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Durability of Insulating Glass

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Proceedings of a Seminar on the Durability of Insulating Glass

Held at the National Bureau of Standards Gaithersburg, Maryland, November 14-15, 1968

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

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Abstract

A two-day seminar on the Durability of Insulating Glass was attended by some 130 persons on November 14 and 15, 1968. The seminar was held at the Gaithersburg, Maryland, facilities of the National Bureau of Standards and featured fourteen speakers who participated in panel discussions or delivered individual papers. Numerous agencies interested in design, manufacture, specification, purchase, installation or maintenance of windows were represented at the seminar.

Among the topics considered in the panel discussions were: (1) The need for reliability and durability of insulating glass; (2) manufacturers' test methods; (3) proposals for future action. The Canadian experience with an accelerated test method and acceptance program was presented and discussed, as were the Norwegian accelerated test methods and their correlation with field experience. A review of current practices leading to new test methods and standards was also presented, and a "round robin" program that would compare various test methods now employed in the industry was proposed. Affirmative interest in participating in the proposed round robin was expressed by about a score of manufacturers present at the seminar.

Key words: Accelerated laboratory tests; double-glazed window units; factory-sealed insulating glass units; field performance tests, correlation with laboratory tests; sealant performance; test methods; standardized testing.

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Foreword

The use of factory-sealed double-glass insulating units is increasing in both Government and privately owned buildings. Seal failure on some of the units leads to moisture penetration of the air space, with ultimate fogging and loss of clear vision through the unit. Such failure is of concern to users, fabricators, and specifiers of insulating units.

To provide a first forum for exchange of information and suggestions for assuring improved seals, the National Bureau of Standards jointly with a subcommittee of ASTM Committee E-6, and with the Building Research Institute and the Construction Specifications Institute, Inc., sponsored a Seminar on Durability of Insulating Glass, held November 14 and 15, 1968, at Gaithersburg, Maryland. Registered attendance totaled about 130 persons, including contingents from two other countries.

This publication contains the proceedings of the sessions of the Seminar, and the texts of thirteen papers or panel presentations contributed at the Seminar.

Lewis M. Branscomb, *Director*

Contents

Contents (continued)

Proceedings of a Seminar on the Durability of Insulating Glass

Introductory Remarks

James R. Wright[1]

**National Bureau of Standards,
Washington, D. C. 20234**

Introductory remarks were made by the author to the attendees of a seminar on the Durability of Insulating Glass. The National Bureau of Standards Building Research Division was a cosponsor of the seminar held at the NBS on November 14-15, 1968.

Key words: Accelerated testing; insulating glass units; standardized testing.

Gentlemen: In welcoming you here to participate in the seminar on Durability of Insulating Glass, of which the National Bureau of Standards is privileged to be a co-sponsor with ASTM Committee E-6, the Building Research Institute, and the Construction Specifications Institute, I am much impressed that one type of product, among the hundreds that compose the fabric of a building, should receive such manifest attention and consideration, looking toward improved durability in service applications. That is not to say that many other products might not also benefit from similar attention; I point out simply that in the case of insulating glass units, a worthy and necessary step forward is being attempted here and now. I wish you success and effective action in this direction.

The seminar program is designed to bring you contributions from architects, builders, and large users of insulating glass. The contributions are from: four sources primarily concerned with testing methods for evaluating units; four sources of similar interests as producers of units or component materials; and one source from a leading manufacturer of windows who is well aware of his dependence, and the dependence of his customers, on the quality of insulating glass units that he can incorporate in his finished product. These contributions will be made richer by those from highly respected laboratories of two other countries—from the Division of Building Research of the National Research Council of Canada, and from the Norwegian Building Research Institute. It is gratifying to have representatives from these organizations here, and we welcome them cordially.

With the wide spectrum of information that will be put before you, we can be encouraged as to the prospects for useful action stemming from this seminar. Nevertheless, one must not expect automatic success. As I visualize it, yours is one of the more difficult of technological tasks—to ascertain, on a sound and reliable basis, by means of accelerated laboratory tests, in as short a time as possible, the prospective durability in service of sealed insulating glass units. The goal, of course, is assured, satisfying performance for periods up to or beyond the expected life of a building. The fact that this seminar has been convened, and so well attended, attests that this goal has not been generally and adequately met at this point in time.

Speaking now as Chief of the Building Research Division of the National Bureau of Standards, I can say that the Division has had considerable experience in accelerated tests to ascertain durability of building materials in service, and we know something of the problems, and the efforts needed to solve them. One instance that may be cited is a project undertaken to study the durability of asphalt roofing materials, accomplished by means of a research associateship sponsored by the Asphalt Roofing Industry Bureau, research programs sponsored by NBS, and related projects sponsored by other Federal agencies. We have learned much from this combined research effort, and have replaced tests requiring months to produce qualitative data with tests that yield quantitative results in a few hours. The Materials Durability Section of the Building Research Division conducts studies on the durability of plastics, organic coatings, polymeric coatings, metals, and inorganic building materials. However, time does not permit more than a mention of this fact.

[1] Chief, Building Research Division.

Out of this experience, I would suggest to you that a concerted effort by your industry, however or whenever launched, would be the most promising course of action. It is interesting that the program of certification established by Sealed Insulating Glass Manufacturing Association could be a nucleus for such an undertaking, provided that developmental or evolutionary research was given ample support.

In closing these introductory remarks, I would like to mention an important practical matter that must be well appreciated among you. The cost of laboratory testing of one manufacturer's lines of sealed insulating units is at present quite considerable, and the testing capability required to test all manufacturers' products in a reasonable time does not exist at present. There is, therefore, an urgent need to develop standardized testing methods, and apparatus capable of standardized testing of large numbers of units, effectively, uniformly, quickly and at lowered costs. I would suggest to you that contributions in this direction, that might be accomplished through the action of this seminar, would well justify it, quite apart from the cooperative understanding and concerted effort that it is hoped the seminar will engender.

Introductory Remarks

Willis MacLeod

American Society for Testing and Materials, Philadelphia, Pennsylvania 19103

Introductory remarks were made by the author to the attendees of a seminar on the Durability of Insulating Glass. The American Society for Testing and Materials (ASTM) was a cosponsor of the seminar held at NBS on November 14-15, 1968.

Key words: Insulating glass units, standards, uniform test methods.

It is indeed a privilege to welcome you on behalf of the American Society for Testing and Materials which, along with the National Bureau of Standards, the Building Research Institute, and the Construction Specification Institute is a cosponsor of this Seminar on the developing technology in research and testing of insulating glass window units in building and housing construction.

The American Society for Testing and Materials, organized in 1898 and incorporated in 1902, was formed for "the promotion of knowledge of the materials of engineering and the standardization of specifications and methods of testing." There are about 16,000 members in the Society and 100 main technical committees which develop standard methods of test and specifications for materials and products and recommend practices. The Index of ASTM Standards lists more than 4,000 standards and specifications covering the materials of engineering. These are developed under procedures representing a consensus of the producing, consumer, and general interest participant in the technical committee having jurisdiction for the standards. For this reason, a large majority of the present U.S.A. Standards was developed by ASTM.

The Durability Task Group, Subcommittee VIII of ASTM Committee E–6 initiated the Seminar.

Our distinguished Chairman of the Seminar Committee, Mr. McKinley, is a member of ASTM Committee E–6 on Methods of Testing Building Construction which originated and has spearheaded this project presenting to you a program of knowledgeable and competent authorities including our colleagues from Canadian and Norwegian Building Research on the subject of double glazed window unit durability. It is our expectation that these presentations and deliberations will lead to the development of uniform test methods for measuring in meaningful terms the serviceability and durability of insulated glass units in order to insure levels of serviceability commensurate with the several types of building construction in which they are used. ASTM is organized and stands ready to respond to any conclusions resulting from the Seminar.

1. Panel Discussion I

Introduction of the First Panel

Robert W. McKinley

Thank you, Mr. MacLeod. Mr. MacLeod's realization of the need for this Seminar helped very much to get things launched and to obtain ASTM sponsorship.

I hope that members of the Building Research Institute and of the Construction Specifications Institution will understand if we do not take time now to detail their help. We do appreciate their sponsorship. The program now is under way. You will find the qualifications of our first panel summarized in the biographical sketches that came in your registration packet. I call upon our first panel, the members of which are: Mr. Harold J. Rosen, Chief, Specifications Department, Skidmore, Owings, and Merrill, Architects and Engineers; Lynford K. Snell, Jr., Architect, Federal Housing Administration, Washington, D.C.; Willard Bryant, Assistant Director Technical Services, National Association of Home Builders, Washington, D.C.

Our primary target during the seminar is an exchange of information and an understanding . . . and we're starting with the consumers, the users of insulating units, in order that we may understand what they believe their needs to be and what we may do to help them satisfy those needs.

Mr. Rosen.

1.1. The Roles of Architects, Manufacturers, and Contractors in the Prevention of Early Failure of Insulating Glass Units

H. J. Rosen[1]

Skidmore, Owings & Merrill,
New York, New York 10022

Architects, manufacturers, and contractors can play distinct roles in the prevention of product failure. If each fulfills his own obligations as set forth in the AIA policy statement of a few years ago, he will be contributing to the life of the product. Another way to diminish the problem of failure would be for these three parties to join together in research for methods of preventing such failure.

Key words: Design; installation; materials failure; production.

1. Introduction

Mr. Chairman, for the next two days apparently you are going to hear a good deal in depth and in detail about the problems of insulating glass . . . and I would think that although the program indicates that I am to talk about how one gets involved with additional cost as a result of a failure of insulating glass, that I can best address myself to the subject if I speak about the area of involvement of each of us—architects who design, manufacturers who produce, and contractors who install. I think if we all understood our relationship and our responsibility, we would have an area of agreement and perhaps in that way reduce the problem.

[1] Chief, Specifications Department.

Now, where does responsibility lie when materials failure occurs? It is with the architect who selects the material, the manufacturer who produces and furnishes it, or the contractor who installs it? Each of the parties has an obligation to the owner in selecting, furnishing, and installing the product. Too many times we think only in terms of a product failure involving the product itself because of certain inherent defects. We fail to recognize that product failure can also be attributed to a poor design on the part of the architect or improper installation on the part of a contractor. Who is responsible for fogging of insulating glass when it occurs after three or four years of service? Who is to be responsible for cracking of insulating glass after the one year guarantee runs out? Architects and engineers are prone to think that their judgment is infallible and that they can do no wrong. But they should also remember that a judicial decision in a court of law will be resolved on the pertinent facts of a particular case. Thus architects, manufacturers, and contractors fare no better or worse than anyone else when they enter into contractual relationships. We cannot resolve here today a hypothetical case of who is responsible for insulating glass that has "gone sour" for one reason or another. We can join in research for methods of preventing materials failures rather than try to fix responsibility after a failure occurs.

2. Architect's Role

Now what is the architect's role in the selection of materials? When a man practices architectural engineering, he is expected to have an adequate knowledge of the science of design and construction and to exercise reasonable care, judgment, and technical skill to see that the design is properly executed and the work properly done. Court decisions have held that an architect is responsible for proper selection and application of materials, and for adequate research, and that reliance on advertising literature of the manufacturer or other representations of the manufacturer, do not necessarily protect the architect. About two or three years ago, the AIA issued what it calls a policy statement on building product development and uses, and it makes the following observations concerning the obligations of each of the parties: Now first, with respect to what the architect is obligated to do—He is expected to inform himself with respect to the properties of the products he specifies, though he is entitled to rely on manufacturers' written representations. He is advised to seek the technical opinion of the research or application engineering departments of the manufacturer when his intended use is not clearly included in the printed data of the manufacturer. He is further responsible for uses contrary to supplementary written information on proper use in installation procedures of the manufacturer. The architect's use of a product and its installation should extend to its compatibility with and relationship to adjacent materials and assemblies, notwithstanding the manufacturer's similar obligations. Now the AIA hasn't any guide rules on what to do when we are confronted with two major insulating glass manufacturers, each advocating a different method for installing insulating glass in a structural neoprene gasket. Perhaps if you want to ask me separately what I think about it, I'll give you that kind of information.

3. Manufacturer's Role

Now how about the role of the manufacturer? The AIA in the same policy statement suggests that manufacturers be guided by the following rules: The manufacturer should supply the architect with all essential data concerning his product, including pertinent information which would involve its installation, use, and maintenance. Particularly important is information on the product's compatibility and interfitting with interrelated products, as well as precautions and specific warnings on where the products should not be used, based on conditions of known or anticipated failures. Whenever the manufacturer has specific knowledge of a new proper use of his product, he should furnish such information in writing to the architect. The manufacturer is expected to recognize that he is responsible for the failure of his product to perform in accordance with his written data supplied by him or his authorized representative, as well as for misrepresentations of such data. And, finally, the manufacturer is expected to investigate the relationship of his product to other components likely or logically expected to be used in association with his product. Such information should be available to the architect.

4. Contractor's Role

Now, how about the contractor? A contractor's basic responsibility is to perform substantially according to the drawings and specifications set forth by the architect. A contractor who has, in fact, performed substantially and built the building accordingly, would be absolved from any legal responsibility.

Now the AIA policy statement sums up the contractor's obligations as follows: It is the responsibility of the contractor to inform himself concerning the application of the product he uses and to follow the directions of the architect and manufacturer . . . and in the event of disagreement, between the contract documents and the manufacturer's directions, the contractor is expected to seek written instructions from the architect before proceeding with the installation.

If the contractor has knowledge of, or reason to believe the likelihood of a failure, he is expected to transmit such information to the architect and ask for written instructions before proceeding with the work. This policy statement outlines the AIA's position.

5. Conclusion

Today's sophisticated construction techniques and esoteric materials require knowledgeable persons on the staffs of architectural, manufacturing, and construction firms. These skilled people must be able to cope with the problems related to building products and their incorporation into complex designs. To reduce the problems the following do's and don'ts are suggested as a guide to selecting materials and reducing the possibility of a materials failure.

Do be certain that the manufacturer knows how his material or equipment will be used. Don't use an unfamiliar material unless it is known to have been used successfully in installations similar to the proposal under review. Don't rely on a manufacturer's statements and claims as the only basis for using the material.

1.2. The Need for a Method to Evaluate the Performance Life of Insulating Glass Units

Lynford K. Snell, Jr.[1]

**Federal Housing Administration,
Washington, D. C. 20412**

The FHA's interest in insulating glass is growing as the product's use is growing. This agency has reviewed various specifications for evaluating units, but there is no consensus on a procedure which can be used successfully. A reliable method of estimating service life of glass units is badly needed.

Key words: Durability; test method: sealed insulating glass unit.

1. Introduction

In reviewing the docket on the subject of sealed insulating glass units the other day, I found that as far back as mid-1964, shortly after I started with FHA, several of our field offices had expressed concern and asked for guidance in selecting suitable sealed insulating glass units.

The increase in the number of manufacturers and types of manufacture, coupled with the absence of a way to evaluate the performance life of these units, amplified the need to pursue efforts toward some type of solution. This was added to our list of project assignments in March 1965.

2. The Need for a Test Procedure

FHA has reviewed various specifications for evaluating sealed insulating glass units. There were, and still are, differences of opinion on a procedure which can be successfully used. Our interest, of course, is in a procedure to measure (estimate) the service life (durability) of these units.

Large areas of glass are used widely in today's architecture, and as the consumer demands further sophistication in the control of his environment, the additional comfort provided by sealed insulating glass units will result in increased use of these products.

One generally considers glass to be a very durable building material; excluding breakage, it is one of the few products capable of lasting the useable lifetime of a building. Based on the foregoing premise, it would indeed be tragic to discover suddenly that unanticipated failures necessitate replacement.

The Methods and Materials section of FHA's Architectural Division is responsible for providing our field offices with the best technical advice possible and in many ways is comparable to the specification department of an architectural firm. When there are concerns about product performance, ways and means must be devised and measures taken to provide protection commensurate with the estimated risk.

During the next two days, we will all have the opportunity to review and discuss various methods used to measure or estimate the durability of sealed insulating glass units.

For several years FHA has been trying to determine if there is one test method for insulating glass that can be depended upon for estimating service life. If there is a margin of error in using such a method, what percentage of success can be expected? In view of the fact that there is uncertainty about an acceptable test method, we can understand why specification writers sometimes use empirical precautionary measures.

It may be advisable for FHA to consider reserves for replacement of units that fail in programs where such reserves are required. In regard to single family programs there are no reserves; consequently, the homeowner will face the expense of replacing these units on his own.

[1] Architect, Architectural Division.

3. Conclusion

Several articles have been published in recent months relative to the liability of the architect, engineer, and manufacturer in regard to building materials and systems. Who is to be placed in the position of ultimate responsibility? The architect who makes the selection? Or the manufacturer who has offered evidence of performance for his product?

The selection and use of new materials and systems could be seriously deterred by attempting to single out a source of responsibility.

It would seem to me more logical to think in terms of a team effort whereby responsibility is reasonably distributed and ultimately placed. I believe if we can show that we have exercised the best of our current knowledge in arriving at such decisions, such as by selecting an appropriate test method, then we will be able to endure criticism that may arise from our decision.

If we share an interest in development and innovation (in other words in progress), then we must share in assuming the probable risk and responsibilities of this adventure.

1.3. Problems Resulting from Early Failure of Insulating Glass Units

Willard E. Bryant[1]

National Association of Home Builders, Washington, D. C. 20034

Appropriate standards and test methods would improve the quality of insulating glass units and also the meaningfulness of manufacturers' warranties. As the situation is now, the builder is not fully protected from loss of money, time, and labor, or from loss of business resulting from failure of units even though the units are covered by warranties.

Key words: Insulating glass industry, product evaluation, product failure, warranties.

1. Introduction

I think it is important to make one comment before I get into my discussion. Much of what I have to say is equally true of many, many other building products so I'm not taking a potshot at the insulating glass industry.

The major problem with regard to durability, other than accidental breakage, is the failure of the seal with its attendant and very attention-producing element of fogging or vision-obstructing moisture. Due to limited time, I won't go into detail on the topics but I believe you can break the builder's viewpoint down into two categories involving periods of time: The first, you might call the short term, which would be the time when the house or the building is under construction or if there is a one-year warranty period. And the second, the longer term, is when the unit is under the manufacturer's warranty.

2. Failure Problems

The short term problem presents the builder with a number of questions rather than answers, and these concern how meaningful the warranties are. In other words you have a 5-, 10-, 20-year warranty . . . are these warranties really indicative of the expected life of the unit, and are there meaningful test procedures to back up these warranties? When a builder purchases an insulating unit, how does he know what he's really getting? Of course, as with any other products on the market, he pretty much has to rely on the manufacturer. Let's assume that during the time when it's the builder's responsibility, that a unit does fail. Now what can the builder expect to happen? Well typically the manufacturer will replace the unit.

This is only a partial answer because the builder still has to take it down to his dealer, bring it back, and reinstall it. Therefore, merely replacing a unit that fails does not compensate the builder for all his costs. I think this is really the most important aspect of the problem because the warranty doesn't really protect the builder insofar as his total cost is concerned, and therefore it in itself is not a completely adequate means of recourse.

Now to take the longer range aspect, where the unit is now under the manufacturer's warranty. As far as we are concerned, there is a single problem in this area. If a unit does fail say after 2, 4, or 5 years, who gets the blame? Well, I'm sitting here, and because the buyer bought the house from me, I'm responsible to that buyer. And I'll tell you, this is not a very satisfying answer to give to one of your buyers—"Well, it's not my responsibility any more, you have to go see the manufacturer." So, in effect, the builder's public image suffers as a result of this. Now I think it's important to realize for this particular aspect, that the average home mortgage today is slightly over 7 years, and this means that repeat business to a home builder is equally as important as it is to any other business, and the manner in which the manufacturer backs up his product is extremely important. I think the fact that the glass unit is typically manufactured by someone other than the window manufacturer has a tendency to compound the problem.

3. Conclusion

Now the question is: What are some of the conclusions or solutions to this problem. I have made a short list, and they are not necessarily in order of importance, but I thought I would put them forth to you.

First is an establishment of appropriate standards and test methods. Second would be a certification program. Third would be the issuance

[1] Assistant Director of Technical Services.

of adequate installation instructions, which I believe Mr. Rosen briefly commented on, as to how to properly install and where not to install such windows. I think in general there has to be a method of evaluating existing products that are on the market. This won't go over very big, but I think that the solution to the failure problem, from the builder's standpoint, is that perhaps the manufacturers and the dealers should consider some method of servicing, or at least evaluating, failures on the job site, particularly with regard to establishing responsibility as to whether it was improperly installed, improperly manufactured or whatever the case might be. And, in addition, I believe that the producers of glass, and the window manufacturers should cooperate to the fullest degree to produce a window unit that will give the desired end results.

1.4. DISCUSSION SESSION I

Mr. McKinley: Thank you, Mr. Rosen, Mr. Snell, and Mr. Bryant. You have presented a challenge. We hope to develop a fruitful response from the audience.

I would like to have a question put first to Mr. Bryant since his comments are most recent and fresh in your mind. A second question to Mr. Snell. A third question to Mr. Rosen. Having those questions presented we'll all adjourn for coffee. That will start what Mr. Rosen referred to at breakfast as "the fracas". Who has a question for Mr. Bryant? Yes sir? The question: What are the builders doing to evaluate units? The second question, this one for Mr. Snell (FHA). Yes sir? The question: How are insulating glass units now being selected? Thank you very much. Coming from Canada I think it's very important because they do have a unit testing system. I hope you'll talk about that with Mr. Snell also. Now who wants to present a problem to Mr. Rosen. Yes sir?

Clark D. Moore: I'd like to ask Mr. Rosen what his criteria are for using insulating glass with reflective coatings as opposed to just standard reflective glass?

Mr. McKinley: A very perceptive question. I think most of you know that there is something new in the insulating glass market referred to as a reflecting unit. That's an excellent question for Mr. Rosen.

Mr. Bryant, I wonder if you'd care to give us your response to the question put to you earlier.

W. Bryant: I believe the question is, "What have the home builders done to evaluate insulating glass units?" There is no easy answer to this and I am not trying to be evasive at all. You in the glass industry have one product with which you are concerned. I don't think anybody's ever taken the time and effort to tabulate the total number of different products that go into housing construction so the answer to the question as to what we have done is, quite frankly, "nothing in the way of research." Now we do have a research foundation which is a totally owned subsidiary of NAHB and which does research into products built for us and for manufacturers. But I think really the solution is that there has to be a much greater dialogue between the builder, the dealer, the manufacturer, supplier, etc., as to where the problems lie. As a National Trade Association, we only hear of the problems that are told to us. If we had received an enormous number of complaints about insulating glass quite possibly there would have been a research project by this time. As I say, it's very difficult to give you a definitive answer to your question but I think that everybody needs to really get together and discuss the entire issue, and this is true for many products. I think we often fail to appreciate the viewpoints and the problems of each other with regard to any product.

Mr. McKinley: Thank you, Mr. Bryant. Mr. Snell.

Mr. Snell: Very briefly, I believe the question was, "How do we now select units?" and I think I can limit my answer to "Hopefully".

Mr. McKinley: Thank you. I think that is understandable to all of us. Mr. Rosen.

Mr. Rosen: I think the question that was posed was "What are the criteria for using insulating glass with reflective coatings, as opposed to just standard reflective glass?" I think that the answer to that question, and to all questions of that same nature—how do you make a determination of a material to use—depends upon what the industries themselves have done. When there are standards available for the specification writer to use in the determination of whether a material meets an ASTM standard, a Federal specification or a USASI standard, he utilizes them, and if he wishes he can modify them too. But he has a basis for making some sort of a decision that is concerned with an industry acceptance of a specific standard. We're now dealing with a product for which we have no standards whatever. Hopefully, our Canadian friends and our Norwegian friends may have some answers for us with respect to the type of criteria that should be established for insulating glass and for insulating glass having reflective coatings. This would perhaps be the start or the basis for the beginning of a standard somewhere, promulgated by ASTM or USASI or some other organization that has an interest in developing that kind of a standard.

Mr. McKinley: Thank you, Harold. May I ask that you continue the discussion over coffee, or at lunch or dinner with all of the speakers. We do thank you three for your contribution. You've launched this Seminar most effectively.

Mr. McKinley: Earlier we mentioned formal technical sponsorship of several well-known organizations. I think it's significant that our audience includes a heavy representation of fabricators of insulating units from all over the world with specific emphasis on fabricators from Canada. Following the next paper, because they've had specific experience, we will ask them to comment as specifically as they can, and with as much vigor as they care to, about their Canadian experience.

The next paper is entitled, "The Development of Evaluation Procedures for Factory-Sealed Double-Glazing in Canada." The authors are Mr. A. Grant Wilson, Head, Building Services Section, National Research Council of Canada, and Mr. K. R. Solvason, Research Officer, Division of Building Research, National Research Council of Canada. Mr. Solvason will present the paper. Following his presentation, there will be an opportunity for discussion.

2. Canadian Experience With an Accelerated Test Method and Acceptance Program

2.1. The Development of Evaluation Procedures for Factory-Sealed Double-Glazing in Canada*

K. R. Solvason and A. G. Wilson[1]

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The Division of Building Research, National Research Council of Canada began a long process of developing test methods for evaluating insulating glass units. The primary requirement was the maintenance of a low dew point temperature in the air space which, in turn, required an adequate sealing system. The test methods indicate the resistance of the seals to failure from stresses in service. A national standard has been accepted in Canada and insulating glass units made there have steadily increased in quality since the program began.

Key words: Ambient pressure: dew point temperature; Canadian Government Specifications Board (CGSB) standard; factory-sealed double-glazing units; high humidity cycle; mechanical stress; moisture transfer; organic sealants, ultraviolet radiation; water vapor diffusion; weather cycling apparatus.

1. Introduction

Over the past 10 years a large number of manufacturers of factory-sealed double-glazing units have entered the Canadian market, and there has been an increasing use of these components in both residential and commercial buildings. In 1961, when the Dominion Bureau of Statistics first began to keep records on their use, the total value of annual production was about 9 million dollars; by 1965, the last year for which records are published, the value had risen to about 16 million dollars.

The development and availability of new organic sealing materials applicable to the construction of sealed glazing units has been one of the factors that has led to this growth, and all of the new manufacturers have utilized an organic-type sealing arrangement.

The appearance of such large numbers of brands of sealed double-glazing for which there was no history of field performance presented a difficult problem to the Central Mortgage and Housing Corporation (CMHC). This Crown Company has responsibility for administering the National Housing Act of Canada, including the determination of requirements for acceptability of materials and components used in houses constructed under the Act. Because there were no published standards or test methods for sealed double-glazing units, the Corporation asked DBR/NRC to assist in developing a basis for establishing their acceptability as quickly as possible.

2. Developing a Test Program

During the early stages of the study that followed, discussions with experienced manufacturers provided much valuable background information. The provision and maintenance of a low dewpoint temperature in the air space was quickly identified as the major criterion of performance. A low dewpoint temperature is necessary to avoid condensation and eventual fouling of the glass surface from leaching of sodium salts, which are a normal component of soda-lime glass. A test method, described in Reference [1],[2] to measure the relative dewpoint temperatures of the air space was established; initial measurements showed a wide variation among units, a number having high values of moisture content.

It was evident from calculations of the amount of moisture required to produce excessive dewpoint temperatures that only very small amounts of moisture transfer to the air space could be tolerated over the service life of a unit, even when desiccants were employed. Moisture is transferred to the space by diffusion of water vapor, or, if a leak exists, as a result of the movement of liquid water or air caused by pressure differences across the seal. These pressure differences are induced by temperature or barometer pressure changes, or by wind action, and result in the transfer of large amounts of moisture if leaks are present. Thus,

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* This paper is a contribution from the Division of Building Research, National Research Council of Canada, and is published with the approval of the Director of the Division.

[1] Building Services Section, Division of Building Research.

[2] Wilson, A. G., and Solvason, K. R., Performance of sealed double-glazing units, J. Can. Ceram Soc., 31, 68-82 (1962).

the unit must be hermetically sealed with materials having a high resistance to water vapor diffusion and must remain sealed throughout its life. The primary problem of evaluation is, therefore, the determination of the adequacy of the seal.

In service, stresses leading to seal failures (and glass breakage) are imposed on double-glazing units in several ways: by pressure differences between the air space and surrounding air due to temperature and barometer pressure changes; by differential expansion or contraction of components caused by unequal thermal expansion coefficients and differential temperatures; by wind pressures; and by forces that may develop due to faulty installation. Sealing systems must withstand the repeated action of these forces and must also retain the necessary physical properties under normal conditions of exposure over their required service life.

The development of methods to determine the resistance to chemical degradation of the sealing system under service conditions was regarded as a long-term problem and efforts were, therefore, concentrated on developing methods of evaluating the ability of the sealing systems to withstand repeated cycles of stress without developing leaks. Attention was directed towards methods that could be applied to the units as a whole, rather than to the individual components, because the performance of the unit depends upon the interrelation of components and manufacturing techniques.

It was decided that for this purpose it was necessary to accelerate both the effects of various kinds of mechanical stresses that could occur in service and the moisture transfer process, particularly that due to total pressure differences across the seal, so that tests could be conducted in a reasonable time. It was also considered desirable to stress the sealing systems over the range of temperatures that could occur in service in order to expose weaknesses associated with temperature-dependent properties of sealants. The test established for this purpose consisted of exposing one side of the specimens to room conditions controlled to 73 °F (23 °C) and 50 percent relative humidity (RH) while exposing the other side to a simulated weather cycle of: heating to 125 ± 5 °F (52 ± 3 °C) over a period of 90 min, air circulation alone for 25 min, water spraying at 75 ± 5 °F for 5 min, air circulation alone for 60 min, and cooling to -25 ± 5 °F (-32 ± 3 °C) over a period of 60 min. The apparatus is shown in figure 1.

The dewpoint temperature of the air space after exposure to the weather cycle was taken as the criterion of seal adequacy.

Because of the possibility of wide variations in quality from faults in the assembly process, it was decided that several specimens of each brand should be tested. Owing to space limitations and the large numbers of specimens involved, there

Figure 1. *Weathering apparatus for sealed double-glazing units.*

was considerable incentive to use small specimens. A size of 14 by 20 in. (35.5 by 51 cm) was selected, somewhat arbitrarily as a practical minimum.

The size (the small dimension, particularly), the air space thickness, the glass thickness, and the rigidity of the edge, all influence the air pressure differences developed between the air in the space and ambient. The pressure difference, in turn, largely determines the stress imposed on the sealing system under the conditions of test. A rise in air temperature within the space results in an increase in pressure, a glass deflection and, hence, an increase in volume. The pressure rise and deflection are interrelated, so that on small units the deflection is relatively small and the pressure rise relatively large. A larger pressure rise occurs with thick glass than with thin, because of the smaller deflection. Both pressure rise and deflection increase as the air space thickness increases. The shape of the deflection curve on the glass is influenced by the rigidity of the edge arrangement. Larger pressure increases occur with rigid edges as this arrangement results in a smaller mean deflection (and hence a smaller volume increase).

Exposure in the weather cycling apparatus sometimes results in breakage of glass adjacent to the spacer on units having rigid sealing arrangements. As there was no evidence of such occurrences in the field, it had to be assumed that this effect was peculiar to the unit size, glass thickness, and rate of change in the cycle. The weather cycling apparatus was, therefore, deemed unsuitable for tests on units having all-glass edges or glass-to-metal seals.

The structural arrangements at the edges of various units utilizing an organic-type seal are very similar. Brands with several years of good field performance withstood many cycles in the apparatus, whereas units having poor field performance records failed in relatively few cycles. The apparatus, therefore, provides a good basis of comparison of different units of this type, provided that the unit size, glass thickness, and air space thickness are the same. Thirty-two oz(4 mm) glass and a ½-in. (1.3 cm) air space were selected for purposes of acceptance testing.

Some tests were conducted on 20- by 28-in (51 by 71 cm) and 28- by 40 in. (71 by 102 cm) (approx) units to assess the influence of size. It was possible to test only a few units because of space limitations. The larger sizes did, however, withstand many more cycles than the smaller ones.

There was no way of comparing combined effects of stresses and moisture transfer potentials produced in the weather-simulating apparatus with those in service, and it was not possible to relate laboratory exposure directly to field conditions. It was accepted from the beginning that the test provided only a basis for comparing the behavior of sealing systems under conditions of fluctuating mechanical stress and temperature comparable to those that might occur in service. Tests were therefore conducted on specimens of most of the units on the market, including a few for which there was some history of field performance. In addition, a simple initial screening test to identify gross leaks in the seal was adopted; this consisted of determining the ability of a unit to maintain a deflection of the two panes induced by a small change in ambient pressure.

While these initial laboratory tests were being conducted, a few specimens of each brand were exposed to outdoor weather, mounted in a vertical position on a plywood support facing south, and dewpoint temperatures were measured periodically (fig. 2). The primary purpose was to expose the specimens to ultraviolet radiation to determine whether the sealing systems were sensitive to failure from this cause.

The results of these initial studies have been reported [1]. Based on the results, CMHC established initial requirements for acceptability. In tests on 18 specimens submitted by the manufacturers, at least 17 were required to pass the initial screening seal test and to have dewpoints no higher than 30 °F (−1 °C). Twelve of the specimens were exposed to 320 cycles (2 months) in the weather cycling apparatus and at least ten were required to have dewpoints no higher than 30 °F at the end. Results of tests on 33 sets of units were as follows: units from 23 sources passed the initial seal test on first submission; units from 10 sources failed and 9 subsequently passed on re-submission. Of the 32 sets that ultimately passed the initial seal test, at least 17 failed the weather cycle based on the above requirements. Fourteen of 32 sets mounted on the outdoor racks had at least one failure after one year of exposure.

Following the establishment of these acceptance requirements in 1961 DBR began to conduct tests on a commercial basis for manufacturers, who were required to submit a detailed description of the units in applying to CMHC for acceptance. No attempt was otherwise made to ensure that specimens submitted by manufacturers for qualification testing represented typical production. Acceptance of products by CMHC was therefore based on the ability of manufacturers to meet the current test requirements rather than on any positive assurance that the units being marketed met these requirements.

Figure 2. *Outside exposure racks.*

At this time, development was begun on a further qualifying test procedure involving exposure of the units to an elevated temperature cycle (70 to 130 °F) (21 to 54 °C) and high humidity atmosphere. One of the purposes of the test was to provide a high average water vapor pressure, not present in the weather cycling apparatus, in order to obtain some indication of the resistance of the sealing systems to water vapor diffusion. In addition, there was need for a simpler qualifying test because of the large volume of testing and the limited capacity of the weather cycling apparatus; and for an inexpensive apparatus that could be reproduced by manufacturers for use in product development. The final form of the apparatus is shown in figure 3. Again, the dewpoint temperature of the air space, following exposure to the elevated temperature cycle, was taken as the criterion of seal adequacy.

During the development phase, an extensive series of tests was conducted to compare the performance of a number of sets of units exposed to

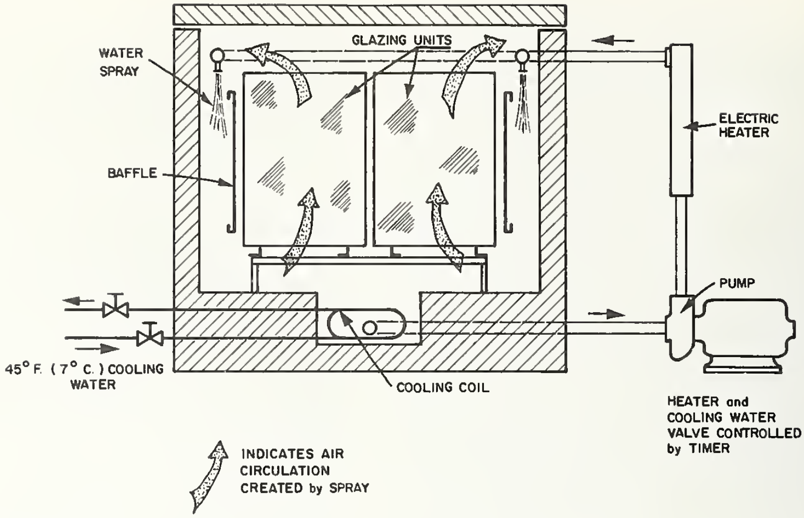

FIGURE 3. *High humidity cycling cabinet.*

both the weather cycle and the high humidity cycle. In general, brands that failed in the weather cycling apparatus in less than 320 cycles failed in the high humidity cycling apparatus in less than 24 cycles (4 weeks); brands that withstood more than 320 cycles of the former, usually withstood over 8 weeks of exposure in the latter. Exposure to the high humidity cycle did not cause abnormal failures, such as breakage of the glass adjacent to the spacers, in units having rigid edges. The apparatus was therefore used in evaluating sealing systems of this type as well as those with organic seals.

In 1963 CMHC included exposure of six specimens to the high humidity cycle as a part of its acceptance requirements, and the number of specimens in the weather cycle was reduced to six. In 1964, the requirements for acceptance were reviewed in relation to the range of test results being obtained. It was apparent that the majority of manufacturers could produce units that provided initial dewpoint temperatures below −40 °F (−40 °C) and values after weather and humidity cycling below 0 °F (−18 °C). It was observed during the weather cycle that condensation sometimes occurred between panes with reference dewpoints above 0 °F (−18 °C). As a result, CMHC altered the initial and final dewpoint requirements to −40 °F (−40 °C) and 0 °F (−18 °C), and a new round of qualification testing was begun on this basis.

3. Development of a Standard

As a result of widespread recognition of the qualifying tests being used for CMHC acceptance, they were accepted as the basis of a national standard, preparation of which was begun in 1965 under the auspices of the Canadian Government Specifications Board (CGSB). The CGSB Committee on Sealed Double-Glazing Units consisted of representatives of sealed glazing manufacturers, sealant suppliers, and government users. Consideration was initially given to establishing requirements for two grades of units, one based on the existing CMHC requirements and a second, higher grade based on initial and final dewpoint temperatures of −60 °F (−51 °C) and −40 °F (−40 °C). Results of the most recent qualifying tests for CMHC at that time indicated that a large percentage of the manufacturers were capable of making units that could meet the requirements of the higher grade. At the urging of the industry representatives, the Committee decided to include only the higher grade.

The Committee was concerned that the tests developed for CMHC acceptance did not include one to determine the likelihood of glass staining by the condensation of organic vapors evolved from the sealing system. Staining problems had been experienced with many early brands. Tests on individual components were considered, but preference was given to a single test on an assembled unit. The "Ultraviolet Exposure Fogging" test (fig. 4) was developed for this purpose. Test units are heated to about 150 °F (71 °C) so that if volatiles are present in the sealing system components or have been absorbed by the desiccant they will be driven off and condense on the glass area cooled by the cooling plate. An ultraviolet lamp is used for heating because it was suspected that a breakdown of components of the sealing system might occur under ultraviolet exposure. Very faint deposits can be detected if an appropriate lighting and viewing technique is used. Deposits appear to be produced by traces of oil on spacers, small amounts of resin binder on mineral wool used to retain the desiccant in spacers, certain glass cleaning agents, and some plastic inserts for spacer corners, as well as by the sealants used.

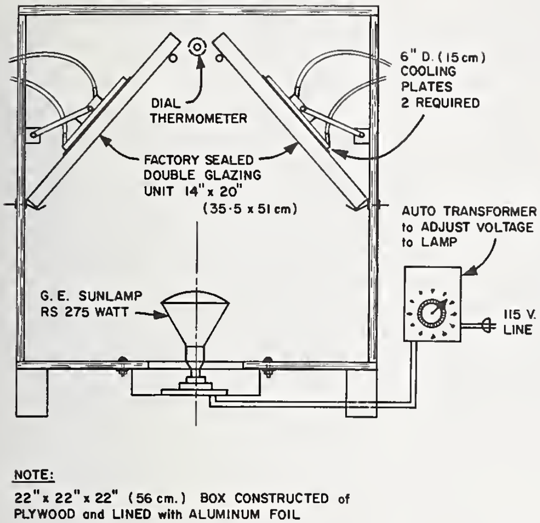

FIGURE 4. *Ultraviolet fogging test apparatus.*

To assess the implications of the method, tests were conducted on specimens, from all manufacturers, that had met the other test requirements. Among some 174 units, no deposit was visible on 54, a faint deposit was visible on 42, a medium deposit was visible on 43, and a heavy deposit was visible on 35.

The results indicated that many manufacturers could produce units having no deposit or only a faint deposit. Furthermore, there was no evidence of field problems on brands having only faint deposits. A viewing arrangement was therefore developed in which a faint deposit is not apparent but a medium deposit is readily visible.

CGSB Specification 12–GP–8 is now being applied widely in the specification of sealed double-glazing for federal government buildings. The test apparatus has been reproduced by the testing laboratories of the Department of Public Works and results of tests in accordance with the standard are being used by an Inter-Departmental Qualification Board to develop a list of qualified brands. The results of laboratory as well as outdoor exposure tests indicate a steady and marked improvement in the quality of units produced since the program was started.

Interim results for 33 sets of units received before 1961 are given in Reference [1]. Only five of these sets would have passed the 1964 CMHC requirements and three sets the CGSB requirements. Six units from 29 of the sets were exposed outside and dewpoint temperatures measured periodically. After one year all units had failed on seven sets; after two years all had failed on 14 sets; after three years all had failed on 21 sets; and after six years all had failed on 22 sets. After seven years only one set was free of failures. Stains from materials in the sealing system appeared on at least three sets. At least two of the failures resulted from a rapid degradation of the sealant, presumably from ultraviolet radiation.

The results for some 67 sets of units received from November 1960 to July 1963, analyzed on the basis of the standards set by CMHC in 1964 (−40 °F (−40 °C) initial dewpoint and 0 °F (−18 °C) after weather cycle) and on the basis of the present CGSB specification (−60 °F (−51 °C) initial and 0 °F (−18 °C) after weather cycle), are as follows:

	1964 CMHC		CGSB	
Pass	18	27%	11	17%
Failed seal leakage	7	10%	7	10%
Failed initial dewpoint	16	24%	18	27%
Failed weather cycle	26	29%	31	46%

Units from 37 of these sets were exposed outdoors. Seventeen failed in 2 to 5 years; ten show essentially no change in dewpoint; stains are visible in six.

The results for units received from August 1963 to July 1965 are as follows:

	1964 CMHC		CGSB	
Pass	36	37%	20	20%
Failed seal test	14	14%	14	14%
Failed initial dewpoint	21	22%	25	26%
Failed high humidity cycle	6	6%	10	10%
Failed weather cycle	6	6%	11	11%
Failed in both H.H. and W.C.	15	15%	18	19%

Units from this group were exposed outdoors in November 1964 and to date only three of 16 have failed. One set has evidence of staining.

Units received from July 1965 to the present time performed as follows on the basis of the CGSB standard:

Pass	58	44%
Failed seal test	10	7%
Failed initial dewpoint	10	7%
Failed high humidity cycle	18	14%
Failed weather cycle	8	6%
Failed both H.H. and W.C.	29	22%

After one and a half years' outdoor exposure on two units each of 39 sets, one unit in each of three sets has failed; and three of the sets show signs of staining.

These figures include the results of tests carried out for manufacturers for purposes of product development and qualification by Central Mortgage and Housing Corporation. Some of the sealing systems were never marketed or were marketed for only a brief period. A substantial improvement in quality of specimens submitted since the program began is, nevertheless, apparent. Approximately 9 percent of the units received up to November 1960 would have passed the current CGSB requirements; 17 percent received from November 1960 to July 1963; 20 percent received from August 1963 to July 1965; and 44 percent received from July 1965 to the present. Essentially, all of the units currently marketed incorporate a design that has met the test requirements of the Canadian Government Specifications Board standard. Although there has been no formal survey of field performance, the incidence of seal failure reported to the Division has greatly decreased. It seems, therefore, reasonable to assume that the average quality of units has greatly improved since the beginning of the research program.

4. Conclusion

The procedure for evaluating sealed double-glazing now in wide use in Canada appears to provide a reasonably good basis for judging the quality of assembly and the relative ability of the various sealing systems to withstand mechanical stresses in service. It is mainly deficient in not identifying the effects of aging on the required physical properties, and some further consideration of this is desirable.

The severity of the acceptance requirements set by CMHC were gradually increased during the period of development of procedures, so that there was continuing pressure on the industry for improvement of the product. Competent manufacturers have responded and there has been a major increase in the average quality of units since the program began, to the benefit of both customer and producer. The CGSB standard now provides a good technical basis for specifying sealed double-glazing and for further development and improvement of both the methods of test and the product.

2.2. DISCUSSION SESSION II

H. E. Robinson: Has your group been able to get field information or experience as to the durability or failure of units in service in Canadian buildings?

Mr. McKinley: Grant, would you like to respond?

A. G. Wilson: I think the answer is, as far as we're concerned, that we haven't had any planned program of getting information from the field. Most of our contact with conditions in the field has come directly from the manufacturers. We have enjoyed a very good relationship with all the manufacturers, have gotten to know them very well, and we've received from them some sort of feeling for the situation in the field, but we have had no planned program of our own.

The feedback mechanism of Central Mortgage and Housing Corporation as far as I know is again not a planned one, and I think the answer is that there is not good information on the statistics of failure in the field. We have been brought into a number of situations, mainly in the earlier days, when there were certain specific types of units that were involved in widespread failures. We have this kind of evidence, but we don't have any statistics on what is happening in a general way in respect to units as they are presently being manufactured.

Mr. McKinley: Mr. Rosen.

Mr. Rosen: Mr. Moderator, here's a question to you as a representative of one of the major American glass companies. In manufacturing insulating glass units, have you taken advantage of the Canadian program to utilize the Canadian standards of testing for units?

Mr. McKinley: Yes, like most manufacturers, we have submitted units for Canadian approval tests. We find them effective.

Mr. McKinley: Yes, Mr. O'Shaughnessy.

Mr. R. O'Shaughnessy: Mr. Wilson, in the Canadian programs do all manufacturers submit units to you or only those who are selling units in programs in which government monies are involved? Is there a mandatory program for this before sales can be made to the public?

Mr. Wilson: The incentive for manufacturers to submit the units to us in the first instance, aside from their interest in getting assistance with their own developments, was to get acceptance or listing by the Central Mortgage and Housing Corporation. And there is a very strong incentive because a very large percentage of the housing units which are constructed in Canada are constructed under the National Housing Act. This means that their mortgages are guaranteed by the federal government, although the mortgage money usually comes from private sources. So there's a strong incentive for any major producer to have his product listed by the Central Mortgage and Housing Corporation. This means that a very large percentage of the manufacturers submitted units for this reason.

Participant: One of the tests you described—the fogging test—appears quite severe for some types of units. How can excessively severe, or unrealistic, tests be guarded against?

Mr. Wilson: This is one of those things we are very much concerned about. We are always aware of the fact that some condition imposed in an accelerated test may be completely ridiculous and that units that can withstand it may be practically impossible to make. We try to avoid ruling good products off the market because of some unrealistic test condition. To get back to the fogging situation, there has been a considerable amount of evidence of fogging in the field, and I think some manufacturers almost went broke replacing units that were showing stains. To avoid getting back into this situation the CGSB committee decided that they should have some test to insure that this didn't happen. As I said, one of the things we are most concerned about in a test like this is to avoid unnecessary tests, or tests so severe that they rule out all the good products on the market.

Mr. McKinley: Thank you.

Mr. Solvason: I might comment further that practically all the manufacturers in Canada can produce units that meet the requirements of CGSB, so while this testing as I said involves a fair number of development tests, eventually practically every manufacturer in Canada becomes able to produce sets that will meet the requirements. If something is sent in that doesn't quite meet them, the manufacturer goes back to try and find out what's wrong with his operation and straightens that out, until eventually he can get a product out that will meet the requirements.

Mr. McKinley: Yes?

Mr. Robinson: Are the units that are placed out on the board for field exposure samples those that have previously passed the laboratory weathering test?

Mr. Solvason: The later sets that have gone on the field are samples of those which have passed the laboratory tests so that of the samples that are out on the board, there are none from sets that failed in the weathering test. The selection put outside was a fairly good selection, much better than the overall selection as reported in the weathering test.

Mr. McKinley: Yes?

Participant: Does CMHC require periodic resubmission of units for testing in order to keep their acceptance list current?

Mr. Wilson: The Central Mortgage and Housing Corporation, and I shouldn't really be speaking for them, because we're not representatives for them although we are fairly aware of their requirements, does not have any fixed period for resubmission of products for their acceptance list. In the case of sealed glazing units, there was a requirement from CMHC for resubmission much more often than would normally be the case, because as Mr. Solvason said, the information on unit performance, the tests themselves, and particularly the requirements that were being used by CMHC were gradually evolving. As these changed, and as information came in, and as they began to know more about what was reasonable and what was possible, they would ask for resubmissions in the history that Mr. Solvason has given you. The most recent has been in connection with the CGSB specification which came out in 1966. Subsequent to that, all of the units in Canada wanting CMHC acceptance have been reexamined.

Participant: How does CMHC police its acceptance list?

Mr. Wilson: I'll begin trying to respond on behalf of CMHC. The Corporation operates on an honor system, believe it or not. They have no policing systems. They have certain requirements for listing and one is that the listing is only good so long as the manufacturer is manufacturing the product on which the original acceptance was based. That's understood by the manufacturer when he gets his product listed. If he chooses to ignore that, I suppose it's a matter for his conscience to begin with. Of course, there is always the concern that he might be found out, in which case I suspect, it would be rather difficult for him to get on the list again. CMHC doesn't, as I say, run any sort of continuing certification program. When a manufacturer is listed on the CMHC list, all this indicates is that the manufacturer has shown he could meet whatever happened to be the CMHC requirements for listing at that time.

Mr. McKinley: I think we might temporarily postpone further discussion of this paper until perhaps around the luncheon table. The Canadian fabricators have said on the one hand, that they do endorse the views that have been expressed and yet in this insurance idea they are going beyond the present situation. That has a great deal of significance for us here. I would like to thank Mr. Solvason and Mr. Wilson again for their contribution.

The gentleman who in many respects has gone to the greatest trouble to join us and share with us his experience is our next speaker. His subject is "Norwegian Experience with Accelerated Test Methods for Sealed Glazing Units and Their Correlation with Field Experience." It's a pleasure to introduce Mr. Tore Gjelsvik, Senior Research Officer, The Laboratory, Norwegian Building Research Institute, who has flown all the way from Trondheim and arrived promptly on schedule. Mr. Gjelsvik, we are very much pleased to welcome you, sir.

Mr. T. Gjelsvik: Mr. Chairman, ladies and gentlemen. I am very glad to be here to talk a little to you about our accelerated test methods and also something of our experience from field studies. But before I start I have to say a few words about our Norwegian Building Research Institute, which is somewhat different from your Building Research Institute here in the United States. We are doing research into building programs and we are testing materials and constructions.

3. Norwegian Experience With Accelerated Test Methods and Their Correlation With Field Experience

3.1. Norwegian Experience With Accelerated Test Methods for Sealed Glazing Units and Their Correlation With Field Experience

Tore Gjelsvik

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The Norwegian program was begun 10 years ago, starting with the design of an apparatus for accelerated aging tests. The device was built after scientists analyzed actual stresses on insulating units. Carried on concurrently with the laboratory tests were field studies. The most important of these was made in 1963 and involved 2,040 units. In general there is a good correlation between lab tests and field studies.

Key words: Accelerated test program, climatic strains, dew formation time, dewpoint temperature, field studies, glass-to-metal seal, glued seal, mechanical stresses, pulsation stresses, visible damage.

1. Introduction

The work on the subject of sealed glazing units at the Norwegian Building Research Institute started back in 1958, independent of similar work in other countries. The first part of the project was sponsored by a Norwegian company, and led to the construction of an apparatus for accelerated aging. At that time, the accelerated aging tests constituted the whole test program.

Systematic field studies were introduced in 1959, to check the results of the accelerated tests and to gain more general experience. The results of the field studies and the information available from other sources have resulted in successive modifications of the accelerated aging tests. The test program has been changed, and the apparatus itself improved several times. The basic apparatus has, however, been the same all the time.

2. Stresses on the Edge Seal

The actual strains on the edge seal of sealed glazing units were thoroughly examined before the apparatus for accelerated aging was designed. The following types of strains were considered as actual:

- Transportation stresses
- Assembling stresses
- Variations in atmospheric pressure
- Temperature changes
- Wind stresses
- Sunlight
- Water
- Mechanical stresses caused by vibrations.

Details shall not be given here, reference is made to earlier publications [1], [2].[1]

Of the types of stresses mentioned above, transportation and installation strains must be considered as more or less arbitrary. Transportation strains can easily be reduced by suitable measures, and with the present installation recommendations [3], the assemblage strains can be virtually eliminated. The real climatic strains must be said to be variations in the atmospheric pressure, changing temperatures, wind and sunlight. Water and vibrations can certainly be of importance in special cases, but whether they shall be included in normal test methods or not, is an open question.

In general, there seems to be agreement between scientists in the different parts of the world about the types of strains acting on sealed glazing units. The importance of the different types of strains, however, is judged to be somewhat different by different scientists. This is unpleasant, perhaps, but not really surprising. Some of the strains on sealed glazing units are fairly well known, while for others, the available information is rather limited. The different judgment is then only a natural result of the differences in the basic material. The situation is now considerably better than in 1958, but still an accelerated test program has to a high degree to be based on common sense.

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

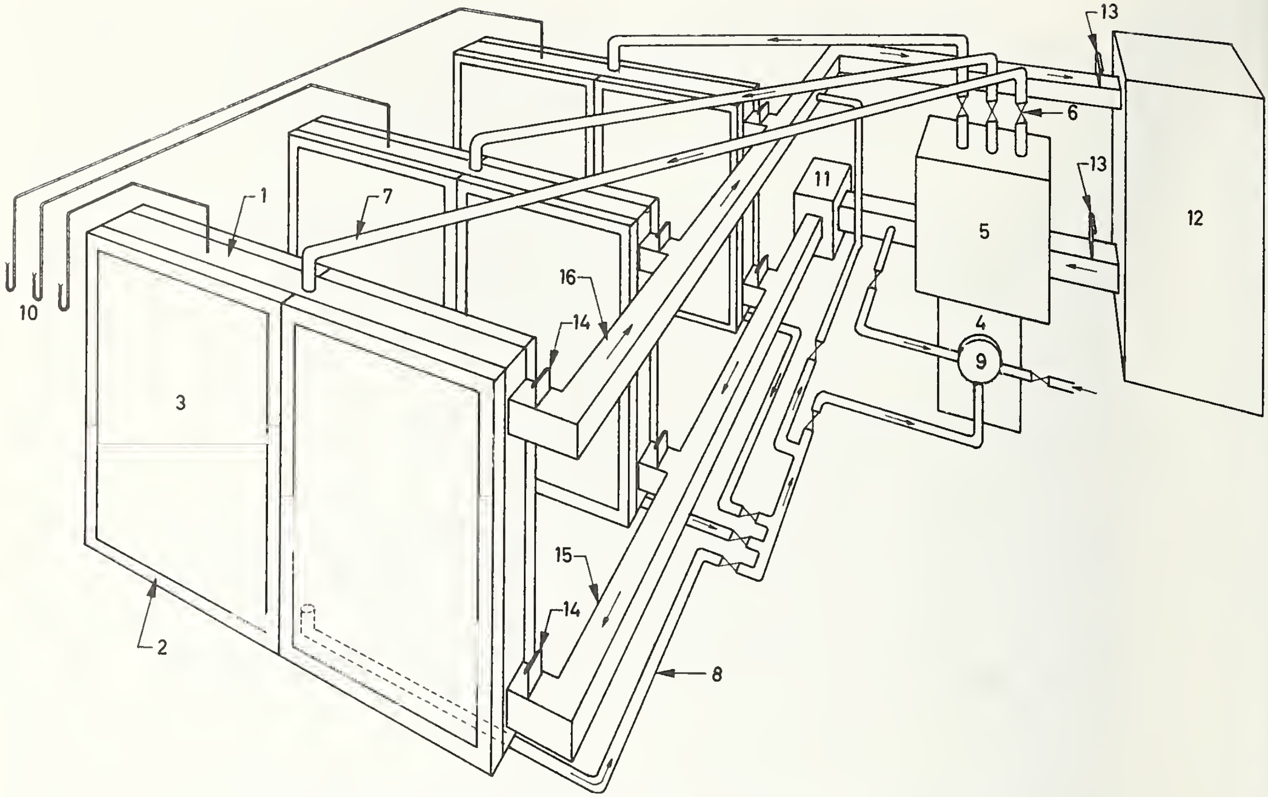

FIGURE 1. *Apparatus for climatic strains on sealed glazing units.*

1. Frame
2. Casement
3. Sealed glazing unit
4. High pressure fan
5. Hot chamber
6. Regulating valves
7. High pressure supply pipe
8. Return pipe
9. Pulsating damper
10. Manometer
11. Cold air fan
12. Cold chamber
13. Main sliding damper
14. Sliding damper
15. Cold air supply pipe
16. Return pipe

3. Apparatus and Test Procedures

On the basis of earlier considerations, the Norwegian Building Research Institute (NBRI) decided in 1958 to build an apparatus where installed units could be subjected to temperature changes and pulsating wind pressure. It was found that variations in the atmospheric pressure could be omitted, as the stresses derived from the two other factors would be considerably stronger. On the other hand it was thought desirable to include sunlight. This factor, however, for practical reasons, had to be dropped. Water was also left out, as at that time it was considered possible to avoid the entry of water into the rebate with perfect installation. The last factor, vibrations, was more or less unknown at that time.

A unit size of 120 × 170 cm with about 12 mm air space and a glass thickness of about 4 mm was estimated to correspond most correctly to actual conditions.

Figure 1 shows the NBRI apparatus for climatic strains on sealed glazing units. Actually, the apparatus on the figure is the second main version from the period 1963–66, with several improvements compared with the original version of 1959. The principle, however, is the same for both.

The system consists of three frames made of teak wood. In each frame four casements can be attached, each bearing one sealed glazing unit 120 × 170 cm, or a higher number of smaller units. When the installation is completed, closed chambers are formed, in which air with adjustable pressure and adjustable temperature can be circulated. In other words, the air in the closed chambers represents the outdoor climate. The complete apparatus is located in the laboratory which represents the indoor climate with a temperature of about +20 °C.

The apparatus can be adjusted in two ways. One method is to let a high pressure fan supply the air to the chambers. A pulsating damper regulates the air supply, so that the pressure within the chambers pulsates, like wind gusts. The pulsating damper had in the beginning a frequency of 6 periods per minute, but was changed to 5 periods per minute after the first series of tests, in 1960. The maximum super-pressure within the chambers during the wind gusts can be varied between 10 and 100 mm water column, corresponding to wind force Beaufort No. 5 to 11. The temperature inside the chambers, measured centrally in front of the units, can be varied between +10 and +55 °C. The lowest temperatures are reached by adding in cold air from the cold chamber.

The second method is to let a low pressure fan blow cold air directly from the cold chamber through a larger set of pipes. In this way the temperature inside the chambers can be lowered to about −10 °C. The super-pressure, however, is insignificant, and pulsation is not possible. By changing from a hot to a cold period, and vice versa, the units can be subjected to temperature changes.

The installation of the units in the apparatus has in the period 1959–1966 been done with plastic glazing compounds, in the first series of tests without spacers, later with spacers to avoid extrusion.

In the first series of tests the wind stresses were started at a moderate level, and gradually increased step by step. The details of this program appear in NBRI Report No. 33 [1]. In the later tests, from 1961 to 1966, the stresses have been in accordance with a somewhat revised test program. In carrying out this program, an attempt was made to include 20-yr wind stresses in comparatively exposed places. The wind pressure and air temperature were fixed to follow a day-cycle consisting of 4 hours cooling at a low and constant air pressure to an outside air temperature of about −10 °C, followed by a 20-hr period with 5 wind gusts per minute under simultaneous heating to a prescribed temperature level. The actual temperatures, the maximum wind pressures during the wind gusts and the number of day-cycles at each period of strain are indicated in table 1. This 45-day program has been repeated once, making a total effective operation time of 90 day-cycles.

Table 1

Period of strain	I	II	III	IV	V
Day-cycle number	1-10	11-30	31-34	35-44	45
Maximum pressure during the windgusts, mm water column	40	25	70	15	100
Corresponding to wind force Beaufort No.	8	7	10	5	11
Air temperature, °C	25	35	15	50	15

The units have always been inspected regularly for visible damage during the operation of the tests. Dewpoint measurements have been taken at regular intervals. Finally the units have been taken out for inspection. Usually they have also been taken apart and the edge seal examined in detail.

All dewpoint measurements have been carried out with the apparatus developed at the NBRI Laboratory in Trondheim. Figure 2 shows a cross-section of the cooler. This is made of brass and the cooling surface is polished and nickel and chrome plated. When dewpoint measurements are taken, the cooler is filled with a mixture of dry ice and

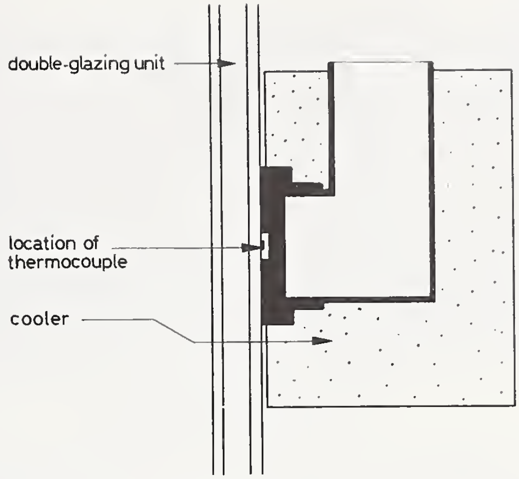

Figure 2. *Dewpoint measurement on double-glazing unit.*

alcohol, having a temperature of −75 °C. Originally the method was based on thermocouples glued to the outside glass surfaces. Later on, the method was further developed [4] and investigated. The thermocouples are now left out, and the measurements simply taken by placing the cooler against the glass with good thermal contact, and measuring the time from the contact is obtained till visible condensation can be detected by an experienced observer. This "dew formation time" is then converted to real dewpoint temperature with the help of the curves in figure 3.

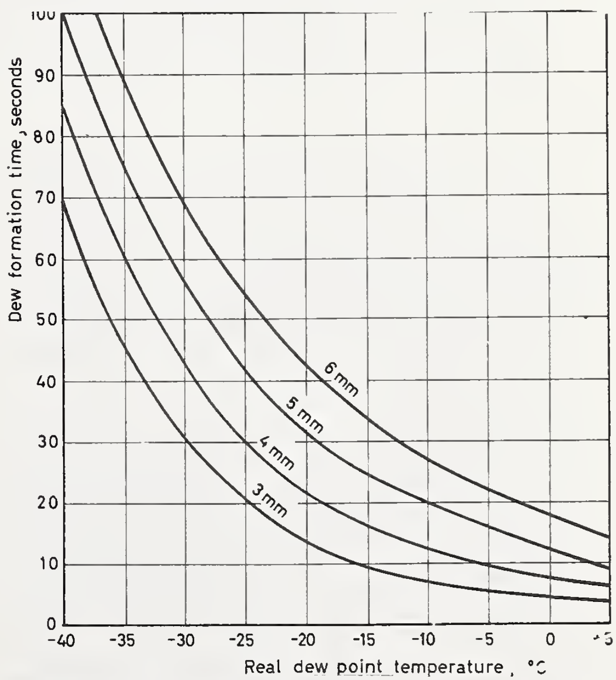

Figure 3. *Dew formation time versus real dewpoint temperature, NBRI measuring method.* (Unit temperature +20 °C, glass thickness 3 to 6 mm.

The NBRI dewpoint method is a typical dynamic method, suitable to give very fast readings with an acceptable accuracy. In practice, readings are usually taken in less than one minute, while dew formation times above two minutes occur very rarely. The measurements are also carried out with the units in a vertical position, and this makes the method specially suitable for measurements in the field. The only drawback is that the method is dependent on a well trained observer. Inexperienced people will usually see the condensation too late, and this will result in dewpoint readings which are too low and too good.

4. Field Experience

Systematic field studies were organized by the NBRI in 1959, 1960, and 1963. The most important is the west coast field study of 1963. In this study, an attempt was made to cover all types of units which had been on the Norwegian market, and units of different age, as far back as possible. The final result was 2040 units, divided into 10 different brands and installation years from 1951 to 1963. The investigations covered inspection for visible damage as well as dewpoint measurements, and the results have been treated statistically [5]. It is not possible to give all details here, but the main conclusions of the report are the following:

> The study has clearly shown that it is not an easy job to manufacture durable sealed glazing units. Even large, reputable companies have failed to do so, and have obviously put their units on the market before they have been sufficiently thoroughly developed and tested.
>
> For all types of units there has so far been a wide variation in the dewpoint temperature of new units. Although the manufacturing of sealed glazing units is an industrialized process, it has still maintained its character of manual work. Extreme care in the dehydrating of the units as well as all other steps in the production seems to be necessary to obtain units of uniform quality with low dewpoints.
>
> The average damage frequency for the units covered by the study is rather high. The old production of certain types of units is responsible for this high figure. For the rest of the units the number of damaged units is comparatively low, and has been found to be either a result of special strains or quite simply failures in the production.
>
> Even the intact units of the improved types are not absolutely tight, at least not those with a direct glass-to-metal seal or a glued seal. For these types there is an increase in dewpoint with age of unit, indicating certain leakage rates. The units must be considered to have a finite span of life. The rate of increase in dewpoint temperature is, however, so low that the expected span of life is fully acceptable.
>
> Very small units as well as oblong units with one really short side are weakened more rapidly than the normal and bigger sizes.
>
> The special strains mentioned above include vibrations and other types of rapid pulsating mechanical stresses. Units installed in doors with a heavy traffic frequency may be weakened rapidly or even have the edge seal broken. Units installed adjacent to such doors may also be weakened or broken down if the frames are not sufficiently rigid to reduce the transmission of vibrations from the doors. When properly installed, units in doors with moderate traffic seem to serve all right.
>
> Heavy and gusty wind has proved to have a weakening influence similar to vibrations from doors. Units broken down by wind stresses have, however, not been found in practice so far.
>
> Prolonged contact with water has been the reason of early seal failure of several units, particularly those with a glued seal. This has been the case especially with units installed in top and bottom hung windows, and to a certain extent also horizontally pivoted windows. The improved types of units seem to be less sensitive to prolonged contact with liquid water. There is, however, every reason to take appropriate precautions. Rebates and beads must be properly dimensioned to give the necessary clearances and edge coverage. Bottom bead and sash or frame as well as the glazing compound must be sufficiently sloped to shed water, even when the windows are put in a ventilating position. The glazing must be as perfect as possible, preferably incorporating a two-stage sealing system with ventilated and drained rebates. It is probable that the results of the field study might have been better if better installation methods had been used.

Field studies have also been carried out in the years after 1963, but none of these studies has been of the same order as that on the west coast. The experience gained in the later studies fully supports the conclusions drawn on the material from 1963. It has been planned to go out to the west coast again and check the same units once more, but so far it has not been possible to get any support for such a project from the manufacturers involved.

5. Results of Laboratory Tests and Their Correlation With Field Experience

The major part of the accelerated aging tests in the period 1959–1966 has been carried out with units 120 × 170 cm. The first series in 1959 were run on a tentative basis, while the later tests have followed a fixed program. These tests cover a total of 26 sets of units from 18 different sources.

The results can be divided into visible damage in the units and changes in the dewpoint.

The visible damage comprises cracks in the glass, cracks in the metal seal, and displacement of the metal seal.

Cracks in the glass have occurred in different types of units. It has appeared, however, that the cracks have always started at the edge of a spacer block. The reason has been that the bead has been forced back so hard that the unit and spacer have jammed. Similar cracks have also occurred in practice. Mounting with spacers must always be carried out with some care. Some types of all-glass units must either be installed with special types of spacers or entirely without such.

Cracks in the metal seal have occurred only in units with a direct glass-to-metal seal. The cracks have been localized to the central part of the long sides of the units, in some cases also to the short sides. In the laboratory tests the cracks have occurred at a comparatively late stage, after the units have been subjected to prolonged strains. In practice, however, they have so far only occurred in units installed in doors with a heavy traffic frequency or close to such doors. The cracks have always had the appearance of typical fatigue breaks at the weakest and most heavily strained part of the edge seal, and are undoubtedly due to pulsation stresses.

Displacement of the metal seal is characteristic of certain periods of production in some types of units with glued seals. Deflections up to 2 cm have been measured in practice, in the laboratory as much as 7 cm.

The changes in dewpoint during the laboratory tests have differed greatly for different types of units. Some typical cases are shown in figure 4.

Curve A is typical of a good unit where the dewpoint is not influenced significantly by the stresses. In Curve B there is first a certain increase, which may be due to changes in temperature, separation of water from the adhesives during curing, etc. Also units with this type of dewpoint curve have, however, to be considered as good. In Curve C, the situation is quite different. Here the dewpoint rises so rapidly towards the critical limit that the units undoubtedly have considerable leaks. Curve D must be considered as showing a real production failure, as the dewpoint has been much too high from the outset. Something between Curves B and D can be judged somewhat differently, according to where the curves start and end.

Curves A–D represent units without visible damage. In the case of units with visible cracks in the metal seal, the dewpoint will follow Curve E and suddenly rise above the critical limit when the cracks have occurred. For units with displacement of the metal seal, there will be a corresponding rapid increase, as for instance Curve F.

The field experience [5] has confirmed that the dewpoint of good units will rise slowly in course of time as in Curves A and B. For bad units, the dewpoint can easily rise above the critical limit, as in Curves C, D, and E, and result in condensation. Units with a much too high incipient dewpoint, Curve F, have also occurred.

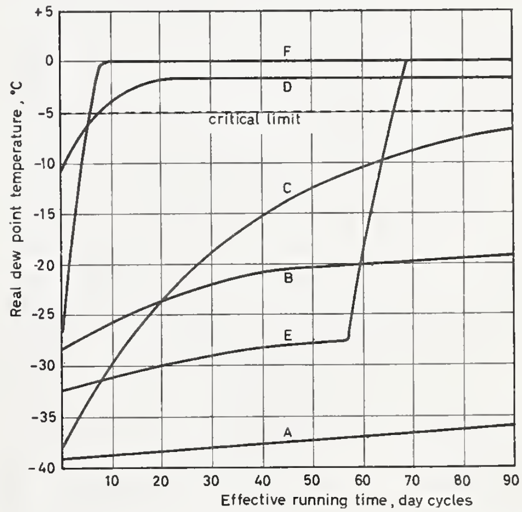

Figure 4. *Typical examples of measured dewpoint temperatures.*

The correlation between the results of the laboratory tests from 1959 to 1966 and the field experience has in many ways been surprisingly good. The types of damage that have occurred have been exactly the same, and the dewpoints have developed in a completely parallel way. Some factors have, however, indicated that the strains have not been on just the right level. In the units with a direct glass-to-metal seal, cracks in the metal spacer, as mentioned before, did develop in the later part of the laboratory tests. In practice, such cracks have only been found in units installed in doors or adjacent to doors, while the great mass of units have shown good performance. A more detailed analysis showed that the wind loads used in the period 1959–1966 had been too high. The test program was therefore taken up for revision. This was coordinated with the development of the draft Scandinavian specification.

6. Draft Scandinavian Specification of 1967

This specification was worked out by the four leading manufacturers in Scandinavia in joint cooperation with the NBRI. The specification is much influenced by the American SIGMA specification, but is otherwise completely redrawn to take into account Scandinavian experience.

One point worth noting is the inclusion of initial tests, which cover visual inspection, measurement of initial dewpoint, and control of initial seal. The purpose is to avoid running expensive and time-consuming aging tests with units which are not of a reasonably high quality.

The accelerated aging tests are based on the NBRI method, but with several modifications. The size of the unit has been reduced to 120 × 82 cm, i.e., about half the original size, by mounting a crossbar in the sashes. On the other hand, ultraviolet radiation has been included. The actual UV-lamps are fluorescent black light tubes with radiation mainly between 3000 and 4000 A. The units are also mounted with the bottom edge in a metal tray. This is filled with water once a day so that the bottom edge is subjected to wetting and drying cycles. The number of temperature changes has been maintained and the temperature strains even slightly increased, while the number of wind gusts have been reduced to about half. The present accelerated aging test program amounts to 50-day cycles. Details are given in table 2.

TABLE 2

Period of strain	I	II	III	IV	V
Day-cycle number	1-8	9-27	28-29	30-49	50
Temperature changes per day cycle	2	2	1	1	1
Maximum pressure during the wind gusts, mm water column	40	25	70	15	100
Corresponding to wind force Beaufort No.	8	7	10	5	11
Air temperature, °C	25	35	15	55	15

The most important novelty in the revised program is perhaps the wetting and drying cycle. The reason for this is that the field studies have clearly shown that water will sooner or later reach the edge seal. Then the combination of humidity and ultraviolet radiation becomes of importance.

7. Future Plans

Testing in accordance with the draft Scandinavian specification has now been going on for 1½ years. A total of 31 sets from 23 different sources has been tested in Trondheim. The experiences gained in these comprehensive tests have shown that some improvements in the aging tests are desirable. First of all, the black light tubes should be replaced with the American type of sunlight tubes specified by the SIGMA organization. Further, the wetting and drying cycle should be made a little more effective. Finally, the size of unit should be increased, at least a bit towards the original NBRI size 120 × 170 cm. The available material shows that 142 × 121.4 cm will probably be a future common Norwegian and Swedish standard size. This size is recommended as the basis for type testing. For control testing, it is also desirable to have possibilities to test units of different sizes, at least sizes deviating a little from the base size. A completely new apparatus for accelerated aging tests has now been outlined at the NBRI laboratory. This new apparatus will be completely different from the old apparatus, but perform the same basic functions. The apparatus is expected to be far more effective, and all the desired improvements can be realized. There also seems to be a real chance to obtain a temperature of about +70 °C in Period IV, as originally wanted by the Scandinavian manufacturers.

8. References

[1] Gjelsvik, Tore, Tests with factory-sealed double-glazing window units. Norwegian Building Research Institute, Report No. 33, Oslo 1962 (in English).

[2] Gjelsvik, Tore, Laboratory testing of sealed glazing units. RILEM Bulletin No. 35, June 1967. Norwegian Building Research Institute, Reprint No. 145, Oslo 1967 (in English).

[3] Sealed glazing units. Installation in frame or sash of wood or directly into wooden framework. Architectural Data Sheet NBI(31).202.2. Norwegian Building Research Institute, April 1965 (in Norwegian).

[4] Gjelsvik, Tore, Humidity in the dehydrated air space of sealed glazing units. Norwegian Building Research Institute, Report No. 48, Oslo 1967 (in English).

[5] Gjelsvik, Tore, Performance of sealed double-glazing units in severe Norwegian climate. The west coast field study 1963. Norwegian Building Research Institute, Report No. 44, Oslo 1965 (in English).

3.2. DISCUSSION SESSION III

Mr. McKinley: Thank you. I think we can all join in genuine admiration of Mr. Gjelsvik's ability to speak to us in our own language. We have about 15 minutes before lunch is due and I am sure that there are many questions you would like to present to Mr. Gjelsvik. Yes sir?

Participant: I would like to know if the report that you referred to several times, your No. 44 report, is available in English?

Mr. Gjelsvik: We have some of our reports available in English and in English only. The numbers I have referred to are Reports Nos. 33, 44, and 48 and Reprint No. 145, and all of them are available in English.

Mr. McKinley: Very good. I am sure that Mr. Gjelsvik will be glad to give you detailed references later on. Yes sir?

Participant: I would like to know what types of units were tested in your programs, and I would also like to know what drying agents were used.

T. Gjelsvik: The units I have referred to and that we have tested during the period of years have not only been manufactured in Norway. In fact, only a few of them were manufactured there. Most of them came from abroad, from Denmark, Sweden, Germany, France, or England and we also had one set from the United States and one from Canada. The manufacturing methods are completely different. We have, I would say, all types of units. We have had the all glass units made in the United States, we have had units with the glass to metal seal made in different countries, and we have had a fairly large number of units with the edge seal made with completely different types of sealing materials and different types of space and edge construction. The desiccants have partly been silica gel and partly activated alumina.

Mr. McKinley: Yes sir, Mr. O'Shaughnessy.

R. O'Shaughnessy: You have evidently been taking the opposite method, not method but procedure, in using large units versus the small units we use. Have you in your tests correlated some difference in the test results utilizing the same test with the different size units?

T. Gjelsvik: Our test method is very strong, at least partly, on simulating gusty wind pressures, and applying variable wind pressures on extremely small units would be really nonsense. So we have generally tested the fairly large units. We have not only tested the size mentioned but also some smaller sizes, but most of the units have been the large size. We have field experience with different sizes of units and, in general, we have found a reasonably good correlation. But we also found that the very small units are weaker and much more likely to fail than the larger sizes in practice.

Mr. McKinley: Yes?

R. Fentress: When you have your wind gust test as part of your test, how long a duration of the different gusts do you put on?

T. Gjelsvik: Well, as I said before, we are using five wind gusts a minute. The units are subjected to the pressure pulsations throughout the 24 hours of the day, except for the few hours when units are being cooled to 14 °F on one side.

R. Fentress: The peak wind load is sustained how long?

T. Gjelsvik: The top of the peak lasts only for a part of a second. The shape of the wind gust is approximately sinusoidal.

Mr. McKinley: Mr. Robinson?

Mr. Robinson: Mr. Gjelsvik, in view of the extensive field investigations that you have made, I would like to know if you found any correlation or difference in the failure or breakage rate of windows that face north and have little sun upon them as compared to those that face the sun?

T. Gjelsvik: We tried to find if there was any real difference, but we were not able to prove any difference.

Mr. McKinley: Yes sir, Mr. Beatty?

J. A. Beatty: In view of the requirement of the Canadian specification for 32 oz. glass, do you specify one particular thickness of glass to make your evaluation of units, and can you make the same evaluation on other thicknesses of glass?

T. Gjelsvik: Well, to be able to get results which you can compare directly, you should always use the same thickness of glass. If you use a different thickness you can never be sure how you should interpret the final results. When we tested a very large size of units, we always specified the glass thickness of 4 mm which corresponds roughly to your double strength. When we wrote the Scandinavian specifications, we reduced the size of unit and we reached a size where most manufacturers would supply the units with glass thickness of only 3 mm, but some of these manufacturers do not make units with 3 mm, they make it with at least 4 mm, so in fact we have run into trouble due to this. And that's one of the reasons we want to increase the size of units again. We want to get up into sizes where all manufacturers will supply the units with the same glass thickness and that will be 4 mm.

Mr. McKinley: Do we have perhaps one more question? Yes sir?

Mr. Robinson: Would you agree, sir, that you can affect your test results by making the glass thinner rather than thicker on the sizes of units that you are talking about? By this I mean that you would reduce the pressure difference from inside to outside because of the greater deflection of thinner glass near the central area of the unit.

T. Gjelsvik: If you reduce the glass thickness you will put heavier strength on the units and if you increase the thickness you will, of course, reduce it. But I must admit that we have not made any really systematic study of that problem.

Mr. McKinley: As we all adjourn for lunch, I want to thank Mr. Gjelsvik once again, I want to thank Mr. Backman from Sweden who contributed the fabricator's view, and I want to thank all of you.

4. Panel Discussion II

Introduction of the Second Panel

Robert W. McKinley

As we get underway this afternoon, the theme for our second panel discussion is, Manufacturers' Test Methods; Correlation with Field Experience; Expected Service Life. The panel will step forward: Mr. Joseph S. Amstock, Technical Manager, Eastern Division, Products Research and Chemical Corporation. Mr. Amstock has been very active in SIGMA. He is Chairman of the SIGMA Standards Committee. Mr. James D. Gwyn, Assistant Director, Research Products, Libbey-Owens-Ford Company, Toledo, Ohio. Mr. Renato J. Mazzoni, Head, Building Materials, Glass Research Laboratory, PPG Industries, and Mr. James A. Box, Industrial Products Development Manager, The Tremco Manufacturing Company, Cleveland.

Now, as in the case of our panel discussion this morning, we have asked each of these gentlemen to make a brief presentation, and we then will invite questions from the audience.

4.1. Test Methods for Evaluating Organically Sealed Insulating Glass Units

Joseph S. Amstock[1]
Products Research & Chemical Corporation, Gloucester City, New Jersey 08030

The performance of a sealed insulating glass unit in service is dependent on many factors. These include: dewpoint temperature; bond integrity of the sealant to glass, and spacers; thermal stress and strain; extremes in temperature and weather; exposure to moisture and ultraviolet radiation; type of glazing compounds used; method of glazing; and workmanship during installation.

Key words: Accelerated weathering; dewpoint temperature; moisture vapor transmission (MVT); polysulfide sealant; sealant adhesion; sealed insulating glass units; test methods.

1. Introduction

Fifteen years ago the polysulfide sealants were not expressly designed for the insulating glass industry. As the industry grew, the requirements changed and PRC embarked on an intensive research program to develop a sealant system specifically for insulating glass.

The polysulfide unit consists of a hollow T-shaped spacer separating two or more lights of glass. A desiccant is used to dry the air space. The unit is then sealed with an organic sealant based on a liquid polysulfide rubber polymer. This type of unit may have the edges protected with a metal wrap or tape, if desired. A majority of American and European manufacturers have adopted this method (fig. 1).

What was needed?—What did we look for and what tests did we utilize to screen these products?

Some basic tests for screening the sealants were first used prior to determining what objective tests should be performed on a sealed unit to determine its service life.

Aside from the normal handling characteristics of the sealant which were required by the manufacturers, it was an acknowledged fact that one of the most important characteristics of a well made insulating glass unit is the adhesion of the sealant to the glass and metal as well as the retention of that initial adhesion after prolonged exposure to ultraviolet radiation, rain, and other material elements.

2. Tests

Several pieces of 1 × 5 in double strength glass which has been thoroughly cleaned are bonded to 1 × 10 in pieces of high strength aluminum foil. These test panels (fig. 2) are allowed to cure for 7 days at room temperature. At the end of this period an initial test is run for peel strength.

[1] Manager, Market Development.

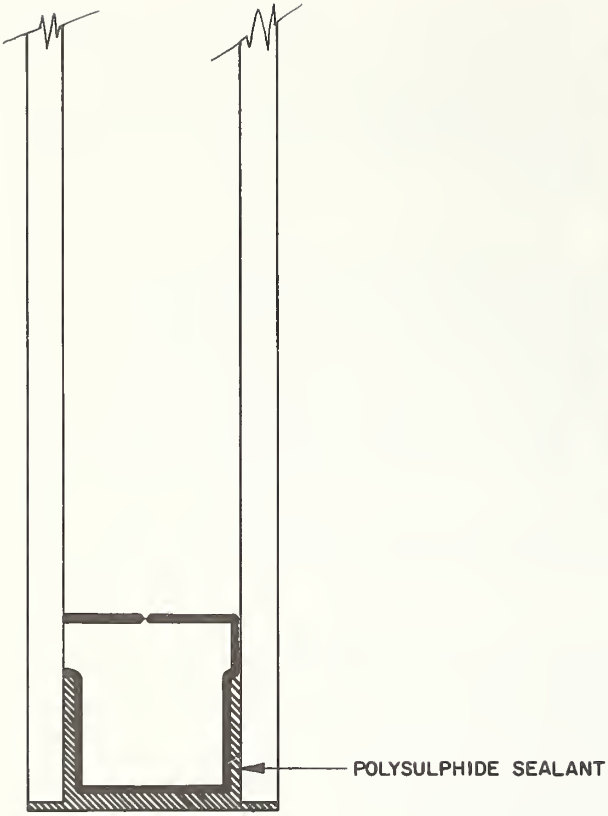

FIGURE 1. *Polysulfide unit.*

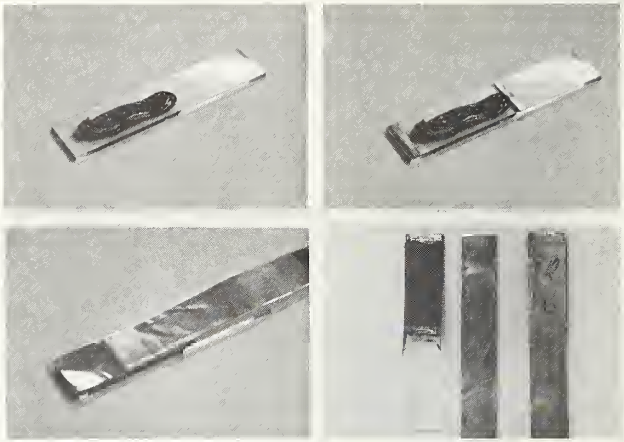

FIGURE 2. *Test panels—glass/aluminum samples.*

Variation of aging and exposure ranges were adopted from 2 days to 30 days. Sets of these glass/aluminum samples are exposed as follows:

Room temperature
Oven aging at 70 °C.
Water immersion at 50 °C.
UV/Water—Ambient
Linseed oil

Generally the samples are tested for peel adhesion after exposure at 2-day, 6-day and 30-day intervals. For the purpose of long term experimentation the samples are tested additionally at 30-day intervals up to one year.

Over a six month period several hundred peel adhesion coupons were tested. Values averaged 12 to 15 pounds per inch width after six months exposure to the above mentioned aging conditions for the conventional manganese dioxide-cured polysulfide systems. For a system which is highly resistant to various glazing compound vehicles (generally vegetable oil based), the values were in the magnitude of 30 to 34 pounds per inch width.

In addition to the long-term study of adhesion, moisture vapor transmission (MVT) data were obtained using ASTM E 96 test method. MVT rates range from 0.354 $g/m^2/24$ hr to 0.533 $g/m^2/24$ hr. The average specimen thickness used was 35 mils to correlate to the normal thickness of sealant between the spacer and the glass.

Based on these preliminary data of peel adhesion values and of MVT rates, sealed insulating glass units were then made and subjected to tests for seal integrity, initial dewpoint, accelerated weathering (dewpoint rise) fogging for both architectural and refrigeration applications and resistance to glazing compounds.

It should be noted that the data being presented are for commercially built sealed insulating glass units, not laboratory samples. Therefore, the type of workmanship generally used was indicative of what can actually be obtained in field units and makes the results more realistic. Our study involved several hundred sealed units of all descriptions.

3. Type of Study

The initial seal test was adopted to determine the seal integrity or seal leakage prior to subjecting the units to long-term accelerated interior weathering. The units, after being subjected to vacuum (3 in of mercury) for 2.5 hr, must show no signs of seal leakage and must not deviate from the zero deflection reading by more than 15 percent. This test has also proved to be a valuable research tool in determining glass deflection, effects on various thicknesses of glass, and the capabilities of sealants to withstand strain and stresses.

This change of 3 in Hg represents an altitude of 3,000 feet, so you can readily see the severity of this initial test.

Figure 3 illustrates the test chamber used for checking the seal integrity. In this phase of our test program we evaluated 450 organically sealed insulating glass units. The failure rate was approximately 10 percent; these failures were attributed generally to poor workmanship. There was no significance as to the type of cured polysulfide (PbO^2 or MnO^2).

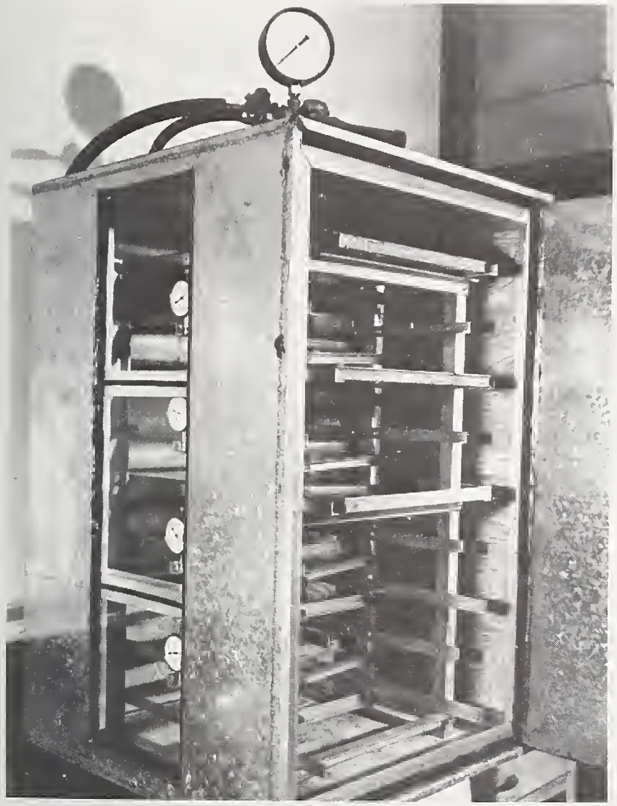

Figure 3. *Test chamber used for checking seal integrity.*

4. Dewpoint Temperature

Chamber's Technical Dictionary defines dewpoint temperature as the temperature at which a given sample of moist air will be saturated and deposit dew. Water or moisture vapor transferred to the air space is evident by a rise in dewpoint temperature. Dewpoint is a function only of the volume of the air space and the amount of water sealed into or transferred into it.

The reason for using dewpoint temperature measurements was to find a means of correlating the MVT values and transposing these into actual moisture vapor transferred into a sealed unit. Moisture can be transferred to the air space by diffusion of water vapor through the sealing material. The amount transferred depends upon vapor transmission or the vapor permeability of the sealant, the length of the path of sealant, and the vapor pressure differential.

We have attempted through laboratory data and field experience to give you the best possible MVT rate material, yet keeping in mind many of the other requirements needed of a good sealant system.

Two important facts must be known when discussing dewpoints. The first is the type and amount of desiccant used in fabricating the unit. Secondly, it is necessary to readily distinguish a measured dewpoint from an actual dewpoint temperature. Figure 4 shows an approximate calibration curve for various glass thicknesses. The measured dewpoint temperatures are recorded from the thermometer in the vessel on the glass

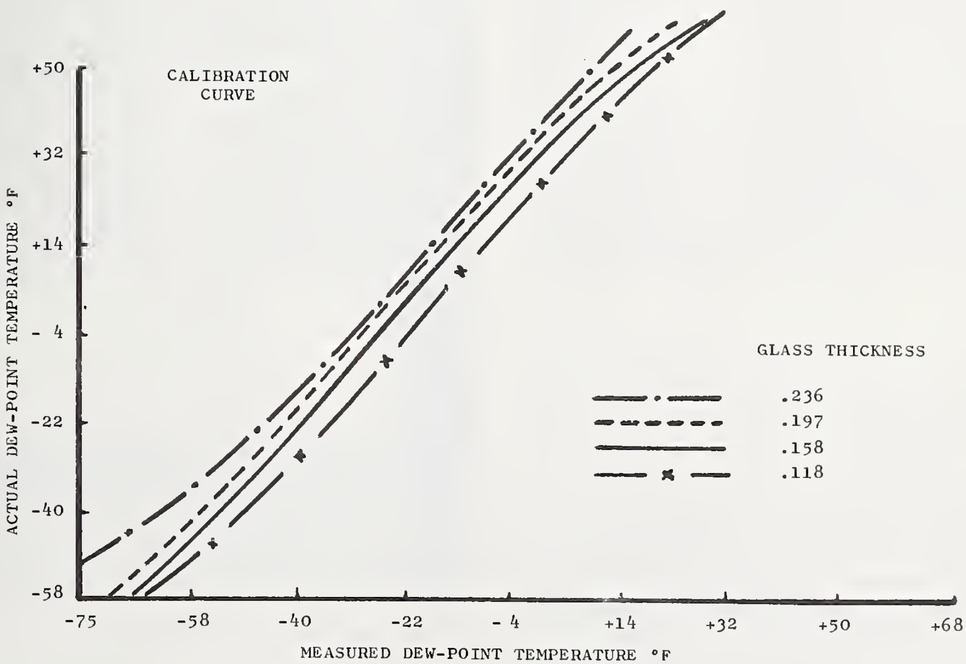

Figure 4. *Calibration curve for various glass thicknesses.*

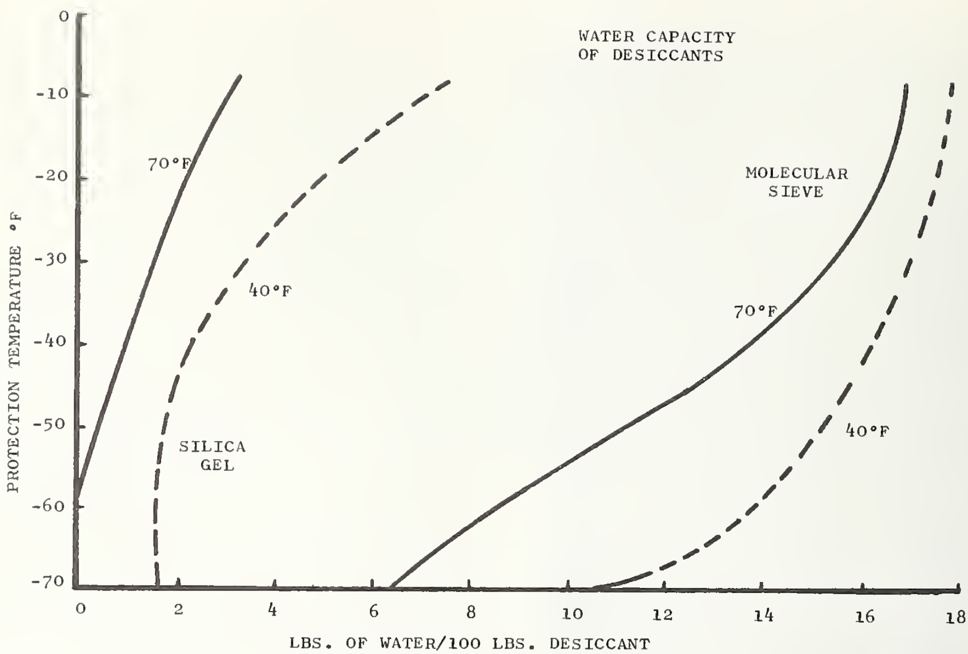

FIGURE 5. *Curves indicate the moisture content for a given dewpoint protection.*

surface and actual dewpoint readings are those measured by a thermocouple cemented on the interior glass surface in the air space.

TABLE 1

Sealant cure system	Group	Number of specimen	Results
MnO_2	A	86	**All units passed the —60° F. temperature requirement although the majority were greater than —100° F.**
	B	56	
	C	93	
PbO_2	A	—	
	B	43	
	C	51	**Four units failed to meet the —60° F. requirement in Group C.**
Misc.		88	**Four units failed to meet the —60° F. requirement.**

Figure 5 is the moisture isotherms of silica gel and molecular sieve. These curves indicate the moisture content for a given dewpoint protection. As many of you are aware, these two materials and variations of these are the most common desiccants in use today.

For those manufacturers of insulating glass who wish a simple and inexpensive method of establishing a quality control system, the dewpoint temperature reading method is unique. It is quite reproducible and can be learned readily by a novice. Figure 6 illustrates the type of vessel that is used. The test procedure can be obtained from the author.

In order to determine the MVT correlation, we built a limited number of sealed units in the laboratory with moisture probes inserted in the air space. This probe was attached to a meter which reads the free water vapor in grains of

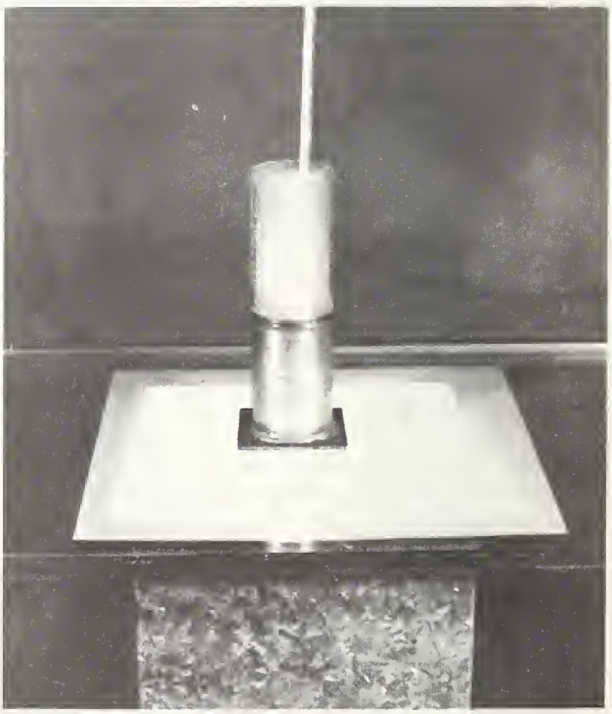

FIGURE 6. *Vessel used for dewpoint temperature reading method.*

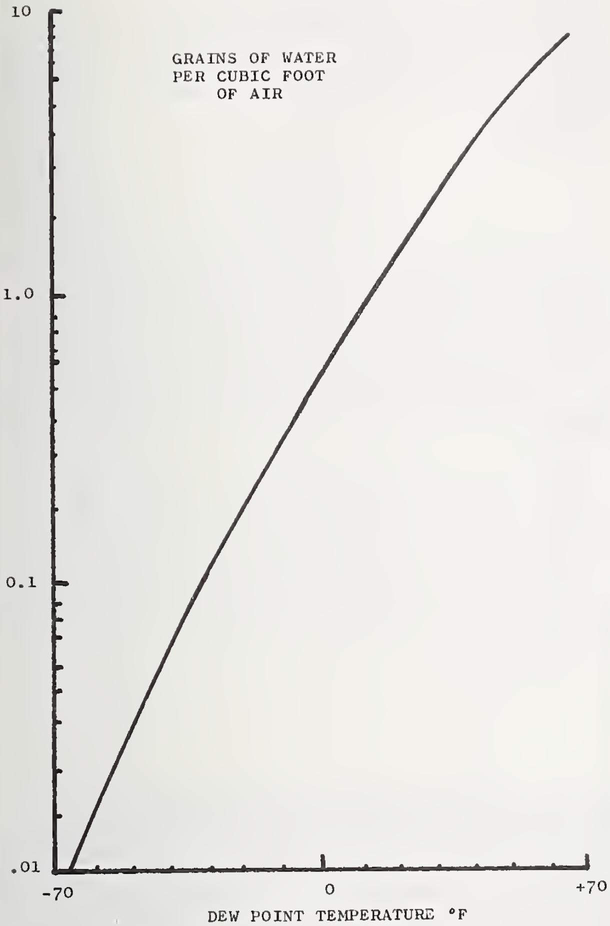

Figure 7. *Correlation of measured dewpoint versus free water for a given volume of air space.*

water. At the same time, we continued to take dewpoint readings and have been able to correlate measured dewpoint versus free water for a given volume air space. We are continuing to run this study on new improved sealant systems.

Figure 7 gives you some early values of these studies.

5. Accelerated Interior Weathering

In attempting to correlate the short-term field experience of most manufacturers, and a test for evaluating the hermetically sealed unit, an accelerated interior weathering test was developed to check a unit in a variety of environmental conditions. This test included freezing, thawing, rain exposure, ultraviolet radiation exposure and high humidity, all on a uniform programed cycle. We were looking for variations of performance based on the different formulations of sealants we developed.

What were we measuring?

(a) Adhesion after exposure to ultraviolet radiation (uv).
(b) Adhesion after exposure to water.
(c) MVT as measured by dewpoint temperature rise after high humidity exposure.
(d) Seal fatigue due to flexing caused by barometric pressure differentials.

The apparatus is pictured in figure 8. This equipment has been adapted from that used at National Research Council—Canada for several years. However, we have modified it by the addition of a series of black lights and uv sunlamps, to closely approximate that of natural uv. We have included a water pump which would give us an equivalent of an inch of rain per hour. In addition, we have also opened up the distance between lights of glass giving a greater air flow around the sealed units.

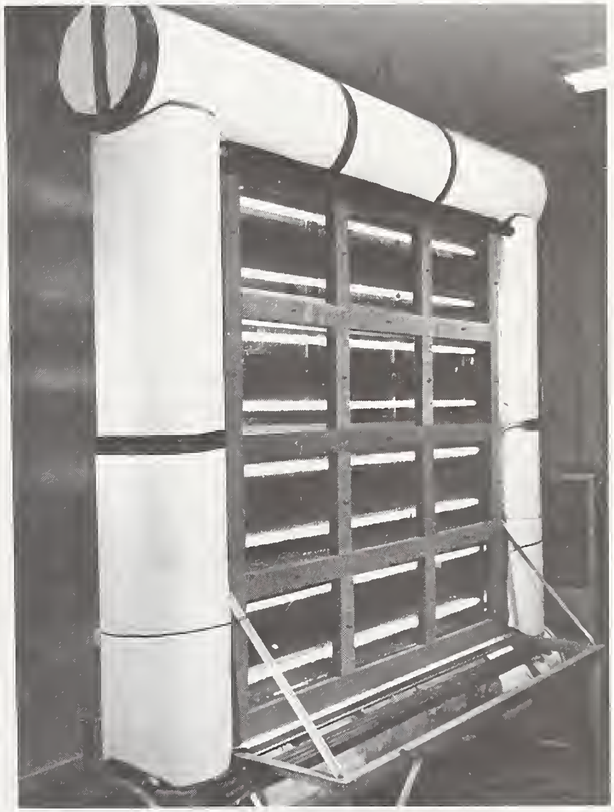

Figure 8. *Apparatus for interior weathering test.*

A typical cycle consists of:

2 hr at −20 °F followed by

1 hr recovery at room temperature followed by

1 hr of uv exposure followed by

1 hr of rain exposure followed by

2 hr at 120 °F. and 100 percent relative humidity followed by

1 hr recovery at room temperature.

Dewpoint readings are taken at five-day intervals to record the rise in temperature. Table 2 shows the number of units tested and their values after 120 cycles.

Table 2

Sealant cure system	Group	Dewpoint temperature				
		Less than −100 °F	−100 °F to −80 °F	−79 °F to −60 °F	−59 °F to −30 °F	Above −30 °F
MnO_2	A	80	20	4	4	4
	B	50	36	14	14	15
	C	43	22	—	—	—
PbO_2	A	10	2	—	4	—
	B	8	10	4	2	—
	C	2	—	—	6	—
Misc.		18	4	—	—	—

Table 3

Sealant cure system	Group	Dewpoint temperature				
		Less than −100 °F	−100 °F to −80 °F	−79 °F to −60 °F	−59 °F to −30 °F	Above −30 °F
MnO_2	A	50	24	16	2	6
	B	20	30	6	4	10
	C	12	20	4	—	4
PbO_2	A	8	4	2	2	8
	B	6	6	2	2	2
	C	—	2	—	4	4
Misc.		12	8	—	2	7

In addition to the accelerated interior weathering test, duplicate test units, unglazed, are placed outdoors at a 45 deg. angle facing south. Periodic dewpoint readings are taken in order to compare these with the readings on the accelerated interior weathering.

6. Fogging

Fogging tests in both architectural and refrigeration type units were developed to check the sealant against depositing a permanent layer of contaminate on the inside surface of the glass. These tests are for a 14-day duration at 150 °F. If no fogging occurs after that period, the units are considered to have passed the requirements of the test.

Many sealant manufacturers attempt to produce a more economical product by the addition of various low cost dilutes, etc. This type of test weeds out the poor sealant. Many times fogging will show up during the accelerated weathering cycle. Figures 9 and 10 illustrate the apparatus used in this test.

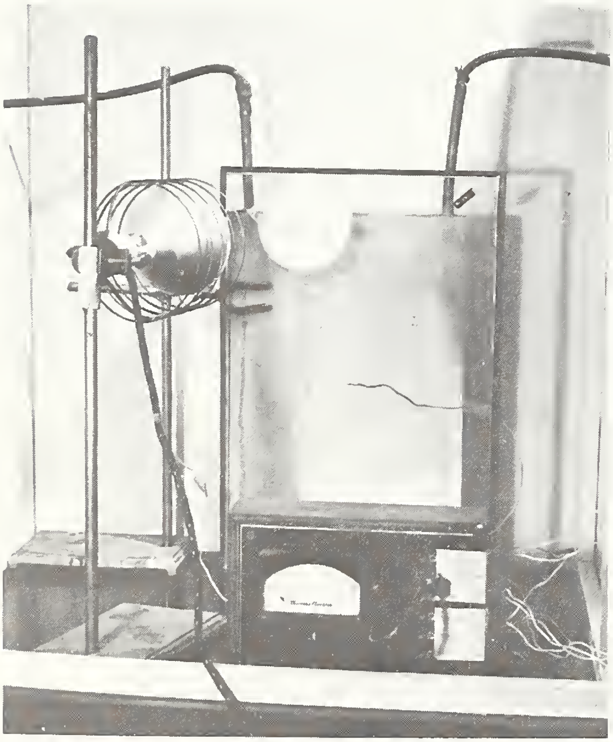

Figure 9. *Apparatus for fogging test.*

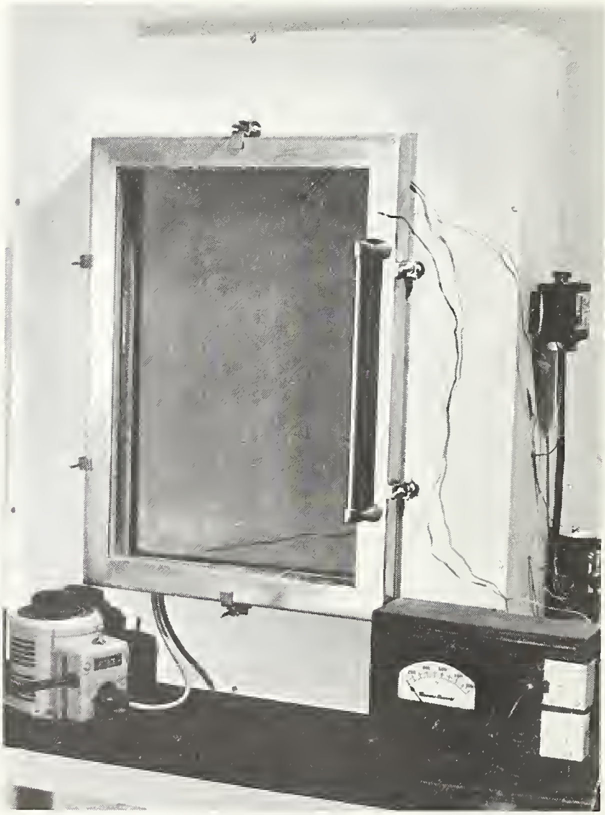

Figure 10. *Apparatus for fogging test.*

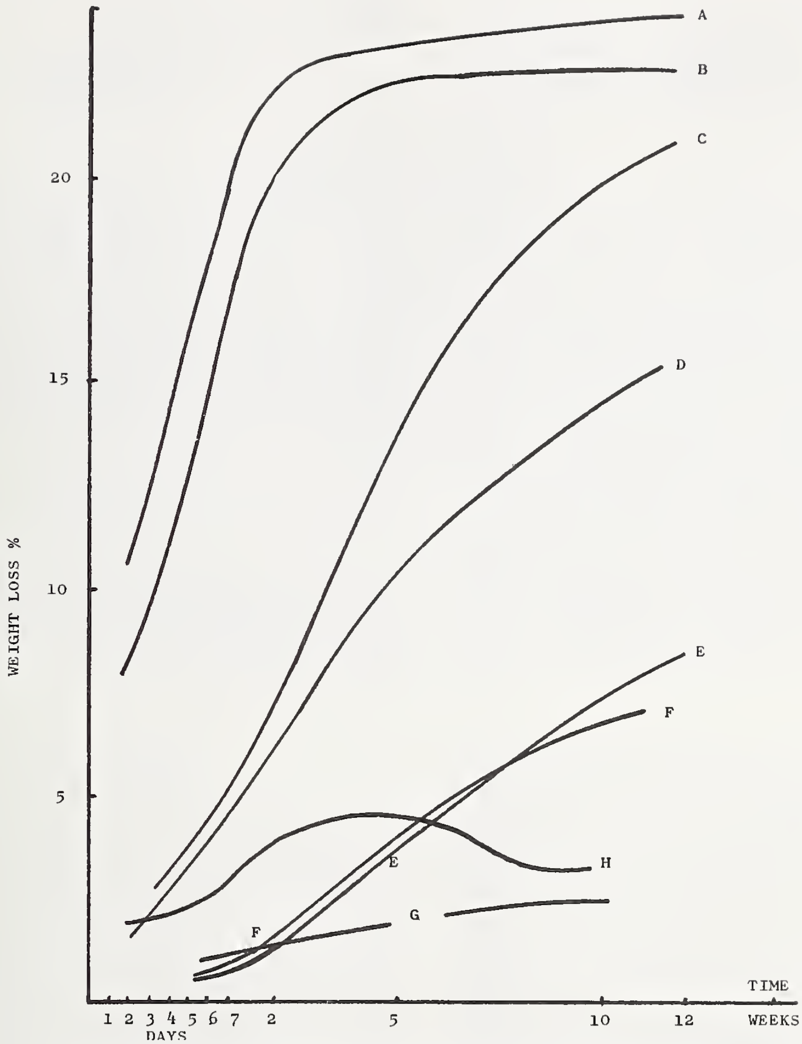

Figure 11. *Chart illustrating weight loss of various sealant systems after exposure to oil at a 50° C. temperature.*

Curve A—Polysulfide sealant without barrier coat; Curve B—Polysulfide sealant with aluminum pigmented barrier coat; Curve C—Polysulfide sealant with nitrile rubber coating; Curve D—Polysulfide sealant with barrier coat, clear; Curve E—Polysulfide sealant with nitrile rubber coating and aluminum barrier coat; Curve F—Polysulfide sealant with nitrile rubber coating and barrier coat, clear; Curve G—Oil resistant polysulfide sealant and latex barrier coat. Curve H—Oil resistant polysulfide sealant without barrier coat.

7. Glazing

Certain oil-based glazing compounds, used to install insulating glass units, have an effect on polysulfide sealants used in their manufacture. To check if a sealant is compatible, we have developed three specific tests.

1. The first we call static testing; it is done by taking the actual glazing compound and glazing a 6 × 6 in test unit into an aluminum sash and subjecting the unit for at least 30 days at 158 °F. The test sample is inspected for bleeding once a week. Bleeding shows up generally as a clear droplet of oil on the air space side of the glass. Sometimes the sealant is attacked causing reversion of the compound, or cracking, discoloration, etc.
2. The second method is of a dynamic nature, where a cross section of a sealed unit is fabricated. The sealed portion is exposed to both the glazing compound and ultraviolet radiation while being flexed at 60 cycles/minute. The flexing is equivalent to barometric pressure changes of 2,000 feet. As yet we have not been able to cor-

relate the static versus the dynamic method, but these studies are continuing.

3. Method three is a direct immersion of a sealed unit in the respective oil vehicle at 158 °F. This test is the most dramatic and without a doubt the one which produces the quickest results.

A simple test on the sealant system alone is accomplished by means of weight loss. The sample of cured sealant is subjected to various glazing oil vehicles for a definite time period at an elevated temperature.

Figure 11 is a chart illustrating the weight loss of various sealant systems after exposure to oil at a 50 °C. temperature. Curve H is based on results of a new development on a sealant which is highly resistant to oil.

Those who do not wish to pay a premium for a highly resistant sealant can use a series of barrier coats. A barrier coat is used to prevent bleeding of these oils through the sealant. The coating is applied after the sealant has become tack-free. The system of sealant and barrier coat provides protection against defective installation techniques and materials. One sure way of eliminating this problem at its source is to specify a compatible glazing compound.

8. Conclusion

The insulating glass industry is in a great growth period, and, from all indications, this growth will continue. This means that more manufacturers will be making more units than ever before. Now there are formal means at the disposal of all manufacturers to check the quality of their units— a new specification with a certification program. Component parts have been improved over the years and more improvements will be forthcoming. All are aimed at product improvement so that extended warranties may be offered.

It looks as though the future of our industry is assured.

The author wishes to thank the PRC Laboratory staff for their assistance in furnishing and compiling the data.

4.2. Manufacturers' Test Methods: Correlation With Field Experience; Expected Field Life

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Laboratory test procedures used by Libbey-Owens-Ford Co. to evaluate insulating glass are chosen to simulate the cyclic temperature and moisture effects which may occur for actual windows. Because the edge seal construction of the insulating glass contains no organic materials, ultraviolet radiation produces no deleterious effects and this item is not normally included in the testing. Testing is conducted in chambers capable of producing rapid changes in temperature and relative humidity when required.

Many test-cycle configurations and test durations are used, depending upon the time available and other factors. Most commonly the procedure recognized by General Services Administration is employed. This procedure requires the insulating glass to be subjected to 175 continuous weathering cycles each consisting of alternate exposure to 48 hours at 0° F and 48 hours at 145° F and 95 percent relative humidity. At the conclusion the dewpoint of the air space must not exceed −18° F. During testing the glass is not moved, thereby eliminating the damage which may occur to the glass or seal when two separate test chambers are used.

The long period required to conduct the above test precludes its use as a routine procedure for acceptance of insulating glass. Development of a shorter test procedure which also reflects the weatherability of insulating glass units is needed. Investigations in this area are presently underway.

Key words: Accelerated weathering; field experience; insulating glass units; outdoor weathering; pressure changes; test cycles.

1. Introduction

Before discussing our test methods and the experience we have had with our insulating glass units in the field, I believe it will be helpful if I briefly describe their construction. The edge seal construction is of especial interest. In the fabrication of the units, the glass is first washed, cleaned, and dried after which metallizing and tinning are applied to the glass surface around the periphery. This forms an integral bond much stronger than the cohesive strength of the glass itself. To the metallized and tinned glass is applied a lead calcium alloy separator strip formulated to withstand movement that may occur in an insulating glass unit. As a point of interest, this alloy is the same as that used for protecting outdoor telephone cables; therefore, its long term weathering properties have been thoroughly tested and are well recognized. The lead separator is soldered to the metallizing using a specially designed soldering iron and a compatible soldering material.

The construction described to this point is that which was used for many years in our insulating glass. Field experience was excellent and trouble occurred only in cases where the sash was grossly misdesigned or other improper conditions were excessive in one way or another. Even though failures were rare, we felt improvements should be made so that the chances of failure were even further reduced.

To arrive at this goal we developed several improvements. One of these is the application of a wax coating to the outside of sealing materials to prevent any electrolytic contact between these materials and the surrounding aluminum or steel sash. Besides this, a polyethylene freeze tube was installed. This was to accommodate for any moisture that may penetrate to the edge of the unit and subsequently freeze. Expansion upon freezing would be taken up by a partial collapse of the freeze tube. A third item was the addition of an aluminum edge channel. This channel is expendable. Its only function is to provide protection of the edge of the units during handling and glazing. Should this channel for some reason entirely corrode once the glass is in place, the hermetic seal would not be affected.

2. Testing

Testing of our insulating glass units begins with the material suppliers who are required to furnish materials to rigid specifications and perform prescribed tests. We conduct similar tests in our laboratories to make certain that the materials meet specifications. We realize the important item for an insulating glass unit is not the performance of individual parts but the performance of the assembled unit and the majority of our tests are on this basis.

In our laboratory we have two cyclic test cabinets for accelerated weathering. In these the temperature and relative humidity are automatically controlled and if desired can be preprogramed.

The primary advantage of these cabinets compared with earlier ones used by ourselves and others is that the insulating glass is not manually moved from a cold chamber to a warm chamber during each cycle. If the tests involve a large number of cycles, there is a good chance of damaging the glass when it is moved negating the results of the tests.

We have used various test cycles and have found no short duration test that remotely reflects the field performance. Most short duration tests tend to be unduly severe causing damage that could never occur in the field or are not severe enough thus giving misleading results. Of the many weathering cycles studies we have found two which we believe will result in failure of inferior insulating glass units. One of these consists of an 8-hr cycle with a dwell time of 48 min at 145 °F and 48 min at 0 °F, the relative humidity maintained at 95 percent when the temperature is above 40 °F. Heating and cooling is at a uniform rate. We believe that for a sampling of 6 test units, not more than one unit should have an air space dewpoint above 0 °F after 200 cycles. Passing this test does not necessarily mean the unit is adequate but if the unit is grossly inadequate it should fail.

Another test similar in many respects consists of a 6-hr cycle with 30 min dwell time at 120 °F and 30 min at 20 °F. Again, the relative humidity is maintained at 95 percent when the temperature is above 40 °F. We believe a sampling of 6 units should withstand at least 600 cycles of this test with not more than one unit above 0 °F dewpoint.

In the early stages of our testing we studied the effect of ultraviolet radiation on the edge seal of our units and found no effect. Therefore, units of our manufacture which we evaluate are not subjected to ultraviolet radiation. Of course with mastic type units ultraviolet testing is very necessary since these units are affected to some degree by extended exposure to ultraviolet radiation.

Besides the various cyclic tests we conduct in our test cabinets, we also conduct what we call a "huff and puff" test. The apparatus used for this consists of two insulating glass units with a narrow air space between. To this air space is attached an air line and necessary pressure regulating and timing controls. The pressure is fluctuated within the space causing the units to bow inwardly and outwardly as the pressure is changed. The purpose of this test is to simulate gust wind loading to see if the edge separator materials are affected. The amount of pressure and the frequency of fluctuation depend on the particular goal of the test.

We also test units by exposing them to outdoor weathering. At present we have about 4,000 units in our two outside test areas. They are not glazed in openings but are open to the weather on both sides allowing rain and snow to reach the edge channel and exposing the edge seal to all weather factors. We have had units exposed up to 12 years in this type of testing.

3. Conclusion

In attempts to correlate our laboratory tests with actual field experience we have found no conclusive correlation. We do know, however, that duplicate units of those which have weathered for 12 years and are still in good condition will withstand in excess of 1000 cycles of the 120 °F to 20 °F cycle test previously described .

The two cyclic tests described earlier are, of course, much too long for quality control. The shorter one requires about 70 days to complete. Obviously there is a strong need for a test method requiring less time while accurately reflecting field experience. This is an overwhelming task to accomplish. After exhaustive testing we have a fair idea of the service life to be expected in climates similar to Toledo. We don't know precisely what should be expected for other climates such as might be found in Minneapolis, Miami, or Phoenix.

Because of the lack of supportable correlation between laboratory tests and field experience, the expected service life of our insulating glass units is not definitely determined. We have manufactured insulating glass units for over 30 years and even the early units which lacked the many later improvements have performed well to the best of our knowledge. We have no precise records of these early units but do have information regarding units produced up to about 20 years ago. The largest installation of over 20 years ago was one containing 14,000 units and to date the units are performing satisfactorily. A small stock of replacement glass was ordered with the original glass and has been adequate for replacement for breakage and other types of failure.

At present our insulating glass is warranted for 20 years. Based on our field experience, accelerated tests, and outdoor weathering of units, we are confident that the 20 year warranty is fully justified.

4.3. Test Methods and Field Experience With Double-Glazed Units

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Performance criteria for double-glazed units intended to assure building owners of a satisfactory period of performance in service must cope with field environments through accelerated testing procedures. Quantitative knowledge of performance variability and a minimum acceptable standard of satisfactory performance are essential ingredients of any program of this kind.

The accelerated testing program we use includes:

1. Temperature cycling
2. Water vapor diffusion
3. Solar radiation
4. Outdoor exposure
5. Water immersion

We have tested large numbers of units manufactured in our own plants and by others according to these procedures.

A significant difference in performance among groups of units tested has been observed. Differences in the sealant composition and performance, in manufacturing procedures, in type and conditions of desiccant used are factors which explain the wide range of performance demonstrated by superficially similar units.

Our service experience, because of the long guarantee which has been in effect for many years, is based both upon our replacement records and upon formal field exposure studies.

Correlation between accelerated test procedures and field tests in recent years has been good. We believe that this correlation provides sufficient justification for establishing a minimum performance level in the accelerated tests.

Key words: Accelerated lab tests; dewpoint measurement; double-glazed insulating units; exponential distribution; field performance; outdoor aging tests; organic seal units; pressure tests; polysulfide rubber sealants; temperature cycling test; water vapor diffusion.

1. Introduction

During the past decade, serious attention has been devoted increasingly by government agencies to the problem of evaluating in-service life of double-glazed insulating units. I believe that the Canadian [3,4][1] and Scandinavian [1,2,6,7,8,9] Government Agencies first recognized this need several years ago. Perhaps this is explained because of the severe winter climates in their regions and the greater proportional use of double-glazing. Domestic interest is growing and it is apparent from the interest demonstrated in this Seminar that progress will be made.

We hope in this paper to point out the importance of tight correlation between accelerated laboratory testing and orderly monitoring of field performance at the job site. The foundation for this work was described in an earlier ASTM paper [5].

From the very beginning of our participation in the Insulating Glass Market over twenty years ago, it was apparent that a sophisticated and extensive testing and development program would be needed. While close correlation between accelerated laboratory tests and field performance has been acquired over a period of years, our initial experience, including both success and failure, taught us that product reliability on the job could be determined in advance by accelerated tests that simulate environment factors encountered in service.

To make accelerated testing practical, it was important to evaluate test unit sizes. Based on careful studies of stresses in glass and the edge seal joints, we arrived at a standard test unit size of approximately 14 × 20 in with a ¼-in air space and glass thickness of ⅛ in or less.

We learned early that a great deal of time and effort could be saved if certain very rapid "screening tests" could be applied to eliminate test units of poor design or careless fabrication. These screening tests include dewpoint measurements and pressure differential tests of seal tightness. Generally, test units with air space dewpoints above 0 °F are obvious indications of seal leakage and should be discarded since their performance is so poor as to result in early failure.

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

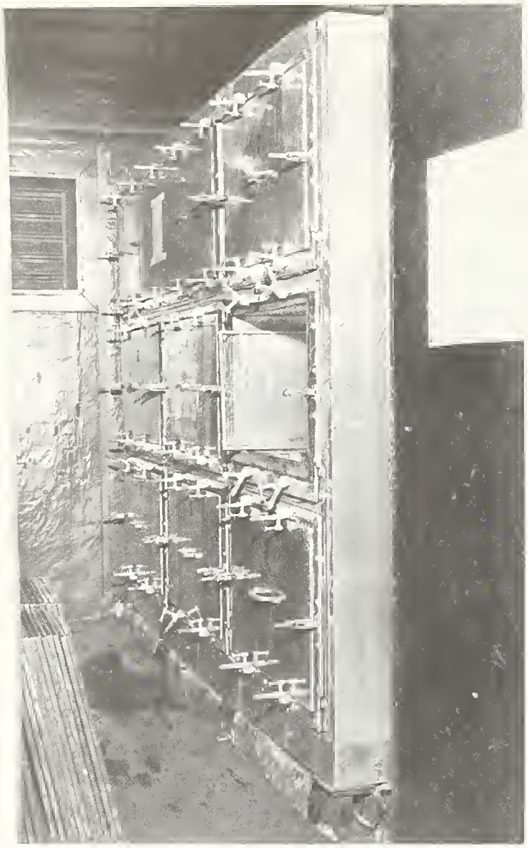

FIGURE 1. *Chamber for 120° to 20° F. cycling test.*

FIGURE 2. *90 percent relative humidity chamber in 110° F. room.*

2. Accelerated Tests

Figure 1 shows the 120 to 20 °F cycling test equipment. The units are mounted above a 1-in pool of water to maintain high humidity throughout the test. Within the cabinet, the atmosphere is cycled from 120 to 20 °F. This test is controlled automatically to give four 6-hr cycles each day, seven days a week.

This test checks the ability of the sealant to withstand pressure loading caused by temperature fluctuations and expansion and contraction forces between dissmilar materials.

A relatively simple test and one which can readily check the water vapor diffusion characteristics of the sealant is carried out at 110 °F and 90 percent relative humidity (see fig. 2). Air temperature is thermostatically controlled at 110 °F and a pan of water in the bottom of the cabinet maintains the high humidity throughout the test. The specimens are supported on wood frames and continuously exposed to conditions in the cabinet.

The sunlamp test is used to obtain ultraviolet light exposure (see fig. 3). RS 275 watt sunlamps are positioned 14 in above and perpendicular to the specimens, and the light is directed on Test Unit corner areas. The aluminum surface below the specimens reflects the radiation to the opposite surface. We have found this test to be very effective when it is followed by the 120 to 20 °F temperature cycling test.

The 130 to −30 °F cycling test, shown in figure 4, includes a circular table that rotates automatically according to a predetermined time schedule. Specimens are glazed into each of the five 4 × 4 ft panels which are mounted vertically on the table so that the exterior surfaces of the units are exposed to conditions within test chambers lo-

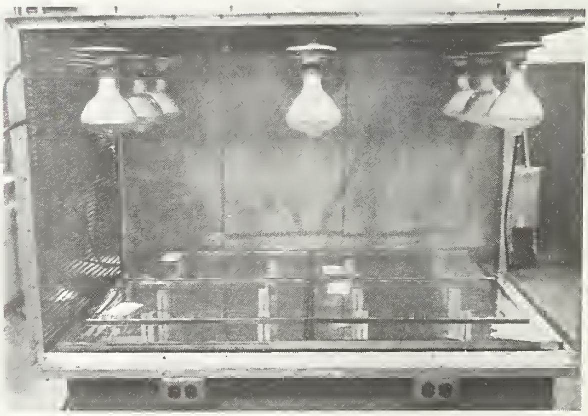

FIGURE 3. *RS 275 watt sunlamp test.*

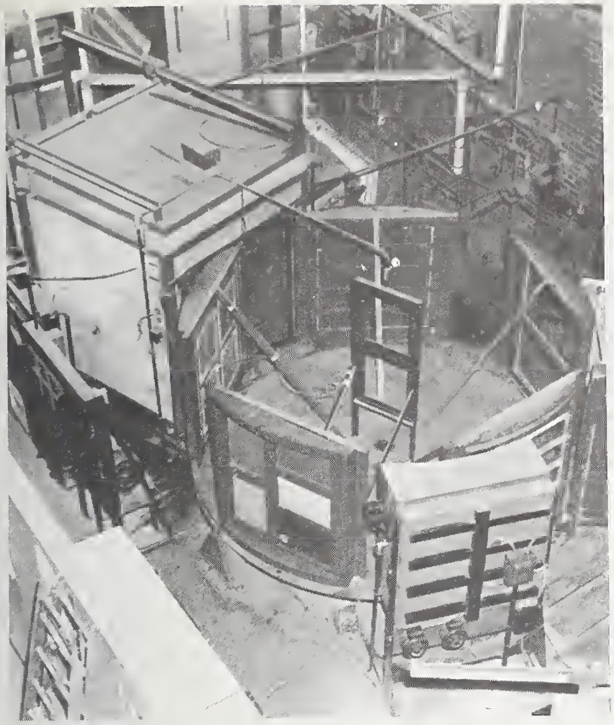

Figure 4. *Indexing table for 130° F. to 30° F. cycling test.*

cated at fixed positions around the table. The opposite surfaces are exposed to prevailing room conditions. Each specimen is subjected to four complete cycles each day, six day a week. Specimens are exposed sequentially to (1) −30 °F, (2) room conditions (70 to 90 °F), (3) 130 °F, (4) water spray, and (5) room conditions (70 to 90 °F).

Figure 5 shows how the specimens are mounted in the outdoor exposure rack. The units are facing south and inclined at a 45-degree slope to prevailing conditions at Harmar Twp., Pa., and Fort Lauderdale, Fla.

Water immersion, Fadeometer, Weatherometer, elevated temperature and pressure tests are useful also.

Our field testing program includes exposure of test units in the outdoor wall of our Creighton, Pa., laboratory building and full-size production unit installation in buildings selected geographically for exposure conditions. To provide statistical validity, a large number of units in many different installations is required. Let me show typical data for organic seal units obtained from specific field tests. For reference, let me remind you of the data first presented in our earlier ASTM paper [5]. The following data are in addition to those data.

Figure 5. *Specimens mounted in outdoor exposure rack.*

3. Accelerated Test Results

Curves in figures 6, 7, and 8 are for seven groups of units from five manufacturers obtained within the past four years. Most of the unit groups were sealed with polysulfide rubber sealants. These are representative of most organic sealed units. The minimum number of units in each group was 18 distributed among four to five accelerated tests. The data presented are from the 120 °F to 20 °F cycling, 110 °F −90 percent R.H. (relative humidity) and the combination ultraviolet and 120 °F to 20 °F cycling tests. Recommended exposure periods for these tests are made relative to 20-yr service life with 10 percent or less failure potential. The basis for these recommended periods will be discussed later.

The significant difference in performance obtained among groups tested in the 120 °F to 20 °F cycling test can be seen in figure 6. The mean

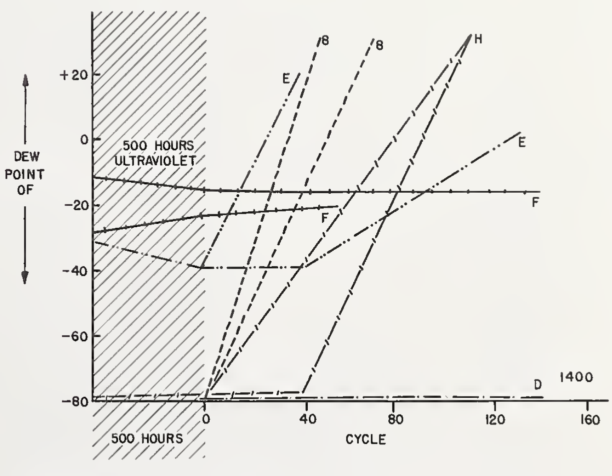

Figure 6. *RS sunlamp and 120° F. to 20° F. test.*

life in this test can be as low as 300 cycles and extend to over 5000 cycles. Group D shows no change from the initial −80 °F dewpoint after 2300 cycles. Factors explaining the wide range in performance are (1) differences in sealant composition and performance, (2) manufacturing procedures, and (3) type and condition of desiccant used. Ineffective fabrication process control is another contributing factor. Groups B, C and G from the same manufacturer were obtained within a period of 18 mo.

For 20-yr service life in the building we would like to see a minimum exposure period of about 1200 cycles with an allowable average change in dewpoint of less than 30 °F from an initial of −60 °F. This requirement was met by Groups C, D and F.

A similar scattering of results was obtained in the 110 °F, 90 percent R.H. test (see fig. 7). For some types of sealants, this water vapor diffusion test is more severe than the 120 °F to 20 °F temperature cycling test. This test reinforces the data obtained in the 120 °F to 20 °F test. Group G had a mean life of only 40 days, while Group D is still performing well after 600 days.

Groups B, C, and G utilize molecular sieve as the desiccating medium. This desiccant has the capacity for maintaining lower dewpoints than silica gel but the opposite is true at the higher dewpoints. We expect 20-yr units to perform satisfactorily up to 300 days in this test.

Figure 8 shows ultraviolet effect on sealant. While all specimens showed no change in dewpoint from initial dewpoint, the relatively poor resistance of the sealant to ultraviolet radiation becomes evident when followed by short exposure periods in the 120 °F to 20 °F cycling test. For Groups B, E and H, this test was 12 to 20 times more severe than the 120 °F to 20 °F cycling test alone. However, Groups D and F were unaffected by the ultraviolet exposure and the former has

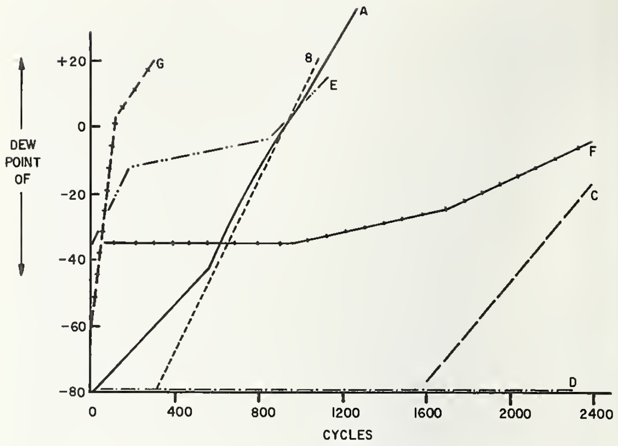

FIGURE 8. *+120° F. to +20° F. test.*

now received a total of 1400 cycles with no change from the initial dewpoint of −80 °F.

Experience with this two-part test indicates 500 hr in the RS Sunlamp exposure followed by the 120 °F to 20 °F cycling test produces similar results to the outdoor aging test. We would recommend the total exposure be 1000 hr in the RS Sunlamp exposure and 500 cycles in the 120 °F to 20 °F test.

4. Field Test Program—Correlation with Accelerated Tests

Figures 9, 10, and 11 will cover the results obtained in the service tests.

The four groups of units in the laboratory wall test also were 14 × 20 in and were glazed in steel sash using elastic glazing compound (see fig. 9). These groups are from the same manufacturers as those in the accelerated tests but obtained at different times. The number of units in each group and the disposition of failures are also indicated.

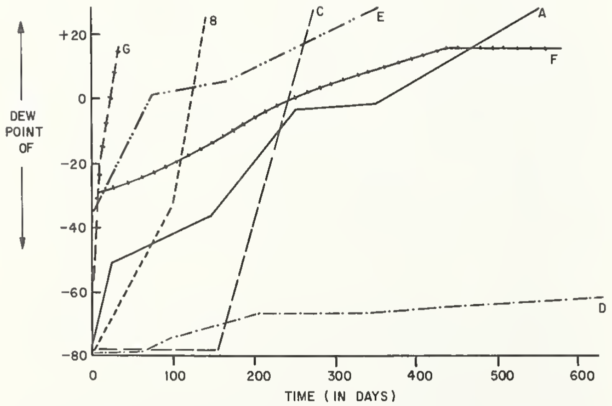

FIGURE 7. *110° F. — 90 percent R.H. test.*

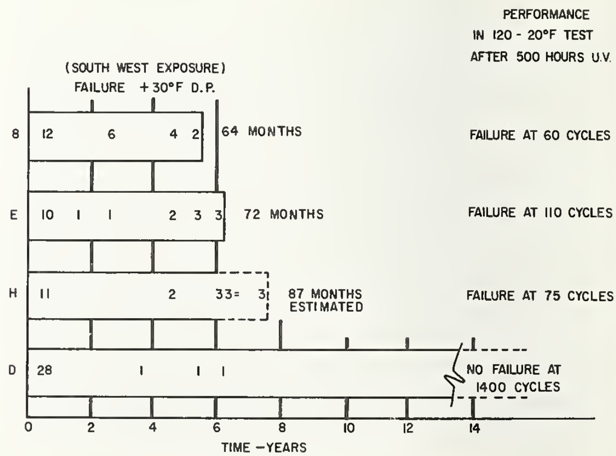

FIGURE 9. *Laboratory wall.*

The total life of Groups B, E and H glazed in 1962 ranged between 64 to an estimated 87 mo with failures recorded as early as 18 mo. These results substantiate the relatively poor performance obtained in the accelerated aging tests. The types of failure were the same as those in the ultraviolet exposure followed by the 120 °F to 20 °F cycling tests.

The performance of these groups in the 120 °F to 20 °F test after 500 hr exposure to ultraviolet can be found in this same chart. A rough correlation indicates that 500 hr ultraviolet and 100 cycles in the 120 °F to 20 °F tests is equivalent to approximately 2 to 7 yr exposure in the wall. Looking at it another way, the performance of Groups B, E and H would have to be upgraded by a factor of six to eight to insure reliability for a period of 20 yr at a mortality level of 10 percent or less. Group D with three failures in six years and no additional failure in 7½ yr has the potential for an extended life.

Results of a field study started in 1960 are shown in figure 10. The letter designation again indicates the same manufacturer as for the accelerated and wall test units. Some of these sites have been abandoned because of gross failures or other problems.

Figure 11 shows the correlation between the accelerated tests and the field study. The total life of six of the nine sites ranges between four to an estimated ten years which parallels that obtained in the laboratory wall test for the same type of unit. Once again the Group D units are showing a superior performance with an estimated life span greater than 20 yr. This correlation gives further justification to the recommended 1000 hours of ultraviolet and 500 cycles in the 120 °F to 20 °F cycling test.

				Dew Point Results °F							
Location	Year of Installation	No. of Units	Specimens Checked	Date Checked	Avg.	Range	Date Checked	Avg.	Range	Increase Avg.	Increase Range
N. Y. (E)	1962	115	14	1963	5	-10,31	1965	+21	5,31	16	1, 38
Pa. (B)	1961	340	7	1963	50	18,50	1965	all failed			
	1963	62	6		-15	-35,6		40	-22,50	37	13, 64
Ill.	1963	400	9	1963	-40	---	1967	40 (5 failures)	30,50	80	70, 90
W. Va. (B)	1959	28	13	1964	8	-10,50	1967	50	8,50	42	4, 48
	1962	22	6		-60	---		-28	-50,4	32	10, 64
Wash.	1965	900	16	1965	-40		1966	-40	-40,-30	0	0, 10
Ill.	1965	200	28	1965	-40	---	1968	-25	-40,0	15	0, 40
Mich. (D)	1963	102	11	1963	-40	---	1966	-40	---	0	
Ill. (D)	1960	1700	15	1960	-50	---	1966	-50	---	0	
Ohio (D)	1962	45	14	1962	-50	---	1966	-50	---	0	

FIGURE 10. *Field study.*

FIG. 11 - FIELD STUDY VS ACCELERATED TESTS

				Dew Point Results °F					Failure-Accelerated Tests-Cycles		
Location	Yr. of Inst.	Units	Specimens Checked	Date Check	Avg.	Date Check	Avg.	Increase Avg.	Failure Years	120°-20°F	500 hrs Sunlamp 120°-20°F
Pa.(B)	1961	340	7	1963	50	1965	all failed		4		
	1963	62	6		-15		40	37	5 est.	1100	60
W. Va.(B)	1959	28	13	1964	8	1967	50	42	8		
	1962	22	6		-60		-28	32	10 est.	1100	60
N. Y.(E)	1962	115	14	1963	5	1965	+21	16	6 est.	1300	110
Ill.	1963	400	9	1963	-40	1967	40 5 failed	80	4	---	---
Ill.	1965	200	28	1965	-40	1968	-25	15	10 est.	1500	---
Wash.	1965	900	16	1965	-40	1966	-40	0	---	---	---
Mich.(D)	1963	102	11	1963	-40	1966	-40	0	20 est.	5500	140 no failure
Ill.(D)	1960	1700	15	1960	-50	1966	-50	0	20 est.	5500	140 no failure
Ohio (D)	1962	45	14	1962	-50	1966	-50	0	20 est.	5500	140 no failure

FIGURE 11. *Field study versus accelerated tests.*

5. Statistical Analysis of Field Data

A statistical analysis was made of our field data in an attempt to predict the probability of failure of a 20-yr period. In this analysis, the performance of millions of units was involved with field follow-up work covering more than 17 yr. We have found that an exponential distribution fits the available data and describes probability of failure. This is given by $F(x) = 1 - \exp.(-x/\theta)$ where x is the time to failure. θ is the mean value and $F(x)$ is probability of failure within time x (see fig. 12).

If mean failure time is 50 yr, the proportion of defective units one can expect to develop in 10 yr is about 18 percent of an original population installed at time 0. In 20 yr the percentage will increase to about 33 percent. If the mean life is 100 yr, then the percentages will decrease to 9.5 percent and 18 percent requiring replacing in 10- and 20-yr spans, respectively. Therefore, a manufacturing unit needs to know the risk of failure with the guarantee period desired.

FIG. 12 - STATISTICAL ANALYSIS TO PREDICT PROBABILITY OF FAILURE

$F(x) = 1 - \mathrm{EXP}(-x/\theta)$

x = TIME TO FAILURE

θ = MEAN FAILURE TIME

F (x) = CUMULATIVE PROBABILITY OF FAILURE

FOR θ = 50 YEARS		F (x)
x =	10 YEARS	18%
	20 YEARS	33%
FOR θ = 100 YEARS		F (x)
x =	10 YEARS	9.5%
	20 YEARS	18%

FIGURE 12. *Statistical analysis to predict probability of failure.*

An attempt to translate this statistical analysis to the 120 °F to 20 °F cycling test (since the type of failure is the same as that encountered in service) suggests that assuming a probability of failure of 10 percent in 20 yr the number of test cycles should be over 700. However, statistically it is necessary to use 25 samples or more to get meaningful and reliable estimates. Earlier, I recommended 1200 cycles in this test to compensate for the small number of samples generally used. This analysis shows what can be done once field information becomes available.

This type of correlation analysis is needed to determine the minimum acceptable standard for satisfactory performance.

6. Conclusions

A significant difference in performance among groups of units tested has been observed in the accelerated tests. Differences in the sealant compositions and performance, in manufacturing procedures, in type and condition of desiccant used are factors which explain the wide range of performance. Ineffective fabrication process control is another contributing factor.

The formal field testing studies show relative performance differences similar to those obtained in the accelerated aging tests. The total life of several test sites ranged between 4 to an estimated 10 yr while the life span of those with high quality units is estimated to be greater than 20 yr.

The good correlation obtained between accelerated test procedures and field tests provides sufficient justification for establishing a minimum performance level in the accelerated tests. Our recommendation for a minimum exposure period in the accelerated tests to insure reliability for extended periods should include:

> 1200 cycles—120 to 20 °F temperature cycling test
> 300 days—110 °F, 90 percent R.H.
> 1000 hr RS Sunlamp Test and 500 cycles in the 120 to 20 °F
> Allowable average change in dewpoint should be less than 30 °F from an initial of −60 °F dewpoint.

Our experience with long guarantee periods further substantiates these minimum requirements.

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4.4. Insulated Glass Sealants—Function and Types

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The purpose of this article is to review the sealants available to manufacturers of insulated glass units and point out the service properties that are necessary and available in current sealants. I primarily want to point out how we believe optimum performance from the sealant standpoint can be obtained for long term service.

Key words: Butyl-polyisobutylene; insulated glass units; laboratory tests; optimum performance; polysulfide sealants; sealant performance ratings; standardized test chamber.

1. Introduction

There are two major families of sealants used in the fabrication of insulated glass sealants: (1) chemically curing, two-package, gun-applied materials typified by polysulfides, and (2) pre-extruded, noncuring, elastomeric tapes typified by butyl-polyisobutylene tapes. Each of these serves the required functions, each having its own strong points and weaknesses. Both types may be used singly or in combination obtaining varying degrees of performance.

To best analyze the sealant problem and then accomplish a logical conclusion or selection of sealant types, let's take a look at what we expect the sealant to do for the insulating glass unit.

First, the sealant must hold the unit together. Structural rigidity is nearly always accomplished through the sealant. There are other methods of doing this, where the unit may be held together by some mechanical means such as a spring steel surrounding band, but the usual method is to utilize the sealant.

The next most important function the sealant must perform is to act as a barrier to gases and vapors, preventing or reducing, to an acceptable level, their entry into the interior air space of the unit.

An additional property necessary in sealants used in constructing insulating glass units is the ability to compensate for thermal and barometric movement of individual glass unit members.

A last, and obvious requirement of the sealant, is that it must be compatible with the fabricator's production methods and cost allowances.

Now, let's enumerate the performance properties or qualities necessary in sealants to achieve the functions we have just outlined, and, for the moment, we will not consider the unit which utilizes a mechanical means for structural rigidity.

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1. The sealant must develop satisfactory adhesion to the various components or adherends which usually are aluminum (mill finish or anodized), galvanized steel, stainless steel, and, obviously, glass.
2. It must be resistant to the weathering it will encounter in service; moisture and temperature variations between minus 40 °F. and 200 °F., and particularly important, ultraviolet energy.
3. Flexibility, or perhaps a better term, controlled internal mobility, is necessary to compensate for movement between the joining members of the unit.
4. It must have the lowest possible transmission rates of moisture and other volatile materials. An added desirable quality is to be nonvolatile itself.
5. Application qualities vary with the type material and are too numerous to go into their details here but pumpability, mixability of two package materials, nonslump qualities, cut-off and extrudability are all extremely important but, to a large extent, are defined by individual fabricator's requirements.

2. Performance Ratings of Sealants

Initially, we divided the sealants into two major families: two-package, pumpable materials which chemically cure in place, and extruded materials which initially, at least, are pressure-sensitive in their adhesive properties. Taking these two types of sealants, which can be typified by polysulfides in the one case and butyl-polyisobutylene tapes on the other, let us take a look at what each of these has to offer in the construction of a typical insulated unit which does not rely on a mechanical means for holding the unit together.

2.1. Structural Rigidity

Structural rigidity is easily accomplished by pumpable sealants. Two part polysulfides can be made which rapidly cure to a reasonable hardness and adequately hold the unit together. The necessary adhesion and cohesion can be built into these sealants without too much difficulty. Extruded tapes, on the other hand, demonstrate good adhesion but the cohesive properties are only poor to fair. The problem with extruded tapes is really one of flow under pressure. Even though it is possible to formulate a material which will not be squeezed completely out of the joint between the glass and the interior core or separator, the perfect material which will not permit lateral movement of the glass and at the same time accomplish all the other necessary properties of adhesion, compressibility, etc., has not been made satisfactorily to our knowledge.

2.2. Barrier Properties

Barrier properties of the pumpable materials should be rated as good. Using the same reference, top-quality extruded materials must be rated as excellent or outstanding. Using the same evaluation methods, the extruded materials have a 20 to 40 fold advantage. This is the primary advantage of using the butyl-polyisobutylene type tapes. It is an inherent property of the base polymers used in the formulation of these materials and it offers an advantage that has not been met by the best two package pumpable materials.

2.3. Resistance to Weathering and Ultraviolet Energy

Resistance to weathering and ultraviolet energy of top-quality two-package insulated glass polysulfides is good. This requires sophisticated formulating knowledge and is available in some currently marketed polysulfides. Traditional polysulfides used in construction or industrial applications do not fill the bill. They are more than adequate for the job they have but do not have the long-term heat and ultraviolet resistance necessary for insulated glass service. The resistance possible with top-quality butyl-polyisobutylene tapes to ultraviolet energy and heat is excellent.

2.4. Resistance to Fogging

Fogging of the interior surfacees of an insulated unit is caused by two general weaknesses: (1) moisture traveling through or under a sealant, and (2) volatiles emitting from the sealant. Either or both of these are then condensed and deposited on the interior glass surfaces. The moisture problem has just been discussed under barrier properties, but the fogging caused by volatiles coming from the sealant itself is an equally serious possibility.

Two-package, pumpable sealers which have been used up until quite recently would be rated poor to fair. Recent materials have been made which are definite improvements in this characteristic of volatile emission. Depending on how the material is evaluated, the new generation of sealants just emerging can be rated as good for this characteristic.

The second major strength of an extruded butyl-polyisobutylene tape is the absence of the risk in causing a fogging condition because of volatiles which might come from the sealant itself. The materials used in formulating this type of material do not contain low molecular weight fractions which would permit a fogging condition to occur.

2.5. Handling

From the handling standpoint, both materials can be rated as good. Each have their own characteristics of pumping, mixing, extruding, and placement.

If we look at the composite picture made by the ratings assigned to both types of materials related to the required performance qualities, it is apparent why the use of both sealants in the fabrication of high quality units has been developed and used. Where one sealant does not measure up to an excellent rating, the other does. By using both sealants, it is possible to obtain an excellent rating and performance for each of the necessary qualities. One sealant complements the other with the end result being a higher quality unit than is possible when using either sealant individually.

3. Methods of Evaluating Performance

A brief description of methods used in evaluating these qualities is in order. To a large extent, it is necessary to rely upon laboratory data. Facts concerning field failure are not widely publicized for the normal reasons. When a failure occurs, none of the parties involved is particularly anxious to have the information circulated and so it is difficult to know where or when failures in service occur unless your organization is directly involved. Sealant companies, therefore, are hampered in relating field failures to laboratory evaluations of their materials because, after all, when the question is asked, the answer usually is, who has any failures?

So, specific data are difficult to obtain. In addition, the conditions in service are not uniform. Location, ambient weather conditions, thermal movement, handling of the units prior to installation, and the installation itself is seldom the same and so there is seldom a uniform base from which to draw conclusions.

The various sealant qualities listed are necessary and are a concern or they would not be demanded by their users. Specifications such as NRC's 12GP8 and the Sigma Specification contain requirements which measure barrier qualities, weathering resistance, and fogging properties because they are recognized problems by the people who are in the business of making and using insulated units.

The laboratory tests which are most meaningful to us in sealant development are quite simple in principle. We use test applications of the sealants involved on the substrates the fabricator is using. Exposure of these test applications to long term high temperature conditions, ultraviolet energy, both dry and in the presence of moisture, is a very empirical and reliable test. What adheres to one aluminum alloy will not necessarily adhere to another. A sealant may have excellent resistance to ultraviolet energy but as soon as moisture is introduced along with the ultraviolet energy, the sealant can fail adhesively.

Resistance to pressure buildups in the interior of an insulating unit can be simulated with a standardized test chamber where pressures can be controlled and exerted on the sealant which is unsupported other than by its own adhesion and cohesive forces.

The barrier qualities can most reliably be tested by use of the ASTM Test Method E–96. Procedure E of this method is most severe. Results from this test must be tempered with the sample size involved and the conditioning of the sample prior to the test. A sealant tested at a 20 mil thickness may have an MVT rating of 2 grams $(H^2O)/24\ hr/m^2$ but when tested at different thickness or aged in a weatherometer prior to testing, the MVT value will vary. One study made with a two-part polysulfide, which was tested at various thicknesses before and after weatherometer exposure, showed the barrier properties degrading from 3 to 20 at 20 mils thickness.

I would like to go into a little more detail on the individual laboratory test that we use in evaluating our sealants before we think they are ready to go into a unit and then be tested in the unit itself. Adhesion and cohesion is rated by the normal method using overlap shears made up of adherends of the aluminum or stainless steel or glass involved. A two part polysulfide should typically give an overlap shear value of over 100 pounds per square inch. A butyl-polyisobutylene tape will give a very low value, and it should fail cohesively. Actually, it does not contribute anything to the structural rigidity and the value that it gives is not really important. Barrier properties, as mentioned, are measured by the ASTM E–96 Method and a good polysulfide underneath the conditions stated in Procedure E (0 to 90 percent relative humidity) at a 20 mil thickness un-aged, should give values between two and five grams of moisture through a square meter area in 24 hours. Using the same set of conditions, a butyl-polyisobutylene tape will give a value of .1 to .2 gram.

Resistance to ultraviolet is best tested on glass and, in this case, polysulfides should give at least a 60 day resistance to ultraviolet in a dry condition and 30 days in a wet condition. The manner of testing is to simply put a casting of the sealant down onto the glass, expose it 12 inches away from the sun lamps, periodically peeling off the polysulfide. A cohesive failure should result. Fogging resistance can be tested in a chamber which contains the polysulfide or other test material. The air temperature is kept at 160 °F. A glass plate on top of the vessel is cooled at 50 °F. by circulating water. Volatiles that are inside the compound which could come out after it is in the unit, will be condensed on the glass surface.

4. Conclusion

In summary, there are a set of qualities desired in any insulated glass sealant which, simply stated are:

1. Adhesion/Cohesion
2. Ultraviolet and Heat Resistance
3. Flexibility
4. Low Permeability
5. Nonfogging

Two-package sealants and pre-extruded tapes both have advantages and a portion of the qualities necessary. It is necessary to use both types of materials in a single unit and obtain the optimum performance for each property or quality desired. If the butyl-polyisobutylene sealants are not used, it is not possible to obtain the optimum combination of service performance properties of low permeability, non-fogging, and long term resistance to degradation.

Because of the variations in field use and conditions, and the elusiveness of reliable data concerning field failures, it is necessary to rely primarily on laboratory tests which measure the qualities required for good, long-term, performance.

Performance of Sealants in Insulated Glass Units

Performance quality	Pumpable sealants	Extruded tapes
1. Structural rigidity		
(a) Adhesion	Excellent	Good
(b) Cohesion	Excellent	Poor to fair
2. Barrier property	Good	Excellent
3. Resistance to u.v. and weathering	Good	Excellent
4. Nonfogging	Poor to fair	Excellent
5. Handling in production	Good	Good

4.5. DISCUSSION SESSION IV

Mr. McKinley: Could we now have questions from the floor for our four speakers? Mr. Beavers?

Mr. Beavers: I have a question for Mr. Amstock. If a manufacturer uses an accelerated cure of a polysulfide sealing system, is the performance of the seal impaired in any way?

Mr. McKinley: Thank you. May we have a question for Mr. Gwyn?

Participant: Can Mr. Gwyn give us any information on the effect of using reflectively-coated glass in sealed double-glazed units?

Mr. McKinley: Thank you. A question for Mr. Mazzoni?

Participant: Has Mr. Mazzoni's company conducted tests recently on polysulfide sealed double-glazed units?

Mr. McKinley: Thank you. One for Mr. Box?

Participant: Could Mr. Box expand his previous remarks to include discussion of other types of sealants than those made by his company for insulating-glass units?

Mr. McKinley: Thank you. Sir?

Participant: (Inaudible)

Mr. McKinley: I belive the question is, how can we cope with glazing problems, and it is directed to all four speakers. Thank you.
Let's go and get a cup of coffee and be back here at 4:00 o'clock. On your way, if you would like to pick up an extension to your registration list Mr. Cook has these at the registration desk.

Mr. Amstock: I will attempt to answer Bill Beavers' question first. His question was: if a manufacturer accelerates the cure of the polysulfide system, does he get a degradation of the seal? On the contrary, most good polysulfide seals manufactured will gain properties such as adhesion, resistance to UV and moisture and combinations of them because of this accelerated cure by heat. Again, most manufacturers have the capability of adjusting application time or cure rate by means of different retarders in their system and this by no means will detract from the ultimate properties of the cured sealant system, or the performance of the sealed unit. And if I may answer my glazier friend back there, who claims that he has quite a bit of breakage or failures because of glazing techniques.

Participant: Almost everybody in the industry has.

Mr. Amstock: Well, I can't agree with you fully on that one, I'm sure there are a lot of problems in the field because of this condition. I don't know if you were there, but yesterday the SIGMA organization had a lengthy meeting on glazing techniques for installing lights into the sash or building as well as a discussion on the various types of compounds that are used. I would say that with the type of potential specification that was discussed, which is a very difficult one to develop, and the experience that we've had from the two major glass suppliers, I think this will be resolved. Again many glaziers, and I've seen it happen in the field, just slap the unit in as though they could hardly care less about clearances or setting blocks. This is the responsibility of the glazier himself or the foreman or supervisor on his job, and of no one else.

I would think that breakages due to poor glazing practices should not be charged to the manufacturer of the glass, or to the component manufacturer, because I personally couldn't accept that type of logic in such cases.

Mr. McKinley: I think you've uncovered a very practical side of our problem and I believe when we get to the wind-up this is one of the items that ought to be on our list. Thank you for the question, and thank you, Joe.

Dan Gwyn: The question that was asked me has to do with a reflective copper film and really doesn't pertain to this meeting. I talked to the young man back there. . . . I think he is satisfied with the answer. It has nothing to do with the edge seal of our unit.

R. W. McKinley: Very good. Do you care to comment on the glazing question?

J. D. Gwyn: I certainly am not the best one to discuss glazing but I have the strong impression that my company, as well as PPG, has, and offers, detailed information on glazing. I do know that we have a department which looks into all large buildings that are under consideration, as far as sash is concerned, to see the glazing matters appear satisfactory.

Mr. McKinley: Perhaps it is time to move along. Mr. Mazzoni.

Mr. Mazzoni: The question put to me was, "Have we done any recent testing on polysulfide double glazed units?" I would like to point out that I purposely did not identify any type of unit that we have in there, at least I tried not to. The main purpose of the paper was to try to correlate the accelerated test data with the field data and, once having a correlation, to use this as a basis for projecting, from the results of the accelerated test of any new material that may be used, an estimate of how well the material will do in the field, because you can't very well have field data come to you all the time. In other words, if you have made a variation you can't practicably put this into the field and wait five years or ten years. So the prime purpose of the paper was to show that there is some kind of a correlation that can be made with a PPG type accelerated test and the service type test.

Mr. McKinley: Thank you, Ray. Mr. Box.

J. A. Box: The general question to me was, "Why didn't I include discussion of other types of sealants in my remarks? I hesitate to say specifically why in many cases because we don't manufacture these other types of sealants for insulating units so I would be knocking someone else's line of products. The reason we don't use them is because we think that what we're using for insulating glass is the best.

There are many sealants that are excellent for various specific applications, but they are not suitable for sealed double-glazed units because of the combination of properties required for this application. Among essential characteristics needed are satisfactory rate of cure, very low vapor permeability, adhesion, strength, low creep, and resistance to uv. For one reason or another, many otherwise good sealants are therefore screened out as regards use for insulated glass units.

As far as the glazing question is concerned, I'd like to say that the way the unit is glazed is also a source of a lot of problems.

Mr. McKinley: Yes, Mr. Orbeson.

Mr. Orbeson: I would like to comment in part on this glazing problem. Concerning the information that we have published, let's say that in a general way, we will work with any manufacturer of glazing materials or sash to develop his methods to fit our units, but why should we publish a book of lengthy practices on some 203 installation methods—to help our competitors.

Mr. McKinley: I think our panel deserves a real hand . . . I want to thank each of you and I'm sure your questions will not end as you step back into the audience.

Mr. McKinley: Very early in the game, one of the reasons for focusing our attention on the National Bureau of Standards was the possibility that the next paper might be available. The subject is "An Exploratory Study of Laboratory Testing Methods and Standards for Factory-Sealed Double-Glazed Window Units." Our speaker is Henry E. Robinson, Chief, Environmental Engineering Section, National Bureau of Standards.

5. A Review of Current Practices Leading to New Test Methods and Standards

5.1. An Exploratory Study of Laboratory Testing Methods and Standards for Factory-Sealed Double-Glazed Window Units

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Failure of edge-seals of factory-sealed double-glazed insulating glass window units to exclude moisture from the air space of the unit leads to permanent fogging, obscuring view through the unit. A review was made of three fairly well standardized extant laboratory methods for accelerated testing of such units aimed at evaluating the intrinsic initial quality and prospective in-service durability of the seals. In addition, visits were made to four laboratories with extensive experience in such testing for detailed discussion of test methods. Among the information sought was evidence of the degree of positive correlation between the results of the accelerated tests and long-time satisfactory performance of units in service. It is tenable to conclude that units that fail the present accelerated tests would not have had satisfactory durability in service. However information at present as to a positive correlation between successful test performance and long-time service performance is too limited to enable predictions as to service durability generally for the spectrum of units now marketed. In part, a correlation is impeded by the fact that the present test methods have not been in use for a period as long as the desired life of a unit, i.e., the useful life of a building.

Current trends in the development and needs of accelerated testing methods for such units are discussed, and an apparatus is suggested for satisfying them. Certain research possibilities offered by the suggested apparatus are outlined.

Key words: Accelerated laboratory tests; correlation of test and service performance; double-glazed window units; durability of edge-seals; insulating-glass; factory-sealed; permanent fogging of insulating-glass.

1. Introduction

In the last two decades there has been an accelerating use of factory-sealed double-glazed insulating window units in buildings. Several factors have combined to promote increasing use of such units. Among these are decreased discomfort near windows and less condensation on them in winter, reduction of air conditioning loads in summer, reduced noise transmission, neat and unitary installation, improvements in materials and factory production, and architectural tendencies toward use of increased areas of fenetration. Nevertheless, cases of failure of factory-made seals to exclude moisture from the air space of the units have occurred sufficiently to concern producers and users alike. Such failure leads in a relatively short time to permanent fogging or filming of the inaccessible glass surfaces and permanent obscuration of clear view.

Users will expect that units should have an in-service durability equal to the life of a building, barring accidental damage, and producers must expect that they must provide it. Thus, during the development of sealed units, manufacturers and others have developed various tests of accelerated types, by which to evaluate the quality and durability under the accelerated test conditions, of the factory-made seals of the units. Undoubtedly these have contributed to improvement of seal designs and materials, and quality control in production.

At the present stage, in addition to the accelerated tests adopted and used in-house by individual manufacturers for their own guidance, there are in use in North America two principal specifications of testing methods and requirements—that of the Canadian Government Specifications Board (12–GP–8) [1] [1] and that of the Sealed Insulating Glass Manufacturers Association (65–7–2) [2]. Testing of units according to each specification is now available to manufacturers generally, at designated laboratories.

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

This exploratory study was conducted for the Federal Housing Administration of the Department of Housing and Urban Development. The purpose of the study was to make a review of extant laboratory procedures, and to summarize information obtained in visits to four laboratories [2] having extensive experience in the manufacturing and/or testing of sealed insulating units. Among the information sought was data showing the degree of positive correlation between the results of accelerated tests and long-time satisfactory in-service performance of units. It had to be concluded that although some manufacturers have actively pursued efforts to establish correlations for some time, and perhaps in some instances had some favorable results, no general correlation applicable to the broad spectrum of marketed units had been established. Two strong reasons for this are that there are not many installations of ten or twenty year age for which consistent performance data have been accumulated, and that practically no units installed for such lengths of time had first been tested or screened by means of the current accelerated tests. It is to be noted that with the availability and use of the developing test methods and specifications for sealed insulating units, the latter essential for developing correlations is more likely to be satisfied.

Practical considerations concerning the accelerated testing of sealed insulating units are discussed in this paper, and some suggestions are made as to ways in which improvements might be made in respect to accelerated test conditions and testing apparatus.

2. Statement and Discussion of the Problem

Factory-sealed double-glazed insulating glass units are intended to provide a permanently hermetically-sealed space between the glass panes containing air at a moisture content or dewpoint so low that no moisture will condense on the inner surfaces of the panes under use-conditions.

In general, three different types of edge construction are used for commercial factory-sealed insulating units. These are:

1. *Fused-edge*, in which the two sheets of glass are fused together at the edge.
2. *Glass-to-metal*, in which the glass near the edge is metallized and soldered to the edges of a thin lead alloy strip spacer.
3. *Organically-sealed*, in which the glass at the edges is glued to a spacer strip by means of an organic sealant or adhesive. The spacer may be of steel, aluminum, or an organic material and is usually hollow and filled with a desiccant which, through small holes, is exposed to the interior air.

[2] Please see acknowledgements, page 56.

In the last two types of construction, a U-shaped external channel of metal or tape is often applied to the outer edges of the unit to protect the glass edges and sealants, and to help hold the glass panes together. In the first two types of construction, the air space is purged with clean, very dry, air through a small hole in the seal after assembly, after which the hole is sealed. For units containing desiccant, the desiccant is relied on to dry the space air after assembly. Most units are sealed at room temperature and barometric pressure; for units to be used at substantial altitudes, final sealing at the ambient pressure may be effected after shipment.

There are significant differences among the constructions in regard to edge-rigidity. The fused-edge units are rigid at the edges; the glass-to-metal units are not wholly rigid, due to bending of the thin spacer strip; organically-sealed units can range from rigid to nonrigid, depending on the materials used, but probably most are nonrigid at the edge. The rigidity at the edge affects the deflection of the glass panes nearer the center of the unit, which in turn affects pressure differences between the air space and the exterior. Such pressure differences may be due to change in air space mean temperature or to barometric or wind pressures. Other things being equal, interior pressures depart less from the exterior pressure when the unit size is increased, and when the air space thickness is decreased. This factor makes it questionable whether the force tending to separate the panes due to a given condition favoring an interior pressure excess, per foot of edge, increases with the size of the unit. With rigid edges, greater stresses are developed in the glass near the edge; with nonrigid edges, glass rotation about the spacer may cause separation from the sealant. It is apparent however that in evaluating sealed units by laboratory tests it is desirable that more than one size of unit should be tested.

Avoidance of condensed moisture on the inner surfaces is an essential requirement for satisfactory performance. This is not simply because of the obscuration of clear vision by the condensation (which might be endured for brief occasional periods), but because the condensation will eventually leach soluble salts from the glass and leave a permanent scumming or cloudy film on the inaccessible glass surface.

Ideally, a once-dry hermetically-sealed unit should remain dry indefinitely. In actuality, the seal may be or become imperfect, allowing moist air or water to enter the air space as a result of pressure differences, or the material of the seal may not be wholly impermeable to the inward diffusion of water vapor as a result of water vapor pressure differences. These are the practical problems to which laboratory tests of sealed units must be addressed. The test must subject units to conditions adequately simulating, and accelerating, the stressing conditions which units in service must withstand for periods up to the life of a building. Presumably, tests adequate to examine units in regard to the important aspects of performance will cause failure of inferior units, and pass better units. The very important practical question that remains to be answered is what intrinsic durability in service can be realistically predicted for units that pass the imposed tests.

3. Literature Review of Extant Test Methods

The references listed on page 58 present detailed descriptions of various test methods that have been developed for laboratory testing of factory-sealed units. The process has been one of evolution, which undoubtedly is not completed. The extensive work carried out, and still in progress, at the Division of Building Research of the National Research Council at Ottawa [3,4] has eventuated in the Canadian Standard 12–GP–8 for sealed units [1], which sets forth specific tests and testing procedures, and establishes certain required performances for sealed units in Canadian service in buildings.

Some of the larger manufacturers of factory-sealed units in this country have been engaged in developing tests, and in testing such units, for many years, antedating the work at Ottawa. Some of this work has been published [5], and some of it undoubtedly has influenced the development of Interim Specification SIGMA No. 65–7–2 [2].

In many respects the testing methods of the Canadian Standard 12–GP–8 and of SIGMA No. 65–7–2 are similar, but there are distinct differences also. For both, test units are approximately of the same size (14 by 20 inches).

Both use measurements of the deflection of the glass panes, when a unit is subjected to an exterior pressure lowered by about 0.1 atmosphere, to detect initial leaking-seal failure, with similar limits for indicating failure.

Both measure the initial dewpoint of the air in the airspace, using similar apparatus and with the same higher limit for an acceptable desiccant-containing unit (−60 °F). They differ in that 12–GP–8 calls for conditioning the unit at 70 °F for one week before the dewpoint measurement, while No. 65–7–2 allows a minimum conditioning period of only two hours at 73.5 °F. For units containing desiccant, a long conditioning period is preferable to assure equilibrium of air moisture content and desiccant.

Both methods subject one face, and the edges, of the sealed units to repeated cycles of temperature change, with intervals of water spraying on that side, and with the other face exposed to air at 73 °F. The testing apparatus is essentially similar for both methods. Following a required number of cycles of exposure, both methods require that the air space dewpoint not exceed a specified value. The similarities and differences of the two tests are indicated below.

	Canadian 12-GP-8	SIGMA 65-7-2
Test method, paragraph No.	4.2.4	5.2.4
Test is applied to:	Organic-seal units only	All types
Cycle events:	90 min to 125 °F 25 min air circul. 5 min 75 °F water spray 60 min air circul. 60 min to −25 °F	2 hr at −20 °F 1 hr at 73 °F 1 hr at 75 °F water spray 1 hr uv rad. 2 hr at 120 °F 100% RH 1 hr at 73 °F
Cycle duration, hr.	4	8
No. of cycles required	320	120
Total hours of test	1280	960
Max. dewpoint, after test	−40 °F	−30 °F

The temperature range, and rates of temperature change of the units, are greater in the Canadian test than in the SIGMA test, as are also the number of cycles, duration of the test, and the restriction on allowable dewpoint. However, in several ways the SIGMA test may be more searching: in providing for 60 min of water spray versus 5 min in 12–GP–8, and in providing 2-hr exposure at 100 percent RH at 120 °F, not required in paragraph 4.2.4 of 12–GP–8 (but see below). In addition, the SIGMA test cycle includes 1 hr of ultraviolet radiation at a time when the units are wet from water spraying, which may be a matter of importance for organically sealed units. It should be noted that both methods call for (dry) ultraviolet exposure in other tests (paragraph 4.2.3 of 12–GP–8, and 5.2.5 of 65–7–2), which are conducted rather similarly. The Canadian requirement is that there shall be no evidence of fogging of the cooled area of the unit after 7 days of uv exposure; the SIGMA requirement is the same for 14 days of exposure. Both the Canadian and the SIGMA test methods apply (dry) uv exposure tests to all types of sealed units. There seems no reason to subject to uv the inorganically sealed units.

The Canadian Standard includes a High-Humidity Cycling test (paragraph 4.2.5), not required in 65–7–2, although the 2-hr exposure to 100 percent RH at 120 °F in the test of paragraph 5.2.4 of the latter subjects the units to similar inwardly-directed vapor pressure differences. The Canadian high-humidity cycling test is probably more severe, in the direction of vapor diffusion into the air space, because of higher temperatures (to 130 °F) and vapor pressures. On the other hand, the exposure to high humidity in the SIGMA test occurs with the unit subject to a considerable temperature difference ($\approx$ 25 °F) pane-to-pane, which may strain edge-seals, while the Canadian test is conducted with substantially equal temperatures pane-to-pane.

Other comparisons between the two methods include the following:

	Canadian 12-GP-8	SIGMA 65-7-2
No. of units in a test-set	18	12
Est. min time to complete tests, weeks	15	11
Failures permitted per test-set, units	1	1
Max dewpoint allowed at end of test	—40° F	—30° F

A considerable amount of testing and investigation of sealed units has been done at the Norwegian Building Research Institute, some of which is reported in English [6,7]. A rapid translation to English of a draft interim Scandinavian Specification, adopted 21 June 1967 by representatives of the Norwegian Building Research Institute and several Scandinavian window manufacturers, has been available for study. It appears to be largely based on N.B.R.I. work.

The testing methods it specifies include, as do the tests above, initial seal tests under moderate vacuum, and initial dewpoint determinations, made on 10 units comprising a set. The units are large: approximately 32 by 48 inches in size. An "accelerated aging" test is conducted for 51 days, with five different "periods of strain", each involving one or two selected cycles of air temperature change daily on one side (changes range from (14 °F to 59 °F) to (14 °F to 131 °F), with almost continuous exposure to ultraviolet radiation (some occurring with the lower edge of the unit in water), and with pulsating pressures simulating wind gusts exerted on the face subject to temperature change, the other face being exposed to air at 72 °F. The pulsations occur at a frequency of 5 per minute, with a maximum pressure magnitude established for each of the "periods of strain" within a range from 0.6 to 3.9 in of water column. The units are subjected to the pressure pulsations during most of the twenty-four hours of the day, except for the few hours when air temperatures on one side of the units are being cooled to 14 °F. Six units of the set of ten are subjected to this test. The maximum dewpoints allowable are −4 °F initially, and 14 °F after the accelerated aging test. No requirement as to the limits of effects due to uv exposure is stated. Failure of more than one unit in the initial dewpoint test fails the set; all six units must pass the accelerated aging test.

Assessment of the Norwegian testing method is difficult, in part because it differs considerably from the other cycling tests described. The large size of the unit is also a factor difficult to evaluate with the information available. Although the pressures exerted on windows by wind gusts are normally not large compared to those due to barometric pressure or temperature changes, the many pulsations imposed on the units, at unit mean temperatures ranging approximately from 66 °F to 102 °F, must subject the edges and seals to considerable working over a range of shear and stress conditions. It should also be noted that the pulsations are exerted on the face of the unit when it is subject to a pane-to-pane temperature difference. The duration of uv exposure used seems extreme, but no data are available as to incident intensity on unit edges. The apparatus used for the accelerated aging test is large and complex, and differs from any known to be used on this side of the ocean. In view of the large amount of work done by N.B.R.I. in development of sealed-unit testing methods, and their extensive field studies of sealed-unit performance, the 1967 adoption of the draft as an interim Scandinavian specification suggests that the method is considered to be meaningful.

In addition to the extant test methods discussed above, data have been presented giving results of laboratory and some service exposure tests conducted by a manufacturer [5] on a variety of factory-sealed units of 14 by 20 in size. The laboratory test methods were approximately similar to those of the Canadian and SIGMA tests, including initial seal and dewpoint tests, and accelerated aging tests involving (a) 6-hr temperature change (120 °F to 20 °F, isothermal, in high humidity); (b) 6-hr cycles of temperature change (130 °F to −30 °F on one side, 60 to 80 °F on other), with a period of water spray; and (c) steady temperature exposure of the entire unit to 110 °F and 90 percent RH. In addition, units were exposed to outdoor weather and sun at 45-deg slope facing South at Southern and mid-Northern sites. Considerable differences in laboratory test performance were found among units of different manufacturers, and among units of some manufacturers at different times, especially for some types of organically sealed units. Failures of organically sealed units were generally associated either with water vapor diffusion, or loss of adhesion to glass, or both. In this connection, advice was received that the polysulphide sealants used in the units involved were relatively poor in water vapor impermeability, as compared with much better polysulphide sealants that are now available. Fused-edge units performed without failure in the laboratory tests; some glass-to-metal units failed by seal failure in the 130 °F to −30 °F, one-sided, test in a relatively short time. Failure was based on a rise of air space dewpoint to 0 °F. Performances of various kinds of units in field service and in a laboratory exterior wall were roughly in keeping with the results of the laboratory cycling tests.

Mazzoni and King [5] conclude with suggested and recommended performance tests and limits. The recommendations include the usual initial tests, and call for the cyclic 120 °F to 20 °F test and of the steady 110 °F, 90 percent R.H. exposure test. They include also exposure to artificial uv radiation or outdoor exposure to strong sunlight.

In summarizing this review, it is noted that none of the extant methods contains recommendations or representations that success in meeting the laboratory tests assures a particular expectation of satisfactory durability in service. This is not surprising. Only many years of field service can provide the essential durability information needed, and the units involved should also have been tested for their evaluation by the selected laboratory test methods; failures due to other than intrinsic qualities [8,9] must be screened out; and some statistical size for the investigation is necessary.

The accelerated and service test information provided in [5] is favorable in indicating fairly good agreement between laboratory and service performance, but is too limited to provide quantitative correlations pertinent to present needs.

On the other hand, although positive quantitative correlations between field service durability and successful performance in the laboratory tests are not available, it seems tenable to conclude that units failing present accelerated laboratory tests do not have reasonable service performance expectation.

4. Visits to Laboratories Engaged in Testing Sealed Units

Technical discussions were held with professional personnel of the four laboratories listed on page 56. All discussions were conducted in a helpful atmosphere of courtesy, candor and informative exchange; in all instances laboratory facilities and operations were viewed, and in two the factory production of sealed units was observed in detail. A summary of the obtained information significant for the purposes of this study is given below, without attribution.

4.1. Evaluative Methods

The test methods previously discussed were used in some degree, and with various differences in the four laboratories visited as to cycle-period, or events, or number of cycles of exposure.

There are certain differences in aim and objectives among the laboratories, which affect the tests being conducted. The BRD–NRC Canadian laboratory has responsibility for testing units in accordance with Standard 12–GP–9, by a standard procedure, although other test research is also carried on. The industry laboratories are less constrained to a standard procedure for much of their work, and therefore adopt variations or nonstandardized procedures and methods considered useful for specific purposes. As a result, although it is probable that the industry laboratories could effectively conduct the standardized Canadian or SIGMA tests, it was my impression that they did not routinely do so.

What is more important is the general trend, the directions in which laboratory testing is going. The nonisothermal weather-cycling test (e.g., the 12–GP–8 Paragraph 4.2.4 test) is in use, but ultraviolet exposure is added to it, as in the SIGMA specification. At all laboratories, there is recognition of the importance of uv as regards organically-sealed units, and it is evidenced by use of both outdoor solar exposures and artificial uv irradiation in the laboratory. The importance of concomitant water during uv exposure is generally appreciated, although it is not yet included in all uv exposures now called for. Use of uv to develop failures due to volatiles released from organic sealants, which cause fogging of the air space surfaces, is general. The test is much more severe when the unit is at a high temperature, as it appears to be in the Canadian test (150 °F, paragraph 4.2.3). In one instance it was stated that the high temperature alone is severe in connection with fogging by volatiles. This condition applies with special force to units used in refrigerated food display cabinets, which often are heated at the edges.

Although it is among the oldest of tests, there appears to be an increased use of isothermal high-humidity tests over cycles of temperature change. By means of such tests, units are subjected to positive and negative internal pressures, relative to the barometer, and consequently to stresses of the seals, under conditions favoring vapor or liquid entry through the seal to the air space. Being isothermal (although the temperature of the unit is cycled), the unit is not subjected to the same stresses as one having the two panes of glass at different temperatures. The tests seem effective in causing failures of units, even when the units are kept at a steady temperature, without cycles. Clearly, the high-humidity isothermal tests are well aimed at testing the vapor permeance of the seal, and possibly the adherence of the sealant to the glass.

All laboratories used the initial vacuum deflection tests, and the initial dewpoint test, to screen out imperfect seals before more expensive testing was undertaken. At one laboratory it was suggested that the deflection test was not essential, provided that the units had a satisfactorily low initial dewpoint. The point is well taken, but the vacuum test may have a useful value in examining the stresses developed in the sealed unit, or in subjecting a seal to forces tending to part the two glass panes.

It was plain that all laboratories put considerable weight on outdoor solar exposure tests, either on racks (isothermal) or in test or field fenestrations. Programs of periodic monitoring of the dewpoint of installed fenestrations are under way by several laboratories, and it seems clear that producers rely strongly upon such findings in evaluating the confidence with which durability guarantees can be advanced.

It is desirable to emphasize that there are distinct differences among sealed insulating units that compound the problem of evaluating them. Inorganically sealed units are not subject to uv degradation, as organically sealed units may be. On the other hand, the inorganically sealed units may be more severely stressed at edges by unavoidable nonuniformity of temperatures in service, while organically sealed units may be seriously affected by chemical incompatibility with caulkings, glazing compounds, etc., especially in the presence of water. Field fenestration monitoring should provide comparable durability data for all kinds of sealed units, if all types are included, but requires too much time for present purposes.

Because of the possible vulnerability of organically sealed units to chemical effects, it is necessary to examine such effects under laboratory conditions where chemical attack is subject to controlled conditions not attainable in field or service situations. Such investigations were discussed at one laboratory, but probably are carried on at several. Among such investigations at one laboratory were:

(a) flexings in air of short lengths of organically sealed joints with uv exposure;
(b) use of vacuum deflections of joints to find best sealant properties, and dimensions of seal spacers and joints;
(c) exposure of samples of sealants to a variety of solvents, fluids and oils, at selected temperatures, to evaluate chemical effects and changes;
(d) applications to organically sealed edges of various caulking compounds and materials for observation of chemical effects, and use of sealers to separate caulking and edge to reduce chemical effects;
(e) improvements in organic sealants due to formulations or fillers which result, for example, in much lower vapor permeance of seals of current availability.

One result of such investigations, it was stated, is that a specification that would yield excellent sealants is possible, but for commercial reasons may not find easy acceptance. However, it was also stated that even though excellent sealants can be supplied, some manufacturers may fail to do what is additionally necessary to assure satisfactory units, in respect to such matters as quality of glass, or glass edges; uneven sealant application; dirty (or not clean) glass; added solvents; poor temperature or chemical or desiccant control; or mismatched expansion coefficients of spacers and glass.

The importance of these manufacturing matters as regards production of satisfactory units was strongly indicated during the tours made to see factory production of sealed units. Organization to promote and realize close quality control was plainly a result of experience and much effort, and was regarded as a primary responsibility.

4.2. Practical Considerations in Laboratory Testing of Units

The cost of conducting the tests called for in the Canadian and SIGMA standards is high, being estimated variously as from $1,500 to $3,000 per set of units. In part, the high cost is due to the cost of apparatus such as the Canadian Weather Cycling equipment, which accepts only 24 units, and the time required to install units for test. This apparatus also imposes constraints on the size of units that can be installed. The high-humidity test chambers, with or without temperature cycling, are preferable in respect to acceptance of a variety of unit sizes, speed of installation of units, and number of units that can be accommodated, provided that the exposures satisfactorily examine the units. However, there may be some question as to the uniformity of conditions from place to place in such chambers.

The matter of test-unit size is important for several reasons. Testing a range of sizes of the same unit design seems advisable until it is known that size is not a material factor. Further, there are disadvantages in having a single standard test-unit size (14 by 20 in) that is not a stock or common size generally procurable over the counter. Specific orders to manufacturers for the test-size units might well receive special production attention. It is also desirable that the testing equipment be able to test units of various sizes which might be involved in field service fenestration monitoring programs.

5. Recommendations and Conclusions

1. Procurement of factory-sealed double-glazed units for architectural service should be based on successful performance in meeting laboratory tests of the kinds reviewed in this study.

2. At present two fairly well evolved specifications are available for conducting laboratory tests of sealed units—the Canadian Government Specifications Board 12–GP–8, and the Sealed Insulating Glass Manufacturers Association Interim Specification SIGMA No. 65–7–2. The two specifications are approximately similar, with some differences in detail, and in requirements. Some sealed-unit manufacturers have the equipment for the SIGMA tests; a certifying laboratory for SIGMA tests is now available to manufacturers.

3. It has not been fully established that success of units in meeting the requirements of these specifications assures their intrinsic in-service durability for a predictable term of years. It is tenable to conclude that sealed units that fail to meet the requirements of these specifications do not have reasonable service performance expectation.

4. Further evolution of the specifications and test methods is to be expected. Among modifications thought desirable are: ability to test a range of sizes of sealed units; increased use of ultraviolet irradiation in the presence of water or high humidity, at least for organically sealed units; increased exposure to high humidity at edges of units, preferably with temperature cycling; better assurance that all units under test are subjected uniformly to substantially the same test conditions.

5. It is recommended that in view of the present high cost of the specification tests, and the large testing capacity that will be needed if test data are required for sealed-unit procurement, a strong effort should be made to simplify the testing, and to evolve testing apparatus and methods that increase testing capacity and lower the unit cost of tests.

6. Comment

The recommendation that procurement of sealed units be based on satisfactory performance in meeting laboratory tests is based on the general experience that the necessity of meeting a suitable performance specification upgrades product quality. This requirement is especially desirable when the service demands on the product are severe, as they are for sealed glazing units. A further advantage is that by excluding units of poor intrinsic quality, the gradually accumulated in-service performance and durability experience with only accepted units will provide more definite information leading to improvement of the testing specification. The clarification of problems, and solutions to them, should be made easier, and product improvement be advanced.

7. Proposal for Improved Testing Apparatus

Following up Recommendation 5, exploratory consideration has been given by the author to a possible testing apparatus that might meet the needs expressed in Paragraphs 4 and 5 above. The apparatus is illustrated schematically in figure 1. In brief, it would consist of a circular chamber subjecting many individual units to isothermal exposure to high humidity with cycled temperatures from about 35 °F to 125 °F, somewhat similar to the Canadian 12–GP–8 (Paragraph 4.2.5) High Humidity Cycling Chamber. The units would sit on edge on supports forming a large wheel turning slowly on bearings about a

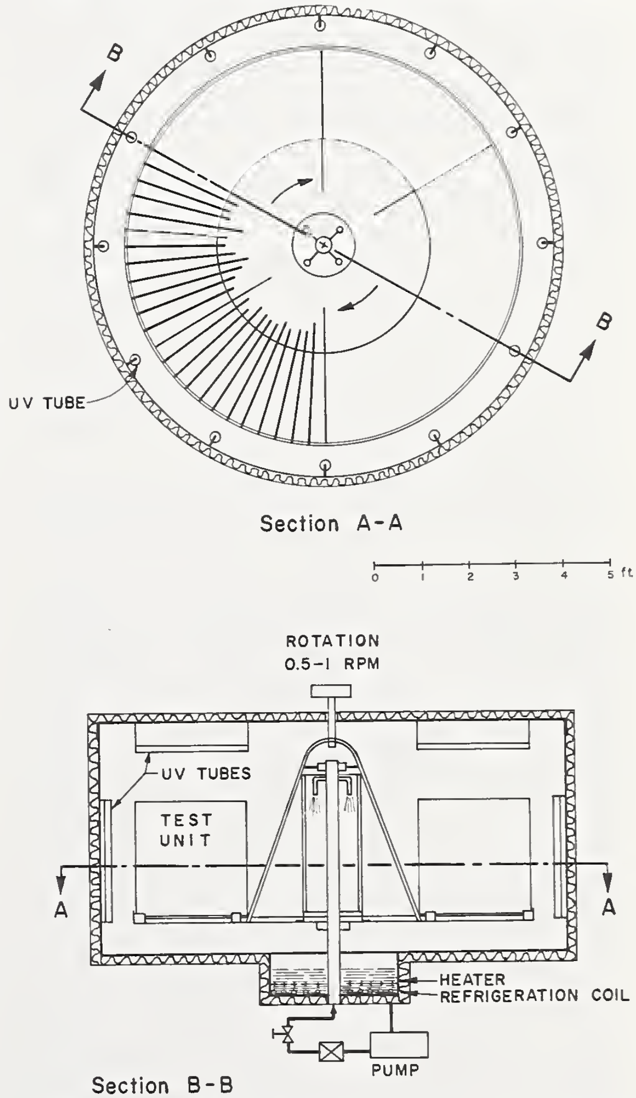

Figure 1. *Schematic drawing of apparatus for laboratory testing of insulating glass units.* Air temperatures in apparatus are governed by controlled temperature of the continuous recirculated water sprays in cylinder at center; air circulation is induced by the sprays. The specimen-holding turntable is rotated slowly by the drive at top.

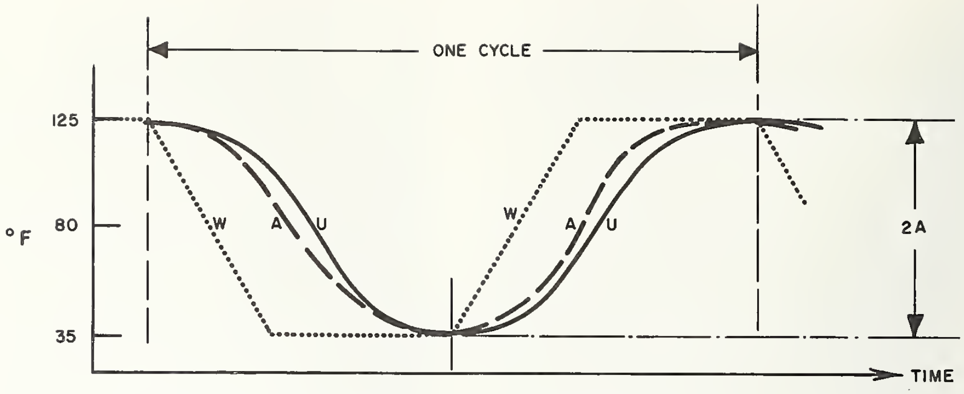

FIGURE 2. *A possible cycle of temperatures in the apparatus: W, of the spray-water; A, of the air in the apparatus; U, of a unit undergoing test.*

vertical pipe axis, and would be exposed, as they passed, to uv irradiation from suitably disposed lamps. Chamber conditions would be cycled by control of the temperature of continuous recirculated water sprays causing air circulation downward through an open cylinder at the wheel axis. A possible cycle of temperature variations in the apparatus is shown in figure 2. By placing the units on a slowly turning wheel, uniformity of exposure conditions for all units would be improved. Loading on of units would be done through a door in the side of the chamber; it is believed that some 100 units, of various sizes, could be accommodated. The diameter of the chamber would be 10 or more feet, depending on maximum size of units to be tested.

Although the apparatus, as pictured, is in keeping with the presently strong tendency toward vapor-pressure testing of factory-made seals, and does so in a way assuring uniformity of exposure conditions, it does not strain the seals, because individual units are substantially isothermal. However, it may be desirable to be able to subject unit seals to edge-strains during the exposure tests. A means to do this in the apparatus is readily developed, as follows.

Suppose two units were sandwiched closely together, with a gasket or perhaps even a pad of material between them. Exposed in the apparatus, the outer pane of each would respond in temperature to the time-varying ambient temperatures established in the apparatus. The inner pane of each, however, would be heated or cooled chiefly by heat exchange with the outer pane across the air space. Thus, the temperature of the inner pane would lag that of the outer, and the temperature difference between them would cause dimensional strains on the unit seals. An estimate of the maximum pane-to-pane temperature difference thus set up can be made approximately, on the basis of reasonable assumptions, as set forth in the appendix (section 8). The analysis shows that substantial pane-to-pane temperature differences can be developed twice in each cycle.

One advantage of this possibility is that it enables a determination of the importance of strain at unit edges in accelerated testing of factory-sealed units. The Canadian weather cycling test, the SIGMA test, and the Norwegian accelerated aging test all include edge-strains as significant variables. Using the proposed apparatus, half of a set of units can be exposed to isothermal test conditions, and the other half to the same ambient conditions with edge-strains superimposed by means of pane-to-pane temperature differences, to varying degrees if desired, all with uniformity of ambient exposures and uv irradiation. Further, it enables experimental consideration of the effect of unit size on the performance of the factory-made seals, since the edge-strain developed for similar pane-to-pane temperature differences probably depends on unit size.

These research possibilities—and there are more that can be developed—make it desirable to explore an apparatus of this type. There seems no reason to doubt that the apparatus can be duplicated so that tests in one would be comparable to those in another.

The author wishes to acknowledge the helpful assistance and information obtained from the officers and technical personnel of the following four laboratories visited in connection with this study during the period November 1967 to January 1968:

The Division of Building Research of the National Research Council of Canada, Ottawa, Canada.

Pittsburgh Plate Glass Company, Pittsburgh, Pa.

Products Research and Chemical Corporation, Gloucester City, New Jersey.

Libbey-Owens-Ford Glass Company, Toledo, Ohio.

8. Appendix. Calculation of Pane-to-Pane Temperature Difference

Assume that two similar sealed insulating glass units, U_1 and U_2, are sandwiched together with a gasket at the edges, or a pad of suitable material of thickness, a, between them, and that the sandwich is then placed in the proposed apparatus for cyclical exposures. Figure 3 shows a cross-section of the assembly. The temperature, T, of the outer pane of a unit and that, v, of the inner pane, are cyclical functions of time due to the temperature variations in the apparatus. The thermal resistance of the air space from pane to pane is taken as R ($R \approx 0.7$ deg F/(Btu/hr ft²) for most units). The heat capacity from the air-space surface of the inner pane to the centerline of the sandwich is designated as C (Btu/ft² deg F), which can be estimated when circumstances are selected.

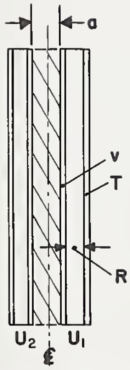

FIGURE 3. *Partial cross section of two units sandwiched together with a pad between.*

It is assumed, as a reasonable approximation, that T varies sinusoidally with time, i.e.,

$$T = A \sin bt \qquad (1a)$$

where A is the amplitude of T, and $b = \frac{2\pi}{P}$ where P is the cyclic period, in hours.

Then
$$\frac{T-v}{R} = C\frac{dv}{dt}$$

or,
$$\frac{dv}{dt} + mv = mA \sin bt \quad \left(m = \frac{1}{RC}\right) \qquad (2a)$$

A solution is

$$v = \frac{mA}{b^2+m^2}\left[m \sin bt - b \cos bt\right] + Be^{-mt}$$

After sufficient time the transient term will vanish, and

$$\frac{v}{A} = \frac{m^2}{b^2+m^2}\left[\sin bt - \frac{b}{m} \cos bt\right]$$

and

$$\frac{T-v}{A} = \frac{m^2}{b^2+m^2} \sin bt + \frac{bm}{b^2+m^2} \cos bt \qquad (3a)$$

$$= \frac{k^2 \sin bt + k \cos bt}{1+k^2} \quad \left(k = \frac{b}{m} = \frac{2\pi RC}{P}\right) \qquad (4a)$$

To find the extreme values of $\frac{T-v}{A}$, we obtain the derivative with respect to t, and set it equal to zero:

$$\frac{d}{dt}\left(\frac{T-v}{A}\right) = \frac{bk^2 \cos bt - bk \sin bt}{1+k^2} = 0$$

whence $\tan bt_{M'} = k$, or $bt_{M'} = \arctan k + n\pi$

Evaluating $\frac{T-v}{A}$ for this value of $bt_{M'}$ we find

$$\left|\left(\frac{T-v}{A}\right)_{\substack{max\\min}}\right| = \sin bt_{M'} = \sin\left(\arctan \frac{2\pi RC}{P}\right) \qquad (5a)$$

Similarly, it is found that for $\frac{v}{A}$, the extreme values occur when $\tan bt_{M''} = -\frac{1}{k}$ and that

$$\left|\left(\frac{v}{A}\right)_{\substack{max\\min}}\right| = \sin bt_{M''} = \sin\left[\arctan\left(\frac{-P}{2\pi RC}\right)\right] \qquad (6a)$$

For numerical illustration, values of $(T-v)_{max}$ are tabulated below for three cases. In the first, the units are separated slightly by a gasket at the edges, with no interposed pad. In the second and third, pads of ¼-in and 1-in cement-asbestos board, respectively, are used to form the sandwich. In all cases, the cycle period was assumed to be 4 hr, and the amplitude A was taken as 45 deg F.

Case	C	k	$\left(\frac{T-v}{A}\right)_{max}$	$(T-v)_{max}$
	Btu/ft² deg F			*deg F.*
No pad	0.26	0.29	0.28	12.4
1/4-in C.A.	0.47	0.52	0.46	20.6
1-in C.A.	1.09	1.20	0.77	34.6

The pane-to-pane temperature differences shown in the last column above are of magnitudes similar to those to which units are subjected in service.

9. References

[1] Canadian Government Specifications Board Standard for Factory-Sealed Double-Glazing Units, 12-GP-8 (15 July 1966).

[2] Interim Specification for Sealed Insulating Glass Units, SIGMA No. 65-7-2, Sealed Insulating Glass Manufacturers Association (1967 Edition).

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[8] Solvason, K. R., and Wilson, A. G., Factory-sealed double-glazing units, Canadian Building Digest, CBD 46 (Division of Building Research, NRC Canada, Oct. 1963).

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5.2. DISCUSSION SESSION V

Mr. McKinley: Thank you very much, Henry. I am sure that you have not only provided a very important and objective review of the several methods, but now have challenged all of us with a proposal that may speed testing, increase reliability and reduce costs. We have about 15 minutes remaining so Henry can respond to the first questions that come to your mind.

We'll see if we can lead into some of the first reactions. Perhaps it would be a good idea to start with Mr. Wilson or Mr. Solvason and ask if they care to comment.

Mr. Wilson: I'll say a few things just to give Dick Solvason a chance to get his mind clear so that he can say something worthwhile. I think both Dick and I fully support many of the things that Henry has said. A test method for certification purposes has got to be simple, has got to be capable of handling large numbers of units, it's got to be an economic proposition and I think that if one can demonstrate that this isothermal kind of apparatus that Henry has described, which is not too dissimilar from some of the other kinds of apparatus we have heard about, is adequate, then it does provide a very good answer because it's capable of handling large numbers of units and therefore may be able to provide, hopefully, an economic way of going about certification. I'm sure we both agree that it's extremely desirable to be able to introduce ultraviolet effects in the presence of water; I know Dick's been thinking about this. We've been under great pressure in Canada to get on with the business of getting some sort of standard method that can be used by the manufacturers and by the users. We've responded to this pressure and have not conducted as much by way of research as we would have liked because we had this primary responsibility to fulfill. I think we both agree, as I'm sure the other people doing tests would agree, that ultraviolet exposure in the presence of water is a very desirable feature in a testing program at this stage.

Dick, do you wish to add anything?

Mr. Solvason: Henry made a couple of comments about the dew points after weathering tests. In general, these don't make very much difference because when a unit fails in these kinds of weathering tests it begins to fill up with water so that it doesn't matter very much whether the dewpoint cutoff is made −30 or −40 °F.

Another comment I want to make is that most of the test methods that are in vogue at the present time are really a mechanical-stressing type of test conducted with fairly high water vapor pressure differences so that they will accelerate the mechanical stressing of the units and give a little higher water vapor diffusion rate. I would like to point out further that the accelerated tests may serve to demonstrate whether a manufacturer can make a unit that will stand up mechanically when it is new, but that little information is provided as to the effect of time and exposure on the materials in the sealing system itself. When the accelerated tests are finished, the units are still only 4 or 5 months old at the most. This does not tell us anything about what they're going to be like 5 years later, or 10 years later, or 20 years later.

Mr. McKinley: Thank you, Dick. I wonder if Ted Pritsker from the Dallas Laboratories would care to comment?

Mr. Pritsker: For the apparatus described, what would be the duration of one cycle of exposure?

Mr. Robinson: I think the apparatus described could be operated on a 4-hour cycle or thereabouts; it hasn't been built so I can't be more specific. I think a 4 or 6 hour cycle would be quite feasible. It may perhaps depend on the temperature range that you want to cover and the equipment you can lay your hands on to get that job done.

In connection with what Dick Solvason just finished saying, it is true that the units may be only 4 or 5 months old when the test is finished. I wonder if anyone here has taken new units, exposed them let us say to solar radiation for a 6-month or one-year period, and then put them through the laboratory tests. I think this would be possibly worth doing.

Mr. McKinley: Thank you very much. I was going to ask Dan Gwyn if he wished to say a word.

Mr. Gwyn: (Inaudible)

Mr. McKinley: Ray Mazzoni, do you wish to say a word?

R. Mazzoni: (Inaudible)

Mr. McKinley: Henry, do you have something to add?

Mr. Robinson: I would like to say a few things that touch upon what has just been said by several people. First, the apparatus described is not offered with an idea of it being "the answer." It is to indicate to you one way of producing conditions, and uniformity and control of conditions, which it appeared to me from the study are needed in testing these units. I can not guarantee or assert that this apparatus will do as well as any present one. I think it has a good chance of being made to work by suitably selecting temperature ranges, and so on, so that it would be effective. But this would have to be shown.

I would add the thought that one of the essentials in your growing industry is to have enough test facilities and it's unlikely that any one place would have enough. First of all, the geographic distribution of the country is too great. Therefore, I believe it is quite essential or desirable that a standardized or standard apparatus be developed which can be reproduced on the Pacific Coast, Gulf States, or anywhere else, and replicated so that manufacturers can be assured of comparability of results obtained at various places. This is an evident need that requires cooperative attention and solution by the whole industry and its customers.

R. W. McKinley: Yes, Mr. Orbesen.

G. Orbesen: Mr. Robinson, you have referred several times to the Canadian test method, and the SIGMA test method. Is there not a GSA specification for insulating glass units?

Mr. Robinson: The Public Buildings Service of GSA has an Interim Guide Specification for glazing (PBS 4–0885 (INT), June 1967) which sets up requirements for insulating glass units (Paragraph 2.1). Few details are given concerning testing procedure or equipment. It requires that units withstand one of two optional alternative tests. It will be of interest that one option calls for tests of 250 days, and of one year, duration; the other option requires 700 days for completion. I have no information as to who has conducted certifying tests under this guide specification.

R. W. McKinley: Yes, Roger?

Mr. O'Shaughnessy: Have you worked on any costs involved for the suggested apparatus?

Mr. Robinson: No. I think the cost could vary by 2 to 1 depending on who has the building of it.

6. Proposals for Future Action—Panel Discussion III

Introduction of the Third Panel

Henry E. Robinson

The clock is moving and we have a full schedule. I'd like to ask the meeting to come to order. We are about to have, I think, the action part of this Seminar take place.

Up to now we have been getting educated and have discussed various aspects of the questions. The motif for today is, I think, action. The title of this part of the program is "Proposals for Future Action." Action is the key word but the agenda now is soliciting proposals. To put these before you, the program calls for a panel which will consist of Mr. Lynford K. Snell, would you take position . . . ; Mr. Roger O'Shaughnessy, President of the Cardinal Insulated Glass Company; Mr. Robert W. McKinley of PPG Industries; and Mr. C. C. Stout, Treasurer and Product Development Manager of the Andersen Corporation.

This panel is convened to give you in short form their suggestions as to what course of action this Seminar and your industry might consider. I say again the motif of this session is action. After the four panel members have made their suggestions, I think we will not have time for much discussion because we will have a coffee break.

After the coffee break, I hope that the fifth member of the panel, yourselves, will swing into action and help us to define and understand what should be done and what might be done.

I will call upon the first member of the panel, Mr. Lynford K. Snell, to start off.

6.1. Proposals for Future Action

Lynford K. Snell, Jr.[1]

**Federal Housing Administration,
Washington, D. C. 20412**

I believe FHA's needs are two-fold—an immediate one and the desire for a future or longer range plan.

I think that this seminar and FHA's study with NBS have indicated that no one test method can be viewed as the ultimate answer and that more development work is needed. I would suggest that this be done as soon as possible.

Perhaps our immediate need could be fulfilled by use of the Canadian or SIGMA test method on a temporary basis, while we move toward the development of an improved testing method which could be nationally recognized.

I do believe that by using one of the existing test methods we would have a temporary stopgap measure, whereby, at least the very poor units could be eliminated. Perhaps additional effort could be placed on standards for sealant systems.

As to longer range plans and desires; perhaps development using ASTM—NBS—Industry—Government cooperation is appropriate. I believe those who follow will expound on some possible suggestions along this line.

[1] Architect, Architectural Division.

6.2. Proposals for Future Action

Roger O'Shaughnessy

Cardinal Insulated Glass Co.
Minneapolis, Minnesota 55440

Mr. Roger O'Shaughnessy did not present a formal paper and no transcript of his remarks is available. Some of his ideas, however, appear in the discussion following Mr. Stout's paper.

6.3. Proposals for Future Action—Round Robin Comparison of Test Methods

Robert W. McKinley,[1] Chairman

PPG Industries, Inc.
Pittsburgh, Pennsylvania 15222

Preceding speakers and discussions have made it clear that there are a variety of test methods, facilities, and procedures now in use by various organizations which have, in at least some respects the same general objective, namely; reliable accelerated evaluation of insulating glass unit performance.

Key words: ASTM; insulating glass unit; round robin; test farms; test methods.

1. Introduction

At present accelerated testing methods rely, at least in interpretation, calculation, and application of their results on judgmental processes not necessarily constrained by similar guidelines. Since the original purposes of these methods have varied as their creators, important differences in results are to be expected. It is indeed fortunate that there exists such a wide experience from which to draw. Practical correlation of accelerated test results with on-the-job performance is difficult at best, and impossible without experience.

Within the durability task group of subcommittee VIII, ASTM Committee E-6, the preparation of a durability test method for glazed sash has been proposed. Drafts have been circulated and discussed. It seems appropriate, therefore, that we propose and perhaps undertake a comparison of existing test methods for insulating units.

2. Proposal for Comparing Test Methods

For your consideration and discussion, it is our proposal that the durability task group plan and conduct a round-robin program of test method comparisons. Such a program might include the following features:

(1) Assemble a group of representative manufacturers, laboratories and test farms. Encourage interested manufacturers to assemble a number of units following their usual production practice. Insofar as possible, these units should represent product characteristics typical for their process. They should be of a size selected to facilitate testing.

(2) Identify each such test specimen permanently with a non-proprietary code (ASTM NO. ———). Omit or remove proprietary labeling.

(3) On ASTM order, each manufacturer would ship (at no charge) fifteen (15) of these test specimens to each laboratory and/or test farm and retain fifteen (15) as control samples.

(4) Each participating laboratory and test farm would test samples (submitted by ASTM) following its usual procedure and report results to ASTM in a uniform fashion. A suggested data format follows.

Task group E would assemble and analyze the results and prepare a formal report. This might be published in Materials, Research, and Standards. It would report on the test methods—not on the test units.

[1] Manager, Technical Services, Glass Division.

ASTM COMMITTEE E-6
SUBCOMMITTEE VIII
TASK GROUP ON DURABILITY

ROUND ROBIN REPORT
TEST METHOD EVALUATION
DURABILITY OF INSULATING GLASS

Date: ______________________________

Laboratory/Farm: ______________________________

Address: ______________________________

Engineer in Charge: ______________________________

Telephone Number: ______________________________

Test Method: ______________________________

Usual Purpose of Test: ______________________________

Number of Units previously tested: ______________________________

Results normally reported: ______________________________

Means of correlation with on-the-job performance: ______________________________

____

Facilities and Equipment: ______________________________

Procedure: (Start with receipt of test samples at laboratory and go all the way through to describe storage after tests are completed.)

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____

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RESULTS

ASTM Test Unit No. Performance Criteria

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6.4. A Manufacturer's Experience with Insulating Glass

C. C. Stout[1]

Andersen Corporation,
Bayport, Minnesota 55003

In this paper the author reviews the growth in the use of insulating glass in buildings and presents data from his company's experience in regard to replacement cost for field failures, which was approximately 0.1 percent of annual sales. Good performance of units over the life of a building was described as the result of production of insulating glass units aimed at value rather than price.

Key words: Field performance; insulating glass; replacement cost; service procedure.

1. Introduction

The following comments indicate our belief that insulating glass has become an important customer benefit to producers of window units and sliding doors.

The figures that will be presented to you are not intended to impress you, but I hope they will add some validity to this presentation.

I represent a window and sliding door manufacturer that has had experience in the marketing of insulating glass since 1946. At that time our insulating glass interests were principally at our distributor level. These distributors had started to supply our picture units glazed with insulating glass. We've been very active in the sale of insulating glass since 1953.

2. Growth of Insulating Glass Production

During the past fifteen years over 10 million window units and sliding doors produced at our plant have been factory glazed with hermetically sealed insulating glass. Over 50 percent of all sash and door panels that we produce are glazed with insulating glass.

Insulating glass now represents over one-third the cost of all materials used in our products. It is the NUMBER ONE component that we use in the products we produce today.

When we started glazing our products with insulating glass, our suppliers and our company believed there was a joint responsibility to provide the end user with a product that would give satisfactory performance. We wanted a low incidence of field failures and, most important, to back up the product in the event of failures.

3. Incidence of Failure

Our field experience records have been compiled on both an annual and cumulative basis. Our record of field failures has been excellent. The causes of field complaints are:

- Stress cracks
- Seal failures
- Glass quality
- Scratched glass
- Collapsed air space

The following data covers the years from 1956 through 1967, a period of 12 years. On the basis of cumulative replacements, it has cost the Andersen Corporation approximately $40,000 a year as an average over the past 12 years.

Our sales over the past 12 years have averaged $41 million dollars per year. Cost of replacement to the Andersen Corporation is approximately 0.1 percent of annual sales. This figure represents our company's replacement cost. Our insulating glass suppliers share in the overall replacement cost. This is divided 75 percent by Andersen and 25 percent by our suppliers.

Our experience shows that if failures occur, they develop the first year or two after installation. We find the incidence of failures based on percent of glazed sash to be the same for both ventilating and stationary openings.

4. Comment

To successfully back up a product, you commit yourself to a policy and then administer that policy effectively. Field complaints on insulating glass are followed up by our Service Department which operates under our Sales Department. Over the years we've developed a procedure to service insulating glass complaints by good coordination between our distributors, dealers, and our field sales and service people.

Although we use a much larger share of glass edge type of insulating glass, we've had satisfactory field experience with non-glass edge type of insulating glass.

With the increased use of tempered insulating glass in sliding doors, we will use more of the non-glass edge type of insulating glass.

We expect our suppliers to produce tempered insulating glass that provides field performance equal to our past experience.

[1] Treasurer—Product Development Manager.

We believe that under normal exposure glass is a permanent material. We also believe that when glass is used to produce insulating units, the product should be permanent and last for the life of the building.

A five-, ten-, or twenty-year warranty, in our judgment, does not appear to be the solution to satisfactory field performance of insulating glass. There's not much satisfaction to the end user when a product fails during the sixth, eleventh or twenty-first year.

Producing insulating glass that has value and not price would appear to provide the best assurance of good performance during the life of the building. We have learned from experience that when a firm makes a product that performs well, and provides adequate adjustment for product failures, the product can be marketed successfully.

6.5. DISCUSSION SESSION VI

H. E. Robinson: Thank you, Mt. Stout. I think it goes without saying that you have helped us all look through clear glass at a clear picture, namely: "Value rather than price." Mr. Stout's position should receive our earnest attention because of his dual consumer and producer concern in this matter.

Before the break for coffee which is due shortly, I would like simply to summarize the suggestions and proposals that have been made to us so far, so that we can chew them along with the coffee that we take.

Mr. Snell has recommended, in view of the immediate needs of his agency and undoubtedly of GSA and other governmental agencies, that our position should be to adopt what is now available, which is the SIGMA specification in this country, or the Canadian Specification, so that at least there can be a beginning of exclusion of poor units. He has also suggested the importance perhaps of developing some sort of specification on sealant systems or materials which others of our speakers have indicated are near or could be effected. He has also suggested the cooperation of governmental agencies, of the SIGMA organization and of the industry and possibly NBS to improve the current testing methods and requirements of the specifications. Mr. O'Shaughnessy has expressed the actions on the part of SIGMA recently and in the past to tighten the present SIGMA specification in several respects, to revise some of its test cycles in ways which he feels will improve them and perhaps give them more impact, as far as accelerated testing is concerned. He has mentioned the efforts they have made to summarize the available information on glazing and to make recommendations with respect to both mechanical and chemical aspects. And he proposes for us the adoption of the SIGMA effort and its glazing recommendations. This is a matter for you to consider. Mr. McKinley has proposed a Round Robin series of tests, not of units, but of the testing methods and procedures now being used, which could be initiated perhaps by the Task Group of ASTM E–6, Subcommittee VIII. Mr. Stout's information which we just heard, I found very interesting myself, especially his mention that generally fogging failures occur early, in the first or second year, which sounds very much as though the first or second year period of use represents a screening test for the quality of units being supplied to him. Mr. Stout did not say how they purchase their glass, whether on specifications or otherwise, nor did he indicate directly how they control the glazing practices in their own production. These are matters some of you may wish to discuss with Mr. Stout.

I leave the matter with you at this point. We will come back in 20 minutes after coffee and then I hope the floor will make itself heard.

I hope you all enjoyed your coffee as much as I did. Before we consider and discuss the suggestions we have already received, does any member of this Seminar have a suggestion other than those we have heard . . . for action by this Seminar?

H. E. Robinson: Sir?

Participant: Just one request and that is in all of these testing procedures, for the southern half of the United States, please include some kind of testing procedure for reflective glass.

H. E. Robinson: Thank you. Your request is noted. Are there others, or another? Mr. O'Shaughnessy?

R. O'Shaughnessy: We are involved in a rather major effort right here. Since these reflective products are new and are just coming onto the market, it may be well in the future to consider the various tests that already are being performed by professors at various universities and then to institute some type of program whereby we can consolidate the information and proceed from there, but I think the immediate proposal is a bit beyond our realm.

H. E. Robinson: I think it's one we should keep in mind and develop possibly in the way you suggest.

I think we can subdivide the present situation in the way that Lyn Snell did, into the immediate need, and the longtime need or program which your industry may require.

For the immediate need it appears that the chief suggestion we have is that an extant test method, as it now appears or is being modified, such as the SIGMA test method, might be the quickest avenue to action to improve the product at the present time for the purposes of large and other purchases. For FHA, GSA, the government generally, I think that the pressure is in this direction. Whether this is equally so for private purchases, I don't know. I gather from the expressions here that the architects would be of similar mind. Whether this is the avenue they would prefer I cannot myself say . . . I'd be glad to have the audience give its views in that connection.

It was mentioned by Lyn Snell that possibly now is the time to start developing a specification for the sealant system components. This is an element which your industry may wish to consider. We have not dwelt on it much at this meeting but in some way action on this should be taken, whether by SIGMA or an ASTM group, I am not able to recommend at this moment. I think you should consider that.

It was also suggested that there should be as much cooperation as possible among governmental agencies, companies, SIGMA, and NBS perhaps to try and improve the testing methods. The chief avenue that to us at least appears possible and appropriate here is that of the research associateship. Although this was discussed at the dinner last night, I'm going to ask Dr. George Gordon, who is here, to briefly summarize the nature of such arrangements and perhaps to answer any questions that may come from the floor.

Dr. G. Gordon: For the benefit of some of you who weren't here last evening and who didn't hear Dr. Kushner's talk about NBS in general and, particularly, about the research associate program, let me say a couple of things that may be repetitious to some. First, I am speaking as one who until yesterday was utterly ignorant of the technical problems that affect the insulating window industry. Now that I have learned something of your problems at this Seminar, I would like to describe our research associateships as something that might be useful and acceptable to your industry in solving some of these problems. Before that, however, I'd like to state something about NBS and its relation to the voluntary standards or engineering standardization methods of this country. With very few exceptions, and these are prescribed to us by Congress, we do not make engineering standards. In no case do we police or enforce engineering standards. We do not certify products or procedures and our sole responsibility in this area is to provide technical backup useful in the making of these standards.

Dr. G. Gordon: One of the methods that has been found extremely useful, for a period of about 39 years, is what we call the Research Associate Program. Very briefly, the Research Associate Program is an arrangement by which a company, an association, or perhaps a group of individual companies, can send a person here to work for a period of 6 months, a year, 2 years, sometimes longer, not as an employee of the National Bureau of Standards but working here with our people, under our supervision, and producing research or engineering results in the same way that one of our employees does. This man comes here with his salary paid by the sponsoring organization. We supply supervisory assistance, clerical help, laboratory space, and ordinary supplies and equipment. If there is need for extraordinary services like computer work, large amounts of shop work, or special equipment, a special fund is set up by the sponsor here from which we draw and pay for these special services.

What are the advantages to the sponsor of having a man working here instead of somewhere else? First, the associate has access immediately and continuously to a very wide range of technical competence that we have here at the Bureau. Not only competence, but special facilities. For example, as it might affect the insulating window industry we have, of course, the Building Research Division, but aside from that in other Institutes we have a large group working on glass, we have in the Polymers Division people who are deeply involved with adhesive problems, we have expertise in the use and application of sealants, and we now have half a dozen widely scattered outdoor exposure sites which would be available for the use of the program . . . all the way from Puerto Rico to Alaska . . . and any other parts of the Bureau that could be useful are available. Well, what are the advantages to NBS . . . why do we like to see this program used? I think it is pretty obvious that it is not because we want to stick our noses into the standards making process and do anything like set up a government standard . . . that isn't it at all. We need the input though from industry and it often comes most usefully through a research associate. We need the input that allows us to plan more efficiently for industrially-related work that we have been given the mandate to do by our original legislation. I'd be less than candid if I didn't admit to the fact that a research associateship helps us beef up our own research effort a little bit. The presence of an associate here adds to the amount of research that we can do in the face of financial limitations. Se we see it as a good thing for the sponsor, we see it as a good thing for ourselves.

In setting up a research associateship the first step is to identify the problem that a research associate can work on here that fits somehow into something of mutual interest that would be an ongoing piece of engineering work. Second, of course, is to find a suitable man to come as a research associate. The third is to find the money to support him, his salary.

Once a problem is identified, and a man is located, setting up an associateship is quite a simple thing to do. The paper work is very simple and a man can come to work here almost immediately. We like to keep a project fairly short, say 1 or 2 years, with a well-defined beginning and end . . . we like to make sure that fairly frequent reviews take place involving our NBS people, the research associate himself, and his supervisor, and representatives of the sponsoring body . . . and with that procedure we usually find that we have a program that is satisfactory to everybody concerned. More and more we are trying to bring programs here that have real substance to them. There have been cases in the past where programs continued on and on and lost their effectiveness. I think this is fairly easily avoided by being careful to describe the program especially at the very start, and to keep a close watch on what's going on. Briefly, to illustrate what we are doing, I will give you a couple of examples within the Building Research Division. For example, the Porcelain Enamel Institute, whose members are generally quite small companies, have had a program here for 2 to 3 years involving the examination of the mechanism of spalling of porcelain enamel from various metal substrates under different physical and chemical conditions, with the idea that on the basis of this research satisfactory accelerated test methods can be set up and used as the basis of standards of performance for porcelain enamel.

We have another group supported and sponsored by the Manufacturing Chemists Association for 4 years now, involved with determining the weatherability of plastics used in buildings, including the effect of outdoor climatic conditions, such as solar radiation, moisture, and temperature.

These are just a couple of examples. We have them ranging all the way over into much more scientifically oriented directions as well, but these, I think, will give you some idea of the kind of program that could be applicable here. If there are any questions, I'd be happy to try to answer them.

W. MacLeod: Do you have any research associate program that involves joint sponsorship, such as by industry, a trade association, and governmental agencies other than NBS?

Dr. Gordon: Not currently, no.

Mr. Robinson: George, would it be feasible to do that? Dr. Wright?

Dr. Wright: I might answer Mr. MacLeod's question. We don't have a research associateship that is jointly sponsored in just that way but we do have programs that involve government agencies, ourselves, research associates, and so on. I might cite one in our Structural Engineering Section—our Masonry Research Program. We have a program involving various facets of masonry research. This is supported No. 1 by our own NBS research dollars; No. 2 by three agencies of the government, the Army, Navy and Air Force; No. 3 by a Dow Chemical Company Research Associateship; No. 4 by a grant from the National Concrete Masonry Association. So there's an illustration of how many groups can get together to carry out one particular type of research. And a key point, I think, in any research associate program, particularly from the standpoint of a sponsor, is that as a part of an integrated program of that type, everything developed in it is open to you.

Dr. Gordon: Another possibility, even though it doesn't have all the advantages of a research associateship here, is the furnishing of a grant in dollars to NBS so that we with one of our own employees can carry out work of interest to an outside organization or group. I say it isn't quite as advantageous to the outside organization because our own employee presumably stays here, he doesn't go back to the industry, and the maintenance of long continuing contacts is not as easy as if you had one of your own people here for a period.

Mr. O'Shaughnessy: If I may address Mr. McKinley and yourself directly, in Mr. McKinley's program for future action, would the ASTM in its round-robin on test methods be able to work in conjunction with a research associate, as it possibly would wish to do?

Mr. McKinley: I would picture the sponsored research associateship as a very flexible and inclusive kind of thing. The focal point for conducting this round robin then could be here at NBS. For example, the National Bureau of Standards Test Farms from Puerto Rico to Alaska might be useful. You know the question has come up, what about the differences in weather exposure. In my ASTM proposal I mentioned Test Farms specifically. If this kind of ASTM program can be started it would greatly expedite results.

I would think that the research associate would mean that the test program would move much more rapidly. I don't think that it would change it very much in any significant way except in speed.

Mr. Robinson: If I could add a few points to that, I agree that that would be one way to staff the Round-Robin, which is important. Another is that the statistical planning and interpretation of the results might be advantageously carried out with some of the assistance easily available at the Bureau. Further, I think that if this were done, the research associate would be learning things from the field that he should know about in his experimental work for you.

Mr. McKinley: He might serve as the technical secretary for the ASTM committee.

Dr. Gordon: I might throw in the idea too that any work that goes on here is completely out in the open, the results are open to everybody, anyone who wants to can come in and look at them; if they are publishable, they'll be published. It's a way that some other standards-making organizations have found useful to avoid built-in biases that sometimes interfere with the standards-making process. And I might repeat, because I repeat and repeat and still it sometimes isn't understood, we are here only to furnish technical back-up, to give what technical help we can, and not to influence the making, the acceptance, of an actual standard.

Mr. Robinson: Thank you very much, Dr. Gordon.

I think we have come to a certain juncture. This has been a Seminar of people with interests and concerns and problems who represent a broad cross-section of the sealed insulating glass unit industry and its customers. You are all interested . . . you have been a most satisfactory audience and have been very responsive but I see here at present no motor by which to effect action on the part of this Seminar or this industry except possibly through the agency of the association which you have—The Sealed Insulating Glass Manufacturing Association. There may be other ways. It's not for me to organize them, it is for me to try to call them forth for whatever action can be effected at this meeting. I call upon those of you who have views as to what this Seminar might do and how it might do it to come forward now and generate some of the action or set up the nuclei for action. As regards what NBS can do, we plan to publish in some form the proceedings and the papers of this Seminar, and make the publication available to each of you who are attending and to the wider population of your industry. This we can do and will do but it is now up to the members of this Seminar and this industry to pull themselves up by their own bootstraps.

I call for your suggestions or comments in this regard.

Sir?

Participant: I'm speaking as a very small manufacturer and until the man from Andersen spoke today I was wondering whether it would continue. I'm sure that there is no manufacturer here who wants to make defective units. There is no architectural acceptance of units that are going to be defective. When the man from Andersen said their failures in field operation amounted to 1/10 of 1 percent of their dollar value and then when I hear the different manufacturers who have testing laboratories speak, the opinion I get—and it may be wrong—is that they designed their tests to show how the other man's product won't work rather than what is good about it. I'm saying that if the FHA feels a need to work with the industry to upgrade insulating glass units then they should work with SIGMA and go over the standards they have set for the betterment of the products . . . I don't know how else to do it.

Mr. Robinson: I see the point you are referring to. I will say that one of the great advantages of having access to highly objective and well respected laboratories, such as those our neighbors in Canada have and those they have been developing in Norway, is for protection against such a situation as you have foreshadowed. Thank you for your comments.

Mr. O'Shaughnessy?

Mr. O'Shaughnessy: I think, in talking with the other SIGMA members, that we feel that the adoption of the SIGMA specification with its new revisions is a realistic move. The next steps are a bit obscure to us; however, I think they will come out. I do think the ASTM proposal for a round-robin is a good one and I think it should definitely be enacted. And I do feel I have to speak personally now, that the research associateship is an extremely good move to speed things along which is obviously necessary. However, there's a certain reluctance on the part of the SIGMA organization and it does not stem from lack of desire by any means. We have, should I say, expended our budget every year in the past in the work we have done and I cannot make a commitment for the organization because there just are not funds available for the moment. However, in view of FHA's acceptance for an interim type thing, conceivably a new membership program would generate some funds which would definitely be contributable to the research associateship. Here again I can't propose this and then not be able to back it up. So we're faced with somewhat of a dilemma here and I'd like some discussion from the group to see if they have any proposals.

Mr. Snell: Now, Bob, I'm going to try to open this thing up a little bit for discussion. Do you feel that your group, the SIGMA group, at this time with what they have, do you feel that you've moved as far ahead as you can? In other words I'm asking do you feel that you have a specification that would give us the protection that we need?

Mr. O'Shaughnessy: The specifications that we are proposing are undoubtedly far ahead of what we had before. However, in the committee meetings on Wednesday, a lot of proposals were pushed out or thrown out to the members of the committee and I by no means think that our proposals as now on the board are going to be the end of what SIGMA can do independently. I think we can take it a long way from there. However, there are certain areas which we cannot contribute to substantially and one is additional methods of testing or variations of the present methods.

Joe, over here, wants to say something.

J. Amstock: Actually SIGMA was formed to get the specification done. We've worked for the past couple of years and moved right along. No, we're not at the end, Lyn, and if ASTM or this Seminar had not come up we would still continue. We have the same interest that Bob mentioned earlier, we have the faithfulness to the companies that pay us as individuals. But secondly, we have a certain relationship with SIGMA to keep the industry thriving for the betterment of each one of us because this is where we're going to make our money in the end and I think this ties in with your comments, Bob, with ASTM.

We're going to continue work, definitely. It's not because of the equipment. Many of the private organizations do have substantial funds and are willing to pass on their data to other members. SIGMA definitely would cooperate in a Round Robin program. I am sure there would be an overlap of many of these people in the SIGMA organization who would continue the upgrading of the existing specification. We had a rather extensive meeting Wednesday which is going beyond what Roger has on the board. As private companies we're going to add research and I think it's not at an end, definitely not. We're staying with the organization and it's going to grow. I think we've added a half dozen new members in the past few days because of the proceedings here and what they've seen has been happening.

All we need is FHA, GSA to give us this basic sanction of O.K., we're going to go further with you, and I think the industry is going to jump in and get on the bandwagon.

Mr. Robinson: Thank you, Joe. Sir?

Participant: I felt this group would be interested in knowing just what one specification writer thinks of groups such as SIGMA and the use of this specification for groups of this type and the comparison of the use of such specifications by ASTM. The one thing that all specification writers have to bear in mind in the use of these specifications is that these specifications are formed by single interest groups. They do not incorporate the broad interest of the entire spectrum of the manufacturer of the product parts, the manufacturer of the sealed unit, the installer, the contractor, the user and the specifier, as ASTM generally incorporates them.

Participant: I would have to take exception to that. As a general basic rule, excuse me, I also included the present specifications too. The difficulty that you have here really in using just a single specification is fabulous. Yes, it may exclude a great many dogs but, on the other hand, it's interesting to me to note that the great majority of members of SIGMA are indeed component manufacturers and not installation glass manufacturers. It's also interesting to me to note that the major glass manufacturers in this country do not belong.

Participant: There is a very good reason why they do not belong.

Participant: I'm sure that there is. My point is this, that these are the things we have to consider as specifiers. Yes, I think you have a tremendous organization in SIGMA. I think that you've made tremendous strides and I'm most interested in getting a copy of this specification. In fact, I asked for one, 3 or 4 weeks ago before I got here but something got mixed up and it never got to me. I would like to study it thoroughly but by golly don't think for a minute that because a single interest group has drawn up a specification and may not have had this thoroughly checked by the user and by the contractors, that we're just going to buy it hook, line, and sinker. What you're asking us architects to do is to buy something on face value and when it fails you know they don't come back to you, they come back to us. We're No. 1 on the list, we're the ones that made the mistake.

Mr. Robinson: Thank you for expressing that point of view sir.

Mr. MacLeod.

W. MacLeod: I do want to speak, Mr. Chairman and gentlemen, on this point that was made here. It is true that in developing standards in any group that I know of, and like many of you I have been associated with such developments for several years, that the greatest input of technology generally comes from the producing areas. This is true of any standard that I know of, including federal specifications with which I'm very familiar. Now if you look at the procedures under which these national standards are developed, what you find is a means by which the least of us can make known our position, through the consensus principle that is applied.

Now I have had the very fortunate experience of sitting two years actively on the Standards Committee of ASTM and I've read every negative ballot that was written by any of you during that period and considered it objectively and independently from the viewpoint of your position. And I have the privilege of saying that I stopped one standard when one negative ballot was present . . . and this was from a user . . . this was from a typical man like this. We stopped the quorum. I would not vote "yes" on that standard. And it was a technical question that the man raised. Now under these procedures, for example, if SIGMA should transmit, and I want you to know this, its standard to the USA Standards Institute, it will not measure up to a consensus. It would not be cast as a USA Standard at this writing and your Seminar has demonstrated this, so try it for size if you wish . . . this is an action you should take. Submit all of your specifications, all of your support, all of your endorsement of your standard to the USA Standards Institute, and I have an idea it would go before the Miscellaneous Standards Board.

This Seminar has demonstrated that you do not have any national consensus on your standard. You have but one segment of a very good consensus but you haven't gone this distance. Now in consequence what procedure do you use?

In answer, I point out that the consensus principle is the best solution we have in our kind of system of production, distribution and utilization of parts. But something has to be done to achieve an effective coordinating process of all the experience available.

In conclusion I repeat what I said yesterday. The American Society for Testing Materials stands ready to serve in this field. You are the groups that will decide in what degree the professionals in our organization can be utilized to serve you. Thank you very much.

Mr. Robinson: I would like to add to Mr. MacLeod's answer to the gentlemen who raised the point, that at present the SIGMA specification could be charged with being a limited-field producers' document. It is my feeling that this cannot be said about the Canadian document. It is also true that the SIGMA specification at present does not have direct correlation with field durability. However, if this were supplied it would probably satisfy you even though it was still a limited producer's document. If it also were modified in accordance with the evolution of testing methods which might come about through these actions, I think you would be satisfied. I hope this is so.

Participant: I would like to say that in my opinion the sensible course for us is to go ahead and take something. I believe that the only way we're going to get this off the ground is to accept the best that we have available now, in hopes that people gathered here today will assume their proper positions relative to this working out of a better developed standard that perhaps can be nationally recognized.

Mr. Robinson: Thank you.

As moderator I would like now to refer to a different matter which has previously been mentioned at this Seminar, namely, the question of a specification for sealants for insulating units. I understand that a superior specification can now be drafted or perhaps has already been drafted. I would like to ask Mr. Box and Mr. Amstock—and others who may be familiar with the subject—How would such a document be instituted? Would it be done in a normal course through an ASTM group like B–20?

I would like any expression of opinion on this somewhat more limited subject which is nevertheless important. Is Mr. Box here?

J. Box: To be perfectly honest we at Tremco haven't considered it too seriously so any comments I make are my own comments which I might regret later on. I personally look to what you're actually trying to accomplish and that is to prove or guarantee performance of the insulating unit itself, and you are testing the unit itself, which is what the owner of a building is interested in, and what the architect is interested in. I'm not sure how much we advance ourselves by having a specification for one individual component. It's true that the sealant itself is involved, and that it needs equally close attention, considering the properties it must have.

So there might be a very good reason for having an individual specification for the sealant itself to assure users of this material, that is, the manufacturers, that they are working with a satisfactory material. However, you also have to look at the fact that very few manufacturers make the units the same way. Each one has his own methods of production, possibly affected by economies. And so what is good for one unit in one set of manufacturing procedures certainly isn't necessarily good for all manufacturers. And then, assuming that we decided that we are going to have a sealant specification, I think it would have to be universally accepted. In that case, a certain organization would have to exist, and if that were the case then obviously you should start with SIGMA. But we haven't agreed yet upon what we are going to do with SIGMA so far as the insulating unit itself is concerned, so it's difficult to say what we are going to do as regards individual SIGMA specifications.

J. A. Box: Tremco, for whom I can speak, really hasn't made up its mind on that point.

Mr. Robinson: Would you also be willing to follow the ASTM route?

J. A. Box: Yes, I should have said that. Either way which will effect universal acceptance most readily is the way we should go.

Participant: Would a specification of the type we are discussing be a material specification or a performance specification? Performance specifications may be ideally suited to this area.

Mr. Pritsker: I am on some ASTM committees. At a regular committee meeting I have been told that ASTM does not allow performance specifications.

Mr. MacLeod: I would like to correct a possible misconception here. It depends on the scope written to allow performance specifications. In other words, it depends upon the motion of the committee itself.

Mr. Robinson: Thank you very much. I think Joe Amstock wanted to speak.

J. Amstock: As producers of individual components, each of us has to have specifications for our own quality standards. Unit manufacturers can use some of these in their own quality control. The desiccant people I am sure are in a similar position. I think we're stepping out of our bounds at this particular time to consider all these other outside specifications and to forget about the main one we intend to discuss, that is, the specification for testing the insulating unit itself, the thing that you people are really interested in. Let's continue with the growth of the insulating unit specification as we know it.

Participant: I suppose most of you know about the old chestnut that's been bouncing around SIGMA for so long—to the effect that if a manufacturer made his unit out of bubble gum and it passed a rigorous performance test, well then it should be accepted. If enough manufacturers of insulating glass units want some kind of test method for sealants, you should test the sealant in the same way as you use it. Then maybe through SIGMA they could get together and request ASTM to develop the test method for the sealants for insulating glass.

Mr. Robinson: Thank you.

Participant: I'd like to divorce myself from SIGMA for a second and speak as a fabricator of units. Now, undoubtedly in our plant we have sealant materials, and certainly we would like to see some sort of uniformity regarding their qualities, but I feel that this is a matter between me and my supplier whoever he may be. I could conceivably take that same product out of the same drum, and one day build a really fine unit, and then simply by losing my in-plant quality control or changing my machinery a bit, build a unit that would fail performance tests in half the time. So I think that rather than specifying sealants you almost have to approve manufacturers and then keep some type of a check on his workmanship. Because that's really what a unit is all about . . . selection first of materials and then using them properly for your construction.

Mr. Robinson: Thank you.

Participant: I just wanted to say that we are manufacturers, and I suppose there are many of us in SIGMA, who have been manufacturers for over ten years now. I can assure you that we are very grateful to the manufacturers of sealants for their having upgraded their sealants because I know they have. With the help of the sealant manufacturers and their standard quality control, and SIGMA, and the testing that we have done, units today are much better than they could possibly have been ten years ago. It only stands to reason that in-plant quality control must be taken care of.

Mr. Robinson: Well, here's a question that we've discussed at some length and with many views expressed, so unless someone feels very strongly I would suggest we retire that particular question for this meeting. I see a hand.

Participant: Could we hear from Mr. Stout about his feelings as a consumer of insulating glass? He's one of the few here . . . what his feelings are on specifications and what he's going to look for.

Mr. Robinson: Mr. Stout, do you care to comment on this?

C. C. Stout: The manufacturing of high quality insulating glass units, as we have seen it, depends on the combination of materials, the combination of design, the combination of production techniques, and of in-plant quality control and testing. I brought that out earlier. It seems to me that perhaps you're looking for the government or some Joe Smoe or someone to solve your problems, and I think a lot of them have to be solved by yourselves. There is one thing that I would like to impress upon you. I go back to that little analysis I made on the board concerning value vs. price. May I read something to you—It comes out of Webster's Dictionary. The word is value and one way they define it is this . . . "the quantity of money which an article is likely to command in the long run, as distinct from its price in an individual instance."

Participant: I think Mr. Stout and the preceding manufacturer who spoke are both correct in what they said. Mr. Stout and I think the problem is that of manufacturers here today. We can learn a good deal from manufacturers, and I think it will be interesting to learn what I do as specifier, how I go about specifying material to be used in the buildings we design. There are hundreds of materials that go into a building and I couldn't possibly become conversant with all of them. Now for each of these hundred materials that are manufactured, there are at least two dozen manufacturers of that material. So I would have to be conversant with 25,000 manufacturers in this country, and I couldn't possibly expect to have knowledge about every material.

What do I do if I don't have a suitable standard, and apparently we don't have the standard today that I would use.

I go to the most eligible manufacturers that I know and use their material because I don't have the time to look into and investigate all of the materials that are made. And so, I have to limit myself to those people that I think can do the job based on their own research, their own know-how, and their capability.

I don't want those specifications by the customer. I like to have competition. I don't want my clients job-priced out of the market if I have choice of specifications. Specifically, there are individual manufacturers' specifications, that are used in the absence of the manufacturer's name. If I don't like that particular specification I am not obliged to use it directly if I can find a manufacturer who can meet the qualifications. And so for your own welfare, if you want to get the right specifications, you had better adopt a standard because I don't have the time to look into your own material when I have hundreds of other materials to look into. I couldn't possibly begin to have time to investigate all these materials and so we must abide by or rely on a standard that is acceptable to the manufacturer, the consumer, and to all of the general interest that made that standard.

Mr. Robinson: Gentlemen: I am sorry to say that there are only 18 minutes before lunch. I think as moderator I should attempt here to summarize matters at least as they look to me.

It appears first, in regard to standards for sealed insulating units, that there is one possible course of action somewhat independent of your industry directly. The needs of Governmental agencies in procurement and investment for this advantageous product may require them to adopt some present specification, or something else, depending on what it was thought would provide the best results, to assure their procurement of high-quality units. Such unilateral action might not be the best way—it would seem preferable that there be joint action by industry and Government, to assure that the similar needs of both the private and the public purchasers of insulating units are recognized and met. If the industry has developed, is developing, or will develop, a standard that can be generally accepted, and that can be implemented feasibly, then the immediate need would be met, and a necessary progressive step accomplished.

At the same time, in the report given yesterday, I was not able to tell you that meeting the specifications now existing provides assurance, at present, as to the prospective satisfactory life of units in service. Inversely, there is a better case for the conclusion that units that fail present specifications have weak prospects for long satisfactory service. It is of interest that one of our panel members, having the consumer point of view, has reported to us that in the experience of his company if failures occur in service they tend to occur in the first year or two.

It seems to me important to emphasize the long-term need of the industry—correlation of data on field performance and accelerated laboratory test performance. Much work and considerable time are required to develop reliable correlations. Nevertheless, the acceptance and growing use of insulating glass products depends on satisfactory performance in the field, and on predictable durability from laboratory testing. I interject here the comment that the immediate need of the industry for a good standard or specification is related directly with the need for correlations. Field experience with units that would not have passed the laboratory tests would not assist in developing reliable correlations; on the contrary, it would obscure the effort.

The laboratory techniques that are selected or developed to conduct accelerated laboratory tests on units for determination of compliance with specifications are quite important for another reason. A good deal of expenditure, and a large testing capacity for determining compliance of the units of the various manufacturers in a reasonable time, will be required. For this reason—and in addition to the need that the selected test methods be realistically meaningful and reasonable—there is need for selection or development of testing apparatus that is well standardized so that it can be duplicated in several places at not too much cost, and can handle a large number of units, preferably of various sizes, at one time under uniform and controlled conditions. There is also a need for assurance that the testing equipment and procedures at one testing-facility yield test results satisfactorily comparable or equivalent to those of another, if there is more than one.

The round-robin that Mr. McKinley suggested, to be undertaken under the auspices of ASTM Committee E–6, is aimed at an evaluation of existing test methods and procedures for laboratory testing of insulating glass units. It would appear, from the discussion that took place, that many in your industry would like to participate in it. Let us take a sounding. How many here would be interested in cooperating with the Task Group in conducting this round-robin? I see 15 hands. Now, can we ascertain what percentage these represent of all the unit manufacturers that are here? Will all such manufacturers present make a show of hands? It looks to me that, in round numbers, about 75 percent are interested, and willing to participate. That is very promising. If we can elicit a similar response from others who are not present, the round-robin will have a fine potential. May I suggest that each of you who has indicated an interest in participating drop a line to Bob McKinley so that he can keep you informed and keep in touch with you. I think we can assume that Bob would equally like to hear from any others of similar mind who may not have been represented here this morning.

Before we conclude, does anyone here wish to make a further comment or statement? . . . Mr. Pearl.

Mr. J. Pearl: I would like to summarize here the position and attitude of SIGMA. We are going to continue working on our present and prospective association programs. We want to cooperate in every way as regards establishing a standard, and to cooperate in the round-robin with Mr. McKinley of ASTM. At this time I cannot state that SIGMA can involve itself in something like the Research Associateship. However, it will be taken under consideration. That is essentially what I have to say.

Mr. Robinson: Thank you very much . . . Mr. Stout.

Mr. Stout: Just a comment. We obviously would heartily support a good performance improvement beginning in the industry. We think it is essential, and I am sure there are many others who recognize the need for a good standard. I think that most people in this industry are trying to improve their products and I am sympathetic with them. We go to the people that have the talent to produce a good performing part that will last for the life of the structure. And don't get frightened about this "life of the structure" thing. I think you have to take a step. We stuck our neck out 11 years ago. We're glad we did, we didn't go broke, and we did make some progress. The day of recognition came when we started to depend on the capabilities of good producers.

But standards are important. I have worked on a few committees and I am familiar with, and I encourage that you work with, the Canadians; and because I am a Swede, I would add a few Swedes too. Finally I want to say that there is an awful lot of insulating glass business in the world and the future. Tremendous.

Mr. Robinson: Thank you, Mr. Stout. That has a good sound. Gentlemen, the future beckons and what will happen depends on what you do now and tomorrow. I want to thank you as an audience, and as a most participative fifth element of this panel, and I now turn the meeting back to Chairman Bob McKinley.

Mr. McKinley: Thank you very much, Henry. I really believe that most of you have had almost as good a time as I have had and we have learned a great deal. It has been pleasant to be with you. The National Bureau of Standards' hospitality certainly has been wonderful.

I think Dr. Wright can report to Dr. Astin that you all deserve credit for personal hospitality. All Americans can be proud of our NBS facilities and I suspect that all of our foreign visitors are pleased that we have set a good standard. The number of people here from the Construction Specifications Institute makes it apparent that their interest is active. The Building Research Institute, another one of the sponsors, helped also to build attendance. Mr. MacLeod's active participation, representing the ASTM Board, has been a major contribution.

Mr. McKinley: We are going to adjourn immediately. Luncheon is scheduled. The joint seminar committee will be meeting around the luncheon table to wind up their assignments. Among the things we will do is prepare a brief formal report to our sponsors. We will arrive at some decision on publication of the papers and material presented here, which, I believe, each of those who registered will receive. I thank you all.

7. Biographies of Speakers

H. J. Rosen

H. J. Rosen, Chief Specifications Writer, Skidmore, Owings, & Merrill, Architects, New York, New York, received a Bachelor of Chemical Engineering degree from the College of the City of New York. Since then he has accumulated over 25 years of experience in specification writing and materials research.

A registered Professional Engineer in the State of New York, Mr. Rosen is a Fellow of The Construction Specifications Institute and a member of the American Society for Testing and Materials and the American Concrete Institute. He is a Lecturer at Pratt Institute on specification writing, is author of *Progressive Architecture's* monthly column, "Specifications Clinic," and recently authored a book, *Principles of Specification Writing.*

Mr. Rosen has also served on several Building Research Advisory Board task forces in the development of reports on the use of materials in construction and is a member of the Commerce Industry Board. He was chairman of the committee that developed standards on architectural concrete. He is also a member of theNational Council of Architectural Registration Board's Committee on Examinations.

W. E. Bryant

W. E. Bryant is currently Assistant Director of Technical Services for the National Association of Home Builders.

Prior to being employed by NAHB in 1966, Mr. Bryant worked for the Bureau of Public Roads in Washington, D.C., as an area engineer, where he was engaged in planning, design, and construction of Federal-aid highways. He has worked extensively on building, plumbing, electrical, and housing codes, and is a recognized expert in the field of underground wiring. He is a member or alternate on numerous USASI and ASTM committees.

Mr. Bryant received a B.S.C.E. degree from the University of Michigan in 1868, and an L.L.B. degree from George Washington University. He is currently a member of the Virginia Bar Association.

A. G. Wilson

A. G. Wilson graduated from the University of Saskatchewan with a B.E. degree in 1946. He received his M.S.C. degree from the University of Illinois in 1949. He has been employed by the Division of Building Research, National Research Council of Ottawa since 1949. He is a member of ASHRAE and ASTM Committees E6 and C16.

K. R. Solvason

K. R. Solvason received his B.E. degree from the University of Saskatchewan in 1944. This was followed in 1953 by an M.S.C. degree from the same university. Mr. Solvason has been employed by the Division of Building Research, National Research Council of Ottawa since 1949. He is a member of ASHRAE.

T. Gjelsvik

T. Gjelsvik is Senior Research Officer at the Laboratory of the Norwegian Building Research Institute, Trondheim, Norway. He joined the Norwegian Building Research Institute in 1959, where his main fields of work include sealants and other types of jointing materials, sealed glazing units, and related subjects.

He received a degree in technical physics at the Norwegian Technical University, Trondheim, Norway, in 1954.

Mr. Gjelsvik has authored numerous papers and is a member of "Den Norske Ingenirforening" and "Norsk Fysisk Selskap."

J. S. Amstock

J. S. Amstock presently holds the position of Technical Manager, Eastern Division, Products Research and Chemical Corporation. He attended Drexel Institute of Technology where he majored in chemical engineering.

Mr. Amstock holds Chairmanships in:

A. Sealed Insulating Glass Manufacturers Assoc.
 (1) Quality Standards Committee
 (2) Certification Committee

B. Building Research Institute
 (1) Sealants Committee

He also represents Products Research and Chemical Corporation in the following organizations:

A. ASTM (American Society for Testing and Materials) C–24 Committee
B. The Construction Specifications Institute (CSI)
C. Joint Sealant Coordination Conference

J. D. Gwyn

J. D. Gwyn is presently the Assistant Director of Research at Libbey-Owens-Ford Glass Company. He has also held the position of Chief of the Products Section during his tenure at this company since 1934. He is also a member of the L.O.F. Policy Committee.

Mr. Gwyn graduated from the University of Michigan with a B.S. degree in chemistry.

R. J. Mazzoni

R. J. Mazzoni received his B.S. degree in mechanical engineering at the University of Pittsburgh in 1949. Following this he spent 3 years in the Engineering Division of Kopper's Company.

He has been engaged in double-glazing and glazing-sealant development at the Glass Research Center of Pittsburgh Plate Glass Industries since 1952. Since 1960 he has been Head of the Building Materials Department at PPG.

J. A. Box

J. A. Box is Manager, Industrial Product Development, Tremco Manufacturing Company. In this capacity he manages the research and development effort for new products in various fields such as insulated glass sealants, automotive sealants and glazing tapes, metal building sealants, and anti-corrosive mastics.

Mr. Box received his B.A. degree in chemistry from the Hiram College in 1951.

Mr. Box is active in Technical Committee support work for the Sigma, NRC 12GP8 specification and the younger, Insulated Glass Manufacturers Association of Canada (IGMAC).

H. E. Robinson

H. E. Robinson is currently Chief, Environmental Engineering Section, NBS Building Research Division. Prior to holding this position, he was Chief of the Heat Transfer Section.

Mr. Robinson has been a Bureau employee for 31 years, during which time he has done extensive work in the fields of heat transfer and thermal conductivity.

Mr. Robinson received his B.S. and M.E. degrees from the College of the City of New York.

R. D. O'Shaughnessy

R. D. O'Shaughnessy is currently President of the Cardinal Insulated Glass Company in Minneapolis, Minnesota. Previous to holding this position, he was Director of Quality Control, Director of In Plant Cost Control, and Vice President of the same company.

Mr. O'Shaughnessy attended the University of Minnesota where he majored in business administration.

He is Secretary of the Sealed Insulating Glass Manufacturers Association and is also Chairman of the Glazing Specification Committee SIGMA.

R. W. McKinley

R. W. McKinley is presently Manager, Technical Services, Glass Division, Pittsburgh Plate Glass Industries. He received his degree in electrical engineering and architecture from the Massachusetts Institute of Technology in 1940.

Mr. McKinley's professional experience includes the following positions: Application Engineer, Sylvania, Lighting Division and Westinghouse, Lamp Division; Electrical Engineer, U.S. Navy, where he served under Admiral Rickover; Editor Lighting Handbook, Illuminating Engineering Society; and Development Engineer (Research) Pittsburgh Corning Corporation.

Mr. McKinley is active in numerous professional organizations including the following: American Society for Testing and Materials, American Society of Heating and Refrigerating Engineers, Illuminating Engineering Society, Optical Society of America, and the Building Research Institute.

C. C. Stout

C. C. Stout is Treasurer and Product Development Manager for the Andersen Corporation, Bayport, Minnesota. He received his B.C.E. degree from the University of Minnesota in 1933.

From 1935 to 1936 Mr. Stout was employed by the Wood Conversion Company where he was engaged in research. In 1936 he began his career with the Andersen Corporation as a sales representative in New York State. He was transferred to Bayport in 1953 as Assistant Sales Manager. He was appointed Sales Manager in 1961 and Marketing Manager in 1964. He has held his present position since 1967.

Mr. Stout is a member of the Board of Directors of the Andersen Corporation. He is also a member of the Forest Products Research Society and American Marketing Association.

L. K. Snell, Jr.

L. K. Snell, Jr., received the degree of Bachelor of Architectural Engineering from Washington State College, Pullman, Washington, 1953. He is a licensed architect in the State of Washington and has previous experience in building contracting, construction supervision for Washington State College, and the University of Idaho.

Mr. Snell is presently the Deputy Coordinator of the Methods and Materials Section, Architectural Division, Office of Technical Standards, Federal Housing Administration. He is also a member of ASTM.

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The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

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> Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations in the development of technological standards, and test methodologies; and provides advisory and research services for Federal, state, and local government agencies. The Institute consists of the following technical divisions and offices:

> Engineering Standards—Weights and Measures — Invention and Innovation — Vehicle Systems Research—Product Evaluation—Building Research—Instrument Shops—Measurement Engineering—Electronic Technology—Technical Analysis.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center consists of the following divisions:

> Reactor Radiation—Linac Radiation—Nuclear Radiation—Applied Radiation.

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in the selection, acquisition, and effective use of automatic data processing equipment; and serves as the principal focus for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

> Information Processing Standards—Computer Information — Computer Services — Systems Development—Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System, and provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

> Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.