NISTIR 88-3870

Suggested Research Topics for the Construction Engineering Research Laboratory (CERL) Program, Evaluation of Roofing Materials Degradation Processes

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November 1988

Prepared for:
U.S. Army Construction Engineering Research Laboratory
P O Box 4005
Champaign, IL 61820-1305

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U.S. DEPARTMENT OF COMMERCE
C. William Verity, Secretary

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Ernest Ambler, Director

ABSTRACT

This document was prepared at the request of U.S. Army Construction Engineering Research Laboratory (CERL) to provide assistance in developing plans for conducting roofing research under its program entitled, "Evaluation of Roofing Materials Degradation Processes." Five areas of needed research dealing with service-life prediction of membrane performance were suggested:

- Identification of Failure Modes and Mechanisms
- Service-Life Criteria for Polymer-Modified Bitumen Membranes
- Service-Life Criteria for Adhesively-Bonded Weathered Vulcanized-Rubber Membranes
- Service-Life Criteria for PVC Membranes
- Techniques for Quality Assurance of Membrane Materials

The suggestions are based on needs of the industry in the area of service-life prediction as described in the NIST research plan and the summary of the Round Table Seminar on Roofing Research. Although the research topics proposed cover the wide range of newer membrane products currently available in the U.S. industry, the link between the topics is that of service-life prediction and quality assurance. Completion of the studies recommended in this report would provide valuable information on membrane properties and predictive methodologies.

Key words: low-sloped roofing, membranes, performance, quality assurance, roofs, research needs, service-life prediction

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1. INTRODUCTION

This document was prepared at the request of CERL to provide technical assistance in its preparations for carrying out the program. It presents some recommendations for research on low-sloped roofing systems to be included in the U.S. Army Construction Engineering Research Laboratory (CERL) program entitled, "Evaluation of Roofing Materials Degradation Processes."

1.1 Background

The current U.S. roofing industry scarcely resembles that of the mid-1970s. Fundamental changes, often described as revolutionary, have occurred in the types of materials used for membranes and insulations, and also in the application methods for systems. Elastomeric and thermoplastic single-ply and polymer-modified bituminous membranes are now used in considerable amounts whereas, only a decade ago, built-up membranes were almost the only type of waterproofing used for low-sloped roofs. Where built-up roofing is now specified, fibrous glass mats and, in some cases, polyester fabrics have essentially eliminated organic- and asbestos-based felts as the reinforcement of choice. Data on membrane use compiled by the U.S. National Roofing Contractors Association (NRCA) illustrate the changes. For example, NRCA indicated that, in early 1983, about 175 membrane products were available for low-sloped roofing whereas, in late 1987, the number had increased to 544 [1].

Before the mid-1970s, components of membrane roofing systems were all adhered, one layer to another. Now, the systems also may be partially attached, loose laid with ballast, or a combination of two or more methods. The different application procedures have resulted in problems with performance that were unknown a decade and one-half ago. For example, inadequately ballasted roofs may be readily damaged or destroyed by high winds.

The changes which have occurred in the industry have, for the most part, been beneficial [2]. Low-sloped roofing today is generally performing better than in the early 70s. Moreover, the changes of the last decade have heightened the industry's awareness that the factors affecting roofing performance must be more fully understood to assure success with new materials and systems.

Although the new materials and systems have generally performed satisfactorily, their use has not been trouble free. One of the key concerns facing the industry is the lack of techniques for reliably evaluating service-life of membranes based on short-term tests [3]. Many of the current membrane materials are new to the market and were introduced with only limited in-service history. Consensus standards and minimum levels of performance have not been developed for the newer membrane materials and a technical basis for their development is needed. Moreover, an urgent need exists to develop methods for assuring the quality and reliability of the long-term performance of low-sloped roofing.

1.2 Past Documents on Research Needs and Service-Life Evaluation

1.2.1 NBS Special Publication 659. In 1983, the National Bureau of Standards (NBS) published Special Publication 659, "Low-Sloped Roofing Research Plan" [4]. The development of this plan was motivated by the changes that have occurred in roofing technology and the need to provide solutions to roofing performance problems. The major thrust of the plan was directed towards materials and systems research and the application of measurement technology to roofing research. The intent was to establish, through the suggested research, the technical bases for developing standards and performance levels which can form the rationale for the selection of cost-effective and durable roofing materials. The plan was reviewed by a broad segment of the roofing industry's leaders before publication.

Four major areas for research for low-sloped roofing were covered in the NBS plan: (1) low-sloped roofing systems, (2) roofing membranes including built-up and single-ply, (3) thermal insulations used in roofing systems, and (4) condition assessment and repair. The proposed tasks within the four research areas were concentrated in the following categories:

- Characterization of failure mechanisms of roof membranes and systems as a basis for understanding roofing performance and advancement of roofing technology.
- Development of minimum levels of performance for roofing systems, membranes, and thermal insulations.

- o Theoretical analysis of roofing system performance and the development of models for predicting performance.
- o Advancement of the in situ condition assessment and repair of roofs.

Figure 1 is taken from the NBS report [4]. It illustrates the four major research areas included in the plan, some specific tasks associated with each area, and the inter-relations between the research areas. As is evident from Figure 1, the suggested research is extensive. Its achievement is expected to require the joint efforts of many research laboratories in the roofing community.

1.2.2 Roofing Research Round Table. In December 1987, the National Bureau of Standards, the National Roofing Contractors Association (NRCA), and the Roofing Industry Educational Institute (RIEI) published a summary of the Round Table Seminar entitled, "Roofing Research: the Challenge and the Opportunity" [2]. The Round Table convened about 50 individuals representing a cross-section of the U.S. roofing industry to discuss the needs for research to improve the performance of low-sloped roofing and to recommend research actions. The discussions of the Round Table were divided into two parts: elastomeric and thermoplastic roofing systems, and bituminous roofing systems. Although no attempt was made to reach consensus during the discussions,

numerous suggestions for needed research were made by the participants. The suggestions are summarized in Table 1. Of the items listed in Table 1, strong support was given for the development of:

- o diagnostic techniques and measurement tools for roofing condition assessment
- o a statistical database on in-service performance and failures to provide a basis for selecting the problems that require study
- o improved methods for the characterization of membrane materials, and the changes experienced in service
- o more relevant accelerated exposure tests and techniques for measuring incipient changes in membrane properties
- o performance testing and criteria for systems.

A comparison of the Round Table summary of research suggestions (Table 1) with the major areas of proposed research in the NBS plan (Figure 1) shows them to be consistent with each other [2,4]. Both draw attention to performance testing and criteria for membrane systems, characterization of membrane materials and deterioration mechanisms, durability testing, and condition assessment. These areas of research are suggested as essential elements for inclusion in the CERL program on "Evaluation of Roofing Materials Degradation Processes."

1.2.3 ASTM Standard Practice E632. From the evidence provided by the NBS plan [4] and the Round Table Seminar [2], it is clear that studies to improve the long-term performance of low-sloped roofs are needed. Experience has shown short-term laboratory tests for predicting how innovative materials and systems will perform in service over the long term often are seldom fully satisfactory [3]. The shortcomings of short-term tests include [5]:

- o They are seldom developed to assure that the mechanisms of degradation are the same in the short-term test and in service.
- o Some of the key factors which can contribute to early failures or poor performance (such as application quality) are often not accounted for.
- o The levels of performance required of the material or system are not defined.
- o Recommendations are usually not made as to how the results of standard tests for different materials should be compared to each other.

In response to the need to overcome these shortcomings and to have available a systematic approach for developing improved tests for durability of building materials and systems, ASTM E 632, "Standard Practice for Developing Accelerated Tests to Aid Prediction of the Service Life of Building Components and Materials," was developed [6].

The Practice outlines a logical sequence of steps to be undertaken in developing tests for predicting the service life of building materials and components. It is applicable to innovative materials and components and to existing materials and components even if used under conditions outside the normally expected range. The sequence of steps given in the ASTM Practice is shown in Figure 2. As seen in this figure, the procedures are divided into four parts: (1) problem definition, (2) pre-testing, (3) testing, and (4) interpretation and reporting of data. The application of ASTM E 632 to new roofing membrane materials and systems has previously been discussed [3]. Studies conducted as part of the CERL program on "Evaluation of Roofing Materials Degradation Processes" should be based on the E 632 methodology.

1.3 Objective of the CERL Program

The objective of the CERL program, "Evaluation of Roofing Materials Degradation Processes," is to provide methods for evaluating the quality and service life of membrane roofing systems which can become the basis for standards and specifications[1]. The task description for the CERL program indicates that:

- In conducting the research, the procedures given in ASTM E 632 should be followed. Processes by which roofing materials degrade while in the service environment should be determined, and the parameters of change are to be identified.

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[1]The summary of the CERL program given in this section was taken from a personal communication from D. Bailey, CERL.

- Models which describe the essential aspects of system performance should be developed and include relationships between specific modes of failure and properties of the roofing materials.
- Based on the identification of failure modes, laboratory studies should be undertaken to develop new or improved methods for characterizing the important properties of membrane materials, and for evaluating their resistance to failure through the more commonly occurring degradation processes. The methods for service life evaluation should be based on probabilistic procedures for predicting long-term performance. Such statistically-based techniques can provide increased confidence in extrapolating the results of short-term tests to long-term performance [7].

The development of understanding about degradation mechanisms and the factors that affect changes in material properties will provide knowledge necessary to prepare specifications that minimize material degradation, thus reducing long-term maintenance and repair costs. As a long-term goal, it also will help the development of standard test(s) which will more reliably predict serviceability and performance of membrane roofing.

1.4 Objective of the Present Report

As mentioned in the introduction, this report was prepared at the request of CERL. Its purpose is to provide technical assistance in planning studies to develop improved methods for evaluating the quality and service-life of low-sloped roofing membrane materials and systems. The report outlines studies for research in the areas associated with the evaluation of the long-term performance of membrane materials and systems. The studies proposed for consideration were selected primarily based on consideration of the NBS plan [4] and the Round Table recommendations [2], as previously mentioned. Because of concerns about the long-term performance of relatively new, but widely used, roof systems such as those incorporating elastomeric, thermoplastic, and modified bituminous membranes, the proposals for needed research, described herein, emphasize the elastomeric, thermoplastic, and modified bitumen systems.

In selecting the research topics that follow in the next section of the report, it was kept in mind that they must be consistent with both:

1. the key needs of the industry (primarily as recommended by the NBS Research Plan and the Round Table Seminar), and
2. the objectives of the CERL roofing research program.

The important needs of the industry include the establishment of a means of providing a database on in-service performance and failures, the development of improved techniques for assessing the service-life of roofing materials and systems, and the development of improved methods for characterizing membrane materials. These topics are addressed in the five research areas that are suggested for the CERL program in the next section of the report. The first area deals with analysis of in-service performance; the next three concern service-life assessment; and the fifth focuses on techniques for quality assurance of membrane materials.

2. SUGGESTED RESEARCH AREAS FOR THE CERL PROGRAM

This section of the report presents areas of research suggested for inclusion in the CERL program. These research areas are:

- Identification of Failure Modes and Mechanisms
- Service-Life Criteria for Polymer-Modified Bitumen Membranes
- Service-Life Criteria for Adhesively-Bonded Weathered Vulcanized-Rubber Membranes
- Service-Life Criteria for PVC Membranes
- Techniques for Quality Assurance of Membrane Materials

These studies focus on serviceability and encompass field and laboratory studies, as well as the development of mathematical models on rates of deterioration. Though the studies are complementary, each is intended to stand alone. The link between the individual studies is the evaluation of service life and improvement of long-term performance.

The approach taken to outline each proposed study is to state a title and objective. These are followed by comments concerning the background and significance of the proposed study. Then a suggested technical approach is given. Finally, an estimate of the time required to conduct each study is provided.

2.1 Identification of Failure Modes and Mechanisms

Objective: To obtain and analyze information on the in-service performance and failure modes of low-sloped roofing membranes and systems, particularly those that have a relatively short history of in-service performance such as the single-ply and modified bitumens.

Comments: One of the major topics of discussion at the Round Table Seminar on Roofing Research [2] was the lack of a significant database on field performance which could aid service-life predictions. A database on field performance also is needed to guide research efforts and to aid the selection of important research projects. The information obtained from the field can help direct the development of accelerated exposure tests. In addition, analysis of information on in-service performance and failure modes can help form the basis for the development of models used to describe the interactions of the various components of low-sloped roofing systems. It is anticipated that assistance in obtaining data on in-service performance will be needed from industry associations such as NRCA, MRCA, and RCI[2]. It would be beneficial to explore mechanisms for receiving non-proprietary data from manufacturer and related associations.

Recommended Approach:

- Conduct field inspections of newer roofing systems to obtain information on in-service performance; where possible, obtain field specimens from new and existing roofs for measurement of selected performance-related properties.
- Where problems are experienced, identify probable failure mechanisms.
- Work with industry associations such as NRCA, MRCA, and RCI to obtain data on in-service performance; analyze data as to probable causes of the problems identified.
- Explore the potential for development of an industry database on in-service performance to identify the major performance problems and recommend research activities as solutions to the problems identified.
- Prepare a report on the findings of the field investigations including recommendations for needed research.

Estimated Duration: Concurrent with laboratory studies.

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[2]National Roofing Contractors Association (NRCA), Midwest Roofing Contractors Association (MRCA), and Roof Consultants Institute (RCI).

2.2 Service-Life Criteria for Polymer-Modified Bitumen Membranes

Objective: To develop a methodology for evaluating the long-term weathering performance of polymer-modified bituminous membrane materials.

Comments: The use of polymer-modified bituminous membranes as the waterproofing components of low-sloped roofing systems is increasing rapidly in the U.S. Recent estimates indicate that these materials account for 15 percent of the membranes currently installed and predictions are that the use will increase to 25 percent by 1990. Voluntary consensus standards in the U.S. are not available to evaluate these products and are not expected for 3 years or more. NIST has been assisting the Department of Defense (DoD) in the development of interim criteria for use in guide specifications. Research conducted in the DoD-sponsored study has indicated that test methods for assessing long-term weathering are not available. In particular, preliminary UV-resistance (xenon arc) tests of selected modified bitumens raised questions concerning the applicability of a proposed ASTM procedure for assessing the UV resistance of these materials. Recommendations were made that research be conducted to provide a weathering test method for incorporation in the criteria.

Recommended Approach:

- Develop a research plan following the methodology outlined in ASTM E 632. It is anticipated that the key degradation factors incorporated in the test program would be heat and UV radiation.

- Investigate the use of sensitive analytical methods for detecting changes in membrane material properties, uniformity of membrane material, or the phase distribution of the polymer-bitumen matrix.

- Develop a test procedure for exposing selected modified bitumens to heat and UV radiation using statistical techniques. It is anticipated that the membrane materials in this laboratory program could be some of the same products that CERL has under investigation in its field studies on modified bitumens.

- Subject the specimens to the heat and UV conditions over time, and measure the changes in properties. Analyze the data using reliability theory and develop degradation models on the rate of deterioration.

- Publish reports describing the progress and interim results of the study. Include recommendations for a laboratory procedure for assessing the long-term performance of modified bitumens in the final report.

- Draft a test method suitable for presentation to ASTM and incorporation in guide specifications.

Estimated Duration: 3-4 years.

2.3 Service-Life Criteria for Adhesively-Bonded Weathered Vulcanized-Rubber Membranes

Objective: To develop a methodology for assuring the quality of bonded seams in weathered vulcanized-rubber membranes.

Comments: The use of vulcanized-rubber materials (primarily EPDM) for low-sloped roofing membranes has become common in the U.S. Current estimates indicate that over a billion square feet are now applied annually. EPDMs are non-polar, relatively inert rubbers; this makes the adhesive-bonding of sheets, forming membrane seams, a critical parameter associated with long-term performance. This may be even more critical as time passes, and patches and splices are needed. A key concern expressed in the roofing industry is that, as these membranes weather, the rubber's surface characteristics may be altered such that successful bonding of the aged material may become difficult. For example, in the CERL study of EPDM roofing at Ft. Benning, it was found that repairs to cut sheets delaminated within months after formation. This occurred even though industry guidelines for repair were followed. A technical basis for making sound repairs to weathered EPDM is lacking and should be developed.

Recommended Approach:

- Investigate methods for characterizing EPDM surfaces regarding properties relevant to bonding, such as scanning electron microscopy, Fourier transform infrared spectroscopy, surface energy, and other analytical surface chemistry techniques.

- Obtain samples of weathered EPDM membranes and characterize their surfaces; compare the characteristics of the weathered surfaces with those of unaged samples.

- Investigate techniques for preparing surfaces of weathered EPDM for bonding; characterize the surfaces of the materials before and after using the surface preparation techniques.

- Prepare seams from weathered EPDM sheets; measure the initial strength of the bonds as a function of the cleaning procedures.

- Based on the results of the bond strength tests, conduct time-to failure experiments on seams prepared from weathered material; compare the results to those obtained in previous NIST time-to-failure studies on unaged EPDM; develop a degradation model related to the rate of seam delamination.

- Prepare an interim report of the progress of the study would be prepared; publish a final report including recommendations for properly preparing the surface of weathered EPDM before bonding.

- Prepare a draft cleaning method suitable for presentation to ASTM and for incorporation in guide specification.

Estimated Duration: 2 years.

2.4 Service-Life Criteria for PVC Membranes

Objective: To develop a methodology for evaluating the long-term weathering performance of poly(vinyl chloride) (PVC) membrane materials.

Comments: Poly(vinyl chloride) (PVC) is the major thermoplastic polymer that has been used as single-ply membranes in low-sloped roofing systems. The Corps of Engineers has a guide specification for PVC roofing. PVC is a rigid material which must be plasticized to provide flexibility so that it may be used as a sheet membrane. A key performance requirement associated with the long-term performance of PVC membranes is the permanency of the plasticizer. Plasticizer loss can cause shrinkage and embrittlement of the material, which can lead to cracking and splitting of the membrane. ASTM has developed a specification for PVC membranes that contains requirements dealing with heat and UV exposure. Although these requirements concern, to a limited extent, the permanency of the plasticizer in a sheet, they do not provide for an evaluation of its long-term performance in service. Considering the critical nature of the ability of a sheet to retain plasticizer, a methodology to evaluate long-term performance, including plasticizer permanency, needs to be developed.

Recommended Approach:

- Develop a research plan following the methodology outlined in ASTM E 632. It is anticipated that the key degradation factors incorporated in the test program would be heat and UV radiation, perhaps in conjunction with water immersion.

- Investigate the use of sensitive analytical methods for detecting changes in membrane material properties and loss of plasticizer; it is anticipated that thermal analysis techniques and microscopy would play a major role in this regard.

- Develop a test procedure using statistical techniques for exposing selected PVC membrane materials to heat and UV radiation. If available, unaged materials comparable to those CERL has under investigation in its field studies on PVC systems should be used.

- Subject the specimens to selected exposure conditions (e.g., heat and UV) over time and measure the changes in properties. Analyze the data and develop degradation models on the rate of deterioration.

- Publish reports describing the progress and interim results of the study. A final report would contain recommendations for a laboratory procedure for assessing the long-term performance of PVC membrane materials.

- Draft a test method suitable for presentation to ASTM and for incorporation in guide specification.

Estimated Duration: 2-3 years.

2.5 Techniques for Quality Assurance of Membrane Materials

Objective: To investigate the use of quality assurance techniques for characterizing the properties of membrane materials.

Comments: One of the subjects discussed at great length by the Round Table participants was the characterization of low-sloped roofing membrane before and after aging. They acknowledged that materials change and that the changes may not always be detrimental, but presently the basis for making such determinations is not available. A suggestion of the Round Table was that a need exists to develop sensitive methods for the characterization of membrane materials and to develop criteria for judging whether the changes are within acceptable limits. Most importantly, the development of the characterization methods should keep in mind the fundamental chemical processes that materials undergo during aging. The CIB/RILEM Roofing Committee has recently recommended that thermal analysis (TA) techniques be applied to membrane characterization. Although the Committee presented preliminary data on some typical properties of new or laboratory exposed specimens, no data were available for materials that had aged in service. The technical bases for using thermal analysis techniques for membrane characterization does not exist and needs to be developed.

Recommended Approach:

- Selected samples of elastomeric, thermoplastic, and bituminous membrane materials would be subjected to thermal analysis (TA) techniques. The techniques used in the investigation would include thermogravimetric analysis (TGA), dynamic mechanical analysis (DMA), and differential scanning calorimetry (DSC). The initial analyses would set baseline data for the samples.

- Subject the selected samples to pre-testing, as described in ASTM E 632, to determine changes occurring in the materials that can be detected by the TA techniques.

- Conduct field inspections of aged roofs and obtain membrane samples. Include roofs both performing satisfactorily and with problems. In addition, sample so that some specimens are taken from sections of the roof that have received relatively little exposure. To the extent possible, include in the inspections roofs for which unaged, original material was available. It is anticipated that the inspections will be selected with the assistance of industry associations such NRCA, MRCA, and RCI.

- Conduct TA analyses on the specimens removed from the roofs. Analyze the data for changes experienced by the membrane materials over time; make recommendations for allowable change in material properties (as related to type of material and roof condition).

- A report would be prepared including recommendations on TA methods for assessing the quality of membrane materials.

Estimated Duration: 2-3 years

3. SUMMARY

This document was prepared at the request of CERL to provide assistance in developing plans for conducting roofing research under its program entitled, "Evaluation of Roofing Materials Degradation Processes." Five areas of needed research dealing with service-life prediction of membrane performance were suggested:

- Identification of Failure Modes and Mechanisms
- Service-Life Criteria for Polymer-Modified Bitumen Membranes
- Service-Life Criteria for Adhesively-Bonded Weathered Vulcanized-Rubber Membranes
- Service-Life Criteria for PVC Membranes
- Techniques for Quality Assurance of Membrane Materials

The suggestions are based on needs of the industry in the area of service-life prediction as described in the NBS research plan and the summary of the Round Table Seminar on Roofing Research. The research would be conducted according the outline given in ASTM E 632.

Although the research topics proposed cover the wide range of newer membrane products currently available in the U.S. industry, the link between the topics is that of service-life prediction and quality assurance. As discussed in the Round Table Seminar, the roofing industry lacks predictive tests on long-term performance. Roofing materials are often not properly characterized regarding

long-term performance before introduction into the market, placing the owner in the position of providing the testing ground for the materials [2].

The laboratory-based research studies recommended in this report would provide valuable information on membrane properties and predictive methodologies for each classification of newer material. The benefit would be gained by the industry as a whole and not limited only to CERL. A major benefit is the tutorial factor in that such studies would demonstrate a methodology for performing service-life tests and developing such methods for incorporation in standards. One significant result may be that industry task groups, working through an organization such as ASTM, could continue to develop service-life tests as needed.

From the point of view of benefits to the CERL program, the accomplishment of the studies outlined would contribute to its long-term goal of providing improved Army guide specifications that minimize material degradation. The ultimate result would be the construction of low-sloped roofs for Army buildings having reduced maintenance and repair costs.

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5. ACKNOWLEDGMENTS

The preparation of this report was sponsored by the, U.S. Army Construction Engineering Research Laboratory (CERL), whose support the authors gratefully acknowledge. The encouragement of David Bailey, CERL, who assisted in the development of the project, is sincerely appreciated. Thanks are also extended to the authors NIST colleagues, Geoffrey Frohnsdorff, Jonathan Martin, and Mary McKnight, for their valuable comments and suggestions on a draft of the report.

Table 1. Summary of Research Needs Suggested by the Round Table Participants.

1. Elastomeric and Thermoplastic Roofing Systems

Diagnostics

- Performance testing and criteria for systems
- Methods and equipment for diagnostic testing
- Characterization after in-service performance
- Statistical database on in-service performance
- Requirements for good maintenance practice

System Characterization

- Sensitive methods for characterization
- Material characterization as related to systems and environment
- Relevant accelerated tests and techniques for incipient change
- Database on in-service performance

In Situ Moisture

- Definition of excessive moisture and its effects
- Understanding of moisture migration under dynamic conditions
- Improved NDE techniques for determining moisture content
- Definition of potential corrosion with mechanical fasteners

Looking Ahead for Single-Ply

- Improved communication among all segments of the industry
- Understand roof performance as related to envelope performance
- Modelling techniques for performance prediction
- Improved methods for adhering components together

2. Bituminous Roofing Systems

Selection Criteria for Polymer-Modified Bitumens

- Development of performance standards
- Development of test methods for performance standards
- Investigation of the applicability of the Agrément concept

Application Techniques for Polymer-Modified Bitumens

- Definition of temperature limitations
- Development of substitute methods for torch application

Base Flashings for Bituminous Roofing

- Development of prescriptive and performance requirements
- Definition of the state-of-the-art of flashing performance

Insulation

- Development of performance requirements for insulations
- Determination of performance requirements for fasteners

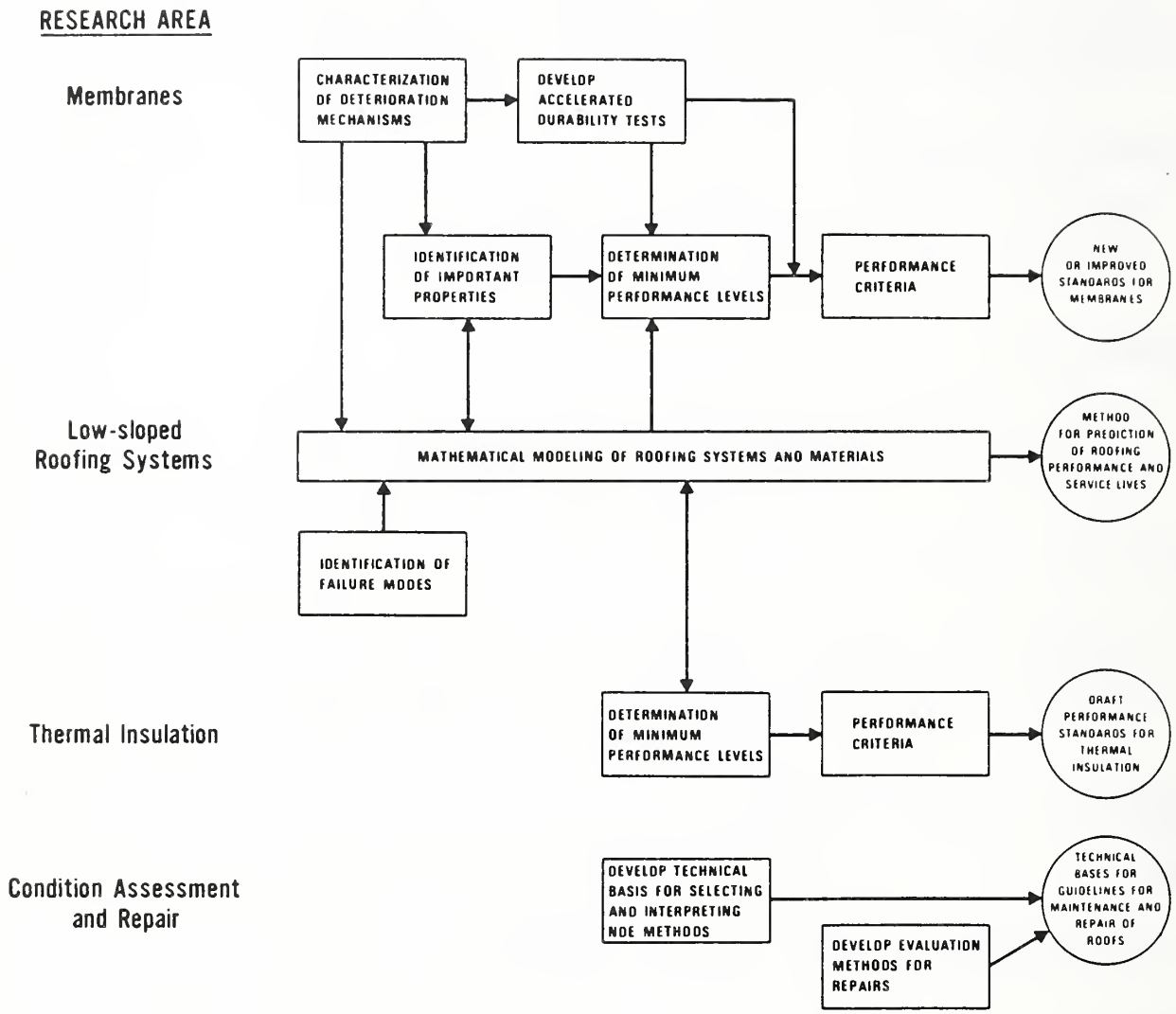

Figure 1. Sequence of Major Roofing Activities and Goals Proposed in the NBS Roofing Research Plan [4].

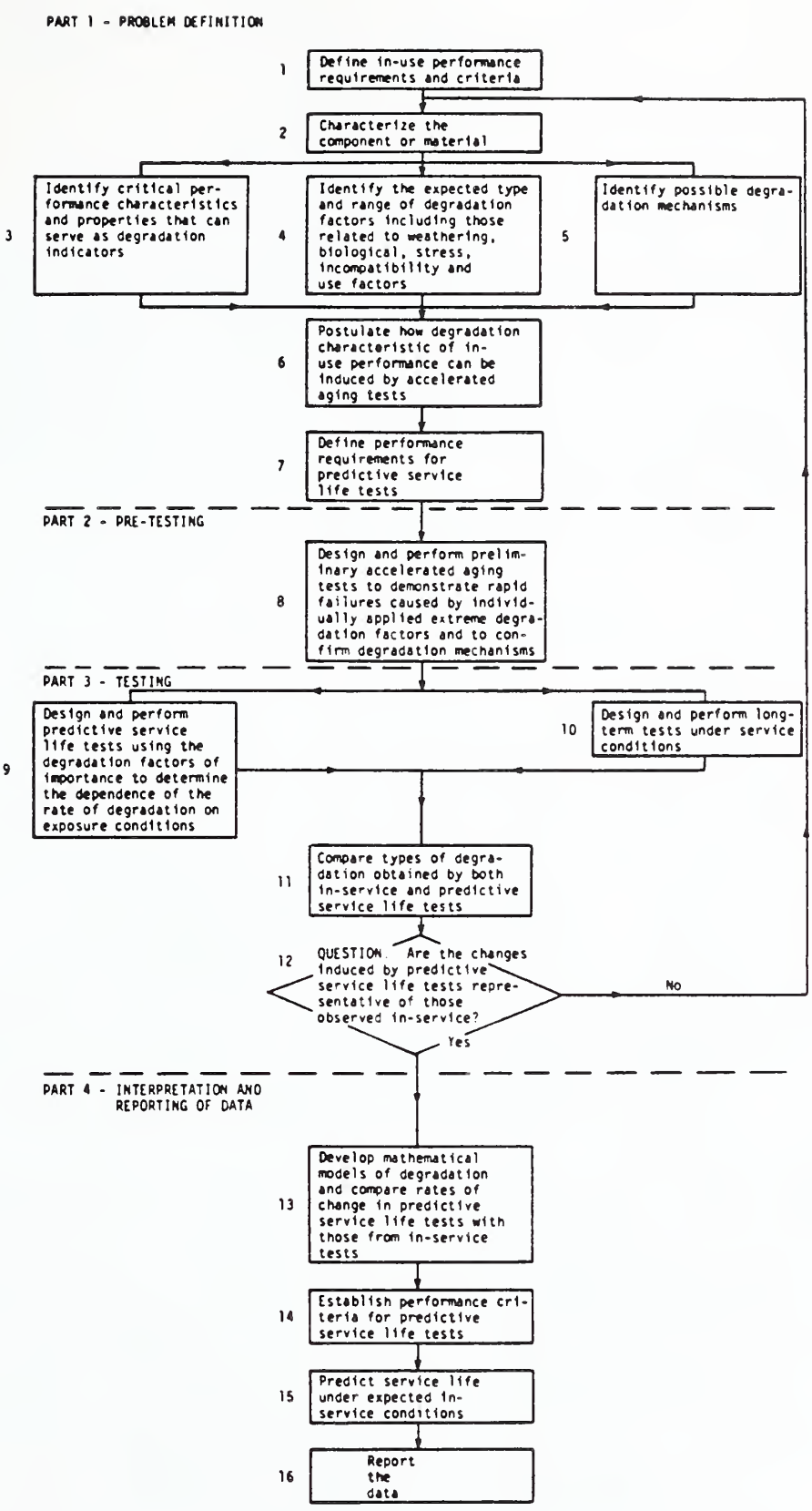

Figure 2. Steps in the Practice in ASTM E 632 for Developing Predictive Service-Life Tests [6].

NBS-114A (REV. 2-8C)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NISTIR 88-3870	2. Performing Organ. Report No.	3. Publication Date NOVEMBER 1988

4. TITLE AND SUBTITLE

Suggested Research Topics for the CERL Program
Evaluation of Research Materials Degradation Processes

5. AUTHOR(S)

Walter J. Rossiter, Jr. and Larry W. Masters

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)

U.S. Army Construction Engineering Research Laboratory
PO Box 4005
Champaign, IL 61820-1305

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This document was prepared at the request of U.S. Army Construction Engineering Research Laboratory (CERL) to provide assistance in developing plans for conducting roofing research under its program entitled, "Evaluation of Roofing Materials Degradation Processes." Five areas of needed research dealing with service-life prediction of membrane performance were suggested:

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- Techniques for Quality Assurance of Membrane Materials

The suggestions are based on needs of the industry in the area of service-life prediction as described in the NIST research plan and the summary of the Round Table Seminar on Roofing Research. Although the research topics proposed cover the wide range of newer membrane products currently available in the U.S. industry, the link between the topics is that of service-life prediction and quality assurance. Completion of the studies recommended in this report would provide valuable information on membrane properties and predictive methodologies.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

low-sloped roofing; membranes, performance, quality assurance, roofs, research needs; service-life prediction.

13. AVAILABILITY

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14. NO. OF PRINTED PAGES

29

15. Price

$11.95

USCOMM-DC 6043-P80