UFC 3-110-03
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UNIFIED FACILITIES CRITERIA (UFC)

ROOFING

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UNIFIED FACILITIES CRITERIA (UFC)

ROOFING

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes MIL-HDBK-1001/5, dated 28 February 1990.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

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- Whole Building Design Guide web site http://dod.wbdg.org/.

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AUTHORIZED BY:

DONALD L. BASHAM, P.E.
Chief, Engineering and Construction
U.S. Army Corps of Engineers

DR. JAMES W WRIGHT, P.E.
Chief Engineer
Naval Facilities Engineering Command

KATHLEEN I. FERGUSON, P.E.
The Deputy Civil Engineer
DCS/Installations & Logistics
Department of the Air Force

Dr. GET W. MOY, P.E.
Director, Installations Requirements and Management
Office of the Deputy Under Secretary of Defense (Installations and Environment)

UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Description of Changes: UFC 3-110-03 unifies the roofing design criteria for DOD.

Reasons for Changes:

- Uses industry standards such as National Roofing Contractor Association and Metal Building Manufacturer's Association to meet DOD requirements.

Impact: There are negligible cost impacts. However, the following benefits should be realized.

- By using the industry standards, on-going revision due to industry changes will minimize the need for future revisions.

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TABLES

CHAPTER 1 INTRODUCTION

1-1 **PURPOSE AND SCOPE**.

Use this UFC in conjunction with the current edition of the National Roofing Contractors Association (NRCA) *Roofing and Waterproofing Manual* (NRCA Manual) and the Metal Building Manufacturers Association (MBMA) *Metal Roofing Systems Design Manual* (MBMA Manual) to provide specific design guidance for Military roofing projects. This UFC explains how to apply the NRCA Manual and the MBMA Manual to the design of Military projects (including **Army**, **Navy**, and **Air Force**). It cannot be used independently as a design guideline. Further, use this UFC in conjunction with UFC 3-330-02A *Commentary on Roofing Systems*, which provides considerations in the selection of a roofing system.

1-2 **APPLICABILITY**.

This UFC is applicable to all military projects and contractors responsible for roofing system design, installation, and maintenance. Family housing requirements may differ from the requirements stated herein. Where one Military Service's criteria vary from the other Services' criteria, it is noted in the text.

1-3 **CONTENTS**.

Roofing design begins with system selection documented in UFC 3-330-02A followed by system design using this UFC, the NRCA Manual, and the MBMA Manual.

1-3.1 **System Selection**.

UFC 3-330-02A provides the major considerations in selecting a roofing system. It covers both new construction and reroofing existing structures. UFC 3-330-02A compares produce cost effective, long-lasting roofing systems. While UFC 3-330-02A provides general guidelines for selecting a system, Chapters 2 through 5 of this UFC provide details on many roofing systems and offer guidelines to selecting a system.

1-3.2 **System Design**.

The NRCA Manual and the MBMA Manual provide information regarding the design and construction of roofing systems. However, because of the emphasis on low life cycle cost, this UFC limits the applicability of certain techniques permitted by NRCA and MBMA. The NRCA Manual (fifth edition) comprises four volumes. Table 1-1 illustrates the relationship of this UFC with the NRCA Manual. Use the MBMA Manual for the design of metal roof systems in combination with the NRCA Manual. See Appendix B as appropriate.

Table 1-1. Relationship With NRCA Manual	
UFC 3-110-03	**NRCA Manual**
	Volume 1
Chapter 2	Low slope Membrane Roofing
Chapter 2	Design Guidelines for Low slope Membrane Roof Assemblies
	Volume 2
Chapter 3	Steep-slope Roofing
Chapter 4	**Use MBMA in combination with NRCA**
Chapter 2	SPF-based Roofing
	Volume 3
Chapter 5	Reroofing
	Volume 4
Chapter 2, 3 & Chapter 5	Construction Details

1-3.3 **Appendices**.

Appendix A is the glossary of acronyms and abbreviations. Appendix B is a reference list. Appendix C provides considerations on roof warranties. Appendix D provides quality assurance guidelines. Appendix E provides other resource documents.

1-4 **BACKGROUND**.

At no time in the history of roofing has there been such a wide choice of materials and roofing systems available. Satisfactory roofing performance comes from careful selection, design, specification, installation, and maintenance.

Roofing systems are exposed to the full brunt of the weather and can leak or fail prematurely if not properly designed, installed, and maintained. Leakage can be costly and adversely affect the functions within the building. Since modern roofing systems contain considerable thermal insulation, moisture intrusion lowers thermal efficiency and hinders energy conservation. Wet materials support fungus or mildew and can emit odors leading to sick buildings and occupants.

1-4 **SYSTEM SELECTION**.

There are two starting points in roofing system selection:

1-4.1 **New Construction**.

In new construction, the roof system selection is an integral part of the overall building design. For example, the building can be designed to support a heavy roof system or the roof can be sloped to accommodate the minimum requirements for the desired roof system.

1-4.2 **Existing Structure**.

When dealing with an existing structure, weight, slope, and existing materials all become constraints. For example, the weight of the roof has a major impact on structural design. Further, with an occupied building, construction noises, fumes, fire hazards, and roof access all take on increased importance.

1-5 **SYSTEM TYPES**.

The two main types of roof systems are steep slope and low slope.

1-5.1 **Steep Slope**.

Steep slope roofing systems are water-shedding types of roof coverings installed on slopes greater than 3:12 (14 degrees) and typically consist of asphalt shingles, slate, tile, and metal roofing.

1-5.2 **Low Slope**.

Low slope roofing systems are weatherproof membrane types of roof systems installed on slopes at or less than 3:12 (14degrees). Types of low sloped roofing systems include bituminous built-up (BUR), modified bitumen (MB) roofing, single-ply (i.e., PVC, EPDM), sprayed-in-place polyurethane foam (SPF), and standing seam metal roofing (SSMR).

CHAPTER 2 LOW SLOPE ROOFING DESIGN REQUIREMENTS

2-1 GENERAL.

The NRCA Manual provides a wide range of information for design and construction of low slope roofing assemblies. This chapter reinforces particularly salient information with regard to military use or limits the applicability of certain techniques in the NRCA Manual. Where contents of the NRCA Manual are acceptable without modification those sections are not mentioned herein.

2-1.1 Design-Bid-Build.

Prior to the specification of low slope roofing systems designers must analyze the life-cycle costs associated with various low slope roof system alternatives. Designer shall also refer to UFC 3-330-02A for roof selection criteria. Compliance with the appropriate Unified Facilities Guide Specifications (UFGS) is mandatory.

2-1.2 Design-Build.

Because of the wide variety of materials available and the variation in quality in similar materials, design-build contracts for low slope roofing systems must name the specific desired low slope roofing system (BUR, EPDM, etc.) and identify relevant performance requirements to be provided under the contract. It is not sufficient to simply specify a low slope roofing system per the NRCA Manual. Compliance with the appropriate UFGS is mandatory.

2-2 GENERAL LOW SLOPE ROOFING CONSIDERATIONS.

2-2.1 Thermal Expansion.

Design all low slope roofs for a minimum temperature difference of 66 ^{0} C (150 ^{0} F).

2-2.2 Moisture Control Using a Vapor Retarder.

The designer must perform a dew point calculation to verify that the vapor retarder has been positioned correctly in the roof assembly. Provide a moisture/ condensation analysis in a project's design analysis based on the current version of ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* and Standard 90.2, *Energy-Efficient Design of Low-Rise Residential Buildings.* Care must be taken to maintain the continuity of the roof vapor retarder, which is critical to its performance. Moist air leakage through poorly installed vapor retarders defeats their purpose and creates interior moisture problems.

2-2.3 Positive Drainage.

The minimum slope for construction of new buildings is ½:12 to achieve positive drainage.

A slope of ¼:12 may be acceptable for large roof areas in certain conditions. On Navy projects a slope of ¼:12 may be acceptable for large reroofing projects in certain conditions such as where existing construction constraints (e.g. windows sills) limit the ability to increase slope. Prepare calculations to determine the minimum drainage requirement using the calculation method as specified in the Sheet Metal and Air Conditioning Contractors National Association's (SMACNA) *Architectural Sheet Metal Manual* (current edition) in addition to recognized standards and applicable Code requirements. Obtain the rainfall component for the calculation from the building official local to the project site or UFC 3-400-02, *Engineering Weather Data*.

2-2.4 **Roof Curb Heights**.

Curbs must be high enough to not void the roof system warranty: 200 mm (8 in.) above the finished roof surface is the minimum for military construction. Roofs with slope may need additional crickets to assure positive drainage around equipment.

2-2.5 **Roof Hatch**.

All buildings over two stories must have a roof hatch or building-attached exterior ladder for roof access. Roof hatches are recommended for all buildings over one story. Coordinate with UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings*.

2-2.6 **Snow and Ice Considerations**.

Most steep roofs drain over their eaves. Some low slope roofs also drain to eaves, but most drain internally. Over-the-eaves drainage in cold climates can be problematic if snow and ice issues are not considered early in the design process. Issues that designers should consider are contained in the Cold Regions Research & Engineering Laboratory (CRREL) report MP-01-5663, *Minimizing the Adverse Effects of Snow and Ice on Roofs.*

2-2.7 **Wind Resistance Rating**.

Determine roof pressures and pressure zones in accordance with ASCE-7, *Minimum Design Loads for Buildings and other Structures*. Coordinate component selection and required attachments to obtain the required wind resistance rating.

2-3 **ROOF DECKS**.

2-3.1 **Deck Slope**.

For new construction, the minimum slope noted in paragraph 2-2.3 must be accomplished in the structural deck.

2-3.2 **Types of Roof Decks**.

2-3.2.1 **Steel Decks**. Steel roof decks are common on military facilities. When properly designed, they provide an economical and dependable roof deck. They are lightweight and are particularly useful where relatively large clear spans are desired.

Mechanically attach roof insulation for this type of roof deck, however, due to their lightweight and flexibility, take care to prevent mechanical fasteners from backing out enough to disengage the deck. Also, the design of the roof insulation must be tolerant of a small degree of fastener back out. Two layers of insulation are required. The first layer must be mechanically fastened. The second layer should be mechanically attached or fully adhered in order to obtain the desired FM wind resistance classification.

2-3.2.2 **Structural Concrete Decks**. Structural precast and poured-in-place concrete roof decks are also commonly used on military projects. They are heavy and are best suited to roof decks with relatively short spans. Minimize the use of mechanical insulation fasteners to ensure the structural integrity of the deck. Due to the inherent moisture in the concrete, take care during system selection and installation to ensure that adequate bonding takes place between the roof system and the deck.

2-3.2.3 **Wood-Plank and Structural Wood-Panel Decks**. Wood-plank and structural wood-panel decks were used in the past on many military facilities. Generally this material should only be used on small buildings or in reroofing when the existing material is in fair or better condition. Use of this material on new buildings must be supported with strong arguments demonstrating that neither steel nor structural concrete decks fulfill the specific functional requirements.

2-3.2.4 **Cement-Wood Fiber Deck Panels**. Cement-wood fiber deck panels have limited utility due to concerns about moisture susceptibility. This type of deck shall not be used for new construction.

2-3.2.5 **Lightweight Insulating Concrete Decks**. Lightweight insulating concrete decks have limited utility due to concerns about ease of repair. Do not use this type of roof deck for new construction.

2-3.2.6 **Poured Gypsum Concrete Decks**. Poured gypsum concrete decks have limited utility due to difficulty in attaching membranes to the deck and difficulty in repair. Do not use this type of roof deck for new construction.

2-3.2.7 **Precast Gypsum Panel Decks**. Precast gypsum panel roof decks have been used on many military facilities. However, where membrane leaks have occurred, these roof decks pose a safety hazard due to structural instability. Do not use this type of roof deck for new construction.

2-3.2.8 **Thermosetting Insulating Fills**. Thermosetting insulating fills have limited utility. Do not use this type of roof deck for new construction.

2-4 **RIGID BOARD ROOF INSULATION**.

2-4.1 **General**.

Roof insulation is a very cost-effective means of reducing energy consumption. Depending on climate and the type of membrane selected, the position of the insulation in the roof system greatly affects the performance of the roof system. Insulation system shall be selected and designed to meet the mechanical system's design and energy requirements of the facility.

2-4.2 **Types of Roof Insulation**.

2-4.2.1 **Cellular Glass Insulation**. Cellular glass roof insulation is not widely used due to its high cost. It is most commonly used in cold storage facilities and other areas where excessive amounts of moisture would degrade the insulating capabilities of other types of insulation.

2-4.2.2 **Perlite Board Insulation**. Perlite board insulation is commonly used and may be specified where factors other than insulating efficiency per unit thickness are the primary design considerations. It is particularly useful in roof assemblies where fire resistance is of primary concern and the potential for water vapor intrusion is limited.

2-4.2.3 **Polyisocyanurate Foam Board Insulation**. Polyisocyanurate foam board is the most commonly used roof insulation. It is often specified where insulating ability is the primary design consideration. However, it is frequently necessary to use perlite or wood fiberboard in the roofing assembly to protect the polyisocyanurate from physical damage, to improve fire resistance, or to provide a suitable surface for adherence of the roof membrane.

2-4.2.4 **Polystyrene Board Insulation**. Polystyrene board roof insulation is used by the military and is made in two types: molded expanded board (EPS) and extruded expanded board (XPS). In terms of moisture resistance and insulating capability, XPS is superior to EPS. It is also more expensive but appropriate for use in inverted membrane systems and cold storage facilities. Do not use polystyrene in direct contact with hot mopped systems. For the same reasons as with polyisocyanurate insulation, it is frequently necessary to use perlite or wood fiberboard to meet other design requirements in the roof assembly. When polystyrene is used on the interior of a building it must be encased with a fire resistive material.

2-4.2.5 **Wood Fiberboard Insulation**. Wood fiberboard roof insulation has been commonly used in military roof systems and may be specified where factors other than insulating efficiency per unit thickness is the primary design consideration. It most commonly used as the top layer of insulated roof assemblies where the roof membrane will be adhered to the wood fiberboard. Wood fiberboard is more stable in assemblies where moisture is limited.

2-4.2.6 **Composite Board Insulation**. Composite board roof insulation may be specified where a multiple layer type of insulation does not satisfy all design requirements, and where there are cost savings available from reducing the number of construction operations needed to install two different kinds of roof insulation. Single layer applications should be limited when possible.

2-4.2.7 **Phenolic Foam Board Insulation**. Phenolic foam board insulation causes severe corrosion when in contact with steel roof decks. It is no longer manufactured in the United States. When this material is found in existing installations it must be replaced as part of the project and may not be specified for use. An in-depth evaluation of the metal deck condition is required when phenolic foam insulation is found.

2-4.2.8 **Tapered Insulation Systems**. Tapered rigid board roof insulation systems are more expensive per square unit than non-tapered insulation. As a result, do not use tapered insulation to create the primary slope in new construction. Use tapered insulation in crickets and saddles to ensure positive drainage when adequate drainage already exists in the roof deck as a whole.

2-4.2.9 **Silicon-modified gypsum board**. Commonly used as a recover board provides improved impact resistance to single ply membranes and improved fire resistance.

2-5 OVERVIEW OF ROOF MEMBRANES.

The NRCA Manual discusses all available roof membranes, however, some membranes do not provide the long-term performance objective of military buildings. Some new products may not be judged suitable because of the lack of proven performance. Other existing membrane systems may not be suitable because experience has shown a lack of cost effectiveness over the required life cycle.

2-5.1 Types of Membranes.

Generally roof membranes that are suitable for use by the military are limited to the following:

a. Hydrostatic metal roofing (covered in Chapter 4).

b. Built-up roof membranes.

c. Styrene butadiene styrene (SBS) or Atactic polypropylene polymer (APP) modified bitumen membranes.

d. Ethylene propylene diene monomer (EPDM) single-ply membranes.

e. Weldable thermoplastic polyvinyl chloride (TPC) single-ply membranes.

f. Spray applied polyurethane foam (SPUF) membranes.

2-5.2 Other Roof Membranes.

Other roof membranes will be considered and evaluated on a case-by-case basis.

2-6 GUIDANCE FOR ROOF MEMBRANES.

This Section provides requirements and considerations for the design and construction of the above roof membrane types.

2-6.1 **Built-up Roof (BUR) Membranes**.

BUR systems have broad applicability for dependable low slope roof systems with low service life cost. Consider this roof system unless it can be shown that it fails to meet important design criteria. Positive attributes of BUR membranes include:

a. Durability with long service life

b. Inexpensive

c. Easily modified for additional penetrations after the initial construction

d. Low maintenance

e. Well-understood maintenance procedures.

However, the success of this roofing system is based upon sound installation techniques accompanied by suitable quality control. More information on quality control can be found in Appendix D.

2-6.1.1 **Cant Strips**. Provide cant strips for all built-up roof systems.

2-6.1.2 **Fiberglass Mat Material**. BUR systems must use fiberglass mat felt material and no less than three-ply or as limited by the UFGS.

2-6.1.3 **Coal Tar Bitumen**. Use coal tar bitumen with caution due to the smell and caustic effect of fumes during construction. Do not use coal tar pitch on slopes above ¼:12.

2-6.1.4 **Roof Vents**. On BUR membrane systems, moisture relief vents have proven to be of no value in drying wet materials, and their effectiveness for pressure relief is questionable. Ventilating base sheets are required on all wet fill decks.

2.6.1.5 **Types of BUR Membrane Surfacing**. The three types of top surfacings for BUR membranes are smooth, mineral surfaced cap sheet, and aggregate.

2-6.1.5.1 **Smooth Surface BUR Systems**. Smooth surface BUR systems using coatings for protection tend to have a shorter service life than cap sheet or aggregate surfaced membranes. The most common coatings for smooth surface BUR systems are hot- and cold-applied, asphalt-based emulsions which may include aluminum or acrylic pigments. Aluminum coatings have a low emissivity and contribute to heat island effect. Smooth surface BUR systems require re-coating at two- to 10-year intervals depending on the type and quality of the coating, which significantly increases the life-cycle cost.

2-6.1.5.2 **Mineral Surface Cap Sheet BUR Systems**. These surfacings are mineral surfaced cap sheets embedded into hot or cold liquid applied asphalt. The surface granules are not organic; therefore, the surfaces last longer without maintenance than coatings used with smooth surface BUR systems. This fact tends to reduce somewhat their lifecycle cost. However, the BUR membrane temperature is the same as the temperature of the surfacing which adversely impacts the service life of the roof system. Therefore, expected longevity is approximately the same or just slightly more than a smooth surface BUR system. Mineral surfaced modified bitumen cap sheets can also be used where a mineral surface cap sheet BUR system is desirable and will provide longevity over the mineral surface cap sheet.

2-6.1.5.3 **Aggregate Surface BUR Systems**. The most common type of BUR surfacing is aggregate embedded in a bituminous flood coat. The thickness of 180 kg (400 lb.) gravel surfacing per square of roofing is 12 to 18 mm (0.5 to 0.75 in.). This surfacing allows the temperature of the BUR membrane to remain somewhat cooler than smooth surface or mineral surfaced cap sheet BUR systems. Aggregate surface BUR systems tend to have a longer expected service life than smooth surface or mineral surfaced cap sheet BUR systems because of lower membrane temperature and due to protection of the membrane by the aggregate. Restrict the use of embedded aggregate in areas with wind speeds of 161 km/hour (100 miles/hr) or greater and near aircraft flight lines.

2-6.2 **Modified Bitumen (MB) Membranes**.

MB roofing systems have low maintenance cost, and should be considered when long service life is required but aggregate surfacing is not practical. The polymers modify the asphalt bitumen and improve the performance characteristics of the asphalt. The addition of polymers increases low temperature flexibility and high temperature stability. MB membranes must have at least two-ply or as specified by the UFGS.

2-6.2.1 **Polymer Modifiers**. The two major types of bitumen modifiers used are an elastomeric Styrene Butadiene Styrene (SBS) polymer and a thermoplastic Atactic Polypropylene (APP) polymer. SBS systems are usually applied by hot mopping asphalt, however, torch varieties of SBS membranes are gaining prominence. Some SBS products are applied with cold adhesive or torching, and torch varieties of SBS membranes are becoming more common. APP systems are typically applied with propane torches, which necessitate special requirements for safe handling and storage. All torch-applied MB systems will utilize non-combustible cant strips at parapets and curbs. Only non-combustible materials may be used for torch-applied systems. The UFGS specifies a fire watch is required for each day for a period of time after the last torch is extinguished.

2-6.2.2 **MB Membrane Surfacings**. The three common types of surfacing used for the top sheet of MB systems are mineral surfaced, metal foil faced, and smooth surfaced.

2-6.2.2.1 **Mineral Surface MB Systems**. The addition of mineral granules reduces the temperature effect on MB systems. However, as granules are lost, degradation due to ultraviolet (UV) radiation will negatively impact performance. Longevity of these systems on average is not as great as aggregate surfaced BUR systems.

2-6.2.2.2 **Metal Foil Surface MB Systems**. Metal foils surfaced MB roof systems may be used to achieve for solar reflectivity or to improve fire resistance. Field experience indicates that metal foils can delaminate from the MB sheet, resulting in degradation of appearance and longevity.

2-6.2.2.3 **Smooth Surface MB Systems**. Many APP roofing systems are smooth surfaced. These membranes must be field coated for heat reflection and UV protection. These systems typically require maintenance recoating at five- to eight-year intervals.

2-6.3 **Ethylene Propylene Diene Monomer (EPDM) Membranes**.

EPDM roof membranes provide exceptional serviceability in roof systems where exposure to extremely cold temperatures is normal.

EPDM sheets are resistant to the effects of UV radiation and are very durable. Field seams of EPDM sheets have been problematic; however, seaming technology and adhesives have improved reliability with the use of tape-applied adhesive. Tape applied seams should be used when possible. Due to the adverse effect of moisture on seam adhesives, most manufacturers prohibit the use of EPDM membranes over deck materials with high moisture content such as lightweight insulating decks or poured gypsum decks.

2-6.3.1 **Mechanically Fastened EPDM Systems**. Mechanical fastening of EPDM roof systems allows some billowing of the membrane. This can be reduced by the use of fabric reinforcement sheets. The amount of billowing is dependent on the spacing of the mechanical fasteners and the pressure differential between the interior of the building and the exterior surface of the roof. Excessive billowing has been known to cause failure at the fasteners and at the seams.

2-6.3.2 **Fully Adhered EPDM Systems**. Fully adhered EPDM systems do not allow billowing of the membrane and are the preferred method of EPDM installation.

2-6.3.3 **Ballasted EPDM Systems**. Ballasted EPDM roof systems use larger sheets with factory made seams which are proven to be superior to field seams. The downside of ballasted roof systems is the need for stone ballast or concrete pavers, and the increased difficulty in detecting sources of leaks. The ballast is relatively heavy at 4.5 to 5.5 kg (10 to 12 lbs.) per 0.1 m^2 (1 $ft.^2$) that also increases the cost of the structural system. Factory Mutual accepts ballasted systems for Class 1-60 wind resistance rating; however, higher wind resistance ratings cannot be achieved with ballasted systems.

2-6.4 **Weldable Thermoplastic (PVC) Membranes**.

Thermoplastics are materials that are soften when heated and regain their physical properties upon cooling. PVC membranes are appealing as roofing systems because when the seams are properly heat welded they can exhibit seam strengths comparable to the membrane sheet. PVC membranes are usually white or other light colors to reduce solar heat gains. While the material costs are higher than bituminous-based roofing, labor costs are generally lower. Properly constructed PVC membrane systems may last 15 years or more.

2-6.4.1 **Mechanically Fastened PVC Systems**. Mechanical-fastened PVC systems allow some billowing of the roof membrane; however, this is greatly limited by reinforcement fabrics.

2-6.4.2 **Fully Adhered PVC Systems**. Fully adhered PVC systems do not allow billowing of the roof membrane and are the preferred method of installation.

2-6.4.3 **Ballasted PVC Systems**. Ballasted PVC systems can make use of larger sheets to reduce the amount of field seaming. The ballast is relatively heavy at 4.5 to 5.5 kg (10 to 12 lbs) per 0.1 m^2 (1 $ft.^2$). The downside of ballasted systems is the need for stone ballast, the increased cost of the building structure, and the difficulty of finding the source of leaks. Factory Mutual accepts ballasted systems for Class 1-60 wind resistance rating; however, higher wind resistance ratings cannot be achieved using a ballasted system.

2-6.5 **Spray Polyurethane Foam (SPUF) Membranes**.

SPUF systems provide good serviceability where non-planar surfaces prevent the use of other roofing systems. SPUF roof systems should be considered when leaking corrugated metal roof systems require repair and for curvilinear shapes that do not permit the use of other approved roof systems. In use over existing metal roofs careful review of impact on fire classification is required.

The principle components of the SPUF system are the polyurethane foam and the coating.

2-6.5.1 **Foam**. Trained and certified applicators are required because the foam is difficult to apply in uniform thickness, and is highly sensitive to moisture, UV radiation, and wind velocities in excess of 19 km/hr (12 miles/hr). Even brief exposure to UV radiation in sunlight significantly degrades the foam. Degradation is progressive and will eventually result in system failure.

2-6.5.2 **Coating**. Coatings are required for all SPUF roof systems. The coating protects the foam from UV degradation and must be applied to the foam as soon as possible after the foam has cured, but not more than 72 hours after foam installation.

The base coating should be a distinctly different color to provide an indication of the need for re-coating the roof system. The cost of replacing coatings is a significant component of the life cycle cost of SPUF roof systems.

2-7 **LOW SLOPE ROOF SPECIFICATIONS**.

The UFGS are more appropriate for the long-term needs of the military than the low slope specifications provided in the NRCA Manual. UFGS shall remain the basis for all roofing designs.

2-7.1 **Recommended Low Slope Construction Details**.

Use the NRCA Manual Volume 4 construction details as applicable, except as noted in Table 2-1. For details pertaining to low slope metal roofing, refer to Chapter 4 of this document. Design documents for individual projects must supplement these standard details with additional information related to closures, terminations, transitions, corners, lap and joint conditions, materials interface, sealant requirements, and other project specific conditions. Address all flashing requirements with a complete set of detail drawings. Minimize the use of pitch pans.

Table 2-1. Construction Detail Limitations For Low Slope Roofing	
NRCA Detail	**Comments**
BUR-4	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
BUR 4S	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
BUR 7A.	Do not use.
BUR-7AS	Do not use.
MB-4	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
MB-4S	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
MB-7A	Do not use.
MB-7AS	Do not use.
TS-4	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
TS-4S	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
TS-5	Termination Bar holes must be slotted for expansion and contraction.
TS-5S	Termination Bar holes must be slotted for expansion and contraction.
TS-7B	Do not use.
TS-7BS	Do not use.
SPF-4	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
SPF-4S	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
SPF-5AS	Lightweight insulating concrete not applicable.
SPF-7A	Do not use.
SPF –7AS	Do not use.
SPF-2 (FB)	Fleece-backed membrane not applicable.
SPF-5 (FB)	Fleece-backed membrane not applicable.
SPF-6 (FB)	Fleece-backed membrane not applicable.
SPF-11 (FB)	Fleece-backed membrane not applicable.
SPF-18 (FB)	Fleece-backed membrane not applicable.
SPF-20 (FB)	Fleece-backed membrane not applicable.
SPF-TABLE 2.2	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
Table 2.2	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
TP-4	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
TP-4S	For use only with concrete parapet walls where installation of a reglet and counter flashing inserted into the reglet joint is not possible.
TP-5	Termination Bar holes must be slotted for expansion and contraction.
TP-5S	Termination Bar holes must be slotted for expansion and contraction.
TP-7A	Do not use.
TP-7AS	Do not use.

CHAPTER 3 STEEP SLOPE ROOFING DESIGN REQUIREMENTS

3-1 **GENERAL**.

Steep slope roofing systems provide excellent performance and long service life. However, these roofing systems require structural supports that may become prohibitively expensive for large buildings. When considering the use of steep slope roofing systems, compare the cost with the cost of low slope systems. Cost comparisons should include maintenance as well as the cost of the roof and structure. Very steep sloped roofs present additional safety and maintenance issues that must be considered.

Chapter 3 limits the applicability of certain techniques permitted by the NRCA to focus on long life cycle military requirements. Where contents of the NRCA Manual are acceptable without modification, those sections are not mentioned.

3-1.1 **Design-Bid-Build**.

Prior to specifying steep slope roofing systems, analyze the life-cycle costs of the various systems, and refer to UFC 3-330-02A for additional selection considerations. Compliance with the appropriate UFGS is mandatory.

3-1.2 **Design-Build**.

Because of the wide variety of materials available and the variation in quality in similar materials, design-build contracts for steep slope roof systems must name the specific roofing material desired and identify relevant performance requirements to be provided under the contract. It is not sufficient to simply require a steep roof system per the NRCA Manual. Compliance with the appropriate UFGS is mandatory.

3-2 **GENERAL STEEP ROOFING CONSIDERATIONS**.

3-2.1 **Thermal Expansion**.

All metal roofs must be designed for a temperature difference (Delta T) of 93 ^{0} C (200 ^{0} F). All other roofs must be designed for a temperature difference of 66 ^{0} C (150 ^{0} F).

3-2.2 **Moisture Control – Vapor Retarder**.

The designer must perform a dew point calculation to verify that a vapor retarder is needed, and if needed, it has been positioned correctly in the roof assembly. A moisture/ condensation analysis must be provided in a project's design analysis based on the current version of ASHRAE Standard 90.1 and Standard 90.2.

3-2.3 **Curb Heights**.

Provide crickets on the up-slope side of all non-round penetrations on steep slope roofs. Curbs must be high enough to not void the roof system warranty, but shall not be less than 100 mm (4 in.) above the high point of a cricket.

3-2.4 **Roof Hatch**.

All buildings over two stories must have a roof hatch or building-attached exterior ladder for roof access. Roof hatches are recommended for all buildings over 280 m^2 (3000 $ft.^2$).

3-2.5 **Flashing**.

Flashing must be one of the following materials:

a. Prefinished aluminum at a minimum thickness of 0.813 mm (0.032 in.),

b. Aluminum at a minimum thickness of 0.813 mm (0.032 in.),

c. Copper at a minimum thickness of 454 g (16 ounces),

d. Stainless steel at a minimum thickness of 0.635 mm (0.025 in.),

e. Prefinished galvanized (G90) at a minimum thickness of 0.607 (0.0239 in.) may be used in locations expecting significant physical abuse or a building /roof life less than 15 years,

f. Lead coated copper 454 g (16 oz.) may be used at historical sites, and

g. Galvanized steel (G90) at a minimum thickness of 0.607 mm (0.0239 in.) may be used for a building/roof life less than 10 years.

3-2.6 **Snow and Ice Considerations**.

Most steep roofs drain over their eaves. Some low slope roofs also drain to eaves, but most drain internally. Over the eaves drainage in cold climates can be problematic if snow and ice issues are not considered early in the design process. Consider design contained in the CRREL report MP-01-5663, *Minimizing the Adverse Effects of Snow and Ice on Roofs*.

3-2.7 **Wind Resistance Rating**.

Determine roof pressure zones in accordance with ASCE-7. Coordinate component selection and required attachments in order to obtain the required wind resistance rating.

3-3 **ASPHALT SHINGLES**.

Asphalt shingles provide versatile, low-cost steep slope roofing. To ensure a quality consistent with other roofing systems the following requirements apply.

3-3.1 **Slopes**.

Asphalt shingles may not be used on slopes lower than 4:12 for new construction.

3-3.2 **Wind Pressure**.

In areas where the roof deck design is required to resist wind pressures of 220 kg/m^2 (45 $lbs./ft.^2$) or more as determined by ASCE 7, the manufacturers' high wind design and installation requirements apply. This may include requiring six (6) nails per shingle as determined by applicable building code, wind speed, slope, and building height.

3-3.3 **Perimeter Drip Edge**.

Perimeter drip edges are required for all high slope roof systems installed over wood decks.

3-3.4 **Valley Flashing**.

Closed cut valley flashing may not be used.

3-3.5 **Special Underlayment**.

Special underlayment is defined as one layer of self-adhering polymer-modified asphalt bitumen membrane. Special underlayment is to be located where frequent infiltration is anticipated. General placement locations are eaves, valleys, sidewalls, headwalls, and penetrations.

3-4 **TILE ROOFING**.

Clay and standard concrete tiles are the preferred tile system. Avoid using lightweight concrete tiles unless required for structural and aesthetic reasons. The following requirements apply to tile roofing.

3-4.1 **Fasteners**.

Tile fasteners must be stainless steel or copper, 1-inch engagement in the substrate. Fastener heads shall be of sufficient diameter to prevent pull over of tile. Galvanized fasteners may not be used. Do not use wire ties to fasten tiles to the roof deck.

3-4.2 **Flashing**.

Flashings must be copper, lead, or stainless steel.

3-4.3 **Perimeter Drip Edge**.

Perimeter drip edges are required for all high slope roof systems installed over wood roof decks.

3-4.4 **Batten Boards**.

Provide batten boards under tiles in cold climates to assure the coldest roof surface possible. Batten board applications also promote ventilation and drying of tile and under tile. Battens should be considered in all climates where tiles can be lug-hung.

3-4.5 **Snow Guards**.

Provide snow guards in cold climates where required.

3-4.6 **Roof Cement**.

Use polymer modified bitumen roof cement.

3-4.7 **Underlayment**.

Use polymer modified bitumen membrane as underlayment.

3-5 SLATE ROOFING.

Slate roofing materials are extremely long lasting but expensive. Consider slate only when it is required for architectural compatibility with adjacent buildings. In order to receive full value for the use of slate roofing, other building materials should provide comparable longevity. Slate should also be limited to buildings having a long projected life without the need for significant exterior modification. A structural analysis must be made prior to installing slate where other roofing systems were used before. Only slate conforming to ASTM C406-00 *Standard Specification for Roofing Slate* may be used.

3-5.1 **Roof Cement**.

Use polymer modified bitumen roof cement.

3-5.2 **Underlayment**.

Use polymer modified bitumen membrane as underlayment.

3-6 OTHER STEEP SLOPE ROOFING.

Other roofing materials are presented in the NRCA Manual. Designers who chose to specify these materials must research the products and demonstrate their life-cycle cost benefits.

3-6.1 **Metal Shingles and Panels**.

While metal shingles and metal panels offer some advantages in appearance and wind and fire resistance over other steep roofing products, the potential for corrosion must be considered. Prior to specifying these products, the designer must demonstrate the life cycle cost benefits by confirming with actual case histories the longevity of these materials in similar service conditions.

Do not use metal shingles and metal panels in areas where the average rainfall exceeds 380 mm (15 in.) per year, and in areas where extreme freeze-thaw cycles occur, unless there is good empirical data to support performance estimates. The manufacturer’s warranty may not be used to support performance claims.

3-6.2 **SPUF Membranes**.

SPUF roof systems provide good serviceability where unusually shaped (non-planar) surfaces prevent the use of other systems. SPUF roof systems are often used as a repair alternative for leaking corrugated metal roof systems. Care should be taken in this application due to fire classification resulting changes. See Chapter 2 for further details.

3-6.3 **Wood Shakes and Shingle Roofing**.

Wood roofing materials shall not be used.

3-7 **STEEP SLOPE ROOF SPECIFICATIONS**.

Specify using the UFGS system in lieu of the NRCA Manual.

3-7.1 **Recommended Steep Slope Construction Details**.

Use the NRCA Manual Volume 4 details as applicable, except as noted in Table 3-1.

Table 3-1. Construction Detail Limitations For Steep Slope Roofing

NRCA Details & Figures	Comments
Shingles	
Figure 1, page 337	Do not use.
Figure 15, page 349	Do not use.
Figure 22, page 354	Use only when building life expectancy is less than 20 years.
Figure 27, page 357	Do not use.
Figure 28, page 357	Do not use.
Asphalt Shingles	
ASPH 1-2	Flashing to be 200 mm (8 in.) minimum height.
ASPH 3-3a	Must have an integral (welded) cricket attached to curb for roof penetrations greater than 305 mm (12 in.) (i.e. no dead valleys wider than 305 mm (12 in.).
ASPH 4	Eave and rake flashing to extend a minimum of 305 mm (12 in.) under shingles.
ASPH 7	Closed cut valleys strongly discouraged (woven or open valley encouraged).
Clay Tile	Historic Roof Consultant to design or review details.
Figure 1, page 362	Do not use flat interlocking, french interlocking, plain tiles.
Figure 2, page 363	Do not use unless matching existing.
Figure 12, page 381	Do not use.
Slate Tile	Roof Consultant to design or review details.
Wood Shakes	Not allowed.
Wood Shingles	Not allowed.
Sheet Metal	
SM 1-8	Sealant beneath cover plate to be high quality non-curing butyl, Depth of face side metal to be 200 mm (8 in.) minimum
SM 4,6,8	Fasteners may not penetrate both pieces of sheet metal, must allow for thermal expansion.
SM 14	Surface mounted counter flashing should be limited to non-permanent construction. Use thru wall or recessed counter flashing with lead wedge securement in permanent construction.
SM 16-20	Concealed sealant to be non-curing butyl.
SM 17 D	Not allowed.
SM-18 E/F	Not allowed.
SM-19	Not recommended for permanent construction.
SM-21	Not allowed.
SM-23	Minimum of two lines of non-curing butyl tape, three lines for permanent const.
SM-24 1/2	Not allowed.
SM-25 3	Not allowed.
SM 25-4	Recommended but normally will include two end dams with UV resistant sealant.
SM-26	Not recommended: Lap seam, mechanically fastened seam, overlap standing seam.
A-Mtl	Do not reference NRCA details, use SMANCA.
S-Mtl	Do not reference NRCA details, use MBMA.

CHAPTER 4 METAL ROOFING DESIGN REQUIREMENTS

4-1 **GENERAL**.

Metal roofing can provide excellent performance, durability, and long service life. Metal roofing can be used at virtually any slope. All projects are to be hydrostatic (water tight) in design, not hydrokinetic (water shedding), including both low and steep slope applications. They may be installed over open framing (known as structural systems), or over structural decks (architectural systems). They may be used for new roofing, reroofing, and are notably effective for recover of deteriorated metal roofs or in low-slope to steep-roof conversions without tear-off.

There are many metal roof types. Types other than described herein may only be used when approved by the appropriate authority. These include special site-formed projects, curved applications of profiles other than described herein, crafted metals (soft metals, e.g., copper, terne, and zinc), and all face-fastened panel types.

4-1.1 **Reference Standards**.

Use the MBMA Manual as the primary reference for design. This chapter limits the applicability of certain techniques permitted by the MBMA Manual. Where contents of the MBMA Manual are acceptable without modification, those sections are not mentioned herein.

4-1.2 **Metal Roof Advantages**.

Metal is generally lightweight, highly wind resistant, and environmentally friendly as it is both sustainable and more than 60% recycled. In most environments, coated steel will render a service life of 40 years or more, and aluminum will render an even longer service life. When properly designed and installed, metal roofing requires very little maintenance. Coated steel and aluminum substrates can be factory painted with coatings that are highly reflective and qualify as “cool” roofs. Uncoated metals have very low emissivity and contribute to a heat island effect. Standing seam profiles provide excellent attachment substrates for photovoltaic (PV) arrays. Specify non-penetrating attachment points for PV mounting. Metal roofing is not combustible and will not support flame. With paint coatings, metal can add color and definition to most architecture. Metal is constructible year-round.

4-1.3 **Metal Roof Disadvantages**.

Standing seam systems are less forgiving of installation error and more difficult to remedy than multiple-ply roof materials, hence highly qualified installers are essential. Individual standing seam metal panels that are mechanically seamed are not easily replaced. Replacement can be expensive, but it is rarely necessary. Rooftop mechanical equipment must be procured from special sources to ensure compatibility with both the roof installation systems and types of metals. Internal drainage systems are more expensive to install correctly. Complex roof geometries involving multiple planes, hips, valleys, and dormers may drive costs disproportionately upward.

4-1.4 **Cost Considerations**.

Metal generally has greater initial cost than other roofing alternatives, but studies have found that life cycle costs are among the lowest of any roofing material. In some specific re-roofing situations, metal may have the lowest initial cost, particularly when low-slope to steep-sloped conversions are undertaken. This is due to the avoidance of tear-off, the cost effectiveness of light gauge subframing for slope build-up, the avoidance of asbestos abatement, the ease and cost efficiency of re-insulation.

4-1.5 **Design-Bid-Build**.

Prior to the specification of metal roofing systems designers should analyze the life-cycle costs associated with each system. Compliance with the appropriate UFGS is mandatory.

4-1.6 **Design-Build**.

Design-build contracts for metal roofing systems must name the specific type of metal roofing system desired and identify all critical performance requirements. It is not sufficient to simply require a metal roofing system per the MBMA Manual. Compliance with the appropriate UFGS is mandatory.

4-2 **MATERIAL**.

Material must be either sheet aluminum or Galvalume™ coated sheet steel. Both materials may be factory painted, and in either case substrate life will exceed paint life. In non-industrial, inland, moderate climates, the service life of unpainted Galvalume™ steel can be expected to be in the range of 40 years. In desert climates, the service life may exceed 60 years. In humid or industrial environments, the service life will be under 40 years depending upon severity of environment. Galvalume™ steel does not perform as well when in direct contact with salt spray. It is commonly used in coastal applications, but will not render a 40-year service life. In some of the aforementioned environments, aluminum may be the better choice, albeit at increased cost and lesser availability. Contact of either metals with strong acids and alkalis should be avoided. Avoid the use of dissimilar metals. Jacket any copper lines to isolate and prevent copper ion water runoff.

4-2.1 **Metallic Coatings**.

Protective coating for carbon steel must be 55% (by weight) aluminum-zinc alloy, Galvalume™ in application rate of 15.6 g minimum per 0.1 m^2 (.55 oz. minimum per $ft.^2$) for unpainted material (AZ55) and 14.2 g minimum per 0.1 m^2 (.50 oz. minimum per $ft.^2$) for pre-painted material (AZ50). When unpainted Galvalume™ material is used it must have an additional protective coating of acrylic at a nominal thickness of .0076 mm (0.3 mil) to protect against handling stains.

4-2.2 **Organic Coatings**.

When paint coatings are used for exterior applications they must be 0.0254 mm (1 mil) dry film thickness consisting of .00635 mm (0.25 mil) prime coat and 0.019 mm (0.75 mil) finish coat minimum applied by the continuous coil coating method. Paint resin, with noted exceptions, must be 70% polyvinylidene fluoride (PVDF) containing 100% inorganic pigments. Exceptions include interior applications, soffit applications, and surfaces painted white. In these cases, the resin type may be siliconized polyester (SMP) with organic or blended pigments. Many other resin types (including PVF) are available but should only be considered for unusual environments or uses.

Paint coatings must be applied over metallic coatings for carbon steel. Organic coatings must be directly applied to aluminum material.

4-2.3 **Metal Thickness**.

When aluminum substrates are used the minimum required thickness is .81 mm (.032 in.). When coated steel substrates are used, the minimum required thickness is 24-gauge. (The nominal thickness according to industry standards (not including metallic coating) for 24-gauge steel is 0.6071 mm (0.0239 in.), and the minimum thickness is 0.5309 mm (0.0209 in.).) Heavier gauges may be necessary to meet wind uplift criteria. The specification mandate of heavier section thickness such as 1 mm (0.040 in.) for aluminum and 0.76 mm (22 gauge) for steel may improve the aesthetic with respect to oil canning.

In any event, the minimum panel material thickness must be consistent with the material thickness as it was tested for structural capacity in ASTM E1592-01 *Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference.*

4-3 **PANEL TYPE**.

Use a flat pan, vertical leg standing seam profile with minimum finished seam height of 38.1 mm (1.5 in.) with a double fold (180 degree) seam or a 50.8 mm (2 in.) minimum seam height with single fold (90 degree) seam and capable of meeting wind resistance requirements. In general, the greater the seam height the greater the beam strength and wind resistance of the panel and the less potential to leak in ice damming situations.

Ultimately the panel type decision is aesthetic, economic, and functional. It may also be dictated by wind uplift performance. The effects of oil canning are minimized by fluting, striation, pencil rib or other formations to disrupt the panel flat. However, formations such as these that result in an offset dimension greater than 3 mm (0.125 in.) in height are not allowed due to excessive voids created at panel termination points. When flat pan configurations are used (no disruptions in the flat), tension level coil must be specified to ensure flatness. Panel width must be between 300 and 450 mm (12 and 18 in.) with a 400 mm (16 in.) panel type widely available. Panels must be furnished in lengths of 18 m (60 ft.) or longer, when possible, to minimize or eliminate end-to-end joints (panel laps). Panels must be factory fabricated wherever possible. Site forming can be considered only with special approval.

4-3.1 **Seam Configuration**.

Panel edges must be of male and female interlocking design with a machine folded (mechanically seamed) finishing of the seam. There can be no gap between any surface of interlocking male and female seam portions. Finished seam configuration may be either 90-degree, single fold (resembling an inverted "L") with horizontal dimension of 16 mm (0.62 in.) minimum, or a 180-degree, double fold.

4-3.2 **Seam Sealant**.

Each seam must have a pre-applied bead of non-curing, non-hardening polyisobutylene-isoprene copolymer or terpolymer (butyl) to ensure complete hydrostatic performance. Sealant may be a hot melt butyl formulation if applied at the point of panel manufacture. Gas entrainment of sealant is permitted. The roll-forming machine must apply sealant. Continuity of seal with field applications through all panel termination points is critical. Silicone sealant is not allowed. Primary seals must always be concealed within a joint. When secondary seals are used, they may be exposed one-part polyurethane.

4-4 **SLOPE**.

The minimum allowable slope is ½:12 for Military projects.

With specific approval, the **Army** will allow ¼:12 for large new roofs and reroofing whereas the **Air Force** and the **Navy** will only allow ¼:12 for large reroofing projects. Material and weather tightness warranties typically exclude slopes below ¼:12. Care must be taken to ensure that structural deflection and/or fabrication camber does not result in slopes below the allowable.

4-5 **PANEL ATTACHMENT**.

Attach panels with concealed clips. Thermal expansion clips are to be of a two-piece design, having a top portion that folds into the panel seam and a base that attaches to the structure. The joining of base to top components must anticipate the full range of thermal cycling of the panels, using panel temperature delta T of 93 degrees Celsius (200 degrees Fahrenheit). Higher delta T may be necessary in cold climates when using dark roof colors. Maximum frictional resistance between top and base components must not exceed 2.25 kg (5 lbs.) in the finished, folded seam. When eave-to-ridge in-plane dimensions are less than 7.6 m (25 ft.), fixed (one piece) clips may be employed. Clips must be "wetted" to the male seam component with butyl sealant as necessary to ensure complete hydrostatic performance of the joint and as required by ASTM E1592.

4-5.1 **Fixed Point**.

Panels must be rigidly fixed (pinned) to the building structure at a single point along their length. Normally that point is at the panel's ridge or eave end. Such attachment must be designed to resist all in-plane service loads including snow and other environmental loads, thermal cycling and frictional resistance experienced at the clips, and the interface of the panel to the supporting structure or deck.

4-5.2 **Exposed Fasteners**.

Minimize the use of fasteners that penetrate the weathering surface of the roof panels and flashings. Use these fasteners in panels only at end-to-end joining and at the lower termination point (point of fixity) of the panel. Fastening through the flat of the roof panel in the ridge or hip areas should be concealed behind rib closures and under flashings. Sealing washers must be EPDM (not neoprene). When fastening sheet-to-sheet, back-up plates are required to stiffen the joint and provide solid attachment for screws.

4-6 **FLASHINGS AND PENETRATIONS**.

Care must be taken that thermal movement characteristics and hydrostatic performance are preserved. Panels should be free to cycle thermally independent of building structure. Curbs, flashings, and penetrations should not restrict movement by pinning the panels to the structure. With limited exception, all connections of flashings, curbs, and penetrations must be hydrostatic in design to a minimum height of 150 mm (6 in.) above the drainage plane, above which they may be hydrokinetic. In some cases, especially where differential thermal movement occurs, consider using sheet membrane material, such as EPDM, for a hydrostatic connection. When doing so, the membrane should be protected from exposure using a sheet metal shroud flashing.

Exceptions to these practices may be where a ridge is a venting design. In these cases, hydrostatic construction will be to the height of the panel rib seam (top of ridge closure). Such exceptions to hydrostatic construction should be scrutinized. Concealed sealants must be non-curing polyisobutylene tapes, supplemented with butyl tube grade when necessary to improve flow characteristics into crevices and other difficult areas. These compounds should be sandwiched between joint components, in concealed locations, and not exposed. Curing compounds are not permitted. Exposed sealants are to be high-grade polyurethane.

4-6.1 **Round Pipes, Flues, and Soil Stacks**.

Flash small, round penetrations with pre-manufactured EPDM black rubber boots having a laminated aluminum compression ring at their base and secured at the top using a stainless steel draw band. Application may not interrupt a seam location.

4-6.2 **Roof-mounted HVAC Equipment**.

Use minimum 2 mm- (0.080 in.)-thick aluminum or 300 series stainless steel, welded prefabricated curbs for curb-mounted HVAC. Curb flange must underlay roof panels at the upslope detail and overlay panels at the down slope detail. Panel seams must terminate well before the curb wall and use built-in diverters to prevent ponding at curb wall.

4-6.3 **Perimeter, Parapet, and other Miscellaneous Flashings**.

Utilize the same factory finished material as roof panels for exposed flashings and shrouds. Provide slope for all parapet and coping caps and all horizontal projections of transitions.

4-7 **OTHER ROOFTOP APPURTENANCES**.

Minimize other roof accessories that penetrate the roof panels. When painted products are used, every effort should be made to use the same sheet material as the roof, incorporating the same factory finish.

4-7.1 **Snow Guards**.

Provide snow guards for any project where sliding ice and snow may pose a hazard or nuisance. Select snow guards to resist all in-service loads considering roof slope and design snow load. Prove adequacy on a site-specific basis by calculation and lab-tested holding strengths of devices. Only non-corrosive metal seam clamping (non-penetrating) type snow guards may be used. Snow guards that glue to panel surfaces or use attachments that penetrate roof panels are prohibited. Any device that voids material and coating warranties must be avoided, such as attachments that penetrate the standing seam or scar the surface such as concave set screws.

4-7.2 **Lightning Protection**.

Use aluminum lightning protection on metal roofs where appropriate. For locations where the average snowfall exceeds 100 mm (4 in.), snow guards must be used in conjunction with lightning protection.

4-7.3 **Dormers, Equipment Screens, and other Mountings**.

When possible, avoid interrupting roof planes with dormers and other geometries that impede drainage or interrupt the drainage surface. Dormers and equipment screens that are used for ornamentation, or to conceal vents or other small mechanicals, must be attached to the seams with non-penetrating seam clamps—avoiding breach of the weathering surface. Attach other appurtenances (lightning arrestors, condensate lines, conduits, roof walks, satellite dishes, etc.) with non-penetrating seam clamps. Avoid the use of dissimilar metals. Jacket any copper lines to isolate and prevent copper ion water runoff.

4-8 **WIND DESIGN**.

Determine roof pressures and pressure zones in accordance with ASCE-7, *Minimum Design Loads for Buildings and Other Structures.* Show zone sizes, design pressures, and clip spacing on the plans. Prove panel capacities by ASTM E1592 testing to resist pressures as shown on plans for each zone.

On Army and Air Force projects, panel clip spacing must be a maximum of 1525 mm (5 ft.) on-center in the field and 760 mm (30 in.) on-center in the wind zone on the edge and corners.

Construction should replicate tested assembly with respect to clip type, gauge, spacing, and attachment. This test is typically conducted over heavy gauge purlins; if the construction assembly uses a structural deck and rigid insulation rather than purlins, pull testing of clips may be necessary to verify adequacy of attachment.

4-9 **SYSTEM WARRANTY**.

Specify a comprehensive, single source manufacturer warranty. The warranty terms, exclusions, and limits must be enumerated in the specifications. Good watertight warrantees generally add some additional cost to the project since most roof manufacturers will inspect the work one or more times during construction as a condition of the warranty. For additional information on warrantees refer to Appendix D.

4-10 **STM TEST METHOD**.

The test method for hydrostatic joint performance is ASTM E2140-01, *Standard Test Method for Water Penetration of Metal Roof Panel Systems by Static Water Pressure Head.* The test normally tests only the panel side and end-joints, but it can be adapted to test other assemblies also. In addition to the standard standing seam testing, test the eave of the metal roof system.

4-11 **METAL ROOFING SPECIFICATIONS**.

Use the UFGS instead of the specifications shown in the MBMA Manual or the NRCA Manual.

4-12 **RECOMMENDED METAL ROOFING CONSTRUCTION DETAILS**.

Regardless of actual project slope, use the "Vertical Rib Low Slope Details" (2-1 through 2-30) in the MBMA Manual, as applicable. Do not use NRCA or SMACNA details for metal roofing.

CHAPTER 5 RE-ROOFING REQUIREMENTS

5-1 OVERVIEW.

Eventually every roofing system will reach the end of its economic life. Reroofing options include removal and replacement, re-cover (where a new system is superimposed over an existing system), and partial replacement. Reasons to re-cover include reduced first costs and reduced impact on the building occupants. Do not re-cover over wet or deteriorated materials.

Re-roofing can be considered a problem or an opportunity. Re-roofing can be a problem since the work is typically performed while the structure is occupied. Often there are concerns with noise, fumes, access, and interruption of building use. Re-roofing can be an opportunity since there is no better time to upgrade the roof system than while re-roofing. Changes in the roof system may be mandated by revisions to ASCE 7 or by needed improvement in drainage or thermal performance. It can be an opportunity to elevate or redesign problem roof elements; to install deck supported curbs that are flashed independently of the wall (resolving persistent flashing problems due to differential movement), and to resolve condensation problems or thermal insulation deficiencies.

Re-roofing decisions begin with a survey of existing conditions. This may include visual inspection, infrared moisture surveys, and roof cut analysis. Structural analysis may also be required, especially if a different type of roof is contemplated which affects dead load, drainage, or seismic behavior. One method of analyzing the condition of an existing roof is to use the ROOFER *Engineered Management System* (EMS). The ROOFER EMS is a decision-making tool to help manage an installation's low-slope membrane and asphalt shingle roofing assets. It includes procedures for collecting inventory and inspection information, evaluating roof conditions, identifying repair/replacement strategies, prioritizing projects, and developing work plans. Micro ROOFER, a microcomputer application, provides data storage and analysis and generates management reports.

5-2 GENERAL CONSIDERATIONS.

The NRCA Manual provides typically allowable re-roofs over existing roofing. See below for other considerations.

5-2.1 Low Sloped Versus Steep-Sloped Considerations.

The low slope and steep sloped roof present different challenges in re-roofing. An attic space, typically found in steep slope roof construction, provides separation of construction activities from the interior of the building. However on steeper slope roofs, scaffolding and protected access to the building may be major construction cost items.

5-2.1.1 Recovering Steep Roofing. Re-covering steep roofing such as asphalt shingles is easily done. Building codes permit either one or two direct recovers with missing shingles replaced first and curled shingles flattened. No more than one layer of re-cover roofing may be specified on Military buildings. In recover, new metal flashing is required.

Generally, underlayment is not required in shingle re-covers. Wood shakes and shingles are not a suitable substrate for new shingles or shakes and must be removed.

Table 5-1. Typical Code: Allowable Re-Roofs Over Existing Roofing*

Existing Roofing	**New Overlay Roofing**						
	Built-Up	**Shake**	**Asphalt Shingle**	**Tile Roof**	**Metal Roof**	**Modified Bitumen**	**SPF**
Slate	NP	NP	NP	NP	NP	NP	NP
Built-Up	Yes	NP	Yes (1:6)	Yes (2.5:12)	Yes	Yes	Yes
Asphalt Shingle[1]	NP	NP	Yes	Yes (2.5:12)	Yes	Yes	NP
Asphalt shingle Over Wood	NP	NP	Yes	Yes[2]	Yes[2]	Yes	NP
Asphalt shingle Over Asphalt shingle	NP	NP	Yes	Yes	Yes	Yes	NP
Tile Roof	NP	NP	NP	NP	NP	NP	NP
Metal Roof	NP	NP	NP	NP	Yes	NP	Yes
Modified Bitumen	Yes	NP	Yes	Yes (2.5:12)	Yes	Yes	Yes

* See Chapter 3 for Military limitations on roofing types.

NP = Not Permitted
(X:X) = (Minimum Roof Slope)
[1] See specific requirements
[2] Board and batten leveling system must be fire stopped
[4] Type 30 nonperforated (30 lb.) felt underlayment required for re-roofing.

5-2.2 **Recovering Low Slope Roofing**.

5-2.2.1 **Analysis of Existing System**. Recovering of an existing roof is not allowed without a detailed analysis of the existing roof deck, roof insulation and the roof structure. This analysis shall include non-destructive moisture testing, core sampling and a review of the structure by a licensed structural engineer. See NRCA Manual for additional information. The appropriate authority must approve recovering of an existing roof.

5-2.2.2 **Slope**. In existing construction, every effort must be made to achieve the ½:12 slope required for new construction. However, where ½:12 slopes cannot be achieved, ¼:12 may be used with specific approval by the appropriate authority. When increasing slopes of existing roof decks, clearances for rooftop structures such as curbs, base flashings, access doorsills, etc. must be increased to the minimums recommended in the NRCA Manual. Do not use coal tar pitch specifications above ¼:12 slope.

5-2.3 **Recovering Bituminous Low Slope Roofs**.

Re-cover of existing built-up and MB roofing may take the form of mechanically or spot attaching a base sheet (to aggregate-free substrates), or mechanically or spot attaching re-cover insulation when aggregate is present (where only the loose aggregate is removed). Full attachment to an old troubled membrane is never recommended.

5-2.4 **Recovering Single-Ply Systems**.

When re-covering old single-ply systems, the old membrane should be removed—especially if it is shrinking or otherwise experiencing dimensional instability. If not removed, it may drag and distort the new membrane. At this time most plastic and rubber membranes are not recyclable.

5-2.5 **Re-roofing Poorly Draining Low Slope Roofs**.

Poorly draining low slope roofs may require use of tapered insulation to improve drainage or may be converted to a steep roof (refer to Construction Engineering Research Laboratories (CERL) Technical Report M85/05 *Steep Roof Conversions*). Slope conversions are often more expensive than in-kind reproofing, but may offer the opportunity to convert to a system with lower maintenance.

5-2.6 **Tapered Roof Insulation Systems**.

Tapered rigid board insulation should generally be used only when the existing facility has inadequate slope, and other means of providing adequate slope are more expensive over the lifecycle of the facility. Tapered rigid board roof insulation systems are more expensive per square unit than non-tapered insulation. Do not use wet fill to accomplish slope in existing systems. Use tapered rigid board in crickets and saddles to ensure positive drainage.

5-2.7 **Metal Roofing**.

Metal roofing is frequently selected for steep roof conversion since new lightweight structural members easily accommodate increased slope requirement, and the new metal roof may not need a new deck. The fire hazard concern about the newly created attic space must be addressed (FM Global Data Sheet 1-31). Ventilation concerns must also be addressed. Watertight sealing of penetrations of new framing connections through and old roof and maintaining adequate drainage of the old roof during the construction period must be addressed.

5-2.8 **New Trusses and Decking**.

Adding lightweight steel or wood trusses or rafters and a nailable deck permits the use of most conventional steep roofing systems.

5-2.9 **Secondary Protection**.

Re-roofing invariably means disruption of building operations. For some sensitive occupancies (e.g., top floor computer rooms, surgical suites, laboratories, or telephone equipment) a total tear-off may be an unacceptable risk. The addition of a secondary membrane should be analyzed for condensation considerations.

5-3 **CLIMATE/WEATHER CONSIDERATIONS**.

A complete tear-off requires good weather since the building is usually occupied and nightly tie-offs may not provide adequate protection. The demands of protecting the building may prompt phased construction—especially when a thicker insulation system is being added and it is not feasible to run from eave to ridge in a single day.

5-3.1 **Nightly Seal-off of New Penetrations**.

When new structural members are added it is necessary to carefully seal where the new anchor bolts penetrate the old roof system. This seal might be little more than asphalt mastic or it may be more complex. Existing drains must remain in working order until the new roof and associated drainage system is completely functional.

5-3.2 **Upgrading Insulation**.

Adding new insulation and/or an air space above the existing roof will change snow-melting characteristics. Generally the added insulation reduces vapor condensation problems; however, the effect of the new insulation on vapor condensation must be determined.

5-4 **LOGISTICAL CONSIDERATIONS**.

Planning a re-roofing project must include all the logistics of the project, especially if the re-roofing occurs over an occupied building. Items to consider in the planning include the following:

a. Protecting the newly applied roof covering from tear-off debris and construction traffic. This is critical to the longevity of the new roof;

b. Planning for the possible presence of asbestos-bearing materials and landfill or recycling rules and regulations that may require separation of construction materials;

c. Staging of new materials when existing materials are being torn off;

d. Providing for material removal when dust management is used;

e. Removing surface dirt and loose aggregate on aggregate-surfaced roofs prior to tear-off;

f. Providing protection of building interior and protection of exterior finishes to remain;

g. Providing interior dust control; and

h. Evaluating potential impact of new work on deck underside fireproofing.

5-4.1 **System and Site Safety Considerations**.

Safety is of paramount importance. Protect occupants from fumes by coordinating the shut down of air handling units. Protect occupants in areas where roofing work is taking place directly overhead by directly cordoning off the area, especially if deck repairs are taking place. Protect all occupants entering or leaving the building from falling materials. Identify the location of underground tanks and other sensitive, sub-surface items so that heavy vehicles do not overload these areas.

5-4.2 **Deck Replacement**.

If deck replacement is necessary, the operations directly beneath the deck being replaced will require shut down for safety and leakage reasons. Additionally, since it may be impossible to maintain HVAC services, humidity control, and air exchange with the building roof being open, a more extensive shutdown may be required.

5-5 **LIFE CYCLE COST CONSIDERATIONS**.

It is unlikely that a re-cover will last as long as a total tear-off and replacement. Since the military limits re-cover to one layer, eventually total roof replacement must occur. Therefore, carefully weigh the life-cycle cost of re-cover versus removal and replacement. The cost of replacement is greatly affected by ease of access, the need for slope buildup, and the need to raise mechanical equipment for access. Reroofing is an excellent time to remove obsolete equipment and stacks from the roof.

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APPENDIX B BEST PRACTICES

B-1 **INTRODUCTION**.

Use this UFC in conjunction with UFC 3-330-02A *Commentary on Roofing Systems,* which provides considerations in the selection of a roofing system.

Appendix C

glossary

A-1 ACRONYMS AND ABBREVIATIONS

APP. Atactic Polypropylene

BUR. Built-up roof

EPDM. Ethylene Propylene Diene Monomer

EPS. Molded expanded polystyrene board.

MB. Modified bitumen

PUF. Polyurethane foam (also see SPF)

PVF. Polyvinylidene fluoride

RCI. Roof Consultants Institute

RRO. Registered roofing observer

RRC. Registered roofing consultant

SBS. Styrene Butadiene Styrene

SPF. Spray-applied polyurethane foam (also see PUF)

SSSMR. Structural standing-seam metal roof

UV. Ultraviolet

XPS. Extruded polystyrene board

UL. Underwriters Laboratories Incorporated

A-2 DEFINITIONS. See UFC 310-100-10N DESIGN: GENERAL ARCHITECTURAL AND INTERIOR DESIGN REQUIREMENTS for a more complete list of definitions.

Aggregate. (1) Crushed stone, crushed slag, or water-worn gravel used for surfacing a built-up roof; (2) Any granular mineral material.

Alloys, polymeric. A blend of two or more polymers, e.g., a rubber and a plastic to improve a given property, e.g., impact strength.

Asphalt. A dark brown to black elastomeric cementitious material whose predominating constituents are bitumen's that occur in nature or are obtained in petroleum processing.

Asphalt felt. An asphalt-saturated felt.

Atactic. A chain of molecules in which the position of the side methyl groups is more or less random. (Amorphic; Low Crystallinity)

Ballast. Loose aggregate, concrete pavers, or other material designed to prevent wind uplift or flotation of a loose-laid roof system.

Base sheet. A saturated or coated felt placed as the first ply in a multi-ply bituminous roofing membrane.

Batten. (1) Raised rib, in a metal roof, or a separate part or formed portion in a metal roofing panel. (2) One of a series of strips laid in a matrix under tile roof applications.

Bitumen. (1) A class of amorphous, black or dark colored, (solid, semisolid, or viscous) cementitious substances natural or manufactured, composed principally of high molecular weight hydrocarbons, soluble in carbon disulfide, and found in asphalts, tars, pitches, and asphaltites; (2) A generic term used to denote any material composed principally of bitumen; (3) In the roofing industry there are two basic bitumens: asphalt and coal-tar pitch. Before application they are either (a) heated to a liquid state, (b) dissolved in a solvent, or (c) emulsified.

Bituminous (adj.). Containing or treated with bitumen. Examples: bituminous concrete, bituminous felts and fabrics, bituminous pavement.

Bond. The adhesive and cohesive forces holding two roofing components in intimate contact.

Boot. A bellows type covering to exclude dust, dirt, moisture, etc., forming a flexible closure.

British thermal unit (BTU). Heat energy required to raise the temperature of one pound of water by 1^0F (= 1055 joules).

Building Code. Published regulations and ordinances established by a recognized agency describing design loads, procedures, and construction details for structures. Usually applying to designated political jurisdiction (city, county, state, etc.). Building codes control design, construction, and quality of materials, use and occupancy, location and maintenance of buildings and structures within the area for which the code was adopted (see Model Codes).

Built-Up Roofing (BUR). A continuous, semiflexible membrane consisting of plies of saturated felts, coated felts, fabrics or mats assembled in place with alternate layers of bitumen, and surfaced with mineral aggregate, bituminous material, or a granule surfaced sheet (abbreviation, BUR).

Butyl Rubber. A synthetic rubber based on isobutylene and a minor amount of isoprene. It is vulcanizable and features low permeability to gases and water vapor and good resistance to aging, chemicals and weathering.

Capflashing. See Flashing.

Capsheet. A granule-surfaced coated felt used as the top ply of a built-up roofing membrane.

Caulk. To seal joints, seams, or voids by filling with a waterproofing compound or material.

Caulking. A composition of vehicle and pigment, used at ambient temperatures for filling joints, that remains plastic for an extended time after application.

Chalk Resistance. A measurement of performance for paint systems; the ability to resist a dusty/chalky appearance over time.

Chalking. A powdery residue on the surface of a material resulting from degradation or migration of an ingredient, or both.

Chlorinated polyethylene (CPE). Family of polymers produced by chemical reaction of chlorine on the linear backbone chain of polyethylene. The resultant rubbery thermoplastic elastomers presently contain 25- 45% chlorine by weight and 0-25% crystallinity. CPE can be vulcanized but is usually used in a nonvulcanized form.

Chlorosulfonated polyethylene (CSPE). Family of polymers that are produced by polyethylene reacting with chlorine and sulfur dioxide. Present polymers contain 25-43% chlorine and 1.0-1.4% sulfur. They are used in both vulcanized and nonvulcanized forms. Most membranes based on CSPE are nonvulcanized. ASTM designation for this polymer is CSM. Best known by the DuPont Tradename “Hypalon.”

Closure Strip. A resilient strip such as neoprene, flat on one side and formed to the contour of ribbed sheets on the other, used to close openings created by joining metal sheets and flashings.

Coal Tar. A dark brown to black cementitious material produced by the destructive distillation of coal.

Coal Tar Felt. A felt saturated with refined coal tar.

Coating Weight. Weight of coating on surface (both sides), usually expressed in g/m^2 or oz./ft.^{2}.

Coefficient of Thermal Expansion. The change in length per unit of length for a unit change in temperature. (Thus the coefficient per ^{o}F must be multiplied by 1.8 for the coefficient per ^{o}C.)

Condensation. The conversion of water vapor or other gas to liquid as the temperature drops or atmospheric pressure rises (see also Dew point).

Conductance, Thermal. The thermal transmission in unit time through unit area of a particular body or assembly having defined surfaces, when unit average temperature difference is established between the surfaces. C=(W/ m^2•K) C=(Btu/h•ft^2•^{0}F).

Conductivity, Thermal. The time rate of transfer of heat by conduction through a unit thickness across unit area for unit difference of temperature.

Copolymer. A mixed polymer, the product of polymerization of two or more substances at the same time.

Counterflashing. Formed metal or elastomeric sheeting secured on or into a wall, curb, pipe, rooftop unit, or other surface, to shield the upper edge of a base flashing and its associated fasteners.

Coverage. The surface area to be continuously covered by a specific quantity of a particular material.

Covering. The exterior roof and wall covering for a metal building system.

Cricket. A relatively small, elevated area of a roof constructed to divert water from a horizontal intersection of the roof with a chimney, wall, expansion joint or other projection.

Curb. A raised member used to support roof penetrations such as skylights, hatches, etc.

Cure. To change the properties of a polymeric system into a more stable, usable condition by the use of heat, radiation, or reaction with chemical additives. NOTE: Cure may be accomplished, for example, by removal of solvent or cross-linking.

Deck. The structural substrate to which the roofing or waterproofing system (including insulation) is applied.

Degree-Days. The sum of the positive or negative differences between a reference temperature (usually 18ºC (65ºF)) and the mean temperature for each day in the heating or cooling season). Degree-days are used to compare the severity of cold or heat during the heating or cooling season

Delamination. Separation of the plies in a membrane or separation of insulation layers after lamination.

Design loads. The "live load" and "environmental load" (i.e. superimposed loads) that a structure is designed to resist (with appropriate safety factor) plus "dead load" (i.e., weight of permanent loads).

Dew point. The temperature at which water vapor starts to condense in cooling air at the existing atmospheric pressure and vapor content.

Dry (n.). A material that contains no more water than one would find at its equilibrium moisture content.

Eave. The line along the sidewall formed by the intersection of the planes of the roof and wall.

Eave Height. The vertical dimension from finished floor to the eave.

Edge venting. The practice of providing regularly spaced protected openings at a low-slope roof perimeter to relieve water vapor pressure in the insulation. (It is of doubtful efficacy.)

Elasticity. The property of matter by virtue of which it regains its original size and shape after removal of stress.

Elastomer. A macromolecular material that returns rapidly to its approximate initial dimensions and shape after subsequent release of stress.

Embedment. (1) the process of pressing a felt, aggregate, fabric, mat, or panel uniformly and completely into hot bitumen or adhesive to ensure intimate contact at all points; (2) the process of pressing granules into coating in the manufacture of factory prepared roofing, such as shingles.

Emulsion. A dispersion of fine particles or globules of a liquid in a liquid. Asphalt emulsions consist of asphalt globules, an emulsifying agent such as bentonite clay and water.

Endlap. The overlap where one panel or felt nests on top of the end of the underlying panel or felt.

EPDM. A synthetic elastomer based on ethylene, propylene, and a small amount of a non-conjugated diene to provide sites for vulcanization. EPDM features excellent heat, ozone and weathering resistance, and low temperature flexibility.

EVA. Family of copolymers of ethylene and vinyl acetate used for adhesives and thermoplastic modifiers. They possess a wide range of melt indexes.

Fabric. A woven cloth of organic or inorganic filaments, threads, or yarns.

Fabrication. (1) The manufacturing process performed in a plant to convert raw material into finished metal building components. The main operations are cold-forming, cutting, punching, welding, cleaning, and painting; (2) the creation of large panels of rubber from smaller calendar width sheets as in EPDM.

Fascia. A decorative trim or panel projecting from the face of a wall, serving as a weather closure at gable and endwall.

Felt. A flexible sheet manufactured by the interlocking of fibers through a combination of mechanical work, moisture, and heat, without spinning, weaving, or knitting. Roofing felts are manufactured from vegetable fibers (organic felts), glass fibers (glass fiber felts) or polyester fibers (synthetic fiber mats).

Fiberglass insulation. Blanket insulation, composed of glass fibers bound together with a thermoset binder, faced or unfaced, used over or under purlins to insulate roofs and walls; semi-rigid boards, usually with a facer.

Field. The “job site,” “building site,” or general market area.

Flashing. The system used to seal membrane edges at walls, expansion joints, drains, gravel stops, and other places where the membrane is interrupted or terminated. Base flashing covers the edges of the membrane. Cap or counterflashing shields the upper edges of the base flashing.

Flood coat. The top layer of bitumen used to hold the aggregate on an aggregate surfaced roofing membrane.

Fluid-applied elastomer. An elastomeric material, fluid at ambient temperature, that dries or cures after application to form a continuous membrane. Such systems may not incorporate reinforcement.

Galvalume. Trade name for steel coated with aluminum-zinc alloy for corrosion protection.

Galvanized steel. Steel coated with zinc for corrosion resistance.

Glass felt. Glass fibers bonded into a sheet with resin and suitable for impregnation in the manufacture of bituminous waterproofing, roofing membranes, and shingles.

Granule. See Mineral Granules.

Gravel. Coarse, granular aggregate, with pieces larger than sand grains, resulting from the natural erosion of rock.

Green Building Technology. Technology that reduces impact on the earth. Includes recyclability, reduction in carbon dioxide, ozone or other atmospheric pollutants, and reduction of urban heat islands.

Gutter. A channel member installed at the eave of the roof for the purpose of carrying water from the roof to the drains or down spouts.

Heat Seaming. The process of joining two or more thermoplastic films or sheets by heating areas in contact with each other to the temperature at which fusion occurs. The process is usually aided by a controlled pressure. In dielectric seaming, the heat is induced within films by means of radio frequency waves.

Heat transfer. The transmission of thermal energy from a location of higher temperature to a location of lower temperature. This can occur by conduction, convection or radiation.

Humidity. The amount of moisture contained in the atmosphere. Generally expressed percent relative humidity. (The ratio of the vapor pressure to the saturation pressure for given conditions times 100.)

Hydrocarbons. An organic chemical compound containing mainly the elements carbon and hydrogen. Aliphatic hydrocarbons are straight chain compounds of carbon and hydrogen. Aromatic hydrocarbons are carbon-hydrogen compounds based on the cyclic or benzene ring. They may be gaseous (CH4, ethylene, butadiene), liquid (hexene, benzene), or solid (Natural rubber, napthalene, cispolybutadiene).

Inorganic (adj.). Comprising matter other than hydrocarbons and their derivatives, or matter not of plant or animal origin.

Insulation. See Thermal Insulation.

Internal Pressure. Pressure inside a building, a function of wind velocity, building height, and number and location of openings.

Isocyanate. A highly reactive chemical grouping composed of a nitrogen atom bonded to a carbon atom bonded to an oxygen atom: =N=C=O; a chemical compound, usually organic, containing one or more isocyanate groups.

Isoboard. Abridgement of polyisocyanurate foam insulation board.

Lap. Dimension by which a felt covers an underlying felt in BUR membrane. “Edge” or side lap indicates the transverse cover; “End” lap indicates the cover at the end of the roll. These terms also apply to single-ply membranes.

Lapped joint. A joint made by placing one surface to be joined partly over another surface and bonding the overlapping portions.

Loose-laid Membrane. A unadhered roofing membrane anchored to the substrate only at the edges and penetrations through the roof and ballasted against wind uplift by loose aggregate or pavers.

Mastic. Caulking or sealant normally used in sealing roof panel laps.

Membrane. A flexible or semi-flexible roof covering or waterproofing whose primary function is the exclusion of water.

Metal flashing. See Flashing—frequently used as through-wall, cap, or counterflashing.

Mineral fiber. Inorganic fibers of glass, asbestos or mineral wool (slag).

Mineral granules. Natural or synthetic aggregate, ranging in size from 500µm (1µm = 10-6m) to 1/4 in. diameter, used to surface BUR or modified bitumen cap sheets, asphalt shingles, and some cold process membranes.

Model Codes. Codes established to provide uniformity in regulations pertaining to building construction. Examples: Uniform Building Code published by ICBO, National Building Code by BOCA, Standard Building Code by SBCCI, International Building Code (New), which will eventually replace the other three code bodies.

Moisture conduction. Migration by wicking as contrasted to vapor movement.

Monomer. A simple molecule which is capable of combining with a number of like or unlike molecules to form a polymer.

Mopping. Application of hot bitumen with a mop or mechanical applicator to the substrate or to the plies of a built-up or modified-bitumen roof. There are four types of mopping: (1) solid—a continuous coating; (2) spot—bitumen is applied in roughly circular areas, generally about 460 mm (18 in.) in diameter, leaving a grid of unmopped, perpendicular area, (3) strip— bitumen is applied in parallel bands, generally 200 mm (8 in.) wide and 300 mm (12 in) apart; (4) sprinkle—bitumen is shaken on the substrate from a broom or mop in a random pattern.

Nailer. Wood member bolted or otherwise anchored to a nonnailable deck or wall to provide nailing anchorage of membrane or flashing.

Nailing. (1) Exposed nailing of roofing wherein nail heads are bare to the weather; (2) Concealed nailing of roofing wherein nail heads are concealed from the weather (see also Blind nailing).

Neoprene. Synthetic rubber (polychloroprene) used in liquid or sheet-applied elastomeric roofing membranes or flashing.

Nondestructive Testing (NDT). Methods for evaluating the strength or composition of materials without damaging the object under test.

Nonwoven Fabric. A sheet material produced by bonding or interlocking of fibers (or both) by mechanical, thermal or solvent means (or combinations thereof).

Olefin. An unsaturated open-chain hydrocarbon containing at least one double bond: ethylene or propylene.

Olefin Plastics. Plastics based on polymers made by the polymerization of olefins or copolymerization of olefins with other monomers, the olefins being at least 50 percent of the mass.

Organic (adj.). Composed of hydrocarbons or their derivatives; or matter of plant or animal origin.

Organic coating. Coatings that are generally inert or inhibited. May be temporary (e.g., slushing oils) or permanent (paints, varnishes , enamels, etc.).

Organic content. Usually synonymous with volatile solids in an ashing test; e.g., a discrepancy between volatile solids and organic content can be caused by small traces of some inorganic materials , such as calcium carbonate, that lose weight at temperatures used in determining volatile solids.

Panel clip. Independent clip used to attach roof panels to substructure.

Panel Creep. Tendency of the transverse dimension of a roof panel to gain in modularity due to spring-out or storage-distortion.

Parapet. Portion of wall above the roof line.

Pea Gravel. Small gravel with a diameter approaching that of a pea. Size roughly defined by ASTM D448-03 *Standard Classification for Sizes of Aggregate for Road and Bridge Construction,* Number 7 or smaller.

Peak. The uppermost point of a gable.

Penetration. The consistency of a bituminous material expressed as the distance in tenths of a millimeter (0.1 mm) that a standard needle or cone vertically penetrates a sample of material under specified conditions of loading, time, and temperature.

Percent Elongation. In tensile testing, the increase in the gauge length, measured after fracture of the specimen within the gauge length.

Perlite. An aggregate used in lightweight insulating concrete and in preformed perlite insulating board, formed by heating and expanding siliceous volcanic glass.

Permeability. (1) The capacity of a porous medium to conduct or transmit fluids; (2) The amount of liquid moving through a barrier in a unit time, unit area and unit pressure gradient not normalized for but directly related to thickness; (3) The product of vapor permeance and thickness (for thin films, ASTM E96-00e1 *Standard Test Methods for Water Vapor Transmission of Materials*—over 3.2 mm (.125 in.), ASTM C355 Usually reported in perm inches or grain/h•ft2•in. Hg per inch of thickness. 1 perm inch = 1.46 x 10-12 kg/Pa•s•m.

Permeance. The rate of water vapor transmission per unit area at a steady state through a membrane or assembly, expressed in ng/Pa•s•m^2 (grain/ft^2•h•in. Hg).

Phenolic Plastics. Plastics based on resins made by the condensation of phenols, such as phenol and cresol, with aldehydes.

Pitch. See Incline; Coal tar pitch; or Petroleum pitch.

Plastic. A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight. It is solid in its finished state and at some stage in its manufacture or processing into finished articles can be shaped by flow.

Plasticizer. Material, frequently solvent-like, incorporated in a plastic or a rubber to increase its ease of workability, flexibility, or extensibility. Adding the plasticizer may lower the melt viscosity, the temperature of the second order transition, or the elastic modulus of the polymer.

Plasticizers. May be monomeric liquids (phthalate esters), low molecular weight liquid polymers (polyesters) or rubbery high polymers (EVA). The most important use of plasticizers is with PVC where the choice of plasticizer dictates under what conditions the membrane may be used.

Ply. A layer of felt in a roofing membrane; a four-ply membrane should have at least four plies of felt at any vertical cross section cut through the membrane.

Plywood. A flat panel built up of sheets of wood veneer called plies, united under pressure by a bonding agent to create a panel with an adhesive bond between plies as strong as or stronger than, the wood. Plywood is constructed of an odd number of layers with grain of adjacent layers perpendicular. Layers may consist of a single ply or two or more plies laminated with parallel grain direction. Outer layers and all odd numbered layers generally have the grain direction oriented parallel to the long dimension of the panel.

Polyester Fiber. Generic name for a manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of an ester of a dihydric alcohol and terephthalic acid. Scrims made of polyester fiber are used for fabric reinforcement.

Polyisobutylene. The polymerization product of isobutylene varying in consistency from a viscous liquid to a rubberlike solid, with corresponding variation in molecular weight from 1,000 to 400,000.

Polyisocyanurate. Thermoset polymer formed by polymerization of isocyanate; rigid foam insulation meeting ASTM C1289-02 *Standard Specification for Faced Rigid*

Cellular Polyisocyanurate Thermal Insulation Board; a thermal insulation similar in appearance to polyurethane foam, but with improved fine resistance or rating.

Polymer. A macromolecular material formed by the chemical combination of monomers having either the same or different chemical composition. Plastics, rubbers, and textile fibers are all high molecular weight polymers.

Polyvinyl Chloride (PVC). A synthetic thermoplastic polymer prepared from vinylchloride. PVC can be compounded into flexible and rigid forms through the use of plasticizers, stabilizers, filler, and other modifiers; rigid forms used in pipes; flexible forms used in manufacture of sheeting.

Ponding. Water in low or irregular roof areas that remains longer than 48 hours after the cessation of rainfall, under conditions conducive to evaporation.

Preventive Maintenance. The regular, scheduled, inspection for and the repair of normal, expected breakdown of materials and equipment.

Prime coat. First liquid coat applied in a multiple coat system.

Primer (bituminous). A thin liquid bitumen applied to a surface to improve the adhesion of heavier applications of bitumen and to absorb dust.

Protected Membrane Roof (PMR). Roof assembly with insulation on top of membrane instead of vice versa, as in conventional roof assembly (also known as inverted or upside-down roof assembly).

Puncture Resistance. Index of a material's ability to withstand the action of a sharp object without perforation.

R-Factor. Resistance to heat flow. The summation of individual thermal resistances in an assembly.

Rake. The sloped edge of a roof at the first or last rafter.

Rake trim. A flashing designed to close the opening between the roof and endwall panels.

Re-covering. The process of covering an existing roof system with a new roof.

Reglet. A groove in a wall or other surface adjoining a roof surface for the insertion and attachment of counterflashing.

Relative Humidity. The ratio of the mass per unit volume (or partial pressure) of water vapor in an air-vapor mixture to the saturated mass per unit volume (or partial pressure) of the water vapor at the same temperature, expressed as a percentage.

Replacement. The removal of all roof system components down to the structural deck followed by installation of a completely new roofing system.

Reroofing. Replacement or re-cover of an existing roof system.

Resistance, Thermal. See Thermal resistance.

Retrofit. The modification of an existing building or facility to include new systems or components.

Ridge. Highest point on the roof of the building, a horizontal line running the length of the building.

Ridge Cap. A transition of the roofing materials along the ridge of a roof. Sometimes called ridge roll or ridge flashing.

Roll Goods. A general term applied to rubber and plastic sheeting, usually furnished in rolls.

Roll Roofing. Coated felts, either smooth or mineral surfaced.

Roof Curb. An accessory used to mount and level units (such as air conditioning and exhaust fans) on the sloped portion of the building roof.

Roof Jack. An accessory used to cover pipes (such as vents or flues) that penetrate the roof covering.

Roof Seamer. Machine that crimps panels together or that welds laps of E/P systems using heat, solvent or dielectric energy.

Roof Slope. The angle a roof surface makes with the horizontal, measured in a ratio such as ½:12.

ROOFER Engineered Management System (EMS). The ROOFER EMS is a practical decision-making tool to help manage an installations or bases low-slope membrane and asphalt shingle roofing assets. It includes procedures for collecting inventory and inspection information, evaluating roof condition, identifying repair/replacement strategies, prioritizing projects, and developing work plans. Micro ROOFER, a microcomputer application provides data storage and analysis, and generates management reports.

Roofing System. A combination of interacting components designed to weatherproof, and normally to insulate, a building's top surface; does not include the roof deck.

Rubber. A material capable of quickly recovering from large deformations, normally insoluble in boiling solvent such as benzene, methyl ethyl ketone, and ethanol toluene azeotrope. A rubber in its modified state retracts within 1 mm to less than 1.5 times its original length after being stretched to twice its length.

Sacrificial Protection. Reducing the extent of corrosion of a metal in an electrolyte by coupling it to another metal that is electrochemically more active in the environment, i.e., galvanic protection.

Scupper. Channel through a low slope roof edge or parapet, designed for peripheral drainage of the roof, usually a safety overflow to limit accumulation of ponded rainwater caused by clogged drains or intense rainfall.

Scrim. A woven, open mesh reinforcing fabric made from continuous filament yarn. Used in the reinforcement of polymeric sheeting.

Sealant. Any material used to close up cracks or joints to protect against leaks. Lap sealant is applied to exposed lap edges in E/P systems.

Sealing Washer. A metal-backed rubber washer assembled on a screw to prevent water from migrating through the screw hole.

Seam Strength. Strength of a seam of material measured either in shear or peel modes, reported either in absolute units, e.g., pounds per inch of width—or as a percent of the sheeting strength.

Service Life. Anticipated useful life of a building, building component or building subsystem (e.g., roof system).

Shelf Life. Maximum safe time to store a fluid construction material or non-cured sheet before use.

Shingle. (1) A small unit of prepared roofing designed for installation with similar units on overlapping rows on inclines normally exceeding 25%; (2) To cover with shingles, and (3) To apply any sheet material in overlapping rows like shingles.

Shingling. (1) The procedure of laying parallel felts so that one longitudinal edge of each felt overlaps, and the other longitudinal edge underlaps an adjacent felt. (See also Ply). Normally, felts are shingled on a slope so that the water flows over rather than against each lap; (2) The application of shingles to a sloped roof.

SI. The international symbol for the metric unit (Le Systeme International d'Unites).

Sidelap. The continuous overlap of closures along the side of a panel or sheet material.

Sill. The bottom horizontal framing member of an opening such as a window or door.

Single Slope. A sloping roof with one surface. The slope is from one wall to the opposite wall of rectangular building.

Skylight. A roof accessory to admit light, normally mounted on a curbed, framed opening.

Slippage. Relative lateral movement of adjacent felts (or sheets) in a roof membrane. It occurs mainly in roofing membranes on a slope, sometimes exposing the lower plies or even the base sheet to the weather.

Slope. Tangent of the angle between the roof surface and the horizontal plane, expressed as a ratio. (See also roof slope)

Smooth Surfaced Roof. A roof membrane without mineral aggregate surfacing.

Soffit. The underside covering of any exterior overhanging section of a roof, gable or sidewall.

Softening Point. Temperature at which a bitumen becomes soft enough to flow as determined by an arbitrary, closely defined method.

Square. A roof area of 9.29 m^2 (100 ft^2), or enough material to cover 9.29 m^2 of deck.

Stack Vent. A vertical outlet designed to relieve pressure exerted by water vapor between a membrane and the vapor retarder or deck.

Stainless Steel. An alloy of steel which contains a high percentage of chromium. Also may contain nickel or copper. Has excellent resistance to corrosion.

Standing Seam. Watertight seam type featuring an upturned rib, which may also be structural. It is made by turning up the edges of two adjacent metal panels and then folding them over in one of a variety of ways.

Stress. (1) A measure of the load on a structural member in terms of force per unit area (MPa) (kips per $in.^2$); (2) The force acting across a unit area in solid material in resisting the separation, compacting or sliding that tends to be induced by external forces. Also the ratio of applied load to the initial cross sectional area, or the maximum stress in the outer fibers due to an applied flexural load.

Stress Concentration. A condition in which stress is highly localized, usually induced by an abrupt change in the shape of a member or at a substrate joint (e.g., between insulation joints)

Substantial Completion. The stage in the progress of the work when it is sufficiently complete for the owner to occupy or utilize the space for its intended use.

Surface Cure. Curing or vulcanization which occurs in a thin layer on the surface of a manufactured polymeric sheet or other items.

Susceptibility. When not otherwise qualified, the degree of change in viscosity with temperature.

Tearoff. Removal of a failed roof system down to the structural deck surface.

Tensile Strength. (1) The maximum tensile stress per unit of original cross sectional area applied during stretching of a specimen to break; units: SI-metric—Megapascal or kilopascal, customary—lb per $in.^2$; (2) The longitudinal pulling stress a material can bear without tearing apart; (3) The ratio of maximum load to original cross-sectional area. Also called ultimate strength.

Tensile Test. A test in which a specimen is subjected to increasing longitudinal pulling stress until fracture occurs.

Therm. A unit of heat commonly used by utilities, equivalent to 100,000 BTU = 1.05 x 108 joules.

Thermal Conductivity (k). The rate of heat flow through a stated thickness of material with a stated temperature differential Btu/h.ft^2•^{0}F (W/m2•^{0}C).

Thermal Insulation. A material designed to reduce the conductive heat flow.

Thermal Resistance (R). Resistance to heat flow. The reciprocal of conductance (C).

Thermal Shock. Stress-producing phenomenon resulting from sudden temperature drops in a roof membrane—when, for example, a rain shower follows brilliant sunshine.

Thermoplastic Elastomers. Polymers capable of remelt, but exhibiting elastomeric properties; related to elasticized polyolefins. They have a limited upper temperature service range.

U-Factor. The heat flow across an entire assembly e.g., from air within a building to outside air; the inverse of R-Factor.

Uplift. Wind load on a building which causes a load in the upward direction.

Vapor Barrier. See Vapor retarder.

Vapor Pressure. The pressure exerted by a vapor that is in equilibrium with its solid or liquid form.

Vapor Retarder. A material that resists the transmission of water vapor.

Vent. Opening designed to convey water vapor or other gas from inside a building or a building component to the atmosphere.

Viscoelastic. Characterized by changing mechanical behavior, from nearly elastic at low temperature to plastic, like a viscous fluid, at high temperature.

Viscosity. Index of a fluid's internal resistance to flow, measures in centistokes (cSt) for bitumens. (Water has a viscosity of roughly 1 cSt, light cooking oil 100 cSt.)

Waterproofing. Treatment of a surface or structure to prevent the passage of water under hydrostatic pressure.

APPENDIX D WARRANTIES

D-1 **GENERAL**.

Many roofing systems include a warranty or guarantee. To safe guard the interest of the client, it is necessary to have a thorough understanding of what is and is not covered by the installer or manufacturer under the warranty. Careful attention to written details of the contractor's obligations and field installation of the products will improve the viability of the roof and enhance its performance. Although warranties by themselves will not guarantee a long lasting, watertight roof, they can be an important part of the process.

D-2 **WARRANTY TYPES**.

D-2.1 **Manufacturers' Warranties**.

Manufacturers warranties are often offered as an "off the shelf" item. Most manufacturers offer several different warranties for the same product.

D-2.1.1 **Materials Warranty (five to 20 years)**. Material warranties focus on the durability of the product installed on the roof. Labor to remove and reinstall may not be included in this warranty unless specifically required by the contract. Exclusions should be carefully reviewed since they vary widely—from reasonable exclusions such as unusual weather conditions and owner neglect to unreasonable exclusions.

D-2.1.2 **Watertight Warranty (System Warranty) (five to 20 years)**. Watertight warranties are used to obtain quality installation. Manufacturers will list requirements in the warranty necessary for the warranty to remain intact—such as regular inspections (two or more times a year). The watertight roof system warranty should include all roof penetrations and flashing (interface with all adjacent surfaces). To maintain the warranty, the roof must be installed according to manufacturer's requirements—which often specify the roof installers. When other than an approved roof installer installs features on the roof (mechanical contractors, etc.), problems may occur in obtaining watertight warranty coverage for those features. This issue should be addressed in the contract specification. Signatures on Warranty must be from the roof SYSTEM manufacturer and the Government User, not the General Contractors. This helps to avoid issues if the general contractor goes out of business.

D-2.2 **General Contractor's Warranties (one to five years)**.

Recently some government roof specifications call for a General Contractor's Watertight Warranty to add another method of ensuring a quality roof installation.

D-2.3 **Roof Installers Warranty to General Contractor (one to five years)**.

The government does not have a direct contractual relationship with any subcontractor, including a roof subcontractor. General Contractors will attempt to achieve the same legal protection as the government by requiring the roof subcontractor be responsible to maintain the roof. Because the roof subcontractor may go out of business, the government specification should require the General Contractor be responsible for the required repairs.

D-3 **BONDING**.

Bonding may be appropriate for mission critical buildings. The signatures on the bond must be between the Bonding Company and the Government User. A bond is an insurance policy with a maximum monetary value. The holder of the bond will receive the bond value in case of default, so it is important that the government be the agency named on that bond. Bonds are typically for one or five years. Bonding may be an issue for some contractors because it reduces their bonding capacity for those five years.

D-4 **WARRANTY REVIEW**.

The warranty wording should be carefully reviewed during the shop drawing review.

D-5 **CONTRACTORS WARRANTY**.

The final Contractor's warranty wording should be compared to the requirements included in the contract specification.

D-5.1 **Roof Manufacturer's Warranty**.

The wording of the roof manufacturer's warranty should be carefully reviewed. The Roofing Materials Guide published each year by NRCA is a good source of information on what different manufacturers offer in manufacturer warranties. Key elements to review are listed below:

D-5.1.1 **Qualified Installer**. Many manufacturers' warranties are available ONLY if a certified contractor is used to install the material.

D-5.1.2 **Length of Warranty**. Verify that the length of warranty matches the contract specification. Verify that the warranty value is not prorated over the warranty period.

D-5.1.3 **Exclusions**. Exclusions can reduce the value of the warranty to user AND prevent normal legal options to enforce standard construction rights. Some typically exclusions include the following:

D-5.1.3.1 **Legal**. Note that the term "sole and exclusive remedy" often takes away other legal rights.

D-5.1.3.2 **Technical**. Technical exclusion should be carefully reviewed. As an example, excluding wind coverage for commonly occurring wind speeds should not be allowed.

D-5.2 **Warranty Claim**.

Review process for claiming under warranty. Verify that the warranty's procedure for creating a warranty claim is reasonable and alert the building user to the procedures.

D-6 **CLOSE-OUT**.

Warranty information needs to be provided to the building user during the project close-out phase.

D-7 **BUILDING MAINTENANCE**.

Building maintenance is one of the keys to maintaining the warranty. Contracts can include prepaid yearly inspections to comply with manufacturer's requirements for keeping the warranty in effect.

APPENDIX E QUALITY ASSURANCE CONSIDERATIONS

E-1 **GENERAL**.

The success of a roof's performance over its expected lifespan depends upon using qualified designers familiar with local conditions and engaging qualified contractors to construct the project. Quality Assurance is the determination that the designer and contractor followed established quality control guidelines.

The NRCA Manual provides excellent guidance. Quality control requirements must be clearly defined and enforced. The cost and benefits of inspection by a registered roof consultant (RRC) or a registered roof observer (RRO) should be considered for all Military roofing projects.

The NRCA Quality Control Guidelines are particularly well suited for reference in design-build contract requirements where BUR systems are to be constructed. The benefits of full time inspection through an RRC are particularly high when this type of contract is used. In addition to inspecting the construction process, the full-time inspector should review contract documents prior to the commencement of construction.

E-2 **DESIGN**.

One of the major decisions in developing a quality roofing system is the choice of roof type. Many factors will influence a designer's roof choice, and many of these factors will be regional. A designer and the reviewer should be familiar with these issues and should reference UFC 3-100-10N *General Architectural and Interior Design Requirements* for further guidance if needed. The critical elements are climate, wind force, resistance to ultraviolet rays, and design for local conditions. In addition to these critical elements, the experience of the local contractor will greatly affect the quality of the installation. The design of the roof should be reviewed by a knowledgeable person such as a RCI.

E-3 **SPECIFICATIONS**.

Once the roof system is designed, the project specifications should be developed. The UFGS must serve as the basis for the project specifications. Key elements to consider in development of the specifications are listed below:

E-3.1 **Roof System**.

Specify a roof SYSTEM -- not just the components -- to assure clear responsibility for correction.

E-3.2 **Maintainability**.

The designer should factor into the design process the ability of the user to maintain roof. Some roof systems require more maintenance than others. The warranties of some roofs require inspection at least two times a year.

E-3.3 **Submittals**.

Require submittals (shop drawings) to verify quality in the details and in components. Assure that the roof specification requires complete shop drawings.

E-3.4 **Roof Manufacturer Inspection**.

Consider requiring roof manufacturer's representative to inspect the roof at least three times (beginning, middle, and end) during installation.

E-3.5 **Warranty Selection**.

Warranties should be utilized for fully conditioned human occupied spaces. Refer to Appendix C for more information on warranties.

E-3.6 **Pre-installation Meeting**.

Attendance at the pre-installation meeting is required for all key players. The government representative, general contractor, roof contractor, and roof manufacturer' technical staff should be present at this meeting.

E-3.7 **Minimum Installer Qualifications**.

Require sufficient qualifications from the installer to achieve good workmanship. Five years of experience and five jobs of similar complexity, size, and cost are the minimum requirements.

E-4 **FIELD INSPECTION(S)/CQM**.

E-4.1 **Installation**.

The field inspector should verify that roof is installed according to shop drawing details. The inspector should look for complex situations not previously identified and discuss with QC personnel and the on-site roof installer foreman. He should also spot check critical areas for quality watertight construction.

E-4.2 **Leaks**.

If leaks exist before close-out, do not accept the roof per the contract or pay the General Contractor in full. Test and remove defective material/installation to locate problem and repair. Consult a RCI inspector if local expertise is not adequate.

E-5 **CLOSE OUT OF CONTRACT**.

Warranties are the legal means of users to get a new roof repaired. The facility manager should have a copy of the warranty and be familiar with all requirements an owner is required to do to keep the warranty in force.

APPENDIX F OTHER RESOURCES

GOVERNMENT PUBLICATIONS:

ETL 90-1, *Built-Up Roof Repair/Replacement Guide Specification*, Air Force Civil Engineer Service Center (AFCESA), Tyndall Air Force Base, 139 Barnes Dr., Florida, 32403

ETL 90-8, *Guide Specification for Ethylene-Propylene Diene Monomer (EPDM) Roofing*, Air Force Civil Engineer Service Center (AFCESA), Tyndall Air Force Base, 139 Barnes Dr., Florida, 32403

Instruction 32-1051, *Roof Systems Management*, 1994, Air Force Civil Engineer Service Center (AFCESA), Tyndall Air Force Base, 139 Barnes Dr., Florida, 32403

FM-93/11, *ROOFER: Membrane and Flashing Condition Indexes for Single-Ply Membrane Roofs - Inspection and Distress Manual*, 1993, Construction Engineering Research Laboratory (CERL), 5285 Port Royal Rd, Springfield VA, 22161, (order from NTIS: www.dtic.mil.)

M87-13, *Membrane and Flashing Condition Indexes for BURs: Inspection and Distress Manual*, Vol II, 1987, Construction Engineering Research Laboratory (CERL), 5285 Port Royal Rd, Springfield VA, 22161, (order from NTIS: www.dtic.mil.)

M-90/04, *ROOFER: Membrane and Flashing Condition Indexes for Single-Ply Membrane Roofs - Inspection and Distress Manual*, 1993, Construction Engineering Research Laboratory (CERL), 5285 Port Royal Rd, Springfield VA, 22161, (order from NTIS: www.dtic.mil.)

MP 1498, *Venting of Built-Up Roofs*, 1981, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

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MP 3443, *General Considerations for Roofs*, 1994, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

MP 3527, *Ventilating Attics to Minimize Icings at Eaves*, 1994, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

MP 3858, *Snow Guards for Metal Roofs*, 1996, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

MP 5050, *Freeze-Thaw Durability of Common Roof Insulations*, 1997, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

MP 5090, *Electric Heating Systems for Combating Icing Problems on Metal Roofs*, 1997, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

MO 5106, **Attic Ventilation Guidelines to Minimize Icings at Eaves*, 1998, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

MP 5420, **Ventilating Cathedral Ceilings to Prevent Problematic Icings at Their Eaves*, 1999, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

MP 5778, **Guidelines for Ventilating Attics and Cathedral Ceilings to Avoid Icings at Their Eaves*, 2002, Cold Regions Research & Engineering Laboratory (CRREL), 72 Lyme Rd, Hanover, NH, 03755, http://www.crrel.usace.army.mil/techpub/CRREL_Reports/index.html

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NBS Report 86-3418, *Performance Criteria for Load-Elongation of Bituminous BUR Membranes; Alternative to the Tensile Strength Criterion*, 1986, National Institute for Standards and Technology (NIST), Structures and Materials Division/Center for Building Technology, Gaithersburg, MD, 20899 (order from NTIS: www.dtic.mil.)

NISIR 88-4638, *Performance Approach to the Development of Criteria for Low Sloped Roof Membranes*, 1991, National Institute for Standards and Technology (NIST), Structures and Materials Division/Center for Building Technology, Gaithersburg, MD, 20899 (order from NTIS: www.dtic.mil.)

NIST Special Publication 811, Guide for the Use of International System of Units (SI), 1995, National Institute for Standards and Technology (NIST), Structures and Materials Division/Center for Building Technology, Gaithersburg, MD, 20899 (order from NTIS: www.dtic.mil.)

ORNL-6520, *Decision Guide for Roof Slope Selection*, 1988, Air Force Civil Engineer Service Center (AFCESA), Tyndall Air Force Base, 139 Barnes Dr., Florida, 32403

ORNL CONF 9405206, *Low Slope Reroofing*, 1994, Oak Ridge National Laboratories, Oak Ridge, TN, 37831-2008

TR 99/100, *ROOFER: Steep Roofing Inventory Procedures and Inspection and Distress Manual for Asphalt Single Roofs*, 1999, Construction Engineering Research Laboratory (CERL), 5285 Port Royal Rd, Springfield VA, 22161, (order from NTIS: www.dtic.mil.)

NON-GOVERNMENT PUBLICATIONS:

29, *Design Manual for Composite Decks, Form Decks, Roof Decks and Cellular Deck Floor Systems with Electrical Distribution*, Steel Deck Institute (SDI), Fox River Grove, IL, 60021

207-RR-85, *Plain Facts About Buckled Shingles*, 1993, Asphalt Roofing Manufacturer Association, 6000 Executive Blvd., Suite 201, Rockville, MD 20852-3802

210-RR-71, *Color Shading of Asphalt Shingle Roofs*, 1993, Asphalt Roofing Manufacturer Association, 6000 Executive Blvd., Suite 201, Rockville, MD 20852-3802

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ANSI/SPRI RP-4, *Wind Design Standard for Ballasted Single -Ply Roofing Systems*, 1997, American National Standards Institute (ANSI), 11W. 42nd St., New York, NY, 10036

Building Materials Directory, Underwriters Laboratories (UL), 333 Pfingsten Rd., Northbrook, IL, 60062

Clay Roof Tile Manual, Western States Roofing Contractors Association (WSRCA), 8000 Airport Blvd., Suite 412, Burlingame, CA 94010

Commercial Roofing Materials Guide, Annual, National Roofing contractors Association (NRCA), 10255 W. Higgins Rd., Suite 600, Rosemont, IL, 60018-5607

Concrete and Clay Tile Roof Design Criteria Manual for Cold, Snowy Regions, 1998, National Tile Roofing Manufacturers Association, Inc, Eugene OR, 97404

Copper In Architecture, Copper Development Association, 260 Madison Ave., New York, NY, 10016

Florida Building Code, Florida Department of community Affairs, 2555 Shumard Oak Blvd., Tallahassee, FL, 32399-2100, www.dca.state.fl.us.

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Quality Control Guidelines for Application of Polymer Modified Bitumen Roofing Systems, National Roofing contractors Association (NRCA), 10255 W. Higgins Rd., Suite 600, Rosemont, IL, 60018-5607

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R-186, *Roof Maintenance*, 1994, Roofing Industry Educational Institute (RIEI), 14 Inverness Dr. E., H-110, Englewood, CO, 80112

Repair Manual for Low-Slope Roof Systems, 1997, National Roofing contractors Association (NRCA), 10255 W. Higgins Rd., Suite 600, Rosemont, IL, 60018-5607

Repair Methods for Re-Attaching EPDM Membrane and Flashing Experiencing Shrinkage, 1997, National Roofing contractors Association (NRCA), 10255 W. Higgins Rd., Suite 600, Rosemont, IL, 60018-5607

Roofing Materials and Systems Directory, Underwriters Laboratories (UL), 333 Pfiingsten Rd., Northbrook, IL, 60062

Slate Roofs, Vermont Structural Slate, Inc., PO Box 98, Fair Haven, VT, 05713

SPE-1025, *Guidelines for Proper Installation for APA Rated Sheathing for Roof Applications, Residential and Commercial Manual, Design/Construction Guide*, APA-The Engineered Wood Association, 7011 S. 19th St., Tacoma, WA, 98411-0700

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