy. Seeded in the 19th century and taking bloom in the 20th, this movement, called functionalism, captivated architects the world over. It proved to be an effective purgative of academicism and eclecticism but in the main it failed to satisfy user needs. One need only review jury comments in architectural awards programs to realize how poorly the user fared under functionalism.

In summary, European man on this North American continent, after developing honest and adaptive building methods, traveled a disorienting trip through over-concern with symbolic performance, through a period of animosity toward, or subservience to, the machine and its wares, and finally, through a functionalist period which expelled idiom but which failed to measure up to the human fulfillment expected of it.

We advocates of performance are striving to exploit this venerable approach to building through the use of today's techniques for organized thinking. We are trying to give technology the benefit of judicious application and to encourage the further development of a technology suited to human needs. We are trying to fit buildings to man rather than the other way around.

The performance approach is an organized procedure within which it is possible to state the desired attributes of a material, component, or system in order to satisfy the requirements of the user without regard to the specific means employed in achieving the results. The invocation of the user - man - is of the essence; it is not embroidery.

I was interested, recently, to read the comment of an architect for a project hailed as a progressive solution in the housing of the poor when it was built 17 years ago, but which today is considered a social disaster. His client was "government," the architect said in reflecting on possible causes of the project's failure, "not the people who were going to live there."

The performance approach to building rests on the satisfaction of people's needs. At the same time, it stimulates innovation by its emphasis on ends rather than means, by its disdain for the slavish imitation of experiential models, and its preference for widening the field of competition to the broadest variety of solutions.

Without prescirbing - and thus delimiting - the means of delivering the performance wanted, the performance approach makes possible the formulation of a statement of what is expected from a material, component, or system in terms of performance itself. This statement identifies a requirement, quantifies this in the form of criterion, and sets the method or methods of assessing a candidate solution for compliance with the criterion. Requirements are cast in human terms - the significance of this shift in focus from the building itself to man as the measure of all things built has major implications for us all.

Performance statements encourage innovation; through them builders and manufacturers of building components and systems are furnished the level of performance expected without regard to means. On the one hand they benefit from knowing what to achieve, and on the other they are given the widest possible latitude in reaching that achievement. This has the effect of reducing the number of imitative products while stimulating the development of truly innovative ones.

2. Emergence of Performance Approach

Interest in the performance approach to building has been rekindled by several developments, the most direct and obvious of which is the growth of organized thought and control procedures. Scientific management principles go back 60 years and the organized procedure known as systems analysis some 30 years.

Some observers who are more knowing than I on this subject view systems analysis and the performance approach as distinct methodologies; others see the performance approach as a part of systems analysis; and still others regard the two as closely related and complementary kin.

Systems analysis and the performance approach do appear to have much in common. Both seek a high degree of problem definition; both defer the obvious, conventional solution; both invite the widest possible field of candidate solutions; both have an evaluative routine for selected solutions; both emphasize the importance of feedback so that inputs can be modified to produce results more in line with objectives; both insist on procedurally organized methods; and both demand an open-minded, wide-scope view of the problem and its range of solutions.

Against a backdrop of problem-solving conquests through organized thinking - most notably in space exploration - many down-to-earth problems with which today's world is beseiged seem to belie man's supposed intellectual capabilities. Not the least of these is one drawing the attention and concern of this assembly - housing. Millions of families the world over are ill-housed, and on top of this quantitative need, qualitative problems also afflict us. John Eberhard, who in his service as Director of the National Bureau of Standards' Institute for Applied Technology gave building researchers at the Bureau their performance orientation, and who has done much to foster the performance approach generally, articulated in an article some years ago a forceful plea for reinstating in the built environment what he termed "emotional content." He advocated this content - this symbolic performance - to counter the loneliness he saw as the dominant characteristic of urban life.

I cite the great need for more decent housing and the kind of need Mr. Eberhard wrote about because both are human needs and both are interwoven with societal forces which, in the opinion of some observers, could have far more impact on the field of building than anything in the technological sphere. The building industry has its own dynamics, however, and they have been at work for some time. "There is a ferment in the entire building field, the result of discussions, trends and developments that have been going on for the past 20 years," noted Professor Albert Dietz at what was perhaps the earliest U. S. Symposium on the performance concept in building. This conference occurred seven years ago in Chicago under the auspices of the Building Research Advisory Board, U. S. National Academies of Sciences and Engineering.

It is difficult to have a reliable global perspective on what was happening where, and who was the first to do what - if, in fact, that matters - but we are able to cite a few events in the re-emergence of the performance approach. We know that as far back as the 1930's the British Building Research Station made a proposal that health and safety considerations be based on performance requirements. George N. Thompson of the National Bureau of Standards in 1949 published a paper urging the judicious application of the performance approach in the formation of building codes and gave examples of the advantages offered by this approach. In South Africa, a 1954 publication of the National Building Research Institute included a comprehensive statement on performance requirements and evaluation methods. We know that the Scandinavian nations have been conspicuous in their early and significant contributions to performance. And of course France's performance-based Agrement System, established some 18 years ago, was a pioneer.

The performance concept was outlined in 1962 at the Cambridge, England, Congress of the International Council for Building by Dr. F. Lea, who at that time directed the British Building Research Station. It was clearly expressed at the CIB Congress in Copenhagen in 1965 in papers presented by Mr. Klaus Blach of Denmark and Mr. Tenho Sneck of Finland. In 1968 building researchers at the National Bureau of Standards presented a report to the Federal Housing Administration on the subject of performance criteria for exterior wall systems. But the first project to use performance requirements on this continent was the School Construction System Development project begun in 1961 under the leadership of Ezra Ehrenkrantz, who had previous experience in performance building in Great Britian. I suspect there has been considerable international cross-pollenization; the criteria for the Study of Educational Facilities project in Toronto, for example, was loosely based on prior work by architect Ian Moore of the United Kingdom.

In 1968 the National Bureau of Standards held a landmark symposium called "Man and His Shelter," a conference notable for its emphasis on the Bureau's own experimental work with practical measurement problems in performance.

3. Performance Procedures

A performance statement, according to the National Bureau of Standards, has three essential parts - Requirement, Criteria and Test. An optional fourth part, called commentary, was included in performance statements the Bureau developed for the U. S. Department of Housing and Urban Development's Operation BREAKTHROUGH program. This portion of the performance statement afforded the opportunity to state the origin of the criteria, their intent, and the degree of confidence the Bureau had in the performance levels and evaluation methods indicated.

A Requirement is a qualitative statement which identifies a user need. In my opinion all needs reduce to user needs. For example, structural criteria which seek the point of wisdom between safety and cost meet human needs by providing for the user's safety without a needlessly large imposition upon his resources. Such criteria meet human needs in a very important way.

When possible, the Requirement, a qualitative statement, is converted to a quantified statement which is called the Criterion. This statement provides specific levels for attaining compliance with the intent of the Requirement.

The test portion of the performance statement indicates the method of assessing materials, components or systems for compliance with the Criterion. This evaluation can be by analysis, physical measurement or judgment, the most subjective method and therefore the most needful of objectivity.

Criterion levels must be thought of as indeterminately tentative. This is because of two prominent aspects of performance: 1. The final level of the performance required of a material, component or system depends on its inevitable interaction with other materials, components and systems, and 2. Desired performance levels are continually subject to change due to the information feedback mechanism that is part of the performance approach.

Initially, performance criteria tend to be existing building practices cast in performance language. From experience we know these practices to be generally acceptable, but by scientific measurement they may represent over-design or under-design.

4. Some Issues of the Performance Art

The mere representation of the state of the art in performance terms has distinct advantages, however. Instead of recipes, it supplies values for the development of new products and techniques, and it lends an impartiality to the important matter of acceptance of innovation. If performance guidelines for the evaluation of innovations are not developed, the only evaluative means left is comparison with existing models.

Performance provides the means for guiding and evaluating the accelerating growth of building technology while imposing none of the constraints of the prescriptive approach. This, of course, may have adverse self-interest implications for the producers of conventional products. We must expect established interests to protect their markets; at the same time, however, we must possess a resolve commensurate with our conviction that the performance approach to building best serves the needs of the user.

We must do a great deal of research in the area of user needs. Concurrently, we can consider a strategy that allows the user himself to make as many decisions as possible about his environment, and we can lean heavily upon feedback.

Feedback facilitates the discernment of needs not imagined and the correction of inputs which fail to adequately satisfy established needs. Feedback can work at four points - during the design phase, the prototype phase (if the nature of the project includes prototype evaluation), and most decidedly, during the pre-occupancy and in-use phases. Building should be viewed more as in-field models - as possible answers - and less as final solutions from which we walk away.

Evaluation under the performance approach is an art and a science requiring a high degree of acuity and judgment. We have much to do in all areas of performance building but evaluation, in my opinion, warrants our particular attention. Are test methods realistic? Do we have sufficient test methods? Can we evaluate a material without knowing its intended use in the building? Are reproducible results as important as accommodating the structural role the material is to play? Do we tend to measure essential qualities or the readily measurable but trivial ones?

And finally, how reliable is subjective measurement? As defined by the National Bureau of Standards, subjective measurement is based on the value judgments of the human observer or on human response to selected test situations with results being expressed in narrative form or by assigned numerical ratings. Value judgments of the observer should not alarm us. Man has become the dominant life form through innumerable judgment decisions, many of which were based on uncertain data.

The functioning of the object in the field must be emphasized in evaluation. That is, the interactive functioning of the object with other objects, with its environment and with, if you will, the user. This kind of evaluative technique requires multiexpertise and interdisciplinary judgments that will not be replaced by test methods but will be supplemented by them.

The question of durability can be especially troublesome; the development of short-time tests to predict the long-term retention of desired properties is most difficult. Unlike other physical measurements, the results of accelerated weathering tests are more or less indicative but fall short of being decisive. With their strong emphasis on expert judgment, the French may be pointing the way - perhaps the only way - in this important matter of assessing durability, and that is to combine expert judgment with measurement; in other words, measure what you can, then give the data to the experts and let them come up with the judgments.

Replaceability and costs that are commensurate with material life expectancies become crucial concerns in cases of questionable durability. Costs, indeed, are central to performance considerations, and I understand that several symposium papers offer interesting techniques for manipulating the cost/benefit equation. In performance we think of the "best buy" and of life-cycle costs, and we are beginning to think in terms of new realities. For example, when we view an office building not as an inert, inactive enclosure but as a machine which works - performs - or does not work, we begin to see economic considerations in a different way.

5. Performance Examples

Performance statements can be used to procure, as do performance specifications, or to regulate, as do performance provisions of building codes. In the former application they are sometimes used to achieve levels of performance not possible through existing hardware. An objective here is the stimulation of the research and development capabilities of private industry, and one customary aspect of this kind of approach is a guaranteed market for participating manufacturers.

The School Construction System Development project mentioned earlier sought new products coordinated in such a way, and having a wide margin of flexibility, as to provide superior educational environments for 13 California school districts at no increase over conventional costs.

The University of California's University Residential Building System project, on the other hand, sought to reduce the costs of ownership (in construction, operation and maintenance), while the Academic Building Systems project, a joint undertaking of the Universities of California and Indiana, endeavored to provide equal performance for lower cost or better performance for the same or lower cost.

These and similar projects were stimulated by the Educational Facilities Laboratory, an agency of the Ford Foundation, and they illustrate how generative criteria and specifications can be developed by institutional builders. Criteria and specifications for such projects are frequently specialized according to building types; they generate programmatic requirements apart from the essentially health and safety concerns of the regulatory apparatus. Again, these requirements distill to user needs: A school which accommodates enriched educational programs--programs which gratify the instructor and profit the pupil--is a school which meets user needs.

Agrément enjoys justified renown as a pioneer performance-based evaluative system. Systems similar to this French system have been adopted in a number of countries and the State of New York here in the United States employs in part the Agrément concept. A number of other states are using the Agrément principle of objective, third-party evaluation under statewide, factory-built housing laws. These laws provide for evaluation approvals at the state level, pre-empting regulation at the local level where responsibility for such control (a responsibility delegated by the states) is customarily lodged.

6. PBS and OBT

An example of a generative project with which the National Bureau of Standards is associated is the Performance Specifications for Office Buildings. The Bureau prepared this document for the Public Buildings Service of the General Services Administration which creates a $200 million annual market for Federal office buildings.

The Public Buildings Service intends to use these specifications for the government's benefit while at the same time demonstrating the advantages of performance over prescriptive specifications. The objective is the attainment of facilities in less time than under conventional design and construction procedures and with no increase in cost.

The National Bureau of Standards' role in the Operation BREAKTHROUGH experimental program of the Department of Housing and Urban Development has been more user needs-oriented. The major objective of BREAKTHROUGH is to increase the supply of housing by reducing the constraints on volume production. Its keystone is the ideal of making a decent home available to every American family.

The Bureau, which serves as technical arm to the Department of Housing and Urban Development, has developed criteria for the evaluation of housing types ranging from single-family detached dwellings to multi-family low-rise towers.

BREAKTHROUGH is designed to put housing research into practice. The program solicited housing system proposals from industry, and out of more than 600 proposals submitted, selected 22 producers, and, in cooperation with state and local officials, nine sites throughout the nation for the erection of prototype, experimental housing.

Since innovative systems were sought, the reference standards of the building codes could not be applied on a one-to-one basis as in the case with prescriptive specifications. Rather, the intent of the code was met without necessarily satisfying the letter of the code. Moreover, performance criteria accommodated evaluation for liveability and durability characteristics - characteristics appropriate for measurement since the housing systems had been subjected to neither the test of marketplace nor the test of time. The criteria are being continually updated and improved as a result of NBS interaction with, principally, the Housing System Producers and an Advisory Committee to the Department of Housing and Urban Development. This committee of technical advisors was established at the Department's request by the National Academies of Sciences and Engineering.

Construction of the nearly 3,000 prototype houses is well on toward completion and some of the houses are now occupied. A key aspect of the program as far as the Bureau is concerned is its feedback track. The Bureau is making strenuous, systematic efforts to gather data from the prototype sites with respect to the suitability of the experimental housing in its satisfaction of user needs.

7. Performance: General Implications

However important and indeed indispensable this philosophical framework, this technique, this performance approach may be, it by no means supplants many other approaches and nuances surrounding the art and science of building. Intuitive solutions by people for people will continue to produce great buildings. Performance, I submit, will support rather than supplant intuitive or extrarational approaches to building design.

It is my impression that some architects are seeking methodological assistance in coordinating the bits and pieces - and in synthesizing the many considerations - which characterize the complex practice of architecture. As additional dimensions of what constitutes a good building accrue, the designer's problem becomes even more staggering. The application of the performance approach assists a more rational evaluation of both proposed and built solutions. In short, it is the opinion of designers for whom I have respect, and with whom I have contact, that the performance approach will effect profound alterations in the design process.

The design process involves information - input information on client and user needs, site information, product information and so on, and output information in both graphic and verbal communicative forms. Indeed, virtually all that we do in this earthy and tangible field of building in the final analysis reduces to information. The performance approach with its orderly sequence, or format, if you will, offers promising information-handling possibilities.

This very symposium is intended, of course, to produce and impart information which we who are concerned with buildings might apply on a global basis.

We are gathered here in what I trust will be a fruitful examination of the issues inherent in the present state of the performance art, remaining mindful that this technique of organized thinking is itself complex in its ramifications and applications. We have had many fine papers submitted, and I am certain that the summary papers of the rapporteurs, along with the open discussions which are planned and the informal discussions which are inevitable, will combine to make the next several days most profitable to us all - and to the public, the users, we are privileged to serve.

Thank you.

Le Point de Vue "Performance": Son Passé et Son Etat Actuel

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Mesdames, Messieurs,

C'est pour moi un grand honneur d'avoir l'occasion de parler avec vous du point de vue de la "performance" appliqué à l'art et à la science de construire.

Il y a deux limites cependant que je voudrais vous signaler avant de continuer. Tout d'abord, ce colloque ne traite que de la technologie du bâtiment, en dépit du fait que les travaux de deux des organismes organisateurs (RILEM et ASTM) s'étendent au delà du domaine de la technologie de la construction. L'autre limite se rapporte à mes propres perspectives. Je suis forcé de me baser en grande partie sur l'expérience acquise aux Etats Unis. Je vous prie donc de bien vouloir m'excuser si ce que je vous dis vous semble faire preuve d'esprit de clocher.

1. Une Notion Ancienne

A des colloques tels que celui-ci, quelqu'un doit, tôt ou tard, faire remarquer que la notion de performance ne représente rien de neuf. C'est vrai. Il s'agit en fait d'une idée déjà ancienne.

A un certain point de notre histoire, nous, les Américains du Nord, nous étions certainement orientés vers la "performance." Les populations indigènes des régions Arctiques, tout comme celles des régions sèches et torrides du Sud-Ouest, ne satisfaisaient pas seulement leurs exigences en matière d'abri mais parvenaient à obtenir aussi une "performance" symbolique. Les colonisateurs Européens, ayant constaté que certaines de leurs techniques de construction ne se laissaient pas facilement transplanter dans le Nouveau Monde, ont créé une des architectures les plus directes et les mieux adaptées que ce continent ait jamais connues. Ensuite, ils ont essayé de trouver un "performance" symbolique bien à eux. Ils se sont tournés vers les livres sur l'architecture Georgienne d'Outre-Mer et, plus tard, quand leur pays devint un état souverain, ils se sont attachés à intégrer leur art avec le nouveau système de gouvernement, et ont emprunté à la Rome républicaine. Plus tard encore, au cours de cet épisode où l'homme a doué les machines d'habileté et d'intelligence: la Révolution Industrielle, certains d'entre eux sont devenus riches, d'autres désenchantés, et tous se sont tournés vers l'éclectisme, soit pour trouver une base culturelle pour étayer leur nouvelle condition économique, ou bien pour se libérer, par un essor romantique, d'un monde qui avait perdu son humanité.

Le progrès de la technologie de la construction a suivi le progrès des connaissances générales sur des lignes plus ou moins parallèles. On a mis au point des techniques nouvelles et de nouveaux matériaux. On les a évalués en les comparant avec les anciens. On avait trouvé que certains matériaux remplissaient bien leurs fonctions--en termes de performance implicite--et on s'est orienté vers des normes de construction prescriptives. C'était pratique. Il ne fallait pas chaque fois consulter l'usager, mesurer tout le temps si ses exigences étaient satisfaites de façon rationnelle et efficace. On n'avait qu' à se baser sur ce mur en briques qui l'avait servi si bien depuis des siècles.

Nous étions tributaires des progrès technologiques et de la satisfaction <u>implicite</u> des besoins de l'usager. Longtemps après le départ du soleil de l'été, quand les soirées devenaient fraîches, nous étouffions dans nos chambres closes, alors que l'homme primitif,

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qui suivait les principes que nous avions si stupidement négligés, se reposait très confortablement. Bien sûr, certains d'entre nous avaient eu la chance de pouvoir acquérir des machines de divers genres pour refroidir l'air, mais ces dernières ont une consommation d'énergie très onéreuse et n'oublions pas qu'on vient de nous avertir que les sources d'énergie ne sont pas inépuisables.

Il y avait cependant un mouvement qui promettait un remède. Fondé pendant le 19 ème siècle, il prit son essor pendant le 20 ème: il s'agit du "fonctionalisme" qui fit la conquète des architectes du monde entier. Il s'est avéré efficace contre les excès de l'académisme et de l'éclectisme mais, en général, il n'a pas réussi à satisfaire les besoins des usagers. On n'a qu'à lire les commentaires des jurys qui octroient les prix dans les concours d'architecture pour se rendre compte de la position désavantageuse de l'usager sous le régime du fonctionalisme.

En résumé: Sur ce continent Nord-Américain, l'homme Européen ayant mis au point des méthodes de construction honnêtes et souples, a traversé une crise de désorientation en attachant trop d'importance à la "performance" symbolique, a passé par une période d'animosité envers la machine et ses produits et a connu ensuite une phase de fonctionalisme qui lui a permis de rejeter certains éléments trop figés mais n'a pas réussi à créer la satisfaction humaine qu'on en espérait.

Nous qui favorisons le point de vue de la "performance," nous essayons d'utiliser cette approche bien établie à l'art de construire en employant les techniques modernes pour l'organisation de la pensée. Nous nous efforçons d'apporter à la technologie le bénéfice d'une application judicieuse, et d'encourager le progrès d'une technique adaptée aux besoins humains.

En d'autres mots, nous voulons adapter les bâtiments à l'homme plutôt que l'homme aux bâtiments.

Approcher cette question du point de vue de la performance est une procédure organisée, nous permettant de définir les charactéristiques désirées d'un matériau, élément ou système pour satisfaire les exigences de l'usager, sans devoir tenir compte des moyens spécifiques employés pour arriver à ce but. Ce recours à l'usager--à l'homme--est une chose fondamentale et intrinsèque; ce n'est pas une fioriture.

Récemment, j'ai lu avec grand intérêt la remarque de l'architecte d'un projet qu'on avait accueilli comme une solution d'avenir pour le logement des pauvres au moment de sa construction il y a 17 ans, mais qu'on considère comme un désastre du point de vue social aujourd'hui. En réfléchissant aux causes possibles de l'échec de ce projet, cet architecte a dit: "Mon client, c'était le gouvernement et non pas les gens qui allaient y habiter." L'approche du point de vue "performance" se base sur la satisfaction des besoins de l'usager. En même temps, elle encourage l'innovation en soulignant la fin plutôt que les moyens en dédaignant l'imitation basse de modèles expérimentaux, et en ouvrant une plus grande chance de concurrence à toute une gamme de solutions.

Sans prescrire--ce qui veut dire restreindre--les moyens d'obtenir la performance désirée, cette approche permet de formuler une déclaration de ce qu'on attend d'un matériau, élément ou système, en termes de sa "performance" même. Cette déclaration définit une exigence, la quantifie en tant que critère, et fixe la ou les méthodes pour évaluer une solution possible pour conformité à ce critère. Les exigences sont exprimées en termes humains--l'importance de ce changement d'emphase qui passe du bâtiment à l'homme même, en tant que mesure de tout ce que l'on construit, a des répercussions majeures pour chacun d'entre nous.

Les déclarations de "performance" encouragent l'innovation; c'est par leur intermédiaire que les constructeurs et les fabricants d'éléments et systèmes de construction sont informés du niveau de performance à obtenir, quels que soient les moyens employés. D'une part, ils ont l'avantage de savoir ce qu'il faut obtenir, d'autre part on leur donne la liberté la plus complète pour y arriver. Cela a pour effet de diminuer le nombre de produits imitatifs, tout en stimulant la mise au point de ceux qui représentent une innovation véritable.

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2. Emergence du Point de Vue "Performance"

L'intérêt suscité par le point de vue "performance" a pris un nouvel essor avec plusieurs initiatives dont la plus évidente et la plus directe est le développement de la pensée organisée et des procédures de contrôle. Les principes de la gestion scientifique remontent à 60 ans déjà et la procédure organisée qu'on connait sous le nom d'analyse des systèmes, à 30 ans environ.

Certains observateurs qui en savent plus que moi dans de domaine, considèrent l'analyse des systèmes et l'approche du point de vue "performance" comme des méthodologies séparées. D'autres considérent l'approche "performance" comme faisant partie de l'analyse des systèmes; d'autres encore pensent que les deux sont étroitement liées et se complètent.

Il semble bien que l'analyse des systèmes et l'approche "performance" ont beaucoup de points communs. Toutes deux aspirent à un haut degré de définition du problème; toutes deux remettent en question la solution évidente, classique; toutes deux font appel à la plus large gamme possible de solutions concurrentes; toutes deux possèdent une routine d'évaluation pour les solutions choisies; toutes deux soulignent l'importance d'information en retour afin de pouvoir faire les modifications voulues pour obtenir des résultats plus conformes aux buts fixés; toutes deux exigent des méthodes organisées en procédures; et toutes deux demandent une attitude ouverte et dénuée de préjugés envers le problème et la gamme de solutions envisagées.

Si l'on considère les conquêtes dans le domaine de la résolution des problèmes par la pensée organisée--plus particulièrement dans l'exploration de l'espace--beaucoup des problèmes journaliers qui accablent le monde semblent nier les capacités intellectuelles qu'on attribue à l'homme. Parmi les plus notoires est celui que engage l'attention de cette assemblée--le logement. Dans le monde entier, des millions de familles sont mal logées; en plus de ce besoin quantitatif, nous sommes également affligés de problèmes de qualité. Dans un article, publié il y a quelques années, John Eberhard qui, en sa qualité de Directeur de l'Institut de Technologie Appliquée du "National Bureau of Standards" avait inculqué la notion de "performance" aux chercheurs du bâtiment de ce Bureau, et qui avait beaucoup fait pour sa propagation, avait présenté un fervent plaidoyer en faveur de la restitution de ce qu'il appelle "la teneur spirituelle" à notre milieu urbain. Il a promulgué cette valeur--cette "performance symbolique"--pour combattre la solitude qu'il considère comme la caractéristique principale de la vie urbaine.

Je viens de citer le grand besoin de logements convenables en plus grand nombre et le genre d'exigence dont parle Monsieur Eberhard, parce qu'il s'agit d'exigences humaines intimement liées aux forces sociales qui, comme le pensent certains observateurs, pourraient avoir beaucoup plus d'influence dans le domaine de la construction que n'importe quel développement dans celui de la technologie. Cependant, l'industrie de la construction possède son propre dynamisme qui s'est manifesté depuis quelque temps déjà. "Il y a quelque chose qui fermente dans tout le domaine de la construction, le résultat de discussions, de tendances et de mises au point qui ont eu lieu au cours des dernières vingt années," faisait remarquer le Professeur Albert Dietz lors de ce qui fut probablement le premier Colloque aux Etats Unis sur la notion de "performance" dans le bâtiment. Il s'agit du Colloque organisé il y a sept ans à Chicago sous les auspices du "Building Research Advisory Board" de l'Académie des sciences et du Génie Civil. Il est difficile d'avoir une bonne perspective globale sur tout ce qui se passe et dans quel endroit, et de savoir qui a été l'innovateur en supposant d'ailleurs qu'il soit utile de le savoir--mais nous pouvons toute fois citer quelques évènements dans le renouveau d'intérêt pour la notion de "performance." Nous savons que dans les années 1930, la "Building Research Station" Britannique avait proposé des considérations d'hygiène publique et de sécurité basées sur des exigences fonctionnelles. En 1949 George N. Thompson du "National Bureau of Standards" publia un article conseillant l'application judicieuse de cette notion à l'élaboration des Codes de Bonne Pratique et donnant quelques exemples de ses avantages. En Afrique du Sud, une publication de l'Institute National du Bâtiment, datée de 1954 donnait un exposé très complet sur les exigences de "performance" et les méthodes d'évaluation. Nous savons que les pays scandinaves ont apporté des contributions très importantes dès les premiers temps. Evidemment, le Système d'Agrément basé sur la notion des exigences fonctionnelles, établi en France il y a 18 ans déjà, met ce pays au rang des pionniers dans de domaine.

La notion de "performance" a été définie en 1962 au Congrès du CIB à Cambridge en Angleterre par le docteur F. M. Lea qui était alors directeur de la "Building Research Station." On en a parlé clairement au Congrès de Copenhague en 1965 dans les exposés de M. Klaus Blach, du Danemark et de M. Tenho Sneck, de Finlande. En 1968 les chercheurs du bâtiment du "National Bureau of Standards" présentaient un rapport à l'Administration Fédérale du Logement au sujet des critères de performance pour systèmes de murs extérieurs. Mais le premier projet à employer cette notion sur notre continent fut le "School Construction Systems Development Project" commencé en 1961 sous la direction de Ezra Ehrenkrantz qui avait acquis une certaine expérience dans ce domaine en Grande Bretagne. Je pense d'ailleurs qu'il y a en beaucoup d'échanges à l'échelle internationale. Les critères pour l'étude des bâtiments scolaires à Toronto, par exemple, étaient plus ou moins basés sur les travaux antérieurs de l'architecte Ian Moore du Royaume Uni.

En 1968 le "National Bureau of Standards" a organisé un Colloque qui a marqué une étape. Il s'intitulait "L'Homme et son Abri," et a souligné les efforts du Bureau dans la recherche expérimentale sur les problèmes de mesures pratiques dans le domaine de la "performance."

3. Procédures de "Performance"

D'après le National Bureau of Standards, un énoncé de "performance" comprend trois parties essentielles--Exigences, Critères et Essais. Les énoncés établis par le Bureau pour le programme "Operation BREAKTHROUGH" du Département pour le Logement et le Développement Urbain, comprenait une quatrième partie facultative intitulée "Remarques." Cette partie de l'énoncé permettait d'expliquer l'origine des critères, leur intention et le degré de confiance que le Bureau avait dans les niveaux de performance et les méthodes d'évaluation données.

Une Exigence est une déclaration de qualité qui identifie un besoin de l'usager. A mon avis, tous les besoins se réduisent à ceux de l'usager. Par exemple, les critères structurels qui cherchent à établir un équilibre entre la sécurité et le prix, sont axés sur les besoins humains puisqu'ils permettent d'assurer la sécurité de l'usager sans imposer de servitudes exagérées sur ses ressources. Ces critères répondent aux besoins humains d'une manière très importante.

Autant que possible, une Exigence, c'est à dire une déclaration de qualité, est transformée en un déclaration de quantité qu'on appelle un Critère. Ce dernier prévoit des niveaux spécifiques de conformité aux intentions de l'Exigence.

La partie de l'énoncé de performance ayant trait aux essais indique la méthode employée pour évaluer la conformité des matériaux, éléments ou systèmes au Critère en question. Cette évaluation peut se faire par analyse, mesure physique ou jugement, ce dernier étant la méthode la plus subjective et donc celle qui a besoin de la plus grande objectivité.

Il faut considérer les niveaux des critères comme indéterminés tant que provisoires. Il en est ainsi à cause de deux aspects importants de la performance: (1) le niveau de performance final exigé d'un matériau, élément ou système dépend de ses réactions inévitables avec d'autres matériaux, éléments et systèmes, et (2) les niveaux de performance désirés sont continuellement sujets à des changements à cause du mécanisme d'information en retour qui fait partie de la notion même de performance.

Au début, les critères de performance tendent à être empruntés à la pratique établie en matière de construction, mais formulés dans un language appartenant au point de vue "performance." On sait par expérience que ces pratiques sont généralement acceptables mais, considérées du point de vue des mesures scientifiques, elles peuvent représenter une surestimation ou sousestimation dans les projets.

4. Quelques Points Relatifs à l'Application de la Notion de Performance

En établissant simplement l'état de l'art en termes de la notion de performance on obtient déjà des avantages bien distincts. Au lieu de formules, cela nous donne des valeurs pour la mise au point de nouveaux produits et techniques et crée une attitude impartiale dans la question très importante de l'acceptation de l'innovation. A défaut de directives pour l'évaluation d'innovations, le seul moyen qui reste serait la comparaison avec des modèles existants.

La notion "performance" permet d'évaluer et de guider la croissance toujours plus rapide de la technologie de la construction sans toutefois imposer les servitudes des méthodes prescriptives. Evidemment, cela pourrait avoir des répercussions néfastes à l'intérêt des fabricants de produits traditionnels. Nous devons nous attendre à un effort pour protéger les marchés des produits existants; d'autre part nous devons aussi faire preuve de résolution allant de pair avec notre conviction que le point de vue de la performance est celui qui sert le mieux les besoins des usagers.

Il faut encore faire beaucoup de recherche dans le domaine des besoins des usagers. En même temps, nous pouvons envisager une stratégie qui permette à l'usager lui-même de prendre autant de décisions que possibles au sujet de son environnement, et nous pouvons nous baser largement sur l'information qui nous parvient en retour.

Ces informations en retour aident à découvrir des besoins dont on ne s'était pas encore rendu compte et à corriger les mesures qui n'avaient pas réussi à satisfaire les besoins établis.

L'information en retour peut agir en quatre points différents--à l'étape de l'élaboration du projet, à l'étape du prototype (si la nature du projet exige une évaluation de prototype), et très certainement dans les phases avant l'occupation et en service. On devrait considérer les bâtiments plutôt comme des modèles de solutions possibles, et non pas comme des solutions définitives qu'on laisse sur place.

L'évaluation sous l'angle de la performance est un art et un science qui exigent un haut degré de perception et de jugement. Le travail ne manque pas dans tous les aspects de la performance dans la construction mais, à mon avis, c'est l'évaluation qui mérite le plus notre attention. Est-ce que nos méthodes d'essai sont réalisties? En avons-nous un nombre suffisant? Pouvons-nous évaluer un matériau sans connaître à quel usage il est destiné dans le bâtiment achevé? Est-il aussi important d'avoir des résultats qu'on peut reproduire que de tenir compte de la fonction structurelle que le matériau doit remplir? Essayons-nous de mesurer les qualités essentielles ou bien les qualités moins importantes mais plus facilement mesurables?

Et, finalement, jusqu'où peut on se fier à un jugement subjectif? D'après la définition du National Bureau of Standards, la mesure subjective est basée sur les jugements de valeur de l'observateur humain ou sur la réaction de l'être humain à des situations d'essai spécialement choisies, les résultats étant exprimés sous forme de texte narratif ou par une cote numérique. Il ne faut pas s'effrayer à l'idée de jugements de valeur de la part d'un observateur. C'est grâce à d'innombrables decisions fondées sur des jugements souvent basés sur des données incertaines, que l'homme est devenu l'être dominant de notre planète. L'évaluation doit souligner le fonctionnement pratique de l'objet de son observation. Il s'agit du fonctionnement de l'objet en réaction avec d'autre objets, avec son milieu et, si vous voulez, ses usagers. Ce gentre de technique d'évaluation exige des jugements multidisciplinaires et des expertises diverses qui ne seront jamais remplacés par des méthodes d'essai mais que ces méthodes viendront suppléer.

La question de la durabilité peut causer des difficultés, particulièrement quand il s'agit de mettre au point des essais de courte durée pour prédire le maintien des caractéristiques désirées pour une longue période de temps. Contrairement aux autres mesures physiques, les résultats des essais de vieillissement accéléré donnent plus ou moins une indication mais ne sont pas vraiment décisifs. En soulignant fortement l'importance des jugements d'experts, la France peut bien nous montrer la voie--peut-être la seule voie possible--dans cette importante question de l'évaluation de la durabilité: qu'il faut associer un jugement d'experts aux mesures. En d'autres mots, mesurez ce que vous pouvez, soumettez les résultats aux experts et laissez leur le soin de juger.

Quand la durabilité est douteuse, la question de facilité de remplacement et de frais, en rapport judicieux avec la vie probable des matériaux, devient des plus importantes. Les considérations de frais figurent au centre du point de vue de la performance et j'ai cru comprendre qu'un nombre d'exposés présentés à ce Colloque présentent des techniques intéressantes pour manipuler l'équation frais/bénéfice. Du point de vue performance, nous pensons à un "achat judicieux" et aux frais répartis sur toute la durée de vie, et nous commençons à penser à de nouvelles réalités. Par exemple, quand nous considérons un immeuble à bureaux non pas comme une enveloppe inerte et inactive, mais comme une machine qui fonctionne--une "performance"--ou ne fonctionne pas, nous commençons à voir les aspects économiques sous un angle différent.

5. Exemples de "Performance"

On peut employer les énoncés de performance pour produire, comme le font les normes de performance, ou bien pour contrôler, comme le font les clauses de performance dans les Codes de bonne pratique. Dans le premier cas, on les emploie parfois pour obtenir des niveaux de performance impossibles à obtenir par les moyens matériels existants. Un des buts visés est de stimuler les capacités de recherche et de développement de l'industrie du secteur privé; un des aspects normalement associés à cet angle est la garantie d'un marché pour les fabricants qui y participent.

Pour le projet de système pour bâtiments scolaires que j'ai déjà mentionné, on s'efforçait de trouver de nouveaux produits coordinés de telle manière et avec suffisemment de souplesse d'adaptation pour créer de meilleurs milieux d'éducation dans 13 régions scolaires de Californie sans augmentation sur les prix conventionnels.

D'autre part, le projet pour bâtiments résidentiels de l'Université de Californie, s'attachait à réduire le côut de la propriété (en tant que construction, exploitation et entretien), alors que le projet "Academic Building Systems" entrepris en collaboration par les Universités de Californie et d'Indiana, avait pour but de produire une performance égale à moindres frais ou une performance meilleure à côut égal ou réduit.

Ces projets et d'autres du même genre ont été encouragés par une agence de la Ford Foundation qu'on appelle "Educational Facilities Laboratory" et démontrent comment les constructeurs dans ce secteur peuvent élaborer des règles et des critères prometteurs. Critères et règles pour ce genre de projet sont souvents specialisés par catégories de bâtiments; ils posent des exigences de programmation en plus des processus de contrôle visant l'hygiène et la sécurité. Encore une fois, ces exigences ont rapport aux besoins de l'usager: Une école capable de s'adapter à une plus grande richesse dans les programmes d'éducation--programmes dont l'éducateur peut se réjouir et dont l'élève peut tirer profit--est une école qui satisfait les besoins des usagers.

Le système d'Agrément jouit d'une réputation bien méritée de pionnier comme système d'évaluation basé sur la performance. Des systèmes semblables à ce système Français ont été adoptés dans de nombreux pays et, aux Etats Unis, l'Etat de New York emploie en partie cette notion d'Agrément. D'autres Etats ont incorporé le principe d'une évaluation objective de la part de tiers dans leur législation pour les logements construits à l'echelle industrielle. Cette législation prévoit une approbation évaluative au niveau de l'Etat, anticipant les règlements au niveau municipal où la responsabilité pour ce contrôle (déléguée par les Etats) se situe généralement.

6. PBS et OBT

Un exemple de projet prometteur auquel le National Bureau of Standards est associé est celui des Spécifications de Performance pour Immeubles de Bureaux (PBS). Le Bureau a préparé ce document pour le Service des Bâtiments Publics, du Service Général de l'Administration, qui ouvre un marché annuel de 200 millions de dollars pour les bâtiments des bureaux fédéraux.

Le Service des Bâtiments Publics a l'intention d'employer ces spécifications à l'usage du Gouvernement, tout en démontrant l'avantage des spécifications de performance sur les spécifications prescriptives--le but est d'obtenir des réalisations en moins de temps qu'avec les projets et procédures de construction conventionnels sans augmentation de frais.

La participation du National Bureau of Standards dans le programme expérimental "Operation BREAKTHROUGH" du Département du Logement et du Développement Urbain s'est orientée plus distinctement vers les besoins de l'usager. Le but principal de "BREAKTHROUGH" est d'améliorer la provision de logements en diminuant les restrictions sur le volume de production. Il est basé sur l'idéal que chaque famille Américaine doit pouvoir disposer d'un logement convenable.

Le Bureau qui fait fonction d'organisme technique du Département du Logement et du Développement Urbain, a mis au point des critères pour l'évaluation de catégories de logements allant des pavillons individuels à des immeubles à plusieurs étages.

"BREAKTHROUGH" vise à mettre en pratique la recherche sur le logement. Pour ce programme on a demandé à l'industrie de soumettre des projets et 22 fabricants ont été choisis parmi les 600 soumissions.

Avec la collaboration de l'Etat et des Autorités Locales on a également choisi neuf terrains, répartis sur tout le territoire, pour la construction de logements prototypes expérimentaux.

Puisqu'il s'agissait de systèmes innovatifs, les normes de référence des Codes de construction ne pouvaient pas être appliquées aussi sévèrement qu'avec des spécifications prescriptives. On s'en est tenu plutôt à l'intention du Code, sans nécessairement le suivre à la lettre. De plus, les critères de performance permettaient l'évaluation des caractéristiques de viabilité et durabilité--caractéristiques intéressantes à mesurer dans ce cas, puisque ces systèmes de logement n'avaient subi ni l'essai du marché libre ni celui du temps. Les critères sont revus continuellement et améliorés par les soins du NBS, des producteurs et du Comité Consultatif du Département du Logement et du Développement Urbain. Ce Comité de conseillers techniques fut créé par l'Académie Nationale des Sciences et du Génie Civil à la demande de ce Département.

La construction de près de 3000 maisons prototypes a fait bon progrès et certaines sont occupées. Du point de vue du Bureau, les informations en retour forment un des aspects les plus importants de ce programme. On s'efforce de rassembler systématiquement des informations concernant ces logements pour établir s'ils permettent de satisfaire les besoins des usagers.

7. Performance: Conclusions Générales

Tout importante que soit cette philosophie, cette technique, cette notion de "performance," elle ne doit cependant pas supplanter les autres nuances et façons d'aborder les questions de l'art et de la science de bâtir. Les solutions intuitives continueront à produire de grandes réalisations architecturales. A mon avis, la notion de performance va renforcer plutôt que remplacer les conceptions intuitives des projets de construction.

J'ai l'impression que certains architectes cherchent une aide méthodologique leur permettant de coordiner les divers aspects--et de faire une synthèse des différentes considérations--qui caractérisent la pratique complexe de l'architecture. Au fur et à mesure que le jugement de ce qui constitue une bonne construction acquiert un plus grand nombre de dimensions, les problèmes qui se présentent au constructeur deviennent plus énormes. Bref, dans l'opinion des constructeurs que je respecte et que je connais, la notion de performance aura une influence profonde sur la conception des projets.

L'élaboration d'un projet exige des informations-sur les désirs du client, les besoins des usagers, sur les produits, etc. - et produit également des informations sous formes de graphiques et de communications verbales. En fait, on peut dire qu'en fin de compte presque tout ce que nous faisons dans ce domaine bien concret de la construction se réduit à une question d'information. La notion de performance, avec sa séquence ou format bien ordonnés, offre de bonnes perspectives d'organisation de l'information.

Ce Colloque même vise à produire et à diffuser les informations que nous, praticiens de la construction, pourrions appliquer à l'échelle mondiale.

Nous sommes réunis ici pour faire un examen, que je souhaite fructueux, des aspects de la performance dans l'état présent de nos connaissances, tout en nous rapplant que cette technique d'organisation de la pensée est elle-même complexe dans ses ramifications et ses applications. Nous avons reçu un grand nombre d'exposés très intéressants, et je suis certain que les rapports de synthèse des rapporteurs, les discussions libres prévues au programme, et aussi les autres échanges de vue qui s'organiseront spontanément, vont contribuer à rendre ces journées extrêmement utiles, non seulement pour nous mais aussi

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Je vous remercie.

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SESSION IIA

Buildings

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Papers Reviewed by Mrs. Saeterdal

I intend firstly to give a brief summary of each paper, focusing on the criticism of the present use of the performance concept and on the proposals for further application. Secondly I will try to draw some conclusions for our future work. Of the sixteen papers in this group, almost all of them include a general discussion of the performance concept and proposals for application both in research and design.

The first ten papers are primarily concerned with establishing the requirements. The last six papers mainly concern different aspects of evaluation. The variation in users' characteristics, and the user in an institutional context, are treated in two of the papers. Three of the papers deal with sociological methods: measurement of overt behaviour, verbal response measurement, and attitude scaling as part of an evaluation of physical facilities. Three papers deal with user benefit, cost, and performance. Several of the papers discuss procedures for integrating the performance research in the planning process. All of the papers are concerned in some way with the users' requirement.

The first part of the Halldane paper includes a critical discussion of the performance concept. In the second part suggestions are made for an interdisciplinary design specification. As an illustration, lighting problems are discussed.

A product is evaluated within a broad context. In the process of evaluating, a great number of professionals take part, each with his own specialized point of view. We often find that the different professions operate "on their own" rather than working in cooperation within the broader context or existing goals. These goals are not always stated clearly in the design process. Halldane maintains "that where there is a delegation of responsibility, a specification should state the design goals in an operational way. In this manner all groups can address the common problem." Goal statements formulated as "user needs" and "user wants" are often too general and may contain inherent inconsistencies, and are therefore not operational.

The paper criticizes the present work on the performance concept for its narrow concentration on physical entities, and argues for the inclusion of organismic factors. Performance criteria today often become no more than new ways of presenting accepted building practices. Often test procedures used do not correlate with human responses. They might be useful for a manufacturer, but are irrelevant and of no use to the occupant and to a proper design evaluation based on human response-criteria.

The need for going beyond a generic user concept, taking into consideration the changes and differences from one user group to another, is well illustrated. This paper is limited to age variations and spatial requirements, but the approach is relevant for other variations (variation in mental/physical health, in group membership etc. and for other types of requirements like safety, comfort etc.).

A checking procedure for design evaluation is outlined.

The next two papers were produced by a team of people, T. Cronberg, A. Hallquist, R. Hanson, J. Nordan, and A. Saeterdal, and may well be reviewed together. Both papers are concerned with establishing human requirements for building. The first paper starts with information about the user and the users' activities as the basis for identifying the human requirement. Outlines of the information needed are suggested. The importance of taking into consideration the variation in user groups and to extend the activity concept to include also the activities that are not available for direct observation, is stressed. A procedure for identifying the human requirements is suggested.

The second paper presents a way of structuring the performance requirement according to the basic functions of a building. The physical properties are structured accordingly. This is meant to serve as an analytical link between functional systems and physical properties.

The paper by Nevins and McNall does not deal with the performance concept or human requirements in general, but discusses one specific aspect: The Thermal Environment. However, the purpose of this paper is much the same as the preceding: "to suggest that the performance of a building environmental system must include the human occupants as part of the system and to recommend performance requirements based on human responses."

The paper gives a good example on how to analyze the whole functional system as it influences one certain aspect of performance.

The paper by Pẽna and Focke deals with the problems of architectural programming defined "as a process leading to the statement of an architectural problem and the performance requirements to be met in offering a design solution." Performance requirements are defined in this paper as those conditions which must be satisfied by the entire architectural solution. Performance specifications state the conditions which the building system must satisfy. A five step process of architectural programming is suggested.

The paper by Pastalan deals with the variations in user needs during the life cycle. It concentrates on the aged, and treats some parameters associated with designing housing environments for this group. We respond to the environment through our senses. Change with age in sensory and perceptual mechanisms very directly affect the environment experienced.

The two principally different attitudes in this respect are:

-- to adapt the environment to this change in the sensory and perceptual mechanisms.

-- to make the aged adjust, resulting in a limited range of behavior.

The first attitude is underlying in this work. Taking into consideration the most vulnerable user groups will lead to facilities with a higher serviceability in general, and should not be considered as specialized solutions for special groups.

The paper by Lemer and Moavenzadeh suggests "a conceptual structure and operational approaches for the description of a user-based economic concept of performance." Three principal parameters are treated as means of measuring the performance:

-- Serviceability - the ability to provide service for the user.

-- Reliability - the probability that service will remain throughout the lifetime of the facility.

-- Maintainability - measures the degree to which continued action is required to assure that the service is adequate.

The paper describes these three parameters in economic terms and suggests methods for measuring them. The intention is to be able to predict and evaluate economic performance of a system. This approach has been implemented in the case of highways, which is not as complex as the problem of building or housing. At present, I doubt if we have clearly enough identified the human requirements to carry out this type of analysis for housing without revealing biased results.

The paper by Hattis concerns the relationship between the performance concept and the planning process. The relationship is considered in the first part through a theoretical discussion; in the second part through a description of a project where the performance concept was actually used in systematizing the planning process.

The "hierarchy of performance" is discussed as a means of defining the relation between systems and subsystems, and to decide on the scope of a system. He suggests that a performance specification on a particular scale should be complemented by prescriptive statements of the next higher scale. The author raises the question of how to determine the scope of a system in order to maximize the benefits of performance specifications.

He asks "why could not the performance concept offer a much wider range of options?" To attempt this he suggests distinguishing between clear and ambiguous building types. Performance specifications may be used with reasonable results for a "clear" building type like, for instance, office buildings or retail shopping. For writing performance requirements for a new more "ambiguous" building type like, for instance, Community Mental Health Centers, no consistent set of requirements can be given in advance.

This calls for a planning process which in itself will contribute to the establishment of the requirements. The last part of the paper describes the Planning Aid Kit which is a proposal for such a planning process for Community Mental Health Centers.

Handler's paper is entitled "Institutional Performance and Building Performance: Some Implications of the Judicial Facilities Study." In performance work the users' activities are taken (at least ideally) as the starting point of the analysis. But Handler argues that this is not sufficient and puts the question: "What about the institutions or organizations that buildings are meant to serve?" If the institutional requirements are not considered, the buildings may "hamper rather than help the performance of the institution." Taking the performance of institutions into consideration means expanding the scope of architectural analysis to include a thorough study of the institutions themselves. It might result in reevaluation of the present operation of the institution, which in turn might mean other requirements. Put in terms of the Hattis paper, it might mean that a building type classified as "clear" becomes "ambiguous".

An experience, which presumably is common to people who have worked with social surveys in residential areas or buildings, is that many of the problems and conflicts occurring may be traced to the lack of institutional insight by the decision-makers.

Handler's paper gives as an example a description of "the Judicial Facilities Study" which attempts to "relate building requirements to performance criteria for the system of judicial administration."

The paper by Mann and Bender starts with a critique of the assumption that overall systems of performance variables are possible and useful. In the second part the performance concept is related to the planning and decision-making process.

A planning process is suggested where research on performance measures for industrialized housing is included as part of the process. It is argued that the underlying assumptions of much of the present performance work are unrealistic.

The first objection deals with the "user needs" concept. The statements of user needs involve many problems:

-- "user needs" change over time, people are different;

-- "user needs" are dependent on the social environment and on technology;

-- "user needs" may be conflicting, counteracting or mutually exclusive.

Decisions of this kind can only be taken on the basis of personal values, which means that the concept of a "natural system of user needs" cannot be maintained. They must be developed in a decision-making situation.

The second objection concerns the tendency to concentrate on the "hard objective" criteria which are easy to measure, and to neglect those that are not so easily defined.

The third objection has to do with the setting of standards. There is a tendency to set standards as close as possible to the minimum acceptable values so that we are left with solutions that are barely acceptable.

The authors want research to be integrated in the planning process, not before the project starts but actually integrated in the project so as to be influenced by the problems occurring. Research should not give answers. Value judgements belong elsewhere.

Both of the next papers, written by Preiser, treat methods for performance evaluation. In the first paper, unobtrusive observation techniques are used in evaluating a public plaza. In the second paper, verbal user response is used in performance appraisal of a residence hall of a university.

Both papers describe the importance of "behaviour-based design criteria as a precondition for user-relevant programming." The data derived will form a necessary complement to the traditional "hardware" criteria both in the programming and in the evaluative phase of planning. The result will, however, be limited to certain given conditions and therefore such a basis for performance requirements and criteria must be developed specifically for different types of setting.

The conclusion of these papers is that empirical evaluation of existing buildings and physical settings will help create relevant performance criteria, and that the complementary use of direct observation and verbal response measurement should be applied.

This next paper, by Blasdel, suggests that the user evaluations of buildings in use should be added to the traditional laboratory research. Only a limited number of variables can be tested in laboratories. Only by measuring human responses in a full-scale functioning environment can the criteria have a sound basis.

The paper discusses new methods available for analyzing "each person's data in the context of his own responses, and thereby taking into account several interpretations of the same question, and different perceptions of the same environment." The example treated is the evaluation of the visual environment of ten campus libraries.

The last three papers deal with the relationships between user benefit, performance and cost evaluation of buildings.

The paper by David J. Parsons suggests methods for analyzing and illustrating these relationships as a basis for decision-making. The relation between the three concepts has to be made clear because information on "user needs" is not sufficient for making design decisions. Consequences of different levels of performance and different benefit levels for the cost must be considered.

The paper by George S. Birrell contributes to the Performance/Cost evaluation of buildings, suggesting an expansion of the basis for such evaluations and proposing means of integrating such evaluation in the design process. It is in the design process that the evaluation of performance is most crucial. Decisions made during the design process set the cost and performance levels. Afterwards they are difficult to adjust. A tool for cost/performance evaluation in the design process is presented.

The paper by John T. Malarky discusses architectural economics of the capital costs, operating costs and "people" costs of a building. People costs refer to wages etc. A survey of costs for the different categories is shown for a 10 story office building 10 years after construction. The operating costs and especially the "people" costs represent high percentages, yet often little attention is paid to this fact. The capital costs are usually watched closely, whereas operational costs are not clarified. The paper gives examples of possible savings if the latter are taken into consideration. A comfortable environment invluences the productivity of the people and thereby the "people" cost. The question is: how sensible are people of the degrees of comfort? These questions are discussed by means of an example of glass-"environmental factors", comfort and productivity related.

Conclusion

I will summarize the criticism and proposals in the following three points:

1. Users Requirements Must be Considered

The tendency in present performance work to limit the requirements to factors easily measured, and to use physical requirements based solely on information about materials and constructions etc., is criticized in many of the papers.

All the papers seem to agree that efforts should be made to expand the basis for establishing requirements to include information about the ultimate user of a product. The physiological, psychological and sociological characteristics of the user and his response to the environment must be taken into consideration.

Different proposals on how to get this information are made:

- -- through psycho/physics studies
- -- through surveys
- -- through observation of behaviour
- -- through verbal measurements and attitude scaling
- -- through studying users as part of an institutional context
- -- through considering the variations in user characteristics and the users' activities

If performance work neglects these kinds of considerations, the result will be no more than new ways of presenting accepted building practices. The performance specifications will not be valid as a basis for evaluation. The tests will seem irrelevant to the occupants.

2. Establishing the Users' Requirements Must be Integrated into the Planning Process

The assumption that overall systems of requirements and criteria may be stated is criticized. This has lead to proposals for planning and decision-making processes which integrate performance research in planning.

The contribution to the planning process will be a more systematic approach where decision-making as far as possible will be based on knowledge about the relations between environmental stimulus, human responses and physical facilities. The benefit to performance work will be, first, research governed by actually occurring problems, and second, an improved basis for stating the requirements.

3. Goals/Objectives Must be Stated Clearly

Many of the proposals for procedures stress the need for goal statements, operational goals, objectives, prescriptive statements on higher levels etc. This is to serve as a frame of reference for the different requirements and for the different professions and interests promoting them. Otherwise inconsistencies and contradictions will occur. The performance concept should primarily be used as a frame of reference for information and recommendations from the research side, and for value judgements and decisions from the users.

There are problems involved in the setting of standards based on performance work. Setting standards implies making value judgements and should thus be done by the user. It is important for our work that it is made clear where and when goal statements and value judgements will enter.

My impression from reviewing these papers is that there is some sort of general agreement about the performance concept and its advantages. There are differences in the practical approach to the work according to the professions represented and according to the field of application. These differences are needed and wanted. But the framework of performance must be made clear enough to assure proper communication between the different participants. I propose the following three suggestions:

<u>A coordination of the varieties of terms used, would be one contribution to this</u>. Some papers use terms not defined, and other papers define terms they do not use such as goals, objectives, functions, operations, activities, user needs, user wants, user characteristics, organismic factors, users requirement, human requirements, functional requirements, performance requirements, hardware/building requirements, performance specification, design specification, performance criteria etc.

I would not recommend a discussion of terms at this conference, but we should find ways to sort out and agree on a terminology in future work.

<u>Another contribution would be to clarify the different types of application of performance thinking and relate to these adequate procedures and methods</u>. Several different procedures are suggested. Some of them are shown in <u>Figure 1</u>. The papers submitted to this conference could form a basis for a systematic survey and comparison of procedures and methods related to different fields of application.

Halldane	Cronberg et.al.	Pẽna & Focke	Hattis
1. Operational Goals What is the design for?	1. Choosing Activities relevant to function	1. Establish Goals	1. Problems relate problems to different groups of community
2. Parameters What are the factors to consider in design?	2. Defining Users and their relevant characteristics	2. Collect, Organize and Analyze Facts	2. Course of Action mobilization of resources to solve the problems
3. Synthesis How are the factors related?	3. Identifying & Structuring user requirements on the basis of step 1 & 2	3. Uncover and Test Programmatic Concepts	3. Activities display alternative sets of activities for each course of action
4. Performance Criteria What attributes and magnitudes are needed for the factors to meet the goals?	4. Defining the Given Conditions (such as climate, law, restrictions etc.)	4. Determine Needs	4. Environmental Characteristics quantifying environmental requirements
	5. Identifying & Structuring Performance Requirements on the basis of step 3 & 4	5. State the Problem	

Figure 1. Different procedures for identifying users' requirements as suggested by various authors.

A third contribution to the coordination of the performance work would be agreement on certain ways of structuring the requirements and the types of information needed. Figure 2 shows different proposals for structuring requirements put forward in the paper.

Pẽna & Focke	T. Cronberg et.al. (p. 23)
Form Function Economy Time	Source Enclosure Filter in/out Supply/waste (performance requirements)
T. Cronberg et.al. (p. 13)	Lemer & Moavenzadeh
Accessability/usability Safety/protection Perception/comfort Social adjustability (users requirements)	Serviceability Reliability Maintainability

Figure 2. Different ways of structuring the requirements as suggested by various authors.

A comparison and coordination as suggested above of: (1) Terminology, (2) Procedures for different types of application, and (3) Ways of structuring the needed information and the requirements would be a worthwhile task for the participants of this conference.

John Halldane

The term "organismic" is used so as not to limit ourselves to humans alone. Future environments will go beyond that of our present ideas of a "building" on a plot of land to those of confined, even self-contained, environments. Examples include space stations, underwater habitats, and perhaps even our "homes" in a geodesic complex as Archigram or Fuller might have it. With this extension, people must be considered along with plants and animals for their very existence.

Since writing the paper I have projected the ideas into the area of technology assessment. A seminar was presented to the Program of Policy Studies on Science and Technology, The George Washington University, Washington, D.C. a couple of months ago on "Design Evaluation in Technology Assessement - Illustrated by Auditory Impedance and Sound Distribution Problems." It will be published as a monograph at a later date.

"User needs" as pointed out on Page 2 is not all embracing. Needs in fact come from the definition of the operational goals and can be either of an environmental or organismic activity.

Tarja Cronberg

As already stated by the rapporteur, there seems to be a general agreement on the need of systematic user information input into the design process and on the necessity of establishing a general framework for this. In our paper we propose a procedure for introducing this information into the planning process based on the individual characteristics of the user, his activities, and the change of these factors over time.

In our paper we have not presented a detailed discussion regarding which parts of the environment this information, and the resulting requirements, should be applied to. Information on users is generally acknowledged as a basis for planning of residential areas and buildings. I would therefore like to stress the need for a more systematic use of this information when stating requirements on building hardware, components, and materials, for two reasons:

1. the performance concept has so far almost exclusively been applied on these levels,

2. the existing building codes and regulations are traditionally mainly concerned with these aspects.

Performance requirements on building components and materials already stated should also be critically studied in relation to their user-information content in order to establish some of the value judgements falling in between those of "a decent home" and "the frost-resistence of concrete."

Ralph G. Nevins

The importance of the thermal performance of the building, the control system, and the air conditioning system must be emphasized. As stated by President Johnson and others when discussing the upgrading and redevelopment of the inner city, any building constructed today without air conditioning will be obsolete the day it is finished.

It is very important to recognize that many factors must be considered when evaluating human thermal comfort, not only air temperature and humidity but also air motion, mean radiant temperature, clothing, and activity level. Understanding the inter-relationships is absolutely necessary. Since the activity in a given space will change, as will other factors, an "adaptive control system" may be required, a system responding to inputs in addition to air temperature.

In addition, a specification of one temperature, center of the room or at the thermostat, ; not enough. Satisfaction of the gross heat gain or heat loss is not enough. The revised ;HRAE standard for comfort criteria will include a procedure for evaluating the environment ; a given space which requires measurements of all factors throughout the space to prove mpliance.

To illustrate the complexity of our problem, I give you the following from Ogden Nash:

Some hoist the window and gasp for air
While others find it chilly.

Some turn up thermostats a hair
While others find them silly.

Some freeze, while others smother
And as if by some fiendish, fatal plot
They marry one another.

lfgang F. E. Preiser

The issues brought up in my paper might be expanded by adding the following important ints:

1. An expanded scope of analysis in man-environment interaction, which nowadays is considered essential, would include not only the physical, tangible and easily quantifiable variables but would address itself also to the qualitative aspects of the social environment as well as the built environment. Consequently, criteria relating to value systems, cultural differences and the symbolic meaning attached to aspects of the environment must be included in environmental analysis. If the larger context of building is to be incorporated in environmental planning this means the social, economic, political and general cultural context. As the disasterous example of Pruitt-Igoe shows, the blame for the failure of that originally much praised high-rise apartment development must be laid primarily on the social and political decision makers, not the well intended architects. The high-rises would have been suitable for middle class families, not for the poor who were uprooted from their original neighborhoods and social networks and who lacked the mobility and means to survive in high-rise buildings.

2. In order to evaluate real life situations criteria have to be derived from explicitly stated goals in behavioral and environmental terms. These goals should be those of the eventual user, at least they should not conflict with them. Therefore, research is needed into user perception and user requirements as a basis for design decisions.

3. An attitudinal change in regard to environmental design is necessary, i.e., the need to consider all designing and building activity as an experiment from which we can learn through evaluation and feedback into experience and information banks for future reference. Consequently, in order to minimize the loss of experiences gained through the user evaluation of the built environment the cost for such evaluative research should be provided for by allotting a standard low percentage of the building cost to research, e.g., as in the proposed post-construction evaluation of government sponsored projects.

4. Finally, I would like to stress the need for alternative solutions and the provision of variation and choice for the user. Often the performance of buildings in other than direct cost terms can only be measured in negative outcomes, avoidance responses, non-use or the absence of certain expected activities in a particular space. Such signs should be taken seriously. The following example may illustrate the point: Since there are no places where young people can go and enjoy themselves as a group in suburban

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communities, they will "hang out" at shopping centers, the only focus of activity in their neighborhoods. There, of course, they are considered undesirable, because they are not shopping but "loitering" in search of something exciting to do. But, as the author observed, because the shopping centers have been designed for shopping only, these poor youngsters are frequently driven off the premises by the management. Should there not be a variety of things to do and a place for everybody?

H. G. Blasdel

Mrs. Saeterdal has made a fine summary of my paper. However, in the conclusions she draws from the set of papers she encourages an emphasis on further development of terminolog and classification of user needs rather than the aquisition of new data - data directed toward the determination of which variables are affecting the users and how these variables may be manipulated (or at least controlled by limits) in design. If anything, existing applications (SCSD and onwards) have generated more questions about current knowledge than they have added to that knowledge of human needs. Unfortunately, these questions tend to be swept under the rug of expediency, a practice common to design and politics. The near universal call for more "information on user needs" is empty without the active interest in research and methods for doing research.

In contrast, much existing work on "user needs" involves the remanipulation of criteria whose adequacy has never been tested in a wholistic sense. Where a small effort to re-evaluate some criteria in lighting can yield a range of attributes apparently relevant to the subjects which are not a part of the literature, the adequacy of existing research approaches can be questioned. Beyond these limitations, the question of the balance of emphasis on which of the various criteria are more important in the context of limited resources remains virtually unapproached.

John T. Malarky

Gentlemen, my paper is offered as a challenge to professionals to identify and qualify all the factors influencing overall performance in building design. If one were to consider building a black box which performs a function, such as making a product or providing a service, the TOTAL COSTS which go into the building would be considered and evaluated.

In the paper I have considered a "typical" office building and define TOTAL COST as capital costs, maintenance costs, and people cost. I have shown that during the life of a building PEOPLE COSTS are most significant and least considered; initial costs are least significant and get most consideration; and factors related to comfort influence people performance.

Considerable work has been done to define conditions under which people are comfortable but little has been done to quantify the "benefit" comfort achieves. For example, why should a building owner pay for air conditioning and sophisticated air temperature and movement controls? He knows he benefits, but not by how much.

The paper suggests a method to evaluate the benefits of comfort in understandable terms-cost benefits. The paper attempts to establish some guidelines for the building owner to evaluate his return on investment when considering capital costs which achieve comfort such as improved insulation with high performance glass. (When considering improved insulation a direct added benefit is reduced energy requirements.) The confort/benefit evaluation method considers glass as the building material but other building materials may also be considered in a similar way.

Is the method accurate, I don't know. Is it reasonable, I believe so. I look to the professional for criticism and suggestions.

érard Blachère

1. First I want to point out that it seems generally accepted that the performance approach at the level of a whole building lies on the positive concept of the satisfaction of the user's requirements, not on the negative concept of defense against external stresses, and never on a set of physical properties or so called functions. The consideration of user's requirements solely, opens the door to radical new solutions, like jet after propeller, or air cushion after wheel.

2. What we need is an operational list of user's requirements, not a list of headlines, but a list of precisely defined needs.

3. And there I want to pinpoint the fact that we have at our disposal a list of human requirements issued by the CIB Working Group 45, with physiological, psychological, sociological aspects, which in my mind is operational. You can find it in the 5th CIB Congress book and in the excellent magazine of CIB: Build International. Naturally I am conscious of the changes in the requirements with time, location, economic level, and also of individual differences. But they are secondary to the primary level of listed requirements.

4. I think the work to be done now is research to augment the list and fill its gaps, for example:

   - the influence of noise on sleep,

   - the necessity of communication from the interior of a building with the external environment, through windows or otherwise,

   - establishing the requirements of a family related to its way of life, in a usable way.

5. We want also to draw, from the list written for housing, lists of requirements for schools, hospitals (not so different from a house) and also for pig stables, or grain silos; what can be more different?

6. But in any case, we have to remember that what we need is a list that can be used by the designing and evaluating people.

nho Sneck

The Symposium is divided into three sessions: Buildings-Components-Materials. As a mber working at the materials level I have the feeling that I represent something that is necessary evil in building.

The WHOLENESS is the most attractive idea of the performance concept. If we split the OLE into parts, we have to secure the TRANSFORMATIONS necessary to associate the parts. rther, some SELF-REGULATION is needed.

All buildings are built of real materials. The importance of links between the levels nnot be overestimated. The materials ought to be developed for specific application in ildings. Also the "Materials" level must be based on the study of human needs. The pers of Preiser and Blasdel are helpful in this connection, but the paper of Halldane is pecially important. Halldane analyses the needs and gives also some indications for ssible applications on the "Materials" level.

A. F. E. Wise

I want to comment on the application of criteria of thermal environment, bearing in mind the papers of Nevins, and McNall, and Malarky. Before doing so I would like to complim Handler and Preiser on their papers and remarks, which seem to me to show the way towards getting to the heart of the problem. But for the present one can only treat design in a more limited way, dealing separately with the physical parameters - heat, light and sound - and being somewhat in the dark about the effects of the various social forces at work.

As an example, consider thermal requirements. For sketch-plan design the architect wants to know how the thermal requirements may be met in terms of such parameters as weight of structure, window size, ventilation rate, shading and so on. At the Building Research Establishment we have developed information for such use in the U.K. and an example is shown in the Figure. The terms used have the following meanings. The graphs relate to a 2 person office, 20 x 11 x 9 ft. in size.

Light Weight - light partitions, carpet on floor, false ceiling.

Heavy Weight - brick or concrete partitions, no carpet, solid ceiling.

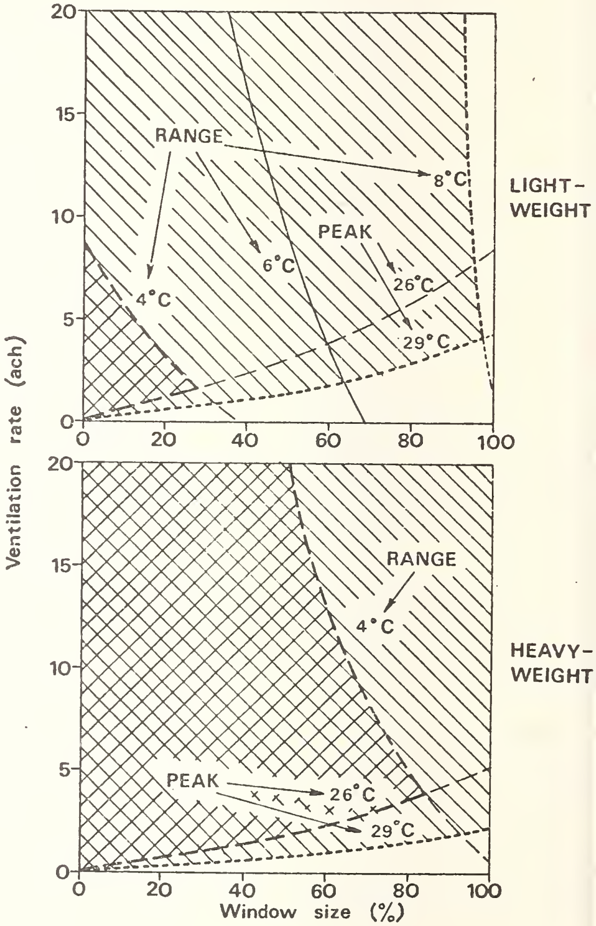
Glazing - expressed as a percentage of the external wall area.

Temperatures - represent standards of room temperature in terms of an "environmental" temperature including both radiant and air temperature components. The standards have two parts and in these figures represent a peak indoors in summer and a limit to the swing during a hot sunny day. Standards may be taken in the U.K. as follows, based on our thermal comfort records:

26°C peak, 4°C swing - a "good" standard

29°C peak, 8°C swing - a "borderline" standard, above which complaints are likely to increase markedly

Ventilation - for rate of ventilation with outside air to achieve the good standard, the architect should keep within the double shaded zone; the borderline standard may be achieved within the single shaded area. Similar graphs are available for other conditions including glass with reflective film, heat absorbing glass, external shading and so on, also for cooled air i.e. an air conditioned situation. The graphs may be developed to include other information e.g. daylight contours. I suggest that the general development of information on these lines would make a worthwhile contribution to the work of the architect in sketch plan design.



Variation of ventilation rate with window size for double clear glazing with mid-pane venetian blind

W. Phillips

Much emphasis and detail have been addressed in these papers, and related comments, to e identification and incorporation of "user needs" in the performance concept of building sign. Some mention has been made to various means for "Feedback" from users occupying e buildings as designed.

It is important that careful attention be given to rigorous determination of the actual rformance of the building, before evaluating the feedback. It should not be assumed that e building and its subsystems have been so constructed and installed as to satisfy the sign requirements. The first step of any feedback analysis should be determination of e actual performance stimulating the feedback.

ter Cradock

The more we attempt to define performance standards the more, in general, the solutions e likely to cost if considered in terms purely of initial capital. Yet over the life cle of a building the running and maintenance costs can vary widely. New approaches are cessary toward the vital relationships between performance and costs in use.

We did some studies recently in a comparison of landscaped and conventional office ildings in the U.K. - the one, open planned fully airconditioned, with carpeted floors, ftly surfaced and fully serviced; the other, in accordance with more traditional standards. r findings showed that if we considered the capital at loan rates, plus running and main-nance costs, and general rates etc. over the life cycles of the buildings, the improved rformance of the landscaped alternative, although appearing to cost more initially, tually provided for an equivalent number of staff to be accommodated in buildings utilizing e much higher performance standards. Thus we could say that, by considering the total sts of the more efficient building on a "cost in use" basis, greatly improved performance andards were possible at no greater cost than the conventional alternative.

I would most strongly suggest that the future of the performance concept applied to ildings depends on such standards as seen relative to levels of costs in use.

We must also seek to encourage a progressive modification of current financial, tax-ion, and legislative procedures so that these may in turn encourage improved "performance use" for complete buildings. Some invited papers suggest that we may be gaining an over terest in components. We should be emphasizing the performance values of complete ildings.

The sum of the whole can be much greater - or much less - than the component parts, cording to our skill as designers and this applies as much to costs as to performance.

ck E. Snell

I agree that we must be quite cautious not to embrace too closely analytical tools or dels that have not been thoroughly tested nor which fail to include all known factors fluencing building performance. On the other hand, I believe little attention will be rected to the research issues which Mrs. Saeterdal and the authors she has reviewed have entified until the potential benefits of such work have been identified clearly to those o finance and operate buildings.

In this light, work of the sort reported by Malarky must receive a high priority. The sential economic life-cycle cost-benefit trade-offs to the building owner/user have not en evaluated. The approach developed by Lemer and Moavenzadeh though as yet untested on ildings has been demonstrated successfully in other areas and offers great promise in this eld as well.

Sandor Kiss*

Research activity in this field in Hungary is performed primarily by the Institute for Building Science; related work is under way at the Information Centre of Building.

An essential element of the natural/macro-/, settlement/mezo-/ and building/micro-/ environment system accommodating m a n, as a "whole", is the building/micro-/ environment. The basic function of this microenvironment is partly to protect him against harmful effects originating from the macro and mezoenvironment, respectively, partly to provide optimum conditions for his physiological, psychological, and sociological functions. Consequently, this function is a fundamental, more primary determinant of the realization of the building creating the microenvironment than anything else.

The main tasks in connection with the application of the performance principle can be summarized as follows:

1. The determination of those building categories/levels concerning which it is expedient to perform performance analyses at present.

2. Function analyses.

3. Technical-economical/value/analyses.

4. Preparation of /check-lists/ for categories established in point 1 as system components and systems, respectively.

5. The collation of methods suitable for the determination of the degree of assertion/numericalization/ of the individual structural properties.

6. The actual determination of performance values.

The title of the research project of the Information Centre of Building for 1972 is "The compilation of parameters necessary for the evaluation of structures and parts of buildings." Within this, as partial tasks, have been assigned

- The compilation of parameters necessary for the evaluation of dwellings,

- The compilation of the parameters of prefabricated reinforced concrete structures for building construction.

The above research objectives were justified by the fact that the investigation and evaluation of the economic efficiency of new materials and structures is becoming more and more important in the Hungarian building industry. The proper process of evaluation is greatly facilitated if the collection of parameters for all structures to be evaluated is available, elaborated, and compiled according to the requirements which can be made concerning them.

* Condensation of a prepared discussion titled "The Optimum Formation of the Environment of Man and the Formulation of Requirements Concerning Buildings, on the Basis of the 'Performance' Principle," by Tibor Kiss and Zoltan Gereben, Institute for Building Science, and Sandor Kiss, Information Centre of Building, Budapest, Hungary.

tional Bureau of Standards Special Publication 361, Volume 2: Performance Concept in Build-
gs; Proceedings of the Joint RILEM-ASTM-CIB Symposium, held May 2-5, 1972, Philadelphia,
nnsylvania (Issued August 1972).

SESSION II B

Buildings (Continued)

John A. Robertson, Chairman

Gérard Blachère, Honorary Chairman

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Papers Reviewed by Mr. Atkinson

rchitect

Specification by performance is a dynamic concept. The range of approaches adopted within even a group of papers selected for being more physical and technical in content is wide. Some discuss work which will have developed further since reported in the papers. To take two examples: Eberhard describes the development and application of a computer-based system for building codes - regulations in Anglo-Scottish language - which by May 1972 should be available for demonstration; Karlén refers to work on the 1972 edition of the CIB Master Lists, and their application to the Scandinavian ER-system for quality description, which is still in progress. Both items of work will have been taken further since reported. Experience gained will be of interest to the Symposium.

Among the papers are some, like those of Robbie and Vilett, which arise directly from application of systems and performance concepts; Karlén also discusses these two concepts. Other papers, like those of Markus, and of Haider and Khachaturian, deal particularly with appraisal and evaluation. With these may be grouped that by Macalik which refers to a new programme designed for computer evaluation of the performance of building systems and components. (It is not mentioned how far development of the mathematical model making has been taken.)

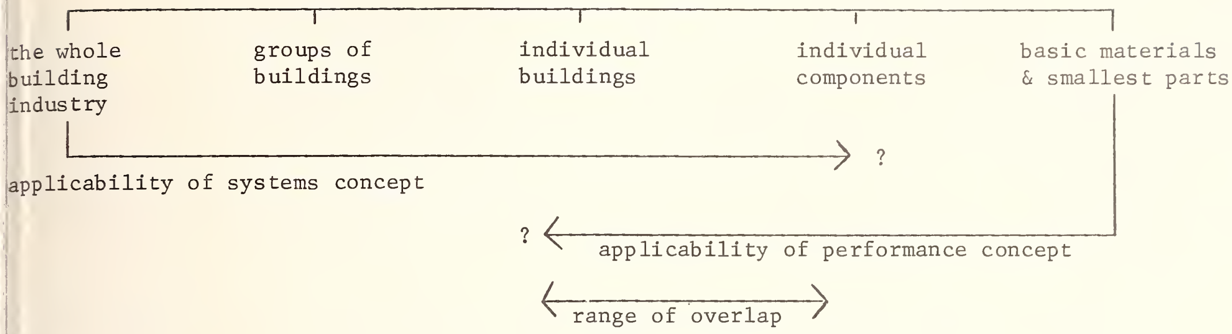
Sneck comments on the difficult problem of evaluating the performance of elements of a building, and of the products used in their construction, from the properties of materials used and their inner structure. He lists external factors affecting an object in use and the internal factors which affect the object's performance through the fact that they determine the properties of the materials from which it is composed. In his first paper, Blachère questions whether it is possible to evaluate the performance of materials without taking into account the way they are shaped "i.e. roughly speaking a component." In a second paper, Blachère discusses the relationship between the set of physical properties - chemical, geometrical and mechanical - presented by a building, and its parts of elements, and user requirements, a topic discussed in more detail in the first group of papers of Session II.

Three papers, by Yokel, Somes and others, draw their themes from the evaluation and specification of structural performance. With the paper by Wright and Ang, they give attention to the problem of variability and serviceability. Brill describes a technique used for developing a performance specification for any type of building.

Despite differences in terminology due in part to the different background and experience of the authors, a number of common themes can be identified relating to the design process; levels in the building hierarchy; and performance evaluation. One theme, that of the relationship between systems thinking and the performance approach, is clarified by Vilett. His suggestion that "the systems concept is most applicable when the problem at hand is large-scale and more or less complex, includes values difficult or impossible to quantify, and calls for an emphasis on interactions" as contrasted with the performance concept which is "more relevant to problems associated with individual components when the emphasis is more properly on measurable properties," merits serious examination. It could well be a central theme for discussion.

That there is a considerable overlap between systems and performance concepts is demonstrated diagramatically:

Range of Building Problems



Vilett suggests that the performance approach is applicable to situations like the development of an innovative product where it is desirable and feasible to specify precisely measurable characteristics of objects without reference to the particular means of producing them. The systems approach, on the other hand, is applicable to situations like the generation of a plan for a group of buildings, implementation being either conventional or using performance specifications for component parts.

Robbie also refers to the systems approach, though not making as clear the distinction between performance and systems thinking. Rather he suggests that "the entire performance approach to building (is) something of a wildly popular hoax, the best hoax since modular coordination." It is because the approach is compromised by what he calls "the local factor" which, though not defined, seems to include the values and aspirations of a society at a given time in its history.

Vilett's description of a systems approach to building suggests that it would provide the methodology for Robbie's "performance-judgement"; indeed one wonders whether Robbie's difficulties are not caused by attempting to extend the applicability of "the pure performance approach" beyond Vilett's "range of overlap." Incidentally Vilett points to inherent practical disadvantages in both performance and systems approaches which must be carefully weighed against their presumed problem-solving capabilities in any particular case. "Implementation of the performance approach, for example, usually requires the development of precisely defined test procedures and a corresponding test program. It may also require special legal documentation which at present has relatively little precedent. Application of the systems approach may involve very elaborate analysis of the problem and evaluations of alternative solutions which cannot be justified in terms of time or cost-benefit. It is also susceptible to political sabotage because of the need for questioning existing procedures and other matters in which there may be sensitive vested interest."

Karlén underlines an advantage of systems thinking in that it can ensure a good chance that "all relevant parameters are taken into account, measurable as well as non-measurable", but he does not so precisely give it a place in the range of building problems except to state that it has a particular use for the "description of the wanted result, the final system."

Robbie, like Blachère in his second paper, stresses that "performance requirements can only be established if the user's requirements are known." They must be established first at the building type level and, secondly, at the building part level. He proposes a set of "generic categories of building" based on a list of (conventional) building types. Lists of this kind have a disadvantage in that the names given do not necessarily distinguish uses with similar requirements or differentiate between occupancies which result in dissimilar needs. The increased complexity of building schemes, which may include in a single structure private dwellings, hotel bedrooms and public rooms, shops, a department store, auditoria, offices, car parking, and unloading bays for heavy vehicles; as well as spaces for boilers, pumps and air conditioning equipment; makes rational classification of uses and occupancies a difficult task.

A direction in which a solution may be found is pointed out by Vilett and by Marcus. Vilett refers to the conceptual model proposed by Mainstone, Bianco, and Harrison in a discussion on hierarchies of choice and performance in architectural design. From the objectives of an undertaking which building aims to serve, activities are identified for which space and, usually, enclosure are needed. The activities likely to take place in the spaces and enclosures are reflected in descriptions given to types of occupancies and to user requirements for proper functioning. An important task is to develop an adequate framework for describing and classifying activities and occupancies.

One application of the performance concept is in building regulation. Eberhard lists some key problems: separation of design from code enforcement; delays due to understaffing and the multiplicity of authorities to be consulted; little or no feedback from innovation; and regulations structured around conventional products and techniques.

In the United Kingdom and a number of other European countries, regulation systems have made use of the performance approach for some time. Comparative studies of European regulation systems suggest that a performance-based system should include:

-- Statements of requirements in terms of functional criteria - what is required, from what part of a building, under what conditions of use.

-- Guidance on performance likely to satisfy criteria either by specification of acceptable levels for relevant attributes in 'performance standards' or reference to a 'model' the performance of which is accepted as satisfactory.

-- Information on design data and methods of calculation, assessment, and test accepted as good practice.

-- Procedures for examination of proposals by calculation, test, or expert judgement to check whether performance is likely to satisfy criteria.

-- Procedures for control of quality of manufactured products and sitework to ensure that a completed building also satisfies criteria.

Storage and updating of calculation procedures and design data, and their use for examining proposals under building regulations, are not yet computer based. An increasing number of programmes suitable for computer use are available, and serve in design offices for checking and rapid evaluation of alternatives. But a number of organizational and technical problems have to be overcome before they are widely adopted in regulation systems. One problem is how best to deal with the questions of variability and reliability, discussed by Yokel and Somes in their two papers and by Wright and Ang. Another is the development and operation of effective site control procedures which meet the needs of complex building technologies.

To conclude, the papers reviewed suggest four themes of particular significance:

1. The relevance of systems and performance approaches to different kinds of building problems, and the difficulties of applying a performance approach at the building level;

2. The value of a rational system for classification of activities and occupancies;

3. The problems and benefits of developing computer-based systems for checking and evaluating designs, including those for regulation work;

4. The need to extend procedures developed for dealing with variability and reliability in terms of structural performance to other functions.

DISCUSSION *

elix Y. Yokel

In connection with our paper on the "Philosophy and Scope of Structural Performance equirements" it is noted that many Structural Engineers will question the need for performnce criteria, since the introduction of limit state design, which is increasingly used in any countries, is actually a performance approach to structural design. It is therefore nportant at this time to define performance criteria and design limit states and to show how nese concepts complement each other.

Limit States define modes of failure for particular material applications and design olutions. These include not only failure by instability or fracture, but also failure to erform an intended function. Performance Criteria define required levels of safety and unctional performance, which are related to user requirements and independent of specific aterial applications and design solutions. Performance criteria therefore provide a common asis, applicable to all materials solutions, for defining the resistance level at which arious limit states can be permitted to occur.

The paper indicates that a probabilistic approach is used to determine structural afety. While presently the probabilistic approach is limited to structural safety criteria, : is realized that eventually all criteria will have to specify reliability, as well as evel of performance.

Traditionally, extreme loads are used in structural design. The introduction and evelopment of performance criteria will eventually require the determination of structural esponse at load levels which frequently occur in service. This need is illustrated by the nalysis of structural response to wind loads that was done for the World Trade Center in ew York City. In this case wind loading with a recurrence interval of one month was conidered rather than a 50-year recurrence interval, which is commonly used in design in the S.

orman F. Somes

In our paper on the "Philosophy for Physical Simulation Using Performance Criteria" it noted that evaluation is the determination of compliance with the performance criterion d the process may require one or more of the following tools:

analysis
professional judgement
physical simulation

nere is an urgent need to develop and standardize a philosophy and a set of criteria for nysical simulation. This need is one which should be addressed by organizations such as ne American Society for Testing and Materials.

The figure identifies the parameters considered in a physical simulation and the extent standardization permitted by varying degrees of innovation. For conventional concepts it frequently possible to have a fully standardized test which addresses each of the paraeters. Examples of these include the concrete cylinder test, tensile test on reinforcing teel, and the masonry prism test. In such cases physical simulation is really quality ontrol.

When physical simulation is used for innovative concepts, it is necessary to address ne interface between the user and the system. It is thereby possible to define a forcing unction (load) and an appropriate measurement process. The evaluation of a floor with espect to vibrations and human comfort can be used to illustrate the point. The excitation the floor may be standardized as may the procedure for recording, say, the decay of dislacement-amplitude with time. The other parameters, specimen geometry, boundary conditions, ervice life environment defects, and variability of response can only be taken account of by ne application of criteria for physical simulation. From this process a suitable test can e developed.

For affiliations and addresses of discussors, see list of Symposium Registrants, p. viii.

In conclusion it has to be realized that the number of tests capable of standardization is relatively few and that the evaluation of innovative systems will increasingly call for a carefully-considered set of criteria for physical simulation.

○ Require criteria for physical simulation

● Capable of standardization

Parameters for Physical Simulation	Extent of standardization permitted by varying degrees of innovation			
	Conventional	→	→	Very Innovative
Specimen geometry	●			○
Boundary conditions	●			○
Service life environment	●			○
Variability of Response	●			○
Forcing function (load)	●			●
Measurement process	●			●

F. Y. Yokel

Our paper "Field Test of Conventional Buildings for Static and Dynamic Deflections," describes measurements of performance of traditional systems. Such measurements may provide a basis for comparison between the performance of innovative and traditional systems but the limitations of this approach should be realized. A good case in point is the measurement of drift under lateral load. While two buildings may drift equally under a given lateral load, the velocity and acceleration to which occupants are subjected under a given wind load acting on these buildings may be different. A valid comparison between the performance of any two systems can only be made if all the relevant parameters of performance which are a function of user needs are correctly identified. This is not always possible, considering the present state of the art. Many performance characteristics, inherent in traditional systems, are not yet identified.

Ingvar Karlén

I have in my paper tried to bring in some aspects on the application of the performance concept, aspects of a more general character.

Performance as a general concept which is close to the concept "behaviour in use" or "effectiveness" from a "black box" is one interpretation, and a useful one. Another interpretation is when the performance concept is used in a system. Here the relation between system and function is expressed by help of a model. This interpretation requires a more difficult discipline in use. I think one must recognize these differences and difficulties.

If you use systems and sub-systems in your problem-solving or your communication you have to identify them, and you can by the help of analysing and synthesizing get new integrations. You have thereby good help in the structuring of sub-systems, at least those sub-systems you often meet.

You can make lists for checking and ordered (arranged) lists for communication purposes, inter alia for communication in the building process. Certain relations exist between this listing work and general work with classification categories. In my paper some comments are given concerning hierarchies, kinds of variables, etc.

My comments can possibly give some help in bridging between performance application and the building process and the information flow in the process. Concerning this help, I would like to refer to Mrs. Cronberg's statement that it is important to know how and when information on user needs should come into the process. I will add to it also other important matters.

As demonstrated in my paper some work within CIB working commissions, inter alia the now revised Master List of Properties, concerns the mentioned types of questions. The CIB work referred to can support the introduction of efficient design tools, such as different system and performance factors.

The example of the ER System - now operating with its three "coordinates": objects (for defined purposes), properties (in broad sense) and rating - demonstrates one way of introducing performance characteristics in building.

My paper is too short to treat carefully additional problems which some other papers also state to be important. My opinion is that the discussion of general matters and matters of principle character concerning performance must continue.

R. S. Ferguson

My comments relate to the suggestion of the Rapporteur that there is a need to define certain terms. A growing problem with building codes is ambiguity regarding classification of buildings according to occupancy.

The classifications used are building types such as hotels, railway stations, hospitals, etc., and while these are well understood they bear no relationship to the hazards in the buildings and provide no guidance regarding appropriate controls.

We can abandon the present system in favour of one which controls hazards directly but to do this we would have to abandon the familiar building-type terms. The problem is therefore more than to decide which of the many terms to use for a given concept. The problem is to choose between using terms which already have widespread familiar meanings but which are ambiguous respecting hazards; and finding new terms for the more appropriate hazard concepts and educating the building industry to what the new terms mean. For example: In North America "fire resistive construction" is commonly understood, in the East at any rate, to mean construction that is non-combustible. Newcomers to codes, and westerners, often think that "fire resistive construction" relates to construction rated according to the ASTM fire resistance test procedure and that the term includes combustible as well as non-combustible components.

To avoid this confusion in Canada, the National Building Code of Canada abandoned the term "fire resistive construction." It now calls non-combustible construction "Non-Combustible Construction!" This change toward clarity was welcomed by the uninitiated but the Easterners, steeped in the old tradition condemned the change as a retrogressive step (even though the force of the rules had not been altered).

W. P. Ellis

In reading the weighty first volume of proceedings of this symposium, in digesting the reviews of the Rapporteurs, and in listening to the comments presented by the participants, I have attempted to evaluate the "performance" of this mass of data, experience and opinion in advancing the "art" of the performance concept in buildings. Unquestionably the net "performance" is stunning, and by the very breadth and depth of the presentations, even bewildering.

Some confusion was expressed and questions raised in comments at the sessions concerning fundamental concepts of performance, terminology, and even semantics. Perhaps this response is to be expected because of differences in the cultures and languages of the participants; but it does point up the need for an improved frame of reference.

The papers by Blachère, Karlén, and the Research Group of Japan; the review of Rapporteur Atkinson, and others refer specifically to the importance of classifying concepts, criteria, and components in a framework common to all cultures and languages. I believe it is crucial that we accelerate our efforts in the field of building technology to standardize on the framework within which performance criteria and design specifications can be programme

With international agreement, such a system of classification will provide a strong foundation upon which both traditional and innovative building systems can achieve truly international recognition. This goal must not be diluted or lost in the welter of other aims.

Tibor Csizmadia

I wish to congradulate Robbie in succeeding to provoke this audience even without appearing in person. He can probably forsee that since "modular coordination" has failed as a means of salvation, "performance" will be a favorite term of many conferences during the coming years. We like this theme and can contemplate it undisturbed by the many "unpleasant" things which go on in the industry, namely the building process.

"Performance" like "System" or "Operation Breakthrough" means many things to many people and can lead to much idle talk if we do not make the definition of the word, the context, and the purpose explicit. Performance, being many things, is also a language. As a language it must communicate. It must communicate to the participants of the building process the things they need to know to do their work, e.g., to program design, to manufacture, to erect, etc. The problems I am referring to would automatically become evident if a successful manufacturer, a builder, or a practicing design professional was appointed as a rapporteur at one of these symposiums.

Wright pointed out this morning that the early settlers of this country were faced with the problem of performance. The buildings patterned in the tradition of the "old country" somehow did not perform the same way on the unfriendly rocks of the New World. They did not have the benefit of learned societies for research and testing, and the benefit of scholarly publications. May I suggest that even if they existed, they would not have used a language the rough and ready self-made carpenters of Plymouth could understand. Thus the good intentions of these institutions would have been of no use to them. What they really wanted was "on-line" research (See paper by Mann-Bender). One curious peculiarity of the building process is that it does not usually take place in an air conditioned laboratory.

Summarizing: Performance must be communicated to the right people in the building process at the right time, otherwise: WHAT IS THE USE!

Anthony Guy

Some observations relative to the definition of user and practitioner are in order. Many of the published papers relate to the translation of user activities or needs into performance specifications through the identification of goals, objectives, and user requirements related to the technical aspects of provision. This commendable concept appears to have evident in it some rather fundamental problems.

Firstly, to effect the translation the user must be identified as his needs are to be sufficed. Is he the owner - he pays the bills; the occupant, corporate or individual - he benefits from the environment; the maintainer - he administers the physical entity; or is it the visitor - he benefits from the services provided in the structure by the occupant?

If these possibilities are listed with their criteria it becomes apparent that some conflicts may exist.

Owner - economy - marketability and profitability - life

Corporate Occupant - productivity - location - economy - cost

Individual Occupant - comfort - safety - location (also the user may change over time and therefor the degree of requirement may alter, as also may the corporate occupant).

Maintainer - cost - ease - reliability

Visitor - service - access - comfort - location (also a variation of degree is apparently class/type of visitor).

Secondly, a conflict not restricted to the performance concept exists in the role of the designer. Is he interested in innovation as a means to achieve recognition from his peers, or as a benefit to the undefined user?

One attempt to answer these conflicts is to project "flexibility" or provide the most acceptable mix or trade off between all attributes. It is considered that this may in fact be valid in the case of a corporate body or individual being, users who control design by edict, such as in the case of a house, but it does not satisfy any other user.

These conflicts place a great burden on the person charged with the concepts use. This ethical burden indicates that he must translate the needs, equate them with the law, temper them with the political and economic constraints, and introduce design integrity. Then the whole must be easily understandable to both the implementor or supplier and the user.

As a means of overcoming or at least reducing these difficulties it is suggested that there is a need to differentiate between the various uses of the performance concept.

Separation of the social benefits from the technical evaluation is suggested as a means to provide clarity; both can still be expressed in terms of performance but to attempt to combine them is confusing to all.

Within the context of an individual project the concept can be used to great advantage in proposing the most favorable trade-offs while still conforming to the greatest pressures.

To encourage innovation within the industry, considered to be one of the fundamental objectives, the development of technical performance specifications together with modeling and testing techniques which relate to materials and system evaluation can be developed. This would hopefully, in time, change the legal definition and acceptance of systems and materials.

In summary let us first develop the systems, both social and physical, in concert of course, letting the benefits occur through spillover at first and then if necessary a merger of the two sciences can be attempted.

J. G. Sunley

I wish to make two points. First, why are so many people wishing to use performance standards? In many countries building approval rests in local hands. They often have an impossible task of being experts in a wide range of materials and designs. I would suggest that many people are using the performance concept as part of a power struggle to remove the control of building approval from local authorities. We have, therefore, an 'unholy alliance' of Central Government Agencies, University Researchers and Architects in trying to obtain control of approval. This is fine, but I suspect that when they succeed the alliance will collapse because government agencies will want laws which they control, whereas creative designers will want freedom.

However, performance standards are probably the best way to get control. Structural engineers have kept control of structural functions and have worked with performance requirements of load factors and deflection. The dangers in this type of control are that we play too safe and structural engineers have been guilty of this with a resultant high cost in building. We could have had more less-safe buildings from the same total cost.

My second point concerns demands being made for more statistical information to enable probabilistic design methods to be used. This will raise a number of problems which will have to be faced. Thus, someone will have to say how many buildings should be allowed to fall down and even how many people should be killed (dare we use the automobile analogy, say we should kill one in 5000 every year to have such cheap and convenient transport). Also can our legal system deal with probabilistic theory in settling claims.

Neil Hutcheon

We should not forget that building codes are written for use as building law. The law ought to be clear and definitive and the courts ought to be spared the difficult problem of establishing what is good practice or what constitutes a good judgement, if this can be avoided. We must agree, therefore, that while we may prefer to frame code requirements in performance terms the legal side might be much better served by prescriptive specifications.

On the subject of computers, we tend to forget that the computer can only deal in its present state of development with relationships which are already known and can be programmed explicitly. It cannot, at this stage in its development, introduce on its own matters of judgement or of non-conscious knowledge.

C. N. Watson

If one assumes that the ultimate measure of building performance is the user's (potential) performance in that building, then one must pay much more attention to basic questions of what a "building" ought to be. This point can be illustrated at two levels:

1. The building as part of a system of buildings.

2. The building as part of a work environment.

1. I am left with the impression, after reading the papers and listening to the participants, that the performance concept in buildings currently relates to the performance of individual buildings or of their components or materials.

However, just as a building is composed of a number of subsystems, it is, itself, a part or subsystem of a larger system. The larger system should incorporate all other facilities occupied by the user which are used cooperatively to pursue some common purpose. This might include buildings on a military base, a university complex, a chain of service outlets, or a fragmented head office operation.

The user's success in pursuing his activities in any one building may be directly dependent on the extent to which his entire system of buildings has been properly planned. To ignore the user's operating system is, therefore, to jeopardize his performance in any single building.

2. As everyone is aware, the way work is carried out is changing significantly, partially in response to technological innovations in the communications media and data processing equipment, and partially because of changing public attitudes.

The role of buildings in this newly-emerging approach to work must be examined, and the trade-offs identified between building structures and the other support service needs of organizations.

Possibly one cannot reasonably expect this kind of work to be undertaken by technical organizations such as RILEM-ASTM-CIB, but some organization/discipline must assume responsibility for it.

William Mann, Jr.

In lesser developed countries the prognosis appears to be negative at present with regard to the applicability of the performance concept for buildings.

In general the lesser developed countries do not have the necessary level of human resources, technological sophistication, industrial advancement, and institutional competency - prerequisites for the successful application of this concept. In some of these countries, standards for building materials are inadequate, and compliance with these standards is lax. Testing facilities are also inadequate.

There is the question as to whether performance methods may be successfully applied by North American or European consultants in lesser developed countries. Given prevailing conditions mentioned above, it would be difficult to justify the effort. In any case the foreign consultant may not understand sufficiently well the social and cultural dynamics influencing the human requirements which must be met under the performance concept.

The conclusion must be that the lesser developed countries have not reached a stage at which they should give significant attention to the performance concept, except as a useful thought process for approaching the design, construction, maintenance, and operation of buildings.

G. A. Atkinson

Though having no direct responsibility for building regulation, the United Kingdom Building Research Station has been helping responsible authorities since the early 1930's. At that time two approaches to statement of requirements had already been identified. The first was by the specification in detail of materials and methods of construction regarded by the authority as satisfactory. The second depended on statements of functional requirements, leaving it to the applicant to decide how best they should be satisfied. The first had the disadvantage that it was not easy to introduce innovations in materials and construction techniques. The second relieved authorities of the practically impossible task of covering by detailed specification every material and combination of materials and every construction method. Onus of proof of suitability was on the applicant who was, however, at a disadvantage unless there was guidance on what was considered acceptable practice. Moreover authorities had to have at their disposal the necessary technical facilities for assessing whether a proposal was likely to perform satisfactorily in use.

Building regulation in Great Britain makes use of both approaches. Where the state of knowledge permits, requirements are stated in functional terms and guidance given on what is acceptable practice. But regulations also contain descriptions of materials and methods of construction 'deemed-to-satisfy' requirements. The Building Research Station gives help to authorities in the development of appropriate ways of stating requirements and assessing or testing compliance. It also helps to give guidance directly or through British Standards documents. Since 1934 when it proposed functional criteria against which the 'efficiency' of different methods of construction for working-class flats could be judged, it has taken a leading role in the development of procedures for appraising the likely performance of proposals for new forms of construction for public authority housing.

A performance-based system should include:*

1. Statements of requirements in terms of functional criteria - what is required, from what part of a building, under what conditions of use. Five 'dimensions' are involved: scope and aims; occupancy and usage; physical environment; 'built-form hierarchy'; and list of requirements.

2. Guidance on performance likely to satisfy criteria either through the specification of acceptable levels for relevant attributes in 'performance standards' or by reference to a 'model' the performance of which is accepted as satisfactory.

3. Information about design data, methods of calculation, assessment and test accepted as good practice.

4. Procedures for examination of proposals by calculation, test or expert judgement to check whether performance is likely to satisfy criteria.

5. Procedures for control of quality of manufactured products used in building and work on site to ensure that building when completed meets requirements.

Specification by performance is a dynamic concept. Its evolution is dependent on knowledge gained from research, and on technological experience drawn from many countries. At any one time this knowledge and experience and the organisational framework within which it operates is imperfect. It is necessary to appreciate these difficulties and limitations, to understand the interdependence of the main constituents, and to identify and remedy weaknesses. Among important current tasks are the development of adequate frameworks for classification of occupancies and usages, and a check list of the more significant features of the physical environment to be taken into account in drafting regulations; collaboration internationally on 'general approvals' and quality control schemes; and the development of site control procedures which meet the needs of complex building operations.

* These components of a performance based system are examined more fully in a paper by the author entitled "Performance-Based Regulations: A Review of Current Developments and Some Problems"

National Bureau of Standards Special Publication 361, Volume 2: Performance Concept in Buildings; Proceedings of the Joint RILEM-ASTM-CIB Symposium, held May 2-5, 1972, Philadelphia, Pennsylvania (Issued August 1972).

SESSION III

Experiences and Examples

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Papers Reviewed by Mr. Allen

Report of the Rapporteur

We have only eight papers to discuss, but they are important papers because they report comprehensive real-life experience.

Ware describes the performance specifications for office space prepared at the U. S. Bureau of Standards on commission from the Public Buildings Service of the U. S. Government, and this I understand is now about to be put to its first use in practice.

Meyer, Bender and Arnold report on several projects in which the development of building systems has been based upon carefully researched performance requirements. This paper comes from the firm formed by Ehrenkrantz, and includes his pioneer project, now famous, for the California Schools System.

Forsberg and Birrell discuss the assessing of performance in existing housing and explain a process they have developed for analyzing the costs of improvements and evaluating these in relation to benefits obtainable.

Hallenbeck describes work done for the New York State University Construction organization on performance criteria for the environment and functioning of the large amount of university building for which this body is responsible.

Bezman, from the University of Montreal, reports the development of performance requirements for schools for the Catholic School Commission of Montreal. He relates his project to some of the Ehrenkrantz work described by Meyer, Bender and Arnold, and reports both on the research and the application to a construction program.

Harrison, from the U.K. Building Research Establishment, describes a procedure for the preparation of performance specifications for components of buildings, monitoring their use when purchasing the components, and the evaluation of alternative proposals put forward by manufacturers. This work was done for a range of public building programs in Britain.

King, formerly at the Education Facilities Laboratory in New York, which helped to promote the work done by Ehrenkrantz and his colleagues, must be counted among the pioneers of the current phase of performance thinking. He is now with a major American firm of architects and engineers. His paper takes a broad view of the performance approach and its application, and then examines particularly the problem of deciding, in the light of experience in using buildings completed in accordance with performance intentions, whether the requirements proved to be right. This is an important aspect of feedback, and is difficult and sometimes embarrassing to obtain.

And finally my own firm in England reports on a low-income housing project. built in a low-rise construction system, selected in competitive bidding based upon performance specifications and outline designs which we had prepared. The problem in this kind of situation is that because national specifications do not yet exist but builders are developing systems, these systems do not offer equal performance and therefore the purchaser does not know what comparative quality he is buying in a cost-competition unless he can state what he requires and evaluate what he obtains.

The idea of stating performance requirements and criteria as a method of regulating the provision of new buildings, instead of specifying the construction to be used, is an essential aspect of building in the age of science. Until a country moves in this direction, its building programs cannot be exposed safely to the technological innovation by which mankind now seeks to adjust itself to new situations by invention, development, and competition to provide the best environment for the least use of resources of work and materials.

Let me then draw to your attention the fact that in this Division of the Conference five of the eight papers are from the United States, two are from Britain and one from Canada. We all know that innovative construction is taking place on a large scale in many parts of eastern and western Europe, and in Japan, and elsewhere in the world. What is the meaning, I wonder, of the fact that so few papers reporting the use of performance requirements for whole buildings and large construction programs have come from these areas? Do they not yet have comprehensive performance requirements of this kind? Or do they concentrate only on requirements for the components of construction systems? Or do they still rely on a mixture of old and new methods of control? Or are they past their experimental phases and no longer concerned? It would have been valuable to know, and I hope the discussion will reveal answers.

Although the idea is simple, as many fundamental ideas are, the statement of requirements and criteria is far from easy. One might expect that it is largely a question of restating the conventional requirements of building codes and controls, but these traditionally have been limited in principle to the protection of public health and safety, and they have avoided the protection of public comfort, the owner's and user's functional requirements, and their economic interests, many of which are new. Unless the term "performance" is deliberately defined in some narrowly limited way, it has been taken by almost all concerned in our present papers as having the wider meaning that I have indicated, covering both the public and the private interests. Yet there is a difference as to who should be responsible for what, and perhaps we should discuss this. The problem can be stated thus; the public authority must safeguard the public interest, and it cannot be responsible for the private interest; yet the architect and the systems developer must encompass both areas of concern and naturally will wish to refer to one consistent and compatible statement of requirements. How are we going to achieve this?

This raises an international question, for the marketing of building systems and the design of buildings are both becoming international in character. It is unreasonable that one country or one state should have requirements different from another unless there are reasons of climate, resources, natural risks, or other unavoidable differences. The differences of traditional requirements by different cities and states in the United States, the provinces of Canada, and Scotland and England in many cases have no logical basis and we ought to see the end of them. But how?

A moment ago I separated the problem of what areas of performance were a public and which a private responsibility. Harrison's paper raised an interesting point because in the work with which he has been concerned at the Building Research Station, the emphasis has been on specification for components almost alone, but they are for large public authority programs, mainly schools. It may help in discussing his paper if we recall that he mentions the existence of codes of practice which are performance based and carry much of the broader design requirements in Britain, and we can further note that the regulations which control UK building are also performance oriented. Thus a larger performance framework exists; yet as a practicing architect in Britain I can say that the existence of three areas of performance statements - mandatory regulations, non-mandatory codes of practice, and specifications for individual classes of components - confuses and dilutes the influence of the performance concept, and omits important design requirements. It is unsystematic and contrasts now with the national pattern of performance codes emerging from the U.S. National Bureau of Standards for Operation BREAKTHROUGH; yet one then has to recall that Operation BREAKTHROUGH is only for housing, and all building types have eventually to be covered. A National Building Specification now being prepared in Britain may either clarify the picture there or add merely a fourth element with new language and status to the other three, which could be troublesome.

Bearing the different national contents in mind, there are interesting comparisons to be made between the work described by Harrison, Bezman, King, and Meyer, Bender and Arnold, all of whom are mainly concerned and experienced in schools. We should consider how far this work helps us forward with other types of buildings.

The problem of testing or otherwise evaluating performance to see if it is up to specification is mentioned in several papers. There are numerous technical difficulties, the solving of which must go hand-in-hand with the development of performance requirements, for as Harrison, King, Ware and others point out in various ways these are explicitly or by implication part of a legal contract between owner and supplier, - with the architect as usual in the middle. These legal problems could valuably be discussed.

One curious difference exists between some of the American papers and those from the U.K. Meyer, Bender and Arnold, Ware, Hallenbeck, Bezman, and to some extent King, Forsberg and Birrell, all in the U.S., focus their attention upon the interiors of buildings. In particular, all but King, who is generalising, deal with interior hardware, and are much concerned with satisfaction of the users both with the hardware as such and the environment created for the user. Harrison from the U.K. has a preoccupation at present with non-structural components, door sets, partitions and windows, but of course his work is within an already familiar context of complete building systems, while my own co-author and I had to deal with the complete provision of houses and apartments. It would be interesting to know why in America the external building enclosure has taken so small a place in the work of the authors mentioned. Is it more acceptable to the U.S. and Canadian market to leave the architect free to clad his buildings to some extent independently of the interior system? Or is it merely that the cost of the outer skin is too small a proportion of the whole to be worth the effort at present? The National Bureau of Standards work is of course complete.

A valuable aspect of Ware's paper is his description of systems thinking applied not only to the user requirements and the hardware, but to the whole preparation of the project, the contractual procedure, and other logistic problems. It is certainly impossible to avoid realisation that the performance approach affects the entire procedure of building, from the initial budget and statement of the client's requirements through the contracting and construction stages to the maintenance of the buildings.

This leads me to raise a question which is giving cause for much concern, and that is the ability of designers, and to an even greater degree the ability of builders, to carry out work in this new manner to the necessary standards. Builders have a particular difficulty in that so many of their personnel are deficient in the education necessary for safe innovation. I think we could wisely spend some time in discussing how we are transforming the education in the building industries and professions to deal with the new ways of building.

I liked the sensitivity of King's paper, and I think it contains much wisdom about the relation between goals and results, between facts and judgements in the evaluation of the end-product, and between the satisfaction of the owner-client and the direct user. He was the key man in assisting every use, I think, of the performance and systems approach which is discussed in the American and Canadian papers on schools. He had both philosophic and technical perceptions, and his influence has largely shaped the American scene. For this reason I commend his short but valuable over-view. In particular he poses one vital question: have the issues which lead to the performance criteria been the correct ones on which to focus? And he remarks that the studies to evaluate this have been too superficial. Feedback of the highest quality is vital to all of us at this stage in what is a huge learning process; and he says in effect, 'it is not good enough'. I agree, but let us discuss it for improvement.

I have said little about Hallenbeck's paper, but it has the weight of the immense building program of the New York State Construction Fund to give it significance, for the amounts of money involved would make anyone concentrate with great care upon his actions. Apart from the environmental studies, which are paralleled in other work, I noted with appreciation his concern for the handicapped, and the firm attack upon the qualities required in the interior finishes of university buildings. Perhaps only the URBS program (Meyer, Bender, Arnold) is truly comparable.

Finally there is that interesting but entirely different paper by Forsberg and Birrell, devoted to using a performance approach to evaluate deficiencies in existing housing and to provide a cost/benefit basis for helping occupants to set priorities in selecting improvements to make which are within their expenditure range. This could help not only in the kinds of situations that arise among minority groups such as were their immediate concern, but presumably could be extended to much larger programs of rehabilitation in other kinds of situations.

I have said nothing of the roles of building research or agrément organisations in all these matters, but I am sure that they will be in all our minds as we discuss this great impact of science upon all our work in the planning and building of mankind's environment.

G. A. Atkinson

In his paper, Harrison summarizes and comments on recent British experience in the use of performance specifications for procurement of innovative components by public building agencies. There is a long tradition of public-sponsored building of an innovative character. The Building Research Station was set up after World War I to help evaluate then novel materials and techniques aimed at solving the country's postwar housing shortage.

An early attempt to develop evaluative criteria was made by BRS in the 1930's to help assess new ways of building blocks of flats for rehousing families from slums. The criteria followed the familiar pattern of functional (or human) requirements mentioned yesterday by Blachère and others. The criteria were taken further by Fitzmaurice and others to screen proposals for new house building techniques after World War II. The experience is well documented. In the 1960's BRS looked again at the houses built as a result of these appraisals. Some of the techniques, like no-fines concrete, have become "traditional".

The work was analytical and evaluative. Many architects criticized it because it was not, and was not meant to be, creative. For school building a more directly creative approach was adopted. Architects first in Hertfordshire and later in Nottinghamshire and elsewhere developed with manufacturers building systems which are now known by names like CLASP. Ehrenkrantz in California adopted this "creative" approach to innovation to an U. S. environment.

The development of these systems was evolutionary. CLASP is now in "Mark V". BRS helped with related experimental work; for example it has recently completed work on site production and erection which was fed back into the latest "Mark" of CLASP. For some years Harrison has been an active member of the technical working party which brings together under the Department of Education the different school building consortia. To create a larger market for key components, the group developed with BRS help, and has published statements of, performance requirements and methods of assessment and test. They are being used to encourage manufacturers to innovate.

To do so they need not only clear statements of requirements and of the way proposals will be evaluated, but also time for design, development and testing. (Harrison suggests upwards of a year). They also need an economic incentive.

The most attractive incentive is to have a reasonable chance of being awarded a substantial supply, or supply and fix, contract (say over £ 1 million or U.S. $ 2.5 million) over a period of years (say 1 1/2 - 3 years). Alternatively he needs part of his R and D costs, at least at the second (detailed development and testing) stage, met by the purchasing authority; or else to be assured through market research of opportunities for wider sales.

Public building agencies have issued performance specifications to encourage manufacturers to develop products which are listed in "catalogues", and which agencies are encouraged to use, but for which no firm orders are available. This approach seems less attractive to manufacturers.

There is becoming available in Britain useful experience on the business end of procurement through performance specification which it is hoped will be analyzed and summarized before performance work is reported on again at an international symposium.

Michel Bezman

I do not have too much to add, thanks to Allen's remarkable review. I would just like to make some comments on two points.

First, I would like to emphasize a particular aspect of Performance Concept implementation: the incidence of the contextual resources (i.e. the Industry) on the decisions one has to make when preparing performance specifications. In other words, how to scale one's levels

* For affiliations and addresses of discussors, see list of Symposium Registrants, p. viii.

of performance requirements to the real world constraints. Such an undertaking should have the following objectives:

- to relate to the present "state of the arts"
- to ensure that there will be enough competition amongst the bidders, and
- to ensure the target cost will be met.

Two types of complementary activities are then necessary to meet these objectives:

1. To conduct an analytical survey of available resources.

2. To open direct channels of communication with the building industry.

The second point is related to the question raised by Allen: Why do the North American System Building Projects have a tendency to exclude exterior cladding from their program? I can only answer for the RAS Project. Exterior cladding was not included in the RAS project for the following reasons. First, we had to contend with serious timing constraints, namely: one year to conduct a survey of the users requirements, identify the resources and prepare the performance specifications as well as the tendering documents; the industries were allowed only a 6 month period to develop their proposals. Considering our prime objectives, we had then to concentrate our efforts only on the determinant subsystems.

It should be noted that the survey of contextual resources had shown that a range of acceptable off-the-shelf exterior skin solutions are already available. For obvious interfacing reasons, the inclusion of an exterior cladding subsystem would also imply the addition of roofing, its complementary exterior skin subsystem.

We therefore preferred to include a set of interfacing requirements in the performance specifications covering the structural subsystem. By requiring the structure to provide a range of attachment and support means, we made sure that the designers, who will implement the building system, would be able to choose from a wide "palette" of exterior treatments.

I would like also to mention that the decision was not the result of "statics" generated by the architectural profession. We had, in fact, a positive response from the profession when we presented the project to the Association during the research phase. An industrialized exterior cladding subsystem was not considered a critical constraint providing that it was evolved from a properly handled set of performance requirements.

To summarize our strategy, I could say that we had to concentrate only on those subsystems which were critical for the educational environment we wanted to achieve.

George S. Birrell

In carrying out the research on the evaluation process of performance and cost as applied to existing housing prior to rehabilitation it was found that aspects of his house the user wanted rehabilitated, according to his own priority rating, had to be overridden by the federal government's rules that the house had first to be brought up to "code standards" if federal money was put into that rehabilitation process. This creates an inefficiency between maximizing the benefits to the user, and the rehabilitation work which has to be carried out with very limited funds, albeit aided by Federal Government money.

It would be of considerable educational benefit to physical scientists interested in the Performance Concept to either advise, or assist in advising, people with limited available funds to achieve maximum user benefits from the expenditure of such limited funds.

Editors Note

During the presentation of his report Allen wrote four items on the blackboard as follows:

1. Flow of knowledge and pattern of requirements

2. Legal

3. Education

4. Process

Each of these was discussed in his paper, and several were referred to in the discussion which followed. In response to a suggestion from the floor a fifth item, Politics, was added to the list.

G. A. Atkinson

Allen refers to the organization of knowledge. When at the Building Research Station, he was responsible for a guide series on factory design. Recently the BRS looked again at the series. The guidance given, it was found, fell under two heads: procedures for calculation, evaluation, or selection; data required for use in these procedures.

The procedures range from consulting tasks and using formulae requiring mental arithmetic or a slide rule, nomograms, geometrical apparatus like the BRS daylight protractor, models for use in wind tunnels, heliodons, electric and other analogues, and computer programs. Their development seems best to be a cooperative venture between practitioners and researchers, the latter have a major contribution to make in providing data derived from observation and experiment.

Data may well be updated with increasing knowledge but, as reference to handbooks confirms, much data has a long life. Sometimes an event like the British metric change programme provides an opportunity for reviewing data. For example the English Department of Education has recently published new anthropometrical data on school children needed for design of school buildings and furniture. Publication resulted from the need for data in metric units and from the fact that health and body dimensions of children have changed over the 20 years since earlier data was published. It was possible because sufficient data was available for analysis from school medical records.

There is unlikely to be a single procedure for manipulating data which is suitable for all design purposes. To select the most suitable is a matter of professional judgement, taking into account the kind and importance of the problem at hand, the reliability and relevance of data, and the resources and skills available. More than one procedure may be used to deal with a single problem.

Professional organizations, including regulatory authorities which are professionally staffed, institutionalize judgement and adopt as codes of practice procedures which by consensus of experience are deemed to be useful and reliable. Because these codes of practice are institutionalized they tend to be conservative. Over a period of time they become out of date and a hindrance to progress. Their periodical review and revision is necessary. A radical reform of basic frameworks and principles will sometimes be necessary.

W. Allen

My first heading relates to the flow of information and carries over from Mr. Atkinson's discussion. The pattern of requirements is too unsystematic. We have typically:

- mandatory building controls generally intended to cover health and safety only, but in the U.K. they wander beyond this to thermal and sound insulation, for reasons of national policy.

- quasi-mandatory requirements from public authority clients, which extend unsystematically into a variety of performance requirements. This applies also to some well-informed and expert clients.

- codes of practice, non-mandatory, and often good, but little known because of their low status, and with uneven coverage and a poor interface with the mandatory regulations.

- the requirements of many categories of occupants who have no one to speak for them unless they are researched.

Viewed from the position of the practitioner, whose needs seem not to be very sympathetically considered but should in fact be almost paramount (since he has to apply them), the irregularity of status, hierarchy, language, coverage, and interfacing is a nuisance (to the point of danger or omission), a serious addition to our overheads (now mounting dizzily), and a barrier to efficiency and high performance.

My second heading was 'legal', and I lead on from my remarks about controls and requirements. In a period of innovation the risk of encountering unknowns is high, and the extension of performance requirements to many new items in building design and construction adds greatly to the areas in which the practitioner can be exposed to legal pursuit for faulty performance or omission.

In this situation the unsystematic state of affairs on requirements enhances our hazards, and the constant uncovering of unforeseen interactions, and the difficulties of transmitting new ideas and processes successfully into completed buildings underlines this and generates fear of innovation, and the loss of insurability with all its damaging consequences. Is an architect responsible when a research result of which he should have made use appeared only in some science journal far removed from his normal reading coverage? What is reasonable? And what interpretation will the courts place on 'reasonable'?

In some cases, such as SCSD, SEF and others in that train, the external support they had for prototyping and testing, and the timetable possible for development, removed many areas of risk, but innovation in huge numbers of more conventional programs has no such support but is virtually inescapable all the same. The whole context of design, industry, and economics forces it upon us, even if we had no wish to move forward ourselves, which we have.

In these circumstances the neglect, as I see it, or the misunderstanding of the needs of normal practitioners in respect of the current information stream and the development of requirements is open to justifiable criticism.

My third heading was 'education'. To put the matter briefly and bluntly, the effort put into the education of the building professions for technological innovation is wholly inadequate, and the situation in respect to the education of builders and the training of operatives is much worse. Under these conditions, how can an extensive period of innovation proceed without unreasonable risks, serious diseconomics, unnecessary set-backs, and constant recourse to legal proceedings? Implementation of new techniques and new knowledge is not in the hands of researchers; it is the function of the professions and builders. But the knowledge-flow is from the laboratory, and must be matched by adequate effort to make an effective transfer to those who have to implement.

In the way in which I have stated these matters, the necessity for a matching effort of feed-back, which Mr. Finger and Mr. King have underlined, needs no further comment.

Nor, I think, does the problem of the changes of process required in an age of innovation. I can only say that design and contractual procedures, testing, supervision, and several related matters need research, monitoring and feed-back quite as urgently as does the science and technology itself.

Gérard Blachère

The present statement is related to the first three points Allen put on the blackboard. In France the movement for the "exigence" concept (exigence is what the performances meet, in brief, requirements) started in my Research Institute from two causes: The first was to give a reasonable basis to the approval of innovations, and the second was to give an answer to the constant request of architects for non-descriptive regulations.

So we were led to propose to the French government an "exigental" code for buildings, issued in 1969 - but, because we were conscious that most of the practitioners are not able to deal with a performance code, we wrote "examples of solution" in the field of various requirements (acoustics, thermics and ventilation, fire) which are deemed to satisfy the performance code.

I must say that almost all architects use the solutions but not the liberty given by the code.

That is a reason for teaching practitioners in such a way that they will become able to take advantage of this liberty. We have a handbook (Savoir Bâtir=how to reasonably build) based on the exigence-performance concept, and what we call a Synopsis. We consider the general synopsis, i.e. the general conception of a building, and the various secondary synopses for the various families of building parts and components. Courses are given to engineering's students and post graduates in architecture.

Jack Snell

I'll take issue with Allen's comment (editors note: the comment was not submitted in writing for inclusion in the Proceedings) in reference to using the performance concept to compare traditional and innovative construction that we may be "comparing oranges and apples instead of apples with apples which is what we want." The basic issues of the economics of the market place are imbodied in the questions of "what to produce?" as well as "how much and at what price?", i.e. I'm not at all sure we dare say apples are what we want.

In general, innovative housing offers characteristics or features to the user-buyer different than those offered by traditional construction as well as at different costs and with other performance levels. I certainly agree that our performance models should be capable of supporting rational evaluations of alternative building types, and that such models should be tested on traditional as well as innovative construction. However, we must not presume that these various solutions are identical, or that they necessarily represent responses to the same or identical requirements. The performance concept, and the quantitative requirements we develop in its name, must permit even more user-needs-responsive product differentiation in building than we've seen in the past.

Robert Blake

Allen has posed four questions with regard to actual implementation of the performance concept applied to building:

1. Who organizes the pattern of knowledge?

2. How can existing legal (and political) patterns be accomodated?

3. How can education (and training) be fostered (to expand usage)?

4. What are process implications?

My comments are from the viewpoint of an involvement within a public agency that is attempting to change procedures within the process of building -- Requirements, Planning, Programming, Design, Construction, and Ongoing Operation and Maintenance. The assertion is made that changing procedures within the process is the crux of the matter. Large public building agencies are reluctant to change procedures, because of the large sums of money involved, and the necessarily conservative nature of the public agency participants in requirements planning and programming where the high cost-associated decisions are made. Attitudes of the "in-house" professionals in a changed and untried situation generate fear of failure, quite properly.

The "special project" approach becomes the vehicle to test a new procedure, with special exceptions granted to the project manager. Also needed are special managerial controls to "keep the pulse" of the project so as to be able to forewarn the accountable institutional managers of problems, the point(s) of no return, and the possible need for reversion to "fail safe" procedures if the innovation begins to look too risky.

Little success in large scale change is considered possible when innovative approaches are entered into a "machine" that is designed to accept standard approaches. The argument is made that management devoted to process changes is a prerequisite of seeking accomodations within the law, and within the political system. The same situation prevails with regard to re-organization of a pattern of information that can be utilized by participants in new roles, e.g. the manufacturer who is asked to develop, manufacture, and install on a performance-cost basis. Process affects product, and process change means emphasis on management.

George S. Birrell

In my view there is an inconsistency in form and character between the rapporteurs four factors: (1) pattern of requirements, (2) legal, (3) education, and (4) process.

I suggest all of them are formats of information about Building Product and Process. Conceptually, information has (a) Structure and (b) Content. The common denominator is a repeated similar structure of information used to relate the issues of 1, 2, 3, and 4 together.

The object of such information structure is buildings (or building projects as end products) and this should be analyzed in the context of buildings, i.e. the structure is derived from buildings, and not something imposed upon it from outside e.g. by a library classification system.

The process of understanding and executing political change in a society can be greatly facilitated by studying the 'Disjointed Incrementalism' of Prof. Lindblom (Political Science) at Yale.

Ingvar Karlén

I refer to the five items which Allen put on the blackboard. I have the opinion that performance thinking and system thinking will help the mutual understanding between R & D and the building process. The work going on in many countries concerning improvement of data for decision making in the design process and concerning improvement of the information flow in the building process can benefit from performance thinking and system thinking, both to each other related tools for handling the complexity of the "hardware", the building, and the management of the total process. But then the questions should be considered in common. As a result work with requirement patterns as well as with systems for production and handling of reliable data and for assessment of durability etc. should be recognized in that context.

I have drawn attention to work within CIB, e.g. pattern for information about objects (hardware), properties of objects, human requirements. They could be used and developed and extended as common tools. My hope is that these tools are studied carefully and that one really tries to use them. They create part of those very few internationally developed aids we have and thus a part of a common language. They are in a way cores for future development.

Can the performance and the system concepts be expressed in terms recognizable and useful to different contexts and languages and very rapidly? This will give a good start in our work to reduce the "distance" between the user and the programming, design and production of building and urban systems.

D. P. Van Court

One comment from the floor questioned the absence of experience-backed papers by occupants of completed "Performance Concept" structures or by personnel of the contractors involved.

It is this writer's belief that such papers will not be forthcoming for several reasons: (1) Calls for papers are circulated primarily in academic and research circles and do not reach these essentially action-oriented people; and (2) The people with accurate, experience-based information do not have the protective cloak of academic freedom covering their speaking or writing for publication. They therefore hesitate to open themselves to the economic reprisals which may follow revelation of such information, which many people at intermediate levels of management see as strictly internal matters which are not for publication.

The researcher can tap this lode of extremely valuable information best by personal contact with building maintenance personnel, plant engineers, and contractor's personnel on an informal basis. Even with strong pledges that no information source will be named, it may take several interviews, over a period of time, before such social contacts bring the possessor of the information to trust the researcher sufficiently to be honest and candid with him.

Jack Snell

Referring to the paper by Ware, one of the most significant aspects of the PBS specification, which I believe received inadequate attention in the paper or its review, is the mechanism by which the total-life-cycle costs of a building are included in the bid evaluation procedures.

Ideally perhaps, the legal framework for building procurement should be adapted to include actual operating and maintenance costs. Short of this, and in the context of the traditional minimum-cost-bid-wins procedure, the PBS specification used a bid equalization factor. This factor is meant to provide a means to account for predicted/anticipated operating costs in an adjusted bid price. This could be an effective approach if widely accepted cost predicting models were available; unfortunately they are not. However, the needed analytical methods and data do exist. I believe, if high priority were placed on development of such models, that the bid equalization factor approach would provide significant near term benefits.

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SESSION IV A

Components

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1. Introduction

The previous speakers and authors of this symposium have dealt primarily with the general concept of building performance and its application to complete buildings or building units. After listening to the distilled wisdom of more than 40 authors, the likelihood of another author presenting any substantially new idea becomes exceedingly small. Nevertheless the application of the performance concept to the service systems and related subsystems in a building offers some new dimensions to the meaning of performance and additional opportunities for research and analysis in building science.

A review of the assignment of papers and subject matter to the various symposium sessions leads me to the conclusion that the scope of the presentation might cover the subsystems and components listed in Table 1. The list is not entirely homogeneous, since it includes the more common mechanical and service systems in buildings, windows, stairs, and the acoustic components of buildings.

Table 1
Building Environment Subsystems and Components

* Heating	Electrical
* Air Conditioning	* Drainage
Ventilation	* Water Supply
Air Cleaning and Purification	Cooking
Refrigeration	Communications
* Illumination	Laundering
* Acoustical	Security
Doors	People Movers
* Windows	Chimneys and Vents
Stairs	

The eleven papers assigned to this rapporteur for review are related to the subjects marked with asterisks in Table 1. Time does not permit discussion of all of the subsystems shown in the table, but after citing some of the highlights of the submitted manuscripts a few other subjects will be used to illustrate certain characteristics of the performance approach to environmental subsystems.

2. Performance Characteristics of Environmental Subsystems

The environmental subsystems of a building should meet the same four broad categories of performance requirements that all other building components and the whole structure should meet; namely

Strength
Safety
Durability
Functional Effectiveness

However, most of the subsystems in Table 1 have certain additional performance characteristics that are different in kind or in degree from those that apply to the building structure itself. The more important of these different characteristics are listed in Table 2. A few comments on the items in Table 2 will clarify the differences.

Table 2
Performance Characteristics Peculiar to Environmental Subsystems

Energy Use Characteristics
Dynamic Characteristics
Control of Waste Products or Effluents
Distribution Aspects
Diversity Aspects
Statistical Demands
Sensory Interface with Occupants
Subjective Aspects

Many of the subsystems listed in Table 1 utilize some form of energy -- they may convert energy from one form to another, with the final form being thermal energy in nearly every case. Many of the service subsystems listed have moving parts that utilize mechanical energy and which utilize streams of gas or liquid to convey energy or for some other purpose. The energy conversion processes typically produce waste products in the form of effluent gases or liquids containing gaseous, liquid, or solid pollutants. Thus, the performance requirements for these service systems have come, in recent years, to place great emphasis on the manner in which these system effluents are discharged and on the effect of the polluting components thereof on the community and its ecology.

The majority of the environmental subsystems listed in Table 1 involve a distribution system or a collection system that makes the service of the particular subsystem available at a number of building locations on a continuous or intermittent basis as desired by the user. Thus the adequacy of the distribution system in time, location, and quantity becomes a part of the performance requirements for these subsystems. Also, when more than one user is being served by a given subsystem, diversity of usage and statistical analysis of the total demands on the system become significant factors in design and evaluation.

Finally, the subsystems enumerated above serve some social, physiological, psychological, or physical need of the user on an intermittent or continuous basis. Some of the services are activated by manipulating a switch; others are automatically controlled; and still others, such as doors, windows, and acoustical treatment, are more or less static operators provided as a part of the initial construction of the building. Thus it is evident that many of the subsystems described have a sensory interface with the building occupants and that some of the performance requirements are subjective in nature. Experience has shown that individuals do not always prefer the same level of service from some of these subsystems, but that the performance level desired by users tends to follow a normal distribution curve covering a range of values. Thus, user requirements must be handled statistically, and the subsystems must be adjustable within a suitable range, unless they are custom designed for a particular group of individuals. It is this latter human characteristic of individual choice that is catered to in our dwellings to some degree. It lends uniqueness, charm, and self-fulfillment to our houses, but it also creates problems for those persons trying to prepare performance requirements and performance criteria for broad-scale use.

Turning now to the group of reports prepared for this symposium on the subsystems listed in Table 1, it is my privilege to describe the significant contributions of the various authors and to relate these to the overall theme of this program. Since all of the valuable material in each paper cannot be discussed in this brief summary, it is hoped that various authors will supplement this summary during the discussion period of the conference session.

2.1 Heating and Air Conditioning

Our colleagues from Australia -- Anson, Kennedy, and Spencer -- have brought us an interesting analysis of the effect of envelope design on cost performance of office buildings which clearly illustrates one of the important capabilities of computers in effectively comparing the return on investment for a broad set of variations of the construction features of an office building. It is pointed out that air conditioning cost is the biggest cost item in an office building when both initial and operating costs are included. On a present-worth basis, up to 40 percent of the life-cycle costs of a building can be attributed to air conditioning.

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The authors calculated the required air conditioning capacity, the capital cost of the building envelope and the air conditioning equipment, and the total cost, expressed as present worth, for 122 different hypothetical office buildings. The variation in design parameters is summarized in Table 3.

Table 3
Variations in Hypothetical Building Design

(a) Size. 40,000 to 325,000 sq. ft. rentable space.
(b) Shape. Aspect ratio varied from 1 to 3 at constant height. Height varied from 10 to 23 stories at constant aspect ratio.
(c) Glazing ratio. 20 to 60% on a face-by-face basis.
(d) Fenestration. Shading coefficients and sunbreaks varied face by face.
(e) Wall type. Half, 11-in. cavity brick Half, 4-in. concrete.
(f) Orientation. Long side north and south. Alternatively, east and west.

Of the total, 98 designs had identical rentable floor space of 1.5×10^5 sq. ft. (1.39×10^4 m^2). In this group, the required air conditioning capacity varied by 42%, the capital cost of the building envelope and air conditioning equipment varied 27%, and the total cost in terms of present worth varied 33%. These three factors did not attain an optimum for the same building design. The variations analyzed in this study indicated the possibility of raising the return on investment by 1%, from 10 to 11%.

The more important cost reductions brought about by variation in envelope construction are shown in Table 4.

Table 4
Effect of Construction Variations on Unit Costs

Construction Detail	Cost Reduction, $\$/ft^2$	
	First Cost	Total Cost
Reduction of building height, at constant area		
15 to 10 stories, 60,000 ft^2	1.14	2.21
25 to 16 stories, 235,000 ft^2	0.84	1.56
Change aspect ratio, constant size and height	Half of above values	
Orientation	Minor effect	
Reduction of glass area, 5 ft^2/100 ft^2 floor		
North and West exposures	0.50	1.00
South and East exposures	Half of above values	
Sunbreaks, 60% North and West exposures	0.20	0.80

The authors concluded that it is worthwhile in economic and performance terms to evaluate a range of envelope designs for any office building project.

Kusuda and Powell illustrated the progress that has been made in developing computer programs to evaluate rather accurately the heat transmission rates and resulting indoor conditions in typical structures under cyclic or variable exterior conditions and internal heat release. The authors used the following examples to illustrate the versatility and power of current computer programs:

(a) The conversion of radiant heat gains from lighting and solar-radiation into cooling loads on a dynamic basis;

(b) Determination of indoor temperature, humidity, and occupant comfort by several physiological indices on an hour-by-hour basis for a typical non-air-conditioned apartment;

(c) Prediction of temperature pull-down time in a refrigerated enclosure; and

(d) Comparison of the predicted and observed dynamic heat transfer in an experimental building for several different constructions.

Figure 1 illustrates the agreement between measured and calculated heating load in an experimental masonry structure exposed to a sol-air temperature cycle ranging from about 45°F to 105°F.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers is sponsoring a field study at Ohio State University to determine the precision of a computerized calculation of year-around energy usage in a three-story educational building on the campus by comparing the calculations with observed data, and thereby evaluating the elaborate calculation procedures [1][1] developed by the Society for this purpose. The collection of data will be completed in the fall and reported a few months later. Preliminary analysis showed that the energy use profiles agree rather well with predicted values most of the time, although there are some periods of wider deviation that have not been satisfactorily explained as yet.

Probably the most comprehensive summary of the state of the art in applying computer technology to heating and air conditioning and other environmental engineering problems in buildings is the Proceedings [2] of a symposium held on this subject at the National Bureau of Standards about a year and a half ago. The Proceedings, issued just recently, comprise about sixty papers on various aspects of the use of computers in environmental engineering, including about thirty contributions from countries other than the United States.

2.2 Control of Moisture Movement

Saarimaa provided a comprehensive outline of the problems caused in buildings by moisture, under the headings:

Moisture sources
Moisture movement
Moisture fixation
Effects of moisture
Prevention of harmful effects

Although the author describes no test methods nor any detailed guide to construction, his model is a comprehensive and orderly guide for the examination of moisture phenomena.

2.3 Plumbing Subsystems

Røsrud developed the performance requirements for plumbing systems in dwellings in relation to human needs. According to the author all user needs for plumbing fixtures can be classified into four groups; namely

1) personal hygiene
2) preparation of food
3) cleaning the house and furniture
4) spare time activities

The plumbing system must also cope with four natural phenomena; namely,

1) rainwater
2) groundwater
3) fire
4) the needs for maintenance and repair

[1] Figures in brackets indicate the literature references at end of this paper.

The author presents a three-dimensional matrix showing type of fixture, performance requirements of the fixture, and activities of the user. He advanced the concept of a scoring technique for plumbing fixtures or subsystems with six levels of performance ranging from very high performance to very low performance. An example of the scoring system was presented in terms of the amount of noise caused by bubbles flowing through an idle trap while another fixture is being discharged. The six gradations of bubble noise were describe by the adjectives none, very little, little, moderate, high, and very high -- and these gradations are related during a test to the amount of water discharged or rate of water discharge from a fixture. Mr. Røsrud does not describe how the scoring system might be used in actual practice.

Holtz described the performance requirements, test procedures, and criteria for the piping of sanitary drain, waste, and vent systems in residential service developed by a task group of Committee A 112 of the American National Standards Institute (ANSI). The Committee chose to use the following constraints in formulating the performance requirements, tests, and criteria: they should be representative of use conditions in housing; handling and transport conditions would be excluded; and both initial performance and durability would be taken into account. It was recognized that some variations in criteria and test methods might be required for different applications, such as low-rise and high-rise housing, above-ground and below-ground use, and in non-residential buildings. The work of the Committee covered the range of application and use conditions shown in Table 5. The committee report described the kind of usage simulated by each requirement and test, the test procedures and materials to be used, and the level of performance deemed to be acceptable. The evaluation procedures were designed to be applicable to any type of material and to provide a good measure of the probable performance in actual service.

Table 5
Application and Use Conditions Used in Evaluation of the Performance of Piping for Sanitary Drain, Waste, Vents

1. Chemical Environment

   1.1 Internal exposure to cleaning agents, sewage, household chemicals
   1.2 External exposure to soil and moisture conditions

2. Thermal Environment

   2.1 Hot water exposure
   2.2 Thermal shock exposure

3. Mechanical Environment

   3.1 Impact
   3.2 Earth burial load
   3.3 Internal pressure
   3.4 Beam loading

4. Biological Environment

5. Weather Environment

6. Fire Exposure

The test procedures developed by the ANSI task group under Holtz' leadership were designed principally to be applied to specimens of piping material. At the present time the National Bureau of Standards is carrying out research studies under the sponsorship of the Department of Housing and Urban Development on the actual performance of the more frequently used plastic and conventional piping materials using test procedures similar to those described by Holtz, and also is studying various properties of typical drainage systems up to five stories in height. These system studies will include fire and smoke-spread effects for plumbing built into typical wall sections; expansion and contraction under usage conditions; deflections and deformations in vertical and horizontal runs under typical usage and support conditions; the hydraulic and pneumatic properties; and the performance of various jointing technologies. The results of these studies will provide the basis for a set of performance requirements, criteria, and test procedures for plumbing piping in residential structures that can be developed into a consensus standard or referenced by specification writers or regulatory bodies.

2.4 Hot Water Supply Subsystems

Spielvogel presented extensive metered data on hot water usage in seven different classes of application; namely, men's and women's dormitories, motels, nursing homes, office buildings, foot service establishments, high-rise and garden apartments, and elementary, junior, and senior high schools. Metered hourly usages in 162 installations were taken for a period of a week in a few cases, for several months in many cases, and up to 1-1/2 years in some instances. Tabulated in the report were maximum hourly demand, maximum daily demand, and average daily demand of hot water for the various types of buildings. Recovery versus storage curves were derived from the various hourly profiles of water usage in each type of building. Figure 2 is a typical set of curves showing the relationship between recovery capacity per apartment and usable storage capacity per apartment for buildings containing different numbers of apartments.

The extensive data presented by Spielvogel in tabular and graphical form are valuable for design purposes, keeping in mind that no allowances were made for storage heat losses or for "unusable capacity" of the storage tanks. The author recognized the need for further research on: hot water usages in other types of buildings, the heat loss from storage tanks and the effect of water supply temperature on usage.

2.5 Illumination Subsystems

Lewin and Griffith describe the important characteristics of visual performance and provided an illustration of four types of illumination systems having widely different visual performance characteristics for table-top tasks. Visual performance depends on the size of the object, the time of viewing, the background brightness, and the contrast in brightness between object and background. Specular reflections of light from the object into the eyes of the viewer reduce contrast and also visual performance. Both the location of the light fixture relative to observer and task, and the candlepower distribution of the fixture affect the amount of specular reflection, or "veiling reflection", directed toward the observer. The authors used the data from four different illumination systems to illustrate the improvement in visual performance obtained by reducing veiling reflections from the work task. They recommended the use of a visual performance specification based on contrast for evaluating illumination systems, rather than simply brightness. Further research is needed on the quality of illumination because there are a number of additional characteristics of a light source and the immediate environment of a visual task beyond those discussed by the authors that have a bearing on visual performance. Some of these are: spectral composition of the light source, spectral reflectance and gloss of the surround, and the interaction between daylight sources and fixture illumination.

2.6 Acoustical Performance

A few building codes in the United States now contain provisions that attempt to regulate the following aspects of acoustical performance: sound transmission loss of building elements, impact sound attenuation, maximum permissible sound power radiated by mechanical equipment, and isolation of structural vibration sources. As the environment becomes more noisy, field measurements of sound transmission will more often be required to determine whether or not code compliance has been achieved.

Kodaras described the methods outlined in various standards for measuring sound pressure levels, and points out that at least 88 separate observations must be taken to evaluate the airborne and impact transmission of each room in a building. This elaborate procedure is needed to determine whether each room passes or fails the acoustic requirement. The author described how a magnetic tape recording of all the acoustical data at the site and the use of a real time analyzer at the laboratory could simplify and speed up the field test proceedure. According to the author, personnel without acoustical education can readily learn the data collection routines at the site, and after conducting a few tests under the supervision of a qualified acoustic engineer could perform the measurements without error.

It should be pointed out that Kodaras viewed the field test techniques from the standpoint of the inspector who renders a simple pass-or-fail decision. In situations of failure, however, considerably more analysis would be required of the builder, his subcontractors, or an acoustical consultant to determine which building component was principally at fault, and to advise how the deficiency can be remedied most economically. A considerably greater body of technical data and recorded experience will be necessary on instrument location, sound absorption, and sound transmission through structural members, ducts, plumbing systems, electrical conduits, and other flanking paths before building acousticians and engineers can design to meet a given requirement with a minimum of effort and uncertainty.

2.7 Window Performance

Two interesting papers on the performance of windows were prepared for this symposium. In the first paper Paulsen provided a comprehensive list of performance requirements stated in narrative terms. These requirements cover not only the essential functions and the unfavorable environmental characteristics of windows, but also the performance needed in terms of durability and serviceability. For a number of characteristics he cited test methods developed in the Norwegian Building Research Institute (NBRI) and the level of performance which NBRI accepts. The characteristics for which performance requirements are stated are listed in Table 6.

Table 6
Performance Requirements for Windows

Transparency and Vision	Resistance to Accidental forces [a,b]
Light Transmission	Control and maintenance of movable sections
Glare	Security against entry
Control of solar radiation	Fire resistance
Thermal insulation and Condensation [a,b]	Escape from fire
Sound insulation	Appearance
Ventilation	Dimensional Fit
Air-tightness [a,b,c]	Durability of operating parts
Rain-tightness[a,b]	Durability of materials
Strength and stiffness [a]	Performance of sealed glazing units [b,c]
Operating forces	

[a] Test methods are described

[b] NBRI requirements are cited

[c] Acceptable performance is indicated

In the second report, Wilson and Sasaki provided an alternative analysis of window performance. The authors set forth the principal functions of windows as:

(a) Entry of natural light
(b) View of outdoors
(c) Ventilation

and the derived requirements as:

(a) Openability for cleaning
(b) Emergency egress
(c) Venting under fire conditions

They also clearly identified the unfavorable characteristics of windows that are usually accepted as tradeoffs for the principal functions as follows:

(a) High heat transfer
(b) Low mean radiant temperature in winter
(c) Possible surface condensation
(d) Air infiltration
(e) Air pollution entry
(f) Leakage of rain
(g) Noise transmission
(h) Breakage due to wind, movement, expansion and contraction
(i) Excessive solar heat and light

Wilson and Sasaki have provided an excellent reference document of test methods, standards, and design guides related to a great many performance characteristics of windows as summarized in Table 7.

Table 7
Test Procedures, Standards, and Design Guides for Windows

Characteristic	Reference
Transparency and Light Transmittance	ASHRAE Handbook of Fundamentals, (1967)
Infiltration	ASTM E283-68
Rain Leakage	ASTM E331-70, NAAMM TM-1-68T, Specification Associate 12 (1970)
Heat transmission	ASTM C236-66
Window condensation	Canadian Govt. Spec. Board 63 GP Series NBRI Test (See Table 6)
Interpane condensation	ASHRAE Trans. 65 (1959)
Noise transmission	ASTM E90-70
Wind load	ASTM E330-70
Concentrated load	Can. Govt. Spec. Board 63 GP Series NAAMM SW-1-687, AAMA 302.6
Thermal-breakage resistance	Pittsburgh Plate Glass Industries Tech. Series Report No. 104B
Accelerated aging	NBS BSS 20 (1970)
Weathering of glazing compounds and sealants	ASTM C509-70, C510-66, C542-69 D2249-67, D2451-69 Can. Govt. Spec. Board 19 GP Series
Wear resistance of sash balances and sash operator	AAMA 902.1, ASTM E405-70
Weatherstripping	AAMA 701.1

Even though there is an extensive list of available test methods and much good work has been done toward improving the performance of windows, there remain a number of deficiencies in the application of performance concepts to the practical use of windows. Those deficiencies, identified directly or indirectly by the authors, include the following:

(a) No statistical evaluation has been made of the user's esthetic requirements for windows with respect to size and shape,

(b) There is a strong interdependence between the desirable functions of windows and the environmental requirements of indoor space,

(c) Present window standards contain only minimum requirements, and

(d) It is difficult to relate test results obtained from existing test procedures to in-use performance.

2.8 Total Energy System Performance Study

Achenbach and Coble described a field study of a total energy system serving a 500-unit apartment complex in Jersey City, New Jersey. The study is being carried out by the National Bureau of Standards as a part of the BREAKTHROUGH* program of the Department of Housing and Urban Development. The total energy system was designed to comply with a performance specification which sets forth the design conditions, the requirements for reliability, stability, and safety of the system, and the environmental quality that must be attained. Diesel-powered reciprocating engines will drive the electric generators, and energy for space heating and cooling and domestic water heating will be obtained from recovered waste heat from the engines and from supplementary hot water boilers. The installation is being extensively instrumented for data collection over a period of one or more years to evaluate the following performance characteristics:

(a) The thermal efficiency of a combination engine-generator and waste-heat-recovery boiler under a range of load conditions,

(b) The overall thermal efficiency of a total energy plant serving an apartment complex, along with limited commercial and school facilities,

(c) The amount of heat energy that must be discarded because of any mismatch of the electrical loads and heat-energy demands,

(d) The stability of the electrical service in terms of steady voltage, frequency, and load division among the operating prime movers,

(e) The reliability of electric and heat-energy services and its relation to the amount of standby equipment available,

(f) The nature and frequency of malfunction of diesel engines under continuous heavy duty,

(g) The ability to predict the need for routine maintenance and overhaul based on performance rather than elapsed running time,

(h) The ability to control on a small site the levels of noise, air pollution, vibration, heat, and odor produced by a central utility plant,

(i) The maximum demand and diversity in usage of electric-energy and heat-energy services in apartment buildings of different design, and

(j) A detailed record and analysis of all owning and operating costs.

It is believed that the results developed for this particular site can be reliably extrapolated to other developments of different size or composition.

3. Scope of Performance Characteristics for Environmental Subsystems

Returning now to the broad application of the performance concept to the building subsystems that provide the various kinds of services to the occupant, it can be said that standards, test procedures, and specifications for these subsystems follow a somewhat consistent pattern, although there are probably more exceptions than examples of consistency.

Performance tests and criteria are usually applicable to new products and are most often used to evaluate new products. Safety and health aspects of the subsystem usually are given the greatest attention in standards and specifications. These characteristics are often covered by a combination of performance-type and materials-type requirements. The first

*The BREAKTHROUGH housing program is a special program of HUD designed to stimulate industrialization and innovation in dwelling unit production.

use-related characteristic covered by most test procedures, and sometimes the only one, is the capacity of the subsystem to perform a specified duty under a set of design conditions. Some standards include evaluation of performance under partial load conditions, and under over-load conditions, and some include performance under adverse conditions of climate, energy input, deterioration, neglect, and improper use. Subsystems designed for automatic control are often tested to determine performance over the range of control, and to evaluate the precision and reliability of control. Some standards include tests to evaluate durability and serviceability and the rate of decrease in capacity with time or the change in the properties of materials with time. Performance of subsystems for durability and serviceability is not usually treated in a comprehensive manner because of the difficulties in interpretation of accelerated laboratory tests in terms of in-use conditions.

3.1 Performance Tests for Household Refrigerators and Freezers

A summary of the requirements contained in recently revised ANSI standards [3,4] for household refrigerators and freezers, B 38 and B 97.1, will be used to illustrate these comments about the nature and scope of performance coverage. The example used represents a fairly comprehensive set of performance requirements and tests, and is probably comparable in completeness to those summarized by <u>Wilson</u> and <u>Sasaki</u> for windows. Many of the building environment subsystems do not now have such a comprehensive set of requirements and tests. At the same time, there are a number of important performance characteristics for household refrigerators, freezers, and windows for which test procedures have not been developed. The reasons for incompleteness may be the complexity of the test, lack of adequate technical information, lack of consensus on procedures in cognizant committees, lack of demonstrated need, or cost of the test.

Table 8
Performance Requirements and Tests for Household Refrigerators and Freezers
(adapted from ANSI B38 and ANSI B97.1)

Performance Requirement	Test Procedures
1. Size and Shape	Measurement of Storage Volume Measurement of Shelf Area
2. Cooling Capacity	No-Load Pull-Down Test (110 F Ambient) Simulated Load Test (70,90,110 Ambient) Ice-Making Test (90 F Ambient)
3. Reserve Capacity	Operating Time (70,90,110 F Ambient)
4. Energy Requirement	Energy Consumption (70,90,110 F Ambient)
5. Temperature Distribution	Temp. at Several Stations in Each Refrigerated Compartment
6. Temperature Control Range	Average Compartment Temp. for Full Range of Control Setting
7. Adequacy of Insulation	Surface Condensation Test
8. Adequacy of Vapor Sealing	Internal Moisture Accumulation Test
9. Durability	Cracking of Plastic Liner Test Bottom Breaker Strip Impact Test Endurance Test of Defrost Control
10. Strength	Handling and Storage Test Pressure Tests of Refrigerant Circuit

11. Safety	Current Leakage Test Temp. Rise on Wiring, Motors, Controls System Temp. and Pressure During Defrost Dielectric Strength of Electrical System System Temp. and Pressure during Failure of Condenser and Evaporater Fan Motors Temp. Rise of Stalled Compressor Motor Fire Hazard during Short Circuit Grounding Requirements Pressure Relief during Fire Materials Requirements

4.0 State of Development of Performance Concept for Environmental Subsystems

It should be emphasized that the performance requirements, test procedures, and criteria for the subsystems described in this report can not always be fully self-contained or self-serving. The characteristics of the subsystem, the building of which it is a part, and the activities of the building occupants, contribute to the performance of most of the building environment subsystems listed in Table 1. Additionally, the climatic or environmental conditions outside of the building play an important role in the performance of the subsystems controlling the illumination, acoustic, and thermal environment. The division of responsibility for the different segments of this overall system makes it difficult to attain a desired performance for the entire system.

Furthermore, there is a considerable body of opinion that only those systems and subsystems of a building that are related to health and safety should be subject to enforceable regulations. In the past, this opinion has led to an indifferent or negative attitude toward the development of consensus standards describing the desirable environmental conditions in buildings, which in turn has permitted rather wide latitude in certain performance characteristics of the environmental subsystems. In my opinion the building industry has an economic responsibility to produce building systems and components that are functional and durable, as well as safe and healthful. Building research organizations, professional societies, and standards bodies should join forces with the building industry in producing performance standards to meet this three-pronged objective.

An overview of the application of the performance concept to the environment subsystems in buildings indicates that performance requirements have been rather completely stated in narrative form for a significant number of these subsystems, but not for the majority.

One effort of this type is the development of the Guide Criteria[5] for the Design and Evaluation of Operation BREAKTHROUGH Housing Systems by the National Bureau of Standards for use by the Department of Housing and Urban Development. It is recognized that similar interdisciplinary efforts have been carried out in France and other European countries. A considerable amount of work remains to be done for some of the subsystems shown in Table 1. Adequate test procedures exist for a relatively smaller number of the subsystems, and quite often the procedures measure the physical performance of a piece of hardware or equipment, with only an indirect assumption that it reflects the real needs or desires of the user. That is, the systematic and statistical determination of what constitutes the user's valid expectations of performance has hardly been started. Perhaps this is not too surprising since it is a complex and expensive undertaking to conduct well-planned experiments and surveys of sufficient magnitude to serve as a basis for statistically significant correlations between the measurable properties of the environment and man's response to it.

In the disciplines of auditory environment, illumination, and the physiology of thermal comfort, there is a considerable amount of experimental data obtained from various laboratory studies that provide guidance on desired performance objectives for designers of buildings and environmental subsystems. Yet a careful review of these laboratory studies reveals that the test conditions for the experiments were considerably simplified in comparison with the situations in real buildings, and in some cases did not constitute a good simulation of real life situations, or, they were conducted with a limited sample of the population. Thus, there is some uncertainty about extrapolating the laboratory findings to real life situations involving more variables.

Nevertheless, the lack of completeness of data on a given human response phenomenon should not deter the building fraternity from making optimal use of available information, and it should stimulate researchers to greater efforts to plan more relevant experiments in order to close some of the gaps in our knowledge. I believe that the performance concept provides a viewpoint and a platform from which the combined efforts of physical, behavioral, and life scientists can make research and technology serve man's welfare to a higher degree in the future than has been achieved in the past.

5. References

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3. Standard Test Methods for Household Refrigerators, Freezers, and Combination Refrigerator-Freezers, American National Standards Institute, B38 - 1970.

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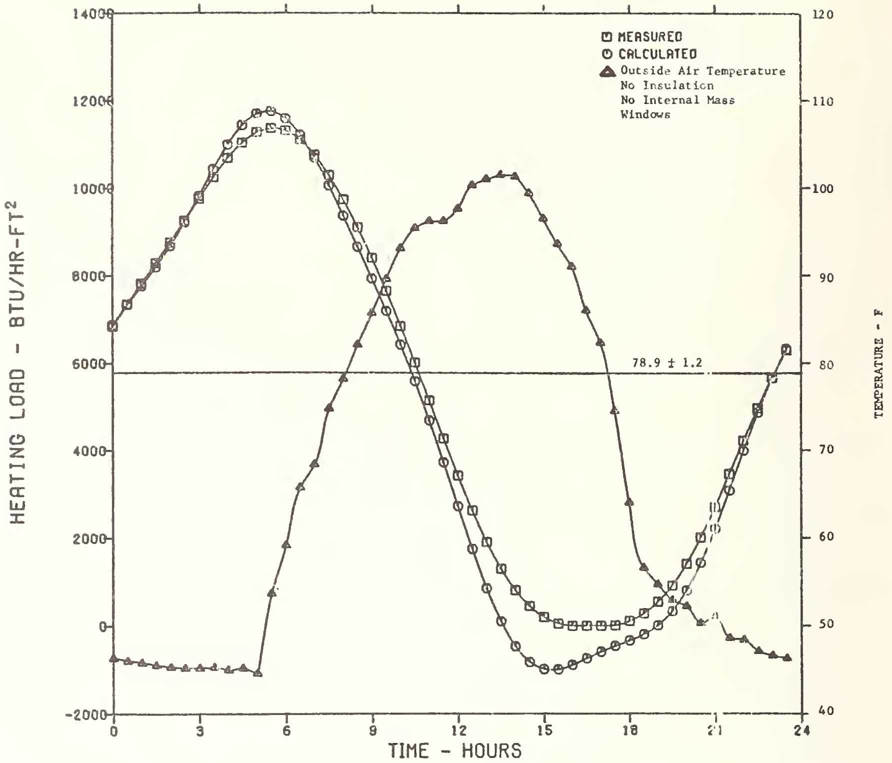

Figure 1 Comparison of predicted and observed energy requirement on an NBS experimental house

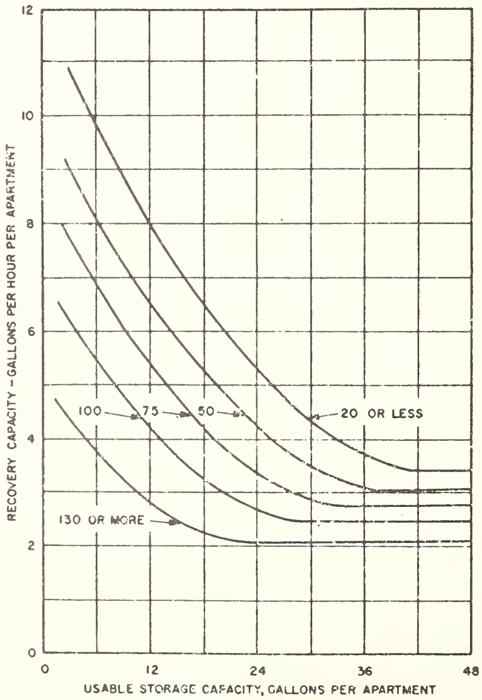

Figure 2 Relationship of hot water recovery capacity vs required usable storage capacity for various numbers of apartments.

DISCUSSION *

A. G. Wilson

In our paper, we indicate that "A procedure for selecting glass sizes to control breakage of single,heat absorbing glass due to solar radiation has been developed by one manufacturer, but the basis for it has not been published." We have recently been informed that at least some of the information forming the basis for this procedure appears in a paper, "Engineering Properties of Glass", by Leighton Orr, Pittsburgh Plate Glass Company, Conference Report No. 11, BRI, 1956, "Windows and Glass in the Exterior of Buildings".

I would like to develop further one point about window performance referred to in our paper.

Windows generally are the weakest component in an enclosure from the thermal point of view. They limit the humidities that can be carried in cold climates; and also adversely affect thermal comfort conditions (through reduction of mean radiant temperature) in their immediate vicinity.

This raises some questions about hygro-thermal design criteria and standards for space. We heard yesterday from Nevins about the status of development of thermal criteria and standards in North America. He mentioned that designers and others sometimes consider thermal criteria at only one location in the space, e.g., at the thermostat; and that the ASHRAE Standard 55-66 refers to a specified zone within the space to which the criteria apply. Consideration of the influence of windows on these comfort conditions introduces another dimension for these criteria--that of time. What percentage of the time are the conditions in the specified zone to be maintained within the specified range?

For example, it is not difficult to design and economically justify windows that permit the maintenance in Saskatoon, Saskatchewan, of an interior humidity of 25% over a substantial percentage of the time in winter, say, 80% of the time from December through January. It is much more difficult and costly to provide windows that will permit 25% relative humidity 95 or 100% of the time without excessive interior surface condensation. Similarly, is it necessary to maintain thermal comfort conditions in the vicinity of windows within the specified range 100% of the time--or is some lower percentage acceptable? Where safety is involved, such as in structural design, a very high confidence level is necessary. Where comfort conditions are involved, a much lower confidence limit might be appropriate.

Tore Røsrud

In my paper dealing with performance requirements for plumbing systems, two lists of performance requirements are drawn. One relates to human needs connected with use of water in the building, and the other deals with influence on the environment. The performance requirements have been given quantitative criteria graded from 1 to 6. These enable us to test the quality level of the installation.

The rapporteur has suggested that a description of how the grading system is used in actual practice would be useful. I will try to give it here. There are four reasons for describing different levels of quality criteria:

1. Public health officials ask for some minimum quality criteria through application of a plumbing code. The setting of these minima may also be a political problem. The minima will however not always conform with the quality criteria desired by occupants, designers, or contractors.

2. Grading of quality criteria will give occupants and designers an opportunity to choose the degree of quality according to given examples which are specifically described, and make them able to choose the desired level of comfort in their houses and buildings.

* For affiliations and addresses of discussors, see list of Symposium Registrants, p. viii.

3. Levels of quality criteria according to contracts and specifications can be controlled and tested by the designer. He will be able to specify penalties for delivering a substandard degree of quality criteria. In certain occasions he might be willing to pay a premium for delivery of a higher quality degree than specified, because houses and buildings with a higher quality criterion might be easier to sell. Such premiums and penalties have to be described beforehand in order to prevent argument about the economic losses and gains.

4. Working conditions and qualities might be increased because high levels of quality criteria very often accompany a high level of workmanship. This is a very important point according to plumbing contractors with whom I have had the opportunity to discuss these problems.

Designers and contractors that I have talked with said that they would very much welcome levels of quality criteria according to contracts based upon specified penalties and premiums.

David Lee Smith

During Wednesday's sessions, the problem of semantics was discussed. While it is not my intent to undertake an extensive presentation of this problem I feel that I must comment on the difference between performance criteria, which are directly concerned with user needs, and system performance, which is concerned with system operation. For example, in the two papers presented on windows, Paulsen (Norway) and Wilson and Sasaki (Canada), methods of evaluation of windows are excellently presented, but in the context of a system. Without an understanding of performance criteria for what is referred to as "window", expressed in terms of user needs, the evaluation procedures presented in the papers can be interpreted not as a means of effective evaluation of performance criteria, but only as a means of evaluation of a preconceived solution. What is a window? Is it necessarily a combination of view, light, and ventilation source? Without a clarification of purpose, in terms of performance criteria, any method of formal evaluation is without a valid and meaningful value base, regardless of the sophistication of the evaluation techniques.

Neil Hutcheon

I must congratulate Achenbach on a magnificent job of reporting and reviewing. The comprehensive reviews provided also by some of the papers, notably those on windows, make it quite clear that serious studies of performance of buildings and components are not new but go back at least twenty-five years to the time when building research institutes were established in a large number of countries around the world. It should be evident also, and this has some relevance to Allen's questions this morning, that evaluation and prediction of performance cannot rely on new knowledge to be developed quickly on demand, but must always be based substantially on that which is already known and available as the cumulative results of research, studies, and experience over a long period of time.

Jack Snell

I wish to comment on Achenbach's excellent synthesis and with particular reference to developing means of obtaining needed data and models for user requirements for the products of the various service subsystems he has identified.

Lest there may be some who are reluctant to join in, as Achenbach requests, to develop these requirements, let me briefly review some data presented yesterday by Malarky. Looking at Malarky's building cost data one notes that roughly 24% of the first cost of building is devoted to the service subsystems defined by Achenbach. Further, these subsystems may account, depending on fuel cost assumptions etc., for as much as 42.5% of the operating costs that will arise in the life of a building, and for an as yet to be determined but undoubtedly equally significant proportion of the 88% "people" costs Malarky has identified. Clearly subsystem performance in relation to user needs is a matter of very real import to most of us.

Towards establishing better data and models on user requirements for building subsystems, I wish to enjoin our social science colleagues to join with us in conducting the needed studies. I wish to suggest several approaches which may offer some light on the subject.

In view of the energy and water conservation forces developing in the U.S. it may be well to examine closely the uses of these scarce resources in performing household functions and activities -- either by traditional or innovative means.

Other options include user (occupant) activity analyses -- again, in both the contexts noted above -- which would provide service-system performance requirements based on analysis of occupant time, motion, and effort profiles.

Paul R. Achenbach

A review of the test methods now in existence for the service systems in buildings and the various types of performance requirements applicable to these systems suggests that a broad outline of performance requirements might be generated that would be applicable in whole or in part to all service systems. Such an outline would provide guidance to the various organizations and committees that carry out test development for evaluation performance and should result in greater consistency and thoroughness in the growing use of the performance concept. I believe that organizations such as the sponsors of this symposium would be in a good position to develop such a guide for performance test development.

I also want to describe an intersociety effort that has been initiated under the leadership of the American Society of Heating Refrigeration and Air-Conditioning Engineers to develop a set of standards for the environmental conditions in buildings. Cooperating with ASHRAE are the Illumination Engineering Society, the Acoustical Society of America, the American Institute of Architects, the Public Health Service, and the National Bureau of Standards.

This special task group will attempt to develop standards for thermal environment, visual environment, acoustic and vibration control, and air quality in buildings beginning with office buildings as a pilot effort. It will use the best state-of-the-art information available at the present time. The objective is to provide a consensus standard that can be referenced by architects, designers, and specification bodies.

A. F. E. Wise

Kodaras in his paper on acoustical measurement suggests that the Building Inspector should be able to carry out sound insulation measurements to check the performance of new construction. I am very skeptical of this idea and mention some experience in the U.K. At the Building Research Establishment we invited about a dozen acoustical consultants to carry out a measurement (using the standard procedure) of the sound insulation between a pair of dwellings. This entailed a measurement of transmission loss over a range of frequencies. We found that the mean insulation obtained in the measurements varied by several decibels in 50 dB, a very significant amount in subjective terms. If there is this sort of variation when acoustic specialists do the measurement, what will be the variation if an inspector, unskilled in the subject, does the work? We have since proposed a somewhat tighter specification for sound insulation measurement to the I.S.O. committee. These tighter requirements about halved the scatter when the acoustic specialists repeated the measurement of our pair of dwellings. I believe that, in practice, the measurement must remain in skilled hands if the results are to be acceptable. It will be very difficult if not impossible to devise a method which is sufficiently reliable in unskilled hands in the variety of situations that arise in practice.

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SESSION IV B

Components

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Papers Reviewed by Mr. Christensen

When I agreed to review the papers in this group I was very glad to do so because it was my hope that a great number of performance test methods developed for the evaluation of components would be described. I had hoped also that methods in the development stage would have been described so that discussions about the methods could take place at this symposium.

I must admit, however, that when I got the 16 papers I had to review, and I took a quick glance through the contents, I was at first very disappointed. I did not find the number of evaluation methods for performance purposes I had expected, and I was consequently forced to revise my own conjectures about what to expect from such a symposium. I then realized that the world around me was somewhat different from what I had hoped it to be. I had to realize that the performance concept is mainly a loose framework of words, and a great technical effort is necessary before the ideas can be used on a large scale for practical use I also now realize that we are moving ahead rather slowly, and for a number of years we must live with the traditional way of treating the problems for each category of materials while at the same time moving slowly towards the general use of the performance concept.

The papers I am going to review clearly show the necessity of seeing the evaluation problems from the point of view of the specific industries as well as from the more philosophical side presented in papers written by research people. In Figure 1 you will see the two typical groups in which the papers fall. In the group on the right all papers are prepared (except two) by people working in materials research branches within the field of steel, concrete, ceramic products, wood etc. whereas the other group represents, if I may say so, people from the more philosophical world who deal with problems without regard to the specific materials. I believe that these conflicting approaches from the two groups will give a fruitful dialogue, and consequently, after a second look through the papers I was not quite as disappointed as after the first look.

I would like to start with a paper of a rather general nature by Blachère from CSTB who presents the "agrément" idea on the level of components. For a number of years in Europe we have had a discussion about differences between the "agrément" approach and the performance approach. I was, however, very glad to read this paper because it proved to me that differences are a matter of language problems and that no practical difference exists between the two approaches. In Figure 2 I tried to demonstrate this statement. From the top you will see that in the English language the word performance covers the whole range of evaluation methods ranging from calculation, over physical simulation, to judgement by experts. In the bottom you see that Blachère takes out physical simulation tests and calls these performance tests. This means that the word performance is of a much more restricted use in the agrément approach.

In Figure 2 I have also shown three typical examples of problems which are dealt with when we are concerned about components. I have marked by circles the way they are most often dealt with in the two systems, and of course it is basically the same - there is no reason why they should be different. Also, in both systems we try to move to the left as science becomes able to solve the problems. Both systems have in common the fact that they do not start with what could be called the technical problem, but try to start with needs related to use. Fortunately, the procedure used in the agrément system is exactly the same as that used in the performance concept as is illustrated in Figure 3, which shows as an example how statements about U-values are dealt with within the agrément system and the performance system. The one example I have taken from the Operation BREAKTHROUGH procedure. The agrément example is taken from "Façades Légères" published by the European Agrément Union.

As a conclusion I must state that in my opinion the differences between the two viewpoints are of a formal nature, and fortunately, both ways lead to the same result.

The paper by Dobson from South Africa underlines the need for a procedure which can tell whether building innovations are of a reasonably good quality. It is further stated that the agrément procedure is a very good way to do this and that the agrément system has been working very satisfactorily on the performance basis in South Africa for a number of years. In the paper it is also stated that there seems to be a good reason to have the agrément administration within a Building Research Organization, which is an independent body. At the Danish Building Research Institute we operate a similar system, and like Dobson, I can say, after eight years experience, that the integration of general research and an official evaluation system gives a very good contact between the world of research and practical building. As some of you may know, the Scandinavian countries do not belong to the European Agrément Union, but our way of dealing with the evaluation procedure is based on the performance idea, and approval systems quite similar to that of the "agrément" exist.

In Dobson's paper it is also mentioned that we now need a terminology which can be agreed upon internationally and that we need a number of generally accepted performance test methods. Here I can mention that work is now going on concerning these subjects in the CIB working group 60.

The first part of my own paper similarly deals with some general aspects concerning the acceptance of the performance concept by those outside the world of the Building Research Institutes, and my conclusions are very close to the line of Dobson. I must, however, add a warning at this point because I have sometimes had the feeling that the performance concept was often pushed a little too much in the foreground in cases where evaluation methods were not yet developed. This I think is just as dangerous as walking on thin ice, and from now on we must take more seriously the two conflicting considerations:

1. If we wait to use the performance concept until all necessary evaluation methods are worked out and checked in detail, we will never get started.

2. If we push forward with the performance concept without having reasonably good evaluation methods, the building industry may lose confidence in the performance concept.

In the second part of my paper I have described a couple of user oriented test methods for surfaces. I think that, e.g., surface scratching resistance and water repellant properties which are described are direct user oriented performance characteristics which need much more attention than they have received so far.

While most papers deal mainly with the performance concept for development purposes, the two Japanese papers by the Research Group on the Systematic Method for Selecting Materials both cover a system for selection on a performance basis. The system is very detailed and is the most logical system I have seen in this field. The system brings, in principle, the evaluation procedure into a stage where the computer can take over much work that is impossible for man alone. Especially today when designers have so many materials, components for building systems etc. to choose from, some kind of automatic selection system is a clear advantage. I must especially note the grading system where user needs can be graduated, thus making possible trade-offs between different performance requirements. I think that this idea must be taken up in other countries as well, because much resistance against the performance concept in the building industry has been caused by the assumption that performance requirements are identical to minimum requirements. I regret very much that the great number of test methods which are mentioned only by short titles are not available in English, and if they are not yet translated, I urgently ask our Japanese colleagues to do so for the benefit of all those who work in this field.

I am quite sure that if we do not get international cooperation in this field, a lot of money will be wasted on developing test methods which have already been developed.

The paper by Bring from Sweden gives a very detailed description of a performance-based classification system for flooring materials. Here again I notice the great advantage resulting from giving performance requirements for quality classes so that trade-offs can be made in the selection process. We have often heard that a class-system will not work in practice because those specifying will always select the best quality in order to be on the safe side. I do not believe in this concept and think that economic factors will soon show such an approach to be unrealistic. On the other hand more information about relevant factors for selection e.g. of flooring materials should be published, so that designers have a good background for the selection.

The paper on floors by Saarimaa, Sneck and Wäänänen gives an outline of the general approach for selecting appropriate levels for the use of the performance concept on flooring. I noted especially the parallel between a traditional design procedure and the proposed method in the selection of external factors and internal factors. This is quite similar to e.g., strength calculations. External factors become similar to loads, strength properties become equal to internal factors or properties, and the juxtaposition of external and internal factors are similar to calculation methods. The same grading system as used by Bring is applied. Two tables in the paper show the relations between "external factors" and properties. Both tables have the same entrances, but it is shown how different relations exist between external factors and properties depending on whether you consider the floor as a surface or a separator.

In the paper by Dietz on composites the importance of avoiding prescriptive specifications is again underlined. Of course, this is so because new materials, and among these the composites, would not have a chance if traditional prescriptive specifications were always used. However, I must disagree that composite materials should be treated differently from other materials in a performance evaluation procedure. If this is really so, it must be the evaluation methods which are wrong. However, I admit that, for a number of years, we must treat those materials somewhat differently. This is not because they are composites, but because we do not know enough about the durability of the special bonds which hold the composite materials together. As soon as science can tell more about these problems, no difference in evaluation procedure ought to exist.

These eight papers were all of a more general nature and the next eight papers deal mainly with one aspect of one component and in most cases also only with one material.

The paper by Seigel, United States Steel Corporation, shows very clearly how the performance of a structural member in many instances can be evaluated based on calculations where we hitherto thought the physical simulation, e.g. a fire test, was the only possible evaluation method. This is a logical consequence of the fact that very often fire tests cannot take into due consideration all boundary conditions, and consequently calculation methods offer a better alternative. This is one of the cases where it is quite obvious that it is an advantage to move from the right to the left in Figure 2. This means we are replacing physical simulation by calculations. Steel structures exposed to fire is here a good example of how this can be fairly easily obtained if the temperature rise in the steel can be considered as the critical factor for the performance of a steel structure during a fire.

The next paper, by Hanson, Corley and Hognestad from the Portland Cement Association, describes how it is possible to design concrete load bearing members with a number of holes and still have an adequate margin of strength to resist overload and also remain serviceable under normally expected loads. The paper shows how performance in most cases can be predicted by calculations, but sometimes physical simulation tests are necessary for evaluation. This paper actually touches a very soft point in the whole philosophy of building with components. Here I am thinking about the traditional kind of design procedure where space for installations e.g. pipes, air ducts, and so on is not taken into consideration until a rather late stage of the design process. Then it becomes a problem where the installations can safely penetrate the load bearing structure. When this problem is taken up at a late stage of the design procedure it is very often necessary to make special tests with physical simulation of the loads because the structural elements are already calculated just to the limit. On a calculation basis they will not be able to allow for holes. This procedure is of course all wrong. The best way to deal with this problem will be in most cases to establish "freeways" in vertical as well as horizontal directions of the building body. Such freeways should give ample room for all installations which are commonly used today and also leave room for new systems not yet invented. When using component building systems, I believe that such measures will be much more profitable than designing holes in the structures for each special building. Here it would be very valuable again if an agreement were reached on the size of such "freeways". Although this paper deals mainly with the problems of reinforced concrete, I think that it is such a general problem that it should be given much more attention in the future for all kind of structures.

The next two papers deal with the problems of brickwork exposed to lateral forces. They are written by Astbury, West, and Hodgkinson from the British Ceramic Research Association and both papers have as a background the tragic event at Ronan Point where progressive collapse of a high rise building followed an explosion of gas. The first paper deals with some experiments where brick walls in the laboratory are loaded vertically and then further horizontally by means of a bag with compressed air pressing on one side of the wall. The conclusion is that a solid brick wall of a thickness more than 7" is sufficient to withstand the lateral load of 5 $lbf/inch^2$ laid down as a performance requirement by British authorities today. This rule applies to buildings more than five stories high. Where the first of the two papers describes how performance can be evaluated by means of traditional laboratory testing, the second describes the effect of tests using real gas explosions. Different claddings, windows, and masonry walls have been tested, exposed to explosions from mixtures of gas and air in proportions which simulate the effect of a real explosion. All pressures have been recorded and some typical pressure-time relationships are presented in the paper. One of the main objectives of the tests was to evaluate the effectiveness of claddings and windows for relieving the pressure and thus lessening the explosion pressure. Further, it was an objective to study damage to load-bearing brick walls. The main results of the testing were that brick work will withstand considerable force from explosions, because ordinary venting due to windows and doors made it impossible to raise the pressure to more than 3 $lbf/inch^2 \sim 2 \times 10^4\ N/m^2 \sim 2$ m water gauge, even under the most unfavorable conditions. Further it was not possible to create progressive collapse in the structure tested. I think that these results confirm what we all feel, that brick work forms a substantial structure. The most important result, however, must be to deduce such realistic time-pressure relationships for different structures, that it some day becomes possible to predict by calculations the effect of explosions and then, with this background, establish reasonable performance requirements. I hope that the tests will be further analyzed and supplemented so that more general conclusions can also be made.

The paper by Suddarth from the Department of Forestry and Conservation at Purdue University and Percival from the University of Illinois deals with the strength properties of wooden trusses. It is a very good example of the benefits obtained when changing from physical simulation to calculation in order to evaluate the performance of structures. In the paper it is shown how a computer will easily solve problems, if only a basic knowledge of the behaviour of the system is obtained by testing a few prototypes. It is interesting to note in this paper that it has been possible to establish a mathematical model of the forces transmitted in all connections of wooden trusses. By making measurements on deflections it has been shown in a number of cases how well the model corresponds to real conditions. One of the other advantages of using such a method is that the wood is better utilized by taking into consideration how forces will be distributed in ways other than traditionally assumed. It is my hope that a similar approach will be developed for many complex components in order to save time on physical testing. I think that we should make it quite clear, as in this example, that the use of the performance concept does not mean that we are going to make tests for physical simulation in cases where an analytic procedure is adequate.

The paper by Hansen from the Norwegian Building Research Institute shows how the performance concept can be used for the design of wood joist floors. Already in the very first lines of the paper, Hansen makes a very important observation on the background for stating performance requirements in general. Two ways exist. One way is to begin with the process of use, analysis of activities and user characteristics, trying not to be limited by traditional concepts of possible solutions. The other approach is to abstract the functional requirements from existing solutions. The first procedure is correct from an academic point of view. However, in many cases it will be necessary to take into consideration what kind of performance people usually expect to get for their money. This means that the second way -- an approach whereby the functional requirements are derived from how existing solutions perform -- must be used. The paper by Hansen uses this second way and shows how this approach can be used for the design of timber joist floors. However, it is always quite difficult, on behalf of the user, to make an evaluation of what should be considered satisfactory. In this particular case I note that in Norway a deflection of the floor of 2 mm is claimed to satisfy user requirements, whereas in Denmark it is claimed that users will tolerate 2.5 mm for a single load of 1000 N. It would have been a lot easier to have something different than the "general opinion" on this subject. The paper also explains how it is necessary to take vibration effects into account, and gives some calculation methods by means of which it can be estimated whether vibrations will cause inconvenience to the user. Hanson also criticizes the sand bag test as being too unrealistic for dynamic testing. I fully agree and hope that this method will be further elaborated in order to get a better correspondance with actual conditions. In this connection it is noted that a special elastic layer has been developed at the Technical University in Lund, Sweden, and it is now in use in Scandinavia for the testing of certain roof constructions for dynamic load.

The next paper also deals with wood. It is written by Bohannan from the Forest Products Laboratory, U.S.A. and deals with the Strength Criteria of Glued-Laminated Timber. It mainly deals with the problem that wood, in comparison with most other engineering materials, is an inhomogeneous material. This means, especially for glued laminated beams, that the effect of local weaknesses in the outer layers will cause the structural performance to vary considerably. For many years insuring a more reliable engineering material has been a problem for the wood industry, and this paper suggests that research work has brought glued-laminated timber a great deal nearer to the perfect structural material. I also think that it is interesting to note that prestressed glued-laminated beams seem to offer new possibilities. A number of tests briefly mentioned in the paper indicate a significant improvement in flexural strength of structural-laminated beams by giving special attention to the inhomogeneities of a small portion of the outer few tension laminations.

The paper by Stern which deals with nails as seen from the performance point of view is interesting in the way it shows how much development work on a traditional building component can be undertaken, and how many new types of nails this will leave room for. Especially, I noted the effects which can be accomplished by changing the working operation. Here I am thinking of the nails which must be driven into the material at high speed in order to develop heat so that a special resin on the nail will melt and then glue the nail to the wood. I do not think such solutions can be derived directly from user performance requirements, but it shows that a performance analysis on lower levels of the hierarchy also creates new and interesting technical solutions.

Stern also touches a major problem within the performance concept by mentioning the working operations. For the final user it must be just the same whether it was easy or not to drive the nail into the wood, but of course a difficult operation must give a higher price for the product. We are then back again to the user, who wants a good ratio between benefit and cost and therefore he is also indirectly interested in the working operation.

As a conclusion I want to state that in my opinion the papers did not have the content I had hoped for when I agreed to make the review. But the papers have shown to me that the use of the performance concept calls for consideration of the more general problems, as well as for the specific material oriented problems. Since this section deals mainly with components, I am surprised that the problem about compatibility is not touched upon at all. I think that a lot of work besides the technical aspects also remains in the field of compatibility, and here a close cooperation between building research and the component industry is the only way to get results which will work in practice. I do hope that such cooperation will be established in the years to come -- if this is not so, I am very pessimistic about the future of component building.

GENERAL PROBLEMS		PROBLEMS RELATED TO SPECIFIC MATERIALS		
Title of paper	Author	Title of paper	Material	Author
Technical evaluation of components: agrément	Gérard Blachère CSTB, Paris, France	A performance approach to the design of fire-resistive buildings	Steel	L.G. Seigel U.S. Steel Corporation Pennsylvania, U.S.A.
The performance concept in the service of technical evaluations of building innovations	D.E. Dobson NBRI, Pretoria, South Africa	Evaluation of structural concrete members penetrated by service systems	Concrete	Hanson, Corley, and Hognestad PCA, Illinois USA
Performance of components with special attention paid to the practical implementation	G. Christensen Danish Building Research Institute, Denmark	The resistance of brick walls to lateral loading	Brickwork	West, Hodgkinson British Ceramic Research Ass. Great Britian
Performance requirements in a systematic method for selecting building materials	Research Group at the Building Research Institute, Tokyo,Japan	Experimental gas explosions in load-bearing brick structures	Brickwork	Astbury, West, Hodgkinson British Ceramic Research Ass. Great Britian
Proposed method of test for evaluating performance of buildings, building elements, and materials	Research Group at the Building Research Institute, Tokyo, Japan	Increasing the application efficiency of performance tests with analytic procedures	Wood	Suddarth & Percival Department of Forestry & Conservation Purdue University,USA
Performance requirements for floors	Christer Bring, KTH, Stockholm, Sweden	Strength criteria of glued-laminated timber	Wood	B. Bohannan Forest Products Laboratory Forest Service, Madison, Wisc.
Performance analysis of floors	Saarimaa, Sneck, Wäänänen Otaniemi, Finland	Performance characteristics for timber frame joist floors	Wood	H. Hansen Norwegian Building Research Institute, Norway
Performance criteria for composites in building	Albert G.H. Dietz MIT, USA	Performance requirements for mechanical fasteners used in building	Steel	E.G. Stern Virginia State University USA

Fig. 1 Survey of papers presented in the group "Components".

	PERFORMANCE PROCEDURE		
	CALCULATIONS	PHYSICAL SIMULATION	PANEL OF EXPERTS
EXAMPLES			
U-values	X	X	X
Resistance to Dynamic Loads	X	X	X
Durability	X	X	X
	PHYSICAL MEASUREMENTS	PERFORMANCE TESTING	JUDGEMENT
	EVALUATION PROCEDURE (agrément)		

Fig. 2 Comparison between the Performance Procedure and the Evaluation Procedure used by the UEAtc system.

UEAtc Directives communes pour l'agrement des Façades légères	HUD Guide criteria for the Design and Evaluation of Operation BREAKTHROUGH
Thermal comfort (winter) The heat insulation quality of the wall should be so that a. Heat losses during winter conditions should give reasonable costs. b. The inside surface temperature should not fall to a level causing discomfort.	Atmospheric Environment Requirement Thermal resistance should be provided to limit heat transmission through exterior walls to decrease the cost of air-conditioning (heating and cooling), to improve the comfort of occupants in respect to MRT (mean radiant temperature) and to avoid problems of moisture condensation on wall surfaces.
Rules derived from hygrothermal comfort a. The average U-value of the ordinary wall area should be equal to or less than 1 kcal/m^2h °C. b. Inhomogeneities in the inside surface temperature should not cause condensation or risk of a bad appearance.	Criterion Heat loss through non-window areas of exterior walls, under winter design conditions with indoor air temperature at 75°F, should not exceed 15 Btu/hr ft^2.
Verification of hygrothermal rules a. The U-value should be determined either by calculations based on known or measured conductivities or by direct measurement. Finally a combination of the two methods can be used when the direct method only applies to a part of the wall. b. The factor of inhomogeneity can be calculated either directly or with analog methods.	Test Calculation/Laboratory Test

Fig. 3. Comparison between UEAtc and HUD procedure.

Christer Bring

The two papers by Shirayama et. al. ought to be considered in comparison with the one on "Performance Analysis" by Sneck, Saarimaa, and Sneck (p. 219). These interesting papers are similar in many respects. Shirayama's system is directly meant for computer use, while Sneck's is meant for manual use. We will probably need both in the future.

If there are not too many requirements, Sneck's system can easily be handled and a solution close to the optimal one can be chosen. If there are a lot of requirements and a lot of proposed solutions, a computer may be helpful. But you have to take care that the optimal solution is not excluded. There are certain risks if you use only pass or fail as results of the evaluation. It might happen that Shirayama's proposed selection rules in Table 1 of his first paper give no solution at all.

In my opinion the computer program ought to include the possibility of putting in several quality levels for all properties where this is possible. The output may then consist of several proposals for different solutions given in some kind of quality order. It seems quite possible that the final choice will be, for instance, number three on the list.

Both Shirayama and Sneck show that for one and the same purpose it may be possible to evaluate the performance on different levels. The level chosen for the evaluation is generally the cheapest possible. According to my experience this type of educational discussion is necessary.

The paper "Performance Analysis of Floors" by Saarimaa, Sneck, and Wäänänen contains a Table on "Classification of External Factors" (Table 4). These are given in five classes. This approach seems to me unnecessary and in some respects misleading; misleading because the classes are too wide. The transformation from factors to properties and requirements will be simpler and safer if you make direct quantitative statements of the factors, without any classification.

The mentioned Table 4 has been used as a basis for room classification in Table 5. This could in my opinion better be based on the classification in Table 6 and on surveys of actual floors, which in any case must be made. If so, you have a direct link between the classifications of rooms for different properties on one side, and the requirements on the other. You need no transformation formula. I have tried to give an example in Tables 1 and 2 of my symposium paper.

Kazuhisa Shirayama

Bring has raised several good questions in connection with our papers and I would like to offer some further explanation.

I must point out regretfully, that our whole system as shown in Table 1 on pages 512 and 513 was mostly developed in 1953. After that we have been making efforts to complete many subsystems in order to make our selecting system fully practicable. It has needed, and will need certainly a lot more work, to finish it. We dare say that this work is a challenge to our knowledge and ability, and because of this we emphasize its study.

The horizontal column (9) in Table 1 shows only the classification of type of judgement for selection, and does not intend to show the selecting system itself. Among those different types of judgement, we have been using mainly the second or third one because they are rather simple and easily used.

We found that it is more practical to prepare different selecting systems corresponding to each way of use of materials. In the case of one of our selecting systems for floor finishing materials, the output of the computer has the form of a table, composed of the names of flooring materials available in Japan at present, and the characteristic properties

* For affiliations and addresses of discussors, see list of Symposium Registrants, p. viii.

of those materials corresponding to the required properties. It is also accompanied with the judgement (fail or pass) for every item of the required properties of each material. So here can be found the several materials which have passed according to the computer judgement. The final decision is left to the judgement of the architect or client.

Juho Saarimaa and Tenho Sneck (Presented by Saarimaa)

Bring comments on the similarity of our paper on "Performance Analysis" which was reviewed yesterday and the papers by Shirayama et al. The authors agree that the similarity of the systems is evident when they are applied on the level of building element and lower levels. The Japanese work is mainly based on "requirements" while our work relies on "external factors". The system of Shirayama is for selection. Our paper is mainly for development of products, materials, etc.

Our paper on "Performance Analysis of Floors" is based on the technique outlined above. The draft has been prepared as an example of the performance analysis.

Bring comments on the classification procedures of the papers. As our system is based upon the "external factors" we tried to list them in Table 4. We agree that the classes are too wide. In some cases more classes would be needed.

Tables 4 and 6 in our paper on floors seem to lead to misunderstandings. Any "class" of external factors may correspond with any of the requirement "classes" of Table 6. It seems to us that we have to develop some way to express the matter.

Rooms can be classified on data concerning "average" rooms. Table 5 classifies rooms on the principles of Table 4, e.g. external factors. In the opinion of the authors, this kind of listing is needed, but we agree with Bring that a classification based on requirements would be helpful for practical purposes.

Gérard Blachère

I have an important question for our rapporteur.

As he has just said, I can believe that his approach to the problem of assessment of components, and also the approach of the E. R. people are very close to the Agrément procedure.

If so, why do they and others not merely use the agrément procedure? Why try to create something different where the agrément procedure has been operating 20 years and now extends throughout Europe and even in South Africa? Thousands of agréments have been delivered, many have been confirmed from country to country under the aegis of the UEAtc (European Union for Agrément), 15 common guide lines for agrément have been issued and 7 are under preparation.

There will be a large saving of time and effort, larger possibilities for trade, and at the end a gain for all the consumers if they join us. Why not?

Ingvar Karlén

In reply to Mr. Blachère, as you have changed the principles of the Agrément System, the possibilities of getting closer together have been greater.

J. G. Sunley

Over the course of the last few days there have been many conflicting statements on whether or not performance standards can be exact and how far they should leave room for judgement. Building law in the form of regulations and codes tends to be interpreted in an exact manner.

I would contend that in many building applications, particularly those involving long term durability, any approval system which does not permit the use of judgement will restrict innovation. In assessing long term durability under a wide range of conditions, test methods can only be an aid to judgement and cannot replace it. This is one of the reasons why the Agrément system exists in many countries as an aid to innovation because of tight legal building control.

Roger Camous

Only "pure" performance specifications (developed from users' needs) leave the door open for innovation; for the moment, however, we have to consider that they are an inaccessible "ideal". Nevertheless, every possible development concerning performance requirements is indispensable, if we ever wish to evaluate buildings in terms of user needs.

Performance specifications, which can be prepared today (developed from performance characteristics of existing solutions) do not make innovation easy and cannot solve the problem of evaluating new products.

The only answer to this problem is the approach of assessing performance. Assessments can only be made by experts, because of the complexity of performance testing and because of the two difficult points which have to be resolved in the case of a new product: its integration with other components in a building (compatibility) and its durability.

On the problem of the evaluation of new products, we ask: How should we act? However, another question ought to be explored, namely: Who should act? The answer to this further question depends principally on the socio-economic context of the country.

One thing is certain: information provided by the manufacturers - however good this information may be - does not really allow the designer to make a proper assessment. Performance tests, it would seem, could be developed by the manufacturers to not necessarily introduce products on the market place that are fit for a purpose! We know that some people think that "bad" products are automatically eliminated through competition; in building, however, this is a lengthy process, since products have a long life; and the user risks having to bear the consequences.

This does not imply that the tests must necessarily be conducted by independent laboratories. The tests can be developed by the manufacturers, but controlled and interpreted by experts who represent the users as well as the other participants in the building industry. Such a system is near to Agrément; experts carry out the assessment and make known their opinion; the designer, taking this opinion into account, retains his responsibility for specifying the product or not. The difference is that he decides on a basis of full knowledge.

We should note that a system of assessment of the Agrément type is not incompatible with the development of performance specifications; both use the performance concept.

Tenho Sneck

In his excellent report the general reporter said that composite materials should be subjected to the same evaluative techniques as other materials (see discussion on paper by Dietz).

In a glass fiber reinforced plastic we have to consider evaluation at the "level" of a combination i.e., glass and resin. In a brick this condition does not arise, and the "materials" level is thus different for this type of product.

In practice, there is the problem of determining to what degree the product will resist the action of certain external factors. In composite materials, e.g., glass-reinforced plastic, the compatibility of the two materials also has to be studied. The combination of these studies may, in fact, serve as the evaluation of the materials.

Dietz says that the durability of components has to be evaluated by methods which are specifically useful for components.

T. P. R. Lant

I had hoped that this Symposium had settled one issue: that evaluative methods depend on the product being evaluated e.g. the difference between working stress and ultimate stress is a function of material or method of construction and not performance.

This leads to the following pardox:

1. A performance specification does not anticipate any given solution.

2. To be complete, a performance specification must include evaluative methods.

3. Such evaluative methods depend on the nature of the solution.

4. Therefore, the performance specification cannot be written.

Agrément thrives on this paradox.

D. P. Van Court

While the paper "Evaluation of Structural Concrete Members Penetrated by Service Systems" by Hanson, Corley and Hognestad gives some reassurances to the designers of preconstruction penetrations in reinforced concrete members, it ignores what is often an even more significant problem to the owners and operators of factory buildings--post-construction penetrations of varying sizes needed at specific points (almost without regard for the fabric of a building) by revised manufacturing machinery layouts.

Once the design of a multiple story or single-story-and-basement reinforced concrete structure is complete, there are no generally accepted, published guides for locating or making penetrations larger than one bar spacing in size in flat slab floors, or for transferring stresses across such holes. Up to now, the theoreticians have ignored these inevitable future needs of the occupants by stating that such holes were not permissible. However, the real world does not fit such a neat pattern and new unplanned penetrations do become necessary, often when a factory is only a year or two old. After all, a good factory building is not a monument, but just another tool to be modernized when necessary or discarded when it cannot be updated. In too many cases, operating requirements make it undesirable to reduce headroom on the floor below to accommodate the traditional supplemental framing around large new openings.

There is, therefore, a need for research to develop acceptable means for transferring stresses across post-construction penetrations by means of plates attached with fasteners or adhesives or other techniques which could be employed in operating factories and would result in minimum intrusion into the adjacent horizontal or vertical spaces.

Tibor Csizmadia

I wish to say a few words in defense of the building process. Van Ettinger once said "Quality cannot be inspected into the product, it must be built into it." Paraphrasing this: Performance cannot be tested into the product, it must be manufactured into it.

The performance of our buildings is dependent on the various processes used in their design, manufacture, erection, and maintenance in use.

Charles T. Mahaffey

I would like to point out that the learned discussions occurring here, regarding the potential problems and benefits of a sound application of the performance concept in the evaluation of buildings, should be heard by those public officials responsible for writing building regulations. One would be hard pressed to identify a group more in need of just such an informed discussion.

In the United States we are witnessing a rapidly developing trend towards the establishment of mandatory statewide building regulatory systems. At the present time some 40 of the 50 states either have passed, or are attempting to pass, legislation specifically aimed at putting the State in charge of promulgating building regulations and of operating an evaluation mechanism. Many of these pieces of legislation are attempting to institute some form of performance based regulations.

Performance based statewide building regulatory systems offer the advantage of providing the desired degree of building safety while keeping the door open to the introduction of safe, innovative building techniques and materials. I would suggest that those of you who do have an appreciation of the complexities of this subject area take the time to help these State officials.

National Bureau of Standards Special Publication 361, Volume 2: Performance Concept in Buildings; Proceedings of the Joint RILEM-ASTM-CIB Symposium, held May 2-5, 1972, Philadelphia, Pennsylvania (Issued August 1972)

SESSION V

Materials

Tenho Sneck, Chairman
The Institute for Technical Research
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and
Member of Symposium Committee

S. Bergström, Rapporteur
Institute of Technology
Lund, Sweden

Papers Reviewed by Mr. Bergström

1. Introduction

At this session, 15 invited papers on the performance concept applied on the materials level are in hand. They differ widely with regard to properties treated, level, and proximity to the performance concept which, after all, is the fundamental idea of this symposium.

In papers in other sessions and on other occassions, experts have expressed doubts of, as well as belief in, the possibility of applying performance thinking on a materials level. Both doubters and believers will find that the papers support their cause.

One of the papers presents a general discussion of the performance concept applied to building materials. Of the other papers, 6 or 7 treat performance problems in a manner where they may be identified by the consumer, for example, resistance to the action of frost; 3 papers treat problems on a lower level, for example, pore structure characteristics, but with relation to the level of materials. The other papers are more or less traditional descriptions of material properties and the effect of different factors on these properties. Several papers have used a certain function in the building as a starting point, from which they have analysed the performance requirements and discussed the available test methods. This is in the opinion of the Reporter the most interesting approach, and it demonstrates the difference between classical materials research, where the properties of a specified material were studied in every detail, and the performance based research, where several materials in the same function are studied by means of the same methods and the same evaluations.

In this general report, a very short review of all papers will be presented. The Reporter will then show four examples of how performance may be applied on the level of materials. Two of these examples are not taken from papers in this symposium. After that, the Reporter will quote and comment upon some statements made by experts as a rounding off of the general report.

2. Short Review of the Papers

Valenta has reviewed and analysed some methods and standard specifications for the determination of water absorption, water permeability, and capillary rise of building materials.

These properties are not always of primary importance from the point of view of performance requirements, but they are nevertheless of great importance in connection with the performance under natural weathering conditions, for instance for the frost resistance of materials.

Haynes and Sneck have stressed the importance of pore properties for the performance characteristics of porous materials. Essential pore structure parameters and methods for their determination are presented. They have also listed examples of cases where pore properties influence the performance, for instance capillarity, frost resistance, ease of cleaning etc. The example "capillarity" demonstrates that this paper is on a level below Valenta's paper, i.e. closer to the basic structure of materials.

Gross and Fang have studied so called low intensity fires, i.e. fires in wastebaskets or pieces of furniture. Low intensity fires may start real fires and may of course also directly cause damage to surrounding structural components. Such studies are consequently of importance in a performance system. The behaviour of materials and structural components under the influence of fire is an excellent example of application of the performance concept, as will be demonstrated later on.

Sneck reports on a draft Finnish standard for masonry mortar, where the responsible body has tried to apply the performance concept. One of the fundamental points in the draft is the interaction between the mortar and masonry units, where especially the suction of the masonry unit is assumed to be of a deciding importance. It has however not been possible to base the standard exclusively on performance. Consequently, the standard is partly conventional. It is for instance worth noticing that the approval of a mortar or a combination of mortar with a masonry unit has to be decided upon by an expert panel.

Kuhlmann has reported on performance evaluation of a certain type of thin bed adhesive mortar for gluing concrete blocks together. Different strength tests demonstrate the very good bonding properties of the mortar. Bond is of course an essential part of the total performance of the materials in a masonry wall, but even other properties ought to be included, c.f. Sneck, p 687.

Li, Stewart and Ramakrishnan have in their paper pointed out the major functional requirements for concrete in different building components, for instance for columns: high modulus of elasticity, low creep, low shrinkage, durability, early form stripping, finish-ability, adaptability to any sound aggregate, high strength and low cement requirement, all fairly obvious. They advocate that these requirements will in a very efficient way be met by gap-graded concrete. Examples demonstrate the danger of too detailed specifications, for instance regarding allowable limits for the grading curves of aggregates.

A similar but more principle argumentation is delivered by Mather in his report. Mather states that too much attention has been directed to cases where the performance of the concrete has been insufficient. From an economical point of view, the stipulated levels of quality should not be higher than necessary. Concrete appropriate to its intended use could in many cases be made with materials which are not allowed by the specifications. Mather demonstrates a model of how to choose concrete materials, proportions of materials etc., starting from an analysis of the performance of the system and consequently the desired performance of the concrete. Mather's model could, however, very well result in prescription specifications.

Saarimaa has discussed a morphological technique to be used in the evaluation of corrosion of reinforcement in concrete. In this method, all factors influencing the corrosion are listed and given possible independent values. In this way, chains are formed which describe possible solutions of the problem. The author also indicates a method of calculating or forecasting the probability of a certain performance. In the opinion of the Reporter, there is a risk in resolving a problem into too many factors, because the overall survey may get lost. Some of the factors may cooperate to a more directly deciding parameter, for instance porosity and/or permeability in the case of corrosion of reinforcement. A careful study of the main factors seems to be needed, an opinion which is evidently shared by the author.

Blakey and Martin have presented a very stimulating and provoking paper where they state that "the performance approach to design of buildings is probably a sound frame-work for teaching, and by which codes of practice and building regulations should be guided, but it is virtually impossible to apply it rigorously to the specification and control of building materials." They support this thesis with examples in relation to concrete and plastics.

The Reporter believes that this paper will serve as an excellent introduction to the discussion and will consequently sum up some of the ideas and statements of the authors in a special part of this report together with a few comments from the Reporter.

Gamski has treated methods of testing thermosetting binders with regard to reactivity, mechanical strength, post-polymerisation, dimensional stability and volume changes in water, as well as for fillers and composites. These tests have no direct relation to the performance concept but may be regarded as "means of controlling the parameters on which the performance and durability depend." Gamski also describes an accelerated method of testing the dimensional stability of an element made of a resin-bound mortar under the influence of one-sided heating and cooling.

Stedman has reported on the very important and complex problem of weathering performance of plastics, especially rigid PVC. Studies have demonstrated that "not all of the phenomena produced outdoors were being duplicated by artificial weathering methods." Laboratory methods have been studied where different external factors are investigated, isolated or combined, for instance UV-radiation and moisture. It is of great importance that reliable accelerated methods of studying weather resistance, ageing, durability and similar properties of materials are developed if it will ever be possible to apply performance requirements on all building materials and building components. This is especially important for new materials, where knowledge of past performance does not exist.

Reichard, Masters and Pielert have reported on the evaluation of adhesives in structural components in some of the housing systems in "Operation BREAKTHROUGH". The authors state that "the adhesives industry consists of a few major manufacturers and hundreds of small formulators who produce thousands of adhesives. In general, these adhesives are sold without guarantees as to their performance." In the authors' performance testing, the bond was tested for short term and long term load, and with different environmental effects operating (temperature, moisture conditions). To minimize the testing, structures were divided into three classes, depending on the consequences of a bond failure. Examples from two of the tested systems are shown. It was possible to find out weaknesses in the bond, to make a better choice of adhesive, and to evaluate which factors are of importance for the performance (temperature, adhesive thickness, sustained loading).

Hoiberg has analysed the performance requirements for bituminous roofings in a way which makes it a more or less general study, applicable even to other types of roofs.

The Reporter, therefore, has preferred to give a more detailed presentation of Hoiberg's paper in the next part of this report, where some examples of application of the performance concept on materials are shown.

Soroka has studied abrasion tests and wear resistance of concrete terrazzo flooring tiles. In the experiments, the Böhme abrasion test has been used, although the author expresses doubts regarding the correlation between the test results obtained by this method and performance in practice. Correlation is instead sought between test values and two primary factors which are known to influence the wear resistance, i.e. cement content and hardness of aggregate. Correlation was found, and it was suggested that acceptance should be based on abrasion resistance supplemented with a specified minimum content of cement.

In the opinion of the Reporter, this does not seem to be a consequent application of the performance concept, since in the end a detailed specification of how to do it is added. It also strikes the Reporter that an abrasion test ought to be valid even for other floor surfaces than concrete terrazzo. The main problem seems to be to design a reliable method of testing.

Wolfe has made a state-of-the-art report of performance tests regarding finish floors. This paper, like Hoiberg's, seems to be of general interest in a performance discussion and is therefore presented more in detail in the next part of this report. With reference to Soroka's discussion of abrasion and wear, the Reporter wants to draw attention to Wolfe's summing-up of "durability or wear."

3. Examples of Performance Applied to Building Materials

3.1 Frost Resistance

A functional requirement of materials for outdoor use is of course that they should not be damaged by frost. For every porous and brittle material it is possible to determine a critical degree of water saturation, S_{cr}. If the degree of saturation in the material is equal to or higher than S_{cr}, the material will be damaged by freezing. The performance criterion could consequently be expressed by

$$S_{act} < S_{cr}$$

where S_{act} is the degree of saturation of the material in the actual structure in its actual environment at the time of exposure to freezing.

The actual degree of saturation, S_{act}, depends on the environment, the design, the moisture transport properties of the material, the pore characteristics and, finally, on molecular and atomic structure; S_{cr} depends on strength, deformation properties, permeability, pore characteristics, molecular and atomic structure. S_{cr} may be regarded as a material property although it summarizes the effect of several properties. Fagerlund has applied this reasoning on all porous and brittle materials [1][1] and has also determined S_{cr} as a material property or constant for several materials.

It is, in the opinion of the Reporter, quite evident that this approach to the frost resistance problem is in the spirit of performance. It may be applied to all materials vulnerable to frost action as soon as we know the use of the material in the building, which determines S_{act}. On the other hand, with a known value of S_{cr}, known moisture transport properties of the material, and known environment it ought to be possible to design the component in such a way that $S_{act} < S_{cr}$.

In Fig. 1, the reporter has also indicated the levels of the papers by Valenta and by Haynes and Sneck with regard to frost resistance.

The same system may also be used to illustrate where the responsibilities of consumer and producer (of materials) enter, Fig. 2. The consumer has to identify the need for frost resistance, know the environment and make the design. The producer is responsible for all material properties entering in the picture. The producer alone is responsible for S_{cr}, the consumer, partly together with the producer, is responsible for S_{act}.

FROST RESISTANCE		FUNCTIONAL REQ.
S_{ACT} <	S_{CR}	PERF. CRITERION
ENVIRONMENT	STRENGTH	
DESIGN	DEFORMATION	
MOISTURE TRANSP.		Valenta
PERMEABILITY		Valenta
PORE CHARACTERISTICS		Haynes and Sneck
MOL., ATOM. STRUCT.		

FIG. 1

FROST RESISTANCE		CONSUMER
S_{ACT} <	S_{CR}	CONSUMER-PRODUCER
ENVIRONMENT		CONSUMER
DESIGN		CONSUMER
MOISTURE TRANSP.		PRODUCER
PERMEABILITY		PRODUCER
PORE CHARACTERISTICS		PRODUCER
MOL., ATOM. STRUCT.		PRODUCER

FIG. 2

3.2 Fire Resistance of Components and Materials

A very logical model for studying the behavior of components made of any material under the influence of fire has been suggested and applied by Pettersson [2][1]. His starting point is the fire load in the building. From the fire load and the properties of enclosing walls, floors and ceilings it is possible to calculate the fire development, which many times deviates markedly from standard time-temperature curves. The time-temperature fields in the surrounding structures are then calculated. With a knowledge of the effect of temperature on the properties of the materials in structures, it is finally possible to calculate the load bearing capacity of these structures or components as a function of the fire endurance.

This reasoning has been applied on concrete and wooden structures by Pettersson and his co-workers. It seems to be in accordance with the ideas put forward by Seigel (p. 557).

This approach to the fire problem is also in the spirit of performance. The same approach may be used, independent of material.

3.3 Performance Requirements for Bituminous Roofings

As mentioned before, Hoiberg has analysed factors related to the performance of the shingle and the built-up membrane bituminous roofings. The performance requirements treated by Hoiberg are listed in Table 1.

[1] Figures in brackets indicate the literature references at end of this paper.

TABLE 1
Performance Requirements for Bituminous Roofings (Hoiberg)

Durability
- Movements in roof membranes
- Weather resistance
- Wind resistance
- Hail damage
- Fire resistance and hazard

Other Considerations
- Roof traffic resistance
- Roof appearance

Economic Evaluation

It strikes the Reporter, that these requirements are not necessarily limited to bituminous roofings. Almost any material for a roof should fulfill the requirements. Independent of the type of material in the membrane, the stress pattern will be the same when a crack or joint opens. The methods of test should also be the same; with joint movement, time, temperature, and humidity as basic variables.

All roofing materials should of course be weather resistant. For established materials, like bitumen, Hoiberg's statement "Much dependence is placed upon knowledge of the past performance of the components making up the roofing" is valid. For new materials, it ought to be possible to develop test methods, c.f. Stedman's paper. Further, all roofing materials should of course be wind and hail resistant, and as for fire, reference is made to part 3.2 of this report. All roofing materials must of course be resistant to the traffic on the roof, and requirements on roof appearance should be the same irrespective of material. Hoiberg points out the importance of durability with respect to appearance, a question which also was treated in Stedman's report.

3.4 Performance Tests for Finish Floors

Wolfe's paper on performance tests for finish floors seems to be another excellent example of how the performance concept may be applied on the level of materials. The performance properties discussed are listed in Table 2.

TABLE 2
Performance Properties of Finish Floors (Wolfe)

- Cleanability and stain resistance
- Slip resistance
- Static charge and conductivity
- Indentation and resilience
- Water resistance
- Durability or wear
    - Resistance to cutting
    - Resistance to tear
    - Resilience
    - Stress-strain relationship
    - Changes in any of the above by heat, aging, light, moisture, or conditions of stretch or distortion

Even in this case, the requirements seem to be valid independent of the material. Wolfe's report indicates that many different methods of test exist, in some cases too many. The following statement is quoted: "Development of a standard method for stain removal or spotting will also be difficult due to the great variety of methods presently used."

The question of wear is evidently difficult, which also has been stressed by Soroka. Table 2 demonstrates properties on a level below "wear" which are of importance for the wear resistance of a material. Wolfe quotes the following statement by Harper: "The fundamental approach to the measurement of wear resistance appears not to have been attempted for flooring materials."

It may be added that the fundamental approach must take into consideration still lower levels.

4. Some Statements and Comments on Statements Regarding Performance and Building Materials

The Reporter would like to sum up the present situation, as reflected by the papers for session V, quoting and commenting upon some statements made by experts.

4.1 ".......it is not possible to evaluate a material if we do not know what its exact use will be" (Blachère, p. 170)

The Reporter agrees.

The case of frost resistance showed that the performance concept is applicable on materials but at the same time it is absolutely necessary to know how the material is going to be used in the building, because S_{act} is highly dependent on the use. Other examples are fire, finish floors (the materials are used for finish floors!), roofings (the materials are used for roofings!) and the tests to evaluate the performance of adhesives (Reichard, Masters and Pielert).

4.2 "The philosophy of performance evaluation has to be developed further. The old way of looking at standardized methods...... without any real connection with the behaviour of the object in practice, has to be rejected" (Sneck, Saarimaa and Sneck, p.224)

The Reporter agrees.

If standardized methods have no connection with the behaviour in practice, then they should of course be rejected. But many standardized methods have, after all, such connection. This is for instance the case with the strength of a material. Strength is always determined by standardised test methods and has close connection with the load bearing capacity of components made of the material in question.

Standardized methods are very often connected with specifications. Is it possible, by means of the performance concept and performance based methods of test, to develop better specifications? This seems to be possible, as indicated in the papers by Sneck, by Li, Stewart and Ramakrishnan and by Mather. On the other hand, it has been demonstrated by for instance Sneck and Soroka that our knowledge of performance evaluation is insufficient today, which makes it difficult to make specifications exclusively based on performance.

4.3 "The performance concept applied to building materials - an unattainable ideal" (Blakey and Martin)

The authors state that the performance concept is the only logical basis for building regulations for the selection of building systems and for the design process but it is impractical when one attempts to apply the concept to specification and control of materials. The reason is that neither of the following two conditions exists to any useful extent

1) definition of quantitative performance levels
2) reliable methods of test

Examples are taken from two groups of materials: concrete and plastics. In the field of concrete many performance requirements are, for instance, connected with crack resistance and surface hardness, but no reliable test methods exist. Many other important properties should be required, but in general only compressive strength is specified. Besides, "provision of a wide range of testing facilities is expensive." In the field of plastics, the authors mention aesthetics, durability and fire resistance as important performance characteristics "and none of these are easily identified in objective terms." The performance concept is important to guide the development of the fire resistance, "but it is unlikely that plastic materials will be controlled by valid performance tests in the foreseeable future." In the conclusions, the authors state that even if difficulties could be overcome by continued research, "it would seem almost certain that the resulting sequence of tests would be much too complex for practical implementation."

The Reporter is of the opinion that many of the statements made by Blakey and Martin regarding the present situation are true. It is difficult to quantify performance levels and to develop reliable methods of test. But this fact should not stop the development of performance evaluation tests.

Many of the test methods we use today have little relation to the real performance, which has been stated by Sneck, Saarimaa and Sneck and by Blakey and Martin themselves (cf. what the authors have said about compressive strength of concrete!) Is it not, then, better that we try to develop other methods, which are correlated to performance requirements and - when we have been successful - abandon the old ones? Every time we make a specification today, we have also made a decision with regard to performance. Would it not, then, be better to try to analyse the performance requirements first and from them derive suitable methods of test?

Finally, the Reporter wants to make the following statement. If we succeed in preparing performance based specifications over the whole building field instead of the old prescription type specifications, it will certainly not make it easier for the designer. He must in the future be much more clever than today, when he is supported by a lot of detailed specifications telling him how to do the thing. In the future, he must himself decide how to do it to arrive at the required result.

5. Summary

1. It is possible to apply the performance concept on the level of materials - provided that the intended use of the material is well defined.

2. Many methods of tests or other methods for performance evaluation exist today, but there seems to be a great need to develop these methods further and to develop more methods. The existing methods by no means cover the whole field.

3. It seems to be difficult today to prepare specifications exclusively based on performance, because of the lack of evaluation methods mentioned above.

4. A complete system of performance specifications instead of prescription specifications will cause great demands on all who are engaged in the process of planning, designing, and erecting the building.

6. References

1. Fagerlund, G.: Degré critique de saturation. Un outil pour l'estimation de la résistance au gel des matériaux de construction. Matériaux et Constructions, no 23, vol 4, 1971.

2. Pettersson, O.: Structural fire engineering research today and tomorrow. Acta Polytechnica Scandinavica, Stockholm 1965.

Juho Saarimaa

I would like to say a few words about the remarks that Bergstrom made about the technique which I have introduced in order to evaluate corrosion of reinforcement in concrete. I would like to stress that it is again a question of the wholeness. As you may know, corrosion of reinforcement in concrete is influenced by many factors. In order to be able to give some direction to the prediction of possibilities of corrosion of reinforcement under different conditions, we need an evaluative technique which takes all essential "corrosion factors" into consideration.

I don't quite agree with the rapporteur that the number of factors should be restricted, not at least in the first stage of evaluation. I agree however that the number of factors which have importance in an actual situation may be restricted.

Once again: The first stage of evaluation has to be based on a system where all the possible influencing factors are considered.

Harold F. Stedman

I would like to take this opportunity to correct some data which was included in my paper on "Natural and Artificial Weathering Performance of Rigid Polyvinyl Chloride and Other Plastic Materials" and to add some additional data which has been developed since the paper was prepared.

Errata in Table I - NBS Units

Since the compilation of the data presented in Table I, the Judd equation, expressing color difference (Δ E) as NBS units, has been programmed on our IBM 360 Model 30 computer. A check of the computer values against the original calculations revealed several arithmetical errors in the latter. The corrections to Table I are as follows:

Instrument	Color	Sample	NBS Units Original	NBS Units Corrected
Photovolt 670	White vs. Tan	1	25.2	25.1
		2	19.8	22.9
		3	11.7	23.3
	Tans	2	4.1	3.8
	Beiges	3	14.8	14.9
	Yellows	1	3.2	1.6
Colormaster V	Black	1	4.6	4.9
	Beiges	1	20.4	14.0
Hunter D25A	Beiges	2	14.3	14.4
	Yellows	1	1.7	1.6
Color-Eye, D1	Greens	3	46.1	46.0
G.E. Spectrophotometer	Yellows	2	1.8	1.9

The four large corrections have generally improved the agreement of NBS units between the different instruments used, but we are still left with differences in (Δ E) values associated with the several methods of calculation and the differences related to various colors.

* For affiliations and addresses of discussors, see list of Symposium Registrants, p. viii.

From the viewpoint of the performance concept, it may be necessary to use two methods of color difference calculation, such as Reilly-Glasser Cube Root and Judd NBS units, to reveal any range of (Δ E) values which may exist as associated with specific data.

New, Comparative Data Using Various Sources of UV Radiation

A third plastic material which performs quite differently during FSL/BL exposures, with and without vapor cycling, from outdoor and xenon arc exposures is white ASA-acrylonitrile-styrene-acrylic elastomer. The following tabulation reveals, through Yellowness Index values, the wide range of results obtained with the different sources of UV radiation:

UV Source	Exposure	Yellowness Index			
		0 time	165 hrs.	500 hrs.	1110 hrs.
FSL/BL	UV only	4.6	7.1	23.6	30.4
FSL/BL	UV-Vapor	4.8	7.4	25	26.1
Xenon arc	UV only	10	5	4.8	6
Xenon arc	UV-Vapor	10	5	5.8	9.8
Outdoors	45° T.D. - SSW	4.7	2.8	0.6	0.2

Both the xenon arc and outdoor samples showed a decrease in Yellowness Index during the first 350 hours of exposure. More work is being done in this area.

Arnold Hoiberg

Your comments were of interest, Professor Bergstrom, and certainly valid. I agree that the analysis presented would of course apply to other roofings than bituminous. My paper was limited to bituminous roofing; however, as implied, the built-up roof in particular responds as part of an entire system. This includes the deck, often a vapor barrier, and usually insulation.

In design of this system, not only the building structure but also the use and occupancy of the building needs to be considered. In the future it would seem that the performance concept for the entire roof structure should be developed, and test methods based on such a concept devised. To some extent this already is practiced in wind uplift and in fire hazard and resistance ratings. A beginning has been made in evaluating durability by Koike and by Martin as discussed on page 780 of my paper, and needs to be further extended.

Winthrop C. Wolfe

My paper was written as a result of experience with performance specifications, such as the Guide Criteria for Operation BREAKTHROUGH and the PBS Specification for Office Buildings. There were some gaps and weaknesses in these specifications. For example, the requirements for flooring in the Guide Criteria called for levelness, but there was no criterion. Bring presented a paper in this symposium which fills some of these gaps. He presented criteria and tests for flatness and surface evenness of floors and a criterion and test for warmth to touch, which we have not considered.

In my paper I referred to some of our previous studies on resilience as related to foot comfort. Our studies showed that soft floor coverings, such as carpet, absorb more energy in compression than do hard floorings, but the values are too low to be significant. I mentioned in my symposium paper that Holden and Muncey in 1953 reported a small impact peak which occurs when people walk on hard flooring but disappears when soft flooring (lawn) is walked on. This impact peak was also reported by Harper, Warlow, and Clarke in 1961.[1]

[1]F. C. Harper, W. J. Warlow, and B. L. Clarke, "The Forces Applied to the Floor by the Foot in Walking," National Building Studies, Research Paper 32, Department of Scientific and Industrial Research, Building Research Station, H.M. Stationery Office, London, 1961.

Bring pointed out to me in a private conversation that this peak may be significant, and that some additional work has been done in Norway. Reported values at this impact peak show considerable force, but it requires sensitive instrumentation with rapid response to record this force. It also remains to be shown whether or not this force is relevant to foot comfort or to medical problems, as with people's feet and legs. If such a correlation could be established, it would be a basis for a performance requirement related to a trade-off advantage of soft flooring.

N. F. Astbury

The model of a pore structure derived from mercury porosimetry and from similar methods is inadequate to account for the rate of absorption of water by porous materials, it does not correctly describe permeability, and it cannot give any account of internal surface area. It is suggested therefore, that attempts to relate the results of such tests to materials performance is unlikely to be profitable and indeed there is a good deal of experience to confirm this view. The problem has recently been approached in a new way at the British Ceramic Research Association. A model pore system is proposed based on pores which are tortuous axially and in which the radius varies randomly between upper and lower limits. Such a model has been shown to account for the long times observed in absorption tests and it accurately describes permeability. In addition, although the model was not designed to account for internal surface area, it does in fact do so quite accurately.

In the apparatus used for the measurements of the model parameters, the rate of capillary absorption is measured and when the specimen has reached equilibrium, a permeability test is made. The information is acquired electrically and passed to a computer programmer which yields:

(i) a distribution profile of the lower bound of radius

(ii) a distribution profile of the upper bound of radius

(iii) a number Z (>1) giving the ratio of upper to lower bound

(iv) a distribution profile of all voids in the specimen

(v) an axial tortuosity-factor and

(vi) a lower bound to the internal surface area.

The number Z is of special significance, and may sometimes be of the order of 10 or more.

A systematic study using the new method is being made on a wide range of bricks, specimens of which have been built into test walls exposed to weather for the past 8 - 10 years. The most recent publication (which contains references to earlier work) is by Astbury in the Berichte of the German Ceramic Society for February 1972.

Bruce Foster

The paper by Blakey and Martin gives the impression that the authors believe the proponents of the performance concept have as a goal the replacement of all prescriptive tests with simulation-type tests. I have encountered this belief, which I believe to be incorrect, in talking to a number of people. A corollary to this belief is that simulation-type tests are necessarily better than prescriptive ones.

At some point in the design process a decision has to be made on which material to use for the purpose at hand. This decision should be based on information available on performance of candidate materials as measured by observation of actual use in similar applications, on simulated tests, on expert judgement, or through a combination of these.

At this point the selected material should be specified in a manner readily useable as a purchase specification and for quality control. The specification should properly characterize the material whose performance potential has been assessed, so as to insure that the material delivered has the properties upon which its selection was based. Simulation-type tests may be employed, but more likely proprietary test requirements will be less costly and require less time. They will also probably be standardized and familiar to the manufacturers.

As an example, one of the performance requirements of copper tubing, as well as other piping, is that it should not be subject to stress corrosion. Several years ago a failure of copper tubing used to conduct natural gas underground into a house was diagnosed as resulting from stress corrosion(1). The tubing was found to contain eight times the specified limit for phosphorous content. Obviously it is less costly and takes less time to measure the phosphorous content of copper tubing than to run a long-time simulated test for stress corrosion. Also the former is more suitable from a quality control standpoint. Each type of test has its place in the specification system.

The performance concept is applicable to materials selection, but the need for proprietary specifications remains.

Øivind Birkeland

The three last papers in this session, taken in connection with the short discussion we had during the preliminary session, are raising some very important questions regarding tests, performance tests, methods of evaluation, etc.

The performance we require regarding the load-bearing capacity of a floor is characterized in this way: We require that the floor shall be able to carry a certain load. We can evaluate the performance of the floor by making some simple tests controlling the quality of concrete and reinforcement and from this we evaluate the performance through structural calculations. This is a performance evaluative technique.

Within other fields our knowledge is not sufficient to evaluate in this way. Take as an example rain penetration. This we evaluate through a laboratory test where we try to subject a test panel to stresses as close as possible to the natural ones. This we do because our knowledge is not sufficient to evaluate the performance through calculations based on the measurement of a few parameters simple to measure.

Some authors tend to state that only this type of testing is performance testing. This is not true. We do this only because of lacking knowledge. An evaluative technique such as making structural calculations is much to be preferred.

May I also take this opportunity to state that I consider the methods of the social sciences as methods of performance evaluation.

Judgement by experts is also a possible evaluative technique which can be expressed in figures.

Tarja Cronberg

As a comment to the Blakey and Martin paper I would like to make a distinction between the material properties and tests used in quality control in production; and the properties, and tests, to be used when appraising the performance of a material for a certain use in building.

While the performance approach defines the required properties of materials in terms applicable to all materials and is related only to the use of the materials, the material-based approach specifies properties inherent in the materials and not necessarily to their use.

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(1) Logan, Hugh L. and Ugiansky, Gilbert M., "Two Cases of Stress Corrosion Cracking in Copper Tubing", Materials Protection, Vol. 4, No. 5, p. 79 (1965).

These two types of properties may of course coincide in certain cases, but usually several "material-specific" properties combine to a "use-specific" property. Thus weatherability, essentially a "use-based" property, is a combination of several "material-specific" properties; for plastics for example, of UV-degradability, water absorption, temperature resistance, etc.

When the correlations between the performance-based test used (or to be developed) to determine weatherability, and the tests used to measure the latter properties are established (and this needs to be done only once), the latter test methods, material-specific as they may be, lend themselves well for quality control, being both less expensive and less time consuming.

The statement made by Blakey and Martin about existing physical tests having been adopted as performance tests without correlation to the important parameters in field performance having been established, is of course agreed with. However, this should not lead us to consider the performance approach unapplicable for materials, but instead to critically examine the test methods used and to develop performance tests wherever needed.

W. J. McCoy

Blakey and Martin point out the performance concept is the only logical basis for the selection of building systems, but experience has shown it to be impractical to apply the performance concept to specifications for materials and this is most evident for concrete and plastics. They discuss the testing and properties of these two materials and then conclude with a proposal that there should be a widespread return to prescription specifications for materials.

My comments pertain to specifications for concrete in which case the authors have specifically recommended a return to prescription specifications with emphasis given to content of cement, water, and air. They finalize their justification for a return to prescription specifications for concrete by stating that the proposed redraft of the American Concrete Institute Building Code Requirements for Reinforced Concrete (ACI 318-66) specifies maximum water/cement ratios and minimum cement contents to ensure durability.

The new ACI Building Code Requirement for Reinforced Concrete (ACI 318-71) has now been issued. Chapter 4 covers Concrete Quality and clearly states that except for the special requirements of Sections 4.2.5, 4.2.6, and 4.2.7 the proportion of ingredients for concrete including water/cement ratio shall be established on the basis of compressive strength tests either of laboratory trial batches, or of the actual concrete as furnished for the structure. The performance criteria regarding strength uniformity is a very important part of the new ACI Code. If suitable data from trial batches or field experience cannot be obtained, then permission may be granted to base concrete proportions on water/cement ratio limits. As experience becomes available on the project, the accumulated performance data can be applied to modify the approved proportioning. One of the significant changes in the 1971 ACI Code, compared to the 1966 Code, is the increased use of performance requirements with regard to the quality of concrete.

The special requirements of Section 4.2.5 pertain to concrete subjected to freezing temperatures while wet and provides for air entrainment and a maximum water/cement ratio. The special requirements of Section 4.2.6 pertain to concrete intended to be water-tight or for exposure to sea-water, and provides for maximum water/cement ratios. Section 4.2.7 pertains to concrete that will be exposed to injurious concentrations of sulfate. It specifies that in addition to the requirements of Section 4.2.6 that sulfate resisting cement be used.

Mather's paper which is included in this Session (V) explains the value, importance and practicality of performance specifications for concrete. The advisability of returning to prescription type specifications for concrete is seriously questioned.

D. P. Van Court

Throughout this symposium much attention was paid to human factors when determining the needs of the user or future occupants. However, only Blakey and Martin even hinted that human factors may exist during the Process phase. The "If I can draw it, he can build it!" syndrome which afflicts so many designers seemed to be tactitly accepted as valid by the other authors and participants.

Experience has led this writer to believe that the success or failure of a component or material depends in large part on job-site human factors. In fact, some failures appear traceable to direct sabotage by inept and/or fearful workers. Therefore, it is vital for designers to consider the impact of the "Supremacy of Second Rate Materials." This theory holds that an inferior item in the hands of a worker who is familiar with it yields better results than a technically superior item which is new to the worker or is not personally acceptable to him. Furthermore, while the same results ensue, if the worker's immediate supervisor disapproves of an item for any reason, a strong positively-motivated superior can get good results out of a fearful but not hostile worker by combining instruction and cajolery.

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SESSION VI

Conclusions

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Report of the Rapporteur

I was given a broad specification not of the performance type, for the service I was expected to render as your general rapporteur. Since it was broad and in no way quantified, the product which it calls up must naturally be assessed on the basis of judgement. The only difficulty is that the product will have been delivered, irrevocably, before any judgement is possible. This is, perhaps, one of the hazards of the performance approach also.

If, as some of you have already said to me, it is difficult to know what anyone can now contribute by way of a general report, I can sympathize with your point of view. We have had two excellent opening addresses which reviewed very ably many aspects of the performance concept, particularly as it has developed in the United States. We have had the opportunity to read the papers and we have had six very excellent reports from the rapporteurs. We have had in addition many hours of discussion over the past three days, including those very pleasant informal discussions which are one of the great bonuses of meetings such as this.

What am I to do in 30 minutes? I have not been able to read all the papers carefully. I have not understood all that I have read; I do not now remember all that I understood at the time. I took copious notes which I have condensed, until they have lost their original impact. Having reached this point, I recalled a true story from my University days. It has to do with a student taking a course in French literature which he had not taken seriosly until shortly before the examinations were to be held. He had not yet read all the assigned books in French and was finally disposed to do something about it. Being a resourceful and persuasive person, he talked the reference librarian into finding for him the English translations of the French reading assignments. The little lady librarian worried most of the night about the ethics of what she had done but was very provoked the next morning when the young man returned to ask if there were not summaries of the books because he did not have the time to read the full length versions, even in English.

I did not intend to draw a moral from this story. I have been somewhat more provident than the student in my story. I have spent many days putting down my own analysis of what it is we really do in general terms when we attempt to design and construct a building. I had hoped to combine some of this with other material drawn from the presentations and the discussions here. Clearly, however, we must at this point avoid plunging back into detailed discussions. The rapporteurs have given us excellent reviews of the many papers and it would not be useful to repeat these, apart only from some selected portions. As I have thought about this, it seemed to me that we badly need some basis for organizing the information and the many points of view which have been presented. Indeed, a few speakers have emphasized this need. We have also had difficulty in agreeing on some ideas and definitions which suggests that perhaps we could with benefit go back to first principles, so to speak. So let me begin.

It is now quite evident that this Symposium has been a tremendous success. It promised from its inception to be unusual, since it marked a joint effort by three great organizations to promote an international meeting in this country on a subject related to the field of building and construction. This did not, however, guarantee greatness since the success and significance of any conference depends critically on the response to the opportunities presented and to the resulting benefits.

The subject selected for the Symposium has served us well. It has attracted international attention, and it has brought together a distinguished group of people with widely differing backgrounds and interests to consider some vital aspects of building. The success of this Symposium does not now depend on what we conclude finally about the performance concept itself. It has led us to serious discussion of the important matter of the nature of the building design process in a way which has never previously been equalled in history. We shall have made substantial progress if we can now agree that we have significantly advanced our understanding of it.

Some eighty-two (82) papers have been reviewed and discussed under the four subject headings of Buildings, Experiences and Examples, Components, and Materials, in that order. While these rather arbitrary divisions have served very well to provide a reasonable grouping of similar papers, they have posed the rapporteurs with some difficulty in their efforts to bring their respective group contributions into focus on the main theme.

In the traditional building roles it has been the owner's prerogative to say what his requirements are, and the task of the designer, whether he be one man or, more commonly today, a group of professionals, to devise a total solution matched to the owner's requirements. It has also been the designer's responsibility, as the owner's agent, to describe his design in drawings and specifications so that a clear basis is provided to judge what is to be supplied and what the firm price will be. The contract documents often name specifically the materials, form, and methods to be used. The performance concept has relevance in the context of these traditional procedures.

The concept itself is very simple. It involves identifying and describing what the building or the component or the material must do, leaving it to others presumably more knowledgeable or more skilled than the designers to offer solutions which in their opinion will perform as required.

1. Requirements at the Building Level

Much has been said about user requirements and their relevance and importance in the application of the performance concept at the level of complete buildings. Those who are concerned largely with public buildings, including public housing, tend to argue that user requirements and human requirements are one and the same. Others recognize that there are also owners as well as occupants, and that the occupancy served by a building may include pigs, products, and processes whose requirements may differ from those of people.

Buildings are always constructed to serve the objectives of some owner. This owner may be an individual or a private or public body of some kind. The purposes to be served may vary from the provision of a private residence to be occupied by the owner to the accommodation of a commercial venture or a public activity. There will thus always be owner's requirements associated in the first instance with the owner's objectives in constructing the building. They will include considerations of size, cost and levels of quality and amenity related to the requirements of the particular enterprise which is the primary reason for building.

Also included under the owner's requirements, but recognizable as a group, are the requirements of the occupancy. It may be a deliberate choice on the part of the owner to accept the consequences of some compromise in the conditions provided. Thus, the requirements of the occupancy may have to be reconciled with the owner's objectives. Human requirements may be regarded as part of the occupancy requirements to the extent that people are involved.

There is a third group which may be called socio-political requirements and which includes all regulations imposed by governments in the interests of safety, hygiene, control over the use of land, and other restrictions on the rights of individuals for the greater good of the community or the state. It is not entirely inappropriate to include social and political influences, which, though not imposed in any mandatory way, might still be sufficiently strong so that they have the same effect. These might include cultural matters, such as aesthetics, religious beliefs, and local customs.

All of these considerations taken together lead to a set of requirements for the building as a starting point for purchase of an existing building or for the design and construction of a new one. It has become evident in the course of the Symposium that in some languages, notably those of Scandinavia, the literal translation of "requirement" means mandatory or required by law. A broader interpretation is intended here.

2. Specification Levels

The owner has the right to say what he wants and also has the need to exercise control over what is to be provided. He is faced with much the same problem as any purchaser, apart from the fact that the product he wishes to procure is large and complex and in most cases has yet to be designed and constructed. He must declare his requirements in a specification of some kind. If he proposes to act as his own purchasing agent in the purchase of an existing building, the specification must be appropriate for the owner-supplier level. If the building is to be designed and constructed by others for the owner, there must be specifications to serve at the owner-designer level and at the designer-supplier level. One can think readily of other levels involving the contractor, trades contractor, materials supplier and manufacturer, but these are not of primary concern here, though all can have their own special features. The formal and detailed specifications produced at the architect-supplier level, supplier in this can being interpreted broadly, are the ones which are the most familiar and most commonly prepared in a formal way, often serving most of the other levels.

There is no reason to dispute the idea that the requirements for any building should be identified and set out clearly. There is the specification of the owner's requirements which may have to be established with the help of the designer at the initial stage of his commission. Since the need for compromise in the final solution must always be expected, it is desirable to allow as much flexibility as possible, and this in general can be achieved by formulating requirements in performance terms. It would be foolish, however, to ignore requirements which are already firmly set out or committed in positive terms allowing little freedom of choice. These must be accepted, at least initially, until evidence gathered in the course of the design forces a reconsideration of them. Together with the more flexible conditions imposed by the requirements formulated in performance terms they become the bounding conditions for the design problem.

3. The Nature of Specifications

There is an important characteristic of specifications which has relevance to the level at which they are to be applied. This is most easily shown by reference to a normal product-procurement specification. A general delineation of what is wanted, in either prescriptive or performance terms or both, can be given in the invitation to offer a product and to name a price. When all offers with their product descriptions have been received the purchaser may then make a choice. He can select the product at the lowest price which meets his stated requirements. If he is going to do this he must make very certain that he has included all relevant requirements and that these are stated in unambiguous measurable terms, otherwise he may be forced to accept a product which he does not want. More often, however, the quotation requisition will not be complete, and the prospective purchaser reserves the right to decide, even changing his views if he chooses on what he wants the product to do, after he sees what is available and at what price.

Clearly, it is possible to procure products quite satisfactorily on the basis of broad statements of requirements, so long as there is an adequate response from suppliers and there is no penalty involved in postponing any further commitment as to what is wanted until the offers have been made. There are, however, situations where the penalty for delay may be severe. There are others where the requirements may already be closely defined and ought to be recognized at the outset. It may be noted that prescriptive specifications may also be broadly stated.

4. The Designer-Supplier Level: Specifying Components

When we wish to buy a single component for an existing building or automobile, it must be compatible with the remainder of the system. In the words of systems engineering, it must provide a proper interface, not only geometrically but also functionally. That part of the specification of the new part which is needed to ensure interfacing must define clearly what is wanted. When performance terms are included they must be framed with a clear recognition of the bounding conditions established by the interface requirements.

The preparation of component specifications may be regarded in part as the delineation of components to fit particular preconceived or pre-selected bounding conditions. The designer must define the boundaries or interface conditions for various components. To fail to do so forces the supplier of each component to guess what the interface conditions for his product or component are likely to be, with consequent confusion.

Freedom to make changes in the bounding conditions cannot be given to the supplier without reference to the designer. He may ask for changes, but whatever is done must be closely controlled by the designer who must ensure always that it is consistent with the over-all requirements. The reasons for this are bound up in the nature of the design process.

5. The Design Process

It hardly seems necessary to elaborate on the design process, but a few pertinent aspects of it merit comment. The first is that there are not just two levels of consideration, the component and the total building, there are interface compatibility considerations of various kinds at various levels and also as between components at the same level. These can seldom be dealt with independently, since what is tentatively committed at one point may be found to have serious effects elsewhere in the system. All design decisions may have to be re-appraised, and if necessary readjusted, in the light of subsequent decisions. It is in the handling of this highly inter-related total package of design considerations that the principles of systems engineering may be able to make a contribution in assisting with the development of more rational and systematic procedure for building design.

Regardless of the method by which the ordering of the decision-making is accomplished, there always exists the need to know as much as possible about the effect of each decision or choice at the time it is made. There can be no escape from this if design is to be carried out in a rational way.

These essential features of the design process provide a strong basis for arguing that there must be an overall design solution devised by a central design authority and sufficiently well developed so that it provides the necessary guidance to all suppliers. It must provide assurance that the outcome can be controlled so that it will be an acceptable solution to the owner's requirements. The possibilities for applying the performance concept may now be assessed against this background. It seems necessary to assume that the need for a central design control capability eliminates the possibility that the owner's requirements stated in performance terms can be used to provide much direct guidance to the component supplier. Correspondingly, component specifications, whether written in performance terms or not, must always be related to the bounding conditions for that component hich are established by the design. There may be limited possibilities, therefore, in the se of broad performance specifications if as a consequence there is a delay in defining ome essential feature of the component to be provided or a need for costly design changes.

It is not evident, however, that the use of performance requirements in component pecifications properly devised to take account of the bounding conditions is in any way nvalidated by the discussion to this point. Their merit must be assessed on the basis of nother important issue, which is the extent to which the performance of the range of components offered under any given specification can be predicted in advance of incorporation n the building. There is little point in calling up a novel solution if it cannot be valuated as to the probability that it will perform as required.

6. Tests, Standards and Prediction

The ability to design in any rational way is strongly dependent on the ability of the esigner to predict the outcome of his design decisions. Without this, decision-making is educed to the level of tossing a coin, and everything committed on such a basis becomes an xperiment, the outcome of which is in doubt.

The ability to predict grows out of knowledge. This may involve conscious consideration of known cause and effect relationships. Predictability may also arise out of direct r parallel experience or out of judgement, which encompasses also the possibility of xploiting related knowledge as well as a vast store of information of all kinds. When irect knowledge is adequate, predictability may be provided on the basis of a few simple ests to define basic properties for use in calculations. Correspondingly, when directly pplicable experience is available this may be used as a basis for prediction. Another way s to establish a test situation which represents the proposed use situation and to make bservations. This may be regarded as a kind of contrived experience on demand, and when xtended to include systematically arranged series of tests it becomes research. There is danger, however, that when knowledge is lacking it may not be possible to tell when the xperience is relevant. Standards covering such tests for various kinds of performance equirements have been devised. They have, however, some serious limitations which must lways be kept in mind.

The most obvious approach to a performance test is to attempt to reproduce the use onditions anticipated. Since most conditions of service are variable, and often highly so, rom one application to the next, it is seldom practical to consider any widespread exploration of the full range of possible conditions in the test employed in standards. Normally uch tests provide for evaluation of an operational or functional characteristic under test onditions carefully selected to provide a suitable way of comparing a range of products one ith the other. There must be due consideration for reproducibility and cost, and the value f the test results in making the necessary final judgements of the performance under the eal use conditions of specific applications.

Since it is the end result and not the means of achieving it which is important, it is uite proper to use any and all possible means of achieving predictability. Great advantage an be taken of known relationships between particular factors or properties and certain erformance characteristics. Where a strong correlation is known to exist it may only be ecessary to measure the property involved and to judge the related performance characteristic accordingly. A good example is provided by standards for concrete unit masonry for hich a reasonable correlation exists between compressive strength and several other esirable properties. Thus, the prime requirement in most standards is based on this roperty, but it is by no means true to say that other properties related to performance ave been ignored. Unfortunately, this lack of appreciation of the real nature of standards as given rise to much criticism.

It is not possible to tell from the items included in a standard whether or not it alls up a product with good performance characteristics, unless one also knows the extent f the correlations which exist between the factors which are specified and the properties hich are wanted. Great benefit could result by adding to all standards a statement setting ut in general terms the kind and level of performance in use which they can be assumed to over.

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These fundamental aspects of standards and the prediction of performance raise most interesting questions on what constitutes a performance standard. It can now be seen that it is not essential to deal with readily recognizable performance parameters in a standard design to call up products which will provide a reasonable probability of a given level of performance. A prescriptive type of standard may well call up a product having the desired performance characteristics, while a product standard, for example on vinyl floor tile, may consist almost completely of performance requirements, such as strength, hardness, slipperiness, and wear-resistance.

Standards can never be the magic device which somehow will resolve all problems of specifying and evaluating products in terms of performance. They are at best only aids, although essential ones, which must be well understood by the designer. He must know or be able to judge how closely the product standard or the test method selected will meet his requirements. Performance tests will not resolve these difficulties since they are not clearly distinguishable from other kinds of measurements which can be used in conjunction with knowledge and judgement in support of prediction and evaluation.

The challenge to the designer is greatest when he must frame performance requirements in clear and definitive terms as a firm and complete basis for procurement. His immediate problem is much easier if he can set out his requirements in a general way leaving final judgements to be exercised on the basis of what is offered at the time of procurement. This delay in deciding on what is to be provided is not always acceptable and can have serious implications for the development of a total solution, competitive bidding, and the control of the procurement process. It can only be justified if in return a wider choice leading to improved solutions is possible.

Performance specifications are inherently of a type which invites a broad choice of solutions, while prescriptive specifications are usually quite specific. These characteristics are not exclusively related, however, to one or the other type. The prescriptive specification is usually appropriate when there has been a fairly firm decision on what is wanted, at the time of preparation, leaving only the question of which product will meet the requirement. The performance requirement, on the other hand, may not attempt to visualize the solution in any detail and thus makes it necessary for the designer to exercise judgement at the procurement stage. He may, of course, attempt to incorporate in his specification the aids to judgement, such as the test methods, criteria, and standards which he himself will use. He cannot avoid, however, the need to exercise the final judgement that what is called up in this way is in fact satisfactory. Incidentally, there can be some confusion because of the multiple roles of tests and standards as instruments of standardization and communication as well as aids to judgement and elements of specifications as just described.

The need to include means of measurement is normally associated with standards for regulatory and procurement purposes where it is desirable to have clear and unambiguous means by which conformance with the requirements of the standard can be determined. This requirement is commonly associated also with performance standards since it is hoped that in this way the need for final judgement will be avoided. Some thought will show, however, that all that can be done is to substitute the judgement already incorporated in the standard of those who prepared it but who could not know what the particular application involves. If, as is frequently proposed, the exercise of some judgement at the time of procurement must be accepted, there is then no compelling reason why performance requirements framed in descriptive terms should not also be accepted.

Let us now go back and view the design-procurement system as a whole. We can recognize three sub-systems, that is, three parts which can usefully be thought about as entities for some purposes. They are designated in Fig. 1 as Owner, Designer and Supplier, these words being used to identify these three groups of considerations. We cannot, I suggest, break the system down much farther if we wish the model to be a general one. We can, on the other hand, using it, begin to fit together most of the things that have been discussed at this Symposium.

The papers reviewed by Mrs. Saeterdal relate almost entirely to the Owner's Requirements. They have dealt with the identification and elaboration of human requirements, and the philosophy and methodology of establishing performance requirements for buildings.

The papers reviewed by Atkinson ranged across all three sub-systems and their interfaces, from codes and building and component performance appraisal to the philosophy of the various levels of application of the performance concept. The same was true in part of the papers reviewed by Allen dealing with experiences in the application of the performance concept. The materials and components discussed in Sessions IV and V can be regarded in the first instance as being in the supplier domain. However, the evaluation of them and particularly the manner of specifying are strongly related also to the design function and to the designer-supplier interface.

Allen, recognizing the need for some structuring of the discussion proposed four points which we may identify briefly as Organization and Knowledge, Legal, Education and what he called Process. Later a fifth, Political, was added. All except the last, which can be regarded as both an owner's and a designer's concern, relate strongly to the designer role and emphasize its dominant position.

If we accept the proposition that the designer's role is indeed a central one and that it must provide a strategy, if not an overall design solution, we must accept also the need for control of the outcome to the satisfaction of the owner's requirements. It follows from this that there must be a capability to predict and to evaluate behind every step in design and procurement. The supplier may require much of this kind of competence to be applied in his own interest, but the overall responsibility must rest with the designer and his role. He is the practitioner, a member of a profession, recognized under the law as one who is competent to provide professional judgements, with the limits of his legal responsibilities already defined. I speak loosely here of the designer as one man, for simplification. There may commonly be several, but regardless of this the work of all must be combined in a single overall design for the building.

There is no way of avoiding the need for the designer to know as much as possible about what is involved at the time design decisions are made. It is not acceptable to regard knowledge, essential for prediction, in the same way as product data, to be called up on demand. There must be a strong core competence on the part of every designer.

Thinking further about Allen's four points, there is a great need today to exploit for the benefit of all, those unplanned, unwanted experiments in which industry engages every day to the extent of fifty or more times the official expenditure on building research. The responsibility to collect, collate and communicate essential knowledge, including that gleaned from experience, is the attribute of a learned profession, and is one which must be assumed by the building design professions. This brings us finally to education, which can and must be fitted to the overall pattern. There is need for the development of an adequate knowledge stream to serve all other levels in the building industry and this must be fed and promoted by the profession or professions.

It all fits so well into an overall pattern, providing a strong indication of the direction in which developments must take place. No other aspect of building requires change so urgently. Many of the difficulties we have talked about can be seen against the background of this necessarily long range objective to be symptoms, not the ailment itself.

7. Conclusion

It must be concluded that the performance concept makes no fundamental change in the problem of design for performance. Knowledge and understanding on the part of the designer are the basic and critical factors. The performance concept is useful if it can promote order and rationality in the design and procurement processes and can bring increased resources of skill and knowledge to bear on them.

It was stated at the outset in this paper, and may now be repeated, that this Symposium has been one of the most significant ever held to consider building and construction. Further questions about the performance concept must now be answered in the light of continuing experience in its application. This Symposium has, however, become involved in something even more important, since the fundamental issues we have been discussing really relate to the nature of the design process and, indeed, to the very nature of knowledge itself.

The full benefits of this Symposium have not yet been realized. It is unlikely that any of us has been able to study all the papers in depth. These together with the reports of the rapporteurs and the discussions which have taken place constitute a formidable body of material which will only be fully exploited over many months and years to come.

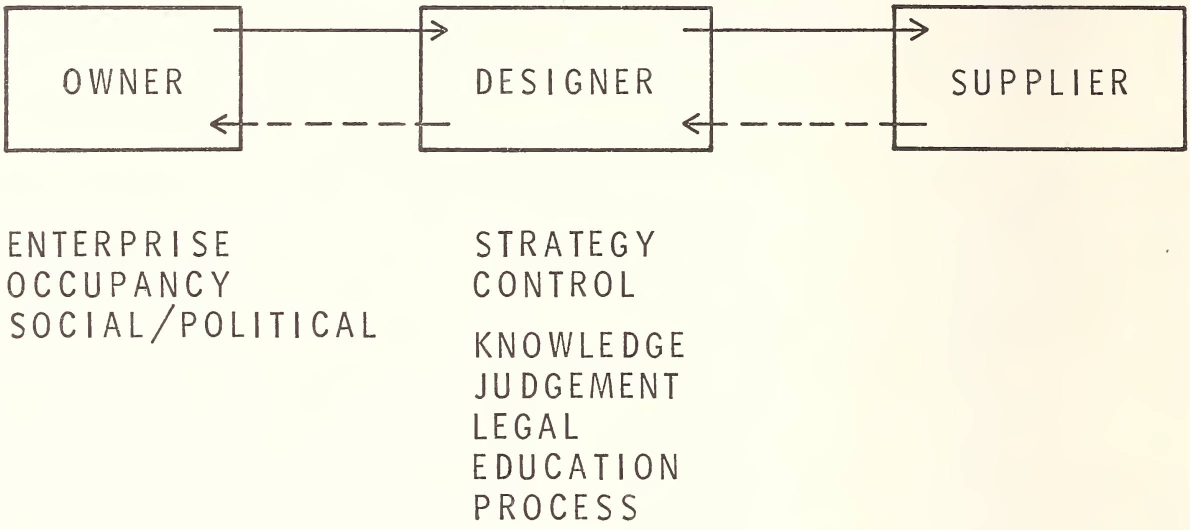

FIGURE 1 THE DESIGN-PROCUREMENT SYSTEM

Chairman

During these meetings several of those present have asked if plans have been made for another Joint Symposium on the Performance Concept sometime in the future. The answer is that as of now no consideration of another symposium has taken place - we have been too busy with the present one. The questions, however, have led the Symposium Committee to request three of its members to make brief statements about the present and future work on the Performance Concept by the sponsoring organizations that each represents. These are presented here:

For RILEM - Tenho Sneck, Chairman, Advisory Group of RILEM

RILEM Philosophy

The Advisory Group of RILEM has discussed the need for a working philosophy to be applied in the future work of RILEM. The philosophy ought to be reviewed from time to time.

The promotion and application of the performance concept in the work of RILEM is considered most important in this connection. The AG has discussed the performance concept on several occasions. Without trying to give any very specific definition to the concept, the AG believes that the performance concept is a dynamic method which allows the study of building projects as a whole by evaluating the logical succession of the goals set, and the relevant attributes of the solution, at each stage of decision making. The goals can be, for instance, human, operational, economic, or legislative, and the relevant environmental factors have to be taken into account. In the application of the performance concept, all factors which affect the performance have to be optimized. The compatibility of the whole set of decisions taken has to be checked. Practical experience will give the needed feedback and regulation.

The performance concept is a method based upon the wholeness of the treatment. The whole solution, e.g., a building, is taken as the starting point, and it is then divided into sequences going into details, e.g., materials.

More important than the mere definition of the concept is the development of methods to apply it in practice. This could be judged as the most important aspect of RILEM in this field.

When the levels of building, i.e., building, component, material, are considered, the AG believes that the level of materials is the main responsibility of RILEM. As the materials requirements are not independent of the requirements at higher levels, the requirements at the higher levels have to be taken into account.

However, it seems that the role of RILEM would be best taken care of if the RILEM activities would be generally concentrated upon the lower levels (materials and products) of a building. The main focus of effort has to be concentrated on the development of evaluative techniques. This has to be kept in mind but it seems that RILEM also has to make efforts to develop evaluative techniques which may be useful in the development and design of materials and products (components). The approach would then be innovative.

Because of ecological and other environmental reasons, as well as the scarcity of raw materials, RILEM has to develop certain methods and techniques connected mainly with the general building materials policy. These activities ought to be concentrated on efforts to aid the decision makers.

The attempts to create a working philosophy for RILEM will lead to the listing of some priority areas. As examples could be mentioned:

1. The identification of fields where the development of performance evaluative techniques are needed.

2. Investigations on the dependence of performance characteristics on basic parameters.

3. Investigation of psycho-physical "properties". This means, in all probability, the development of certain reference series or standards.

4. Investigation of the time factor in the life of building products.

5. Building materials policy.

Looking at the proposals for new working groups, the AG feels that the philosophy outlined above is already functioning.

Table 1 gives the outlines for the work concerning evaluative techniques and Table 2 a list on the proposals made to the AG concerning possible objects for the work of RILEM.

Table 1. Evaluative Techniques

Identification of fields where development of evaluative techniques is needed.

Dependence of performance characteristics on basic parameters.

Investigation of psycho-physical properties.

Time as a factor in the life of building products.

Table 2. AG Proposals at the Meeting of the Permanent Committee of RILEM in Washington (1972) for Possible RILEM Activities

PERFORMANCE

Testing and evaluation of external vertical surfaces of buildings.

Testing and evaluation of moisture insulation materials.

Testing and evaluation of thermal insulation materials.

MATERIALS POLICY

Reuse of materials (use of waste materials).

Evaluation of materials found in the sea.

DEVELOPMENT

Composite materials, interface problems.

Synthetic silicates.

Technology of precast concrete components.

SPECIAL PROBLEM

How to destroy concrete?

GENERAL

Education of materials scientists and engineers.

For CIB - Øivind Birkeland, Vice President, CIB

Within CIB the performance thinking has, as I said in my opening statement Wednesday, been very discernible even if the word performance has not always been used. Several of the CIB working commissions are using performance thinking in their work.

About one and a half years ago a special working commission on the performance concept was organized, (CIB W 60). The Terms of Reference for this Working commission are:

1. To provide an overall conceptual framework for a performance approach to building - identifying various levels - but initially dealing with houses and with components used in the construction of houses and other types of building, and the area between, and to keep this in review as work proceeds.

2. Drawing on national contributions, to prepare within the space of one year an agreed-upon terminology and a commentary on the existing situation, including use of performance specifications, difficulties in application, etc.

3. To agree, in conjunction with W 31, what attributes and parameters would be included in the various levels and to provide a commentary on why and how these were being set.

4. To provide a forum for the continuing exchange of experience with methods of assessment and test or calculation with a view to achieving international consistency (and possible future standards).

5. To set up and coordinate the activities of specialist subgroups dealing with particular areas of performance.

6. To carry out any necessary liaison with the Agrément Union, RILEM, and ISO for work in the performance field.

7. To prepare a statement for issue at the next CIB Congress declaring CIB initiative in this field.

The commission has set up a small subgroup with the aim of reaching an agreement on definition of the Performance Concept and the most necessary terminology. A list of corresponding terms in different languages has been prepared (among them English and American English). It has, however, proved difficult to formulate definitions, the reason being that the terms, even if they are corresponding, are not synonyms.

The working commission has started to develop performance specifications for the following parts of a building: Exterior walls, floors, roofs, partitions, windows, doors, sanitary installations, and interior surfaces. The performance is to be stated for each relevant property according to the master list of properties developed by CIB W 31 (will be published as a CIB publication, now in print). For each property the following is to be stated:

Requirement (qualitative in general terms)

Method of evaluation

The necessary comment for understanding and using the information

There has been discussion on whether or not another item, Stresses (to which the part of the building is subjected when fulfilling its function), ought to be inserted between Requirement and Method of Evaluation.

On the basis of documents as outlined above it will be possible to state quantitative requirements to be used for development, tendering etc. It is hoped that the work will result in more international agreement in such work. One of the more important tasks involved in the above outlined procedure is to collect available methods of evaluation and organize international cooperation on development of the lacking ones. It is hoped that this eventually will lead to some kind of international agreement on methods of evaluation.

It has not been possible yet to start the cooperative work on the performance on dwellings. It is hoped that this will be possible in the beginning of 1973. The work on the performance of dwellings will be organized in cooperation with CIB W 45. It is also hoped that work on sanitary installations can be organized in cooperation with CIB W 62.

It is important to organize liaison with other international organizations active within the field, ISO and the Agrément Union. This is now taken care of through members who are active both within CIB W 60 and one of the other organizations.

For ASTM - Rudard Jones, Vice President, ASTM

Where is ASTM going in relation to "the performance concept in buildings"? Briefly, I should say that the Society as a whole has no particular policy on this subject. At the same time I can say that certain committees of the Society will continue to be active in this field.

To clarify this brief statement it is necessary that I give a more detailed explanation on the form and function of ASTM.

There is one central thrust to ASTM activities - the writing of standards. These standards take the form of standard methods of test, standard specifications, standard definitions, and standard recommended practices.

These standards are <u>not</u> written by the Society as a whole, but rather they are written by individual committees. Each committee pursues its standards writing activity in its own way, limited only by its scope and by the general procedural regulations of the society. In fact, the best description of ASTM is that it is a confederation of "tribes" working more or less independently to produce the Society's product - standards. At the present time there are 110 "tribes" participating in the work of the confederation. The Society has 22,000 members - but when individuals that are working on more than one committee are accounted for, there are, in effect, 45,000 members participating.

Let me go back to the original question: "What is ASTM going to be doing about the performance concept in buildings"? I shall try to answer this in the context of committee activity.

> Committee E-6 - <u>Performance of Building Constructions</u>.
> Those of you that attended the preliminary Research Review session sponsored by Committee E-6 are well aware of this committee's interest in measuring performance.
>
> Committee E-5 - <u>Fire Tests of Materials and Construction</u>.
> The primary activity of this committee, as indicated by its name, is the measurement of building and building material behavior under fire loading.
>
> <u>Other Committees</u>
> Many other so-called "materials" committees have performance criteria as part of their standard specifications.

It is clear, then, that ASTM will continue to be active in this sector of the performance concept.

<u>Chairman</u>

This concludes the final technical session of the Joint Symposium on the Performance Concept in Buildings. It is gratifying to note that such a very high percentage of the registrants are still in attendance on this Friday afternoon. I think this is an indication of a highly successful meeting, and I would hope that our host's farewell wine and cheese party to which we are now adjourning is not a significant factor (delightful though it will be) in the sustained Friday afternoon interest.

ERRATA (Volume 1)

Page 80

At the end of the first paragraph add the following sentence: "This project was carried out under the direction of Michael Brill and Richard Krauss."

Page 193

Second paragraph, line 6, read:
"...analysis.), there..."
instead of "...analysis.). There..."

Third paragraph, line 4, read "...can be used for. An object which is said to have a function by virtue of its own behaviour is said to have an intensive function) are essentially probabilistic."

Page 359

Last paragraph, line 4, read "...Eberhard[(1)]" and add a footnote:
"(1) Dean, School of Architecture and Environmental Design, State University of New York at Buffalo."

Page 362

Change footnote to read: "PBS Building Systems Project Status Report, NBS No. 9668, published at the National Technical Information Service, U.S. Department of Commerce."

Page 371

Add a final paragraph reading: "The principal authors of the PBS Performance Specification, Messrs. Robert W. Blake, Michael Brill, and David B. Hattis, should be recognized for their contribution to this paper."

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