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NATIONAL BUREAU OF STANDARDS REPORT

6966

REPORT ON THE PERFORMANCE OF GLASS FIBER BASE BUILT-UP ROOFS

by

William C. Cullen

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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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William C. Cullen

Organic Building Materials Section
Building Research Division

Sponsored by

Office of the Chief of Engineers
Department of the Air Force
Bureau of Yards and Docks

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REPORT ON THE PERFORMANCE OF GLASS FIBER-BASE BUILT-UP ROOFS

1. INTRODUCTION

Asphalt built-up roofing has been used for over 30 years as a covering for roofs of low slope. This type of roofing can be applied to both nailable and non-nailable decks and consists of alternate layers of asphalt and a reinforcing medium. The reinforcing medium most commonly used is a 15-pound asphalt-saturated organic base felt, although, in some cases, an asphalt-saturated asbestos felt is employed. Other materials have been proposed for use as the reinforcing medium from time to time and some of these have been used to replace the conventional felts in a built-up roof. Aluminum foil, burlap cotton fabric, and glass membranes in various forms are among the materials which have been used or suggested for use. Asphalt-saturated glass fiber roofing felt, which is probably the most common in use next to the organic and asbestos felts, has been employed as a roofing felt for approximately 10 years. This felt is described by Interim Federal Specification SS-R-00620, "Roofing Felt, Glass, Fiber, Asphalt-Saturated, Uncoated".

The various construction agencies of the United States Government became interested in this concept of built-up roofing and, in fact, many have accepted it for use on a ply-for-ply basis with the conventional organic base felt roof. As a result of this interest, the National Bureau of Standards was requested to study the performance of glass base built-up roofs as part of the Tri-Service Building Materials Investigations Program sponsored by the Office of the Chief of Engineers, U. S. Army; the Bureau of Yards and Docks, U. S. Navy; and the Office of Civil Engineering, U.S. Air Force.

This report gives the results of field studies of 33 glass fiber-base built-up roofs carried out in 1956 and in 1960. The field studies included roof inspections in 15 cities located in 8 states. In addition, the results of a limited laboratory investigation as well as the results of a letter survey are included.

Sections 2 and 3 of this report state the conclusions and suggestions, respectively, which have been drawn from the study, while Appendices I, II, and III describe in detail the respective phases of the study.

2. SUMMARY AND CONCLUSIONS

2.1 Field Studies

1. Generally the examinations made of 33 glass fiber-base built-up roofs up to 6-1/2 years of age indicated that good performance was obtained from this type of roof.

2. No correlation was established between the observed performance of the roof and the number of plies of felt in the membrane. This conclusion was anticipated prior to the study, due to the relatively short term exposure of glass fiber-base roofs.

3. There was no evidence that blistering or buckling of the felts had taken place on the roofs examined. This condition indicated the excellent adhesion between the asphalt and the glass felts and the non-hydroscopic nature of the glass felt.

4. The field survey indicated that the performance of glass-base built-up roofs in the Eastern United States was approximately equal to their performance in the Western United States where they have a longer history.

5. Mineral-surfaced roofs (gravel or slag) appeared to give better service than their non-surfaced counterparts.

6. Adequate service was obtained on roofs with slopes from dead-level up to about 5 in. per foot.

7. It is our strong opinion that good service from a given built-up roof depends more on the initial workmanship and subsequent maintenance than on the materials which are used. This conclusion is not entirely a product of this investigation, but is based, rather, on considerable field experience.

2.2 Laboratory Studies

2.2.1 Examination of Specimens Cut Out from Actual Roofs -

1. The age of the roofs from which the cut-outs were taken varied from those under construction up to 6-1/2 years old.

2. Frequently, the number of plies determined in the laboratory analysis was either more or less than reported to the observer in the field survey. Of the eight cut-out specimens, two were 2-ply, three were 3-ply, two were 4-ply, and one was 5-ply.

3. The average weight of the asphalt per mopping was, with two exceptions, less than the 30 pounds per 100 sq. ft. generally specified for this type of roofing. Of the seven specimens examined, three had 15 pounds or less per mopping, two had 20 to 25 pounds, and the remaining two had 30 and 47 pounds, respectively.

4. The analysis of the specimens indicated two types of binder were employed in the manufacture of the glass felt depending on the age of the roof. The glass felt using the phenolic binder (most recent specimens) appeared to be of higher strength than those extracted from the older roofs and consequently in better condition.

5. No correlation could be established between the tensile breaking strength and elongation and the number of plies, the weight of bitumen between plies, and the age of the roof from which the specimen was taken.

6. Excellent adhesion between the glass felt and the asphalt was evident on all 8 specimens confirming the observations made during the field survey about the lack of blistering and buckling.

2.2.2 Laboratory Tests -

1. The built-up roof specimens prepared with glass-base felts in the laboratory appeared to be more resistant in both the accelerated weathering tests and the outdoor exposure test than those prepared with asphalt-saturated organic-base felts.

2. Specimens of glass felt and built-up membranes prepared with glass felt indicated less tendency to absorb and retain moisture than their counterparts prepared with organic-base felts.

3. Conventional felts and built-up membranes constructed with these felts exhibited greater tensile strength than the glass felt specimens. However, in regard to the elongation properties, the glass specimens performed slightly better.

2.3 General Conclusions

From the results of the laboratory tests, the replies of the letter survey and the observed behavior of some 33 roofs in the field, it can be concluded that glass-base felt built-up roofs will provide at least equal service as those constructed with organic-base felts, provided that the materials meet applicable specifications as to quality and quantity and, most important, that the workmanship is in accordance with good roofing practice.

3. SUGGESTIONS

In the event that built-up roofs constructed with glass-base felts are accepted for use, the following suggestions are offered as a guide to insure that quality roofs are obtained. The suggestions are based not only on the information obtained during this investigation, but also on considerable field experience.

1. The built-up roof constructed with glass-base felts should be specified on the basis of either one or both of the following:

(a) A ply-for-ply basis with the conventional organic base felt roof requiring not less than 25 pounds of asphalt per 100 sq. ft. of roof area between each layer of felt.

(b) The total amount of bitumen (mopping + surfacing asphalt) should be equal to or greater than that required for a comparable organic base felt roof now specified. The amount of asphalt between the layers of felt should in any case be not less than 25 pounds per 100 sq. ft. of roof area.

2. A membrane of not less than 3 plies of felt should be specified, i.e., not less than two moppings of bitumen in addition to the surfacing asphalt.

3. A requirement be provided to make mandatory the taking of cut-outs in order to insure that provisions described in 1 and 2 above are carried out.

4. ACKNOWLEDGMENT

The author acknowledges the assistance, counsel, and guidance provided by Dr. H. R. Snoke, former Chief of the Organic Building Materials Section, Building Research Division, National Bureau of Standards, in this study. The assistance of the Owens-Corning Fiberglas Corporation in furnishing the lists of roofs of known history and in making the inspections is also acknowledged.

APPENDIX I.

FIELD SURVEY

1. INTRODUCTION

The purpose of the field survey was to evaluate the performance characteristics of built-up roofs constructed with glass fiber base felts in lieu of the conventional organic or asbestos base felts. It was realized, of course, that many factors other than the type of reinforcing membrane must be considered in evaluating the performance of a built-up roof and that serious failures may occur that are in no way related to the type and character of the base felt employed. For example, it is our opinion that more premature roof failures are caused by faulty workmanship than by inferior materials going into the roof. Proper and timely maintenance is also of great importance in determining the service of any built-up roof.

Built-up roofs constructed with glass fiber felts have been under observation by personnel of National Bureau of Standards since 1956. In August of that year, in connection with another project on built-up roofing, 10 fiber glass roofs were inspected on the West Coast. In addition, annual inspections have been conducted on built-up roofs in the Baltimore, Maryland, and Washington, D. C. areas since 1956. In 1960, at the request of agencies of the Defense Department, additional roofs were inspected throughout the country, including a reexamination of some of the roofs observed in 1956.

Since the observations and conclusions drawn from the field survey are based on the behavior of the roofs inspected, it should be stressed that all of the roofs examined were less than 7 years of age. One roof (Zellerbock Paper Co., Seattle, Washington) was reported to be 9 years old when it was inspected in 1956. However, it was also reported that this roof was not applied with the materials or by the method now recommended by the manufacturer.

2. SELECTION AND INSPECTION OF ROOFS

In order to obtain glass base built-up roofs of known history for the inspections during the field survey, it was necessary to rely upon a manufacturer of this type of roofing material. In 1956, in compliance with a National Bureau of Standards request, the Owens-Corning Fiberglas Corporation submitted a list of 63 roofs located in 5 West Coast states. In 1959, again at the request of this Bureau, the same manufacturer supplied a number of lists of built-up roofs located in various areas throughout the country. The actual roofs to be inspected were selected by lot from these lists.

All roof inspections were made in company with representatives of the manufacturer and frequently with the owner or manager of the building.

In order to secure the greatest possible uniformity in the roof inspections, a check list was developed and used during the examination of each roof. This check list included a history of the roof, as well as the elements which are important in the performance of a built-up roof. A copy of this check list is presented in Figure 1.

In order to obtain the maximum information about a given built-up roof, permission was asked and granted to remove a 24-in. by 12-in. cut-out specimen from one out of each four roofs examined. The roofs from which the cut-out specimens were taken were also selected by lot prior to the inspections in the area. The areas from which the cut-out was made was selected by the National Bureau of Standards observer. Figure 2 shows the removal of a cut-out specimen, while Figure 3 shows the roof area after the specimen was removed. The specimens were shipped to the National Bureau of Standards for analysis and the results of the laboratory examinations of these specimens are reported in Appendix II.

3. AREAS INCLUDED IN THE FIELD STUDY

Critical inspections were made on approximately 33 roofs in 15 cities located in 8 States and the District of Columbia. The areas and the number of roofs examined in each area are shown in Table 1.

TABLE 1.

Areas Where Roof Inspections Were Made

	Area	No. of Inspections
1.	Seattle, Washington	3
2.	Tacoma, Washington	1
3.	San Francisco, California	2
4.	Los Angeles, California	5
5.	Phoenix, Arizona	2
6.	Albuquerque, New Mexico	1
7.	Edwards Air Force Base, California	2
8.	Richmond-Norfolk, Virginia	5
9.	Baltimore, Maryland	2
10.	Washington, D. C.	5
11.	Hagerstown, Maryland	1
12.	Martinsburg, West Virginia	1
13.	Greencastle, Pennsylvania	1
14.	Philadelphia, Pennsylvania	2

FIGURE 1. ROOF INSPECTION CHECK LIST

1. Building ________________ 2. Location ________________

3. Year applied ____________ 4. Manuf. & Spec. __________

5. Deck ____________________ 6. Slope ___________________

7. Insulation ______________ 8. Surfacing _______________

9. Bonded __________________ 10. Roof area ______________

11. Other remarks ____

GENERAL

1. Appearance ______________ 2. Water tightness _________

3. Repaired areas __________ 4. Other ___________________

FELTS

1. Blisters ________________ 2. Cracks __________________

3. Fismouths _______________ 4. Buckled _________________

5. Edges curled ____________ 6. Delaminations ___________

7. Condition of exposed felts ______________________________

8. Condition at flashings __________________________________

9. Condition at bends ______________________________________

10. Other observations _____________________________________

BITUMEN

1. Top pouring or surfacing ________________________________

2. Between plies ____

3. Water standing or dry ___________________________________

4. Alligatoring, cracking, etc. ____________________________

5. Water-soluble products __________________________________

6. Condition ____

7. Other observations ______________________________________

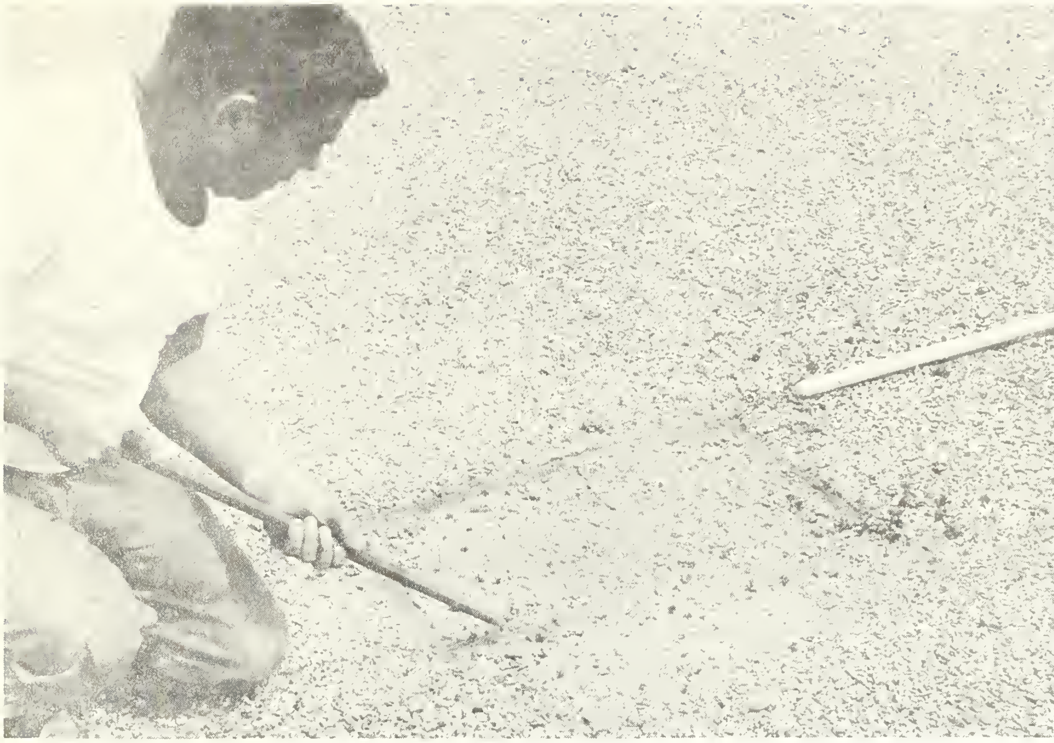

FIGURE 2. REMOVAL OF A CUT-OUT SPECIMEN.

FIGURE 3. AFTER REMOVAL OF SPECIMEN.

4. OBSERVATIONS

The roofs selected for examination were applied to many types of roof decks on slopes ranging from dead-level up to 5 inches per foot. Smooth roofs as well as those protected with several types of mineral surfacing were also examined. In addition, the inspections included roof coverings on both insulated and non-insulated decks. The following types of decks were representative of those on which glass fiber built-up roofings were applied:

1. Insulated steel
2. Sheet rock
3. Gypsum, poured and precast
4. Concrete, insulated and non-insulated
5. Wood
6. Corrugated galvanized.

The performance of the glass-base built-up roofs on each of the above decks appeared to be satisfactory with one exception. The roof applied directly to the corrugated metal deck on a roof in the Los Angeles area was in poor condition as shown in Figure 4. The application of any type of built-up roof directly to a corrugated metal deck is, of course, not in accordance with good roofing practice and is to be condemned.

It is significant that blistering or separation between the plies of the glass-base built-up roofs was not detected in a single instance. In addition, the absence of wrinkling or buckling of the glass felts even after direct exposure to the weather for a week or more was noted. In a few cases, fishmouthing was observed along the edge of the felts as shown in Figure 5. However, it is felt that this deficiency is not inherently present in the felt, but rather in the quality of the workmanship.

In still other cases, defects such as alligatoring, cracking, excessive flow of bitumen, etc., were observed in the surfacing asphalt as shown in Figures 6, 7, and 8. These defects, of course, are not significant in relation to the performance of the reinforcing medium.

Actual cracking of the glass felt was observed on one roof, as shown in Figure 9. However, a similar type failure was also observed on an asphalt-saturated, asbestos-felt roof on an adjacent bay on the same roof.

The reinspection of the roofs after periods of up to 4 years exposure revealed no apparent change other than may normally be expected in any built-up roof. This observation was not unexpected, since the proponents of this system claim a life of 20 years and unless a roof is failing prematurely, no significant change should occur after such a relatively short period of exposure.

FIGURE 4. BUILT-UP ROOF APPLIED TO CORRUGATED METAL DECK.

FIGURE 5. FISHMOUTH ON A SMOOTH, BUILT-UP ROOF.

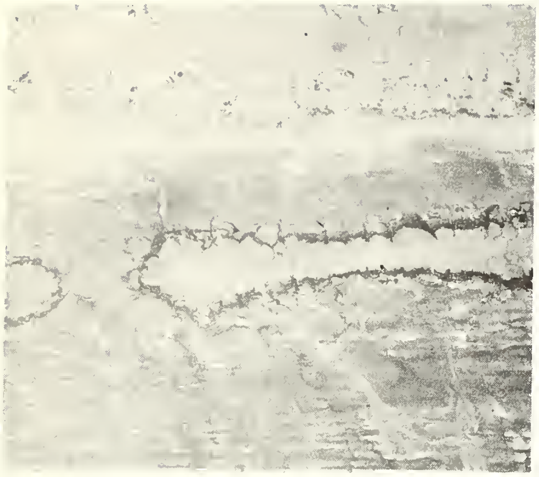

FIGURE 6. ALLIGATORING OF SURFACING ASPHALT.

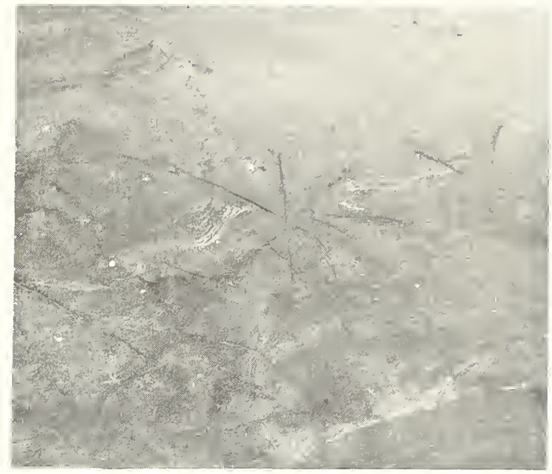

FIGURE 7. CRACKING OF SURFACING ASPHALT.

FIGURE 8. FLOW OF SURFACING ASPHALT.

FIGURE 9. CRACKING IN FELT.

Concerning the merits of the one ply less approach for glass fiber base built-up roofs, it was not possible to correlate the expected durability of a given roof with the number of plies of the reinforcing medium, although roofs of 2, 3, 4, and even 5 plies were observed. For example, one roof which appeared to be in excellent condition after 6 years exposure proved to be only a 2-ply membrane, while other roofs of the same age were in poor condition and were reported to be of 3-ply construction.

The observations made during this study confirmed the conclusions drawn from previous roof surveys that four major factors determine the useful life of any built-up roof. They are: 1) well designed and well constructed roof deck; 2) good quality of roofing materials; 3) adequate maintenance; and 4) good workmanship during application. Not the least of these is good workmanship.

5. RATINGS

A rating was assigned to each roof on the completion of the inspection. The rating was based on the overall appearance, the defects which were noted, and adequacy of service reported by owner. The ratings were as follows:

Excellent	3
Good	17
Fair	3
Poor	2

A number of roofs were not rated as they were new or under construction.

APPENDIX II.

LABORATORY STUDY

1. INTRODUCTION

A limited laboratory investigation was carried out to supplement the information obtained during the field survey. Some of the physical characteristics of the glass-base felts as well as of built-up specimens prepared with these felts were compared with the characteristics of similar specimens prepared with the conventional organic-base felt. The specimens were prepared in the laboratory and subjected to the following tests:

1. Accelerated Weathering
2. Outdoor Exposure
3. Water Absorption
4. Tensile Strength and Elongation.

In addition, the specimens which were cut out of the actual roofs during the field survey were examined in the laboratory to determine their composition and physical characteristics.

2. LABORATORY TESTS

2.1 Accelerated Weathering

Duplicate specimens, 6-in. by 2-3/4-in., of 3-ply glass-base and 3-ply organic-base built-up roofs were prepared in the laboratory and exposed in a carbon arc type accelerated weathering apparatus for 500 hours. This test was carried out in accordance with ASTM Designation: E42-57, Type A.

There was no apparent change noted in the specimens prepared with the glass-base felt after 500 hours exposure. However, the organic-base felt specimens indicated a separation as large as 1/8 in. along each edge between the first and second plies of felt. The results of this test indicated the specimens prepared with the glass-fiber felts were more stable under the conditions of test than those prepared with the conventional felts.

2.2 Outdoor Exposure

Specimens of both types of felt, as well as built-up specimens which were prepared in the laboratory, were exposed outdoors on the roof of the Industrial Building, National Bureau of Standards. The 5- by 5-in. specimens were exposed on a dead-level deck during July and August 1960.

The effect of the outdoor exposure on the specimens was similar to that observed in the simulated service test described in Section 2.2 above. The specimens prepared with the organic felts appeared to be less stable than the glass-fiber specimens and a separation between the plies of these specimens was also observed after a few weeks exposure.

2.3 Water Absorption

The water-absorption tests were conducted on specimens of both types of felts as well as on built-up specimens prepared with both the glass-fiber and organic-base felts. The tests were conducted in accordance with ASTM Designation: D570-57T. for a period of 120 hours.

The results of the tests are reported in Table 2 and are expressed in grams of water absorbed and percent of water absorbed in relation to the dry weight of the specimens after 120 hours immersion.

2.4 Tensile Properties

The tensile properties of built-up specimens prepared in the laboratory were determined essentially in accordance with the method described in ASTM Designation: D638-58T. Specifically, the specimens were tested on an Instron Testing Machine with an initial jaw separation of 4 inches. The results of the tensile tests expressed in pounds of force required to rupture the specimen and the percentage elongation of the sample prior to rupture are reported in Table 3.

3. RESULTS OF LABORATORY EXAMINATION OF ACTUAL ROOF SPECIMENS

The cut-out samples of the actual roofs obtained during the field survey were examined in the laboratory to determine the character of the specimen as well as the number of plies of felt in the reinforcing membrane and the approximate weight of bitumen used as the adhesive between the plies of felt. The information which was obtained in the laboratory analysis, together with the name, location, and reported age of the roof from which the sample was taken are reported in Table 4.

TABLE 2. Results of Water-Absorption Tests.

Specimen	Dry Weight	Water Absorbed	Water Absorbed
	grams	grams	percent
Glass felt, asphalt-saturated	1.172	0.126	10.8
Organic felt, asphalt-saturated	2.176	0.954	43.8
Built-up, 3-ply glass	13.047	0.240	1.8
Built-up, 4-ply glass	14.691	0.239	1.6
Built-up, 3-ply organic	14.966	1.685	11.3
Built-up, 4-ply organic	17.946	2.040	11.4

TABLE 3. Results of Tensile Tests

Specimen	Breaking Strength	Elongation
	lbs	percent
Built-up, 3-ply glass	47	5.0
Built-up, 4-ply glass	91	8.3
Built-up, 3-ply organic	175	5.0
Built-up, 4-ply organic	194	3.3

TABLE 4. Results of Examination of Cut-Out Specimens.

Name of Structure	Location	Age	No. of Plies	Average Weight of Asphalt Between Plies
				lbs/100 ft^2
Rocket Storage Shed	Andrews AFB, Md.	1	4	25
Corning Glass	Martinsburg, W. Va.	*	3	47
Robertshaw Fulton	Los Angeles, Calif.	6	2	L20
Standard Oil	El Segundo, Calif.	2	2	**
Housing	Edwards AFB, Calif.	1	4	L15
Firestone Store	Phoenix, Ariz.	6	3	L15
Roach and Mercer	Richmond, Va.	1	5	15
Power Plant	Hagerstown, Md.	4	3	30

*Roof under construction when examined.
**Impossible to calculate amount of mopping asphalt due to character of specimen.

APPENDIX III.

LETTER SURVEY

1. INTRODUCTION

In order to supplement the data obtained during the field survey, a letter was prepared and distributed to a number of owners of glass-fiber built-up roofs to develop information about the behavior and maintenance requirements of this type of roofing. Those who received the letter were selected by lot from the same list of 63 roofs described in Appendix II, submitted to the National Bureau of Standards in 1956. Figure 10 is a copy of the letter which was distributed.

2. RESULTS

A summary of the results of the letter survey are presented in Table 5.

TABLE 5. Results of Letter Survey

Number of Letters Distributed	20
Number of Replies Received	12*
Average Age of Roofs Reported On	5 yrs.
Number Reporting:	
Very good service	2
Satisfactory service	8
Poor service	1**

*One reply stated that they had not used glass-fiber roofing.
**This user also reported unsatisfactory service with other types of built-up roofing.

FIGURE 10. FORM LETTER FOR LETTER SURVEY

Gentlemen:

The National Bureau of Standards has undertaken, for the benefit of other agencies of the Government, a study of the performance characteristics of the newer types of roofing materials. In this connection, we are soliciting your assistance as a user of one of the new roofing materials.

It is our understanding that you have one or more buildings covered with a built-up roof which employs glass-base felts in place of the conventional organic or asbestos base felts. It would be most helpful if you could furnish us with information regarding the age, performance, and the maintenance required for such roofs in comparison with built-up roofs of the conventional type. Any information we receive will, of course, be considered as confidential.

Your cooperation will be appreciated greatly.

Very truly yours,

William C. Cullen, Chemist,
Organic Building Materials Section.

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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METROLOGY. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

HEAT. Temperature Physics. Heat Measurements. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research. Equation of State. Statistical Physics. Molecular Spectroscopy.

RADIATION PHYSICS. X-Ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

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