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Improved and New Roofing for Military Construction

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Construction of Experimental Modified Bitumen Roofing at Fort Polk, LA

by
David M. Bailey

This report describes the initial construction phase of test roofs at Fort Polk, LA, as part of a projected 10-year field evaluation of modified bitumen roofing systems. This work is part of a research effort being conducted by the U.S. Army Construction Engineering Research Laboratory (USACERL) to attempt to identify alternative, easy-to-instal roofing systems that can improve the performance of Army roofing while reducing life-cycle costs.

Three different modified bitumen roofing systems were installed on Building 920 at Fort Polk. To determine performance, samples from the test roofs will be laboratory tested and the roofs will be visually inspected annually for 10 years.

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FOREWORD

This research is being conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project 4A162731AT41, "Military Facilities Engineering Technology"; Task AO; "Facility Planning and Design"; Work Unit 044, "Improved and New Roofing for Military Construction." The technical monitor is Mr. Rodger Seeman CEMP-ES.

The work is being performed by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Laboratory (USACERL). David M. Bailey is the principal investigator. Dr. Paul Howdyshell is Chief of USACERL-EM. The technical editor was Gloria J. Wienke, USACERL Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL and Dr. L.R. Shaffer is Technical Director.

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CONSTRUCTION OF EXPERIMENTAL MODIFIED BITUMEN ROOFING AT FORT POLK, LA

1 INTRODUCTION

Background

Army installations have traditionally used built-up roofing (BUR) for their low-slope roofs, in both new construction and reroofing. Because of several variables such as building design, local labor force, environmental conditions, local construction inspection and quality control practices, and level of maintenance, some of these built-up roofs have failed prematurely, resulting in high life-cycle costs that are difficult for overburdened Army Operation and Maintenance (O&M) budgets to absorb. Therefore, Headquarters, U.S. Army Corps of Engineers (HQUSACE) asked the U.S. Army Construction Engineering Laboratory (USACERL) to investigate low-slope roofing systems that can provide alternatives to BUR systems and improve the performance of Army roofing while reducing life-cycle costs. This investigation includes (1) evaluating innovative roofing systems and materials as alternatives to BUR, (2) providing a means to improve Army roof performance and reduce life-cycle costs, (3) improving contractor quality control (CQC) of roofing construction, and (4) developing guide specifications for selected alternative systems.

Roofing research previously published by USACERL has included an overview of alternative reroofing systems,[1] investigations of polyvinyl chloride (PVC) single ply systems,[2] sprayed polyurethane foam roofing with protective coatings,[3] uncured elastomeric systems,[4] and standing seam metal roofing systems.[5] As a result of an investigation of modified bitumen roofing systems for use in military construction,[6] it was determined that modified bitumen roofing should be installed and evaluated in service at military installations in the continental United States.

Objective

The objective of this interim report is to document the construction phase of the test roofs at Fort Polk, LA, as part of a 10-year field evaluation of modified bitumen membrane roofing.

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[1] E. Marvin, et al., *Evaluation of Alternative Reroofing Systems*, Interim Report M-263/ADA071578 (U.S. Army Construction Engineering Research Laboratory [USACERL], June 1979).

[2] M. Rosenfield, *An Evaluation of Polyvinyl Chloride (PVC) Single-Ply Membrane Roofing Systems*, Technical Report M-284/ADA097931 (USACERL, March 1981).

[3] M. Rosenfield, *Evaluation of Sprayed Polyurethane Foam Roofing and Protective Coatings*, Technical Report M-297/ADA109696 (USACERL, November 1981).

[4] M. Rosenfield, *Initial Investigation of Three Uncured Elastomeric Roofing Membrane Materials for Use in Military Construction*, Interim Report M-86/03/ADA165620 (USACERL, February 1986).

[5] M. Rosenfield, W. Rose, and W. Dillner, *Investigation of Standing Seam Metal Roofing*, Technical Report M-86/10/ADA172614 (USACERL, June 1986).

[6] M. Rosenfield, et al., *Initial Investigation of Modified Bitumen Roofing Systems for Use in Military Construction*, Interim Report M-86/21/ADA177002 (USACERL, November 1986).

Approach

Researchers developed a test plan using standard test methods published by the American Society for Testing and Materials (ASTM), when available, and other tests developed by Government or private agencies when needed. Test sites at Fort Polk, LA; Fort Lewis, WA; and Fort Dix, NJ; were selected and test guide specifications were developed. The test roofs were installed at Fort Polk. Contracting difficulties have delayed installation of the test roofs at Fort Lewis: funding difficulties have delayed installation of the test roofs at Fort Dix. The subject of this report is the construction of the modified bitumen test roofs at Fort Polk.

Mode of Technology Transfer

It is recommended that the results of this study be used to help develop Corps of Engineers Guide Specifications for modified bitumen membrane roofing.

2 PROCEDURE

Test Plan

Although only one generic material, modified bitumen, was being tested, different manufacturers' products were to be installed side by side using different installation techniques. This was done for the following reasons:

1. Manufacturers formulate their products differently. Most modified bitumen products use one of two different asphalt modifiers: atactic polypropylene (APP) or styrene butadiene styrene (SBS). Manufacturers use different reinforcement materials (e.g., polyester, glass fiber mats).

2. Modified bitumen membranes commonly are installed by torch-fusing, hot asphalt embedment, or self-adherence. It is necessary to evaluate these different installation methods.

3. The test plan was designed to determine how weathering would change the physical and mechanical characteristics of the membrane materials and compare the results between the different types.

Testing provides data on changes the physical and mechanical properties undergo as the membranes age in service, and allows comparisons to be made between the magnitude of any changes in properties and the observed performance of the roofing.

Table 1 lists the properties to be tested and the basis of the test procedures to be used. At the time of initial testing, standard ASTM test methods were not available for polymer-modified bituminous membrane materials. For most of the properties listed, the tests were selected from draft proposals of the ASTM task group developing standard test procedures for polymer-modified bituminous membrane materials. These test procedures were incorporated in the National Institute of Standards and Technology (NIST) suggested preliminary criteria for modified bitumen membranes, and reprinted in the NIST criteria with permission of ASTM.

The static and dynamic puncture tests listed in Table 1 were selected from the recommendations of the CIB/RILEM* Committee on Elastomeric, Thermoplastic, and Modified Bituminous Roofing. This committee considered puncture one of the important engineering properties of membrane materials that should be considered in assessing membrane performance.

After initial measurements of the selected membrane properties, subsequent tests are scheduled at 1-year intervals for 10 years, accompanied by annual visual inspection. Two reports documenting these results will be published; one after the first 3 years of testing and one at the completion of the 10 years of testing.

* International Council for Building Research, Studies, and Documentation/International Union of Testing and Research Laboratories for Materials and Structures.

Table 1

Properties Determined for the Modified Bitumen Membrane Materials

Property	Basis of the Test Procedure
Thickness	ASTM draft, section 5[a]
Tensile Strength at 0 °F	ASTM draft, section 6
Elongation at 0 °F	ASTM draft, section 6
Strain Energy at 0 °F	ASTM draft, section 6
Tear Strength	ASTM draft, section 7
Moisture Content	ASTM draft, section 8
Low-Temperature Flexibility	ASTM draft, section 11
Static Puncture	UEAtc MOAT No. 27, section 5.4.1[b]
Dynamic Puncture	NF P 84-353[b]

[a]The ASTM draft procedures are available in NIST Building Science Series 167, entitled "Interim Criteria for Polymer-Modified Bituminous Roofing Membrane Materials."

[b]This test procedure is given in the 1988 report of the CIB/RILEM Committee on Elastomeric, Thermoplastic, and Modified Bituminous Roofing. The report is entitled "Performance Testing of Roofing Membrane Materials."

Test Site Selection

Site selections for the test roofs were based on the following criteria:

1. The availability of buildings that were structurally divided into two or three parts or that were large enough to divide into separate parts,

2. The availability of a local (in-house) engineer staff that could prepare contract drawings and administer the construction contract, and

3. The availability of local (site) funding for the construction work.

Three Army installations representative of the geographical and climatic variations in the continental United States were chosen as test sites: Fort Polk, LA; Fort Lewis, WA; and Fort Dix, NJ.

Test Guide Specification Development

An initial investigation of modified bitumen roofs was conducted as part of ongoing research into alternative roofing systems for military construction.[7] Material requirements and construction guide

[7] M. Rosenfield, et al, (November 1986).

specifications were developed from a thorough reading of manufacturers' literature and articles published in various roofing periodicals, and information distributed during technical sessions at roofing contractors association annual meetings and biennial roofing symposia. Drafts of the proposed specifications were sent to each manufacturer of a product selected for the test program. Original plans were to test 18 products, so 18 drafts were circulated. The final test program was much smaller in scope, although there was considerable interest and input on industry's part. The fact that no ASTM material standards existed created a hurdle that was overcome with industry assistance; a workable guide specification was produced. This document was then tailored to fit the products and conditions at each site.

The Technical Provisions for the contract specifications designed specifically for this program were prepared in accordance with a format recommended by HQUSACE (Appendix). They were written on a generic, nonproprietary basis, although it was realized that the contract would have to be specific if selected materials were to be compared. Federal Acquisition Regulation (FAR) 35, *Research and Development Contracting*, permits this action for research and development (R&D) work.

Contracting Procedure

With the technical specifications portion of the construction contract being provided by USACERL, the Fort Polk Directorate of Engineering and Housing (DEH) prepared the remainder of the contract. Normal advertising procedures were followed, although a bidder's list of manufacturer-approved applicators was provided.

After the contract was awarded, but before the work began, a preconstruction site conference was held. The contracting officer, manufacturers, contractor, USACERL representatives, and local engineering inspectors attended. All specifications and drawings were carefully reviewed and the experimental goals of the program explained and discussed. In particular, it was emphasized that the project was to serve as a demonstration for future material and specification selection, that requirements for application procedures and materials would be monitored very closely, and that nonconforming work would be rejected. An important point of discussion was the requirement for periodic sampling and the procedures needed to accomplish this.

3 INSTALLATION

Researchers selected Building 920, the Non-Commissioned Officers' (NCO) Club at Fort Polk, LA, for application of three types of modified bitumen roofing systems. The building is used for a club, dining facility, and small retail operations. The building has a ribbed metal roof deck. To separate the different roofing systems, the existing roof was divided into three major areas by two expansion joints. Area A is separated from the other areas by an expansion joint running north and south across the building. An expansion joint running east and west separates areas B and C. Area B includes a small entryway roof on the north side of the building. The major roof areas are structurally sloped to drains on the north and south edges at the rate of 1/2-in./ft.* The entryway roof structure is sloped wood plank construction. Figure 1 shows the three different roof areas.

Membrane Materials

The three membranes selected for the Fort Polk project were specified as follows:

- Membrane A -- a torch-applied APP modified bitumen with polyester reinforcement and factory-applied granule surfacing (area A),
- Membrane B -- a hot-mopped SBS modified bitumen with polyester reinforcement and factory-applied granule surfacing (area B), and
- Membrane C -- a self-adhering modified bitumen membrane with a polyester film carrier sheet and a vinyl acrylic coating applied in the field (area C).

The initial properties of the three membrane materials, as determined from samples prepared by the contractor during installation of the roofs, are listed in Table 2. The membrane A specimen was tested as a composite of the modified bitumen sheet with the glass fiber base sheet. The torch application of the modified bitumen resulted in a two-ply composite that could not be readily delaminated without damaging the modified sheet. The membrane B specimen was tested as a single sheet since the modified bitumen ply was readily delaminated from the base ply by cooling the composite specimen. The membrane C specimen was tested with the white vinyl acrylic coating in place.

Suggested criteria (NIST Building Series 167) have been recommended for only three of the tests being performed: strain energy (minimum, 3 lb x in/sq in**), low temperature flexibility (maximum, 0° C) and moisture content (maximum, 0.5 percent). All three membranes met the low temperature flexibility and moisture content requirements. However, membrane A did not meet the minimum strain energy criteria with reported values of 2.3 and 1.9 lb x in/sq in. in the longitudinal and transverse directions, respectively. For these test roofs located in Louisiana, where extremely harsh cold temperature conditions may not occur, the membrane should not be subjected to temperature-induced stresses as great as if it were located in colder regions of the country. The result is that the risk of membrane splitting may be reduced. It will, thus be of particular interest in the study to follow the long-term performance of a membrane whose initial properties do not meet the strain energy criteria suggested in the NIST publication.

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* 1 in. = 2.54 cm; 1 ft = 0.305 m.

** 1 lb = 0.453 kg; 1 sq in. = 64.5 cm^2.

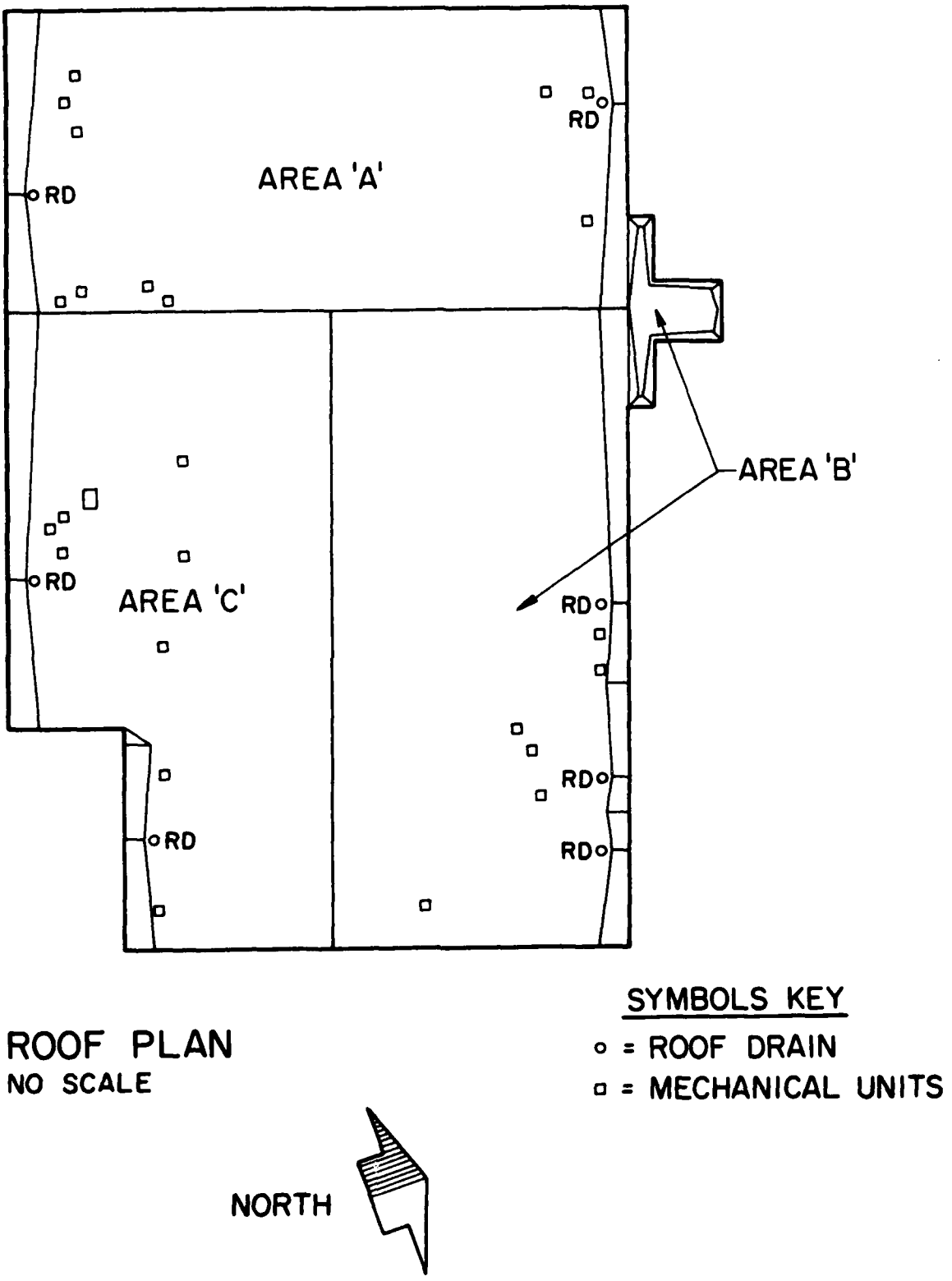

Figure 1. Roof plan for Building 920 at Fort Polk.

Table 2

Initial Properties of the Three Test Membranes

Property	Membrane A	Membrane B	Membrane C
Thickness (in.)	0.31	0.25	0.11
Tensile Strength (lb/in.)			
Longitudinal	207	148	135
Transverse	171	109	130
Elongation (%)			
Longitudinal	1.5	21	24
Transverse	1.6	25	27
Strain Energy (lb x in/sq in.)			
Longitudinal	2.3	23	23
Transverse	1.9	20	26
Tear Strength (lb)			
Longitudinal	232	148	122
Transverse	175	123	136
Moisture Content (mass %)	< 0.2	< 0.2	< 0.2
Low-Temperature Flexibility (°F)	0	-24	-32
Static Puncture (lb)	55	53	55
Dynamic Puncture (Joules)	20	18	7.5

The data in Table 2 also show that the tensile strength and elongation of membrane A were about 200 lb/in. and 1.5 percent, respectively. These properties were characteristic of a modified bitumen sheet having glass reinforcement and not polyester, which was specified for this product. Reasons for this discrepancy were not known. A possibility is that the tensile strength and elongation properties were influenced by the presence of the glass fiber base sheet in the composite membrane that was tested.

Installation Methods

The contract for reroofing Building 920 specified complete removal of the existing built-up roof system down to the deck. The only components reused were the existing drain hardware and wood blocking found to be dry and sound. After removing the existing roof, a layer of perlite insulation board was mechanically fastened to the metal deck using steel self-tapping screws and plates. A two-ply asphalt and felt vapor retarder was installed in solid moppings of hot asphalt over the perlite. Two layers of polyisocyanurate board, complying with Federal Specifications HH-I-1972/GEN and HH-I-1972/2 Class I, were installed in solid moppings of asphalt over the vapor retarder. The boards were faced with asphalt/glass fiber felt or polymer/glass fiber mat for all of the roof systems. The insulation thickness for the field of the roof was calculated to provide a minimum 0.16 K-value for all roof areas.

Discussion

Construction began on August 26, 1987, and was essentially complete by November 10, 1987. Work began on area A and proceeded to area B. On several occasions, construction on areas B and C was performed at the same time. The relatively long duration of the project was due to bad weather, fluctuating crew size, and the unexpectedly long time it took for the contractor to install the specified sheet metal flashings. The sheet metal installation started on October 19 after the basic roofing work was complete. Some delays were also experienced due to shortages of membrane A material and the specified base sheet for the membrane B installation.

Specifications were written to allow each manufacturer's installation methods to be followed. Specific instructions were written into the contract only when manufacturers' instructions were vague or when specific modifications were desired.

Membrane A

Area A was reroofed with the torch-applied APP modified bitumen membrane. The use of hot asphalt was required throughout the job and kettle temperatures were monitored in compliance with the project specifications. The first step in installing membrane A was to remove the existing roofing system down to the metal deck (Figure 2*). The second step was to mechanically fasten perlite insulation to the deck. The perlite insulation is UL-approved as a thermal barrier for Class I fire rated roof assemblies. The vapor retarder was installed over the perlite in two plies and was broomed to ensure full embedment as shown in Figures 3 and 4. The polyisocyanurate insulation was installed in two layers with full moppings of asphalt. The end joints were staggered in the first course, and all joints were staggered between courses (Figures 5 and 6). Rigid insulation sumps were installed at drains (Figure 7) and crickets were installed at roof edges (Figure 8) using tapered perlite insulation to ensure good drainage at the roof drains.

* Figures 2 through 22 are on pages 18 through 28.

A nonperforated base sheet was installed over the completed insulation in spot moppings of hot asphalt (Figure 9). The membrane was torch-applied over the base sheet (Figure 10). The copper napthenate solution was brushed on at end cuts of all wood nailers and boards (Figure 11). The base flashing consisted of the membrane sheet as the first ply extending above the roof surface a minimum of 6 in. The second ply was cut to fit (from the membrane material) and torch-applied (Figure 12).

Due to the fire hazards associated with torch-applied systems, the project specifications required an infrared scan to be conducted after each day of torch-applied installation. The scan would identify any materials that were hot or smoldering. The results of these scans were negative (no hot spots) throughout the entire job.

Debris, mostly dust and loose gravel, was frequently found scattered over the base ply before installation of the modified bitumen ply. Because loose gravel could puncture the overlying membrane, it was removed. The problem was not severe enough to slow the project significantly.

Another potential problem was encountered when the contractor removed more materials than could be replaced in the time remaining during a particular work day. In this case, a temporary roof was installed and there was no damage to the work in progress or the building interior. The complexity of the work (removing the old roofing; mechanically fastening a layer of insulation; and installing a vapor retarder, multiple layers of insulation, and the roof membrane and flashings) led to misjudging the area of old roofing that should be removed.

Membrane B

Reroofing of area B with the hot-mopped SBS modified bitumen membrane began on September 8. Installation of the perlite thermal barrier, two-ply asphalt vapor retarder, polyisocyanurate insulation, drain sumps, and crickets were the same as described for area A.

The base sheet for the membrane installation of area B was solid-mopped rather than spot-mopped as was done on area A (Figure 13). The membrane B material was also fully mopped to the base sheet (Figure 14). The installation involved softening the end lap area with a torch before mopping on the next sheet. This provides a situation where the modified asphalt in the two sheets is softened and forms a fused or welded lap when pressed together (Figures 15, 16, and 17). The completed roof membrane is shown in Figure 18.

The problems encountered during installation of the hot-mopped modified system included basic "housekeeping" (keeping debris from the demolition operation off the new roof system) and proper seal-offs between new and existing systems. One failed seal-off allowed a large amount of water to enter the building. Moisture also entered the completed new system and approximately 900 sq ft of new roofing (including vapor retarder, insulation, and membrane) was subsequently rejected and replaced. Figure 19 shows the subsequent removal work.

Membrane C

Installation of the self-adhered modified bitumen membrane on area C involved the same preparation work as for areas A and B. The vapor retarder and insulation systems were also the same except that the top layer of insulation was installed in parallel courses without staggering the end laps. This was done to facilitate installation of the insulation joint tape, which was required by the membrane manufacturer.

An adhesive primer was used at parapet walls, insulation joints, and crickets before installing the membrane. Figure 20 shows the primer installation.

The membrane C material is manufactured with a factory-applied adhesive on the bottom. The membrane is protected from sticking to itself with a paper protection sheet, often called release paper. This sheet is removed as the material is installed (Figure 21). The end joints for the sheets are sealed with a special compound. The compound is also used with flashings. The primer used for the joint tape is also used to cover sheet metal flanges for accessories such as the pressure relief vents.

The completed membrane was coated with a white vinyl acrylic. This material was sprayed on at the rate of 1 gal/square for each of two coats. Figure 22 shows the coating application. The spray equipment broke down a few times but did not delay operations. The handling of construction traffic created a problem during the installation on area C. The completed membrane on adjacent parts of area B had to be protected with plywood during the completion of this work.

General Comments

All three installations experienced housekeeping problems: contamination by debris such as loose gravel and pieces of the removed insulation and dust. Housekeeping problems are common to any construction work and for this project they were handled well enough to preclude compromising the quality of the finished roofing systems.

Lack of availability of specified materials during the work also caused some delays and, in one case, required routing construction traffic across a completed roof section to finish an area previously delayed due to unavailability of materials.

Problems due to careless handling of insulating materials and improper seal-offs were also encountered. In one case, some polyisocyanurate insulation was delivered to the project site containing unacceptable amounts of moisture. In another case, a poorly installed seal-off caused damage to the building interior and the completed roof system.

The installation of the modified bitumen systems used on the project did not contribute any problems that would not have been expected for any roofing application. The initial steps (completely removing existing materials, mechanically attaching a layer of insulation, followed by solid moppings of multiple layers of insulation) provide a substrate appropriate for installing many roofing systems, including modified bitumen. Most of the materials, procedures, and equipment used for these test installations have been used by roofing contractors for a long time in more conventional roof system construction.

The self-adhered system used on area C requires more expertise in installation and more attention to detail because there is no base ply and, therefore, two fewer moppings of asphalt between the primary waterproofing system and the insulation.

Overall, these systems proved to be relatively easy to install and incurred no problems directly related to the new roofing materials.

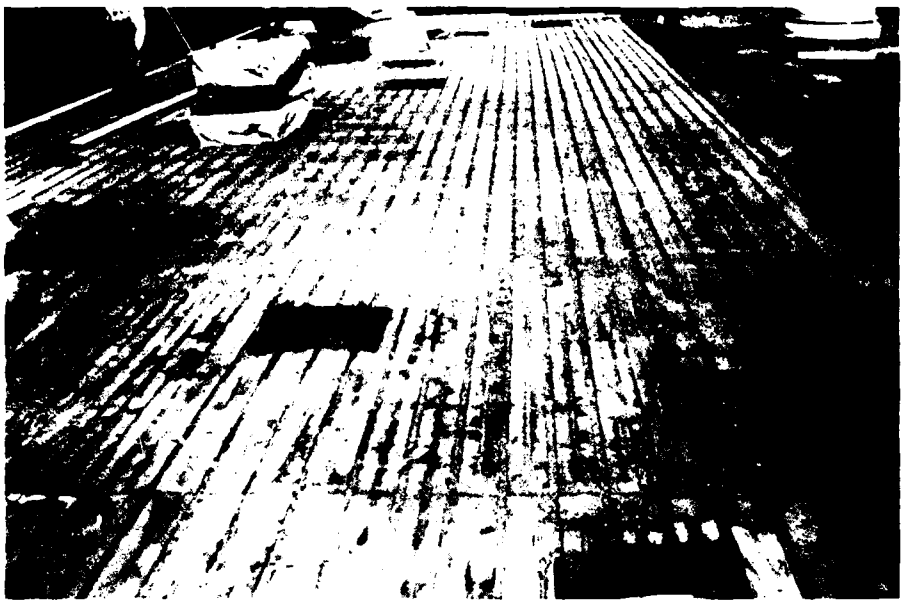

Figure 2. Exposed metal deck after removing existing roof.

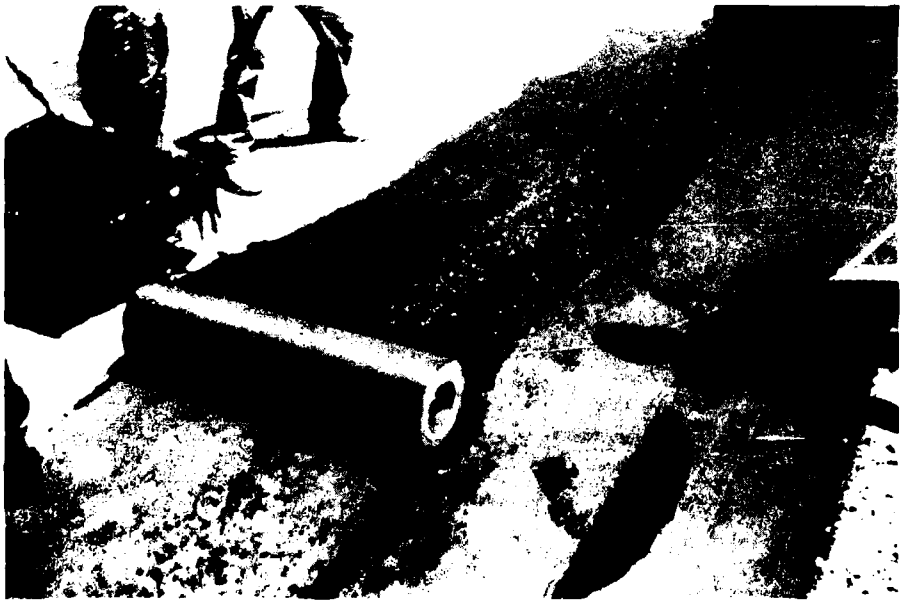

Figure 3. Vapor retarder rolled onto perlite insulation.

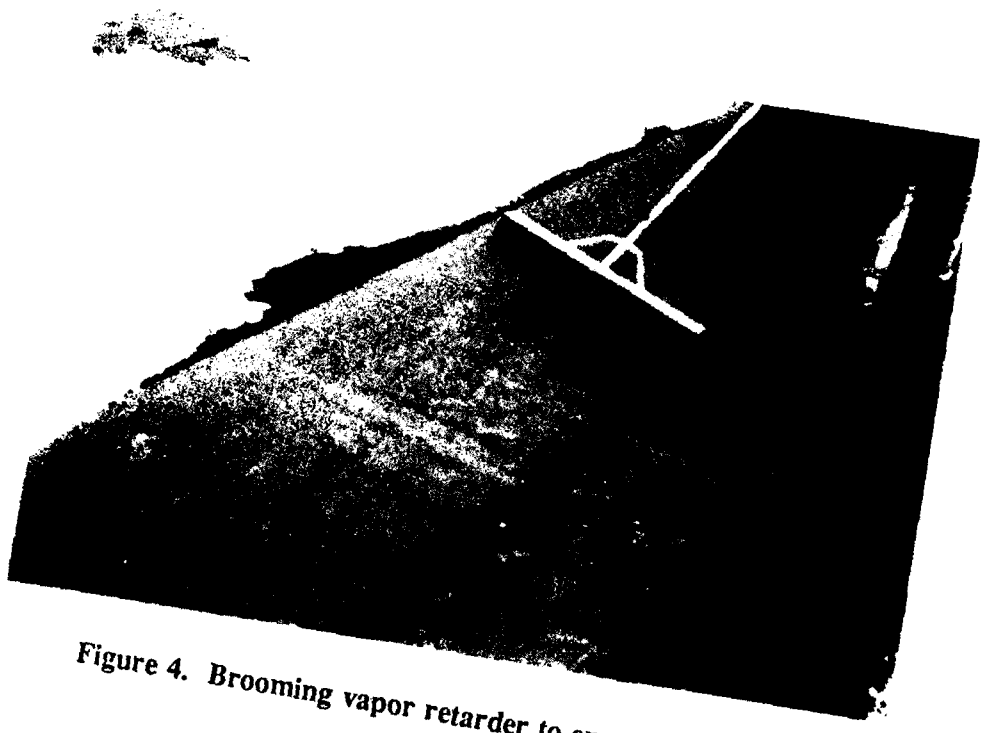

Figure 4. Brooming vapor retarder to ensure embedment.

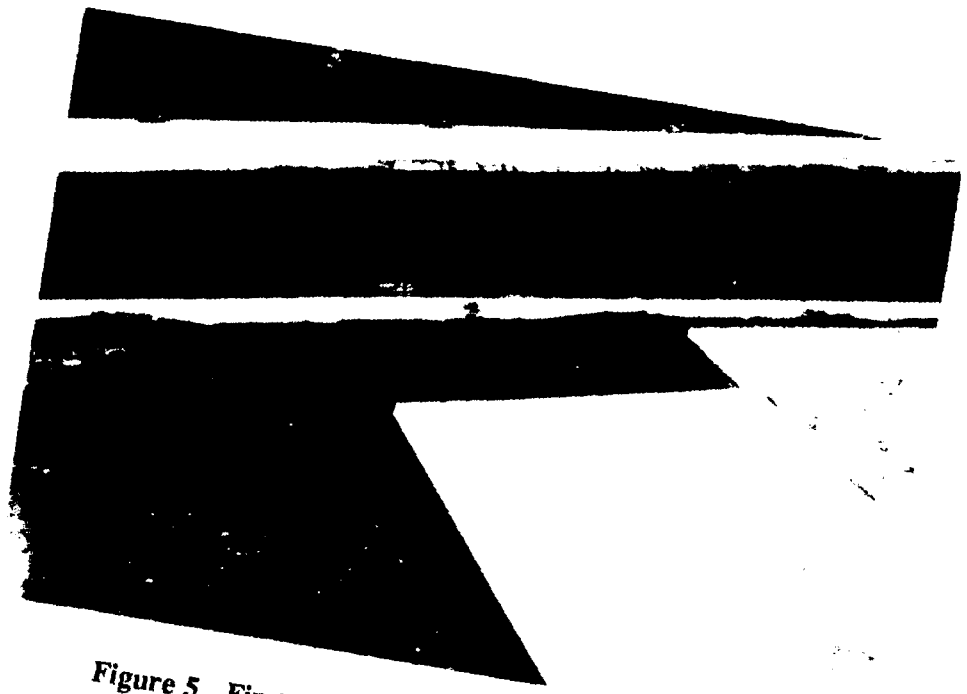

Figure 5. First course of polyisocyanurate insulation.

Figure 6. Installing second course of polyisocyanurate insulation.

Figure 7. Installing insulation sumps at drains.

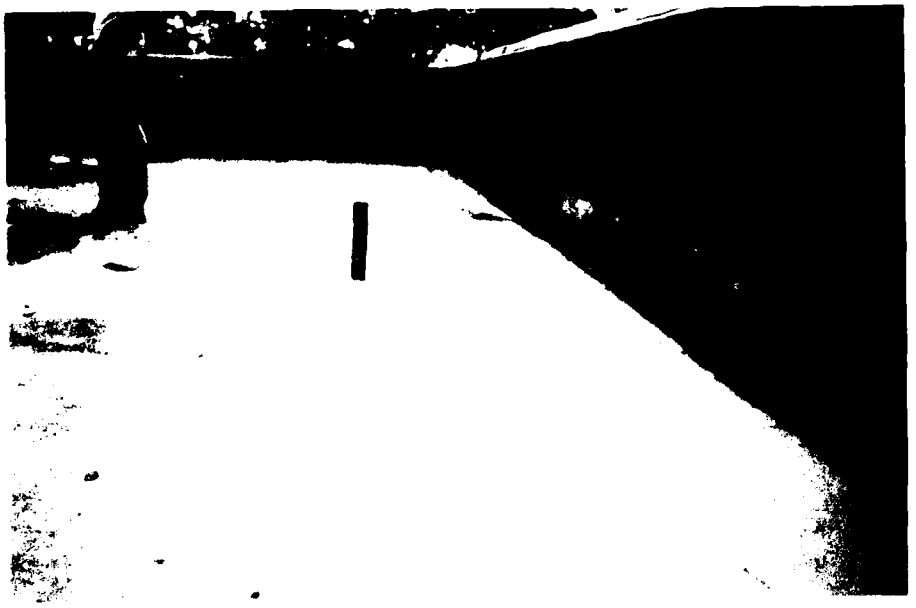

Figure 8. Cricket installed at roof edge to provide good drainage.

Figure 9. Installing base sheet over spot moppings of asphalt.

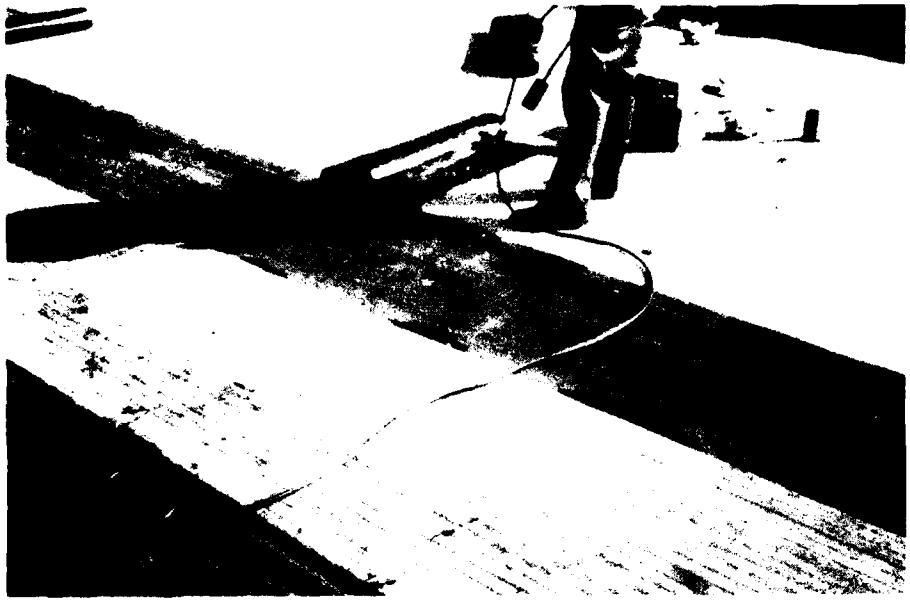

Figure 10. Membrane roll being torch-applied over base sheet.

Figure 11. Treating cut edges of wood nailers.

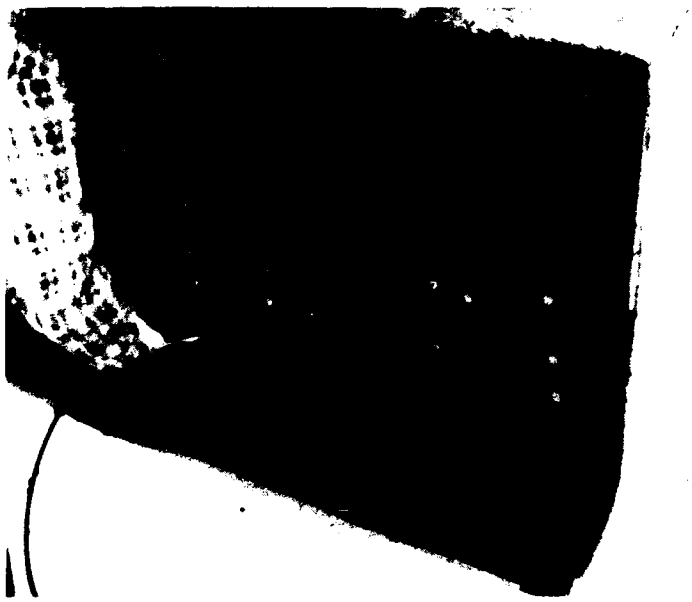

Figure 12. Installing second ply of base flashing.

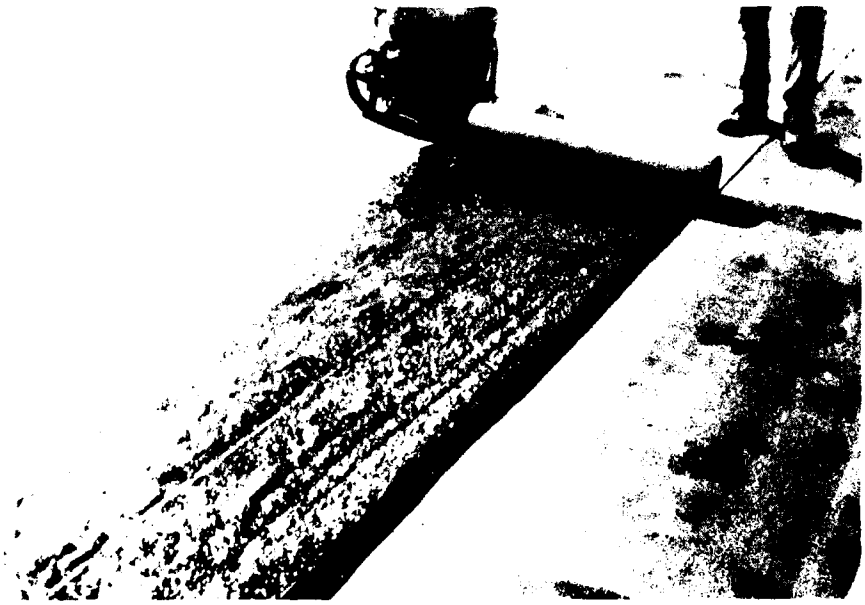

Figure 13. Installing base sheet over solid mopping of asphalt.

Figure 14. Membrane roll being rolled over solid mopping of asphalt.

Figure 15. Heating end lap with torch before applying next sheet.

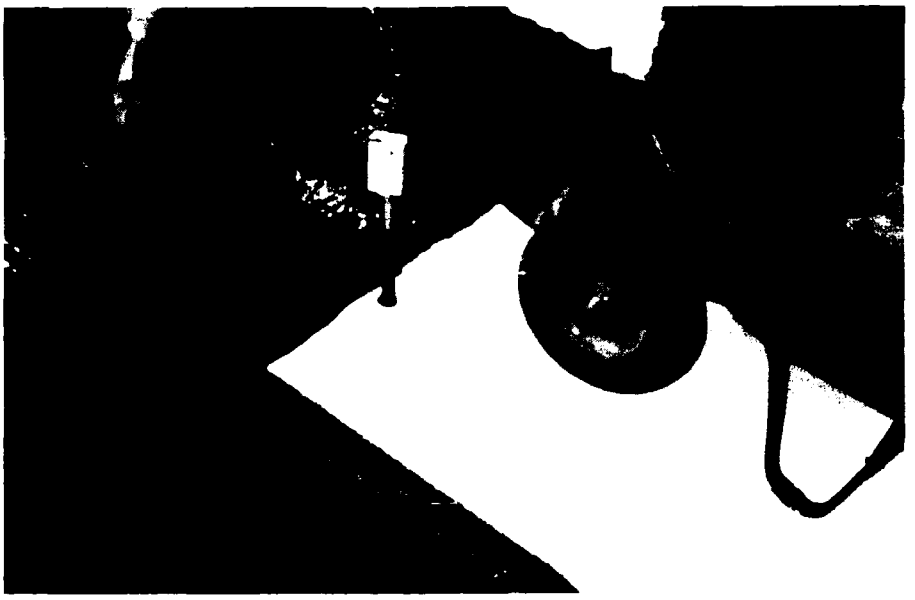

Figure 16. Applying hot asphalt at end lap.

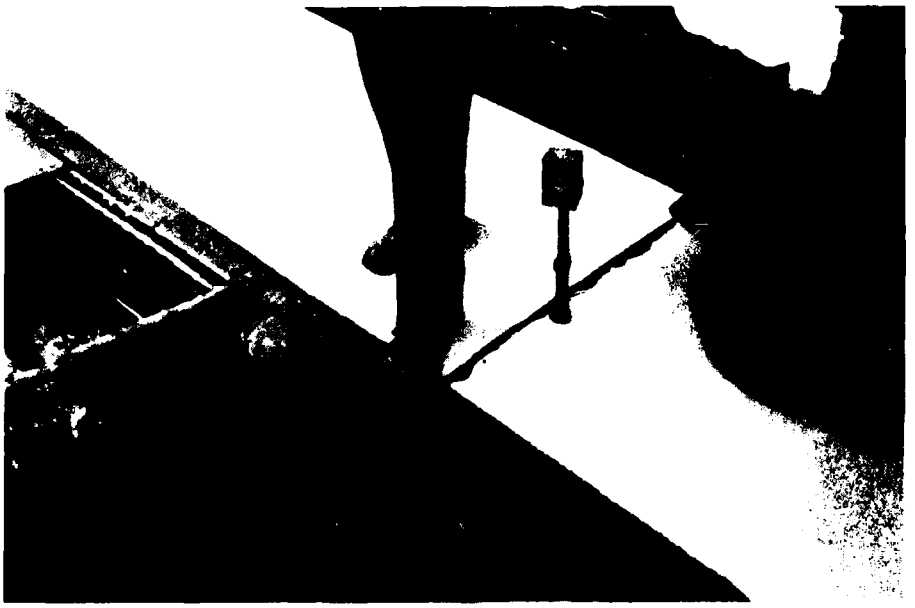

Figure 17. Finished end lap.

Figure 18. Completed roof membrane - area B.

Figure 19. Removing roofing system damaged from failed seal-off.

Figure 20. Installing primer on insulation cricket.

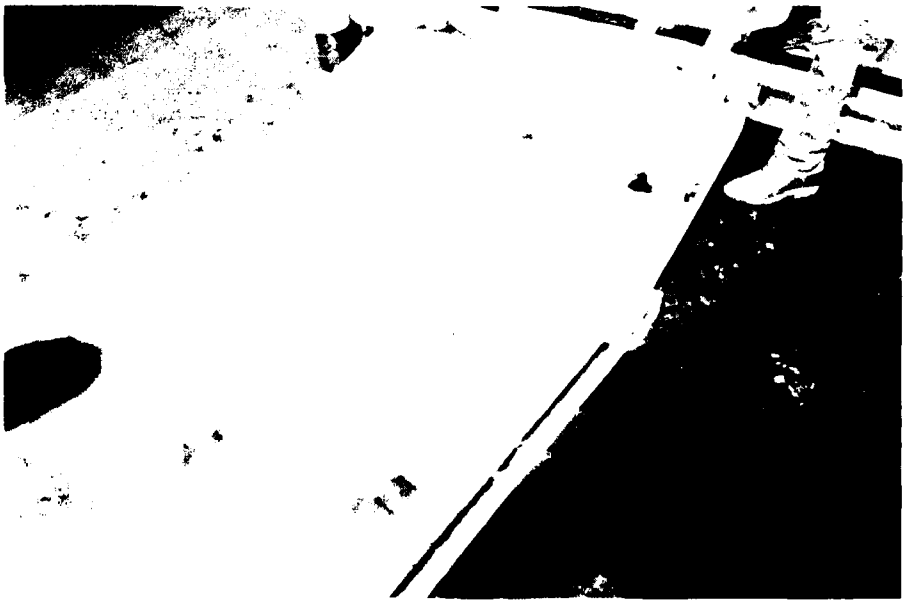

Figure 21. Removing release paper from bottom of membrane roll.

Figure 22. Applying white vinyl acrylic coating.

4 SUMMARY

Three modified bitumen test roofs were constructed on Building 920 at Fort Polk, LA: a torch-applied APP modified membrane, a hot-mopped SBS modified membrane, and a self-adhered modified membrane. Construction of the test roofs was satisfactory with minor problems such as inadequate housekeeping, nonavailability of materials, improper material handling, and inadequate seal-offs between the new roofing and existing roof. These problems were not attributable to modified bitumen roofing systems specifically but are problems characteristic of roofing practice in general.

Testing of samples from these roofs each year, as well as annual visual inspections, will be performed for 10 years.

REFERENCES

E. Marvin, et al., *Evaluation of Alternative Reroofing Systems*, Interim Report M-263/ADA071578 (U.S. Army Construction Engineering Research Laboratory [USACERL], June 1979).

M. Rosenfield, *An Evaluation of Polyvinyl Chloride (PVC) Single-Ply Membrane Roofing Systems*, Technical Report M-284/ADA097931 (USACERL, March 1981).

M. Rosenfield, *Evaluation of Sprayed Polyurethane Foam Roofing and Protective Coatings*, Technical Report M-297/ADA109696 (USACERL, November 1981).

M. Rosenfield, *Initial Investigation of Three Uncured Elastomeric Roofing Membrane Materials for Use in Military Construction*, Interim Report M-86/03/ADA165620 (USACERL, February 1986).

M. Rosenfield, et al., *Initial Investigation of Modified Bitumen Roofing Systems for Use in Military Construction*, Interim Report M-86/21/ADA177002 (USACERL, November 1986).

M. Rosenfield, W. Rose, and W. Dillner, *Investigation of Standing Seam Metal Roofing*, Technical Report M-86/10/ADA172614 (USACERL, June 1986).

APPENDIX:

TECHNICAL PROVISIONS FOR CONTRACT SPECIFICATIONS

MODIFIED BITUMEN INVESTIGATION

STATEMENT OF WORK

1. BACKGROUND. This project is part of an ongoing Research and Development Testing program. Since 1978, USA-CERL has been investigating non-conventional roofing systems for potential use by the Army. The objective of these investigations is the development of guide specifications to be included in the Corps of Engineers Guide Specification (CEGS) system. Several roofing systems have already been installed at various installations in CONUS (see attached map). Other systems are planned for future years. During the 10-year period after installation, the systems are tested by taking periodic samples to determine changes in properties and to develop maintenance and repair methods for use as the systems age and deteriorate. The guide specifications for installation of these systems will specify procedures which will result in a reduction of maintenance costs during their subsequent life.

2. ROOFING SYSTEMS.

a. Three specific modified bitumen systems will be installed where indicated under this contract. Other specific systems will be installed at other locations in CONUS. The systems included in this contract are as follows:

Torch applied:
Hot mopped:
Self-adhered:

b. As far as is practicable, the manufacturer's complete system will be installed, including insulation, vapor retarder where specified, adhesives, bitumens, and all other materials furnished or recommended by each manufacturer for his own system. Each roofing system shall bear a UL Class A rating.

3. WORK TO BE PERFORMED.

a. The existing system shall be completely removed down to the deck. The deck shall be inspected, cleaned, repaired and prepared as necessary to receive the new roofing system. Existing sheet metal roof edges and other flashing items shall be removed and disposed of as directed in the SPECIAL CONTRACT REQUIREMENTS. New stainless sheet metal shall be installed.

b. All roof-top equipment shall be carefully removed, stored as directed, and reinstalled after completion of the work. Nailers and curbs shall be removed and replaced with new lumber. All penetrations and expansion joints shall be approximately 8 inches above the top of the finished roof surface. Openings shall be covered temporarily with plywood and roof membrane while equipment is stored elsewhere. Air intake and exhaust openings shall not be sealed but shall be hooded to permit flow of air. Existing drains shall be completely cleaned of dirt and asphalt. Broken screens shall be replaced with new cast iron screens.

c. All work shall be coordinated so that all materials removed each day shall be replaced the same day with the complete roofing system and sheet metal flashings. Smoking will not be permitted on the roof.

SECTION 7A

INSULATION FOR MODIFIED BITUMEN MEMBRANES

1. APPLICABLE PUBLICATIONS: The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

1.1 American Society for Testing and Materials (ASTM) Publications:

C 726-81	Mineral Fiber and Mineral Fiber, Rigid Cellular Polyurethane Composite Roof Insulation Board
C 728-82	Perlite Thermal Insulation Board
D 41-78	Asphalt Primer Used in Roofing, Dampproofing and Waterproofing
D 226-81	Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing
D 312-84	Asphalt Used in Roofing
D 2626-81	Asphalt-Saturated and Coated Organic Felt Base Sheet Used in Roofing
D 2822-75	Asphalt Roof Cement
E 96-80	Water Vapor Transmission of Materials

1.2 Federal Specifications (Fed. Spec.):

HH-I-1972/GEN	Insulation Board, Thermal, Faced Polyurethane or Polyisocyanurate
HH-I-1972/2	Insulation Board, Thermal, Polyurethane or Polyisocyanurate Faced with Asphalt/Organic Felt, Asphalt/Asbestos Felt or Asphalt/Glass Fiber Felt on Both Sides of the Foam

1.3 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Publication:

Handbook, Fundamentals (1981 and Errata).

1.4 Factory Mutual System (FM) Publications:

1-28 (May 1983)	Insulated Steel Deck
Approval Guide 1987	Equipment, Materials and Services for Property Conservation

1.5 American Wood Preservers Bureau (AWPB) Publications:

LP 2-80	Softwood Lumber, Timber and Plywood Pressure Treated with Water-Borne Preservatives for Above-Ground Use
LP 22-80	Softwood Lumber, Timber and Plywood Pressure Treated with Water-Borne Preservatives for Ground Contact Use.

2. STORAGE OF MATERIALS: Insulation and felts shall not be exposed to moisture in any form before, during or after delivery to the site. Insulation and felts shall be stored in an enclosed building or in a closed trailer. Wet materials shall not be used and shall be removed from the worksite. Felt rolls shall be stored on end. For 24 hours immediately before laying, materials shall be maintained at a temperature above 50 degrees F. Urethane, isocyanurate and composite board insulation shall be stored away from areas where welding is being performed or where contact with open flames is possible.

3. SUBMITTALS:

3.1 Computations used for determining insulation thickness shall be submitted for approval. Where a vapor retarder is to be installed, computations shall show that the dew point is above the vapor retarder.

3.2 Adhesives and Fasteners: The Contractor shall submit proof that adhesives and fasteners meet the requirements of Underwriters Laboratories, Inc., or Factory Mutual Corporation.

3.3 Certificates: The Contractor shall submit certificates that materials meet specification requirements.

3.4 Samples shall be submitted as follows:

3.4.1 Insulation Board: One square foot minimum of each type, showing manufacturer's label.

3.4.2 Asphalt: One quart in a sealed can, drawn from the kettle.

3.4.3 Felt: One square foot showing manufacturer's label.

3.4.4 Fasteners: Six of each type.

3.4.5 Tape: One foot of each type.

3.5 Quality Control Documentation: Reports of actual quality control observations and inspections shall be documented and a copy of the documentation furnished to the Contracting Officer at the end of each day. This paragraph does not apply if Quality Control is performed by others.

4. LABELS: The flash point (FP), equiviscous temperature (EVT) and ASTM specification number and type shall be indicated on each container of asphalt or the delivery ticket for asphalt delivered in bulk.

5. THICKNESS OF INSULATION: Installed thickness of insulation shall be such as to provide a coefficient of heat transmission or U-value, through the completed roof construction air-to-air, not in excess of _____ BTU per hour per square foot per degree F temperature difference, when determined for winter conditions in accordance with recognized methods in agreement with the ASHRAE handbook. The thickness of isocyanurate insulation or the urethane component of composite board insulation shall be calculated using a K-value of 0.16. Roof construction air-to-air may include finish ceilings, provided unceilinged areas do not occur under the same roof area, or space above the ceiling is not vented to the exterior or used as a plenum. (Unceilinged mechanical rooms

need not be considered when computing the required thickness of insulation.) Insulation thickness shall be uniform over common roof areas. Insulation boards shall be furnished in the manufacturer's standard thicknesses.

6. MATERIALS:

6.1 Insulation:

6.1.1 Perlite Board: ASTM C 728, in 3-foot by 4-foot boards. Thickness shall be as recommended by the manufacturer to span the flutes in steel decks.

6.1.2 Mineral Fiber Board: ASTM C 726, faced with asphalt and kraft paper, in 3-foot by 4-foot boards, not thicker than 2-7/16 inches. Thickness of boards installed directly on steel decks shall be as recommended by the manufacturer to span the flutes.

6.1.3 Polysiocyanurate Board: Fed. Spec. HH-I-1972/GEN and HH-I-1972/2, Class 2 or 3, with a minimum compressive strength of 35 psi, faced with asphalt/glass fiber felt, in 3-foot by 4-foot boards.

6.2 Fasteners shall conform to Factory Mutual Approval Guide requirements for Class I or II Fire Rated Steel Decks and I-___ Windstorm. Fasteners shall be corrosion-resistant. Galvanized or zinc or cadmium plated fasteners shall not be used.

6.3 Tape for Insulation Joints: As required and furnished by membrane manufacturer.

6.4 Asphalt: ASTM D 312, Type III or IV, as specified in SECTION 7B.

6.5 Asphalt Cement: ASTM D 2822, Type II.

6.6 Asphalt Primer: ASTM D 41.

6.7 Vapor Retarder:

6.7.1 Asphalt-Saturated Felt: ASTM D 226, Type I.

6.7.2 Laminate Sheet: Laminate shall consist of polyethylene sheet between plies of reinforced kraft paper. Laminate sheet shall have a vapor permeance rating of less than 0.5 perm when tested by the water method in accordance with ASTM E 96 and shall be resistant to puncture, abrasion, and tearing.

6.8 Wood Nailers: Number 2 or better grade lumber treated with water-borne preservatives in accordance with AWPB LP 2 or LP 22, except that acid copper chromate (ACC) shall not be used. Fasteners for attaching new or replacement nailers to the deck or structure shall be similar in size and type to the existing fasteners.

7. APPLICATION:

7.1 Surfaces shall be inspected and approved by the Contracting Officer prior to application of materials.

7.2 Materials shall not be applied under damp or wet conditions, excessive wind conditions, or unless the ambient temperature is at least 40 degrees F and rising.

7.3 Perlite Insulation shall be applied as the first layer on steel decks if isocyanurate boards are used as the upper layers. Perlite boards shall be mechanically attached to the steel deck in accordance with FM Data Sheet 1-28 for I___ wind conditions. Boards shall be laid in parallel courses with end joints staggered. Edges shall be fully supported on the steel deck. Boards shall be tightly butted against each other but shall not be kicked into position. Boards shall be cut to fit neatly against adjoining surfaces.

7.4 Mineral Fiber Insulation shall be mechanically fastened to steel decks as specified for perlite insulation if the deck is to be considered as uninsulated or if applied as the first layer of only mineral fiber insulation. Joints in mineral fiber insulation shall be taped in accordance with the manufacturer's instructions.

7.5 Vapor Retarder shall be applied to the surface of the first layer of insulation on steel decks or directly to the primed surface of a concrete deck. Primer shall be applied at a rate of one gallon per square. Joints in pre-cast concrete decks shall be taped after priming with a 4-inch strip of roofing felt, embedded in and coated with bituminous cement.

7.5.1 The asphalt-applied vapor retarder shall consist of two plies of asphalt-saturated felt, mopped on at right angles to the direction of slopes. Felts shall be solid mopped directly to the concrete deck or insulation. Plies shall be lapped 19 inches and solid mopped between plies. Felts shall be laid in 15 to 25 pounds of asphalt per square. As each course of felt is mopped into hot asphalt, it shall be broomed-in full width to obtain complete adhesion between plies and to eliminate air pockets. Asphalt shall be visible at each edge of each sheet as felt is applied. The method of mopping a half-sheet width and turning the sheet back to mop under the other half shall not be used. Workmen shall not walk on the felts while laying them or brooming or while the asphalt is sticky. At walls, eaves and rakes the two layers of felts shall be extended and turned back 9 inches or separate sheets shall be applied with not less than 9 inches on the roof deck or insulation and turned back 9 inches. The turnback shall be mopped in over the top of the vapor retarder. Bitumen or bituminous plastic cement shall be used at eaves and rakes under the vapor retarder for not less than 9 inches. Vapor retarder or separate sheets shall be turned back over edges of insulation board at roof penetrations and locations other than parapet walls, eaves and rakes.

7.5.2 In lieu of the saturated-felt vapor retarder described above, laminate sheet-type vapor retarder may be used. The laminate sheet-type vapor retarder may be used. The laminate sheet shall be solidly cemented to the substrate as recommended by the manufacturer. Single-sheet membranes shall be applied with not less than 2-inch side laps and 6-inch end laps solidly cemented. Adhesive shall be compatible with contact surfaces.

7.6 Installation Requirements for Insulation:

7.6.1 Insulation shall be laid in two layers above the vapor retarder. Boards shall be laid in parallel courses with end joints staggered. Joints in second layer shall be staggered with respect to joints in first layer. Boards shall be cut to fit neatly against adjoining surfaces. Each layer shall be set in a full mopping of at least 20 pounds of asphalt per square. Boards which can be readily lifted after installation shall not be considered to be adequately secured. Boards shall not be kicked into position but may be stepped on and scored as required to establish complete securement. Asphalt shall not be applied farther than one panel length ahead of the roof insulation board being installed.

7.6.2 Asphalt shall be solid-mopped or applied with a spreader. Asphalt shall be applied at a temperature range between 25 degrees F below to 25 degrees F above the EVT as stated by the manufacturers. Application temperature shall be measured at the mop bucket or mechanical applicator. Asphalt below this temperature range shall be returned to the kettle. Asphalt shall not be heated higher than 75 degrees F above the EVT or 50 degrees F below the flash point, whichever is lower. Kettleman shall be in attendance at the kettle at all times during heating to ensure that the maximum temperature is not exceeded. Kettle shall have visible accurate thermometer and thermostatic control set to the required temperature. EVT and flash point temperatures shall be conspicuously posted on the kettle.

7.7 Protection Requirements: The insulation shall be kept dry at all times and shall be laid just before the application of the roofing membrane. No more insulation shall be laid than can be covered with same day with the complete roofing system. Exposed edges of the insulation shall be protected by cutoffs at the end of each work day or whenever precipitation is imminent. Cutoffs shall be two layers of roofing felt set in asphalt cement. Insulation edges shall be straightened as necessary by using loose-laid cut boards prior to sealing the termination. Cutoffs and cut boards shall be removed and discarded when work is resumed.

7.8 Nailers and Boards:

7.8.1 Wood nailers shall be installed on the perimeter of roof surfaces, curb flashing, expansion joints, and similar penetrations. Replacement members shall be same size as existing unless otherwise indicated. Surface of all nailers shall be flush with the surface of the insulation unless otherwise indicated. Nailers shall be installed using fasteners to match the existing with size and spacing as indicated.

7.8.2 Wood blocking two or more pieces high shall have end joints staggered at corners and with at least 12 inches offset in long runs. Top of blocking for penetrations and expansion joints shall be at least 8 inches above finished roof surface except as indicated. Wood surfaces cut in the field shall be brushed with copper naphthenate solution.

7.8.3 Cants shall be made of treated wood and shall be installed where indicated. Cants shall be set in asphalt cement and nailed to adjacent blocking or nailers.

SECTION 7B

MODIFIED BITUMEN MEMBRANE ROOFING AND METAL FLASHING

1. APPLICABLE PUBLICATIONS: The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

1.1 American Society for Testing and Materials (ASTM) Publications:

A 167-82	Stainless and Heat-Resisting Chromium Nickel Steel Plate, Sheet and Strip
D 312-84	Asphalt Used in Roofing
D 2822-75 (R1982)	Asphalt Roof Cement
D 2824-82	Aluminum-Pigmented Asphalt Roof Coatings
D 3672-84	Venting Asphalt-Saturated and Coated Inorganic Felt Base Sheet Used in Roofing

1.2 Federal Specifications (Fed. Spec.):

TT-S-00230C & Am 2	Sealing Compound: Synthetic Rubber Base, Single Component (for Caulking, Sealing and Glazing in Buildings and Other Structures)
TT-S-01543A	Sealing Compound: Silicone Rubber Base (for Caulking, Sealing and Glazing in Buildings and Other Structures).

2. GENERAL: The specified roofing membrane materials shall be applied to the roof surfaces indicated. Membrane shall be furnished in rolls of the manufacturer's standard width and shall be free of pinholes, lumps, foreign materials, and other imperfections. The complete roofing system shall bear a UL Class A Rating.

2.1 Delivery and Storage: Materials shall be delivered to the job site in the manufacturer's original unopened packages, clearly marked with the manufacturer's name, brand name and description of contents. Membrane materials shall be stored in clean, dry areas at a temperature between 60 degrees F and 80 degrees F. Membrane rolls shall be stored on end. Materials stored out-of-doors shall be on pallets and covered with canvas tarpaulins. Canvas shall end just below the top of the pallet but shall not touch the ground. Plastic sheets shall not be used as covers.

2.2 Coordination: Membrane application shall be coordinated with roof insulation work so that all insulation applied each day is weatherproofed the same day with the complete roofing system.

2.3 Performance Test: The proposed procedure for forming seams shall be demonstrated on two pieces of membrane at least 10 feet long and 18 inches wide. Demonstration shall include lapping and sealing the two pieces of membrane together along the long dimension, inspecting the completed seam, correcting identified faults, and sealing the seam edge if part of the manufacturer's procedure. Upon completion, the Contracting Officer will inspect the seam using cut samples, and approve the procedure before any work is initiated

on the roof. If the procedure is found unacceptable, the Contracting Officer may require a second test or changes in the procedure or both. The accepted seam shall remain with the Contracting Officer for further Government testing.

3. SUBMITTALS WITH THE BID: The following shall be submitted with the bid in accordance with the SPECIAL CONTRACT REQUIREMENTS:

3.1 Certificate from the membrane manufacturer identifying the installer and certifying that the installer has been approved by the manufacturer for at least one year prior to the date bid opening.

3.2 Complete list of modified bitumen roofing systems applied by the installer during the preceding two years stating the size of each job, the specific material installed, and the name and telephone number of a person at the location of each job to contract.

4. SUBMITTALS AFTER AWARD: The following shall be submitted within 30 days after the contract is awarded, in accordance with the SPECIAL CONTRACT REQUIREMENTS. Work shall not begin until all submittals have been approved.

4.1 Certificate of Compliance certifying that all materials for the complete system meet the specification requirements and the standards as published by the manufacturers.

4.2 Samples: The following samples will remain the property of the Government:

Membrane:	1 complete roll of each material as shipped from factory
Sheet Metal:	1 foot of each formed section
Primer:	1 gallon of each type in a sealed container
Adhesive:	1 quart of each type in a sealed container
Sealant:	1 standard tube or container of each type

4.3 Manufacturer's Instructions for installation of each roofing system, including separate instructions for cutoffs and terminations if printed instructions do not contain such procedures, and coating application.

4.4 Shop Drawings showing arrangement of sheets, location of splices, and complete details of roofing installation, including all flashings at roof edges and penetrations. Standard manufacturer's catalog or other typical details shall not be reproduced and submitted as shop drawings.

4.5 Manufacturers' Literature describing the membrane systems, including copy of standard warranty.

5. MATERIALS:

5.1 Membranes shall have modifier contents as follows:

5.1.1 SBS modifier not less than 10 nor more than 15 percent.

5.1.2 Polypropylene modifier not less than 30 nor more than 45 percent.

5.2 Coating: ASTM D 2824, Type I, or as recommended by the membrane manufacturer.

5.3 Primer Adhesives and Seam Sealers: as recommended by the membrane manufacturer.

5.4 Base Sheet: ASTM D 3672, Type II, as follows:

5.4.1 Unperforated for torched systems

5.4.2 With spot-mopping holes for hot-applied systems.

5.5 Fasteners for attaching membranes and flashings to nailers and curbs shall be as furnished or recommended by the membrane manufacturers. Stainless steel flashing members shall be fastened with Type 302 or 304 stainless steel fasteners.

5.6 Sealant: Fed. Spec. TT-S-00230C, Type II, Class A, or Fed. Spec. TT-S-001543, Class A, one component elastomeric type.

5.7 Foam Tape: Norton Co. Type 780, PVC closed cell, medium density, 1/4-inch by 2-inch.

5.8 Expansion Joints: Expand-O-Flash prefabricated covers as indicated, with stainless steel flanges.

5.9 Asphalt: ASTM D 312, Type III or IV, as recommended by membrane manufacturer, with EVT, flash point, and ASTM Specification number and type indicated on each container or the delivery ticket for asphalt delivered in bulk. Asphalt shall have an EVT no lower than 425 degrees F.

5.10 Bituminous Cement: ASTM D 2822, Type I.

6. INSTALLATION: Installation shall comply with membrane manufacturer's approved instructions except as otherwise specified. Insulation surfaces shall be inspected and approved by the Contracting Officer prior to installation of base sheet or membrane. Sheets shall be lapped so that water flows over the lap. End laps shall be staggered, or may be spaced as recommended by the manufacturers.

6.1 Asphalt shall be applied at a temperature range between 25 degrees F below to 25 degrees F above the EVT as stated by the manufacturer. Application temperature shall be measured at the mop bucket or mechanical applicator. Minimum temperature for application of hot-mopped membrane shall be 400 degrees F. Asphalt at temperature below the allowable shall be returned to the kettle. Asphalt shall not be heated higher than 75 degrees F above the EVT or 50 degrees F below the flashpoint, whichever is lower. Kettleman shall be in attendance at the kettle at all times during heating to ensure that the maximum temperature is not exceeded. Kettle shall have visible accurate thermometer and thermostatic control set to the required temperature. EVT and flash point shall be conspicuously posted on the kettle.

6.2 Coating shall be applied to smooth surfaces if recommended by the manufacturer, after at least 30 days have passed following completion. Coating shall be applied in two coats, at an application rate of approximately one gallon per square for each coat. First coat shall be allowed to dry thoroughly before second coat is applied. Second coat shall be applied perpendicular to direction of application of first coat. Granular surfaces shall not be coated.

6.3 Cutoffs: If work is terminated prior to weatherproofing the entire area, the insulation edges shall be straightened as specified in SECTION 7A. The membrane shall be sealed as recommended by the manufacturer.

6.4 Installation of Torched Membrane:

6.4.1 Unperforated base sheet shall be spot-mopped to isocyanurate insulation. Spots shall be on nominal 9-inch centers, staggered, and shall provide for not less than 33 percent hold-down. Side laps shall be at least 2 inches and end laps at least 3 inches. A glaze coat of asphalt shall then be applied.

6.4.2 Membrane shall be heated with torches as rolls are applied. Edge of roll and lap edge of previously applied sheet shall both be heated so that roll is unrolled into liquid bitumen. When half the roll has been installed, pressure shall be applied to the lap while the remainder is being installed. Pressure shall be applied to end laps while being made. Membrane at curbs and other penetrations shall extend to the top of the blocking, or 8 inches above the finished roof surface. A second layer of membrane shall be applied as base flashing and nailed in accordance with the manufacturer's instructions or as indicated, and shall extend at least six inches out onto the roofing surface.

6.5 Installation of Hot-Mopped Membrane:

6.5.1 Perforated base sheet shall be laid dry on isocyanurate insulation and other surfaces as recommended by the membrane manufacturer, except that side laps shall be 2 inches and end laps 3 inches, minimum.

6.5.2 Membrane shall be unrolled into hot asphalt, applied at a rate of 15 to 25 pounds per square. Membrane shall be installed in one or two layers as recommended by the manufacturer. Laps in second layer shall be staggered with respect to laps in the first layer. Pressure shall be applied as membrane is unrolled to obtain complete adhesion and to eliminate air pockets. Asphalt shall be visible at each edge as membrane is applied. Membrane at curbs and other penetrations shall extend to the top of the blocking, or 8 inches above the finished roof surface. Metal base flashings shall not be installed. An additional layer of membrane shall be applied as base flashing and nailed in accordance with the manufacturer's instructions, or as indicated, and shall extend at least six inches out onto the roofing surface.

6.6 Installation of Self-Adhered Membrane:

6.6.1 Insulation surface shall be primed in accordance with the membrane manufacturer's approved instructions, using his recommended primer.

6.6.2 Starter roll at low edge of roof shall be set in accordance with the manufacturer's approved instructions. Subsequent rolls shall be set to the printed lap line. In the absence of printed lines, Contractor shall snap a chalk line to the manufacturer's recommended lap width. A roll of membrane shall be set to this line with the selvage edge at the field of the deck, and unrolled half way with the release paper still attached. Release paper shall be cut across the roll, taking care not to cut into the membrane. Pressure shall be applied to the unrolled portion next to the roll. Release paper shall be pulled and the roll applied, keeping the release paper in contact with the roll as close as possible to the substrate surface. Release paper shall not ride up the face of the roll. Care shall be taken to keep the edge of the roll aligned with the lap line. The unrolled half shall be rerolled to the cut end of the release paper and then applied in the same manner. Lap and end seams shall be made and sealed as recommended by the manufacturer. Membrane at curbs and other penetrations shall extend to the top of the blocking or 8 inches above the finished roof surface. An additional layer of membrane shall be applied as base flashing and nailed in accordance with the manufacturer's instructions, or as indicated, and shall extend at least six inches out onto the roofing surface.

6.7 Sheet Metal: Stainless steel flashing members shall be furnished in 5-foot maximum lengths cut from the length of the sheet.

6.7.1 Roof edges: The lower edge shall be turned out to form a drip and turned back at least 3/4 inch to grip the edge strip or cleat. Ends shall be spaced 3/4 inch apart, with 4-inch wide cover plates over the gap. Roof flange and splice plates shall extend out on the roof not less than 4 inches and shall be set in bituminous cement on top of the membrane. Roof flange shall be secured with nails spaced not more than 3 inches on centers, staggered, with one row located within one inch of the edge of the flange. The fascia section shall not be nailed. Edge strip or cleat shall be nailed through the membrane into the wood blocking with nails spaced not more than 3 inches on centers. Each cover plate shall be fastened to the wood blocking with two nails centered between the ends of the roof edge lengths. Factory-fabricated corner units with mitered joints shall be provided with short dimension of each leg to be 12 inches. The flange shall be primed if recommended by the membrane manufacturers. A 12-inch wide strip of membrane material shall then be applied over the flange and back onto the roof.

6.7.2 Counterflashings shall be turned around exterior corners at least 2 inches, shall be secured to vertical surfaces with approved fasteners on 8-inch centers, and shall be sealed with sealing compound as specified. A strip of PVC foam tape shall be placed between the counterflashing and vertical surface. Perforations for fasteners shall be sealed with neoprene washers under the fastener head or nut. Top edge shall be turned out to form a groove for sealant. Bottom edge shall be turned out to form a drip and turned back at least 3/4 inch to grip the cleat. Ends shall overlap at least 3 inches. Cleats shall be secured to vertical surfaces with approved fasteners on 8-inch centers. Ends of cleats shall be spaced approximately 1/2 inch apart. Sealant shall be gun-applied with a nozzle of proper size to fit the width of the groove and shall be forced into the groove with sufficient pressure to expell air and fill the groove solidly. Sealant shall be uniformly smooth and free

of wrinkles. Joint shall be tooled slightly concave after sealant is installed. Surfaces adjoining the sealed joint shall be cleaned of smears and other soiling resulting from the sealing application as the work progresses.

7. WALKWAYS shall be provided where indicated. Walkways shall consist of an additional layer of membrane applied as recommended by the manufacturer.

8. WARRANTY: For one year after date of final acceptance by the Government, Contractor shall comply with the paragraph WARRANTY OF CONSTRUCTION in the GENERAL or SPECIAL CONTRACT REQUIREMENTS. Manufacturer's warranties shall be provided to warrant the roofs for the time as approved. The warranty shall be based on the standard warranty, modified as follows:

8.1 Areas of membrane which become unbonded from the base sheet or insulation surface shall be removed and new membrane shall be installed.

8.2 Areas of membrane which deteriorate because of fungus or algae attack shall be removed and new membrane shall be installed.

8.3 Insulation which becomes wet because of leaks in the membrane or flashings shall be removed and replaced with new insulation and membranes of the same type.