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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 Concrete Industry Board. He was chairman of the committee that developed standards on architectural concrete. He is also a member of the National 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 1968, 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 anit-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.

Durability of Insulating Glass Seminar
Introductory Remarks

James R. Wright[1]
National Bureau of Standards

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

Key Words: accelerated testing; insulating glass units; standardized testing.

[1]Chief, Building Research Division

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 towards 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 products. 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.

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 unsulating 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.

Durability of Insulating Glass Seminar
Introductory Remarks

W. MacLeod
American Society for Testing and Materials

Introductory remarks were made by the author to the attendees of the seminar on Durability of Insulating Glass. The American Society for Testing and Materials (ASTM) was a co-sponsor 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 co-sponsor 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 against which may be measured in meaningful terms the serviceability and durability of insulated glass units such as 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.

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

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]Chief, Specifications Department

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.

Now, where does responsibility lie when materials failure occurs? Is it 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 to be 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 namufacturers' 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 compatability with and relationship to adjacent materials and assemblies, notwithstanding the manufacturer's similar obligations. Now the AIA hasn't any guiderules 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 separtely 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 suggest 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.

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.

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]Architect, Architectural Division

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.

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.

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 full 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]Assistant Director of Technical Services

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 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.

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

K. R. Solvason and A. G. Wilson[1]
National Research Council of Canada
Ottawa, Canada

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, ultra-violet radiation, water vapor diffusion, weather cycling apparatus.

[1]Building Services Section, Division of Building Research

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 dew-point temperature in the air space was quickly identified as the major criterion of performance. A low dew-point 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, to measure the relative dew-point 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 dew-point 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, 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 per cent 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 dew-point 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 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 1/2-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 dew-point temperatures were measured periodically (Fig. 2). The primary purpose was to expose the specimens to ultra-violet 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 dew-points 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 dew-points 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.

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 becuase 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 dew-point 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 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 dew-point 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 dew-points above 0°F (-18°C). As a result, CMHC altered the initial and final dew-point 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 dew-point 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 "Ultra-Violet 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 ultra-violet lamp is used for heating because it was suspected that a breakdown of components of the sealing system might occur under ultra-violet 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.

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 dew-point 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 ultra-violet radiation.

The results for some 67 sets of units received from November 1960 to July 1963, analysed on the basis of the standards set by CMHC in 1964 (-40°F (-40°C) initial dew-point 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 dew-point	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 dew-point; stains are visible in six.

The results for units recieved 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 dew-point	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 sets 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 dew-point	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 per cent of the units received up to November 1960 would have passed the current CGSB requirements; 17 per cent received from November 1960 to July 1963; 20 per cent received from August 1963 to July 1965; and 44 per cent 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 consumer 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.

References

(1) Wilson, A.G. and K.R. Solvason, Performance of Sealed Double-Glazing Units, J. Can. Ceram Soc., Vol. 31, p. 68-82, 1962.

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Evaluation of Factory-Sealed Double-Glazing in Canada

by

K.R. Solvason and A.G. Wilson

Figure Captions

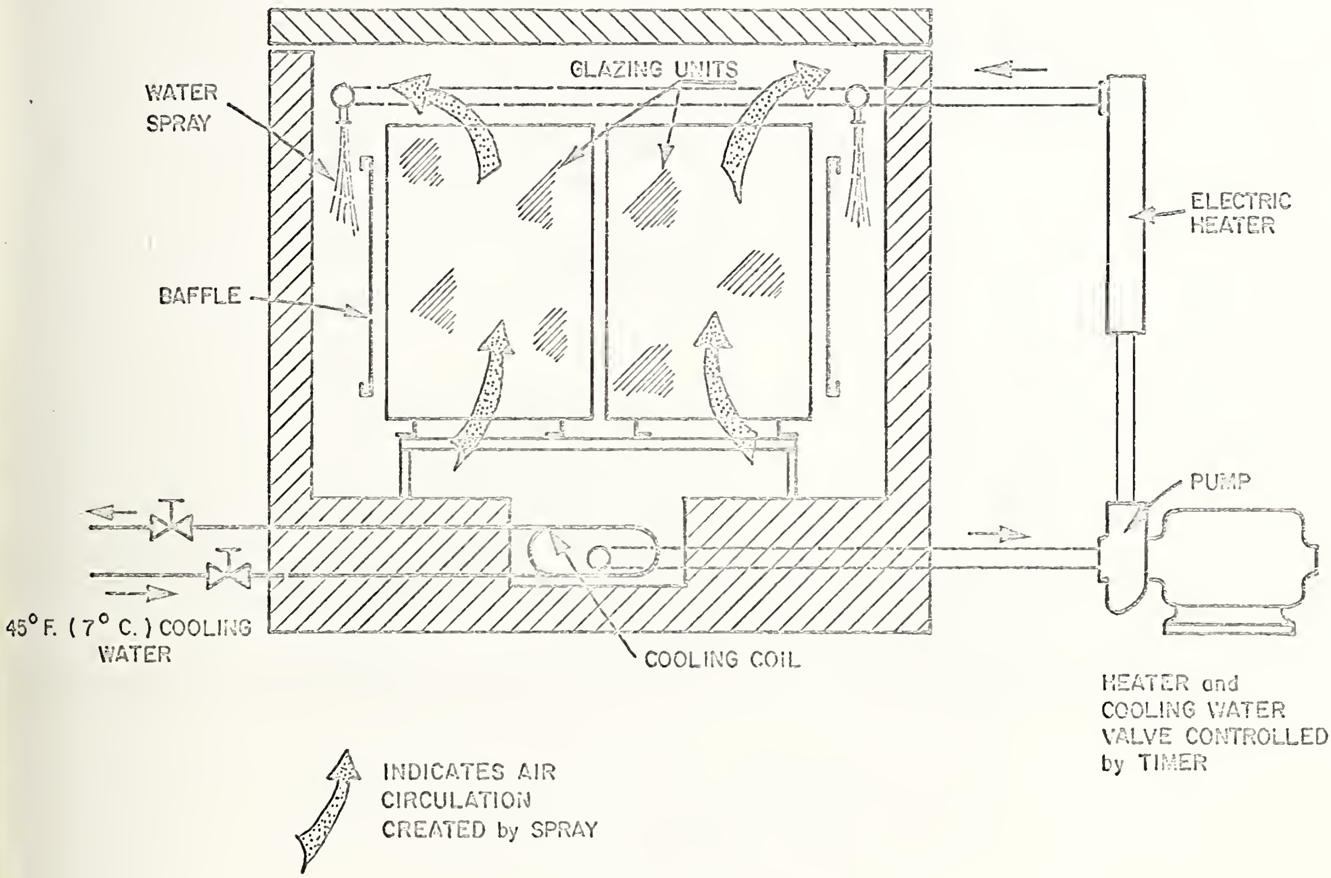
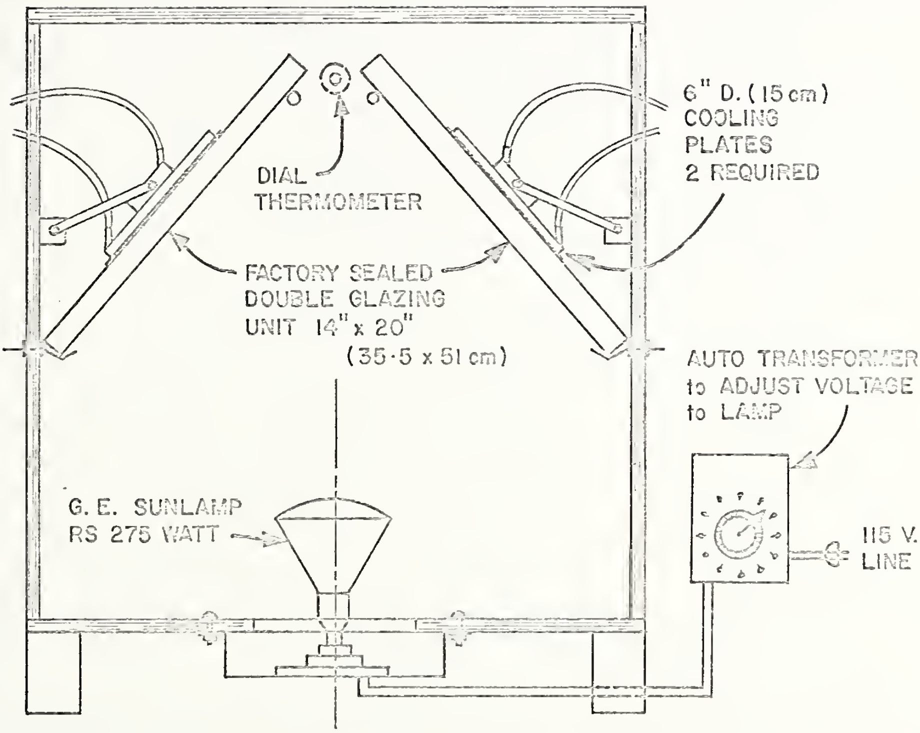


FIGURE 3 HIGH HUMIDITY CYCLING CABINET



NOTE:

22" x 22" x 22" (56 cm.) BOX CONSTRUCTED of PLYWOOD and LINED with ALUMINUM FOIL

FIGURE 4 ULTRAVIOLET FOGGING TEST APPARATUS

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

Tore Gjelsvik
Norwegian Building Research Institute
Trondheim, Norway

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, dew-point 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 programme.

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 programme 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 judgement 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.

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

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 120x170 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 120x170 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 test 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 programme 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 programme. In carrying out this programme, an attempt was made to include 20-year 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-hour 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 I. This 45-day programme has been repeated once, making a total effective operation time of 90 day-cycles.

Table I

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. Dew point 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 dew point 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 nickle and chrome plated. When dew point measurements are taken, the cooler is filled with a mixture of dry ice and 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 dew point temperature with the help of the curves in Figure 3.

The NBRI dew point 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 draw-back 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 dew point 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 dew point 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 in doing 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 dew point 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 dew points.

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 dew point 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 dew point 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 support 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 120x170 cm. The first series in 1959 were run on a tentative basis, while the later tests have followed a fixed programme. 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 dew point.

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 unit. 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 laboaratory as much as 7 cm.

The changes in dew point 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 dew point 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 dew point curve have, however, to be considered as good. In Curve C, the situation is quite different. Here the dew point 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 dew point has been much too high from the outset. Something between Curves B and D can be judged somewhat different, 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 dew point 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 dew point of good units will rise slowly in course of time as in Curves A and B. For bad units, the dew point 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 dew point, Curve F, have also occurred.

The correlation between the results of the laboratory tests from 1959-1966 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 dew points 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 programme was therefore taken up for revision. This was co-ordinated 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 dew point 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 120x82 cm, i.e., about half the original size, by mounting a cross-bar 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 the half. The present accelerated aging test programme amounts to 50 day cycles. Details are given in Table II.

Table II

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	25	35	15	55	15

The most important novelty in the revised programme 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 1 1/2 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 120x170 cm. The available material shows that 142x121.4 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.

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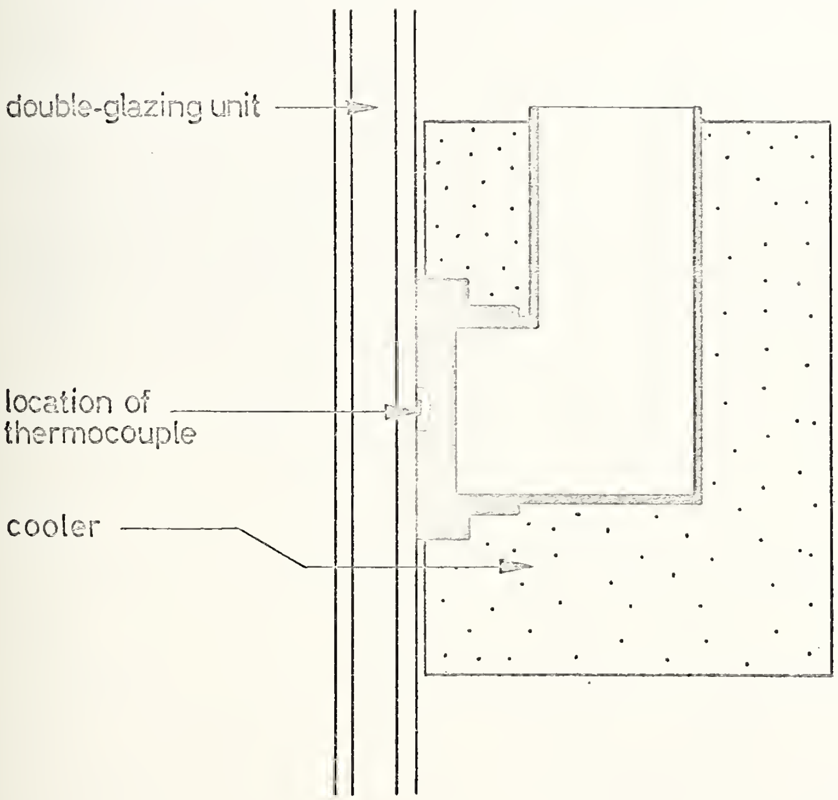

Fig.2. Dew point measurement on double-glazing unit.

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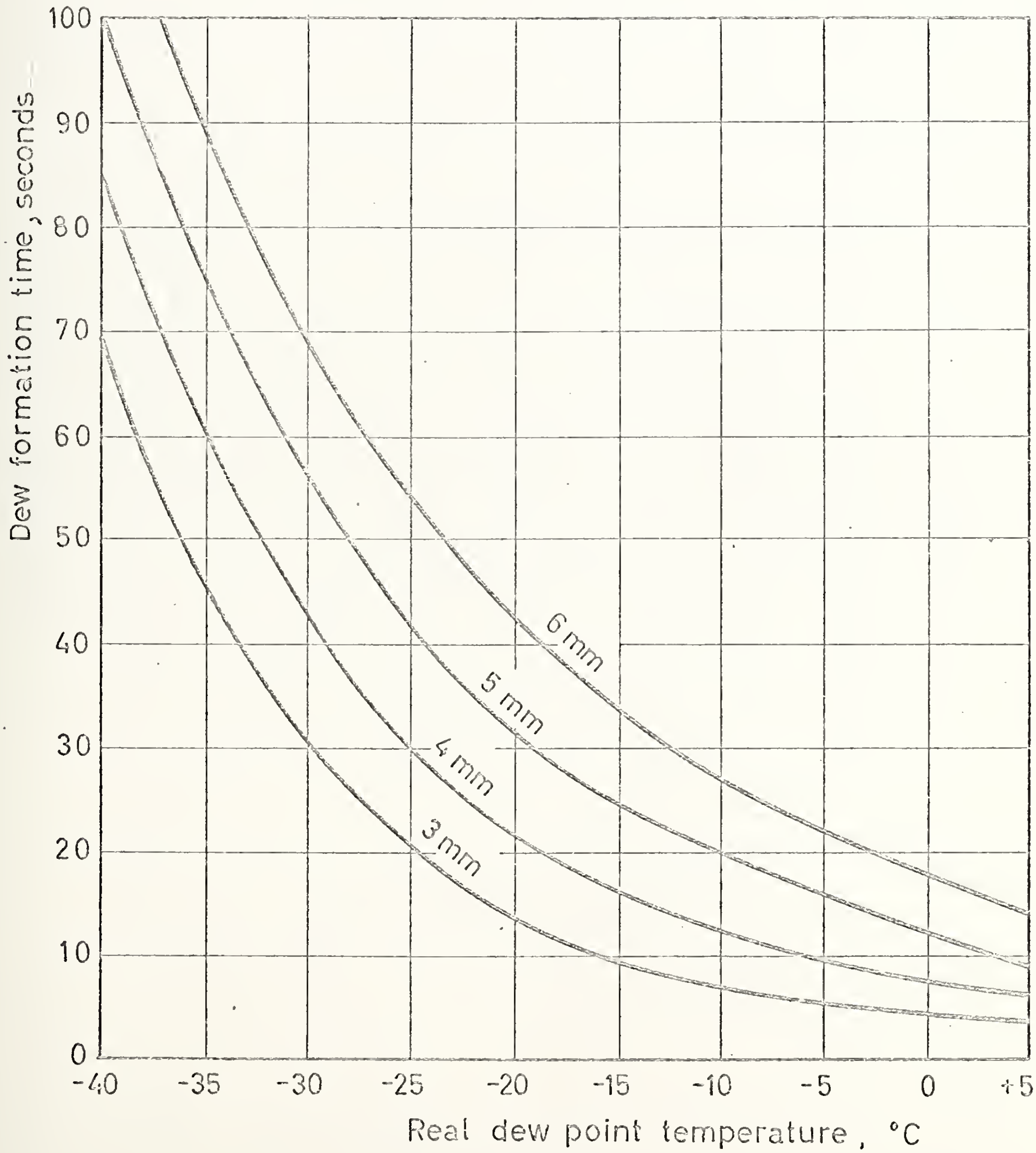


FIG.3. Dew formation time versus real dew point temperature, NBRI measuring method. Unit temperature +20 °C, glassthickness 3 to 6 mm.

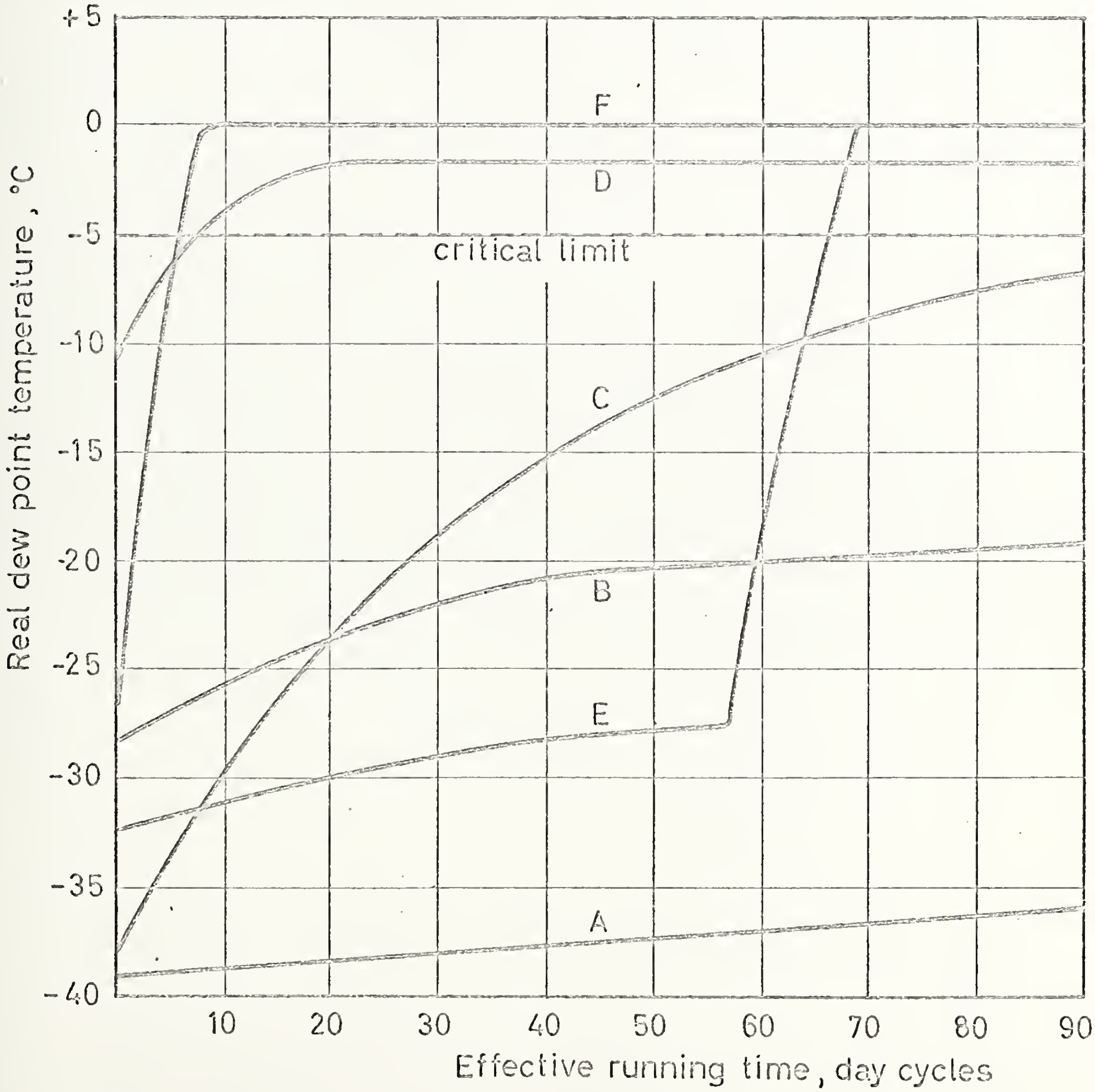


FIG.4. Typical examples to measured dew point temperatures.

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: dew point 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, dew-point temperature, moisture vapor transmission (MVT), polysulfide sealant, sealant adhesion, sealed insulating glass units, test methods.

[1]Manager, Market Development

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. I).

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" X 5" double strength glass which has been thoroughly cleaned are bonded to 1" X 10" pieces of high strength aluminum foil. These test panels (Fig. II) are allowed to cure for 7 days @ R.T. At the end of this period an initial test is run for peel strength.

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 @ 70°C.
- Water immersion @ 50°C.
- UV/Water - Ambient
- Linseed oil

Generally the samples are tested for peel adhesion after exposure @ 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 12-15 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 30-34 pounds per inch width.

In addition to the long term study of adhesion, moisture vapor transmission (MVT) data was obtained using ASTM E 96 test method.

MVT rates range from 0.354 grams/square meter/24 hours to 0.533 grams/square meter/24 hours. The average specimen thickness used was 35 mils to correlate to the normal thickness of sealant between the spacer and the glass.

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

It should be noted that the data being presented is of commercially built sealed insulating glass units - not lab 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 inches of mercury) for 2.5 hours, must show no signs of seal leakage and must not deviate from the zero deflection reading by more than 15 per cent. 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" Hg represents an altitude of 3,000 feet, so you can readily see the severity of this initial test.

Figure III 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%; these failures were attributed generally to poor workmanship. There was no significance as to the type of cured polysulfide (PbO_2 or MnO_2).

4. Dew Point Temperature

Chamber's Technical Dictionary defines dew point 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 dew point temperature. Dew point 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 dew point 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 lab 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 dew points. First, is the type and amount of desiccant used in fabricating the unit. Second, it is necessary to distinguish readily a measured dew point from an actual dew point temperature. Figure IV shows an approximate calibration curve for various glass thicknesses. The measured dew point temperatures are recorded from the thermometer in the vessel on the glass surface and actual dew point readings are those measured by a thermocouple cemented on the interior glass surface in the air space.

TABLE I

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 -60°F. requirement.

Figure V is the moisture isotherms of silica gel and molecular sieve. These curves indicate the moisture content for a given dew point 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 dew point temperature reading method is unique. It is quite reproducible and can be learned readily by a novice. Figure VI 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 water. At the same time, we continued to take dew point readings and have been able to correlate measured dew point vs. free water for a given volume air space. We are continuing to run this study on new improved sealant systems.

Figure VII gives you some early value of this data.

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 programmed 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 UV

(b) Adhesion after exposure to water

(c) MVT as measured by dew point temperature drop after high humidity exposure.

(d) Seal fatigue due to flexing caused by barometric pressure differentials.

The apparatus is pictured in Figure VIII. 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 sunlamp, 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.

A typical cycle consists of:

2 hours @ -20°F. followed by
1 hour recovery @ R.T. followed by
1 hour of UV exposure followed by
1 hour of rain exposure followed by
2 hours @ 120°F. -100% R.T. followed by
1 hour recovery @ R.T.

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

TABLE II

Sealant Cure System	Group	Dew Point Temperature Less -100°F.	-100°F. to -80°F.	-70°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	--	--	

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

TABLE III

Sealant Cure System	Group	Dew Point 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

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.

Fogging many times will show up during the accelerated weathering cycle.

Figures IX and X illustrate the apparatus used in this test.

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" X 6" test unit into an aluminum sash and subjecting the unit for at least 30 days @ 158F. 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 correlate the static vs. the dynamic method, but these studies are continuing.

3. Method three is a direct immersion of a sealed unit in the respective oil vehicle @ 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 XI 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.

For those who do not wish to pay a premium for a highly resistant sealant, they 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.

9. Acknowledgement

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

FIGURE XI

Curve A - Polysulfide sealant without barrier coat.

Curve B - Polysulfide sealant with aluminum pigmented barrier coat.

Curve C - Polysulfide sealant with nitrile rubber coating.

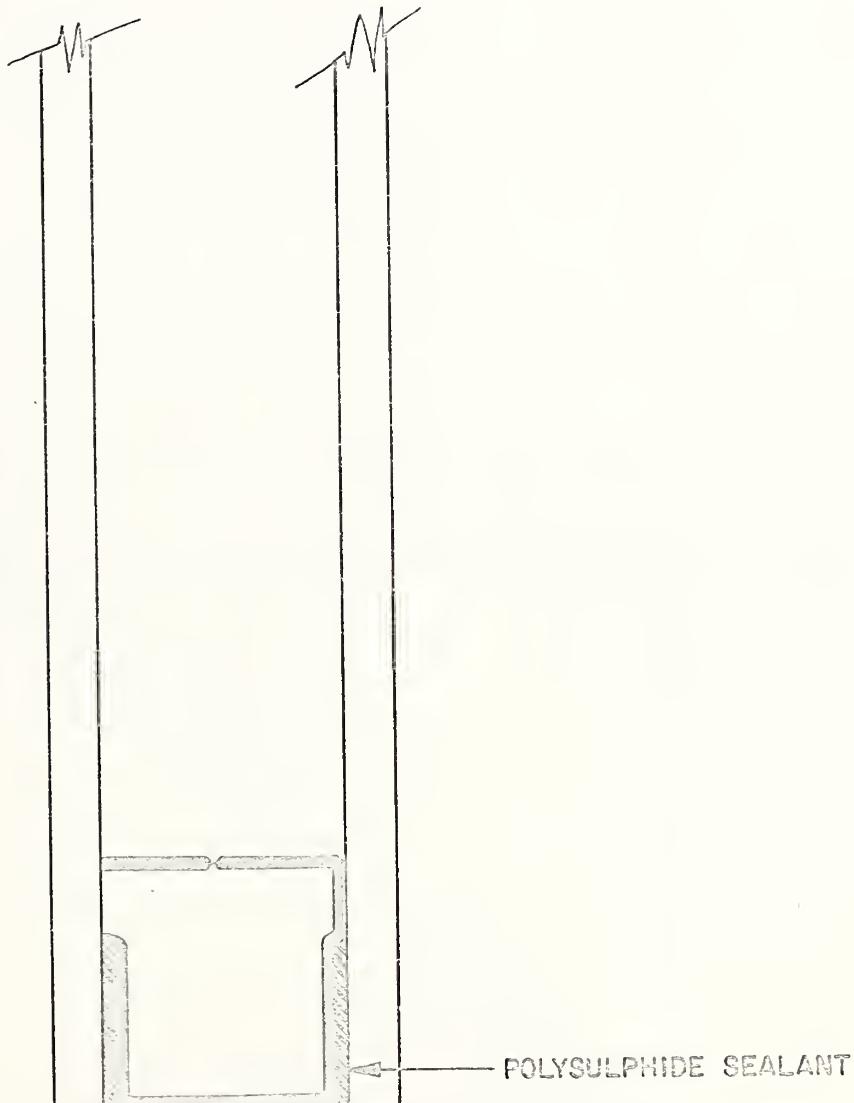
Curve D - Polysulfide sealant with barrier coat, clear.

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.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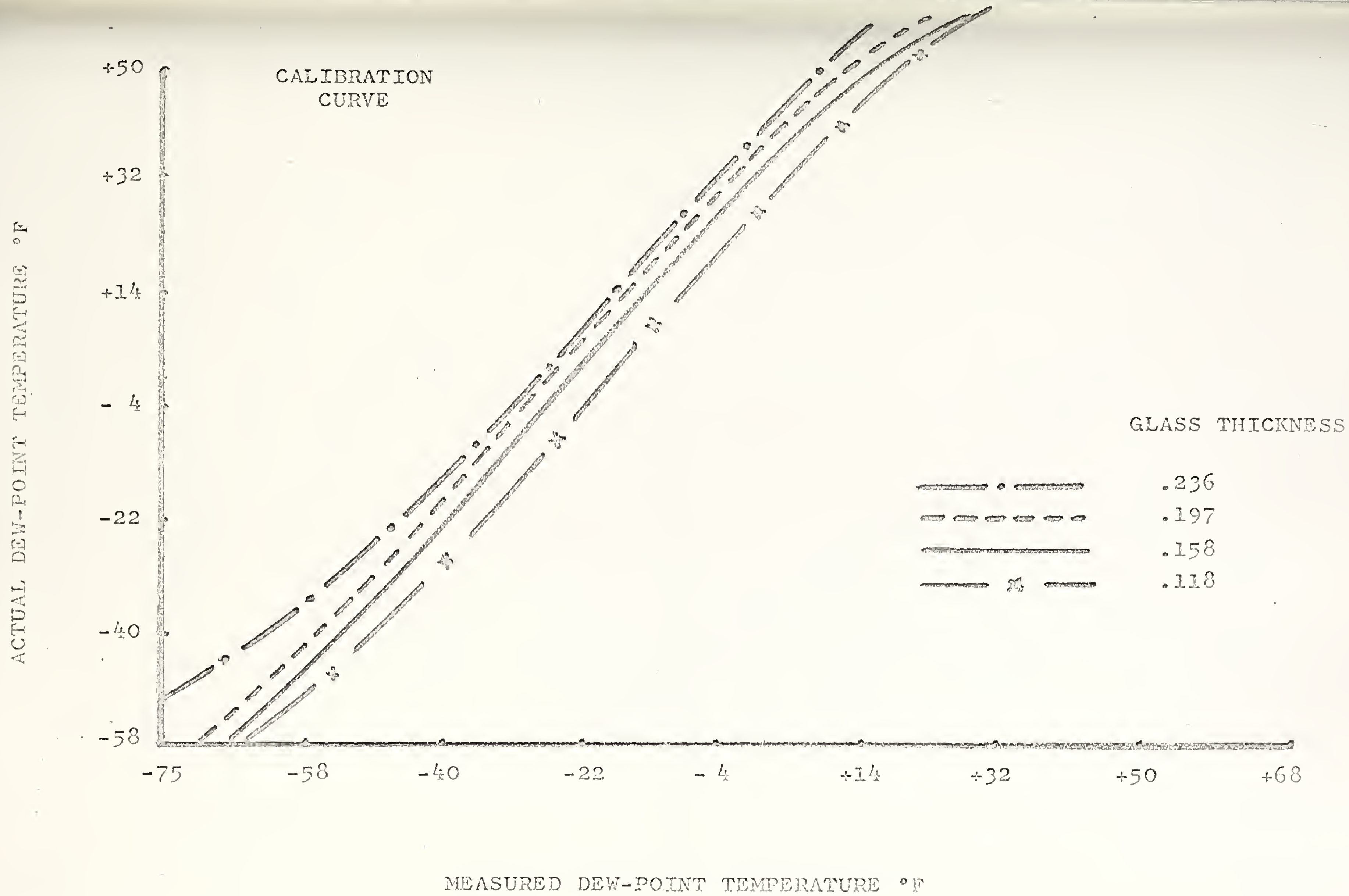
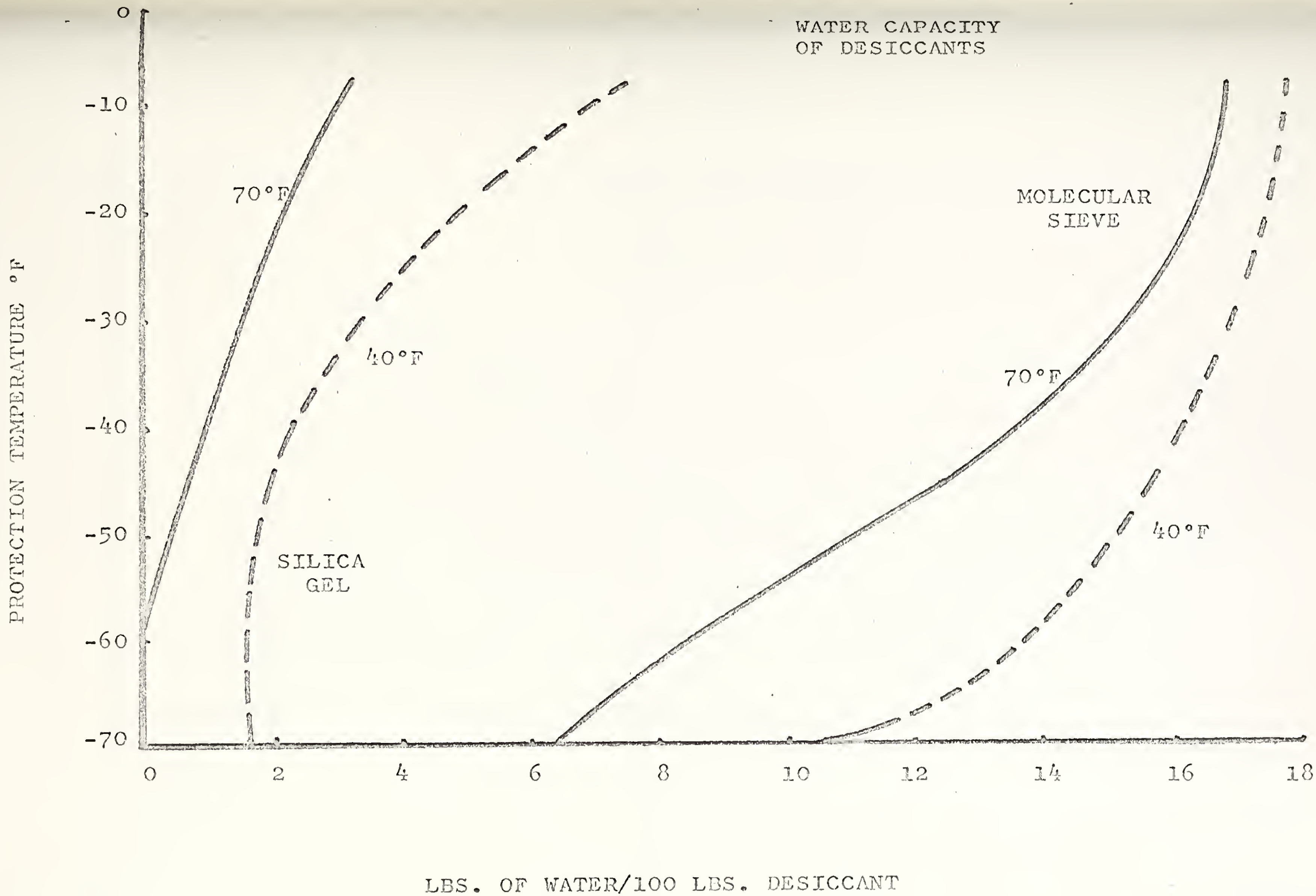

CALIBRATION
CURVE
ACTUAL DEW-POINT TEMPERATURE °F
+50
+32
+14
- 4
-22
-40
-58
-75
-58
-40
-22
- 4
+14
+32
+50
+68
MEASURED DEW-POINT TEMPERATURE °F
GLASS THICKNESS
.236
.197
.158
.118

FIGURE IV


WATER CAPACITY
OF DESICCANTS
PROTECTION TEMPERATURE °F
0
-10
-20
-30
-40
-50
-60
-70
0
2
4
6
8
10
12
14
16
18
70°F
40°F
SILICA
GEL
MOLECULAR
SIEVE
70°F
40°F
LBS. OF WATER/100 LBS. DESICCANT

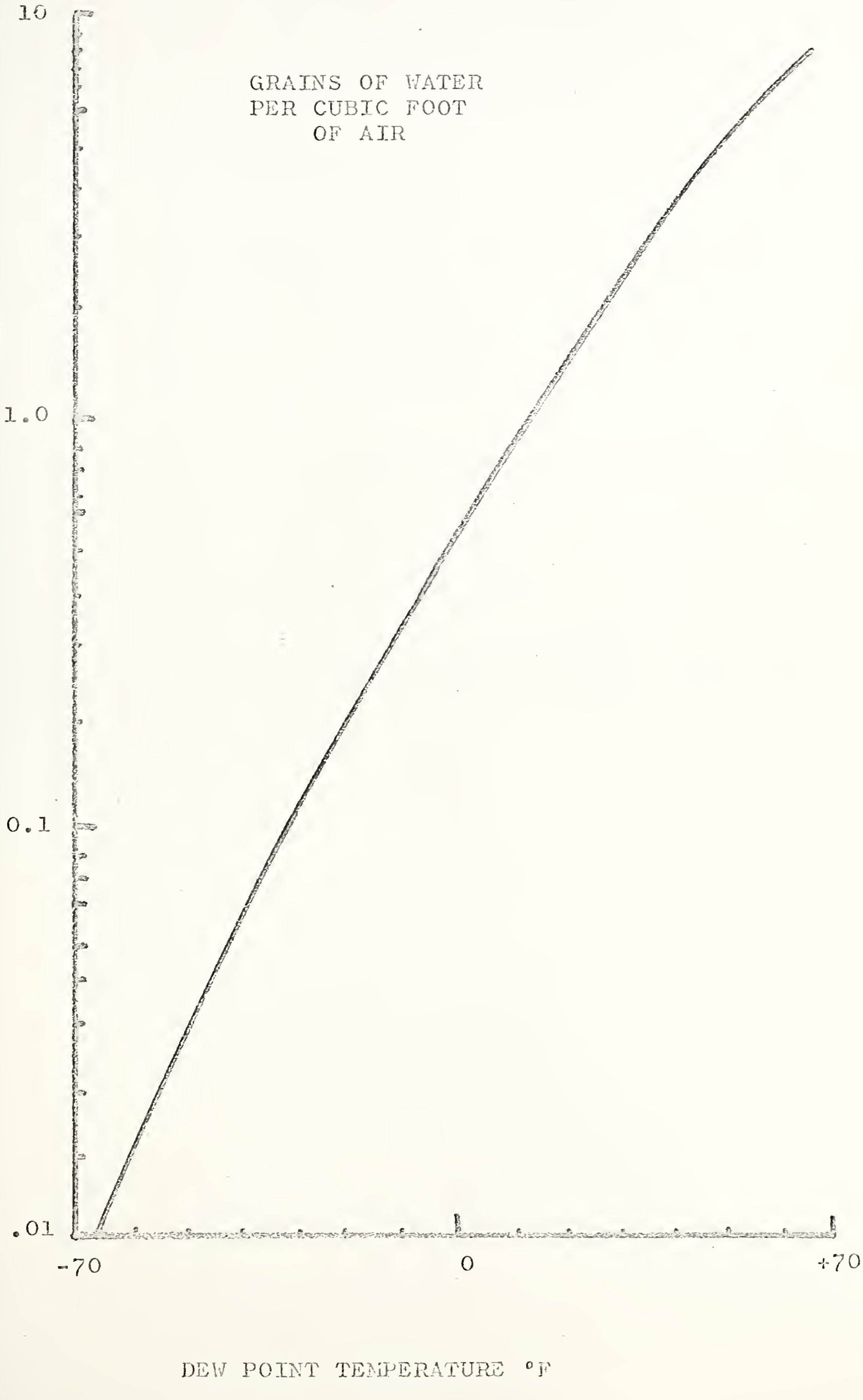

10
GRAINS OF WATER
PER CUBIC FOOT
OF AIR
1.0
0.1
.01
-70
0
+70
DEW POINT TEMPERATURE °F

FIGURE XI.

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.

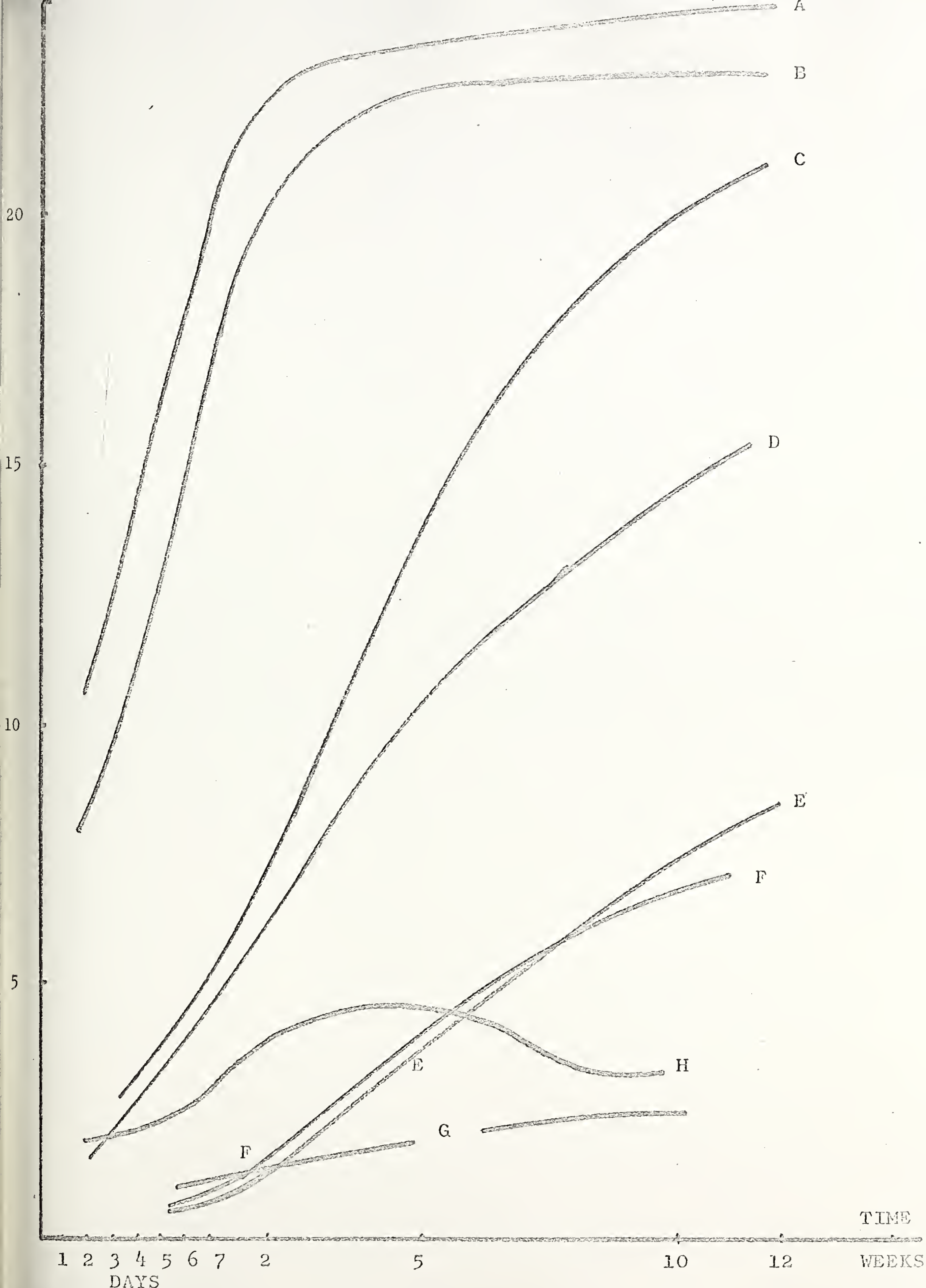
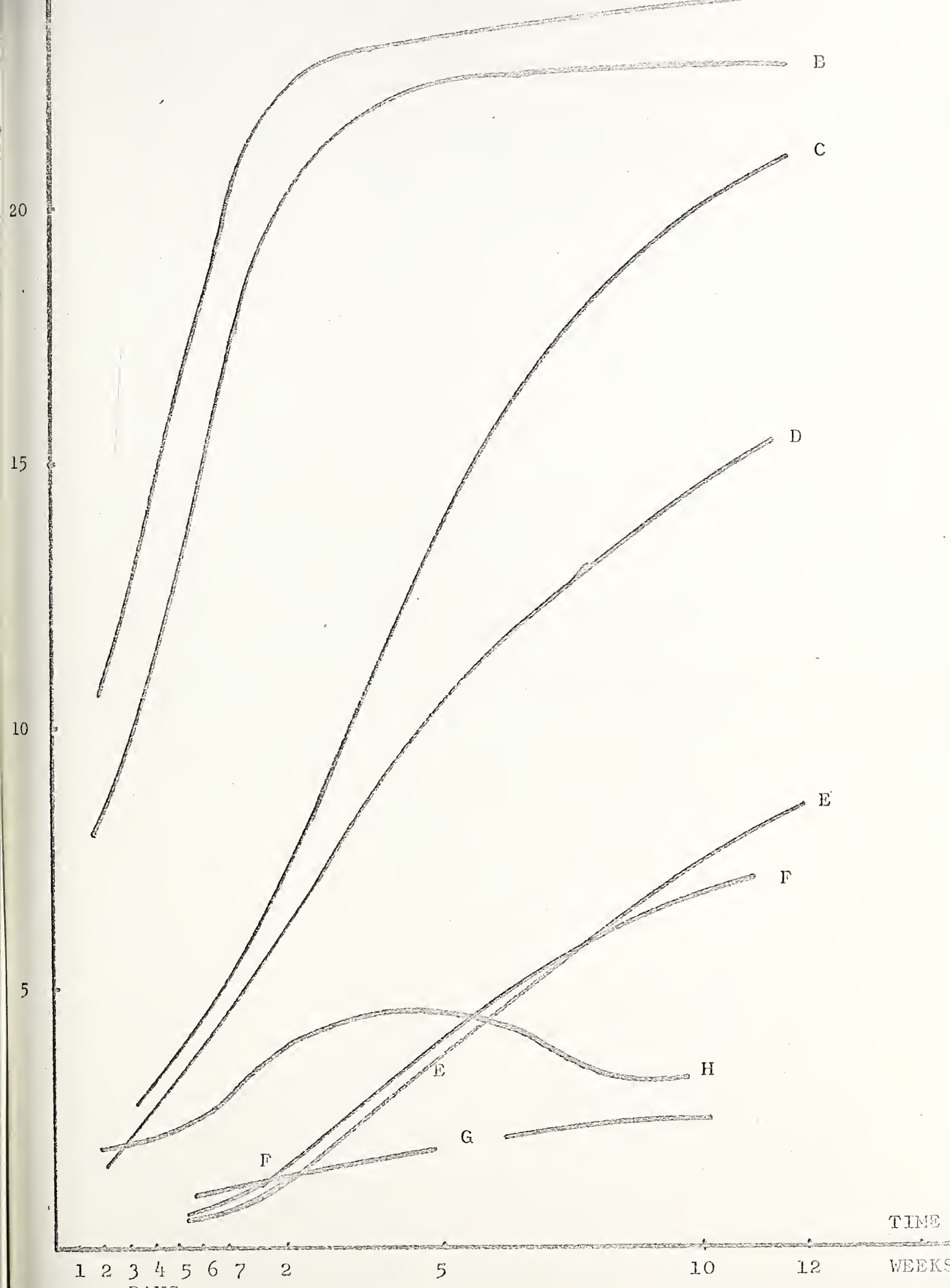


FIGURE XI



IGURE XI

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

J. D. Gwyn
Libbey-Owens-Ford Company
Toledo, Ohio 43605

Abstract

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, ultra-violet 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 dew point 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. Figure 1 shows an exploded view of the edge seal construction. 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 mis-designed 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 improvements as illustrated in this drawing. 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, shown in red in the drawing. 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

Figure 2 shows an assembled view of our insulating glass using the components shown in the previous slide.

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 pre-programed. Figure 3 shows the exterior of one of these cabinets. To the right is shown the automatic control equipment. Figure 4 shows one of our test cabinets with the doors open showing how we put insulating glass units in racks for testing. 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 studied we have found two which we believe will result in failure of inferior insulating glass units. One of these consists of an eight-hour cycle with a dwell time of 48 minutes at 145°F and 48 minutes at 0°F, the relative humidity maintained at 95% 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 dew point 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 six-hour cycle with 30 minute dwell time at 120°F and 30 minutes at 20°F. Again, the relative humidity is maintained at 95% 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 dew point.

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. Figure 5 shows a cross-sectional view of the apparatus used. In essence it 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. Figure 6 shows a general view of a portion of these units. As you can see, 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.

Test Methods and Field Experience With Double-Glazed Units

R. J. Mazzoni and G. H. Bowser
Glass Research Laboratory
PPG Industries
Creighton, Pennsylvania 15030

Abstract

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, dew point 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-glaze insulating units. I believe that the Canadian [3,4] 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][1].

From the very beginning of our participation in the Insulating Glass Market over twenty years ago, it was apparent that a sophisticated and expensive 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.

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

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 x 20-inches with a 1/4-inch air space and glass thickness of 1/8-inch 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 dew point measurements and pressure differential tests of seal tightness. Generally, test units with air space dew points 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.

2. Accelerated Tests

Figure 1 shows the 120 to 20°F cycling test equipment. The units are mounted above a 1-inch 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 hour 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% relative humidity (see Figure 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 continously exposed to conditions in the cabinet.

The sunlamp test is used to obtain ultra-violet light exposure (see Figure 3). RS 275 watt sunlamps are positioned 14-inches 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 x 4 foot panels which are mounted vertically on the table so that the exterior surfaces of the units are exposed to conditions within test chambers located 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 days 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.

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% R.H. and the combination ultra-violet and 120°F to 20°F cycling tests. Recommended exposure periods for these tests are made relative to 20-year service life with 10% 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 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 dew point 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 months.

For 20-year service life in the building we would like to see a minimum exposure period of about 1200 cycles with an allowable average change in dew point 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% R.H. test (see Figure 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 dew points than Silica-gel but the opposite is true at the higher dew points. We expect 20-year 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 dew point from initial dew point, 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 ultra-violet exposure and the former has now received a total of 1400 cycles with no change from the initial dew point of -80°F.

Experience with this two-part test indicates 500 hours 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 hours 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 x 20 inches and were glazed in steel sash using elastic glazing compound (see Figure 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. The total life of Groups B, E and H glazed in 1962 ranged between 64 to an estimated 87 months with failures recorded as early as 18 months. These results

substantiate the relatively poor performance obtained in the accelerated aging tests. The types of failure were the same as those in the ultra-violet 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 hours exposure to ultra-violet can be found in this same chart. A rough correlation indicates that 500 hours ultra-violet and 100 cycles in the 120°F to 20°F tests is equivalent to approximately two to seven years' 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 years at a mortality level of 10% or less. Group D with three failures in six years and no additional failure in 7-1/2 years 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 years. This correlation gives further justification to the recommended 1000 hours of ultra-violet and 500 cycles in the 120°F to 20°F cycling test.

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 year period. In this analysis, the performance of millions of units was involved with field follow-up work covering more than 17 years. 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 Figure 12).

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

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% in 20 years 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 four to an estimated ten years while the life span of those with high quality units is estimated to be greater than 20 years.

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% R.H.

1000 hours RS Sunlamp Test and 500 cycles in the 120 to 20°F

Allowable average change in dew point should be less than 30°F from an initial of -60°F dew point.

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

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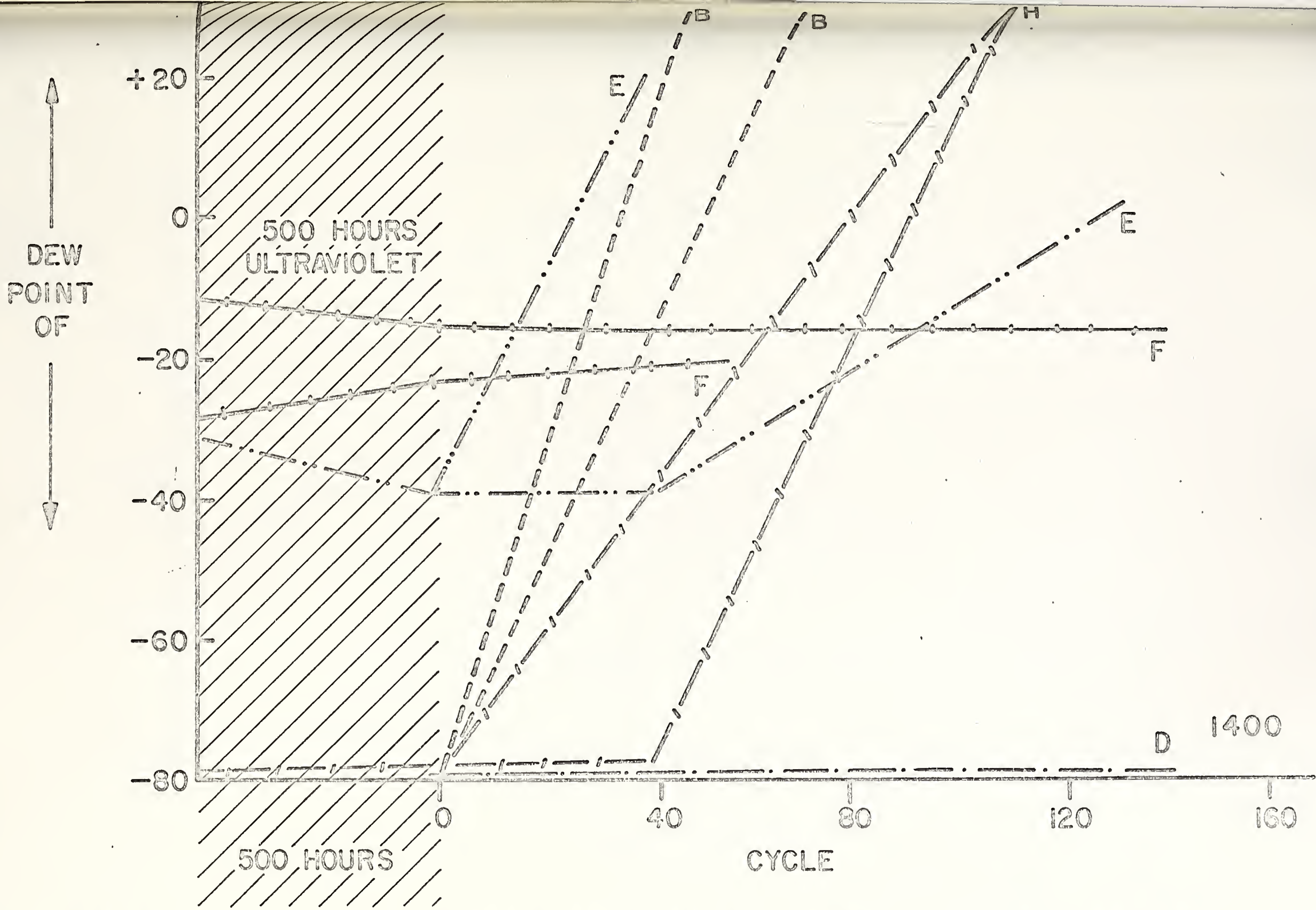

FIGURE 6 RS SUNLAMP AND 120°F - 20°F TEST

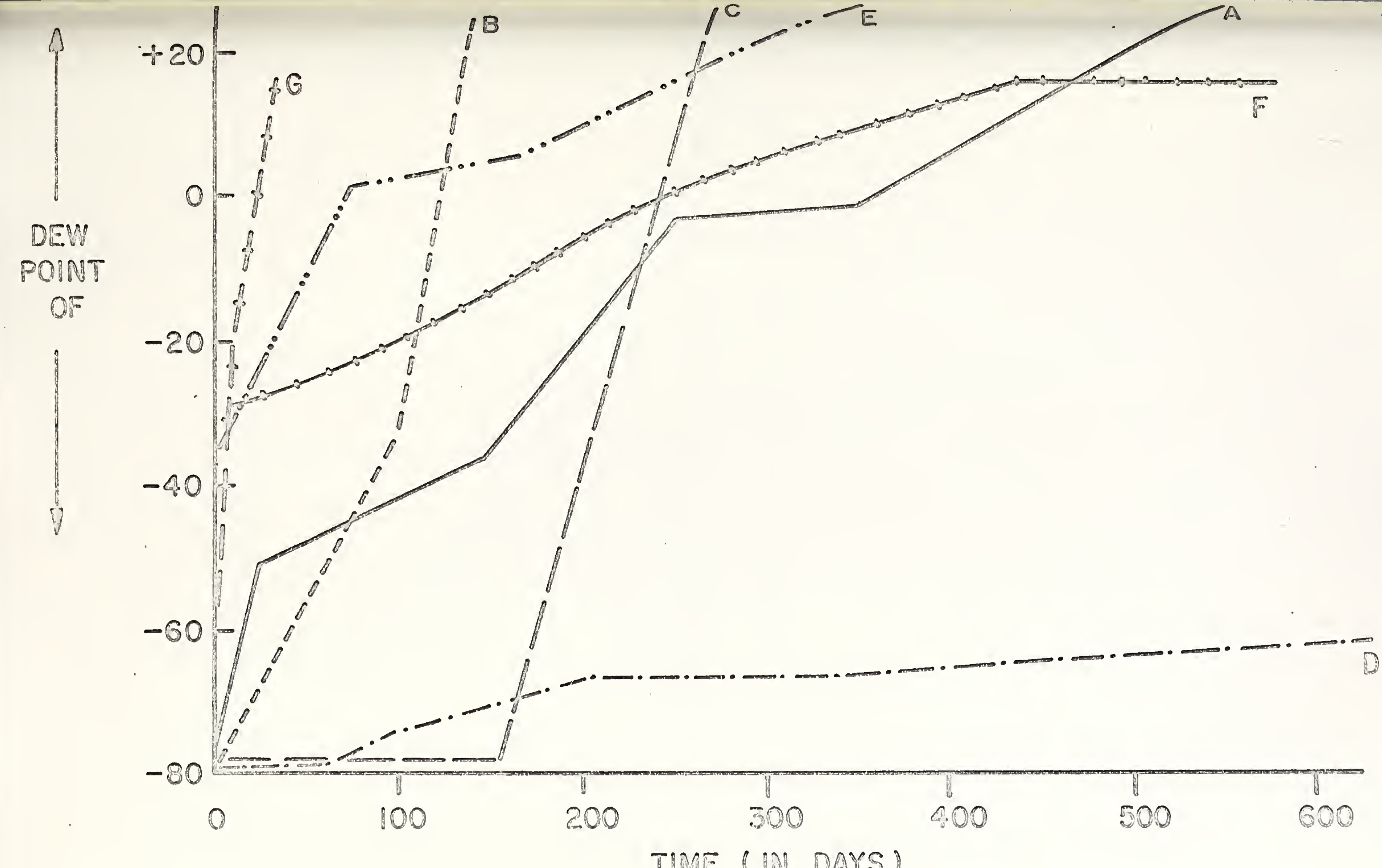

FIGURE 7 110°F - 90% R.H. TEST

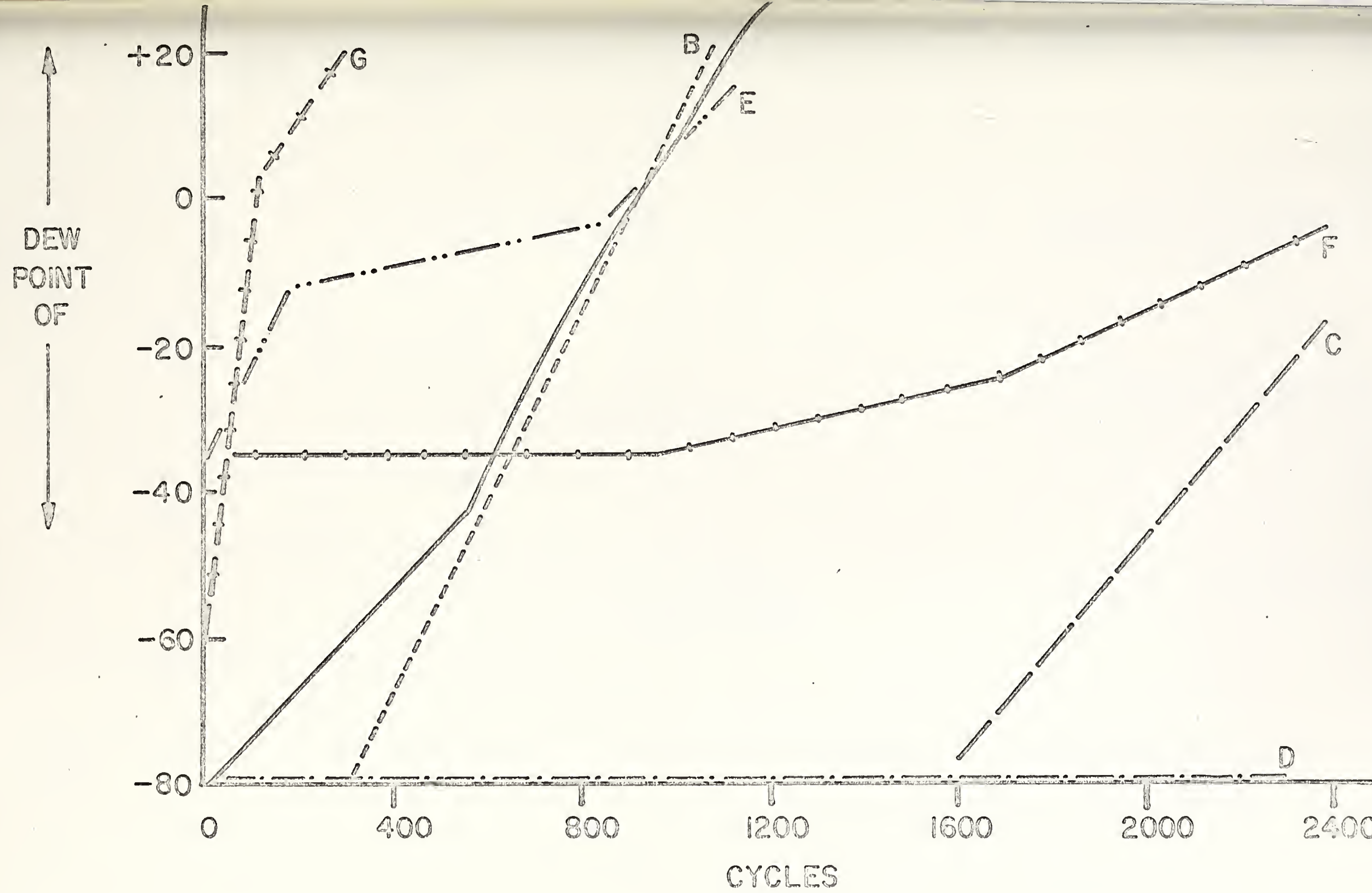

FIGURE 8 +120°F TO +20°F TEST

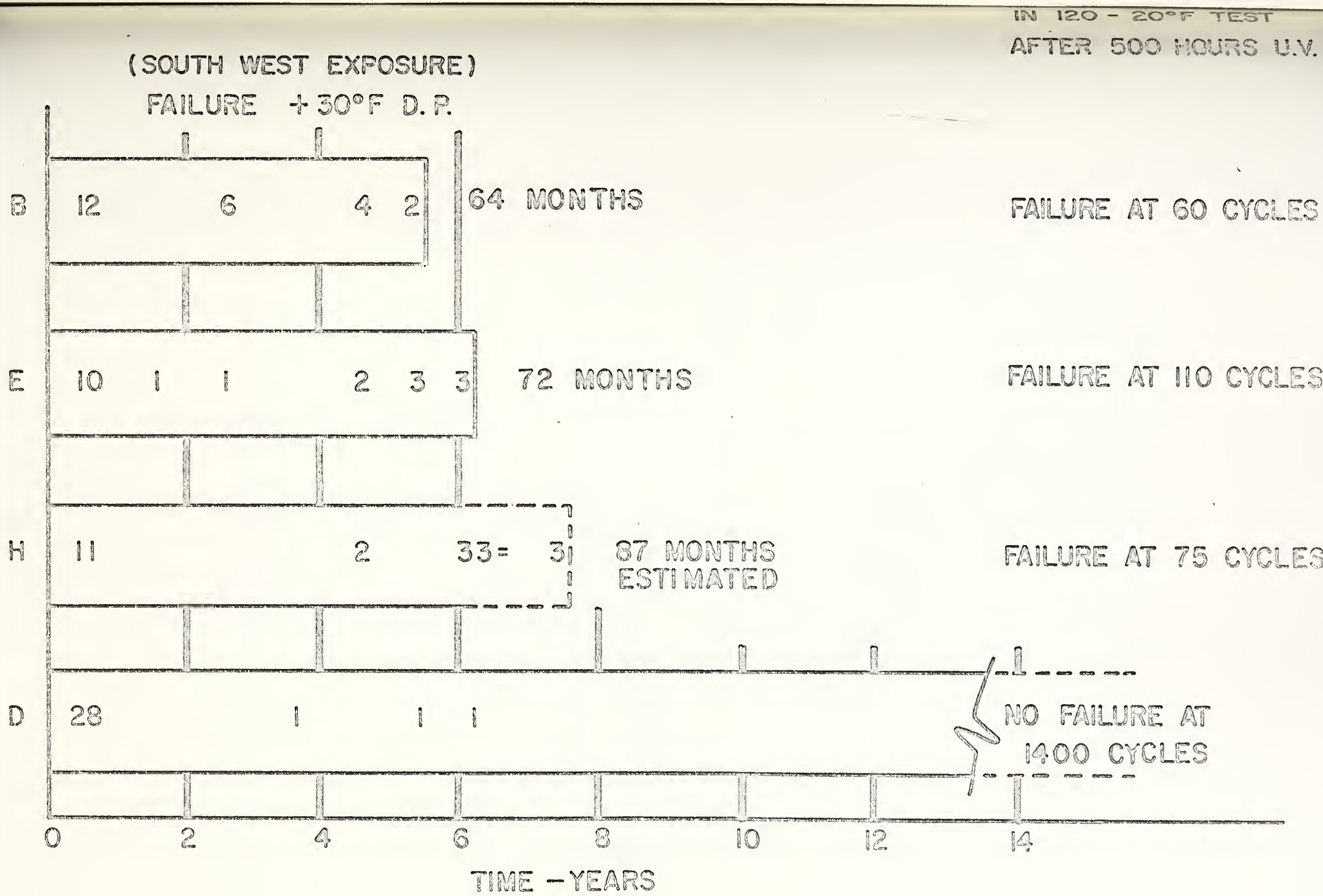
IN 120 - 20°F TEST
AFTER 500 HOURS U.V.
(SOUTH WEST EXPOSURE)
FAILURE +30°F D.P.
B
12
6
4
2
64 MONTHS
FAILURE AT 60 CYCLES
E
10
1
1
2
3
3
72 MONTHS
FAILURE AT 110 CYCLES
H
11
2
33=
3
87 MONTHS ESTIMATED
FAILURE AT 75 CYCLES
D
28
1
1
1
NO FAILURE AT 1400 CYCLES
0
2
4
6
8
10
12
14
TIME - YEARS

FIG. 10 - FIELD STUDY

Location	Year of Installation	No. of Units	Specimens Checked	Dew Point Results °F 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	

FIG. 11 - FIELD STUDY VS ACCELERATED TESTS

Location	Yr. of Inst.	Units	Specimens Checked	Dew Point Results °F: Date Check	Avg.	Date Check	Avg.	Increase Avg.	Failure Years	Failure-Accelerated Tests-Cycles: 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

FIG. 12 - STATISTICAL ANALYSIS TO PREDICT PROBABILITY OF FAILURE

$$F(x) = 1 - EXP(-x/\Theta)$$

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%

Insulated Glass Sealants
Function and Types

James A. Box[1]
The Tremco Manufacturing Company
Cleveland, Ohio

Abstract

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] Industrial Product Development Manager

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, non-curing, 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 bands, 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.

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, ultra-violet 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 non-volatile 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, non-slump qualities, cut-off and extrudability are all extremely important but, to a large extent, are defined by individual fabricators 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 initally, 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 ex-

truded 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 Ultra-violet Energy

Resistance to weathering and ultra-violet 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 ultra-violet resistance necessary for insulated glass service. The resistance possible with top quality butyl-polyisobutylene tapes to ultra-violet energy and heat is excellent.

2.4 Resistance to Fogging

Fogging of the interior surfaces 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 is 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 compliments 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 is 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, ultra-violet 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 ultra-violet energy but as soon as moisture is introduced along with the ultra-violet energy, the sealant can fail adhesively.

Resistance to pressure build-ups 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./sq. meter 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% 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 grams.

Resistance to ultra-violet is best tested on glass and, in this case, polysulfides should give at least a 60 day resistance to ultra-violet 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 to 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. Ultra-Violet and Heat Resistance
3. Flexibility
4. Low Permeability
5. Non-Fogging

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.

A Manufacturer's Experience with Insulating Glass

C. C. Stout[1]
Andersen Corporation
Bayport, Minnesota 55003

Key Words: field performance, insulating glass, replacement cost, service procedure.

[1]Treasurer - Product Development Manager

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 per cent 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 .1% 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% by Andersen and 25% 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.

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.

Exploratory Study
of
Laboratory Testing Methods and Standards For Factory-Sealed Double-Glazed Window Units

Henry E. Robinson
Environmental Engineering Section
Building Research Division
Institute for Applied Technology

for

Department of Housing and Urban Development

1. Introduction

This report summarizes a study of test methods and testing procedures for evaluating by laboratory tests the quality and performance of the air-space seal of factory-sealed double-glazed insulating glazing units, as a guide to the prospective durability and satisfactory performance of such units in service in buildings. The study was undertaken at the request of the Federal Housing Administration (Agreement IAA-FH-4-67) with the following objective set forth:

1. Asses the maintenance of permanence of the air-tight seal of the enclosed airspace in insulating glazed units.
2. Review test procedures and assess the correlation between laboratory test results and actual in-use performance of these units as available.
3. Recommend performance requirements for insulating glazing units.
4. Recommend test procedures for determining compliance.

The study was conducted by means of visits and discussions at four laboratories which have engaged extensively in the testing of sealed insulating glazing units, as follows:

--The Division of Building Research of the National Research Council of Canada, Ottawa, Canada--Nov. 28, 1967.

--Pittsburgh Plate Glass Company, Pittsburgh, Pa.--Dec. 20, 1967.

--Products Research and Chemical Corporation, Gloucester City, New Jersey--Jan. 25, 1968.

--Libby-Owens-Ford Glass Company, Toledo, Ohio--Jan. 31, 1968.

The study also included documents and published papers and reports on the testing of sealed insulating glazing units, listed below for references:

1. Canadian Government Specifications Board Standard for Factory-Sealed Double-Glazing Units, No. 12-GP-8 (15 July 1966).
2. Evaluation of Factory-Sealed Double-Glazed Window Units--A. G. Wilson, K. R. Solvason and E. S. Novak--Research Paper No. 85 (NRC 5270) of the Division of Building Research, N.R.C., 1959.
3. Performance of Sealed Double-Glazing Units--A. G. Wilson and K. R. Solvason--Research Paper No. 168 (NRC 7042) of the Division of Building Research, N.R.C., 1962.
4. Performance of Double-Glazed Units in Accelerated and Service Tests--R. J. Mazzoni and L. K. King--ASTM Materials Research & Standards, Vol. 5, No. 10, 1965.
5. Interim Specification for Sealed Insulating Glass Units--SIGMA No. 65-7-2, Sealed Insulating Glass Manufacturers Association, 1967 Edition.
6. Humidity in the Dehydrated Air Space of Sealed Glazing Units--Tore Gjelsvik--Norwegian Building Research Institute, Report No. 48 (in English), Oslo, 1967.
7. Factory-Sealed Double-Glazing Units--K. R. Solvason and A. G. Wilson--Canadian Building Digest, CBD 46, DBR-NRC, 1963.
8. Glazing Design--G. K. Garden--Canadian Building Digest, CBD 55, DBR-NRC, 1964.

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.

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 latter 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 non-rigid, depending on the materials used, but probably most are non-rigid at the edge. The rigidity at the edge affects the deflection of the glass panes nearer the center of the unit, and therefore affects the pressure differences between the air space and the exterior, whether these be due to air space mean temperature changes 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 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 non-rigid edges, glass rotation about the spacer may cause separation from the sealant. It is apparent however that in evaluation 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, 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 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 practically very important question that remains to be answered is as to what intrinsic durability in service can be realistically predicted for units that pass the imposed tests.

3. Review of Extant Test Methods For Factory-Sealed Double-Glazing Units

The references listed in the Introduction present detailed descriptions of various test methods that have been developed for laboratory testing of 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 (reported in Refs. 2 and 3) has eventuated in a Canadian Standard for sealed units (Ref. 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 reported (Ref. 4), and some of it undoubtedly has influenced the development of Interim Specification SIGMA No. 65-7-2 (Ref. 5).

In many respects the testing methods of the Canadian Standard 12-QP-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 atomsphere, to detect initial leaking-seal failures, with similar limits for indicating failure.

Both measure the initial dewpoint of the air in the air-space, 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 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 minutes of water spray versus 5 minutes in 12-GP-8, and in providing 2 hr exposure at 100% 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 ultra-violet 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) UV 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 requirements 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% 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 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 (25 deg F) pane-to-pane, which may strain edge-seals, while the Canadian test is conducted with substantially equal temperatures pane-to-pane.

Other comparsions between the two methods include the following:

	12-GP-8	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 tests	-40 °F	-30 °F

A considerable amount of testing and investigation of sealed units has been done at the Norwegian Building Research Institute, som of which is reported in Ref. 6. A rapid translation to English of a draft interim Scandinavian specification, adopted 21 June 1967 by representatives of the Norwegian Building Research Institute and others, has been abailable 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 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 ultra-violet 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 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 seal or 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, Ref. 4 presents results of laboratory and some service exposure tests conducted by a manufacturer on a variety of factory-sealed units of 14 by 20 in. size. The labortory

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) cycles of temperature change (120 °F to 20 °F, isothermal, in high humidity); b) cycles of temperature change (130 °F to -30 °F on one side, 60 - 80 °F on other), with a period of water spray; and c) steady temperature exposure of the entire unit to 110 °F and 90% RH. 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, I was advised elsewhere that the polysulphide sealants used in the units involved were relatively poor in water vapor impermeability, and that much better polysulphide sealants 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 wall were roughly in keeping with the results of the laboratory cycling tests. Ref. 4 concludes with suggested and recommended performance tests and limits. Its recommendations include the usual initial tests, and call for the use of the cyclic 120 °F to 20 °F test and of the steady 110 °F, 90% 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 test 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 (Refs. 7 and 8) must be screened out; and some statistical size for the investigation is necessary.

The accelerated and service test information provided in Ref. 4 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 laboratory tests do not have reasonable service performance expectation.

4. Visits to Four Laboratories Engaged in Testing Sealed Units

Technical discussions were held with major personnel of the four laboratories listed in the Introduction. All discussions were conducted in an 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 thought to be 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 as to cycle-period, or event, or as to number of cycles of exposure, in the four laboratories visited.

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 non-standardized 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, or the directions in which laboratory testing is going. The non-isothermal weather-cycling test (e.g., the 12-GP-8 Paragraph 4.2.4 test) is in use, but ultra-violet 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 of artifical

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 exposure 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 food display cabinets, etc., 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 test, 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 non-uniformity 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 inves-

tigations were discussed at one laboratory, but probably are carried on at several. Among such matters are flexings in air of short lengths of organically-sealed joints with UV exposure; use of vacuum deflections of joints to find best sealant properties, and dimensions of seal spacers and joints; exposure of samples of sealants to a variety of solvents, fluids and oils, at selected temperatures, to evaluate chemical effects and changes; application 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; and 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 $1500 to $3000 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

1. Procurement of factory-sealed double-glazing 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. A recommendation or representation that success of units in meeting the requirements of these specifications assures their intrinsic in-service durability for a predictable term of years cannot now be made. 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. It is believed that 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 of 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. Following up the last recommendation, exploratory consideration has been given to a possible testing apparatus that might meet the needs expressed in Paragraphs 4 and 5 above. In brief, it would consist of a circular chamber subjecting units to isothermal exposure to high humidity with cycled temperatures from about 35 °F to 120 °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 about a vertical 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. By placing the units on a slowly-turning wheel, uniformity of exposure conditions for all units would be achieved. 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 accomodated. The diameter of the chamber would be 10 or more feet, depending on maximum size of units to be tested.

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, and 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 or modification of the testing specification. The clarification of problems, and solutions to them, should be made easier, and product improvement be advanced.

Proposals for Future Action
Round Robin Comparison of Test Methods

R. W. McKinley [1], Chairman
PPG Industries, Inc.
Pittsburgh, Pennsylvania 15222

Abstract

As preceding speakers and discussions have made clear, 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] Manager, Technical Services, Glass Division Task Group E on Durability-Subcommittee VIII, ASTM Committee E-6.

1. Introduction

At present, all of these 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 is attached.

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.

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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____

____

RESULTS

ASTM Test Unit No. Performance Criteria

____

____